5

Cumulative Effects on Environment and People

CARL ÖSTERLIN[1], HANNU I. HEIKKINEN, CHRISTIAN FOHRINGER,
ÉLISE LÉPY[2], GUNHILD ROSQVIST

Introduction: Multiple Pressures cause Cumulative Effects

Industrial extraction of natural resources and appropriation of land and freshwater areas have led to degraded ecosystems, loss of biodiversity, and extinction of species (IPBES, 2019). The negative effects have often resulted from a history of local changes in the use of land and freshwater resources (Chhabra et al., 2006). Improved management of such resources has therefore become an urgent global concern. In this chapter we address how resource extraction, and particularly mining, has impacted traditional land and freshwater use in the Arctic region Fennoscandia. We use the multiple pressures concept (e.g., Holsman et al., 2017) to explain how effects from seemingly independent human activities have accumulated and now interact with climate change. To illustrate this, we use examples from reindeer herding in Laevas Sámi Reindeer Community (SRC) in northern Sweden, and salmon fishing along the Kemijoki river valley in northern Finland (Figure 5.1).

Environmental assessments have generally been focusing on the impacts of individual industrial or infrastructure projects (Atlin & Gibson, 2017), while less attention has been paid to the combined cumulative effects from multiple types of pressures. This is scientifically problematic, as the focus on individual projects disregards the accumulating, synergistic, or antagonistic effects that the complex interaction between multiple types on pressures in fact may cause (Jones, 2016). It is also ethically problematic because the combined impacts of both historical and proposed human disturbances on species or ecosystems may be downplayed or masked by focusing on individual projects. In this context, a pressure can be defined as the "result of a driver-initiated mechanism (human activity/natural process) causing an effect on any part of an ecosystem that may alter its environmental state" (Oesterwind, Rau, & Zaiko, 2016: 11). The direct impacts from changes in land or freshwater use may be relatively minor in isolation, but

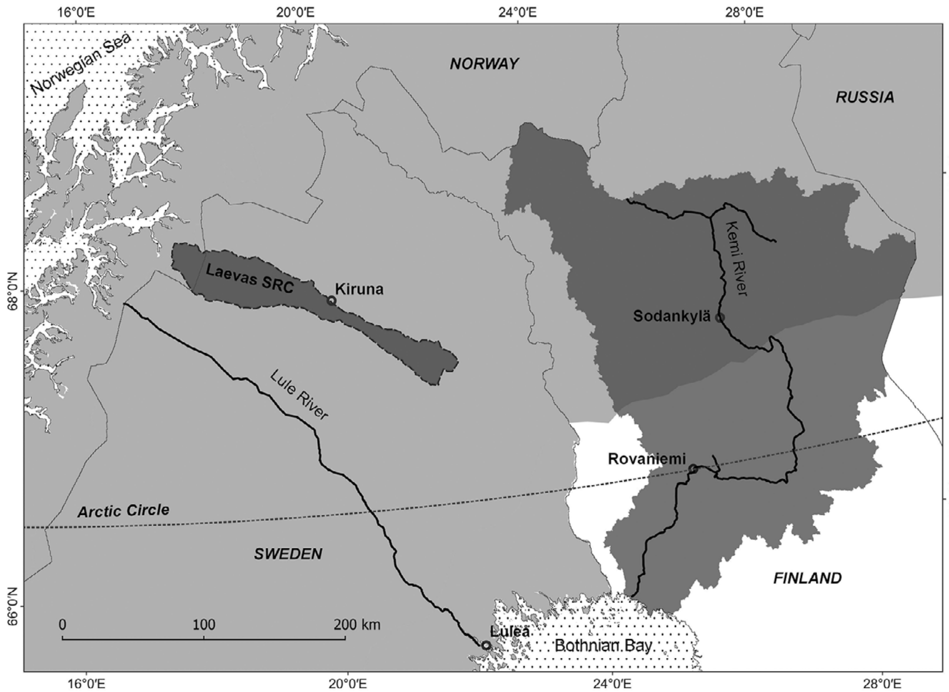

Figure 5.1 Overview of Arctic Fennoscandia, Laevas Sámi Reindeer Community, and the Kemi River catchment area. Drawn by Christian Fohringer

their cumulative effects may significantly change the environmental status of ecosystems. As assessments of impacts from individual industrial projects tend to focus on the local environment, cumulative effects on the larger land- and seascape level are often missed. Therefore, cumulative effects from multiple pressures often remain overlooked in land use planning and natural resource management, despite their potential severity (Bidstrup, Kørnøv, & Partidário, 2016; Atlin & Gibson, 2017; Rosqvist et al., 2023, see Chapter 6).

Arctic Fennoscandia is a resource-rich region with valuable ore minerals such as iron and copper, vast forested areas, and topographic gradients allowing for hydropower developments. The mountains, rivers, cold winter climate, northern lights, and Sámi culture also attract tourists (Rosqvist et al., 2020; Bungard, 2021). It is also a region where reindeer (*Rangifer t. tarandus*) and salmon (*Salmo salar*) are keystone species defining their ecosystems. These two species seasonally migrate over large distances and therefore represent a unique composition of different ecosystems in this Arctic region (CAES, 2002; LaMere, Mäntyniemi & Haapasaari, 2020). Both reindeer herding and salmon fishing are culture-bearing activities that have shaped identities and provided livelihood for residents in Arctic

Fennoscandia for centuries. Traditional herding of migratory semi-domesticated reindeer is an integral part of indigenous Sámi culture, which was developed in a pristine type of landscape without competition from industrial activities (Brännlund & Axelsson, 2011). Similarly, availability of suitable spawning areas in unregulated free-flowing rivers was a prerequisite for the historical abundance of wild Baltic salmon (Karlsson & Karlström, 1994).

The increasing demand for iron and copper drove the establishment of large-scale mining in Arctic Fennoscandia at the end of the nineteenth century (Avango et al., 2019). The mining industry required efficient transport systems and a vast amount of energy. A railroad was built connecting inland mines in Sweden with the Baltic and Atlantic coasts (Hansson, 1998). Energy was at first produced locally using charcoal. To facilitate the increased power needs, the Swedish state constructed a system of major hydropower plants and dammed the headwaters of the Lule river (Figure 5.1) (Hansson, 2006; Avango et al., 2023, see Chapter 10). Similarly, to supply the growing forest industry in northern Finland with electricity, several major rivers were harnessed for hydropower, for example, Kemijoki, and vast reservoirs were built (Figure 6.1) (Lähteenmäki, 2006). Successively, industrial "mega-systems" were formed in both countries during the twentieth century (e.g., Hansson, 1998; Avango et al., 2019).

Once established, the mega-system functions allowed for more industrial development. The transport infrastructure has also stimulated development of inland and mountain area tourism (Lähteenmäki, 2007; Byström, 2019). Both forestry and damming significantly impacted the spawning of Baltic Salmon and decreased and fragmented reindeer pastures (Magga, 2003). The damming of Lule river was completed with disregard to Sámi opposition and negatively impacted reindeer herding, as the dammed river interrupted migration routes, fragmented landscapes, and flooded grazing areas that were lost or became inaccessible (Össbo, 2014).

Laevas: Impacts on Reindeer Herding

Reindeer have provided vital ecosystem services to humans in the region since the last ice age. In Sweden and Norway, reindeer herding is typically practiced by the Indigenous Sámi people. In contrast, all EU citizens can practice reindeer herding in Finland if accepted by the local herding community. In Russia, reindeer herding is also practiced by multiple ethnic groups (Forbes & Kumpula, 2009). Reindeer herding relies on extensive access and distribution of key reindeer habitat. Its vulnerability depends on the reindeer migration strategy, which can be distinguished into two main types in Fennoscandia: large-scale longitudinal migration between coastal/montane habitat and boreal forest, or small-scale circular migration within boreal forest habitats (Tyler et al., 2021). The varying need for space and access to different habitats means that also neighboring SRCs may be subject to variable degrees of vulnerability depending on the disturbances from anthropogenic activities. Today, reindeer herding in Sweden is practiced by fifty-one SRCs, and their grazing area spans over nearly half of Sweden.

Prior to the onset of resource exploitation, the semi-domesticated reindeer of Laevas SRC could migrate over large distances between winter pastures in the eastern forested lowlands and summer pastures in the western mountains and their neighboring SRC (Figure 5.1). The boundaries for Laevas SRC, once determined based on natural borders such as rivers and mountain ridges, form a geographic bottleneck where reindeer migration corridors aggregate. This bottleneck coincides with the location of the expansive mining town Kiruna, where mining commenced in the late nineteenth century and induced a cascade of subsequent infrastructural developments (Figure 5.2). The formation of the mega-system of which Kiruna is part led to increased appropriation of land that in turn encroached and fragmented pastures and led to a loss of key migration corridors.

Current anthropogenic activities within Laevas SRC include mining, establishment of wind farms, clear-cutting of forest, roads, railroads, tourism, military activity, as well as contested pastures with a neighboring reindeer herding community (Fohringer et al. 2021). These anthropogenic activities also generate disturbance zones for reindeer, causing avoidance behavior beyond the activity itself (Polfus, Hebblewhite, & Heinemeveret, 2011). By applying a conservative 500-meter buffer representing the disturbance zone around anthropogenic developments (Figure 5.3), reindeer pastures were shown to have rendered at least 34 percent of Laevas SRC's of their total area and 64 percent of winter pastures functionally unavailable to grazing (Fohringer et al., 2021). This substantial reduction of available grazing areas is highly concerning for Laevas SRC, especially regarding the winter pastures. Winter is a naturally limiting season for reindeer during which they depend largely on forest ecosystems to provide food – terricolous and arboreal lichens (Heggberget, Gaare, & Ball, 2002; Sandström et al., 2006). However, lichen-abundant forests were shown to have decreased by approximately 70 percent across Swedish reindeer herding territory since the 1950s as a consequence of industrial forestry (Sandström et al., 2006; Berg et al., 2008; Horstkotte & Moen, 2019). Therefore, loss of winter grazing areas is particularly threatening for SRCs, such as Laevas.

Climate change contributes significantly to the accumulating pressures and deteriorating conditions in winter grazing areas, as weather and snow conditions strongly determine temporal and spatial grazing opportunities for reindeer (Kivinen et al., 2012; Turunen et al., 2016; Rosqvist et al., 2022). Air temperature has increased during all seasons over the past sixty years in northern Sweden (Berglöv et al., 2015). The largest temperature increase has occurred during the coldest

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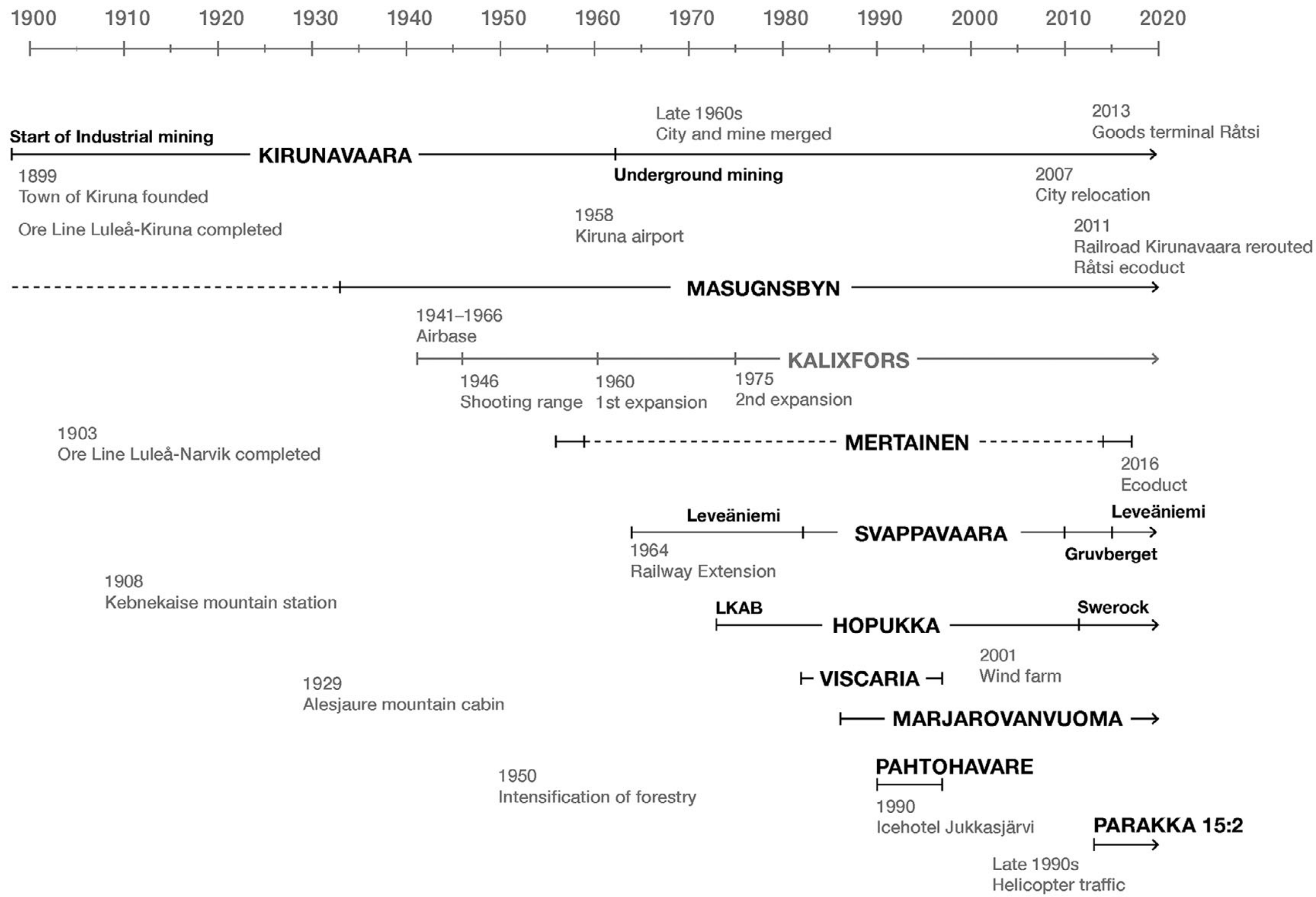

Figure 5.2 Timeline illustrating the establishment of industrial developments since their onset on Laevas Sámi Reindeer Community's grazing grounds from 1900 to present. Grey text represents mines and quarries, while black text represents other infrastructural developments associated with mining. Arrows indicate the ongoing operation of mines. Line breaks indicate changes within development and single dates indicate the establishment and gradual build-up of a factor. Dates refer to the commissioning and further continuation of anthropogenic developments and activities that are considered to have reduced reindeer pasture availability. Gradual changes of land use factors include general dating, e.g., the intensification of forestry or when Kiruna and the Kirunavaara merged. (Modified from Fohringer et al., 2021, People and Nature)

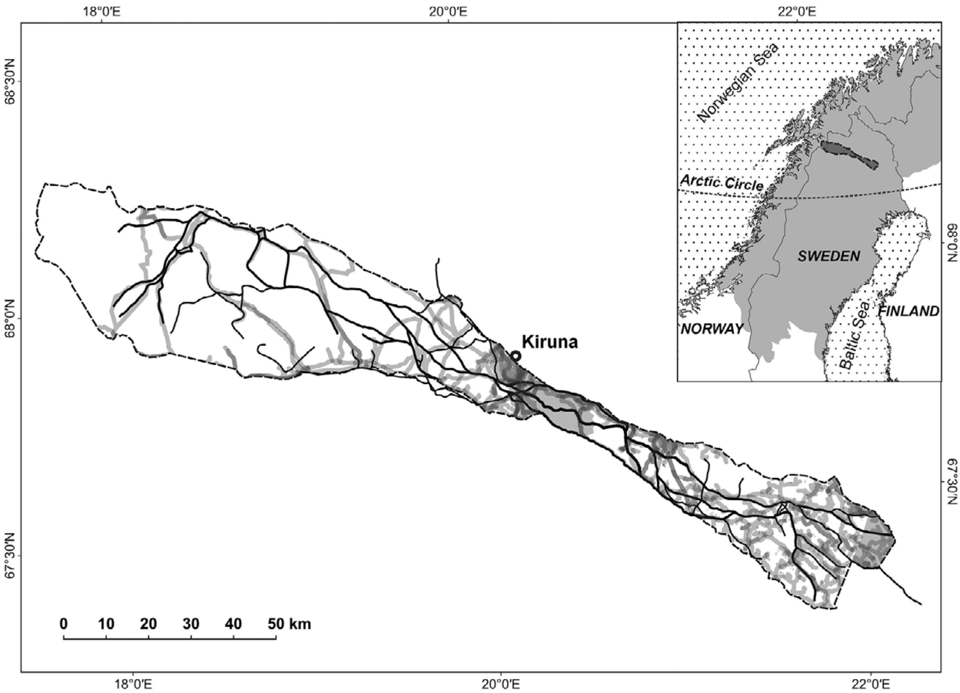

Figure 5.3 Laevas Sámi Reindeer Community (dark grey) in the Swedish portion of Sápmi (light grey), the homeland of the Sámi people, overlapping disturbance zones, based on 500-meter buffers and total area of factors encroaching Laevas SRC's grazing grounds. Grey shades intensify by accumulation of land use from multiple factors. Migration corridors are included as black lines to illustrate where impacts are most pronounced. (Modified from Fohringer et al., 2021, People and Nature)

winter months (December–February). An increase in winter precipitation amounts was recorded during the past thirty years compared to the reference period (1961–1990) (SMHI, 2019a, 2019b). The amount of precipitation falling when the temperature was above 0°C during winter (December, January, February) has also increased, especially at locations in the eastern lowlands toward the Baltic coast.

Results from a study of the impacts from rapidly changing weather and snow conditions on Laevas SRC show that rain-on-snow and high snow accumulation events are particularly disruptive, preventing access to lichens and inhibiting migration, respectively (Rosqvist et al., 2022). As a result, transport of trapped reindeer with trucks toward suitable pastures increases during times of weather-imposed stress and is sometimes necessary to complete migration past the centrally located hotspot of accumulated land use. Reindeer often disperse when snow conditions inhibit grazing in the mountains, which also requires a more frequent use of helicopters to locate and gather them. Due to more frequent land- and climate change-induced emergency situations there is an increasing need to supplementarily feed reindeer, a non-traditional practice that is both expensive and increases the risk of infectious diseases (Tryland et al., 2019; Horstkotte, Lépy, & Risvoll et al., 2020). The effects from accumulating land use and weather changes have now exerted so much pressure that the reindeer number of the Laevas SRC herd can only be maintained if fewer animals are being slaughtered, which results in loss of household income (Fohringer et al., 2021).

Reindeer herders have traditionally responded to weather-induced grazing limitations by employing flexible herding strategies, that is, by guiding their reindeer to alternative forests providing terricolous and/or arboreal lichens (Brännlund & Axelsson, 2011). This adaptive capacity needs to increase when climate warming continues (Berglöv et al., 2015; Meredith et al., 2019; Rosqvist et al., 2022). Instead, there is a high risk that this capacity will be reduced due to competing industrial land use in the eastern forested lowlands (Österlin, 2020).

Kemijoki: Cumulative Effects and Salmon Fishing

The Baltic salmon is a subspecies of Atlantic Salmon that forms an important part of coastal and riverine ecology in northern Fennoscandia. It is a "keystone species, providing irreplaceable ecosystem services in both marine and freshwater environments" (LaMere et al., 2020: 2). Salmon is also one of the traditional key resources for Sámi culture (Hiedanpää et al., 2020), and Baltic salmon fishing is one of the oldest traditional livelihoods in the area (Vilkuna, 1974) (Figure 5.1). Baltic salmon is still a very important natural resource for coastal and riverine settlements of the remaining unregulated rivers such as the Torne. The cumulative impacts of industrial and economic developments throughout the twentieth century have caused a decline in Baltic salmon stocks (HelCom, 2021).

The decline of the Baltic salmon stock was a result of almost simultaneously accumulating failures in open sea, offshore, and riverine management policies after the mid-twentieth century. One result was overfishing. The efficiency of fishing fleets increased, while at the same time the salmon stock was threatened by fish diseases, and hydropower development and concomitant inland developments endangered the spawning grounds of the Baltic salmon (Karlsson & Karlström, 1994; Romakkaniemi et al., 2003; LaMere et al., 2020). Throughout the Baltic Sea drainage area, approximately seventy rivers supported salmon spawning before its industrialization, with forty of these rivers located in Sweden and seventeen located in Finland (Karlsson & Karlström, 1994). After the expansion of hydropower and consequential destruction of habitats, only twenty-nine rivers flowing into the Baltic sea supported salmon spawning at the end of the twentieth century. Today, wild salmon only occur in fourteen rivers draining into the northernmost part of the Baltic Sea (ICES, 2020). Another cumulative impact source is the high nutrient (nitrogen and phosphorus) load from waste waters and upstream sources that are contributing to the overall eutrophication of the Baltic sea (HelCom, 2021). As a result of accumulated impacts, 80–85 percent of all Baltic salmon stock is reared and released from fish-farms, and only 15–20 percent originates from naturally spawning salmon (Coalition Clean Baltic, 2021). Here we focus particularly on how industrial development has resulted in devastating cumulative effects on salmon stocks in the Kemijoki catchment area and concomitant fishing traditions of riverine settlements.

Kemijoki has the largest catchment area in Finland that drains into the Baltic Sea. The catchment covers 51,127 square kilometers of a sparsely populated area (Figure 5.1). Numerous tributaries are regulated by hydropower plants, making it one of the most heavily regulated rivers in Arctic Fennoscandia. The lowest discharge typically occurs in winter when watercourses are frozen, and precipitation accumulates as snow. The highest discharge occurs during the spring thaw (HelCom, 2011a; Huusko et al., 2018), which also makes flood protection an important local issue.

Large-scale industrial development occurred after the second world war in the Lapland region of northern Finland. Industry and infrastructure were then rebuilt after the destruction caused by the retreating German army. The reparations payments to the Soviet Union speeded up the expansion of, for example, the timber industry. Impacts on terrestrial and aquatic ecosystems began to accumulate fast (Lähteenmäki, 2006). The Kemijoki and its tributaries had been used since the nineteenth century for timber floating (Vilkuna, 1974) but also the floating increased rapidly after the Second World War, which itself necessitated major changes, damming and dredging of rivers and rapids (HelCom, 2011b; Krause, 2011). However, salmon fishing – a very important traditional livelihood for centuries for riverine settlements, especially in a form of weir fishing (Figure 5.4) – continued despite the heavy disturbance caused by timber floating. For example, 184 weir fishing dams were documented in the Kemijoki system between 1869 and 1870, and the salmon catch could be up to 3,390 kilograms per day per weir (Vilkuna, 1974).

The overall expansion of economies necessitated improvements of infrastructure. The construction of hydropower plants along the Kemijoki from 1945 onward was particularly devastating for salmon and traditional weir fishing (Vilkuna, 1974). The need for hydropower was connected to the concomitant industrialization of Finland and particularly to the development of paper and pulp industry areas along the coast. The development of northern Finland was justified in a level of industrialization of the whole nation (Lähteenmäki, 2007). Large-scale harnessing of the majority of the river valley for industrialization led to emigration; for example, people from seven Sámi and Finnish villages had to move, and 750 reindeer grazing ranges and forty farms were flooded when two large

Figure 5.4 Fishing weir in Kemijoki Tervola, 1922. Photo V. Jääskeläinen, Finnish Heritage Agency, Ethnographic Picture Collection, FINNA

reservoirs were built (Lähteenmäki, 2006). The establishment of the reservoirs were therefore particularly devastating for local reindeer herding (Magga, 2003). Disappointment for local habitants about the induced environmental changes resulted in a long struggle for a fish stocking obligation for the power companies, political movements for building fish ladders, and the so called rapid wars to save the last remaining free tributaries of Kemijoki (Suopajärvi, 2001; Krause, 2015).

Today the combined pressure exerted from human activities is very high in the Kemijoki catchment area. Salmon stocks are maintained by large annual compensatory release of hatchery-raised smolts by the power companies along the river (Romakkaniemi et al., 2003; Huusko, 2018). Since the 1980s, approximately "615,000 reared salmon have been stocked at the river mouth as a compensation for the lost wild reproduction" (HelCom, 2011a).

Future Outlook: Will Pressures Continue to Increase?

Reindeer and salmon are keystone species that require large, interconnected land- or seascapes in the form of a green/blue infrastructure. If these connections are broken, then reindeer and salmon, and the cultures and ecosystem functions that depend on them, will be negatively impacted. As reindeer and salmon are users of large geographic areas, they also bear the brunt of all the multiple pressures they are exposed to in these areas. In this chapter we have shown how the formation of industrial mega-systems has led to an accumulating appropriation of land and water areas that has reduced connectivity between ecosystems and the size of grazing and spawning areas. Which, in turn, have negatively impacted reindeer herding and salmon fishing, which are both also traditional livelihoods and bearers of local and indigenous cultures. However, assessments of impacts from industrial activities far too often singlehandedly focus on impacts on a project-by-project basis (Atlin & Gibson, 2017) rather than the aggregated cumulative effects over a larger area. To reindeer and salmon, the impact of just one industrial project, assessed in isolation, and often deemed by impact assessments as only causing minor disturbances (Rosqvist et al., 2023, see Chapter 6), is in reality not a minor impact when aggregated together with all other pressures.

With one of the largest mineral extraction sites in Europe located in the narrowest section of its hourglass-shaped pastures, the cumulative impacts in the Laevas SRC are unique. Still, the de-prioritization of reindeer herding in favor of extraction of minerals or hydropower is experienced in many places, and Laevas SRC is not alone in struggling with increasing pressure from industrial encroachments on pastures. Many reindeer herding communities in Sweden bear witness to how pressures are mounting (e.g., Lawrence & Larsen 2019; Österlin & Raitio 2020; Larsen et al., 2021). The story is the same also for reindeer herding communities in Norway (Lien, 2023, see Chapter 12) and Finland (e.g., Kivinen, 2015; Landauer et al., 2021) and also for Nenets in Arctic Russia (Forbes et al., 2009). The problems are in essence the same; traditional pastoralism developed in a landscape with a low degree of industrial impact now experiences increasing encroachments. As most types of industrial developments cause irreversible effects in terms of land conversion, the pressure is continuously accumulating. The effects of climate warming challenge reindeer across the Arctic, and regional weather patterns determine which parameters are most critical. Often a combination of changes in temperature and precipitation cause problems, for example, rain-on-snow events or heatwaves in summer causing droughts. Challenges are now mounting for reindeer herding communities because mitigation of and adaptation to changes in weather and snow demand high flexibility in reindeer land use, which is increasingly hampered by the expanding industrial footprint.

The ambition to reach carbon neutrality has inspired the governments of Sweden and Finland to promote generation of renewable energy, further mineral exploitation, and intensification of forestry in Arctic Fennoscandia. Building a low-carbon future is claimed to require minerals for production of batteries for electric vehicles, renewable energy sources, and new infrastructure developments (e.g., European Commission, 2018), which is now being implemented both in Finland and Sweden through various programs. To decrease import dependency from outside the EU there is an ambition to increase mining of “critical minerals” within the EU (European Commission, 2008). As northern Finland and Sweden constitute one of the core mining areas within the EU, it is very likely that the pressure to exploit more mineral resources in the region will continue to increase.

In Finland, further exploitation occurs in the Kemijoki catchment area, especially in the area around Sodankylä (Figure 6.1) where, for example, the Kevitsa copper and nickel mine has recently opened (Boliden AB), and the multi-metal Sakatti mine (Anglo-American Ltd) is under licensing procedures. Large scale wind power developments are emerging as well on the northern Finnish coast (Yle News, 2020; Finnish Wind Power Association, 2021). Therefore, pressures on riverine and coastal salmon stocks, and salmon fishing for livelihood and recreation, continue to increase.

Currently, there are several applications for mining concessions in permit processes in Sweden (e.g., Boliden Mineral AB for Laver K nr 1; Beowulf Mining Ltd for Kallak K nr 1 Permit issued March 22, 2022). Production of fossil-free steel is planned by “Hydrogen breakthrough Ironmaking Technology” and “H2 Green Steel” in the vicinity of Luleå . These new developments require large amounts of fossil-free energy, possibly produced by wind turbines placed on reindeer winter grazing areas. Thus, both future exploitation of minerals and production of fossil-free energy could continue to reduce the size of pastures and the connectivity between remaining pastures. We fear that predicted future climate changes, together with an increasing resource extraction and industrial developments will cause further and harmful cumulative effects on terrestrial and aquatic ecosystems in this region. Climate stress on reindeer will increase because climate scenarios predict higher temperatures and increased winter precipitation in Arctic Fennoscandia. By integrating experience-based and scientifically collected data, Rosqvist et al., (2022) showed high vulnerability of reindeer herding to further warming and that adaptation to especially severe snow conditions will be hindered by further exploitation of minerals and forests. Likewise, remaining salmon stocks are not only threatened by pollution and changes in hydro-regulation for energy production but also by higher water temperatures and climate change mitigation policies (Jonsson & Jonsson, 2009; LaMere et al., 2020). For example, Baltic cod is spreading northward in the Baltic Sea, possibly due to higher water temperatures, which may increase the predation pressure on salmon post-smolts (Friedland et al., 2017). Climate change mitigation policies, particularly policies for reducing the use of fossil fuels, may increase price peaks for hydropower as renewable energy. This may lead to hydropeaking – releasing of pulses of water to meet electricity demand – which may change behavior, mortality, and spawning of the Baltic salmon (Ashraf, 2020; LaMere et al., 2020).

If the goal is to avoid, or at least mitigate, longlasting effects on the environment and people, the governments of Sweden and Finland need to ensure adequate assessments of cumulative effects from proposed industrial activities in order to be thoroughly informed before prioritizing between different potential futures. Potential impacts that may arise from industrial or societal projects on environment and people need to be assessed on appropriate temporal and spatial scales, including the total effects from climate change with the impacts following climate change mitigation policies. A more holistic perspective would allow decision-makers to keep a better balance between further resource exploitation and resilience of ecosystems such as, for example, those represented by reindeer and salmon.

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