ENVIRONMENTAL EVIDENCE

SYSTEMATIC REVIEW PROTOCOL Open Access

What are the impacts of reindeer/caribou (*Rangifer tarandus* L.) on arctic and alpine vegetation? A systematic review protocol

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Abstract

Background: Reindeer and caribou (both belonging to the species *Rangifer tarandus* L.) are among the most important large herbivores in Eurasia's and North America's arctic, alpine and boreal zones. In Sweden, the impact of reindeer grazing on arctic and alpine vegetation has recently been re-evaluated. In the 1990s, records of grazing-related vegetation degradation helped to form a widespread perception that some mountain areas were overgrazed. However, later analyses have shown no evidence of large-scale overutilisation of reindeer ranges in the Swedish mountains.

The present-day consensus is that overgrazing has been temporary and local, and that it rarely has caused permanent damage, but it is imperative to examine the scientific support for these views. Moreover, the Swedish Parliament has adopted an environmental quality objective according to which it is essential to preserve 'a mountain landscape characterised by grazing'. No details have been given on how this goal is to be interpreted, which is another reason why the significance of reindeer grazing for arctic/alpine vegetation needs to be assessed. This protocol presents the methodology that will be used in a systematic review of the impact of reindeer herbivory in arctic and alpine ecosystems. The focus will be on Fennoscandia, but data from other parts of the range of *R. tarandus* will be used when deemed appropriate.

Methods: The review will be based on primary field studies that compare vegetation subject to different degrees of reindeer/caribou herbivory (including grazing and browsing as well as trampling). Such comparisons can be either temporal, spatial or both. The review will cover impacts of herbivory in arctic, subarctic, alpine and subalpine areas (including the forest-tundra ecotone) across the range of *R. tarandus*, but not in boreal forests. Relevant aspects of vegetation include cover (abundance), biomass, diversity (e.g. species richness), structure, composition (including functional groups) and productivity.

Keywords: Reindeer, Caribou, *Rangifer tarandus*, Herbivory, Grazing, Browsing, Vegetation, Alpine, Arctic, Tundra

Background

Reindeer ecology and husbandry

The reindeer (*Rangifer tarandus* L.) has a natural range extending over much of Eurasia's and North America's arctic, alpine and boreal zones. In considerable parts of this region, reindeer are the only large herbivores. In the 20th century, the species was also introduced into several areas where it never occurred naturally. These areas included South Georgia in the South Atlantic and a number of islands in the Arctic.

Rangifer tarandus is the only species of the genus *Rangifer*, but it includes several subspecies. The Eurasian subspecies are referred to as reindeer, while those native to North America generally are known as caribou. We will normally use the term caribou only when specifically referring to studies from North America.

Wild reindeer are still numerous in parts of the world, notably in Canada and Alaska. In northern Europe and Siberia, however, the majority of the reindeer populations have been domesticated or semi-domesticated for several centuries. Here, they are to a large extent being

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herded by indigenous peoples. In most parts of Sweden and Norway, reindeer husbandry is the sole preserve of the Sami. The only exceptions are northeasternmost Sweden and two minor areas in southern Norway, where non-Sami residents are also allowed to own reindeer. In Finland, reindeer husbandry is not restricted to the Sami population. Wild reindeer remain in southern Norway and southeastern Finland, but in Sweden all reindeer are semi-domesticated.

Reindeer are renowned for their unique ability to digest lichens, and lichens make up a substantial part of their diet in many of their winter ranges. In summer, reindeer prefer green plants such as graminoids (grasses, sedges etc.), forbs, and leaves of shrubs and deciduous trees. Over the seasons, many reindeer herds migrate over large distances between summer and winter pastures, and between pastures of different kinds within the seasonal ranges. Reindeer in Sweden normally spend the winter in boreal coniferous forests, but during the snow-free season most of them forage in treeless mountain areas, forest-tundra areas with sparse tree vegetation, or subalpine birch forests.

Conditions in winter ranges are usually a strong determining factor for the population size of reindeer [1]. During some winters, foraging is made difficult by ice or deep snow, and herd sizes can therefore vary considerably from one decade to another. In Sweden, the number of reindeer has oscillated repeatedly between c. 150,000 and c. 300,000 over the last 125 years, with a long-term average of about 225,000 (Figure 1). These statistics refer to sizes of post-slaughter winter herds. In summer the numbers are considerably higher due to calving during spring.

The impacts of reindeer on arctic and alpine vegetation

Reindeer, like other large herbivores, may impact vegetation directly, through the removal of plant parts during foraging, and indirectly through changing competitive interactions and nutrient cycling. It has been suggested that reindeer can cause transitions between vegetation states in tundra ecosystems [6], such as from lichen- to bryophyte- to graminoid-dominated vegetation. Evidence for such transitions has been found in experimental studies of the effects of reindeer activity [7], or where reindeer behaviour has been manipulated, e.g. along fences regulating reindeer migration [8,9]. Yet, the evidence for transitions of this kind has not been corroborated by studies assessing rangelands of freely roaming semi-domesticated reindeer [10,11]. These seemingly inconsistent results may reflect the fact that *Rangifer* grazing systems are particularly variable, spanning domestic and wild populations, and introduced and native populations, as well as climatic, geographical and biotic gradients. The response of vegetation to herbivory depends on factors such as productivity [12] and the long-term history of grazing [13], conditions that are likely to vary within *Rangifer* grazing systems.

It is thus hard to predict what the outcome of management of a reindeer population will be for the vegetation. To facilitate evidence-based management of reindeer grazing systems, a systematic review is therefore required. The aim of the systematic review, the protocol for which is

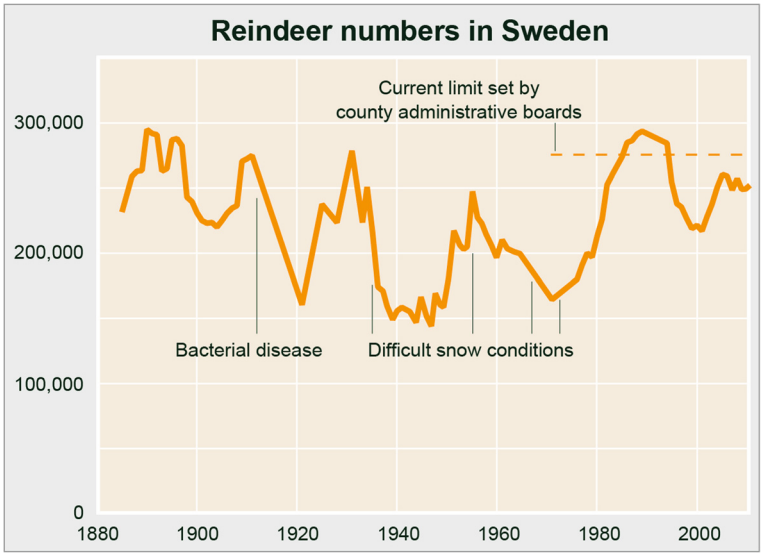

Figure 1 Reindeer numbers in Sweden. The diagram shows Sweden's total reindeer population for the period 1885 to 2011 following the autumn slaughter [2-5]. After calving in spring, herds are significantly larger.

detailed here, is to review the impacts of reindeer grazing on arctic and alpine vegetation, with a specific focus on Fennoscandian conditions.

Swedish perspectives on the impacts of reindeer grazing

During the last decades, public opinion on how reindeer grazing affects mountain vegetation has shifted in Sweden. In the 1990s, several well-publicised records of grazing-related vegetation degradation helped to form a widespread official perception that some mountain areas were overutilised, and a concern that Swedish reindeer husbandry was not sustainable [14]. This was, for instance, reflected in a Swedish government bill stating that some areas had become overgrazed over a long time because of 'an imbalance between reindeer numbers and available forage' [15].

In other parts of Fennoscandia, severe overexploitation of reindeer ranges had been noted, especially on lichen heaths in Finnmark in northernmost Norway and in Finnish Lapland [16,17]. Most of the damage was done by summer grazing on low-productive alpine heaths formerly used as winter pastures, with lichens being worst affected due to their sensitivity to trampling during the snow-free season.

More recently, however, the impact of reindeer grazing on mountain vegetation was subject to re-evaluation in Sweden. Analyses of available data on reindeer numbers and grazing effects indicated that the fears of overgrazing were based on local effects around a few enclosures and fences – no evidence of large-scale overutilisation of reindeer ranges in the Swedish mountains could be found [14]. The present-day consensus is that overgrazing of Swedish reindeer ranges has been temporary and local, and that it rarely has caused permanent damage. Drawing on a literature review, Linkowski & Lennartsson [18] concluded that even heavy grazing during a limited period can promote the diversity of alpine vegetation in the long run. Today, many environmentalists actually fear that parts of the Scandinavian mountain range are becoming overgrown because of limited grazing pressure.

Moreover, the Swedish Parliament has adopted an environmental quality objective for the mountains. One of the specifications of this objective declares that it is essential to preserve 'a mountain landscape characterised by grazing' [19], referring to the conservation of key ecological functions in the landscape. However, no details have been given on how this specification is to be interpreted in ecological terms, which means that there is a need to evaluate the significance of reindeer grazing for arctic and alpine vegetation. For instance, one study suggests that grazing impacts on species richness are small, while effects on rare species and species composition (i.e. changes of relative species abundances) are stronger [20]. It is not clear how this translates into a 'landscape characterised by grazing'.

The recent re-evaluation of what reindeer grazing means for arctic and alpine vegetation (species distribution, richness, relative abundance and other qualities) is another reason why it is imperative to examine the scientific support for today's prevailing opinions on this issue. To the best of our knowledge, no systematic review of the significance of reindeer grazing for mountain vegetation has been performed earlier. This systematic review will include studies from any arctic or alpine region where reindeer are present, either as native or introduced populations, provided that the data is informative for Fennoscandian conditions (e.g. by referring to vegetation types similar to those found in Fennoscandia).

Proposal and stakeholders' input

This systematic review of impacts of reindeer herbivory, for which the protocol is set out here, was proposed by the Swedish Environmental Protection Agency. The topic has since been approved by the Executive Committee of the Mistra Council for Evidence-Based Environmental Management (EviEM). The review will be managed by the EviEM secretariat.

Prior to completion of the draft review protocol, a meeting was arranged with stakeholders with an interest in reindeer husbandry and environmental aspects of reindeer herbivory in Sweden. The meeting was attended by representatives of the Swedish Environmental Protection Agency, the Ministry for Rural Affairs, the Sami Parliament, Jämtland County Administrative Board, Stockholm University, the Swedish Polar Research Secretariat and the Swedish University of Agricultural Sciences (represented by the Swedish Biodiversity Centre and the Swedish Species Information Centre).

Several suggestions made by the stakeholders have been adopted by the review team, e.g. that the review should not be restricted to impacts on biodiversity but should consider other aspects of vegetation too, and that it should include vegetation in subalpine birch forests as well as treeless mountain areas. We will thus cover studies on treelines and on the forest-tundra ecotone, including subalpine birch forests but not coniferous forests at lower elevations. Moreover, it was pointed out that overgrazing of reindeer pastures is a questionable concept. Being perspective-driven, its definition tends to vary between stakeholders [21], and no attempt to define or apply the concept will be made in this review.

Some of the stakeholders also suggested that the review should be extended to cover impacts on the fauna or the entire ecosystem of reindeer pastures. However, this has been judged by the review team to be unfeasible due to the topic breadth, and outside the scope approved by the EviEM Executive Committee.

Objective of the review

The primary aim of this review is to clarify how grazing, browsing and trampling by reindeer (or caribou) affect the vegetation of arctic, subarctic, alpine and subalpine areas, including the forest-tundra ecotone.

Primary question

*What are the impacts of reindeer/caribou (*Rangifer tarandus *L.) on arctic and alpine vegetation?*

Components of the primary question:

Subject (population): Vegetation (as a whole, or divided into major groups such as graminoids, forbs, dwarf-shrubs, lichens, mosses etc.) in alpine/subalpine areas or arctic/subarctic tundra, including the forest-tundra ecotone.

Exposure: Herbivory (including grazing, browsing and trampling) by reindeer (or caribou).

If available, data on reindeer density (number of reindeer per unit area) will be used as a quantification of the intensity of herbivory. Where such information is unavailable, qualification will be used (i.e. high/low density or presence and absence of reindeer).

Comparator: Lower (or no) herbivory by reindeer (or caribou).

Outcome: Change of vegetation.

Relevant aspects of vegetation include cover (abundance), biomass, diversity (e.g. species richness), structure, composition (at both species and functional group levels) and productivity.

Methods

Search terms

Exposure: herbivory, graz*, brows*, trampl*

Agent: reindeer, caribou, *Rangifer*

The terms within each of the categories 'exposure' and 'agent' will be combined using the Boolean operator 'OR'. The two categories will then be combined using the Boolean operator 'AND'. An asterisk (*) indicates 'wildcard' truncation.

Searches will also be made for Swedish, Norwegian, Finnish and Russian counterparts of the above terms. The following search strings will be used (although they in some cases will have to be simplified as some sites do not allow wildcards or Boolean operators):

English: (herbivory OR graz* OR brows* OR trampl*) AND (reindeer OR caribou OR *Rangifer*)
Swedish: renbet* OR ((herbivori OR bet* OR tramp*) AND (renar OR caribou OR *Rangifer*))
Norwegian: reinbeit* OR renbeit* OR ((beit* OR gressing OR tramp*) AND (*rein OR *ren OR reinsdyr OR rensdyr OR karibu OR caribou OR *Rangifer*))
Finnish: (herbivoria OR laidun* OR tallata OR talloa OR polkea) AND (poro OR karibu OR *Rangifer*)
Russian: (травоядные OR пастбище OR пастись OR выпасать OR выбирать OR высматривать OR вытаптывать) AND (олень OR карибу)

No time, language or document type restrictions will be applied.

In addition to the exposure and agent terms mentioned above, the following terms for 'subject' have been tested during a scoping exercise:

vegetation, vascular, plant*, herb*, forb*, gramin*, lichen*, moss*, bryophyte*, flora, shrub*, tree*, forage, tundra, alpine, subalpine, arctic, subarctic, heath*, pasture*, rangeland*

However, it was found that searches using the exposure and agent terms alone were specific enough to return a quite reasonable amount of articles. Including the above subject terms would restrict the search and reduce the number of hits by a factor of about two. The subject terms were therefore excluded – the loss of specificity was judged to be less important than the increase of sensitivity.

Publication databases

The search aims to include the following online publication databases:

1) Academic Search Premier
2) Agricola
3) Biological Abstracts
4) BioOne
5) COPAC
6) Directory of Open-Access Journals
7) GeoBase
8) IngentaConnect
9) ISI Web of Science
10) JSTOR
11) Scopus
12) SpringerLink
13) SwePub
14) Wiley Online Library

Search engines

An Internet search will also be performed using the following search engines:

Google (www.google.com)
Google Scholar (scholar.google.com)
Dogpile (www.dogpile.com)
Scirus (www.scirus.com)

In each case, the first 100 hits (based on relevance) will be examined for appropriate data.

Specialist websites

Websites of the specialist organisations listed below will be searched for links or references to relevant publications and data, including grey literature.

Alaska Department of Natural Resources (dnr.alaska.gov)
Alberta Conservation Association (www.ab-conservation.com)
Alberta Reindeer Association (www.albertareindeer.com)
Arctic Centre (University of Lapland) (www.arcticcentre.org)
Arctic Council (www.arctic-council.org)
Bioforsk (www.bioforsk.no)
Bureau of Land Management, US Dept. of the Interior (www.blm.gov)
Conservation of Arctic Flora and Fauna (CAFF) (www.caff.is)
Environment Canada (www.ec.gc.ca)
European Commission Joint Research Centre (ec.europa.eu/dgs/jrc)
European Environment Agency (www.eea.europa.eu)
Finland's environmental administration (www.environment.fi)
Finnish Environment Institute (SYKE) (www.environment.fi)
Finnish Game and Fisheries Research Institute (www.rktl.fi)
Food and Agriculture Organization of the United Nations (www.fao.org)
Greenland Institute of Natural Resources (www.natur.gl)
GRID Arendal (www.grida.no)
International Centre for Reindeer Husbandry (icr.arcticportal.org)
International Union for Conservation of Nature (www.iucn.org)
Ministry of Natural Resources of the Russian Federation (www.mnr.gov.ru)
Natural Resources Canada (www.nrcan.gc.ca)
Nordic Council for Reindeer Husbandry Research (*Rangifer* journal) (site.uit.no/rangifer)
Nordic Council of Ministers (www.norden.org)
Northern Research Institute (NORUT) (www.norut.no)
Norwegian Directorate for Nature Management (www.dirnat.no)
Norwegian Institute for Nature Research (NINA) (www.nina.no)
Norwegian Polar Institute (www.npolar.no)
Norwegian Wild Reindeer Centre (www.villrein.no)
Reindeer Herders' Association (www.paliskunnat.fi)
Reindeer Research Program, University of Alaska (reindeer.salrm.uaf.edu)
Reindriftsforvaltningen (www.reindrift.no)
Reinportalen (www.reinportalen.no)
Russian Guild of Ecologists (www.ecoguild.ru)
Russian Regional Environmental Centre (www.rusrec.ru)
Sámediggi (Finnish Sami Parliament) (www.samediggi.fi)
Sámediggi (Norwegian Sami Parliament) (www.sametinget.no)
Sámi Reindeer Herders' Association of Finland (www.beboedu.fi)
Sápmi (Sami Parliament in Sweden) (www.eng.samer.se)
Swedish Environmental Protection Agency (www.naturvardsverket.se)
Swedish University of Agricultural Sciences (SLU) (www.slu.se)
United Nations Environment Programme (www.unep.org)
United States Environmental Protection Agency (www.epa.gov)
United States Fish and Wildlife Service (www.fws.gov)
University of Alaska Anchorage (www.uaa.alaska.edu)

Other literature searches

Relevant literature will also be searched for in bibliographies of literature reviews such as those by Moen & Danell [14], Linkowski & Lennartsson [18], Suominen & Olofsson [22] and Forbes & Kumpula [23].

Study inclusion/exclusion criteria

Articles found by searches in databases will be evaluated for inclusion at two successive levels. First they will be assessed by title and abstract. In cases of uncertainty, the reviewer will tend towards inclusion. A subset consisting of at least 10% of the articles will be assessed by at least two reviewers. A kappa statistic relating to the assessments will be calculated. If this statistic indicates that the reviewers are inconsistent in their assessment ($\kappa < 0.5$), discrepancies will be discussed and the inclusion criteria will be clarified or modified.

Next, each article found to be relevant on the basis of title and abstract will be judged for inclusion by reviewers studying the full text. Again, the reviewers will tend towards inclusion in cases of uncertainty.

Studies or datasets found by other means than database searches may be entered at any of the two stages in this screening process.

A list of studies rejected on the basis of full-text assessment will be provided in an appendix to the review together with the reasons for exclusion.

Each study must pass each of the following criteria in order to be included at any of the two screening stages:

- *Relevant subject(s):* Vegetation in alpine/subalpine areas or arctic/subarctic tundra, including the forest-tundra ecotone. Reindeer may also occur in boreal coniferous forests, but studies of vegetation in such regions will not be included.

- *Relevant types of exposure:* Grazing, browsing or trampling by reindeer. Modern reindeer husbandry may also affect vegetation through disturbances caused by reindeer herders' all-terrain vehicles, but such impacts will not be considered by this review.
- *Relevant types of comparator:* Lower or no grazing, browsing or trampling.
- *Relevant types of outcome:* Change in cover (abundance), biomass, diversity (including species richness), structure, composition or productivity of vegetation.
- *Relevant types of study:* Any primary field study (observational or manipulative) comparing vegetation in areas and/or time periods with different degrees of reindeer herbivory. Remote-sensing studies will also be included, but not simulation-modelling studies or field studies of simulated herbivory since these do not represent direct impacts of reindeer.

Potential effect modifiers and reasons for heterogeneity

The following potential effect modifiers will be considered and recorded:

Latitude and longitude
Elevation and topography
Local climate (e.g. temperature, precipitation and snow conditions) and quantified climate change
Plant phenology
Soil conditions/productivity
Vegetation type (e.g. species present)
Quality of vegetation as forage (contents of nutrients, proteins, herbivore-defence compounds etc.)
Reindeer subspecies involved
Seasonality of grazing (whether reindeer are present permanently or only during parts of the year)
Domestication status of the reindeer
Presence of other herbivores
Presence and species identity of predators
Grazing history of the site (e.g. whether formerly used by cattle or sheep)
History of herd (e.g. whether native or introduced, or affected by large-scale exclosures etc.)
Variation in husbandry (e.g. supplemental feeding)
Presence and history of other land management activities in the area
Proximity to other human activities
Presence of fences and other artificial barriers to migration
Study and intervention timescale and seasonality

Further modifiers and causes of heterogeneity will be identified and defined in an iterative process.

Study quality assessment

Most studies in this field compare vegetation in areas that for a long time have been subject to different levels of reindeer herbivory, or vegetation inside and outside areas that for a number of years have been fenced to exclude reindeer. Thus, they are usually 'CI' (Comparator/Intervention) studies describing effects of various levels of reindeer herbivory relative to a control site similar to the intervention site in all aspects other than the variable of interest. Some studies may alternatively present data on vegetation before and after fencing or throughout a period when herbivory has changed; 'BA' (Before/After) studies. A few studies combine these two approaches in 'BACI' (Before/After/Comparator/Intervention) designs, where site control and intervention comparisons are made both before and after herbivory has changed. Randomised control trials (RCT) are also possible within this field of research – some investigators have applied a certain element of randomisation e.g. when selecting locations for exclosures.

A general problem is that data on reindeer density are usually very uncertain. Many studies simply describe areas as subject to 'heavy grazing' or 'no/light grazing', with no further attempt of quantification being made. In some cases, however, reindeer densities have actually been estimated, e.g. using trampling indicators or counts of reindeer droppings.

As a result of these differences in study quality and susceptibility to bias, the following factors will be assessed and used to categorise studies as having high, medium, or low susceptibility to bias:

Selection of plot locations
Study design (BA/CI/BACI/RCT)
Temporal extent of study
Methodological detail (e.g. number of plots, number of visits, data on reindeer density)
Accounting for confounding variables
Appropriate use of statistics and statistical analysis

Detailed reasoning will be recorded in a transparent manner. Study quality will be critically appraised by one reviewer, but a subset of at least 25% of studies will be appraised by a second reviewer. Conclusions will be compared, and where reviewers differ, discrepancies will be discussed and reconciled individually.

A list of studies rejected on the basis of quality assessment will be provided in an appendix to the review together with the reasons for exclusion.

Data extraction strategy

Means and measures of variation (standard deviation, standard error, confidence intervals) will be extracted from tables and graphs, using image analysis software when

necessary. If only raw data are provided, summary statistics will be calculated. Data on potential confounding variables or effect modifiers will also be extracted.

In addition to extracting data from articles, it may be useful to ask authors of relevant articles for access to unpublished primary data, since the articles usually present only a fraction of all vegetation data that have been collected. Thus, it may be possible to get information on total species richness even from studies where published data refer only to biomass or abundance or to the species richness within certain groups of vegetation. Similarly, some data on reindeer density may be available even if they have not been published. Authors will be contacted for this information where possible, and a time limit on the acceptance of responses set before data are synthesised.

Data synthesis and presentation

A narrative synthesis of data from all studies included in the review will describe the quality of the results along with the findings of studies of sufficient quality. Tables will be produced to summarise these results. Where studies report similar outcomes meta-analysis may be possible, and in these cases effect sizes will be standardised (using standardised mean effect size) and weighted according to inverse variance. Precise details of the quantitative analysis will only be known when full texts have been assessed for their contents and quality.

Separate analyses will be undertaken for studies that report reindeer density as categorical (high or low) and those that quantify reindeer density in some way. Meta-analysis of heterogeneity in effect size will take the form of random-effects models, and meta-regression will be performed where effect modifiers cause significant heterogeneity between studies. Subgroup analysis of categories of studies will also be performed where sufficient studies report common sources of heterogeneity. Publication bias and sensitivity analysis will also be carried out where possible. Overall effects of reindeer herbivory will be presented visually in plots of mean effect sizes and variance.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors participated in the drafting, revision and approval of the manuscript.

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References

1. Moen J, Andersen R, Illius AW: **Living in a seasonal environment**. In *Large Herbivore Ecology, Ecosystem Dynamics and Conservation.* Edited by Danell K, Bergström R, Duncan P, Pastor J. Cambridge: Cambridge University Press; 2006:50–70.
2. Bernes C: *Biodiversity in Sweden.* Swedish Environmental Protection Agency, Monitor 22; 2011.
3. Renbetesmarksutredningen: *Renbetesmarkerna.* Stockholm: SOU 1966:12; 1966.
4. Statistics Sweden: *Historical statistics of Sweden II.* Stockholm; 1959.
5. Statistics Sweden: *Yearbook of agricultural statistics 2012.* Örebro; 2012.
6. van der Wal R: **Do herbivores cause habitat degradation or vegetation state transition? Evidence from the tundra.** *Oikos* 2006, **114:**177–186.
7. van der Wal R, Brooker RW: **Mosses mediate grazer impacts on grass abundance in arctic ecosystems.** *Functional Ecology* 2004, **18:**77–86.
8. Olofsson J, Kitti H, Rautiainen P, Stark S, Oksanen L: **Effects of summer grazing by reindeer on composition of vegetation, productivity and nitrogen cycling.** *Ecography* 2001, **24:**13–24.
9. Olofsson J, Stark S, Oksanen L: **Reindeer influence on ecosystem processes in the tundra.** *Oikos* 2004, **105:**386–96.
10. Bråthen KA, Ims RA, Yoccoz NG, Fauchald P, Tveraa T, Hausner V: **Induced shift in ecosystem productivity? Extensive scale effects of abundant large herbivores.** *Ecosystems* 2007, **10:**773–789.
11. Ravolainen V, Yoccoz N, Bråthen KA, Ims RA, Iversen M, Gonzalez V: **Additive partitioning of diversity reveals no scale-dependent impacts of large ungulates on the structure of tundra plant communities.** *Ecosystems* 2010, **13:**157–170.
12. Olff H, Ritchie ME: **Effects of herbivores on grassland plant diversity.** *Trends Ecol Evol* 1998, **13:**261–265.
13. Milchunas D, Sala O, Lauenroth WK: **A generalized model of the effects of grazing by large herbivores on grassland community structure.** *Am Nat* 1988, **132:**87–106.
14. Moen J, Danell Ö: **Reindeer in the Swedish mountains: An assessment of grazing impacts.** *Ambio* 2003, **32:**397–402.
15. Swedish Ministry of the Environment: *Hållbar utveckling i landets fjällområden.* Stockholm: Government Bill 1995/96:226; 1996.
16. Johansen B, Tømmervik H: *Finnmarksvidda – vegetasjonskartlegging.* Tromsø: FORUT; 1992.
17. Käyhkö J, Pellikka P: **Remote sensing of the impact of reindeer grazing on vegetation in northern Fennoscandia using SPOT XS data.** *Polar Research* 1994, **13:**115–124.
18. Linkowski WI, Lennartsson T: *Renbete och biologisk mångfald – kunskapssammanställning.* Länsstyrelsen i Norrbottens län, Rapport 18/2006; 2006.
19. Swedish Ministry of the Environment: *Svenska miljömål. Miljöpolitik för ett hållbart Sverige.* Stockholm: Government Bill 1997/98:145; 1998.
20. Olofsson J, Oksanen L: **Effects of reindeer density on plant diversity in the Fennoscandian mountain chain.** *Rangifer* 2005, **25:**5–18.
21. Mysterud A: **The concept of overgrazing and its role in management of large herbivores.** *Wildl Biol* 2006, **12:**129–141.
22. Suominen O, Olofsson J: **Impacts of semi-domesticated reindeer on structure of tundra and forest communities in Fennoscandia: A review.** *Ann Zool Fennici* 2000, **37:**233–249.
23. Forbes BC, Kumpula T: **The ecological role and geography of reindeer (*Rangifer tarandus*) in northern Eurasia.** *Geography Compass* 2009, **3:**1356–1380.

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