HERITAGE BREEDS OF LIVESTOCK IN PROTECTED FOREST LANDSCAPES: AN APPROACH TO CONSERVING NATURAL AND AGRICULTURAL DIVERSITY

by

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A PhD dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy (Forest Sciences)

Faculty of Natural Resources Management
Lakehead University

December 29, 2011

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ABSTRACT

Rosenthal, J. (2011) *Heritage breeds of livestock in protected forest landscapes: An approach to conserving natural and agricultural diversity*. 249 pp.

Keywords: Protected landscapes, historical ecology, traditional agriculture, heritage breeds, grazing, anthropogenic disturbance, semi-natural meadows, forest pastures, grazed woodlands.

In landscapes with a long history of traditional agricultural activity, some protected areas are using heritage breeds of livestock to conserve disturbance-dependent habitats and combat the loss of natural and agricultural biodiversity associated with the widespread decline in traditional agriculture. This dissertation examines this phenomenon on a broad scale through a global review, as well as on a regional scale through a case study at Koli National Park in eastern Finland.

A review of protected areas around the world was conducted to understand the ways in which protected areas and heritage breeds contribute to each other's conservation. Benefits were found in terms of the contribution of heritage breeds to the management objectives of protected areas (such as controlling invasive vegetation, maintaining disturbance-dependent habitats, enhancing biodiversity, reducing soil erosion, creating habitat for wildlife, serving as tourism attractions and fostering good relationships with local residents via incentive programs). Reciprocally, protected areas contributed to the conservation of heritage breeds by increasing awareness of the breeds, supporting incentive programs that encourage local farmers to raise heritage breeds, and creating opportunities for niche-marketing.

A case study in Koli National Park, Finland, examined the reintroduction of two heritage breeds in a boreal forest landscape that had a history of traditional agriculture involving livestock from around 1450 -1600 AD through to the 1960s. Since 2003, two heritage breeds, Eastern Finncattle and Finnsheep, have grazed at Koli National Park in the summer months with the intent of restoring traditional agricultural habitats to the landscape. Habitats that are associated with traditional agriculture (e.g., semi-natural grasslands, grazed woodlands and forest pastures) are now endangered or critically endangered in Finland, and Europe in general, because of modernisation of agricultural practices, especially after 1960. An examination of the agricultural history in eastern Finland revealed that the efforts to reinstate traditional agricultural activities in Koli National Park were mainly consistent with traditional practices. One exception related to livestock husbandry included pasturing the livestock in open fields, which would have been reserved for crop cultivation or haymaking. Another exception was the lack of

leaf-hay from the shoots and branches of deciduous trees, which would have traditionally been used as fodder for the animals.

In a few areas of Koli National Park, Finnsheep have been grazing vegetation regenerating in swidden sites that had been burned eight to nine years prior to sampling. In these sites, there was a much greater abundance of dead and dying woody vegetation than in similar aged swidden sites without livestock. In these sites, the Finnsheep damaged birches (*Betula pendula* Roth and *Betula pubescens* Ehrh.) more than rowan (*Sorbus aucuparia* L.), whereas rowan and Scots pine (*Pinus sylvestris* L.) were the most damaged species in the sites without sheep – likely because of the preference of moose (*Alces alces*) for these species. Decreased percent cover of two tall, dominant plant species (*Epilobium angustifolium* L. and *Calamagrostis arundinacea* [L.] Roth) in the field layer of the swidden regeneration sites grazed by Finnsheep were found along with an increase in cover of two shorter species (*Agrostis capillaris* L. and *Trientalis europaea* L.), though no differences in overall species richness were found between grazed and non-grazed swidden habitats. No significant differences in tree condition or species richness were found when comparing the forest pastures currently grazed by Finnsheep at Koli National Park and forest habitats that had been used as wooded pastures earlier in the 20th century. Where Eastern Finncattle and Finnsheep were pastured in open fields with some tree cover (<10% cover), damage to grey alder (*Alnus incana* [L.] Moench) trees was particularly high, suggesting that woody vegetation may be necessary in the diet of these heritage breeds that had traditionally been raised in forest conditions.

A number of recommendations for further study include collecting additional data on the use of heritage breeds of livestock in protected areas world-wide through the next round of FAO's State of the World's Animal Genetic Resources reports. Additional research on the ecological effects of Eastern Finncattle and mixed species grazing was recommended, as were empirical comparisons between heritage and imported mainstream breeds within traditional agricultural production systems. Recommendations also included investigating whether historically consistent sources of food (i.e., leaf hay and forest pastures) have any effect on the physical attributes of heritage breeds, such as their susceptibility to internal parasites. Longer-term research on the ecological impacts of heritage breeds in Koli National Park is recommended to help determine the role of the livestock in shaping ecologically valuable habitat and ensuring temporal habitat continuity.

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ACKNOWLEDGEMENTS

I would like to begin by acknowledging the support and input from my co-supervisors Dr. Reino Pulkki and Dr. Lesley Lovett-Doust and from committee members Dr. David Kemp and Dr. Scott Hamilton. The comments and advice from Dr. Marek Sammul, the external reviewer of this dissertation, is also greatly appreciated. This work would not have been possible without the financial and in-kind support from Lesley Lovett-Doust, the Northern Scientific Training Programme and Koli National Park. Thank you also to Hanna-Maija Kehvola, Riina Jorasmaa, Miriam Pfähler, Tuuli Tikkamaki, Emma Määttä and Lea Hayes for their assistance with translations. Kiitos paljon to Lasse Lovén, Kaija Eesto and Eevi Neimenen for facilitating the logistics of my time at Koli National Park. Lasse Ruokolainen was very generous to share raw data from his and Kuko Salo's swidden regeneration study. I am also grateful for the time and assistance from Marja and Veera Saaralainen from the Koli Museum as well as from Erin McGauley. Finally, I would like to thank my husband, William Wilson, for his patience and loving encouragement throughout this endeavour.

CHAPTER 1: INTRODUCTION

INTRODUCTION

Over the past century, meadow and grazed forest habitats associated with traditional agricultural practices have become increasingly rare in Europe in general, including Finland. Meanwhile, there has also been a global reduction in the diversity of livestock breeds, particularly among heritage breeds, mainly due to a modern preference for a select few breeds that perform well in industrial agricultural production systems (Henson, 1992; Mendelsohn, 2003; 2008). There is an opportunity to address both of these problems, at least in part, by reinstating grazing by heritage breeds in habitats dependent on traditional grazing activity. Protected areas now include many landscapes[1] that have a long history of human use and may serve as important areas in which to conserve high-priority grazing-dependent habitats as well as the breeds of livestock that originally shaped them.

There are conceptual challenges regarding what constitutes a heritage breed (e.g., how long must a breed exist on a landscape before it can be considered part of an area's heritage?). The FAO (2004) defines a breed as:

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[1] The term landscape refers to "ecological systems that exist at the scale of kilometers and comprise recognizable elements, such as forest patches, fields and hedgerows, human settlements, and natural ecosystems" (Pickett and Cadenasso, 1995, p. 331).

> A sub-specific group of domestic livestock with definable and identifiable external characteristics that enables it to be separated by visual appraisal from other similarly defined groups within the same species, or a group for which geographical and/or cultural separation from phenotypically similar groups has led to the acceptance of its separate identity (p. 29).

Heritage livestock breeds in this study are breeds that developed their identifiable characteristics within the traditional agricultural practices of a particular geographical region. Such breeds have not been recently (i.e., within the past 150 years) imported from another region, nor are they progeny of crosses involving breeds imported from other regions. Furthermore, such breeds have not been developed outside the confines of a particular geographical context (e.g., within a genetics laboratory for use within a non-pasture system).

A timeframe of at least 150 years was chosen to differentiate newly imported breeds from those that dispersed much earlier in an area's settlement history. This timeframe was chosen because several developments in agriculture within the past 150 years have reduced (but not eliminated) the effects of local agricultural practices, preferences and environments as agents of human and/or natural selection upon the individuals that comprise the breeds. For example, within the past 150 years, increased availability of high quality, and often imported, feed reduced pressures to select for thrifty foragers of locally available plants; advancements in veterinary medicine reduced pressures to select for disease resistance or ease of birthing; specialization in high output agricultural production reduced selection for multipurpose (e.g. milk/meat/traction) characteristics; improved housing reduced selection for tolerances to extreme environmental conditions, etc (Hiemstra *et al.*, 2010). So a breed imported in the past 150 years would not have been exposed to the same kinds of forces of selection as a breed with a much longer history in a given area. Moreover, it is possible that heritage breeds that are now raised within modern agricultural systems using the advancements described above may be losing some of the characteristics that an area's more traditional production systems had reinforced.

In most cases the *species* discussed in this dissertation are generally not indigenous to the regions examined – the species dispersed from their centres of domestication via various groups of settlers or traders through time. Thus, the term "indigenous breed" is avoided in this dissertation. The term "local breed" is often used as an alternative to "heritage breed"; however, a newly developed breed such as the Canadian Arcott, which was developed from crossing five imported breeds, can arguably be called a local breed in the Ottawa area of Canada, because it was developed in that location, albeit in 1970s (Demirören *et al.*, 1995). The short timeframe of this breed's existence in the area would disqualify it as a heritage breed for the purposes of this study.

The term "heritage breed" is sometimes used to refer to breeds that have primitive characteristics regardless of their place of origin. In this study, emphasis is placed on the places of origin of the breeds and the agricultural traditions that are/were practiced as the breeds were shaped over time. So, in cases where historic breeds are used outside their region of origin, such breeds would not be considered a heritage breed in this dissertation. For example, where Scottish highland cattle are used for the purposes of nature conservation in Estonia (Kokovkin *et al.*, 2005) the breed is not considered a heritage breed in this study.

By definition, then, heritage breeds were shaped in part by human selection for particular desirable traits over several generations, but they also evolved under the natural pressures influenced by climate, topography, and local flora and fauna of their particular geographical area. Conversely, over lengthy periods of time, the physiology and behaviour of heritage breeds in turn likely influenced the ecology of the landscapes they evolved in, particularly through selective herbivory (i.e., preferentially grazing one plant species over another). If this is the case, then logic would suggest that changes in the use of these breeds (e.g., cessation of grazing, change in breed, and/or change in husbandry of the heritage breeds) would likely affect the local vegetation and overall ecology of the landscape.

The use of heritage breeds to restore biodiversity in protected areas shaped by centuries of traditional agricultural use may be perceived as a win-win situation. That is, allowing heritage breeds to graze within protected areas may help to restore disturbance-dependent habitats that are increasingly rare, while providing incentives and a rationale to conserve the heritage livestock breeds. To examine the actual and potential roles of heritage breeds of livestock in protected areas, this dissertation undertakes both a broad review of programs involving the conservation of heritage breeds within protected areas worldwide and a detailed case study of the use of heritage breeds of cattle and sheep for the restoration of habitats associated with traditional agriculture in Koli National Park, eastern Finland.

RESEARCH QUESTIONS AND APPROACH

The global overview coupled with a detailed case study aim to balance geographical breadth and temporal depth in this study of the role of heritage breeds of livestock in protected areas. Overall, this research takes a perspective of historical ecology, which is “concerned with the interactions through time between societies and environments and the consequences of these interactions for understanding the formation of contemporary and past cultures and landscapes" (in Balée, 2006, p.76). Forest history is a sub-discipline of historical ecology that specifically examines the natural and anthropogenic mechanisms that shaped forest conditions through time (Agnoletti, 2000). Historical ecology and forest history are necessarily interdisciplinary and incorporate data from various temporal and geographical scales (Balée, 1998; Agnoletti, 2000). Drawing from diverse sources of data, historical ecology aims to piece together evidence of the causes and consequences of landscape changes through time (Russell, 1997; Swetnam *et al.*, 1999).

Sources of historic data are often inherently limited by degradation over time, recent collection (i.e., data may not have been collected in early periods), variation in measurement procedures or tools, or incompleteness. However, the use of various sources of data helps verify and complete data that may be less reliable or incomplete on their own (Russell, 1997; Swetnam *et al.*, 1999). Although much emphasis in historical ecology is on developing an understanding of the past, not all data used are historic in nature nor are they simply used to understand the past. Indeed, one of the greatest contributions of historical ecology, according to Swetnam *et al.* (1999), is its ability to provide context for the evaluation of current ecological conditions. Egan and Howell (2001) suggest that historical ecology is most successful when using "multiscale, multisource, cross-referential historical analysis that is compared to contemporary data" (p. 14).

Global Overview

A review was conducted to understand the role of heritage breeds of livestock in protected areas on as broad a geographical scale as possible. To do so, a content analysis was conducted of reports from 167 countries submitted for the United Nations Food and Agriculture Organization (FAO) State of the World's Animal Genetic Resources reporting process. The aim of the content analysis was to determine the extent to which national bodies reporting on the state of their country's animal genetic resources recognize protected areas as means to conserve domestic animal diversity. The 167 country reports, as well as other published literature, were reviewed to characterize the roles of, and relationships between, the protected areas and the livestock. Although the focus of the global overview was on the use of heritage breeds of livestock in protected areas, cases were also examined involving imported breeds that are at risk of extinction according to the FAO's domestic animal diversity information system (DAD-IS) (FAO, 2008). This review is presented in Chapter 2 and was published in 2010 in FAO's peer-reviewed journal, *Animal Genetic Resources*, in a special issue for the International Year of Biodiversity.

Case Study

To gain a deeper understanding of the ecological role of heritage breeds of livestock in protected areas, a detailed case study was conducted in Koli National Park. At Koli

National Park, two heritage breeds of livestock, Eastern Finncattle and Finnsheep[2], were reintroduced at two of the park's old farmsteads. The objective of resuming traditional agricultural activities such as swidden cultivation, livestock grazing and haymaking in Koli National Park since the 1990s was to restore anthropogenic habitats that are now rare within the predominantly forested boreal landscape of eastern Finland. The following site-specific research questions were formulated for the case study:

i. How and where were heritage breeds of livestock raised in the Koli region in the past?
ii. How and where are heritage breeds of livestock used in Koli National Park today?
iii. How have changes to agricultural practices involving heritage breeds of livestock influenced the landscape in and around Koli National Park over time?
iv. What differences, if any, in vegetation diversity, structure and composition are associated with grazing by heritage breeds at Koli National Park at today?

These questions investigate the possibility that heritage breeds of livestock have had a distinct ecological role in shaping the landscape in the past and that restoration of such landscapes is dependent upon the use of heritage breeds of livestock in historically consistent ways.

The case study of the use and effects of heritage breeds of livestock in Koli National Park involves a mixed methods approach including literature and cartographic reviews, quantitative vegetation analysis, participant observation, as well as qualitative, semi-structured interviews with farmers and other livestock experts. These multiple approaches enable each site-specific research question to be examined from more than

[2] Also known as Finnish Landrace sheep

one perspective (Table 1.1) and can increase the reliability of results, particularly if findings from more than one research method are consistent with one another (Creswell, 2007).

Table 1.1. Methods used to investigate each site-specific research question.

Research Question	Lit.	Phot.	Cart.	P.Ob.	Int.	Veg.
How and where were heritage breeds of livestock used in the Koli region in the past?	X	X	X		X	
How and where are heritage breeds of livestock used in Koli National Park today?	X		X	X	X	
How have changes to agricultural practices involving heritage breeds of livestock influenced the landscape in and around Koli National Park over time?	X	X	X		X	X
What differences, if any, in vegetation diversity, structure and composition are associated with grazing by heritage breeds at Koli National Park today?	X			X		X

Lit = literature review, Phot. = Analysis of historic photographs & rephotography, Cart. = Cartographic review, P. Ob.= Participant Observation, Int.= Interviews, Veg. = Vegetation analysis.

The literature review examined the historical background of agricultural practices involving livestock and pastureland, from the earliest archaeological and palynological evidence of agricultural activity in eastern Finland to current park management practices that are attempting to restore historic forms of agriculture to the landscape. The literature review also examined research associated with the ecological effects of livestock grazing in other parts of Finland and Europe.

An investigation of the Koli Museum's collection of over 1 400 photographs from the Koli area taken by local resident Einar A. Saarelainen between 1920 and 1960 provided evidence regarding the use of heritage breeds of livestock in the Koli area at that time. Where possible and relevant to this study, photographs were retaken in 2008 from roughly the same vantage points as Saarelainen's original photographs to document changes in the landscape between the early 20th century and present day.

The review of maps of the Koli area from 1922 to present enabled a spatial exploration of land use and broad vegetation changes over time within Koli National Park and adjacent lands as agricultural land use practices changed.

Opportunities for participant observation during the 2007 and 2008 field seasons included participating in a community event of traditional haymaking, assisting with two swidden burns, providing daily care for a flock of Finnsheep at Koli National Park for a month and raising Finnsheep in Canada for over a year. These opportunities for the research phenomena to be experienced first-hand enabled a richer understanding of the ways in which traditional agricultural practices in the region are/were carried out.

The qualitative semi-standardized interviews with past and current farmers, park staff and agricultural college staff helped verify whether current grazing practices in Koli National Park reflect traditional animal husbandry methods and whether there are any characteristics unique to the heritage breeds that are absent from imported[3] mainstream breeds with which the interviewees had experience.

The literature review, photographic and cartographic analyses, interviews and participant observation opportunities are synthesised in Chapter 3, to set the historical context of the case study, with a particular emphasis on the role of heritage breeds in the changing agricultural practices of the landscape in and around Koli National Park.

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[3] According to the breed census data available on FAO's DAD-IS (2011), there are three heritage cattle breeds in Finland. In total, their numbers represent around 1.5% of the national cattle population. The rest of Finland's cattle are from 13 breeds imported from other countries. Although census data for all sheep breeds are not available, Finnsheep – a heritage breed– remains the most common breed in the country, although two other heritage sheep breeds and six imported breeds are also used in Finland.

In Chapter 4, an analysis of vegetation in Koli National Park examines the effects of grazing with heritage breeds in swidden regeneration sites, forested areas, and open field and meadow habitats in comparison with similar non-grazed sites. This part of the study documents and compares plant species richness[4], plant community composition and vegetation structure observed under different management conditions.

Additional details regarding the methodology used for each component of this research are provided in Chapters 2, 3 and 4.

BACKGROUND

This section explores the linkages between the discontinuation of traditional agricultural practices, the loss of livestock diversity and the decline in disturbance-dependent habitats in Europe, with a particular focus on eastern Finland. These linkages form the basis of a rationale for reintroducing traditional agricultural practices involving heritage breeds within protected areas.

Discontinued Traditional Agriculture, Habitat Loss and Biodiversity

Across Europe, habitats associated with traditional agricultural practices are becoming increasingly rare as pastureland is abandoned, converted to cropland, or subjected to intensive rather than extensive grazing systems (Ostermann, 1998; Krebs *et al.*, 1999;

[4] Species richness is a measure of biological diversity that considers the number of different species occupying an area. Species richness, however, does not account for the relative abundance of each species.

Luoto *et al.*, 2003a; Luoto *et al.*, 2003b; Isselstein *et al.*, 2005). Such habitats created, at least in part, from anthropogenic activities can be highly biodiverse, and many are recognized as warranting protection through the European Commission's Habitats Directive. This Directive stipulates that habitats "of community interest" listed in its Annex 1 must be protected and maintained in a "favourable conservation status[5]". Ostermann (1998) found that 25 of the 198 habitats identified in Annex 1 of the Habitats Directive are likely to have originated from grazing and/or hay-making, including eight habitats that are priority[6] habitat types. Further, the abandonment of grazing and/or hay-making is considered a threat to 27 of the habitats in Annex 1, including 10 priority habitat types (Ostermann, 1998).

Conserving such habitat types by grazing or haymaking may also have favourable impacts on wild species at risk of extinction. For example, Buckingham and Peach (2005) report that grazing contributes to avian diversity in farmlands in the United Kingdom in several ways. Insectivorous birds benefit when livestock movements flush insects from foliage and when coprophagous insects are attracted to the livestock dung. Furthermore, livestock grazing and trampling results in a patchy sward structure that supports bird species that feed on ground-dwelling invertebrates, as well as birds that forage on seeds and invertebrates associated with taller swards. Winter feed (hay and grains) given to livestock also provides important sources of winter food for corn buntings (*Emberiza calandra*) and cirl buntings (*Emberiza cirlus*) (Buckingham and Peach, 2005), both of which are Red-Listed in the United Kingdom (Royal Society for the Protection of Birds, 2009).

[5] Meaning that the habitat and its typical species are maintained in such a way that prevents their further decline on a long-term basis.
[6] Meaning a habitat type is in danger of disappearance and a considerable proportion of its range is within the territory overseen by the European Commission.

Further evidence of the positive correlation between biodiversity within some habitats and traditional agricultural practices is evident in studies that show that biological diversity of such habitats decreases when the traditional agricultural activities cease to be practiced (Persson, 1984; Hansson and Fogelfors, 2000; Dullinger *et al.*, 2003; Luoto *et al.*, 2003a; Luoto *et al.*, 2003b; Myklestad and Saetersdal, 2004; Huhta and Rautio, 2005; Pykälä, 2005). Therefore, to conserve, restore and/or maintain biodiversity in habitats dependent on disturbances related to traditional agricultural activities, there is an ecological rationale for encouraging the continuation or re-initiation of these activities (Wallis De Vries, 1995; Amend *et al.*, 2008).

Finland's semi-natural meadows and forest pastures are examples of habitats that are dependent on traditional agricultural activities for their creation and maintenance (Ostermann, 1998; Raunio *et al.*, 2008). In Finland, very few meadows are naturally occurring; rather the majority were created by human activities (clearing forest using fire, followed by growng crops and then grazing and/or haymaking) within a forested landscape. These patches of disturbed vegetation support a different mix of flora and associated fauna than is normally found in the surrounding forested matrix, thus contributing to increased gamma (landscape level) diversity. Because of the discontinuation of traditional forms of agriculture in Finland, these habitats are disappearing. Since 1880, the proportion of agricultural land in Finland categorized as semi-natural meadows has declined from 62% to less than 1% due to the intensification of land use (e.g., crop cultivation) or abandonment of former hayfields and pastures (Luoto *et al.* 2003b). Cessation of grazing or haymaking is cited as the primary threat to 27% of Finland's threatened plant species (Marttila *et al.*, 1999). Finland's semi-natural meadows are listed with old-growth forests as the two habitats with the greatest numbers of threatened species in the country (Luoto *et al.* 2003b). Semi-natural meadows within a forested matrix require disturbances associated with traditional agriculture to prevent the meadows from reverting to the composition of the surrounding forested habitats: succession that would ultimately lead to the loss of landscape-level heterogeneity and associated biodiversity.

Wooded pastures (in which tree cover is 10 – 35%) and grazed forests (in which tree cover is over 35%) have also declined dramatically in Finland due, in part, to changes to, and reduction of, traditional agricultural activities. Between the late 1930s and the 1950s one quarter to one third of Finland's 375 000 ha of wooded pastures disappeared, and less than 1% are still in existence today (Raunio *et al.*, 2008). Wooded pastures are therefore listed as critically endangered[7] in Finland's assessment of threatened habitats. In addition, of the 1 560 000 ha forest pastures that existed in Finland in the 1950s, only 1% remain today (Raunio *et al.*, 2008). Grazed forests in general are considered endangered[8] habitats in Finland, and grazed deciduous forests and those that are dominated by a mixed canopy of deciduous and coniferous trees are classified as critically endangered. These critically endangered forests are threatened mainly by logging, reforestation, cessation of grazing, land clearing for cultivation, eutrophication, encroachment by Norway spruce[9] (*Picea abies* [L.] H. Karst) and reduced amounts of decaying woody debris (Raunio *et al.*, 2008).

[7] Generally, habitats that have decreased in area by 80% or more are categorized as critically endangered. The timing of the decline, expected future trends, and quality of the remaining remnants can upgrade or downgrade the habitat by one or two categories.
[8] Generally, habitats that have decreased by 50 – 80% are categorized as endangered, with the possibility of adjustment as in footnote 7.
[9] Although *Picea abies* is native to Finland, it is considered a threat to mixed and deciduous grazed forest habitats when it becomes a dominant species at the expense of others (e.g., shade-intolerant species).

Loss of Livestock Breed Diversity

Changes in agricultural practices are also associated with a decline in agricultural biodiversity. The United Nations Food and Agriculture Organization (FAO) reports that 643 (12%) of the world's 5 559 documented mammalian breeds of livestock[10] have become extinct (Rischowsky and Pilling, 2007), mostly within the past 100 years (Hall and Ruane, 1993). Furthermore, an additional 16% of mammalian livestock breeds are at risk of extinction, and the status of 34% mammalian livestock breeds is unknown (Figure 1.1).

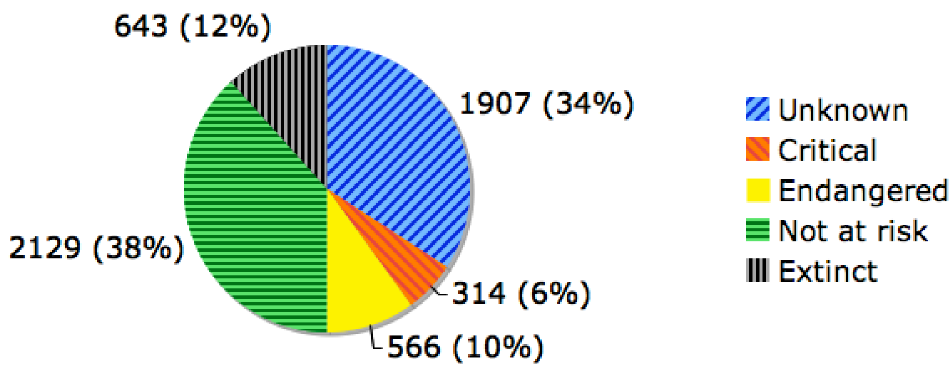

Figure 1.1. At-risk status of the world's known mammalian livestock breeds (Rischowsky and Pilling, 2007).

Since the mid-20th century in Finland, the multi-purpose (dairy/beef) heritage breeds of cattle were replaced mainly by highly productive dairy breeds (Ayrshire and Holstein, which together represent approximately 80% if the nation's cattle population)

[10] An additional 40 breeds are known but were not classified by risk status.

and internationally popular beef breeds (Aberdeen Angus, Charolais, Hereford, Limousin and Simmental, which together comprise nearly 15% of Finland's cattle). Heritage Finnsheep remain the dominant breed in the country's sheep sector despite some experimentation with imported breeds from the UK, Norway and Sweden. However, two breeds (Åland sheep and Kainuu grey sheep) originating in their namesake regions within Finland have populations under 350 individuals and are at risk of extinction[11].

Breeds at risk of extinction are declining mainly because they are perceived to hold little value within current conventional industrial production contexts. That is, they are often out-performed and replaced by breeds that better meet economically paramount production criteria such as milk quantity, carcass size for meat, speed of maturity, or fineness/strength of wool fibres (Yarwood and Evans, 2000; Mendelsohn, 2003; Evans and Yarwood, 2008).

Although heritage breeds are rarely preferred in mainstream production systems, the economic merits of various breeds are not always straightforward. Signorello and Pappalardo (2003) compared the net income from raising at-risk heritage breeds of cattle, sheep, goat, horse and pig, compared with that from highly productive mainstream breeds[12] of the same species in Italy. They reported that farmers experienced a net loss of income from each of the six at-risk breeds studied, even when subsidies for such breeds were taken into consideration. The highly productive mainstream breeds in their study all generated net profits, even without subsidies.

[11] Data on cattle and sheep breeds in Finland were derived from FAO's Domestic Animal Diversity Information System (DAD-IS, 2011).

[12] Not all highly productive mainstream breeds are imported - one of the highly productive breeds in Signorello and Pappalardo's study was also a heritage breed. One was a recently developed composite of two heritage breeds, and the remaining three were imported breeds.

Economically, this can place farmers of lower-yielding heritage breeds at a disadvantage especially if income is calculated per head of livestock. However, if productivity was measured as a function of other criteria (such as production per hectare of land of heritage breeds that may be efficient foragers or value of niche products from specialty breeds), economic analyses could possibly favour heritage breeds, particularly given the possibilities for niche marketing of heritage products (Gandini *et al.*, 2007).

Arguments supporting the conservation of livestock breeds at risk of extinction include their current or potential economic value, possible scientific use, cultural significance and their inherent existence value (Henson, 1992; Mendelsohn, 2003). Where the traditional grazing grounds of heritage livestock overlap with land for which ecological conservation is a priority, efforts to conserve heritage breeds may complement natural resource protection. Proponents of the conservation of domestic animal diversity specifically mention protected areas as a means to prevent the loss of rare breeds while conserving ecologically important habitats (Henson, 1992). Yet there is little emphasis on such opportunities in most strategies that outline priorities for conserving heritage breeds.

Means to conserve domestic animal diversity can be characterized as: 1) *in vitro* methods (i.e., cryopreservation of reproductive material or other tissue samples); and 2) *in vivo* methods (i.e., maintaining live populations either *in situ* [within the landscapes in which they were developed]) or *ex situ* (outside of their original landscapes, [e.g. in zoological parks]). Geerlings *et al.* (2002) advocate *in vivo*, *in situ* approaches as the most realistic ways to conserve locally adapted breeds of livestock, particularly if the production systems in which the breeds evolved can also be maintained. Köhler-

Rollefson (2000) explains that heritage breeds (referred to as indigenous breeds in the original text) are:

> products of specific ecological and cultural environments, and their genetic make-up and integrity will be affected if they are removed from their original contexts. Transfer of domestic animal populations into the controlled environments of government farms poses the danger of a gradual erosion of their adaptive traits (p. 1).

The case of North Ronaldsay sheep illustrates how a breed's unique traits can be lost if the breed is removed from the environment in which it evolved. North Ronaldsay sheep graze on the shores of North Ronaldsay, the northernmost island of the Orkneys, Scotland. Their diet consists of nearly 100% seaweed (Hansen *et al.*, 2003), which has low copper content in comparison to terrestrial forage normally consumed by other breeds of sheep (Haywood *et al.*, 2001). Over time the North Ronaldsay sheep developed an enhanced ability to store copper to meet their metabolic needs from the limited reserves of copper in their seaweed diet. When some North Ronaldsay sheep were removed from their natural shoreline environment and allowed to graze on mainland pastures, four out of five of the sheep died from copper poisoning due the breed's heightened ability to absorb copper from the terrestrial herbage, which had normal copper levels (MacLachlan and Johnston, 1982). Selection within this "ordinary" pasture environment would favour individuals with reduced capacity to absorb copper, a trait that would be disadvantageous in the breed's traditional environment. Thus, conservation of this breed outside of its traditional environment would fundamentally change some characteristics that make the breed unique.

Certainly not all examples of the ways in which heritage breeds are adapted to their local environments are as dramatic as the case of the North Ronaldsay sheep. However, this example does provide a strong argument for conserving breeds within the environments in which they evolved, even if the adaptive traits or environmental pressures are less apparent.

Protected Areas and Traditional Agriculture

The World Conservation Union's (IUCN) definition of a protected area is:

> a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley, 2008, p.8).

Where protected areas overlap with landscapes created and utilized by people engaged in traditional agricultural and/or pastoral practices involving heritage breeds of livestock, a potential exists for protected areas to contribute to the *in situ* conservation of domestic animal diversity. At the same time, resuming traditional agricultural activities can restore or maintain disturbance-dependent environments, and their associated flora and fauna, within protected areas.

Traditionally, however, the concept of a protected area follows the "Yellowstone Model" (Shelhas, 2001) requiring the area in question to be an example of pristine wilderness, free of human influence with the exception of tourism and recreation (Phillips, 2003). Amend and Amend (1995) detail many instances in which local communities' traditional subsistence activities, including cultivation and grazing, were prohibited within protected area boundaries, as such activities were deemed incompatible with conservation objectives. Indeed, protected area management is replete with the challenges of balancing and/or rectifying the needs of local human inhabitants with those of the natural environment (Brandon and Wells, 1992; McNeely and Ness, 1995).

Some argue that landscapes modified by human activities have no place within a system of protected areas. For example, Locke and Dearden (2005) assert that recognising areas modified by humans as worthy of protected status undermines the fundamental goal of protected areas to protect wild diversity. Such an argument assumes that human use of a landscape necessarily comes at the expense of wild biodiversity. This notion that human-environment interactions are necessarily deleterious underlies approaches to protected area designation and management throughout most of the history of protected areas; however, philosophies driving approaches to protected area designation and management are changing (Kalamandeen and Gillson, 2007).

Increasingly many areas that have been, and continue to be, modified by human activity are being recognised, nonetheless, as ecologically valuable and worthy of protection (Phillips, 2002; Brown *et al.*, 2005; Kalamandeen and Gillson, 2007). Consequently, some protected areas are now concerned with actively restoring and conserving traditional cultural practices that have formed, and maintain, such cultural landscapes (Aitchison, 1984; Participants of the International Symposium on Protected Landscapes, 1987; Phillips, 2002).

Most protected areas fit into one of the following six categories identified by the IUCN, though there are certainly instances in which a protected area conforms to more than one of the category descriptions. The six IUCN categories of protected areas are:

I. Strict Nature Reserve/ Wilderness Area, managed primarily for science and/or wilderness protection;

II. National Park, managed mainly for ecosystem protection and recreation;

III. Natural Monument, managed primarily for the conservation of specific natural features;

IV. Habitat/Species Management Area, managed mainly for conservation through management intervention;

V. Protected Landscape/ Seascape, managed mainly for the protection of landscape/ seascape, traditional land uses and recreation; and

VI. Managed Resource Protection Area, managed primarily for the sustainable use of natural ecosystems (IUCN, 1994).

These categories reflect the range of management objectives that have expanded as philosophies related to the protection of nature have diversified. As mentioned above, protected areas were initially established to preserve examples of pristine wilderness, protecting them from what was perceived as the destructive nature of humankind, even though the very "wilderness" in early parks such as Yellowstone National Park and Kruger National Park actually had been inhabited and used by indigenous peoples for centuries (Kalamandeen and Gillson, 2007). In the early 20th century, Gifford Pinchot championed a different approach to resource management, advocating "wise use" of natural resources; e.g., a sort of utilitarian middle ground between wasting resources through non-use (strict preservation) and destroying resources through over-use (unregulated exploitation) (Pinchot, 1909/2000). In time, concern shifted from establishing protected areas for their outstanding scenic value or development potential as natural resources to preserving species for their intrinsic and scientific values (Kalamandeen and Gillson, 2007). An extension of this concern to prevent species extinction was another shift that focussed not only on the conservation of individual species but also of these species' habitats and overall ecosystem functions within the "ecosystem approach" to protected area management (Kalamandeen and Gillson, 2007). Key elements of the ecosystem approach that are absent from earlier approaches to conservation include: a) its emphasis on multiple scales of biological diversity; b) its recognition of the importance of ecosystem functions including the role of disturbance; and c) the inseparability of humans from nature (Grumbine, 1994).

BIOLOGICAL DIVERSITY

In 1992, the Convention of Biological Diversity called for global concerted efforts to halt the loss of genetic, species, ecosystem and landscape diversity. Biological diversity (or biodiversity) was defined at the convention as:

> the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Several factors are associated with biological diversity and influence the distribution, abundance and variability of terrestrial organisms. Globally, there is a general gradient of greater biological diversity from the poles towards the equator (Gaston, 1996) and from higher to lower altitudes (Stevens, 1992). Time is also associated with biological diversity when considering the patterns of species colonization and extinctions. MacArthur and Wilson's (1963) classic study of island biogeography suggests that species richness is determined by a point at which the rates of recruitment and extinction are equal: the number of species reaches equilibrium. The species themselves may come and go, but species richness is stabilized by new species appearing just as fast as existing species become extirpated. MacArthur and Wilson's (1963) theory predicts that area and isolation are also important factors in determining biological diversity as these factors are related to rates of recruitment and retention of species. Thornton *et al.* (1988) found when revisiting MacArthur and Wilson's study site, Krakatau, that repetitive disturbances to some habitat patches delayed extinction rates – new volcanic eruptions created early successional habitats that attracted species that were declining as vegetation on the older islands was developing into more mature habitats.

A Finnish example of this latter phenomenon, also called global habitat continuity, involves the marsh fritillary butterfly (*Eurodryas aurinia*) in eastern Finland, as its host plant depends on clearings in the forest that are 2 to 10 years old. Provided that new habitats become available within the dispersal range of the host plant (and the butterfly) as existing habitats mature and become unsuitable, the butterfly may persist in the long-term (Hanski, 1999).

In the next section the role of disturbance is discussed in relation to the maintenance of biological diversity and ecosystem functions, which are two of the main priorities of protected areas that adhere to the ecosystem management approach to conservation.

DISTURBANCE

Whether or not one accepts the contested notion of an ultimate climax community (Glenn-Lewin and van der Maarel, 1992), it has long been observed in a number of environments and at a variety of scales that some form of succession occurs, that is, assemblages of organisms in a given area change over time, even if environmental variables (e.g., precipitation, air temperature) remain constant[13] (McCook, 1994). The dynamics of succession are affected by factors such as life histories, inter- and intra-specific competition and adaptability of individuals and groups of organisms to various points along environmental gradients (McCook, 1994). In addition, disturbance can have a major impact on the dynamics of succession (White, 1979).

White and Pickett (1985) define disturbance as "any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment" (p.7). The intermediate disturbance hypothesis (Connell, 1978) proposes that moderate levels of disturbance (along continua of frequency, size and intensity) result in the highest levels of diversity. This hypothesis states that the frequency of disturbance affects levels of biodiversity. Between frequent disturbances, according to this hypothesis, there is not enough time to enable any but the earliest colonisers to become established. At the other extreme, when intervals between disturbances are maximal, the most efficient competitors and/or those that are most resistant to damage or death will dominate and eliminate those that are competitively less efficient and/or prone to damage or death. Presumably the early colonizers are different organisms than those that dominate long after disturbances; thus, at moderate disturbance frequencies a mix of early colonisers and those that take more time to colonize can become established. At moderate disturbance frequencies, disturbance theoretically reoccurs before any of the organisms becomes too dominant.

With respect to spatial scale, the intermediate disturbance hypothesis postulates that if a disturbance kills all organisms in a large area, only the organisms able to disperse the furthest and also withstand exposed conditions can colonize the centre of

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[13] The organisms, themselves, may drive micro-environmental changes by fixing nitrogen, increasing organic content of the soil, creating shade, etc.

the disturbed area. In very small sized disturbances, those organisms attempting to colonise the small, disturbed area are likely propagules from mature organisms that remain in adjacent areas and these propagules would have to be highly efficient competitors. Intermediate sized disturbances would allow for both types of organisms (long-distance dispersers tolerant of exposed conditions and short-distance dispersers efficient at competing in more closed environments) to become established.

Finally, the intermediate disturbance hypothesis suggests that moderately intense disturbances would result in higher diversity. Following the most intense disturbances that eliminate all organisms in an area, the area would become re-established by new propagules. With minimally intense disturbances, few organisms would be affected and the most competitive species would dominate, likely at the expense of many early colonizers. When disturbances are moderately intense, some organisms survive and others do not, so a mix of survivors and new colonisers would result in higher diversity.

TRADITIONAL AGRICULTURE

In addition to natural disturbances, human activities can cause disturbance. European forests evolved in response to thousands of years of both natural and anthropogenic disturbances (Bengtsson *et al.*, 2000). In this section, various forms, roles and effects of traditional agriculture are examined as anthropogenic disturbance mechanisms. But before discussing the ways in which traditional agricultural practices contribute to ecological disturbances, “traditional agriculture” should be defined.

Defining “traditional”

It is difficult to define what constitutes “traditional” (Finnegan, 1991), as what was traditional or historic at one moment in time was modern and new in relation to earlier times. Shils (1971) explains that:

> the terms ‘tradition’ and ‘traditional’ are used to describe and explain the recurrence in approximately identical form of structures of conduct and patterns of belief over several generations of membership or over a long time within single societies (with a more or less delimited territory and a genetically continuous population) and within corporate bodies as well as over regions which extend across several bounded territorial discrete societies which are unified to the extent of sharing in some measure a common culture – which means common traditions (pg 123).

Although commonalities can be found among agricultural practices within a community, Johnson (1972) cautions against the common assumption that those who practice traditional agriculture rigidly conform to a set of rules that dictate how, when and why their agricultural activities are practiced. Instead, Johnson points out that there is variation in the ways such rules are adhered to based on social (e.g., amount of labour and skill available in a farmer’s family, the number of family members to feed) and environmental (e.g., soil conditions, climate, aspect, etc.) circumstances of individual farming households. “Experimentation is probably as natural as conformity in traditional communities”, states Johnson (1972, p.156), who highlights a number of examples of traditional farmers’ enthusiasm to try new farming technologies, such as experimenting with new varieties of crops. Thus, traditional agriculture is rooted in past practices that are passed down through time, but these practices are bound to change as variations and experimentation lead to innovations that are subsequently passed down from generation to generation.

Thus, the dynamic nature of traditional agriculture presents a definitional problem of distinguishing between innovations within an evolving tradition and importing of non-traditional technologies. For the purposes of this study, Franklin's (1990) discussion of technology is drawn upon. *Holistic technology*, according to Franklin, occurs when all aspects of production can be performed by an individual whereas *prescriptive technology* exists when different actors each control a specific aspect of production. Because agricultural tasks in traditional practices were often beyond the capacity of one individual and involved cooperation from family and neighbours, Franklin's definition of holistic technology is extended here to the household or community level. Traditional agricultural practices would involve holistic technologies: i.e., the farmer (and family and neighbours) would decide the amount and quality of seed reserved from previous crops; they would obtain fertilizer for fields either through burning vegetation or spreading manure from the family's livestock; the livestock would be raised by the family, possibly exchanged among kin for breeding purposes; harvesting would be done by hand and/or using livestock for traction; and knowledge of these practices would be transferred experientially between generations. In traditional agriculture, supplies, energy and knowledge are generally endogenous to the household or community, and production is more or less under the control of the farmer from sowing to harvest.

On the other hand, for the purposes of this study, non-traditional agricultural practices tend to employ prescriptive technologies. Examples include practices that place control of agricultural production from sowing to harvest primarily outside the control of the farmer/family/community: e.g., obtaining seeds from corporations that specialize in the development of "superior" seeds; utilizing manufactured chemical fertilizers; using tractors that are made of and run on non-local materials; breeding livestock through artificial insemination whereby genetic material is ordered from a distant source and likely administered by specialists unrelated to the farmer; and acquiring training and knowledge from specialized training institutes or government representatives. Of course, even traditional practices have some reliance on tools, for example, that cannot be sourced from or made by the farmer or his/her land (e.g., even if harvesting is done by hand, the sickles probably are not made on the farm from mineral deposits therein). Nevertheless, agricultural production (other than environmental factors) is *primarily* within the traditional farmer's control whereas non-traditional farmers tend to rely on an ultimately global network of suppliers of genetic material, machinery, energy and information for the majority of the production of agricultural goods.

In the following sections, three traditional agricultural practices are described that are related to livestock husbandry along with a discussion of ways they act as forms of ecological disturbance and/or their effects on biological diversity. Traditional agricultural practices such as some forms of crop cultivation or fruit production that do not, or minimally, involve livestock are not included in the discussion. Although many practices are common in several areas around the world, a characterization of all regional variations of each practice is beyond the scope of this dissertation. A broad description of each practice is provided and the discussion of the practices' ecological implications is based on the ways the traditions are/were implemented in eastern Finland and other parts of northern Europe.

Swidden Cultivation

Burning to create temporary clearings and increase soil fertility has been practiced in many areas of the world, including France, Germany, Switzerland, Belgium, Finland, Sweden, Russia, Estonia, India, South Africa, North America, Sri Lanka, Indonesia, the Philippines, Japan and Korea (Brown, 1883; Brown, 1884; Froment, 1981; Otto and Anderson, 1982; Raumolin, 1987; Jordan and Kaups, 1989; Myllyntaus *et al.*, 2002; Poska and Saarse, 2002). Although several different terms are used to describe such practices (e.g., burn beating, *sartage*, shifting cultivation, slash and burn, *svedjebruk*, etc.), the term swidden, in accordance with Raumolin (1987), is used throughout this dissertation. In general terms, swidden cultivation is a means of both clearing and fertilizing otherwise non-arable land. It involves felling the existing vegetation, usually forest, then allowing the felled vegetation a period to dry sufficiently to enable it to burn more or less thoroughly. Crops are then planted in the ash-fertilized clearing for as long as the soil produces an adequate yield. After the last harvest, the clearing would be left fallow and possibly grazed by livestock. Once the vegetation ultimately regenerated back to its original condition, the cycle would begin again.

As a form of ecological disturbance in Finland, swidden agriculture had considerable impact. Because the objective of burning was both to clear and to fertilize, as complete a burn as possible would be desirable. The burns would affect the entire clearing and efforts would be made to ensure a complete burn by rolling partially burned logs towards the flames or piling and reburning the logs a second time (Soininen, 1959). Therefore, all aboveground matter would have been exposed to the fire. If the fire was not too intense, some plant species could regenerate vegetatively or from the release of fire-tolerant seeds in the seedbank (Schimmel and Granstrom, 1996) whereas other colonizers would have to disperse from unaffected areas. When crop seeds are sown in the first few years post-burn, swidden cultivation likely inhibits, at least in part, the initial colonization of natural vegetation through competition with the sown vegetation; however, no studies were found that researched post-fire competition between cultivated plants and wild plants within swidden plots.

The intensity of burn and the pre-burn accumulation of biomass influences the effect of swidden practices on soil characteristics. Delgado (2004) found that the swidden fires decreased soil acidity, with an increase of pH by up to 1.3 units in a *huuhta*[14]-type swidden burn conducted in Koli (site "r&s B96" in this study, see Appendix A and Table 4.1). A less pronounced increase of 0.24 pH units was detected in the *kaski*-type swidden burn in the park (site "oll sab" in this study, prior to sheep grazing). Burns of both types significantly increased calcium levels in the soil with 1.66 g/kg in non-burned sites versus 3.94 – 4.33 g/kg in burned sites (Delgado, 2004).

The various forms of swidden cultivation described by Soininen (1959) differ in the length of time between swidden cycles from as little as 15 years to as many as 50 years. Between 1450 and 1550 AD clear palynological (pollen-based) evidence in Lake Pitkälampi, approximately 90 km southeast of Koli (Grönlund and Asikainen, 1992) indicates swidden cultivation using rye (*Secale cereale* L.) on a 30 year cycle. At Patvinsuo National Park (approximately 50 km east of Koli) fire scars on Scots pine (*Pinus sylvestris* L.) revealed fire intervals associated with swidden cultivation[15]. From

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[14] Descriptions of different types of swidden burns can be found in Chapter 4, pages 91 and 92.

[15] Since the fire frequencies were much higher than frequencies of natural wildfires in other boreal forest environments, the fires are interpreted to have anthropogenic origins

these fire scars, Lehtonen *et al.* (1996) found fire intervals ranging from seven to 67 years, with the greatest number of fires and shortest interval between fires occurring from around 1770 to 1830.

Ruokolainen and Salo (2006) documented the patterns of vegetation succession for 10 years following swidden burning and cultivation treatments in the boreal forest of Koli National Park. Plant species richness peaked six years post-burn and remained more or less constant in the following four years. The year of the burn and one year post-burn, species richness of vascular plants and bryophytes was lower (19 spp and 26 spp, respectively) in the swidden plots than in the unburned control plots (42 spp). Plant species richness was approximately equal to the unburned control plot two to four years post-burn (+/- 2 species). Plant species richness was higher six, eight and 10 years post-burn (68 spp, 59 spp and 60 spp, respectively) than in the unburned control plots. Fireweed (*Epilobium angustifolium* L.) and raspberry (*Rubus idaeus* L.) were the first two vascular plant species to colonize the post-burn plot. *Epilobium angustifolium* remained the dominant species for the following six years after which a reedgrass (*Calamagrostis arundinacea* [L.] Roth) dominated. The percent cover of *R. idaeus* peaked in year two and gradually declined in coverage to negligible levels by year eight. The percent cover of each of the woody species (*Betula spp., Picea abies* [L.] H. Karst*,* *Pinus sylvestris*, *Prunus padus* L.*, Salix caprea* L. and *Sorbus aucuparia* L.) remained below 1% for the first six years, except for birch (*Betula spp.*), which reached 3% cover in years six and eight. The tree species that reached the highest percent cover was *P. abies* at 11% cover in year 10 of the study. The swidden sites examined in Ruokolainen and Salo's (2004) study had not had any grazing activity by livestock – a condition that

as intentional swidden burns or swidden fires that got out of control and escaped their intended boundaries.

normally would have been common when swidden cultivation was regularly practiced in the area prior to 1930. Their results, therefore, represent only the effect of burning and post-burn recovery and do not represent any changes that would occur as a result of selective herbivory of livestock in the swidden cycle.

Like the periodic volcanic eruptions on Krakatau, the cyclical nature of swidden cultivation may have served as a means of creating global habitat continuity as plots in every stage of regeneration continued to be created.

Grazing and Haymaking

Traditionally, grazing in eastern Finland involved pasturing livestock in semi-natural meadows, woodlands or forests. In Finland, the land is covered with snow for 90 to 210 days, with an average of 150 – 180 days of snow cover in eastern Finland (Finnish Meteorological Institute, 2011). So harvesting winter forage for livestock is necessary. Traditional haymaking involved harvesting vegetation from clearings using manual labour and tools such as a sickle or scythe. In traditional techniques for making hay, vegetation was not sown[16], fertilized or irrigated, nor had the drainage of the harvested area been physically altered by tiling or creating ditches. The clearings used for haymaking likely originated as swidden fields that remained in an open state as a result of annual haying, rather than being left for woody vegetation to regenerate. Such meadows are termed semi-natural meadows, referring to their anthropogenic origin, yet composition of wild grasses and herbs.

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[16] Use of hay seed was uncommon prior to the 1890s (Marttila *et al.* 1999).

Grazing and making hay are discussed together in this section because they are linked as necessary components of livestock husbandry, their effects on vegetation are similar and because several studies related to the traditional management of meadows include both grazing and mowing.

Habitats created or maintained by grazing and/or haymaking are rare in Finland, with semi-natural meadows, grazed woodlands and forest pastures each currently representing less than 1% of their extent from the late 1800s (Luoto *et al.* 2003b, Raunio *et al.* 2008). As mentioned earlier, Marttila *et al.* (1999) report that 27% of Finland's threatened plant species are in decline mainly due to the cessation of grazing or haymaking. Of all Finland's threatened[17] species, over-growing of meadows following cessation of grazing or hay cutting is listed as one of the threats to five (10%) vertebrate species, 256 (34%) invertebrate species, 77 (43%) vascular plant species, 17 (12%) cryptogram species, and 43 (11%) fungi species (Rassi *et al.*, 2001). Of Finland's 111 threatened species found in "wooded pastures and meadows" in particular, 81% are threatened at least in part by cessation of grazing or haymaking in such habitats (Rassi *et al.*, 2001).

As agents of anthropogenic disturbance, both haymaking and grazing result in a reduction of above-ground biomass. In the case of haymaking, cropping occurs at a more or less uniform height and takes place over a short period of time (1-2 days). In contrast, grazing is a not a discrete event, though in rotational grazing practices it can be periodic (with short periods of intense grazing followed by periods without grazing). The greatest difference between mowing and grazing, according to Rook *et al.* (2004) is a function of the behaviour of the grazing animal, which, through selective herbivory,

[17] Listed as Critically Endangered, Endangered or Vulnerable in the 2000 IUCN list of Threatened Species.

trampling and nutrient cycling, leads to structural heterogeneity of the vegetation. Grazed swards are inconsistently distributed depending on the species (and possibly breed) of grazer, plant palatability, the presence of any mechanisms that the plant developed to deter herbivory, and when and how often the plant is encountered (Rook *et al.*, 2004; Wissman, 2006).

Haymaking or grazing can inhibit the growth or reproduction of some plants, though some species can tolerate over 50% defoliation without any noticeable effect on fitness (Hendrix, 1988). Some plant species may benefit from grazing; McNaughton (1979) found that plant growth could be stimulated under moderate grazing pressure by native wild ungulates, a phenomenon that he termed "compensatory growth". The removal or reduction of tall vegetation may provide improved access to sunlight for shorter plants that are otherwise competitively disadvantaged by shading. In a six-year experiment in upland hay meadows in the Czech Republic that contrasted intensive grazing, intensive grazing following annual mowing, extensive grazing, extensive grazing following annual mowing and an unmanaged control plot, species richness increased moderately in all grazed plots (Pavlu *et al.*, 2007). In their experiment, Pavlu *et al.* (2007) found that grazing significantly reduced the percent cover of tall grasses and tall forbs, whereas both of these groups increased significantly in percent cover in the unmanaged control. Meanwhile, short grasses and prostrate herbs increased in percent cover in grazed plots and were suppressed in the unmanaged control plots.

The timing of grazing or mowing may affect plant reproduction. Wissman (2006) found that fruit production and seedling density was lower in semi-natural meadows continuously (May to early October) grazed by steers at a density of 1.8 steers per hectare than in comparable meadows with delayed grazing (from late July to early

October), or with grazing occurring only every second year. The delayed grazing and bi-annual grazing allowed a longer period for plants to mature and set seed prior to disturbance by the cattle, favouring earlier-flowing plants. After six years of delayed grazing, species richness was significantly higher than in continuously grazed semi-natural meadows. Delayed grazing and allowing one fallow year for every two years of grazing creates a possible a risk of reduced seedling germination and survival due to increased competition with already established plants and thicker litter layer. However, Wissman found 4-5 times greater seedling density in the delayed and biannual grazed sites than in the continuously grazed site. Thus, Wissman (2006) concluded that the negative effects of disturbance within continuous grazing treatments were greater than the negative effects of increased competition among plants within the delayed grazing treatment.

Hellström *et al.* (2006) evaluated the effects of different mowing treatments: mowing in late June, mowing in August, mowing in August plus ground disturbance and an untreated control. No statistical difference in species richness was found between treatments, but abundance of some individual species was affected by the treatments: e.g., late mowing favoured tall herbs such as *Geranium sylvaticum* L., while small herbs such as *Campanula rotundifolia* L. increased with late mowing plus ground disturbance. Early mowing prevented the decline of *Pilosella officinarum* F. W. Schultz & Sch. Bip. [coll.], which declined in the other treatments.

When livestock consume plants and when humans harvest hay, they remove nutrients and organic matter from pastures that would otherwise be incorporated and recycled into the soils upon decomposition. Unidirectional nutrient flow as meadows are harvested for hay, and as manure is collected and deposited on crop fields (rather than back on the hay meadows), is considered to be one of the factors that characterises some of Finland's most valuable meadows. The rarer meadow species appear to be adapted to low nutrient conditions as they fare better without competition from plants that thrive in nutrient rich conditions (Hansson and Fogelfors, 2000). These findings are consistent with Myklestad and Sætersdal's study (2004) that found higher levels of plant species richness in traditional meadows than in meadows that had been fertilized.

Pykälä (2003; 2005) investigated the response of mesic semi-natural meadow vegetation in Finland to continuous long-term cattle grazing and cattle grazing resumed only three to eight years prior to sampling. He compared these treatments with meadows in which grazing had not occurred for over 10 years. Plant species richness was highest in the meadows that had not had an interruption in annual grazing (252 spp, including 50 spp exclusive to these old pastures), followed by the meadows in which grazing recently resumed (209 spp, including 13 species exclusive to these re-established pastures), followed by the abandoned areas (156 spp, including 19 species exclusive to these fields) (Pykälä, 2003). Forty-two plant species were positively associated with grazing, four tall species were positively associated with abandonment and 31 species did not differ significantly in frequency or percent cover between grazed and abandoned treatments (Pykälä, 2005).

Hellström *et al*. (2003) investigated the effects of reintroducing sheep grazing for five years on semi-natural grassland that had been used as pastureland until 1969 and then occasionally grazed in the 1980s. They found that grazing at a stocking rate of 15 sheep in an area of ~1.5 ha increased the average number of plant species per plot by 29.5%; however, the increase was mainly a result of the dispersal of species already present in the community rather than the reestablishment of extirpated species from the seed bank or dispersal of new species from distant sources. Early flowering tall herbs were little affected by grazing. Grazing did have a significant negative effect on late flowering tall herbs ($P < 0.001$), suppressing *Epilobium angustifolium* and *Filipendula ulmaria* [L.] Maxim. by the end of the experiment. Small herbs indicative of rich soil (i.e., *Cerastium fontanum* Baumg., *Geum rivale* L., *Ranunculus acris* L., *Silene dioica* [L.] Clairville, *Stellaria graminea* L., *Trifolium pratense* L. and *Trollius europaeus* L.) increased in both grazed and ungrazed plots over time, but declined in the ungrazed plots by the end of the study. Small herbs indicative of poor soil (i.e., *Botrychium lunaria* [L.] Sw., *Campanula rotundifolia* L. and *Rhinanthus minor* L.) increased in the grazed plots over time, but the increase was not significant relative to the ungrazed plots. No significant effects of grazing were found on grasses indicative of rich soils. Grasses indicative of poor soil, mainly *Agrostis capillaris* L., significantly increased in cover with grazing ($P < 0.001$) over time; whereas this group decreased in the ungrazed plots by the end of the study.

Lindborg and Eriksson (2004) compared dry, dry-to-mesic and mesic-to-wet meadows that had been continuously grazed for at least 50 years by imported beef cattle (Lindborg, personal communication, February 2009) with meadows of similar moisture regimes that had historically been grazed by cattle, abandoned and then grazed again by cattle for up to the past seven years. Species richness was consistently higher in the continuously grazed meadows compared with those that had been abandoned and then grazed again. They also found that time since grazing had been resumed was positively correlated with plant species richness. Presence of trees and shrubs was also positively associated with plant species richness, probably because trees and shrubs along with grazing created a range of conditions suitable to a greater variety of plant species. Over the seven years of restoration investigated by Lindborg and Eriksson (2004), no rare or endangered species had reappeared at any of the meadows in which grazing had resumed after a period of abandonment.

Kotiluoto (1998) evaluated the effectiveness of thinning and mowing on vegetation in the SW Archipelago National Park, Finland, where grazing occurred in all treatment areas. Her research revealed that all three treatments (grazing, mowing and thinning of woody plants) combined was most effective at restoring richness and cover of herbs and grasses; however, these effects in the absence of grazing could not be ascertained.

Hansson and Fogelfors (2000) evaluated the effects of burning, grazing, mechanical and chemical removal of woody vegetation, mowing once per year and mowing once every three years on semi-natural grasslands in Sweden, each as separate treatments over a 15-year period. They found that annual mowing significantly increased species richness of the site over the 15-year period. Continuous grazing and mowing every three years resulted in relatively stable levels of species richness over the treatment period, each with slightly fewer species in the final year of the study than in the annually mowed plots. The remaining treatments all resulted in significantly lowered plant diversity over the 15-year period with final levels of plant species richness lower than in the annually mowed and continuously grazed plots.

The Role of Heritage Breeds in Traditional Agriculture

With the exception of Hellström et *al.'s* (2003) study, which likely involved Finnsheep grazing[18], none of the studies cited in the above section on grazing and haymaking involved heritage breeds of livestock. Little research has been conducted to ascertain whether grazing by heritage breeds in particular has any ecological benefit over grazing by more conventional imported breeds. The fact that the breed (e.g. Tamm, 1956; Hansson and Fogelfors, 2000; Krahulec *et al.*, 2001; Hellström *et al.*, 2003; Pykälä, 2005; Wissman, 2006; Pavlu *et al.*, 2007) and sometimes the species (e.g. Lindborg and Eriksson, 2004) of grazing animal escapes mention in some published research findings about the effects of grazing suggests that the authors of such papers attribute little consequence to the type of animal grazing on the phenomena studied. These factors though, do warrant attention, as discussed below.

Rook *et al.* (2004) highlight many anecdotal statements from the literature that suggest that heritage breeds are better suited for use in nature restoration programs, but point to the need to substantiate such claims with sound research. Results from the few studies that have compared grazing effects of heritage versus imported, mainstream breeds indicate that biodiversity is not affected by breed origin. Recent studies (Rook *et al.*, 2004; Scimone *et al.*, 2007; Wallis De Vries *et al.*, 2007) found no difference in biodiversity between sites grazed by conventional versus traditional breeds of cattle and sheep when stocked at similar densities. However, one of the cattle breeds classified as "traditional" in these studies was actually a recently developed crossbreed between an

[18] The authors did not specify the breed of sheep involved, but because Finnsheep are the most common breed of sheep in Finland, this assumption is made.

exotic breed and a heritage breed. In addition, one pair of conventional and traditional breeds of cattle in the study originated from nearly the same area, which suggests that both may have been well adapted to the local conditions to begin with. Overall, these studies, although involving breeds in four different countries over three years, may have failed to detect differences between breeds that could not be captured by their experimental design (e.g., only summer grazing was observed), or the differences were more subtle and may require longer observation periods to detect.

Jauregui *et al.* (2008) also did not find any significant differences in plant species richness or diversity, nor in grasshopper density, between heather-gorse shrubland sites grazed by heritage goats versus sites grazed by imported goats (both at high stocking densities). However, they did find that grazing by the heritage breed over three years resulted in significantly greater structural heterogeneity with decreased shrub cover and increased dead matter compared with grazing by the imported breed over the same time period.

The context of swidden agriculture and wooded areas associated with grazing in particular may point to ways in which heritage breeds of livestock in eastern Finland are uniquely adapted versus imported breeds. Both the Eastern Finncattle and Finnsheep are reputedly well adapted to extensive conditions and have a propensity to browse woody vegetation in addition to grazing herbs and grasses. It is possible, then, that they play a significant role in altering succession patterns in burned swidden clearings and in areas used as forest pastures.

INSEPARABILITY OF HUMANS AND NATURE

A final concept that underlies an ecosystem approach to the management of protected areas is the notion that anthropogenic and natural elements of ecosystems cannot always be easily disentangled from one another. In fact, rather than describing natural and anthropogenic effects as exclusive, dichotomous categories, some authors suggest that they form two ends of a continuum that range from strictly human–caused effects, through effects of both human and natural origin, and finally to outcomes caused strictly by natural forces (Melnick, 1996; Dale *et al.*, 1998; Perera and Buse, 2004). Ecologically, anthropogenic and natural forces can have similar effects, as described earlier in this chapter, and when their impacts are different from one anther, it is not necessarily the case that anthropogenic elements of landscapes are ecologically detrimental (Dale *et al.*, 1998). It is also the case that past management actions have effectively eliminated some natural forms of disturbance to the point that human intervention may be necessary to maintain or reinitiate natural-like disturbance regimes (e.g., the use of prescribed burns in protected areas surrounded by lands in which natural fires are actively suppressed).

Furthermore, support from the public, especially from those living in and around protected areas, is vital to the success of conservation initiatives. Though ideally informed by scientific knowledge, human values ultimately drive decision-making in the management of natural resources (Grumbine, 1994; Grumbine, 1997). Consequently, protected area managers must not only consider the ecological consequences of management decisions, they must also consider the impacts of such decisions on human stakeholders. Many such stakeholders own or utilize land within or adjacent to protected area boundaries and are personally affected by decisions that dictate how they may utilize such lands. So while there may be strong ecological rationales for encouraging traditional forms of agriculture and restricting non-traditional agricultural practices, the economic and social well-being of local citizens must be considered by managers of protected areas. Beresford and Phillips (2000) state "whereas protected areas were once planned *against* people, now it is recognised that they need to be planned *with* local people, and often for and by them as well" (p. 19).

ANTICIPATED SIGNIFICANCE OF THIS WORK

Much has been made of the role of protected areas in conserving plant genetic resources of interest for food and medicine (Prescott-Allen and Prescott-Allen, 1983; Oldfield and Alcorn, 1987; Guzmán and Iltis, 1991; Vaughan and Chang, 1992; Nabhan *et al.*, 1998; Nabhan and Tuxill, 2001; Phillips, 2002; Stolton *et al.*, 2006; Argumedo, 2008; Bassols Isamat *et al.*, 2008; Nozawa *et al.*, 2008; Sarmiento, 2008). However, the contribution of protected areas to the conservation of domesticated animal genetic resources has received relatively little attention until recently (Henson, 1992; Woelders *et al.*, 2006; Bassi and Tache, 2008; Cole and Phillips, 2008; Ivanov, 2008; Pokorny, 2008; Rosenthal, 2008). Previous attempts to describe the role of parks in conserving the diversity of livestock breeds generally focussed on no more than seven examples (Maijala, 1987; Henson, 1992; Delescaille, 2002; Harrington, 2002; Gugic, 2008), a single country (Audiot, 1983; Matzon, 1986; Audiot, 1995; Audiot *et al.*, 2005) or one region (Lauvergne, 1980). While the global review in Chapter 2 of this dissertation is by no means an exhaustive account of every protected area that allows or promotes the use of heritage and/or at-risk breeds within its boundaries, it is, to the author's knowledge, the most comprehensive attempt thus far to list and characterize the locations and ways in which heritage and/or at-risk breeds of livestock are used in protected areas.

Further, the case study of heritage sheep and cattle grazing in Koli National Park in Chapter 4 will add to the few studies addressing the gap in knowledge relating to the use of grazing as a vegetation management tool for disturbance-dependent meadows and woodlands when compared with other vegetation management options. The emphasis on the use of heritage breeds for this purpose provides much needed information for decision-makers, especially given increased interest in conserving heritage breeds within protected areas. The use of historic ecology as a framework for the case study will inform decision-making for the management of current and future landscapes – what Swetnam *et al.* (1999) term Applied Historical Ecology. Such an approach is advocated by Hellberg *et al.* (2003), for example, to avoid oversimplifying and incorrectly interpreting reference conditions for the ecological management of vegetation.

In addition, the use of traditional knowledge held by local farmers in Chapter 3 to provide context to field studies is an under-used approach (Riley, 2004), especially in developed countries and when involving non-aboriginal informants. Finally, this research will be the first attempt to describe and analyse the role of heritage livestock grazing as a form of vegetation management within the context of restoring traditional swidden agriculture in the boreal forest.

SUMMARY AND OVERVIEW OF CHAPTERS TO FOLLOW

This introductory chapter highlighted the problem that the discontinuation of traditional agricultural practices has led both to the loss of many heritage breeds of livestock and to the decline in disturbance-dependent semi-natural habitats. The resumption of these practices could help reverse such losses and protected areas may be a good place to do so. This dissertation examines how protected areas can benefit from, and contribute to, the conservation of heritage breeds of livestock through an examination of the extent and nature of their use in protected areas world-wide, as well as through an in-depth case study of the Koli National Park in eastern Finland where heritage cattle and sheep are used to restore and maintain disturbance-dependent habitats within a boreal forest landscape. Key concepts of ecological diversity, the contribution of natural and anthropogenic disturbance to ecological diversity, traditional agricultural practices as forms of disturbance, and the characteristics of heritage breeds of livestock as potentially unique elements of disturbance were discussed in this chapter. Chapter 2 presents the broad review of the use of heritage and/or at-risk breeds in protected areas worldwide. Chapters 3 and 4 contain the results from the case study. Chapter 3 focuses on the assessment of current versus historic agricultural practices in the case study area. Chapter 4 presents the analysis of the effects of grazing by heritage Finnsheep and to a lesser extent heritage Eastern Finncattle, and other forms of vegetation management related to traditional agricultural practices at Koli National Park. Chapter 5 concludes with a summary of the nature of the problem addressed through this research. Key findings and implications of these findings for future directions in protected area management and suggestions further research are also included in Chapter 5.

CHAPTER 2: GLOBAL OVERVIEW OF THE ROLE OF HERITAGE LIVESTOCK IN PROTECTED AREAS[19]

INTRODUCTION

To understand the extent to which heritage breeds are currently conserved through and used in protected areas worldwide, a content analysis of documents related to the conservation of global domestic animal diversity was undertaken. The content analysis was supplemented with a review of literature specifically focussed on protected areas in which heritage breeds exist. The content analysis of 167 country reports submitted for the FAO's State of the World's Animal Genetic Resources for Food and Agriculture initiative was used as a starting point to determine the extent to which protected areas are recognized as means of conserving domestic animal diversity. For countries where protected areas were reported to help conserve the diversity of domesticated animals, additional details were sought from a review of related literature. This overview was not exhaustive, and no-doubt under-represents the actual number of cases in which heritage breeds are used within protected areas; however, it does represent a comprehensive overview of the current information. Results of the content analysis and themes deriving from an extended review of literature are presented. A discussion of the trends revealed by the content analysis and additional literature summarizes the various ways in which protected areas and heritage breeds of livestock can coexist. Finally, recommendations

[19] The majority of this chapter has been published as Rosenthal, J. S. (2010) A review of the role of protected areas in conserving global domestic animal diversity. *Animal Genetic Resources* 47, 101-114.

are provided for future research that could lead to a more exhaustive assessment of the extent to which heritage breeds are conserved within protected areas.

METHODS

This component of the study was designed to assess the extent to which national bodies recognize that parks and protected areas may serve as suitable sites to conserve domestic animal diversity. Specific examples of how such areas are utilized for this purpose are reviewed in an attempt to characterise the various roles of protected areas in the conservation of heritage breeds and/or rare breeds of livestock.

In 2001, the FAO invited 188 countries to participate in the preparation of the first report on the state of the world's animal genetic resources (AnGR) by preparing an assessment of their national animal genetic resources by the end of 2005. Guidelines and training were provided by the FAO in an attempt to standardize the content of each country's report as much as possible. The objectives of the country reports were:

> "a) to analyze and report on the state of AnGR, on the status and trends of these resources, and on their current and potential contribution to food, agriculture and rural development; b) to assess the state of the country's capacity to manage these essential resources, in order to determine priorities for future capacity building; and c) to identify the national priorities for action in the field of sustainable conservation and utilization of AnGR and related requirements for international co-operation" (FAO, 2001, p.8).

Information on the role of protected areas in conserving domestic animal diversity was not explicitly solicited in the FAO guidelines (FAO, 2001).

In January 2008, reports from 169 countries were available on-line from FAO's Domestic Animal Diversity Information System (DAD-IS) (FAO, 2008). Of those reports, 119 were available in English, 28 in French and 20 in Spanish. Some reports were submitted in English or French, as well as in an additional language. One report was submitted only in Italian and another only in Portuguese. Because translations could not be obtained, these two reports were excluded from the analysis. Thus, the 167 reports in English, French, or Spanish were reviewed for terms relating to protected areas.

Using the search functions of Adobe Reader version 8.1.0 or Preview version 3.0.8, case insensitive searches were conducted for the following terms in English: Natur*, *Reserv*, Protect*, Park; in French: Natur*, *Réserv*, Prot*, Parc, Aire; or in Spanish: Natur*, *Reserv*, Prote*, Parque. Asterisks indicate that search terms were structured to allow for variations, mainly in suffixes, of relevant words (e.g., searching for "reserv" could return terms such as reserve, preserve, preservation area, etc.). The term "conservation" and its equivalent in French and Spanish were not used in the searches because of the frequency of their use in the body of the documents in relation to the conservation of animal genetic resources, rather than in the context of environmental conservation.

For the purposes of this analysis, a protected area is defined according to the IUCN definition (Dudley, 2008) and includes nature reserves, national parks, world heritage sites (natural), UNESCO biosphere reserves, etc. Farm parks (i.e., individual farms established to demonstrate breeds and/or farming practices) were not included in this analysis. In order to verify whether any terms relevant to protected areas were missed in the content analysis using computer software, 10% of the documents in each language (12 English, 3 French and 2 Spanish) were read in their entirety. No additional relevant cases were found from these complete reviews.

The country reports that included any of the searched terms were examined to determine the context in which the term was used. The country reports that mentioned protected areas were then categorized as: 1) currently including animal genetic resources within protected areas; or 2) advocating the involvement of protected areas in animal genetic resource conservation. Each case was further classified as: a) referring to domesticated livestock; and/or b) referring to wild forms of animal genetic resources. Sub-themes were coded in each case where heritage and/or at-risk breeds were reported within protected areas. Sub-themes included information such as whether the breeds were actively conserved (e.g., breeding programs were initiated or supported by the protected areas) or passively conserved (e.g., the breeds were simply allowed within the protected area boundary, but no actions were taken to encourage their use or reproduction) and whether the breeds were described as contributing to protected area objectives (e.g., by contributing to ecological restoration efforts, promoting tourism, etc.).

The results from the analysis of the country reports served as a starting point from which an additional literature review of scholarly publications and technical reports was conducted to obtain further information on the ways in which protected areas contributed to the conservation of domestic animal diversity and, conversely, on the ecological and socio-economic benefits offered by the breeds to the protected areas. The analysis was limited to initiatives involving heritage breeds but also considered programs involving imported breeds that are at risk of extinction according to the DAD-IS. The information from this additional literature review was used to elaborate on circumstances in which the country reports indicated some use of heritage breeds and/or at-risk imported breeds within protected areas, though full details on the nature of this use were not provided in the country reports. This literature review led to the discovery of some documents that indicated heritage breeds and/or at-risk imported breeds were used in ways or places not mentioned in the country reports; however, literature was only explicitly sought to obtain further information about the cases mentioned in the country reports. Except in regard to Benin and Croatia, no attempt was made to directly obtain further information from protected area personnel or national coordinators for animal genetic resources.

Themes from the content analysis of FAO country reports and supplementary documentation emerged inductively and the data were cyclically reanalysed and coded for common themes and trends. The themes were analysed both quantitatively (e.g., the number and proportion of reports in which a particular theme was expressed) and qualitatively (e.g., the context in which the theme was characterized, such as whether the breed was actively or passively conserved within the country's protected areas, whether livestock grazing was deemed compatible with or incompatible with protected area objectives, etc.). Data were coded manually and entered into a MS Excel spreadsheet in which each report was listed in a separate row and each theme was listed as separate column. A "1" was entered in a cell to indicate that a report for a particular country (row) did comment on a particular theme of interest (column). Simple totals of the numbers of reports expressing each theme were calculated for each column. Quantities were based solely on whether or not the theme was mentioned in the report (presence/ absence) rather than the amount or proportion of text within each report discussing each theme (Forbes, 2000). The exact wording of the relevant text was copied in adjacent cells to enable quick reference to the context in which the themes were expressed in each report. When additional information was obtained about each country's initiatives involving heritage breeds and/or at-risk imported breeds in protected areas through the review of supplementary scholarly and technical literature, these data were also analysed for congruence with the country reports.

RESULTS

Sixty-one (37%) of the 167 State of the World's Animal Genetic Resources Country Reports that were analyzed mentioned protected areas, at least in relation to conservation of biodiversity in general (Table 2.1). One third of the reports mentioning protected areas (21 countries) referred to protected areas specifically as means to conserve wild relatives of domesticated animals and/or wild game species. Sixteen reports (10% of the country reports analysed) simply mentioned protected areas as a means to conserve biological diversity in general, but were not clear whether they were referring only to wild animal species or also to domesticated species. Three countries (Peru, Philippines, Swaziland) suggested that the presence of domesticated animals served as tourist attractions in protected areas. Two reports (Chad, Burkina Faso) simply indicated that livestock existed in protected areas.

Only 15 country reports (9%) revealed that the use of some forms of domestic animal diversity was actively encouraged through programs involving protected areas. Two of these countries (Japan and the Republic of Korea) designated some at-risk breeds as natural monuments, which afforded the animals and their habitats protection. Benin reported that one nature park was involved in the conservation and development of the Somba cattle, a heritage breed, though no further details about the nature of the

Table 2.1 Contexts in which protected areas were mentioned in country reports.

Country	General Biodiversity	Wild Animals	Domestic Animals	Bees	Identified Potential[20]	Nature Conservation
Algeria	x				x	
Australia			x (feral)			
Barbados		x				
Belarus		x				
Belgium			x			x
Benin			x			
Bhutan	x					
Bolivia		x				
Burkina Faso			x			
Cameroon	x				x	
Canada		x				
Chad	x		x		x	
Chile	x					
China	x			x		
Columbia	x					
Croatia			x			
Cyprus		x				
Denmark			x		x	x
Djibouti	x					
Ecuador			x			
El Salvador				x		x
Equatorial Guinea		x				
France			x			x
Gabon		x				
Germany			x			x
Ghana		x				
Greece	x					
Guinea Bissau	x				x	
Haiti	x					
Hungary			x			x
Ireland			x			x
Japan			x			
Kenya		x				
Malawi		x				
Malaysia	x				x	
Nepal		x				
The Netherlands			x			x
Nigeria	x	x				
Pakistan		x				
Paraguay		x				
Peru		x				
Philippines			x			
Poland			x	x		x
Republic of Korea			x			
Romania			x		x	x
Saint Kitts & Nevis		x				
Sao Tome e Principe		x				
Serbia & Montenegro			x		x	x
Sierra Leone		x				
South Africa			x			
Spain			x		x	
Sri Lanka		x	x (feral)			
Suriname		x				
Swaziland			x			
Sweden			x			x
Tajikistan		x & “½ wild”			x	
Tanzania			x		x	
United Kingdom		x	x			x
Uruguay	x					
Venezuela	x					

[20] The column “identified potential” indicates that the potential for protected areas to contribute to the conservation of AnGR was identified in the country report, but no indication was given that any initiatives were actually underway.

conservation activities were provided nor could be obtained from the Benin AnGR country coordinator. Poland reported that the Konik horse (*Equus ferus f. caballus*) is maintained in forest reserves. In Ecuador, the husbandry of domestic camelids is encouraged both in and around Cotopaxi National Park. The Nepalese country report indicated that the nearly-extinct, heritage Bampudke pig is found in and around the Chitwan and Bardia National Parks, and called for the creation of a breed conservation plan to be developed in partnership with the protected area authority. In France, Parc Interregional du Marais Poitevin was noted to provide assistance to breeders of seven breeds of at-risk livestock. The French report stated that the French Federation of Regional Natural Parks also initiated a network of stakeholders to exchange knowledge and encourage collaboration for maintaining protected areas through extensive grazing, particularly with heritage breeds. Priorities in Malaysia included showcasing *in situ* conservation efforts in a park specifically dedicated to agriculture. Eight countries (Belgium, Croatia, Germany, Hungary, Ireland, The Netherlands, Sweden and United Kingdom) stated that the conservation of domestic animal diversity was encouraged by protected area managers through the use of these animals as tools for ecological management (e.g., to maintain disturbance-dependent habitats, to control invasive vegetation, to create habitat for wildlife and/or to promote biodiversity). Where information was available on the specific breeds and parks involved in conservation programs, this information has been summarized in Table 2.2.

An additional three reports (Denmark, Romania, and Serbia and Montenegro) recognized that domestic animals could provide such services in protected areas and recommended that domestic animals, especially older breeds, be encouraged to assist with nature conservation efforts. The Romanian country report indicated that domesticated animals are permitted in the Economic Zone of the Danube Delta Biosphere Reserve/World Heritage Site, but they are not allowed in national protected areas. The Romanian country report stressed the need for protected area authorities to acknowledge that heritage breeds can be important components of natural landscapes where they could be conserved while contributing to nature protection initiatives. Similarly, the Tanzanian country report identified the exclusion of heritage breeds of livestock from protected areas and game reserves as limiting the conservation of domestic animal diversity.

Themes from review of additional literature

The following discussion summarizes the themes that emerged from the additional review of scholarly articles and technical reports related to cases initially mentioned in the country reports. The main ways in which protected areas currently contribute to the conservation of global animal genetic resources for food and agriculture are discussed.

Wild animal diversity

Because the primary objective of most protected areas is to conserve wild biota, it is not surprising that the context in which most of the country reports mentioned protected areas was in regards to the conservation of game species and/or wild relatives of

Table 2.2. Specific protected areas in which heritage breeds and/or at-risk breeds are reported in the literature reviewed.

Country	Park or Protected Area	IUCN Protected Area Category	Breed	Risk Status	Source
Belgium	Hautes – Fagnes – Eifel	V	Red Ardennes sheep	END	(Delescaille, 2002)
	De Houtsaegerduinen Nature Reserve	-	Konik horse	- [21]	(Cosyns *et al.*, 2001)
Croatia	Lonjsko Polje Natural Park	V	Slavonia-Syrmian Podolia cattle Turopolje hogs	CR-M END	(Gugic, 2008)
	Nature Park Kopacki rit	V	Slavonia-Syrmian Podolia cattle Posavac horse Black Slavonian pig	CR-M NAR END-M	(Jeremic, 2008)
Ecuador	Cotopaxi National Park Chimborazo Faunal Production Reserve	II VI	Llamas Alpacas	NAR NAR	Ecuador Country Report (Rosenthal, 2008)
France	Volcans d'Auvergne	V	Farrandaise cattle	END-M	(Lauvergne, 1980; Audiot, 1983)
	Cévennes	V	Raïole sheep Poney Ariégeois Mérens	NAR NAR[22]	(Audiot, 1983) (Lauvergne, 1980)
	Landes de Gascogne	V	Landais sheep	END-M	(Lauvergne, 1980; Audiot, 1983)
	Marais Poitevin	IV	Poitou ass Poitevin horse Marachîne cattle Poitou goat Blanche du Poitou goose Gris du Marais Poitevin Marans chicken	END END-M END NAR END - NAR	(Audiot, 1983) France Country Report
	Luberon	V	Rove goat	NAR[23]	(Audiot, 1983)
	Armorique	V	Bretonne Pie-Noir cattle Monts d'Arrée (Ouessant)	END NAR[24]	(Audiot, 1995) (Lauvergne, 1980)
	Camargue	V	Camargue horse	END	(Audiot, 1995)
	Corse	V	Corsican horse	EXT	(Audiot, 1995)
	Grands Causses	V	Raïole sheep Rouge du Roussillon sheep Caussenard des Garrigues sheep	NAR NAR[25] NAR	(Audiot, 1995)
	Caps de Marais d'Opale	V	Boulonnais sheep Boulonnais horse	NAR[24] END-M	(Audiot, 1995)
	Morvan	V	Nivernais horse	EXT	(Audiot, 1995)
	Marais de Bruges	IV	Casta cattle Landais poney	END-M CR	(Audiot, 1995)
	Tour du Valat Chérine	IV IV	Casta cattle	END-M	(Audiot, 1995)
	Marais de Lavours	IV	Camargue horse Pottok poney	END END-M	(Audiot, 1995)
Germany	Rhön Biosphere Reserve	V & IV	Rhön sheep Gelbvieh cattle	NAR[26] NAR	(Pokorny, 2008)
	Solling-Vogler Nature Park	V	Exmoor ponies Heck cattle	END[27] END[27]	(Gerken and Sonnenburg, 2002)
Hungary	Hortobágy National Park	II	Hungarian grey cattle Racka sheep Mangalica pigs	NAR NAR[28] END-M	(Megyesi and Kovách, 2006)
Ireland	Killarney National Park	II	Kerry cattle Droimeann (Drimmon) cattle Maol cattle Dexter cattle	NAR[29] CR CR CR	(Harrington, 2002) (National Parks and Wildlife Service, 2005)
Japan	Misaki horse breeding area	-	Misaki horse	CR-M	Japan Country Report
	Mishima cattle place of origin	-	Mishima cattle	CR	Japan Country Report
Nepal	(Royal) Chitwan National Park (Royal) Bardia National Park	II/IV II/IV	Bampudke pig	UNK	Nepal Country Report (Gautam *et al.*, 2008)
Netherlands	Oostvaardersplassen Veluwezoom National Park	III/IV II/IV	Heck cattle Konik horses	END UNK	(Vulink and Van Eerden, 1998) (Piek, 1998)
Poland	Biebrza National Park	No Category	Konik/ Tarpan horses	END-M	(Borkowski, 2002)
	Roztocze National Park	II	Konik horse	END-M	(Sasimowski and Slomiany, 1986)
Romania	Danube Delta Biosphere Reserve	II	Sura the Stepa cattle Romanian buffalo	END-M NAR	(Meissner, 2006)
United Kingdom	North Wessex Downs AONB Cranborne Chase & West Wiltshire Downs AONB	V V	Wiltshire horn sheep	NAR	(Cole and Phillips, 2008)
	Lake District National Park	V	Herdwick sheep	NAR	(Cole and Phillips, 2008)
	Cotswold Area AONB	V	Cotswold sheep	END-M	(Cole and Phillips, 2008) (Yarwood and Evans, 2000)
	Lincolnshire Wolds AONB	V	Lincoln Red cattle	END	(Cole and Phillips, 2008)
	Dartmoor National Park	V	Dartmoor pony	END-M	(Yarwood and Evans, 2000)
	Yorkshire Dales National Park	V	Beef Shorthorn cattle Swaledale sheep	NAR NAR	(Cole and Phillips, 2008) (Yarwood and Evans, 2000)
	Northumberland National Park	V	Cheviot sheep Beef Shorthorn cattle	NAR NAR	(Cole and Phillips, 2008)
	New Forest National Park	V	New Forest ponies	UNK	(Spencer, 2002)
	Burnham Beeches	-	Exmoor ponies White park cattle Berkshire pigs	END END END	(Spencer, 2002)
	Norfolk Coast AONB Suffolk Coast & Heaths AONB	V V	Red poll cattle	NAR	(Cole and Phillips, 2008)
	High Weald AONB	V	Sussex cattle	NAR	(Cole and Phillips, 2008)
	Sussex Downs AONB	V	Sussex cattle Southdown sheep	NAR NAR	(Cole and Phillips, 2008)
	East Hampshire AONB	V	Southdown sheep	NAR	(Cole and Phillips, 2008)

CR: Critical. Total # of breeding females ≤ 100 and/or total # of breeding males ≤ 5 or total population size is ≤ 120 and decreasing and % of females bred to males of same breed is < 80%; CR-M: Critical-Maintained. Critical populations for which active conservation programmes are in place; END: Endangered. Total # of breeding females is between 100 and 1000; END-M: Endangered-Maintained. -Endangered populations for which active conservation programmes are in place; EXT: Extinct; NAR: Not at risk; UNK: Risk status is unknown

[21] This breed is not included in the list of breeds for Belgium in DAD-IS, but is END-M in Poland
[22] Was END from 1983-1990
[23] Was END in 1983 when the conservation program began
[24] Was END in 1983
[25] Was CR in the 1990s
[26] Fewer than 100 were registered in 1975
[27] These breeds are not included in the list of breeds for Germany in DAD-IS, but are both END in other countries
[28] Listed as END-M in Austria and END in Romania
[29] Was END in 2005, currently listed as CR in the United Kingdom and USA

domesticated animals. The role of protected areas in the conservation of wild species is well established and its characterization is beyond the scope of this dissertation.

Feral and free-ranging livestock

In some cases it is difficult to categorize wild versus domesticated forms of animals (Clutton-Brock, 1989), as there are not always clear-cut boundaries between wild animals used in part by humans and free-ranging domesticated animals with little to no management by humans. Vicuñas (*Vicugna vicugna*), for example, are generally considered wild but are corralled annually in some national parks by local community members to harvest fibre for textiles (Wheeler and Hoces, 1997). For the purposes of this study, vicuñas are treated as wild species so further details of their conservation within protected areas were not sought.

Some country reports (e.g., Australia and Sri Lanka) referred to the existence of feral animals within protected areas. In Australia, feral Brumby horses[30] and in Sri Lanka, feral buffalo (*Bubalus bubalus*) are considered threats to natural features conserved within the protected areas, including endangered wild species. Management actions undertaken by several Australian protected areas aimed to reduce, if not eliminate, feral Brumby populations (Norris and Low, 2005). If populations of feral animals must be removed from protected areas for ecological reasons, consideration should be given to find appropriate venues for the *ex-situ* conservation of potentially unique genetic resources in feral populations.

[30] Unless otherwise noted, all horses/ponies in this study are *Equus caballus*, cattle: *Bos taurus*, sheep: *Ovis aries*, pigs: *Sus domesticus*, asses: *Equus asinus*, goats: *Capra hircus*, chickens: *Gallus domesticus*, and geese: *Anser anser.*

Konik horses and Heck cattle are animals that were derived from domesticated stock with the intention of reconstructing the characteristics of extinct wild tarpan horses (*Equus ferus ferus*) or auroch (*Bos taurus*), respectively. These breeds are treated as domesticated animals for the purposes of this study as are free-ranging animals such as Exmoor ponies or Camargue horses that are owned or have some human management regarding breeding. Details of the use of these breeds in protected areas are included in the following discussion.

Bees

The country reports were intended to focus on mammalian and avian species of interest to food and agriculture; however, some countries also provided commentary on bee species (*Apis spp.*). Because of the difficulty in classifying bees as either domesticated or wild life forms, and in light of the widespread decline in bee populations and their importance to food and agriculture as sources of honey and agents of pollination (Nabhan *et al.*, 1998) they are briefly given special consideration here. In particular, China, El Salvador and Poland identified protected areas as important reserves to prevent declines in bee populations. Efforts directed towards the conservation of bees both within and outside protected areas may be worth further examination and possible inclusion in future State of the World's Animal Genetic Resources for Food and Agriculture reporting.

Grazing for nature conservation

In most of the countries that reported active promotion of domestic animal diversity within protected areas, livestock grazing was integrated as a means of achieving environmental conservation objectives, such as controlling invasive vegetation, maintaining disturbance-dependent habitats, increasing biological diversity, reducing soil erosion, or creating habitat for wildlife. Examples of these nature conservation initiatives associated with heritage breeds of livestock grazing within protected areas are described below.

Heritage and imported breeds

Although conservation grazing can be done with most breeds of livestock, some countries (e.g., Belgium, Ireland and Sweden) are beginning to prioritize the use of heritage and/or rare breeds for this purpose. Because heritage breeds are reputed to be hardier and better adapted to the local environment and extensive grazing conditions (e.g., Telenged, 1996; Wright *et al.*, 2002), they are believed to be well suited for conservation grazing projects. However, as was discussed in Chapter 1, several empirical studies comparing the impacts of heritage versus mainstream breeds were inconsistent with this belief, and many more studies are necessary to determine whether heritage breeds are more or less suitable than other breeds for fulfilling conservation grazing objectives.

Imported, at-risk Exmoor ponies or Konik horses and Heck cattle (the latter is a composite of heritage and imported breeds) are used in protected areas in Germany and the Netherlands as surrogates for extinct aurochsen and tarpan horses that once occupied the landscape (Piek, 1998; Bunzel-Drüke, 2001). Whether it is appropriate to use at-risk breeds for this purpose is debatable. Although inclusion within protected areas does contribute to the conservation of these at-risk breeds, it may be held that imported breeds are inappropriate elements to include in protected areas as they may result in unauthentic representations of landscapes (Yarwood and Evans, 2000). In contrast, others recommend the use of these particular breeds for nature conservation because of their primitive nature and suitability for free-range grazing, especially where the original wild horses and cattle are now extinct (Bunzel-Drüke, 2001).

It should be mentioned that there are many protected areas in landscapes that have no history of livestock grazing. In these cases it may be inappropriate, and possibly ecologically detrimental, to introduce any domesticated animals where they have never been before. Therefore, the following discussion should not be interpreted to suggest that heritage breeds of livestock are a panacea for all nature conservation challenges. Indeed, any livestock grazing program in ecologically sensitive areas should be carefully planned and monitored, allowing for adaptive management[31] when necessary.

Control of invasive species

Several protected areas made use of heritage breeds to address the spread of invasive species. A flock of 300 endangered Red Ardennes ewes with lambs was introduced in 1997 to the Hautes-Fagnes plateau, Belgium to control invasions of purple moor-grass (*Molinia caerulea* [L.] Moench) on heaths and moors. The sheep uprooted *M. caerulea*

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[31] A form of resource management that recognizes and plans for uncertainty by coupling actions with careful monitoring and periodic evaluation to determine whether any modification to the plan is necessary (Grumbine, 1997).

tussocks and opened the litter layer, allowing the germination of plants that tended to become rare during *M. caerulea* invasions (Delescaille, 2002). In Ireland's Killarney National Park, summer to autumn grazing by Kerry cattle at a density of 0.5 – 1.0 head per hectare effectively reduced the dominance of *M. caerulea* in upland habitats and increased overall plant species diversity compared with control plots without grazing (Dunne and Doyle, 1988). Attempts to control *M. caerulea* through grazing were not always successful. Grazing by heritage heath sheep in Dutch nature reserves could not curb the spread of this grass, though experiments using imported breeds of cattle were more effective (Piek, 1998).

In Croatia, heritage cattle were used to restore pasture that had become overgrown with false indigo (*Amorpha fruticosa* L.), an invasive species that had been introduced to Europe from North America in 1724 (Loviic, 2002). In Lonjsko Polje Natural Park, 19 cows and one bull of the critical-maintained Slavonia-Syrmium Podolia cattle breed were acquired by the Croatian Nature Park Public Service. Grazing by this breed, after mechanically mulching the overgrown pasture once, was found to be the most effective means of reducing *A. fruticosa* in the pastureland (Gugic, 2008).

The cessation of grazing in semi-natural meadows in Europe often significantly reduces the species richness of wild plants (Persson, 1984; Hansson and Fogelfors, 2000; Luoto *et al.*, 2003a; Luoto *et al.*, 2003b; Huhta and Rautio, 2005; Pykälä, 2005). Ostermann (1998) found that of the 198 ecologically important habitats identified by the European Commission's Habitats Directive, 26 habitats (including 8 priority habitats) are threatened due to abandonment of grazing. Grazing by heritage and/or at-risk breeds was resumed in some protected areas to maintain such habitats and prevent encroachment of woody vegetation in disturbance-dependent ecosystems. For example, in response to encroachment of willow-alder-birch scrub in marsh habitats, an experiment using Konik horses to graze small patches of marshland in Biebrza National Park, Poland began in the 1970s. Browsing and scratching by the horses stopped or slowed encroachment of woody growth in all cases (though the level of effectiveness depended on season and intensity of grazing) and maintained or increased the number of breeding birds of species targeted by the management practice (Borkowski, 2002).

Increasing biological diversity

Livestock grazing in Croatia's Lonjsko Polje had many positive effects on biodiversity: e.g., seed dispersal by pigs, cattle and horses; creation of sparsely vegetated, shallow, warm pools of water for dragonflies (*Ischnura pumillo* and *Lestes barbarus*); creation and maintenance of amphibian habitat (for frogs such as *Bombina bombina* and *Hyla arborea*); and development of landscape heterogeneity that supports about 300 plant species, including 13 species that are specifically associated with pig pastures (Poschlod *et al.*, 2002).

Soil conservation

In Ecuador, alpacas were purchased in cooperation between a protected area authority, an international development agency and local communities to encourage community members to reduce the numbers of sheep, which were believed to be responsible for high levels of soil erosion in the Chimborazo Faunal Production Reserve. The alpacas were reported by local residents to have less impact on the soil and vegetation while providing economic development opportunities as breeding stock and as fibre-producing animals (Rosenthal, 2006).

Sustainable development

Although conserving natural environments is a priority of many protected areas, landscapes with a history of anthropogenic influence are increasingly being recognized as ecologically valuable, and in some cases these landscapes are dependent on the continuation of traditional agricultural land use. A special category of protected area (Category V, Protected Landscape/Seascape) was established by the World Conservation Union (IUCN) to acknowledge the importance of conserving areas where interactions between humans (including their livestock) and their environment have "produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity" (Phillips, 2002, p. 9). In these protected landscapes, managers are concerned not only to protect natural biological diversity, they also have a vested interest in promoting the continuation of traditional cultural and economic activities that have helped shape the landscape for generations. Thus, their roles extend beyond simply conserving and monitoring natural environments to incorporating social concerns into protected area management through cooperation with local landowners and forming partnerships for sustainable economic development. Many of the protected areas in which heritage breeds of livestock are actively being promoted fall within the Category V Protected Landscape designation (Table 2.2), although such practices can also be justified within the management foci of other protected area categories (Dudley, 2008).

Examples of the synergies among nature conservation, livestock breed preservation and economic development objectives in many of the protected areas involved in promoting the use of heritage breeds of livestock are summarized below.

Compensation for nature management

Incentives and cost reductions associated with cooperating with protected areas for conservation grazing may at least partially offset the economic disadvantage of working with breeds that are perceived to be commercially inferior due to their smaller carcass size, limited milk production, and/or coarser wool fibre, for example. Beyond simply allowing heritage breeds and/or rare breeds of livestock to graze within protected area boundaries, which in itself can reduce costs and help develop positive relationships between local residents and protected area managers (Feremans *et al.*, 2006), further economic incentives may be offered to farmers in exchange for the "nature management services" provided by their livestock. For example, in Belgium, herders' wages and winter feed for their livestock are provided by the park service (Delescaille, 2002). In Sweden funding for bush clearing, fencing, transport or farm buildings, or payments per head of livestock are offered to farmers involved in conservation grazing programs (Matzon, 1986). Conversely, Meissner (2006) found that when farmers in Romania were charged a fee to pasture their animals on protected land within the Danube Delta, free-ranging horses were unclaimed by farmers and their numbers increased to the point that they began to overgraze and damage ecologically sensitive areas.

In addition to the economic opportunities associated with conservation grazing, protected area managers have contributed to the conservation of domestic animal genetic resources by initiating or supporting innovative sustainable development strategies involving heritage breeds of livestock. In Croatia, Ireland and France, for example, protected area authorities initiated "seed herd" programs in which interested local residents can obtain a small number of breeding animals at no cost to establish their own small flock or herd of a breed in need of conservation. After a few breeding seasons, the recipients must return the same number of breeding animals to the authority which can then be used as another seed herd for an interested resident (Audiot, 1995; Harrington, 2002; Gugic, 2008). The design and implementation of seed-herd programs should ensure that inbreeding is avoided. Grazing by these animals could also be integrated within the protected areas' vegetation management plans.

Raising livestock within protected areas using practices that are ecologically beneficial creates unique marketing opportunities to promote so-called "ecological" products from the meat, milk or fibre of livestock raised in these conditions. In Hungary's Hortobágy National Park, for example, heritage Hungarian grey cattle, Racka sheep and Mangalica pigs are raised in the traditional extensive manner to maintain grassland vegetation by the Hortobágy Public Company for Nature Conservation and Gene Preservation. This group of nearly 60 herders manage one-fifth (17 000 ha) of the National Park area – reportedly the largest continuous area of organic agricultural production in Hungary and Europe (Megyesi and Kovách, 2006). Meat from these breeds is featured in local restaurants, appealing to tourists who visit the national park. Similarly, Germany's Rhön Biosphere Reserve encourages direct marketing of local agricultural products such as products from heritage varieties of apples and traditional Rhön sheep though organizing cooking competitions using Rhön sheep products and forming partnerships with a gastronomic association that promotes items "From the Rhön for the Rhön" (Pokorny, 2008). Additional examples of niche marketing of products derived from heritage breeds of livestock in protected areas may develop in the future. For example, the Killarney National Park management plan indicates that the possibility of marketing meat from the park's herd of Kerry cattle to local restaurants and hotels (National Parks and Wildlife Service, 2005).

Research and Public Education

Protected areas are often used as sites for scientific research. Monitoring vegetation management strategies, as discussed in the section above on grazing for nature conservation, provides much needed information to evaluate the effectiveness of using local breeds of livestock for such purposes. Protected areas may also establish partnerships with breeding associations and research institutes to conduct other types of research that aid with the conservation of domestic animal diversity. For example, the French regional parks authorities, together with various partner organizations, have undertaken genetic studies, animal health studies, breed inventories, market analyses, and created and maintained breed registries, in addition to conducting research to assess the ecological effects of grazing by heritage breeds within their protected areas (Audiot, 1995; Martin and Morceau, 2006).

Protected areas may also contribute to public awareness of heritage breeds of livestock as part of their overall public education strategies. Information about heritage breeds of livestock is available at many parks' visitor information centres and on several parks' and protected areas' websites. Other approaches to build awareness include the breeding centre for the Poitou donkey in France's Parc Naturel Régional du Marais Poitevin. The breeding centre is open to the public and receives approximately 30 000 visitors annually who can view the animals, observe a presentation on the historic mule (*Equus caballus x E. asinus*) breeding industry and visit the breed documentation centre (Martin and Morceau, 2006). Several approaches to raising awareness and promoting acceptance of conservation grazing initiatives using Exmoor ponies and Heck cattle in Germany's Solling-Vogler Nature Park, include guided walks, evening lectures, media releases, information boards, a project video, and field trips, which are particularly popular (Gerken and Sonnenburg, 2002). Additional plans for building public support for the grazing initiatives in Solling-Vogler Nature Park include leaflets, a book about the project, construction of more nature trails and an "adopt-an-animal" sponsorship program (Gerken and Sonnenburg, 2002).

DISCUSSION

As regards domestic animal diversity, protected areas received relatively little attention within the country reports submitted for the FAO's State of the World's Animal Genetic Resources reporting. Where protected areas were mentioned at all, rarely was more than a paragraph or two devoted to describing the nature of the involvement of protected areas in the conservation of domestic animal diversity. The wider search for literature to obtain additional details about these initiatives revealed that there are more cases in which protected areas are engaged in the conservation of domestic animal diversity than were acknowledged in the country reports. Indeed, some countries in which heritage breeds and/or rare breeds are used in conservation programmes within protected areas (e.g., Austria, see Schermer, 2004), failed to acknowledge such initiatives within their descriptions of the current mechanisms in place to conserve animal genetic resources for food and agriculture in their nation. Other countries (e.g., France and Ecuador) mentioned one or two protected areas involved in conserving domestic animal diversity, but overlooked important initiatives in other protected areas within their nation (c.f., Audiot, 1983; Audiot, 1995; Audiot *et al.*, 2005; Rosenthal, 2008). Furthermore, when a protected area was identified as being involved in the conservation of at-risk and/or heritage livestock, the number of breeds conserved in the park was under-reported at least in one circumstance (e.g., in the Ireland country report, only one heritage breed was identified as being conserved in Killarney National Park, even though three critically-endangered heritage breeds are also raised there according to the Killarney National Park management plan [National Parks and Wildlife Service 2005]). In addition, new initiatives to conserve heritage breeds of livestock within protected areas have begun since some countries submitted their country reports to the FAO (e.g., Finland, see Lovén and Äänismaa, 2006). Thus, the results of this content analysis under-represent the extent of involvement of protected areas in the global conservation of domestic animal diversity. This fact may encourage those involved in developing national reports and strategies for the conservation of animal genetic resources to give the role of protected areas greater recognition and consideration in their future plans and reports.

The review of country reports submitted for the FAO's State of the World's Animal Genetic Resources assessment revealed that where protected areas were mentioned in these reports, they were primarily acknowledged as contributing through the protection of *wild* forms of animal genetic resources of interest for food and agriculture. This emphasis on the conservation of wild biodiversity is consistent with early concepts of the role of protected areas to protect elements of an unspoiled wilderness (Beresford and Phillips, 2000). Though a shift in protected area paradigms is beginning to also value cultural landscapes and recognize the value of conserving agricultural biodiversity therein (Amend *et al.*, 2008), the content analysis of the FAO country reports suggests that the role of protected areas in the conservation of *domesticated* animal diversity on a global scale is minimal, at least from the perspective of those who are reporting participating countries' national efforts to conserve animal genetic resources. Indeed additional examples of the use of heritage breeds and/or at-risk breeds of livestock in protected areas were found in the review of wider literature that had not been reported in some country reports submitted for the state of the world's animal genetic resources initiative. Thus the means of conserving heritage breeds and/or at-risk breeds of livestock through their use in protected areas is under-recognized if not under-utilized.

The majority of protected areas that were reported to be involved in the conservation of domesticated animal diversity were located in Europe, with a very few additional examples mentioned in reports from Asia, South America and Africa. The high proportion of European countries reporting the involvement of protected areas in the conservation of livestock diversity is likely a product of available resources, a recognised need for such initiatives, as well as the adoption of amenable protected areas models. According to Rischowsky and Pilling (2007), Europe and the Caucasus have the most complete population data on their breeds and are home to the greatest number of mammalian and avian livestock breeds compared with any other region. Further, Europe and the Caucasus have the greatest proportion of Endangered-Maintained and Critical-Maintained[32] breeds, indicating that efforts are in place to actively halt (and ideally reverse) the population decline among many of their threatened breeds. Furthermore, the concentration of cases using heritage and/or at-risk breeds in protected areas in Europe appears to be associated with the type of protected areas predominant in this region. Most of the protected areas found in the literature review to be involved in conserving heritage and/or rare breeds of livestock fell into the IUCN Protected Area

[32] Endangered or critical populations, respectively, as defined by Rischowsky and Pilling (2007) for which active conservation programmes are in place.

Category V: Protected Landscapes. Most of IUCN's Category V: Protected Landscapes/ Seascapes (by area) are also located in Europe, and Category V represents the most common type of protected land (by area) in the region (Chape *et al.*, 2003). The management of category V protected landscapes is aimed towards maintaining the ecologically "harmonious" traditional interactions between humans and the landscape, including where applicable, traditional forms of livestock grazing. These protected areas recognize the distinct character of landscapes in which traditional lifeways were practiced and value their aesthetic, ecological and/or cultural worth. A rationale for the use of heritage breeds could reasonably be made in Category V protected areas, as the breeds themselves are arguably integral components of the aesthetic and/or cultural character of some landscapes (Yarwood and Evans, 2000).

Incentives to raise heritage breeds included direct economic benefits to some farmers such as wages for herders who tended to livestock within protected areas or payments per head of livestock. Also, subsidies of the cost of raising heritage breeds were available to some farmers through the provision of "seed herds", winter feed, pastureland, fencing or housing. Such incentives could help offset possible economic disadvantages farmers may otherwise experience from comparatively reduced yields from working with heritage or rare breeds. However, Gandini *et al.* (2010) found that economic subsidies were not always motivating factors for raising heritage breeds. Their survey of 371 farmers in eight European countries who raise at least one of 15 heritage breeds revealed that the most common motivations for raising heritage breeds was their historic significance, functional characteristics, and/or their productivity. Current subsidy programs (not necessarily associated with grazing in protected areas) were not a common reason for farmers' decisions to raise heritage breeds. This is perhaps because subsidies were not sufficient to bridge the difference in profitability between heritage and imported breeds (Pappalardo, 2003; Gandini *et al.*, 2010). If farmers are eligible for general subsidy programs to conserve heritage breeds plus receive economic incentives or cost reduction opportunities from their involvement with protected areas initiatives, the combination of subsidies may be sufficient support to offset potential economic disadvantages from raising heritage breeds.

Protected areas also provided farmers niche-marketing opportunities for livestock raised in protected areas as ethical products and through special events held within or associated with protected areas. Although no economic evaluations were found specifically of the niche market for products associated with livestock raised in protected areas, Gandini *et al.*'s (2007) study of the special brand of cheese from the Reggiana breed of cattle attests to the power of niche marketing for heritage breeds. Gandini *et al.* (2007) compared the profitability of heritage Reggiano dairy cattle compared with imported Holstein cattle. When income from annual milk yield/ cow alone was the unit of comparison, Reggiano cattle were €679 less profitable than Holsteins. Taking into consideration the costs to feed, milk, replace, and inseminate the cattle, Reggiano cattle were only €460 less profitable than Holstein, mainly because of the longer lifespan and reduced costs to feed the heritage breed. When accounting for niche marketing opportunities for Parmigiano Reggiano cheese specifically from the Reggiana breed of cattle (which is valued at nearly twice the price of cheese from Holstein milk), the Reggiana cattle were €1953 more profitable per cow per year.

The increased awareness and appreciation of heritage breeds via initiatives involving visitors to protected areas may create demand and enhance willingness to pay for niche products from the breeds conserved within the protected areas.

CONCLUSIONS

This global overview highlighted a number of ways in which some protected areas contributed to the conservation of domestic animal diversity. Through public education projects, some protected areas inform or reinforce appreciation for the need to conserve agricultural biodiversity in addition to the biodiversity of wild species. More directly, economic incentives and technical support from protected areas authorities for farmers raising heritage breeds may be important ways to facilitate the continued use of these breeds by local farmers. Niche marketing associated with the ecological reputation of protected areas may also help to encourage the conservation of heritage breeds.

Reciprocally, heritage breeds of livestock provided benefits to the protected areas in which they were allowed and encouraged to exist. The economic benefits to farmers mentioned above help to foster positive relationships with local community members, whose support is critical for effective protected area management. Serving as tourism attractions, heritage breeds of livestock may also draw visitors to parks or protected areas, or at least contribute to a variety of attractions that together form unique visitor experiences. Although no literature was found that investigated the relative importance of heritage breeds as a motivating factor in tourists' visitation to a particular park nor their relative importance in visitor satisfaction, such information would also be beneficial to understand the contribution of such breeds to the tourism values of protected areas.

In several protected areas around the world where heritage and/or at-risk breeds were kept, the livestock were reported to contribute to the ecological well-being of protected areas by controlling invasive vegetation, increasing biological diversity, maintaining disturbance-dependent habitats, reducing soil erosion and/or creating habitat for wildlife. Ecological rationales for the use of heritage breeds of livestock in protected areas are likely to be the most important justifications for their use, especially in categories of protected areas that do not have management objectives that explicitly aim to conserve agricultural traditions or domesticated agricultural biodiversity. Thus, the conservation of heritage breeds of livestock may be compatible with management objectives not just in Category V protected areas, but also in other types of protected areas that focus more on ecological rather than aesthetic or cultural values. The ecological benefits provided by heritage breeds may in turn provide economic benefits for protected areas, especially where they are more cost effective than alternative means of vegetation management such as labour-intensive scything or mechanical mowing using expensive equipment and hydrocarbon fuels.

Although protected areas are not presently considered a major contributor to the conservation of domesticated animal genetic resources for food and agriculture, several examples from this overview illustrated how protected areas are uniquely positioned to provide incentives for the use of under-utilized breeds. From the literature detailing how rare and/or heritage breeds of livestock are used in protected areas, it is clear that there are many opportunities for protected area managers and authorities responsible for conserving animal genetic resources for food and agriculture to explore options to fulfil mutually compatible objectives. However, what is also clear is that more information is necessary from existing initiatives that involve protected areas in the conservation of heritage breeds regarding the processes, benefits and limitations of such approaches. There is increasing awareness that under careful management and when implemented in appropriate locations, the conservation of heritage breeds of livestock can be compatible with nature conservation. This may be persuasive in areas where such proposals are met with resistance, such as was reported in the Romanian country report.

In summary, few country reports from FAO's State of the World's Animal Genetic Resources initiative recognized the role of protected areas in conserving heritage breeds of livestock. However, closer examination of literature from the countries in which heritage breeds were reported to exist within protected areas revealed a variety of ways in which such initiatives contribute to the mandates of protected areas, especially in Category V Protected Landscapes. This literature review revealed that initiatives involving heritage breeds in protected areas helped to control invasive species, increase biological diversity, maintain open environments, conserve soil, contribute to local economic development, and provide opportunities for research and public education.

CHAPTER 3: THE ROLE OF HERITAGE LIVESTOCK IN THE HISTORICAL ECOLOGY OF KOLI NATIONAL PARK

INTRODUCTION

The overview presented in Chapter 2 pointed to a need for additional case studies that detail the processes, benefits, drawbacks and limitations of the use of heritage breeds of livestock in protected areas. This chapter provides an historical context for the case study of the use of two heritage breeds, Eastern Finncattle and Finnsheep, in Koli National Park, eastern Finland. The heritage breeds were reintroduced to Koli National Park as part of a resource management strategy that aimed to restore anthropogenic habitats associated with traditional agriculture to the landscape because such habitats are now endangered in Finland. A particular emphasis in this chapter is placed on the changing agricultural practices involving livestock since humans first occupied the Koli area and on the consequences of such changes to the landscape of the case study area. An assessment is made of the historical accuracy of the current practices involving the reintroduction of heritage breeds in Koli National Park.

Various sources of information were used to assemble this contextual information including primary and secondary written documentation, maps, photographs, interviews and participant observation. Primary and secondary (e.g., reviews) literature was used to obtain information on the climatic, geological, geomorphological, floristic, and prehistoric conditions of the study area and Finland in general. Interviewees who practiced farming in the Koli area in the mid 20th century provided personal accounts of the agricultural practices of the region in their lifetime. The older interviewees could remember the agricultural practices of their families and neighbours as far back as the 1940s and 1950s and their responses were very consistent with one another. Photographs obtained from the Koli Museum dating mainly from the 1930s provided some insights on the character of the landscape and some agricultural practices prior to the time that the oldest interviewees would have remembered. Other interviewees included those who currently practice agriculture or were involved in the reintroduction of Finnsheep and/or Eastern Finncattle at Koli National Park. Interviewees provided a wealth of information about historic and current practices relating to livestock husbandry with these breeds, as well as details about how the present-day use of livestock at Koli National Park developed. The investigator's first-hand experiences engaging in traditional haymaking and swiddening, as well as caring for the livestock at Koli National Park also provided in-depth information regarding the park's current initiatives to restore traditional agricultural practices to the landscape. These data are synthesised and contrasted throughout this chapter to present a more or less linear chronology.

In landscapes with long histories of anthropogenic influence it is important to understand the natural and anthropogenic forces that have shaped the landscape through time in order to set ecological benchmarks and evaluate ecological management options. In areas where the landscape has a long history of use within cultural traditions, traditional land uses are linked with the maintenance of ecological integrity and protected area management efforts include safeguarding and/or restoring such traditional land uses to the landscape (Phillips, 2002). This chapter examines the changing agricultural practices that, in combination with natural forces, helped shape the landscape of the Koli area and the region of eastern Finland. This chapter provides context to contemporary ecological data described in Chapter 4 by determining:

i. How and where were heritage breeds of livestock raised in the Koli region in the past?

ii. How and where are heritage breeds of livestock used in Koli National Park today?

iii. How have changes to agricultural practices involving heritage breeds of livestock influenced the landscape in and around Koli National Park over time?

Results from these questions are analysed to assess the historical consistency and potential implications of current practices involving heritage breeds at Koli National Park. Furthermore, these results provide historical context to interpret the ecological effects of activities involving heritage breeds at Koli National Park, which are examined in greater detail in Chapter 4.

METHODS

Case Study

A case study is a methodological approach that combines several data-gathering techniques to provide a comprehensive understanding of a particular person, social setting, event or group (Berg, 2001). Koli National Park was chosen as a site for a case study after the broad overview of heritage breeds in protected areas worldwide revealed few detailed cases of the use of heritage breeds of livestock in protected areas. Although Finland's country report did not identify the fact that heritage breeds were being conserved through protected areas within the country[33], the review of supplementary literature for the global overview revealed two potential case study sites involving grazing animals in protected areas in Finland. Another potential site through the Vainameri Project in nearby Estonia was also found (Kokovkin *et al.*, 2005). To confirm the viability of the potential case study sites, a reconnaissance visit was conducted in 2007 to both countries in order to evaluate the three potential study sites where livestock were actively being used for vegetation management. Koli National Park was the only one of the three sites examined where heritage breeds were still being used to manage vegetation. Further, the grazing at Koli occurred in woodland and meadow patches within a boreal forest matrix whereas at the two other sites grazing mainly occurred along insular shorelines in the Baltic Sea. Koli National Park therefore presented an interesting opportunity to study the effects of grazing by heritage breeds of livestock specifically within a boreal forest landscape.

Furthermore Koli National Park is one of the only areas in the world where swidden cultivation has been re-established in a temperate environment. Only two other protected areas in Finland have been restoring swidden cultivation to the landscape: Telkkämäki Nature Reserve, where only horses grazed in its regenerating swidden plots in 2008, and Linnansaari National Park where swidden plots are not grazed. Thus, Koli

[33] Programs in Finland in which heritage breeds are used in protected areas were initiated after Finland's contribution to the State of the World's Animal Genetic Resources for Food and Agriculture reporting had been submitted.

National Park provided a unique opportunity to study the ecological effects of sheep and cattle grazing on regenerating vegetation after the last harvest of crops on a swidden plot, a practice that was common throughout Finland prior to the 20th century.

This case study involved a concordance approach to data collection by comparing ecological data on plant composition and cover in grazed and ungrazed forests and meadows (which is presented in detail in the next chapter), and combining that information with sociological data from unstructured and semi-structured interviews, and participant observation regarding traditional forms of agriculture and current livestock husbandry practices. Historical data from maps and photographs were also used to determine how closely the reintroduced ways of using livestock in Koli National Park area resemble practices in the past. These data and their method of collection are described in more detail following a brief description of the study area.

Study Area

Koli National Park (*Kolin Kansallispuisto* in Finnish) (63°5'3" N 29°50'22" E) is located in eastern Finland, in the province of North Karelia (Figure 3.1). The park is approximately 3 000 ha and is located in an transition area between the southern boreal and middle boreal vegetation zones of Finland (Heikkinen, 2005). The altitude in the park ranges from 94 m above sea level (a.s.l.) to 347 m a.s.l. The average temperature in the area is 2-3ºC with annual precipitation between 600-650 mm (Finnish

Meteorological Institute, 2001). The growing season (average number of days with a mean temperature > 5°C) in the Koli area is approximately 160 days (METLA, 2009).

Figure 3.1. Map of Finland indicating location of Koli National Park (red circle). Base map of Finland used with permission from www.appliedlanguage.com

Koli National Park was established in 1991, though core areas of the territory that now comprises the park had been state owned since 1907 and managed by the

Finnish Forest Research Institute since 1924 (Eerikäinen and Nieminen, 2006). In 2008, the management of the national park was transferred to Metsähallitus, Finland's government agency that is responsible for the national park system and the management of other natural resources.

Koli National Park is classified as a Category II (National Park) in the IUCN system of protected areas. IUCN Category II Protected Areas are "large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities" (Dudley, 2008, p.16).

Koli was identified by Finland as a "site of community importance" under the European Commission's Habitats Directive. National sites of community importance comprise the "Natura 2000" network of sites that together protect the organisms and habitats identified as being "of community interest" in Annex 1 of the Habitats Directive. These sites are eligible for funding to undertake management actions to ensure the "favourable conservation status" of the Natura 2000 network. The most significant habitat types represented in Koli National Park are Fennoscandian herb-rich forests with Norway sprice (*Picea abies* [{L.} H. Karst]) (9050[34]), bog woodland (*91D0), Fennoscandian wooded pastures (9070) and hay meadows (6510 & 6520). Management of the wooded pastures and hay meadows include restoration of swidden activity, grazing and haymaking in Koli National Park. One of the primary objectives of Koli National Park is to conserve relict examples of past swidden activity and restore the

[34] These numbers correspond to the codes assigned to the habitat types in Annex 1 of the Habitats Directive. An asterisk indicates a priority habitat type.

traditional practice to the landscape. Swidden cultivation was practiced in the area of Koli National Park until the 1930s and then again beginning in 1994 (Lovén and Äänismaa, 2006). Since 1994 between 0.3 ha and 2.5 ha of the park area each year has been felled and burned according to traditional Finnish swidden methods (Lovén, 2004). Maps in Appendices A, B and C provide a more detailed overview of the park and highlight a number of sites within the park that are specifically mentioned in this and the following chapters.

Interviews

Interviews with farmers can be important sources of information pertaining to past and current land use practices in rural areas, providing a greater depth of information than ecological field studies alone (Riley, 2004). The use of traditional ecological knowledge held by farmers is especially recommended as a way to collect data about heritage breeds of livestock because conventional scientific methods of studying livestock tend to focus mainly on production traits and overlook other important characteristics of breeds that outside observers without extensive experience with the animals would fail to detect (Lokhit Pashu-Palak Sansthan and Köhler-Rollefson, 2005).

Knowledge and input held by experts[35], who have a wealth of experience with the breeds used at Koli, was gathered through semi-standardized interviews. The interviewees were asked about current and past agricultural practices related to livestock

[35] The term "experts" refers both to individuals with high levels of technical training as well as those with life-long experience with these animals.

keeping in the Koli area and about the behaviour and management of Eastern Finncattle and Finnsheep versus introduced breeds. Twelve individuals participated in a total of seven interview sessions. Among the interviewees were families that practiced farming in the Koli area until 40 years ago, farmers currently using heritage breeds of livestock, staff and managers of an agricultural college where the largest herd of Eastern Finncattle are kept, and managers and staff of Koli National Park. Interview sessions ranged in length from one to four hours and involved one to three interviewees per session. Interviews were digitally audio-recorded when convenient (some interviews were conducted while walking through barns or in otherwise loud surroundings, therefore the recording device was not used then) and agreed to by the interviewee. The audio recording device was a Macintosh 60G iPod with a Belkin microphone attachment. Three of the interview sessions involved the use of a translator (the remaining interviewees had excellent English language skills so a translator was not necessary). All interview cover letters and consent forms were provided in Finnish. Lakehead University's Research Ethics Board approved the interview protocol prior to the 2008 field season when the interviews were conducted.

Participant Observation

Participant observation is a qualitative research method that allows researchers to make sense of phenomena from an insider's point of view through direct observation and other methods of data gathering as a participant in particular aspects of a way of life

(Jorgensen, 1989). The use of participant observation is recommended as a way to observe and experience typical, everyday experiences of lifeways (Jorgensen, 1989). However, traditional agriculture is no longer practiced as a whole way of life in the Koli area; rather, elements of traditional agriculture have been revived as special events or special circumstances. To add depth to the data gathered about traditional agricultural practices in the region, the investigator engaged in several opportunities to experience these "relict" traditions first-hand.

On August 5, 2007 and July 31, 2008 the investigator participated in *huuhta*-type swidden burns conducted by the managers and staff of Koli National Park. The investigator was assigned roles of igniting the fire, preventing the spread of the fire outside the desired burn zones and extinguishing smouldering embers after the burn was complete.

In addition, on July 4, 2008 the investigator was among 50 people who participated in an event organized by a group of community members to involve the public in a "traditional day" that included manual haymaking using scythes, rakes and two-pronged hayforks to stack hay to dry on individual hay poles at a farm near Koli National Park (Figure 3.2). Field notes were written within 24 hours of participating in these experiences, documenting the methods in which the traditional activities were conducted as well as any information about the practices as stated by the event organizers.

Another practice that has been restored is the summer pasturing of traditional breeds of livestock in Koli National Park. From July 7 to July 11, and August 4 to August 20, 2008, the investigator was responsible for the daily care of 10 Finnsheep ewes (providing water and minerals in granular form, and determining when to move the flock to a new pasture) at the Seppälä farm site in Koli National Park. Furthermore, since December 2008, the investigator has been raising four to eight mature Finnsheep on her farm in Thunder Bay, Ontario, and contrasting their behaviour with her experiences raising four other sheep breeds in similar conditions.

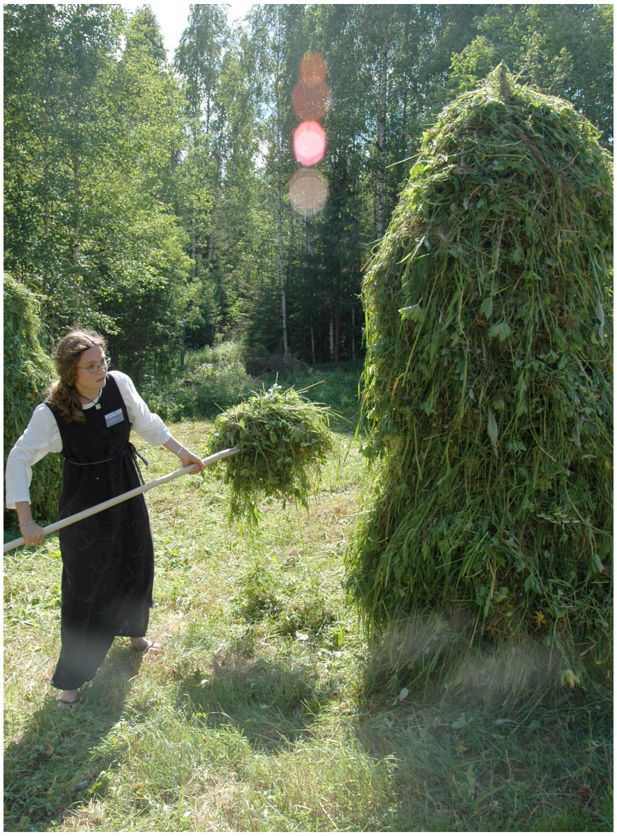

Figure 3.2. Traditional haymaking.
A volunteer places scythed hay to dry on an upright post during "traditional day" a community event organized by the Koli cultural society.

Historic Photographs and Maps

Historic photographs and maps provide insight into the nature of the landscape in and around Koli National Park in the past. While Prosser and Schwartz (1998) warn that such data are subject to the biases of their creators, they nevertheless provide evidence of some aspects of the region's past, such as documentation of the breeds of livestock present, fencing structures and materials, general vegetation types, crops grown, harvesting techniques and tools. Curators and staff of the Koli Heritage Museum kindly granted permission to examine over 1 400 photographs of the Koli area taken primarily by Einar Akseli Saarelainen and other local residents. Though most of the photographs from the Koli Heritage Museum were family portraits, several showed scenes of the landscape and/or typical agricultural activities in the Koli area mainly in the early 1930s, when Saarelainen's photographic interest was most intense (Koli Heritage Museum, n.d.). Dates, however, were not provided on the photographs, and they could have spanned Saarelainen's adult lifetime until his death at age 70 in 1966. All of the photographs in the Museum collection were examined, and a subset of 52 photographs was selected for content related to agricultural landscape use or techniques. These 52 images of livestock or of identifiable elements of the landscape (e.g., features that could be recognized and therefore compared with current day landscape features) were scanned at high resolution and retained as digital images with permission from the museum curators. Where possible, comparable landscape photographs were retaken during the 2008 field season using a Nikon D70 SLR digital camera with a Sigma DC 18-50mm lens. The intent was to revisit the same or similar vantage points to those in some of Saarelainen's landscape photos. This provided direct visual evidence of some changes to the landscape over time (Russell, 1997).

Historic maps of parts of the Koli National Park area were also available at the Koli National Park headquarters and at the Joensuu office of the National Land Survey of Finland (*Maanmittauslaitos*) including a basic trail map with the locations of trails and farmhouses from 1922 (Kyander, 1922) and several maps with boundaries of broad vegetation types (e.g., forest, meadow, field, marsh) spanning five decades (Knuuti, 1936; Vilén, 1961-1962; Vilén, 1971; Lohilahti and Pajari, 2007). These maps provided insight on the changing sizes and uses of clearings and adjacent forest land through time. The historical maps were used in conjunction with current maps of the area in recent Koli National Park publications (Lohilahti *et al.*, 2006; Lovén and Äänismaa, 2006; Lohilahti and Pajari, 2007) and with physical evidence of past land use remaining at some of the locations within the park. Examples of such physical evidence include old stone walls or wooden fences, which marked the edges of old fields, piles of stones, which suggest past clearing and cultivation (Figure 3.3), the diameter and approximate age of trees now growing in dug-out pits that were used to store turnips (*Brassica rapa* L.), etc.

Figure 3.3. Physical evidence of past land use.
Rock piles within this 80-year-old stand of Norway spruce suggest the area had once been cleared of rocks and cultivated.

Analysis

Photographs from the Koli Museum were examined for evidence of past land use patterns related to agriculture and for evidence of past agricultural practices (notes were made of the breeds and numbers of livestock, field crops, agricultural tools and machinery, harvesting techniques, gender roles, etc.). Wherever possible, the geographical locations of the photographs and the probable position of the photographer were interpreted based on landscape features and landmarks in the photograph that could be recognised either from familiarity with the Koli area and/or triangulation using current cartography.

Changes in the area of agricultural clearings (meadows and cultivated fields) were assessed using the dot grid technique, which was found by Naylor (1956) to be a reliable means to determine area of irregular shaped vegetation polygons. The boundaries of meadows and fields that appeared on more than one of the maps from 1936 to 2006 available were traced onto parchment paper, which was then laid over a grid of dots spaced one cm apart. The dots that fell within the boundary were tallied and converted to hectares based on the scale of the map (1:4000). The map from 1971 was rescaled digitally from (1:5000 to 1:4000) and then the meadow and field polygons were traced to enable comparison using the same grid throughout the time series. Each polygon was repositioned in a random orientation on the grid of dots at least five times and the area for the polygon was calculated using the average number of dots counted for the repeated placements.

Interviews were not transcribed, but were listened to several times and notes were taken to record common themes among respondents. Like the content analysis of the global overview of heritage breeds in protected areas, themes from the interviews emerged inductively and the notes generated from repeated listening to the recorded interviews were cyclically reanalysed and coded for common themes and trends as well as discrepancies between respondents.

All qualitative data from the case study (interviews, photographic analysis and participant observation) were assessed for substantive significance based on consistency among and between the data sources and with information from published literature. The results of this mixed-methods approach to determining the influence of agricultural practices through time in and around Koli National Park is presented chronologically in the following section.

HISTORY OF AGRICULTURE IN EASTERN FINLAND

Settlement patterns and food acquisition strategies of the human population in Finland have always been influenced strongly by the region's geology, geomorphology and northern location, which have remained more or less constant since the retreat of the Weischelian ice sheet from the area over 9 500 years ago. However, changes in climate and flora, as well as in political, legal, economic and technological environments, greatly influenced the character of agriculture in eastern Finland over time.

Influence of Geology, Geomorphology, and Climate

Much of the bedrock in Finland is Archaean schist, quartzite and greenstone (Smeds, 1960). The relatively lowland country (90% of the land is <300 m a.s.l.) was not dramatically affected by more recent orogenies that gave rise to the Caledonian mountains and the Alps; these events merely stressed and fractured the bedrock, resulting in the relatively shallow lakes of Finland's lake region that generally run in a NW-SE direction (Smeds, 1960).

The most recent glaciation of the region reached its maximum at 23 000 – 15 000 BP, covering northern Europe with a layer of ice over 1 km thick (Dolukhanov, 1997; Lambeck *et al.*, 2000). The continental ice retreated in a northwesterly direction and the lake Pielinen area of North Karelia was uncovered around 10 000 – 9 500 BP (Hyvärinen, 1973). Birch (*Betula spp.*) soon became established (around 9 000 BP), spreading from the southeast (Appelroth, 1987). Between 6 000 and 4 000 BP the climate was warmer than at present, with typically southern European tree species such as linden (*Tilia*), hazel (*Corylus*), oak (*Quercus*), ash (*Fraxinus*), and elm (*Ulmus*) present, though not dominant (Alenius *et al.*, 2007; Taavitsainen *et al.* 1998). Norway spruce (*Picea abies*) arrived from the southeast around 5 000 BP (Appelroth, 1987). Briffa *et al.* (1992) reported considerable variance in summer temperatures in Fennoscandia from 500 AD to present. Fluctuations in Finland's climate continue today and temperatures currently reveal a warming trend. Over the past 100 years Finland's annual mean temperature has increased by 0.7 °C, but no statistically significant trends in precipitation fluctuations occurred during this time period (Jylhä *et al.*, 2004).

Current mean annual temperature in Finland ranges from 5 to 6 °C in the southwestern part of the country to -3 to -2 °C in the northernmost areas of Finland while most of the country receives 550 to 600 mm of precipitation annually (Finnish Meteorological Institute, 2001). Today, forests cover 20.2 million ha, approximately two thirds of Finland's land base, and an additional 2.7 million ha are classified as scrub land (Finnish Forest Research Institute, 2008). Roughly two thirds of Finland's forests are Scots pine-dominated (*Pinus sylvestris* L.), one quarter are dominated by *Picea abies* and around 10% are broadleaf-dominated (mostly *Betula spp.*) (Finnish Forest Research Institute, 2008).

Early Anthropogenic Influences

No documented evidence of human occupation of Finland prior to the Weischelian glaciation was obtained. However, there is evidence that humans occupied the region soon after the continental ice began retreating. A Mesolithic bark float from around 7280 BC (± 210 years) was found near the present-day Finnish border in Russian Karelia (Dolukhanov, 1997). The earliest settlers were hunter-gatherers; swidden cultivation and livestock husbandry are not believed to have arrived from the coastal areas of Lake Ladoga and the Gulf of Finland until 1550 BC (Sarmela, 1987). The earliest evidence of crop cultivation in Eastern Finland, reported by Taavitsainen *et al.* (1998), was from 1300 – 500 BC near Kuopio, approximately 250 km west of Koli. Further evidence of crop cultivation in the area around this time is documented by

Grönlund *et al.* (1992), who found Cerealia-type pollen grains dating prior to 665 BC, which coincided with a decrease in *Picea abies* and increase in *Betula spp.* pollen.

Although there is evidence that areas of northern Häme, northern Savo and north Karelia had been used for crop cultivation as early as the Bronze Age (1500 – 500 BC), it is generally considered that permanent settlement did not occur in these parts until after Medieval times (~1550 AD) (Smeds, 1960). Early, discontinuous evidence of swidden agriculture from 665 BC to 1550 AD in the pollen record from parts of these wilderness areas (Grönlund and Asikainen, 1992; Grönlund *et al.*, 1992; Alenius *et al.*, 2007) is thought to represent the use of swidden cultivation as a way to augment hunting grounds distant from permanent settlements (Taavisainen, 1987; Parviainen, 1996; Taavitsainen *et al.*, 1998; Björn, 2001). The cleared and regenerating vegetation would provide habitat for game species, and since the effort to fell or otherwise dry the fuelwood would be required anyway, it would be efficient to plant a crop in the swidden area prior to its regeneration.

Permanent Settlement of Eastern Finland

The clearing of these distant forests for hunting is considered a precursor to permanent settlement (Taavisainen, 1987). Between 1450 and 1550 AD clear palynological evidence of swidden cultivation using rye in a 30 year rotation developed at Lake Pitkälampi, approximately 100 km southeast of Koli, near the present-day Russian border (Grönlund and Asikainen, 1992), which suggests permanent settlement and greater local reliance on swidden agriculture in the forestlands for food acquisition. Closer to Koli, charcoal and pollen records from Lake Pönttölampi, approximately 60 km from Koli National Park, indicate the start of swidden cultivation with rye in that area around 1600 AD (Pitkänen and Huttunen, 1999).

Over time various forms of swidden cultivation were developed. Four main forms of swidden cultivation are described by Soininen (1959), summarized here:

1. *Huuhta*:
   - Norway spruce forests felled in early spring and/or ring-barked, burned 3 years later at height of summer.
   - Rye (*Secale cereale* L.) planted, sometimes turnip in areas of greatest ash deposit. A variety of rye, *korpiruis*, used specifically in this form of swidden. Rye yield could be very high (1 grain returned 20-50 grains; up to 100).
   - Total land base of at least 2500 acres/ family needed (Montelius, 1953).
   - After 17th century, a 2-burn system developed: only 2 years of drying before burn, second burn of remaining material done in 3rd year, followed by sowing.
   - Only one year of crop available from either the single- or double-burn form of *huuhta* swidden.

2. *Kaski*:
   - Deciduous or mixed forest. 15-30 year old trees, preferably of more or less uniform age. Felled when leaves at maximum development.
   - In the following year, burned in early summer for autumn rye or early spring for barley (*Hordeum vulgare* [L.]). The rye used in *kaski* swidden was same as in field cultivation (i.e. different from *huuhta* rye) and was less productive (only 8-15-fold return). Oats (*Avena sativa* L.), turnips and/or buckwheat (*Fagopyrum esculentum* Moench) could be planted for 2 to 6 years after.
   - First harvests produced greatest yield.

3. *Rieskamaa* or *vierumaa*:
   - Young deciduous or mixed forest.
   - Felled in early spring and burned in same season.
   - Additional fuel wood could be imported from adjacent areas to ensure complete burn.
   - Barley or, less often, turnips sown. Oats, buckwheat, or turnips sown in second year.

4. *Pykälikkömaa*:
   - Limited primarily to northern Karelia.
   - The objective was to convert coniferous to deciduous forest.
   - Conifers, mainly *Pinus sylvestris*, killed by notching or ring-barking and left standing.
   - Deciduous trees became established around the dead conifers.
   - Once the deciduous trees were old enough (20-50 years later), swidden cultivation following the *kaski* method was done.

Pyne (1997) reasons that *huuhta*, which was practiced in coniferous or conifer-dominated mixed forests, was a necessary precursor to *kaski* cultivation, which was practiced in stands dominated by broadleaved species. It is possible, though, that the *kaski* form of swidden could have occurred in broadleaf stands in previously uninhabited areas such as sites disturbed by natural wildfire. Since the earliest grain pollen detected in association with an increase in charcoal particles was of the *Hordeum* type (barley) as opposed to *Secale* (rye) pollen (Taavitsainen *et al.*, 1998), one should be cautious about interpreting *huuhta* as the earliest form of swidden cultivation. Orrman (1993) suggests that the barley could have been cultivated in early *kaski* type swidden burns in patches of mixed or primarily broadleaf forest within the otherwise conifer-dominated landscape, or early varieties of barley may have been effectively grown in *huuhta* type burns even though more recent documentation suggest only rye and turnips could effectively grow in *huuhta* clearings.

Nevertheless, *huuhta* is generally thought to be associated with the first wave of pioneers to practice swidden cultivation in the wilderness areas of eastern Finland, followed by *kaski* techniques in the broad-leaved forest that became established in the former *huuhta* swidden areas (Pyne, 1997; Richards, 1999). Since *huuhta* could generally not support barley cultivation, Soininen (1959) infers from tax records from 1559 AD that *huuhta* was more commonly practiced in newly settled areas than in old settlements at that time as taxes were paid primarily in rye (61.9%) in new settlements and primarily in barley (86.3%) in older settlements of Talvinsalmi (approximately 100 km west of Koli National Park). These same tax records indicate that some families paid their taxes both in rye and barley, suggesting that some families may have practiced both *kaski* and *huuhta* cultivation at that time.

Although the Kalevala, Finland's national epic, is based on Finnish mythology, it provides insight into the everyday elements of Finnish life at the time of its compilation by Elias Lönnrot from songs and poems within the oral history of the people from these "wilderness" areas in the mid 1800s. Rune II of the Kalevala (Crawford, 1888) attests to the practice of *kaski* and acknowledges the fertilizing effect of the ashes for the cultivation of barley, as can be seen in the following verses.

> Thence to sow his seeds he hastens,
> Hastes the barley-grains to scatter,
> Speaks unto himself these measures:
> "I the seeds of life am sowing,
> Sowing through my open fingers,
> From the hand of my Creator,
> In this soil enriched with ashes,
> In this soil to sprout and flourish.

Heikinheimo (1915 cited in Huttunen, 1980) reports that a 25 year *kaski* swidden rotation would include five years for felling, drying, and crop cultivation; three years for haymaking in the fallow field; and 17 years for pasturing livestock as the forest regenerated until the next cycle began. At what point in time livestock husbandry became a regular component of swidden cycles is difficult to discern. Because there are no pollen types that exclusively indicate grazing activity, palynological evidence of livestock must be interpreted with caution (Taavitsainen *et al.* 1998). Although some pollen of species typically (but not exclusively) found in grazed habitats was detected in the pollen-stratigraphy from times when swidden cultivation was first practiced sporadically in eastern Finland, Taavitsainen *et al.* (1998) suppose that seasonal hunters practicing swidden cultivation were unlikely to transport their livestock long distances to their seasonal hunting grounds. Osteological evidence was found of horse (*Equus caballus*), domestic pig/wild boar (*Sus scrofa*), sheep/goat (*Ovis aries/Capra hircus*) cattle (*Bos taurus*), and chicken (*Gallus domesticus*) from Mikkeli (approximately 200 km southwest of Koli National Park) and Savonlinna (approximately 140 km south-southwest of Koli National Park) dating from the late Iron Age (600-1300 AD) (Taavitsainen *et al.*, 1998). This osteological evidence of livestock coincided with palynological evidence of regular swidden cultivation activity that suggested permanent settlement of these areas at this stage of the region's settlement history.

Use of swidden cultivation was not a result of unfamiliarity with permanent field cultivation. By 400 – 800 AD a transition from a mixed lifestyle of hunting, fishing and cultivation to permanent field cultivation in southern Finland was already complete (Zvelebil and Dolukhanov, 1991), long before the practice of swidden cultivation finally died out in eastern Finland early in the 20th century (Huttunen, 1980). According to Tvengsberg (1995) the standard of living of the Finns practicing *huuhta* in 1640 was higher than that of farmers cultivating permanent fields. Thus the practice of swidden cultivation was likely deliberately chosen rather than an obligatory practice resulting from a lack of awareness of other options.

Persistence and Spread of Swidden Cultivation

Geographical characteristics of eastern Finland explain the advantages of swidden cultivation in this area and why the practice persisted despite knowledge of permanent field cultivation. The clay and silty soils of lacustrine deposits in south and southwest Finland, being easily tilled, gave rise to permanent field cultivation. However, unlike south and southwest Finland, much of northern Karelia was little affected by post glacial bodies of water (e.g., Baltic Ice Lake, Yoldia Sea or Ancylus Lake) that formed when the ice sheet retreated (Hyvärinen, 1973; Taavitsainen *et al.*, 1998). Instead, the area is dominated by supra-aquatic glacial deposits (eskers, till, moraine) (Huttunen *et al.*, 2003), which by their stony nature and shallow, relatively infertile soils, are less suitable for the establishment of permanent field cultivation. In the few low-lying areas where there was better soil and the potential for permanent field cultivation, frost damage could threaten crops in these northern locations. Swidden cultivation on upland sites reduced frost risk, allowed plots to be cleared, fertilized, and sown without tilling, and despite the short period over which the land could be cultivated, delivered short-term yields much higher than those of permanent fields.

According to Soininen (1959), the high yields are attributed to the specialized variety of rye used in *huuhta* cultivation, which resisted brown rust (*Puccinia triticina* Erikss. & Henn.). This variety could be sown earlier and allowed to tiller before the snow fell. As a result of the advanced tillering, many more stems could sprout the following summer than was the case for varieties that had to be sown later in the autumn due to their susceptibility to the rust. Holopainen and Helama (2009) report the yield of rye sown in permanent fields in southwestern Finland ranged from 3.4 to 8.7 grains per seed sown in the 16th and 18th centuries. Reports of rye yields (grains planted: grains harvested) in *huuhta* fields range from 1:20 or 1:40 (Moring, 1999) to 1:20 or 1:100 (Soininen, 1959; Richards, 1999) to 1:12000 (Tvengsberg, 1995). Even if the most conservative report is accepted, the yields from *huuhta* cultivation are remarkably higher than yields of rye from permanently cultivated fields. Although yields from *kaski* cultivation are much lower than those of *huuhta* (1:8 to 1:15), *kaski* fields could be cultivated for 2 to 7 years, though yields declined with elapsed time since burning (Soininen, 1959). These factors enabled the effective exploitation of Savo and Karelian "wilderness", which was otherwise unsuitable for agriculture.

Successful colonization of these forested wilderness areas was perhaps too successful in the long-run. A study of fire scars on *Pinus sylvestris* reveals that between the years 1412 and 1992, fire intervals in Patvinsuo National Park (approximately 50 km west of Koli National Park) were as short as seven years and as long as 67 years, with an average of 37 years on upper slopes and 59 years on lower slopes (Lehtonen *et al.*, 1996). Examination of figures from Lehtonen *et al.'s* (1996) study reveals that the most fires and the shortest fire intervals in this area occurred from approximately 1770 to 1830. This time period roughly coincides with a threefold population increase in North Karelia that occurred between 1750 and 1870 (Taavitsainen *et al.*, 1998). With increased pressure to produce food, the area under swidden cultivation increased from small isolated patches to a fine-grained mosaic of plots in various stages of regeneration covering the landscape. Rotation times shortened in areas to the point where many trees species could not mature before being cut again for another swidden cycle, as evidenced by pollen rain revealing high proportions of early-maturing grey alder (*Alnus incana* [L.]

Moench) and greatly reduced proportions of other arboreal pollen (Alenius *et al.*, 2007). The great famine of 1867-1868 is linked to this increase in human population, increase in swidden clearings, low rotation times, and consequently poor harvests confounded by particularly cold and wet weather those years (Grönlund and Asikainen, 1992; Taavitsainen *et al.*, 1998).

The rise of swidden agriculture in eastern Finland transformed a landscape with a matrix of mature, mainly coniferous forest with a few insignificant patches of clearing burned by hunter-gatherers to attract game, into one where only small patches of mature forest remained within a mosaic of swidden plots in various states of use or regeneration. Individual swidden sites would have been approximately 2.2 ha (Heikinheimo 1915, in Pyne 1996). Although it is possible to control the edges of a well-planned burn with basic equipment such as *Picea abies* boughs and buckets of water, some swidden fires likely escaped their intended boundaries and burned much larger areas than planned[36]. By the beginning of the 20th century, Heikinheimo (1915, in Parviainen, 1996) reported that swidden cultivation had been practiced on as much as 4 million ha per year, affecting 50 to 75% of Finland’s forested land. Heikinheimo (1915 cited in Parviainen, 1996) also indicated that at that time a shortage of firewood and timber was experienced in parts of central and eastern Finland due to the extent of deforestation caused by swidden cultivation. Swidden agriculture was practiced most intensely and persisted longest into recent times in the core area of Karelian culture west of Lake Ladoga, including the area around Koli National Park (Parviainen, 1996).

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[36] According to Heikinheimo (1915 cited in Pyne, 1996) swidden fires were rarely contained and commonly caused forest fires. However, Heikinheimo’s attitude towards swidden cultivation was unapologetically negative and he did not provide evidence to support this claim.

Swidden Cultivation Declines

The practice of swidden cultivation was initially encouraged by Swedish rulers as a way to increase tax revenues (apparently, in 1587 anyone who did not clear forest and sow rye was threatened with severe punishment [Montelius, 1953]). But 60 years later the Forestry Act of 1647 began to limit, though not abolish, the practice in order to conserve the forest resources that were needed for the mining industry (Montelius, 1953). Another bill enacted in 1734 made it necessary to obtain a licence prior to burning forest land (Parviainen, 1996).

Brown (1883) provided an English translation of a series of papers published in the *Helsingfors Dagblad* based on a 1883 report of the Forest Committee responsible for proposing a new forest law at that time. The Forest Committee responded to calls for the outright prohibition of swidden cultivation by acknowledging that wildfires escaping from swidden burns consumed large tracts of valuable forest, but they also acknowledged that swidden cultivation was necessary for the population of eastern Finland to meet its basic needs, sow grains for other regions, and raise cattle (butter was a particularly valuable export and source of revenue). The Committee recommended that the existing Forest Law be reworded to forbid swidden cultivation on extremely stony soil, on thin soils overlying rock, or in tall forests with sandy soil and heather (presumably *Calluna*) understorey. They also recommended that no more than two crops be harvested from a swidden field and that at least 20-30 years of regrowth be allowed between burnings, depending on the forest type. On the basis of difficulty of enforcement and the high value of cattle and milk products compared to forest products, the Committee suggested the reversal of a regulation promulgated in 1881 that prohibited the use of swidden lands with less than eight years of re-growth as pasture for cattle.

Overall, legislation limiting swidden cultivation was largely ineffective at curbing its use in eastern Finland until the early 20th century (Sarmela, 1987), when the increased value of timber, draining wetlands, and later the use of chemical fertilizers and tractors, were effectively stronger incentives for the cessation of swidden cultivation in favour of permanent field agriculture.

A Shift to Permanent Field Cultivation

Physical evidence of swidden cultivation at Koli was common at several of the sites studied (e.g., turnip pits at Seppälä, Ala-Murhi, and Ylä-Murhi; rock piles within currently forested parts of Mäkränaho, Turusen Autio, Seppälä and Havukkanaho). However, none of the approximately 1 400 photographs that remain from Einar A. Saaralainen's collection depicted the active use of fire in swidden agriculture. Several photographs, though, could be interpreted as having a possible but not necessarily conclusive connection to swidden activity.

One photograph (location unknown) shows a clearing made in a stand of young deciduous trees (probably mostly *Alnus incana*) with larger diameter logs in piles and separate piles for smaller diameter branches (Figure 3.4). Whether the young stand is a result of an earlier swidden burn is unknown. There are no rock piles visible that may have suggested former swidden activity at the site. It is also unknown whether these piles of logs were then burned and/or if the field was then used for cultivation either permanently or temporarily.

Figure 3.4. Clearing in or near Koli National Park with piled logs photographed by E. Saaralainen.

Another photograph (Figure 3.5) reveals a field in the foreground that is full of woody vegetation less than 1m tall. Some boulders are visible among the vegetation, but it is not perfectly clear whether these rocks were piled. The adjacent field in the middle ground contains several distinct rock piles, though the field is in a more open condition, suggesting it was either a newer clearing or was maintained in an open state.

Figure 3.5. View of farm fields adjacent to Koli National Park photographed by E. Saaralainen.

A photo of a field at Mäkränaho (Figure 3.6) taken before the main house was built, appears to have recently been cleared (among the young deciduous saplings in the foreground, ferns and dense moss on the rocks suggest a previously closed canopy). A later photo of the same field (Figure 3.7) after the house was built reveals stones in the field without moss and most of the woody vegetation (except for a few *Betula sp.* and rowan [*Sorbus aucuparia* L.] shade trees) had been replaced by a meadow. According to Lohilahti *et al.* (2006) the Mäkränaho farm site was abandoned in 1934; therefore this activity must have been photographed prior to that date.

Figure 3.6. Field at Mäkränaho photographed by E. Saaralainen.

Figure 3.7. Field at Mäkränaho after house was built, photographed by E. Saaralainen.

The only photograph containing any burning of vegetation portrayed a family cutting down a hedgerow of birch and possibly other deciduous species along the edge of a field, immediately beside a newly dug ditch (Figure 3.8). Presumably the family was engaged in draining and enlarging a field that was otherwise too moist for cultivation. Draining wetlands was one of the notable transitions from shifting swidden cultivation to permanent field cultivation as the soils in the drained wetlands and peatlands could sustain cultivation for longer periods of time than the short-lived individual swidden plots.

Figure 3.8. Burning vegetation by new ditch photographed by E. Saaralainen.

The oldest of the interviewees could remember the agricultural practices of their families and neighbours as far back as the 1940s and 1950s. However, only one of the interviewees mentioned using fire as part of the animal husbandry practices of his youth. This interviewee, who raised Northern Finncattle (a heritage breed of northern Finland) as well as imported Ayrshire and Friesian cattle in Lapland in his youth, recalled burning the understorey in young (approximately 10 years old) forest pastures to encourage fireweed (*Epilobium angustifolium* L.), which he stated was the best fodder for milk production, resulting in milk with a higher vitamin content. None of the interviewees who lived on farms in the Koli area in the mid-20th century mentioned the use of burning in their descriptions of the farming practices of their youth. Considering the swidden cultivation was reported to already be uncommon in Finland by 1913 (Parviainen, 1996) and carried out in the Koli area only until the 1930s (Vehmas *et al.*, 2009), the interviewees may have been too young to have experienced swidden in their lifetime.

The older interviewees from the Koli area recollected that when they were young, families in the Koli area typically fulfilled their household food needs from their own livestock and crops. The interviewees indicated that rye, barley, oats, wheat, turnips, onions (*Allium* L.), peas (*Fabaceae* Lindl.) and beets (*Beta vulgaris* L.) were grown in permanent fields that were ploughed by horses and fertilized using the winter's accumulation of manure from the livestock. Eight of Saaralainen's photographs depicted grain crops being grown or harvested. The type of grain is difficult to determine from the quality of photographs, but was most likely wheat, rye, and/or barley. In at least two of Saaralainen's photographs hay was harvested and stacked to dry on upright stacks supported by a centre pole (as was done during the "traditional day" community event held in 2008) or on horizontal drying racks. Horses are depicted in six of the photographs, harnessed and/ or hitched to wagons or ploughs. None of the photographs contained tractors of any sort. However, one photograph showed a motorpowered thresher in use, with two horses in the middle ground hitched to transportation or harvesting equipment (the hitches are visible, but the equipment is partially obscured by a man standing in the foreground and the rest is outside the frame of the photograph).

Because moose (*Alces alces)* can easily jump over fences even as high as 2 m (Ritcey and Edwards, 1956) any fences erected in Koli National Park in the past must have been to enclose, or more likely to exclude, domesticated livestock rather than wild herbivores. According to the interviewees, the fields would be fenced to keep livestock out and prevent them from eating or trampling the cultivated crops. Fences were clearly visible in the majority of Saaralainen's photographs of cleared fields in the Koli hills. Three types of fences could be distinguished: roundpole fences (*riukuaita* or *pistoaita* in Finnish) where the rails run diagonally; "stake and rider" fences with the rails more or less horizontal; and roundpole fences with the lower half of the fence constructed as a dry stone wall. The upland fields were adjacent to forest at least along one edge. However, some fields in the lower altitude flatlands immediately west of the current boundaries of Koli National Park were not surrounded by wooded areas and did not have any fencing visible around the perimeter of the fields.

The older interviewees from the Koli area indicated that in their youth each household would have six to eight cows, between 10 and 20 sheep, and two or three horses. Some families also had around six chickens and a pig. There were no photographs of sheep visible in the entire collection of photos at the Koli Heritage Museum. Cattle, however, featured in eight photographs, including one photograph taken at the home of one of the interviewees. The photographs showed herds at least as large as seven to 23 head of cattle (some additional individuals in a herd may have been beyond the camera's field of view). In three photos, the cattle were in woody pastures, whereas in four photos, the cattle were in treeless pastures. Milking (by hand) occurred both in wooded areas and in open pastures. All of the cattle in the photographs (one of which was horned[37]) conformed to the typical appearance of Eastern Finncattle.

The interviewees mentioned that most of the sheep and cattle used in their youth were heritage breeds (Finnsheep and Eastern Finncattle). A few head of Western Finncattle, another heritage breed from the western part of Finland, were also kept and the two breeds were allowed to cross. The cattle and sheep were pastured in the forest, sometimes as mixed herds of cattle and sheep; sometimes pastured separately due to differences in fencing that could contain cattle but not sheep. The forest pastures were fenced to keep the livestock within desired boundaries and out of cultivated fields. One interviewee mentioned that his sheep were tethered in one forested area because the fences could not effectively contain the sheep. According to one family, for the purposes of controlling internal parasites, grazing in large forested areas was preferable to grazing in smaller open areas.

A verse from Rune 32 of the Kalevala (Crawford, 1888) attests to the practice of pasturing cattle in a variety of wooded areas:

> "Drive the cows to yonder bowers,
> To the birch-trees and the aspens,
> That they there may feed and fatten,
> Fill themselves with milk and butter,
> In the open forest-pastures,
> On the distant hills and mountains,
> In the glens among the birch-trees,
> In the lowlands with the aspens,
> In the golden pine-tree forests,
> In the thickets silver-laden."

[37] In the 1910s most registered Eastern Finncattle were horned (including females), but by the 1920s the majority were polled (Lilja *et al.* 2009).

A brief mention of "sheep of the forest" is made in Rune 33 of the Kalevala (Kirby, 1907), though in Crawford's (1888) translation the verse refers to ermine.

Though the livestock would be pastured in the forests, it was necessary to harvest hay as winter fodder for the livestock from semi-natural meadows (anthropogenic clearings in which wild grasses and forbs grow without cultivation or fertilization). According to one interviewee, hay from these meadows was sorted. Better quality, less coarse hay was given to the sheep, while the horses and cattle were given coarser hay. In autumn, hay would also be cut from rye fields that were sown in early August (the following year the rye fields would be harvested for grain). Winter fodder for the sheep also included bundles of deciduous branches with leaves on them that were collected no later than midsummer (summer solstice) to ensure that the leaves had ideal levels of protein, vitamins and not too much fibre. These boughs would be fed to the sheep in winter and during the late stages of their pregnancy. The interviewee added that nitrogen content of *Alnus incana* leaves aided digestion and that bark from young *Pinus sylvestris* branches was also fed to sheep in spring as a source of vitamins.

Modernization Begins

According to Westermark (1964), World War II marked the next major transition towards to modern agriculture in Finland. Due to the land ceded to Russia in 1940, Finland lost 11% of its tilled land, while its population stayed relatively stable (due to the relocation of almost all of the inhabitants of the ceded land to areas of what remained of Finland). To feed the population, improvements in technology and infrastructure, as well as the consolidation of small dairies into large ones, led to the intensification of agriculture.

The interviewees from the Koli area indicated that changes to the agricultural practices they remembered as youth mainly came about in the 1960s. At this time, imported Friesian and Ayrshire cattle became available, and fields began to be cultivated with improved grass mixes for hay rather than harvesting hay from semi-natural meadows. Tractors replaced horses for draught power. The number of tractors owned in the province of North Karelia increased dramatically in the late 1950s and 1960s (Figure 3.9). Pastures began to be fenced to contain livestock rather than allow them to graze in the forest.

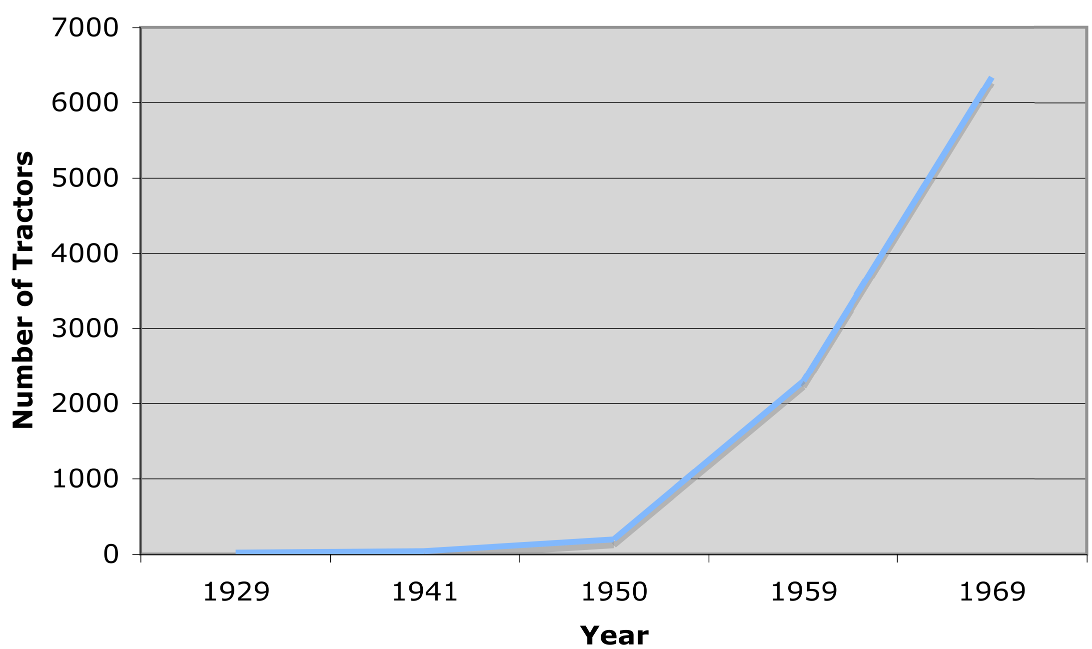

Figure 3.9. Number of tractors in North Karelia 1929 – 1959 (Saloheimo, 1973).

The interviewees reported that the imported cattle breeds produced more milk than the heritage breeds. It is common in many parts of the world to crossbreed heritage breeds of livestock with imported breeds to improve productivity (milk yield and/or carcass size) while retaining some of the traits that make the heritage breeds adapted to local conditions. Such crosses often benefit from the phenomenon of heterosis, in which the first generation (F_1) of crosses outperform the average of both parents because of the greater degree of heterozygosity (Simm, 1998). However, crosses between heritage and imported breeds are not always as successful as they are expected to be (Telenged, 1996; Sneath, 1999; Karugia *et al.*, 2001; Maier *et al.*, 2002; Perezgrovas, 2003). One interviewee recalled that when Friesian semen was used to impregnate Eastern Finncattle, the cows sometimes had troubles birthing because Friesian cattle are much larger than Eastern Finncattle. Replacement and crossbreeding with imported Ayrshire and Friesian cattle in the mid 20th century led to a decline in the numbers of Eastern Finncattle. In 1927, a total of 4 620 bulls and 14 650 cows were registered in the Eastern Finncattle breed society's herdbook, but by the 1980s only approximately 50 cows and 10 bulls remained (Lilja *et al.*, 2009). When asked if the imported breeds fared as well as the heritage breeds on forest pasture, the interviewees did not recall anyone trying to raise the imported breeds in forest pastures, suggesting that the transition to grazing cattle in open pastures had already taken place once the imported breeds were adopted.

One interviewee also mentioned that Norwegian sheep breeds were occasionally used in the Koli area because of their larger size and higher yields of meat and fibre. But Finnsheep were preferred because they were more prolific, typically having three to four lambs (and up to seven lambs) at once. The interviewee stated that the Finnsheep were good mothers, taking care of their large litters, but when five or more lambs were born to one ewe, the ewe might not have enough milk to adequately feed all of the lambs. Unlike modern sheep breeding practices, which "flush" ewes of other breeds with supplementary grain prior to breeding, according to the interviewees no supplementary food was given to the Finn ewes to promote increased ovulation. The investigator's own experience with Finnsheep corroborates this statement: six of thirteen ewes gave birth to triplets or quadruplets without being flushed prior to breeding.

The transition of farming from the 1960s onwards to rely increasingly on imported genetic material for cattle rearing and pasture management, as well as on increased mechanization, completed the shift away from "traditional" agricultural practices towards activities that depend on external inputs and expertise.

Current Farming Practices with Finnsheep and Eastern Finncattle

Information about current practices in raising sheep and cattle in eastern Finland was gained through interviews with current farmers and staff from an agricultural college, as well as from participant observation field notes.

Finnsheep

The sheep farmer whose sheep grazed in Koli National Park in 2008 indicated that most of her Finnsheep (the ones that do not spend their summers at Koli) primarily graze on improved pasture rather than in wooded areas. Two private landowners ask the sheep farmer for some sheep to graze their land every year in order to keep the land open (reduce woody regeneration). In winter the sheep are kept indoors. They are shorn twice per year: once in the spring and again in the autumn.

Winter feed for the sheep is hay from improved hay fields that are ploughed and sown every five years. Winter feed also includes oats, rapeseed (*Brassica nutans* L.), peas, minerals, salt, silage and sometimes dried molasses. Ewes that are expected to lamb within one month and those that are lactating are given 200 g of oats per ewe per day. All feed provided to this farmer's flock must be grown according to the national guidelines for ecological certification. Following guidelines for ecological farming, the sheep farmer provides grain as no more than 40% of the daily diet by dry weight per day. In summer, the sheep are on pasture and are not given any supplementary feed.

If any supplementary feed is given to the ewes prior to breeding, the Finnsheep would have more lambs, but with more than three lambs only very good ewes will produce enough milk for her whole litter. The sheep farmer felt it was preferable to have two or three lambs; her average is 2.1 lambs per ewe. Usually the ewes have no problems lambing.

With respect to breeding decisions, the farmer aims to maintain the distinct colour variants in her flock: i.e., breeding black ewes with black rams, brown ewes with brown rams, grey ewes with grey rams, and white ewes with white rams. Coloured fleece fetches a higher price from the wool mills because coloured fleece is unusual.

Eastern Finncattle

The Eastern Finncattle that grazed at Koli National Park in 2008 were from one of only two conservation herds of this breed, which were kept at the Kainuu Vocational College (*Kainuun Ammattiopisto*). At the college, the cattle that did not go to Koli National Park were pastured on open pasture that is ploughed and sown every four years with a timothy (*Phleum pratense*) hay mixture. In winter the cattle would be fed silage and hay. Those that were milking would get 2 to 6 kg of grain per day, depending on their stage of lactation. Milking occurred twice per day, by machine. Those that were not lactating would be given the poorer quality hay and silage. Supplementary minerals were also supplied to all cattle at the college.

Most of the cows were bred using artificial insemination, though 10 were bred directly with a bull. Breeding decisions were based on a plan devised by agricultural experts to minimize inbreeding and preserve optimal genetic diversity. The breeding strategy was developed to recover the breed from its critically low numbers in the 1980s with as little loss of genetic diversity as possible.

Within a few days of being born, calves are separated from their mothers and raised on self-feeding bottles. Male calves are sold to another farm that specializes in raising them for beef.

How Finnsheep and Eastern Finncattle are Kept in Koli National Park

Finnsheep and Eastern Finncattle were reintroduced to Koli National Park in 2003. Each year, five or six Eastern Finncattle spend the summer at the park. These cattle are part of only two actively conserved living genebanks of Eastern Finncattle that remain. The herd of roughly 60 cattle from which Koli's cattle came were initially kept at the Sukava prison farm, but in 2007 they were transferred to Kainuu Vocational College.

The cattle that spend the summer at Koli are selected from among approximately 20 dry (non-lactating) cows to avoid the need to milk the cows at the park. The cattle graze in three fenced pastures on a rotational basis at the Ollila farm site in the park. The cattle are moved from field to field based on the condition of the grass, subjectively assessed by the park staff responsible for the care of the cattle. The cattle are tended to on a daily basis by park staff, usually those who live in residences close to the fields where the cattle are kept. Daily care involves ensuring that adequate clean water from a hand-pumped well is available in a large tub for the cattle and providing grass hay to supplement the pasture forage. In 2007 and 2008 one of the cows in each year unexpectedly gave birth while at the park. These cows with their calves were returned to the rest of the conservation herd where they would have more experienced caregivers and the cows could then be milked. The cow in 2007 gave birth to twins, which is unusual in cattle, but Eastern Finncattle are known to have a high twinning rate (FAO, 2008).

The 40 Finnsheep that grazed at Koli National Park in 2008 were privately owned by a farmer who specializes in organic sheep farming. The park director approached the sheep farmer in 2003 and proposed that the sheep graze at the park in the summer months. This arrangement was beneficial to the farmer because it reduced the farmer's need to invest in fencing improvements on some of her pastureland. With some of her sheep at Koli, the farmer could keep the remaining flock on the pastures at her farm with the best fencing. This reduced her flock's dependence on other fields with less adequate fencing. To avoid the need for specialized attention for the sheep at Koli, the farmer keeps any ewes that she expects to lamb in autumn at her farm. She sends ewes to Koli that have already weaned their lambs from the spring, and prefers to send ewes that have grazed at the park in previous years. The sheep are kept at three sites within Koli National Park (Ollila, Seppälä and Maatila) and graze on a rotational basis in primarily open fields that were once cultivated, in regenerating swidden sites and/or in forest pastures. The sheep at Ollila are cared for by the same park staff as the Finncattle. The sheep at Maatila are cared for by a group of local volunteers from the Koli area. The sheep at Seppälä are cared for by volunteers in exchange for the privilege of free accommodation at the Seppälä cabin while volunteering at the park. The caregivers for the sheep are responsible for ensuring that adequate clean water from a hand-pumped well and a salt block are always available to the sheep, and for providing supplementary minerals (in granular form) on a daily basis. The farmer felt that after spending the summer (June – Sept) at Koli, the ewes always came back in good condition, that they have enough food there and they are well cared for. There is no financial exchange between the park and the farmer, but the park normally provided funds to cover the cost of gasoline that the farmer used to transport the sheep to and from the park each year.

Influence of Changing Agricultural Practices on the Landscape at Koli

The conversion from swidden to permanent field cultivation in the early 20th century meant that less land was needed overall for cultivation. Forestland again dominated as swidden plots were abandoned and reforestation initiatives were undertaken. Semi-natural meadows maintained in an open state through grazing and/or haymaking, which constituted 62% of Finland's agricultural land in 1880, now represents less than 1% of the total agricultural land in Finland (Luoto *et al.*, 2003). As a consequence of these changes, semi-natural meadows, grazed woodland and forest pastures are now considered critically endangered habitats in Finland (Raunio *et al.*, 2008).

These trends are observable in the present-day landscape of Koli National Park. In 2008, many of the landscape photographs depicting agricultural land use in the Koli area were practically impossible to retake from the same vantage points as Saaralainen's original photographs. This was due to increased growth of trees that obscure much, if not all of the view (evidence in itself of the increased forest cover in the park). Three of Saaralainen's photographs were successfully retaken and provide visual evidence of the changes in the landscape over the past 80 - 90 years. A detailed image analysis of the changes is beyond the scope of this dissertation, however, viewing the new and old photographs side-by-side (Figures 3.10a & 3.10b, 3.11a & 3.11b, and 3.12a & 3.12b) clearly reveal that many of the former fields have been reduced or replaced by forest regeneration and that many formerly deciduous stands are now spruce-dominated.

A cartographic analysis provides a quantitative measure of the reduction in size of Mäkränaho (the farmstead featured in the upper left of Figure 3.10a) and Ikolanaho (the farmstead featured in the middle ground of 3.11a). An examination of maps available for the central part of Koli National Park from 1939 (Knuuti, 1936), 1961-62 (Vilén, 1961-1962), 1971 (Vilén, 1971) and 2006 (Lohilahti and Pajari, 2007) reveals a reduction in size of most of the agricultural clearings over the past seven decades as well as the abandonment of three smaller meadows near one of the sites (Purolanaho). Overall, less than 40% of the cleared area from the central part of Koli National Park that existed in 1939 remained in an open state in 2006 (Table 3.1). Forested areas used for grazing were not indicated on the maps.

Figure 3.10a. View from Mäkrä northwards taken by E. Saaralainen around the 1930s.

Figure 3.10b. View from Mäkrä northwards taken by M. Pfähler in 2008.

Figure 3.11a. View from Ukko Koli southwards by E. Saaralainen around the 1930s.

Figure 3.11b. View from Ukko Koli southwards taken by the investigator in 2008.

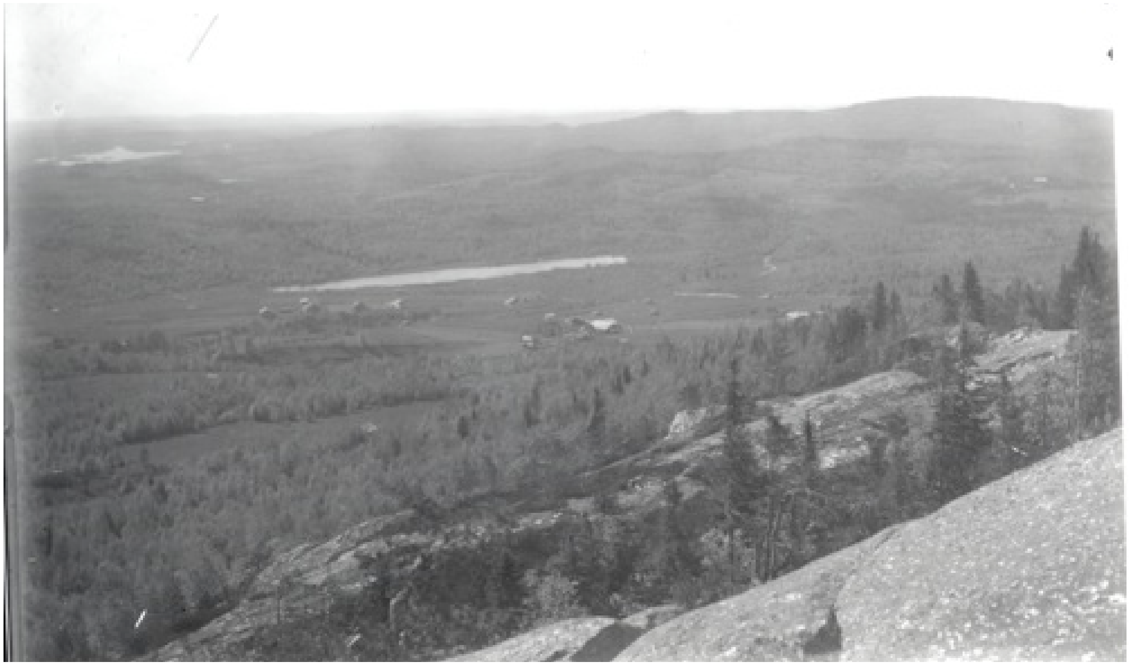

Figure 3.12a.View from Ukko Koli towards north-northwest by E. Saaralainen around the 1930s.

Figure 3.12b.View from Ukko Koli towards north-northwest by the investigator in 2008.

Table 3.1. Size of meadows in central area of Koli National Park 1939 – 2006.

Site	1939	1961-62	1971	2006
Mäkränaho	3.63 ha meadow	Not identified as meadow on map	2.91 ha meadow	0.99 ha meadow
Ikolanaho	2.59 ha meadow	2.16 ha meadow	1.47 ha meadow	1.33 ha meadow
Purolanaho	1.82 ha main meadow + 0.35 ha meadow (~ 90m north of main meadow) + 0.38 ha meadow (~ 600 m southeast of main meadow) + 0.45 ha meadow (~ 40 m northwest of main meadow) Total: 3.00 ha	1.44 ha main meadow + 0.34 ha meadow (~ 90m north of main meadow) Total: 1.78 ha	1.44 ha main meadow only	1.07 ha main meadow only
Mustanniityt	4.00 ha meadow	3.01 ha meadow	2.37 ha meadow	1.86 ha meadow
TOTAL	13.22 ha	6.95 ha	8.19 ha	5.25 ha

Restoration of Traditional Agricultural Practices in the Koli Area

In response to the loss of open, disturbance-dependent habitats associated with traditional agricultural activities, the managers of Koli National Park began to restore some of the early agricultural practices to the landscape.

Swidden burns

Since 1994, swidden burns have been conducted on an annual basis in Koli National Park. Prior to the resumption of this practice, swidden burns had not been conducted in the park for at least 55 years. The two swidden burns that the author attended in Koli National Park in 2007 and 2008 engaged teams of 13 -15 individuals (most of whom were volunteers), who assisted with transporting buckets of water around the burn site, lighting the fire and preventing the fire from escaping beyond the desired area. Several community members and tourists came to observe the burn in 2008. Both fires were *huuhta*-type swidden burns, primarily fuelled by mature *Picea abies* trees that were felled using chainsaws the previous year. The fires were lit primarily using propane torches, though in 2008 a park staff member demonstrated how to start a fire using flint and steel. The fires were ignited using the "ring fire" technique (Ohlenbusch, 1996). The edges of the burn were controlled by smothering small flames with the tops of freshly cut *P. abies* saplings (the lower branches were removed, creating a broom-like shape to the sapling). All participants wore traditional linen clothing similar to the apparel depicted in Eero Järnefelt's (1873) painting "*Raatajat rahanalaiset*" with the exception that modern footwear was worn rather than birch bark shoes, which were depicted in the painting. The linen apparel was employed not only to create an historic atmosphere, but also for practical purposes, as linen insulates against heat (Behera, 2007) and is visible through smoke (the linen shirts were white and therefore visible despite the thick, dark smoke).

Haymaking

As part of an effort to restore traditional landscapes to Koli National Park, hay is cut from several open habitats within the park where haymaking and/or crop cultivation had been done in the past. Hay in some areas is cut using scythes, especially when volunteer labour is available. Otherwise, motorized hand held mowers are used, or in areas with road access tractors are employed to mow and sometimes bale the hay. Unless a tractor is used, the cut hay is stacked on upright wooden posts to dry. Once dry, some of the hay harvested is used as supplemental feed for the cattle. In less accessible areas, the hay had been disposed of at the edge of the clearings, left to compost on site. Hay harvested with tractors was removed from the site.

Livestock behaviour

Finnsheep behaved quite differently from the breeds with which the investigator had previous experience in Canada (Purebred Dorset, Purebred Arcott, Arcott-Suffolk cross, Dorset-Kahtadin-Romney cross and Arcott-Cheviot-Romney cross). The Finnsheep at Koli National Park were remarkably tolerant of human presence. Some even actively sought attention and petting, running *towards* visitors when they were walking along pathways adjacent to the fenced sheep pastures. Since raising Finnsheep at her farm in Canada (since December 2008), the investigator has noticed that they are more tolerant of being handled by humans than any of the other breeds she has worked with (most of her Finnsheep do not try to avoid being touched – some even calmly stand still or lay down without being restrained while being hand-shorn or having their hooves trimmed).

The Finnsheep at Koli National Park not only grazed grasses and forbs, but also tended to browse the foliage and twigs of deciduous trees within their pastures. If leaves were higher than they could reach on all four feet, they would occasionally rise up on their hindquarters to reach higher, even if suitable herbage was still available on the ground. On several occasions, the Finnsheep were observed bending over (but not breaking) a sapling using their necks to access foliage that was otherwise out of reach. Several sheep would browse the canopy of the bent tree until it sprang back up when the first sheep “let go” of it. In these cases, the Finnsheep could access the foliage above the upper limits of the browse height[38] of the vegetation, but only a minority of the leaves could be consumed before the bent tree sprang back to its original position. At Koli National Park, Finnsheep were observed browsing foliage of silver birch (*Betula pendula* Roth), downy birch (*Betula pubescens* Ehrh.) and *Sorbus aucuparia* trees. Sheep were also observed stripping the bark off of *Alnus incana* at the Ollila farm site in one of the old field sites (oll 4[39]), a pasture that was otherwise very open and lacking other trees, as well as at the Seppälä farm site in one of the forest pastures (sep 3b) late in the season when much of the ground vegetation had been consumed. The investigator also observed that Finnsheep made more use of woody vegetation in her pasture in Canada than other breeds, reaching high leaves on their hind quarters and bending or toppling saplings to gain access to their foliage more often than any of the other breeds pastured in the same location. The Finnsheep at Koli National Park also grazed grasses and forbs. Although it was not a direct aim of this study to observe which species were consumed or particularly favoured by the sheep, the sheep were observed eagerly consuming the flowers and upper stems of *Epilobium angustifolium* upon first entering a regenerating 2-year-old swidden site.

While caring for the sheep at Koli, the investigator observed a young wolverine (*Gulo gulo*) within 100 m of the flock of sheep on three occasions over a 10-day period in late summer. Although wolverines are known to predate on sheep, the Finnsheep at Koli were not apparently affected by the presence of the wolverine. The author noted the Finnsheep to be quite watchful and gregarious, which is advantageous to avoid

[38] A clear line of defoliation was apparent at the end of the 2008 grazing season. There was clearly less foliage below a height of 1.4 m on the saplings within the pastures grazed by Finnsheep at the Ollila farm site.
[39] Additional details about each site are presented in the next chapter.

predation. The interviewees, however, did report some occasions when they had lost Finnsheep to wolves (*Canis lupis*) and Eurasian lynx (*Lynx lynx*) in the past.

Although the investigator was not responsible for the care of the Eastern Finncattle at Koli National Park, she did spend some time with the cattle and in their pastures to observe some of their habits. The cattle were usually observed in the open areas of their fields (as most of the area of the cattle pastures was open), the cattle were observed browsing the foliage of *Alnus incana* and trampling *A. incana* under 5 cm dbh, knocking down the canopy and splitting the trunk.

One interviewee mentioned that the Eastern Finncattle have strong anti-predation instincts. The interviewee reported that they could no longer permit the farm dog (which could run freely among the mainstream cattle breeds formerly raised at the same farm) in the vicinity of the Eastern Finncattle because the breed is particularly aggressive towards canines.

<u>Consistency Between Traditional and Current Agricultural Practices at Koli</u>

In general, the descriptions of changes in traditional agriculture over the past 100 years are consistent among the sources of data utilized in this study. Table 3.2 compares some characteristics of agriculture as practiced historically in the Koli area, as well as current practices generally and within Koli National Park. Overall, the practices at Koli National Park today reflect an intention to replicate traditional forms of agriculture through their choice of breed and mainly historically accurate resumption of swidden burning and cultivation. However, the use of modern technologies to accomplish some of the practices (e.g., the use of chainsaws to fell the trees in swidden plots, propane torches to ignite the swidden burns and the use of mechanical means to harvest hay) is inconsistent with historic practices, though is certainly labour-saving. Details of past and current forms of swidden cultivation, hay-making and livestock husbandry are compared and contrasted in the following paragraphs.

Table 3.2 Comparison of some characteristics of agriculture practiced in the Koli area traditionally, in eastern Finland currently, and within Koli National Park currently.

Practice	Traditional agricultural practices in Koli area	Current agricultural practices outside Koli National Park	Current agricultural practices in Koli National Park
Swidden cultivation	Clearings ~2.2 ha Felling with axes Ignition with flint & steel prior to mid 19th century or matches thereafter Livestock graze in regenerating plots after last crop harvest	Not practiced	Clearings 0.3-2.5 ha Felling with chainsaws Ignition with propane torch (flint & steel for demonstration only) Only sheep graze in regenerating plots after last crop harvest
Haymaking	Harvested with sickles or scythes In semi-natural meadows Leaf-hay (pollarded branches or coppiced shoots with leaves) harvested from wooded areas	Harvested with tractors From cultivated fields No leaf-hay harvested	Harvested with scythes, mechanical mowers, and/or tractors In semi-natural meadows and old fields No leaf-hay harvested
Livestock husbandry	Heritage breeds of cattle and sheep used Heritage breed of horses also kept by most households Grazing occurred in wooded areas and regenerating swidden clearings.	Imported breeds of cattle used Heritage breed of sheep used Mostly imported breeds of horses used Grazing occurs mainly in open fields with improved pasture.	Heritage breeds of cattle and sheep used since 2003 Heritage and imported horses used since 2010 Grazing occurs mainly in old fields, some wooded areas and a few swidden regeneration sites.

Swidden cultivation

Elements such as the size of the burn, linen apparel worn by the staff and volunteers conducting the swidden burn, the use of *Picea abies* boughs and buckets of water to extinguish escaping flames, and the types of crops (rye and turnips) sown were in-line with historical descriptions and depictions of swidden cultivation. Since 1450 – 1600 AD, when permanent settlers began to practice swidden cultivation on a regular rotation in eastern Finland, livestock would have traditionally been allowed to graze the regenerating vegetation in a swidden plot. However, only three (the 1999 and 2000 burns at Olilla, and the 2005 burn at Seppälä) of over 30 swidden sites where swidden agriculture has been restored in Koli National Park since 1994 have been subsequently grazed, and in those cases the grazing was only by sheep. From the literature it is difficult to interpret which species of livestock would have traditionally grazed in the regenerating swidden fields because the sources did not specifically mention the species of grazing animal in swidden rotations other than cattle[40].

Swidden agriculture without allowing livestock to graze in the regenerating vegetation after the last crop was harvested is probably inconsistent with historic practices in the Koli area as of the time of permanent settlement (1450 to 1600 AD). The literature and photographs of fences (which indicate that livestock were present, since they would be ineffective barriers for moose) around fields that were likely

[40] The term "cattle" is interpreted with caution because in Finnish and in older English usage the same term is used for livestock in general as well as for cattle (*Bos taurus*) specifically. Sources in Finnish and secondary sources available in English that were based on Finnish or older English texts may have inaccurately interpreted the term to refer exclusively to cattle rather than to groups of livestock in general, which may or may not have included *Bos taurus*.

originally cleared by swidden practices are the only evidence in this study that livestock probably grazed in regenerating fields. Since swidden cultivation was no longer practiced in the Koli area when even the oldest interviewees could remember, this interpretation could not be corroborated.

Haymaking

Although the livestock do not over-winter at Koli National Park, harvesting winter fodder would traditionally have been an important part of the annual routine of local farmers. Semi-natural meadows would traditionally have been maintained in an open state through annual scything. Some of the smaller clearings at Koli National Park are still scythed manually, depending on the availability of staff or volunteers to do so. Motorized string trimmers or tractor-operated mowers are also employed to cut hay, particularly in larger fields. Few of the semi-natural meadows or former fields are cut on an annual basis. According to the management plan for Koli's traditional landscapes, (Lohilahti and Pajari, 2007), the park's 17 major meadows or former fields are cut with a frequency ranging from twice annually to once every four years. The historic maps of the area reveal that the overall size of some of the meadows/fields maintained in an open condition in 2008 is considerably smaller than they were in the past. Thus, the extent, timing and manner of mowing are not entirely consistent with traditional practices, and they likely reflect limitations in the park's financial and/or labour resources.

With the exceptions noted above, the hay cut from the semi-natural meadows and old fields at Koli is one source of fodder that is consistent with historic practices; however, leaf-hay collected from branches and shoots of deciduous trees would have also been traditionally harvested prior to mid-summer (June 21) to provide winter fodder for sheep, according to the interviewees. Currently leaf-hay is not harvested at Koli National Park, nor is it used in modern farms in the area.

Livestock husbandry

The use of heritage breeds is consistent with depictions and descriptions of the breeds used in the Koli area prior to the 1960s. There was considerable photographic evidence of the use of Eastern Finncattle in the Koli area in the 1930s. Although no images of Finnsheep were found in the collection of photographs by Einar E. Saaralainen at the Koli Museum, interviewees recalled both Eastern Finncattle and Finnsheep from their days as youth and young adults on farms in the Koli area. According to the interviewees, and corroborated by the photographs, most households would also have had at least one horse; however, Finnsheep and Finncattle were the only livestock kept within the boundaries of Koli National Park as of 2008 (although Lohilahti and Pajari [2007] report that one horse grazed in addition to the cattle and sheep at the Ollila sites in 2004, and as of 2010, Finnish and Icelandic horses graze in the fields by the Park office).

As regards the husbandry of heritage breeds, pasturing the animals in regenerating swidden plots is consistent with historic practices, though cattle and not just sheep would have likely grazed such areas. Pasturing the livestock in forested areas would also have been consistent with traditional practices. Livestock grazing in open fields would have been uncommon prior to the 1960s, except after hay had been harvested; therefore the primarily open nature of the three cattle pastures and several of the sheep pastures currently grazed in Koli National Park does not represent typical historical grazing conditions.

DISCUSSION

An historic ecological approach enabled contrasting perspectives of past versus present uses of livestock and associated agricultural activity in the landscape in eastern Finland. The challenges to environmental conservation in Finland identified in modern conservation literature (Raunio *et al.*, 2008) contrast starkly with the environmental challenges described in the end of the 19th and beginning of the 20th centuries (Heikinheimo, 1915 cited in Parviainen, 1996). At the turn of the 20th century, there were concerns that too much land had been incorporated into increasingly shortened swidden agricultural rotations, that not enough *Picea abies* remained and that too much *Alnus incana* was replacing *P. abies*. At that time, the practice of swidden cultivation was described by “experts” as evil, wasteful and wreckless destruction of woodland, (Brown, 1883), and the government concerned itself to put an end to the practice. In contrast, today the increasing dominance of *P. abies* is considered a threat to the open habitats that are now extinct or critically endangered because of their dependence on anthropogenic disturbances that are no longer part of today’s agricultural practices (Raunio *et al.*, 2008). Alder meadows are classified as an extinct habitat type in Finland and habitats associated with traditional agriculture (haymaking and grazing) have been assigned endangered or critically endangered status (Raunio *et al.*, 2008). Protected areas such as Koli National Park are encouraged through government funding and legislation to reinstate swidden cultivation and other traditional agricultural practices for the purposes conserving historic anthropogenic habitats. Thus, the pendulum has swung from one extreme of spruce-dominated wilderness associated with low levels of plant diversity prior to human settlement (Alenius *et al.*, 2004), to a young deciduous-dominated landscape highly utilized for swidden cultivation on short rotations (Brown, 1883), back to a spruce-dominated landscape in which plant communities associated with open habitats are now considered rare (Raunio *et al.*, 2008). This situation poses a challenge for determining appropriate target conditions for the management of protected areas.

Although traditional agricultural practices are considered to be more ecologically sustainable than more modern practices that rely on high levels of mechanization and chemical inputs, the low rotation times (as few as seven years) and widespread extent of swidden cultivation at its peak in the mid-1700s to mid-1800s was not ecologically sustainable either. Thus, it would not be appropriate to orient protected area management towards this intensity of swidden cultivation, even if the activity does qualify as “traditional”.

The swidden burns at Koli National Park are planned to take place on at least a 50-year cycle. Because wildfires have been nearly eliminated in Finland (Parviainen, 1996), the restoration of swidden cultivation at Koli National Park serves as a form of ecological disturbance that once affected large portions of the country for several centuries and may provide surrogates to habitats that would have been created if natural fire regimes were still in place in Finland. Ruokolainen and Salo (2006) found that swidden cultivation changed the species composition of vegetation and increased plant diversity over 10 years in their study of swidden burning and cultivation treatments in the boreal forest of Koli National Park. In the year of the burn and one year post-burn, species richness of vascular plants and bryophytes was lower (19 spp and 26 spp, respectively) in the swidden plots than in the unburned control plots (42 spp). Plant species richness was approximately equal to the unburned control plot two to four years post-burn (±2 species). Plant species richness was higher six, eight, and ten years post-burn (68 spp, 59 spp and 60 spp, respectively) than in the unburned control plots (Ruokolainen and Salo, 2006).

When swidden cultivation was first practiced in eastern Finland, the area was probably used as a distant hunting territory and livestock were probably not transported long distances to such seasonal hunting grounds. Therefore the swidden restorations at Koli National Park without livestock grazing are likely consistent with swidden practices prior to permanent settlement of the Koli area. However, for at least 400 years from the time that swidden cultivation was regularly practiced by permanent residents to 1930 when the swidden was last practiced in the Koli area, livestock grazing would have traditionally occurred in swidden fields after the last crop had been harvested (normally about two or three years after the burn) (Parviainen, 1996). If livestock grazing affects the regenerating vegetation in the swidden plots, the absence of livestock grazing in most swidden restoration sites at Koli National Park may not only be inconsistent with historical practices, but might also result in habitats that are significantly different from those that resulted from swidden activity as of the time of permanent settlement of the Koli area. The swidden fields at Koli National Park investigated by Ruokolainen and Salo (1996) had not had any grazing influence in the recent past. Therefore an investigation of succession patterns in swidden clearings that did include grazing by heritage breeds would provide new insight regarding the ecological role of livestock in this traditional practice. This subject is examined in greater detail in the next chapter.

The resumption of traditional agricultural practices at Koli National Park does not include harvesting leaf-hay, a source of fodder that the older interviewees recall being an important source of winter feed for Finnsheep. Slotte (2002) reports that sheaves of leaf-hay, harvested by lopping lateral or terminal branches from deciduous trees, were also an important traditional source of winter fodder in Sweden, particularly for sheep. Although the large-scale harvesting of leaf-hay, which was common throughout Europe prior to the 20th century, must have influenced the character of cultural landscapes, the ecological implications of this practice are little studied and have largely escaped the attention of historians, geographers and ecologists (Halstead, 1998). Slotte (2002) studied the historic use of leaf-fodder throughout Sweden and the Åland islands (ethnically Swedish, but politically part of southwest Finland), and reckoned that prior to WWII the practice must have affected at least 1 million ha of land, influencing the structure of tree and shrub canopies, as well as their distribution. Although some detailed studies of leaf-hay harvesting are available for other parts of Europe (Bargioni and Sulli, 1998; Hæggström, 1998; Halstead, 1998; Rackham, 1998; Slotte, 2002; Petit and Watkins, 2003), further information on this form of fodder production and its ecological implications in Finland other than in the Åland islands was not found and may be an important area for further investigation.

Another major difference between traditional livestock husbandry in the Koli area and the current use of livestock in Koli National Park today is the use of open fields as pastureland for the cattle and sheep. In both swidden and permanent field cultivation, open fields would have been prioritized for making hay or growing crops for human and/or livestock consumption. The adjacent woodlands (or regenerating swidden sites) would have been the areas used as pastures. Currently in Koli National Park, only part of one of the three cattle pastures is even partially forested, and only two of the sheep pastures are within woodlands or forest. The remaining pastures in which the livestock graze were formerly cultivated fields with little to no tree cover. Mainland's (2003) study of Gotland sheep (a breed that, like Finnsheep, was historically pastured in wooded areas) revealed different microwear patterns on the teeth of sheep that browsed on woody vegetation versus sheep that primarily grazed in open pastures. The sheep that grazed in open pastures showed striations in their enamel that resulted from ingesting soil particles while grazing on herbage close to the ground. Whether such effects have long-term implications for the animals' fitness is not as obvious as the mortality experienced by North Ronaldsay sheep when their forage changed from seaweed to grass/herb pasture; nevertheless the shift from predominantly wooded to predominantly open pasture in current agricultural practices as well as at Koli National Park may have implications for the evolution of Finnsheep and Eastern Finncattle breeds. Thus, providing habitats that are similar to those in which the breeds evolved may help to preserve traits that the breeds possess and would be worth investigating to verify whether there are any significant effects resulting from forage-type on these breeds.

Where the heritage breeds of livestock are pastured in areas with abundant woody vegetation, Koli National Park creates historically consistent grazing conditions for the animals. Because forest pastures are now seldom used in today's agricultural practices, forest pastures and grazed woodlands are considered endangered habitats in Finland (Raunio *et al.*, 2008). Since Eastern Finncattle and Finnsheep were typically pastured in wooded areas in the recent past (within the memory of the older interviewees) and had likely been pastured in such areas in the more distant past (around the time of settlement of the Koli area approximately 400 years ago), these breeds are well suited for use in creating and maintaining wooded pasture habitats. The possibility that these environments help to reinforce the traits that the breeds evolved over centuries in these habitats is worth further investigation.

Aside from the exceptions discussed above, the restoration activities related to historical agricultural practices at Koli National Park, are mainly in-line with traditional practices. The use of some modern devices for the sake of efficiency such as propane torches to ignite the swidden fires and motorized mowers and trimmers to make hay may have some ecological implications. The use of propane torches allows a swidden burn to ignite more efficiently. Differences in burn intensity significantly affected the overall cover of vegetation and species assemblages two years post-burn in a boreal forest in western Canada (Lee, 2004). Therefore, the use of propane torches may have a significant effect on the ecological outcome of the swidden burns if they cause the intensity of burns to be greater than they would have been with more traditional ignition sources. No studies were found that contrast the ecological effects of differing methods of haymaking (scything vs. mechanical mowing), but differences in overall sward height and sward height heterogeneity may affect species composition in open areas and may be worth investigation in future studies.

Although the maintenance and restoration of biodiversity is the primary rationale for reinstating “traditional” agricultural practices at Koli National Park, cultural heritage preservation is also an aim. None of the park staff could think of anyone in the Koli area who currently raises Eastern Finncattle. The absence of Eastern Finncattle in modern farms in the Koli area suggests that the park has a unique role in maintaining the presence of this breed in the landscape, albeit only during the summer. A farm adjacent to the park offers horseback riding opportunities and their herd includes two Finnish horses, though the majority of their horses are Icelandic ponies. Certainly Koli National Park’s use of heritage breeds contributes to cultural heritage preservation through the use of breeds that had been historically raised there.

In terms of other possible advantages of using heritage breeds in the park, interviewees mentioned that in conventional production systems, the Eastern Finncattle ate less and defecated less than their mainstream dairy cattle breeds, but could not offer comparisons between the breeds within traditional grazing habitats (i.e., forest pastures or swidden regeneration). The smaller size of the Eastern Finncattle[41] versus Ayrshires[42] may reduce rates of vegetation consumption and soil compaction. Interviewees did not specifically mention any particular advantages of using Finnsheep other than the breed's exceptional fecundity. However, the fact that none of the sheep were adversely affected by the presence of the wolverine at the Seppälä farm site in Koli National Park may point to a potential advantage of using this breed. In Norway, Landa *et al.* (1999) found that ewes are six times less likely to be killed than lambs by wolverines, which, in addition to the young age of the wolverine at Koli, may help to explain why the ewes had not been predated upon by the wolverine. Landa *et al.* (1999) also found significant differences between predation levels of different breeds of sheep. Significantly fewer individuals of heritage breeds (which had greater flocking instincts and faster rates of weight gain) were lost to wolverines than individuals from a composite breed comprised of a Norwegian heritage breed crossed with two British sheep breeds. Hansen *et al.* (2001) found that lighter (heritage) breeds of sheep exhibited stronger responses to predator-related stimuli in Norway than heavier breeds (imported or composites of heritage x imported breeds). It is possible that some of the Finnsheep's characteristics also predispose them to be resistant to predation by wolverines, and this may warrant further investigation.

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[41] Average weight of males: 600 kg, females: 440 kg (FAO, 2008)
[42] Average weight of males: 1000 kg, females: 500 kg (FAO, 2008)

In protected areas where wild predators still exist, anti-predation characteristics of livestock breeds would be particularly advantageous because the protected area would likely be obliged to protect the predators (especially in light of the threatened status of wolverines, lynx, bears [*Ursus arctos*] and wolves in Finland). They would also be inclined to ensure that the owners of the livestock do not suffer losses as a result of grazing their livestock in the protected area. Indeed, livestock predation is often a major source of conflict in and around national parks in Africa, Asia and North America, where local livelihoods are impacted by depredation of livestock by wild animals whose populations are protected and sometimes increased due to the conservation activities of the parks. The potential advantage of using heritage breeds for their reduced susceptibility to predation was not mentioned in any of the documents examined for the global overview of the use of heritage breeds in protected areas, and may be an area worthy of further study.

CONCLUSIONS

Agricultural practices and the character of the landscape in the area of Koli National Park have undergone significant changes over time. Swidden cultivation likely evolved from a practice by seasonal hunters who burned clearings in the boreal forest to attract wildlife. By 1450 to 1550 AD swidden agriculture associated with rye cultivation on a 30-year rotation was established in eastern Finland. This period is thought to represent the beginning of permanent settlement of the area and is probably when livestock were incorporated into the swidden cycle, grazing in the swidden clearings after the last crop was harvested. As the human population grew in the area, swidden cultivation affected greater and greater portions of the landscape, peaking in intensity and geographical extent in the late 1800s. Due to changes in the value of timber and available technology, swidden cultivation ceased to be practiced in eastern Finland by the early 20th century. Permanent field cultivation was the norm from the 1930s onwards in the Koli area, and Eastern Finncattle, Finnish horses and Finnsheep were pastured in forested areas outside of the cultivated fields. The adoption of new agricultural technologies around the 1960s (including farm machinery, modern livestock breeds and artificial insemination) coincided with a shift from grazing livestock in forest pastures to grazing them in improved [cultivated] field pastures and the abandonment of distant semi-natural meadows as sources of fodder. The effects of these changes in agricultural practices in the Koli landscape are observable through comparing present day photographs with photos taken from the same vantage point over 70 years ago, as well as through the examination of maps that indicate a reduction in the size and number of semi-natural meadows in the Koli area.

Actions to restore anthropogenic habitats associated with traditional agriculture to Koli National Park include swidden cultivation, haymaking and grazing. However, some differences exist in the application of these practices between their historic and present forms. In particular, there are a number of areas in which the practices related to livestock husbandry at Koli National Park are inconsistent with historic practices as of the time of permanent settlement of the Koli area. These include the absence of livestock in most of the restored swidden sites, pasturing only Finnsheep and not Eastern Finncattle in the restored swidden sites, the lack of leaf-hay harvested, and pasturing cattle and sheep in predominantly open fields. Swidden cultivation without grazing reflects historic practices prior to permanent settlement of the Koli area, so it is justifiable to have some, but not all, of the swidden sites in Koli National Park regenerating without livestock grazing. The remaining inconsistencies are worth further investigation as they may have significant impacts on the ecology of the habitats associated with these activities and possibly on the grazing animals.

The breeds used at Koli National Park today are in-line with historic practices of the past four to five centuries. Eastern Finncattle and Finnsheep were the breeds used in the area at the time of the oldest interviewees' childhood (1940s and 1950s) when traditional forms of agriculture were still practiced in the area. Presumably these were the same breeds used at the time of permanent settlement of the Koli area, though osteological evidence is not available to confirm this assumption. Where Koli National Park offers historically consistent opportunities for heritage breeds of livestock to exist in the park, it not only creates opportunities for the breeds to be conserved and appreciated by the public, but it also provides unique, historically consistent habitats in which the breeds can graze (e.g., forest pastures and swidden regeneration sites). Outside of the park, the heritage breeds are not normally kept within wooded pastures or in swidden regeneration sites. So, Koli National Park provides some historically consistent habitats in which the heritage breeds can graze, which are not part of heritage breed conservation programs outside of the park. The provision of sush historically consistent habitats may help to reinforce the adaptive traits that the heritage breeds developed over generations in such traditional habitats that are now very rare in Finland.

CHAPTER 4: THE IMPACT OF HERITAGE LIVESTOCK ON VEGETATION IN KOLI NATIONAL PARK

INTRODUCTION

The previous chapter revealed that traditional activities associated with livestock husbandry had been practiced for centuries in the area of Koli National Park. Changes in such practices significantly impacted the landscape in terms of aspects such as the size of clearings and predominant vegetation cover as several former farm sites in the park were abandoned. The objective of resuming traditional agricultural activities such as swidden cultivation, livestock grazing and haymaking in Koli National Park since the 1990s was to restore anthropogenic habitats that are now rare in Finland. In this chapter, the effects of heritage breeds of livestock reintroduced to Koli National Park are examined to better understand their role in shaping and maintaining vegetation structure and composition in the park's anthropogenic habitats. This component of the study addresses the following research question: What differences, if any, in vegetation diversity, structure and composition are associated with current grazing by heritage breeds at Koli National Park?

In the previous chapter, heritage breeds were shown to have been part of swidden cultivation cycles since eastern Finland had been permanently inhabited around 400 –

500 years ago. In this chapter, the effects of Finnsheep grazing on trees and on vascular plants in the field layer are examined in two swidden sites (one burned in 1999/2000 and the other burned in 2005) in Koli National Park. The previous chapter also revealed that heritage breeds were commonly pastured in wooded areas prior to the 1960s. In this chapter, vegetation is examined in one wooded site in which Finnsheep graze at Koli National Park. As of 2008, Eastern Finncattle did not have access to any of the swidden sites at Koli National Park and grazed in primarily open pastures with very small wooded areas. Although it was not usual for heritage livestock to graze in open fields in the agricultural traditions of the Koli area prior to the 1960s, both Eastern Finncattle and Finnsheep currently graze in semi-natural meadows and formerly cultivated fields in Koli National Park. The impact of the heritage breeds in these open habitats is also examined in this chapter.

Each of the grazed habitats described above is compared with similar habitats that have not been grazed by livestock in over 40 years. First, the condition of woody vegetation is assessed in a) grazed and non-grazed swidden sites, b) currently grazed forest pastures and forest pasture sites that had not been grazed in over 40 years, and c) wooded areas of otherwise open pastures currently grazed by Finnsheep and Finncattle. Next, percent cover of plant species in the field layer is examined in comparable swidden, forest and open sites that were either grazed or not grazed. Estimates of species richness are provided for each site and compared across sites. Similarity relationships between each of the sampled sites within Koli National Park are presented in a dendrogram generated by cluster analysis using the Group Average and Ward's method (McCune and Grace, 2002). Finally, these findings are interpreted and discussed in light of the contextual information provided in the previous chapter.

METHODS

Research question and hypotheses

The study sites and methods described in this section were chosen to determine what differences, if any, in vegetation diversity, structure and composition are associated with current grazing by heritage breeds at Koli National Park?

Specifically, the following null hypotheses were tested:

H_{O1}: Condition of trees does not significantly differ among the grazed and non-grazed swidden sites, nor among the grazed and non-grazed woodland sites.

H_{O2}: Condition of trees does not significantly differ between tree species within the grazed and non-grazed swidden sites, nor in the grazed and non-grazed woodland sites.

H_{O3}: Condition of trees does not significantly differ between height classes of trees within grazed sites, nor within non-grazed sites in each habitat type (swidden regeneration, forest, open fields).

H_{O4}: Species richness of vascular plants in the field layer does not significantly differ among the grazed and non-grazed sites in the various habitat types.

H_{O5}: Percent cover of particular vascular plant species in the field layer does not differ between grazed and non-grazed sites of similar habitat type.

H_{O6}: Grazed and non-grazed sites of the various habitat types will cluster randomly within a cluster analysis.

Study Sites

Vegetation was sampled in a number of sites associated with traditional agricultural activities within Koli National Park[43]. Woody vegetation was sampled in 2008 in the following sites:

- One swidden pasture burned in 1999/2000 and grazed[44] by Finnsheep since 2004 (oll sab[45])
- One swidden site burned in 1998 (r&s B98) and one swidden site burned in 2000 (oll b02), each without subsequent grazing by domesticated animals
- One open field used as pasture for Eastern Finncattle (oll 2) and one open field used as pasture for Finnsheep (oll 4). In both of these pastures, some trees existed but represented less than 10% of the vegetation cover.
- Two former swidden woodlands with mature trees grazed by Finnsheep since 2007 (sep 3b and 3c)
- Eight forested areas formerly used as pastures over 40 years ago (mak 3a, mak 3b, mak 4, hav 2, yla 3, yla 4, hav 2, tur *f*), but not currently grazed by livestock.

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[43] For a general description of Koli National Park, see Chapter 3.
[44] The livestock graze at Koli National Park from June to September.
[45] The first three letters in the site codes correspond with the site names indicated in Table 4.1, which are mapped in Appendix A-C. The adjacent letters and numbers correspond with sub-site names in Table 4.1. These sub-site names are consistent with the site names presented in Ruokolainen and Salo's (2006) study of succession in swidden sites, Le Henaff and Degryse's (2003) study of grazing capacity of the Ollila meadows or Lohilahti and Pajari's (2007) description of traditional landscape management in Koli National Park. Sub-site names in italics are names unique to this study as no corresponding names were identified in the reports.

Grasses, forbs and small trees in the field layer were sampled in the above sites as well as in:

- One swidden pasture burned in 2005 (sep 4*k*) and grazed by Finnsheep since 2006
- One swidden clearing burned in 2005 (lak b05), one swidden clearing burned in 2006 (yla b06), and one prescribed burn area, which was felled and burned like a *huuhta* swidden but without sowing crops after the burn (ski b05). All of these clearings have been left to regenerate without further active management.
- Four open fields or semi-natural meadows grazed by Finnsheep since 2007 (in sep 2b and 2d) and since 2003 (in matt 3 and oll 5)
- One open field grazed by Finncattle since 2003 (oll 3)
- Six meadows/abandoned fields that are mowed or scythed as often as twice per year to as seldom as every four years (matt 2, mak 2, mak 1, hav 1, yla 1a, tur 1c).

Additional data from previous studies were used to supplement the field data collected in 2008. Because there was only one grazed swidden site that was 8/9 years old, and no comparable non-grazed swidden sites were burned between 1999 and 2002, additional data from two earlier studies were obtained to enable comparison of the 8/9-year-old grazed swidden site with: a) its condition 3-4 years earlier; and b) similar swidden sites 4 to 10 years post-burn that had not been grazed by domestic animals.

Vegetation data collected in 2003, 2004 and 2007 in the Ollila pastures grazed by Finnsheep or eastern Finncattle were obtained from Koli National Park to enable a comparison of those sites through time. However, only four 1 m x 1 m quadrats were inventoried in the Ollila sites in each of those years, so the data were sparse from those sources. The data from 2003 are reported in Le Henaff and Degryse (2003).

Furthermore, Lasse Ruokolainen kindly provided data collected in 2000 and 2004 from 2 m^2 circular plots in swidden sites without grazing, as well as from an unburned adjacent control site in a 60-year-old Norway spruce (*Picea abies* [L.] H. Karst) forest (all identified as the "Ruokolainen & Salo Sites" in Appendix A and Table 4.1). The three swidden areas were burned in 1994, 1996 and 1998 (r&s B94, r&s B96 and r&s B98, respectively). Raw data were made available from 2004, when these sites had been regenerating for ten, eight and six years, respectively. Data was also provided for the site burned in 1996 from sampling conducted in 2000: four years post-burn. These data are presented as part of a study of the patterns of succession up to 10 years after swidden cultivation (without grazing) in Ruokolainen and Salo (2006).

Moose (*Alces alces*) exist in Koli National Park. The moose at Koli have access to all areas sampled in this study, as the fences that contain the domesticated animals are too low to effectively exclude moose. Härkönen *et al.* (2008) report that local hunters estimated the density of moose in Koli National Park based on track counts to be approximately 0.75 moose/km^2 in the winter[46] of 2006. Härkönen *et al.*'s (2008) counts of moose pellets (faeces) revealed relatively greater densities of moose in the north half of Koli National Park than in the south half, but they did not translate their pellet data into estimates of moose density in each area. Data on the densities of other herbivores in Koli National Park were not available, but Eurasian red squirrels (*Sciurus vulgaris*),

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[46] Moose density in Koli National Park is higher than in surrounding areas in the winter because during the hunting season (which begins the last week of September) the moose take refuge in the park, where no hunting is permitted (Härkönen *et al.*, 2008).

Table 4.1. Characteristics of each site in which herbaceous vegetation were sampled.

Site names correspond to the sites mapped on the maps in Appendix A, B and C. Sub-site names correspond with the site names presented in Ruokolainen and Salo's (2006) study of succession in swidden sites, Le Henaff and Degryse's (2003) study of grazing capacity of the Ollila meadows or Lohilahti and Pajari's (2007) description of traditional landscape management in Koli National Park. Sub-site names in italics are names unique to this study as no corresponding names were identified in the above reports. All vegetation sampling in 2008 and 2010 was done by the investigator. Vegetation data collected in earlier years were obtained from the Koli National Park files or from the authors of previous studies. Vegetation types are derived from an unpublished inventory of habitat types provided by Koli National Park.

Site name	Sub-site (area)	Vegetation type	Vegetation management	Herbaceous vegetation		Woody vegetation # of quadrats (size)
				# of quadrats (size)	Year sampled	
Ruokolainen & Salo Sites (r&s)	B98 (1.9 ha)	Swidden regeneration (burned in 1998)	None	16 (2 m^2)	2004	6 (10 m^2)
	B94 (1.1 ha)	Swidden regeneration (burned in 1994)	None	16 (2 m^2)	2004	
	B96 (0.9 ha)	Swidden regeneration (burned in 1996)	None	20 (2 m^2) 20 (2 m^2)	2004 2000	
	Control *con*	Mature spruce forest	None	16 (2 m^2)	2004	
Mattila (matt)	2	Abandoned field	Mowed	5 (1 m^2)	2008	
	3	Abandoned field	Grazed by 18 ewes/ yr in two-pasture rotation	7 (1 m^2)	2008	
Ollila (oll)	b02	Swidden regeneration (burned in 2002)	None	0	2008	1 (10 m^2)
	2 (0.5 ha)	Abandoned field (dominated by grasses)	Grazed by 5-7 cows/ yr in three- pasture rotation	4 (1 m^2) 4 (1 m^2)	2003 2007	Census of all woody stems in open area in 2010
	4 (0.48 ha)	Abandoned field (dominated by grasses)	Grazed by 10-12 ewes/ yr in three-pasture rotation	4 (1 m^2) 4 (1 m^2)	2003 2007	2 (10 m^2)
	Slash-and-burn *sab* (0.62 ha)	Swidden regeneration (one part burned in 1999, one part burned in 2000)	Grazed by 10-12 ewes/ yr in three-pasture rotation	18 (1 m^2) 4 (1 m^2) 4 (1 m^2) 4 (1 m^2)	2008 2003 2004 2007	6 (10 m^2)
	3 (~0.7 ha)	Abandoned field (dominated by grasses)	Grazed by 5-7 cows/ yr in three-pasture rotation	12 (1 m^2)	2008	
	5 (~0.4 ha)	Abandoned field (dominated by grasses)	Grazed by 10-12 ewes/ yr in three-pasture rotation	16 (1 m^2)	2008	2 (10 m^2)
Ski Hill Burn (ski)	*b05*	Prescribed burn area like swidden, but no crops sown after burn (burned in 2005)	None	12 (1 m^2)	2008	
Mäkränaho (mak)	3*a* (1.08 ha)	Mature swidden forest	None	8 (1 m^2)	2008	8 (~19.623 m^2)
	1 (0.52 ha)	Low herb mesic meadow	¼ mown each year on four year rotation	13 (1 m^2)	2008	
	3*b* (1.08 ha)	Mature swidden forest	None	10 (1 m^2)	2008	9 (~19.623 m^2)
	2 (0.35 ha)	Low herb mesic meadow	½ mown each year on two year rotation	7 (1 m^2)	2008	
	4 (0.93 ha)	Mature swidden forest	None	7 (1 m^2)	2008	6 (~19.623 m^2)
Havukkanaho (hav)	2 (0.34 ha)	Wooded pasture dominated by coniferous and deciduous trees	None	12 (1 m^2)	2008	11 (~19.623 m^2)
	1 (0.36 ha)	Low herb mesic meadow	½ mown each year on two year rotation	6 (1 m^2)	2008	
Ala Murhi (ala)	1b (0.11 ha)	Abandoned field (dominated by tall herbs)	Mown twice/ yr	9 (1 m^2)	2008	
Ylä Murhi (yla)	*b06*	Swidden regeneration (burned in 2006)	None	11 (1 m^2)	2008	
	1a (0.24 ha)	Low herb mesic meadow	Mown once/ yr	10 (1 m^2)	2008	
	3 (0.15 ha)	Mature swidden forest	None	5 (1 m^2)	2008	5 (~19.623 m^2)
	4 (0.16 ha)	Wooded pasture dominated by birch	None	5 (1 m^2)	2008	5 (~19.623 m^2)
Turusen Autio (tur)	*f*	Mature swidden forest	None	14 (1 m^2)	2008	11 (~19.623 m^2)
	1c (0.13 ha)	Tall herb mesic meadow	Mown twice/ yr	11 (1 m^2)	2008	
Seppälä (sep)	2d (0.27 ha)	Graminoid mesic meadow	Grazed by 10 ewes/ year on four-pasture rotation	8 (1 m^2)	2008	
	4*k* (0.60 ha)	Swidden regeneration (burned in 2005)	Grazed by 10 ewes/ year on four-pasture rotation	18 (1 m^2)	2008	
	3c (0.72 ha)	Deciduous forest pasture	Grazed by 10 ewes/ year on four- pasture rotation	5 (1 m^2)	2008	5 (~19.623 m^2)
	3b (0.57 ha)	Wooded pasture dominated by alder	Grazed by 10 ewes/ year on four-pasture rotation	7 (1 m^2)	2008	
	w	Wooded pasture dominated by alder (adjacent to 3b, outside of fence)	None	8 (1 m^2)	2008	
	2b (0.17 ha)	Graminoid mesic meadow	Grazed by 10 ewes/ year on four-pasture rotation	10 (1 m^2)	2008	
Lakkala (lak)	*b05*	Swidden regeneration (Burned in 2005)	None	12 (1 m^2)	2008	

mountain hare (*Lepus timidus*), bank voles (*Clethrionomys glareolus*), European water voles (*Arvicola terrestris*), field voles (*Microtus agrestis*), wood lemmings (*Myopus schisticolor*), Siberian flying squirrels (*Pteromys volans*) and herbivorous insects also exist in Koli National Park and can penetrate the fences erected around livestock pastures. Thus, areas denoted in this chapter as "grazed" are stocked with Finnsheep or Eastern Finncattle in the summer, but can also be subject to herbivory by moose and other wild herbivores/omnivores year-round. Areas that are referred to as "non-grazed" are not stocked with domesticated animals, but are still exposed to herbivory by moose and other herbivores/omnivores.

Characteristics of all sites in this study are listed in Table 4.1 and are presented in order of their location from north to south, (and west to east where sites are at the same latitude) as presented in the attached Maps of Koli National Park (Appendices A, B and C).

Sampling

Sampling of current woody and herbaceous vegetation in grazed and non-grazed swidden, woodland, meadow and field sites was undertaken to determine the ecological effects of grazing with heritage livestock breeds on vegetation in these various habitats. The sampling methods are described below where data were collected first-hand by the investigator in 2008. All vegetation sampling conducted by the investigator within the park was done with written permission from Metsähallitus, the branch of Finnish government responsible for the national park system and the management of other natural resources. Where data previously collected by other individuals are used, the origins of the data are reported.

Woody Vegetation in Swidden Sites

To determine the effects of sheep browsing on woody vegetation in regenerating swidden plots, 2 m x 5 m (10 m^2) rectangular quadrats were sampled in grazed and non-grazed regenerating swidden vegetation of similar age since last burned. In each 2 m x 5 m rectangular quadrat, the species, condition, height[47] (categorized in 0.5 m increments up to 3 m tall[48]), and evidence of browsing and debarking were recorded for every woody stem emerging from the ground within the quadrat. Stems with branches inside the quadrat but with bases outside the quadrat were not recorded. Where multiple stems emerged as a cluster, a stem was recorded as an individual if its base at the soil level did not connect to another stem. The condition of each stem was categorized as:

a) Undamaged: Current year's growth is visible throughout the individual, fewer than 25% of the branches show signs of damage;
b) Somewhat damaged: Current year's growth is visible throughout the individual, between 25% and 75% of the branches are dead or damaged;

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[47] Height was chosen rather than breast height diameter or basal diameter as a size-related variable because a tree's susceptibility to browsing has more to do with its height rather than its girth, e.g. if the tree is under 1.5 m tall, a sheep can theoretically browse any or all of its branches, regardless of the thickness of the trunk.
[48] Above 3 m, trees are generally less susceptible to damage from moose herbivory (Edenius *et al.* 2002).

c) Extensively damaged: Current year's growth is visible mainly as a few shoots near the base of the stem, more than 75% of the branches are dead and brittle;

d) Dead: Twigs are brittle, no foliage or growth from current year.

Woody Vegetation in Open Pastures

Groves of young grey alder (*Alnus incana* [L.] Moench) and rowan (*Sorbus aucuparia* L.) (all < 10 cm in diameter at breast height) covered a small proportion (less than 10%) of the area within two of the open pastures grazed by sheep at the Ollila farm site. Two 2 m x 5 m quadrats were sampled as described in the section above in the wooded areas of each of these otherwise open pastures (oll 4, oll 5). These quadrats encompassed nearly all of the trees within the small groves of the Finnsheep pastures. An additional pasture grazed by Eastern Finncattle (oll 2) at the Ollila farm site is a 0.61 ha former field that primarily has a savanna-like condition with tree cover less than 10%. In this open area, a census of every woody stem was undertaken in 2010 with data recorded as described for woody stems in the swidden sites.

Woody Vegetation in Former and Current Forest Pastures

The condition of woody species in mature forest sites that were grazed in the past, but have not been grazed for several decades, was compared with the condition of woody species in mature forest sites where grazing by Finnsheep was resumed in 2006. The height (categorized in 0.5 m increments up to 3 m), condition, and evidence of browsing and/or debarking were recorded for every individual tree within circular quadrats with a 2.5m radius (~19.623 m^2). The categories for recording the condition of each individual tree followed the criteria listed above in the section on woody vegetation sampling in swidden sites. The centre point of each of the circular plots was also the centre point of the 1 m x 1 m quadrats used to sample the ground layer vegetation for the herbaceous vegetation sampling (see section below) in these sites (Figure 4.1).

Although it may have been preferable to have identical quadrat dimensions to sample woody vegetation in the swidden sites and in the forest pastures, comparisons between the condition of woody vegetation in swidden habitat and forest pasture habitat were not intended. Rather, comparisons would focus between grazed and non-grazed areas of similar habitat (i.e., comparisons between grazed and non-grazed swidden regeneration would be separate from comparisons between grazed forest pasture and non-grazed, former forest pasture).

Field Layer Vegetation

Square quadrats (1 m x 1 m) were used to sample ground layer vegetation within meadow, swidden, and current and former forest pasture sites that were grazed, mowed, and/or burned, or not actively managed. Quadrats were located randomly within areas deemed to be typical of the overall site. Quadrats were spaced at least 5 metres from one another. Within each quadrat, each vascular plant species was identified and its percent cover was estimated. Species were identified using the flora *Suuri Pohjolan Kasvio* by Mossberg and Stenberg (2003) and *Retkeilykasvio* by Hämet-Ahti *et al.* (1998). Patches of bare ground, large boulders, stumps, and fallen logs were also recorded where they covered at least 5% of the quadrat.

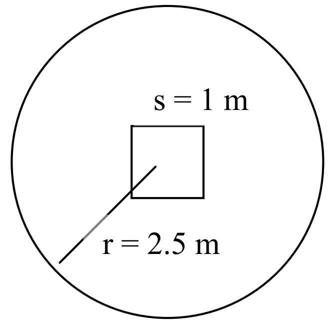

Figure 4.1. Diagram of circular plot with a radius of 2.5 m for woody vegetation sampling and the 1m x 1m square quadrats used to sample the ground layer vegetation.

Analysis

Both woody vegetation and herbaceous vegetation were sampled from a number of sites within Koli National Park. Where woody species were present in the field layer, they were included in the survey of field layer vegetation. However, the survey of woody vegetation did not include records of herbaceous species in the field layer. Methods used to analyze the vegetation data are described below.

Woody Vegetation

Because the classification of the condition of woody vegetation provided ordinal data (i.e. "Undamaged", "Somewhat damaged", "Extensively damaged" and "Dead") a non-parametric test was required to test the first three null hypotheses listed on page 140. The Kruskal-Wallis test may be used when more than two samples are compared. This non-parametric test was chosen for its statistical strength and its ability to accommodate ordinal data. Calculations for H_c (the Kruskal-Wallis test statistic corrected for tied ranks) were manually programmed into Microsoft Excel version 11.5.5 following the formulae provided in Zar (1999). When the Kruskal-Wallis tests revealed significant differences in mean ranks among the groups tested, Tukey-type post-hoc multiple comparisons were conducted using Dunn's (1964, in Zar 1999 p. 224) equation for SE with tied ranks to determine which cases in particular differed significantly from the others.

Field Layer Vegetation

Vegetation sampling in the field layer was used to a) estimate species richness of each site, b) determine the degree of similarity between sites using cluster analyses, and c) examine differences in percent cover of individual plant species. The methods used to analyze the field layer data for each of these purposes are described in detail below.

Species Richness. Species richness estimates were calculated using the 2009 updated SPADE software (Chao and Shen, 2003-2005). The non-bias corrected Chao2 estimator for species richness was chosen because it accounts for the probability that species were missing from the sample based on the number of uniques (species detected in only one quadrat) and duplicates (species detected in only two quadrats) at each site. This Chao2 estimator performs well even when high numbers of species are missing from the samples (Unterseher *et al.*, 2008). This is advantageous because some species were known to have been missed in the field sampling conducted in this study (as they were observed in the sites, but not within the sampled quadrats). Also, because data from previous studies (which used different sampling procedures) were drawn upon in this analysis to account for the lack of non-grazed 8- or 9-year-old swidden sites available during the 2008 field season (Ruokolainen and Salo, 2006) and to provide supplementary data from the grazed swidden sites from previous years (Koli National Park unpublished data, 2004; LeHenaf and DeGryse, 2003), the assumptions within parametric methods of analysis would not have been strictly met. The standard errors of the species richness estimates were derived from 200 bootstrap replications that were run for each site. A single-factor analysis of variance (ANOVA) was performed to test whether any differences in estimated species richness existed among the sites. Because variances were not presumed to be equal among the estimates, the multiple Welch test (Welch, 1951 in Zar, 1999) was employed to conduct the ANOVA. To determine which species richness estimates differed significantly from the others, a post hoc multiple comparison tests using the Games-Howell method (Olejnik and JaeShin, 1990) was conducted. The Games-Howell post-hoc test is recommended when conducting post hoc tests between samples which have differing variances and greater than 15 observations (Olejnick and JaeShin 1990). The Games-Howell comparisons were conducted in a manner similar to conducting a Tukey test, comparing the site with the highest estimated species richness with the site with the lowest estimated species richness, except that differences in variances must be taken into account. If a significant difference in species richness estimates (SRE) was found (at $\alpha \leq 0.05$) between two sites, the site with the highest SRE would then be compared with the site with the second-lowest SRE. If a significant result was again found, then the site with the highest SRE would be compared with the site with the third-lowest SRE, and so on until a significant difference between the SRE of the sites was not detected. As with the Tukey tests, it would be reasonable to assume that the difference between the site with the highest SRE and each of the remaining sites would not be significant, provided that the variances of the SRE of the remaining sites were lower than the variance of the site for which a significant difference was not detected. To determine whether it would be worthwhile to test the remaining sites with lower variances than the site for which a significant difference was not detected, a zero was entered as the variance of the site for which an insignificant difference between SRE was found. If the result was still not significantly different assuming the sample with the lower SRE had zero variance, then no other sites were contrasted with the site with the highest SRE. Otherwise, the comparisons would continue between the site with the highest SRE and those with variances less than the site for which no significant difference was detected in order from lowest to highest SRE. The procedure would be repeated comparing the site with the second-highest SRE with the site with the lowest SRE, then the site with the second-highest SRE with that with the second-lowest SRE, third-lowest SRE and so on. The Welch and Games-Howell tests were calculated by programming the test formulae as presented in Zar (1999) and in Olejnick and JaeShin (1990), respectively, into Microsoft Excel version 11.5.5.

Percent Cover. The field layer data were examined to determine whether there were significant differences in percent cover of vascular plant species in grazed versus ungrazed swidden and forest sites. To do so, a Kruskal-Wallis test correcting for tied ranks was performed with percent cover data from quadrats sampled from grazed and non-grazed sites of similar age. Where significant differences among the sites were indicated at $P \leq 0.05$, a Tukey-type non-parametric multiple comparison test was run using Dunn's (1964 cited in Zar 1999, p. 224) equation to account for unequal numbers of data in each of *k* groups. These tests were performed by programming the test formulae as presented in Zar (1999) into Microsoft Excel version 11.5.5. Unfortunately, all of the open fields grazed by Finnsheep and Eastern Fincattle also had a history of cultivation. Because differences in percent cover of plant species could not necessarily be attributed to grazing pressures as opposed to differences resulting from other site conditions (e.g., soil characteristics related to the history of cultivation in the areas where grazing occurred), this analysis was not performed to compare grazed field sites with non-grazed meadow sites.

Cluster Analysis. To visualize the relationships between the sites in terms of their vascular plant composition, a cluster analysis was run using PC ORD version 5 (McCune and Mefford, 2006). Before groups could be identified using a cluster analysis, a resemblance matrix based on the multiple incidence data[49] for the field layer of each site was generated using a similarity coefficient (Romesburg, 2004). Although Jaccard's and Sørensen's similarity indices are widely used (Magurran, 1988), they do not consider species abundance and they underestimate similarity (or, inversely, overestimate dissimilarity) if sample sizes are small and/or if species richness is high (Chao *et al.*, 2006). Because of the differences in sampling intensity between sites and between data sources, Chao *et al.*'s (2005) adjusted formula for the Sørensen index was used. This formula modifies Sørensen's index to consider multiple incidence data and is adjusted to estimate the number of species that would likely have been common between two communities had there been additional sampling.

To assess the similarity between the vegetation composition of each site sampled, pair-wise comparisons of every site with each other site were run using the two-community similarity analysis functions in the 2009 version of SPADE (Chao and

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[49] In multiple incidence data, the frequency of samples in which a species appears in a community is considered, rather than simply noting whether the species is present or absent in the community. This formulation allows more common species to be distinguished from less common species, which could not be determined from presence/absence data aggregated for the community as a whole.

Shen, 2003-2005). The outcome of each pairwise comparison using Chao *et al.*'s (2005) adjusted incidence-based Sørensen similarity index was entered into MS Excel to form a similarity matrix. A dissimilarity matrix was generated by subtracting each cell of the Sørensen similarity index from 1 (i.e., 1 - similarity index = dissimilarity index). This dissimilarity matrix was then formatted for use with PCORD, and cluster analyses using group average (a.k.a. unweighted pair-group method) and Ward's linkage methods were run. The group average and Ward's methods are two linkage methods recommended for cluster analyses because of their moderate position between methods that are highly prone to chaining[50] and those which are least likely to chain (McCune and Grace, 2002; Romesburg, 2004).

RESULTS

Woody Vegetation: Grazed vs. Non-grazed Swidden Sites

A total of 1 361 stems of five tree species were inventoried in the swidden sites burned in 1998, 1999, 2000 and 2002. Characteristics of each swidden regeneration area and the number of stems sampled in each are presented in Table 4.2.

The condition of woody vegetation was significantly different among the swidden sites ($H_c = 398.074$, $P < 0.001$). The woody vegetation in the grazed swidden site (oll sab) was significantly more damaged ($Q = 17.51$, $P < 0.001$) than in the

[50] Chaining occurs when individual samples are sequentially added to existing groups rather than forming new groups with other samples.

ungrazed sites (oll b02 and r&s B98), which did not significantly differ from one another (Table 4.3). This can be clearly seen in Figure 4.2, which illustrates that only 43% of the stems were undamaged in the swidden site subject to sheep grazing (oll sab), whereas 98% and 92% of the woody stems were undamaged in the swidden sites without sheep grazing (oll b02 and r&s B98, respectively). Tree mortality in the swidden site with sheep was 26% whereas only two individuals of 558 trees sampled (0.3%) were dead within the swidden sites without sheep grazing.

Table 4.2. Characteristics of swidden areas and number of woody stems sampled.

Site Name (Sub-site)	Year Burned	Grazed by Sheep	Total Area of Site	# of 10 m^2 quadrats	Condition of stems sampled	Average stem density ± S.E. (range)
Ruokolainen & Salo (r&s B98)	1998	No	2.5 ha	6	Undamaged: 203 Somewhat Damaged: 11 Extensively Damaged: 4 Dead: 2 Total: 220	3.68/m^2 ± 1.19 (0.5 to 6.4)
Ollila (oll sab)	1999/ 2000	Yes	0.62ha	6	Undamaged: 345 Somewhat Damaged: 94 Extensively Damaged: 150 Dead: 214 Total: 803	11.5/m^2 ± 23.0 (2.2 to 37.9)
Ollila (oll b02)	2002	No	~0.36ha	1	Undamaged: 331 Somewhat Damaged: 3 Extensively Damaged: 4 Dead: 0 Total: 338	33.8/m^2

Table 4.3. Nonparametric multiple comparisons of the tree condition among grazed and ungrazed swidden sites in Koli National Park

Sites compared	Difference in mean ranks	S.E.	Q	*P*
oll sab vs oll b02	379.80	21.69	17.51	$P < 0.001$
oll sab vs r&s B98	348.14	25.46	13.67	$P < 0.001$
r&s B98 vs oll b02	31.67	28.98	1.09	n.s.

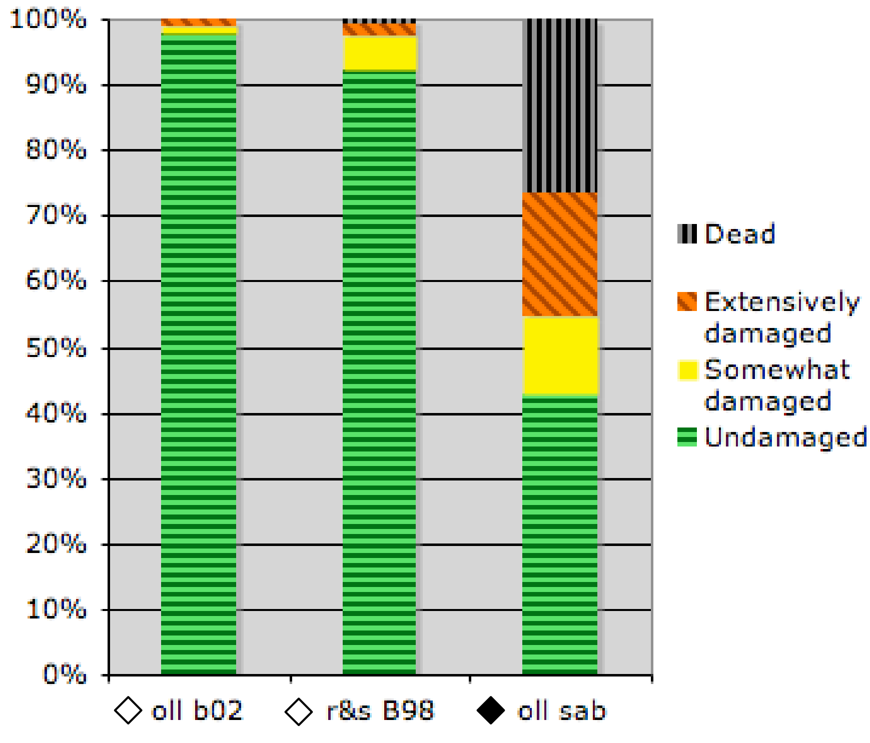

Figure 4.2. Condition of trees in non-grazed (oll b02 and r&s B98) versus grazed (oll sab) swidden sites.
The condition of trees does not significantly differ between sites grouped by a shared horizontal line. Black diamond symbol signifies the grazed swidden site. Unfilled diamond symbols indicate the non-grazed swidden sites.

Analysing only the swidden site subjected to grazing by Finnsheep, the Kruskal-Wallis test rejected the null hypothesis that the tree species were equally affected by exposure to sheep browsing ($Hc = 34.18$, $P < 0.001$). *Sorbus aucuparia*, which had the fewest (10%) dead stems and the greatest proportion of undamaged individuals (59%), was significantly less affected by sheep grazing in the regenerating swidden sites ($P < 0.001$) than both silver birch *Betula pendula* Roth (Q = 5.00) and downy birch *Betula pubescens* Ehrh. (Q = 5.16) (Figure 4.3). There were no significant differences in tree condition between the two *Betula* species (Q = 1.94) within the swidden site with sheep grazing. *Picea abies* and Scots pine (*Pinus sylvestris* L.) comprised a very low percent cover of the swidden site grazed by sheep and were not represented within the quadrats sampled from that site.

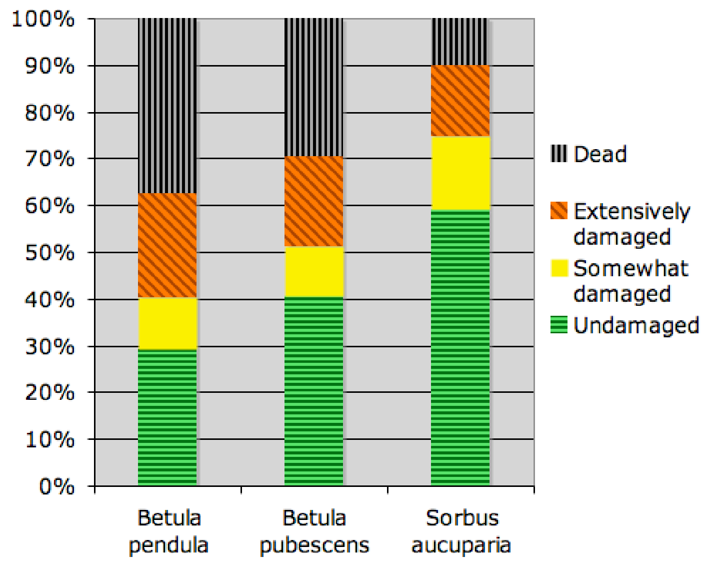

Figure 4.3. Condition of tree species within the swidden site grazed by Finnsheep. The condition of trees does not significantly differ between species grouped by a shared horizontal line.

Analysing only the regenerating swidden sites without sheep grazing, damage to trees was also unequally distributed among species (Hc = 135.86, $P < 0.001$). *Pinus sylvestris* and *Sorbus aucuparia* were both significantly ($P < 0.001$) more damaged in the ungrazed swidden sites than any of the other species (Table 4.4, Figure 4.4). The three *Pinus sylvestris* individuals sampled were either “Extensively damaged” (33.3%) or were “Dead” (66%). Half of the *Sorbus aucuparia* (n = 6) sampled from the ungrazed sites were either “Somewhat damaged” or “Extensively damaged”, but none of them was dead. None of the *Picea abies* sampled (n = 60) was damaged and only 3 percent of the *Betula pendula* (n = 3) and *Betula pubescens* (n = 12) were either “Somewhat damaged” or “Extensively damaged”, but again, none was dead. All but two of the damaged or dead individuals in the sites without sheep grazing showed evidence of browsing, probably by moose (*Alces alces*).

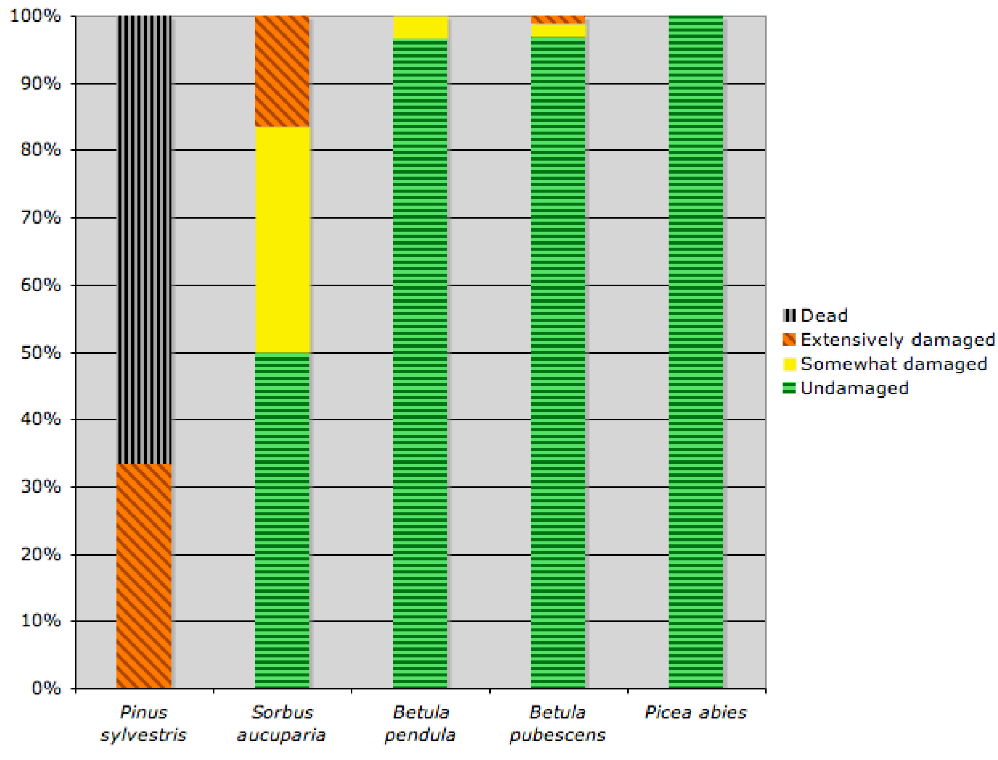

Figure 4.4. Condition of tree species within ungrazed swidden sites.
Tree condition does not significantly differ between species grouped by a shared horizontal line.

Table 4.4. Nonparametric multiple comparisons of the tree condition among trees species in ungrazed swidden sites in Koli National Park.

Species compared	Difference in mean ranks	S.E.	Q	*P*
Pinus sylvestris vs *Picea abies*	288.33	33.53	8.60	$P < 0.001$
P. sylvestris vs. *Betula pubescens*	279.82	7.85	35.63	$P < 0.001$
P. sylvestris vs. *Betula pendula*	279.2	9.44	29.56	$P < 0.001$
P. sylvestris vs. *Sorbus aucuparia*	149.5	17.92	8.32	$P < 0.001$
Sorbus aucuparia vs. *Picea abies*	138.83	17.92	7.75	$P < 0.001$
S. aucuparia vs. *Betula pubescens*	130.33	16.61	7.85	$P < 0.001$
S. aucuparia vs. *Betula pendula*	129.70	17.42	7.45	$P < 0.001$
Betula pendula vs. *Picea abies*	9.13	9.44	0.97	n.s.
Do not test other pairs				

Within the grazed swidden site, damage to trees was unequally distributed among the height classes of the trees (*Hc* = 291.98, $P < 0.001$). Trees 0.5 – 1 m tall were significantly more damaged than all other height classes ($P < 0.001$) (Table 4.5). The condition of trees 1 – 1.5 m tall and trees under 0.5 m tall did not differ from one another, but were significantly more damaged than trees in height classes taller than 1.5 m ($P < 0.001$). The distribution and condition of trees in the grazed swidden site in each height class are illustrated in Figure 4.5. No significant differences in damage levels to trees by height class were revealed in the non-grazed swidden site.

Table 4.5. Results of the non-parametric multiple comparison of tree condition by height class in the grazed swidden site.

Height classes compared	Difference in mean ranks	S.E.	Q	*P*
<0.5 m vs > 3 m	239.14	36.51	6.55	$P < 0.001$
<0.5 m vs 2 – 2.5 m	216.85	32.24	6.73	$P < 0.001$
<0.5 m vs 2.5 - 3 m	212.96	51.88	4.11	$P < 0.001$
<0.5 m vs 1.5 - 2 m	173.62	27.64	6.28	$P < 0.001$
<0.5 m vs 0.5 - 1 m	137.05	22.46	6.10	$P < 0.001$
<0.5 m vs 1 – 1.5 m	44.31	27.64	1.60	n.s.
0.5 – 1 m vs > 3 m	376.19	35.52	10.59	$P < 0.001$
0.5 – 1 m vs 2 – 2.5 m	353.91	31.11	11.38	$P < 0.001$
0.5 – 1 m vs 2.5 - 3 m	350.01	51.19	6.84	$P < 0.001$
0.5 – 1 m vs 1.5 – 2 m	310.67	26.32	11.80	$P < 0.001$
0.5 – 1 m vs 1 – 1.5 m	92.74	21.89	4.24	$P < 0.001$
1 – 1.5 m vs > 3 m	283.45	36.17	7.84	$P < 0.001$
1 – 1.5 m vs 2 - 2.5 m	261.16	31.84	8.20	$P < 0.001$
1 – 1.5 m vs 2.5 - 3 m	257.27	51.64	4.98	$P < 0.001$
1 – 1.5 m vs 1.5 - 2 m	217.93	27.18	8.02	$P < 0.001$
1.5 – 2 m vs > 3 m	65.52	39.00	1.68	n.s.
Do not test other pairs				

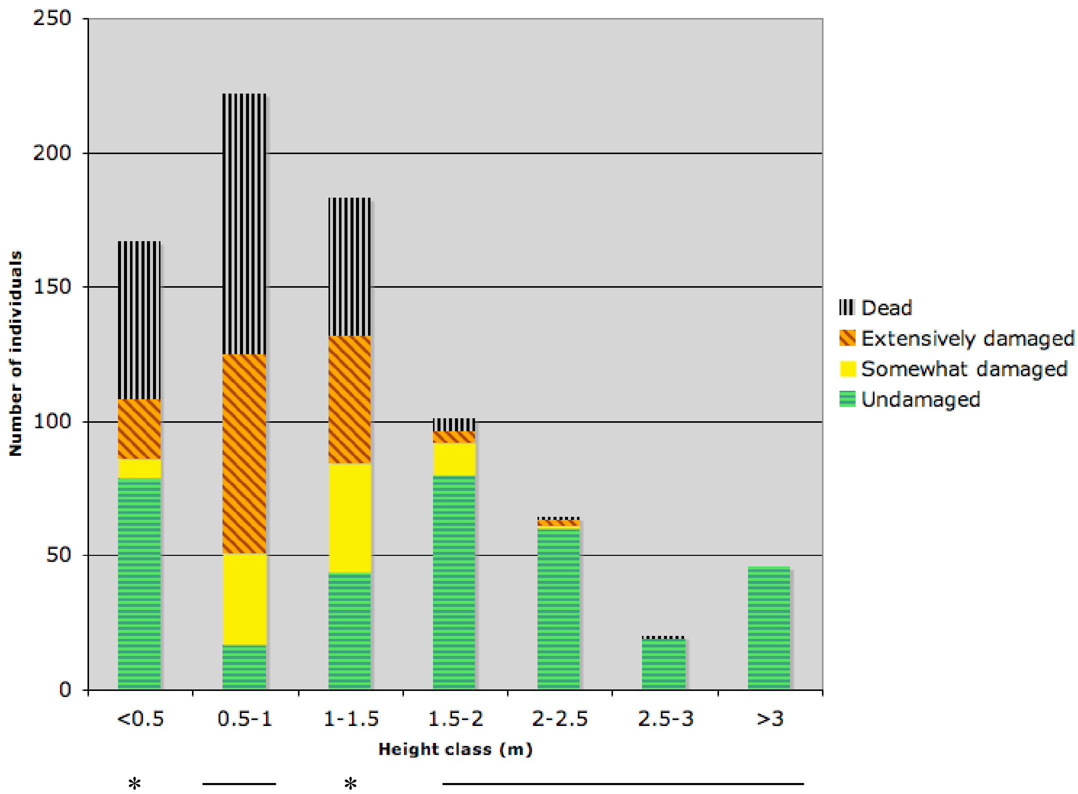

Figure 4.5. Condition of trees in the grazed swidden site by height class.
Tree condition does not significantly differ between height classes grouped by a shared horizontal line. * Although not shown by a horizontal line, tree condition does not differ significantly between the <0.5 m and 1-1.5 m height classes.

<u>Woody Vegetation: Grazed vs. Non-grazed Forest Pastures</u>

A total of 855 trees of nine species were sampled in eight deciduous forest sites. Prior to 1960, cattle, sheep and horses typically grazed in the wooded areas around the former farm sites within Koli National Park. In 2008, the only livestock grazing in wooded areas in Koli National Park were Finnsheep at the Seppälä site (sep 3c). The remaining sites had been used as forest pastures within the past century but are not currently grazed. These non-grazed sites had been classified in an inventory of habitat-types in Koli National Park as forest pastures (hav 2, yla 4, sep *w*) or as mature swidden forests (mak 3a, mak 3b, mak 4, yla 3, tur *f*). Livestock grazed in the forested areas around Ylä Murhi (yla 3, yla 4) and Havukkanaho (hav 2) prior to 1950 (Lohilahti *et al.*, 2006). The former swidden sites and forest sites at Mäkränaho (mak 3a, mak 3b, mak 4) would have been used as forest pastures before the farm site was abandoned in 1934 (Lohilahti *et al.*, 2006).

The condition of trees was not equal among all the sites ($Hc = 31.87$, $P < 0.001$). The site with the lowest ranking in terms of tree condition was a non-grazed former forest pasture (yla 4), which had five dead *Betula pendula* saplings (1.5 – 3 m in height) and 17 dead mature *B. pendula* trees (> 3 m in height) that did not have any evidence of browsing or debarking by moose or other mammalian herbivores (Figure 4.7). At that site only *Sorbus aucuparia* (which accounted for the remaining three dead and five damaged trees) had any signs of browsing, likely by moose. Although the currently grazed forest site at Seppälä had the next worst ranking in terms of tree condition, only one non-grazed forest site was in significantly (α=0.05) better condition (tur *f*) (Table 4.6). No significant differences in condition of woody vegetation were found among any of the other former forest pastures that are not currently grazed.

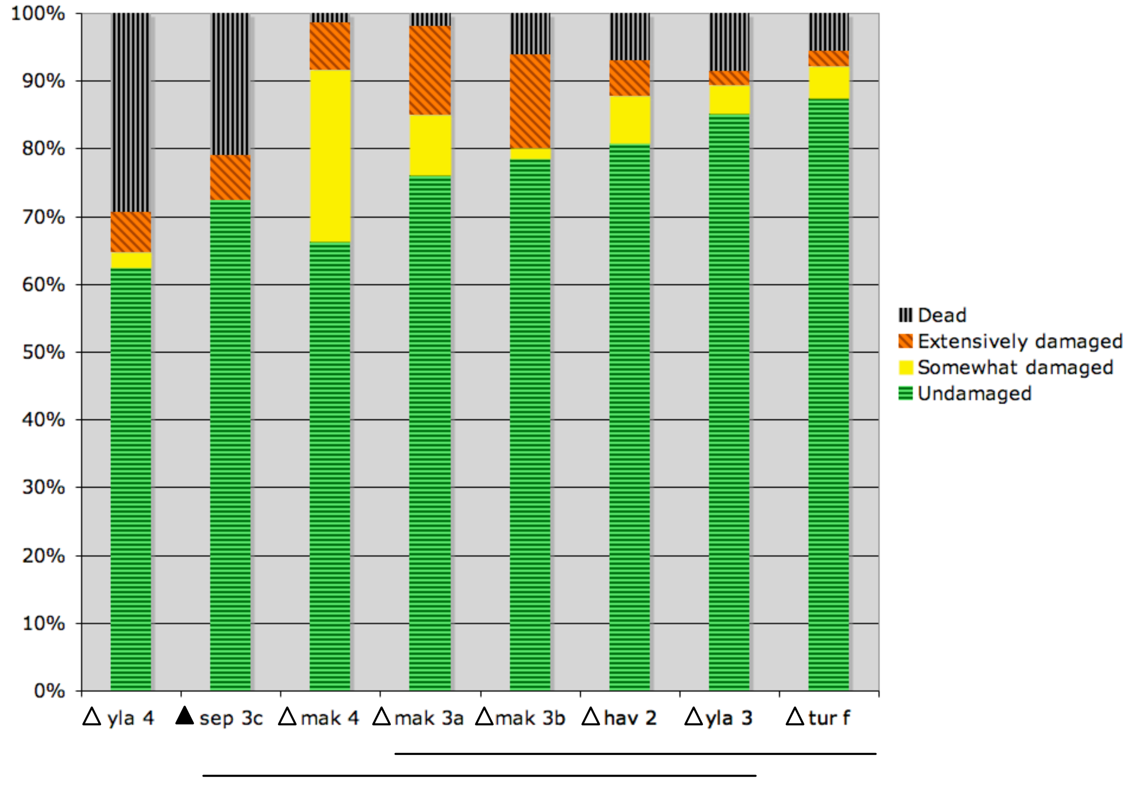

Figure 4.6. Condition of trees in grazed and non-grazed forest pastures.
Tree condition does not significantly differ between species grouped by a shared horizontal line. The black triangle symbol signifies the grazed forest site. Unfilled triangle symbols indicate the non-grazed forest sites.

Table 4.6 Nonparametric multiple comparisons of tree condition among currently and formerly grazed forest sites in Koli National Park.

Sites compared	Difference in mean ranks	S.E.	Q	*P*
yla 4 vs tur *f*	121.64	25.40	4.79	$P < 0.001$
yla 4 vs yla 3	109.64	32.94	3.33	$P < 0.05$
yla 4 vs mak 3a	79.27	26.74	2.96	n.s.
yla 4 vs other sites	Do not test			
sep 3c vs tur *f*	75.56	23.91	3.16	$P < 0.05$
sep 3c vs yla 3	63.71	31.81	2.00	n.s.
sep 3c vs other sites	Do not test			
mak 4 vs tur f	73.38	26.86	2.73	n.s.
Do not test other pairs				

Analysing only the forest pasture currently grazed by Finnsheep (sep 3c), damage to trees was unequally distributed among species (*Hc* = 82.41, $P < 0.001$). In this grazed area (Figure 4.7), all of the Eurasian aspen (*Populus tremula* L.) (n = 15) were either extensively damaged (27%, n = 4) or dead (73%, n =11), and all but three of the *Sorbus aucuparia* were either extensively damaged (20%, n = 3) or dead (60%, n = 9). The condition of *P. tremula* and *S. aucuparia* were not statistically different from one another, and both of these species were significantly more damaged than all other tree species sampled in this grazed area at a significance level of α=0.05 (Table 4.7). No other significant differences in condition among tree species in the grazed forest pasture were found. Because there were insufficient numbers of *Betula pendula* (n = 2) and *Betula pubescens* (n = 1), the birches were analysed together as a single genus. None of the birch trees in the currently grazed forest pasture was damaged, but the only individuals sampled in the grazed area were all mature trees over 3 m tall. At that height they were too tall for the foliage or branches to be affected by Finnsheep browsing, and there were no signs observed of Finnsheep consuming birch bark. All but three of the *Alnus incana* (n = 64) in the sheep pasture were under 1.5 m tall, within easy reach of the sheep. However, only two of these *A. incana* were dead. Nine others exhibited signs of browsing, but none was debarked nor had more than 25% of its branches affected by browsing. Thus, all but the two dead *A. incana* in the forest pasture currently grazed by Finnsheep were categorized as “undamaged”.

Table 4.7. Nonparametric multiple comparisons of tree condition among tree species within the currently grazed forest pasture at the Seppälä site in Koli National Park.

Species compared	Difference between mean ranks	S.E.	Q	*P*
Populus tremula vs. *Picea abies*	53.63	10.62	5.05	$P < 0.001$
P. tremula vs. *Betula spp.*	53.63	15.34	3.50	$P < 0.001$
P. tremula vs. *Alnus incana*	51.92	6.93	7.49	$P < 0.001$
P. tremula vs. *Sorbus aucuparia*	10.53	8.86	1.19	n.s.
Sorbus aucuparia vs. *Picea abies*	43.10	10.62	4.06	$P < 0.001$
S. aucuparia vs. *Betula spp.*	43.10	15.34	2.81	$P < 0.05$
S. aucuparia vs. *Alnus incana*	41.38	6.93	5.97	$P < 0.001$
Alnus incana vs. *Picea abies*	1.72	9.07	0.19	n.s.
Do not test other pairs				

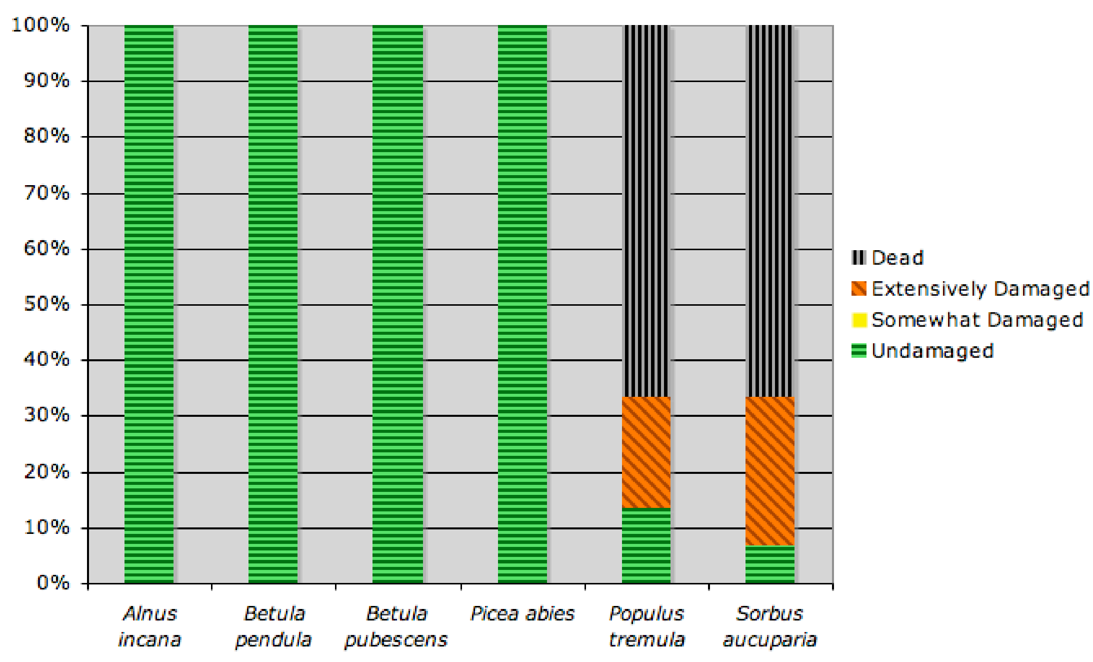

Figure 4.7. Condition of woody species in the currently grazed forest pasture. Tree condition does not significantly differ between species grouped by a shared horizontal line.

In the former forest pastures currently without sheep grazing, *Alnus incana* had the lowest proportion of "undamaged" individuals (56%, n = 27) followed closely by *Betula pendula* (64% undamaged, n = 56) (Figure 4.8). *Alnus incana* and *B. pendula* were significantly more damaged than *Sorbus aucuparia* and *Picea abies* ($P < 0.001$). *Betula pubescens* was also more damaged than *P. abies* (P < 0.01) in these former forest pastures. No other significant differences in tree condition were found among the remaining tree species (Table 4.8). *Pinus sylvestris* was excluded from the analysis because only two individuals of this species were sampled (one dead, one undamaged).

Within the formerly grazed pastures, only trees under 50 cm in height were in significantly (α=0.05) better condition than those in all other height classes except 2.5 - 3 m (probably because of the low numbers: only 14 were sampled in the 2.5 – 3m height category) (Table 4.9). When there was damage to trees under 3 m tall, the most evident damage was from browsing, likely by moose. It is possible that stems under 50 cm tall were browsed right to the base and were therefore undetected as damaged or dead when sampled.

Within the currently grazed pasture, the opposite trend occurred: only stems under 50 cm in height ranked significantly worse in terms of condition than any of the other height classes (Table 4.10). New growth comprises a larger proportion of young shoots, so trees under 50 cm in height may have a larger proportion of palatable parts and therefore sustain more damage from browsing by Finnsheep than taller, more mature shoots.

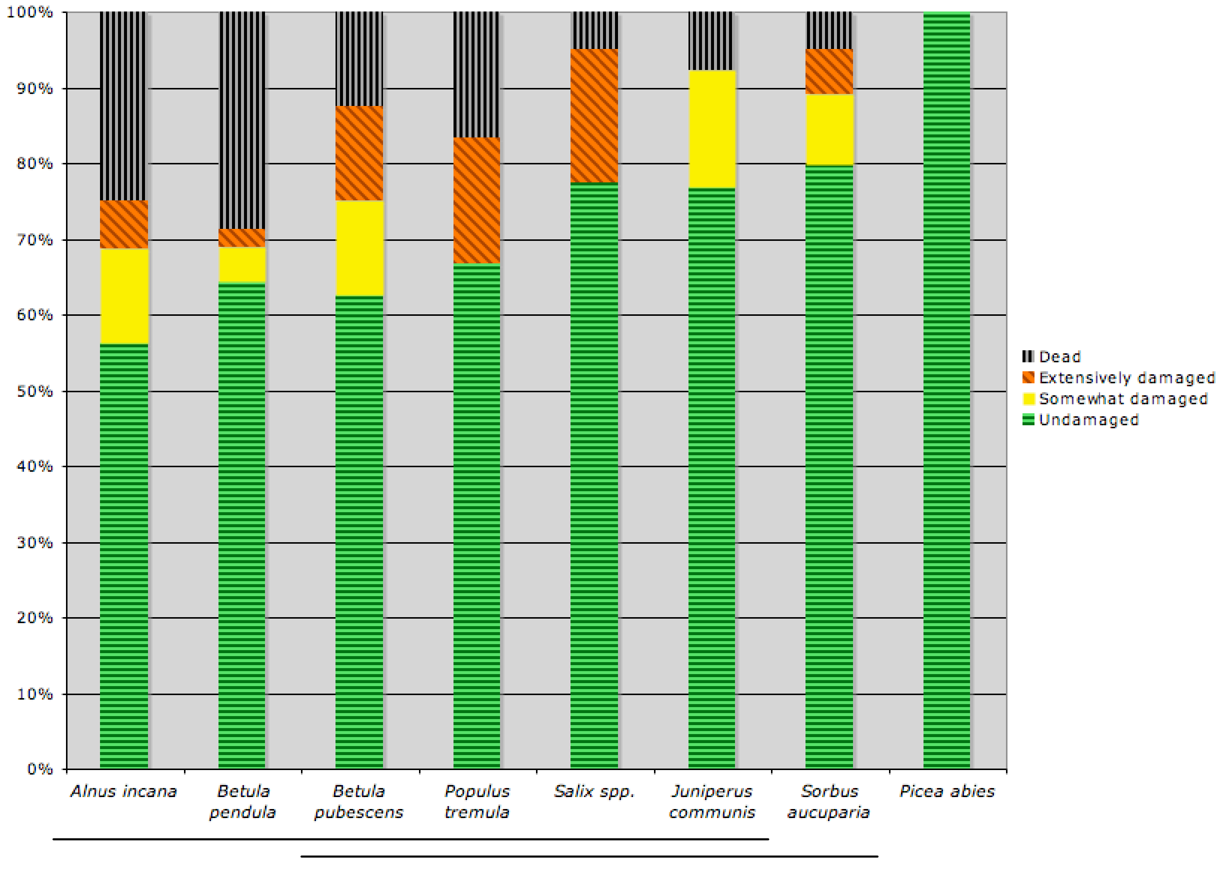

Figure 4.8. Condition of woody species in former forest pastures.
Tree condition does not significantly differ among species grouped by a shared horizontal line.

Table 4.8. Nonparametric multiple comparisons of tree condition among tree species within the former forest pastures in Koli National Park.

Species compared	Difference in mean ranks	S.E.	Q	*P*
Alnus incana vs. *Picea abies*	134.06	16.97	7.90	$P < 0.001$
A. incana vs. *Sorbus aucuparia*	76.55	11.53	6.74	$P < 0.001$
A. incana vs. *Juniperus communis*	69.56	23.47	2.69	n.s.
A. incana vs. other species	Do not test			
Betula pendula vs. *Picea abies*	115.45	15.34	7.523	$P < 0.001$
B. pendula vs. *Sorbus aucuparia*	57.94	8.97	6.462	$P < 0.001$
B. pendula vs. *Juniperus communis*	50.95	22.32	2.283	n.s.
B. pendula vs. other species	Do not test			
Betula pubescens vs. *Picea abies*	109.94	29.58	3.72	$P < 0.01$
B. pubescens vs. *Sorbus aucuparia*	52.43	26.83	1.95	n.s.
B. pubescens vs. other species	Do not test			
Populus tremula vs. *Picea abies*	104.91	33.31	3.15	n.s.
Do not test other pairs				

Table 4.9. Nonparametric multiple comparisons of tree condition among tree height classes within the former forest pastures in Koli National Park.

Height classes compared	Difference in mean ranks	S.E.	Q	*P*
2 – 2.5 m vs < 0.5 m	177.42	37.49	4.73	$P < 0.001$
2 – 2.5 m vs 0.5 - 1 m	120.30	39.20	3.70	$P < 0.05$
2 – 2.5 m vs 2.5 - 3 m	107.17	55.38	1.94	n.s.
2 – 2.5 m vs other height classes	Do not test			
1.5 – 2 m vs < 0.5 m	126.50	22.88	5.53	$P < 0.001$
1.5 – 2 m vs 0.5 – 1 m	69.38	25.58	2.71	n.s.
1.5 – 2 m vs other height classes	Do not test			
> 3 m vs < 0.5 m	111.06	14.98	7.42	$P < 0.001$
> 3 m vs 0.5 – 1 m	53.94	18.85	2.86	n.s.
> 3 m vs other height classes	Do not test			
1 – 1.5 m vs < 0.5 m	103.91	18.14	5.73	$P < 0.001$
1 – 1.5 m vs 0.5 – 1 m	46.79	21.45	2.18	n.s.
1 – 1.5 m vs other height classes	Do not test			
2.5 – 3 m vs < 0.5 m	70.25	43.24	1.62	n.s.
2.5 – 3 m vs other height classes	Do not test			
0.5 – 1 m vs < 0.5 m	57.12	18.43	3.10	$P < 0.05$
Do not test other pairs				

Table 4.10. Nonparametric multiple comparisons of tree condition among tree height classes within the forest pastures grazed by sheep in Koli National Park.

Height classes compared	Difference in mean ranks	S.E.	Q	*P*
< 0.5 m vs 1 – 1.5 m	28.72	6.88	4.18	$P < 0.001$
< 0.5 m vs 0.5 – 1 m	22.72	5.26	4.32	$P < 0.001$
< 0.5 m vs > 3 m	14.72	9.18	1.60	n.s.
< 0.5 m vs other height classes	Do not test			
> 3 m vs 1 – 1.5 m	14.00	10.15	1.38	n.s.
Do not test other pairs				

Woody Vegetation within Open Pastures

Within the primarily open fields in which the Eastern Finncattle and Finnsheep grazed (oll 4, oll 5, and oll 1), some deciduous trees existed, but represented less than 10% of the vegetation cover in these areas. In two of the open pastures (oll 4 and oll 5) grazed by Finnsheep, a total of 224 *Alnus incana* and seven *S. aucuparia* occurred in two densely clustered wooded areas, each approximately 20 m^2. All but one of the *A. incana* was browsed and/or debarked, resulting in damage or death to nearly 72% of the trees[51]. In these sheep pastures, the damage disproportionately affected trees by height (Hc = 120.13, $P < 0.001$), with the greatest proportion of dead trees falling in the 0.5 - 1 m and < 0.5 m height categories and the greatest proportion of undamaged trees falling in the >3m and 2.5 – 3 m height categories (Figure 4.9 and Table 4.11).

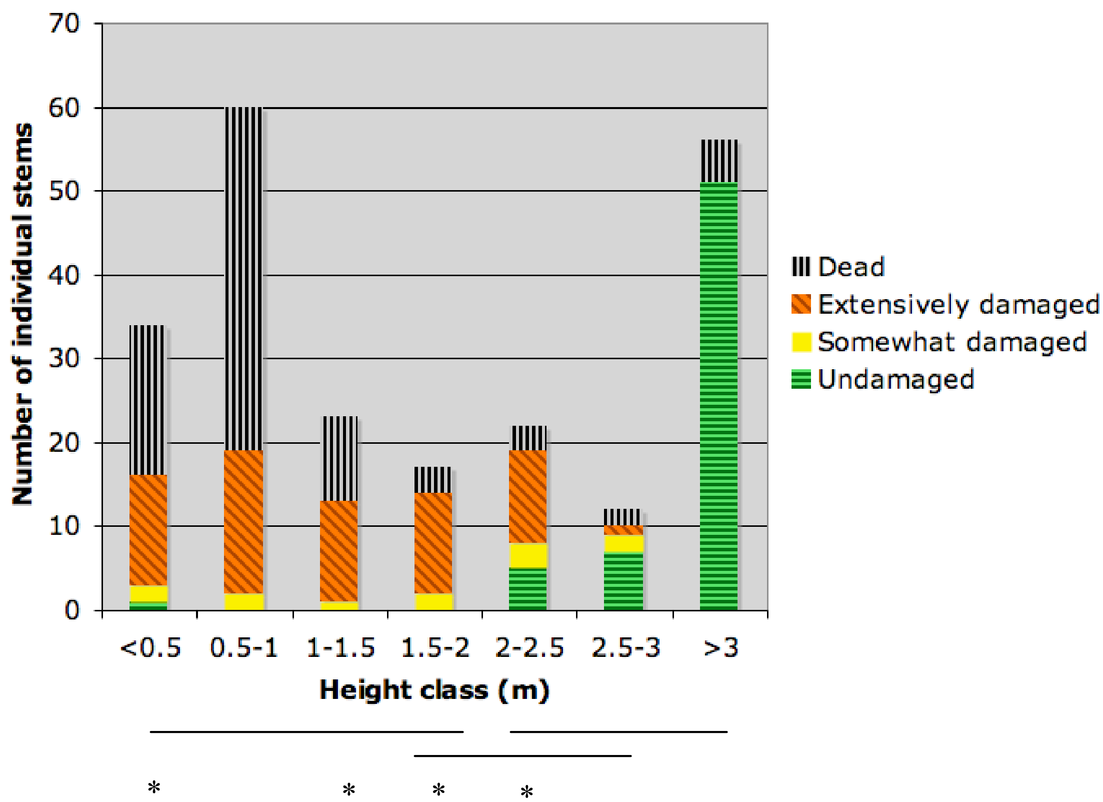

Figure 4.9. Condition of trees by height class in open Finnsheep pastures.
Tree condition does not significantly differ between height classes grouped by a shared horizontal line. * Although not shown by a horizontal line, tree condition does not differ significantly between the <0.5 m, 1-1.5 m, 1.5-2 m and 2-2.5 m height classes.

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[51] Sixty-three *Alnus incana* individuals had been browsed or debarked, but were still classified as “undamaged” because less than 25% of their branches were affected.

Table 4.11. Kruskal-Wallis multiple comparisons of tree condition by height class in open pastures grazed by Finnsheep.

Height classes compared	Difference in mean ranks	S.E.	Q	*P*
0.5 – 1 m vs > 3 m	117.65	11.80	9.97	$P < 0.001$
0.5 – 1 m vs 2.5 - 3 m	92.34	20.08	4.60	$P < 0.001$
0.5 – 1 m vs 2 – 2.5 m	64.74	15.82	4.09	$P < 0.001$
0.5 – 1 m vs 1.5 – 2 m	43.05	17.06	2.52	n.s.
0.5 – 1 m vs others	Do not test			
1 – 1.5 m vs > 3 m	98.09	15.72	6.24	$P < 0.001$
1 – 1.5 m vs 2.5 - 3 m	72.78	22.61	3.22	$0.05 > P > 0.02$
1 – 1.5 m vs 2 - 2.5 m	45.17	18.93	2.39	n.s.
1 – 1.5 m vs others	Do not test			
<0.5 m vs > 3 m	94.96	13.14	7.22	$P < 0.001$
<0.5 m vs 2.5 - 3 m	69.65	20.90	3.33	$0.02 > P > 0.01$
<0.5 m vs 2 – 2.5 m	42.05	16.85	2.49	n.s.
<0.5 m vs others	Do not test			
1.5 – 2 m vs > 3 m	74.60	17.20	4.34	$P < 0.001$
1.5 – 2 m vs 2.5 - 3 m	49.29	23.66	2.08	n.s.
1.5 – 2 m vs others	Do not test			
2 – 2.5 m vs > 3 m	52.91	15.98	3.31	$0.02 > P > 0.01$
2 – 2.5 m vs 2.5 - 3 m	27.60	22.78	1.21	n.s.
2 – 2.5 m vs others	Do not test			
2.5 – 3 m vs > 3 m	25.31	20.20	1.25	n.s.
Do not test other pairs				

Eastern Finncattle grazed in oll 1, which is a 0.61 ha former field that primarily has a savanna-like condition with tree cover less than 10%. In this open area, a census of every woody stem (n = 373) was undertaken. Twenty-six mature (> 3 m tall) trees (*Alnus incana*, *Betula pendula* and *Betula pubescens*) comprised the majority of the tree cover with shoots of *A. incana* (n = 347) under 2 m tall mainly occurring around the base of mature trees of the same species. *Alnus incana* was significantly more affected by grazing than *Betula pendula* (Q = 7.15, $P < 0.001$) and *Betula pubescens* (Q = 6.67, $P < 0.001$). Only 10 (3%) of the 356 *A. incana* stems were undamaged (Figure 4.10), whereas all but one (94%) of the 17 *Betula spp*. trees were undamaged (all *Betula spp.*

were over 3 m tall). Five (36%) of the 14 *A. incana* individuals taller than 3 m were dead, with evidence of broken branches and debarking by the cattle. Because nearly all (87%) of the *A. incana* trees were in the "extensively damaged" classification, it was not possible to perform a Kruskal-Wallis analysis to determine if the condition of trees was equal among the height classes. However, it is worth noting that the only *A. incana* that were not damaged were above 3 m tall (n = 9), as well as a single individual under 50 cm tall.

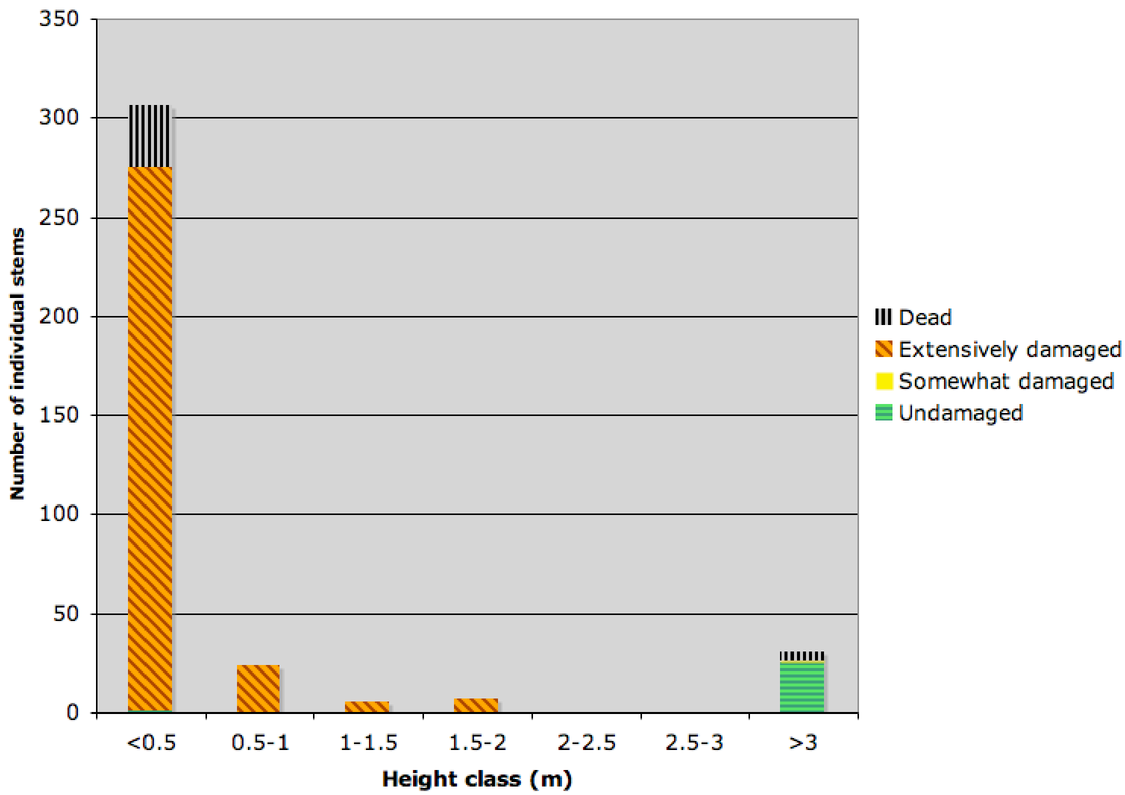

Figure 4.10. Condition of trees by height class in open Eastern Finncattle pasture.

Field Layer Vegetation

A total of 266 quadrats were used to sample the field layer in 30 sites. Additional data from 12 quadrats sampled by Koli National Park staff at the Ollila site in 2003 and 2004 and 68 quadrats from Ruokolainen and Salo's (2006) data from their 2004 and 1998 field seasons were made available. A total of 135 species were observed from the combined sources.

Species Richness Estimates

The Chao2 species richness estimates for the sites ranged from 16.11 (S.E. 3.2) in the mature *Picea abies* forest (r&s con) to 65.77 (S.E. 12.3) in one of the semi-natural meadow sites (tur 1). The five sites with the lowest species richness estimates include the mature *Picea abies* forest used as a control site in Ruokolainen and Salo's (2006) study; the Ylä Murhi swidden site burned in 2006 - two years prior to sampling, and the Ollila sheep pasture sampled by park staff in 2003 and 2004. The five sites with the highest species richness estimates were mowed meadows at the Turusen Autio and Mäkränaho sites, the 6-year-old swidden regeneration site sampled by Ruokolainen and Salo and the mature swidden forest at Havukkanaho (Table 4.12, Figure 4.11).

Welch's ANOVA revealed that the species richness estimates were not equal among all 38 sites ($F' = 7.007$ $\nu_1 = 37$, $\nu_2 = 2722$, $P < 0.001$). The Games-Howell post hoc tests (Table 4.13) revealed a number of significant differences in species richness estimates, mainly between the sites with estimated species richness above 50 species (except those with standard errors of the estimate greater than 8.7) and the three sites with the lowest species richness estimates, all of which had standard errors of the estimate less than or equal to 3.2. Two additional sites with mid-range species richness estimates, a mature swidden forest at Mäkränaho (mak 4) and the ungrazed forest (sep w) adjacent to the Seppälä forest pasture had particularly low standard errors of the estimate (3 and 3.1, respectively) and were found to have significantly ($P < 0.05$) higher estimated species richness than the three sites with the lowest estimated species richness. No significant differences were found between grazed versus non-grazed sites within comparable habitats (i.e., grazed vs non-grazed forests, grazed vs non-grazed swidden regeneration, grazed vs non-grazed fields/ meadows). No significant differences in species richness were detected at sites such as the Ollila grazed swidden area (oll sab) or the Ollila sheep pasture (oll 4) that were repeatedly sampled over time.

Percent Cover

Kruskal-Wallis multiple comparisons revealed some significant differences in percent cover of some plant species in the field layer between grazed sites and ungrazed sites in otherwise similar swidden habitats. Among the young regenerating swidden sites 2-3 years post burn, significant differences were found in the percent cover of *Epilobium angustifolium* L. ($Hc = 16.017$, $P < 0.01$). However, the non-parametric Tukey-type multiple comparison revealed significant differences in cover of this species only between the 2-year old swidden site (yla b06) and the grazed 3-year old swidden site (sep 4k) ($Q = 3.705$, $P < 0.01$) with a higher percent cover of this species in the grazed 3-year old swidden site. No clear patterns of differences in percent cover of any other species were found among the young swidden sites when comparing grazed versus non-grazed sites 2-3 years post-burn.

Table 4.12. Species richness estimates for each site.

Site	Species Richness Estimate	S.E.
r&s con	16.11	3.2
yla b06	16.82	2.4
oll 4 (2004)	17	2.7
oll 4 (2007)	23.59	4.7
oll sab (2004)	26.06	4.6
oll sab (2003)	26.59	6.9
ski b05	28.25	9.4
sep 3b	30.8	10.6
oll 5	31.5	11
sep 3b	32.86	4.2
lak b05	33.67	15.2
matt 3	34	5.1
sep w	34.06	3.1
oll sab (2007)	35	15.3
mak 4	35.05	3
matt 2	35.48	5.8
yla 3	36.68	7.9
sep 4k	37.75	11.8
r&s B96 (2000)	37.88	3.9
oll sab (2008)	38.07	9.7
yla 4	40.6	7.5
mak 3a	40.86	8
sep 2b	44.25	9.7
oll 3	45.46	28.5
tur f	45.73	7.9
oll 2 (2007)	47	11.1
mak 3b	50.86	8
sep 2d	51.24	6.8
hav 1	51.42	9
yla 1a	51.66	8.7
ala 1b	51.67	8.2
r&s B96 (2004)	55.49	9.3
r&s B94 (2004)	56.91	16.4
hav 2	59.73	7.7
mak 2	59.78	9.6
mak 1	60.85	3.3
r&s B98 (2004)	65.5	19
tur 1	65.77	12.3

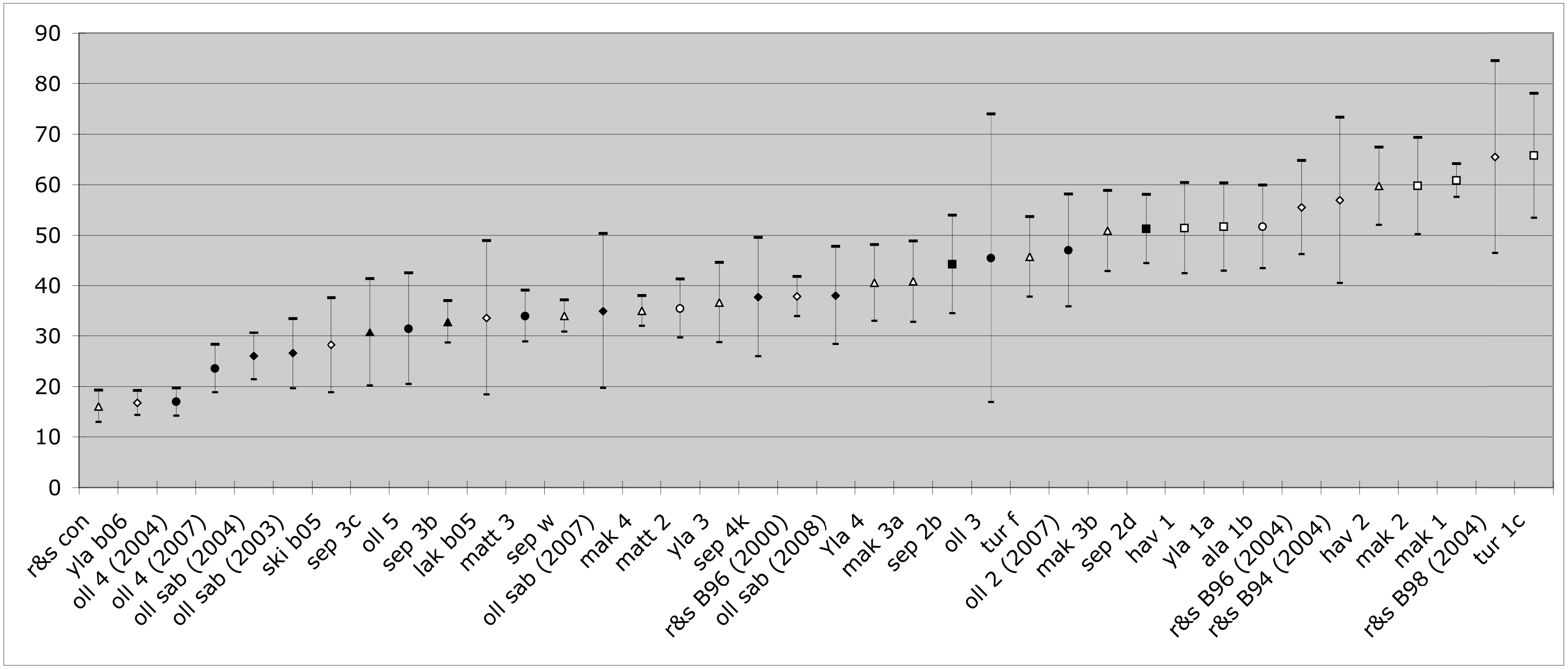

Figure 4.11. Estimated species richness of each site sampled.

Symbols in the centre of each line indicate the mean species richness estimate for each site. A symbol with black fill indicates a currently grazed site, whereas a symbol with no fill indicates sites not recently (e.g. within the past 50 years) subject to grazing. The estimated species richness of meadow sites are represented by squares, wooded sites are represented by triangles, swidden sites are represented by diamonds and open sites on formerly cultivated fields are represented by circles. The bars indicate +/- standard errors of the estimate.

Table 4.13 Results of Games-Howell Post-Hoc Tests.

* indicates that results were also insignificant when the standard error of the estimate of site *k* was artificially set to zero, implying that comparisons between site *j* and any other site *k* is unnecessary.

Comparison		Difference in Estimated Species	95% Confidence Interval	*w*	Significance Level
Site *j*	Site *k*	Richness (mean *j* - mean *k*)	for mean *j* - mean *k*		
tur 1c	r&s con	65.77 - 16.11 = 49.66	0.0564 - 98.756	226	P < 0.05
	yla b06	65.77 - 16.82 = 48.95	0.540 - 97.360	214	P < 0.05
	oll 4 (2004)	65.77 - 17.00 = 48.77	0.125 - 97.415	218	P < 0.05
	oll 4 (2007)	65.77 - 23.59 = 42.18	-8.685 - 93.045	256	n.s. *
r&s B98 (2004)	r&s con	65.50 - 16.11 = 49.39	-25.039 - 123.820	210	n.s. *
mak 1	r&s con	60.85 - 16.11 = 44.74	26.983 - 62.497	398	P < 0.001
	yla b06	60.85 - 16.82 = 44.03	28.268 - 59.792	363	P < 0.001
	oll 4 (2004)	60.85 - 17.00 = 43.85	27.379 - 60.321	383	P < 0.001
	oll 4 (2007)	60.85 - 23.59 = 37.26	15.076 - 59.440	357	P < 0.001
	oll sab (2004)	60.85 - 26.06 = 34.79	12.921 - 56.659	361	P < 0.001
	oll sab (2003)	60.85 - 26.59 = 34.26	4.714 - 63.806	286	P < 0.01
	ski b05	60.85 - 28.25 = 32.60	-5.884 - 71.084	247	n.s. (only test *k* if S.E. < 9.4)
	sep 3b	60.85 - 32.86 = 27.99	7.3567 - 48.623	377	P < 0.001
	matt 3	60.85 - 34.00 = 26.85	3.385 - 50.315	341	P < 0.01
	sep w	60.85 - 34.06 = 26.79	9.300 - 44.280	396	P < 0.001
	mak 4	60.85 - 35.05 = 25.80	8.572 - 43.028	394	P < 0.001
	matt 2	60.85 - 35.48 = 25.37	-0.408 - 51.148	316	n.s. (no other *k* with S.E. < 5.8)
mak 2	r&s con	59.78 - 16.11 = 43.67	4.580 - 82.760	243	P < 0.01
	yla b06	59.78 - 16.82 = 42.96	4.735 - 81.185	224	P < 0.01
	oll 4 (2004)	59.78 - 17.00 = 42.78	4.257 - 81.303	230	P < 0.01
	oll 4 (2007)	59.78 - 23.59 = 36.19	-5.100 - 77.480	289	n.s. *
hav 2	r&s con	59.73 - 16.11 = 43.62	11.409 - 75.831	266	P < 0.001
	yla b06	59.73 - 16.82 = 42.91	11.754 - 74.066	237	P < 0.001
	oll 4 (2004)	59.73 - 17.00 = 42.73	11.210 - 74.250	247	P < 0.001
	oll 4 (2007)	59.73 - 23.59 = 36.14	1.292 - 70.988	329	P < 0.05
	oll sab (2004)	59.73 - 26.06 = 34.79	-0.978 - 68.318	325	n.s. (only test *k* if S.E. < 4.0)
	sep w	59.73 - 34.06 = 25.67	-6.395 - 57.735	262	n.s. *
r&s B94	r&s con	56.91 - 16.11 = 40.8	-23.75 - 105.35	214	n.s. *
r&s B96	r&s con	55.49 - 16.11 = 39.38	1.388 - 77.372	245	P < 0.05
	yla b06	55.49 - 16.82 = 38.67	1.568 - 75.772	225	P < 0.05
	oll 4 (2004)	55.49 - 17.00 = 38.49	1.081 - 75.899	232	P < 0.05
	oll 4 (2007)	55.49 - 23.59 = 31.90	-8.352 - 72.152	294	n.s. *
ala 1b	r&s con	51.67 - 16.11 = 35.56	1.550 - 69.563	258	P < 0.05
	yla b06	51.67 - 16.82 = 34.85	1.845 - 67.855	233	P < 0.05
	oll 4 (2004)	51.67 - 17.00 = 34.67	1.321 - 68.019	242	P < 0.05
	oll sab (2004)	51.67 - 26.06 = 25.61	-10.709 - 61.930	313	n.s. *
yla 1a	r&s con	51.66 - 16.11 = 35.55	-0.0259 - 71.359	252	n.s. (only test *k* if S.E. < 3.1)
	yla b06	51.66 - 16.82 = 34.84	-0.023 - 69.703	229	n.s. (no other *k* with S.E. < 2.4)
only test *j* if SE<8.7					
sep 2d	r&s con	51.24 - 16.11 = 35.13	6.099 - 64.161	283	P < 0.01
	yla b06	51.24 - 16.82 = 34.42	6.564 - 62.276	248	P < 0.01
	oll 4 (2004)	51.24 - 17.00 = 34.24	5.978 - 62.503	260	P < 0.01
	oll 4 (2007)	51.24 - 23.59 = 27.65	-4.282 - 59.582	354	n.s. (only test *k* if S.E. < 2.3)
mak 3b	r&s con	50.86 - 16.11 = 34.75	1.466 - 68.034	261	P < 0.05
	yla b06	50.86 - 16.82 = 34.04	1.776 - 66.304	235	P < 0.05
	oll 4 (2004)	50.86 - 17.00 = 33.86	1.244 - 66.476	244	P < 0.05
	oll 4 (2007)	50.86 - 23.59 = 27.27	-8.572 - 63.112	322	n.s. *
tur f	r&s con	45.73 - 16.11 = 29.62	-3.306 - 62.546	263	n.s. *
only test *j* if SE<7.9					
yla 4	r&s con	40.6 - 16.11 = 23.95	-7.549 - 55.449	269	n.s. *
only test *j* if SE<7.5					
matt 2	r&s con	35.48 - 16.11 = 19.37	-6.219 - 44.959	310	n.s. *
only test *j* if SE<5.8					
mak 4	r&s con	35.05 - 16.11 = 18.94	1.996 - 35.884	396	P < 0.01
	yla b06	35.05 - 16.82 = 18.23	3.389 - 33.071	380	P < 0.01
	oll 4 (2004)	35.05 – 17.00 = 18.05	2.459 - 33.641	394	P < 0.01
	oll 4 (2007)	35.05 - 23.59 = 11.46	-10.079 - 32.999	338	n.s. *
sep w	r&s con	34.08 - 16.11 = 17.95	0.739 - 35.161	398	P < 0.05
	yla b06	34.08 - 16.82 = 17.95	2.536 - 32.824	375	P < 0.01
	oll 4 (2004)	34.08 – 17.00 = 17.06	1.180 - 32.940	391	P < 0.05
	oll 4 (2007)	34.08 - 23.59 = 10.47	-11.279 - 32.219	345	n.s. *
matt 3	r&s con	34.00 - 16.11 = 17.89	-5.368 - 41.149	335	n.s. *
only test *j* if SE<5.1					
sep 3b	r&s con	32.86 - 16.11 = 16.75	-3.647 - 37.147	372	n.s. (only test *k* if S.E. < 3.2)
	yla b06	32.86 - 16.82 =16.04	-2.646 - 34.726	316	n.s. *
only test *j* if SE<4.2					
oll 4 (2004)	r&s con	17.00 - 16.11 = 0.89	-15.284 - 17.064	387	n.s.*
only test *j* if SE<2.7					
yla 06	r&s con	16.82 - 16.11 = 0.71	-14.742 - 16.162	369	n.s.*
no other *j* to test					

Significant differences in percent cover of several plant species were found among the older swidden sites sampled 4 to 10 years post burn. The following paragraphs contrast percent cover between grazed and non-grazed swidden regeneration sites. The non-grazed swidden sites were sampled in 2000 and/or 2004 by Ruokolainen and Salo (2006) in three areas that had been burned in 1994, 1996 and 1998 (i.e., they had been regenerating for 10, 8 and 6 years, respectively by 2004 and the site burned in 1996 had four years to regenerate when it was sampled in 2000). The grazed swidden site in the vicinity of the Ollila farm was burned in 1999 and 2000, and sampled in 2003, 2004, and 2007[52] by staff of Koli National Park and in 2008 by the investigator (i.e., this site was sampled 3-4 years post burn, 4-5 years post burn, 7-8 years post burn, and 8/9 years post burn).

Percent cover of *Epilobium angustifolium* among these grazed and non-grazed swidden sites at the northern end of Koli National Park differed significantly (Hc = 52.290, $P < 0.001$). The 8/9-year-old grazed swidden site at Ollila sampled in 2008 had significantly less cover of *E. angustifolium* than 6-year old non-grazed swidden site (Q = 6.089, $P < 0.001$), the 8-year old non-grazed swidden site (Q = 5.599, $P < 0.001$) and the 10-year old non-grazed swidden site (Q = 3.868, $P < 0.01$). Despite the small number of quadrats sampled in the Ollila grazed swidden site in 2007, significantly lower percent cover of *E. angustifolium* was also detected between that grazed swidden site sampled in 2007 (7-8 years post-burn) and the 6-year-old non-grazed swidden site (Q = 3.711, $P < 0.01$), and the 8-year-old non-grazed swidden site (Q = 3.289, $P < 0.05$). No difference in percent cover of this species was found between the grazed site

[52] Data on the presence and abundance of *Agrostis capillaris* were omitted from the 2007 data due to the possibility that this species was misidentified that year.

sampled in 2003 (the year that grazing was initiated in the Ollila swidden site burned in 1999/2000) and the 4-year-old non-grazed swidden site. By the second year of grazing (2004) there was a lower percent cover of *E. angustifolium,* though the difference in cover in comparison to the previous year was not significant. However, a significantly lower percent cover of this species was revealed in the grazed swidden site sampled in 2004 when compared with the 4-year-old non-grazed swidden site ($Q = 2.894$, $P < 0.05$). So, when grazing first started at the Ollila site (3-4 years post burn), there initially was no difference in percent cover of *E. angustifolium* when compared with a non-grazed swidden site of similar age, but after one year of grazing and for the subsequent four years of grazing, a significantly lower percent cover of this species was found.

There was also a significant difference in cover of *Calamagrostis arundinacea* among the grazed and non-grazed swidden sites ($Hc = 48.245$, $P < 0.001$). The 8/9-year-old grazed swidden site sampled in 2008 had significantly less cover of *C. arundinacea* than the 6-year-old ($Q = 3.137$, $P < 0.05$), 8-year-old ($Q = 4.892$, $P < 0.001$) and 10-year-old ($Q = 4.951$, $P < 0.001$) non-grazed swidden sites. The same grazed swidden site sampled a year earlier also had less cover of *C. arundinacea* than the non-grazed swidden sites; however, this effect was not statistically significant, likely due to the low number of quadrats sampled that year. The percent cover of *C. arundinacea* the year that grazing began at the Ollila site in 2003 was significantly lower ($P < 0.05$) than the percent cover of this species in the non-grazed site of similar age since burning. However, the percent cover of this species in the grazed site in 2004 was not significantly different from the same site in 2003, nor was it significantly different from the percent cover in the non-grazed site 4 years post-burn. So, initially, when grazing first started at the Ollila site in 2003, the percent cover of *C. arundinacea* was lower in the grazed site, but the following year, no difference in cover of this species was found between the grazed and non-grazed site. After five years of grazing, the cover of this species was again significantly lower in the 8/9-year-old grazed site than in the non-grazed sites of similar age. In the non-grazed swidden sites, the percent cover of this species increased from 5% cover at four years post-burn to become the most dominant species at 29% cover 10 years post-burn (Ruokolainen and Salo, 2006).

A significant difference in percent cover of *Agrostis capillaris* was found among the grazed and non-grazed swidden sites ($Hc = 24.437$, $P < 0.001$). This species had a significantly greater percent cover in the 8/9-year-old grazed swidden site sampled in 2008 than in the non-grazed 6-year-old ($Q = 3.328$, $P < 0.05$), 8-year-old ($Q = 4.474$, $P < 0.001$) and 10-year-old ($Q = 2.947$, $P < 0.05$) swidden sites. No significant differences were found in percent cover of this species among the grazed site sampled in 2003 and 2004 and an ungrazed swidden site sampled 4 years post-burn.

The percent cover of *Luzula pilosa* differed significantly among the grazed and non-grazed swidden sites ($Hc = 67.429$, $P < 0.001$), with significantly lower cover in the site grazed by sheep regardless of the year sampled than in all of the non-grazed sites with $P < 0.001$ (except for the 10-year old non-grazed site, which only had a significantly higher percent cover than the grazed site sampled in 2008 [$Q = 3.343$, $P < 0.05$]). A significant contrast with the 10-year-old site sampled in the remaining sampling years may have been lost due to the low number of quadrats sampled in 2003, 2004 and 2007). No significant difference in percent cover of this species was detected from the grazed and non-grazed sites 3-4 years post-burn.

The percent cover of *Trientalis europaea* also differed significantly among the swidden sites ($Hc = 21.901$, $P < 0.001$). The 8/9-year-old grazed swidden site sampled in 2008 had significantly higher percent cover of this species than the 6 year old (Q = 3.829, $P < 0.01$) and 8 year old (Q = 3.000, $P < 0.05$) non-grazed sites. No significant difference in percent cover of this species was detected from the 4-year-old non-grazed swidden site and the grazed swidden site sampled in 2003 and 2004.

There was no significant difference in percent cover of *Betula spp*.[53] among the older grazed and non-grazed swidden sites. However there was a significantly higher percent cover of this genus in the grazed site in the first year of grazing than in the following year of grazing (Q = 4.868, $P < 0.001$), as well as when comparing the grazed site in the first year of grazing with the four year old non-grazed site (Q = 3.919, $P < 0.001$). Despite increased cover of this genus in the grazed site when grazing began in 2003, over time the cover of this genus was reduced to levels similar to those in the non-grazed swidden sites of similar age.

Significant differences in percent cover of *Picea abies* were found among the swidden sites (Hc = 42.095, $P < 0.001$). The percent cover of *P. abies* was not significantly different in the first two years of grazing in 2003 and 2004 from the non-grazed swidden site sampled four years post-burn. The greatest percent cover of *P. abies* occurred in the 10-year-old swidden regeneration site without grazing, which had a significantly higher percent cover than the grazed swidden site sampled in 2008 (Q = 5.962, $P < 0.001$) and sampled in 2007 (Q = 3.876, $P < 0.01$) and the non-grazed 8-year-old swidden site (Q = 3.355, $P < 0.05$). The 6-year-old non-grazed swidden site

[53] Ruokolainen and Salo's (2006) sampling of the non-grazed swidden sites did not differentiate between *Betula pendula and Betula pubescens*; therefore, the two species are grouped as *Betula spp*. for the purposes of this analysis.

also had a significantly higher percent cover of *P. abies* than the 8/9-year-old grazed swidden site sampled in 2008 ($Q = 3.188$, $P < 0.05$). The percent cover of *P. abies* in the 8/9-year-old grazed swidden site was not significantly different from the cover of this species in the 8-year-old non-grazed swidden site. Aside from the low cover of this species in the 8-year-old non-grazed swidden site, the difference in percent cover of this species between grazed and non-grazed swidden sites of similar age became more pronounced with time, with significantly greater coverage in the non-grazed sites.

In summary, the percent cover of *Epilobium angustifolium*, *Calamagrostis arundinacea*, *Luzula pilosa*, and *Picea abies* was significantly lower in the grazed swidden site 8/9 years post burn than in the non-grazed swidden sites of similar age. Percent cover of most of these species did not differ between the grazed and non-grazed sites when grazing by Finnsheep commenced in 2003. *Agrostis capillaris* and *Trientalis europaea* both had significantly greater percent cover in the 8/9-year-old grazed swidden site than in the non-grazed swidden sites of similar age. *Betula spp*. initially had greater percent cover in the grazed swidden site in 2003, but after five years of grazing, there no longer was a greater percent cover of this genus in the grazed swidden site than in the non-grazed swidden sites of similar age.

Grazed and non-grazed forest pastures

Visually, it was apparent that there was an overall lower percent cover[54] of vegetation in the field layer of the forest pastures currently grazed by Finnsheep. However, none of the significant differences in percent cover among the species sampled in the field layer

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[54] More bare ground and less overall biomass was clearly evident in the forest pastures grazed by Finnsheep.

of these sites could be explained by grazing alone (e.g., both grazed and non-grazed sites contained significantly lower percent cover of some species when compared with other non-grazed forest sites).

Cluster Analysis

The cluster analyses using the group average and Ward's linkage methods (Figures 4.12 and 4.13, respectively) very similarly cluster the sites in this study. The dendrograms reveal three major groupings discussed in order from top to bottom of the dendrogram.

The first grouping (A) comprises mainly the swidden sites, which form three sub-groups plus an additional subgroup of forested sites. The repeated sampling from 2003 to 2008 of the Ollila swidden site grazed by Finnsheep forms the first subgroup. It is a very tight grouping of the site sampled in 2003 (ollsab03), 2004 (ollsab04), and 2008 (ollsab08) with a weaker association with the same site sampled in 2007(ollsab07). Some significant changes in percent cover of some plant species occurred in this swidden site over the five years as it had been regenerating and was grazed by Finnsheep. However, over this time period the site did not develop strong affinities with any of the other sites in this study.

The non-grazed swidden sites (r&s B98, r&s B94, r&s B9604, r&s 9600) from Ruokolainen and Salo's (2006) study form an even tighter sub-group with very strong associations regardless of the number of years passed since burning (4-10 years). The younger swidden sites burned in 2005 (sep 4k, ski b05, lak b05) and 2006 (yla b06) were not as strongly grouped with one another, though they were more closely associated with the non-grazed older swidden sites from the Ruokolainen and Salo study than with the grazed Ollila swidden site.

Figure 4.12. Dendrogram of sites using Ward's linkage method.
A symbol with black fill indicates a currently grazed site, whereas a symbol with no fill indicates sites not recently (e.g. within the past 50 years) subject to grazing. Meadow sites are represented by squares, wooded sites are represented by triangles, swidden sites are represented by diamonds and open sites on formerly cultivated fields are represented by circles. Letters indicate the three major groupings.

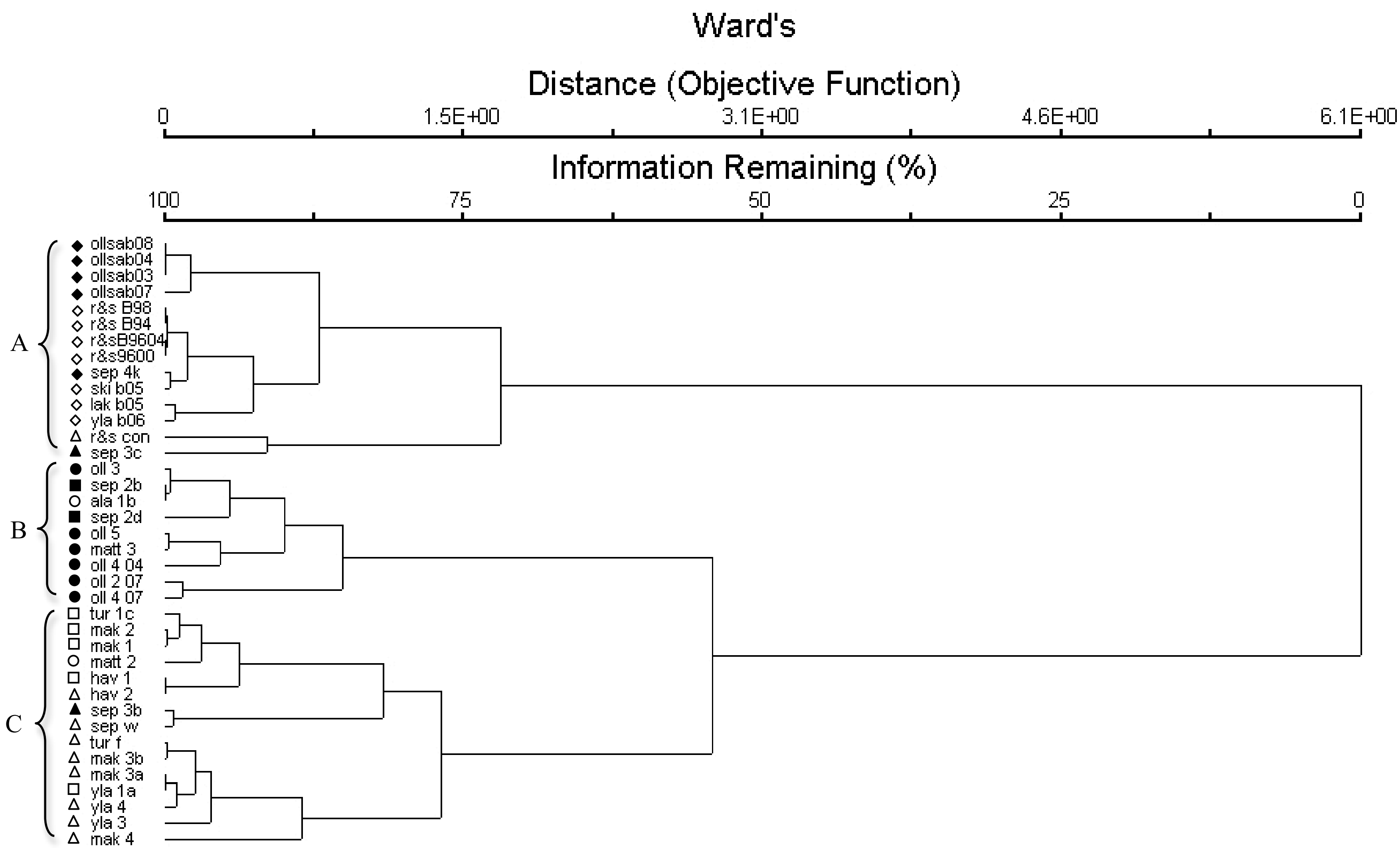
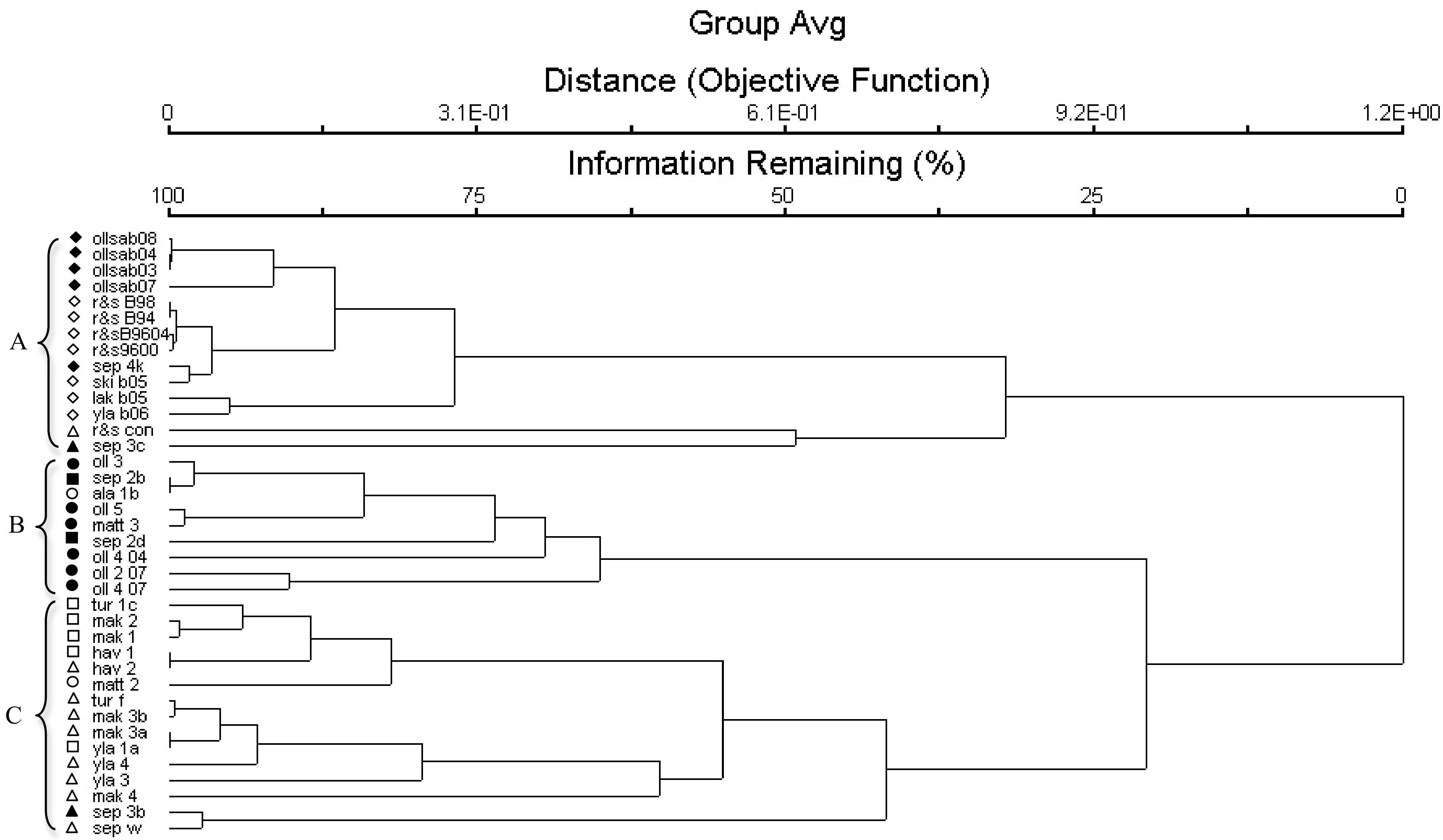


Figure 4.13. Dendrogram of sites using the group average linkage method.
A symbol with black fill indicates a currently grazed site, whereas a symbol with no fill indicates sites not recently (e.g. within the past 50 years) subject to grazing. Meadow sites are represented by squares, wooded sites are represented by triangles, swidden sites are represented by diamonds and open sites on formerly cultivated fields are represented by circles. Letters indicate the three major groupings.



The final sub-group consists of the species-poor, mature *Picea abies* forest site (r&s con) used as a control in Ruokolainen and Salo's (2006) study and one of the grazed forest pasture sites from Seppälä (sep 3c). These two sites had the weakest relationships with any other sites in the study and associated very weakly with the swidden regeneration sites.

The next major group (B) consists mainly of the grazed open sites, most of which were old fields that had not been cultivated for over a decade. The strongest association within this group is between the non-grazed former field at Ala Murhi (ala 1b) and a grazed meadow[55] at Seppälä (sep 2b). The former field at Ollila grazed by cattle (oll 3) is the site with the next strongest affinity with the latter two sites. The former field at Mattila grazed by Finnsheep (matt 3) and the former field grazed by Finnsheep at Ollila (oll 5) are also closely related to one another. The remaining open fields grazed by cattle (oll 2 07) or sheep (sep 2d, oll 4 04, oll 4 07) are clustered in this major group, though the associations between these remaining sites are not particularly strong in relation to others within the overall group.

The final major group (C) comprises three sub-groups, though there is not a clear pattern based on habitat-type or vegetation management that might explain the associations, although none of the sites, except for one, is grazed. The first sub-group consists of three mown meadows at (tur 1c, mak 2, mak 1), a non-grazed abandoned field (matt 2), and another mown meadow (hav 1), which is very strongly associated with a former wooded pasture (hav 2). The next two sub-groups are placed in different

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[55] Although the two open areas grazed by Finnsheep at Seppälä were classified as graminoid mesic meadows in the unpublished inventory of habitat types in Koli National Park, both sites had likely been cultivated in the past, as evidenced by stone piles in and adjacent to these meadows.

orders in the two dendrograms, though they are clustered within the same major group in each dendrogram. One of the subgroups consists of a moderately strong association between the grazed (sep 3b) and non-grazed forests (sep w) adjacent to one another at the Seppälä site. The remaining sub-group consists mainly of mature swidden forests (tur f, mak 3b, mak 3a, yla 1a and mak 4) and former wooded pastures (yla 4, and yla 3).

DISCUSSION

Ecological effects of livestock in Koli's anthropogenic habitats

Of the ecological indicators investigated in this study (condition of woody species, species richness and percent cover of particular vascular plant species in the field layer), the condition of woody species was most influenced by the presence of livestock. Differences in condition of woody species were particularly evident in the swidden regeneration areas and in open fields with less than 10% tree cover. Also associated with grazing activity was a reduction in the cover of some plant species, including *Epilobium angustifolium* and *Calamagrostis arundinacea*, the two most dominant plant species found in the older (6-10 years post-burn) non-grazed swidden sites. Increased cover of *Agrostis capillaris* and *Trientalis europaea* was found in the grazed swidden sites. The cluster analysis tended to group sites into three major groups comprising a) grazed and non-grazed swidden sites, b) grazed and non-grazed open fields and meadows with a history of cultivation, c) regularly mown meadows that are not grazed and former forest pastures/swidden forests that have not been grazed for over 40 years. These results are discussed in light of the findings of other studies. Implications for the conservation of disturbance-dependent habitats, as well as the heritage breeds, are also addressed.

Woody vegetation in grazed and ungrazed swidden regeneration

In recently-burned, grazed and ungrazed swidden sites (sampled 1-2 years post-burn), no difference was detected in percent cover or condition of tree species (sampled within the herbaceous layer quadrats). However, significantly higher damage and mortality of woody vegetation occurred in the older (8/9 year post-burn) swidden regeneration site that had been grazed by Finnsheep for five years than in ungrazed swidden regeneration sites (6 and 10 years post-burn). Short trees (0.5 – 1 m in height) were most susceptible to damage by Finnsheep and were significantly more damaged than trees that were less than 0.5 m tall and trees 1-1.5 m tall, which in turn were significantly less damaged than trees over 1.5 m in height (all $P < 0.001$). Härkonen *et al.* (2008) found that moose damaged mid-sized (5 - 15 m tall[56]) *Populus tremula* trees more than shorter (<5 m) and taller (>15 m) height classes, but only caused mortality in trees under 5 m tall. The authors concluded that although the impact of the moose increased tree mortality, suppressed tree growth and altered size distributions, the majority of young *P. tremula* in Koli National Park could endure both heavy and repeated browsing by moose and survive through the most sensitive size class. Mortality rates of trees exposed to Finnsheep in this study were higher than those reported for *P. tremula* affected by moose

[56] Although moose are unable to browse twigs above 3 m high (Edenius *et al.* 2002), bark stripping was reported as a cause of damage to all tree size classes and severely impacted trees including those with branches above the browsing height of moose.

in Härkonen *et al.'s* (2008) study and result in altered height class distributions with a much higher proportion of dead and damaged individuals in the smaller height classes.

Tree species were differently affected by domesticated and wild herbivores in the older swidden regeneration sites in the present study. Moose affected *Sorbus aucuparia* and *Pinus sylvestris* within the sites without Finnsheep whereas the Finnsheep had a greater effect on *Betula* species than *S. aucuparia*. No *P. sylvestris* were present in the samples from the area grazed by Finnsheep to enable comparison regarding this species. High mortality of young *S. aucuparia* has been found in other studies in which moose, roe deer (*Capreolus capreolus*)[57] and reindeer (*Rangifer tarandus*)[57] were presumed to be the cause of the lack of mature *S. aucuparia* in stands where seedlings of this species were dominant (Linder *et al.*, 1997). In contrast, of the three tree species sampled in the swidden regeneration site grazed by Finnsheep, *S. aucuparia* was significantly less damaged than *Betula pendula* and *Betula pubescens*.

The low numbers of *Betula pendula* in the > 0.5 m size class in the swidden site with Finnsheep suggest that recruitment or survival rates are low for this species in the presence of Finnsheep. Combined with the high damage and mortality rates for individuals of *B. pendula* under 1.5 m tall, an uneven size distribution for this species will likely be the outcome with very few young individuals represented in the stand.

Betula pubescens was the most common species in the site grazed by Finnsheep, particularly in the part of the site that had been burned in 2000. Although the sheep damaged or killed 73% of *B. pubescens* under 1.5 m tall, only 37% were dead, and recruitment of this species remained high, possibly because individuals produce vegetative shoots from rootstock in response to damage. The future size class

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[57] *Capreolus capreolus* and *Rangifer tarandus* do not exist in Koli National Park.

distribution of this species depends on the survival rates of the damaged individuals. However, if each size class receives similar levels of damage as the surviving trees progress to the next tallest size classes, overall abundance of this species in the size classes < 3 m will likely decline.

The increase in tree damage and tree mortality associated with the grazed swidden sites may be alarming upon first consideration if a perspective is held that any anthropogenic damage to natural features is unacceptable within protected areas. However, some taxa may benefit from damage and mortality of woody vegetation. In Spanish heathlands, for example, Jauregui *et al.* (2008) found that density of grasshoppers (*Orthoptera, Caelifera*) was positively associated with increased structural heterogeneity in habitats (e.g. the development of some shrubs in otherwise open grasslands, or the creation of clearings in otherwise dense, shrubby habitats) and suggested that the decreased cover of shrubs and increased proportion of deadwood caused by high-density grazing by a heritage breed of goat could be interpreted as favourable from the point of view of grasshopper diversity.

In Finland, due to intensive forest management in wooded areas outside of protected areas, very little decaying wood is available as habitat for saproxylic (deadwood-dependent) species. Hyvärinen *et al.* (2006) revealed high species richness of red-listed and rare saproxylic beetles (*Coleoptera*) in eastern Finland, likely due to the low intensity of forest management in this region as well as in adjacent parts of Russia. They speculate, though, that the lack of deadwood associated with increased management of forests for timber will contribute to the decline of these species. Overall volumes of coarse woody debris (fallen or standing deadwood) in Fennoscandian forests managed for timber and pulpwood are 92 – 98% lower than in unmanaged forests

(Siitonen, 2001); however, there are differences in volumes of each size class of the coarse woody debris. Siitonen (2001) states that coarse woody debris 6-10 cm in diameter may be more abundant in managed forests than in unmanaged forests, so the dead wood resulting from the damage to young trees under 1.5 m tall in the grazed swidden site may not be filling an under-represented type of coarse woody debris in the Finnish landscape. However, the coarse woody debris of this size class from managed forests is most likely fallen or broken stems or branches on the forest floor rather than standing deadwood as found in the grazed swidden regeneration site at Koli National Park. Some saproxylic species specialize in occupying standing deadwood, and deciduous snags are known to host high numbers of insect species (Siitonen, 2001). So, although there is not a lack of coarse woody debris in the 6-10 cm diameter size class in Finland, the swidden site grazed by Finnsheep may provide a source of standing deadwood in this size class that is less common in the non-grazed swidden sites and seldom found in managed forests. Although richness of saproxylic species tends to increase with the diameter of the woody debris, Kruys and Jonsson (1999) found that fine woody debris (5-9 cm in diameter) hosted more species of wood-inhabiting fungi and cryptograms than the same volume of coarse woody debris (≥10 cm in diameter), likely due to the increased surface area of smaller diameter debris. Thus, the significantly higher proportion of standing dead and damaged deciduous trees in the grazed swidden regeneration site may be an important source of habitat for saproxylic species. A study examining small diameter standing deciduous deadwood in grazed swidden sites as habitat for saproxylic species would be worthy of further investigation.

Woody vegetation in grazed and non-grazed forests

There was no evidence that woody vegetation in the forest site currently grazed by Finnsheep was in worse condition than that of forest pastures that had not been grazed for decades. These non-grazed areas contained trees that had been damaged by moose and/or disease. The species most susceptible to damage in the forest pasture grazed by Finnsheep were *Populus tremula* and *Sorbus aucuparia*. *Alnus incana* was virtually untouched by the sheep in the forest pastures, even though most individuals were within the height classes most accessible for browsing by sheep. Given that sheep damaged a greater proportion of the *Betula spp.* than *S. aucuparia* in the swidden regeneration site, sheep may have disproportionately selected *S. aucuparia* within the grazed forest pasture because of the absence of accessible *Betula* species (all were > 3 m tall).

Finnsheep grazing may suppress survival rates of trees in the shortest cohort. Stems under 50 cm in height were the most impacted by grazing activity in the grazed forest pasture, whereas stems in this height class were least impacted by other sources of disturbance (likely moose browsing and/or disease) in the non-grazed forest pastures.

Woody vegetation within grazed open fields

In contrast to the lack of damage to *Alnus incana* in the grazed forest site described above, extreme damage to this species was observed in the open sheep and cattle pastures with less than 10% tree cover. In Härkönen *et al*.'s (2008) study of moose herbivory on *Populus tremula*, where this species was sparsely distributed, mortality rates were high due to moose browsing and debarking; however, where *Populus tremula* density was high, mortality rates due to moose damage were reduced. They interpreted from this correlation that herbivory by moose thus helped reinforce patchy distribution of the species.

Likewise, where Finnsheep movements are restricted within open areas in this study, high mortality to the already low numbers of trees within the open area helps to maintain open conditions with little tree cover. Damage to trees in areas with greater cover of woody species is much less extensive, enabling the woody cover to persist (although survival of smaller height classes is reduced with possible implications for the continuity of forest structure over time). Similarly, intense damage to the trees within the open pasture grazed by Eastern Finncattle may also be greater than the damage that would occur if the Finncattle had access to a more densely forested area (this could not be verified because cattle did not have access to pastures with greater tree cover in 2008). According to traditional agricultural practices in eastern Finland, open areas were not typically used for grazing except in swidden areas left to regenerate into forest. Otherwise, clearings were used solely as cultivated fields or for haymaking, and such activities would inhibit the growth of *Alnus incana* and other trees in open areas.

<u>Possible implications of pasturing Finnsheep and Eastern Finncattle in open areas</u>

There was extensive damage to the small patches of *Alnus incana* trees within the open pastures in contrast with the minimal effect on this species in the grazed forest pastures. Although there were seemingly abundant grasses and forbs in the open pasture, the Finnsheep's consumption of *Alnus incana* suggests that the non-woody vegetation in the open pastures may not completely satisfy the dietary needs of these sheep[58]. *Alnus incana* was not a preferred species (as indicated by high levels of damage to *Populus tremula* and *Sorbus aucuparia* and the absence of damage to *Alnus incana* in the wooded pasture grazed by Finnsheep), but it may fill a metabolic need for the sheep when confined to an area with no access to other tree species.

Kinnaird *et al.* (1979) documented extensive debarking of *Sorbus aucuparia* by cattle (breed not specified) in wooded pastures in Scotland. The cattle stripped and consumed significant amounts of bark of this species despite the high quantities of palatable grasses and forbs in their pastures. Kinnaird *et al.* (1979) ruled out a number of possible reasons for this phenomenon: because the cattle had easy access to water, the cattle were not likely eating bark to obtain water; because *S. aucuparia* was not markedly rich in manganese or phosphorus, the cattle were not likely using it as a source of these minerals; and because other tree species in the woodland pastures had higher levels of calcium, ash and salt, the cattle probably did not selectively debark *S. aucuparia* for such nutrients. Sorbus aucuparia bark had high levels of tannins (7.9 ±1.4 percent dry weight) compared with eight other tree species in the woodlands, but without providing a rationale, Kinnaird *et al.* (1979) stated that tannin content was "clearly unimportant" (p. 123). They concluded that *S. aucuparia* was either consumed to compensate for a nutrient, mineral, or vitamin in short supply or because it simply had the most "pleasant tasting bark that was readily available" (p. 124).

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[58] On her farm in Thunder Bay, Ontario, the investigator similarly observed Finnsheep aggressively consuming leaves and bark of trembling aspen (*Populus tremuloides* Michx.) with fervor when released from a pasture without woody species into a fresh pasture with abundant grasses and forbs. The windbreak where the sheep consumed the leaves and bark covered less than 5% of the area and consisted of *Populus tremuloides*, *Amelanchier alnifolia* (Nutt.) and *Fraxinus nigra* (Marshall).

Like *Sorbus aucuparia*, the bark of *Alnus incana* is also a source of tannins (Ciesla, 2002). Aerts *et al.* (1999) review a number of studies that reveal beneficial effects of condensed tannins (which are widespread in woody plants) on sheep. Such benefits include increased net absorption of essential amino acids (e.g., methionine and cysteine), increased wool growth, increased ovulation rate, increased liveweight gain, increased milk yield and increased production of milk protein lactose. These increases were attained provided that the concentration of condensed tannins was below 6% dry weight of the total daily forage consumed (higher concentrations of condensed tannins tended to have detrimental effects).

Athanasiadou *et al.* (2001) found that condensed tannins extracted from the bark of South American *Schinopsis sp.* trees have an anthelmintic (anti-parasitic) effect on sheep. One of the interviewees from the Koli area stated that pasturing sheep in a large forested area was better at controlling parasites than pasturing them in a smaller open area, but seemed to suggest that the difference was mainly in the size of the area rather than due to forage type. An account from a Norwegian farmer suggests that the reason to feed leaf hay and pasture sheep in forested areas was at least in part to control internal parasites (Aas, 2003). If it is indeed the case that consuming woody vegetation aids in suppressing internal parasites, maintaining Finnsheep and Finncattle in wooded areas may help to retain the breeds' propensity to browse and possibly naturally resist internal parasites. This could present an advantage for these breeds within organic production systems that do not allow regular applications of synthetic anthelmintics.

Species richness and percent cover

Although there was no significant difference in overall species richness of the understorey vegetation between grazed and non-grazed swidden sites, it would appear that the non-grazed sites of each habitat type were generally more species rich than grazed sites of similar habitat type. Further investigations should be conducted to rule out the possibility of a Type II error (i.e., that no difference was detected even though a difference may actually exist in species richness between grazed and non-grazed sites of similar habitat).

Significant differences in percent cover of some individual species were detected, particularly between the grazed 8/9-year-old site and the non-grazed 6-, 8- and 10-year-old sites. The only species with significantly different percent coverage in the 1- and 2-year-old sites was *Epilobium angustifolium*, which was more abundant in the grazed swidden site than in a non-grazed site burned one year prior to sampling. This difference is more likely a result of site conditions than a consequence of grazing activity.

In contrast, *Epilobium angustifolium* had a significantly lower percent cover in the Ollila grazed swidden regeneration site sampled in 2007 and 2008 than in each of the 6-, 8- and 10-year old non-grazed swidden regeneration sites. Hellström *et al.'s* (2006) study of grazing by Finnsheep also found that *E. angustifolium* was significantly reduced when Finnsheep were reintroduced to semi-natural meadows in northern Finland. Similarly, the percent cover of *Calamagrostis arundinacea* was lower in the grazed 8/9-year-old swidden site at Ollila than in each of the 6-, 8- and 10-year-old non-grazed swidden regeneration sites. These species are two of the most dominant[59] plant species in the 6- to10-year-old non-grazed swidden regeneration sites, according to Ruokolainen and Salo (2006). Because there was a significantly lower percent cover of *C. arundinacea* in the grazed site in the first year of grazing than in a non-grazed swidden site of similar age, either the decrease in abundance had occurred very rapidly upon exposure to grazing or there was a pre-existing difference due to other site conditions prior to the initiation of grazing. All other species that were found to have significantly lower cover (e.g., *Luzula pilosella*) or significantly higher cover (*Agrostis capillaris* and *Trientalis europaea*) in the grazed swidden site sampled in 2007 and 2008 did not originally differ significantly in percent cover between grazed and non-grazed swidden sites when grazing first commenced. Because sheep consume vegetation, and are known to have preferences for some plant species, it is logical to expect grazing activity to result in lowered percent cover of all but the least palatable species. These less-preferred species would in turn increase due to reduced competition from the more heavily grazed species. No significant difference was detected between the grazed and non-grazed sites in terms of percent cover of *Deschampsia cespitosa*, for example, a species generally viewed as unpalatable to sheep (Krahulec *et al.*, 2001). Furthermore, for several palatable species such as *Dactylis glomerata* (Sullivan, 1992), *Deschampsia flexuosa* (Pollock *et al.*, 2007) and *Poa pratensis* (Uchytil, 1993), no significant differences in percent cover were detected in this study between grazed and ungrazed

[59] *Calamagrostis arundinacea* and *Epilobium angustifolium* were the most dominant species in the 6-year-old non-grazed swidden sites with 14% and 12% cover, respectively. In 8-year-old non-grazed swidden sites, the three most abundant plants were *C. arundinacea, Deschampsia flexuosa* and *E. angustifolium* with 23%, 11% and 8% cover, respectively. The most dominant species in 10-year-old non-grazed swidden sites were *C. arundinacea*, *Picea abies, D. flexuosa* and *E. angustifolium*, with 29%, 11%, 11%, and 4% cover, respectively.

areas. In addition, *Agrostis capilaris* and *Trientalis europaea* were found to have significantly *higher* percent cover in the grazed swidden regeneration site when compared with non-grazed sites of similar age, so they would appear not to be preferred by Finnsheep. *Trientalis europaea* was never consumed by sheep in Hejcman *et al.*'s (2008) study of grazing in the Czech Republic. But Hejcman *et al.* (2008) found that *A. capilaris* was one of the plant species most commonly consumed by sheep, and in their study it also increased in frequency after three years of exposure to sheep grazing. So palatability is not likely the only factor affecting a plant's tendency to increase or decrease under grazing pressure in the swidden regeneration site. The reduced cover of the tall dominant *Epilobium angustifolium* and *Calamagrostis arundinacea* within the grazed site may have reduced competition for light, allowing shorter plants such as *Agrostis capilaris* and *Trientalis europaea* to occupy a greater proportion of the ground layer. Other studies report a coincidence of a reduction of tall dominant species and increase of shorter statured species in sites exposed to grazing (Belsky, 1992; Pavlu *et al.*, 2003).

<u>Cluster analysis</u>

The sites in this study did not cluster randomly in the cluster analyses. They tended to form three major groups based mainly on habitat type (A: swidden regeneration, B: former cultivated fields and grazed meadows, and C: mown meadows and mature forests) rather than by current grazing status. Within the swidden regeneration grouping, the older grazed sites (8/9 years post-burn with six years of Finnsheep grazing) were distinct from the 4-, 6-, 8- and 10-year-old swidden sites without grazing. Whether these differences are a result of grazing activity or underlying dissimilarities due to other site conditions cannot be ruled out. Delgado (2004) reports that the *huuhta* burns in the sites without grazing were particularly intense whereas the *kaski* burns in the grazed sites were not as complete due in part to lower amounts of fuel wood and high soil moisture at the time of the burn. However, given the fact that several plant species did not differ in percent cover between grazed and non-grazed swidden sites when the grazing by Finnsheep began, but then did differ significantly after six years of grazing, it is possible that grazing activity in the swidden sites did contribute to the distinct groupings of these sites.

Within the remaining habitat types, the sites with grazing by Eastern Finncattle or Finnsheep did not differ from the non-grazed sites of similar habitat type any more than some of the non-grazed sites differed from one another. The grazed meadows and grazed old fields, along with one of the non-grazed old fields, formed one group (B) that was separate from the non-grazed meadows, which were all within group C. One study (Tamm, 1956) found that the composition of vegetation in part of a meadow that had last been ploughed 65 years prior to his study was still distinct from the adjacent meadow vegetation that had not been ploughed. Given the long-lasting effects of cultivation in abandoned fields, it is difficult to conclude whether the grouping of the grazed former fields in the cluster analyses of this study are a result of vegetation differences due to grazing or due to the residual effects of past cultivation in these fields that are now used as pastures. The fields at Ollila had been fertilized using manure and later using chemical fertilizers in the early 20th century (METLA, 1998). The application of fertilizer tends to reduce biodiversity by favouring a few highly competitive plant species at the expense of other species (Bakelaar and Odum, 1978) and may explain the low species richness of some of the Ollila open field pastures (e.g. oll 4).

CONCLUSIONS

Species richness and percent cover of most vascular plant species at the study sites were not found to be affected by grazing by the heritage breeds in Koli National Park. The clustering of sites based on vascular plants in the field layer was also not strongly affected by grazing activity by the heritage breeds of cattle and sheep in Koli National Park except in the older (8/9 years post-burn) swidden sites grazed by Finnsheep. The condition of trees was clearly impacted by grazing in the swidden, open, and forest sites, particularly at the Ollila sites where grazing by Eastern Finncattle and Finnsheep had occurred since 2003. Grazing activity affected trees of height classes within easy reach of the Finnsheep and Eastern Finncattle amd some species of trees were more affected by herbivory by the heritage breeds than others.

High levels of damage and mortality by Finnsheep to trees up to 1.5 m tall (especially those between 0.5 – 1 m) and selective herbivory that focussed damage on some tree species over others (i.e., *Betula spp.* in swidden regeneration and *Populus tremula* and *Sorbus aucuparia* in forest pastures) suggests that grazing activity by Finnsheep may have long term impacts on the age structure and species composition of the sites over time. The increased levels of standing deadwood in the sites grazed by Finnsheep and Eastern Finncattle may provide important habitat for saproxylic species, of which there are many at risk of extinction in Finland (Hyvärinen *et al.,* 2006).

Since the rationale for reintroducing the heritage breeds to Koli National Park was to restore anthropogenic habitats associated with traditional agricultural activities, and since it was commonplace to graze heritage breeds in swidden regeneration sites and forest pastures in the past, the impacts of the heritage breeds may be important elements for recreating the conditions that shaped the Koli landscape in recent history (the past 400-500 years).

Conversely, the fact that the Finnsheep and Eastern Finncattle both consumed leaves and bark from trees within open pasture areas that had suitable amounts of grasses and forbs, points to a potentially important role of woody vegetation in the diet of these animals. This interpretation is supported by the fact that nearly all the *Alnus incana* (a species that was nearly untouched by the Finnsheep in the forest pasture) was extensively damaged when the sheep did not have access to any other tree species. Access to woody vegetation may help to reinforce adaptive traits that the breeds may have gained over centuries of use in forest pastures and swidden regeneration sites. These observations also point to the potential contribution of leaf-hay to fulfil the role of woody vegetation in the diet of these heritage breeds.

The findings from this chapter suggest that Finnsheep play an important role in the regeneration of swidden sites, affecting both woody and herbaceous species. The high levels of damage to woody vegetation in the open pasture grazed by Eastern Finncattle point to the possibility that this heritage breed may also have an impact on woody vegetation in swidden regeneration sites. If the aim of the resumption of swidden activity in Koli National Park was to replicate past conditions and recreate habitats that existed prior to the cessation of swidden practices by the 1930s, grazing with Finnsheep and Finncattle should be done in more than just two of the swidden restoration sites in the park. With 3 ha of the park burned per year for the purposes of swidden restoration (Eerikäinen and Nieminen, 2006), ample opportunities exist to do so.

CHAPTER 5: CONCLUSIONS & RECOMMENDATIONS

INTRODUCTION

Two complementary questions formed the basis for the global overview of heritage breeds of livestock in protected areas:

a) What roles do heritage breeds of livestock play in protected areas, and conversely,
b) What roles do protected areas play in regard to the conservation of heritage breeds of livestock?

In addition, four more regional research questions were formulated for the case study:

1. How and where were heritage breeds of livestock used in the region around Koli National Park in Finland in the past?
2. How and where are heritage breeds of livestock used in Koli National Park today?
3. How have changes to agricultural practices involving heritage breeds of livestock influenced the landscape in and around Koli National Park over time?
4. What differences, if any, in vegetation diversity, structure and composition are associated with current grazing by heritage breeds at Koli National Park?

Conclusions from the global overview are presented here first, followed by conclusions drawn from the case study, including both the historical investigation and summary of vegetation data from the Koli region. Finally, recommendations based on the findings of this research are offered for further research and for the management of protected areas as regards heritage breeds.

Contribution of Heritage Breeds to Protected Areas

The global overview highlighted the value of maintaining heritage breeds of livestock as part of the tourism, recreation and heritage resources for protected areas in which heritage breeds were part of the areas' long-standing agricultural traditions. However, the most prominent role that justified the use of heritage breeds and/or at-risk breeds of livestock in protected areas was the animals' role in restoring or maintaining ecologically valuable landscape elements. Both the global overview and the case study indicate that grazing by heritage breeds can result in the reduced cover of certain particularly dominant plant species. Results from several studies in the global overview suggested an increase in plant species richness in some grazed sites, though similar results were not found in the Koli case study: no significant increases, or losses, in plant species richness were detected in grazed sites when compared with otherwise similar sites. Where heritage breeds of livestock helped achieve vegetation management objectives of some protected areas, compensation or free access to farmers who owned the animals that grazed within the protected area may be justified. This can promote local support for protected areas as well as local economic benefits. Certainly these findings should not be taken to suggest that heritage breeds of livestock are necessarily beneficial for all types of protected areas. Rather, these examples illustrate the range of ways in which heritage breeds could, where historically appropriate and under carefully planned and monitored initatives, complement management objectives of some protected areas.

Contributions of Protected Areas to the Conservation of Heritage Breeds

By providing incentives directly to farmers raising heritage breeds, protected areas help to offset the potential economic disadvantage of using heritage breeds in comparison with mainstream breeds that may have higher outputs of meat, milk or fibre in industrial production systems. Partnerships pursued and supported by some protected areas also provided lowered start-up costs for farmers converting to or starting out with heritage breeds through “seed herd” programs offered to farmers. Furthermore, the branding associated with protected areas provided niche marketing opportunities for farmers raising heritage breeds in protected areas where consumers may be more likely to seek “ecological” livestock products.

An additional contribution of protected areas to the conservation of heritage breeds that was particularly evident in the Koli National Park case study was the provision of grazing environments consistent with those in which the breeds developed unique characteristics over centuries. Although some farmers outside the park did raise heritage breeds, it is very unusual for the livestock to be raised in forest pastures, and they are no longer raised in swidden regeneration sites anywhere outside of protected areas. These historically consistent habitats may reinforce adaptive traits that the breeds developed over centuries of use in these kinds of environments.

Protected areas have been recognized as areas in which to conserve the biodiversity of plants used for agriculture as a way to complement conservation of such resources in seedbanks. The advantage of retaining living specimens in their places of origin is that they can continue to adapt to changing conditions (such as new pests and diseases, shifting climatic conditions, etc.). To conserve the diversity of animals used for agriculture, genebanks are much more difficult to create and maintain, as collecting and freezing semen, ova, and embryos requires costly specialized expertise and equipment. An alternative approach to the conservation of domestic animal diversity includes living genebanks or conservation herds of livestock. In Finland, conservation herds of Eastern Finncattle were kept within modern agricultural facilities at a prison and later at a vocational college. These modern conditions (e.g. the cattle were mainly housed indoors, fed silage and grain, pastured in open fields sown with improved grass mixes, etc.) were quite dissimilar to the environments in which the breeds were kept traditionally. Where protected areas allow heritage breeds to exist in habitats that reflect the conditions in which the breeds originate, they provide unique situations for living genebanks of livestock to retain the traits enabled them to survive and reproduce in such conditions over centuries. Such traits may not be selectively advantageous within modern agricultural environments where conservation herds are raised. Thus, such traits could erode over time if heritage breeds are conserved in environments significantly different from those in which they originated. However, if favoured production systems change in the future, perhaps relying again on the heritage breeds' original habitat types, it may be important to conserve the traits that allowed them to thrive in such habitats in at least some of the conservation herds. Conserving such habitats and allowing conservation herds of heritage breeds to exist in them are ways in which protected areas uniquely contribute to the conservation of heritage breeds.

Past and Present Agricultural Practices in and around Koli National Park

Many aspects of swidden agriculture and hay-making practiced today in Koli National Park are in-line with pre-1960s practices from the Koli area with some exceptions made for improved labour and/or cost efficiency. The breeds of livestock used in Koli National Park are consistent with breeds used in traditional agriculture in the past; however, in the past every farmstead would have had livestock, and the animals would likely have grazed in the swidden regeneration sites and in adjacent forested areas. Today livestock are absent from most of the former farmsteads in Koli National Park, and in the few former farmsteads where the heritage breeds do graze, the animals mostly graze in open habitats. Thus many of the forests and swidden sites in Koli National Park exist without these agents of disturbance that were found to have some significant impacts on the vegetation.

Impacts on Vegetation Associated with Grazing

The most marked effect of grazing was seen in the structure and condition of regenerating woody vegetation in the 8/9-year-old swidden site at the Ollila farm. Some differences in the percent cover of particular species of plants in the field layer were detected between the grazed and ungrazed swidden regeneration sites nearly one decade post-burn. In the swidden sites grazed by Finnsheep, there was significantly reduced cover of two of the most predominant species of the non-grazed swidden regeneration sites (*Epilobium angustifolium* L. and *Calamagrostis arundinacea* [L.] Roth). Significant differences in the condition of the regenerating woody vegetation were found between grazed and non-grazed swidden sites, with much greater damage and mortality to trees in the swidden site grazed by Finnsheep than in the non-grazed swidden regeneration site. The study sites clustered mainly by habitat type rather than by grazing activity. Species richness of the vascular plants sampled in the field layer of grazed swidden, open, and forest sites did not differ significantly from comparable sites without grazing. However, in the grazed swidden regeneration sites the increased proportion of dead and dying wood and the reduced dominance of two of the most abundant plant species may have secondary consequences for other taxa such as saproxylic species or fauna dependent on heterogeneous sward structure in pastures.

This study represents the first systematic and comparative investigation of the effects of heritage breeds of livestock in swidden regeneration in Finland. Several follow-up studies on the ecological and longer-term effects of these herbivores on the landscape are recommended.

RECOMMENDATIONS

The results from this study have revealed several areas in which further research is warranted. In addition, the results of the case study suggest some areas in which the management of Koli National Park and other protected areas could be adjusted to fully evaluate and make better use of heritage breeds of livestock in support of the objectives of the protected area. These recommendations are provided in detail below.

A More Complete Global Assessment

The content analysis of country reports submitted for FAO's *State of the World's Animal Genetic Resources for Food and Agriculture* report (Rischowsky and Pilling, 2007) revealed that initiatives involving protected areas are not well recognized as an opportunity and a means to conserve heritage breeds of livestock. Review of the literature related to the cases in the FAO country reports revealed additional cases of heritage breeds within protected areas that had not been mentioned in the country reports. If the FAO plans to solicit regular reports from each country regarding the means employed by each nation to conserve animal genetic resources, it may be worthwhile to explicitly solicit information on the conservation not only of wild or feral animals, but also of domesticated animals (especially heritage breeds) in protected areas. Another approach to the compilation of a more complete global assessment of the use of heritage breeds in protected areas could be to compile such a report by directly contacting national coordinators identified in FAO's Domestic Animal Diversity Information System (DAD-IS) to inquire whether they are aware of any such initiatives in their countries.

The Ecological Role of Eastern Finncattle

This research represents the first study that directly examines the role of livestock grazing with heritage breeds in the restoration of habitats associated with traditional agriculture in eastern Finland, particularly in habitats created by swidden activity. The configuration of sites within Koli National Park did not lend themselves well to comparing the effects of grazing by Eastern Finncattle in any but the old field habitats in the park. To reach a better understanding of the effects of Eastern Finncattle and their role in shaping the vegetation in the region, it would be useful to carry out an experiment in which they were stocked in a wider range of different types of habitats. One swidden area immediately north of one of the cattle pastures (between the Ollila and Mattila farm sites) was burned in 2007 and would be a reasonable candidate site in which to investigate the effects of cattle grazing on half the site as it regenerates over the years. Furthermore, there are no forest sites to which the cattle have access, other than a small area of mature *Picea abies* (L.) H. Karst and *Alnus incana* (L.) Moench that line the northern fence line of the northern-most pasture at the Ollila farm. Since the traditional practice was to put cattle in the forested areas, providing a larger area of forest for the cattle would also facilitate study of the effects of grazing by Eastern Finncattle in such sites. It is imperative, for meaningful conclusions to be drawn to ensure that ungrazed control areas (e.g., exclosures) are reserved to enable comparison between grazed and ungrazed treatments. Furthermore, it is important that the effects of wild herbivores be assessed and that site characteristics such as soil analyses, aspect and a full, pre-treatment vegetation analysis be included in such studies as it cannot be assumed that herbivory is the sole factor affecting the composition and structure of vegetation.

Mixed Species Grazing

Additional areas for investigation at Koli National Park should include comparison of the effects of grazing by both cattle and sheep, a comparison of the effects of different stocking rates, as well as a determination of various the effects of continuous, early and later seasonal grazing. Currently the cattle and sheep at Koli National Park are pastured in completely different paddocks. Rotational grazing with sheep following cattle grazing (or vice versa), as well as mixed cattle/ sheep grazing together in the same locations, may show different effects than single-species grazing. This approach would be more consistent with historical practices as described by the interviewees. Some paddocks with single-species grazing should be retained to allow comparison of the effects of cattle only, sheep only and mixed grazing regimes.

Comparisons Using Heritage and Imported breeds

The Koli case study did not enable comparisons between heritage breeds and imported breeds of livestock in anthropogenic habitats in Koli National Park. The results of other studies (Rook *et al.*, 2004; Scimone *et al.*, 2007; Wallis De Vries *et al.*, 2007; Jauregui *et al.*, 2008) do not agree about the ecological effects of heritage versus imported breeds in a variety of habitats. Therefore, further investigation at the breed level is needed.

It would be very useful to study potential differences between breeds of the same species of livestock in terms of grazing preferences. These are likely to be of adaptive significance and reflect past environments and ancestry of the breeds. Investigations involving heritage breeds should consider the types of habitats in which the breeds had traditionally been raised. Researchers and editors should adopt a standard practice of identifying the breed(s) of livestock in their studies, as well as providing some background on the origins of the breed within the context of their study sites. Unfortunately, this is currently uncommon.

Value of *In-situ* Conservation of Heritage Breeds

Although Finnsheep and Eastern Finncattle are still raised on some modern farms, their main source of forage in the summer comes from modern-day open pastures (often "improved" through sowing specialized grass/ herb mixes) and grass-hay (also often from improved fields). Traditionally these breeds would have been pastured in swidden regeneration areas and adjacent forests and provided with leaf-hay in addition to grass/herb hay. The possible implications of this shift in diet were discussed, especially in light of research pointing to the antihelmintic effects of tannins and differential dental wear patterns associated with consuming woody forage. Empirical studies examining internal parasite loads and other physical characteristics exhibited by these breeds under different feeding regimes (open pasture vs forest pasture) could reveal whether there are habitat-related factors affecting the breeds themselves.

<u>Continuity of Habitats via Grazing</u>

The long-term demography of regenerating tree species are likely to be affected by the high levels of damage and mortality caused by the Finnsheep in the swidden regeneration sites at Koli National Park. Longer-term monitoring and modelling of the resulting forest composition should be undertaken to provide additional data to determine if or how grazing influences the composition of the stand as it matures. Some ecologically important habitats, such as herb-rich forests (Hokkanen, 2006) and white-backed woodpecker (*Dendrocopos leucotos*) breeding habitat (Martikainen *et al.*, 1998) are associated with past swidden activity and/or forest grazing. Longer-term assessments of the role of livestock in shaping these habitats could help determine whether grazing activity is a necessary element of the long-term maintenance of these habitats.

Impacts on Other Taxa

Although significant differences in the proportion of dead and dying woody vegetation were found in the sites grazed by Finnsheep and Eastern Finncattle, only a few vascular plant species in the field layer were affected by grazing activity by Finnsheep. The possibility that additional taxa, such as detritivores and saproxylic species could be affected by grazing activity in woody habitats was explored, but additional research is required to measure such effects of grazing by heritage breeds in habitats shaped by traditional agricultural activities.

SUMMARY AND IMPACT

It is apparent that heritage breeds can contribute to fulfilling the management objectives of protected areas objectives (such as serving as tourism attractions, fostering good relationships with local residents via incentive programs, and maintaining desireable ecological disturbance regimes). Reciprocally, there are many ways in which protected areas can contribute to the conservation of heritage breeds (such as increasing awareness about the breeds, supporting incentive programs that encourage local farmers to raise heritage breeds and the creation of niche-marketing opportunities).

The case study examined changes to agricultural practices through time and their impact on the landscape. The gradual introduction of traditional agricultural activities in the Koli landscape began to shape the composition of the forest as early as 665 BC. By the late 19th century the landscape had been transformed by traditional agricultural activities to the point that coniferous forest was uncommon due to the large amount of land used for swidden agriculture. In the early 20th century, swidden agriculture had been largely abandoned and agricultural practices intensified, especially after 1960. Due to abandonment or intensification, habitats shaped by former traditional agricultural activities are now very rare in Finland, and Europe in general, including habitats traditionally associated with grazing.

As part of the efforts to reinstate traditional agricultural activities in Koli National Park, heritage breeds are used with the intent to restore traditional habitats to the landscape. However, pasturing the livestock in open fields is inconsistent with historic practices that would have assigned such clearings to crop cultivation or haymaking. In the few areas in which the heritage breeds of livestock are permitted to graze in swidden regeneration areas, much higher levels of dead and dying woody vegetation are apparent. The decreased percent cover of a couple of dominant species of plants (*Epilobium angustifolium* and *Calamagrostis arundinacea*) in the field layer of the older swidden regeneration site grazed by Finnsheep was associated with an increase in cover of two shorter species (*Agrostis capillaris* and *Trientalis europaea*), though there were no differences in overall species richness between grazed and non-grazed habitats.

Recommendations for further study included:

1) Facilitating the collection of additional data on the use of heritage breeds of livestock in protected areas world-wide through the next round of FAO's state of the world's animal genetic resources reports,
2) Additional research on the ecological effects of Eastern Finncattle and mixed species grazing,

3) Empirical comparisons between heritage and imported mainstream breeds within traditional agricultural production systems.

4) Investigations of the effects of the provision of historically consistent sources of fodder on the physical attributes of heritage breeds,

5) Longer-term research on the ecological impacts of heritage breeds in Koli National Park to help determine the role of the livestock in shaping ecologically valuable habitat and ensuring temporal habitat continuity.

It is important that such studies be designed to allow paired comparisons between grazed and ungrazed plots that are otherwise identical.

This research revealed that although protected areas are generally under recognized as means to conserve heritage breeds of livestock, protected areas can be well positioned to contribute to the conservation of these breeds provided that the livestock help to achieve the management objectives of the protected areas. Where the idea of conserving heritage breeds in protected areas is met with resistance, the global overview offers farmers and managers of protected areas a range of examples in which heritage breeds were conserved while achieving the objectives of protected areas. Of course, a caution should be reiterated that the use of livestock in protected areas should take into consideration the areas' agricultural history: where there was no history of livestock use in the landscape, new introductions should not be encouraged unless there is strong evidence that they can be used as surrogates for other forms of disturbance (e.g. filling a niche for now-extinct herbivores). Furthermore, where historical activities involving livestock were associated with ecological degradation, any plan involving livestock in protected areas should seek to understand the cause of such damage (e.g. overstocking), evaluate the appropriateness of allowing heritage breeds and determine acceptable stocking rates, if any, within the protected area. In all cases, initiatives involving heritage breeds in protected areas should involve regular ecological monitoring and adaptive management.

This research also highlights the significant role of heritage breeds of livestock in restoring habitats associated with traditional agriculture in eastern Finland. The proportions of dead and dying trees in the swidden regeneration sites with Finnsheep are much higher than in the swidden regeneration sites with only wild herbivores. It provides the basis of a longer-term study that could examine the patterns of succession in grazed swidden sites, similar to the ten-year study by Ruokolainen and Salo (2006) of succession patterns in swidden sites without grazing. Outside of eastern Finland, the findings of this dissertation should encourage managers of sites aiming to restore habitats associated with historical agricultural activities to carefully investigate the historic practices of a region. Given the significant difference in tree condition between swidden restoration sites with and without grazing, consideration should be given to how all elements of past practices might have influenced the ecology of traditional agricultural habitats.

The apparent importance of woody vegetation in the diet of Finnsheep and Eastern Finncattle emphasizes the value of conserving heritage breeds in habitats that reflect the environments in which the breeds were developed within traditional agricultural practices over centuries. Protected areas that have ecological rationales for preserving traditional agricultural habitats can provide unique conditions in which to conserve breeds' adaptive traits, which may not be reinforced when the breeds are kept in modern agricultural environments. Thus, conserving heritage breeds in protected areas may be a way to conserve both natural and agricultural biodiversity.

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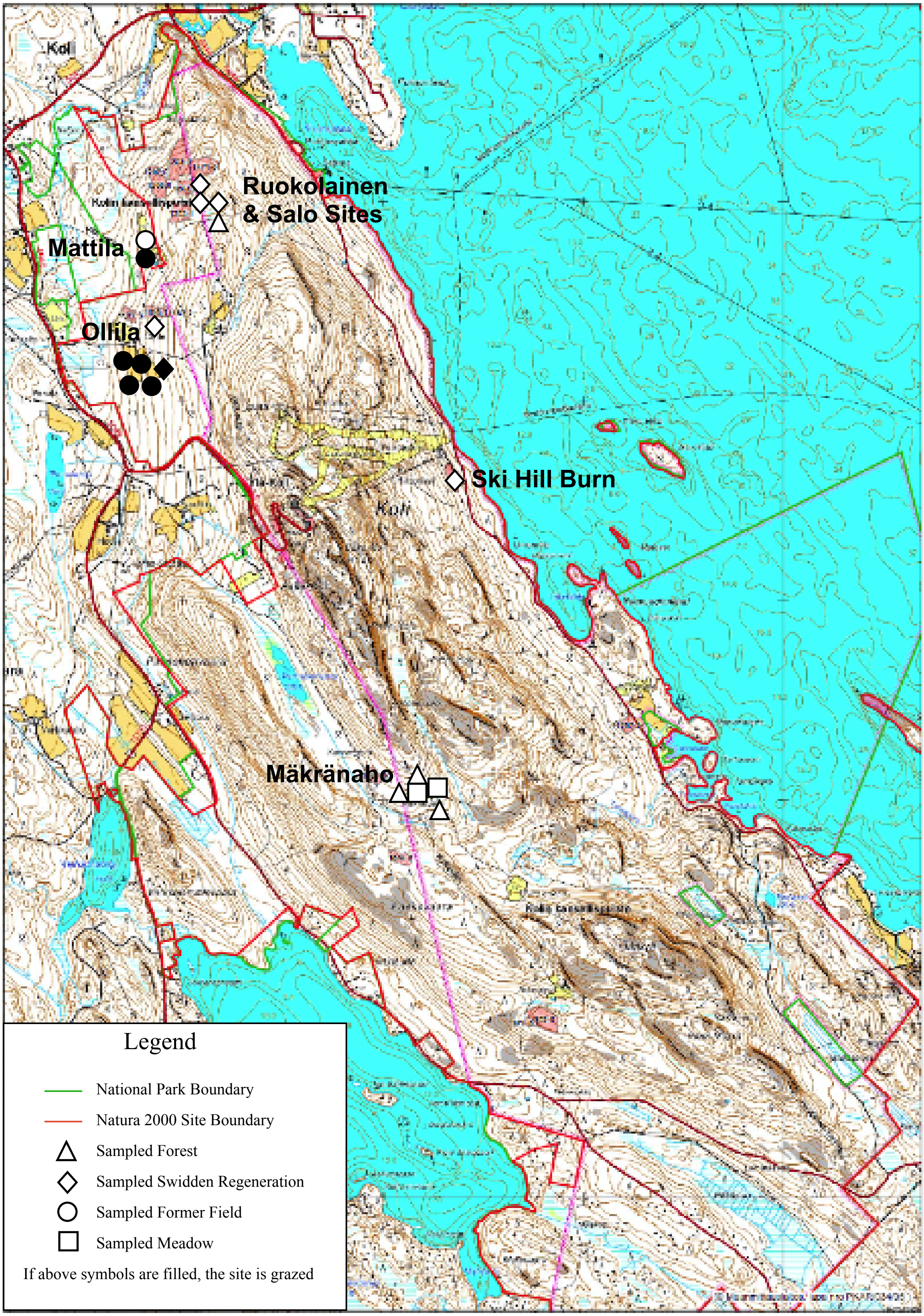
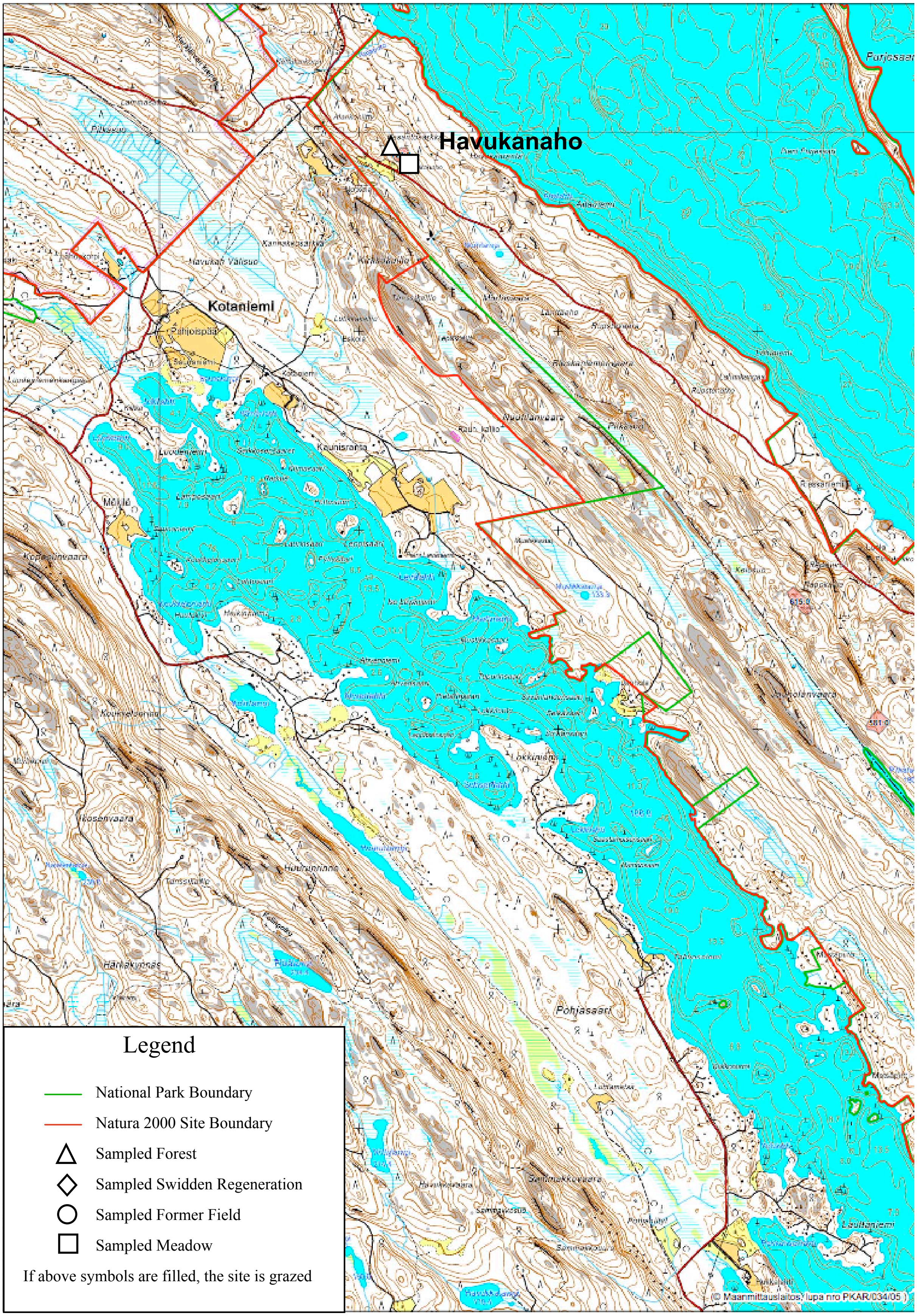
265 References.

APPENDIX A: MAP OF NORTHERN PART OF KOLI NATIONAL PARK



APPENDIX B: MAP OF CENTRAL PART OF KOLI NATIONAL PARK



APPENDIX C: MAP OF SOUTHERN PART OF KOLI NATIONAL PARK