Fodder Productivity and Quality in Two Coastal Seashore Meadows in Eastern Uusimaa, Finland

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Tiivistelmä — Referat — Abstract

Productivity and quality of two grazed coastal seashore meadows in Eastern Uusimaa were examined between May and July, 2002. A total of 18 1m^2 sample sites divided into four separate cutting regimes were cut by hand to simulate grazing in the meadow. cutting regimes of various intensities were used to simulate the short term effects of different grazing pressures on the quality and productivity of the vascular plant forage in the meadows. Samples were dried, weighed and analysed for digestibility and composition.

Digestibility analysis was carried out using *in vitro* digestibility analysis. A CNS-1000 Elemental Analyzer was used to measure carbon, nitrogen and sulphur content of selected samples.

The results showed that cumulative above ground phytomass productivity (AGPP) was dependent upon both biotope and cutting regime in the large (40 ha) Bosgård meadow, and that interaction betweeen these two factors was significant. The results of the smaller (<2 ha) Majvik meadow were highly variable between replicates. This variation overshadowed possible effects of biotope and cutting regime and their interaction. Quality was dependent upon both biotope and cutting regime. D-value decreased over time.

Avainsanat — Nyckelord — Keywords

Meadows, coastal wetlands, seashore meadow, grazing, heritage landscape, meadow management, D-value

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Chapter 1

Coastal Meadows in Finland

Meadows as a Heritage Landscape

Heritage landscapes are formed by Man's traditional types of land use. Heritage landscapes in Finland include different types of semi-natural meadows and permanent pastures where grazing and haying/fodder collection have been practiced under traditional agriculture. The period of "traditional agriculture" in Finland is generally considered to be from the advent of agriculture in the country until the end of the 19^{th} century (Vainio et al. 2001; Luoto et al. 2003).

Meadows, which are defined as treeless and bushless floral communities on untilled land, are key habitat components of the heritage environment (Alanen 1996: ref. Pitkänen and Tiainen 2001.). Semi-natural meadows are untilled and unfertilised grasslands. They are composed of mostly naturally occurring species, including herbs, grasses and sedges (*ibid*). Coastal seashore meadows are only one type of the many semi-natural meadows found in Finland. Other types of meadow include dry upland meadows, lakeshore meadows, wooded meadows, etc. Coastal meadows are divided into two categories: freshwater coasts (lakes and rivers) and seashore meadows (*ibid*). Throughout this paper, coastal and seashore are used interchangeably and refer to seashore meadows along the Baltic Sea. In discussing heritage landscapes generally, "coastal meadow" also includes the freshwater coasts.

Coastal meadows have been economically and ecologically important parts of the traditional landscape throughout coastal Finland, especially in the Finnish Archipelago, southern Finland, and Satakunta province (Pykälä and Bonn 2000). The seashore meadows of these areas are semi-natural, short-growth meadows that have sometimes been expanded upland from their natural boundaries through the traditional animal husbandry practices of grazing and mowing (Haapanen and Heikkilä 1992; Lindgren 2000; Jutila 2001; Vainio et al. 2001). Combined grazing and mowing also maximises the effects of post-glacial rise in land (about 2-9 mm/year) as the meadow zone continuously reclaims area from the sea (Haapanen and Heikkilä 1992; Salminen and Kekäläinen 2000).

History of Coastal (Seashore) Meadows in Finland

Continuous cattle-based agriculture over periods of hundreds to thousands of years has created the traditional meadow landscapes of Finland (Lindgren 2000). It has been estimated that cattle herding began in Finland in the forests during the latter part of the Stone Age, approximately 2000-1300 B.C. (*ibid*). Cattle began opening the forests, but change in landscape was also facilitated by slash and burn agriculture, which was used to open pasture lands and fields (*ibid*). Economically, slash and burn and field agriculture were more important to farmers than livestock care, and cattle manure was considered more valuable than other cattle products (meat, dairy, etc.) (Salminen and Kekäläinen 2000). Manure fertilizer was often the primary limiting factor in expanding agriculture, as one cow's manure was needed for about ¼ ha of field (Vainio et al. 2001). Limited grazing area affected the number of cattle that could be stocked, and poorly nourished herds were the norm (*ibid*). Livestock had, however, a significant impact on both farming and the landscape, as livestock rearing had a greater per land area impact on the landscape than field agriculture (Salminen and Kekäläinen 2000).

Traditionally, meadows were divided and owned as parcels, or strips, of land ("sarka" in Finnish or "skifte" in Swedish). Each farm in a village owned several narrow parcels of meadow, which were first hayed before animals were allowed to graze the fenced areas (Haapanen and Heikkilä 1992; Pykälä and Bonn 2000). Information on how much meadow area was allotted per family is limited, and available semi-natural meadow area varied according to the area in Finland and population density of the region. About 30 ha of different types of meadow per household were used in Kainuu and Keski-Pohjanmaa in the late 1800s to early 1900s, but hundreds of hectares of meadow were available to those farms in Lapland, where at least 12 hectares of meadow were required to meet the winter fodder needs of one cow (Vainio et al. 2001).

By the 1500s, meadow and pasture, including coastal meadows, were fully utilized by coastal people as pasture and hay lands (Lindgren 2000). In the 1700s and 1800s in Satakunta, for example, total meadowlands were four times that of grain field lands (Jutila et al. 1996). In Uusimaa in the late 1700s, meadows covered 2.5 times as much land area as fields (Pykälä and Bonn 2000).

Changes in agricultural policy and practice from the late 1700s through the 1800s and 1900s resulted in the dramatic decline of meadow use in Finland. Although the importance of traditional agriculture continued to grow up until the middle of the 1800s, officials actively worked to change agricultural practices, especially animal production in Finland (Pykälä and Bonn 2000; Salminen and Kekäläinen 2000[1]).

The general parcelling out of land (the land reform known in Finland as the "Isojako") at the end of the 1700s was the beginning of major changes in Finnish agriculture. Pressure to modernize agriculture increased again in the late 1860s after the famine years of 1867-1868, and the first great loss of meadows began in the 1870s (Pykälä and Bonn 2000; Salminen and Kekäläinen 2000; Pitkänen and Tiainen 2001). Animal production was intensified, in part because of increased export possibilities (improved transportation to England and St. Petersburg) and depression of the price

[1] For further information, see history of Finland's "Isojako".

of grain (as a result of increased grain imports to the country) (Luoto et al. 2003). The newly increased need for fields resulted in meadows being put to the plough to open up new arable fields, where feed for animals also began to be cultivated (Salminen and Kekäläinen 2000; Pitkänen and Tiainen 2001; Luoto et al. 2003).

Despite the changes that took place in Finnish agriculture in the 1800s and early 1900s, coastal meadows were still grazed abundantly until about the 1950s (Pykälä and Bonn 2000). In 1876, 13% of all of the land area in Uusimaa was meadow (Figure 1.1), although there was considerably more meadow in western Uusimaa (twice that of field area) than in the east (about the same or less than arable field) (*ibid*). In the 1880s, Finland's permanent agricultural lands were still primarily meadow, while only 1/3 of permanent agricultural lands were tilled fields (Figures 1.1-3) (Vainio et al. 2001; Pitkäinen and Tiainen 2001).

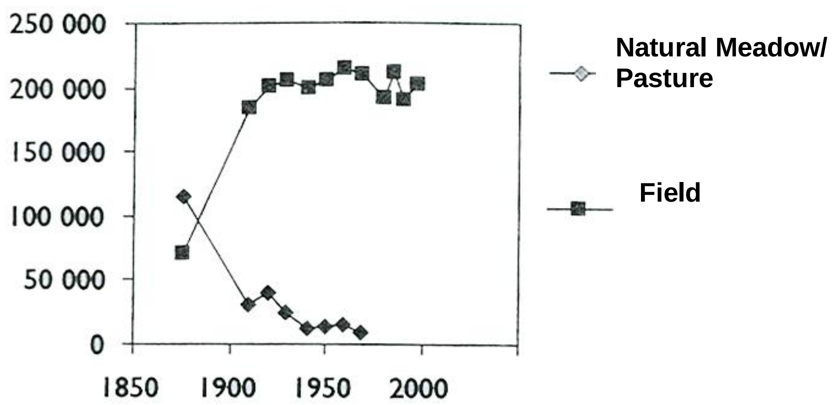


Figure 1.1 Meadow and field area (in hectares) in Uusimaa from the years 1850 to 2000. By 1960, only 4% of the meadow area in existence at the end of the 1800s was in agricultural use as meadow (Pykälä and Bonn 2000).

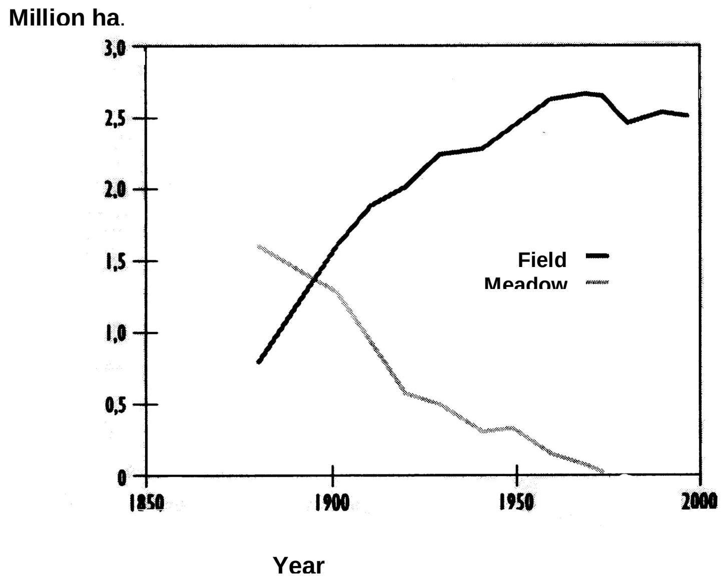


Figure 1.2 Changes in meadow and field area in Finland from the years 1880-1997 (Vainio et al. 2001).

Up until the end of the 19th century, livestock (primarily cattle) farming was still based on meadow grazing, and the majority of the land area was under livestock production (Pykälä and Bonn 2000). In the 1930s, hay was gathered from about 1/3 of the meadows in Uusimaa (Figure 1.3) (Pykälä and Bonn 2000; Vainio et al. 2001). According to Jutila (1997, 2001), management of coastal meadows all but ceased after the 1940s. Others, however, indicate that grazing of coastal meadows in Uusimaa continued strongly until the end of the 1950s, but that it dropped radically in the 1960s and 1970s (Luther and Munsterjhelm 1983: ref. Pykälä and Bonn 2000). Some of this meadow area was taken into use as ploughed fields, while some simply became overgrown through disuse (*ibid*).

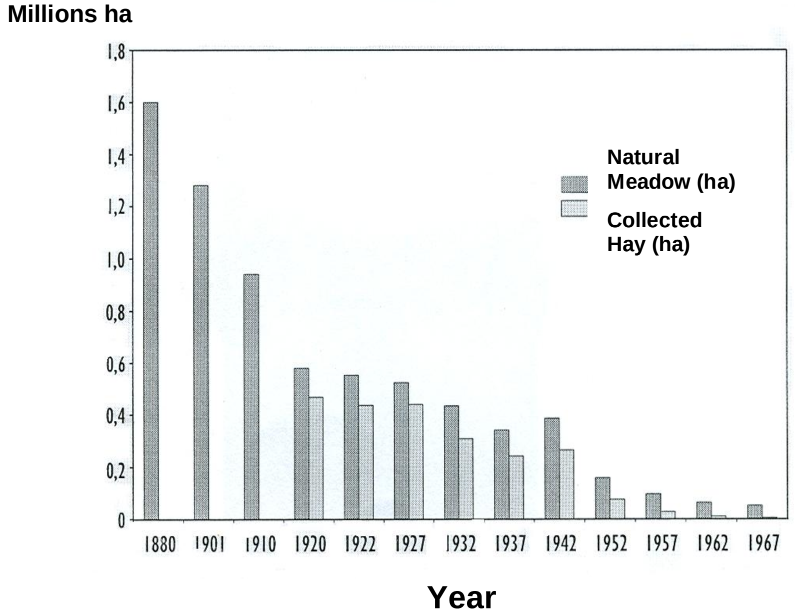


Figure 1.3 Total hectares of semi-natural/natural meadow in Finland compared with that which was hayed in the years 1880-1967. Statistics on hayed area were not available for 1880, 1901 and 1910. (Vainio et al. 2001)

Modern Farming

During the early 1900s, most farms had a small amount of livestock. In 1959, for example, ¾ of all farms in Finland still had dairy production, while more than half had horses and 11% had sheep (Pitkänen and Tiainen 2001). In Uusimaa, the sheep and horse populations crashed in the 1950s, while cattle numbers went into steady decline (Figure 1.4) (Pykälä and Bonn 2000). Industrialization of agriculture meant that farm sizes increased, as monocropping and the use of artificial pesticides and fertilizers became more widespread. The long-term process of intensification and modernization, which began in earnest in the 1950s, picked up in the 1960s (Heikkilä 2001; Pitkänen and Tiainen 2001). Modern agricultural techniques required that animal feed come primarily from cultivated grass. As a result, outdoor feeding (especially extensive grazing) declined dramatically compared to the days of traditional agriculture (*ibid*). Chemicalisation and mechanization of agriculture has meant that the coastal meadow has lost its importance in modern food production in Finland (Salminen and Kekäläinen 2000).

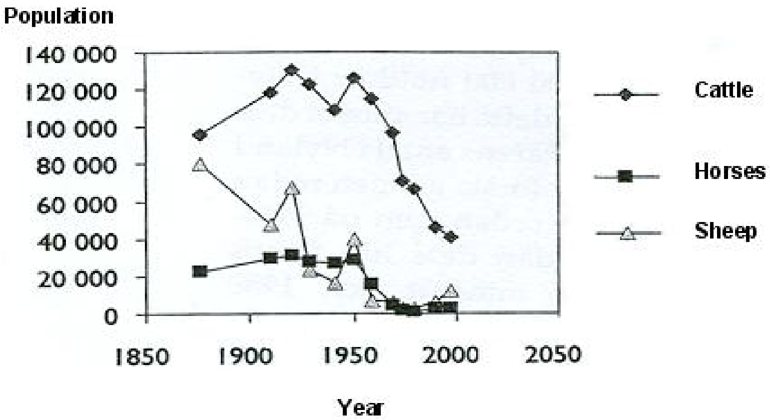


Figure 1.4 Livestock population, according to agricultural statistics, from years 1850- 2000 in Uusimaa. Horses were plentiful in Uusimaa until the 1950s. Horses became redundant on the majority of farms after tractors became widespread in the 1960s and 1970s. (Pykälä and Bonn 2000).

Finland joined the European Union and its Common Agricultural Policy (CAP) in 1995. The CAP brought with it both positive and negative changes in Finnish agriculture. Positive changes include environmental programs aimed to conserve heritage landscapes and increase biodiversity, as well as other programs recognising the multifunctionality of agriculture. Negative impacts include accelerated loss of livestock on farms and drop in overall number of farms, with concurrent increase in holder size (Pitkänen and Tiainen 2001). EU agricultural policy demands that farms be competitive and specialized, and Finnish/EU agriculture policy is currently directed toward reducing the number of farms and increasing the size of holdings. It is projected that, of the 88,000 farms in Finland, only half will be left by 2010 (Heikkilä 2001). Salminen and Kekäläinen (2000) report even more dire predictions, with only 30,000 to 40,000 farms expected to survive to 2008.

Endangered Landscapes

As a result of these changes in agriculture, heritage landscapes, including coastal meadows, in Finland have become endangered. The Helsinki Commission has stated that seashore meadows along the Baltic Sea are heavily endangered biotopes (Von Nordheim and Boedeker 1998: ref. Jutila 2001). According to the 1992-1998 study of heritage landscapes in Finland, there are only 20,000 ha left, (18,640 ha according toVainio et al. 2001) excluding Ahvenamaa (Åland) (Pykälä and Bonn 2000). Of this amount, less than 10 % are coastal meadow (Pitkäinen and Tiainen 2001). This is in contrast to the situation in Sweden, where 8100 ha of coastal seashore meadow (with minimum area of 0.5 to 2 ha, depending upon the census methodology) have been recorded (Pykälä and Bonn 2000). Of the Swedish meadows, it is estimated that about half are being managed through either livestock grazing or other measures (*ibid*).

The total number of hectares of valuable Finnish coastal seashore meadow is listed as 1894 ha in the final report on Finnish traditional landscapes (Vainio et al. 2001). Of this, 1058 ha are grazed (*ibid*). Pitkänen and Tiainen (2001) note that, "Finland now holds less than 1% of the meadows it had at the end of the 19th century" and that, "The remaining meadows and forest pastures in Finland are heritage landscapes, habitats that will not survive unless up kept by specific preservation measures". The Finnish Nature Conservation Act, enacted in 1996, designates low-growth seashore grasslands as protected biotopes, and they have begun to be mapped by regional environmental agencies (Jutila 2001). Figure 1.5, adapted from Vainio et al. (2001), shows the distribution of seashore meadows in Finland. According to Pykälä and Bonn (2000), 41% of coastal seashore meadow in Uusimaa is located in Tammisaari, and this adds up to only 70 ha. 88% of the coastal meadows in Uusimaa are ungrazed (*ibid*).

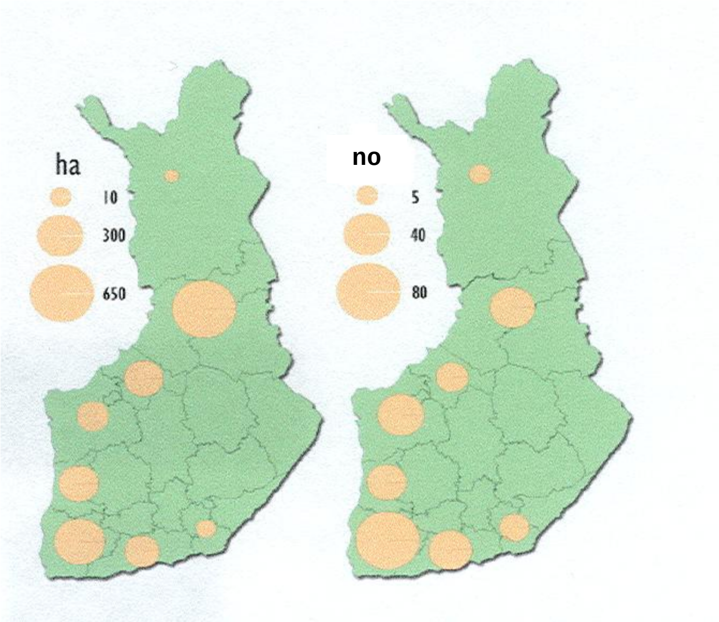


Figure 1.5 Distribution and amount of coastal seashore meadow in Finland. The map on the left shows the total number of hectares of coastal meadow and the regions where they are located in Finland. The map on the right shows the total number of coastal seashore meadows, by region, in Finland. (Vainio et al. 2001)

Currently, only a small proportion of seashore meadows are actively used for agricultural purposes or maintained through other conservation measures. According to Vainio et al. (2001), Finland does not have any seashore meadows that have been continuously hayed. Further, only 2% (about 30 ha) of the inventoried seashore meadow was being hayed during the study year (Vainio et al. 2001). Haying, which is sporadic in the seashore meadow, is less common than grazing in contemporary meadow management (Pykälä and Bonn 2000; Vainio et al. 2001).

Ecology of Seashore Meadows

The ecology of seashore meadows is dependent upon a number of factors, both natural and manmade. Important natural factors influencing meadow formation are climate, geography, and the Baltic Sea.

Coastal meadows in Finland, Sweden and Estonia are dependent upon the Baltic Sea. Although the Baltic Sea has practically no tides, seasonal and daily fluctuations are important factors influencing shore vegetation. The coastal seashore meadow is a multi-stress environment, where water level fluctuation narrows the species pool (Jutila 1997). Studies show that duration and depth of flooding are the most important factors shaping shore vegetation (Jutila 2001). During the growing season, fluctuations in water level are usually within 20 cm, but changes of one meter and more are possible, with greater water level fluctuations generally occurring during the winter (*ibid*).

In addition to water level, temperature is also greatly affected by the presence of the Baltic Sea. The daily impact on temperature is felt up to 10 km inland from the sea, while seasonal influence of the Baltic Sea on temperature reaches 20 km inland (Pykälä and Bonn 2000). Uusimaa receives the greatest amount of precipitation in continental Finland (600-750 mm rain annually), with the rainiest months being July and August (Solantie1992: ref. Pykälä and Bonn 2000). However, low rainfall in May and June result in dry growing season conditions (*ibid*). The growing season in Uusimaa is between 170-180 days (*ibid*).

Shore meadows in Finland are characterized as somewhat sheltered with relatively small-grained soil (Jutila 2001). The depth of the organic layer in these seashores is quite shallow (*ibid*). Warmer microclimates, which are formed in grasslands through grazing and mowing, may also occur in summer if temperatures rise in short growth areas (Thomas 1993: ref. Pykälä 2002). Through this process, thermophilous species may become dependent on the microclimates of the managed landscape (*ibid*).

Vegetation in the coastal meadows is zonal. Reeds and similar types of plants flourish from the water line and lower (Haapanen and Heikkilä 1992). Sedges and grasses are found from the shore inland (*ibid*). Highly competitive, fast growing plants, such as common reed (*Phragmites australis*), are able to dominate their zones if left unmanaged. Soil and water salinity are also stress factors, which affect germination and species survival in the different zones of the meadow (Jutila and Erkkilä 1997).

The dominant vegetation in coastal seashore meadows in Finland is clonal monocote perennial, of which nearly all are graminoids (grasses, sedges and rushes) (*ibid;* Jutila 1997). Studies show that species richness in both grazed and ungrazed meadows increases with elevation and decreases significantly with increase in height of vegetation (Jutila 1997).

Ecological Importance

Plants and animals have adapted over time to the agricultural landscape. In addition to those that belong to the agricultural environment, there are many flora and fauna species that have adapted to the open and semi-open landscapes provided by extensive grazing culture (Salminen and Kekäläinen 2000; Heikkilä 2001). For this reason, traditional landscapes are some of the richest habitats of the agricultural landscape (Haapanen and Heikkilä 1992; Salminen and Kekäläinen 2000; Heikkilä 2001; Pitkänen and Tiainen 2001). Species that are particularly dependent upon meadows include vascular plants, butterflies, and pollinating insects (Pykälä and Bonn 2000).

Internationally, Finland, Sweden and Estonia are responsible for maintaining the ecological heritage of coastal meadows along the Baltic Sea (Salminen and Kekäläinen 2000). Further, Finland has a responsibility under the European Union's Nature Directive to preserve species that fit the following criteria: are endemic to Finland or Northern Europe; the species is rare everywhere; species is dispersed over a wide area but is common only in a small area, of which a significant portion is in

Finland; species in Finland has diverged significantly from its source of origin and may have unique genetic qualities (*ibid*).

Species diversity is threatened not only by the loss of large areas of quality habitat, but also by the increased fragmentation of habitat area. Studies show that the contiguousness of habitat is an important factor in maintaining biodiversity in relatively discreet habitat patches (Luoto et al. 2003). Habitat size affects the stability of populations, including protecting their genetic diversity by improving survival and reproduction strategies.

According to Juha Pykälä of the Finnish Environment Centre, 60% of the indigenous plants of Finland benefit from combined haying and grazing, in addition to birds, butterflies, pollinating insects, beetles, mosses, lichens and mushrooms (Loiskekoski 2002). Additionally, species of the heritage environment make up 75-80% of Finland's total endangered species related to the agricultural landscapes (Pykälä and Alanen 1996; Luoto et al. 2003). Loss of meadows means a loss of the species dependent upon these environments. According to the year 2000 report on endangered species, the closure of traditional and cultural landscapes as a result of disuse and lack of maintenance is the most important reason for species loss in Finland (Heikkilä 2001).

Meadow Biodiversity

A significant proportion of all threatened and endangered species of plant, animal, and insect in Finland are dependent upon the traditional landscape. Systematic species inventorying of traditional landscapes in Finland began in 1992 (Salminen and Kekäläinen 2000). Of the 1505 endangered species in Finland, 338 (22%) are found primarily in traditional landscapes (Vainio et al. 2001). The majority of endangered species dependent upon traditional landscapes are vascular plants and invertebrates (31% of all endangered species) (*ibid*). Inventory data on vascular plant species is available for many individual meadows in Finland, while information on other species is more sporadic (Pykälä and Bonn 2000).

Recent inventories of meadows in Uusimaa indicate that there are at least 31 threatened species (of which 27 are vascular plants) in the traditional landscapes located in Uusimaa. Seventeen of these species are listed as extremely endangered. Eleven of the species in Uusimaa are endangered on a national scale, while 16 are listed as endangered in Uusimaa. Eighteen of the vascular plant species on the list benefit significantly or are entirely dependent upon the traditional landscape. Examples of plant and animal species that are endangered in Finland and are found in Uusimaa are, respectively, *Gentianella campestris* (critically endangered in Uusimaa) and *Tropiphorus terricola* (critically endangered in Finland). (Pykälä and Bonn 2000). The complete catalogue of endangered species in Uusimaa is available in the publication Uudenmaan Perinnebiotoopit (Pykälä and Bonn 2000).

Nutrient Cycling

Salinity, nutrient cycling, temperature, and moisture regime of the coastal meadow are all affected by grazing. These qualities affect species survival and influence plant succession. Removal of grazing from the managed landscape affects species survival and distribution in the landscape. In order to understand nutrient cycling and energy flows in the coastal meadow, the ecology of the meadow in both the grazed and ungrazed/undergrazed state must be examined.

The energy flow of the coastal meadow includes the sources of energy into the meadow habitat and the directions of circulation and exit of energy. In Figure 1.6, a simplified energy flow, based on emergy concepts (Odum 1996), of a coastal meadow grazed by cows is presented.

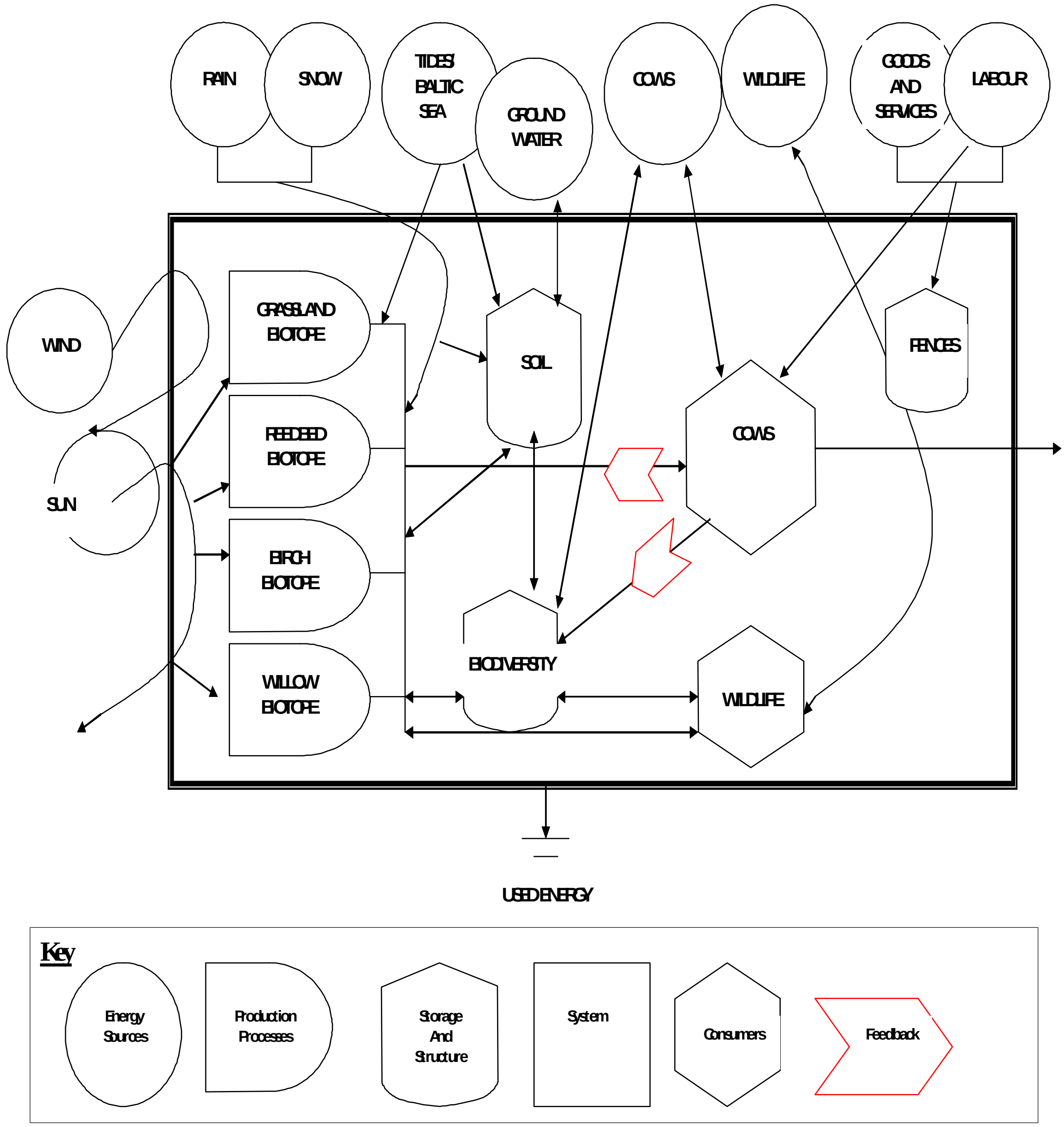


Figure 1.6 Energy flow of a coastal meadow in Finland. The main energy input to the meadow comes from solar, wind and tidal sources. The addition or removal of livestock are the primary factors influencing the energy flow of the meadow.

Natural energy and nutrient sources into the system are solar energy, tidal energy, wind energy, rain/snow, groundwater and water/nutrient run-in, and geo-thermal energy. Geological processes, including landscape topography and composition forming forces like the Ice Age, are also primary determinants of how energy flows in the system. Short-term dynamic processes, such as water fluctuation, and long-term processes, such as land uplift (Figure 2.2), affect species survival and stages of succession (Jutila 1997). Wildlife also migrate in and out of the system, both consuming nutrients and ecosystem services and contributing to them in the meadow.

Erosive forces affecting plant communities in the coastal seashore meadow are waves, ice and wind (Jutila 1997). These forces, combined with fluctuation in water level and disturbance, including grazing, fire (rare in modern ecosystems) and heavy storms, affect plant communities by creating competition-free gaps (Jutila 1997). These stress-disturbance forces affect the coarseness and holding capacity of water and nutrients (*ibid)*. Erosive forces are affected by changes in plant growth, including eutrophication and like phenomena. Irrigation, tilling, changes in windbreak (forestry and windbreaks, for example), and climate change affect erosive forces.

The human input to the grazed coastal seashore meadow is significant. It includes the input of cows, labour, and other goods and services. The level of acceptable energy and nutrient input by the farmer into the system is discussed further in the management section. However, nutrient flow balance in the coastal meadow requires that the cows remove more nutrients (primarily nitrogen and phosphorous) through their growth and maintenance than they deposit into the meadow. For this reason, both fertilisation of the meadow and supplementary feeding of livestock grazing the meadow disturb nutrient balance and negatively affect species biodiversity in the semi-natural grassland (Pykälä and Bonn 2000).

Each of the biotopes in the grassland has production processes that are specific to their microclimatic and biological zone. These habitat types range from shoreline reedbeds to floodplain sedge dominated open areas to willow wetlands and upland birch dominated meadow. Elevation and parent material type, which influence species composition, are primary determinants in zone formation (Jutila 2001). The transitional zones are indicated by height of vegetation and species diversity (*ibid*). All but the upland, slightly forested areas, are wetland habitats. Wetlands typically have a broad range of different types of environmental variables and flora types, which give rise to a diverse seed bank, characterised by wide species diversity and varying dormancy and sprouting times of seeds (Jutila 1994). The diverse flora of the wetland environment also has multiple dispersal and other survival strategies, including response to disturbance, salinity and variation in water level (*ibid*).

The grazing process affects the natural qualities of each of these biotopes. Flood levels, salinity, soil saturation, pH, nutrients, and other factors combine with the effects of browsing and trampling to determine the range of the different habitat types. Trampling alters soil physical conditions and impacts soil moisture content, aeration, stability, etc. (Jarvis 2000). Trampling strongly impacts saline soils. Many of the soils in coastal meadows are fine particle soils with saline sediments close to the soil surface. In these types of soils, dry summers cause evaporation of moisture, which brings salts (chlorides and/or sulphates) to the surface (Salminen and Kekäläinen 2000). These saline soils provide favourable growing conditions for halophytes (salt-loving plants) (*ibid*). Loss of grazing diminishes these salt soil patches, as evaporation of soils decreases with a decrease in grazing (*ibid*). Jutila and Erkkilä (1998) also note that over time, grazed flooded soils may become less saline as salinity is reduced through flooding. In such soils, germination is increased as salinity is reduced (*ibid*).

Storage of energy and nutrients in the coastal meadow is in the soil, plants, animals, and structures in the meadow. Sink capacity (plant shoots) for nutrients is reduced and internal transfers of nutrients within plants are also affected by grazing (Jarvis 2000). Additionally, grazing results in the conversion of nutrients from stable, often relatively immobile, forms in plant materials into mobile forms, which have a greater potential for transfer away from the system (*ibid*). Biodiversity is both a receptacle and a resource that is stored. As a receptacle, it stores energy and nutrients in its web of plants, animals and other living beings. As genetic heritage, it is stored in the living ecology of the biotope.

Nutrients are stored primarily in the soil and biota. In general, biodiversity benefits from limited nutrient availability, as fast growing and tall plants become limited in their ability to completely dominate the habitat (Salminen and Kekäläinen 2000). Grazing and mowing help reduce the nutrient content of the meadow, while also keeping the vegetation short. Short vegetation allows greater competition among species, as light and heat availability increase (*ibid*).

Phosphorus, which is the limiting nutrient in much of the coastal meadow ecosystem, is stored in the soil of the meadow and in the seabed. A considerable amount of phosphorus, whatever the original source, is stored in soil organic matter, and soil microbial biomass (including mycorrhizae) are of great importance in the transfer of phosphorus to plants (Jarvis 2000). Phosphorus is the controlling nutrient for eutrophication in inland waters, while nitrogen is the limiting nutrient in marine waters (Jarvis 2000). The common reed (*Phragmites australis*) is effective in re-circulating accumulated phosphorus from these sources along the shoreline, as it draws phosphorous up through its roots. This plant, which must be cut from below the water line for at least three successive springs in order to kill it, has the quality of bringing up significant stores of nutrients, especially phosphorous, from the seabed (Lindgren 2000). Left undisturbed, the reedbeds expand and choke the waterway, causing eutrophication, decreased oxygen in water and soil, colder temperatures, and decreased habitat for other species (Pykälä and Bonn 2000; Salminen and Kekäläinen 2000). Excess phosphorus in the meadows results primarily from agricultural and other runoff into the waterways. Excess phosphorus and nitrogen also end up in meadows as a result of fencing and grazing tilled and untilled grazing lands together, using fertilisers on or near meadows, night pasturing while animals feed elsewhere, and supplementary feeding of animals while they are in the meadow (Korpilo 1997; Jarvis 2000; Pykälä and Bonn 2000).

Nitrogen is present in organic forms in the soil, but the controlling processes of the nitrogen flow in the system are those of gross mineralisation and immobilisation, as well as the carbon to nitrogen ratio of the soil (Jarvis 2000). As with phosphorus flow, nitrogen processes are dependent upon soil microbial matter, which regulate mineralisation and immobilisation processes (*ibid*). The most important production quality in nitrogen flow is the net mineralisation, which is a measure of the balance between gross mineralisation and immobilisation (*ibid*).

The consumers in the meadow system are the grazing animals and the wildlife. In a properly managed system, more nutrients should be removed from the system than added to it by the consumers. Feedback between the consumers and ecosystem is significant in all aspects. Large herbivores are keystone species in the meadow habitat, creating windows of opportunity for plant species through their grazing and trampling. They are fundamental to maintaining suitable open habitat for birds, insects, and plants (Pykälä and Bonn 2000; Salminen and Kekäläinen 2000).

Grazing in Coastal Meadows

Grazing has an immediate and direct impact on all aspects of the meadow. The effects of grazing generally result from feeding, trampling, dunging and disturbance (van Wieren 1998). Many natural processes, such as nitrogen and phosphorus cycling, become altered as a result of grazing. Grazing of plant shoots disrupts root uptake of nitrogen and results in relocation of plant nitrogen and phosphorus in below ground biomass and greater uptake and enhanced mineralisation rates (30-50%) in plants (Jarvis 2000). Trampling, which reduces plant cover and compacts soil, has been shown to result in doubling of phosphorus runoff and, although insignificant in agronomic terms, contribute to eutrophication of surface waters (*ibid*). Grazing resistance describes the ability of plants to survive and thrive in the grazed landscape (Briske 1996).

Grazing resistance falls into two categories: avoidance and tolerance. Avoidance is based on morphological and biochemical characteristics, while tolerance is dependent upon meristem availability and physiological processes (*ibid*). Stocking rate, season of grazing and species of herbivore all directly influence plant utilisation and relative expression of grazing resistance among species (*ibid*).

As grazing decreases or ceases in the coastal meadows, the common reed (*Phragmites australis*) invades flat meadows, while trees colonize upper elevations (Jutila 2001). Expanded reedbeds and eutrophication are two results of the changes (Jutila 1997, 2001). The common reed is the most competitive and insidious plant that colonises the ungrazed meadow. Research shows that grazing and haying are effective means of controlling the common reed and limiting its range (e.g. Jutila 1997, 1999, 2000; Lingren 2000).

In studies of the seed banks of coastal meadows, Jutila and Erkkilä (1998) found that there were more seeds in the upper geolittoral zones than in the middle, although the results were not significant for all species. They also found that the grazed seed bank showed much greater floristic variation than that of the ungrazed seed bank (*ibid*). This can be attributed to both the emergence of new ruderal species, as well as the survival and seed production of less competitive meadow species (*ibid*).

The common reed (*Phragmites australis*) effectively uses resources and shading to out-compete other species (Pykälä and Bonn 2000; Jutila 2001). Jutila (2001) found that other tall species, such as *Calamagrostis stricta* and *Agrostis stolonifera* form the lower littoral zone with *Phragmites australis*. *Juncus gerardii,* however, dominates this zone in the grazed meadow (*ibid*). In general, the transition zone of the grazed meadows is characterised by a narrow drift wall, while the vegetation boundaries in the ungrazed meadows are less distinct (*ibid*). The results of Jutila's study correspond with those of other, similar studies (*ibid*).

Livestock also aid plant diversity by spreading seeds (through faeces and by carrying in their fur) and breaking up the ground for stored seeds to germinate (Korpilo 1997). Timing and severity of grazing have the greatest effect on annual species and "filler" species that spread vegetatively to cover bare ground (Sheath and Clark 2000). Diversity in plant growth is also enhanced when animals avoid grazing where they have defecated. This provides possibility for plants in these areas to grow to maturity and reproduce (Korpilo 1997).

In general, most seashore species suffer from the effects of grazing, although the most frequent species are indifferent (Tyler 1969 ref: Jutila 1999; Jutila 2001). As a result, it is the stress tolerant monocots and halophytes that seem to most benefit from grazing in the seashore communities (Jutila 1999). The stress tolerant ruderals are most successful in the grazed landscape, while tall, competitive species thrive in the ungrazed landscape (Ekstam 2002). Salt tolerant species (e.g. *Juncus gerardii, Triglochin maritima L.* and *Plantago maritima*), which are often less competitive, appear to benefit from grazing, while *Filipendula ulmaria, Galium palustre, Leontodon autumnalis, Pedicularis palustris, Phragmites australis, Rhinanthus serotinus* and *Vicia cracca* all are negatively affected by grazing (Jutila 1999).

In Jutila's studies of grazed and ungrazed seashore meadows, she found that grazing reduces species richness at the seashore and increases it in the delta (Jutila 1997, 1999, 2001). More specifically, the abundance of annuals and dicots decreased, while the proportion of monocots increased, with more rare species found in the grazed grasslands than in the ungrazed (Jutila 2001, 1999). Grazing without mowing has been found to reduce species diversity, as does too high or too low grazing pressure (Pitkänen and Tiainen 2001).

Intensity of grazing and stage of succession are important factors influencing measurement of plant biodiversity in the meadows, as plant vitality is affected before species composition. Additionally, size of study plots is important in comparing grazed to ungrazed pasture, as the grazed pasture area is coarser in composition (Jutila 2001). Selective grazing in meadows tends to result in more severe grazing of late-successional dominants compared to subordinate species because of their greater growth rate and lesser expression of avoidance (Briske 1996). Although increased stocking rate can be used to discourage selective grazing, stocking rates can easily be exceeded before selective grazing is eliminated (*ibid*).

A wide variety of fauna are dependent upon the grazed meadow landscape for habitat. Many migratory birds are dependent upon short growth coastal meadows for stopover points, while other birds nest during the summer in these areas (Saari et al. 1995; Vainio et al. 2001). Birds take advantage of large herbivore disturbance to prey on insects and amphibians (van Wieren 1998). Dung beetles that live in cattle and horse faeces are dependent upon the continued grazing of these animals for their existence (Pitkänen and Tiainen 2001; Vainio et al. 2001). These dung beetles also provide food for several bird species (van Wieren 1998). Information on insect, moss and lichen species in the coastal meadow is limited, but it is known that many of these species are dependent upon the traditional open landscape for habitat (*ibid*). Butterflies, for example are known to benefit from varied grazing intensity, as different species prefer plants of different heights (Pitkänen and Tiainen 2001). Studies show that butterfly populations are lower in grazed than in ungrazed meadows, but that the populations tend to crash because of overgrowth when the meadows are ungrazed for 20 years or more (*ibid*). High intensity grazing results in a smaller proportion of potential niches for insects (Pöyry 2002). Intermediate disturbance and other non-equilibrium models of community structures suggest that moderate levels of grazing will support a more diverse insect community than either high grazing or no grazing (*ibid*).

Cultural History and Aesthetic Value of Traditional Landscapes

In addition to the ecological importance of traditional landscapes, including coastal meadows, these landscapes are a part of the cultural history of Finland and are valuable for historical and aesthetic reasons. Desire to preserve the knowledge and history of traditional agricultural methods and lifestyle are culturally significant. Further, tools and traditions that have developed through the use of traditional landscapes are an important part of Finnish culture. The traditions of haying, fencing and building, for example, are the source of the Finnish “talkoot”, or volunteering that is an important part of Finnish culture and identity (Salminen and Kekäläinen 2000).

Meadows also add to the completeness of constructed traditional landscapes of farm buildings, kitchen gardens and landscaped lawns that are found throughout Finland. Enhancing these heritage sites through preservation and management serves both aesthetic and conservation purposes. Regional conservation of farm and village landscapes, including the meadows upon which agriculture in the area was once dependent, helps people to better understand the local and regional history of an area. Further, prehistoric artefacts, including graves, foundations of buildings, tools, etc. are often associated with these landscapes (Salminen and Kekäläinen 2000; Vainio et al. 2001).

Traditional landscapes are also valued in research and education. From landscape architecture and natural sciences to outdoors education and leadership, traditional landscapes provide qualities unavailable in other habitats (Salminen and Kekäläinen

2000). Community involvement in the care and maintenance of traditional landscapes also provides opportunities for education and community building.

The beauty of heritage landscapes is a quality that must not be overlooked. Heritage landscapes are a part of a region's identity and inspire pride and a sense of place in people from those areas. Coastal meadows, left unmanaged, lose not only much of their biodiversity, but also their aesthetic qualities that give value to a region. The open meadows of Finland have inspired national poets and painters of the country throughout history, and the landscapes themselves are a part of the regional identities of the people of Finland (Luostarinen and Yli-Viikari 1997; Salminen and Kekäläinen 2000).

Recently, the aesthetic qualities of the cultural landscape have become marketable. The fast growing eco- and farm tourism industry that has become an important source of income for many farmers and others living in the countryside depends upon both the beauty and historical value of the cultural landscape to draw people to the countryside. People come for farm visits and countryside tours for the fresh air, open landscape, relaxation and cultural and historical sites the region has to offer. Loss of the cultural landscape, including the grazing animals of the meadows, will lessen the enjoyment of the countryside and diminish the quality of life for those who live there (Salminen and Kekäläinen 2000).

Chapter 2

Management of Coastal Meadows

Management Recommendations

Management Perspective

Sustainable management of coastal meadows requires an understanding of both the natural ecology and the farm production system. Sheath and Clark (2000) propose that systems management has two parts, design and grazing management. Design includes how the meadow system will fit into the overall farming system and how forage surpluses and nutrition needs of the grazers will be handled. Level and pattern of pasture productivity and feed demand are the two primary components by which the grazing in the context of the farm economic system are defined *(ibid*).

The SWAPAH framework is a useful tool that aids grassland managers in identifying and addressing the critical components driving the outcome of managed grasslands (Stuth and Marachin 2000). SWAPAH, which is an acronym for soil, water, atmosphere, plants, animals and humans is a systems approach to decision making for the grazing and farm system (*ibid*). On a hierarchical scale, all of these key concepts can (and should) be addressed from the global circulation to the individual community level (Figure 2.1). Personal perception, including goals and needs, combine with the realities of politics and economics to complement the ecological considerations of the system for a truly holistic systems perspective.

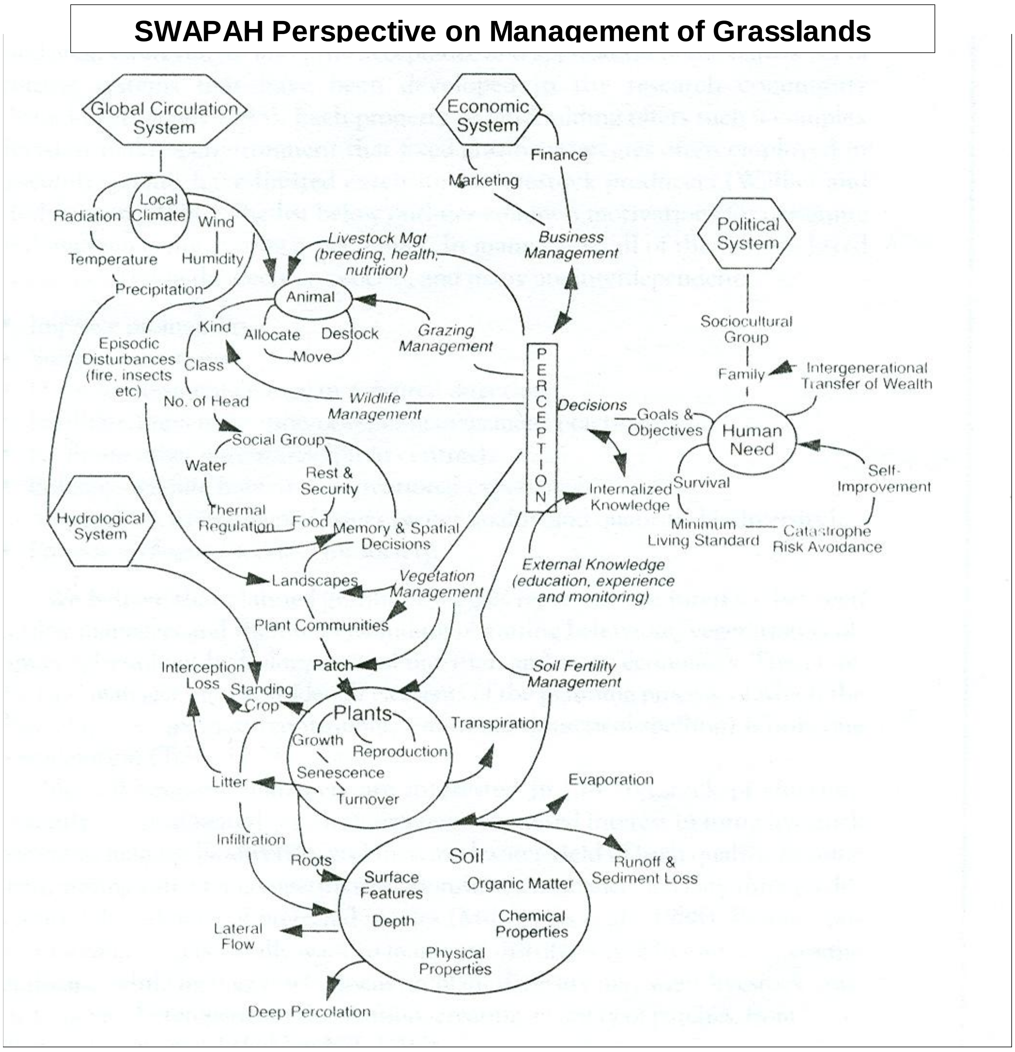


Figure 2.1 Spatiotemporal complexity in the decision-making environment of the grazing system. The schematic illustrates the hierarchical view of the SWAPAH concept of soil, water, atmosphere, plants, animals and humans for management. (Stuth and Marachin 2000).

There are several basic points that must be understood in undertaking management of any traditional landscapes, including coastal meadows. Most importantly, perhaps, is that there is no single optimal management scenario for all coastal meadows (Salminen and Kekäläinen 2000; Jutila 2001; Partanen et al. 2002). The working group on traditional landscapes, formed by the Ministry of Environment to assess the current state of traditional landscapes in Finland, states that the goal of traditional landscape management is to preserve and strengthen the biological, cultural and landscape qualities specific to a particular locality (Salminen and Kekäläinen 2000). Management is dependent upon the goals of the nature conservation and long-term use of the meadow. Management decisions are based on strategic (long-term), tactical (near future) and operational (immediate) goals and needs, and generally include diverse management goals (Stuth and Maraschin 2000).

Environmental concerns are sometimes the primary driving force in heritage landscape conservation. Goals may be to save an individual species or a whole community, increase biodiversity, or return the entire meadow back to its original state as a traditional landscape. Other reasons to take the meadow into use may include the farmer's desire to expand grazing area or diversify farm production. Economic goals may also include desire to increase eligibility for environmental subsidies. The goals of the conservation and use of the meadow will colour the perspective by which appropriate management is determined.

Ideally, management techniques are chosen based on the meadow's own history of use and maintenance (Salminen and Kekäläinen 2000). A well maintained coastal meadow should consist of short growth grasslands with clear zone boundaries (*ibid*). Common reed and other tall plants, as well as bushes, scrub and trees should not be allowed to dominate the landscape or spread too far into the meadow (*ibid*).

Despite differences in management perspective, there are some common points that should be followed in all restoration and management cases regarding seashore meadows. It is absolutely essential to remove more nutrients from the meadow than come into it (Partanen et al. 2002; Salminen and Kekäläinen 2000). Artificial fertilisers should never be used on meadows, as they increase the prevalence of tall growing, nitrogen fixing species and send meadowland specialists into decline (Korpilo 1997; Pitkänen and Tiainen 2001). Ploughing, harrowing, sowing of feed crops, and use of agricultural chemicals should also not be used (Lindgren 2000). Although haying is beneficial for the meadow, lawn mowers should not be used in the meadow, as they damage plants and create fodder for eutrophication processes (*ibid*). Supplementary feeding of livestock on pasture should be avoided. It is better to remove livestock from the coastal meadow when fodder is scarce than to keep the animals on the pasture and supplement their feed with hay, grain or concentrates (Lindgren 2000). Rotational grazing is an excellent way of achieving this end (Korpilo 1997).

Filtering buffer zones have been shown to be an effective means of limiting runoff into waterways, including the Baltic Sea. The minimum width for verges and buffer zones is 15 m (Pitkänen and Tiainen 2001). These verges, with their year round vegetation cover, decrease the amount of solid particles and their bound nutrients reaching the waterways by about 20%, but they are ineffective in filtering dissolved nutrients (*ibid*).

Grazing Recommendations

Significant differences exist regarding impact on, and ability to utilise, meadow forage by different species and breeds (Pykälä and Bonn 2000). While there is still much to learn about differences in breeds, landraces that have been bred with the meadows are the best grazers for these landscapes (*ibid*). In reclaiming and restoring the traditional landscape, it is best to make use of the types of animals that were previously used in the area (Partanen et al. 2002). It has been demonstrated that the Finnish heritage breeds of cattle, horses and sheep are more efficient grazers of natural meadows than the more highly refined production breeds (Korpilo 1997; Lingren 2000). As milk production has become all but non-existent on the coastal meadow, most of the cattle on the meadows are reared for beef production (Lindgren 2000; Pykälä and Bonn 2000). Of the beef cattle breeds, Herefords are best suited to the coastal meadows because of their relatively small size and ability to thrive on a variety of different natural fodder (Lindgren 2000).

Cattle are often referred to as managers of the heritage landscape because of the multiple functions they have in maintaining the open grasslands. The Finnish Ministry of Agriculture and Forestry recommends grazing cattle on coastal meadows for maximum benefit for both plants and animals (Korpilo 1997). Following the Finnish heritage breeds, beef cattle are considered to be the most suitable animals for all meadow types, as they do not graze grasslands too selectively or too short (Pykälä and Bonn 2000).

Animals should begin grazing the meadows as early in the summer as possible in order to achieve good fodder quality in the meadow (Korpilo 1997; Lindgren 2000). It is recommended that animal density be greater in the early part of the growing season, when lush, high quality growth is available (*ibid*). Higher intensity grazing during this time removes nutrients and stimulates growth. Conversely, animal intensity should be lowered during the end of the summer to avoid compaction, trampling, overgrazing and poor animal nutrition (Korpilo 1997). Alternately, rotational grazing (removing animals from the system for 2-3 weeks) has a similar positive effect on the pasture (*ibid*). Continuous grazing by the same number and species of animals during the entire grazing season results in uneven grazing and increases the risk of parasites in the animals (*ibid*). Because shade-grown plants have a lower digestibility than those grown in an open, sunny environment, it is recommended that the meadows be kept clear of trees to facilitate greater nutritional productivity for grazing animals (*ibid*). Grazing intensity should be adjusted during the year depending upon weather conditions, as considerably more biomass may be produced during wet years than dry ones (Partanen et al. 2002).

In addition to cattle, horses and sheep may be pastured on seashore meadows. Sheep are generally not pastured in the coastal meadow as much as cattle, as they prefer drier, more upland meadows (Lindgren 2000). In general, sheep should not be grazed exclusively on coastal meadows, unless annual haying is also practiced, as they are selective grazers and may fail to keep tall growing plants and bushes under control, thus contributing to overgrowth of the meadows (Pykälä and Bonn 2000). Integrating sheep and goats into cattle dominated grazing systems has been shown an effective means of reducing such undesirable plants as ragwort (*Senecio jacobaea*) and gorse (*Ulex europaeus*) (Sheath and Clark 2000). Horses can be used to level the grazing field after cattle have grazed, as they eat coarser grasses than cattle and graze the meadows more uniformly (Korpilo 1997). Horses are best suited to dry, vast meadows. Horses tend to rest regularly in the same area, producing well-fertilised areas with varied flora from other parts of the meadow (Partanen et al. 2002).

Although semi-natural meadow production varies according to location and fluctuates yearly depending upon weather conditions, a general rule of thumb for stocking rate of coastal meadows is one animal unit per hectare (Jutila 2001), or one mother cow and calf per 1.5-2 ha (Partanen et al. 2002). The Finnish Ministry of Agriculture and Forestry has calculated the approximate capacity of coastal meadows in Finland as the following (Table 2.1):

Table 2.1 Average Animal Density (animal/ha) during the whole grazing period on a Finnish Coastal Wetland (Korpilo 1997).

Coastal Meadow 20%-40% harvest productivity					
Heifer	Heifer	Beef Cattle	Breeding Cow	Ewe	Horse
>1 year	*<1year*	*< 1year*	*+ calf*	*+2.5 lambs*	
1.5-3.0	1.0-1.9	0.7-1.4	0.5-1.0	2.0-4.0	0.8-1.6

The numbers in Table 2.1 are based on heifer growth at 600g/day and beef cattle (bulls) growth averaging 1 kg/day. Breeding cows and sheep have the maintenance of their young, while the figures for horses are based upon maintenance and light work. Harvest productivity is an indication of how much of the gross biomass is available as nutrition for grazing animals. The grazing season is generally from the beginning of May until the end of September (*ibid*). The grazing season should end before autumn rains begin, as the ground otherwise becomes muddy (Partanen et al. 2002). Nesting birds benefit when coastal seashore meadows are grazed as long into the autumn as possible, as grazing improves the nesting environment for the following spring (*ibid*).

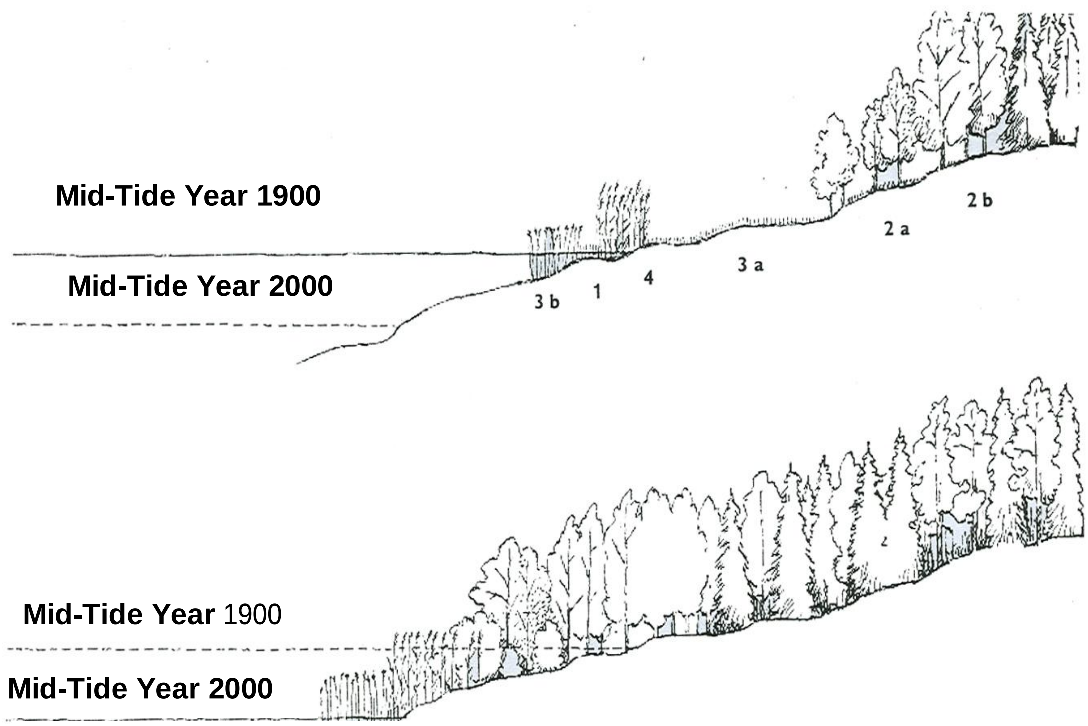
Although hay, silage and other feeds should not be brought into the meadow, it is recommended that livestock be provided with free access to mineral salts (Korpilo 1997). Mineral supplements should be protected from rain and from becoming dirty. Fresh water should also be brought to the meadow if good quality water is unavailable naturally. As watering points suffer from trampling, it is advisable to shift watering points when possible to allow the ground to recover. Creeks, ponds and other natural sources of water are acceptable for animals when the quality is good and the shoreline tolerates the heavy traffic of the livestock (Korpilo 1997).

Haying Recommendations

Haying removes nutrients from the meadows more effectively than grazing (Pykälä and Bonn 2000). The uniform cutting of haying is also beneficial to the meadow in maintaining a short, open landscape without the patchiness often associated with grazed (especially undergrazed) meadows. In addition to haying as primary maintenance for a meadow, it can also be used to “finish” a meadow that has been undergrazed as a result of either understocking, late stocking, or browsing by selective grazers like sheep.

Haying traditionally was carried out once per growing season, after which cattle were allowed to graze the meadows (Figure 2.2). This system, however, was in use when winter fodder for livestock was gathered exclusively from non-cultivated sources. This labour intensive process is no longer practiced in meadows managed through grazing.

Traditional Haying for the Rehabilitation of a Coastal Seashore



1. First, the meadow was hayed by parcel around midsummer.
2. After 12.7, the open meadow above the larch area was hayed (2a). Larch area and patches of birch were hayed and thinned (2b).
3. Primary hay areas were hayed from the end of July until mid-August (3a.). Reedbeds were hayed and the hay was given to the animals as fresh fodder (3b).
4. Lastly, reedbeds hayed at the end of August (4).

Figure 2.2 Zonal conditions in different elevations of a hayed and unhayed coastal seashore meadow. The top illustration shows the results of haying maintenance, while the meadow underneath shows how the abandoned meadow looked before rehabilitation. The example is taken from Hailuoto coast. (Salminen and Kekäläinen 2000).

Ideally, haying should be done after flowering and dispersal of seed (Partanen et al. 2002). Haying is a time and labour intensive process. In the Finnish Archipelago National Park, haying of coastal and other semi-natural meadows has cost approximately 950-1270 euros per hectare (6000-8000 mk/ha) when done by hand by salaried workers (Lindgren 2000). On larger areas, where it has been possible to do the haying by machine, the cost drops to about 95 euros per hectare (600 mk/ha), but raking and collection of hay is not included in the price (*ibid*). The use of machinery in the wet meadows of the coast increases the risk of compaction and lessens the possibility of preserving rare, late seeding plants that will fail to reproduce when cut during hay season (*ibid*).

Periodic clearing of brush and trees (about every five years is enough) is beneficial to semi-natural meadows, as is spring clearing of tuft grasses and other grassland species that were left ungrazed during the previous year (Partanen et al. 2002). This kind of haying is, however, unpractical in the wet meadows and is unlikely to take place on working farms. Clearing of trees and bushes in winter, however, is more feasible and should be incorporated into the meadow management plan.

Projects and Organisations

Finland joined the European Union only in 1995, but the decision to join the EU stimulated changes in agriculture, including interest in traditional landscapes. In the early 1990s, this led to the creation of the Heritage Landscapes Working Group and similar initiatives from the Ministry of Environment. Mapping of traditional landscapes in Finland began in 1992 and was overseen by the Finnish Centre for Environment (previously the Governing Board for Water and Environment) on privately owned lands and the Governing Board for Forestry (Metsähallitus) in publicly owned lands (Salminen and Kekäläinen 2000; Heikkilä 2001). The project was funded through the Finnish Ministry of Environment (Pykälä and Bonn 2000; Salminen and Kekäläinen 2000). The mapping project for heritage landscapes lasted from 1992-1998 (*ibid*). The results of this project revealed a distressing trend toward loss of heritage landscapes and their biodiversity. The goals of the project were to determine the current situation of agricultural heritage landscapes, including defining their care needs and goals for management (*ibid*). One of the results of the project was that the Working Group on Heritage Landscapes classified valuable traditional landscapes into seven categories specified by state, regional and local value (*ibid*). In addition to the contemporary state of traditional landscapes, each area report includes history, land use/management and other relevant information regarding the regional landscape (*ibid*). Another result of this work has been that Finland has set a goal of having all state owned heritage landscapes rehabilitated or in rehabilitation by 2010 (Kekäläinen and Bonn 2000).

One part of the six year MYTVAS II project (Monitoring of the Impact of the Agroenvironmental Subsidy Scheme), begun in year 2000, has substantially clarified the quality and extent to which traditional landscape management has been actualised (Heikkilä 2001). The project also studies grazing effects on meadow plant, butterfly and pollinator species (*ibid*). The FIBRE project for biodiversity research also investigates biodiversity in several different research projects (*ibid*). Another project, LIFE-Nature project, is concerned with the restoration and management of meadows in Finland, Sweden and Estonia (Pitkänen 2002). This project links governmental and nongovernmental organisations in an effort to increase cooperation among the different organisations working for restoration and management of meadow landscapes (*ibid*).

Volunteer efforts involving community and environmental organisations have been important in pioneering and maintaining heritage landscapes in many areas of Finland. World Wildlife Fund (WWF) and Finnish Nature Association (SLL) are two non-profit organisations that have been particularly active in organising rehabilitation, including clearing and haying, of cultural landscapes (Heikkilä 2001; Pykälä and Bonn 2000). Since 1977, WWF has held over 140 volunteer, week long, restoration camps in Finland (Pitkänen 2002). In many cases, meadows that have been rehabilitated by individual groups (Organisation of Biology Students, Finland Fund, etc.) are maintained annually through volunteer hay work (Pykälä and Bonn

2000). The majority of traditional landscape care in Finland is still unorganised on a broader level and, instead, is carried out locally by small groups (*ibid*). In many cases, governmental and non-governmental organisations join forces locally to rehabilitate overgrown and eutrophic meadow landscapes (*ibid*).

Natura 2000

Natura 2000 is a European Union program to increase protections for environmentally valuable sites in the member countries. The program allows each member state to choose the mechanisms it will use to implement conservation measures in its territory (European Commission). The Birds Directive of 1979 and the Habitats Directive of 1992 form the foundation of Natura 2000, but the aims of such European programs as the Helsinki Convention on the Baltic Sea (1974) and the Ramsar Convention on the conservation of wetlands (1971) are also in accordance with those of Natura (*ibid*). All of the conservation areas created under the Birds Directive are included in the Habitat Directive (*ibid*). The terms of Natura 2000 are outlined in the Habitats Directive from the European Union[1]. The primary components of Natura 2000 are (*ibid*):

- Prepare a scientific assessment at the national level of sites of ecological importance
- Identify sites of community importance from the national sites
- Designate special areas of conservation
- Identify special case of bird habitat

Eleven biotopes of the European Union's Habitat Directive, including coastal seashore meadows, are found in Uusimaa (Pykälä and Bonn 2000). Coastal meadows are the most well represented traditional landscapes in the Natura program in Finland (*ibid*). Actualisation of Natura 2000 goals in the traditional landscape is primarily through agreements with landowners and differs significantly from how

[1] For information regarding the EU's NATURA and other environmental programs, see http://www.europa.eu.int/environment

Natura goals are met in other parts of Europe (*ibid*). These differences are due to land use and climatic factors that differentiate the northern heritage landscapes from those in central Europe (*ibid*). 13% of the valued traditional landscape of Uusimaa is included in the Natura 2000 program (*ibid*).

Subsidies and Regulations

The primary funding source for managing and protecting traditional landscapes is the agricultural subsidy system (Heikkilä 2001). Currently, 92% of farmers in Finland receive environmental subsidies (Heikkilä 2001). This is the highest percentage anywhere in the European Union (*ibid*). Farmers have taken advantage of these environmental subsidy programs to the extent that 15,723 ha of traditional landscape were managed under agreement and received subsidies (Salminen and Kekäläinen 2000; Heikkilä 2001). Land area minimums and requirements for active farming have, however, limited subsidies to only 1/5 of the valued traditional landscapes in Finland (Salminen and Kekäläinen 2000).

The environmental subsidy system requires that all farmers that enter into the program perform a basic level of maintenance, as well as additional maintenance specific to the biotope and the farming methods employed (Heikkilä 2001). The aim of the environmental subsidy program, including special subsidies, is to reimburse farmers for their expenses in their environmental stewardship and management work with heritage and other landscapes (*ibid*). The regulations governing basic and additional management activity requirements for environmental subsidies are outlined in Ministry of Agriculture and Forestry's statement 646/2000 Basic and Additional Activities for Environmental Subsidies (*ibid*).

Special subsidies are available to help advance several areas deemed important for ecological sustainability and biodiversity in the agricultural landscape. These subsidies include the following (Salminen and Kekäläinen 2000; Heikkilä 2001):

- Care of traditional landscape
- Advancement of Biodiversity
- Landscape development and management
- Development and management of buffer zones
- Development and management of drainage basins and wetlands
- Ecological agriculture
- Raising of heritage breeds of domesticated animals
- Reduction of acidic area
- Reduction in fertiliser losses

Farmers receive these subsidies for five years at a time and are required to submit a management plan with the application (*ibid*). The first project period for environmental subsidies, 1995-1999, focused heavily on water protection, with traditional landscape management making up only 1% of the program (*ibid*). In the 2000-2006 program, water quality is still of primary importance, but more focus has also been given to reducing pesticide use (*ibid*). The Working Group on Heritage Landscapes recommends that greater emphasis be placed on increasing and protecting biodiversity (Salminen and Kekäläinen 2000).

Because Finland has not had any other programs to specifically address the needs of heritage landscapes, the special subsidies program for heritage landscapes has been, since its inception in 1995, the primary source of support for these landscapes (Salminen and Kekäläinen 2000; Heikkilä 2001). The second most important source of economic support for heritage landscapes is state environmental conservation funds (which were the only long-term form of state support before Finland joined the European Union) (*ibid*). Archipelago and other regions have also been successful in receiving short-term subsidies for environmental management from a variety of different projects (*ibid*). Environmental subsidies seem to be well suited to coastal meadow maintenance, with 56% of coastal meadow area receiving environmental subsidies (Pykälä and Bonn 2000).

The results of heritage landscape management vary. Of 130 farms receiving heritage landscape subsidies, only 38% met the criteria for satisfactory management when followed up (Heikkilä 2001). The primary problem found in the semi-natural grasslands was that additional feed given to grazing animals resulted in an influx of nutrients to the meadow (Salminen and Kekäläinen 2000). Although agricultural officials audit a minimum of 5% of subsidy recipients, environmental officials lack resources to participate in monitoring programs (*ibid*). As a result, expertise in biological impact assessment and effectiveness of management are often incomplete (*ibid*).

Reactions to the environmental subsidy programs also vary. Farmers generally report that the subsidies are barely enough to cover the costs of meadow maintenance (Heikkilä 2001). Farmers also report that they are motivated to care for the landscape and consider the extra income provided by subsidies important (*ibid*). However, the low per hectare price paid in subsidies generally makes haying unfeasible for the working farm (Pykälä and Bonn 2000). Bureaucratic red tape and late decisions tend to frustrate farmers (Heikkilä 2001). Badly planned forms and poorly defined requirements and understaffing in the Centre for Environment have also resulted in a traditional landscape management program that is insufficient to secure the conservation of valuable areas (Pykälä and Bonn 2000).

Other problematic areas with environmental subsidies involve determining who is able to qualify to receive subsidies. Farmers must have a minimum of three hectares of field production in order to apply for subsidies (*ibid*). Additionally, farmers over the age of 65 are unable to apply for environmental subsidies (Heikkilä 2001). These two factors exclude many farms with traditional landscapes from being able to access environmental subsidies. The Heritage Landscape Working Group recommends revision of these policies to help bring more heritage landscapes into the subsidy program.

Part II: Field Research

Chapter 3

Research Question and Methodology

Purpose of the Field Study

The purpose of this study is two-fold. In the literature review of Chapters 1 and 2, I demonstrated the importance of coastal meadows ecologically, culturally, and economically. The purpose of the fieldwork portion of this study is to determine the actual and potential fodder productivity in coastal meadows in Southern Finland.

The goals of heritage landscape management are to preserve the landscape of traditional agriculture and to protect the biotopes formed by the processes of traditional agriculture and the species dependent upon these landscapes (Salminen and Kekäläinen 2000). This study supports these goals by identifying the fodder productivity of the coastal meadows in Itä-Uusimaa. This research adds to the existing information on meadow productivity and should be useful to those working with the conservation of seashore meadows by providing information on the effect of cutting/grazing intensity on fodder quality and quantity. This information may be used in determining grazing rotations and their effects on the ecology of the meadows and nutrition of the grazing animals.

According to Salminen and Kekäläinen (2000), the current heritage landscape area is not enough to ensure the preservation of biotopes and their species diversity. The Working Group on Heritage Landscapes has set the goal of having 60,000 ha of heritage landscape in management by 2010 (*ibid*). This should include, in addition to 20,000 ha of already valuable heritage landscape, 40,000 ha of long-term unmanaged/unused areas in need of rehabilitation (*ibid*). The field research of this study can aid researchers and farmers in planning the rehabilitation and management of new areas of coastal meadows.

Heritage landscapes must continue to be a part of agricultural production if they are to survive on even the small scale that exists today. Salminen and Kekäläinen (2000) state that farmers should carry out the majority of heritage landscape maintenance and that it should be linked to production. Farmers need practical information on how many animals the meadows can support and what kind of production they can expect from animals grazed on the meadows. The experiences and data recorded in this study add to the scant literature on grazing capacity in natural meadows and provide a resource for farmers who may be interested to rehabilitate their own seashore meadows.

Methodology

A holistic systems methodology (Checkland 1981) of data collection has been used in this study. Following the literature review of the previous section is a rich picture (Chapter 4) of the two farms and their coastal meadows studied in this project. The rich picture was compiled through on-site farmer interviews, historical information about the farms, farm visits, etc. After the rich picture are the qualitative and quantitative results of the study (Chapter 6). The methods used for data collection are explained in detail in Chapter 5: Materials and Methods. The study has not been limited to only empirical data collection. Rather, the opinions of the farmers, including their insights into the types of changes that have occurred in the meadows since they have rehabilitated them, the challenges they have faced, etc. are considered. In the discussion, external factors affecting the farmers' decision-making, including the economic and political climate, are also discussed.

Chapter 4

Rich Picture of Two Farms

Uusimaa

Both of the study sites are located in Itä-Uusimaa (Eastern Uuusimaa). The majority of Uusimaa falls into the southern farming region (southern boreal vegetative zone) (Pykälä and Bonn 2000). Although some parts of the coast of Uusimaa and parts of Länsi-Uusimaa (Western Uusimaa) are in the hemi boreal zone (oak zone), both of the sites in this study are in the southern boreal zone.

The climate of Uusimaa is influenced by the proximity of the Baltic Sea (Huovila and Kolkki 1967; Pykälä and Bonn 2000). In the archipelago, rise in temperature in the spring, and its subsequent drop in the autumn, occur later than in inland areas (*ibid*). In addition to climate, differences in pH affect species diversity in Uusimaa. Areas with more chalk in them are clearly more species-rich than those with more of the granite bedrock composition common to many areas (*ibid*).

The vegetation and landscape of Uusimaa gets rougher as one goes north and east. Species diversity also diminishes. Itä-Uusimaa has much clay soil, although Uusimaa consists mostly of moraine soils. Bare bedrock and clay areas are common, and Itä-Uusimaa is dominated by granite bedrock. It is thought that livestock husbandry is probably older than farming in Uusimaa (*ibid*).

Similarly to the rest of the country, the traditional landscape of Uusimaa is endangered. Approximately ¼ of the Finnish population lives in Uusimaa, so some of the agricultural landscape has succumbed to urbanization (*ibid*). However, the region has an above average number of old meadows compared to the rest of the country (*ibid*). The meadows of Majvik Gård and Bosgård (Figure 3.1) are two examples of existing coastal meadows that, like most of the meadow landscape in Uusimaa, were taken out of agricultural production in the late 1950s and early 1960s. These meadows, one small and one large, were taken back into agricultural use in the early 1990s, before Finland joined the European Union. The following rich picture descriptions of the two farms are based on interviews with the farmers conducted in 2003.

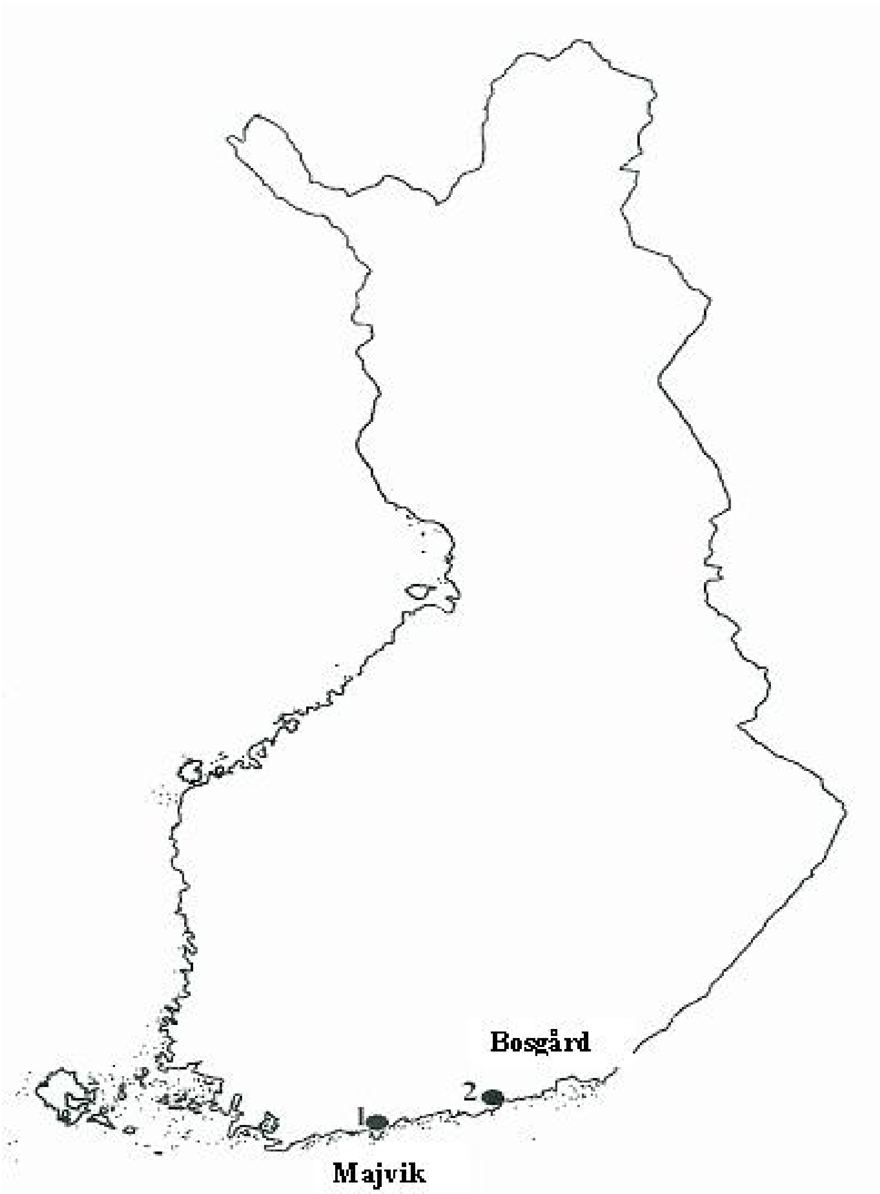


Figure 3.1 Map of Finland showing the locations of the two farms where field research was conducted for this project. Majvik is located approximately 9 km east of Helsinki (11 km from city centre), while Bosgård is located approximately the same distance east of Porvoo.

Majvik

Majvik is a family farm of 50 ha. It is located in Sipoo Municipality, approximately 9 km from the eastern border of Helsinki, in Östersundom. It is a biodynamic farm with integrated grain, garden and animal production. The farm has been in the same family for several generations but was rented out for a few decades. The current owners, Niklas and Myrna Ramm-Schmidt, converted the farm from conventional pig production to biodynamic, integrated farming. In the early years, milking goats were kept at the farm. The farm has been managed biodynamically for more than 20 years.

The number of animals on the farm varies, but is generally in the range of about 25 chickens, one mother pig and her piglets (all living outdoors), and 3-4 cows and their calves. The cows are Eastern Finnish Cattle (Itäsuomen karja). Seven hectares of grain production is spread out over 18 hectares of arable land. Vegetables are produced on about two ha of land. Another two hectares of land are planted with potatoes. The remaining arable land is in hay production (generally 45% of the arable land). Products are sold primarily through direct sales either from the farm's own farm shop or through direct orders.

Farm Family

The farm is operated by Myrna and Niklas Ramm-Schmidt. They are in their 50s and generally in good health. Niklas has a degree in chemistry and worked for some time in that field. They are both ecologically-minded and prioritise the ecological health of their farm over economic considerations. They have two adult sons. The sons live on the farm but work/study off-farm.

In addition to the two farmers, practicants from the biodynamic and other gardening/agricultural schools regularly work on the farm in the summer. Labour may vary from about 2-5 practicants during the summer. In the past, there has also been one year round employee. Machinery on the farm is generally old fashioned and suited ideally to small-scale farming. Much of the work with the vegetables and berries is done by hand.

The conditions on the farm fulfil all of the requirements and recommendations of the livestock well-being indices for both conventional and organic farming (Roiha 2000), except that barbed wire is used in some of the fencing in the coastal meadow.

Coastal Meadow

Permanent pasturage at Majvik is approximately four hectares, of which a bit under two hectares is coastal meadow. The cows graze the coastal meadow extensively during the summer months and alternate between this meadow and other permanent pastures. Grazing in the meadow is rotational, with the grazing period usually about 1-2 weeks before the cows are moved to another pasture. Neither extra feed nor minerals are brought to the coastal meadow. Fresh water is available from a stream running through the meadow. However, the cows are brought in for milking and receive extra feed during this time. The grazing period in the meadow is from about June until October. The cows spend the wetter part of the season and the winter months indoors and in a dry forest pasture.

The coastal meadow was taken into use in 1990. Rehabilitation included clearing of trees and fencing in the area. Before being taken into use by the current farmers, the meadow had been unused for about 30 years. The farmers began cutting trees and rehabilitating the meadow in 1983. Niklas also onces attempted mechanical haying of the meadow and took the grass away for composting. This significantly changed the growth of the meadow, from lush to poor, for a few years.

The farm receives environmental subsidies for grazing and maintaining the coastal meadow. The meadow is predominately wetland and is surrounded almost entirely by forest. The farm includes 28 ha of forest that is sustainably managed by the farmers. Bordering the farm is forest owned by other private individuals. This forest is not managed in the same way as the forest owned by Majvik Gård.

Yearly labour input for the meadow includes cutting and harvesting trees and collecting branches, cutting and composting grass, fencing, and managing the grazing cattle. The highest labour input is with clearing of trees and brush (c. 80 hours), followed by moving the cattle (20 h). Cutting grass and managing the compost takes about 10 hours per year, while maintenance of the fencing takes about six hours per year.

The farmers are generally satisfied with the meadow and its productivity. Improvements they would like to make include safer and better quality fencing. The farmers would graze the meadows whether or not they received subsidies for it. For Niklas and Myrna, the well-being of the cows and the quality of the natural environment means that they want to maintain the natural meadow. Myrna and Niklas are careful about not overgrazing the meadow, as they have observed some rare flowers in meadow and do not want them trampled.

Bosgård

Bosgård is located in the vicinity of Porvoo's Pikku Pernajanlahti (Figure 4.2). Pernajanlahti is a nationally recognised region of environmental importance (valtakunnallisesti arvokas ympäristöalue) (Pykälä and Bonn 2000). Although the smaller Pikku Pernajanlahti does not carry this same designation, it is located within approximately 10 km of Pernajanlahti. According to Hirvonen and Rintala (1995 ref: Heikkilä 2001), about 25 different bird breeds nest in Pikku-Pernajanlahti.

Bosgård consists of approximately 700 ha of field and forest. The farm is specialized in beef production and has about 200 Charolais and Aberdeen Angus cattle at any one time, with 85-100 mother cows. There are currently four insemination bulls, which roam with the individual herds in the summer. Calves are sold when they are approximately 1½ years old. The average age of mother cows is six years. Meat is sold only to order through direct sales (customers pick of the packages at the farm). Wheat, barley, rapeseed and silage/hay are produced on 260 ha of arable fields. The grains are sold wholesale. Almost all of the fields are managed with light cultivation, and integrated pest management (IPM) is practiced. The 280 ha of forest are managed entirely by an outside firm.

The farm has been owned and managed by Kaarlo Schildt since 1980. The farm has been in his family since his grandfather bought it in 1953. The area, however, has been farmed since the 1400's, and the village of Bosgård has existed since at least the 1200's.

Kaarlo (Kalle) Schildt was born in 1953 and is in good health. He has a Master of Science Degree in Agriculture. Kalle was originally a grain farmer and also did consultation work in agriculture. As a farmer, he is concerned about the well-being of his animals and his farm. “The older I get, the greener I get,” he says when asked about his opinions on farm and environment issues.

Bosgård employs one full time employee in addition to Kalle, himself. This employee was born in 1967 and has a professional agricultural education and very professional skills. Other employees include four part-time practicants who work during the summer months. Kalle’s two adult children are both studying business and may be interested to take over the farm in the future.

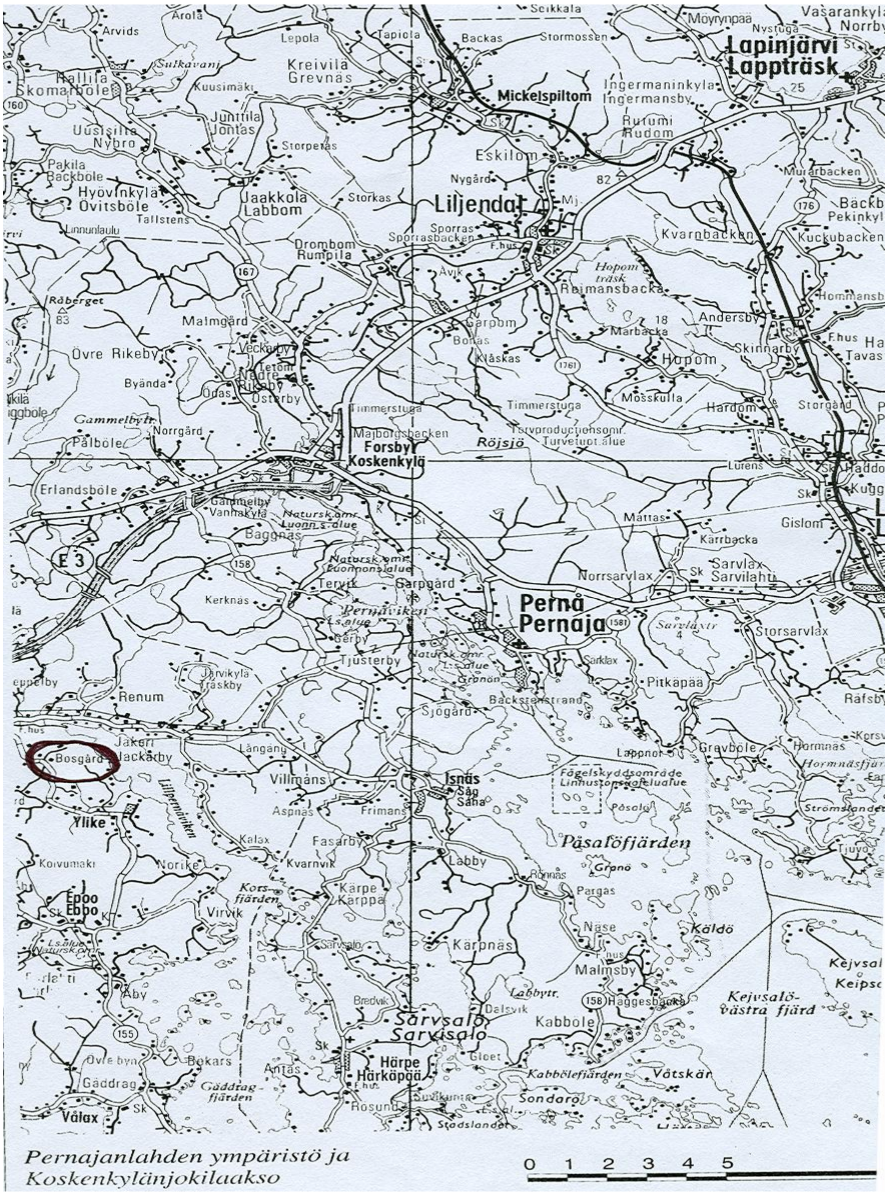


Figure 3.2 Pikku-Pernajanlahti (Little Pernaja Bay) area and Bosgård Manor (circled). The Pernaja Bay environment is listed as an important ecological area by the Finnish Ministry of environment.

Coastal Meadow

Grazing lands in Bosgård consist of 140 ha of own and rented coastal meadows and pastures, which are divided into six different grazing areas, the largest of which is on the coast of Pikku-Pernajanlahti. 70 ha of the grazing area are non-tillable. The largest contiguous meadow is over 40 ha. The next largest is 36 ha. The remainder are smaller meadows scattered throughout the farm. The majority of the Bosgård meadow areas are in the water-bird conservation program area, which is also classified as an internationally valuable location (Heikkilä 2001). The area also has a very high Natura 2000 status (Natura 2000).

Although Kalle's grandfather had milking cows, these cows had not been on the meadows. So, while there were cows in Bosgård until 1980, the meadows had not been grazed since about 1964. During the grazing hiatus, the reedbeds began to encroach upland, and meadowsweet (*Filipendula ulmaria*) was prevalent. The meadows were taken again into use in 1993.

Kalle began keeping cattle after attending a business course in Sweden in 1989-1990. He observed that the price of grain would probably fall in Finland when the country joined the European Union. As he already had the meadows, he decided to diversify his business and graze cattle on the meadows to supplement his income from grain production. He built the farm's cowhouse in 1992 and began rearing cattle in 1993. He received some subsidies for the building but, at the time, there were no environmental or animal subsidies. He sold his first meat in 1994.

Rehabilitation of the meadow consisted primarily of fencing the areas. The fencing consists of two strings of barbed wire and one string of electric wire. Clearing of bushes was left to the cows, but trees have been thinned somewhat.

The grazing period of the meadow is from about mid-May to late September, with a grazing intensity of one mother cow and one calf per hectare. The cows do not come in during the summer grazing period. They receive mineral salts freely outdoors and drink from a long ditch cut through the meadow (water is brackish). Maintenance consists of checking on the animals and repairing fences. Expected meadow production is maintenance of the mother cows and reasonable growth of the calves (average 48 kg live weight at birth, 250-300 kg when taken from meadow). During non-grazing months, the cows are in an open barn with free access to the outdoors. The productivity of the meadow falls short of the farmer's target as a result of fluctuations in productivity and quality during the grazing season.

After 10 years of grazing the meadows, the old cultural pasture landscape is visible again, says Kalle. According to his observations, it comes quickly, in about 2-3 years. Although Kalle cannot say definitely what kinds of changes have occurred in regard to bird populations or flora, he feels that the direction is definitely correct. One change that he has seen is that the reedbeds have retreated towards the sea.

Kalle is generally satisfied with the productivity of the meadow. "That which can be used has been taken into use," he says. He has a secure position with members of regulatory agencies governing the use of the meadows, as he has a good reputation and has worked with the various officials for many years. Kalle, however, knows of many examples where farmers and officials have not had good experiences together. Kalle feels that, overall, the officials have to work with the farmers, rather than presenting them with a set of demands.

Economics

Kalle states that the subsidies he receives for maintaining the coastal meadows are adequate to cover his costs. He receives only 200 euros/ha for the large meadow, because it was fenced before the subsidy program came into effect. For the rest of the meadows, he receives 420 euros/ha. He says he would graze the meadow regardless of whether he got subsidies, just as he did before.

Kalle lists saving labour costs and wanting the animals to be outside in the summer as the most important reasons for grazing the meadows. Enhancing biodiversity through providing habitat for birds and other species is also important to the farmer, as is maintaining the cultural landscape. Saving on feed costs is only a minimal consideration.

Labour costs amount to approximately 300 hours/year. These include moving the animals and checking/repairing fences. In the beginning, the fencing was a major operation and very expensive.

Chapter 5

Materials and Methods

Choosing the Study Sites

Biotope/habitat types were identified in the two meadows. Four different biotopes were identified in the 60 ha Bosgård meadow, but only two were found in the two hectare Majvik meadow. The biotopes were identified by the dominant vegetation of the area. The differences in vegetation in the biotopes are indicative of the unique ecology, including moisture regimes and soil properties, of the habitat areas. The four biotopes in this study are birch, grassland, willow and reedbed. Grassland and reedbed biotopes are found in both Bosgård and Majvik.

After identifying the habitat types in each of the meadows, replicate sites were chosen for each of the biotopes. Three replicates were allocated to each biotope. These replicates were randomised through a combination of choosing sites ahead of time and using randomising techniques on site. Ultimately, however, location decisions were made on-site. In Bosgård, a general area was chosen ahead of time using aerial maps of the meadow. On site, a stick was thrown in the chosen area to indicate the exact place where the sample plot should be located. In Majvik, the replicate sites were chosen randomly on-site without any pre-planning. The replicate sites at both Majvik and Bosgård are considered by the author to be adequately representative of the biotopes of each meadow area.

Birch Biotope

The birch biotope is characterized by small, somewhat elevated and drier "islands" slightly upland, but otherwise located in or near the grassland habitat. In addition to the birches, grasses grow in these areas. However, annual growth is sparse, seemingly due to the dry nature of the habitat. The birch biotope was found only in Bosgård and appears as relatively small patches of 100m^2 to 300 m^2 in size. Birch biotopes in this meadow are natural in the upland areas, but also are a result of raised mounds of soil left over from trench digging.

Grassland Biotope

The grassland biotope is the most dominant biotope in Bosgård. It is characterized by tussocked, open grassland. The uneven grassland terrain is difficult to walk in and is very soft when wet. Ungrazed tussocks provide habitat for some species of birds (Herzon 2003). This biotope ranges from semi-dry in the upland part of the meadow to saturated wetland in the lower part of the meadow. In most of the meadow, the grassland habitat extends from the higher part of the meadow to the reedbed biotope. In some areas, this pattern is interrupted by the willow biotope, which occurs primarily in patches within the grassland matrix.

The grassland habitat in Majvik is markedly different from that of Bosgård. The ground is much more even (like a cultivated or highland meadow) in the majority of the meadow. Tussocks grow only in the lower part of the meadow and are quickly overtaken by marsh grasses (primarily common reed). Although a plant species inventory was not carried out in Majvik, a spot check reveals a greater variety of plants in the Majvik grassland. These species include primarily grasses and perennial herbs (i.e.: *Carex* sp., *Poa* sp., *Filipendula ulmaria*).

Willow Biotope

The willow biotope is found in Bosgård and is located between the reedbeds and grasslands. This biotope has the richest vascular plant diversity and a great deal of biomass growth. Willow species grow in this habitat, but do not seem to be thriving in all areas (many dead and dying willows). The area is otherwise characterized by lush herbaceous growth. The ground is wet throughout the grazing period (with standing water in the early part of the summer) and floods easily. This combination of lush growth and moist conditions seems to encourage a variety of pests, including horse flies, mosquitoes, etc. This may explain why the cows seemed to avoid this area in the latter part of the summer.

Reedbed Biotope

The reedbed biotope is found in both Majvik and Bosgård. The biotope is low in biodiversity, as the area is almost entirely covered by the common reed (*Phragmites australis*). The ground in this biotope is soft and wet during the entire season. The majority of the reedbed is flooded until late June. The habitat floods easily during even moderate rains and experiences sea inundation even in the drier parts during stormy weather (when the sea is high). This area is the least grazed by the cattle. Dense reeds and soft ground limit mobility. Flooding in this habitat limited sample studies for this project.

Experimental Plots

The replicate plots were designed for easy access for the experiment. The complete materials list is found in Appendix 1.

The plots were fenced to 1.5m in height and approximately 1.4m² in diameter. Four fence posts were driven into the ground to a depth of approximately .3m. The height of the fence posts from the ground was approximately 1.2m. Chicken wire was then wrapped around the fence posts and secured firmly with fencing nails on three sides. The fourth side was secured to a loose post about 1.2m in height. This section of the fence served as a gate to enter the replicate plot (Appendix 9 Photo 8). Direction of the gate and other qualities relating to aspect were not taken into account during the construction of the fences. After attaching the chicken wire to the gatepost, the gatepost was then firmly affixed with fence wire to the adjoining fence post. Next, two strings of barbed wire were attached to the fences. The barbed wire was wrapped around the fence and nailed to the three fence posts and the gatepost. The upper wire was placed at approximately .8m height and the lower wire was placed approximately .5m height from the ground. No barbed wire was used at Majvik Gård.

The next step in making the test plots was to define the exact test area inside the fenced replicate plots. While the replicate area need only be $1m^2$, the fenced plot area was slightly larger in each case. This was in order to facilitate sampling and keep from trampling the sample area. It may also have limited effects of shadowing and other possible effects of the fence posts.

The test sites were marked out using plastic sticks and string. First, $1m^2$ was marked out in the centre of the fenced plot. This square was then divided with string into four equal parts of $.25m^2$ (Appendix 9 Photo 8).

Although the aspect of the test plots was unplanned, a specific methodology was used in determining the sample sites inside of the replicate sites. The sample sites were numbered 1, 2, 3 and 4 beginning from the left-hand side of the plot in front of the gate. The sample sites were then numbered counter-clockwise from sample site 1 so that Sites 1 and 2 (the two most frequently cut sites) were directly in front of the gate to the site (Figure 5.1).

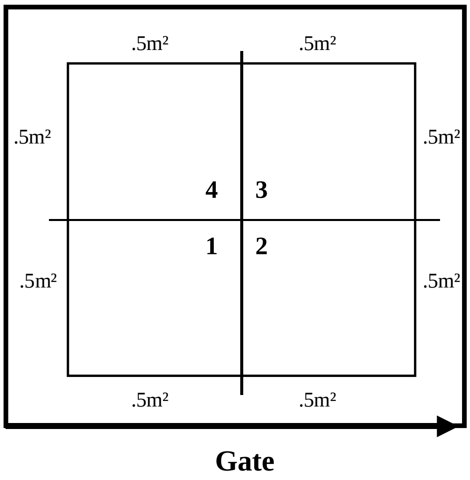


Figure 5.1 A bird's eye view of the layout of the experimental sites for this experiment. The outer square represents the fence around the test plot. The inner square represents the 1m² test area that was divided quadrilaterally into four different cutting regimes. Sample sites 1-4 of each replicate were measured into .25m² plots and marked with string. Labelling of the sites always began from the left hand side of the gate, regardless of which way the gate opened.

The sites were labelled according to biotope, replicate number and frequency of cutting. These site numbers were written in permanent marker on all four of the fence posts of each replicate plot. There were four biotopes, of which each had three replicates. Inside the replicates were four sample sites that were sampled (cut) according to different levels of frequency. The frequency of cutting simulated grazing intensity.

In addition to the four samples taken from within each replicate plot, each replicate also had a grazed reference (control) plot next to it. This reference plot was chosen randomly within a two-meter radius of the replicate plot. The purpose of the reference plot was to monitor the actual meadow activity outside of the replicate plots. These plots were observed throughout the grazing season and sampled either during or soon after the last samples were taken for the experiment. Throughout this paper, the samples and results from the grazed reference sites are labelled "control" or "control/grazed area".

Cutting Regime

Sampling was carried out weekly from 25/05/02 through 2/08/02 at Bosgård and 30/5/02 through 28/07/02 at Majvik. The method of sampling was the same at both of the meadows and an effort was made to have concurrent sampling of corresponding sites at the farms. Due to slightly different starting dates, weather conditions, and other factors concurrent sampling was not possible in all cases. Cutting times for corresponding samples from the two farms vary from a couple of days (in most cases) to weeks as in the case of the reedbed samples, some of which were underwater and unavailable for sampling for significant periods of time at both Majvik and Bosgård.

The purpose of the cutting regime was to simulate different intensities of grazing in the meadow. In order to simulate grazing of, primarily, cattle, but also sheep and horses, sample sites were cut to a height of approximately 5 cm. Samples were cut once a week (weekly), once every two weeks (bi-weekly), once a month (monthly) and when the experiment was over (bi-monthly and control). Samples were cut using regular scissors and were packaged in paper bags labelled with permanent ink. The cutting regime, including the dates and samples collected, are presented in Appendix 3.

Analysis

After collection, the samples were taken immediately to the laboratory at the University of Helsinki, where they were placed in drying ovens at a temperature of 70 C^{o} for a minimum of 24 hours. After drying, the samples were weighed on a digital scale and repackaged in paper bags. The samples were stored in the laboratory in either cardboard boxes or in plastic bags.

Some samples were milled within days or weeks of sampling, but the majority of samples were milled approximately 6-8 months after sampling. They were finely milled using equipment at the University of Helsinki[2]. Milled samples were placed in new paper bags and stored in the laboratory at room temperature.

For reasons of cost and time, I chose not to analyse all of the 261 collected samples. Instead, 82 samples from Bosgård were chosen for quality analysis and composition. The samples were chosen based on their ability to represent the different cutting frequencies (grazing intensities) of the experiment. The extreme wet areas (reedbed biotope) were excluded from quality analysis because of the seemingly low grazing in these areas and difficulty in consistently obtaining samples from these replicates. This corresponds with Jutila (2001), who also separated out plots with dense stands of common reed from the other seashore plots in her study of cattle grazing in coastal meadows. The samples chosen for analysis are from the first, middle (if applicable), and last cuttings from each sample site of the remaining nine replicates at Bosgård.

I analysed Carbon, Nitrogen and Sulphur content of 82 samples using a CNS-1000 Elemental Analyzer[3] at the Department of Forestry at the University of Helsinki. The majority of samples were analysed individually, but four sets of replicates were combined for analysis because of limited available specimen (>2g).

After elemental analysis, a minimum of 5g of each of the samples were analysed for digestibility and ash content using the Cellulose in vitro Digestibility Method. These analyses were performed by the Lapland Research Station of MTT Agrifood Research

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[2] Cyclotec 1093 Sample Mill, Foss Tecator was used for the lighter samples, while Koneteollisuus model 120 (2800 r/min) was used for the heavier samples.

[3] SNS-1000 Elemental Analyzer, Leco® Corporation 3000 Lakeview Avenue, St. Joseph MI 45085-2396 U.S.A.. For more information on this process, see User Manual, Theory of Operation p. 1-7.

Finland[4]. Another set of replicates had to be combined for this analysis, lowering the total number of samples to 80.

Minimum and maximum potential consumption in the four biotopes of the meadows were estimated using the following model, according to biotope:

- Minimum consumption= cumulative weight (g) of least productive cutting regime - weight of control sample

- Maximum consumption= cumulative weight (g) of most productive cutting regime - weight of control sample

The actual amount of fodder consumed in each biotope should fall between the minimum and maximum consumed estimates. The model was worked for the Bosgård meadow but not for the Majvik meadow.

Digestibility Analysis

In the *in vitro* cellulose digestibility analysis, feed samples are incubated in an enzyme solution (Tuori 2004; Friedel and Poppe 1990). The soluble organic matter released through the enzyme activity is measured. The results of this test differ somewhat from actual *in vivo* digestibility in animals (*ibid*). The following formula is used to determine the digestibility value of the dry organic material found in the sample (adapted from Tuori 2004):

Soluble Organic Matter * (100-ash content%)/100= D-value

Inorganic (insoluble) matter from the DM samples is measured as ash. As such, dry matter – ash= organic matter content of the sample. Organic matter is typically

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[4] Lapin tutkimusasema, Tutkijantie 28, 96900 Saarenkylä tel.: (019)331 1600

divided into four categories: raw proteins, raw fats, raw fibres and nitrogen-free extract ingredients (sugars, starches, pectins, organic acids) (Tuori 1994; Näsi undated). The results of the *in vitro* digestibility analysis give only the ash content, soluble organic matter content, and the D-value. Further information on the composition of the organic matter content of the samples can be discerned through the elemental analysis of carbon, nitrogen and sulphur content.

Vascular Plant Species Identification

The percentage of vascular plant species cover was determined by estimating the percentage species cover in each replicate in Bosgård. Vascular plant cataloguing was carried out in September. Sanna Tarmi, of the University of Helsinki, carried out the plant species identification.

Statistical analysis

Completely randomised fixed effect factorial model was used in this experiment, and statistical calculations were carried out using SPSS © standard version statistical program. Univariate analysis of variance for productivity was and means were compared done using Tukey's HSD. Between subject effects were also tested through estimated marginal means. Significance of differences in D-values between biotopes, and dates of cutting, were compared within each of the cutting regimes. The D-values were tested using arcsin-transformed data (note: arcsin divided by 100 because D-value is a percentage). Pairwise comparisons were generated to describe the main effects (biotope * cutting regime) for both productivity and D-values. Elemental analysis means (biotope and cutting regime) are reported with standard deviations.

Chapter 6

Results

Plant Species

The total number of vascular plant species in the samples from the Bosgård meadow was 37 species (the complete species catalogue is given in Appendix 2). A summary of the species profile of each biotope is presented in Figure 6.1. All of the species observed in Bosgård meadow were common meadow species (Tarmi, personal communication; Appendix 2). Nearly all of the vascular plant species identified in Bosgård meadow were perennials (Appendix 2).

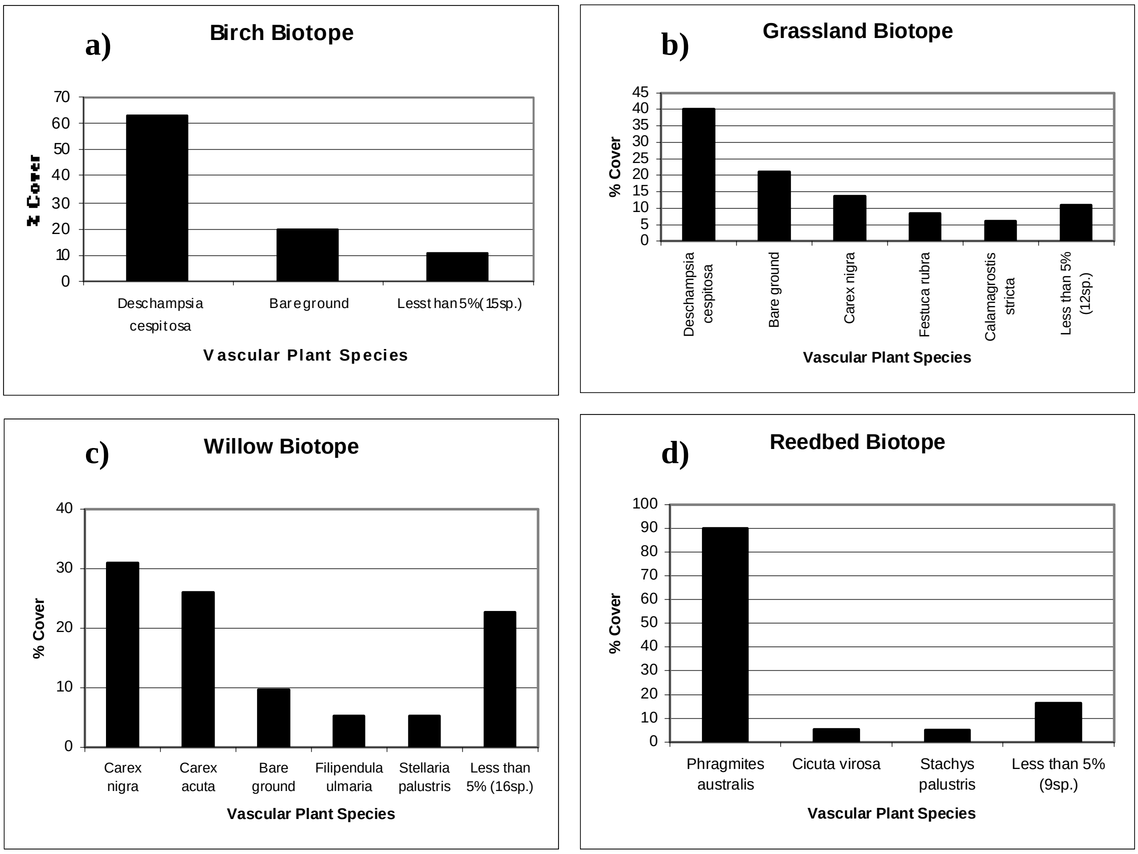


Figure 6.1. Percentage cover of vascular plant species of the Bosgård meadow. Figures represent the mean over the three replicate plots. The values are based on absolute above ground vascular plant coverage.

Birch Biotope

The birch biotope was the least prevalent in the meadows. 17 plant species were found in the three replicates (Figure 6.1; Appendix 2). However, 16 of those plants were found only sparingly (≤ 5%). The sparse growth in the birch biotope was clearly dominated by *Deschampsia cespitosa*, covering between 58%-69% of the area.

Grassland Biotope

The grassland biotope clearly contained different species in Majvik and Bosgård. A spot check of the Majvik grassland revealed that there is likely more species diversity, including more herbaceous plants (i.e. *Achillea* spp., *Filipendula* spp.), than in the Bosgård grassland. For the purposes of this study, it is assumed that the two sites are comparable, though there are differences in species composition were observed.

The replicates of the Bosgård grassland biotope were rather varied, with differences in dominating species, minor species, and the amount of bare ground/leaf litter (Appendix 2). The most dominant vascular plant species were *Deschampsia cespitosa* (tufted hair grass, 40%) and *Carex nigra* (smooth black sedge, 14%). The vascular plant cover of one of the replicates contained 42% dicots (Appendix 2). The other replicates were more mixed between mono and dicots.

Willow Biotope

The greatest species diversity was found in the willow habitat. 20 different species were identified in the three replicates. However, the three replicates had rather different compositions from each other (Appendix 2). All of the plots were dominated by sedge (*Carex*) species, but as much as 78% of the composition of one of the replicates was *Carex acuta*, which was not present in the other two replicates (Figure 6.1c). In addition to sedges, herbaceous plants and wildflowers were also found in this habitat, with 1-3 non-sedge species per replicate.

Reedbed Biotope

The reedbed biotope had the least species diversity of all of the replicates. This is clear in the Bosgård plant species catalogue, as well as in a quick survey of the Majvik reedbed. The biotope is characterised by *Phragmites australis* (common reed), which dominates the entire shoreline of both of the meadows. The reeds in Bosgård and Majvik easily reached a height of two meters and were densely crowded. The reed stands in Majvik were less dense and shorter than those of Bosgård.

Phytomass Productivity

Cumulative above ground phytomass productivity (AGPP) of Bosgård meadow was dependent upon biotope ($p \leq .001$) and cutting regime ($p \leq .001$). Interaction between the two factors was significant ($p = .045$): the effect of cutting regime varied between the biotopes (Figure 6.2; Appendix 5). In the birch biotope, productivity decreased consistently with cutting frequency (Figure 6.2; Appendix 5). Weekly and bi-weekly results were nearly the same in both grassland and willow biotopes (*ibid*). The reedbed biotope differed from the others in that the bi-weekly cutting regime was the most productive, while the other cutting regimes were about equal (*ibid*).

Cumulative AGPP of the Majvik meadow was very variable from one replicate to another, which overshadowed possible effects of biotope and cutting regime, and their interaction (Appendix 5). The general mean productivity (both biotopes) of Majvik meadow was 293.04 g dm/m^2 (std. error 115.33, n=24).

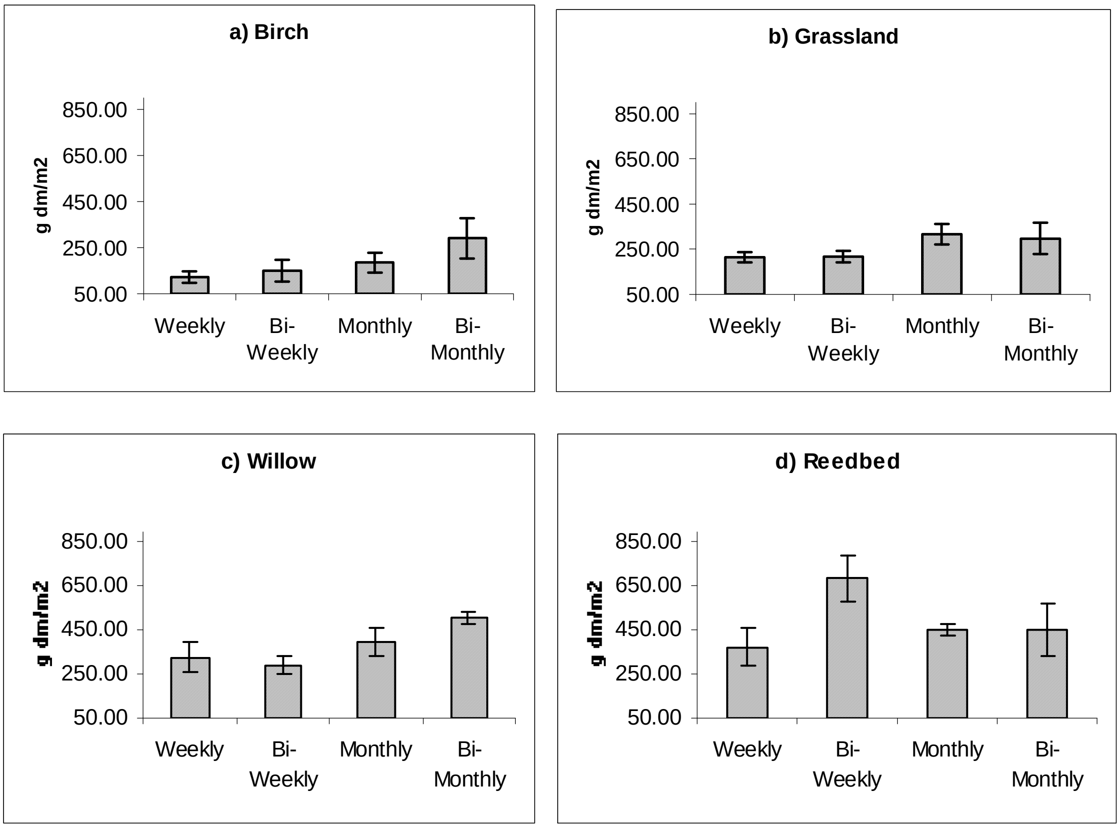
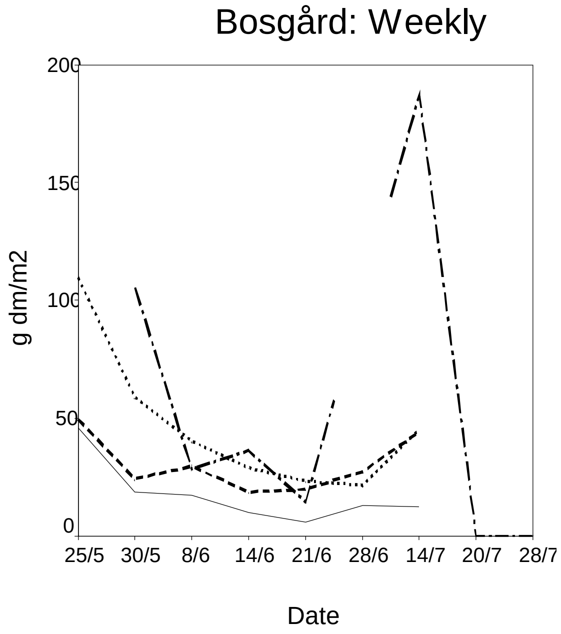
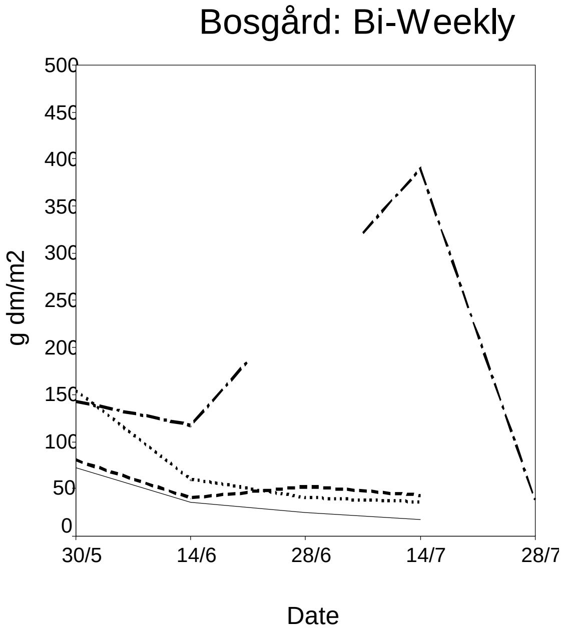
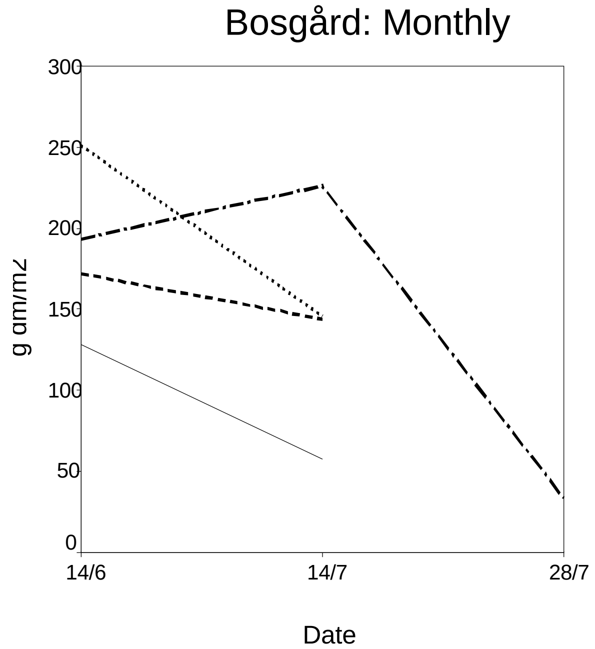


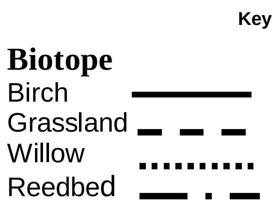
Figure 6.2 Cumulative above ground phytomass production (AGPP, g dm/m2) by cutting regime for Bosgård biotopes. (Error bars stand for ± standard error, n=3).

The reedbed biotope in Bosgård meadow had the greatest range and differed from the other biotopes significantly in both amount and trends in productivity (Figure 6.3). In contrast, the trends in productivity of the grassland and reedbed biotopes were almost identical for weekly and bi-weekly cutting in the Majvik meadow (Figure 6.3). In almost all cutting regimes, first cuttings were larger than subsequent samples. Exceptions to this were in one of the Bosgård grassland samples and in two of the Bosgård reedbed samples (Figure 6.2; Appendices 4&5).


Bosgård: Weekly
g dm/m2
200
150
100
50
0
25/5
30/5
8/6
14/6
21/6
28/6
14/7
20/7
28/7
Date


Bosgård: Bi-Weekly
g dm/m2
500
450
400
350
300
250
200
150
100
50
0
30/5
14/6
28/6
14/7
28/7
Date


Bosgård: Monthly
g dm/m2
300
250
200
150
100
50
0
14/6
14/7
28/7
Date


Key
Biotope
Birch
Grassland
Willow
Reedbed

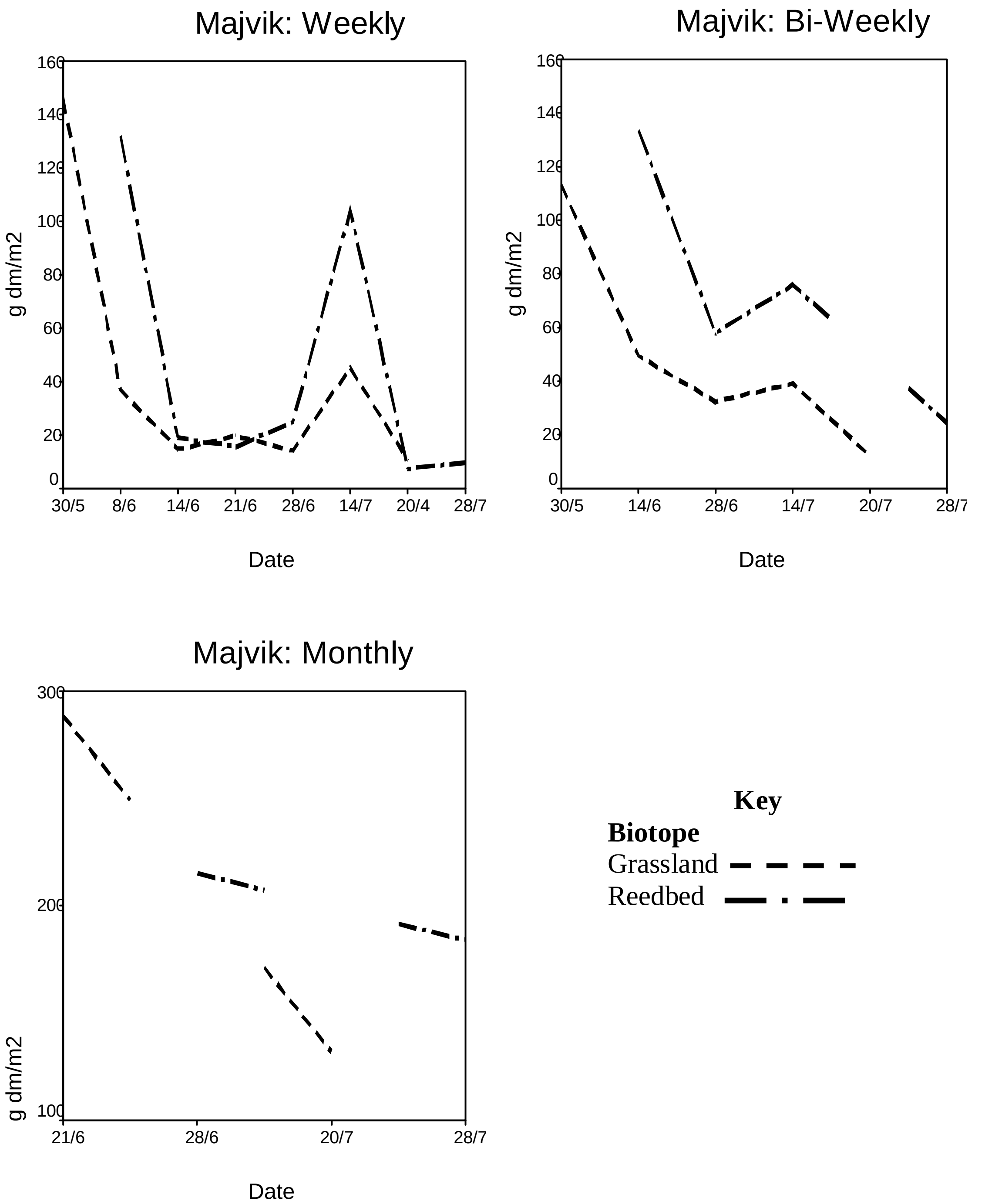


Figure 6.3 Mean sample weights by biotope over time. Break in line indicates missing sample values. Standard deviations for values are in Appendix 4.

Estimated Productivity and Consumption

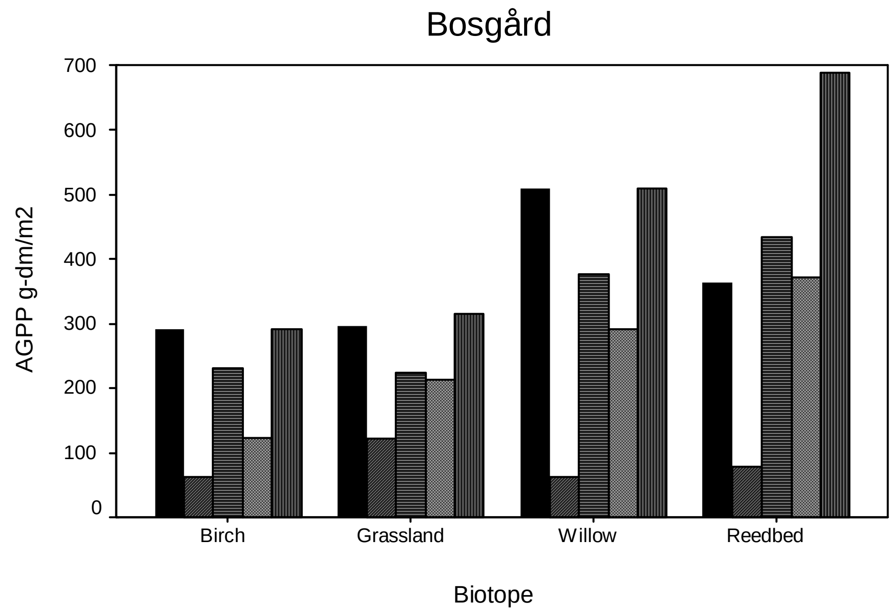
Maximum and minimum consumption were estimated for all biotopes in Bosgård and Majvik meadows (Table 6.1). In Figure 6.4, the minimum and maximum productivity are compared with the bi-monthly cutting.

In the Bosgård meadow, the bi-monthly cutting produced about the same as the maximum estimated for all the biotopes except reedbed (Figure 6.4). This result implies that maximum productivity was achieved in these biotopes when the above ground phytomass was left completely undisturbed. The Bosgård reedbed and Majvik grassland did not follow this pattern, however. Rather, the undisturbed productivity (bi-monthly cutting) was closer to the estimated minimum productivity of the biotopes (Figure 6.3).

Table 6.1 Estimated maximum and minimum consumption in Bosgård meadow. (For the minimum and maximum productivity values of each respective biotope, see table Appendix 5). Values are AGPP in g-dm/m^2.

Biotope *Bosgård*	**Mean Sample Wt. of Control Sample**	**Std. Deviat.**	**Min. consumed AGPP** g dm/m^2	**Max. consumed AGPP** g dm/m^2
Birch	60.76	12.31	62.48	230.96
Grassland	91.65	5.59	121.71	224.39
Willow	132.53	65.59	159.42	376.16
Reedbed	253.69	25.18	79.16	433.55
Total	134.66	27.17	105.69	316.27
Majvik				
Grassland	251.92	82.03	0 (-5.8)	168.52
Reedbed	153.51	42.56	118.89	239.29
Total	202.72	62.30	59.45	203.91

The birch biotope was the only one in which the maximum consumed phytomass was closer to the biotope's maximum production. In all other cases, maximum consumption was closer to the minimum productivity, possibly indicating the extensive nature of the grazing. The Majvik grassland biotope is an anomaly in this model, as the minimum consumption is 0 (or negative), while the maximum consumption in the meadow is below the minimum production (Figure 6.4)



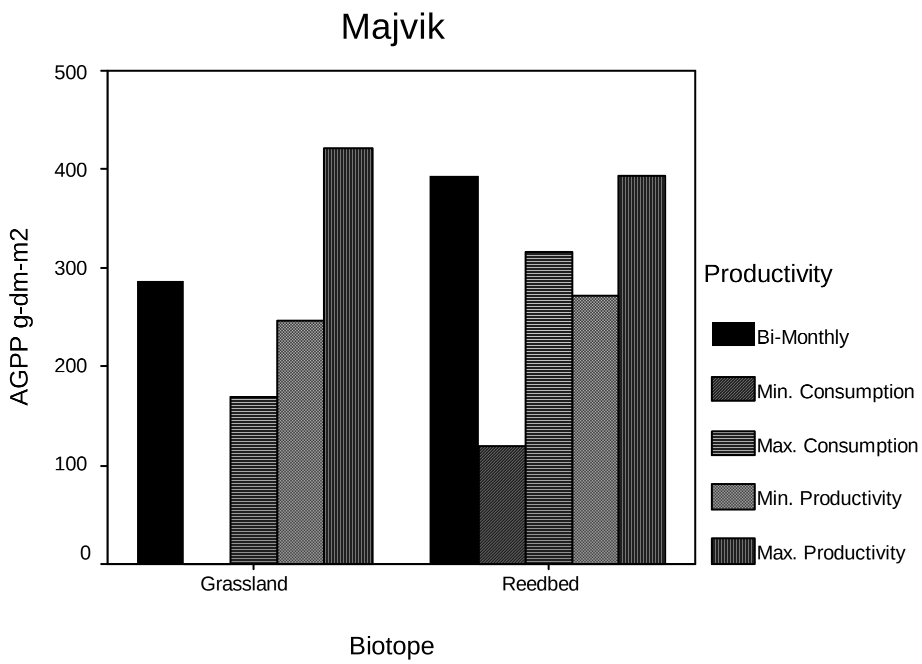


Figure 6.4. Cumulative productivity and estimated consumption in all biotopes. Minimum consumption in Majvik grassland was 0, and therefore has no value on the graph.

Phytomass Quality

Digestibility: D-value

Pairwise comparisons indicate that date of cutting was significant in the weekly cutting regime ($p \leq 0.001$ and $p \leq .05$) but was not consistently significant in the other cutting regimes (Appendix 7). Pairwise comparison of weekly and monthly cutting regime confirmed that biotope was very significant to significant (*ibid*). However, biotope was not significant in all cases in the bi-weekly cutting regime (*ibid*).

Digestibility (D-value) of the Bosgård meadow showed a consistent decline during the duration of the study period (Table 6.2; Figures 6.5-6.6). The average D-value for the entire meadow (all cutting regimes in all three measured biotopes) was 61.29% (std. dev. 5.78). The highest digestibility (D-value over 70%) was found in the earliest samples from the birch and grassland cuttings, while the lowest values were found in the bi-monthly (undisturbed) cuttings of birch and willow biotopes (D-value 48-52 %). Detailed results of ash and organic matter composition (including soluble and insoluble organic matter) are found in Appendix 6.

Table 6.2 Mean D-values (%) (standard deviation) according to biotope and cutting regime.

Biotope	Date	Weekly	Bi-Weekly	Monthly	Bi-Monthly	Control
Birch	**25.5**	71.2 (.04)				
	31.5		66.0 (2.3)			
	15.6	57.4 (0)	56.9 (1.2)	56.4 (1.4)		
	14.7	60.7 (0)	57.2 (0)	55.9 (2.7)	48.3 (4.7)	
	24.7					59.6 (3.0)
	Total	**66.3 (6.8)**	**60.8 (5.1)**	**56.1 (1.9)**	**48.3 (4.7)**	**59.6 (3.0)**
Grassland	**25.5**	72.5 (2.0)				
	31.5		68.8 (2.7)			
	15.6	61.0 (0)	58.0 (3.3)	59.5 (4.6)		
	14.7	62.5 (1.7)	61.3 (1.6)	59.3 (.9)	57.6 (1.1)	
	24.7					56.4 (2.8)
	Total	**66.6 (5.8)**	**62.7 (5.3)**	**59.4 (3.0)**	**57.6 (1.1)**	**56.4 (2.8)**
Willow	**25.5**	68.4 (1.7)				
	31.5		65.5 (4.8)			
	15.6	54.8 (0)	57.6 (3.8)	57.0 (3.6)		
	14.7	56.5 (2.5)	59.8 (3.8)	56.6 (4.8)	52.4 (.06)	
	24.7					53.4 (4.7)
	Total	**59.9 (6.6)**	**61.0 (5.0)**	**56.8 (3.8)**	**52.4 (.06)**	**53.4 (4.7)**

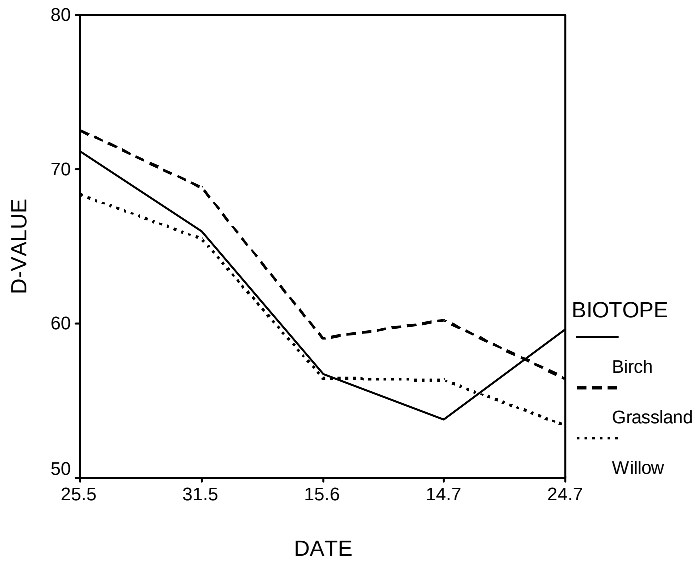


Figure 6.5 Mean digestibility (D-value) in the three Bosgård biotopes over the sampling period. The plots represent mean values for the biotope over all the cutting regimes. Note that Date 24.7 represents the results of the control value only.

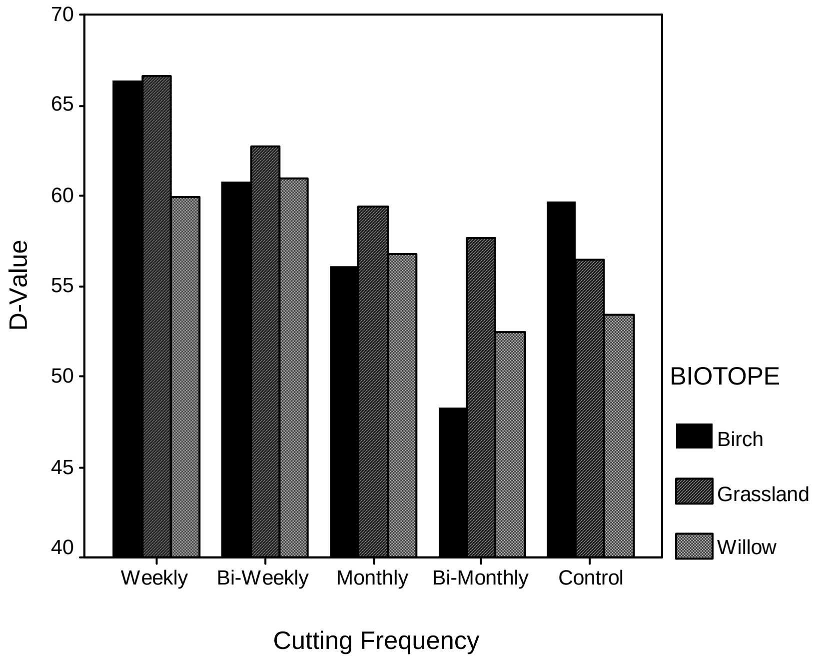


Figure 6.6 Mean D-value according to cutting frequency and biotope.

Elemental Analysis: Carbon, Nitrogen, Sulphur

The results of the elemental analysis indicate a great deal of consistency both within and between the biotopes (Table 6.3. Detailed descriptions of C, N, and S composition in samples are in Appendix 6, mean composition in Appendix 8). Exceptions include the low sulphur content of the weekly and monthly birch samples and the comparatively low nitrogen content of the birch samples in all cutting regimes. Fairly dramatic differences in composition were found between the bi-monthly (undisturbed) and control (cattle-grazed) samples in the birch biotope, where unusually low nitrogen content was recorded in the bi-monthly sample and higher than average nitrogen content in the cattle-grazed sample (Figure 6.7).

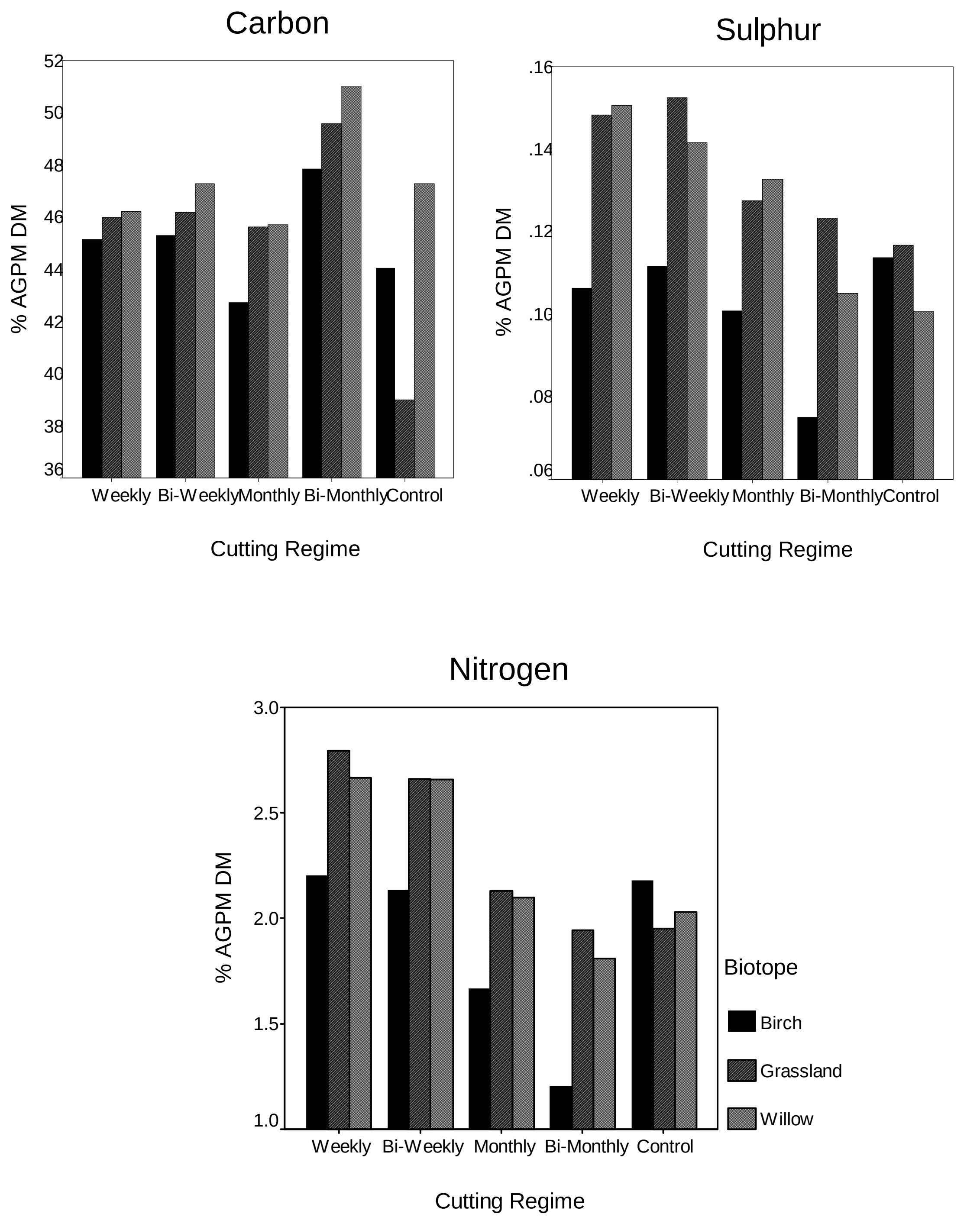


Figure 6.7 Mean carbon, sulphur and nitrogen composition of samples by biotope and cutting regime.

Chapter 7

Discussion

Carrying Capacity and Optimum Grazing Intensity

Meadow grazing strategy, which is dependent upon the goals of meadow maintenance, should be a balance between agricultural production and ecological considerations. According to Jutila (2001), "There does not exist a single optimal management scenario for all coastal meadows. Management and restoration are dependent on the aims of nature conservation; whether the goal is to save meadow bird species, meadow plant communities, individual plant species, species richness, certain habitat types or even open coastal landscape." In the case of the Majvik and Bosgård meadows, the grazing strategy should consider the needs of farm production while optimizing conditions for maximum landscape biodiversity, including habitat preservation and access to open landscape. Appropriate grazing intensity for biodiversity includes nutrient transfer out of the system to limit eutrophication, suppression of reedbeds through grazing or harvesting, maintenance of open grasslands, and maintaining a landscape with multiple microclimates and species variety. These are some of the goals of the environmental subsidy programs discussed in Chapter 2 (p. 35-36).

In the case of both Majvik and Bosgård meadows, it is likely that the meadows are undergrazed in regard to optimal landscape maintenance by the cattle. One of the ways in which undergrazing may be relieved in the Bosgård meadow could be to divide the meadow and use rotational grazing, as the meadow would then have a greater capacity for recovery after more intensive grazing. Environmental officials, who determined that increased grazing capacity would benefit meadow diversity, have suggested this method to the farmer already. From the perspective of bird habitat, however, intensified grazing could result in overly uniform grazing of the landscape, which would eliminate some of the habitat for ground nesting birds (Irina Herzon, pers. com.). In the Majvik meadow, it may not be practical to relieve undergrazing significantly, as the farm has only one dairy herd that comes in daily for milking. Also, "forcing" the cattle to graze the coastal meadow in Majvik more heavily is impractical, as lowered nutritional content of the diet is likely to affect both milk production and animal temperament. Instead, annual hay harvesting of the grassland may be a more effective way to achieve ecological optimisation of the meadow landscape. Currently, hay harvesting is practiced, but not annually. Alternately, other ruminants (sheep, for example) could be grazed in the meadow. Carrying capacity for biodiversity optimisation is currently the focus of many projects in Finland and elsewhere.

It is an accepted ecological tenant that productivity and quality cannot be maximised at the same time. The goal of this project was to find a balance between maximising productivity without significantly compromising quality. Timing and intensity of grazing are the primary factors affecting both quality and quantity of fodder production. Assessment of carrying capacity requires analysis of biomass weight, botanic composition and palatability analysis to determine fodder quality. The primary result of this study was that quality always declines over time during the grazing season, while more frequent harvesting decreases productivity. The optimum grazing intensity lies between the maximisation of these two factors.

Plant Species

The biotopes in the meadows were clearly defined, but differences in species composition between replicates of the biotopes indicate that high variation in biotope vascular plant species composition may be the cause of variation in results throughout the experiment. Jutila (1997) observed that the vegetation pattern in grazed areas is coarser. Coarseness of the matrix of the grazed meadow may in part explain variation found in the meadows. The hypothesis that grazing may be partly responsible for the clearly defined biotope ranges is supported by Jutila (2001) and others, who have found that vegetation boundaries seem more distinct in grazed than in ungrazed meadows.

The predominant vascular plant species in the Bosgård meadow were grasses and sedges (*Poaceae* and *Cyperaceae*). This result corresponds with Jutila's (1997) study near Pori, where 90% of the seashore meadow seed bank of her study was composed of grasses and sedges.

Jutila also found that elevation and waterline had a strong correlation, and that this relationship explained the variation in dicot species richness, while monocots were less affected by elevation (*ibid*). In this study, dicot species were found in all biotopes, irrespective of elevation. All of the biotopes were, however, dominated by monocot perennials.

The strong correlation between species richness and elevation gradient found by Jutila (*ibid*), could not be confirmed with this study, as the willow biotope, which lies between the grassland and reedbed biotopes, had the greatest species diversity and the greatest amount of dicot species (20 sp.). Studies show that grazing often increases the number of species and the abundance of annuals and dicots in grasslands (Jutila 1999), although Jutila's study indicated a decrease in species richness as a result of grazing, at least in the short term (1997). As expected, the reedbed biotope had the lowest diversity (11 species). However, 42% of the coverage of one of the grassland replicates was dicots (Appendix 2). It is unlikely that this high percentage of dicots was a result of grazing, as the area appeared to be minimally grazed by the cattle.

The literature indicates that species richness is related to grazing resistance. Grazing resistance, which describes the relative ability of plants to survive and grow in grazed plant communities, is divided into avoidance and tolerance components (Briske 1996). Modelling generally shows that moderate grazing favours less competitive, small, fast-growing and short-living species (Jutila 1999). The most common species with rapid regrowth after harvesting/grazing found in Bosgård was *Deschampsia cespitosa*, which was found extensively in the birch and grassland biotopes (Appendix 2). During the Bosgård study, it was observed that these two biotopes were the most heavily frequented by the cattle in the meadow. The low to moderate palatability of the majority of the vascular plant species cover found in the meadow may be a more important factor in grazing resistance than tolerance, as the majority of the cover found in the meadow has low to medium regrowth capacity (Appendix 2; USDA 1994).

According to Tyler, (1969: in Jutila 1999, 2001) most seashore species are negatively affected by grazing, although the most frequent species seem rather indifferent. These results are in agreement with those of Jutila (1997, 2001). Dominant species in the Bosgård meadow that have slow to moderate rates of regrowth after harvesting/grazing include *Phragmites australis, Calamagrostis stricta*, and some *Carex* species (USDA 2004). Limited recovery of intensive harvesting (weekly cutting regime) was evident in both Majvik and Bosgård reedbeds, where productivity collapsed before the end of the two-month experiment as a result of intensive harvesting (Appendix 3). In addition to impact directly from grazing, some species may also suffer from increased salinity with trampling (Jutila 1997, 2001). Further, stress caused by fluctuating water level may unexpectedly alter the effects of grazing (Jutila 1999).

Differences in frequency of occurrence of species were found between Jutila's study (2001) and Bosgård meadow. In particular, several of the dominant species in Jutila's meadow were found only sparingly or not at all in Bosgård. Some of these species include *Agrostis stolonifera*, *Calamagrostis stricta* and *Potentilla palustris*. In Jutila's Pori studies, a total of 146 vascular plant species were found in the 411 1m^2 plots and 183 species in the total study area (Jutila 2001). Considering the small sample size of Bosgård meadow, it is likely that there are many more species in Bosgård than were recorded in this study. However, Jutila's study is from Western Finland, where there is generally greater vascular plant species diversity than in Eastern Uusimaa.

The limitation of this study to one growing season in grazed meadows makes comparison to grazed and ungrazed meadow vascular plant composition impossible. However, late successional dominants are often replaced by early or mid-successional species, and structural changes frequently involve the replacement of tall grasses by mid or short grasses as a result of grazing (Briske 1996). If species replacement continues, it often leads to ingress of ruderals and herbaceous and woody perennials (*ibid*). The farmers of both Majvik and Bosgård stated that they have observed that the reedbeds have receded several meters towards the water line and become shorter as a result of cattle grazing in the meadows. In practice, this means the extension of the grassland meadow biotope and its low-growing grasses towards the sea.

Natural Grazing

Environmental Conditions

Natural grazing intensity and recovery by vascular plant species after harvesting appeared to be highly dependent upon a combination of external environmental conditions. These conditions were primarily influenced by soil wetness.

The productivity of the Bosgård meadow showed very similar trends between all biotopes except reedbed. That the birch biotope was consistently the least productive of the biotopes is not surprising, as the higher elevation meant that this area dried quickly and had slow recovery after grazing. This biotope was dominated by *Deschampsia cespitosa*, which normally has a rapid ability for regrowth after cutting (USDA 2004). All of the cutting regimes for this biotope showed steady decline in productivity over time (Figure 6.3). This biotope was grazed very heavily during the entire grazing period, to the extent that the cows even tried to get into the replicate fences. Vascular plant species cover was generally lower in this biotope than in the others (Appendix 2). Many studies indicate that the effects of grazing on above ground net primary productivity are negative (Jutila 1999). Lower ground cover may be a result of both dryness and residual effects of previous grazing.

The natural grazing intensity of the willow biotope appeared to be influenced by a combination of external environmental conditions and plant productivity/digestibility. The wetness of the soil throughout the entire sampling period resulted in a cooler, moister microclimate that was favoured by biting insects. These insects, including mosquitoes, horse flies and midges, did not appear to be particularly problematic in the rest of the meadow. During May-June, the pest concentration was particularly bad in the willow meadow. I never observed any grazing taking place in the willow area during this time, and the lush growth of the area indicated that the animals were probably avoiding the area. However, the difference between bi-monthly cutting regime and growth (bi-monthly/ (bi-monthly-control)) in the grazed area was essentially the same for birch, grassland, and willow biotopes, indicating that the grazing outside of the replicate sites was the same as that of the birch and grassland biotopes by the end of the study period. Whereas the birch biotope was grazed immediately from the beginning of the grazing season and was slow to recover (if it all), it appears that the willow area may have been grazed only later in the season, when the ground was harder and pests less prevalent. The upper part of the grassland appeared to be grazed steadily throughout the study period, except when flooded. The lower grassland area may have been grazed more sparingly, as the ground was extremely soft during much of the grazing period. Observations of this hypothesis are limited, however, due to the vast area in question.

The reedbed biotope of Bosgård differed significantly from the other biotopes in trend and productivity in nearly all cases. This may, in part, be due to the fact that this low-lying region was often flooded and inaccessible. This affected cutting regime quality and may be the primary reason for some of the atypical spikes seen in the Bosgård results (Figure 6.3). Conversely, the Majvik reedbed mimicked the grassland trend in both weekly and bi-weekly cutting regimes, although the productivity was almost consistently higher (*ibid*). The differences in the two meadows may be explained in part by the fact that the Majvik meadow is much smaller and grazed more sporadically. Growth of the reedbeds in the Majvik meadow is less dense and shorter. The borders between the two biotopes are somewhat less well defined than those of the larger Bosgård meadow.

Estimated Consumption

The range of minimum and maximum productivity and consumption in the estimated consumption/productivity model is quite large (Figure 6.4). The broad range indicates that one should be careful in using the max/min model to determine productivity or consumption in the control/grazed areas. The model was successful in estimating Bosgård meadow results, but collapsed with the Majvik data, where the grassland results indicate that minimum consumption was negative and maximum consumption was below minimum production. The reliability of the model may have been compromised as a result of the low grazing intensity and high variation (Appendix 4) in replicate results of the grassland meadow.

Phytomass Quality

The steady decline in D-values in the birch, grassland and willow biotopes support the general literature that quality of meadow fodder decreases during the growing season. Good quality sown hay fields in Finland have an organic material digestibility of about 80% (Palva 2002). The organic matter content of fresh and dry hay fodder generally ranges from as high as 81 % to as low as 58% (Tuori et.al. 1996). The high range in D-value is primarily dependent upon botanical composition and age of plants. Coelho et.al. (1988: in Nousiainen 2004) found that grass hays had a D-value of 54.8%. Fresh herbage was found to have a D-value of 70% by Givens et.al. (1993: in Nousiainen 2004).

69% and above D-value is indicative of good quality fodder (Agronet 2004). In the Bosgård meadow, the D-value was consistently below this level in all analysed samples taken after 25.5. Willow and birch biotope only achieved above 60% digestibility (birch 60.7 on 14/7 weekly cutting) of organic matter composition in the first weekly and bi-weekly cuttings. The grassland biotope maintained above 60% digestibility for a longer time than the other two biotopes (Table 6.2).

Conclusions cannot be drawn from these results regarding the effects of monthly and bi-monthly cuttings on the D-value of the samples, as the analysed samples from these cutting regimes were taken on or after 15/6, when digestibility of organic matter was falling (generally) for all samples. Mid-June is clearly too late to begin grazing the meadows, as palatability will have decreased significantly by this time.

The first bi-weekly samples were taken on 31/5 from Bosgård meadow. The D-values of these samples are consistently lower than those taken as first samples from the weekly sampling regime on 25/5. This decrease in D-value of first cuttings taken less than a week apart are strong indication that early grazing is extremely important in insuring quality fodder production.

Grazing Patterns and Grazing intensity

The primary question that can be explored through the results of this experiment is how meadow productivity and ecological richness can be best enhanced through grazing intensity and grazing patterns. This is relevant from both the agricultural and ecological point of view, as additional feed to grazing animals is the primary problem in meeting the grazing needs of semi-natural landscapes (Salminen and Kekäläinen 2000).

Both the general literature and this study support early grazing as important to ensuring good quality fodder production. The results show a range of as little as 1232.4 kg/ha (weekly birch cutting regime) to as much as 6881.7 kg/ha (bi-weekly reedbed production) of dry fodder, depending upon cutting regime and biotope. This compares to 2930 kg/ha (80% of conventional production) of organic sown hay for 2001 (KTTK 2002). Average conventional dry hay production for 2002 was 3700 kg/ha according to the Finnish Ministry of Agriculture (MMM Tietopalvelukeskus 2003).

This study shows that it is possible to achieve fairly high harvests of fodder from coastal meadows. The Bosgård grassland meadow produced approximately 2138.1 to 2166.8 kg/ha of fodder through weekly and bi-weekly cutting regimes. The average D-values of these two cutting regimes in the grassland biotope were 65.33 and 62.70, respectively. While these fall below the goals for hay fields, they are fairly reasonable values, especially for non-dairy producing animals.

Chapter 8

Conclusion and Recommendations

Grazing intensity at Bosgård is currently 1 mother cow and calf. This grazing intensity falls within recommended ranges given in the literature. Increasing the average number of animals is not recommended by this study, but redistribution of grazing intensity may be helpful.

- Currently, grazing intensity increases as the summer progresses (suckling calves are growing). This trend is contrary to the needs of both the meadow and the cows, as fodder quality decreases over time. Grazing intensity should be higher in the early part of the season and less after midsummer.
- In order to maximise fodder palatability, animals should be allowed on the meadow as soon as is possible in the spring (as is already practiced).
- The number of grazing animals could be increased if they are rotated. Rotation off the meadow and onto the nearby hayfield could alleviate the problem of decreased fodder quality after midsummer. Additionally, rotation would allow the drier areas of the meadow to recuperate from heavy grazing in the early part of the grazing season.
- Rotation without increasing the number of grazing animals in the meadow could result in the reedbeds being less grazed. Decreased suppression of reedbeds is not beneficial for the meadows. However, this study and the literature show that reedbeds are negatively impacted by heavy harvesting. Increased animal intensity in the spring and early summer could help in reedbed suppression.

Bibliography

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Photographs of Field Research

Photo 1 Example of a well-grazed coastal seashore meadow. The photograph is of the seashore meadow in Bosgård in June 2002. The foreground is hayfield. The seashore meadow begins where the cows are. Light-coloured growth farthest away are reedbeds.

Photo 2 Open grassland in Bosgård meadow. The sedge tussocks are the dominant vegetation in the biotope. June 2002.

Photo 3 View of Majvik seashore meadow from the reedbed. May 2002.

Photo 4 Markku Tykkyläinen, of the University of Helsinki, building replicate plot fences in the birch biotope in Bosgård meadow. May 2002.

Photo 5 Fencing of study plot in birch biotope in progress in Bosgård meadow. May 2002.

Photo 6 Study plot in grassland biotope in Bosgård meadow. May 2002.

Photo 7 View of birch and grassland biotopes in Bosgård meadow. Fenced replicate plot in background. May 2002.

Photo 8 Grassland replicate plot in Bosgård meadow. Weekly and bi-weekly samples have been taken from the quarters in the fore of the picture. Sampling regime was counterclockwise, starting from the left-hand corner. June 2002.

Photo 9 The cows in Bosgård meadow contemplate crossing the drainage stream that divides the meadows. The green field in the background is a hay field adjoining the meadow but separated by an electric and barbed wire fence. June 2002.

Photo 10 The Charlais cattle of Bosgård meadow show an interest in the field research. Photograph taken from a grassland replicate plot. June 2002.