Chapter 8
Resilience Thinking in Reindeer Husbandry

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Abstract Resilience expresses the capacity of a social-ecological system to adapt to, absorb, or withstand perturbations and other stressors so that the system remains. Reindeer nomadic husbandry is a coupled social-ecological system that sustains resilience by interacting with the animals and environment: either the herders adjust their actions to animal behavior or change this behavior in ways that suit the herd and pastures. Stressors and shocks affecting Sámi reindeer husbandry are, for instance, sudden warm air temperatures with subsequent snow melting and freezing in winter, bad grazing conditions, loss of grazing lands, and even socio-economic reforms. All these are sudden, unprepared, or forced changes. Climate change resilience includes using reindeer herders' Indigenous knowledge of selective breeding

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by maintaining different phenotypes of reindeer such as non-productive and castrated animals in the herd. Nevertheless, in Sámi reindeer husbandry in Norway today, low numbers of male reindeer and the absence of castrated animals challenge the herders' resilience coping strategies. This chapter discusses factors that constrain resilience in herding societies, contribute to the transformation of reindeer husbandry and the erosion of resilience in the herding society.

Keywords Social-ecological resilience · Reindeer husbandry · Tipping points in reindeer husbandry

8.1 Introduction

What factors build or erode resilience in the Arctic? Huitric et al. (2016) discussed the possible answers to this complex question and concluded that the ability of people to self-organize determines resilience in the Arctic. Arctic case studies exhibited the erosion of this ability and subsequent loss of resilience. Self-organization requires knowledge, local-level monitoring, and the ability of people to define problems and implement an agreed-upon plan (Turi & Keskitalo, 2014; Huitric et al., 2016; Turi, 2016). In Finnmark, reindeer herding has been a traditional way of living for centuries. Herders' cultural practices and well-being are closely linked to ecological dynamics that is undergoing multiple changes. Political, economic, and social pressures have restricted herding in Finnmark with regard to the areas and traditional practices (Fig. 8.6). This chapter contributes to understanding the resilience thinking of reindeer husbandry in times of climate change, economic development, and the cultural conflict between an Indigenous community and modern Norway. It discusses examples of resilience sources in reindeer husbandry (Fig. 8.1). While traditional knowledge of reindeer herding in Finnmark has been a source of resilience, development continues to affect traditional practices (Huitric et al., 2016; Tyler et al., 2007). Rocha (2022) reported that ecosystems worldwide are at risk of critical transitions due to increasing anthropogenic pressures and climate change. With up to 29% of the global terrestrial ecosystem showing symptoms of resilience loss, Arctic tundra and boreal forests are the most affected (Rocha, 2022). Competing land use and climate change threaten the pastureland of Sámi reindeer herding. Reindeer pastures are exposed to infrastructure development, hydropower, mineral exploration, recreational cabin areas expansion, and wind power (Reinert et al., 2009; Eira et al., 2021; Krarup Hansen & Oskal-Somby, 2023). Land use conflicts are exacerbated by the climate policy with wind power plants in reindeer herding areas (Eira et al., 2021; Supreme Court Judgement, 2021).[1] Climate change and projected developments challenge reindeer herders' adaptive capacity and herding resilience (van Rooij et al., 2023; Tonkopeeva et al., 2023).

[1] https://www.domstol.no/en/enkelt-domstol/supremecourt/rulings/2021/supreme-court%2D%2D-civil-cases/hr-2021-1975-s/

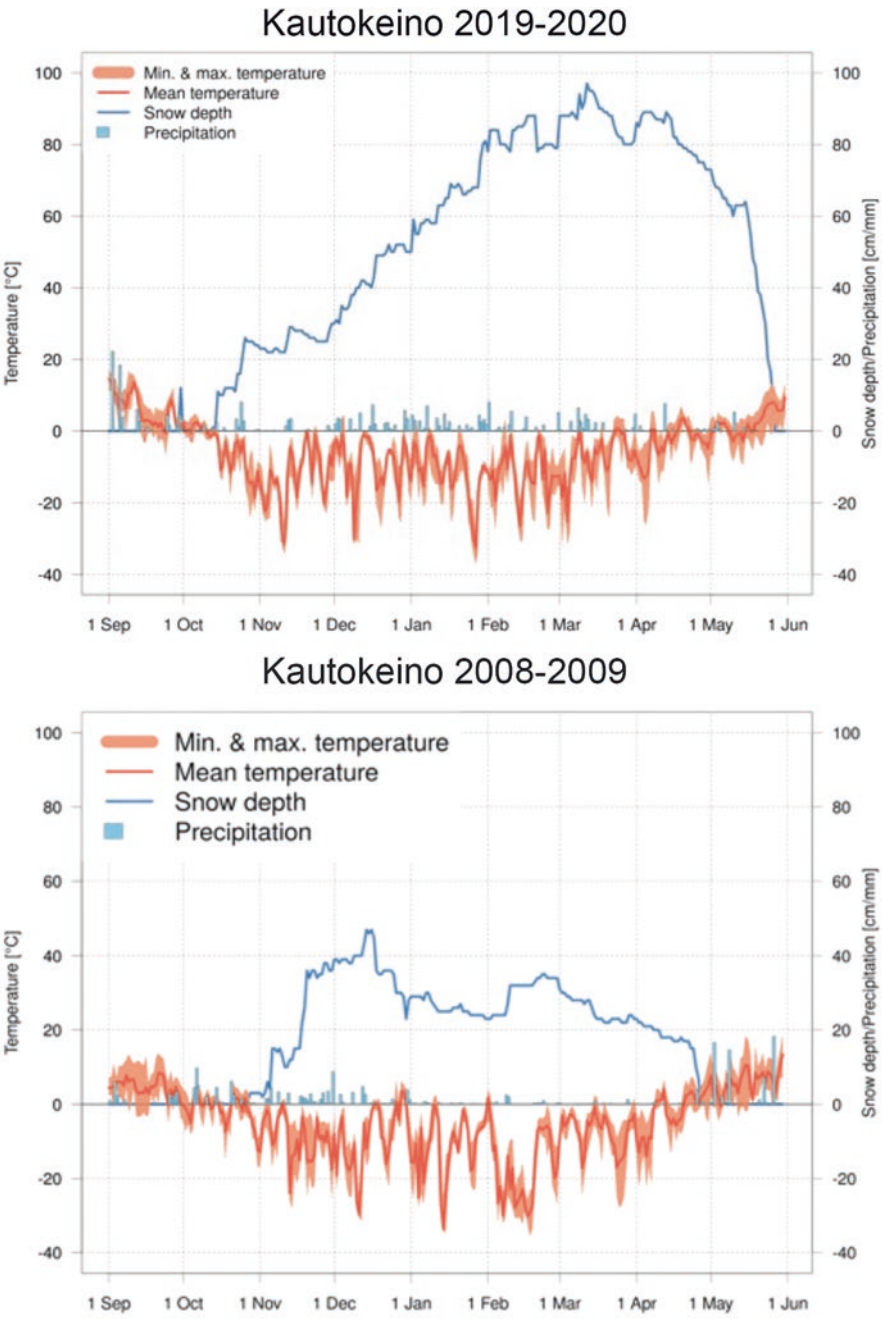

Fig. 8.1 Grazing condition, reflected through snow condition for reindeer in Finnmark. The year 2008–2009 was a good grazing winter, but in 2019–2020, heavy snowfall packed the snow hard and led to a bad grazing year with high animal mortality. The figure shows the minimum, maximum, and mean air temperature in degrees Celsius, snow depth (cm), and precipitation (mm) measured at the Kautokeino meteorological station. (Norwegian Meteorological Institute)

Temperatures in the reindeer pastures are increasing, and inland winter pastures in Finnmark may experience conditions earlier found along the fjords (Krarup Hansen & Oskal-Somby, 2023). Higher temperatures lead to a reduced snow season; model calculations indicate a 3-month reduction along the coast (Fig. 8.1). In contrast, the inland snow season may be 1 month shorter toward the end of the century (Hanssen-Bauer et al., 2023, b). Tonkopeeva et al. (2023) argue that safe operating space for Indigenous reindeer herders in the Arctic must be the ultimate priority for governance and policymaking during rapid changes in reindeer pastures. Anthropogenic impact on the earth system has reached a scale where it is no longer possible to exclude abrupt global environmental change (Larsen et al., 2014; Tonkopeeva et al., 2023). Landauer et al. (2021) reviewed the literature highlighting that land use, climate change, and governance drive the emergence of social-ecological systems' tipping points in Finland's reindeer husbandry (Landauer et al., 2021; Tonkopeeva et al., 2023). Should the global warming range exceed, potential tipping elements may advance to the increased risk of crossing critical thresholds in several Arctic regions. The danger of arriving at the tipping scale under a range of temperature overshoot scenarios was recently discussed by Wunderling et al. (2023).

Publications on the ecological and social-ecological systems provide multiple definitions of resilience. The Arctic Council Interim Resilience Report (Mathiesen et al., 2013) argues that resilience is a property of social-ecological systems that relates to the capacity of the system to cope with disturbances and recover in such a way as to maintain its core function and identity while also maintaining the ability to learn from and adapt to changing conditions and when necessary to transform (Mathiesen et al., 2013). The formal definition used in this book defines resilience as "the capacity of a system to absorb disturbances while retaining essentially the same function, structure, identity, and feedbacks" (Walker et al., 2004; Berkes, 2023). In Western Finnmark, Norway, traditional knowledge is a cornerstone for sustaining the nomadic livelihood and handling unpredictable shocks (Eira, 2012).

However, in the second half of the twentieth century, the Sámi reindeer husbandry in Norway was transformed and strongly assimilated into Norwegian society with the power of money. Mathiesen et al. (2023) and Degteva et al. (2023) argue that the goal of the state reforms in the 1970s was to increase meat production by improving herd structure, slaughtering a higher percentage of calves, changing reindeer ownership, and introducing novel labor standards such as shift working, housing programs, and mobile herding cabins. Norway implemented a reindeer husbandry model with as much as 90–95% females in the herd. Before this reform, the traditional ratio included 45% females (Tyler et al., 2007). The rationale for the change in Norway's management model was that reindeer herders in the north did "not fully utilize the potential for high production offered by favorable winters" in Finnmark (Norwegian Official Report, 1972; Degteva et al., 2023). The top-down productivity policy model for reindeer husbandry in Norway did not fully utilize Sámi herders' traditional cultures and knowledge (Mathiesen et al., 2023; Degteva et al., 2023). Therefore, the ability to deal with stress and shocks while maintaining stability and structure in the herding community might have been reduced.

Resilience thinking is one way to discuss adaptation in reindeer husbandry; it expresses the capacity of a social-ecological system to absorb or withstand perturbations and other stressors so that the system remains within the same regime, essentially maintaining its structure and functions (Holling, 1973; Gunderson & Holling, 2002; Walker et al., 2004). "Nomadic reindeer herders interact with their animals by either adapting their actions to animal behavior or by changing this behavior in ways that suit them" (Istomin & Dwyer, 2010, p. 613).

Nomadic reindeer husbandry is an example of a social-ecological system because of its traditional solid coupling between herders and reindeer (Mathiesen et al., 2013). When resilience is enhanced, the system is more likely to tolerate disturbances without collapsing into a qualitatively different state controlled by different processes. Equilibrium-based views are rooted in a Newtonian worldview in which the universe is orderly and mechanical. In such a clockwork universe, predictable by mathematical rules, it would make sense that a system (such as an ecosystem) experiencing a shock would or could return to its original state, i.e., the equilibrium in ecological and social systems. However, this assumption does not hold (Gunderson & Holling, 2002). Whether talking about a destroyed tropical forest or a mentally disturbed individual, there is no single equilibrium to return to (Berkes, 2023). This chapter presents some examples of resilience factors important for sustainable nomadic reindeer husbandry. It discusses reindeer herders' resilience thinking in perspectives of adaptive capacity and transformation in response to change.

8.2 Resilience Perspectives of Sámi Nomadic Reindeer Husbandry in Norway

Sámi reindeer herder Johan Mathis Turi described the interaction between the reindeer herd, herders, and its environment: "Some periods in the reindeer husbandry calendar are more fixed, such as breeding and calving time, which are pretty fixed times in the reindeer year, but these can also be shifted slightly both ways from year to year and from place to place. We discovered that it is possible to manipulate these established events in reindeer husbandry. Reindeer husbandry in Sapmi areas changed with the modified structure within the herds from using large bucks in the breeding before; today, they have mainly 1.5-year-old bucks to care for the breeding. In general, the calving time in Western Finnmark in Norway has been delayed by 1–2 weeks compared to 30 years ago, with the advantages and disadvantages this entails. Future climate change is a severe threat to reindeer husbandry in this respect and could further change the nature of reindeer husbandry. The adverse effects could, perhaps, be remedied with various aids such as fences or feeding" (Turi, 2002, 2009).

Traditional reindeer husbandry is based on using different seasonal pastures to make the best possible use of the ranges. A significant effort makes it possible to get the industry on the barren outfield pastures that no one else can utilize. It goes without saying that it will be challenging to have many males in an area that lacks the

type of pasture that males prefer. In the same way, it will be challenging to utilize the pastures effectively with only females if the type of areas where females thrive is the minimum factor. The general picture is that the reindeer grazing areas are composed of different types of pastures that cannot be utilized optimally without a differentiated gender and age structure in the reindeer herds. Traditionally, reindeer herders have utilized their grazing areas by operating herds with a nearly 50:50 distribution between the sexes and scattered age distribution of the animals. This rule applies to most reindeer husbandry areas worldwide, including Sapmi (Oskal et al., 2009).

8.3 Building Resilience in Reindeer Husbandry

8.3.1 Castration in the Sámi Reindeer Husbandry

Castration is one of the methods the reindeer herders use to create the composition of their herds to get control of the herd and strengthen the social-ecological resilience of reindeer husbandry (Fig. 8.2). Castration of the reindeer has been regularly mentioned in the historical literature on Sámi reindeer husbandry since as early as 1732 by Carl von Linné (Linnaeus, 1737) and later by Knut Leem (1767). The Sámi *gáskit* castration method was traditionally performed with the teeth, without anesthesia, and was first documented in 1732. Animals castrated with *gáskit* methods sometimes behave differently from those castrated with the later-developed Burdizzo method (Nergård et al., 2010).

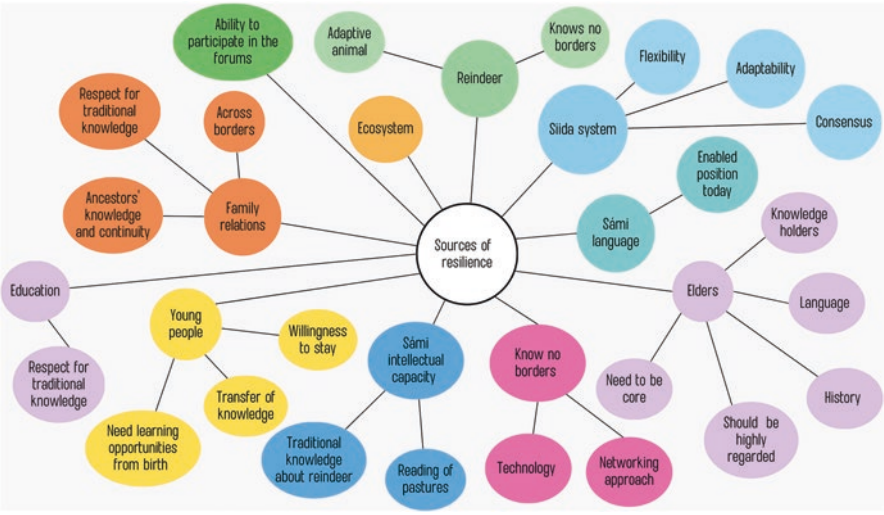

Fig. 8.2 Different sources of resilience were discussed in a workshop with reindeer herders in Kautokeino in November 2013, organized by the International Centre for Reindeer Husbandry and the Stockholm Resilience Centre (Mathiesen et al., 2013; Image: Marina Tonkopeeva)

One category of castrates is *Stohkkenámme-oaivi*, a castrated reindeer with porous antlers and permanent skin on the antler. *Čaloaivi* is the castrates without the skin on the antlers; *heargi* is a reindeer castrated to be a working or sledding reindeer that has undergone various manipulations of the testis anatomy (Fig. 8.3), probably maintaining testosterone production, and it was found that the testes of these male reindeer (> 2.5 years old) are traditionally treated by biting, leaving a small part of the testes tissue that might be responsible for certain hormone production (*Čaloai-spáillit*). These animals grow large, never go into rut, and are sterile but not castrated (Fig. 8.4).

In the 1960s, reindeer herds in Finnmark typically comprised as much as 50% adult males, and many are castrated (Paine, 1994). Modern agronomists have considered adult males unproductive; today, few herds in Norway's Western Finnmark have more than 6% males (Table 8.1). In Russia's Yamalo-Nenets Autonomous Region (YNAO), the percentages of males in the privately owned herds were as high as 28.9%. Lenvik (1990) concluded that a herd of male animals larger than necessary for good insemination results in Sámi reindeer husbandry should be based on factors other than meat production, such as tourism or special management techniques.

Over the last decades in Norway, reindeer herders have reduced the number of castrates compared to other regions of reindeer husbandry (Table 8.1) for several reasons. The Norwegian Animal Welfare Act, introduced in 1935, only allowed the castration of reindeer bulls with anesthesia performed by a veterinarian. In the field, only a bloodless method using the castrating forceps (e.g., the Burdizzo instrument) could be used: the spermatic cord and blood vessels to the testicles, together with the sensitive nerves, were crushed and damaged. This method was considered painful, and anesthesia was required. The procedure was costly and time-consuming and was eventually reduced in addition to other reasons (Nergård et al., 2010). Castrated reindeer in Norway disappeared from the official statistic after the reforms in the

Fig. 8.3 Castration of reindeer by Sven Skjenneberg in the early 1960s. He used the bloodless method of castrating forceps, i.e., the Burdizzo instrument. The spermatic cord and blood vessels to the testicles, together with the sensitive nerves, are crushed and damaged. (Photo: National Library of Norway)

Fig. 8.4 Castrated males are very important since they facilitate the managing of the herd. They obey humans, lead the rest of the herd, respond to calls, and can be harnessed in case of emergency. From a conversation with Nyadma Khudi, brigadier at Yamalo-Nenets Autonomous Okrug, Russia. (Photo: Svein D. Mathiesen)

Table 8.1 Illustration of proportions of male reindeer and percentages of castrates of the total herd (2016 survey analyses) in different regions of reindeer husbandry, including privately and collectively owned reindeer herders in Finnmark, Nenets Autonomous Region (NAO), and Yamal

	Western Finnmark	Nenets AO	Yamal Private Reindeer Herding Unit	Yamal Municipal Reindeer Herding Unit
Intact males	6	18.2	28.9	11.3
Castrated males	0	11	25.1	6.6

1970s also because of the new law on reindeer castration (Skum et al., 2016). The rationale was to increase the number of females and production. On 1 September 1956, a separate regulation on the castration of domestic reindeer entered into force based on Section 5 of the 1935 Act. The Regulations prohibit reindeer owners from using the Sámi traditional *gáskit* method, and violations become punishable. Section 1 of the Regulations requires reindeer owners, who need to castrate reindeer, to use castration tools according to a specified method as stated in the Circular issued by the Director of Veterinary Medicine (Skum et al., 2016).

Therefore, castration of reindeer should only be performed using forceps specially designed for crushing the spermatic cord and the large blood vessels without open bloody intervention. The provision was given for animal welfare reasons, as the old *gáskit* method "violated the Animal Welfare Act and inflicted unnecessary torment on the animals" (Skjenneberg, 1965; Skjenneberg & Slagsvold, 1968). In the years following the 1956 Reindeer Castration Regulations, Burdizzo pliers were actively distributed to all reindeer grazing districts in Norway, and the district veterinarians supervised that reindeer owners only used these pliers for castrations.

Soviet reindeer researcher P. Vostryakov visited Norway several times in the 1960s (Mathiesen et al., 2023). In 1968, he reported in the book *Reindeer Husbandry in Norway*: "Currently, due to the transition of reindeer herders to a sedentary lifestyle, appearance of a dense network of roads and modern means of communication in the reindeer herding (car, snowmobile, radio communication), and changes in the grazing system (hedging, semi-free reindeer grazing) – the importance of reindeer transport has dropped, and the number of sledding reindeer has decreased. Nowadays, transport reindeer in the herd structure make up about 2–3%: the average reindeer herder family has up to 30 sledding reindeer." Furthermore, Vostryakov and Mezhetsky (1968) reported that over the past 5–8 years, strict rules for the castration of reindeer, mainly males used for transport operations, had been developed and applied in Norway (Vostryakov & Mezhetsky, 1968; Mathiesen et al., 2023).

The turning point for reindeer castration in Norway arrived in 2001 when reindeer owners were banned from castration (Skum et al., 2016). The historical events led to the undermining of reindeer owners' traditional knowledge of castration. Before 1956, there was a rich knowledge of castration among reindeer herding Sámi (Rønnow, 1948).

In interviews with reindeer herders, we documented various aspects of reindeer castration: "…In the past, when we castrated [reindeer], they almost always used to be *čaloaivi*, castrated bucks with skin-free antlers…Today, when we use castration tools, they often become *námmeoaivi*, castrated bucks with antlers with skin, and *stohkkenámme-oaivi*, castrated bucks with antlers with skin that never goes..." (Sámi reindeer herder Karen Anna Logje Gaup; Oskal et al., 2009).

J. Antti Magga, a Sámi reindeer owner from Finland, articulated: "If we are not allowed to castrate our reindeer oxen, it will be the end of Sámi reindeer husbandry. Such a ban will put an end to the Sámi reindeer husbandry culture. Although we do not need castrates for transportation, they are important animals in the herd. We need the castrates and non-productive females since they can dig through the snow" (Oskal et al., 2009).

8.3.2 Castration in the Russian Reindeer Husbandry

Vladimir Etylin, a Chukchi reindeer herder from Russia, remarked in a workshop on reindeer husbandry in Oslo in 2007 that "it is impossible to survive in Chukotka without crushing ice during a so-called black ice period when everything gets covered with a layer of ice. When this happens, only castrates are strong enough to break such ice. [...] Females follow them and eat the fodder left over." Etylin commented: "…being an Indigenous representative and having been born on the tundra myself, I consider a ban on castration a severe threat to all reindeer husbandry [...] Castrated males do have their place in the herd's structure. Humans would not have been able to domesticate reindeer without castration. It is one of the cornerstones of the domestication process [...]. Without castrations, building up a controllable reindeer herd is impossible. Castration has many functions in a reindeer herd. The first one is that they are the calmest animals in a herd. It means that a reindeer herd with

castrates quiets down easily. The functions of reindeer in reindeer herding economies are not limited to meat production, reproduction, and transportation." There are many other functional classes of reindeer to which the official statistics remained blind (Istomin et al., 2022). The role of castrated males is not limited to transportation. They could play various other roles in herd operation: for example, digging feeding holes for female reindeer in winter (Istomin et al., 2022). However, the negative result is that males kept with females during winter are weaker and more exhausted by the spring than those kept separately.

Nenets reindeer herders in Russia would traditionally keep a particular category of reindeer called *menorui* in Nenets or *menurei* in the Komi language. These animals were castrated so they would not lose weight and power during the rut and would enter the winter in the best condition. This category was never used for transport and was always kept in the herd (Istomin et al., 2022). Usually, the herd's biggest, heaviest, and strongest males were selected to become *menorui*. They could dig through hard snow impenetrable for most female reindeer, thus enabling reindeer herders to use pasturelands that could not otherwise be used due to snow conditions. Even if the snow conditions were favorable, the presence of *menorui* sometimes significantly improved the spring condition of female reindeer and increased the calf survival rate (Istomin et al., 2022).

Nevertheless, *menorui* did not fit the logic of official categorization, and the Soviet officials launched a campaign against them, which lasted throughout the whole *kolkhoz*/*sovkhoz* period. *Menorui* were classified as *lodyri* (idlers) and *darmoedy* (spongers), and zootechnicians were instructed to have them slaughtered if they were to be found in collective herds (Istomin et al., 2022). Furthermore, using the *menorui* was referred to as *kulak* (upper-class) behavior, which hard-working reindeer herders should not be culpable of (Istomin et al., 2022).

The castrate numbers vary depending on the herds' needs. In Russia, reindeer herds in Nenets Autonomous Okrug and Yamalo-Nenets Autonomous Okrug maintain between 6.6% and 25.1% castrated non-productive males in the herd (Table 8.1). The castrates may lower the females' general activity level since they are stationary and less active in winter, contributing to increased net energy gain in the herd. Privately-owned herds seem to have a higher proportion of castrated males than municipal or state-owned reindeer herds in Russia.

8.3.3 Reindeer Castration: Lessons Learned

People's ability to navigate change and uncertainty, nurture diversity, and learn by combining different types of knowledge contribute to resilience (Huitric et al., 2016). In reindeer husbandry, the knowledge is to maintain control of the herd in uncertain times. Furthermore, improving the monitoring of this control is essential, which we discuss through examples in this section. Castration of ruminants has globally been critical to controlling herds and the pastoral food production systems, as well as in nomadic Sámi reindeer husbandry (Skum et al., 2016).

The low numbers of male reindeer and the absence of castrated animals in the Sámi reindeer herds in Finnmark might be the result of the lack of adaptive capacity caused by the series of reforms implemented in Norway in the twentieth century (see Mathiesen et al., 2023; Degteva et al., 2023). The procedures did not fully include traditional reindeer herders' knowledge, resulting in many losses. Reduced numbers of castrated reindeer in the herds in Norway might have lowered the herds' resilience in winters when temperatures fluctuate and are accompanied by thawing and freezing cycles that induce worse ice conditions.

Returning to castration could be a strategy for better winter survival and welfare for individual animals and the herd (Tonkopeeva et al., 2023). Enhancing the resilience of Indigenous reindeer husbandry in the Arctic requires locally informed and locally relevant knowledge in co-production with scientific knowledge about castration, herd structure, and the role of non-productive reindeer in meat production in nomadic systems.

8.4 Lichen Pastures and Methane Emissions

As discussed earlier in this chapter, the transformation of Sámi reindeer husbandry from traditional pastoralism peaked in the 1970s. This transformation included the exclusion of castrates and decreased number of male reindeer in Sámi reindeer husbandry. This might have affected the natural sexual segregation of the herd, which traditionally took place in most reindeer herds in the spring. This means that the 1.5-year-old males, which traditionally would have followed the male herd during summer, now follow the females with newborn calves. The consequence is increased densities of animals on limited spring pastures and added grazing pressure. Together, the high female reindeer population on spring pastures (Degteva et al., 2023), loss of grazing lands, and tendencies of a sedentary lifestyle might explain the pressure on lichen pastures.

Most Norwegians believe that the number of reindeer in Norway is too high and has reached a critical point regarding the pastures' carrying capacities. Analyzing Norwegian governmental documents and media, Johnsen and Benjaminsen (2017) identified the Norwegian narratives on why there are *too many reindeer* in Norway despite continued state efforts on destocking. The Norwegian government even used methane emissions as an argument to reduce the number of semi-domesticated reindeer in Norway by 30,000 animals (Landbruks-og Matdepartmentet, 2009). Methane is a greenhouse gas released by anthropogenic sources induced by human demands, including oil and gas drilling, coal mining, fossil fuel mining, and burning, as well as microorganisms (methanogens) in the digestive system of domestic ruminants. However, it is also produced by permafrost, termites, wildfires, wetlands, oceans and lakes, hydrates, and microbial fermentation in wild ruminants. Globally, the focus on the carbon footprint of meat production concerning climate and greenhouse gas emissions is high (Willett et al., 2019). However, in the production of different types of meat, significant differences in greenhouse gas emissions

have been demonstrated (Clune et al., 2017). Nevertheless, little was known about the gut methanogens of reindeer and what factors influenced their density, diversity, and methane production.

Reindeer are unique ruminants that have adapted to eat and utilize lichen as a source of energy and nutrients in winter (Aagnes & Mathiesen, 1994; Aagnes et al., 1995; Mackie et al., 2003; Mathiesen, 1999; Mathiesen et al., 2005; Olsen, 2000; Storeheier et al., 2002a; Storeheier, 2003; Storeheier et al., 2003; Sundset et al., 2007, 2008, 2010, 2013). This is despite the high content of antinutrient, antimicrobial, and potentially toxic antibacterial substances in lichens, including usnic acid (Cocchietto et al., 2002; Barboza et al., 2010; Glad et al., 2014; Palo, 1993; Sundset et al., 2008, 2010). Sundset et al. (2008) demonstrated that certain bacterial isolates from the reindeer rumen could resist high concentrations of lichen usnic acid. This finding indicated that the microorganisms in the rumen of reindeer had developed mechanisms for dealing with the antimicrobial lichen acids. Further studies demonstrated that usnic acid could be entirely degraded by microbes in the reindeer rumen and consequently not absorbed by the animal (Sundset et al., 2010). Sundset et al. (2009a, b) showed that the methanogens in the rumen of reindeer on natural pastures are closely related to methanogens found in the rumen of cows and sheep. However, they appeared to occur in lower concentrations. Furthermore, Salgado-Flores et al. (2016) found changes in the reindeer rumen and cecum microflora in response to a lichen diet that suggested lower methane emissions from lichen-fed animals. These findings are examples of new understandings and knowledge about reindeer's digestive physiology and microbial digestion related to the diet, which adds to the adaptive resilience of reindeer husbandry. Lower numbers of rumen methanogens in reindeer (Sundset et al., 2009a, b) suggest that reindeer on natural pasture may emit less methane compared to other ruminants investigated. Nevertheless, as illustrated, Norway's Minister of Agriculture in 2009 pointed out in a climate report that the country's goal was to reduce emissions from all parts of Norwegian agriculture and food industries, including reindeer husbandry: "We then believe that it is right to reduce the number of animals by 30,000 in order to meet the demand for reduced emissions from the industry. We also think it is important based on the sustainability of reindeer husbandry."[2]

Following up on this, Krarup Hansen (2012) and Krarup Hansen et al. (2018) provided novel data on how much methane is emitted by reindeer on different diets: lichen (mainly *Cladonia stellaris*) and concentrates (pelleted reindeer feed from Felleskjøpet in Norway). These studies were performed under controlled conditions in the laboratory using an open-circuit respiration calorimeter, a well-established and robust method for measuring methane emissions in ruminants.

The reindeer methane emission studies performed after 2009 showed that when the reindeer received pelleted feed, methane emissions increased almost sixfold during the first hour compared to when fed with lichens. Mean methane emissions from reindeer ($n = 5$) were only 7.5 ± 0.54 (SE) g CH_4/day when consuming a lichen

[2] https://www.nrk.no/sapmi/_-ogsa-reindrifta-ma-ta-ansvar-1.6635763

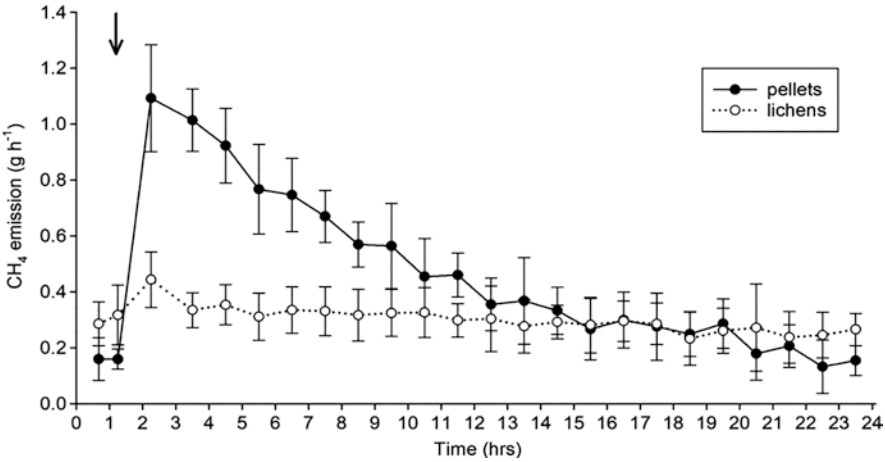

Fig. 8.5 Average methane emissions (± SD) (grams CH_4/h) from five reindeer in 1 day. The reindeer were fed 2 h after the measurement started (arrow) with reindeer feed from Felleskjøpet (solid line) or low (dotted line). (Figure: Krarup Hansen et al., 2018)

diet, compared to a higher emission ($p = 0.001$) of 11.2 ± 0.54 g CH_4/day in reindeer fed with the pelleted feed (Fig. 8.5).

These methane studies underline the importance of lichens as nourishment for reindeer in winter: both as an energy source and a means for methane emission reduction. Therefore, we suggest that lichen pastures should be protected for use by environmentally sustainable reindeer husbandry as a unique food production system. As mentioned in Chap. 4 by Mathiesen et al. (2023), Norway's political aspiration in the 1970s was to increase the female production in domestic reindeer herds to 90–95% (Regional Plan for Northern Norway/Norwegian Official Report NOU 33, 1972). Such a drastic change in herd structure resulted in a high density of female reindeer grazing on lichen pastures, calf slaughtering, unfavorable climate-driven snow conditions (Eira et al., 2018), and a sedentary lifestyle. All these factors might have forced reindeer herders to increase the use of pellets and hay, which might paradoxically have led to increased methane emissions. It resulted in *forced adaptation* and increased feeding of these female reindeer in winter when pasture territories were limited.

Today, the traditional nomadic Sámi reindeer husbandry is transformed: firstly because of the destocking with a high percentage of female reindeer in the herd and secondly due to the direct consequence of supplementary feeding in winter. Vice versa, feeding has become more vital because of the higher number of female reindeer. Reindeer herders addressed the state's emphasis on supplementary feeding to deal with poor grazing conditions (Johnsen et al., 2023). They explained that the focus on feeding undermined other adaptive measures and could negatively affect the resilience of reindeer husbandry. For example, pelleted reindeer feed and grass (hay, silage, round bales) used to feed reindeer today affect reindeer breeding and the herding economy but reconnect herders more closely with the reindeer and build social-ecological resilience in a new way.

8.5 Supplementary Reindeer Feeding

8.5.1 History of Supplementary Reindeer Feeding

To the best of our knowledge, the first documented supplementary feeding of reindeer was in 1927 with the Evenki herders in southern parts of the Republic of Sakha (Yakutia), Russia, who used hay to feed domestic reindeer (Rumyantcev, 2015). As early as 1952, Norwegian newspapers reported bad winter grazing conditions for reindeer in Finnmark (Mathiesen, 2023). The Norwegian experimental station at Lødingen worked with feed development since 1957. In 1964, veterinarian Sven Skjenneberg composed a food for reindeer comprising oats and barley groats, wheat rice and 6% mixed molasses peat litter, 35% ground barley, and 1% seaweed flour and minerals, fed to reindeer in the ratio 4:1 to reduce the protein content (Skjenneberg & Slagsvold, 1968). A commercial RF-71 feed for reindeer was in place in 1971, which consisted of barley, oats, wheat bran, grass flour, and soybean oil, ground and pelleted (Jacobsen & Skjenneberg, 1972; Jacobsen & Skjenneberg, 1975). In 1980, an updated RF-80 version of the commercial feed was produced based on marine fat and silage of fish slag and wheat bran with seaweed flour (Bøe & Jacobsen, 1981; Bøe et al., 1982). In 1984, Mathiesen et al. (1984) tested the usefulness of mill waste products to starving reindeer since it did not develop ruminal acidosis in reindeer compared to many other feeds.

Furthermore, the usefulness of timothy silage, hay, and pelleted grass was also tested as food for reindeer (Aagnes & Mathiesen, 1996; Moen et al., 1998; Hamnes, 2007; Josefsen et al., 1996; Olsen et al., 1997; Olsen & Mathiesen, 1998; Sara et al., 1996). In June 1994, King Harald V of Norway officially opened the Department of Arctic Biology, University of Tromsø, Norway, where most of these studies were carried out: "I would also like to point out the important research that has been carried out on reindeer. It has been particularly important to the reindeer husbandry industry and particularly relevant in the crisis feeding of starving reindeer." Since then, the climate change affecting the reindeer pastures has worsened. However, it was difficult to understand that supplementary feeding might be one of the many factors transforming traditional nomadic reindeer husbandry (Tonkopeeva et al., 2023).

8.5.2 Effects of Supplementary Reindeer Feeding

Sámi reindeer pastoralism in Norway has traditionally been based on the sustainable exploitation of natural pastures from which the animals select a large variety of vascular plants and lichens (Mathiesen, 1999; 2005; Turunen et al., 2009). Reindeer, unlike domestic ruminants, are highly adaptable mixed feeders able to survive without lichens by efficiently adapting their digestive system to fibrous food in winter and efficiently utilizing high-quality forage during the short Arctic summer (Nilsson

et al., 1996a, b; Mathiesen, 1999). Storeheier (2003) investigated the adaptation of reindeer to reduced availability and quality of forage in winter with particular reference to diet selection, forage quality, food intake, forage digestibility, and ruminal absorption of nutrients. The nutrient composition and digestibility of different lichens eaten by reindeer in winter vary considerably. In addition, the extent to which reindeer can utilize lichens depends not only on the species eaten but also on the recent diet composition and whether it has included lichens or not (Storeheier et al., 2002a). It points to the importance of rumen microbial adaptation to the diet. A combined lichens and vascular plants diet helps the reindeer meet their overall nutritional and metabolic needs: scrubs and graminoids, especially the wintergreen parts, have a higher content of nitrogen and minerals compared to lichens and may consequently play a role in the nitrogen and mineral balance of reindeer on winter pasture (Storeheier et al., 2002a, b).

Supplementary winter reindeer feeding could increase reindeer herders' resilience by maintaining closer relationships with the reindeer. It might also become a source of transformation of nomadic reindeer husbandry into a more assimilated Norwegian lifestyle. The amount of supplementary artificially produced pelleted feed has increased in the past decade (Tyler et al., 2007). Pelleted food used for reindeer, 810.400 kg in 2017, boosted to 5,015,659 kg during the winter crisis of 2019–2020. The Norwegian government allocated 40 million NOK to transport the pelleted food by helicopter in units of 800 kg to the respective herds (Johnsen et al., 2023).

8.6 External Factors Constraining Sámi Reindeer Husbandry

One of the pillars in the Sámi reindeer husbandry is grazing flexibility based on Indigenous knowledge (Reinert et al., 2010). Flexibility can be viewed as a strategy to alleviate risks associated with pastoral disasters, such as adverse snow or grazing conditions. Eira et al. (2018) argue the necessity to "spread the herd over the grazing land and let individual reindeer find adequate snow and grazing conditions themselves; increase local mobility of the herd within available winter pastures; migrate to the coast out of season; provide additional feeding for reindeer; and (in the long term) moderate herd structure diversity" (Eira et al., 2018, p. 929).

The formation of modern states of Norway, Sweden, Finland, and Russia and their gradual recognition of their respective borders affected Sámi reindeer herders (Fig. 8.6) practicing nomadic pastoralism rooted in the migration cycles and exercising flexibility of movement over the grazing lands. As immensely important for reindeer herders, pastures include various ecological zones and landscapes intended for different purposes throughout the year: calving grounds, winter pastures, etc. Grazing territories are also linked to the Sámi *siida* system. National governments would consider the *siida* territories and groups when establishing the boundaries in the reindeer herders' pastures (Forrest, 1997).

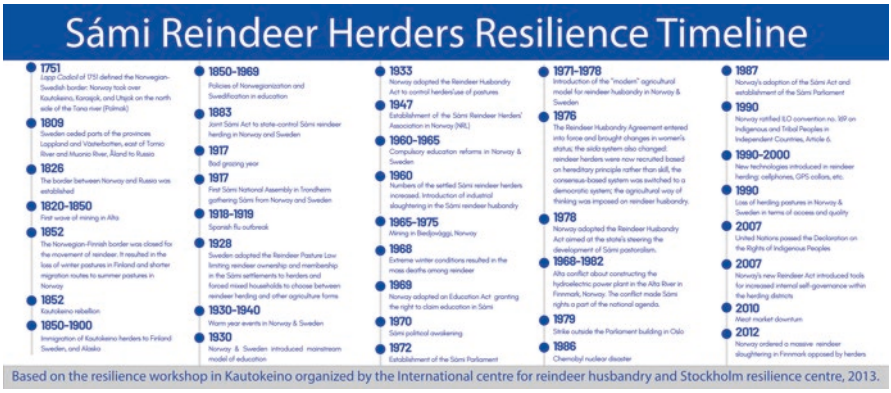

Fig. 8.6 Factors affecting the resilience of the reindeer herders based on the workshop with reindeer herders in Kautokeino in November 2013, organized by the International Centre for Reindeer Husbandry and the Stockholm Resilience Centre (Mathiesen et al., 2013; Image: Marina Tonkopeeva)

Modern reindeer herding districts in the Nordic states could be understood as state-defined administrative units with the responsibility for managing internal issues. These states' herding management strategies are envisaged to increase self-governance through the introduction of internal management plans.

In implementing the regulatory reform, the process of developing and approving internal management plans has proved challenging (Turi, 2016). For example, two out of three winter pasture districts in Western Finnmark declared unable to develop internal management rules since *siida* land rights were not clarified. For Western Finnmark, a central policy priority was reducing the number of reindeer to achieve what had been defined as ecological sustainability (Reindriftsforvaltningen, 2013). The establishment of grazing borders between *siidas* is seen as an instrument toward achieving that goal, as commented by the reindeer husbandry director of the County Governor of Western Finnmark to local media NRK Sapmi (31 October 2014): "…This is imperial for the goal of sustainable reindeer husbandry ... an important prerequisite for achieving a total number of reindeer which is adapted to the pasture foundation so that *siidas* have predictability concerning which pastures they may use." While grazing borders might be seen as a means to increase administrative predictability, i.e., a way to simplify and make the reindeer husbandry sector more manageable for the state, such simplifications diminish the room for reindeer herders' Indigenous traditional knowledge of reindeer, pasture, and climate (Johnsen & Benjaminsen, 2017; Johnsen et al., 2017).

The administrative boundaries developed by the state administrative system reduce reindeer herders' flexibility on snow-covered grazing land, weakening their adaptive capacity (Tonkopeeva et al., 2023). This leads to forced adaptation in reindeer herding and might also increase the level of conflicts in winter pasture areas.

8.7 Sámi Reindeer Husbandry and Social-Ecological Resilience

This chapter focuses on resilience thinking viewed through the lens of reindeer herders' traditional knowledge. Traditionally, nomadic reindeer husbandry in Western Finnmark is a human-ecological system strongly coupled with herders' specialized traditional knowledge about individual reindeer, pasture, and environment (Eira et al., 2023). The concept of a social-ecological system emphasizes that humans are part of nature; we stress that herders are an essential part of the reindeer herding ecological system (Rockström, 2013). Social-ecological systems are interwoven systems of human societies and ecosystems (Rockström, 2013; Berkes, 2023).

With the new governance model, the role of the coupling mechanisms might have been reduced; the ability to deal with socio-economic stress and new climate shocks while maintaining stability and structure in the herding community has later become challenging (Johnsen et al., 2023). It is clear today that the top-down productivity policy model adopted by the government for reindeer husbandry in Norway failed to holistically utilize herders' traditional nomadic cultures and knowledge. Moreover, it did not consider the country's regional differences in reindeer husbandry. Erosion of traditional knowledge and assimilation in Sámi reindeer husbandry (Eira et al., 2018) might affect the social-ecological resilience to external changes. All available knowledge, including Indigenous, is important to build resilience in reindeer husbandry. As stated in the Ottawa Traditional Knowledge Principles (2015), knowledge of Indigenous peoples "enhances and illuminates the holistic and shared understanding of the Arctic environment" (Arctic Council Permanent Participants, 2015).

Further constraints to nomadic reindeer herding include lands divided by fences on the winter grazing pastures. Fences might be a further indicator of a sedentary lifestyle. Soviet reindeer researcher P. Vostryakov, who visited Norway several times in the 1960s, reported in 1968, the transition of Sámi reindeer herders to a sedentary lifestyle. In the book *Reindeer Husbandry in Norway*, Vostryakov wrote that according to Norwegian experts, "it was not easy to teach the former Sámi nomads to use houses and property correctly, to transit to a sedentary way of life" (cited from Mathiesen et al., 2023). Further, he described that the transition of the Sámi reindeer herders to settled life began relatively long ago. At first, it was spontaneous, but later it continued with the intervention and participation of the state. The transition was required due to the country's general technical and cultural progress, the need to intensify reindeer herding, and the state interests (cited from Mathiesen et al., 2023).

Flexible management of reindeer husbandry is a critical component of adaptive capacity (Tyler et al., 2007; Wesche & Armitage, 2010; Hovelsrud & Smit, 2010; Marin et al., 2020). Transformation, erosion, and loss of resilience affect the ability of Indigenous peoples to self-organize. Self-organization requires the best available knowledge, both scientific and traditional-based knowledge. Indigenous and local knowledge are fundamental to Indigenous resilience, but various other factors,

including decolonization and self-determination, are also crucial as enabling conditions. Indigenous and local knowledge can increase the range of available command to solve problems and provides the basis for adaptive capacity. Accumulating knowledge, when shared in networks, enables social learning, leading to social memory, which is vital for remembering responses to past disasters (Berkes, 2023).

The Norwegian Reindeer Husbandry Act of 1978 can be considered a shock: the new law did not incorporate traditional knowledge, and it forced changes that the herders were not prepared for, such as changes in the internal governance model, which could have affected the number of reindeer (Eira, 2012). How Indigenous peoples understand, cope with, and adapt to climate change-related events and other disaster shocks is of universal interest because such Indigenous resilience also informs climate change adaptation in general. However, Indigenous environmental knowledge and understanding have been impacted by colonization. Hence, Indigenous resilience requires decolonization, empowerment, and decision-making responsive to local needs and concerns (Berkes, 2023). A critical first step toward enhancing resilience is understanding the social, behavioral, and ecological processes already building (or eroding) resilience in the Arctic (Huitric et al., 2016).

O'Brien et al. (2009) discussed that Sámi reindeer herders in Norway had been given considerable autonomy through international conventions and within the Norwegian constitution and human rights laws. Nonetheless, reindeer herding is highly regulated and governed by national legislation that imposes a production-oriented agricultural model on traditional herding systems (Tyler et al., 2007). Although Norway's governance of Sámi reindeer husbandry focuses on autonomy and rights, it fails to utilize the knowledge that underpins the herders' livelihoods, such as maintaining diversity in reindeer herds (Tyler et al., 2007). Historically, many policies of Arctic nations have eroded and restricted self-organization. The ability of people to self-organize underlies resilience in the Arctic. Such erosion of this ability was found in cases recently studied in the Arctic (Huitric et al., 2016; Rocha, 2022) and might apply to Sámi reindeer husbandry in times of rapid climate change (Hanssen-Bauer et al., 2023a, b; Stith et al., 2023) and loss of grazing land (van Rooij et al., 2023), and the danger of tipping points might be more pronounced (Moen et al., 2023; Wunderling et al., 2023; Tonkopeeva et al., 2023).

The most critical action in enhancing resilience in reindeer husbandry is maintaining and developing nomadic reindeer pastoralism in the Circumpolar North and their Indigenous knowledge base. Some regions of reindeer husbandry are close to their tipping points, have already experienced a loss of adaptive capacity, and consequently reached their tipping point (Mathiesen, 2023; Tonkopeeva et al., 2023). According to Maria Pogodaeva, "Reindeer husbandry today is no longer the foundation in some regions of the circumpolar civilization of the Indigenous peoples of the Russian Federation and has practically been lost" (Mathiesen, 2023, p. 6). The reason is that since the penetration of other peoples into the respective territories in the sixteenth century, reindeer herding nations have never been treated as equal partners. Other nations made decisions that destroyed their traditional way of life: forced transition to a settled way of life, destruction of small settlements, separation of children from their

parents, deprivation of ownership of reindeer through collectivization, and loss of traditional knowledge, language, and culture (Mathiesen et al., 2023).

When a system of reindeer husbandry has lost its adaptive capacity and consequently reached its tipping point, it is described as a sharp or abrupt change in the climate variables or biological variables where one after the tipping point often enters a state that one cannot say in advance what will happen (Tonkopeeva et al., 2023). In 1935–1936, catastrophic poor winter grazing conditions due to warm weather with high precipitation as snow affected the Sámi reindeer husbandry in the village of Sirges (Sirkas), Sweden, when half of the reindeer died of starvation, and the reindeer herders had to start fishing on the lakes to survive. The fish provided income, so the herds could be rebuilt (Päiviö, 2006). Such tipping points and regime shifts in reindeer husbandry are also discussed by Moen et al. (2023). They may occur when external drivers push a system to an alternative system state, characterized by different feedback than in the original state. Using the lenses of tipping points and regime shifts, Moen et al. (2023) discussed reindeer husbandry as a social-ecological system, highlighting the inseparability of humans, reindeer, and the environment and conceptually exploring the macro-level of emergent phenomena, such as abrupt changes to the livelihood.

Furthermore, extensive infrastructure development in the grazing lands can affect the future socio-ecological tipping points due to an expected increase in holiday cabins, energy wind and water plants, power lines, mines, petroleum terminals, roads, and urban developments (van Rooij et al., 2023). Infrastructure development in the calving ground can seriously impair the ability of reindeer to use the spring and summer pastures. Model studies show that 50% of the original biodiversity in the calving grounds is already lost (van Rooij et al., 2023). The calving ground is the part of the seasonal spring pasture where most female reindeer stay during calving. The most valuable calving land is a gently rolling tundra without steep riverbanks and situated precisely where competition for land exists (van Rooij et al., 2023).

The structural and rational practices of Sámi reindeer husbandry in Western Finnmark increased the proportions of females to as high as 90–95%. They were followed by an increase in the total number of reindeer in Western Finnmark. Furthermore, a regression analysis based on data from 1981–2018 showed a negative correlation between a high percentage of females and calf production in Western Finnmark (Degteva et al., 2023). Paradoxically, the modernization of Sámi reindeer husbandry in Finnmark, with almost 100% more calves born compared to before the reforms, failed due to increased competing land use combined with industrial development in the calving grounds. It is therefore worth noting that the use of terms like “overgrazing” has been debated within a reindeer herding context: unlike the dominant point of view blaming irresponsible reindeer herders for the depletion of pastures, Pilyasov and Kibenko (2023) see the problem as an institutional one – the result of public policies that created wrong incentives for reindeer herding entrepreneurs in recent decades. It would be immoral to assign the solution to the problem of overgrazing only to the most politically weak participant in the conflict – the private reindeer herd (Pilyasov & Kibenko, 2023).

In March 2017, Dolgan reindeer herder Roman Tuprin from the Republic of Sakha (Yakutia) visited a reindeer herd nearby Guovdageaidnu. Looking at the quality of the reindeer, he asked: "Why did the Norwegian state leave Sámi reindeer herders to live with such bad pastures?" Yet three years prior to this, in 2014, the Intergovernmental Panel on Climate Change (IPCC) concluded that protecting grazing lands would be the most important adaptation measure for reindeer herders under climate change (IPCC, 2014).

A resilient social-ecological system may have a high diversity of landscapes, native species, and crop species and varieties, as well as a diversity of economic opportunities and livelihood options for its inhabitants. The diversity of options provides insurance and the ability to cope with, absorb, or adapt to change (Berkes, 2023). Resilience thinking deals with sustainability dynamics and helps operationalize the feedback-related adaptive elements of complex adaptive systems. In practical terms, resilience is common sense: it is about options and flexibility.

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