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Land-use and climate related drivers of change in the reindeer management system in Finland: Geography of perceptions

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ABSTRACT

Drivers of change in the reindeer management system are rather well-known. But when developing the governance to support the traditional livelihoods, it is crucial to understand also practitioner perceptions. Systematic research on these is lacking. We analyzed the land-use and climate related drivers within the reindeer management area (RMA) in Finland, and, using a perception geography approach, studied the herder perceptions towards these. We conducted an on-site questionnaire survey with herders from 51 herding districts. Factors directly affecting the welfare of reindeer were perceived as crucial by herders, for example basal icing affecting the forage availability, and land-use related factors limiting the seasonal pasture access. Perceptions of herders on biophysical factors were rather homogeneous. The regional heterogeneities in perceptions towards land-use related factors could be explained by spatial differences in land-use and varying herding traditions. Cumulative land-use impacts raised particular concerns. Our approach can be utilized in the co-planning of the northern land-use and more widely in the co-management of natural resources.

1. Introduction

1.1. Reindeer management in Finland

Reindeer husbandry[1] is one of the traditional livelihoods in northern Finland (Itkonen, 1948; Kortesalmi, 2007). The Reindeer management area (RMA) covers 36% of Finland's total area. In this area, semi-domesticated reindeer (*Rangifer tarandus tarandus*) have a free grazing right which is not dependent on land ownership (Reindeer Herding Act 1990/848, Heikkinen et al., 2012). There is a vast cultural, historical and geographical diversity within the RMA. Both Indigenous Saami and Finnish people practice reindeer husbandry in Finland, unlike in Sweden and Norway where it is mainly an exclusive right of the Saami (Eide et al., 2017; Soppela & Turunen, 2017). Reindeer husbandry is considered regionally important as it employs people, keeps remote areas inhabited, and provides economic benefits. It also represents cultural continuity and a way of life connected to traditions, indigenous rights, and *trans*-generational values (Helle & Jaakkola, 2008; Kumpula & Siitari, 2020; Turunen & Vuojala-Magga, 2013, 2014).

In a globalizing north, reindeer husbandry shares the same operational space with several other land-use forms. Economic development, such as industrial infrastructure projects and tourism activities, is growing in the Arctic (AMAP, 2017; Finger & Heininen, 2019; Forbes, 2006). In Fennoscandia, reindeer husbandry has conflicting interests with other land-use forms, mainly forestry (timber harvest), agriculture, exploration and extraction of natural resources, outdoor recreation and

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[1] When referring to reindeer as a livelihood, we use the term "reindeer husbandry". "Herding" refers to day-to-day practices (and it also appears in the term "reindeer herding district"), whereas husbandry considers reindeer as a resource and is related for example to the profits, breeding, and social mechanisms. "Reindeer management" is related to all of the practices pertaining to the keeping of reindeer, including governance (Forbes, 2006).

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tourism, and energy production (Pape & Löffler, 2012; Pettersson et al., 2017; Sarkki et al., 2018). Intensifying land use has led to fragmentation and deterioration of reindeer pastures, causing the available pasture area to shrink (Anttonen et al., 2011; Jaakkola et al., 2013; Kumpula et al., 2014). The warming climate poses additional challenges, among them increased risk of ice formation on the winter pastures (Rasmus et al., 2018; 2020a) and lengthening of the heat periods and increased insect harassment during the summer (Soppela & Turunen, 2017; Turunen et al., 2016).

Reindeer husbandry is dependent on management decisions of external public authorities (Heikkilä, 2006). It is steered by the Ministry of Agriculture and Forestry of Finland. Furthermore, the European Union steers the livelihood by means of national livestock and arable area subsidy policy since reindeer husbandry in Finland belongs to the EU's unified food and agriculture sector (Rees et al., 2008; Turunen & Vuojala-Magga, 2014). Other land use in the RMA is governed first and foremost by the National Land Use Guidelines (2017) which steer regional and municipal zoning in Finland. Herders are consulted during planning of land-use projects affecting their livelihood (for example during the Environmental Impact Assessment procedures), but they do not necessarily have enough power to affect decision making (Landauer & Komendantova, 2018). In the Saami homeland, legislation on the rights of the Saami as an Indigenous people plays a central role in land-use planning (Markkula et al., 2019).

Economic profitability of reindeer husbandry depends on several factors such as legislation, markets and historical legacies (Bernes et al.,

Table 1
The drivers of change in the reindeer management system in Finland and examples of their impacts on reindeer husbandry, based on national reviews and reports (1919–2020). The shading marks the drivers considered in our study (Grotenfelt, 1919; Jääskö, 2001; Pakkanen & Valkonen, 2012; Sonnenfeld, 1972; Working committee, 1992).

Drivers of change	Impacts on reindeer husbandry	References
Competing land-use and infrastructure development	Deterioration and fragmentation of pastures; Conflicts with other forms of land-use; Increasing traffic	Grotenfelt 1919 Working committee 1992 Hukkinen et al. 2003 Meristö et al. 2004 Pohjola & Valkonen 2012 Käyhkö & Horstkotte 2017 Soppela & Turunen 2017 Kumpula & Siitari 2020
Predators	Reindeer losses due to predation; Decrease in the productivity of herds; Increase of herding work	Working committee 1992 Meristö et al. 2004 Pakkanen & Valkonen 2012 Soppela & Turunen, 2017
Changing herding practices	Adopting advanced technology; Intensive winter feeding; Changing grazing pressure on pastures	Working committee 1992 Meristö et al. 2004 Käyhkö & Horstkotte 2017 Soppela & Turunen 2017 Kumpula & Siitari 2020
Climate change	Frequent extreme weather events; Effects on pastures and forage; New parasites and diseases	Käyhkö & Horstkotte 2017 Peltonen-Sainio et al. 2017 Soppela & Turunen 2017 Kumpula & Siitari 2020
Social legitimacy shift	Decreasing societal acceptance and public image of reindeer husbandry	Jääskö 2001 Hukkinen et al. 2003 Pohjola & Valkonen, 2012
Economic transition	Problems related to the transition from the subsistence economy to a market-oriented one; Decreasing profitability	Hukkinen et al. 2003 Meristö et al. 2004 Pohjola & Valkonen 2012 Soppela & Turunen 2017 Kumpula & Siitari 2020
Governance	Diffuse legislation and top-down governance; Lack of climate change adaptation strategy, limits to adaptation	Hukkinen et al. 2003 Meristö et al. 2004 Käyhkö & Horstkotte 2017 Kumpula & Siitari 2020
Demographic and socio-cultural factors	Aging of herders; Changes in the availability of workforce; Losses in communality, culture, tradition and identity through potential loss of the livelihood	Meristö et al. 2004 Pakkanen & Valkonen 2012 Soppela & Turunen 2017 Kumpula & Siitari 2020

2015). These are continuously evolving and diversifying. Still, the basis for successful reindeer husbandry is the productive herd of healthy animals (Kynkäänniemi, 2020). The welfare of reindeer is largely determined by the quantity and quality of available forage (Helander-Renvall, 2014; Kitti et al., 2006). Forage adequacy ensures productivity of dams, which, in turn, affects the calving success and calf weight, both being pivotal to the profitability of the livelihood (Muuttoranta et al., 2014). In addition to the area and state of pastures, limited access to pasture resources reduces forage availability: "It is more often a question of access to the forage than the amount of forage as such" (Kitti et al., 2006, p. 149). Factors affecting the accessibility of forage are mostly biophysical (Forbes, 2006; Rasmus et al., 2018); some are related to the management choices or governance of land use (e.g., Eira et al., 2018; Riseth et al., 2016).

Reindeer management represents an example of a social-ecological system (SES) (cf. Ostrom, 2009; McGinnis & Ostrom, 2014) in which biophysical and socio-economic factors are interacting as drivers of change (Käyhkö & Horstkotte, 2017). For reindeer management in Finland, these drivers and related impacts on the livelihood are rather well-known (Table 1). Already about a hundred years ago deterioration of pastures and conflicts between reindeer husbandry and other land-use forms were listed as factors causing pressure on reindeer husbandry (Table 1; Kortesalmi, 2007). A recent national report (Kumpula & Siitari, 2020) presented recommendations on how to support and develop "ecologically, economically, culturally and socially sustainable use of reindeer pastures, as well as the vitality of reindeer husbandry". The fact that reindeer husbandry faces varying challenges in different areas within the RMA in Finland was strongly emphasized in the report. Still, local and regional differences are currently not sufficiently considered in the governance of the livelihood. Systematic research on herders' perceptions on factors affecting their livelihood is lacking. In addition, more knowledge is needed of the cumulative effects of various factors – ones resulting from the combined effects of multiple activities affecting reindeer management over space or time. Our work, for its part, addresses this gap.

1.2. Perception geography approach

We use a perception geography approach (Downs, 1970, Sonnenfeld, 1972), basing our analysis on herder perceptions on and observations of their operational environment. The concept 'Perception geography' or 'Perceptual geography' emerged in the 1960s from the wider conceptual framework of behavioral geography (see Bunting & Guelke 1979; Tuan, 2003) and it provides tools and methods to discuss and quantify landscape research and is applicable also in natural resources management.

Perceptual geography is characterized by a common idea that experience affects perception, which leads to the conclusion that perceptions vary because individuals' life experiences differ (Tuan, 2003). Perceptions are understood as points of contact between people and their environment and as a basis for spatial reasoning and decision making. Perception is the process that encodes the objective environment as a subjective one (Golledge & Stimson, 1997), with the subjective environment and past experiences influencing our behaviour and actions (Sonnenfeld, 1972; Guelke, 2003).

Herder perceptions are relevant when studying the reindeer management SES. Herders are central actors in the system: they experience and deal with drivers of change such as land use and climate change in their daily professional life (Landauer et al., 2021). Their perceptions affect the functioning of the system for example through decision making and risk preparedness. Perceptions also carry culture, and local and traditional knowledge (Forbes et al., 2020; Jaakkola et al., 2018). This means knowledge and practices, developed during centuries and handed down from generation to generation (Berkes 2008). Knowledge also accumates and develops through context-situated learning in new situations. Knowledge can consider for example reindeer behavior, forage and diseases, suitable herding practices during adverse weather conditions, various snow types, and predator behavior (Porsanger & Guttorm, 2011; Turunen & Vuojala-Magga, 2014).

Perception geography approach has been applied for example in studies on risk management (Ren et al., 2016) and urban planning (Bergeron et al., 2014). Using local perceptions together with the quantitative data from monitoring surveys has been as a tool to get to more holistic understanding of the changes in ecosystems and the nature-based livelihoods such as reindeer husbandry (Rasmus, Turunen, Luomaranta, et al., 2020), fishing (Coll et al., 2014) or forest use (Meijaard et al., 2013).

Geographical distribution of perceptions has been studied using map-based methods, which enable the collection and presentation of information about local people's views of their environment and important places, and can make their incorporation to decision-making easier (Nikula et al., 2020; Ren et al., 2016). Public Participation Geographic Information Systems (PPGIS) can be used to locate perceptions on a map and are designed to involve wide audience. During recent years these have been applied in land use studies both in urban and rural areas (Brown & Kyttä, 2014; Kahila-Tani et al., 2016; Kantola et al., 2018; Nikula et al., 2020). Understanding people's perceptions towards for example certain forms of land use may facilitate the management of conflicts between land users with different interests in the same resource (Brown et al., 2020). Understanding the spatial differences both in the drivers of change and in the perceptions towards them will help develop jurisdictional and institutional strategies to support governance and future of the northern livelihoods such as reindeer husbandry.

This work is based on a questionnaire survey conducted during a project "Reindeer health in the changing environment" (2016–2018, Laaksonen, 2016). The survey focused on herders' perceptions on factors affecting reindeer welfare. This means factors related to drivers of change such as climate and weather, pasture conditions and land use (shaded in Table 1). Consequently, this paper also focuses on these concrete factors herders experience in their daily herding work; factors affecting the success of the livelihood through reindeer condition and available forage. In reindeer management, some drivers, such as governance institutions, are of socio-economic or cultural nature (Table 1). In this study we do not focus on these drivers. Our research questions are:

1) Which factors of the climatic, ecological and land-use related drivers of change are perceived by herders as important for reindeer welfare and why?
2) What kinds of regional differences are there in these perceptions within the RMA?
3) Can the regional differences be explained by regional variation in land-use patterns, climatic and ecological conditions, or varying herding traditions and practices?

2. Material and methods

2.1. The study area

The study area covers the RMA in Finland, situated between 64.5°N and 70.1°N (Fig. 1a, Fig. S1). The sparsely populated region is characterized by boreal coniferous forests, mires, subarctic mountain birch woodlands and fells. For the time period from 2000 to 2019, the maximum number of reindeer over one year old allowed within the region has been set at 203,700. The numbers are set by the Ministry of Agriculture and Forestry every ten years. This is the size of the winter stock; furthermore, ca. 100,000 calves are born in spring (RHA 2018). Of this total number, ca. 80,000 calves and 20,000 over one-year-old reindeer are slaughtered in autumn. Finland has 54 herding districts. A reindeer herder can practice herding within one herding district at a time, and every district is responsible for reindeer herding within its area. The districts are regulated by the Reindeer Husbandry Act (1990/848). During the study period, there were approximately 4500

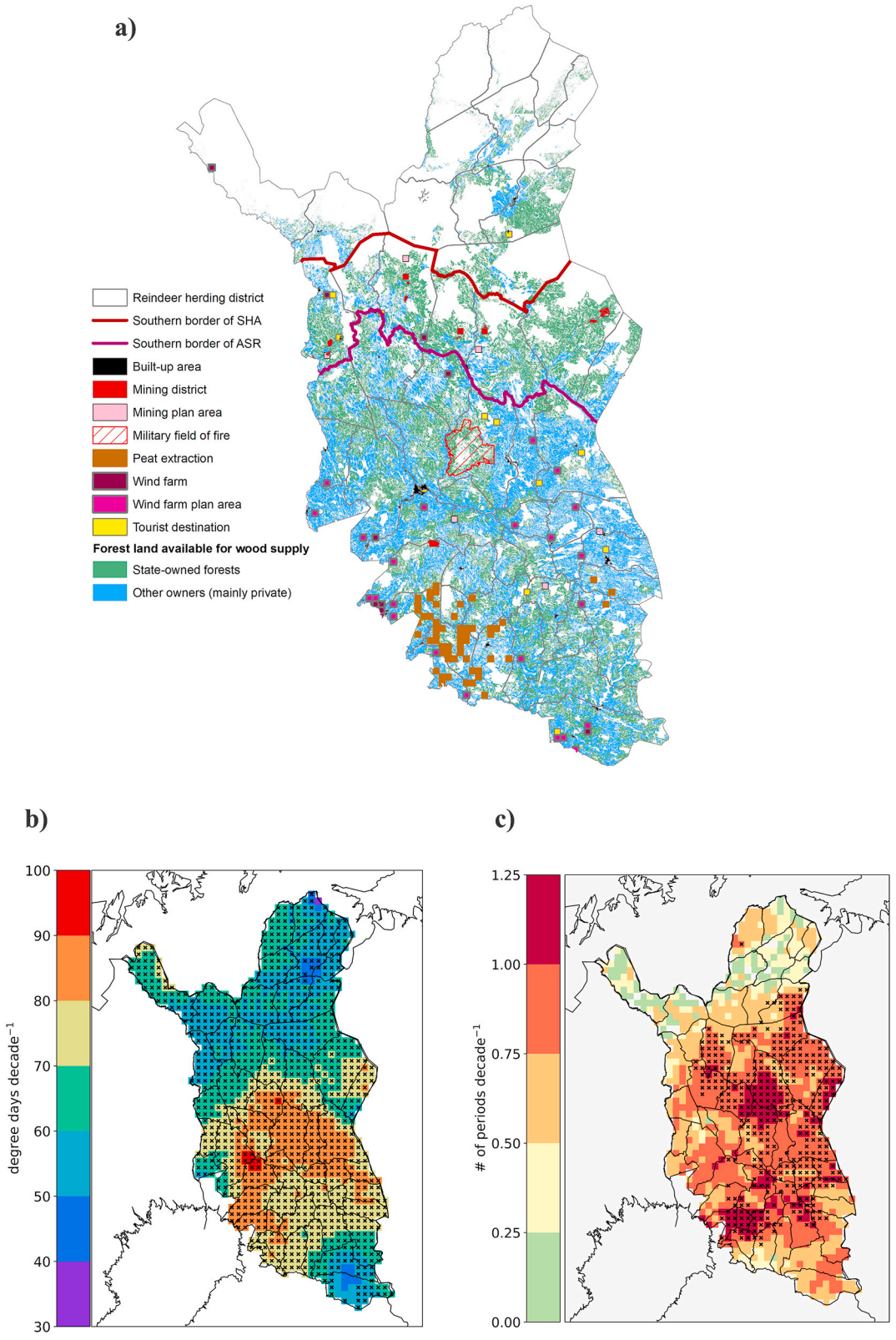

Fig. 1. a) State and privately owned land used for forestry and the present and planned land-use projects in the reindeer management area (RMA; regions with high predator density in the northern area and close to the eastern border, or agricultural regions in the southern area not shown). b) The change in the annual degree day sum and c) in the number of warm weeks in the winter season in 1981–2010; locations with significant trends (at 5% significance level) are marked with black check marks. Data: Finnish Environment Institute (2020) and Finnish Meteorological Institute.

reindeer owners in Finland of which an estimated 900 are full-time herders (RHA 2018).

Herding cultures, seasonal herding practices, reindeer numbers per district, as well as the intensity and type of other land use vary greatly within the RMA (Table S1, Fig. 1a). The 20 northernmost districts belong to the area specially intended for reindeer husbandry (ASR; "northern area"). According to regulation on land-use, the land in this area should not be used in a way detrimental to herding. The 13 northernmost districts belong to the Saami Homeland area (SHA) in Finland (Reindeer Husbandry Act 848/1990, Näkkäläjärvi & Jaakkola, 2017). In the ASR, and especially in the SHA, the herds are generally larger and reindeer husbandry is more commonly the main source of livelihood, whereas in the southern districts, reindeer husbandry is traditionally more often combined with other livelihoods, particularly small-scale agriculture and forestry and reindeer-based tourism (Jaakkola et al., 2018; Soppela & Turunen, 2017). Supplementary winter feeding in enclosures is a more common practice in central and southern parts of the RMA. In the north, especially in the SHA, the livelihood is more based on herding the reindeer on natural pastures (Helle & Jaakkola, 2008; Turunen & Vuojala-Magga, 2014). For these reasons, we present some of the results separately for the northern area (ASR including the SHA) and the southern area (the rest of the RMA).

Topography, vegetation and climate vary within the RMA as well. Clear warming trends have been observed during the past decades (Fig. 1b and c). In reindeer management, impacts of changing climate are experienced through changing seasonal weather conditions. These impacts are already being observed across the area but in varying degree (Rasmus, Turunen, Luomaranta, et al., 2020).

2.2. Data collection method

Data for our analysis were gathered using an on-site questionnaire survey which was part of semi-structured interview conducted with 51 chiefs of herding districts in the RMA. In the survey factors affecting reindeer welfare were considered. The factors were selected by researchers based on existing knowledge of external drivers of change affecting reindeer (Tables 1 and 2 and S1). Herding practices as internal drivers of change were discussed as well (Table 3). More information about the factors considered and their impacts on reindeer welfare and reindeer husbandry can be found in references in the tables. Reindeer management SES and the relationships between the key factors are thoroughly explained and graphically presented e.g. in Käyhkö & Horstkotte (2017) and Landauer et al. (2021).

The survey respondents were asked to estimate their perceptions towards 32 factors on a scale from −4 to 4, whereby −4 denotes a considerable negative effect, 0 denotes no effect and 4 denotes a considerable positive effect. They were asked to consider the latest ten-year period in their answers. Our study covers 94% of herding districts within the RMA (51 out of total of 54). The survey was conducted mainly on-site in the reindeer herding districts the herders represent by one of the co-authors (J.T.) between May 2016 and January 2017. In three cases herders were interviewed by phone. All respondents were male and full-time herders. Chiefs of districts (*poroisäntä*) were selected to represent each district as key informants because they have the most holistic knowledge of the district they represent (purposive sampling; Bernard, 1995).

The key findings are presented in the form of maps, while all answers

Table 2
Factors related to climate and weather, usability of pasture resources, and other land use and disturbances, considered in the survey.

Driver of change	Factor considered	Factor explained
Climate and weather[1,2,3,4]	Timing of spring	Cold and snow are harmful for newborn calves, and lactating reindeer benefit from natural fresh forage.
	Summer temperature	Multiple impacts on reindeer welfare: affecting forage and water supply and insect harassment, causing heat stress.
	Cold spells in winter	Long periods of very low temperatures deplete energy storages of reindeer
	Deep snow	Makes reindeer difficult to access ground lichens; risk of predator attacks increase; herding work gets difficult.
	Icing events: -icy snow structure -basal ice on pastures	Makes reindeer difficult to access ground lichens; decreased usability of pastures.
	Insect harassment in summer[11]	Increases stress, energy consumption and vector borne diseases of reindeer.
	Wild mushroom yield in autumn	Important for reindeer to gain fat and energy storage for winter.
Usability of pasture resources[5,6,7]	Summer pasture condition and availability	Diverse and peaceful summer pastures needed for reindeer to recover from winter and improve the body condition, and for calves to grow.
	Winter pasture condition and availability	Lichen pastures with adequate quantity and quality needed for winter survival, welfare, calving success and calf weight
	Fragmentation of pastures	Fragmented pastures are difficult to utilize, managing the herds and controlling the grazing becomes difficult for herders.
	Availability of nature conservation areas	Less human disturbance and other land use in conservation areas; diverse and peaceful seasonal pastures and increased winter forage availability because of old-growth forests.
Other land use[1,7,8,9,10]	Forestry	Forestry decrease the amount of old-growth forests important for reindeer as winter pastures; increases fragmentation of pastures; harvesting of dense forests can improve lichen growth.
	Mining	Mining districts occupy pasture land and increase fragmentation of pastures; operations and transportation increase the risk of accidents, noise and dust impacts.
	Peat extraction	Peat extraction destroys summer pastures and calving areas, reindeer may drown in deep dikes; areas can be utilized by reindeer to avoid insect harassment.
	Hunting/dogs	Free-running dogs can kill or injure reindeer or cause extra work for herders by scattering the herd. The impacts are most common during rut, and can affect calf production.
	Disturbances by human activities	Reduced forage availability through decreased access or usability of pastures; may disturb calving and grazing.
	Other land use (wind farms, hydropower, infrastructure like roads etc.)	Land use occupies pasture land and increases fragmentation of pastures; reduced forage availability through decreased access or usability of pastures; grazing pressure on remaining pastures increases.
	Predation	Wolverine (*Gulo gulo*), wolf (*Canis lupus*), brown bear (*Ursus arctos*), lynx (*Lynx lynx*) and golden eagle (*Aquila chrysaetos*) hunt and kill reindeer, which can cause severe damage to herds and extra work for herders though mitigating the damage and looking for carcasses (needed to get compensations). Decreases the usability of certain pastures.

[1]Pape & Löffler 2012, [2]Turunen et al.,2016, [3]Jaakkola et al.,2018, [4]Rasmus et al.,2020a, [5]Kitti et al.,2006, [6]Kivinen et al.,2012, [7]Kumpula et al.,2014, [8]Anttonen et al., 2011, [9]Rasmus et al.,2020b, [10]Landauer et al.,2021
[11]not a climatic factor, but related to for example seasonal temperature, precipitation and wind conditions.

Table 3
Factors related to herding practices in use (internal drivers), considered in the survey.

Driver of change	Factor considered	Factor explained
Herding practices	Supplementary winter feeding in enclosures[1,2]	Due to poor winter pasture resources or limited access to forage, for example, due to icy snow, reindeer are taken into enclosures and given supplementary feeds daily for several months; also protects reindeer from predators and keeps them off the roads and settlements.
	Supplementary winter feeding in the field[1,2]	Due to poor winter pasture resources or limited access to forage, for example, due to icy snow, reindeer are fed with supplementary feeds in their natural pastures (often in forests); helps also controlling the herds and protecting reindeer from predators.
	"Herding feeding"[1,2]	Feeding in the pasture area to support active herding.
	Active herding[3,4,5]	On-the-spot management of the movement and foraging of herds; moving herds with or without the aid of hay from one pasture area to another, shepherding.
	Pasture rotation[3,4,5]	Practice where certain pastures are reserved for certain seasons and natural seasonal behaviour of reindeer is supported by fences separating the pastures, and by active herding.
	Antiparasitic medication[6]	Reindeer are annually treated with antiparasitic medication, to improve the condition.
	Managing calving in enclosures[3,4,5]	In enclosure calving, reindeer give birth within a fenced pasture area. The calves are ear-marked immediately after their birth with the owner's earmark
	Earmarking of calves during summer[3,4,5]	In free-ranging type of calving reindeer give birth in their natural calving regions and specific spots such as forested areas or the southern slopes of fells. Reindeer are gathered from pastures to summer round-ups, in which the calves are ear-marked with the owner's reindeer earmark from midsummer onwards.
	Timing of slaughtering[3,4,5]	Impacts on amount of meat to sell and meat quality. The later the slaughter, the poorer the condition of reindeer generally is; they start loosing weight after the snow cover forms.

[1]Pekkarinen et al., 2015, [2]Horstkotte et al., 2020, [3]Forbes 2006, [4]Helle & Jaakkola 2008, [5]Käyhkö & Horstkotte, 2017, [6]Laaksonen et al., 2017.

of the on-site questionnaire survey are shown in Tables S2-S5 – in the Supplementary material. The survey respondents had the possibility to comment on their answers (15 comments received), provide additional information on calving success of reindeer (37 answers received) and give suggestions on how to increase the welfare of reindeer (50 suggestions received). Some excerpts of this free-form material are presented as part of the results to illustrate the themes of this article.

Detailed background information on the herding practices of each district was also collected. Due to the quality and, in some cases, the confidentiality of the material, they are not shared in full as part of the original data set for this study, but referred to under the Results section to provide further insight into the commonness of and regional differences in certain herding practices.

Our study also draws on articles published in the professional journal *Poromies* [Reindeer herder] in order to describe the changes herders have experienced in the pasture environment and the subsequent adoption of the supplementary winter feeding (Supplementary text S1). The journal has been published since 1931 by the Reindeer Herders' Association in Finland, and it is a commonly used source of information in research on reindeer management (Kortesalmi, 2007; Helle & Jaakkola, 2008, Vuojala-Magga et al., 2011; Turunen et al., 2017).

2.3. Analyses

The perceptions of the herders were analyzed by using exploratory data analysis methods and the differences of perceptions between the groups were analyzed using Bayesian generalized linear regression models (GLM). The survey data were combined with existing spatial datasets on land use of the study region (RHA 2018; Metsähallitus, 2019, Finnish Environmental Institute, 2020) to explain and discuss the results. Regional comparisons of the data were conducted by mapping the data into choropleth maps and compared visually. Data preparation, visualisations and analyses were done in R (R Core Team, 2020). The Tidyverse package (Wickham et al., 2019) was used for data preparation and visualisations, the tmap package (Tennekes, 2018) for plotting the maps and the *sf* package (Pebesma, 2018) for spatial data operations. R-package brmss (Bürkner, 2017) was used for fitting the GLMs and bayesplot (Gabry & Mahr, 2021) for creating visualizations from the models.

To show the significance of cumulative effects of different land-use activities we calculated how many of the following factors were considered as harmful per district: forestry, mining, peat extraction, hunting/dogs, other disturbances by human activities (such as outdoor recreation), other land use (such as wind farms, hydropower, infrastructure; see Table 2). We interpreted answers −3 or −4 as a harmful effect and 3 or 4 as a beneficial effect. The dataset was rescaled from range [-4,4] to [-1,1] for the regression models. Essentially all negative values were considered as negative were considered as negative effect (−1), zero values as neutral (0) and positive values as positive (1) effect. Perceptions with only negative and neutral (icing, predation, human disturbance, mining, hunting) or neutral and positive (herding, conservation areas, mushroom yield) values were omitted from the analysis.

We used absence/presence data for analyzing the perceptions regarding peat production and mining. In these models the A/P variable was used as a predictor for the corresponding perception. Perceptions on forestry were analyzed using log-transformed ratio of private and state owned forests within each reindeer herding district as a predictor. Regression models were fitted using tight priors as constraints as suggested by Gelman et al. (2020). Details are found in Table S9 in the Supplementary material.

We divided the observations into two groups according to borders presented in Fig. 1a. The first group (n = 17) consists of herding districts north of the ASR -border, "northern area", including the Saami Homeland area (SHA). For the second group (n = 34) we combined the districts within the rest of the RMA ("southern area"). Differences in herding cultures and practices between these groups, as well as the intensity of other land use and the land-use regulations, justify this division. Considering the SHA separately was not considered possible because of small number of survey respondents from that area (n = 10). We analyzed the group differences on perceptions using Bayesian ordinal regression framework as presented by Bürkner and Vuorre (2018). Cumulative models with probit -link were fitted using each perception as response variable and group as a predictor.

3. Results

3.1. Importance of the drivers

There was a strong agreement among the survey respondents that certain biophysical factors are harmful. For example, 75% of the herders perceived the impact of predators and 80% considered icy foraging conditions as harmful (Fig. 2a; See also Tables S2–S5). The respondents also agreed on benefits of certain biophysical factors such as abundance of mushroom (92% considered beneficial; Fig. 2b) and early arrival of spring (69% considered beneficial). As one herder from the northern area put it: "*Dams' success for becoming pregnant depends on mushroom yield*". Disturbance-related factors such as hunting were generally perceived as harmful. Perceptions on certain herding practices diverged the most. Feeding in enclosures was seen as an important, positive factor in the southern part of the RMA, but in the north it was mostly seen as a method which should not be preferred. Instead, herders in the northern part of the RMA preferred practices such as active herding (moving herds, shepherding) and feeding to support this ("herding feeding").

Depending on the factor studied, the distribution of answers shows agreement, disagreement and even polarization of perceptions. The general agreement on certain biophysical factors is clear (Fig. 3a and b). Perceptions on deep snow cover (Fig. 3c) give a good example of disagreement among the survey respondents. Generally, deep snow makes reindeer foraging more difficult, but in some districts with ample forest pastures it may ease grazing on arboreal lichen. Moreover, snow depth is not a significant factor in districts where most of the reindeer are fed in enclosures. Also, some land-use related factors such as forestry were considered as neutral or even beneficial by some respondents, although forestry was generally seen as harmful for reindeer husbandry (Fig. 3d). All respondents perceived hunting negatively, although the importance of this factor varied (Fig. 3e). Three herders from the southern area explain the effects on reindeer: "*Hunting dogs disturb rutting [reindeer], which has an impact on the calf percentage … Sometimes the [presence of]hunting dogs delays the rut so that calves are lighter when slaughtered … We should put an end to the barking of the elkhounds early in the autumn because it breaks up the herds, and the calves may become separated from the dams.*"

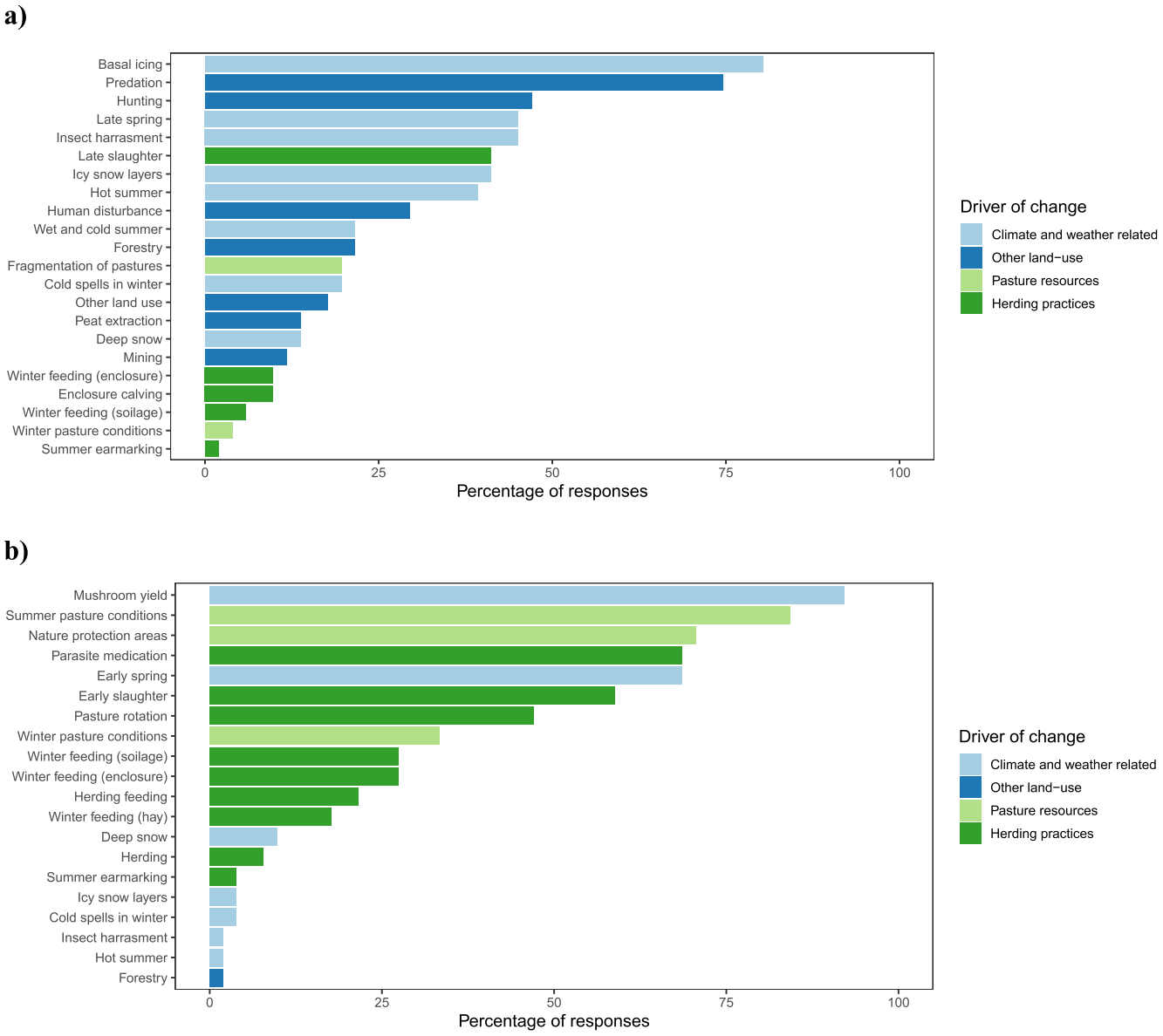

Fig. 2. Factors perceived as harmful (a) for the welfare of reindeer; the percentage of respondents sharing the view (answer −3 or −4; N = 51); Factors perceived as beneficial (b) for the welfare of reindeer, the percentage of respondents sharing the view (answer 3 or 4; N = 51).

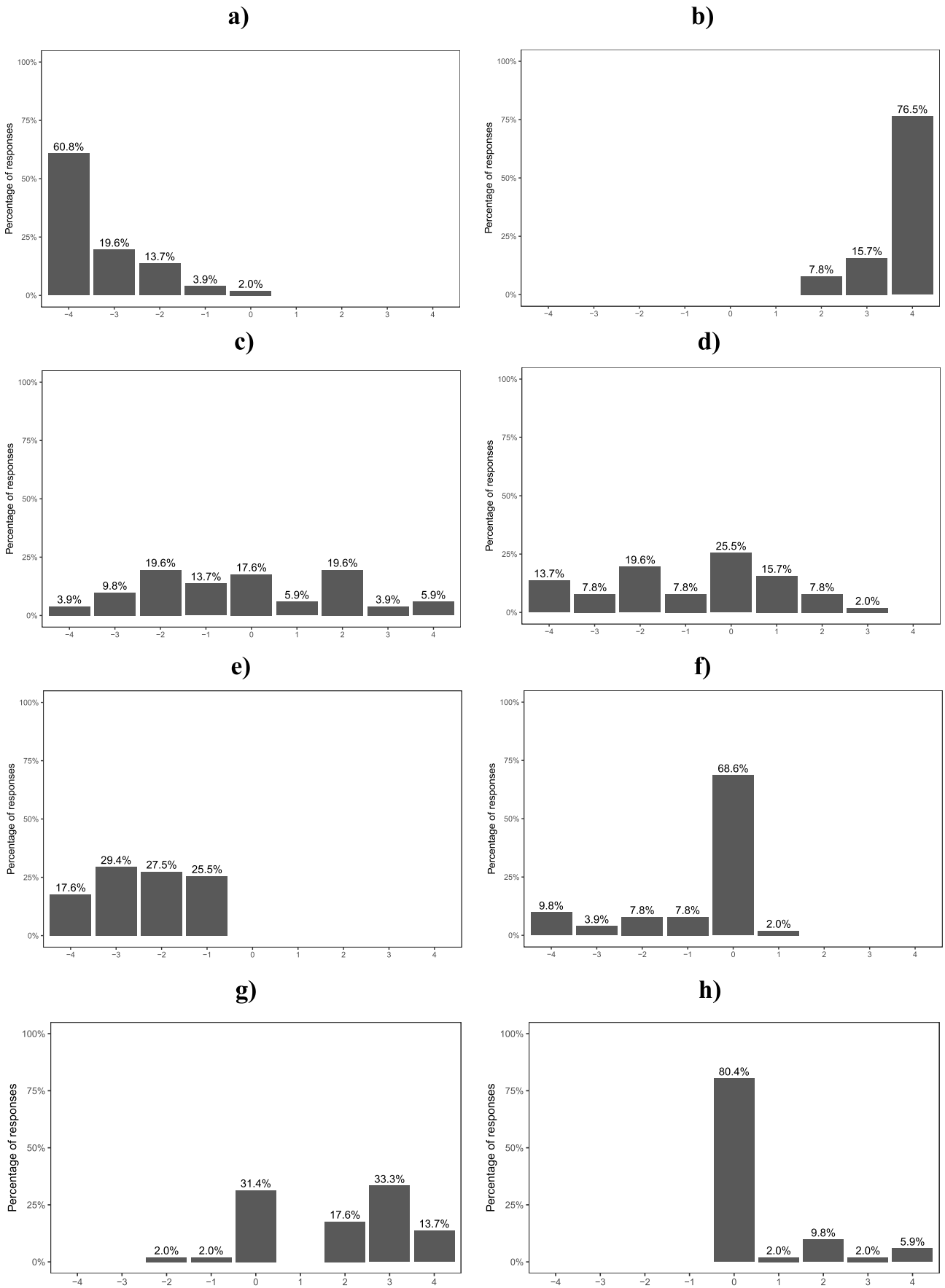

Fig. 3. Distribution of herder perceptions on selected factors: a) basal ice on the pastures, b) abundance of mushrooms, c) deep snow cover, d) forestry, e) hunting/dogs, f) peat extraction areas, g) pasture rotation, h) active herding (−4 denotes a considerable negative effect, 0 no effect and 4 a considerable positive effect).

Perceptions on peat extraction (Fig. 3f) give an example of localized views. Most of the survey respondents considered peat extraction as a neutral factor, but some perceived it as very harmful. Perceptions on some herding practices were also localized, pasture rotation being an example (Fig. 3g). It was perceived mostly as a neutral factor, except by districts benefiting from it in their own work. Active herding was most often perceived either neutrally or very positively (Fig. 3h).

3.2. Regional heterogeneity in perceptions

Perceptions on the importance of factors related to *climate and weather* were rather homogeneous within the whole RMA (Table S2). Cold and rainy summers were mainly perceived as a harmful factor (Fig. 4a), but in some southern districts as a beneficial one. Few districts from the central region viewed also hot summers positively, although this factor is generally considered harmful to reindeer (Rasmus, Turunen, Luomaranta, et al., 2020). Survey respondents explain how climate-related factors directly affect the welfare of the animals and, thus, the future calving success: "*After a hot summer, calf production was very weak. The dams were not in heat*" (Southern area); "*Warm autumns led to a weak rutting period, the stags got lazy … Rutting is delayed in warm autumns. The dams need frosts to be in heat*" (two herders from the southern area); "*A cold winter may also cause dams to abort their calf*" (Northern area).

Perceptions on factors related to *pasture resources* were heterogeneous (Table S4). Summer pastures were nearly unanimously viewed as beneficial for reindeer welfare. Less agreement was seen in the perceptions on winter pastures (Fig. 4b). We assume that the perceptions are linked to the particular situation of each district: quality and usability of seasonal pastures and pasture accessibility. Good summer pastures are most often available, but in some regions lichen pastures for winter foraging are scarce and the quality of the remaining winter pastures is low. Especially interesting is a region in the middle of the RMA, where winter pastures were seen as a factor affecting reindeer welfare negatively, most probably due to the impact of forestry. Nature conservation areas were considered beneficial for reindeer husbandry, also by herders from districts lacking such areas.

The importance of natural pastures was seen in many of the free-form comments of the respondents, as well as the need for actions to foster the pasture quality: "*Grazing peace and diverse pastureland are needed*" (Northern area); "*Old-growth forests should not be cut. In late winter [they are] very important for reindeer*" (Northern area); "*Pasture regeneration would be important*" (Southern area).

Land-use related factors were generally perceived either as neutral or negative (Table S3). For example, perceptions on peat extraction (Fig. 5a) and mining (Fig. 5b) were localized. These forms of land use were considered harmful especially in areas where such activities had existed in the past, currently existed or were under planning (Fig. 5d and e, see also Fig. 1a and Table S1). Several herders from the southern area wanted to see the peat extraction areas restored: "*Reindeer husbandry should be considered in the re-use of peatlands*" (Southern area).

Despite the fact that forestry is practiced in most of the reindeer herding districts (Fig. 1a) and it is considered as a disturbing factor to reindeer husbandry by other studies (Table S1), perceptions of our survey respondents on forestry were diverse (Fig. 5c) and, overall, less negative than expected. Interestingly, perceptions on forestry were more often negative in regions where forests are mostly state owned (Fig. 5f), compared to regions where forest ownership is mostly private.

When reading the results of a 30-year-old comparable survey together with ours (Supplementary text S1), the intensification and diversification of land use within the RMA during the past decades is clearly visible. Approximately 30 years ago, forestry stood out very clearly as the most harmful form of land use affecting reindeer husbandry. Only a few other factors were mentioned by the respondents then, tourism and agriculture being the most common ones. Several other land-use related factors – hunting, human disturbance, peat extraction, other land use and mining – are nowadays seen as equally or more harmful than forestry in the districts in which forestry was considered as the most harmful factor in the 1980s. (Supplementary text S1, Table 4).

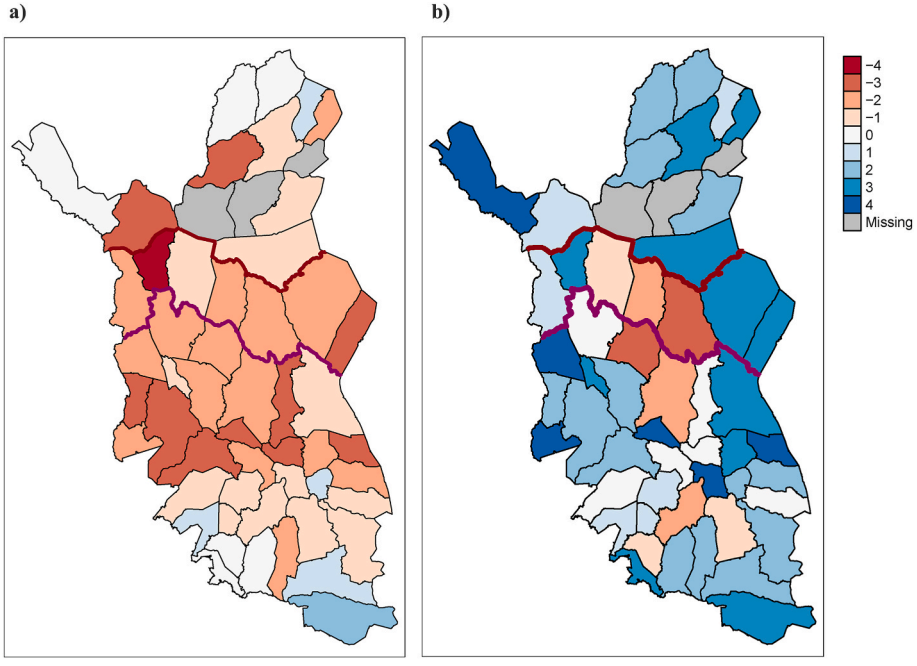

Fig. 4. a) Perceptions of herders on factors "Cold and rainy summer" and b) "Winter pastures" (−4 denotes a considerable negative effect, 0 no effect and 4 denotes a considerable positive effect).
Purple line: southern border of the area specially intended for reindeer husbandry (ASR; "northern area" in this study). Red line: souther border of the Saami Homeland area (SHA). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

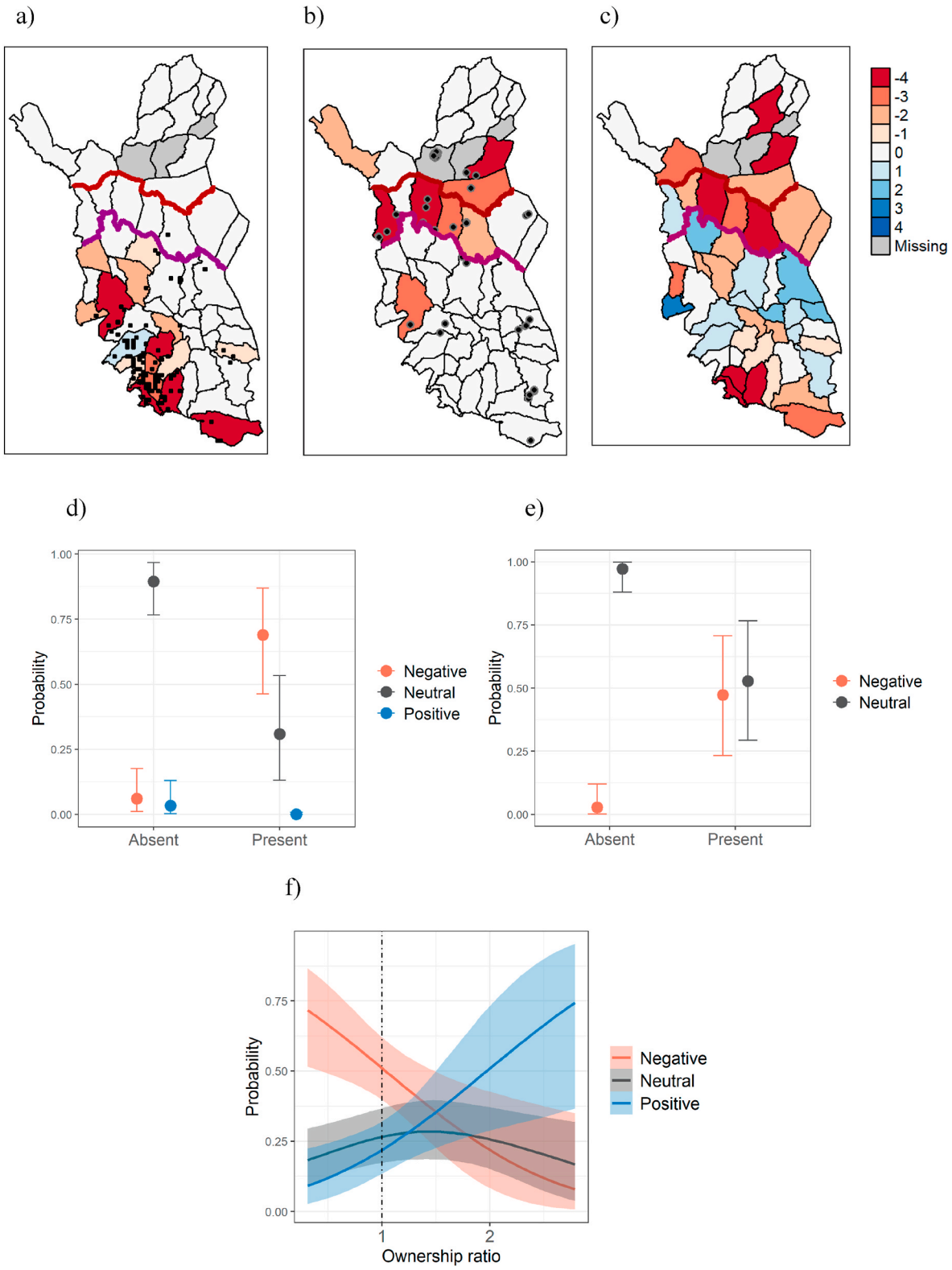

Fig. 5. a) Perceptions of herders on the factor "Peat extraction", the black dots show the peat extraction areas; b) "Mining", the black dots show the locations of the mining districts; c) "Forestry" (−4 denotes a considerable negative effect, 0 no effect and 4 denotes a considerable positive effect), d-e) Marginal effects of absence or presence of peat extraction/mining districts on the perceptions of herders on factors "Peat extraction and "Mining" (posterior mean with 89% credible intervals), f) Marginal effect of forestry ownership ratio (private or state) on the perceptions of herders on factor "Forestry" (posterior mean with 89% credible intervals). See also Fig. 1a, for the land used for forestry. Purple line: southern border of the area specially intended for reindeer husbandry (ASR; "northern area" in this study). Red line: souther border of the Saami Homeland area (SHA). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 4
Percentage of districts where certain land-use related factors were seen as harmful as or more harmful than forestry in our study (number of districts = 34; only those districts analyzed, which had seen forestry as the single most negatively affecting activity within their district during 1986–1987, see Supplementary text S1 for details).

Factor	Factor as harmful as or more harmful than forestry (% of districts)
Hunting/dogs	79
Disturbance (tourism, traffic, etc.)	59
Peat extraction	29
Other land-use[a]	29
Mining	18

[a] including wind farms, hydropower, and related infrastructure (power transmission lines, roads etc.).

3.3. Cumulative effect of land use

At least one land-use related factor was considered harmful by 86% of the survey respondents. Many districts listed several factors as harmful. When the sum of these views (number of these factors per district) was mapped, some hot-spot areas of land use could be seen (Fig. 6a). Characteristic of these hot-spot areas is their location within the forestry region of the RMA, and close to the southern border of the RMA and/or roads with heavy traffic. The pasture lands of districts host active or planned mines and wind farms, hydropower reservoirs and peat extraction areas (Fig. 1b, Table S1). The districts perceiving several land-use related factors as harmful often also considered fragmentation of pastures as a problem (Fig. 6b). Some overlap is also seen with the region where the winter pasture situation was perceived negatively (Fig. 4b).

3.4. Perceptions on herding practices

Antiparasitic medication as well as early slaughtering were generally stated as beneficial factors by the survey respondents (Table S5). Of the districts studied, 92% aimed at early slaughter annually during the study period and 94% gave antiparasitic medication to the majority of their animals. Then again, some herders expressed somewhat critical views of medication: "*Medication should be developed as the reindeer will become immune or new diseases will appear*" (Southern area); "*Medication should be given only to [the reindeer] in poor condition*" (Southern area).

Interestingly, perceptions on some herding practices varied a great deal either locally or regionally (Table S5). Pasture rotation is a practice where certain grazing lands are reserved for certain seasons. Natural seasonal behaviour of reindeer is supported by fences separating the pastures, and by active herding of animals from one area to another. Pasture rotation may not be possible if grazing lands are fragmented due to competing land-use forms and the related infrastructure (Anttonen et al., 2011), or if some seasonal pasture types are missing from the area of the district. Also, low lichen biomass on winter pastures may hinder the use of these (Kumpula et al., 2014). Overall, 39% of the total number of the districts studied – and all districts situated in the northern part of the RMA, including the Saami Homeland area – use pasture rotation. Most respondents considered pasture rotation as beneficial (Fig. 7a), although the importance of this factor varied.

Active herding was a common practice within most of the RMA until the 1960s (Helle & Jaakkola, 2008). Now it is especially considered as a relevant part of the Saami herding tradition (Jaakkola et al., 2018). On the other hand, growing predator populations and increasing predation pressure on reindeer has increased the need for monitoring and controlling of herds also in some of the southern districts (Turunen et al., 2017). In our study, active herding was locally seen as a beneficial factor (Fig. 7b).

Enclosure calving (Fig. 8a) and summertime earmarking of calves (Fig. 8b) were perceived either as beneficial or harmful locally. According to one respondent from the northern area: "[*The animals] should be handled only when necessary. Bringing reindeer to enclosures for calving is not good for reindeer health.*" At least some calvings was managed in enclosures in 49% of the districts studied. Half or more of the calves were born in enclosures only in three districts; these were located in the northern area. Earmarking of calves during summer was common, with 82% of the studied districts practicing this. Herders may also mark calves earlier in the spring in the case of enclosure calving, or marking may be postponed until autumn if there are problems with collecting the animals in the summer or if there is a risk of heat stress during hot periods (Rasmus, Turunen, Luomaranta, et al., 2020).

Particularly heterogeneous perceptions were related to supplementary winter feeding. Some feeding of reindeer has been practiced in northern Fennoscandia for centuries (Helle & Jaakkola, 2008; Salmi et al., 2020). In the past, during difficult foraging conditions in winter lichen has been pulled off the trees, trees rich in lichen have been cut down, and hard snow cover has been broken to make digging easier for reindeer (Turunen & Vuojala-Magga, 2014). Annual feeding was adopted especially in the southern districts in the 1970s. Due to the scarcity of forest pastures rich with ground and arboreal lichen, reindeer are nowadays provided with supplementary feed in the forest, or they are kept and fed in enclosures for some winter months or even throughout the winter (Helle & Jaakkola, 2008; Turunen & Vuojala-Magga, 2014; see also Supplementary text S1.)

According to our data, in 90% of the districts studied majority of reindeer got some supplementary feed during a typical winter during the study period. Several forms of feeding (feeding in the forest/pastures, feeding in the enclosures, "herding feeding" to support moving the herds) were used depending on the need and situation in an individual district. At least some feeding in the forest/pastures was practiced in 55% of the districts (the main form of feeding in four of the studied districts). At least some "herding feeding" was practiced in 29% the districts (the main form of feeding in seven districts, six of them belonged to the Saami Homeland area). At least some reindeer were fed in enclosures in 88% of the districts (the main form of feeding in 34 districts).

Similarly, as feeding reindeer in enclosures seems to divide the RMA in distinct regions (Fig. 9a), also perceptions on it were rather polarized (Fig. 9b and c). According to the free-form answers of the survey respondents, the northern districts emphasized the harmfulness of the intensive winter feeding: "*Keeping reindeer in enclosures is harmful for them. Field feeding [of reindeer] should be controlled to avoid spoiling of the soil.*" Also, several southern districts saw negative sides in enclosure feeding: "*Reindeer will become lazy when they are kept in enclosures.*" "*In some regions the reindeer stag population is weak due to feeding in enclosures, because it keeps the animals in a restricted area.*" However, enclosure feeding was considered necessary in the southern area: "*There should be a shift from enclosure feeding into forest feeding, but predator pressure is too strong*"; "*We would feed [the reindeer]in the forests, if we had some [forests], but on private land it is not possible*". Several development needs and ideas about enclosure feeding were given by herders from the southern area: "*If [reindeer] must be fed in enclosures, the reindeer should have enough space and clean area*".

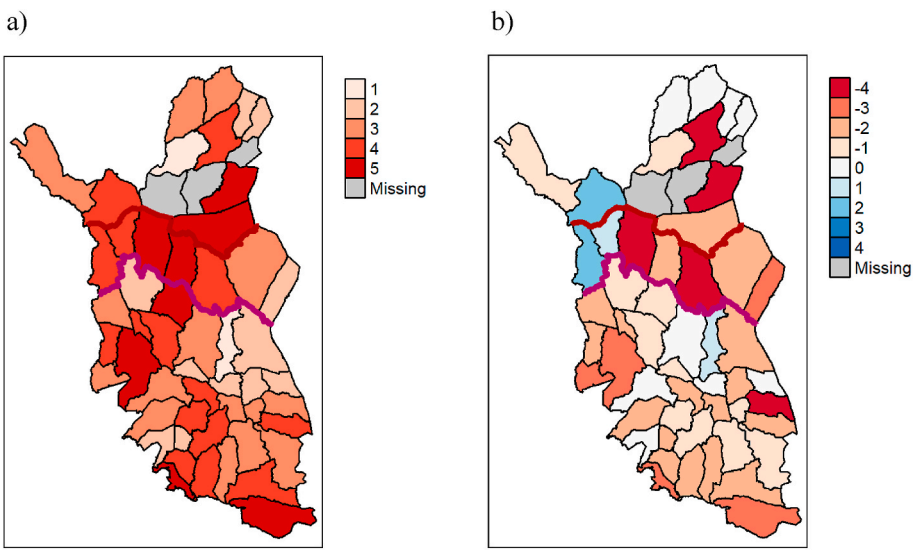

Fig. 6. a) Hot-spot areas of land-use related factors: the number of land-use forms perceived as harmful per district (forestry, mining, peat extraction, hunting, human disturbance, other land-use), b) Perceptions of herders on the factor "Fragmentation of pastures" (−4 denotes a considerable negative effect, 0 no effect and 4 denotes a considerable positive effect). Purple line: southern border of the area specially intended for reindeer husbandry (ASR; "northern area" in this study). Red line: souther border of the Saami Homeland area (SHA). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

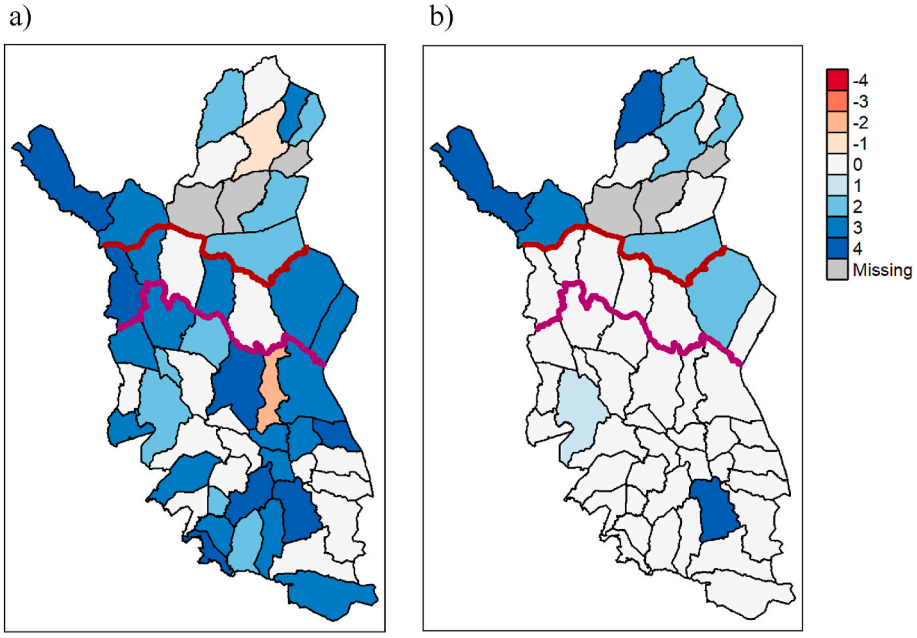

Fig. 7. a) Perceptions of herders on the factors "Pasture rotation" and b) "Herding" (−4 denotes a considerable negative effect, 0 no effect and 4 denotes a considerable positive effect). Purple line: southern border of the area specially intended for reindeer husbandry (ASR; "northern area" in this study). Red line: souther border of the Saami Homeland area (SHA). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

4. Discussion and conclusions

4.1. Herder perceptions on factors affecting reindeer welfare and reindeer husbandry

We studied perceptions of reindeer herders from Finland on factors affecting the welfare of reindeer and the consequent success of reindeer husbandry. These factors could be divided into three categories: 1) factors which were perceived unanimously positively (for example early spring) or unanimously negatively (for example predation), 2) factors on which perceptions were heterogeneous or even polarized (for example supplementary winter feeding), and 3) factors on which perceptions were localized (for example peat extraction). Factors that were most often considered as beneficial were mainly related to pasture resources or certain herding practices. Factors that were most often seen as harmful were mainly climatic or related to land-use factors. Cumulative land-use impacts raised particular concerns.

According to the survey respondents, factors directly affecting the welfare of reindeer and the calving success are crucial. These are climate-related factors directly affecting the forage availability and grazing such as basal icing, and land-use related factors limiting the seasonal pasture access. For example, ample mushroom yield was considered as highly beneficial as it is associated with increasing the body condition of the reindeer by the onset of winter. Furthermore, in autumn, the presence of hunting dogs may disperse reindeer herds during the rutting period and thus disturb the calving success next spring. Nature conservation areas were perceived as beneficial, as they secure pasturelands from development activities. Indeed, nature conservation has prevented industrial land use on important grazing lands such as old-growth forests. However, the disadvantage for reindeer

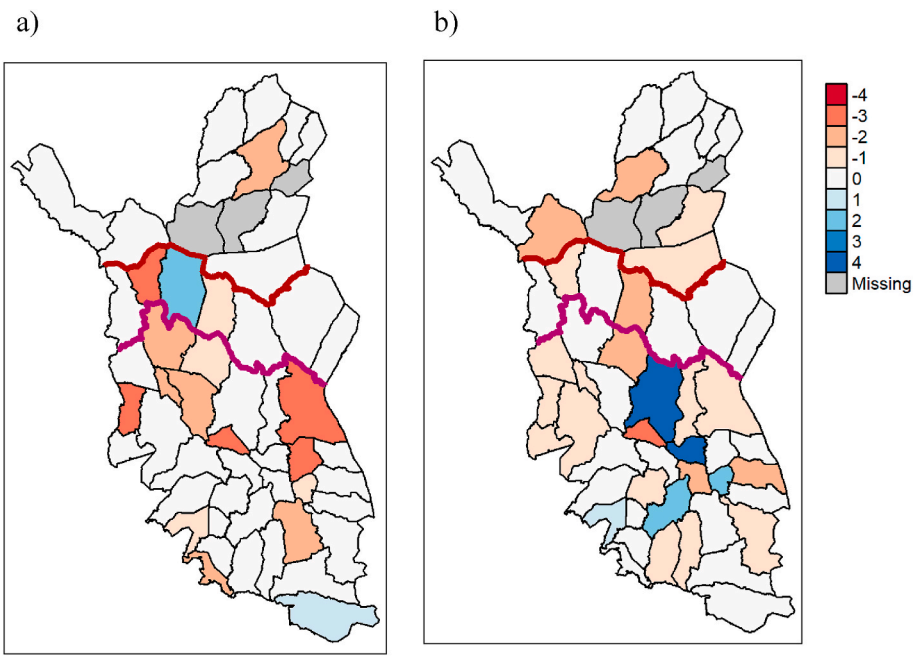

Fig. 8. a) Perceptions of herders on the factors "Managing calving in enclosures" and b) "Earmarking of calves during summer" (−4 denotes a considerable negative effect, 0 no effect and 4 denotes a considerable positive effect). Purple line: southern border of the area specially intended for reindeer husbandry (ASR; "northern area" in this study). Red line: souther border of the Saami Homeland area (SHA). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

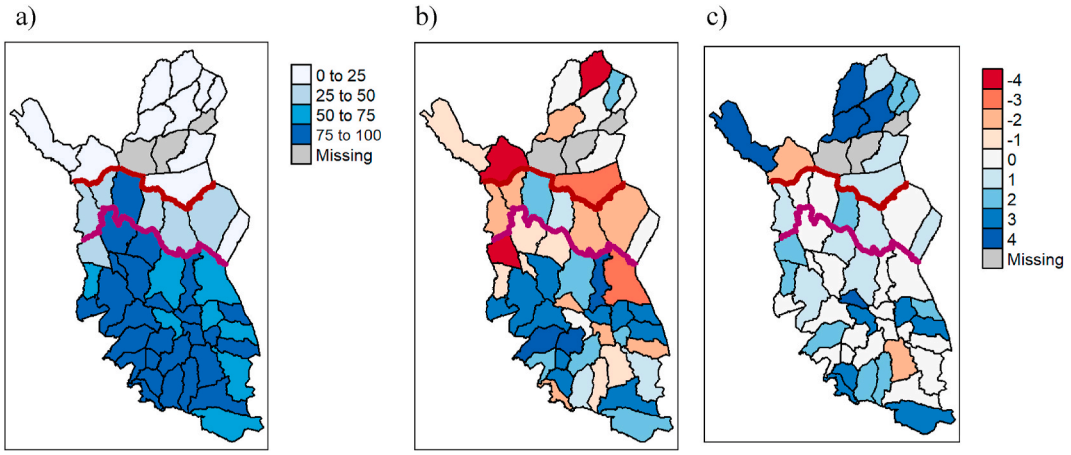

Fig. 9. a) Percentage of reindeer in enclosure feeding during a typical winter, b) Perceptions of herders on factors "Feeding in enclosures" and c) "Herding feeding" (−4 denotes a considerable negative effect, 0 no effect and 4 denotes a considerable positive effect). Purple line: southern border of the area specially intended for reindeer husbandry (ASR; "northern area" in this study). Red line: souther border of the Saami Homeland area (SHA). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

husbandry is that these areas are also habitats for predators (Turunen et al., 2017).

Cumulative long-term effects of other land-use forms on reindeer husbandry have been studied earlier for example by looking at the effects of forestry actions (Kivinen, 2015) or infrastructure development (Nellemann et al., 2003; Vistnes et al., 2001). Combined local effects of individual tourist resorts (Nellemann et al., 2000) and extractive industries (Fohringer et al., unpublished) have also been studied. Tools to assess the cumulative effects of different drivers have been developed (AMAP, 2017) but they have not been empirically tested for reindeer management in northern Fennoscandia. Our analysis of cumulative land use showed the existence of land-use related hotspots as illustrated by herders' negative perceptions. Some land-use activities are harmful during certain seasons (for example, land use in the proximity of calving grounds or on or along the route from one seasonal pasture to another, Anttonen et al., 2011) or in certain locations. The disturbing effects of some industrial land use, for example open-pit mines, can cover large areas, considerably larger than the spot where the activity takes place. Some land-use types raise concerns among the herders even if they do not yet exist but are planned in a particular area.

We compared our results with those presented in a recent national report about the sustainability of reindeer husbandry in Finland (Table S1; Kumpula & Siitari, 2020). Also according to that report at least one land-use related factor was considered as "a moderate or considerable problem" to reindeer husbandry in nearly all herding districts. Multiple land-use types were considered problematic in 63% of the districts.

4.2. *Reasons for heterogeneity in herder perceptions*

Places and landscapes have various meanings which affect the perceptions. What is perceived as important means that it has value for an individual; for biological survival, and for providing cultural good (Tuan, 1990). For herders, places and landscapes are both working environments and grazing lands for their herds. They also carry socio-cultural meanings and heritage. In the language of ecosystem

services: in addition to providing provisional and supporting services for them and for their herds, landscapes and places provide non-material benefits in the form of cultural ecosystem services (CAFF, 2015; Kettunen et al., 2012; Markkula et al., 2019). Working as a herder means communality, social ties and identity (Heikkinen et al., 2012; Helle & Jaakkola, 2008; Kumpula & Siitari, 2020). Herding maintains important features of rural landscape, such as pastures and built structures such as reindeer fences and huts, as well as intangible assets of cultural heritage and tradition (Kumpula & Siitari, 2020). In the Saami Homeland area, reindeer livelihood is linked to vitality of the Saami languages and indigenous rights (Jaakkola et al., 2018; Markkula et al., 2019). Regional heterogeneity in perceptions, especially towards herding practices, can party be explained by varying herding traditions and culture in the northern study area (including the Saami Homeland area) and more southern herding districts.

How a certain factor is perceived among the herders seems to be connected also to historical land-use developments of the district. Forestry serves as a good example. Forestry measures are known to have unfavorable impacts on reindeer husbandry, beginning from the loss and fragmentation of pastures and ending with complicated work conditions (Berg et al., 2008; Helle & Jaakkola, 2008; Jaakkola et al., 2013; Kivinen et al., 2012, 2010; Moen & Keskitalo, 2010; Turunen et al., 2020). On the other hand, forestry as a form of land use has been present in the RMA for over 100 years and reindeer husbandry must have been adapting to it (Helle & Jaakkola, 2008; Turunen et al., 2020). Comparing our results to the results of the 30-year-old survey (Supplementary text S1; Nieminen, 1988; Nieminen & Autto, 1989) provided interesting insights into the diversification and intensification of land use within the RMA. The majority of the survey respondents listed several other land-use pressures that nowadays override the effect of historical and present-day forestry. One might ask whether herders have, for example, got used to practicing herding in managed forests.

Interestingly, also forest ownership within herding districts seem to affect perceptions towards forestry (Fig. 5f). Perceptions were negative in districts where state is the main owner of forest lands. Also, in Saami Homeland area forestry was seen as a harmful factor. This can be referred to environmental and political struggles between indigenous Saami people and state forestry (Jokinen 2014). Meanwhile, in the south-east part of the RMA in Finland forestry was often seen as a beneficial factor by herders. Most of the forest land there is privately owned. Many herders are also forest owners, and historically reindeer husbandry must have adapted to operate on private lands and with private forest owners. In social terms it is probably easier to express critics towards state-based forestry than local private forestry. Our results hint that herder perceptions towards forestry are not determined only by the ecological impacts on pastures, described above. They seem to be based on social, cultural and economic aspects as well.

4.3. From perceptions to action?

One long-term question in perception geography is how perceptions translate into action (Bunting & Guelke 1979). Generally, our survey respondents considered herding practices used by them as beneficial. It may be that practices are valued because choises to use them have already been made and actions taken. On the other hand, developing and adopting herding practices are considered as ways to cope with changing conditions (Armitage et al., 2011; Turunen & Vuojala-Magga, 2014). Herding practices were in this study mainly considered as internal drivers (Table 3), affecting reindeer welfare from their part. On the other hand, they can be considered as coping strategies to mitigate conditions considered as harmful or to utilize the opportunities during conditions perceived beneficial (Table 2). This way the perception (what is harmful/beneficial to reindeer) indeed translates into action (which herding practices to use) and as potential to affect the welfare of reindeer and the success of the livelihood.

Earlier studies on climate change adaptation of reindeer husbandry have also shown that herder perceptions influence their actions (AMAP, 2017; Landauer et al., 2021). Local herding tradition and culture may carry traditional knowledge essential in coping during adverse conditions. They may also limit the willingness to adapt certain new practices, as they may be perceived as harmful to reindeer or the livelihood.

4.4. Limits of the study

We are aware of the fact that our analysis is lacking some important factors. Economic, socio-cultural, and governance aspects were not part of the questionnaire survey although these affect herder perceptions and give preconditions for decision-making and herding practices adopted. As perceptions cannot be objectively measured or observed, misunderstandings and misinterpretations are possible both by those taking part and by those conducting the survey and further analyses. In our case, there is actually also an interesting latent level of interpretation in the study setting. We asked the survey respondents to consider either positive or negative effects of various factors on reindeer welfare and reindeer husbandry as a whole. What herders actually provided was not only their experiential knowledge of the subject, but also their interpretation of "the preferences" of those herded – the reindeer. Thus, when providing their answers they also, whether consciously or unconsciously, came to share their insights on what is good for the reindeer survival and reproduction from the animal point of view.

Also, some framing effect cannot be ruled out due to the selection and phrasing of the factors considered in the questionnaire survey. The human memory tends to emphasize the most recent and unordinary conditions (Gray, 1955), so it is also possible that recent weather events or topical land-use projects affected some of the responses presented in this study. Only one person (although the key informant) was interviewed per district in our study. This means that perception of one individual has been used to represent rather large land areas. This has limited also further data analyses. Developing detailed models to explain the regional differences in perceptions or studying spatial correlations between the actual land-use activities and perceptions in detail did not seem possible, based on our data. It would be very interesting to deepen the analysis by gathering more data per district. Also, it would be valuable to broaden the analysis to encompass other Nordic countries or even those parts of Russia where reindeer husbandry is practiced.

4.5. Challenges for land-use planning

In nature-based livelihood SESs (Käyhkö & Horstkotte, 2017), one biophysical or socio-economic driver can affect another. The impact experienced by reindeer herders over a certain period of time is both the sum of impacts and their accumulation over time. This makes the governance of SESs difficult. Competing forms of land use, predation, degradation and fragmentation of pasture resources pose challenges to reindeer husbandry and give rise to conflicts with other land users (Hukkinen et al., 2003; Käyhkö & Horstkotte, 2017; Meristö et al., 2004; Pohjola & Valkonen, 2012; Soppela & Turunen, 2017). Industrial land use such as mining, wind farms and forest clear-cuts causes local but long-lasting impacts on reindeer husbandry.

Furthermore, climate-related risks affect the livelihood (Kumpula & Siitari, 2020; Peltonen-Sainio et al., 2017; Rasmus, Turunen, Luomaranta, et al., 2020; Turunen et al., 2016). Effects of climate change become visible through seasonal weather events which are stochastic and rather short-lived. The probability of extreme weather events such as hot summer periods, icing events and deep snow covers increases within the RMA in the warming climate (Abram et al., 2019; Jylhä et al., 2008; Rasmus, Turunen, Luomaranta, et al., 2020). During an extreme weather event, welfare of reindeer can be negatively affected. It all comes down to the sufficiency and diversity of pastures as well as pasture accessibility (Kitti et al., 2006) – or if needed, supplementary forage (Lépy et al., 2018; Pekkarinen et al., 2015).

What is particularly detrimental to reindeer husbandry is the

combination of a harmful weather event and intensive land-use. Similar conclusions were also made about the situation in Norway in a recent review by Tyler et al. (2021). Herders need new strategies to adapt to the changes (Peltonen-Sainio et al., 2017; Rasmus, Turunen, Luomaranta, et al., 2020). Their capacity to cope with extreme weather events is limited and climate vulnerability is increasing if there is no flexibility in the use of pasture resources, such as seasonal pasture rotation (Anttonen et al., 2011; Degteva et al., 2017; Eira et al., 2018; Pape & Löffler, 2012). There is a need for more holistic regional land-use planning, which would take several overlapping and neighboring livelihoods into account. One solution would be to acknowledge the needs of reindeer husbandry by allocating space to ensure flexibility in pasture use (Kumpula & Siitari, 2020). However, planning should not be targeted at the mean conditions or even at the most probable event since extreme events tend to cause the most harm.

In land-use planning, the needs of all land users should be understood in order to be able to generate synergies, negotiate difficult trade-offs and manage conflicts. Environmental conflicts are mostly considered to be caused by differences in knowledge and irreconcilable values (Pettersson et al., 2017). Environmental conflicts can emerge and continue to persist because of a clash of diverging cultural models and frames that stakeholders carry in their individual and collective minds (Jokinen, 2019). These concepts come close to the concept of perception used in our study. Improved understanding of local people's perceptions could inform and shape political agendas regarding land use, sustainability and people's rights, and could lead to more equitable societal processes (Meijaard et al., 2013; Raymond et al., 2009).

Practitioner knowledge of herders is about local observations but also about interpretations and preferences. Presently, incorporating these types of facts in the environmental assessments and planning procedures is not easy (Chapman & Schott, 2020) and not adequately recognized by decision-makers and land use planners, but would be urgently needed. Local perceptions carry relevant information about the relationships between people and their environments. These subjective and intangible aspects are part of the knowledge of the experienced environment and cannot be excluded even from practical approaches. This is one argument for bringing the perspectives of local communities and livelihoods to the joint planning table.

4.6. Conclusions - contribution of this study to the participatory environmental governance

We revisit the rather old approach of perception geography, where individual values towards, perceptions on, and observations of the environment are studied. Why study perceptions instead of just concentrating on proven land-use pressures or detrimental weather events? Some of these pressures and climate indicators are scarcely studied and poorly known. Understanding the perceptions is needed in managing the present-day and future environmental conflicts (Brown et al., 2020). Participatory environmental governance and public participation in environmental management are increasingly adopted (Adenskog, 2018; Huntington et al., 2019; Jäske, 2018). Participatory decision making is believed to lead to more deliberate, inclusive and sustainable solutions. These processes have also been criticized for poor stakeholder involvement (e.g., Komendantova et al., 2015). Reindeer herders have experienced power imbalances in the negotiations with the governance of the livelihood, feeling that their herding practices do not get enough recognition and support and their voice is not heard (Landauer & Komendantova, 2018; Markkula et al., 2019). Our approach presents one tool which can be used to facilitate these processes. Local perceptions are needed as a relevant part of balanced discussion. They also carry valid local and traditional knowledge that can be bridged with scientific knowledge of the issues studied (Abu et al., 2019; Chapman & Schott, 2020).

While writing this paper, the process of setting the maximum allowed number of reindeer for the period 2020–2029 for the RMA has just been completed. The number was set by the Ministry of Agriculture and Forestry of Finland, but it was negotiated within a stakeholder working group. The negotiations resulted also in a new process: putting together herding management plans for the pasture areas of every herding district. What this plan will contain in practice is not yet clear, and new biannual negotiations within the stakeholder group and with herding districts will soon begin. In this process, methods to bridge different knowledge sources will be needed. The approach and data presented in this work could be of use in this process, and also in other land-use planning processes aiming at genuine co-management.

Perception is not only subjectively interprating the environment, but also acting accordingly. As Thomas and Thomas (1928) formulated: "If men define situations as real, they are real in their consequences". Herders are central actors in the reindeer management SES. Their perceptions translate into decision making, planning, and risk preparedness. Interpretation of a situation, or in our case, perception on drivers of change, leads to actions and shapes the future of reindeer husbandry.

Author statement

Individual contributions to the paper:

Sirpa Rasmus: Conceptualization; Methodology; Writing - original draft; Writing - review & editing, Project administration.

Henri Wallen: Formal analysis; Methodology; Software; Visualization; Writing - review & editing.

Minna Turunen: Conceptualization; Methodology; Writing - original draft; Writing - review & editing.

Mia Landauer: Methodology; Writing - original draft; Writing - review & editing.

Juho Tahkola: Investigation; Data curation; Validation; Writing - review & editing.

Mikko Jokinen: Methodology; Software; Visualization; Writing - review & editing.

Sauli Laaksonen: Conceptualization, Supervision, Funding acquisition, Resources, Writing - review & editing.

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Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apgeog.2021.102501.

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