EFFECTS OF CONTINUOUS GRAZING IN WETLANDS
Case Study of Current and Future Grazing Management Strategies in the Wetland Steinsvika

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DEPARTMENT OF PLANT SCIENCE
MASTER THESIS 30 CREDITS 2012

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Master thesis in Agroecology

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Autumn 2012

Steinsvika, (1) May 8., (2) June 28., (3) August 21. and (4) September 29., 2012.

Preface

This thesis is written on behalf of the administrators of Steinsletta, national selected agricultural landscape. The project was assigned to me in the spring of 2012 by Kari Astrid Ehrlinger, environmental consultant of the municipality of Ringerike, on behalf of The County Govenorof Buskerud, Buskerud County, the Municipalities of Ringerike and Hole and the Landowners of Steinssletta.

Being the last assignment in the course of my studies of agroecology, this thesis ties together different parts of my academic and practical studies and experience, hoping close the gap between theory and praxis through action oriented research. The conservation of wetlands is a common good to be kept and nurtured as our predecessors have done for millions of years. I have strived to make it a relevant contribution to what I consider an important topic. As the boundaries of a master thesis do not allow a comprehensive study of all relevant aspects of wetland management, this is meant as a contribution to further research, debate and practical testing and implementation in official management plans. A new management plan for the wetlands of Tyrifjorden is currently in the making and hopefully the findings of this thesis may serve as relevant input. Master students of agroecology are encouraged to write the thesis as a scientific article for publishing. Primary data, maps and selected photographs are therefore moved to appendixes.

The contents of this thesis is entirely my responsibility, but I would like to thank the following people for invaluable contributions: Supervisor Prof. Tor Arvid Breland, Ulf Egil Ullring, Marte Lerberg Kopstad, Eva Brod, Kari Astrid Ehrlinger and Jan Fredrik Horneman. Special thanks to my beloved wife Mari Solheim Sandsund.

Abstract

Grazing herbivores are a common tool in wetland conservation management. This thesis studied the effects of continuous grazing by livestock in the freshwater meadow/fen wetland Steinsvika in Southeast Norway. By visual assessment and biological monitoring, soil surface properties, condition of grasses, signs of animal presence and other points of interest were observed and registered. Registrations were conducted through five transects in one month intervals throughout the grazing season of 2012. Results showed that under continuous grazing at low stock density, livestock overgraze patches of grass by regrazing fresh regrowth. This leads to reduced resilience of palatable plants, giving competitive advantage to unpalatable species. In populations of unpalatable species, woody species find refuge to develop, and wetlands most likely move towards a new successional level of shrub. The thesis discusses suggestions on how future grazing of wetlands can be conducted as an ecosystem approach. By subdividing the wetland into homogeneous vegetation zones and flood prone areas, and controlling density and duration of grazing, livestock may provide more predictable results, when management goals is to keep succession at a specific level. This way of managed grazing may influence bird habitats, wanted and unwanted species, nutrient runoff as well as animal welfare and performance in a more considerate way than when managing livestock merely based on stocking density per grazing period (140 days). As the boundaries of a master thesis do not allow a comprehensive study of all relevant aspects of wetland management, this is meant as a contribution to further research, debate and practical testing and implementation in official management plans. A new management plan for the wetlands of Tyrifjorden is currently in the making and hopefully the findings of this thesis may serve as relevant input.

Sammendrag

Beitedyr er et utbredt verktøy i forvaltning og restaurering av våtmarker. Denne avhandlingen studerer effektene av kontinuerlig beiting av strandeng sump-vegetasjon i ferskvann våtmarkslokaliteten Steinsvika, Hole kommune. Observasjoner av jordoverflate, tilstand til gresspopulasjon, tegn på tilstedeværelse av dyr, og andre observasjoner av særlig interesse ble registrert og dokumentert ved fem feltstudier med gjennom beitesesongen 2012. Observasjonene viser at dagens kontinuerlig beiting med lav dyretetthet, bidrar til overbeite av fôrplanter innen mindre felter, ved gjentatt avbeiting av gjenveksten. Dette svekker fôrplantenes gjenveksts evne, og gir konkurranse fortrinn til mindre smakelige planter. Innenfor grupper av mindre smakelige planter, finner ulike pionertreslag tilstrekkelig beskyttelse til å etablere seg, for å dernest bidra til gjengroing.

På grunnlag av observasjonene diskuterer denne avhandlingen hvordan beitestrategier kan brukes som økosystem tilnærming til våtmarks forvaltning. Ved å dele beitene i våtmarkslokaliteten inn etter naturlig sammenhengende vegetasjonsbelter og flom utsatte steder, kan man ved å styre dyretetthet og eksponeringstid i større grad bestemme suksesjons nivå ut i fra de mål som er satt for forvaltningen. Dette er vanskelig ved dagens kontinuerlig avbeitning som kontrolleres av antall dyr per area per beiteperiode (140dager). Endret beiteregime kan gi større mulighet til å kontrollere faktorer som habitat for fugler, ønskede og uønskede arter, avrenning, dyrevelferd og avdrått. På grunn av avhandlingens rammer blir det ingen inngående studier av helheten som forvalting av våtmarker innebærer. Denne avhandlingen er ment å bidra til å belyse et viktig fremtidig forskningsområdet, være et innspill til fremtidig forvaltningsplaner samt debatten rundt gjengroing. En ny forvaltningsplan for Tyrifjorden våtmarksområde hvor Steinsvika inngår, ligger på trappene. Forhåpentligvis vil resultatene av denne avhandlingen kunne bidra med relevante innspill.

Keywords: wetland management, grazing management, holistic management, grazing fens, continuous grazing, rotational grazing, short duration grazing, holistic planned grazing.

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…for Thorvald and future brothers and sister

1.1 Introduction

We are at a point in human history where we have to produce food to a growing population while at the same time restoring the ecosystems that are to sustain us (Foley et al. 2005; Daily et al. 1997). Humanity is degrading our ecosystem services in a pace which we have never seen before (Rockström et al. 2009), placing our terrestrial and hydrologic ecosystems at a tipping point, which if crossed will fundamentally change the conditions for life it self (Scheffer et al. 2005). Our wetlands are one of these ecosystems, classified as endangered super-biotopes of international conservation significance (Ramsar Convention, 1971). As an important provider of ecosystem services, such as water retention capacity, wetlands reduce danger of flooding, filtrate and purify water, especially in areas of eutrophication, as well as being a major carbon sequester, globally containing between 16- 33 percent of the terrestrial soil carbon (Maitland et al. 2002; Bridgham et al. 2006). Over the last 5000 years our wetlands have been shaped by human activity along with domesticated animals (Gordon and Duncan, 1988; Gherardi et al., 2008), providing among other, food, shelter and fuel. Over the past century human imposed degradation of wetlands through draining for agricultural and industrial purposes as well as abandonment, has led to a severe loss of wild plant and animal species. In abandoned wetlands, plant communities have undergone impoverishment towards shrub encroachment (Georgoudis, 1999). Shrub encroachment may contribute to dry up wetlands, which in turn sequester less CO_2 in soils (Sulman et al. 2009), and emit greenhouse gases (Smialek et al. 2005) as well as degrade biodiversity (Houlahan and Findley, 2004).

The importance of conserving wetlands has led to many conservation management programs, practices and theories. The Ramsar Convention, an international treaty for preserving wetland and waterfowl habitat, signed by 161 contracting parties, including Norway, developed the concept of "wise use" to serve as a guideline in wetland management worldwide. It states:

> "*Wise use of wetlands is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development.*"

Management of wetlands mainly consists of four tools: fire, technology, rest and grazing (Alexanderson; 1986; Maitland et al. 2002; Savory and Butterfield, 1998). Fire, the burning of organic material, and technology, mowing, herbicides, rotor-tilling etc., both have undesirable side-effects as pollution, killing of beneficial microbes, herbicide resistance etc., making them less suitable for sustainable wetland management (Launchbaugh and Walker, 2006; Aleksandersson, 1986; Maitland, 2002; and Butterfield, 1998). Leaving nature to succession (rest) on the other hand, is a randomized pathway to afforestation (Walker, 2011), making rest a less feasible tool for maintaining wetlands.

This leaves us with grazing as the most feasible tool for sustainable and resilient management of wetlands. Grazing and browsing herbivores have been part of our wetland's ecosystems for more than 5000 years (Alexandersson et al. 1986, Svenningsen, 2002), and have multiple beneficial effects, if overgrazing is avoided (Georgoudis et.al, 1999). According to Svennings (2002), large herbivores were the main cause of development of the open floodplain vegetation of northwestern Europe. Grazing by livestock is a common conservation praxis, which has extensive and profound impacts on plant communities (Díaz, 2001).

In conservation management, livestock have multiple desirable effects on the ecosystem. They shape the landscape by keeping it at an early successional level; they contribute to the nutrient cycling, as well as creating favorable habitat for a variety of species, and create livelihood for people (Gordon and Duncan, 1997). Research by Pyke and Marty (2005) show "*that grazing can also confound hydrologic changes driven by climate change, and play a critical role in maintaining the hydrologic suitability of vernal pools for endangered aquatic invertebrates and amphibians*".

Using livestock as a tool for wetland management traditionally consists of two grazing practices: continuous and rotational grazing (Alexanderson et. al, 1986, Bokdam, 2003; van Oene et al. 1999). In continuous grazing, grass is exposed to animals without rest for a longer period or throughout the whole grazing season (approx. 140 days) (Sæther, 1996). In Europe, continuous grazing is the dominant grazing system (Briske et al., 2008), as it is in Norway. Rotational grazing on the other hand is a management intensive form of grazing and can be differentiated into for example strip grazing and leader-follower grazing systems. This type of grazing systems is less common, but used in pasture systems. These two types of grazing systems vary in terms of resource requirements and management needs - particularly rotational grazing has many managing variations.

As an alternative to livestock and animal husbandry, some wetlands and nature reserves are managed according to the wilderness concept (WallisDeVries 1998). Wilderness management is based on semi-natural wild ungulates as well as cattle and horses roaming freely within the conservation area in order to keep the ecosystem at early successional levels. Absence of natural predators makes it necessary for humans to go in culling when ungulate populations get to high as well as occasional mechanical mowing when vegetation exceed the wanted state (van Leeuwen and van Essen, 2002).

It is difficult to provide predictable results with continuous grazing both in controlled and wilderness forms in a conservation management context (Bokdam, 2003). The isolated effects of livestock on wetlands may be difficult to pinpoint, as human activity always has occurred alongside ungulates, human activities which have been both diverse and in constant change.

If the management goal either is to develop a new future wanted state of the wetland, or to restore wetlands to a specific previous condition, where man and livestock together shaped the biotope, livestock have to take on an extended role to account for the reduced impact of human activity in wetland areas. Previously, man used wetland areas as a resource for different purposes to a larger extent then what is the case today. This orchestrated behavior of livestock, in the context of our semi-natural wetlands, cannot be done alone without some form of management.

As an alternative to conventional grazing, a third grazing regime has emerged over the past decade. Somewhat similar to rotational grazing, Holistic Planned Grazing (Savory and Butterfield, 1998) takes on an adaptive ecosystem approach to ensure short and long term resilience of range and pasture lands. This method of grazing is based on biological monitoring followed by detailed and customized planning, which takes knowledge about seasonal changes in climate and species populations into account. Holistic planned grazing encompasses economic, ecologic and societal aspects of land management. The method of Holistic Planned Grazing is currently being used on approximately 30 million ha worldwide and is expanding. According to the 2012 UN Sustainable Development Report, Holistic Planned Grazing is one of the proven sustainable agricultural innovations of the 21st century (UN, 2012).

The County Governor of Buskerud has developed a management plan for Steinsletta cultural landscape (Fylkesmannen i Buskerud, 2009) also encompassing Steinsvika wetland. Grazing by livestock is one of the objectives of this plan to enhance the key ecological properties of the wetland. Key ecological properties include a high level of biodiversity, avoiding shrub encroachment, erosion, and eutrophication. Additional goals of preserving a not yet defined aesthetic agricultural landscape and increased accessibility for the public are also mentioned (Fylkesmannen i Buskerud, 2009).

The main objective of this thesis was to determine whether the current grazing regime maintains the management objectives developed for wetland Steinsvika, which was the case area of this study. By visual assessment of immediate effects of grazing on plants and soil, and comparison with published literature on grazing systems and wetland management, I discuss how managed grazing as an ecosystems approach can contribute to maintenance of key ecological properties of wetlands.

When designing grazing systems, there are multiple factors to consider, including some that are not quantifiable. However this thesis looked at the field-level issues and assess if grazing in wetlands were accomplishing these ecological objectives. Although inseparable, social and economic aspects (Folke et al. 2002; Savory and Butterfield, 1998) of wetland management are not discussed in this paper.

2.0 Material and Method

2.1 Area Description

Steinsvika is a 30 hectare (ha) wetland, which is located in the western part of Lake Steinsfjorden within the Steinssletta watershed in (map appendix 1) Southeast Norway (60.10380°N 10.29135° E). Steinssletta is a productive agricultural landscape dominated by annual cropping, situated on top of the last carbonate bed formed in situ in the Steinsfjorden formation. Calcareous sedimentary rock, give natural high pH and fertility to soils (Davis et al. 2005). Steinssletta has the status as cultural landscape of national importance (Statens landbruksforvaltning, 2012).

Steinsvika is a continuous wetland, where three different vegetation zones complement each other as habitats for waterfowl and other bird species (Ree, 2012). The southern boarder towards Steinsfjorden makes out the first zone, consisting mainly of open water with helophytes. The second zone (6.3 ha) is characterized by horsetail (Equisetum ssp. and sedges (*Carex ssp*.) fens. This part of the area is usually flooded most of the summer. The third zone (4.5 ha), bordering the croplands in north, is dominated by horsetail and sedge in wet meadows and grasses in the dry meadows, in addition to willow shrubs (Salix spp.) and some individual trees (Betula pubescens and *Pinus sylvestris*). Most dominant grasses are meadow foxtail (*Alopecurus pratensis*) common meadow grass (*Poa Pratensis*), reed sweet grass (*Glyceria maxima*), tufted hair-grass (*Deschampsia cespitosa*) and purple small reed (*Calamagrostis canescens*).

Three main streams run from catchments in the cropland area, and through the two inner zones making a network of backwaters and streams (1.6 ha). At the west side of the stream, the two dry meadows Steinslandet (3.2 ha), and Halvdansbeitet (1.2 ha) which is partly covered with birch trees (*Betula pubescens*), is also part of the grazing area.
In periods of flooding, water covers most of the wetland area. In a registration of natural habitat by Solvang and Kristensen (2009), Steinsvika has a conservation status as " Very Important" grade A. This is due to likelihood of a rich insect fauna and near threatened (NT) amphibian species.

According to Ree (2012), Steinsvika is seemingly the most important waterfowl location in Lake Tyrifjorden, due to its magnitude of resting, breeding and nesting birds. Steinsvika is a candidate for becoming a nature reserve (Fylkesmannen i Buskerud, 2012) making it a potential Ramsar Conservation area.

The water level of Lake Tyrifjorden fluctuates (appendix 4) between 62 meters above mean sea level (MAMSL) and 65 MAMSL with a mean level at 62,94 MAMSL The highest regulated water level being 63 MAMSL. Spring flooding occurs in May to June due to melting of snow, followed by mean levels during summer and autumn flooding. From a conservation standpoint, stable water levels have negative impact on fens (Alexandersson et al., 1986).

2.2 Climate Conditions

Mean precipitation during the grazing season of 2012 was above normal during the summer months (77.8 mmTOT to 61.2mmNORM) with the least rain in May. Mean temperature was a little below the normal. Water level of Lake Steinsfjorden was normal (62.8 MAMSL) (NVE, 2012) and grazing could proceed throughout the enclosed area.

2.3 Current Grazing Regime

After 60 years of rest, livestock was reintroduced to Steinsvika in the summer of 2010. The stocking rate in 2010 was 150 sheep, five mohair goats, and ten highland cattle heifers, grazing the whole area for the entire grazing season This gave a stock density of 0.85AU per hectare (ha). This thesis uses Animal Unit (AU), which is a measure of forage consumption, manure production and grazing pressure on land by livestock with 450 kg of body weight. Cow and calf pair equaling 1.2 AU, horse equaling 1.0 AU and sheep equaling 0.1 AU (MDA, 2012). During the grazing season of 2011, 70 Norwegian white sheep, nine mohair goats as well as ten highland cattle heifers, five NRF heifers and seven Dexter heifers. Being flooded most of the season, the stock density on approx. 15 ha equals 1.85 AU/ha. The stocking rate of Steinsvika during the season of 2012 was 20 Charolaise cattle, where ten cows, nine calves, one bull giving a rather low stock density (0.4 AU/ha) on the 30 ha area. Wild herbivores are observed by Ree (2012), mostly roe deer (*Capreolus capreolus*) passing through, thought these are mainly browsers and do not compete noteworthy with livestock on the available forage.

2.4 Method: Biological monitoring

According to Vos et al. (1999), biological monitoring can generally be defined as the repetitive measurement of a specified set of variables at one or more locations over an extended period of time according to prearranged schedules in space and time. Basic biological monitoring provides early warning functions, which detect changes in the environment and their causes, which might need remedial action (Savory et al. 2006; Vos et al. 1999).

For the purpose of this thesis, biological monitoring was conducted by transect walks. Five transects walks were conducted within the study area. The first occurred prior to grazing 08. May 2012. The second transect occurred 28. June 2012 one month into grazing season. Third transect occurred 21. August 2012 and the fourth transect was conducted 29. September 2012. An additional monitoring was conducted 08. October 2012, after livestock had left the area, getting an overview of the whole grazing area from the hillside Loreåsen, bordering to Steinsvika in the east. Transects walks consisted of an initial random sampling (Vos et al. 1999) through the different vegetation zones within the fenced area with additional resampling (see map appendix 1). Sampling included, a written description of the nature of the bulk of the soil surface, signs of animal presence, the presence of litter and its condition, in what condition the perennial grasses were, and which grass species that were present. In addition other conditions of interest were also registered. Observations were documented by photography (appendix 3), subsequently analyzed using published research and literature on wetland management, grazing management, grazing ecology, holistic management, grazing fens, continuous grazing, rotational grazing, short duration grazing, holistic planned grazing and targeted grazing.

3.0 Results & Analysis

The primary results from biological monitoring can be found in appendix 2.

3.1 Soil Surface

The result of the biological monitoring showed a continuous trend of moss (Sphagnum spp.) covering the soil surface. Sphagnum moss is a common ground cover in northern wetlands (Kim, 1995). Fine sediments from the seasonal flooding harden and develop a crust on the soil surface, preventing the soil from breathing creating anaerobic soil condition. Moss thrives under anaerobic conditions and contributes to acidifying waters. Under acidic conditions, few bacteria grow and decomposition stops making nitrogen less available. These conditions inhibit germination of seeds, and make favorable conditions for woody species (Hackett, 2009) hence contributing to brush encroachment.

The amount of litter on the ground was rather limited in the meadow areas, presumably because livestock previous year grazed at such intensity that most edible vegetation was gone. The sedge fens on the other hand were flooded for the most part of the grazing season of 2011 and therefore most sedge remained ungrazed and decaying, creating vast areas of sedge litter tussocks. Puddles between tussocks create favorable conditions for parasite populations that in turn might have negative impact on livestock health (Alexanderson et al. 1986). After the grazing season 2011 there was reported gastrointestinal nematodes on three of the sheep (Ree, 2012).

3.2 Animal Signs

The most frequent sign of animals was trampling. Animal trampling caused damage along fences, around feeding areas, saltlicks, stream crossings, watering places, and trails thorough the wetland. Added together, trampling affected a considerable area and caused great damage to meadow, water quality, and soil. In most of the area the soil surface was left un-disturbed, inhibit the full potential plant growth because of anaerobic conditions in soil. This also makes favorable conditions for non-grass species like moss.

3.3 Grass

Throughout the grazing season the livestock migrated between previously grazed patches, searching for fresh regrowth creating a mosaic pattern of lawns and larger patches of mature un-grazed grass. Grazed plants within these mosaics appeared as dwarf plants, creeping leaves and early developing seed heads. According to McNaughton (1984) grasses can evolve rapidly in response to the prevailing defoliation regime, making it possible to detect symptoms of overgrazing by looking at the different escape strategies plants possess. Livestock migrate between previously grazed patches because the fresh regrowth have higher nutritional value (Skarpe and Hester, 2011). Frequent intensive grazing selects for prostrate, small-leaved, dwarfed ecotypes that are short in stature (McNaughton, 1984). These are typical mechanisms of grazing resistance by grazing avoidance (Díaz et al. 2001; Gordon and Prins, 2007). This was confirmed by observations made in Steinsvika. When the photosynthetic leaf area of a plant is repeatedly reduced, it negatively impacts root systems by reducing energy available to support existing root biomass and new root production (Briske et al., 2008; Augustine and McNaughton, 1998) and forage plants will be out-competed by less palatable species (Voisin, 1953). Within a population of unpalatable species, woody pioneer species will get the necessary refuge to develop (Boughton et.al. 2010; McNaughton, 1978). This is supported by Bokdam (2003), who confirms that cattle may act as a driving force in creating and depleting lawns until resistant shrubs or trees invade. Willow (Salix spp.) is one pioneer species that invade fertile, recently disturbed sites and grows beyond the height of browsing by large herbivores through rapid vertical growth rates and large belowground storage of nutrients and energy (Bryant et al. 1983). Early booting in grasses to produce seeds may be another sign that plants are stressed. This symptom was detected on some of the meadow foxtail (*Alopecurus pratensis*) and common meadow grass (*Poa Pratensis)* grasses within the grazed lawns, which had short distance between internodes on the stem and developed seed heads (15-20 cm high).

According to Searle and Shipley (2008) the dispersion of plant parts and physical plant defense can also influence grazing time. Resulting in more time and energy spent on filling up the rumen than they would have if they had foraged on uniform compact bites. This leads to higher energy input per weight gain on the livestock, contributing negatively to the economy of both production and pasture.

Mosaic patterns do have an important function in preserving the biological community dynamics (Alexandersson, 1986) especially some of the ground-nesting birds. Given their access to fresh regrowth of meadow foxtail in the meadows, other vegetation as horsetail and sedge remains for the most part un-grazed thus making the plants mature and senescent. Some grazing of sedge and horsetail has occurred along streams and backwaters, in addition to minor patches in the sedge fens late in the season. These grazed patches remained green until October, demonstrating a positive effect of continued photosynthesis with regrowth, which in turn could prolong the grazing season. Cattle do graze sedge and horsetail, but not as long as grass regrowth is available.

3.4 Other Results

Among the other points of interest were the dung pats within the mosaic lawns. These dung pats were covered by un-grazed broad-leafed grass, suggesting high nutrient availability. These grasses were not grazed, as cattle do not like feeding around their own feces. As the current stock density was low, dung pats were left undisturbed, which increases nutrient leaching.

Nitrophilic plants such as nettles (*Urtica dioica*) and common chickweed (*Stellaria media*) are commonly referred to as indicators plants (Falkengren and Schöttelndreier, 2004) concerning excess nutrients. Docks (*Rumex obtusifolius*) are also an indicator of extremely nutrient rich situations, and usually occur at cattle resting places or near polluted rivers (Hill et al. 1999). These nitrophilic plants are present on both dry and wet meadows especially around supplement feeding area where supplementary feeding of grass silage result in a fertilizing effect on the wetlands. By changing towards a higher animal impact and shorter duration, dunging and urinating happens on the newly grazed vegetation, which is in most need for nutrients (Savory and Butterfield, 1998; Voisín, 1953).

Blue-green algae (cyanobacteria) were observed along the shorelines and in the basin for irrigation water to agriculture purposes. Blue-green algae are usually a result of eutrophication but could also be an indicator of high pesticide runoff (Agarwal, 2005).

4.0 Discussion

The biological monitoring at Steinsvika shows that the current grazing regime stresses patches of grass because of continuous grazing of regrowth. Palatable plants weakened by overgrazing, give woody species a competitive advantage. This happens even though the current stock density in conventional terms is low (0.4 AU/Ha) compared to recommendations for wetland grazing by Alexandersson et al. (1986). The current use of livestock as a tool does not seem to fit the purpose of fulfilling the management goals of the wetland Steinsvika.

4.1 Overgrazing – the absence of predator pressure

Overgrazing is a malleable word with various definitions. The common terminology refers to overgrazing as either to many animals on the land for too long (FAO, 2012) or as when plants cannot sustain themselves over time, because of overgrazing or related processes (Mysterud, 2005).

According to Voisin (1953) overgrazing has nothing to do with animal numbers, but it has everything to do with the time a plant is exposed and re-exposed to animals. When a plant is exposed for repeated grazing without the adequate recovery time, it will tear on its stored root energy, and will be out-competed by less palatable species (Voisin, 1953; Noy-Meir, 1975).

Grazing livestock creates homogeneous patches of high nutrition forage by repeatedly returning to graze previously grazed patches to graze on the fresh regrowth (Searle and Shipley, 2007). Regardless of numbers, animals return to established patches of fresh regrowth as long as no external or internal influence makes them decide otherwise. To understand how grazing functions in an ecosystem, one has to be aware of the connection between grass, grazer and predator (Savory and Butterfield, 1998). Grazing without predators pressure changes the behavior of herbivores, as herbivores and predators have coevolved for over millions of years (Savory and Butterfield, 1998). To fend off predators, herbivores developed defense strategies such as bunching together, as the herd is less vulnerable than a single individual. This behavior leads to intense grazing, defecating, urinating, salivating and trampling on a concentrated area, thus maintaining the overall soil cover and grassland health (Harrison and Bardgett, 2007). As no herbivore enjoy eating around their own excrement, and usually also followed by pack-hunting predators, the heard will be moving towards fresh grass, and there will be a longer period of rest for the grazed grass before the animals return (Savory and Butterfield, 1998).

In a greater perspective, domestication by humans has probably had little influence on the grass - herbivore-predator ecosystems, as the first grazers emerged within the past 10 million years (Gordon and Prins, 2007), and domestication of animals came approximately 9.990.000 years later. According to Noy-Meir (1975), grazing systems used and controlled by man, from intensive pastures to extensive range, may be considered as a special case of 'predator-prey' systems. In order to achieve the same effect as herbivores under predation pressure, grazing systems must mimic those that occur within natural ecosystems (Savory and Butterfield, 1998).

In conventional grazing systems the prevailing measure of stock density is the amount of animals per area, over a timeframe of the whole grazing period. Usually being 140 days. Conventional grazing management operates with three levels of stock density, low, medium and high density. Most research done on overgrazing and rangeland management, recommend that a medium stock density, adapted to local variations is the most beneficial to animals and forage (McNaughton, 1979; Holand and Steinsheim, 2007; van Oene, 1999). Increasing stock density as a measure to maintain a low successional level, will most likely have effect on preventing shrub encroachment due to overrest of plants. However, as low stock densities under continuous grazing lead to shrub encroachment due to overgrazing forage plants, a shift from conventional measurements of stock density and grazing regime should be considered in order to maintain ecological properties.
According to Mysterud (2005), current rangeland management and legislative authorities do not have the necessary tools to quantify overgrazing nor what actions to implement. As livestock are the only feasible tool to maintain a wetland in socio-ecological terms, a new approach to management is important to discuss.

4.2 An ecosystem approach to managing wetlands

Considering the management goal of Steinsvika, though not specified in detail, preserving a high biodiversity requires a new level of managed grazing that simultaneously addresses the complexity of soils, soil organisms, plants, wildlife and livestock (Savory and Butterfield, 1998).

Starting at the soil surface, an ecosystems approach to reducing moss cover can be done by utilizing animal trampling as a tool (Savory and Butterfield, 1998). By managing density and duration, animal trampling can be targeted to break soil crust and reduce moss cover by hoof action as well as exposing the ground to sunlight by eating and trampling shade casting vegetation. Soils without surface crust, produce less water run-off and waters will be less contaminated (Savory and Butterfield, 1998). Animal trampling is also important feature for reseeding the soil, through disturbance of the soil surface enhancing germination of seeds. By removal or reduction of the moss layer, recruitment of seedling will increase significantly (Spacková et al. 1998), also enhancing vegetative regrowth of stolons.

The observations show that overtrampeling damaged a significant proportion of the wetland. This detrimental effect on plants and soils can be turned into an advantage by placing blocks of salt among shrub, tussocks or other things that should be decimated, and moving/removing it when desired trampling effect is achieved. The sedge horsetail fens had an abundant cover of litter tussocks. By utilizing the effect of trampling, livestock can contribute to speed up the decay of dead and un-grazed plant litter by treading it into the soil, increasing the amount of soil organic carbon. Their hoof action distributes dung and urine more evenly through the grazed patch (Savory and Butterfield, 1998) feeding newly grazed plants in need of nutrient supply.

The depositions of animal waste increases microbial biomass and stimulates microbial activity, which in turn increases nutrient cycling rates (Bardgett et al. 1997, 2001) contributing positively to plant growth and carbon sequestration. Animal trampling should be evenly distributed, and trampled plants should have the opportunity to fully recover after exposure to animals. Meadow foxtail, being the most dominating of the forage plants in Steinsvika, is a long lasting very palatable forage that can withstand heavy trampling (Smoliak, 1990), hence overtrampling of less resistant plants may be overshadowed as meadow foxtail still thrives. Research by Weber and Gokhale (2011) shows that animal impact and the duration of grazing strongly influence water retention capacity, which in turn might contribute positively to increase wetlands ability to store water.

Grasses and herbs within the grazed mosaics of the meadows, showed signs of stress due to frequent re-exposure to livestock, resulting in overgrazing of individual plants. Over-grazing and over-rest can be avoided by frequently moving livestock. Livestock should be kept within an enclosure for no longer than it takes to eat 60 percent of the grass, trample another 30 percent and leave last 10 percent standing (Judy, 2008) and not returning before all plants have had adequate recovery time (Voisin, 1953). Recovery time could range form 30 - 90 days depending on weather and season. By managing the amount of time grass is exposed to livestock, livestock can select for their optimum diet, trample 30 percent of the grass, which feeds the soil biota, and leave 10 percent standing as windbreak and shelter for ground-nesting birds (Judy, 2008). Cattle graze swards systematically by first biting the top of all plants, as this is the most nutritious part of the plant, and then graze the horizontally lower level second (Searle and Shipley, 2007). This means rotating livestock frequently will lead to consuming of more high nutritional biomass, in turn affecting the weight gain of the livestock positively (Judy, 2008)

The wetland, especially the sedge fens had multiple puddles among the tussocks, which are excellent hosts for parasites (Alexandersson et al. 1986). Moving animals frequently into fresh paddock, followed by a long recovery period can break the lifecycle of some parasites, reducing animal diseases and the further spreading of parasites (Stromberg and Averbeck, 1999).

As there was limited grazing of the sedge fens, it is recommendable to increase the uptake of sedge and horsetail by the livestock to prevent shrub formation. Considering the palatability of sedge and horsetail is at its highest early in the season, and water levels are statistically at its lowest late June, it would be a good time to enclose grazing animals within the horsetail/sedge fen to the extent that optimum level of grazing and trampling is achieved. This could mean dividing the fen into even smaller paddock to further control the animal impact. Alexandersson et al. (1986), suggest subdivision of pastures into smaller paddocks and rotating livestock to get a more controlled grazing, but the recovery time of plants as discussed by Voisin (1953) must be taken into account when rotating livestock. This is also recommended by Savory and Butterfield (1998). Research by Bak (2012) show that Holistic planned grazing produce more forage and plant diversity, when compared with organic and conventional grazing in Denmark, concluding that grazing management is key to achieve good production results.

As the livestock roamed freely within the wetland, livestock trails resulted in trampling damage damaged to soil and plants throughout the area. By dividing the wetland into grazing paddocks following the natural vegetation zones, flood zones, as well as topography (appendix 5), homogenous areas with similar growing conditions enable the utilization of grazing resources at the most appropriate time and livestock trailing is decimated. Ground-nesting birds and other vulnerable species must be taken into consideration when positioning livestock, so that birds are not disturbed when vulnerable (Ree, 2012). This could include keeping livestock fenced out before and during hatching. According to Alexandersson et al. (1986) the totality of the positive impact of livestock on birds habitat in wetland management, overrides those of potential trampling damage. In reality it should be possible to plan grazing in such way that both birds and their habitat is maintained. According to Blaser et al. (1986) "*using a grazing cycle with both a short duration grazing period and a relatively high stocking density maximizes the amount of time that the pasture is left undisturbed between grazing events and causes no more nest destruction than longer grazing cycles using lower stocking densities. Introducing the animals into the paddock at a greater vegetation height-density and leaving a relatively large amount of residue post-grazing may contribute to nest protection. These factors can be varied within certain limits without affecting the vegetation growth cycle or forage quality"*.

Research by Pain et al. (1996) and Jensen et al. (1990) suggests that controlling vegetation status may increase nest survival at high stock densities, while being minimal at lower stock densities.
In natural ecosystems birds often accompany herbivores, as herbivores provide insect and small vertebrate especially through their dung that birds can feed on (van Wieren and Bakker, 2007). This also helps sanitizing fouled ground as birds feed on parasites populations. Moving animals frequently, allows for undisturbed habitat for birds in the aftermath, as well as providing short grass niches enabling birds to detect predators, they would not see if surrounded by continuous tall grass.
Herbivory by Geese (*Anatidae spp*) also has a significant contribution to the grazing impact, preferably shorter lawns and seeds from mature sedge and reed (Alexanderson et al. 1986). Livestock management must be adapted to create favorable conditions for the benefit of all. Birds are a useful indicator to reflect the overall health of an ecosystem (Olechnowski, 2009; Quinn et al. 2010).

Adaptive ecosystem solutions like this require no great investments other than a single-wire electric fence, but do require planning and regularly moving livestock onto new paddocks. By combining the moving of livestock with mandatory supervision of livestock, the livestock manager has the opportunity to observe animal up close. Norwegian laws require a minimum supervision of livestock twice a week in rangeland, and daily supervision on pastures (Lovdata, 2012a,b), making it possible to move livestock frequently to achieve the wanted grazing and trampling exposure, without significantly increasing workload and cost.

4.3 Limitations and Concepts for future study

4.3.1 The Method of Biological Monitoring

Monitoring is essential in any reserve to maintain the future wanted situation (Gordon and Prins, 2007; Maitland et al. 2003; Savory and Butterfield, 1998) and should always be the starting point of any conservation management. The simplified method proposed by Savory et al (2006) used in this thesis, was developed to make land managers able to look for early warning signs regarding the future state of the land under management. It is modified to serve management needs, not to gather representative data for scientific purposes. Still, biological monitoring gives insight to whether the landscape under management is moving from or towards you management goal (Savory et al. 2006). In either case you can change your management in time to assure that your land is moving in the direction you want it. Studies by Díaz et al. (2001) suggest that prediction of grazing responses on the basis of easily measured plant traits is feasible and consistent between similar grazing systems in different regions. The biological monitoring conducted for this paper gives an estimate of the current state of the vegetation, animal impacts and the surface of the soil. It is however not exhausting, and further field studies over longer periods of time are required to strengthen and elaborate the findings of this thesis. Test trials of an adaptive planned grazing strategy should be carried out over a longer period and monitored to prevent unwanted situations.

The field research required to investigate the full effect of changing the grazing regime of the wetland of Steinsvika is outside the scope of a master thesis. Therefore, this thesis looks at how the current use of livestock as a tool, does not seem to underpin the defined management goals of the wetland. Observations were done through one season, and would have been further strengthened if more seasons were included.

4.3.2 Input to decision makers

To keep our wetlands in a resilient state, grazing plans must be developed as an adaptive ecosystems approach, in cooperation with ornithologists, farmers, landowners, and other stakeholders affected.
For the future management of Steinsvika, stakeholders should together state clear objectives, defining the future wanted situation in detail and setting out concrete goals. Followed by close biological monitoring, which will pick up any deviation from this objective in time and ensure that actions implemented lead towards the management goal.
Future monitoring should include additional measures to determine the state of the general biodiversity of the wetland and control whether progressing towards the maintenance goal. This can be done by implementing acoustic recordings of bird sound within the wetland, and through digital analysis, estimate biodiversity as a factor of bird species present (Quinn et al., 2010).

Ultimately, managing wetlands without considering the values of the people tied to, it will most likely lead away from a future wanted situation. The practical management of whole situations in which land is involved, could only be done by viewing people, their land and their economy as one "*indivisible whole*" (Savory, 2008).

5.0 Conclusion

Even with low stock densities, the grazing management in Steinsvika, led to overgrazing of patches of grass, whereas the majority of grasses and sedge were over-rested. Increasing stock density as a measure to maintain a low successional level will under continuous grazing most likely have little effect in preventing shrub encroachment due to overgrazing. Stress symptoms on grasses and herbs indicated that the wetlands plant community most likely would undergo successional changes towards more woody and herbaceous species, and away from the current management goals. Using “animals per hectare” as a measure of stock density in a continuous grazed wetland may be inadequate to prevent overgrazing. In order to maintain the complex nature of wetlands, human interventions, which have been part of wetlands for more than 5000 years, should be an integral part of management plans. This intervention should take a holistic approach in planning and controlling grazing, in order to ensure that livestock is used to enhance the natural potential of wetlands, rather than obstructing it. A regime of planned grazing should be further tested and continue by planned grazing to achieve the wanted successional level. Understanding and utilizing animals grazing and trampling as tools should be further studied as an ecosystem approach to better maintain and develop important wetland areas. Maintaining wetlands ecosystem character is too important to leave succession to random, as will happen when grazing is not properly managed.

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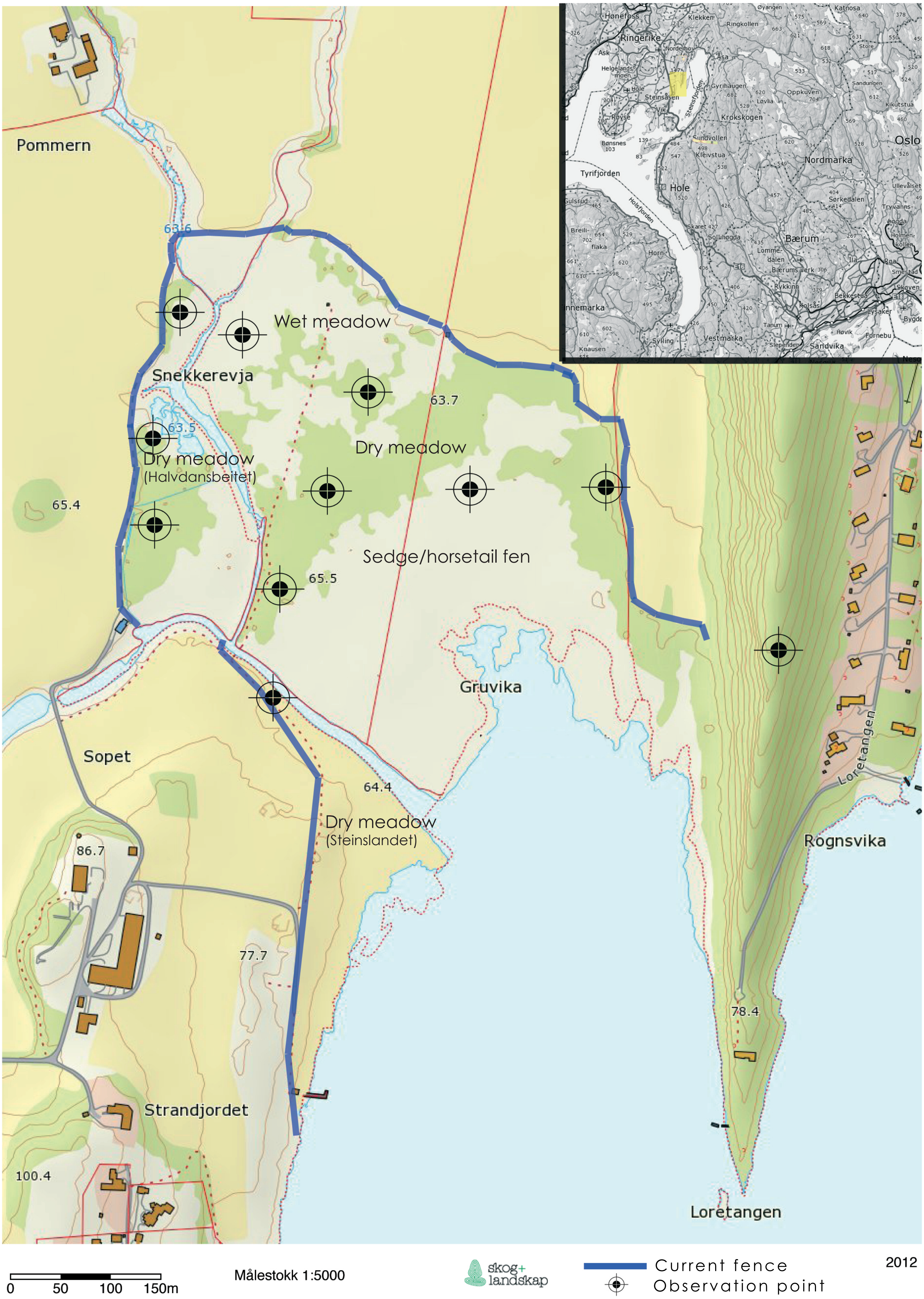
Appendix 1

Map of Steinsvika wetland, including current fence line and observation points from monitoring.

(Primary map data, courtesy of Skog og landskap, illustrations by author.)



Appendix 2.

Results - Monitoring

The following observations were registered during biological monitoring in the wetland Steinsvika, grazing season 2012.

Prior to grazing

Biological monitoring prior to grazing show that the soil surface of the bulk of the area was covered with moss (Sphagnum spp.). There was some litter in meadow areas, while tussocks of sedge litter and puddles of still water covered fens. Along floodline between the border of zone two and zone three, perennial grasses was evenly grazed the previous year, and regrowth was vigorous and dens with little plant litter on ground. The wet meadow had dense grass covered lawn, while the horsetail (Equisetum ssp.) and sedges (Carex ssp.) fen, being the second zone, seemed unaffected by grazing, as the area was flooded the most of the previous grazing season (2011). The dry meadows had close to 100% grass cover, and the grass growth was vigorous. As no animal were let onto the pasture at this point, visible signs of animals was from previous grazing season. Trampling damaged most of the wet meadows, especially flooded parts, but also higher laying parts had trampling damage. No other observations of importance were recorded.

After one month grazing,

The Soil surface was covered with vegetation. Mostly grass, herbs and moss (Sphagnum spp.) and some litter in meadow areas. Sedge fens consist of tussocks of sedge vegetation approx. 40 cm high.
Most grazing occurs inland on dry meadow and wet meadow. Grass species present include Meadow foxtail (*Alopecurus pratensis*) common meadowgrass (*Poa Pratensis*), reed sweetgrass (Glyceria maxima), tufted hair-grass (*Deschampsia cespitosa*) and purple smallreed (*Calamagrostis canescens*) Most grasses had developed seedheads. Grazing occurred in smaller patches (10 to 20 m2), making a mosaic of grazed lawns and un-grazed meadow. Un-grazed grass was close to maturity. Height of grazed grass was approx. 10 - 15cm. Height of un-grazed grass was 40 – 70 cm.

Along backwaters and along streams there were dense populations of soft rush (*Juncus effuses*) horsetail (*Equisetum fluviatile*) common reed (*Phragmites spp),* bottle sedge (*Carex rostrata*) slender tufted-sedge (*Carex acuta*) All exposed to grazing. Sedge fens consisting of tussocks of sedge vegetation (approx. 40 cm) are un-grazed.

The following grazing animals were present: ten charolaise cows, nine calves, one bull. The cattle moved collectively as one herd. Trails indicated patterns of movement, giving high animal impact on

concentrated areas causing trampling damage.
Heavy trampling damaged ground around saltlicks and down to nearby water.

Other points of interest were the cattle rest area in the tall grass dry meadow among willow shrubs. The willow (*Salix ssp.)* functioned as shelter, giving windbreak and shadow. Cattle also rubbed against the shrubs and there were signs of browsing.

After three months grazing

Soil surface was covered with moss and some litter in meadow areas. Sedge fens had dense litter pool. Previously grazed patches continued to be exposed to cattle. There was clear mosaic pattern on meadows, where the plant cover of grazed patches (lawns) was even shorter (5-10 cm) and denser due to tillering. Reduced internode length of the grazed grass, made grass and herbs (*Ranunculus Repens* and *R. acris spp.*) appear as dwarf plants. The bulk of the grass was ungrazed, had reached maturity and was weathering. There had been some grazing of horsetail and sedge fens.
The dry meadow northwest had trampling damage, and there were heavy trails along fence line and the roots of birch trees were exposed due to severe trampling. Half of the birch trees were dead. Five calves and two heifers had jumped the fence and were grazing on along stream north of the meadows. The cattle remaining trailed along fence line, mooing.
There were also holes in mesh fence presumably from animal reaching for grass outside fence. Cows received baled grass silage as supplementary feed. Excess feed was trampled into the ground at feeding area.

After four months grazing

The soil surface was covered with moss and some litter in meadow areas while sedge fens had a dense litter pool. Previously grazed patches continue to be exposed to cattle. There was clear mosaic pattern on meadows where the plant cover of grazed patches (lawns), was even shorter (2 – 5 cm) and denser due to tillering. Reduced internode length, made grazed grasses and herbs (*Ranunculus Repens* and *R. acris spp.)* appear as dwarf plants appear as dwarf plants. Un-grazed grass had reached maturity and was weathering. Some of the previously grazed meadow foxtail (*Alopecurus pratensis*) and Common meadowgrass (*Poa Pratensis*) grasses along the edges of the lawns had short stems with developed seed heads (15 - 20cm high). There had been some grazing of horsetail and sedge fens especially within the fen. One grazed patch, approx. 20 m2, had fresh regrowth and was surrounded by mature weathering sedge.

Severe trampling damage occurred on dry meadow, along fence line, around feeding area and across stream towards wet meadow area. Birch roots were exposed on the majority of trees.

In meadow areas, dung pats layed untouched within the lawns, covered by un-grazed broad-leafed grass. Nitrophilic plants such as nettles (*Urtica dioica*) and common chickweed (*Stellaria media*) and docks (*Rumex obtusifolius*) were present on both dry and wet meadows. Livestock were supplementary fed grass silage in bales. On water surfaces in backwaters and streams, blue-green algae (cyanobacteria) developed along the shorelines and completely covered the basin for irrigation water to agriculture purposes.

After grazing

Observations done from the hillside Loreåsen on the Eastern boarder of Steinsvika gave an aerial overview on the grazing preformed in the studied area. Photographs taken showed that more than half of the forage available to the cattle had not been utilized. This also applied for the sedge/horsetail fens that mostly were left un-grazed. The same time that cattle was taken off the land, grazed patches was still green, while un-grazed patches had decayed having a brown color.

Nitrophilic plants indicate excess nitrogen, which means poor nutrient cycling. Runoff, also supported by dung pats, was not spread by lack of animal trampling.

Appendix 3

Photo 1
08.05.2012
Wet meadow. Moss on soil surface, little litter cover. Wet meadow.

Photo 2
08.05.2012
Trampelig damage, wet meadow.

Photo 3
08.05.2012
Sedge litter tussocs. Sedge/horstail fen.

Photo 4
08.05.2012
Dense lawn, dry meadow.

Photo 5
08.05.2012
Trampling damage, wet meadow.

Photo 6
08.05.2012
Higher parts grazed, lower part sedge litter tussocks ungrazed.

Appendix 3

Photo 7
28.06.2012
Dry meadow. Moss cover soil surface. Grazed grass *(Alopecurus pratensis) approx. 10 - 15 cm high.*

Photo 8
28.06.2012
Moss cover, herbs.

Photo 9
28.06.2012
Grazing top of grasses, wet meadow.

Photo 10
28.06.2012
Cattle. overview dry and wet meadow.
Grazed patches lower left corner. Loreåsen in the back.

Photo11
28.06.2012
Trampling damage, salt lick, dry meadow. Browsing and rubbing on (salix spp.) Bridge to access wetland in the back.

Photo 12
28.06.2012
Grazing sedge and horsetail along backwater edge.
Halvdanshaugen in the back.

Appendix 3

Photo 13
21.08.2012
Severe grazing along fenceline, dwarf size herbs and grasses on inside fence, regular size outside. Grass outside fence is mown once.

Photo 14
21.08.2012
Halvdansbeitet, dry meadow. Trampling damage around suple-mentary feeding area, and on tree roots. Tussocks of (Urtica dioica)

Photo 15
21.08.2012
Trampling damage along fence. Browsing of Salix spp. shoots. Docks, (Rumex obtusifolius) in wet meadow. Cattle jumping the fence in the back. Mooing.

Photo 16
21.08.2012
Dry meadow, heavily grazed patches and mature grass. Tus-socks containing dungpats. Loreåsen in the back.

Photo 17
29.09.2012
Trampling damage along fence. Docks and senescence sedge (carex spp.) in wet meadow.

Photo 18
29.09.2012
Halvdansbeitet. Trampling damage along fence, around feeding area and on tree roots. Non palatable herbs along fence, Grass recently mown outside fence.

Appendix 3

Photo 19
29.09.2012
Grazed patch, dry meadow: dense lawn, dwarf herbs and grasses, prostrate small leafed plants.

Photo 20
29.09.2012
Patches of heavily grazed and senescence grass. Bright green tussocks cover dung pats.

Photo 21
29.09.2012
Dung pat covered with un grazed broad leaf grasses and herbs.

Photo 22
29.09.2012
Cattle entering sedge fen.

Photo 23
29.09.2012
Senesence sedge fens. Grazed patch (approx. $25m^2$) in center of image

Photo 14
29.09.2012
Bluegreen algea in channel. Dead birch trees in the back (Halvdansbeitet) ungrazed sedge along waters edge.

Appendix 3

Photo 25
29.09.2012
Trampling damage, stream crossing between dry meadow and Halvdansbeitet.

Photo 26
29.09.2012
Stream between Halvdansbeitet and the main wetland. Patch of dense and broad leafed grass regrowth in lower right corner.

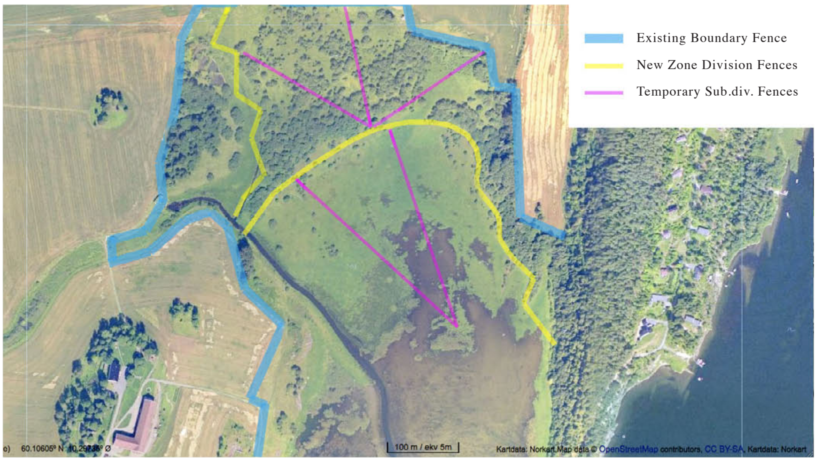
Photo 27
08.10.2012
Overview from Loreåsen. Sedge/horsstail fens vegetation is senescence, small patches grazed. Green cereal fields in the back.

Photo 28
08.10.2012
Dry meadows to the left, wet meadows to the right, sedge fen bottom. Majority of vegetation has a brown/yellow color, indicating senescence, apart from grazed patches within meadows being green.

Appendix 4

Steinsvika, aerialview. Spring 2008. Sedge fens flooded. Courtesy of Nordata.

Steinsvika, aerial view. Summer 2003. Low water levels. Courtesy of Nordata.



Alternative fence layout, for planned grazing in Steinsvika. Semi-permanent division fence (yellow) follows floodline contour. Temporary fences subdivide paddocks appropriate to animal numbers and wanted impact. Design and illustration by author.

Steinsvika, aerial view. Autumn, 2011. Sedge fen flooded. Courtesy of Nordata.

"Alt livet er sol-kraft, sol-eld, skynar eg um natti.
Når soli er burte, sloknar me".

Arne Garborg