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# Landscape perception: linking physical monitoring data to perceived landscape properties

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**ABSTRACT**

Changes in the landscape affect not only people's well-being but also how people perceive and use the landscape. An increasing number of policies have highlighted the importance of conserving a landscape's recreational and aesthetical values. This study develops and evaluates a model that links people's perceptions of a mountain landscape to physical monitoring data. Using a questionnaire, we revealed how respondents working with the Swedish mountains characterise the Magnificent Mountain landscape (as defined by Swedish policy objectives) and translated these characteristics into data from the National Inventory of Landscapes in Sweden (NILS). We found 14 potential indicators that could be derived from the existing NILS physical monitoring data and which could be used to monitor changes in the landscape values as perceived by people. Based on the results, we suggest how to simultaneously utilise field sampling of physical data and field photos to provide temporal information about landscape perception.

**KEYWORDS**

Landscape preference; mountain landscapes; place attachment; space; National Inventory of Landscapes in Sweden

## Introduction

Landscapes are rapidly changing on a global scale as an effect of various drivers such as alterations in land use due to urbanisation, increasing food demand, farmland abandonment, and ongoing climate change (Dale, 1997; Lambin et al., 2001; Queiroz, Beilin, Folke, & Lindborg, 2014; Seto, Guneralp, & Hutyra, 2012; Tilman, Balzer, Hill, & Befort, 2011). This change calls for establishing indicators to assess the degree of change and to guide adaptation and mitigation measures. To date, the work on indicators for monitoring and analysing landscape change has mainly been focused on ecological indicators (Fry, Tveit, Ode, & Velarde, 2009; Hansen & Loveland, 2012) and not on how people perceive these changes per se and how the perception changes over time. Thus, according to Hunziker, Buchecker, and Hartig (2007), there is a 'considerable research gap regarding systematic analysis of the judgements of temporal landscape change'. According to Kienast, Frick, van Strien, and Hunziker (2015), the main reason for the lack of

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Supplementary data for this article can be accessed here.

detailed monitoring programs linking social and natural science data over time is the high cost of gathering such data. In addition, lack of data on human perception of landscape might also be related to the fact that the perception of landscape characteristics/features/properties linked to well-being has only recently been incorporated in the policies (Marselle, Stadler, Korn, & Bonn, 2018) and therefore there has been no demand for such data. Hereafter, the term 'properties' is used throughout the text when referring to landscape variables and the term 'characteristics' is used to describe landscape in a more general way.

One way to overcome the problem of high costs and lack of temporal data on perception is to link physical data from existing monitoring programs to perceived landscape properties. This strategy would make it possible to monitor changes in how humans perceive the landscape using physical indicators. Some previous attempts have been made to translate remote sensing data (or field data) of physical-biological properties to human perceptions of the landscape. For example, Norton, Inwood, Crowe, and Baker (2012) integrated data on habitat types such as forests with data on physical landscape properties valued by people for recreation, and Frank, Furst, Koschke, Witt, and Makeschin (2013) linked different landscape metrics of human preferences to assess the aesthetic value of landscape. However, numerous potential difficulties are linked to the perception of landscape changes over time, including integrating data gathered through natural and social science methods (Hunziker et al., 2007):

> *Data integration was the key challenge given that the two datasets concentrate on very different aspects of the landscape; one focused on quantifying the extent and quality of habitats and landscape features which make up an area of landscape, the other on how the constituent features of a landscape impact upon human wellbeing (the provision of cultural services).* (Norton et al., 2012)

Moreover, although Norton et al. (2012) indicate the potential for forest recreation on national levels, the data are coarse. Evidently, people do perceive the landscape in far more detail such as number of vegetation layers (Wang, Zhao, & Meitner, 2017), amount of biodiversity (Lindemann-Matthies, Briegel, Schupbach, & Junge, 2010), or openness (Conedera, Del Biaggio, Seeland, Moretti, & Home, 2015; Schirpke et al., 2013). These types of detailed data are already monitored in many national monitoring programs such as NILS (Ståhl et al., 2011) and NFI (Fridman et al., 2014); thus these monitoring programs could provide more detailed data for recreation potential than the data used by Norton et al. (2012).

From a natural science perspective, the primary complexity when monitoring landscapes is to deal with spatial scale (e.g. from small plots of the total diversity of flowers to national cover of forests) and sample size (e.g. how many sample plots are needed to provide accurate data to follow landscape changes over time). Scale dependency is also a potential difficulty when assessing landscapes from a social perspective. For example, some changes in landscapes may be accepted by the majority of the country but not by the local population (Hunziker et al., 2007).

From a social science perspective, 'visual beauty' linked to scenic beauty, aesthetic quality, and visual preferences are determined by both subjective responses and objective criteria (Dronova, 2017). The subjective views vary depending on one's age, profession, background, cultural heritage, environmental expertise, and other social social dimensions (de Val, Atauri, & de Lucio, 2006; Dramstad, Tveit, Fjellstad, & Fry, 2006; Gunnarsson, Knez, Hedblom, & Sang, 2017; Kaplan, 1995; Ulrich, 1986). For the objective criteria, aesthetic quality is determined by underlying mechanisms of quality that may be more generally applicable to a group's responses regardless of their backgrounds (Dronova, 2017). Tveit, Ode, and Fry (2006) and Fry et al. (2009) suggest that there are a number of broad common 'evolutionary' landscape properties that seem to be preferred irrespective of culture and personal preferences. Landscape is further related to human views, perceptions, and personal and collective identifications with nature (Knez, 2006; Knez & Thorsson, 2008; Lewicka, 2008; Stobbelaar & Pedroli, 2011). For example, some studies have reported positive relationships between rural (Knez & Eliasson, 2017) and urban (Knez, Sang, Gunnarsson, & Hedblom, 2018) nature and human well-being.

This paper explores a potential method for linking quantitative physical landscape data to information on human perception of landscape properties. Physical landscape data are extracted from the National Inventory of Landscapes in Sweden (NILS) (Ståhl et al., 2011) and data about perceptions are gathered through a questionnaire. The study's objective is to identify indicators that will enable monitoring of human perception of landscapes over time. We frame our study using a theory suggested by Hunziker et al. (2007) that links space and place to structure the complex dimensions of landscape perceptions. We use the Swedish mountain landscape as a case study since one of the 17 major Swedish national environmental objectives named 'Magnificent Mountain Landscape' mentions the need to conserve and manage the services that ecosystems provide such as recreation, aesthetics, and 'open grazed alpine areas' for generations to come. Furthermore, there are no indicators to monitor these services over time.

This study has three specific aims: (1) to develop a model that links physical properties with perceived landscape properties; (2) to explore possible applications of this model in a monitoring program; and (3) to suggest potential indicators based on NILS physical monitoring data that can be linked to perceived landscape properties.

## Methods

### *Background information*

The Swedish mountain region, located in the north-western part of the country, covers about 80 thousand km$^2$, equal to approximately 20% of the total area of Sweden. The eastern border follows the mountain boundary defined by the Swedish Society for Nature Conservation (Hedenås, Christensen, & Svensson, 2016; von Sydow, 1988) and the western border is with Norway. Two of the major vegetation zones in the mountain area are the alpine zone, covering an area of about 32 000 km$^2$, and the mountain birch forest zone, covering about 11 000 km$^2$ (Hedenås et al., 2016). The mountain birch forest (*Betula pubescens* subsp.*czerepanovii*) is a part of the northern boreal vegetation zone (formerly called the subalpine zone) (Sjörs, 1999) and constitutes the alpine treeline forest belt. In this study, we further divide the mountain birch area into subgroups of sparse mountain birch forest and dense mountain birch forest.

One of the key policies regarding the Swedish mountains is the national objective Magnificent Mountain Landscape (MML). The objective emphasises the need for conserving sustainable mountain landscapes for future generations. The presently used indicators measure trends in selected mammal and bird populations typical for the area (e.g. wolverines (*Gulo gulo*), reindeer (*Rangifer tarandus*), breeding birds, Arctic fox cubs (*Vulpes lagopus*)), exploitation, nitrogen in the soil, protected areas, mountain trails, mountain vegetation, noise level, and number of snowmobiles with noise reduction components. In this study, we extract data from the mountain vegetation and mountain trails used by the NILS monitoring program. However, the MML objective also emphasises the importance of many ecosystem uses such as 'the experience of magnificent mountain scenery', 'recreation and outdoor life', 'the nature of the mountains is characterized by grazing, magnificent landscape with maintained extensive coherent areas' (SEPA, 2007), although no indicators are proposed to evaluate their status or changes.

### *Theoretical framework of space and place*

Hunziker et al. (2007) argued that there are two major modes of perceiving landscapes: (1) the physical properties of a landscape linked to biological inheritance where the landscape is considered in *space* and (2) the socio-cultural understanding in which landscape is understood as a *place*. The distinction between these two modes is the amount of attention put into either one of them. The space-focused theory adopts evolutionary assumptions as a basis for rapid affective reactions to spatial and other properties of the physical environment but acknowledges that the initial responses can subsequently be different or modified by personal experience with the place and by cultural background. Places may be involved in human identification processes comprising personal and collective experiences, traditions, views, and memories: ‘places in our lives may locate our past, present and future; triggering of first-person epistemological question of how we come to know who and what we are’ (Knez, 2014). The place-related ‘self’ is conceptualised as a knowledge structure, resulting in a personal autobiographical experience of ‘my place’ (Knez, 2014) as opposed to, for example, the construct of the ecological ‘self’, which accounts for the link between an environmentally responsible behaviour and a world view. Well-being is also linked to places, where a stronger emotional component of place identity increases perceived well-being when people visit these places (Brehm, Eisenhauer, & Stedman, 2013; Knez & Eliasson, 2017). Thus, we interpret space as a landscape that humans are pre-programmed to perceive in a certain way while place includes a landscape that humans learn to perceive in a certain way (as a culture or group). Tveit et al. (2006) and Fry et al. (2009) mention space as links to evolutionary theories and place as links to cultural preference theories to explain landscape perception.

### *NILS monitoring data and indicators*

The monitoring data from NILS are rather complex as it includes both landscape data and detailed field data (Hedenås et al., 2016; Ståhl et al., 2011) (Figure 2). The main function of the NILS program is to monitor prerequisites for biodiversity (www.slu.se/nils). Launched in 2003, NILS is a sample-based stratified inventory. The mountain region, defined as stratum 10, follows the mountain boundary defined by the Swedish Society for Nature Conservation (Figure 2). Stratum 10 includes 145 systematically distributed sampling units, where 1382 of the plots and 270 field variables are surveyed in the field. The field method documents the spatial patterns (Figure 2(d)), habitat, and species status. Some of these variables provide information about configuration at the habitat level (e.g. type of land use), while others are more specifically oriented towards the abundance of individual species or groups of species (Hedenås et al., 2016; Ståhl et al., 2011). Linear objects are sampled in NILS when moving between plots (Ståhl et al., 2011) (Figure 2). In each permanent plot, photographs are taken in five directions (facing north, south, west, and east) and directly down onto one of the small field sampling plots (0.25 $m^2$) (Figure2(d)). In the mountain area, this scheme provides the NILS program with 6910 photos over five years. Manually interpreted aerial photos could also be used to estimate properties such as scree and other inaccessible areas (Figure 2(b)). Landscape photographs for the questionnaire were chosen based on level of birch cover because the main change currently affecting the Swedish mountains is increasing shrub encroachment of species such as willow (*Salix* spp. L.) and mountain birch (Hedenås et al., 2016) due to climate change (Pearson et al., 2013). The photographs used included three types of landscapes but four views: one *alpine* photo with 0% cover of mountain birch, two *sparse* mountain birch habitat photos from the same spot taken facing two directions with <50% cover of mountain birch, and one *dense* mountain birch habitat photo with >75% cover of mountain birch. Photos from areas with semi-dense mountain birch forest (i.e. 50–75% cover of birch) were not used due to the limited ability of the observer to detect differences in visual perception of semi-dense forest. We chose not to use photos with visible mining activities, windmills, or hydropower stations because our focus was on the links between ecosystem structures or functions specified in the physical domain and human perception.

### *Questionnaire*

A questionnaire (see Supplemental online material, S1) was given to participants in a conference devoted to the continuing work of protecting Swedish mountains (Figure 1), targeting the MML objective. All of the questions (see S1) were based on different properties mentioned in the MML. There were three types of questions: (1) open questions (where participants could use their own words); (2) Likert’s scale ratings; and (3) photography ratings (Figure 1).

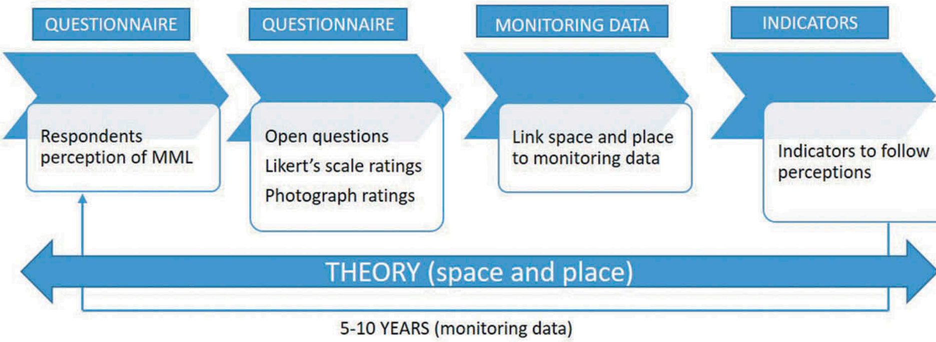


**Figure 1.** Outline of the procedure of linking the questions to indicators framed by the theory from 'space' to 'place' by Hunziker et al. (2007).

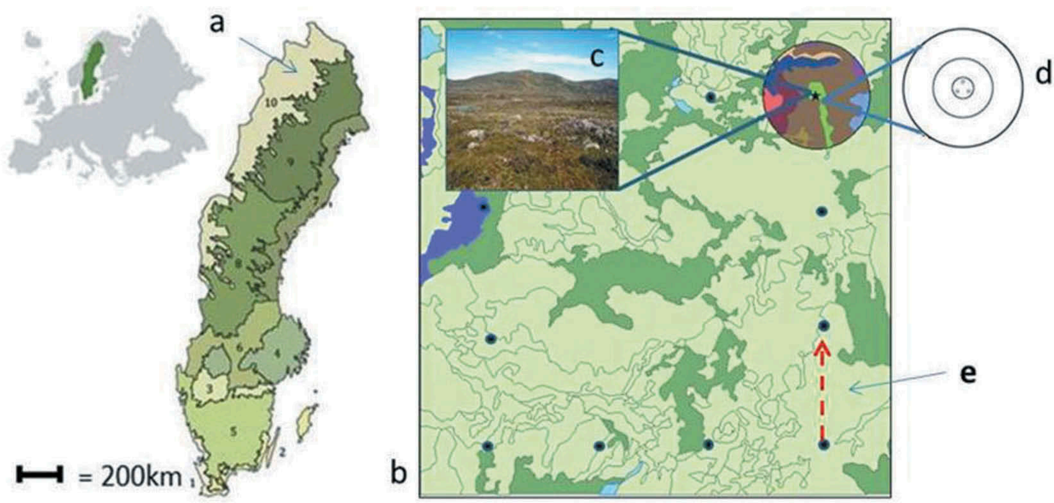


**Figure 2.** National Inventory of Landscapes in Sweden (NILS). (a) Sweden divided into strata representing different biogeographic regions (Ståhl et al., 2011). Stratum 10 is the Swedish mountain area. (b) Illustrates a 1 km$^2$ landscape that was interpreted using aerial photo. Black dots are 12 field sample plots. (c) The landscape surrounding an alpine plot within 125-m radius. (d) Illustrates the field sampling carried out at different radii, i.e., 20 m, 10 m, 3 m, and 0.28 m. A 200 m line transects inventories between the sampling points.

*The first type* of questions were open questions where the participants described their opinion about the MML. Here we did not want to influence the participants in their descriptions of MML by using specific properties (or words) linked to the MML. The purpose was partly to evaluate how our second Likert's scale rated questions responded to the open question and if we missed something there. In the follow-up questions (2–4) on positive or negative perceptions of the MML, we, however, provided some guidance. We stressed that they should write short comments.

*The second type* of questions concerned 30 properties or descriptors that the participants were asked to rate according to their understanding of the MML. These properties were extracted and interpreted from the MML documents where they were mentioned as important properties for the Swedish mountain landscape. Further, we used the answer from a major questionnaire based on Swedish outdoor recreation (Fredman & Hedblom, 2015) that in one question highlighted the Swedish mountains highlighting things as the need of 'being away from other people', 'open landscape', and 'silence' as well as the need to be away from exploitation technologies such as mines, windmills and hydropowers. The rating scale was from −7 ('I do not think this is linked to my perception of what an MML is') to 0 ('I do think this is neutral to my perception of MML') to + 7 ('I very much think this links my perception of what MML is').

*The third type* of questions were linked to visual perception using photos to avoid the abstract form of only words and to evaluate the potential use of the NILS landscape photos. The photos represented the three dominating Swedish mountain landscape, the alpine region (open landscape with no mountain birch), sparse mountain birch forest and dense mountain birch forest. Each photo was rated in the same way as the second type of questions (−7 to +7), that is, open questions where participants could comment on the photos. Photos were extracted from NILS database and were light corrected (similar skies) using Photoshop.

From the responses provided by respondents, NILS monitoring data specialists reviewed and linked existing monitoring variables to perception ratings and open question responses. Here, all researchers and monitoring specialists were involved both in constructing the questionnaire and in identifying monitoring variables and data rather than using separate groups as Norton et al. (2012) for these tasks. All the answers linked to properties and monitoring data were then analysed relative to the theory of space or place (Hunziker et al., 2007). The main obstacle to linking properties to either space or place is to figure out if the participant's preferences are due to evolution (innate) or culture (learned) experiences. Because we do not know that much about each respondent and we did not specifically ask about space or place in the questionnaire, we have to argue for each property that belongs to either space or place.

## Results

In total, 39 participants answered the questionnaire (33 at the conference and 6 after receiving a reminder e-mail). The respondents' average age was 49 years; 39% were women and 56% men (5% unknown). Although the respondents did not provide their occupation, we assumed they worked with issues linked to the Swedish mountains as they chose to attend a conference linked to the MML (organised by the National Environmental Protection Agency).

### *Survey responses*

The first open question—'What do you think characterizes a magnificent mountain setting?'—was answered by 39 participants, producing 93 responses (more than one comment possible per respondent). The responses highlighted a variety of the properties that participants linked to MML. The responses were merged into 20 categories to provide an overview of the key types of properties. The first five categories covered 52% of the responses. The most common properties mentioned by the participants (20 of 93 responses, i.e. 22%) that linked to the MML characterisation were an 'open landscape' where comments such as 'open mountain', 'an open landscape', and 'open landscapes with single mountain birch' were included. The second most common category of the characterisation of MML was linked to the absence of exploitation technologies such as windmills and mining (11%). The third was linked to 'view' such as 'panorama of mountain peaks' (11% of all the responses) and thus closely related to the properties of openness; this was followed by categories such as 'untouched nature', 'pristine areas', and 'unspoiled environment' (4%) and 'reindeer and grazed landscape' (4%). However, more specific spaces such as 'mires' and 'cloudberry mires' were also described.

The responses to the second and third open question ('Are there any specific landscape elements that characterize the magnificent mountain areas? and 'Which positive perceptions contribute to the increase in the magnificence in the mountain areas?') were highly related to the responses to the first question. The responses to the fourth open question ('Which negative perceptions contribute to reducing the magnificence of the mountain areas?') were, as expected, more or less the opposite to the responses to the first, second, and third question. Most of the responses (48 out of 96, i.e. 50%)

focused on the presence of different types of exposure of snowmobiles, helicopters, smell of snowmobiles and the exploitation of windmills, and hydropower dams.

### *Ratings of pre-selected properties*

The participants rated 30 pre-selected properties in response to the question 'How well do the following concepts agree with your idea of what "Magnificent Mountain Landscape" is?' (Figures 3 and S1). Most of the properties were considered by the respondents as positively linked to the MML (n = 27), whereas three (n = 3) were considered negative and two (n = 2) were seen as neutral. As with the responses to the first open question where openness was the most common characterisation of MML, openness was rated highest among all the properties (average score 6.4 out of 7) (Figure 3). The second most positive was 'seclusion, away from others' (6.2), followed by 'silence' (5.9) and 'solitude' (4.7). Noise from aircraft was identified as least compatible with the MML concept (−4.3), followed by 'noise from snowmobile' (−3.9) and ski resorts (−2.5). Properties linked to indigeneous cultural aspects such as 'grazing reindeer' and 'fences and other visible traces of reindeer husbandry' were all positively related to the MML objective. Specific space linked properties such as 'glaciers' (6.0), 'mountain birch forest' (4.1), and 'mountains with a lot of mosses and lichens' (4.0) were seen as rather positive, while pine and spruce were seen as neutral (1.0 and −0.2, respectively).

### *Ratings of photographs*

Out of the four photos (Figure 4) the photo showing the alpine landscape was rated the highest by the participants (average score 5.6, no. 1 in Figure 4), indicating the highest affinity with the concept of MML (Figure 4). The two photos showing a landscape with sparse mountain birch were rated very differently despite being of the same plot. The photo taken uphill ('sparse no view') was rated lowest (1.4, no. 3 in Figure 4), while the other photo taken downhill ('sparse with view') was rated second highest (3.4, no. 2 in Figure 4). The 'sparse no view', however, received both positive comments such as 'you can see quite far' and negative comments such as 'very few magnificent qualities', 'boring shrubland', and 'lack of grazing'. The 'sparse with view' photo was given many

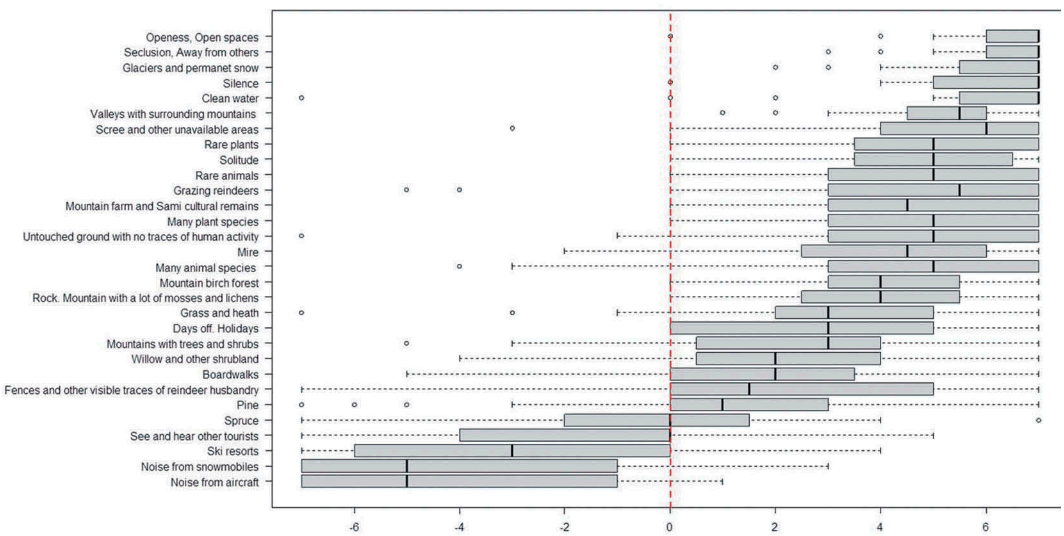


**Figure 3.** Box plots of participant ratings of pre-selected variables on how different variables were linked by the respondents to the concept of 'MMLs' using the scale −7 to +7 (±SE). Boxes represent 50% of the values and whiskers represent 95% of the values.


Figure 4. Photos illustrating a gradient of birch cover, from left (a) Alpine area with no birch cover, (b) Sparse mountain forest facing downhill, (c) Sparse mountain forest facing uphill (same as 2 but opposite direction), (d) Dense birch cover.

positive comments such as 'rich fauna', 'long distance views', and 'mountains on the horizon'. The photo with the highest density of mountain birch was rated quite low but still considered positive overall (1.9, no. 4 in Figure 4). Participants found dense mountain birch to be related to the magnificent mountains area: 'this indicates high numbers of mushrooms [specifically the chanterelle, *Cantharellus cibarius*]' and 'this environment suggests that new views are to be expected around the corner'.

### *Linking rated properties to NILS data variables and creating indicators*

In total, we found 18 properties from the questionnaire that could be linked to NILS data, and 16 of these properties were from the pre-selected rated questions and two properties ('heterogeneity of landscape' and 'forestry in forests close to mountain areas') were added from the responses given to the open questions. Out of these 18 variables, 14 could be translated into corresponding NILS data that could be extracted directly from the NILS database (see Table S1 comments and results). Out of these 14 variables, seven had data that could be separated for all three types of habitats (alpine, sparse, and dense birch forest).

In some cases, it was relatively straightforward to translate the landscape properties identified through the questionnaire into the monitoring data. For example, the properties 'mountain birch forest' could be directly related to NILS field data since the birch forest cover is sampled in the field. Other properties did not have a corresponding variable in NILS data, so data were combined to derive a quantitative variable reflecting the qualitative properties as closely as possible. For example, the property 'willow and other shrublands' was linked to four corresponding NILS variables estimated in the field plots: *Betula nana, Juniperus communis, Salix* spp., and 'other shrubs'. Some other properties were similarly related to a combination of different field variables. For example, 'Mountain with a lot of mosses and lichens' was linked to the NILS data for 'habitat classification' (e.g. >50% lichen in the bottom layer) and 'lichens and bryophytes'.

### *From space to place*

Linked to place, the concept of MML is not relevant for 'a person having the mountains as a home' as it would be difficult to describe one's home as magnificent. Another defined the mountains as 'a living mountain farm culture with active farmers´ and well-kept farms'. One participant also considered the MML as 'a place where I am taken out of the environment that I am familiar with', which supposedly refers to a certain known place where the respondent does not have to experience the ordinary environment. Other place-related comments were linked to well-being (9%) where the participants described the MML using terms such as 'freedom', 'silence', 'free space for the soul', and 'fresh'. The responses to the second open question did not diverge from the first as for place.

The third open question, the number of responses (5%, 8 out of 105) could be linked to the concept of place such as 'the feeling of loneliness', 'feeling of freedom and coming to remote places', 'change from everyday environment', and 'sense of place'. In addition, as many as 26% of the responses related to the different well-being aspects such as 'peace and quiet', 'well-being', 'few people', and 'lack of rush', which could be referred to as place attachment as well.

In the fourth open question, participants referred to 'too many people at the wrong place at the wrong time', 'organized tourism in areas in places where I did not expect it', and 'too many people at the wrong place'. Some of the comments referred to the aspects that negatively influenced well-being and thus linked to place such as 'noise' and 'too many people'.

In Likert's scale ratings, 'seclusion, away from others' was second highest rated (after openness) and could be linked to a place where participants were supposedly alone. The mountain landscape as a space linked to openness, open space, or view were the most common properties mentioned in open question number one and highest rated in the Likert's scale. We interpreted the answers to the fourth open question as also linked to space: 'increasing shrubs', 'harvested forests', 'succession of trees', and 'overgrown formerly cultivated land'.

## Discussion

In our study, we suggest how one can link physical monitoring data from an existing monitoring programme database to the human perception of landscape properties. We combined landscape properties revealed by the open questions, responses to questions through a Likert's scale, and ratings of photographs to reveal the key properties characterising MML, and then we translated these properties to existing data in the NILS monitoring program. The ultimate aim was to derive potential indicators that could be used to monitor how the human perception of landscapes changes over time.

### *Indicators*

Using the monitoring data linked to perception data, we identified 14 indicators extracted from NILS database (additional indicators could also be added with further analyses of existing data). These physical monitoring data may be seen as proxies for the perception of the landscape values. A change in the amount, cover, or length of the indicator, thus indicates a change in the perception of the mountain landscape.

Like Knez and Eliasson (2017), we found that 'openness' and 'open landscapes with view' were the most obvious properties of the MML (open question as well as Likert's scale ratings). This was also confirmed by the highest rating of the photograph representing an open alpine landscape. However, since the photographs were not replicated the high ratings of the alpine photo could be linked to the quality of the photo or distance to horizon (although the photos were corrected to have similar skies using Photoshop). Thus, 'openness' seemed to be important for perception of landscape, a finding also confirmed in other studies (Dramstad et al., 2006; Howley, 2011; Ode, Tveit, & Fry, 2010; Tveit et al., 2006) and specifically the ones focused on mountain areas (Conedera et al., 2015; Schirpke et al., 2013) although Kienast et al. (2015) did not mention openness among any of the indicators that they listed for the Swiss landscape. Swedish mountains provide good opportunities for people to perceive 'openness', since of the alpine area (3.2 million hectares; based on NILS data) is 89.7% ± 0.1% (2.9 million hectares) completely without trees. This may, however, change in the future due to an increase in tree, shrub, and field cover in the alpine region (Hedenås et al., 2016, 2011; Rundqvist et al., 2011). Still, the attitude towards mountain birch forest, even if partially obstructing openness, was rather positive. On the other hand, other indicators related to reduced openness, such as 'spruce' and 'pine', were rated close to zero and below. Thus, coniferous trees in the Swedish mountain areas seem to be something that people, in general, do not find as indicative of a magnificent landscape in the mountains. Other indicators such as 'willow and other shrublands', 'mountains with trees', and 'grass and heath' were on the other hand rated positively.

The presence of 'glaciers and permanent snow' got the third highest ranking among all the landscape features. The loss of glaciers due to climate change is a well-known phenomenon that is mostly mentioned in the context of reduced drinking water (Barnett, Adam, & Lettenmaier, 2005), but very few studies consider their perception values. For example, however, Gagne, Rasmussen, and Orlove (2014) linked the disappearing glaciers to decrease in the number of tourists in China.

'Seclusion' or 'away from others' was rated as the second most important property, 'silence' fourth and 'Solitude´ (i.e. being alone) as the ninth most important while 'see and hear other tourists' had rating 27. Thus, being alone in quiet surroundings seems to be highly linked to the concept of the MML. However, no biotic data in NILS could be linked to these properties because such a link would require data on the number of people and their movement patterns in the mountains. Remarkably, most people visit the Swedish mountains over rather short periods during the year, with the number of visits peaking in early spring (skiing) or late summer (hiking in August and September) (Fredman & Hedblom, 2015) making it difficult to avoid others. Furthermore, any trace of human activity such as windmills, hydropower stations, ski resorts, and noise was rated low and described as negative. Neither of these properties can be covered by NILS data, but with information about their location in combination with a digital elevation model, we could calculate the probability of seeing or hearing them.

The MML objective emphasises 'pristine character' although this quality is not described in detail. However, defining a landscape's pristine character or baseline is not a straightforward process as a baseline is often referred to as 'highly natural', which is difficult to estimate (Normander et al., 2012; Schirpke et al., 2013). Nevertheless, after merging many NILS variables from the field that did not have any traces of humans (i.e. 'untouched ground with no traces of human activity'), we found that rather large areas (e.g. 3.2 million hectares of the alpine region) could still be considered relatively pristine. Although traces of human activity, in general, were rated low, the variables 'mountain farm and Sami cultural remains', 'grazing reindeer', 'living culture', and 'cultural landscape' were rated positively. This indicates that properties linked to the cultural identity of the Swedish mountains are seen as important characteristics of the MML.

Interestingly, in the open question, 'heterogeneity in landscape' was mentioned numerous times. Similarly, several previous studies have linked 'heterogeneity in landscape' to subjective preferences as well as objective scenic beauty criteria (Dronova, 2017). Here, it was also shown in the Likert's scale ratings where 'rare plant species' and 'many plant species' were positively rated which is seen in other studies (Junge, Schuepbach, Walter, Schmid, & Lindemann-Matthies, 2015; Lindemann-Matthies et al., 2010).

### *Space and place*

We interpreted the responses from the questionnaire into either space or place concepts in order to better understand the way participants related to mountain areas. As we did not directly ask the participants to link different properties to either space or place but did it based on our expert judgement, this was a challenging task. For example, the property 'openness' impacts the perception of landscape in complex ways and involves the absence of certain physical data such as trees that restrict the view. According to Hunziker et al. (2007), an open landscape should be described as space since it links to the 'savannah theory' and the 'prospect-refuge theory'. However, when participants referred to a mountainous landscape, they seemed to visualise or perceive a specific place linked to individual emotions, for example, 'views unbroken by infrastructure'. This result is in line with Knez and Eliasson (2017) who showed that what is the most valued attribute in the mountain landscapes are its aesthetics of the landscape (beautiful, wide vistas, and views) and the ability to provide outdoor restoration (relaxation, recreation, silence, peace, and silence). Thus, the results here linked to 'seclusion, away from others', 'silence', and 'solitude' and could all be referred to as properties linked to well-being and thus to place.

Numerous properties appreciated by the participants were difficult to translate into either space or place concept, due to the difficulty in assessing whether the respondent's preferences were developed through evolution (innate) or constructed by culture (learned). For example, in the fourth open question, we suggested that 'increasing shrubs' in space was the opposite of openness. However, in the same open question 'walk through dense willow and birch forest' could be also linked to a place when interpreted as the memory of someone actually walking through an actual place. Based merely on the questionnaire responses for many properties, we could not tell if a participant was remembering a place or perceiving a physical space: 'spruce', 'pine', 'willow and other shrublands', 'mountains with trees', 'grass and heath', 'rare plant species', 'mire', 'many plant species', and 'grazing reindeer'.

Similarly, when the participants rated the presence of human infrastructure such as windmills and mines as negative in the MML, we cannot know if they referred to specific 'windmills' in the mountains (space) or referred to their experiences of a place being ruined or destroyed by 'windmills'. However, quiet areas or 'silence' are strongly correlated to well-being (Gidlof-Gunnarsson & Öhrström, 2007), which relates to the sense of a place where a stronger emotional component of place identity increases perceived well-being when people visit these places (Knez & Eliasson, 2017).

### *Temporal aspects of monitoring landscape variables linked to perception*

One of the current obstacles of linking social with natural science data is the lack of information on how people perceive and rate specific landscape properties. So far, most of the existing knowledge of landscape perception has been derived from questionnaires or interviews, with vague links to actual physical data. Here, we suggest using long-term monitoring data as substitutes for individual perceptions. This method, however, can be complex in long-term studies. For example, a rather low tree cover that is perceived as positive today may be perceived as negative after 100 years when the tree cover has doubled, and we cannot be sure if this negative perception is the result of the tree cover per se or the result of the changes in people's attitudes. Similarly, a forest that is currently considered safe, cosy, and primarily seen as a place for walking may be hypothetically seen as frightening or only as a Pokémon hotspot in the future (Wong, 2017). Thus, it is important to evaluate not only previous and present questionnaires but also previous and present visual landscapes using photos or physical data. This approach is especially needed if changes in perception occur at a smaller and more detailed level than that of the major 'evolutionary' perceptions (such as visual scale, degree of openness, complexity and diversity of landscape properties) (Fry et al., 2009; Tveit et al., 2006). For example, some people may recognise changes that occur in the diversity of plants on an alpine meadow (Schirpke et al., 2013) or perceive their surroundings more positively if they hear more birds singing (Hedblom, Heyman, Antonsson, & Gunnarsson, 2014). NILS data enable assessment of both small-scale and large-scale changes in combination with photos that can be used for future comparisons.

### *Spatial aspects of monitoring landscape variables linked to perception*

People perceive the landscape at different scales, as reflected by the responses to our questionnaire. For example, it was important for the participants to perceive mountains with a lot of lichens and mosses in their immediate vicinity as well as a heterogeneous habitat and general openness at coarser scales of perception. The NILS data consist of detailed data such as lichen cover in sample plots with a radius of 0.28 m and large-scale habitat cover over 1 $km^2$ derived from translating aerial photos into GIS layers. Thus, the data that provide a hierarchical link between small-scale visual properties, and large-scale patterns in the landscape (Hedenås et al., 2016; Ståhl et al., 2011) should be more beneficial than the approach used by Norton et al. (2012), who used a much coarser data resolution.

### *Future adaptation of monitoring program to enable perception indicators*

The results indicate that open questions, property rating, and photos rating to some extent provided similar results. Using photos illustrating mountain landscapes could be seen as a more objective way to gather perception information than the use of specific pre-made questions or pre-selected categories. Thus, photos may be a future tool to enable evaluation of landscape changes. Presently, NILS has an archive of approximately 30 000 photos of all terrestrial landscapes in Sweden that are taken of the same plot every 5th year. This archive provides not only a unique visual database but is also linked to physical monitoring data on the ground. However, using unidirectional photos of a landscape may not always provide an optimal depiction of a local landscape perception. In our study, the same plot received different ratings depending on which direction the photo was taken. A photo taken downhill provided a view of a sparse mountain birch forest with a distant mountain hill in the background and was rated higher than the photo showing the sparse mountain birch forest uphill, even though the physical data of the plot were the same. It would, however, be relatively easy to adapt the present traditional photos taken in a field to a 360° photo that included visual depths. Such a photo could then be used later in a Virtual Reality environment for participants to evaluate the perceptions in a more meaningful way (Annerstedt et al., 2013). Furthermore, to provide realistic environments, other senses should be monitored such as soundscapes (Annerstedt et al., 2013). Another adaptation in the field sampling could be to draw arrows on a map from the plot centre to the longest view, such as to a distant mountain peak, to enable a measurement of openness (see Methods in Dramstad et al. (2006)).

## Conclusion

We combined the participant's personal perceptions of the magnificent mountain landscape characteristics gathered through a questionnaire and linked these to physical monitoring data. This strategy allowed us to establish the links between the participants' responses and the physical monitoring data. The property that was most commonly linked to the characterisation and perception of the Swedish mountain landscape was openness, while the noise from aircraft was rated as least indicative of the magnificent landscape. The perceptions of the mountain areas could be in most cases interpreted as linked to place, particularly in relation to the different aspects of well-being, such as, silence and being alone. In total, 18 indicators were proposed that allow for monitoring temporal changes of different landscape characteristics, for example, increased or reduced openness, glacier distribution, distribution of pristine landscape, lengths of boardwalks, or amount of increasing shrubs. Out of these 18 indicators 14 could be extracted from the NILS database directly, and four could be extracted through minor data compilations.

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