J. Mt. Sci. (2019) 16(7): 1691-1701 e-mail: jms@imde.ac.cn http://jms.imde.ac.cn
https://doi.org/10.1007/s11629-018-5258-x

Defining a mountain landscape characterized by grazing using actor perception, governmental strategy, and environmental monitoring data

Wiebke NEUMANN[1*] https://orcid.org/0000-0002-0000-4816; e-mail: wiebke.neumann@slu.se

Camilla SANDSTRÖM[2] https://orcid.org/0000-0002-7674-6197; e-mail: camilla.sandstrom@umu.se

Lina HOLMGREN[1,2] https://orcid.org/0000-0002-8002-5771; e-mail: lina.holmgren@slu.se

Göran ERICSSON[1] https://orcid.org/0000-0002-5409-7229; e-mail: goran.ericsson@slu.se

**Corresponding author*

1 Department of Wildlife, Fish and Environmental Studies, Swedish University of Agricultural Science, 90 183 Umeå, Sweden

2 Department of Political Sciences, Umeå University, 90 183 Umeå, Sweden

Citation: Neumann W, Sandström C, Holmgren L, et al. (2019) Defining a mountain landscape characterized by grazing using actor perception, governmental strategy, and environmental monitoring data. Journal of Mountain Science 16(7). https://doi.org/10.1007/s11629-018-5258-x

Abstract: In multi-functional mountainous landscapes worldwide, conservation of natural values is a major task. Here, pro-active policies can be a way forward. National Environmental Quality Objectives (EQO) to solve environmental problems for future generations, however, often wrestle with being too visionary and lacking specificity, which complicates their implementation. The EQO "A Magnificent Mountain Landscape" that has been adopted by the Swedish Parliament in 1999 to preserve the pristine mountain environment in Sweden, experiences all these flaws. To aid its implementation, we studied the conditions and processes needed to define, to evaluate, and to preserve its goals across the Swedish mountain chain, using one of its milestone targets (*a landscape characterized by grazing*) as a study system. Applying qualitative and quantitative methods, we analyzed three types of data: 1) referral responses to the governmental strategy document, 2) interviews with relevant actors, and 3) environmental monitoring data (reindeer position data). Nationally, our results suggest a need for geographical differentiation to match regional/local conditions. Regionally, difference in both perception and definition of the milestone target among the actors hinders the formulation, monitoring, and evaluation of a common goal. Next to a culture-nature divide, we found that a "within as a user" and "from the outside as an observer" perspective influenced suggested definitions. Moreover, we found a need for better defining whether the goal is maintaining current conditions or restoring previous ones. Our result supports the use of animal position data as a decision support tool to monitor and to aid evaluation of the target. Given the number of actors involved and conflicts of interests present, we suggest the application of a structured decision process to accomplish agreements on a common goal. Here, environmental monitoring data can aid a "landscape assessment step" as a natural part in the decision process to target landscape management actions resourcefully and effectively.

Received: 9-Oct-2018
Revised: 04-Mar-2019
Accepted: 28-May-2019

Keywords: Milestone target; Structured decision process; Reindeer herding; Herbivory; Environmental

Conservation strategy; Sweden

Introduction

Worldwide mountainous landscapes are under pressure from a mix of human induced climate change, natural resource extraction, and an influx of amenity land buyers modifying local economic conditions (Kotsios 2016; Kang et al. 2017; Mayor et al. 2017; Hunt et al. 2018). This challenges current management methods, calling for more holistic and land inclusive management approaches to conserve natural values. Pro-active policies with well-defined and measurable goals are key preconditions to target management actions, to implement strategies effectively and resourcefully, and to enable evaluation of conservation (IPBES 2018).

Conservation of vast multi-functional mountainous landscapes usually combines numerous stakeholders, challenging to reach common applicable goals. General structures to achieve agreements and definitions are often lacking, leaving conservational management repeatedly with visionary objectives, but without any measurable targets. The Swedish mountain area, considered as one of the most pristine environments in Europe, is no exception to this situation (Moen 2006; Swedish EPA 2014; Tolvanen and Kangas 2016; Lindahl et al. 2018). Being a Sami cultural landscape, reindeer (*Rangifer tarandus*) husbandry and reindeer have utilized the landscape for centuries (Josefsson et al. 2009; Norstedt et al. 2014; Östlund et al. 2015; Ratio et al. 2016). Historical data documents identify three critical resources for Sami communities of equal importance today: alpine heath together with subalpine birch forest, pine-dominated forests, and fishing waters (Norstedt et al. 2014). The long-term, but low-intense, Sami land use has created legacies that affect current ecosystems in northern Sweden (Josefsson et al. 2009; Freschet et al. 2014; Horstkotte et al. 2017).

Reindeer husbandry is an extensive land use that covers large ranges as semi-domesticated reindeers migrate from their mountainous summer areas to their winter areas in the inland and coastal forests, covering up to 23 067 km² (Figure 1). From an ecological point of view, the reindeer is a key herbivore in the mountainous landscape. Reindeer herbivory disturbs the

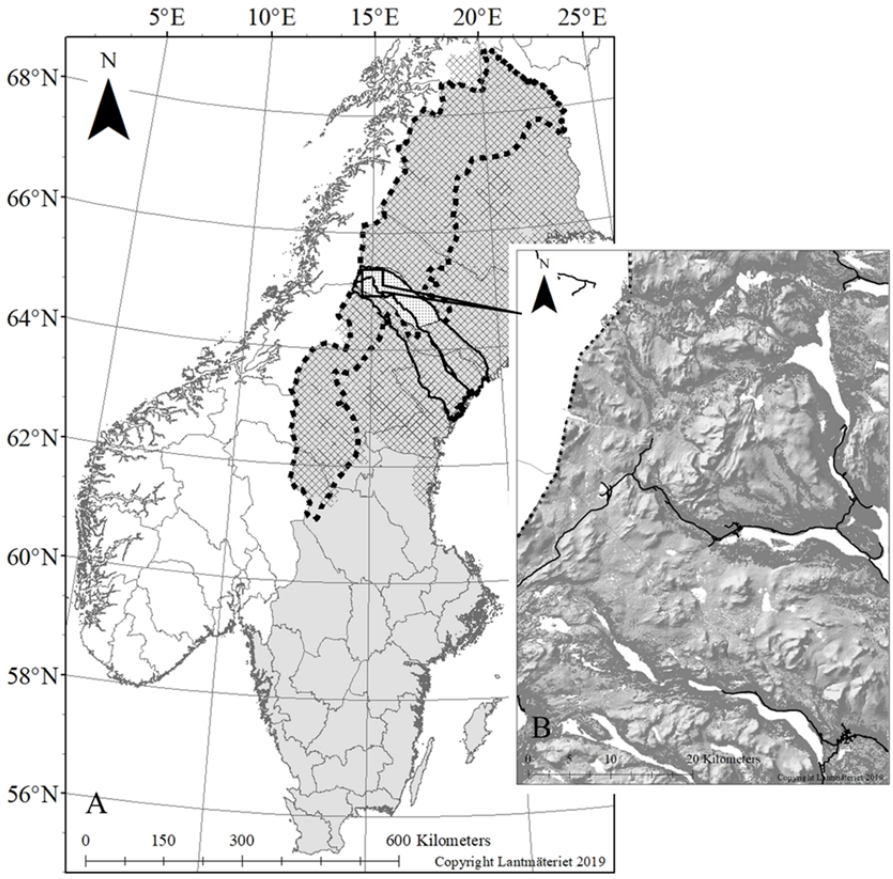

Figure 1 (A) Map of Scandinavia, Sweden in gray. Distribution of Swedish reindeer herding communities in cross-hatched. Acreage of the two reindeer herding communities *Vilhelmina Södra* and *Vilhelmina Norra* delimited by black line. Mountain region delimited by dashed line. Vilhelmina municipality indicated by stippled polygon. Area of the reindeer position data (B) indicated by the black box. Waterbodies presented in white, forested areas in dark grey, and areas above tree line in light grey.

expansion of lowland plant species (Kaarlejarvi et al. 2013; Horstkotte et al. 2017). It influences the biomass and growth of shrubs (Olofsson et al. 2009, 2013), and increases the primary production through enhancing the soil nutrient cycling rate (Olofsson et al. 2004, 2009, 2013). As a result, it alters species richness, moss, and lichen cover (Olofsson 2006). Due to a successive and state supported colonization, which has been on-going for the last 500 years (Norstedt et al. 2014), reindeer husbandry today takes place in a multifunctional landscape simultaneously with other land uses with a need of solutions for sustainable co-existence (Horstkotte 2014; Sandström 2015; Uboni et al. 2016).

Nationally, Environmental Quality Objectives (EQOs) can be one way to conserve natural values and ecosystem services provided by, such as the mountainous landscapes. In 1999, the Swedish Parliament adopted the EQO "A Magnificent Mountain Landscape" to guide policy development (Gov. Bill 2004/05:150; Environmental Objectives 2018). This objective, being one of the 16 EQOs, has been criticized for being rather ineffective in terms of achieving its goal (Edvardsson 2004; Emmelin and Cherp 2016). To achieve the EQO "A Magnificent Mountain Landscape", the Swedish government later commissioned the Swedish Environmental Protection Agency (Swedish EPA) to propose a more precise strategy. The strategy includes milestone targets and associated measures for three key areas: (1) demands on mountain areas, (2) conditions necessary for a *mountain landscape characterized by grazing* (hereafter referred to as "*Grazed Landscape*") and (3) off-road driving (Swedish EPA 2014).

In the new strategy, the Swedish EPA specifically focuses on reindeer husbandry and reindeer herbivory as an important part of the mountain landscape, and as a tool to achieve and to maintain the "*Grazed Landscape*"-target (Swedish EPA 2014). The future of reindeer husbandry thus is defined as a critical component to accomplish the milestone target itself, and on a higher level to bring forward the implementation of the EQO. The Swedish EPA states three major objects to aid this "*Grazed Landscape*"-target for which conditions necessary for sustainable reindeer grazing in the mountains should be set by 2020: sufficient access to continuous pastureland of good quality, undisturbed grazing conditions for reindeer, and functioning conditions in the reindeer winter areas (Swedish EPA 2014). Prerequisites also encompass a reasonable profitability for reindeer husbandry in order to maintain a stable number of reindeer that can result in a sufficient grazing pressure to full-fill the milestone target (Swedish EPA 2014). To maintain an open landscape, herbivory by other mountainous mammals and livestock pasture activity is pointed out as well, yet, being considered to have lower impact than herbivory by reindeer (Swedish EPA 2014). Authorities as well as non-governmental organizations heavily criticized the proposed strategy for being too vague. Based on the vagueness of the target, the National Board of Housing, Building and Planning completely rejected the strategy and suggested that the Swedish EPA should set up a process to include all the relevant actors and in collaboration to find a way forward.

Inspired by this suggestion and by the Structured Dialogue Process (Addisson et al. 2013; Johansson et al. 2018), the overarching objective of our study is to explore the potential of a more inclusive and structured process to make the specific milestone target (*Grazed Landscape*) more explicit. More specifically, we are interested in the conditions needed to set up a structured dialogue process to link a target, via indicators to evaluation in order to preserve a landscape across large spatial scale. To address our objectives, we analyzed three types of data using qualitative and quantitative methods: document analysis, interviews, and analysis of animal movement data. In the interviews, we asked specifically 1) How do the participants define a "*Grazed Landscape*"? 2) What indicator(s) do they propose to describe and measure a "*Grazed Landscape*"?, and 3) Which indicators do they think are important for monitoring a "*Grazed Landscape*"?

1 Analytical Framework

The Structured Dialogue Processes, or Structured Decision-Making processes, has arised from the need to provide informed decisions about environmental policy alternatives in a context of uncertainty (Addisson et al. 2013; Johansson et al. 2018). The goal is to provide better solutions,

inclusive decision-making arenas, and acceptance of resource management (Johansson et al. 2018). As such, structured processes may aid and inform decision makers rather than to prescribe a preferred solution. It is an explicit step-by-step process to clarify possible actions and their implications across a range of relevant concerns by following six distinct working steps: 1) problem framing, 2) formulate measurable objectives and identify indicators, 3) definition of management alternatives 4) analysis of causes and consequences, 5) decide and act; and 6) evaluation. Given these 6 steps, the framework provides a transparent structure in the workflow, taking into account new knowledge and insights generated during the process. In this perspective, the framework thereby nicely combines the concept of Adaptive Management (Rist et al. 2013), social learning (Mårald et al. 2015), and structured decision-making (SDP, Addison et al. 2013). The SDP is particularly capable to identify and to include different views of the involved actors in the working process as it asks for alternative solutions for the decision process. Hence, it asks for both what is important, and what are the consequences, i.e., what is likely to happen if an alternative is implemented. In this study, we primarily analyzed step 1 and 2, which can be defined as the problem definition phase, and step 6 as the evaluation phase, to explore the conditions to establish a link between targets, indicators and evaluation, which may provide important input into the policy processes.

2 Study Area

Sweden covers 14 degrees in latitude and is sparsely populated with a total of 10 million inhabitants and 25 persons per km² (www.scb.se, accessed 31 January 2019). Inhabitants are not equally distributed with 87% living south of latitude 61 (www.scb.se, accessed 31 January 2019). The Swedish mountain landscape covers 113,137 km², stretches over eight degrees of latitude (61-69), and thereby intersects with 15 different municipalities and with 40 of 51 Sweden's reindeer herding communities. It borders directly to the Norwegian mountain landscape, sharing a common flora and fauna. Together the Swedish and Norwegian mountain range build one of longest mountain chains in Europe, the Scandes on the Scandinavian Peninsula. During the last Ice Age, ice covered the entire Scandinavian mountain chain. Particularly, the Swedish mountain chain has been shaped by the ice to a combination of smoothly formed mountains, steep valleys and few sharper-formed higher mountains. Elevation of the Swedish mountain chain ranges from 33 m to 2098 m above sea level. On average tree line is about 700-900 m above sea level, being slightly higher in the southern and lower in northern part of the Swedish mountain chain, respectively. Mountain birch (*Betula pubescens var. tortuosa*) characterizes the forest at the tree line, whereas heathland and mires are typical for the areas above with different *Salix* species, heather (*Calluna vulgaris*), grass, herbs, and mosses being the dominant vegetation. Forestry is the major type of land use in northern Sweden (>61°) with intensive forestry decreasing the availability of mature ground lichen forests in reindeer winter areas (Sandström et al. 2016).

Our analyses included data of two spatial scales: 1) the entire Swedish mountain chain (interviews with the Swedish EPA, referral responses to the governmental strategy and workshop) and 2) on regional scale (interviews and environmental data in the county of Västerbotten, Figure 1). Reindeer position data were provided from two reindeer herding communities within the county of Västerbotten (*Vilhelmina Södra* and *Vilhelmina Norra*, 65°06'25" N 14°50'0.8" E in the municipality of Vilhelmina, 64°37'00" N 16°39'00" E), which is the second northernmost and second largest county of Sweden. In the study area of the position data (Figure 1), elevation ranged between 261 m and 1566 m above sea level.

3 Material and Methods

3.1 Data material

To explore the link between targets, indicators and evaluation in our specific case, we relied on both qualitative and quantitative methods and data collection. The qualitative methods and data collection included both desk-top studies of documents from the formal process to set up a

strategy to make the EQO more precise, interviews and a workshop with the implicated actors. The qualitative methods and data collection included animal position data.

3.1.1 Qualitative data: stakeholders' perceptions of landscape use

We started with the document analysis (Swedish EPA strategy, legal documents, and governmental propositions) to get an understanding of the formal conditions. Secondly, we carried out the first round of interviews with a total of 7 persons who represent the Swedish EPA, the County of Västerbotten, and the two reindeer herding communities. We asked the participants to frame the problem by identifying which attributes are important to define and maintain a landscape characterized by grazing (Table 1). In a second step, we carried out a document analysis of the 35 official referrals to the EPA strategy by different stakeholders and authorities. Lastly, we organized a workshop with 21 persons that included relevant stakeholders and authorities at national and different regional level to develop, in a structured process, ideas around the "*Grazed Landscape*"-target as part of the overarching EQO (Table 1). We concluded with two follow-up interviews with authorities at national and regional level after the workshop. We analyzed the documents, interviews and workshop results with qualitative methods such as frame and thematic analyses, and presented them in a narrative way.

3.1.2 Quantitative data: Reindeer movement and landscape use

Each reindeer herding community has traditional knowledge about grounds for grazing, calving, and resting areas – all central for reindeer within their district. During the last decade, this traditional knowledge has been converted into more formal reindeer husbandry plans (RHP) that map and digitalize communities' land use, and thereby has provided an effective tool and decision support system for land use dialogue and consultation (Sandström 2015). To include the key actor – the reindeer herding communities – to fulfill the "*Grazed Landscape*"-target, the Swedish EPA suggests a partnership to provide support for the reindeer herding communities to work with consultation procedures and to further develop the RHP (Swedish EPA 2014). In addition, analytical tools should be developed to monitor the importance of reindeer for conservation values.

The establishment of a partnership is in line with the environmental policy adopted in the 1980s and 1990s following a more deliberative and consensual political culture (Lundqvist 2005). As a result, arenas were provided where various interests can meet to deliberate collaboration and to find joint solutions for implementation (Bjärstig and Sandström 2016). Advances in sensor tracking technology, e.g., Global Positioning System (GPS) data, provide animal movement data that capture animal trajectories in ecological landscapes (Getz and Saltz 2008). Path analyses may increase our understanding of resource utilization and patterns in space use over time in relation to changing landscape conditions as well as to individuals' constraints, behavior, and survival, and can ultimately aid animal conservation and management (Lima and Zollner 1996; Morales et al. 2010; Neumann et al. 2015). Movement analyses expose functional landscape connectivity and identify critical movement areas as well as critical resources sites (Sawyer et al. 2011; Skarin et al. 2015; Zeller et al. 2012). Within the "*Grazed Landscape*"-target, reindeer position data can act as an input source to study the measurable objectives within the problem formulation as assigned in our analytical frame.

To evaluate the importance of RHP as a decision support tool to achieve the "*Grazed Landscape*"-target, we developed a close collaboration with reindeer herders to base our analysis on the RHP developed by two reindeer herding communities (*Vilhelmina Södra* and *Vilhelmina Norra* (65°06'25" N 14°50'0.8" E). The

Table 1 Questions asked to the key actors at the interviews and to the participants at the workshop,

Question		Interviews (*n*=participants)	Workshop (*n*=participants)
1	How do you define a "*Grazed Landscape*"?	7	21
2	What indicator(s) do you propose to describe and to measure a "*Grazed Landscape*"?	7	21
3	What indicator(s) do you think are important for monitoring a "*Grazed Landscape*"?	7	21

GPS calculated positions of semi-domesticated reindeer on two-hour intervals during 2010-2014, and data combined positions of 119 different tracking devices. Each year in April, reindeer arrived in their mountainous summer ranges and stayed until November/December, depending on weather conditions. We analyzed reindeer spatial movement behavior and resource utilization during May to October using Biased Random Bridges and Step Selection Functions (Fortin et al. 2005; Benhamou 2011; Thurfjell et al. 2014).

4 Results

4.1 Problem formulation phase: defining targets and identifying indicators

The analysis of how the key actors would define a "*Grazed Landscape*" showed that there is no coherent view among them. More specifically, the authority representatives the Swedish EPA and the County Administrative Board (CAB) focused on broad continuous areas that enable and support reindeer husbandry as their central point of departure. Here, however, we found a hierarchical structure. Whereas the Swedish EPA defined the target on a broader, relatively unspecific and theoretical level, the CAB representatives included aspects on a more concrete and practical level, including indicators such as attributes of biodiversity and vegetation or species occurrence and composition typical in grazed ecosystems and lower amounts of bushes and trees. In contrast, the representatives of the reindeer herding communities defined the target on the most practical and hands-on level such as the seasonal areas that reindeer ranged over in mountains and that animals regularly utilized to track phenology, but also calving, resting, and moving in-between areas. Essentially, their definition included most parts of the mountain range as reindeer generally utilize different parts of the mountain range for different resources at different times (e.g., for forage, safety, less disturbances, or insect avoidance). Still, in spite of the different wording, the views of the representatives of the Swedish EPA, the CAB, and the reindeer herding communities were rather close, although expressed from different perspectives ("observer" versus "user" perspective). This also had an impact on how precise the actors were when defining indicators, with the reindeer herders being the most explicit.

Our analysis of the 35 referrals to the Swedish EPA strategy unrolled that the majority of organizations with an interest in the mountain range supported the target in general, but disagreed with the indicators suggested by the Swedish EPA strategy. We found a considerable disagreement among the actors that followed a north-south latitudinal gradient, and included different views on the importance of reindeer to maintain a grazed mountain landscape. More specifically, actors from the northern parts of the mountain chain (municipalities, interest groups) considered reindeer as a natural and central agent in the mountain landscape, but also asked for more specific demarcation of the mountain range with respect to other interests such as exploitative activities (e.g., Kiruna municipality). Actors from the southern parts of the mountain chain (e.g., Administrative County Board Dalarna and Jämtland), where historically livestock activity on mountainous pasture areas was a vital part of agricultural activity, on the other hand, did not consider reindeer necessarily as the single major agent to achieve and to maintain the "*Grazed Landscape*"-target. Instead, they highlighted the importance of other factors such as the traditional use of mountain pastures by livestock to reach the milestone target. Some organizations also motivated their disagreement to the suggestions by the vagueness of the target. In summary, we found that the variation among actors with respect to the key factors to consider in reaching the "*Grazed Landscape*"-target mirrored very much the traditional use of a given part in the mountain chain.

To arrive closer to a possible definition, we invited relevant stakeholders from different regions in the mountain chain to a workshop to define what is meant by the "*Grazed Landscape*"-target and what indicators could be used to follow up the target. Several of the participants defined it as a cultural landscape that has been grazed continuously by reindeer and other herbivores (e.g., cattle (*Bos primigenius*), sheep (*Ovis aries*), and goat (*Capra aegagrus hircus*), but also moose (*Alces alces*)). Others had a more nature-related view, and defined it as a landscape dominated by

pasture favoring plants / structures and as an open landscape characterized by the absence of higher vegetation (e.g., bushes and trees), respectively. Even though, the workshop showed the difficulties to find one single common definition, we found that the disagreements here were not related to the importance of reindeer and reindeer husbandry, but rather based on the perspective of a given actor. More specifically, and once again, we found differences between "within as a user" and "from the outside as an observer" views, but also different perspectives related to the culture-nature divide to what extent the participants took a cultural perspective as the outset for a definition or if they took nature as a point of departure.

The workshop participants also stressed the consideration of regional variation too, including indicators adjusted to local conditions and the consideration of different spatial scales – all in line with the referrals responses. The participants also highlighted the need to specify the temporal perspective in conservation goals of the "*Grazed Landscape*"-target: how far back in time do we want to go? how ambitious should the target be? is it enough to maintain the current status or is the aim to "restore" overgrown places? Last, but not least, the participants emphasized the possibility to combine different data sets to apply indicators that can represent the "*Grazed Landscape*"-target.

In summary, our interviews, document analysis, and workshop unrolled - that depending on how the actors define the target - the actors suggested that the general indicators for the whole mountain range should be complemented with regional or local indicators that also consider historical use. Our follow up interviews from the workshop emphasized four aspects: 1) more research addressing these aspects, 2) to include traditional ecological knowledge, 3) to understand regional variations, and 4) to find relevant indicators that can contribute to understand this regional variation in combination with how changes in land use affect the mountains.

4.2 Evaluation phase

To monitor the progress of the "*Grazed Landscape*"-target, the Swedish EPA strategy suggested the use of environmental monitoring data like by the program National Inventory Landscape Sweden (NILS) and reindeer husbandry plans (RHP) in combination with remote sensing data to create an index describing the development of "subareas" in the mountainous landscape (Swedish EPA 2014). The CABs suggested the use of different environmental monitoring programs by the agency to monitor species composition, area openness, and the distribution of bushes. To evaluate the maintenance of the "*Grazed Landscape*"-target, both the CABs and the Swedish EPA acknowledged the number of reindeer as important indicators, but also, for example, their slaughter weight as an environmental indicator. Simultaneously, they pointed out the difficulties to use the number of reindeer as an indicator, because both natural changes and human decisions can affect herd size next to ecological conditions, demography or economy can influence changes in herd size. The two authorities therefore highlighted the need to include also other indicators such as changes in vegetation through monitoring systems and socio-economic developments.

Our results confirmed that the reindeer utilized large parts of the mountain range by studying the GPS-position data of reindeer. Between May and October when reindeer were in their mountainous summer ranges, animals ranged on average over more than 40,000 ha and had intensively utilized areas of about 6,700 ha. Our results suggested that mountain birch forest was an important habitat next to heathland and meadows. As a result, animal position data may indeed be used as a valuable decision support tool to monitor and subsequently evaluate the target as suggested by the Swedish EPA strategy.

In the interviews with the reindeer herding communities, it became apparent that the suggestion by the Swedish EPA strategy of using RHP to define and monitor the "*Grazed Landscape*"-target, has not been anchored among those who actually own the data from GPS-collared reindeer. All RHP and reindeer GPS-positions are private property and business material, and as such belong to a given reindeer herding community. The representatives of these communities expressed a strong fear that the RHP would end up in unauthorized hands if becoming a part of an official monitoring and evaluation process. Moreover, the reindeer herding communities stressed that the RHP cannot be interpreted

without traditional knowledge, and bearing a great risk of misinterpretation when interpreted without it. Furthermore, it is crucial to note that the RHP are spatiotemporal dynamic tools rather than a fixed map (Sandström 2015). However, despite these caveats the representatives of the Sami parliament could see the usefulness of including the RHP in maintaining the milestone target of the EQO, but only through the inclusion of the reindeer herding communities in the monitoring process.

Within the referrals responses, we noticed few comments about the need for evaluation of the milestone target and assumed that the sparsity of comments may go along with the comments on unclear target formulation. We therefore assumed that the organizations might found it unclear what kind of indicators can be set up and consequently evaluated. However, we noticed a repeated request to consider the regional variation in grazing activities along the mountain range as part of the comments on monitoring and evaluation of the milestone target.

5 Discussion

We found that differences in the perception and definition of the milestone target among the central actors and organizations affected the preconditions to formulate a common target as well as the possibilities to monitor and evaluate it. The actors disagreed on the target and the proposed measure, making it difficult to attain it. Our results indicated a need for geographical differentiation in order to consider regional/local conditions of the "*Grazed Landscape*"-target and the measures to monitor and evaluate it. Moreover, the time perspective on which the target is set need to be more specific defined as well as whether the goal is to maintain current conditions or to restore previous ones.

Our workshop results suggested that a common definition that potentially would include both the user and the observer view could be "an open landscape where grazing animals are an important and integral part of maintaining ecosystem functions and processes in the mountains". From an ecological point of view, previous research clearly show that reindeer is a central factor affecting local vegetation in the mountains, but sometimes with considerable time lags involved (Olofsson 2006; Olofsson et al. 2004, 2009, 2013; Kaarlejärvi et al. 2013). Moose are another important ecological and cultural herbivore of the Swedish mountain landscape. Both reindeer and moose are the two large mammalian key herbivores that range over a broad range in the Swedish mountains (Skarin et al. 2010; Allen et al. 2016). Our results showed that reindeer encompassed large areas of the mountain range and that animals utilized both areas above and at the tree line, suggesting that reindeer herbivory is an important factor to maintain a "*Grazed Landscape*" over a large area. In this context, reindeer's extensive spatial distribution is much due to their distinct spatiotemporal dynamic with which they utilize the mountain range for different purposes within the vegetation period and among years (Hagemoen and Reimers 2002; Edenius et al. 2003; Skarin et al. 2010). As such, reindeer might be indeed the most influential herbivore that can access large areas in the mountains during a single season.

Next to traditional knowledge and historical human use of the mountainous landscape (Norstedt et al. 2014; Östlund et al. 2015; Ratio et al. 2016), we conclude that recent reindeer spatial distribution and habitat selection can contribute to describe a "*Grazed Landscape*" and thereby help to frame its definition. Furthermore, recent distribution of reindeer and in combination with recent status on vegetation and landscape structure given by remotely-sensed data can help to identify areas that need stronger impact by herbivory. Environmental data such as data that define animal distribution and resource utilization help to evaluate and thus to target conservation and management strategies more effectively (Ketz et al. 2016; Wei et al. 2018). We thus suggest a "landscape assessment step" as given by environmental monitoring data (animal distribution and vegetation status over time) as a natural part in the decision process in order to target landscape management actions resourcefully and effective. Our results given by reindeer position data also support the need for management on larger scale to consider functional landscapes, i.e., environmental conditions and human impact on landscape level, in order to preserve continuous areas and to minimize

disturbances that can affect negatively migratory movement patterns. In species management, preservation of migratory movement is important for the population health (Bolger et al. 2008; Harris et al. 2009; Tucker et al. 2018). Therefore, the entire movement cycle has to be considered. For management of semi-domesticated reindeer in Sweden, the mountainous summer ranges cannot be seen without their seasonal counterparts, the winter ranges. The winter ranges define the bottleneck season for reindeer (Horstkotte 2014; Sandström et al. 2016), and ultimately, determine the numbers of reindeer that can range to maintain a sufficient herbivory impact in the mountainous summer areas as also acknowledged in the Swedish EPA strategy (Swedish EPA 2014).

From a social point of view, proactive policies are preferred compared to more reactive ones, because those are response to a problem and designed to remedy problems that already exist. Proactive policies are deliberately chosen and often designed to prevent a concern, problem, or an emergency from occurring. However, proactive policies are often more challenging, since it is often difficult to foresee the future, but also to get enough support (and budget) to a problem that has not yet occurred (IPBES 2018). We judge the Swedish EQOs to be an example of a proactive policy. The main purpose of the 16 EQOs is to provide a framework for obtaining a sustainable environment (https://www.miljomal.se/). Another purpose is to define the quality of the natural and cultural resources in Sweden and to be able to measure the change in environmental quality over time (http://www.sverigesmiljomal.se/). As mentioned initially, the system has been criticized, because of its utopian and vague character, with unclear objectives and subsequent difficulties to follow up and measure the outcome (Emmelin and Cherp 2016). Our study of one these objectives – A Magnificent Mountain Landscape - largely confirmed these shortcomings, but it also provided a potential way forward through the application of a more structured decision-making process. Furthermore, to improve transparency in decision-making processes, and to generate conditions for social learning and understanding across sectors and between actors, the application of a structured decision process looks promising. Stakeholder involvement in an early stage can help to avoid mismatches between important landscape features identified by stakeholders and those suggested by management strategies (Schmidt et al. 2019). The outcome of our study showed that these components in particular can help to specify the target, adapt it to regional variation as well as take different views into consideration, and thereby link the target more closely to indicators and as well as the measures for monitoring and evaluation.

6 Concluding Remarks

Analyzing interviews and referral responses unrolled differences in both perception and definition of the milestone targets to achieve the National Environmental Quality Objective - A Magnificent Mountain Landscape - among the actors, which hinders the formulation of a more specific target, as well as its monitoring, and evaluation. The current lack of a common goal definition or agreement on monitoring and evaluation of it, calls for a new and more inclusive procedure to lay the ground for social learning and understanding across sectors and actors. Here, the application of a structured decision process might be an appropriate tool. In essence, our workshop results suggested that a common definition that potentially could bridge the identified divide between a user and observer view could be “an open landscape where grazing animals are an important and integral part of maintaining ecosystem functions and processes in the mountains”. Moreover, environmental monitoring data suggest a “landscape assessment step” as a natural part in the decision process in order to target landscape management actions resourcefully and effectively.

Acknowledgments

We are grateful for founding by the Swedish Environmental Protection Agency (Swedish EPA) through the research effort ‘A Magnificant Mountain Landscape’. We appreciate very much the constructive comments of all reviewers that helped to improve the manuscript. We thank the RHC *Vilhelmina Norra* and *Vilhelmina Södra* for their support with data and for sharing their in-depth knowledge about reindeer husbandry and

reindeer biology. We thank S. Juthberg for help with editing the English.

Open Access

References

Addison PFE, Rumpff L, Bau S, et al. (2013) Practical solutions for making models indispensable in conservation decision-making. Diversity and Distribution 19: 490-502. https://doi.org/10.1111/ddi.12054

Allen AM, Månsson J, Sand H, et al. (2016) Scaling up movements: From individual space use to population patterns. Ecosphere 7: e01524. https://doi.org/10.1002/ecs2.1524

Benhamou S (2011) Dynamic approach to space and habitat use based on biased random bridges. PLOS One 6: 1-8. https://doi.org/10.1371/journal.pone.0014592

Bjärstig T, Sandström C (2017) Public-private partnerships in a Swedish rural context: A policy tool for the authorities to achieve sustainable rural development? Journal of Rural Studies 49: 58-68. https://doi.org/10.1016/j.jrurstud.2016.11.009

Bolger DT, Newmark WD, Morrison TA, et al. (2008) The need for integrative approaches to understand and conserve migratory ungulates. Ecology Letters 11: 63-77. https://doi.org/10.1111/j.1461-0248.2007.01109.x

Edenius L, Vencatasawmy CP, Sandström P, et al. (2003) Combining satellite imagery and ancillary data to improve mapping of snowbed vegetation important to reindeer (*Rangifer tarandus)*. Arctic, Antarctic and Alpine Research 35: 150-157.

Edvardsson K (2004) Using goals in environmental management: the Swedish system of environmental objectives. Environmental Management 34: 170-80. https://doi.org/10.1007/s00267-004-3073-3

Emmelin L, Cherp A (2016) National environmental objectives in Sweden: a critical reflection. Journal of Cleaner Production 12: 194-199. https://doi.org/10.1016/j.jclepro.2015.08.059

Environmental Objectives (2018) http://www.sverigesmiljomal.se/environmental-objectives/ (downloaded 2018-04-16)

Fortin D, Beyer HL, Boyce MS, et al. (2005) Wolves influence elk movements: behavior shapes a trophic cascade in Yellowstone National Park. Ecology 86: 1320-1330. https://doi.org/10.1890/04-0953

Freschet GT, Östlund L, Kichenin E, et al. (2014) Aboveground and belowground legacies of native Sami land use on boreal forest in northern Sweden 100 years after abandonment. Ecology 95: 963-977. https://doi.org/10.1890/13-0824.1

Getz WM, Saltz D (2008) A framework for generating and analyzing movement paths on ecological landscapes. Proceedings of the National Academy of Science USA 105: 19066-19071. https://doi.org/10.1073/pnas.0801732105

Gov. Bill 2004/05:150. Svenska miljömål - ett gemensamt uppdrag. Miljö- och energidepartementet. http://www.regeringen.se/rattsdokument/proposition/2005/05/prop.-200405150-/ (Accessed 2018-04-16)

IPBES (2018) Summary for policymakers of the regional assessment report on biodiversity and ecosystem services for Europe and Central Asia of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Fischer M, Rounsevell M, Torre-Marin Rando A, et al. (eds.), IPBES secretariat, Bonn, Germany. 48 pages.

Johansson J, Sandström C, Lundmark T (2018) Inspired by structured decision making: a collaborative approach to the governance of multiple forest values. Ecology and Society 23: 16. https://doi.org/10.5751/ES-10347-230416

Josefsson T, Hornberg G, Östlund L (2009) Long-Term Human Impact and Vegetation Changes in a Boreal Forest Reserve: Implications for the Use of Protected Areas as Ecological References. Ecosystems 12: 1017-1036. https://doi.org/10.1007/s10021-009-9276-y

Hagemoen RIM, Reimers E (2002) Reindeer summer activity pattern in relation to weather and insect harassment. Journal of Animal Ecology 71: 883-892. https://doi.org/10.1046/j.1365-2656.2002.00654.x

Harris G, Thirgood S, Hopcraft JGC, et al. (2009). Global decline in aggregated migrations of large terrestrial mammals. Endangered Species Research 7: 55-76. https://doi.org/https://doi.org/10.3354/esr00173

Horstkotte T, Utsi TA, Larsson-Blind A, et al. (2017) Human-animal agency in reindeer management: Sami herders' perspectives on vegetation dynamics under climate change. Ecosphere 8: e01931. https://doi.org/10.1002/ecs2.1931

Horstkotte T, Sandström C, Moen J (2014) Exploring the Multiple Use of Boreal Landscapes in Northern Sweden: The Importance of Social-Ecological Diversity for Mobility and Flexibility. Human Ecology 42: 671-682. https://doi.org/10.1007/s10745-014-9687-z

Hunt TL, Kliskey A, Alessa L (2018) Applying social–ecological systems science to complex mountain landscapes. Frontiers in Ecology and Environment 16(S1): S3-S3. https://doi.org/10.1002/fee.1757

Kang HM, Kim H, Lee CH, et al. (2017) Changes and development plans in the mountain villages of South Korea: Comparison of the first and second national surveys. Journal of Mountain Science 14: 1473-1489. https://doi.org/10.1007/s11629-016-3875-9

Kaarlejärvi E, Eskelinen A, Olofsson J (2013) Herbivory prevents positive responses of lowland plants to warmer and more fertile conditions at high altitudes. Functional Ecology 27: 1244-1253. https://doi.org/10.1111/1365-2435.12113

Ketz AC, Johnson TL, Monello RJ, et al. (2016) Informing management with monitoring data: the value of Bayesian forecasting. Ecosphere 7: e01587. https://doi.org/10.1002/ecs2.1587

Kotsios V (2016) Integrated development planning in mountainous areas - the case of Konitsa, Greece. Journal of Mountain Science 13: 169-182. https://doi.org/10.1007/s11629-014-3012-6

Lima SL, Zollner PA (1996) Towards a behavioral ecology of ecological landscapes. Trends in Ecology and Evolution 11: 131-135. https://doi.org/10.1016/0169-5347(96)81094-9

Lindahl KB, Johansson A, Zachrisson A, et al. (2018) Competing pathways to sustainability? Exploring conflicts over mine establishments in the Swedish mountain region. Journal of Environmental Management 218: 402-415. https://doi.org/10.1016/j.jenvman.2018.04.063

Lundqvist LJ (2005) En idé före sin tid? Valfrid Paulsson,

svensk vattenvård och ekologisk modernisering. In L. J. Lundgren and J. Edman (Eds.), Konflikter, samarbete, resultat: Perspektiv på svensk miljöpolitik [Conflict, cooperation, performance: Perspectives on the Swedish environmental policy] 2005: 124-141. Festskrift till Valfrid Paulsson. Brottby, Sweden: Kassandra. (In Swedish)
Mayor JR, Sanders NJ, Classen AT, et al. (2017) Elevation alters ecosystem properties across temperate treelines globally. Nature 542: 91-95. https://doi.org/10.1038/nature21027
Moen J (2006) Land use in the Swedish mountain region: trends and conflicting goals. International Journal of Biodiversity Science and Management 2: 305-314. https://doi.org/10.1080/17451590609618151
Morales JM, Moorcroft PR, Matthiopoulos J, et al. (2010) Building the bridge between animal movement and population dynamics. Philosophical Transactions of the Royal Society B 365: 228-2301. https://doi.org/0.1098/rstb.2010.0082
Mårald E, Sandström C, Rist L, et al. (2015) Exploring the use of a dialogue process to tackle a complex and controversial issue in forest management. Scandinavian Journal of Forest Research 30: 749-756. https://doi.org/10.1080/02827581.2015.1065343
Neumann W, Martinuzzi S, Estes AB, et al. (2015) Opportunities for the application of advanced remotely-sensed data in ecological studies of terrestrial animal movement. Movement Ecology 3: 8. https://doi.org/10.1186/s40462-015-0036-7
Norstedt G, Axelsson AL, Östlund L (2014) Exploring Pre-Colonial Resource Control of Individual Sami Households. Artic 67: 223-237. https://doi.org/10.14430/arctic4389
Olofsson J, te Beest M, Ericson L (2013) Complex biotic interactions drive long-term vegetation dynamics in a subarctic ecosystem. Philosophical Transactions of the Royal Society B 368: 1471-2970. https://doi.org/10.1098/rstb.2012.0486
Olofsson J, Oksanen L, Callaghan T, et al. (2009) Herbivores inhibit climate-driven shrub expansion on the tundra. Global Change Biology 15: 2681-2693. https://doi.org/10.1111/j.1365-2486.2009.01935.x
Olofsson J (2006) Short- and long-term effects of changes in reindeer grazing pressure on tundra heath vegetation. Journal of Ecology 94: 431-440. https://doi.org/10.1111/j.1365-2745.2006.01100.x
Olofsson J, Stark S, Oksanen L (2004) Reindeer influence on ecosystem processes in the tundra. Oikos 105: 386-396. https://doi.org/10.1111/j.0030-1299.2004.13048.x
Östlund L, Hörnberg G, DeLuca TH, et al. (2015) Intensive land use in the Swedish mountains between AD 800 and 1200 led to deforestation and ecosystem transformation with long-lasting effects. Ambio 44: 508. https://doi.org/10.1007/s13280-015-0634-z
Ratio A-M, Josefsson T, Axelsson A-L, et al. (2016) People and pines 1555-1910: integrating ecology, history and archaeology to assess long-term resource use in northern Fennoscandia. Landscape Ecology 31: 337-349. https://doi.org/10.1007/s10980-015-0246-9
Rist L, Felton A, Samuelsson L, et al. (2013) A new paradigm for adaptive management. Ecology and Society 18: 63. https://doi.org/10.5751/ES-06183-180463
Sandström P (2015) A toolbox for co-production of knowledge and improved land use dialogues. Doctoral thesis. Swedish University of Agricultural Sciences. p 20. https://pub.epsilon.slu.se/11881/1/sandstrom_p_150213.pdf (Accessed on 2019-06-20)
Sandström P, Cory N, Svensson J, et al. (2016) On the decline of ground lichen forests in the Swedish boreal landscape: Implications for reindeer husbandry and sustainable forest management. Ambio 45: 415-429. https://doi.org/10.1007/s13280-015-0759-0
Sawyer H, Kauffman MJ (2011) Stopover ecology of a migratory ungulate. Journal of Animal Ecology 80: 1078-1087. https://doi.org/10.1111/j.1365-2656.2011.01845.x
Schmidt K, Martin-López B, Phillips PM, et al. (2019). Key landscape features in the provision of ecosystem services: Insights for management. Land Use Policy 82: 353-366. https://doi.org/10.1016/j.landusepol.2018.12.022
Skarin A, Nellemann C, Rönnegård P, et al. (2015) Wind farm construction impacts reindeer migration and movement corridors. Landscape Ecology 30: 1527-1540. https://doi.org/10.1007/s10980-015-0210-8
Skarin A, Danell Ö, Bergström R, et al. (2010) Reindeer movement patterns in alpine summer ranges. Polar Biology 33: 1263-1275. https://doi.org/10.1007/s00300-010-0815-y
Swedish EPA (2014) Redovisning av miljökvalitetsmålen Storslagen Fjällmiljö i FU15. REMISSVERSION. 2014-12-12 Nr NV-02144-14.
Thurfjell H, Ciuti S, Boyce MS (2014) Applications of step-selection functions in ecology and conservation. Movement Ecology 2: 4. https://doi.org/10.1186/2051-3933-2-4
Tolvanen A, Kangas K (2016) Tourism, biodiversity and protected areas - Review from northern Fennoscandia. Journal of Environmental Management 169: 58-66. https://doi.org/10.1016/j.jenvman.2015.12.011
Tucker MA, Böhning-Gaese K, Fagan WF, et al. (2018) Moving in the Anthropocene: Global reductions in terrestrial mammalian movements. Science 359: 466-469. https://doi.org/10.1126/science.aam9712
Uboni A, Horstkotte T, Kaarlejärvi E, et al. (2016) Long-Term Trends and Role of Climate in the Population Dynamics of Eurasian Reindeer. PLoS ONE 11: e0158359. https://doi.org/10.1371/journal.pone.0158359
Wei W, Swaisgood RR, Dai Q, et al. (2018) Giant panda distributional and habitat-use shifts in a changing landscape. Conservation Letters 11: e12575. https://doi.org/10.1111/conl.12575
Zeller KA, McGarigal K, Whiteley AR (2012) Estimating landscape resistance to movement: a review. Landscape Ecology 27: 777-797. https://doi.org/10.1007/s10980-012-9737-0