Chapter 9 Electronic Annex

EA Case Study 1. The river Lule: a Sámi river in the heartland of the Swedish North

Primary Author: Tero Mustonen, Snowchange Cooperative

Contributing Author: Stefan Mikaelsson, Sámi Parliament

Introduction

The river Lule (Sámi: Julevädno; Swedish: Lule älv) is a major river of northern Sweden, with a total length of 460 km. The catchment area is approximately 25 000 km^2 (see Figure EA1). The river Lule has been harnessed for energy production with several hydroelectric power stations having been built along its course. These include Harsprånget, the largest in Sweden; other major stations include Porjus, Letsi, Messaure and Edefors. The first hydropower dams on the river Lule were built in 1915. There are both Lule Sámi and North Sámi communities living along the river. At the headwaters, some of the largest conservation areas in Europe constitute the Lapponian Area, an UNESCO World Heritage Site. The municipality of Jokkmokk, widely known as the 'capital' of the Swedish Sámi culture, is located within the basin.

Indigenous Knowledge regarding Hg in this area is predominantly held by those Sámi who are living and practising their livelihoods on the river Lule; the Sámi themselves consider their knowledge to be distinct and unique (Mikaelsson, 2020). They are also an important source of observations regarding Hg concentrations in the area. In this case study, Sámi views on changes to this river and associated water-quality issues are discussed.

Methods

The river Lule is a large, heavily altered river system with a lot of hydropower development. This case study on Indigenous Knowledge regarding Hg uses a literature review, community-based monitoring work mainly conducted between 2003 and 2013 (summarized in Mustonen and Syrjämäki, 2013) and additional interviews and knowledge collection conducted in the Spring of 2020 for the AMAP 2021 Mercury Report. Sámi leaders were invited to respond to current questions regarding Hg in the area by Stefan Mikaelsson, a long-time member of the Sámi Parliament Plenary Assembly, former President of the Swedish Sámi Parliament and board member of the Udtjá Forest Sámi community, who summarized their views in "Reflections on Mercury on River Lule" (Mikaelsson, 2020). Additionally, cartographic summaries are used to illustrate the Sámi communities of the area and the locations and extent of hydropower developments.

Results

The river Lule constitutes a catchment area that has been heavily altered, including the river's main channel. These alterations started in 1915 with the construction of the Porjus hydropower station in the upper part of the river basin. Subsequently, 14 other hydropower dams were constructed between 1950 and 1977, permanently altering the river (Mustonen and Syrjämäki, 2013). This development of the watershed eliminated, for the most part, the capacity of Atlantic salmon to use the river as a spawning area and thus adversely affected a key Sámi sociocultural indicator species. However, since the time the river was first altered over 100 years ago, the Sámi have continued to use the altered river and its reservoirs for subsistence fishing.

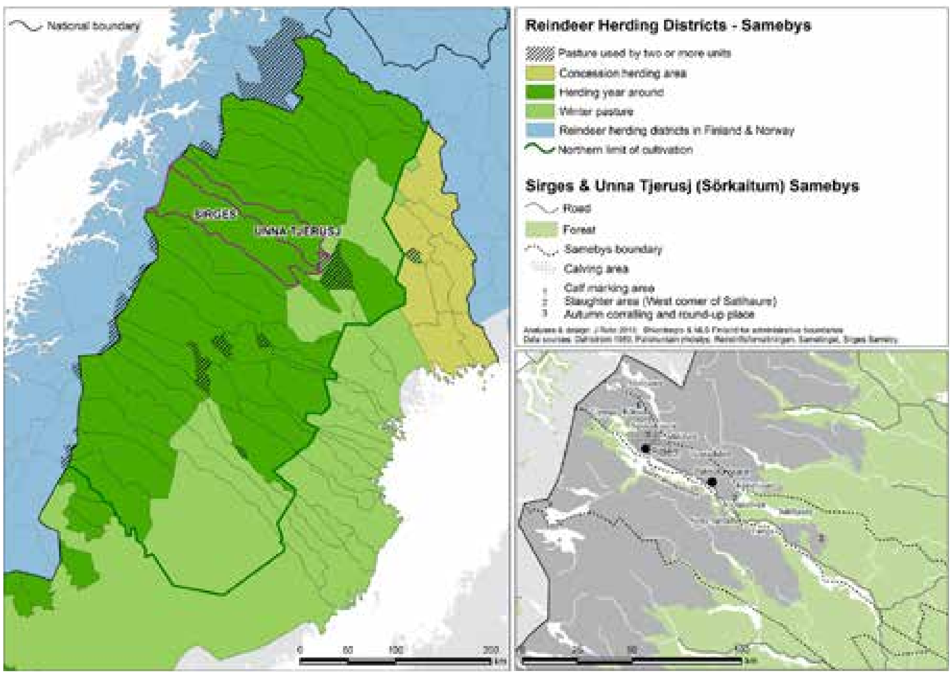

Figure EA1. Map of reindeer herding areas and Sámi communities in the upper part of the Lule River. The insert map documents historic land use and important seasonal sites from 1970s onwards. Information from the 2010s. Source: Johanna Roto/ Snowchange Cooperative, 2022, with some alterations to the map text. Used with permission.

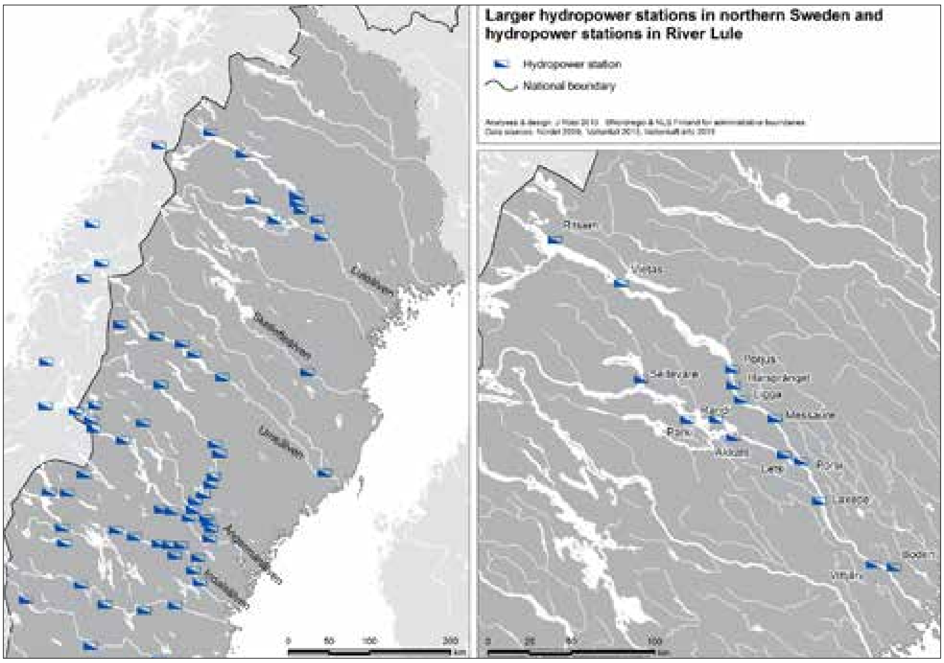

Figure EA2. Hydropower stations on River Lule. Source: Johanna Roto/Snowchange Cooperative, 2022. Used with permission.

Hsu-Kim et al. (2018) describe how releases of Hg (and subsequently of methylmercury) is characteristic of altered rivers such as the river Lule, and the associated risks. Sweden sets the threshold for safe levels of Hg contamination in fish at 0.20 mg/kg. Climate change is expected to make the accumulation of methylmercury in waters worse (Eagle-Smith et al., 2018). Skyllberg et al. (2007) in their review of national methylmercury levels, confirm its presence in the river Lule watershed at multiple locations. Åkerblom and Johansson (2008) state that, nationally, the spatial variation of Hg in lakes and streams is substantial; however, currently, in the river Lule, Hg levels can be up to five times greater than Hg concentrations under 'natural conditions'.

Given the large number of hydropower dams and reservoirs on the river Lule (see Figure EA2), we can assume that there is a large amount of sedimented Hg in all of the 15 reservoirs along its course. A national database on Swedish water bodies (VISS[1]) indicates that Hg is present in all parts of the river system (above the national safe limit of 0.20 mg/kg) and that the river is "unlikely to reach a good chemical status" in the near future (see also Nyberg et al., 2018). However, due to the size of the catchment and multiple reservoirs, the Hg levels vary greatly at different points.

The Jokkmokk area is often hailed as the hub of Indigenous Knowledge in Northern Sweden. Many Elders from the area, such as Elle-Karen Pavval, have mastered the old ways. She recalled, for example, the old weather prediction skills during the oral history work:

> "*You can forecast weather [from] reindeer behaviour. For example, winds make the reindeer run [to specific directions] here and there, [which] predicts wind. Weather was also predicted from the stars. If you wanted to predict the floods in the summer, you needed to catch a big northern pike fish, and take her liver*" (in Mustonen and Syrjämäki, 2013).

According to Mikaelsson (2020), traditional food production is valuable for Indigenous individuals themselves, who maintain better health and wellbeing by consuming traditional food than non-traditional sources of nutrition. It is important for Indigenous People to be able to control their own food and to ensure it is devoid of antibiotics and growth hormones. Water quality should also be under their control, as clean water is essential for Indigenous health and well-being.

One of the most respected knowledge holders in the river Lule Basin, Lars Pirak, discussed the connection of Sámi people to the landscape: "*[When it came to] sacred lakes that were called* saiva*, the thing was to throw some silver there, so that people would get fish*" (Mustonen and Syrjämäki, 2013). Such behaviour reveals the reciprocal relationship the Sámi had with their waters. Respect and careful mindfulness were the keys to maintaining a good relationship with the waters.

Sámi knowledge is interconnected across terrestrial, aerial and aquatic systems (see Figure EA3). Mikaelsson (2020) says that "land on which Sámi live and the natural resources on which we depend are inextricably linked to the survival of our identities, cultures, livelihoods, as well as our physical and spiritual well-being."

Large-scale alterations, such as dams, in any of these components of the Indigenous system cascade and accumulate, much like Hg itself. Sámi knowledge of Hg on the river Lule is intertwined with the experience of the human-induced changes to the basin. It cannot be separated from the history of development of the river. For this case study, a number of key oral history and written materials (Mustonen and Syrjämäki, 2013) are shared below to highlight Sámi perspectives on the situation.

From the perspective of the Sámi, the Suorva Reservoir in the upper part of the river Lule system is of key relevance when considering the history of hydroelectric development in the region. The reservoir sits 90 km upstream from Porjus (the first hydropower dam, built in 1915). The present area of the reservoir originally consisted of six smaller lakes. Water levels

[1] See: https://viss.lansstyrelsen.se/Waters.aspx?waterMSCD=WA33065308

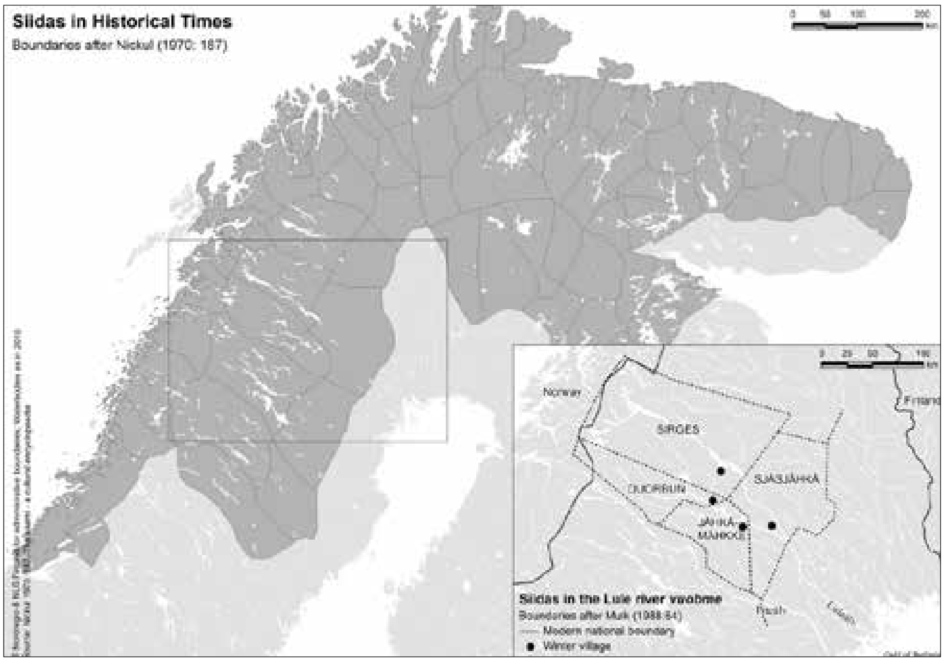

Figure EA3. Major Sámi *siidas* (i.e., historic Indigenous-governed communities of the Lule River area). Source: Johanna Roto/ Snowchange Cooperative, 2022. Used with permission

Sámi fisherman (Pittsa) fishing on Suorva Reservoir, 1970s. Photographer: Jan Håkan Dahlström, Snowchange Cooperative. Used with permission.

were raised, initially, by nine meters. At the time of construction, the county's administrative board assessed the damages caused to reindeer pastures and fisheries to be minimal, ignoring Sámi knowledge of pasture quality and seasonal rotation. Forced relocations from further north also increased the pressures on the Sámi herds in the region.

Throughout the 1900s, the Sámi voiced critical views and expressed their resistance through the media and by forming social organizations opposing the plants. For example, in 1964 Susanna Kuhmunen wrote a long letter in the *Norrbottens-Kuriren*, a regional newspaper, identifying the changes that had taken place in her lifetime (from 1925 to 1964). According to Kuhmunen, damages caused by hydroelectric development included the following:

- Changes to fish and fisheries, including amounts of fish and new damage to nets and places of importance to the Sámi (including through Hg loading)
- The destruction of several places and communal sites of importance to the Sámi, which are now underwater
- Altered conditions on lakes and lakeshores, making subsistence for Sámi much harder (including reindeer herding activity)
- Overall total impact on Sámi uses of the land, including an understanding that both economic opportunities and future land use will be greatly affected by the proposed next stage of Suorva developments in the 1960s (in Mustonen and Syrjämäki, 2013).

In the late 1950s and early 1960s, the journalist Elly Jannes and the photographer Anna Riwkin-Brick wrote about the Sámi's 'awareness' of changes as new developments were pursued, including their knowledge of flooded crossing points for reindeer, loss of spring pastures, dead fish, changes to the shorelines and the resulting impacts on transportation, fisheries and the use of lakes. Jannes and Riwkin-Brick quote Anders Pirtsi, who said at the time: "*Is it right to sell the reindeer grazing grounds of one's descendants for a few thousand crowns?*" Another Sámi person also commented at the time that: "*No matter how much I love my own life in the reindeer forest areas, I would not advise my children to inherit my work. The authorities seem to have made up their minds to destroy us, in spite of all the beautiful words they use in their reports*" (Mustonen and Syrjämäki, 2013).

Lars Pirak linked the destruction caused by the hydroelectric stations to damage to fisheries and, consequently, to income: "*[Before the time of the Vattenfall, Swedish energy company] we went and sold and exchanged our fish [for] food items*

[2] See: http://samer.se/1214

here in Jokkmokk. Now that the rivers have been harnessed and destroyed, fisheries have worsened considerably in some locations" (in Mustonen and Syrjämäki, 2013).

Despite these changes, the Lule River system remained a major commercial and Sámi fishery.[2] Infrastructure to deliver catches of fish was established with fish buyers (Mikaelsson, 2020). The buyers could buy fish from fishers by accessing fisheries by boat, airplane or helicopter and do business with the families who lived and fished on the most remote mountain lakes. Mostly, this fishing was based on catching Arctic char and whitefish, which have a higher economic value than predatory fish species; while these species do make up part of the catch in subsistence fishing, species such as perch and pike are prone to absorb Hg from their environment (as methylmercury).

Mercury loading (as observed by Browne, 2007 and Åkerblom and Johansson, 2008) in the catchment area due to industrial forestry actions has also been observed by the Sámi. Mikaelsson, who has been working as a reindeer herder for most of his life, noted that "*after cutting down a forest, it is a common practise to dig ditches in the soil, which results in faster flow of water from forest to rivers and lakes*" (in Mustonen and Syrjämäki, 2013).

Reindeer herder Per Ola Utsi has observed how the reservoirs are altered through the seasons. As the hydroelectric reservoirs fill in the autumn, waters rise. As the reservoir water levels drop through the season, ice is left 'hanging' on the beach (with water disappearing). Fluctuating water levels lead to greater levels of erosion. This is expected to further increase the loading of Hg from the banks and shoreline (Hsu-Kim et al., 2018).

Additionally, according to Utsi, the alterations to the river Lule basin (i.e., the hydropower dams and artificial lakes) contribute to the local air moisture and weather. It can now become very moist, which means that lichen close to the shores freezes when the temperatures fall. According to Utsi, while people are interested in regulating the waters of the Lule, nobody pays attention to the surrounding areas and how they are impacted by these alterations (Mustonen and Syrjämäki, 2013).

Sara Omma, a young woman at the time the oral history work was conducted, said that the century of development of the river Lule has left people at breaking point: "*This damming has taken place already four times. Four times we have had to move. Each time they have said it will never happen again. Such wrongdoings have been committed against the Sámi. Great benefits have been reaped by harnessing the lakes and now the electricity goes via Norway to southern Sweden. So that where we are living, there is no electricity, but just above our heads there are huge powerlines transferring the electricity to Norway*" (in Mustonen and Syrjämäki, 2013).

Discussion and Conclusions

The river Lule is a major Sámi watercourse, a spawning river for Atlantic salmon and many other salmonid fish as well as a migratory route of the Sámi reindeer herders. Both large-scale nature protection (Lapponia) and 15 hydropower dams have transformed the Indigenous landscapes of the river Lule into a human-controlled system.

The hydroelectric development has released Hg, which has then become methylmercury, across the Lule River system and basin; Hg levels are now consistently above 0.20 mg/kg throughout the system (Browne, 2007; Skyllberg et al., 2007; Åkerblom and Johansson, 2008; Hsu-Kim et al., 2018; Nyberg et al., 2018). Skyllberg et al. (2007) have identified Hg in Lule River sediment. Climate change may be a new driver of releases of Hg and may also affect levels of sedimented Hg (Chen and Driscoll, 2018).

According to Mikaelsson (2020), traditional Sámi food production is small-scale and requires that nature remains unchanged for a long time. The major industrial activities that have taken place have created a great deal of uncertainty in Sápmi (i.e., in Sámi land and among Sámi people; Mikaelsson, 2020). This uncertainty comes from the challenge of maintaining one of the Arctic's many Indigenous cultures, from ongoing emissions from many sources, and ultimately from how these emissions affect other areas according to two basic ecological principles: nothing disappears and everything spreads.

The Sámi had a reciprocal relationship with their waters (see Mustonen and Syrjämäki, 2013) as a part of the interconnected co-being of their home area. A century of alterations on the river Lule have destroyed this complex self-governed system. Early Sámi leaders, like Johan Turi and Elsa Laula Renberg, warned about the dangers of losing the land as a consequence of development. Mercury is one of the results of the macro-level development of the basin.

At the height of the hydropower development in 1964, Sámi women, such as Susanna Kuhmunen, identified the system-wide negative impacts, including Hg loading, that would result from the hydro dams (and from Suorva in particular). Precise monitoring of Hg levels from 1960s onwards will be left for future studies. From the 1990s onwards, forestry actions on the river Lule, included ditching and further clear-cut logging, intensified. Sámi leaders, such as Stefan Mikaelsson, have conveyed their concerns regarding these actions for decades. Browne (2007) confirms that the clear-cutting of trees may already be increasing Hg releases from soils.

Some Hg is found naturally in the environment, but much of the Hg in our environment today is transported over long distances via the atmosphere and originates in other countries (*Länsstyrelsen*/Provincial Administration, in Mikaelsson, 2020). Overall, Swedish emissions have decreased, and Hg in particular has decreased since 1990 (see VISS database). Despite this, the levels of Hg in the environment are still far too great and the levels in fish do not seem to have declined. Mercury continues to leak into lakes and streams. The problem is greatest in southern Sweden (Åkerblom and Johansson, 2008), where the precipitation of Hg is greater than in northern Sweden.

The Sámi by the river Lule have identified Hg as a concern embedded in the larger development actions. They have expressed concern via various means, from opposition and concern at the time of construction of the hydroelectric power

[3] See: https://www.youtube.com/watch?v=ZSrWPSUf8tw

plants (Susanna Kuhmunen), to the detection of loss of fisheries and fish quality (Lars Pirak, Per Ola Utsi) and concerns in connection with new forestry practices, such as ditching and increased clear-cuts. Recent assessments on the presence of Hg in the thawing permafrost areas (Schuster et al., 2018) are also concerning to the Sámi within the Lule Basin (Mikaelsson, 2020). Sámi have also expressed, throughout this time of alteration and development, their deep connections with the river (see, for example, Katarina Rimpi's yoiks).[3]

All of the changes described above are leaching Hg into the waterways. A gradient can be observed from the high mountains (where lower levels of Hg are observed) to the coast (where higher levels of Hg are observed) of the river Lule basin (Mikaelsson, 2020). Another gradient can be observed for the Norrbotten coast, with higher levels in the Piteå region (south) and lower levels towards the Kalix region (north). Earlier industrial releases and distribution of Hg from Rönnskärsverken near Skelleftea further down south is also relevant in the regional view.[4]

Another relevant source of Hg in Norrbotten is the Aitik mining site. The Aitik copper mine is located about 15 km southeast of Gällivare city center. The Aitik case has led the Sámi Parliament to demand that the mining company show in its environmental impact assessment reports how dust produced as a result of mining activity with increased levels of Hg can affect reindeer husbandry, the health of reindeer and reindeer herders, and the quality of reindeer meat (Mikaelsson, 2020; see also Sámi Parliament reply to *Mark- och miljödomstolar*; Land and Environmental Courts, Court number: M 2672-18, 5.2.2020).[5]

The Sámi have no land rights nationally in Sweden. According to Mikaelsson (2020), Sámi culture and business are mostly invisible in official statistics on the Swedish side of Sápmi (Sámi home land). In order to investigate the overall situation with regards to Hg in the river Lule, an assessment of Indigenous Knowledge and science should be conducted (Skyllberg et al., 2007). For example, Arctic char, which accumulates Hg and is a major cultural fish species for the Sámi, would be well worth investigating. Chen and Driscoll (2018) also stress the need for action following Hg research already conducted. Sweden ratified the Minamata Mercury Convention in May 2017. National implementation actions should include responses to questions of equity and Sámi rights as a part of developing a long-term solution to damages done to the river Lule.

EA Case Study 1: References

Åkerblom, S. and Johansson, K., 2008. Kvicksilver I Svensk Insjöfisk – Variationer i Tid och Rum. Rapport 2008:8, Swedish Agricultural University.

Browne, D., 2007. Freshwater Fish in Ontario's Boreal: Status, Conservation and Potential Impacts of Development. WCS Canada Conservation Report No. 2. Wildlife Conservation Society Canada (WCS), Toronto, Ontario, Canada.

Chen, C. and Driscoll, C., 2018. Integrating mercury research and policy in a changing world. Ambio, 47:111-115.

Eagle-Smith, C. et al., 2018. Modulators of mercury risk to wildlife and humans in the context of rapid climate change. Ambio, 47:170-197.

Hsu-Kim, H. et al., 2018. Challenges and opportunities for managing aquatic mercury pollution in altered landscapes. Ambio, 47:141-169.

Mikaelsson, S., 2020. Reflections on Mercury on River Lule. An unpublished manuscript available from Snowchange Cooperative.

Mustonen, T. and Syrjämäki, E., 2013. Oral Histories and Sacred Landscapes of the Jokkmokk Sámi. Snowchange Cooperative, Kontiolahti, Finland.

Nyberg, E. et al., 2018. The National Swedish Contaminant Monitoring Programme for Freshwater Biota. Swedish Environmental Protection Agency. Swedish Museum of Natural History, Stockholm, Sweden.

Schuster, P. et al., 2018. Permafrost stores a globally significant amount of mercury. Geophysical Research Letters, 45:1463-1471.

Skyllberg, U. et al., 2007. Net methylmercury production as a basis for improved risk assessment for mercury-contaminated sediments. Ambio, 36:437-442.

VISS, 2021. Luleälven Vattenförekomst, MS_CD: WA33065308. VISS EU_CD: SE729042-178707, Val av förvaltningscykel, Förvaltningscykel 3 (2017 – 2021). In: Vatteninformationssystem Sverige (VISS). Database. Available at: https://viss.lansstyrelsen.se/Waters.aspx?waterMSCD=WA33065308

[4] See: https://www.sametinget.se/klimat

[5] The Sámi Parliament's opinion regarding Boliden Minerals AB's application for change for operations at the Aitik mine with a new mine in Liikavaara, Gällivare municipality in Norrbotten County (Objective no: M 2672-18). The opinion went to the *Mark- och miljödomstolar* (Land and Environmental Courts) in Umeå and was possible thanks to a referral invitation. See more at: https://www.svt.se/nyheter/lokalt/norrbotten/kort-livslangd-for-ny-gruva-i-liikavaara-i-gallivare-kommun

EA Case Study 2. Lokka and Porttipahta reservoirs, Lapland, Finland

Author: Tero Mustonen, Snowchange Cooperative

Introduction

This case study focuses on the Lokka and Porttipahta reservoirs in Finnish Lapland that were created in the late 1960s and early 1970s. They are the largest of their kind in Europe. Lokka and Porttipahta are located in the northern part of the municipality of Sodankylä, along the tributaries of the river Kemijoki in Central Lapland. Lokka Reservoir is situated in the upper reaches of the river Luiro and Porttipahta reservoir is situated upstream of the river Kitinen.

The maximum height of water for both reservoirs is 245 meters above sea level, and the lowest permitted height of water is 240 meters for Lokka and 234 meters for Porttipahta. Due to their shallowness, the lowering of water levels diminishes the size of their basins significantly. The two reservoirs were connected in 1981 through the creation of the Vuotso Canal. The regulating dam in Lokka Reservoir is situated at the southern tip of the basin; the dam is 30 meters tall, and it has a power station capable of producing 35 MW.

Verta et al. (1989), Wahlström et al. (1996), Berglund et al. (2005), and Browne (2007) all agree that, in general, large-scale hydroelectric dams stimulate and take up a large amount of Hg from the submerged soils. Such was also the case with Lokka and Porttipahta. The creation of these reservoirs displaced a North Sámi Indigenous community and other local (Finnish) wilderness communities, and also drowned many villages. The 1950 census named 56 Sámi individuals in the Lokka area. Villages considered to be majority Sámi included Kurujärvi, Yli-Luiro, Ponku, Laiti (in Porttipahta area) and Lusma. The exact number of Sámi people impacted by the flooding remains unknown.

Vuotso is the central village of the modern Sompio area. Development along the river Kemijoki (see Figure EA4) is a central theme of this case study; the river was first harnessed for hydroelectric power production in 1948. By the late 1960s, construction work on the dams by the electricity industry had reached the headwaters of the river, an area where the Sámi and other local people were living in subsistence economies and practicing age-old traditional cultures. In the span of a few years, a whole culture was destroyed and flooded. The majority of the Sámi and other locals were resettled in Vuotso (see Figure EA5)

The nation-states of Sweden, Norway and Russia started to exercise their powers in the region more forcibly in the 18th and 19th Centuries. Sweden and Norway underwent various border disputes with Russia and between themselves. These disputes impacted the migratory lifestyle of the North Sámi, who lived on the coast of the Arctic Ocean in the summer and in the highlands of the border area between Finland, Sweden and Norway in the winter.

Aikio (1978 and in 1988) reports that families of these North Sámi moved to the Sompio (Vuotso) region in the 1870s to 1890s due to the challenges that border closures imposed on their life herding reindeer and on their seasonal migrations. Rosberg (in Aikio, 1988) provides us with information that makes the case more complex; around the same time as the growing border disputes, the people in Sompio had invited some of the North Sámi to their home areas to herd and manage their reindeer during this period, which also contributed to the migration of North Sámi to the Sompio region (Rosberg, in Aikio, 1988). The hydroelectric development, border disputes between nation states and invitations from the people of Sompio all meant that the Sompio region received a totally new Sámi population at the end of the 19th century. These Sámi started to establish their own seasonal rounds in the community as they navigated the social and political challenges that arose from the land use of the descendants of the Forest Sámi of the region. Aikio (1991:92-93) also states that the North Sámi first settled around lakes Sompiojärvi and Kopsusjärvi and on the Riestovarsi, which is the location of the contemporary Vuotso community. Permanent *gammi*s (turf huts) and households were constructed there between 1883 and 1886. Even today, North Sámi, or 'reindeer Sámi' as they are known, have a clearly separate identity from other local people in the area (Aikio, 1988:65).

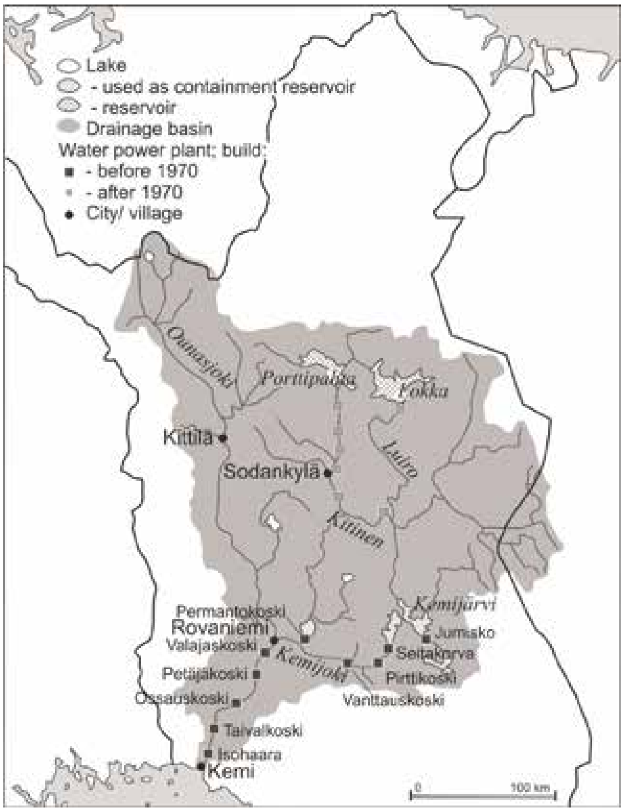

Figure EA4. Map showing the river Kemijoki and the location lakes, reservoirs and the area of the drainage basin along with power plants built before and after 1970. Source: Johanna Roto/Snowchange Cooperative, 2022. Used with permission.

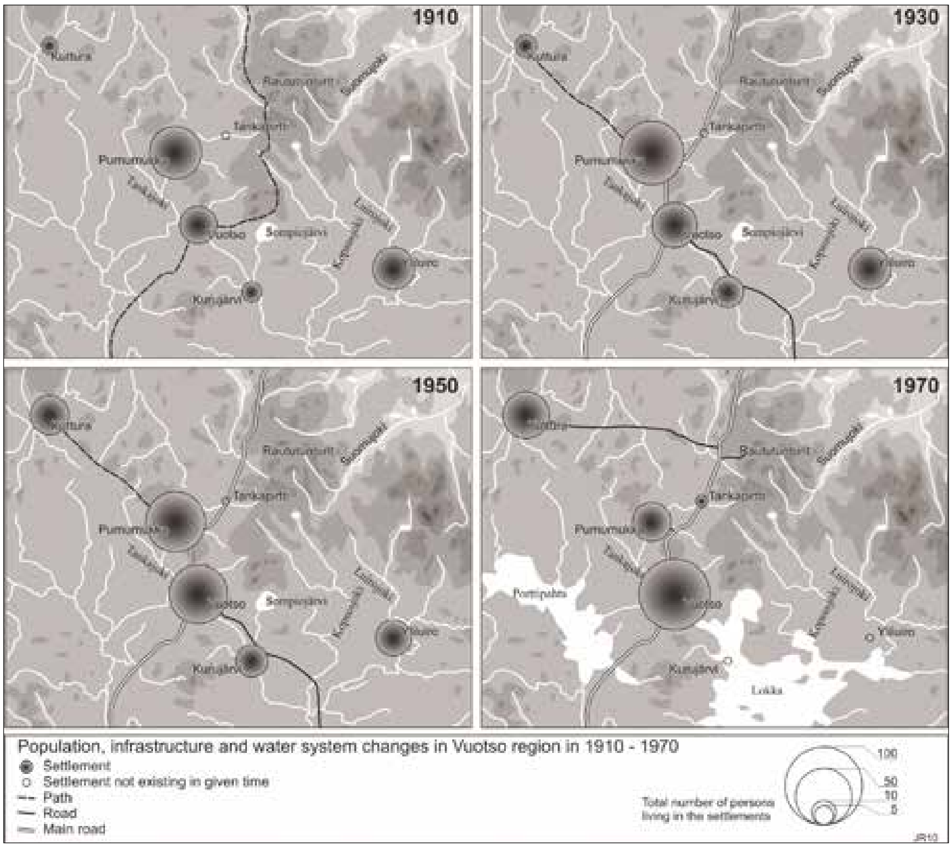

Figure EA5. Map showing changes to population, infrastructure and the water system in the Vuotso region between 1910 and 1970. Source: Johanna Roto/Snowchange Cooperative, 2022. Used with permission.

Methods

For this case study, methods have included a national literature review, community visits between 2000 and 2010, and community-based observation using oral histories and contemporary diary reviews (Aikio family, 1960–1980, summarized in Mustonen et al., 2011 and Murtomäki, 2020). Community-based monitoring (CBM) and visits have been continued after 2010 through the documentation of oral histories, especially in the communities of Purnumukka and Vuotso.

Mercury (Hg) is present in the natural boreal environment. When soils are altered — often through human disturbances such as burning, ditching, mining, and hydropower development — Hg embedded in the soil enters waterways, travels downstream, and reacts with water due to microbial actions (Browne, 2007). This results in methylmercury — a toxic substance that is ingested by wildlife and accumulates in the human body. Due to the process of biomagnification, accumulation is especially prominent among top predators, such as birds of prey and northern pike (*Esox lucius*), yellow perch (*Perca fluviatilis*), burbot (*Lota lota*) and pikeperch (*Sander lucioperca*). When the ground is churned up, and especially when it is then covered by water, Hg in the ground is released into the water system (Wahlström et al., 1996). It has been observed that this happens especially when artificial lakes have been built (Wahlström et al., 1996:159).

A full CBM study of the impacts of the reservoirs was released in 2011 (Mustonen et al., 2011). In this case study, we aim to produce a snapshot of the role of Hg in the life of Sámi and other local peoples in the post-reservoir era; for this, we have used a geographical, literature and CBM analysis. This case study includes new community materials as well as summarized findings from the CBM work from 2000 to 2011.

Results

The area of Lokka and Porttipahta, prior to the construction of reservoirs, was full of *aapa* (marsh mires) intertwined with lakes, river systems and wilderness communities. Both North Sámi and other local people used the Sompio area. The main wilderness economies were reindeer herding, hunting, fishing and small-scale farming (Mustonen et al., 2011). Murtomäki (2020) reports that the construction of the two reservoirs was preceded by large-scale clear-cut logging of an area of up to 417 km^2. The villages of Korvanen, Kurujärvi (a Sámi village) and Riesto were completely submerged; part of Mutenia was also submerged. According to Murtomäki, most of the residents of the wilderness villages were then evacuated to Vuotso.

The clear-cutting was complemented by the use of Agent Orange, a herbicide and defoliant containing toxins and hazardous chemicals. The exact amounts are unknown and have not been reported to the public. The use of Agent Orange was to speed up the removal of timber and unwanted birch trees from the future reservoir sites. Many trees were left in place and submerged underwater. For decades, the Sámi and other local people, such as Oula Aikio and Sulo Alakorva, resisted the creation of the reservoirs, but the reservoirs were eventually built in the 1960s and 1970s (Mustonen et al., 2011).

The Lokka and Porttipahta reservoirs flooded key reindeer herding pastures and hunting areas. They altered the flow of rivers and structure of lakes. Murtomäki (2020) reports that fish catches on the new reservoir (primarily northern pike, yellow perch, burbot, ide and whitefish) were plentiful at first. Murtomäki (2020) conveys an anecdote from the villages from the heyday of the mercury debate in 1970s (during the time of the construction and immediate aftermath of the competition of the reservoirs). One of the older ladies said that by hanging large pike upside down in freezing temperatures the Hg would accumulate in the head of the fish. Then, by cutting the head off the fish, all Hg could be removed. Such stories emerged as a way of addressing and adapting to the system-wide changes created by the reservoirs, which greatly altered natural systems which were previously relied upon for subsistence living; these alterations caused fish stocks and harvesting areas to become toxic, or at least to be perceived to be toxic.

Despite this, according to Murtomäki (2020), fish, including pike, perch and burbot, continued to be consumed as traditional foods in the Vuotso area, even though warnings had been issued publicly in the 1970s about the increased levels of Hg and the related health effects. For example, the culturally significant process of the drying of northern pike for consumption continued. Murtomäki (2020) recalls there were at least two old men living in remote wilderness cabins in the new reservoir area who did not come to the Vuotso settlement at all. They subsisted only on fish and were most likely unaware of the toxins in the reservoir fish.

In the 1970s, the commercial viability of fish catches from the Lokka and Porttipahta reservoirs suffered as a result of the national discussion about the accumulation of Hg in predator fish (Valste, 2008; Murtomäki, 2020). Mustonen et al. (2011) summarized the levels of Hg in fish in the Lokka Reservoir in the early to late part of the post-dam era (see Table EA1 below). These results indicate the progression of initial high levels of Hg present in the northern pike and burbot during the so called 'erosion' phase of a reservoir (10–15 years after construction) towards an abatement of Hg levels associated with the stabilization of the reservoir (over 15 years after construction).

In the 1970s, Sulo Tanhua and other local people had a good harvest spot with their fish traps close to the now drowned river course of Riestojoki. Pike markets collapsed quickly after word spread of high levels of Hg in the pike (see above), a predatory fish that accumulates Hg.

Fish traps targeting burbot were positioned along several of the former river courses, now underwater, which fish continued to follow. Harvests of burbot were plentiful. However, the burbot could not be sold. Only the liver and roe were harvested from the fish; the rest of the fish was not taken to market to be sold as other parts of the fish are regional delicacies. The liver, for example, was consumed by the Sámi and other fishermen themselves in remote cabins. No heed was paid to the levels of Hg in the fish.

Murtomäki (2020) has also observed the emergence of a population of white-tailed sea eagles (*Haliaeetus albicilla*) on the newly constructed reservoirs. The eagles harvested burbot (of up to 78 cm long) available on the Lokka Reservoir.

Table EA1. Levels of mercury in pike and burbot in the early to late post-dam era in Lokka Reservoir. Source: National Board of Waters, Finland, 1980 and Kemijoki, 2012 summarized in Mustonen et al., 2011.

	Pike (1 kg)	Burbot (0.5 kg)
1980	0.43 mg/kg (max 0.99 mg/kg)	0.9 m/kg (max)
2012	0.34 mg/kg	0.56 mg/kg

Two fishermen on Lokka reservoir in 1970s. Photographer: Eero Murtomäki, Snowchange Cooperative.

Reservoirs thus stimulated the growth of a 'new ecosystem' which included large amounts of Hg loading (with maximum reported levels of 0.99 mg/kg in pikes, for example, in the early years) from the submerged lands and *aapa* bogs, affecting the local people and wildlife.

Discussion and Conclusions

Lokka and Porttipahta are large reservoir systems in the Finnish Arctic. They were constructed in the 1960s and 1970s. Local Sámi and Finnish communities were not consulted about the establishment of these artificial lakes which permanently altered the traditional economies and cultures of reindeer herding, hunting and fisheries (Aikio, 1991).

One of the survival strategies for these communities subsequent to the construction of the reservoirs was commercial fishing. Despite fishermen having unsuitable boats (Murtomäki, 2020) for a large lake and the wrong gear for this activity, harvests of burbot, whitefish, ide (*Leuciscus idus*) and northern pike emerged quickly. However, national public awareness of the presence of methylmercury in predator fish (e.g., pike, perch, burbot; see Table EA1 above) soon limited local fishermen's income; as a result of the toxicity levels, few fish could be sold from Lokka to markets in southern Finland.

Messages concerning the released and accumulating Hg were intertwined with and embedded within the context of the larger loss and sadness that followed from the top-down creation of these reservoirs. For the Sámi and other locals, the assumption was that all wilderness fish was 'clean' and healthy, a staple diet throughout the year, as it had been for centuries. The capacity of Sámi and other locals to fully realize that key species like pike and burbot were suddenly contaminated was limited, and the warnings related to the public health hazard represented by consuming these species, insufficient as they were, went unheeded in the early years (Murtomäki, 2020). This difficulty in accepting the threats to health from key subsistence food sources can be considered as a self-defence mechanism in the face of the large, unprecedented alterations of traditional life.

Local anecdotes have also been reported concerning 'how to remove the mercury' from possibly contaminated food sources. These anecdotes can also be seen as mechanisms of social adaptation to cope in a world turned upside-down after events including but not limited to the relocation of many people from the wilderness villages into the Vuotso area. Those who stayed on the land in remote cabins were potentially completely unaware of the Hg pollution in the early years and were not warned of the health impacts, which amounted to a few references in public newspapers which were often not accessible in remote areas at the time.

Lokka and Porttipahta have not been discussed or debated at the national level for decades. Scientific measurements indicate that as soil humus levels have dropped, the levels of Hg in pike, perch and burbot are lower than in 1970s (peaking in the 1980s at a max level of 0.99 mg/kg and declining to 0.34 mg/kg by 2012). The reservoirs have therefore stabilized in ecological terms. For the Indigenous Sámi and other local people, however, the social and cultural cost of the construction of the reservoirs has been immense (Aikio, 1988).

Aikio (1988) also identifies that the development of the two reservoirs led to an acceleration of assimilation (of the Sámi with those already living in the Vuotso region) and, consequently, to the almost complete loss of the Sámi language in Vuotso. Integration, which in practice meant a transition from the Indigenous land-based life into the monetary economy, resulted in a major disruption to Sámi culture. Mercury loading and the presence of Hg in fish species central to Sámi cultural and economic practices, are key elements of the damage done; this damage will continue to influence the area with regards to both the Hg content in sediment (Verta et al., 1989) and in the shaping of human histories (Mustonen et al., 2011) in the long term.

EA Case Study 2: References

Aikio, P., 1978. The breakdown of a Lappish Ecosystem in Northern Finland. In: Papers of the Symposium on Unexpected Consequences of Economic Change in Circumpolar Regions at the 34th Annual Meeting of the Society for Applied Anthropology. Amsterdam, March 19-23, 1975. Boreal Institute for Northern Studies, The University of Alberta, Edmonton, Alberta, Canada. Occasional publication #14, January 1978.

Aikio, M., 1988. Saamelaiset kielenvaihdon kierteessä – Kielisosiologinen tutkimus viiden saamelaiskylän kielenvaihdosta 1910-1980. Mänttä: SKS, 1988.

Aikio, M., 1991. Mikä on Sompion Lappi? In: Aho, S., Aikio, P. and Keränen, T. (Eds). Tutkimuksen ja hallinnon vuorovaikutus ympäristörakentamisessa: Esimerkkitapauksena Lokan ja Porttipahdan tekoaltaat. Oulu: Research Institute of Northern Finland.

Berglund, M., Lind, B., Björnberg, K.A., Palm, B., Einarsson, O. and Vahter, M., 2005. Inter-individual variations of human mercury exposure biomarkers: a cross-sectional assessment. Environmental Health, 4:20.

Browne, D., 2007. Freshwater Fish in Ontario's Boreal: Status, Conservation and Potential Impacts of Development. WCS Canada Conservation Report No. 2. Wildlife Conservation Society Canada (WCS), Toronto, Ontario, Canada.

Murtomäki, E., 2020. Muistoja pohjolasta. (Memories of the North), unpublished diary entries. March 2020.

Mustonen, T. et al., 2011. Drowning Reindeer, Drowning Homes: Hydroelectricity and the Sámi in Sompio. Snowchange Cooperative, Kontiolahti, Finland.

Valste, J., 2008. Myrkkyjen leviämiseen havahduttiin. In: Telkänranta, H., 2008. Laulujoutsenen perintö: Suomalaisen ympäristöliikkeen taival. Helsinki: Suomen luonnonsuojeluliitto.

Verta M. et al., 1989. History of heavy metal pollution in Finland as recorded by lake sediments. Science of the Total Environment, 87/88:1-18.

Wahlström, E. et al., 1996. Suomen ympäristön tulevaisuus. Edita, Helsinki.

EA Case Study 3. Koitajoki: Finnish-Russian Border River

Author: Tero Mustonen, Snowchange Cooperative

Introduction

Koitajoki is a 200-kilometer-long waterway that begins in North Karelia, Finland, enters into the Republic of Karelia in Russia, and then returns to Finland. It is part of the Vuoksi watershed. The catchment area is characterized by large peat and marsh mire areas and lakes, including Koitere and Petkeljärvi.

Of importance to this case study are the endemic whitefish populations (*Coregonus lavaretus pallasi* and *Coregonus lavaretus wartmanni*). The *pallasi* species is an important species for biodiversity nationally. The lower part of Koitajoki, the Ala-Koitajoki, used to be the spawning area of the land-locked Atlantic Salmon (*Salmo salar*) of the Lake Saimaa basin. Historically, more than 30 000 fish would migrate upstream to spawn each year. The hydroelectric power plants at Kuurna, Kaltimo and Pamilo prevent these critically endangered salmon from reaching their ancestral spawning areas.

Large-scale ditching of marsh mires and peatlands for forestry and large-scale peat mining (Albrecht, 2019) have released Hg into the Koitajoki system (for example in the mid-1980s in the Koitajoki lakes, Hg levels in northern pike varied between 0.41 and 0.67 mg/kg); this Hg loading continues. Additional releases may have resulted from industrial gold mining in the catchment area (Albrecht, 2019).

The communities living along the Koitajoki are considered to have special status in Finland. The Finnish-Karelian epic *Kalevala* is based on the rune songs collected in Karelian villages, especially those along the Koitajoki (Ilomantsi, Megrijärvi, Ala-Koita and Möhkö). The population of the Koitajoki catchment on the Finnish side is predominantly comprised of Savo-Karelian (often Lutheran) and Karelian (Russian Orthodox) peoples. The local dialects of Savo-Karelia and the Karelian language are still spoken along the river. On the Russian side, there are few permanent villages left for historical reasons, but the area is used seasonally by Karelian families. Lake Vieksjärvi, part of the Koitajoki catchment, is a key location on the Russian side for traditional fishing. Of special importance is the preservation of the non-commercial river seining targeting *Coregonus lavaretus pallasi*. Seining has also been proven to cleanse the spawning areas of the endangered whitefish populations, helping to keep the spawning areas of the endangered whitefish populations free from humus and other organic matter (Mustonen and Mustonen, 2018). Regionally, plans are under way on an application for the river and its traditional culture to be included in national and international UNESCO Intangible Cultural Heritage Lists.

Residents of Koitajoki villages have been shown to possess traditional ecological knowledge of their river; yet Finland has no legislative recognition of traditional ecological knowledge (Mustonen and Mustonen, 2018). The Indigenous Sámi people in Lapland, who are linguistically related to Finns and Karelians, have secured some recognition for Sámi knowledge through national implementation of the Convention on Biological Diversity (CBD), signed by 150 government leaders at the 1992 Rio Earth Summit, specifically the implementation of Article 8j ('Traditional Knowledge, Innovations and Practices') and related legislation (CBD, 1992). In Russia, Karelians, especially the Veps, enjoy the protection of federal legislation regarding their culture, language and status. Russia considers Karelians a national minority. The Veps, a people who speak the Veps language (one of the Karelian language groups), have the status of a national Indigenous Peoples in Russia. North Karelia and Russian Karelia are today part of the Barents Euro-Arctic Region, positioning them politically as boreal northern regions, even though they reside geographically below the Arctic Circle.

Methods

For this case study, methods included a national literature review, community visits, and participant observation that led to the establishment of a community-based observation network by Snowchange Cooperative in 2016; early oral history documentation also took place between 2001 and 2015. Methods also included consulting with Traditional Knowledge holders, whose observations were geared towards the detection and contextualization of the presence of Hg in and around Koitajoki; open questions were also put to holders of Traditional Knowledge regarding boreal river systems and Hg. The main data for the case study were derived from the Finnish side of Koitajoki.

Mercury (Hg) is present in the natural boreal environment (Browne, 2007). When soils are altered — often through human disturbances such as forestry, burning, ditching, and mining — Hg embedded in the soil enters waterways, travels downstream, and reacts with water due to microbial actions (Browne, 2007). This results in methylmercury — a toxic substance that is ingested by wildlife and accumulates in the human body. Due to the process of biomagnification, accumulation is especially prominent among top predators, such as birds of prey and northern pike (*Esox lucius*), yellow perch (*Perca fluviatilis*) and pikeperch (*Sander lucioperca*).

Browne (2007:50) states that in boreal Canadian catchment areas where clear-cutting is practiced, Hg levels rose to between 2 and 9.6 times greater than normal levels, highlighting the significance of Hg contamination in boreal water systems. Systematic research on the impacts of Hg on boreal water systems began in Finland in 1966 (Valste, 2008). The issue rose to the national level in 1967 when Hg was associated with environmental impacts on the Kymijoki River. A national debate emerged between the prominent fisherman Pentti Linkola, who argued for the continued use of freshwater fish as food, and state environmental specialists, who stressed the health concerns of consuming fish (summarized in Valste, 2008). This debate lasted for over five years and resulted in more stringent public advisory messaging around Hg levels, but left many fishermen, like Linkola, feeling that their livelihoods had been affected negatively by the state environment officials.

At that time, the drivers of Hg levels were mainly industrial plants (Wahlström et al., 1996). Between the 1960s and the mid-1990s, Hg releases from industrial plants in Finland were cut in half (Wahlström et al., 1996). However, Wahlström et al. (1996) indicate that while the discharge of Hg from the pulp and paper-mill industry, as well as other industrial sources, has been diminishing, the environmental and soil sourcing of Hg has stayed the same.

Finland officially considers fish with detected Hg levels of over 1 mg/kg to be toxic. The Food and Agriculture Organization of the United Nations (FAO) imposes a stricter limit on Hg pollution, advising against consumption of most fish with levels above 5 mg/kg (Commission Regulation (EC) No. 1881/2006; see also in Berglund et al., 2005). The impacts of Hg on humans as a result of eating fish are more dangerous when those fish are taken from waters rich in humus (i.e., marsh mire and peatland catchment areas like Koitajoki) due to the way Hg attaches to humus particles; fish taken from humus-rich waters are bound to have more Hg as a result.

Verta et al. (1989) shows that the accumulation of Hg in the sediments of boreal lakes in Finland has been very significant, especially in Southern and Eastern Finland where Koitajoki is located. Wahlström et al. (1996) also stress the role of hydroelectric reservoirs as sources of Hg in northern lakes and rivers.

In Koitajoki the drivers of Hg loading include large-scale hydroelectric development (Pamilo, the largest of Vattenfall's hydropower plants in Finland) and its erosion impacts upstream (e.g., at Lake Koitere; see Albrecht, 2019), peat production and forestry management actions (Mustonen and Mustonen, 2018; Albrecht, 2019) and site-specific potential impacts of gold mining by the company Endomines. Browne (2007) also mentions forestry itself (e.g., ponds created by the forestry tractors) as a driver of Hg loading, with groundwater and surface run-off and logging roads transporting Hg downstream.

Koitajoki Traditional Knowledge has been documented since the early 1800s (Mustonen and Mustonen, 2018). The stimulus for this was outsider interest in the wilderness cultures, economies and villages of Karelia, especially the epic songs and other 'traditional' culture. This early documentation waned during the 1940s, when researchers' interest in Karelia diminished. The years of modernity (1944–1991) altered the catchment area and its ecology. The aforementioned forestry, peat production and hydroelectric development occurred during this period. The regional Snowchange Cooperative started a new round of community-based documentation of traditions and oral histories around Koitajoki in 2001. In 2016, Snowchange was commissioned by the regional environmental authorities to document Traditional Knowledge associated with the river communities. This resulted in an on-going community-based monitoring (CBM) project in which Hg is one of the observed indicators. Mustonen and Mustonen (2018) document the first two years of the CBM work. Miller (2019) documents river seining, a local traditional practice which has cultural and environmental impacts on a national level, to monitor and maintain river health. For this case study, the main summaries of the CBM work and the science results have been included.

Results

Albrecht (2019) links a widespread increase in Hg levels in the 1970s and 1980s to the establishment of the Pamilo hydroelectric power station in 1955. The increase was particularly noticeable in Lake Koitere, where Hg levels are impacted by fluctuations in water level associated with hydropower production (i.e., the increase of Hg in pikes from 0.4 mg/kg in 1970s to 0.7 mg/kg by the 1980s; Albrecht, 2017). On Lake Koitere, water levels have sometimes fluctuated to such an extent that the shoreline has shifted up to 25 meters. Mononen et al. (1989) say that, in one section of the Koitajoki, the levels of Hg increased by a factor of five between the 1970s and the mid-1980s. Forestry has also been identified as a source of Hg in the Koitajoki system; since the 1980s, local communities have drawn associations between the use of fertilizers in forestry with increased Hg levels in the Koitajoki (Parviainen, 2014; Albrecht, 2019). The gold mining operations run by the Endomines company in the center of the catchment area may be an additional source of Hg.

From the CBM and Hg study between 2016 and 2018, Mustonen and Mustonen (2018) report that the lakes in the Koitajoki system with humus waters are a cause of concern. Mercury accumulates particularly in northern pike and burbot (*Lota lota*). For example, pike in Lake Nuorajärvi are perceived to suffer from this problem (with levels above 0.6 mg/kg reported in the mid-1980s). Pike and burbot are used extensively as a food fish in the Koitajoki system.

Markku Uusitalo, a local seine fisherman in his seventies, reports (in Mustonen and Mustonen, 2018) that his body contains twice the national average level of Hg. He feels extremely sad that increased Hg levels have ruined the northern pike fishery. He also discusses the fact that authorities did not warn about the danger of Hg accumulation in northern pike, which he ate daily in the 1970s and 1980s. Uusitalo (in Mustonen and Mustonen, 2018) shares the concerns of many fishermen on the Koitajoki in the oral history by asking: "*How can authorities even today advise eating these fish – calling [northern pike] a health food – when they contain neurotoxins?*" Uusitalo, who is a leader of local fishermen in Möhkö, reports that the fishermen associate the present loading of Hg especially with the forestry ditches that flow into the Koitajoki main stream and lakes. Mononen et al. (1989) agree with Uusitalo on the catalytic impact of ditching in releasing Hg. According to Uusitalo, regional authorities and researchers collected new samples from people living on the Koitajoki River in 2016 and 2017 to assess Hg levels in their bodies but the "*results have never been released, even though I called them and asked for them*" (Mustonen, 2019). Parviainen (2014) reports that the sampling of predator fish in the system has demonstrated high levels of Hg in the system (e.g., 0.74 mg/kg in young pikes in 2014). He says the primary impact of Hg can be most easily detected in the areas close to the Pamilo hydroelectric power station.

Discussion and Conclusions

Koitajoki is a major catchment area on the Finnish-Russian border and a centrally important part of Karelian culture (with the national epic *Kalevala* having been inspired by oral histories and epic songs collected along its course). Ecologically, it has been a very significant spawning stream for land-locked Atlantic salmon and endemic whitefish species as well as other wildlife. The catchment area consists primarily of marsh mires and peatlands (i.e., humus waters low in pH and high in Hg, embedded in the soils and part of the natural environment). Until the early 1900s, Koitajoki was in a well-preserved, close to natural state (largely undisturbed and unaltered by the subsistence fishing and agriculture carried out along its course). Between 1944 and 1991, large-scale forestry, peat mining, ditching and hydro-electric development altered the river system, activities which also led to increases in Hg levels.

Both science and community-based observations confirm the large amount of Hg currently in the system (e.g., Parviainen, 2014 has detected levels of 0.74 mg/kg in pikes; Verta et al.,1989 highlights the role of sediments, where Hg has accumulated as a future driver of concern). In the Koitajoki system, local dialects and the Karelian language have co-developed with the river; deep oral histories, customs and cultural indicators are products of this co-development, all of which local communities rely upon as part of the traditional ecological knowledge they use to assess and monitor the health of the river and the fish. Of high importance is the unbroken tradition of river seining, which is still practiced on the Koitajoki.

Community-based observations regarding Hg (e.g., fish samples delivered for scientific analysis) are in line with expert knowledge (as summarized in Parviainen, 2014). Methylmercury accumulates mainly in predator fish, especially in northern pike and burbot. Both of these culturally important species are consumed in households and are fished as part of small-scale commercial operations in the river system. Some fishermen, such as Markku Uusitalo, have expressed concern over the historic lack of effective bans on fishing for these predator fish or reliable information on the health impacts of neurotoxins.

The question of present-day Hg loading into lakes and rivers in Finland remains sensitive. While the pollution associated with plants and industrial sourcing in the 1960s was curtailed, the pollution from hydroelectricity production, forestry management, and peat mining (collectively termed 'catchment area loading') is ongoing. The specific impacts of this industrial activity, carried out by the state as well as private enterprise, have not been linked to Hg and its impacts to nature and humans clearly enough, according to the CBM data (Mustonen and Mustonen, 2018). Some fishermen even feel that their own test results have been hidden from the public. With regards to Canada's boreal zone, a similar ecosystem, Browne (2007) says that, at present, the accumulation of Hg in waterways cannot be predicted adequately due to clear-cutting. This means that the baseline of Hg loading should be urgently investigated across catchments, and thresholds of Hg for forestry operations should be put in place (Browne, 2007:11).

CBM and Traditional Knowledge holders have much to contribute to Hg monitoring efforts in the Koitajoki system. Traditional river seining is actively maintaining and renewing whitefish spawning locations, thus alleviating humus loading. Large-scale catchment restoration work has begun (e.g., the Landscape Rewilding Programme and LIFE programs, Mustonen and Mustonen, 2018; Albrecht, 2019). The promise of these actions is that they could, at least in part, lessen the impact of catchment area loading (of both organic matter and Hg) to the river and give the fish and the river time and space to recover. CBM monitoring efforts will constitute a central element of this work in the 2020s.

EA Case Study 3: References

Albrecht, E., 2019. Ilomantsin luonnonvarojen käytön historiaa Koitajoen ympäristön tilan muutosten kuvaajana. Raportteja 49. Joensuu: Pohjois-Karjalan ELY-keskus.

Berglund, M., Lind, B., Björnberg, K.A., Palm, B., Einarsson, O. and Vahter, M., 2005. Inter-individual variations of human mercury exposure biomarkers: a cross-sectional assessment. Environmental Health, 4:20.

Browne, D., 2007. Freshwater Fish in Ontario's Boreal: Status, Conservation and Potential Impacts of Development. WCS Canada Conservation Report No. 2. Wildlife Conservation Society Canada (WCS), Toronto, Ontario, Canada.

CBD, 1992. The Convention on Biological Diversity (CBD). Rio de Janeiro, 5 June 1992. United Nations, Treaty Series, vol. 1760, p.79.

Mononen, P., Antikainen, T. and Kiiski, J., 1989. Koitajoen vesistöalueen tila ja siihen vaikuttaneet tekijät v. 1977-1987. Vesi- ja ympäristöhallituksen monistesarja, Nro 244. Helsinki: Vesi- ja ympäristöhallitus, 1989.

Mustonen, T., 2019. Personal communication from M. Uusitalo to T. Mustonen, Snowchange Cooperative.

Mustonen, T. and Mustonen, K., 2018. Koitajoen erämaataloudet muuttuvassa ympäristössä. Snowchange Cooperative, Kontiolahti, Finland.

Parviainen, A., 2014. Kalojen elohopeapitoisuudet Pielisjoen, Pielisen, Höytiäisen, Koitereen ja Koitajoen vesistöalueilla. Mikkeli University of Applied Sciences. 61pp. Available at: https://www.theseus.fi/bitstream/handle/10024/73194/alojen+elohopeapitoisuudet+Pielisjoen+Pielisen+Hoytiaisen+Koitereen+ja+Koitajoen+vesistoalueilla.pdf;jsessionid=C3F91D6669C97A34C1DF26CC01326BD6?sequence=1

Valste, J., 2008. Myrkkyjen leviämiseen havahduttiin. In: Telkänranta, H., 2008. Laulujoutsenen perintö: Suomalaisen ympäristöliikkeen taival. Helsinki: Suomen luonnonsuojeluliitto.

Verta M. et al., 1989. History of heavy metal pollution in Finland as recorded by lake sediments. Science of the Total Environment, 87/88:1-18.

Wahlström, E. et al., 1996. Suomen ympäristön tulevaisuus. Edita, Helsinki.

EA Case Study 4. Linking environmental mercury data with Indigenous Knowledge

Author: Tero Mustonen, Snowchange Cooperative

Introduction

This short paper draws links between Indigenous Knowledge and observations of Hg levels in the environment and official Russian and Soviet limnological data on Hg in the Ponoi River. The 426-kilometer-long Ponoi River and its catchment area are of great ecological and cultural value in Northern Europe (Prusov et al., 2001; Feodoroff and Mustonen, 2013). The Ponoi is located in the eastern wilderness part of the Kola Peninsula in the Murmansk region of Russia. The catchment area of 15 467 km^2 is mostly in an undisturbed ecological state (Prusov et al., 2001; CAFF, 2013, Nikanorov et al., 2016).

The Ponoi, like other northern rivers, is fed by snowmelt, precipitation, groundwater, and (to a lesser extent) glacial melt (AMAP, 1998:127). As with most Arctic rivers, the peak flow of the Ponoi happens during spring melt (AMAP, 1998:19). Ecologically key fish species in rivers of the Kola Peninsula include Arctic char, brown trout (*Salmo trutta*), and Atlantic salmon (AMAP, 1998). Stocks of Atlantic salmon include genetically distinct regional populations (Tonteri et al., 2009; Ozerov et al., 2012, 2013). Salmon stocks are affected by Norwegian harvests (Thorstad et al., 2013; Ozerov et al., 2016). The Ponoi River also contains northern pike.

As well as its biodiversity, the Ponoi region is important for cultural heritage. Sámi communities speaking Eastern Ter Sámi (one of nine Sámi languages spoken across Fennoscandia) are the first historically known peoples of the Ponoi region. Prior to the 1600s, the Sámi had at least six distinct Indigenous community areas or *siidas* (Mustonen and Mustonen, 2013) in the present-day Ponoi River catchment area. Starting in the latter part of the 19^{th} century, Komi people from the Arkhangelsk region expanded into the Murmansk region and settled many of the Ponoi villages (Konstantinov, 2009; Fryer and Lehtinen, 2013; Mankova, 2018), including the former Sámi community of Chalme-Varre, which was renamed 'Ivanovka' by the Komi (Mustonen and Mustonen, 2013; Mankova, 2018). Today, the villages of Krasnochelye, Kanevka and Sosnovka are the last roadless communities in the Murmansk region. In these villages, Sámi, Komi, Pomor and Russian cultures meet (Konstantinov, 2009; Fryer and Lehtinen, 2013; Mankova, 2018).

Methods

The detection of Hg using Arctic Indigenous Knowledge alone would be rather complex. The accumulated impact of Hg may take years to develop and often requires scientific, especially limnological, sampling to detect. For this case study, we draw links between two methods of investigation into elevated Hg levels (i.e., scientific sampling and community-based monitoring; CBM). The community-based network drawn upon for this case study has been in place since 2006.

We analyzed results of oral histories and community-based observation (CBO) from Ponoi and adjacent Sosnovka villages between 2005 and 2020 (see more in Johnson et al., 2015). These oral histories and observations have been collected and approved having secured free, prior and informed consent from participants in the following ways:

- Fieldwork trips to Krasnochelye, Chalme-Varre and Ponoi River (August, 2006)
- Oral history and land use interviews and workshops with co-researchers in Krasnochelye, Kanevka and Sosnovka (2007–2010)
- Training and data documentation by local teams in Krasnochelye, Kanevka and Sosnovka (2011–2017)
- Advanced local documentation teams, review of catch diaries and environmental data forms and collection of oral histories in Krasnochelye, Kanevka and Sosnovka, resulting in over 9000 data items (2018–2020)
- ~80 people involved in the study either as co-researchers and/or interviewees (2006–2020).

Earlier CBO results have been summarized in Mustonen and Mustonen (2013), Feodoroff and Mustonen (2013) and in yearly work reports from 2013 to 2020.

For the CBO observations we are using the analytical frame of 'river health' taken from Huntington et al. (2017), which consists of both community observation and interviews with individuals. Observations are analyzed using both Indigenous Knowledge and traditional knowledge (Ambrose et al., 2014) and available scientific information (Soviet and Russian observational data combined with a literature survey, Velichkin et al., 2013). According to AMAP (1998:51), rivers transport contaminants and also store them in ice. Pollution may have initially made its way into the river from the air, the catchment area and from sediment sourcing (AMAP, 1998). Rivers can transport contaminants away from the immediate sites of pollution events; pollution can concentrate through sedimentation in slow-flowing parts of a river system.

Results

Feodoroff and Mustonen (2013:37-38, also 2014, 2015) worked with Russian researchers to review archival data of the regional environmental monitoring stations from the late Soviet era (1975–1991) for Ponoi River. In the Russian data, high total levels of Hg were recorded (see Table EA2 below).

Other indicators of interest reviewed included phenols, heavy metals and oil substances in the Ponoi limnological data (Feodoroff and Mustonen, 2013:37-38). These Soviet-era data have recently become more accessible; at least for the time

Table EA2. Mercury levels in the Ponoi River during the late Soviet era (1975–1991) collected from regional environmental monitoring stations. Source: Feodoroff and Mustonen (2013).

	Levels of mercury (THg), in µg/L
1979–1983	High levels of mercury*
1980	300 µg/L
1983	80 µg/L
2000	High levels of mercury**

*More accurate mercury levels not available
**Exact amounts have not been made public

being, this has allowed international cooperation with academic and research organizations in Russia. Due to potentially poor scientific and data control standards and concerns with regards to censorship, the data should not be assumed to be entirely reliable. It should, however, be said that the data described above (in Table EA2) were cross-referenced by a Nordic limnologist, Tarmo Tossavainen, and found to be generally consistent.

Ponoi is a wilderness river system that, in the past, has been relatively undisturbed. However, during the Soviet era, the villages of Krasnochelye and the closed military installations in the catchment area may have released the pollutants, including Hg, found in the historical data. The Hg loading most likely dissipated downstream. Potential sedimentation may have taken place on the lake systems close to Chalme-Varre where the flow of the Ponoi slows and where the river widens into a lake. Adding to the list of unknown drivers of change in the Russian Arctic, AMAP (1998:234) identified the presence of polychlorinated biphenyls (PCBs; highly toxic industrial compounds) in sediments across northern Russian rivers, including the Ponoi. This contamination may come partly from sites outside the area via airborne pollution.

Following the discovery of a range of environmental issues in the historical data, community-based monitoring (CBM) efforts focused on documenting oral histories (see Table EA3), especially in Krasnochelye, regarding events that may have taken place in the Soviet era. Convergence or divergence between local knowledge and scientific information regarding the Hg data was sought.

The results are preliminary and will eventually be released in peer-reviewed journals. However, at this time, we can, from the CBM data, give a number of examples of events we do know to have taken place (see Table EA3).

Table EA3. Examples of events described in the CBM data. Sources: Feodoroff and Mustonen, 2013; Mustonen and Mustonen, 2013; and see also 'Methods' section above.

	Events described in CBM
1965	Uranium test sites leaked materials into Lake Yelskii
1968	Large diesel spill took place in the village of Krasnochelye
1969	Waste and hazardous materials released into the Ponoi (most likely by 'the collective farm')
1980	Mercury levels peak – "color of the river changes"
1950–1991	Fertilizers dumped into the Ponoi River (yearly)

Discussion and Conclusions

This case study has mostly focused on methods of detecting Hg and other hazardous-related observations in the Russian Arctic. We have focused on the Ponoi River in Russia's Murmansk region. Critical analysis of Soviet-era environmental data is still needed. However, where accessible, the data can provide crucial leads and identify drivers of change that may affect Hg levels, even today, in waters and sediments. Results from long-term cooperation with community-based monitoring networks in the Ponoi region, which began in 2006, have been cross-referenced with data from archives showing that high levels of Hg were detected in the river, especially in the late Soviet era between 1979 and 1983.

CBM observations were aimed at reconstructing pollution events and assessing convergence or divergence with scientific and historical data. The final conclusions are still to be made as the community work is ongoing. The CBM work, when it is reviewed for 2020–2021, will aim to include fish sampling (of pike and burbot) to determine the exact levels of Hg in different parts of Ponoi.

From looking at both the CBM and the sampling data, a range of human-induced environmental events and their impacts on a river system that was previously considered 'pristine', can be identified; these include the dumping of chemicals, the release of pollutants, including Hg, from mining and uranium sites, agriculture, diesel spills, and other events. This may also include settled sedimentation of harmful substances and toxins in lakes located along the main Ponoi channel, especially lakes close to Chalme-Varre.

Convergence between monitoring data and oral history accounts will emerge more clearly as community monitoring continues. The Ponoi model is important in making use of past environmental data to understand the present, especially in the context of Hg monitoring and how it ultimately affects northern Indigenous communities, their health and their waters. Oral history can be useful in identifying undeclared pollution events and directing future CBM efforts or scientific monitoring and remediation. Traditional, Indigenous and local knowledge has often been critical in the context of a limited flow of government information and has helped both protect community and ecological health.

EA Case Study 4: References

Community-based monitoring and oral history materials

Feodoroff, P. and Mustonen, T., 2013. Ponoi and Näätämö River Collaborative Management Plan. Snowchange Cooperative, Kontiolahti, Finland.

Mustonen, T. and Mustonen, K., 2013. Eastern Sámi Atlas. Snowchange Cooperative, Kontiolahti, Finland.

Mustonen, T. and Feodoroff, P., 2014. 2013 Work Report from Ponoi and Näätämö Rivers.

Mustonen, T. and Local Coordinators, 2015. 'Flow of Life' – Photo Essay of the Community Workshops December 2014-January 2015 devoted to the River Ponoi Traditional Knowledge Work.

Mustonen, T. and Feodoroff, P., 2015. 2014-2015 Work Report from Ponoi and Näätämö Rivers.

Mustonen, K., Mustonen, T. and Kirillov, J., 2018. Traditional Knowledge of Northern Waters. Snowchange Cooperative, Kontiolahti, Finland.

Research literature included in the literature review

Alekseev, M. and Prusov, S., 1998. Estimates of Conservation Limits for Atlantic Salmon Females for Four Russian Rivers. International Council for the Exploration of the Sea (ICES), Copenhagen, Denmark.

Alekseev, M. et al., 2019. Distribution, spawning and the possibility of fishery of the introduced pink salmon (*Oncorhynchus gorbusha Walbaum*) in rivers of Murmansk Oblast. Russian Journal of Biological Invasions, 10 (2):109-117.

Allemann, L., 2018. "I do not know if Mum knew what was going on": social reproduction in boarding schools in Soviet Lapland. Acta Borealia, 35 (2): 115-142.

Azbelov, A. et al., 1963a. Study of the seaward migration of the Pacific salmons and the perspectives of their Acclimatization in the Waters of the White Sea and the Barents Sea. International Council for the Exploration of the Sea (ICES), Copenhagen, Denmark.

Azbelov, A. et al., 1963b. Continued Study of the Seaward Migration of the Pacific Salmons and the Perspectives of their Acclimatization in the Waters of the White Sea and the Barents Sea. International Council for the Exploration of the Sea (ICES), Copenhagen, Denmark.

AMAP, 1998. AMAP Assessment Report: Arctic Pollution Issues. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xii + 859pp.

AMAP, 2017. Adaptation Actions for a Changing Arctic: Perspectives from the Barents Area. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xiv + 267pp.

Ambrose, W. et al., 2014. Interpreting environmental change in Coastal Alaska using traditional and scientific knowledge. Frontiers in Marine Science, 1:40.

Astakhov, V. et al., 2016. Glaciomorphological map of the Russian Federation. Quaternary International, 420:4-14.

Britskaya, T., 2019. Reindeer Under Fire in Sámi Lands. The Barents Observer, 19th February, 2019. Available at: https://thebarentsobserver.com/en/ecology/2019/02/reindeer-fire-sami-lands

CAFF, 2013. Arctic Biodiversity Assessment: Status and Trends in Arctic Biodiversity. Conservation of Arctic Flora and Fauna (CAFF), Akureyri, Iceland.

Colbourne, R. and Anderson, R., 2020. Indigenous Wellbeing and Enterprise: Self-Determination and Sustainable Economic Development. Routledge. 325pp.

Fryer, P. and Lehtinen, A., 2013. Iz'vatas and the diaspora space of humans and non-humans in the Russian north. Acta Borealia, 30 (1):21-38.

Gordeeva, N. et al., 2015. Variability of biological and population genetic indices in pink salmon, transplanted into the White Sea. Journal of Icthyology, 55 (1):69-76.

Helskog, K., 2012. Bears and meanings among hunter-fisher-gatherers in Northern Fennoscandia 9000-2500 BC. Cambridge Archaeological Journal, 22 (2):209-236.

Huntington, H.P., Begossi, A., Fox Gearheard, S., Kersey, B., Loring, P.A., Mustonen, T., Paudel, P.K., Silvano, R.A.M. and Vave, R., 2017. How small communities respond to environmental change: patterns from tropical to polar ecosystems. Ecology and Society, 22 (3):9.

Holmberg, A., 2018. Bivdit Luosa – To ask for salmon. Saami traditional knowledge on salmon and the river Deatnu: In research and decision-making. Master's thesis in Indigenous Studies. UiT – The Arctic University of Norway, Tromsø.

Carter, Jimmy, 2015. Glasnost on the Ponoi. Fly Fisherman, 46:3.

Filatov, N. et al., 2016. Water resources of the northern economic region of Russia: state and use. Water Resources, 43 (5):779-790.

ICES, 2009. Report of the Working Group on North Atlantic Salmon (WGNAS). International Council for the Exploration of the Sea (ICES), Copenhagen, Denmark. 282 pp.

ICES, 2018. Report of the Working Group on North Atlantic Salmon (WGNAS). International Council for the Exploration of the Sea (ICES), Woods Hole, MA, USA. 386 pp.

ICES, 2019. Report of the Working Group on North Atlantic Salmon (WGNAS). International Council for the Exploration of the Sea (ICES), Woods Hole, MA, USA. Available at: https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2019/2019/sal.oth.nasco.pdf

Johnson, N., Alessa, L., Behe, C., Danielsen, F., Gearheard, S., Gofman-Wallingford, V., Kliskey, A., Krümmel, E., Lynch, A., Mustonen, T., Pulsifer, P. and Svoboda, M., 2015. The contributions of community-based monitoring and traditional knowledge to Arctic observing networks: reflections on the state of the field. Arctic, 68 (5; Supplement 1):28-40.

Kalinin, A. et al., 2017. New promising gold-ore objects in the Strelna Greenstone Belt, Kola Peninsula. Geology of Ore Deposits, 59 (6):453-481.

Kalinin, A. et al., 2019. Gold prospects in the western segment of the Russian Arctic: regional metallogeny and distribution of mineralization. Minerals, 9:137.

Kashulin, N., 2017. Selected aspects of the current state of freshwater resources in the Murmansk region, Russia. Journal of Environmental Science and Health, Part A, 52 (9):921-929.

Konstantinov, Y., 2009. Roadlessness and the Person: modes of travel in the reindeer herding part of the Kola Peninsula. Acta Borealia, 26 (1):27-49.

Kritzberg, E. et al., 2020. Browning of freshwaters: consequences to ecosystem services, underlying drivers and potential mitigation measures. Ambio, 49:375-390.

Lunkka, J. et al., 2018. Late Pleistocene palaeoenvironments and the last deglaciation on the Kola Peninsula. Arktos, 4:18.

Magritskii, D., 2008. Anthropogenic impact on the runoff of Russian rivers emptying into the Arctic Ocean, Water Resources, 35 (1):1-14.

Makarova, O. and Khokhlov, A., 2009. The status and management of moose in the Murmans Region, Russia. Alces, 45:13-16.

Makhrov, A. et al., 2014. Historical geography of pearl harvesting and current status of populations of freshwater pearl mussel in the western part of northern European Russia. Hydrobiologia, 735:149-159.

Mankova, P., 2018. The Komi of Kola Peninsula within ethnographic descriptions and state policies. Nationalities Papers, 46 (1):34-51.

Mustonen, T., 2014. Endemic time-spaces of Finland: aquatic regimes. Fennia - International Journal of Geography, 192 (2):120-139.

Mustonen, T. and Mustonen, K., 2016. Life in the Cyclic World – Traditional Knowledge Compendium of Eurasia. Snowchange Cooperative, Kontiolahti, Finland.

Mustonen, T. and Mustonen, K., 2019. Koitajoen erämaatalouksista (Wilderness Economies of Koitajoki River). ELY-Keskus, 2019.

Niemelä, E. et al., 2016. Pink Salmon in the Barents Region With Special Attention to the Status in the Transboundary Rivers Tana and Neiden, Rivers in Northwest Russia and in East Canada. Office of the Finnmark County Governor. Department of Environmental Affairs.

Nikanorov, A. et al., 2016. Many-year variations of water pollution and the state of river ecosystems in different latitudinal zones in European Russia. Water Resources, 43 (5):791-802.

Osherenko, G., 2001. Indigenous rights in Russia: is title to the land essential for cultural survival? Georgetown International Environmental Law Review, 13 (3):695-734.

Ozerov, M. et al., 2012. "Riverscape" genetics: river characteristics influence the genetic structure and diversity of anadromous and freshwater Atlantic salmon (*Salmo salar*) populations in northwest Russia. Canadian Journal of Fisheries and Aquatic Sciences, 69:1947-1958.

Ozerov, M. et al., 2013. Cost-effective genome-wide estimation of allele frequencies from pooled DNA in Atlantic salmon (*Salmo salar L.*). BMC Genomics, 14:12.

Ozerov, M. et al., 2016. Comprehensive microsatellite baseline for genetic stock identification of Atlantic salmon (*Salmo salar L.)* in northernmost Europe. ICES Journal of Marine Science, 74 (8):2159-2169.

Pecl. et al., 2017. Biodiversity redistribution under climate change: impacts on ecosystems and human well-being. Science, 355 (6332):eaai9214.

Polyakova, T. et al., 2016. Diatoms and aquatic palynomorphs in surface sediments of the white sea bays as indicators of sedimentation in marginal filters of rivers. Oceanology, 56 (2):289-300.

Post, E. et al., 2019. The polar regions in a 2°C warmer world. Science Advances, 5, 12.

Prusov, S. et al., 2001. Mark-recapture estimate of the stock abundance of Atlantic salmon done during catch-and-release fishing on the Ponoi River, Kola Peninsula, Russia. International Council for the Exploration of the Sea (ICES), Copenhagen, Denmark.

Rybråten, S. and Gómez-Baggethun, E., 2016. Lokal og tradisjonell økologisk kunnskap i forskning og forvaltning av laks. En forstudie (Local and traditional ecological knowledge in salmon research and management. A preliminary study). Nina Rappot 1290. Norsk institutt for naturforskning (NINA), Trondheim, Norway. 80pp.

Sandlund, O et al., 2018. Pink Salmon in Norway: the reluctant invader. Biological Invasions, 21:1033-1054.

IPCC, 2019. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. Pörtner, H.-O., et al. (Eds.). Intergovernmental Panel on Climate Change (IPCC). In press.

Simpson, L., 2017. As we have always done: Indigenous Freedom through Radical Resistance. University of Minnesota Press, Minneapolis. 320pp.

Slezkine, Y., 1996. Arctic Mirrors – Russia and the Small Peoples of the North. Cornell. 476pp.

Thorstad, E. et al., 2003. Effects of hook and release on Atlantic salmon in the River Alta, Northern Norway. Fisheries Research, 60:293-307.

Thorstad, E., 2013. Factors affecting the within-river spawning migration of Atlantic salmon with emphasis on human activities. Reviews in Fish Biology and Fisheries, 18:345-371.

Tkachenko et al., 2017. Современное состояние зараженности атлантического лосося р. Поной (Мурманская область) личинками нематоды Anisakis simplex/Current Infestation Status of Atlantic Salmon with Anisakis simplex larvae in the river Ponoi (the Murmansk Region). Вестник МГТУ. 2017. Т. 20, No 2. С. 455-462.

Tonteri, A. et al., 2009. Microsatellites reveal clear genetic boundaries among Atlantic salmon populations from the Barents and White seas, Northwest Russia. Canadian Journal of Fisheries and Aquatic Sciences, 66:717-735.

Vasiliev, A. et al., 1973. The system of Serebryansk hydroelectric plants on the Voro'ya River. Gidrotekhniches Stroitel'stvo, 10:1-5.

Velichkin, V. et al., 2013. Radioecological environment and radiogeochemical regionalisation of Northwestern Russia. Doklady Earth Sciences, 453 (1):1154-1157.

Whoriskey, F. et al., 2000. Evaluation of the effects of catch-and-release angling on the Atlantic salmon (Salmo salar) of the Ponoi River, Kola Peninsula, Russian Federation. Ecology of Freshwater Fish, 9:118-125.

Yang, X. et al., 2020. The past and future of global river ice. Nature 577 (7788):69-73.

Zozulya, D. et al., 2009. Lithosphere mantle structure and diamond prospects in the Kola Region: chemical and thermobarometric analyses of kimberlite pyrope. Doklady Earth Sciences, 427 (5):746-750.

Zubchenko, A. et al., 1996. Atlantic salmon from Russian rivers. Fisheries and state of the stocks in 1995. International Council for the Exploration of the Sea (ICES). 10pp.

Zubchenko, A. et al., 1998. Salmon rivers on the Kola Peninsula. Some Results of Acclimation of Pink Salmon. International Council for the Exploration of the Sea (ICES). 8pp. (+ table + figures).

EA Case Study 5. Kolyma: a major river in Northeastern Siberia

Lead Author: Tero Mustonen, Snowchange Cooperative

Contributing Author: Vyacheslav Shadrin

Introduction

Kolyma is a major river in northeastern Siberia. The river is 2700 kilometers long and has a catchment area of over 647 000 km^2 (see Figure EA6). It is home to Indigenous Yukaghir, Even, Chukchi, Evenki and Koryak Peoples. The Kolyma region is known for the numerous Gulags (forced labor camps) that were established by Stalin and the Soviet Union in the mid-20th century around the catchment area in Magadan, Sakha Republic and Chukotka, and the associated gold mining activities.

Community-based monitoring (CBM) and oral history work has taken place along the lower Kolyma (Mustonen and Shadrin, 2021) and the mid-Kolyma (Yukaghirs in the community of Nelimnaya). This case study draws on almost 20 years of research work on the Kolyma River, as well as existing public literature. In this study, we identify and discuss Hg pollution using a systems view that understands Indigenous communities and the lands and waters they inhabit as unified systems. Complementing this systems view are new, analytical maps of key sites and locations. It is impossible to summarize Indigenous Knowledge of several peoples and their diverse ways of knowing. Therefore, in this case study, we have focused on the main drivers affecting Indigenous health and the role Indigenous Knowledge plays in identifying and responding to these main drivers.

Methods

Applying a systems view in the context of Indigenous Peoples and Hg pollution remains challenging for large basins like the Kolyma. The specific detection of Hg impacts may be 'buried under' other drivers affecting Indigenous health. Community observations and impacts diverge from government health-related data both domestically in Russia, where Hg is rarely reported by artisanal small-scale gold mining (ASGM) operations, and internationally. This Kolyma Basin case study highlights the need to link these likely drivers of Hg levels with aquatic and biological sampling from the headwaters to the delta (see Tiaptirgianov, 2016). This study should be considered the start of longer-term monitoring work.

Methodologically, we have collected community voices from the Kolyma Basin (between 2005 and 2020), results from field surveys between 2005 and 2020, remote sensing and satellite image interpretation and geographical analysis (see Tiaptirgianov, 2016) relevant to known drivers of Hg levels in the environment and their impact on Indigenous Peoples. We have also surveyed regional governmental data reports to assess the presence or absence of Hg measurements in official data.

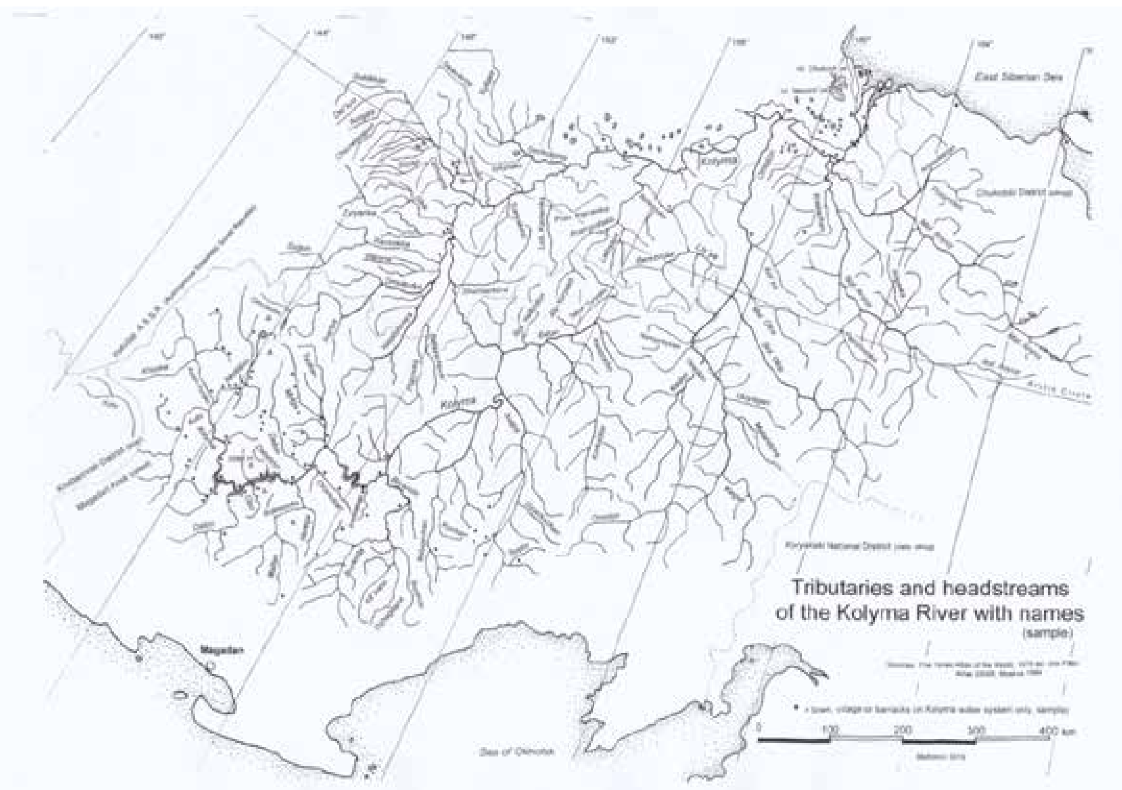

Figure EA6. A map of Kolyma River basin. Source: Jorma Mattsson, Snowchange Cooperative, 2022.

Results

Kolyma is a major Siberian river; the state of this river has consequences on an Arctic and global scale. The Kolyma Basin is home to unique Indigenous cultures, of which the Yukaghir culture and language are the most threatened. This precarious moment in time is captured in a recent oral history from Ekaterina Nikolaevna Dyachkova, a 95-year-old woman living in Nelimnaya, Kolyma, in her oral history:

"Almost all families are mixed.
Even my grandchildren are in mixed families with Russians.
You cannot even tell that they are Yukaghirs.
Such is our life.
We, the Yukaghirs, have our own language and our own traditions ...
But we are disappearing ...
We are doomed to die out.
There used to be a lot of Yukaghirs.
Every one of them used to have [their] own household.
Ten rivers …
they used to be full of people …
Why are they not here now?
They all had their own family …
and their own yurtas.
They are not here any longer. They burned out ...
They burned out completely.
Now I see it in my dreams …
I ask, 'Where have all your friends gone?'
They answer, 'They [have travelled to] other places'"
(Semenov, 2007).

Given the scale of Hg sourcing and the relevance of this pollution to a large number of Indigenous communities — many of which are fully dependent on the Kolyma Basin for their food security, cultural and social well-being and traditional economies — we have divided the main drivers of Hg pollution into several main categories: hydroelectric power stations and associated reservoirs; artisanal gold mining; Gulag and industrial gold mining; and permafrost loading. Each category is discussed briefly below.

In spring 2020, surveys were conducted in Kolyma Indigenous communities (with an emphasis on communities in Nelimnaya, Zyryanka and in the Lower Kolyma area). Results of these documentations included observations on the following:

- The influence of coal mining (Ugolny Razrez LLC) near the urban settlement of Zyryanka is a major source of concern. Local Indigenous residents (mostly Even) say that this coal has a high proportion of radioactivity. In the context of Hg and other pollutants, coal transportation by river remains an unknown factor (i.e., how much impact this has on Hg in the environment). Open boats transport the coal so that pollutants (in the form of coal dust) can easily enter the waters of the Kolyma.
- The use of coal in local heating stations (*kotelnaya, boilers*) is another main concern. The smoke from the burning of coal is never filtered and pollutes not only the air in urban settlements, but also enters the natural environment more widely, including rivers and lakes. Levels of Hg present in the coal itself or that enter the natural environment as a result of coal burning are unknown but remain an issue from the Indigenous viewpoint.
- Logging in the Kolyma Basin has practically been stopped because of its high cost. However, in the 1990s, the forestry industry was actively developing and many parts of the taiga were deforested. Clear-cutting has been identified as a source of Hg in boreal habitats. Indigenous Elders have said that the spirits of the forest are angry. According to Elders, timber floating has also altered parts of the Kolyma. Increased forest fires have also been identified as a source of concern with regard to Hg releases.
- Many local people in the Lower Kolyma area are concerned about the Bilibino nuclear power plant in Chukotka, the only nuclear power plant constructed on permafrost. Elders have also talked about the possible impact of nuclear weapons tests on Novaya Zemlya and underground nuclear explosions in Yakutia (for geological purposes) in the 1970s and 1980s. Additionally, the nuclear lighthouses (lighthouses powered by radioisotope thermoelectric generators and batteries; RTGs) on the tundra coasts of Chukotka have also been sources of contamination. Many herders and reindeer have suffered from exposure to radiation at these sites; because people did not know about the risk of radiation of getting too close to an RTG, they came close, examined these sites and, because reindeer graze along the coast in the summer, set up camps nearby. They are afraid these sites also release Hg.

Tiaptirgianov's assessment of Yakutian fish and freshwater bodies (Tiaptirgianov, 2016) includes Kolyma among rivers which are considered to have major issues with Hg and other pollutants (regional scale 4a – polluted). Tiaptirgianov notes that, due to a number of drivers, fish biodiversity in the Kolyma River is decreasing.

Tiaptirgianov (2016) analyzed Hg in pike and perch, which accumulate Hg through the food chain, along with a number of non-predator fish (roach; *Rutilus rutilus*, crucian carp; *Carassius carassius*, broad whitefish; *Coregonus nasus* and common dace; *Leuciscus leuciscus*). The study showed that the level of accumulated Hg is significant both in predator and non-predator fish (e.g., 1.86 mg/kg of Hg in yellow perch, 3.1 times the allowed maximum levels of 0.6 mg/kg). The accumulated Hg in each fish depends on the type of fish, the age and the season in which the fish was sampled (Tiaptirgianov, 2016). For comparison, hydroelectric power on Vilyuy River elsewhere in Yakutia has also been identified as a major source of Hg.

Kolyma has been shown to suffer from the environmental pollution, including Hg releases, that has resulted from gold mining, especially in the upper parts of the river (Tiaptirgianov, 2016:18); as a result, several species have shown to be declining , including Siberian sturgeon, Salmonidae, Coregoninae, with grayling and burbot also having suffered. Tiaptirgianov (2016) also highlights ASGM events as a source of Hg. At times, Hg levels in the waters of the Kolyma have been between 1 and 3 times the 'allowed mercury levels' (Tiaptirgianov, 2016:116). Tiaptirgianov links this elevation to a century of gold mining in Kolyma and the sediments leaching Hg downstream. Further investigation into precise regional and federal 'allowed mercury levels' is required.

Tiaptirgianov (2016:182) has also reviewed samples of small (young) perch fish from the Indigirka River, a neighboring Arctic basin to the Kolyma. According to the samples, the presence of Hg in these fish was twice as low in the summer as it was in the winter time. On the other hand, larger (adult) perch fish had higher amounts of Hg in the summer (well above the permitted threshold of 0.6 mg/kg). Tiaptirgianov (2016) associates the seasonal differences in Indigirka with the mining activities, which stop in the winter. Roach also displayed high levels of Hg content, although this is conjectured to be a 'natural' phenomenon (Tiaptirgianov, 2016).

In perch sampled from the middle reaches of the Kolyma River (fish aged 4–6 years), Hg levels in muscle were 3 times higher (up to 1.8 mg/kg) than the regional norm; elevated levels were also observed in perch liver (Tiaptirgianov, 2016:188). Again, in the winter, the levels appear to decrease. Tiaptirgianov (2016) also explains this as resulting from the cessation of ASGM activities upstream during the winter months.

Kolyma hydroelectric power stations

Literature has determined that the creation of hydroelectric power stations and associated reservoirs, particularly downstream and in the early part of their life, are major sources of Hg (e.g., Hsu-Kim et al., 2018). The first hydroelectric power station on the Kolyma was constructed in 1986 during the late Soviet period on the middle part of the river, in the Magadan region (see Figure EA7 and EA8).

It took five years for the Kolyma 1 reservoir to fill completely. The hydroelectric dam is the largest ever constructed on permafrost with a height of 134.5 meters and a length of 683 meters. The reservoir contains 15 080 million m^3 of water and measures, at its widest point, 110 km across. The station has a power generation capacity of 900 MW, with five turbines. Kolyma 1 produces over 95% of all electricity in Magadan (Mattsson, 2020).

The Kolyma 2 hydroelectric power station (see Figure EA9) is a second large hydroelectric power station that is currently being constructed on the river, 217 km downstream from Kolyma 1. When completed, it is expected to have an output of 570 MW, with four turbines. Filling the reservoir started in 2013. The reservoir is 2425 meters long with a 325 meter concrete dam structure. A part of the dam is made of earth and is 66 meters high; the other section of the dam is made of concrete and is 74 meters high. Once the reservoir is full, it is expected to have an area of 265 km^2. Kolyma 2 is constructed on permafrost that is 300 meters deep (Mattsson, 2020). The station has been operating since 2013 with the aim of reaching full capacity in 2022.

According to the plans, permafrost thaw has been addressed on the two dams through the use of piping that transports cold air into the earth, keeping the dam soils intact. Both dams are unique as no such constructions exist elsewhere on permafrost soils. Risks remain high. One potential risk associated with Kolyma 1 is that all of the stored water is used during the winter from the reservoir. This results in hydraulic pressure changes against the dam through the year. Additionally, this part of the Kolyma Basin is seismically active. This causes further dangers for dam construction and operation.

Both of these dams are probable sources of Hg downstream. Indigenous Peoples are concerned that Hg released as a result of the dam construction and operation is accumulating in predator fish, which are consumed by communities along the Kolyma (Mustonen, 2009). Mustonen and Shadrin (2020) report that some of the Indigenous Elders have observed changes in fish migration. Dams also prevent fish from travelling upstream. The Kolyma has important endemic and migratory fish (such as lenok, omul, whitefish, various species of Coregonus, muksun, and nelma). Spawning success is impacted by the fluctuation of water levels due to the irregular release of water from the dams. Before the construction of the dams, fish migration in the Kolyma River system followed natural changes in water quality and levels. Dams and their regulatory actions affect migrations and water temperatures at the 'wrong' times of the year; this results in the mislocation of fish stocks by Indigenous harvesters (Mattsson, 2020). For example, Fyodor Innokentyevich Sokorikov, former head of the fishing *sovkhoz* in Pokhodsk (at the Kolyma Delta),

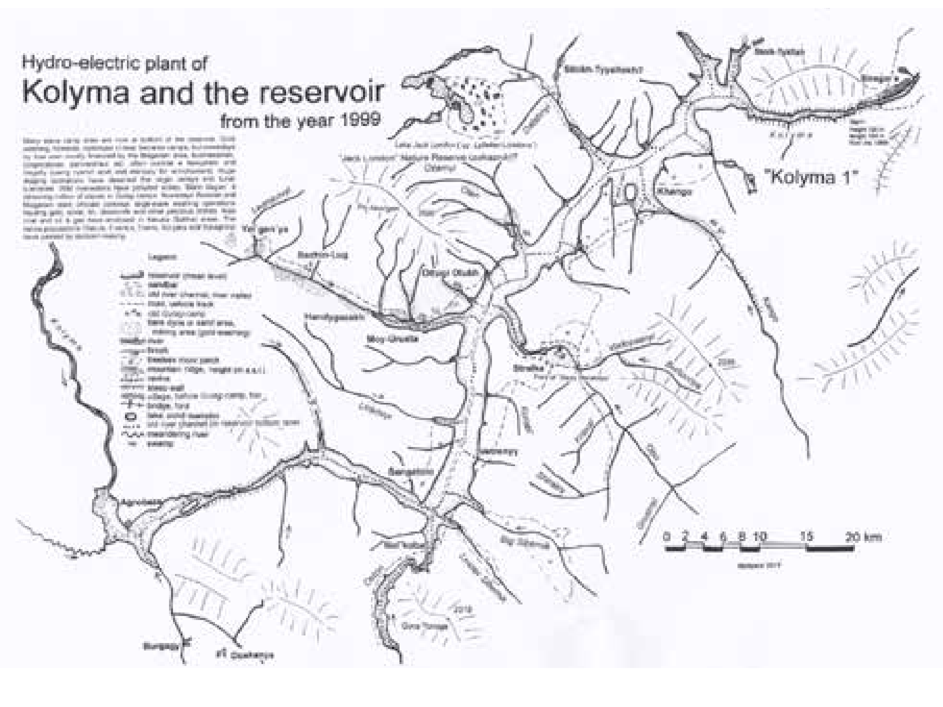

Figure EA7. Map showing the Kolyma River and the Kolyma 1 hydroelectric power station and reservoir. Source: Mattsson, 2019.

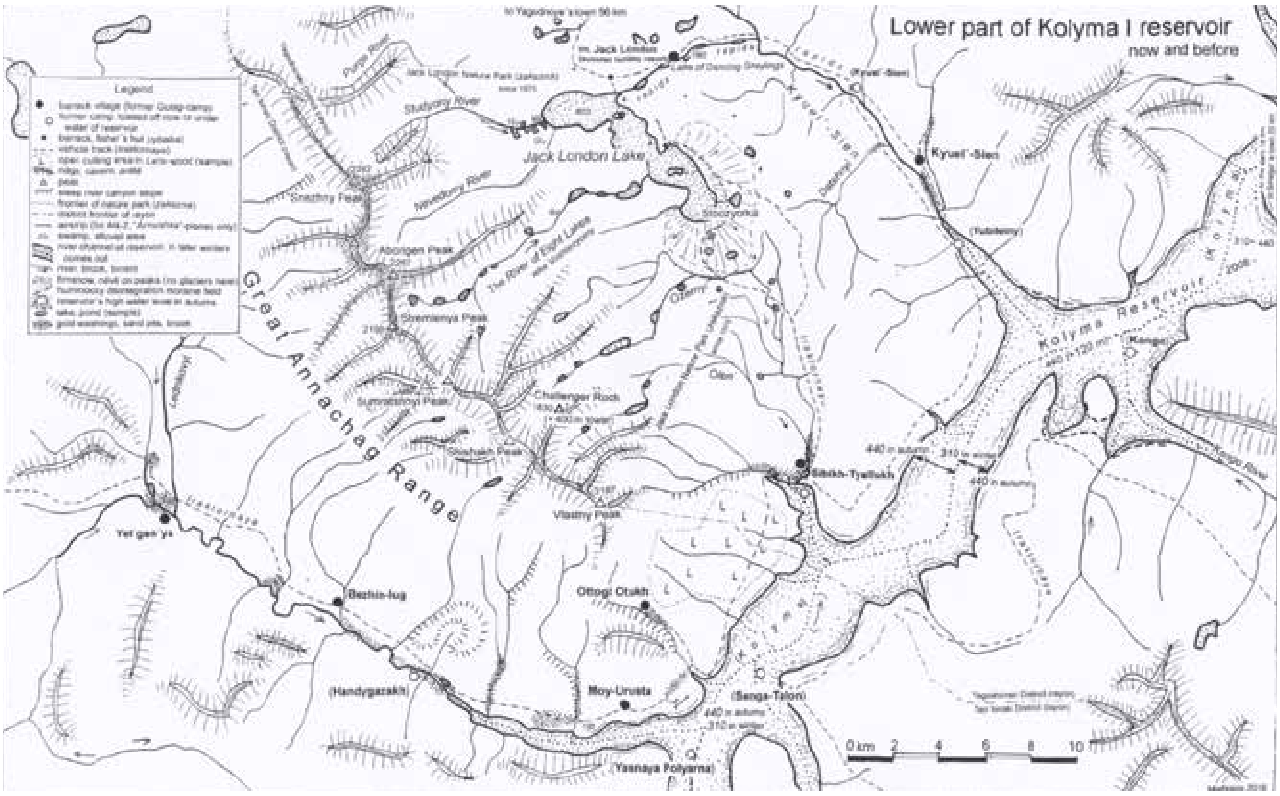

Figure EA8. Map showing the lower (southern) section of the Kolyma 1 hydroelectric power station and reservoir. Source: Jorma Mattsson, Snowchange Cooperative, 2022.

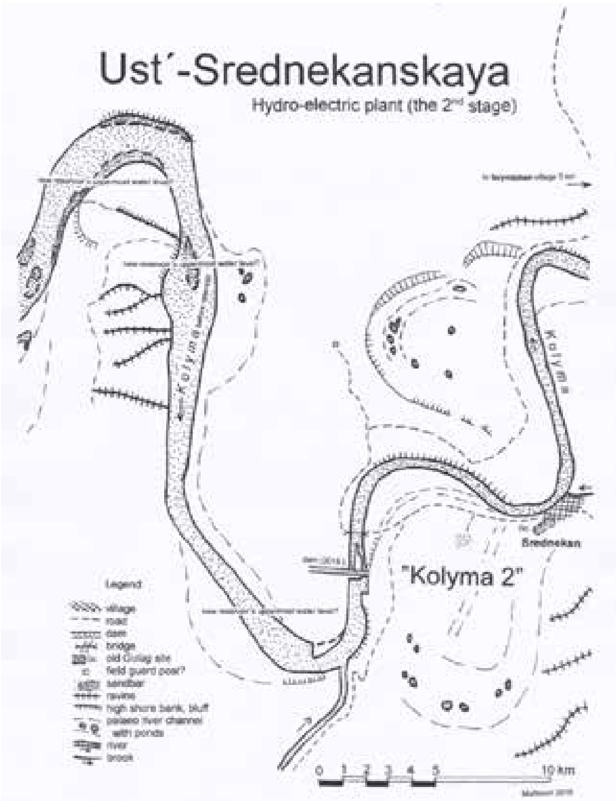

Figure EA9. Kolyma 2 hydroelectric power station and reservoir. Source: Jorma Mattsson, Snowchange Cooperative, 2022.

blames the changes brought about by the gold mining impacts in Kolyma tributaries (in Mustonen and Mustonen, 2016:115). Scientist Matvey Tyaptirgyanov also confirms significant decreases in the numbers of nelma in the Kolyma River.

Other Indigenous observations report that the Kolyma sturgeon stocks have collapsed (Mustonen and Mustonen, 2016). Observers blame the regulation of water levels by the hydroelectric power station for the population collapse; sturgeon need deep spots in the river to spawn and the hydroelectric power station has reduced the number of these spots. According to these observers, the last good year for sturgeon stocks was 1996; for the last 10 years, sturgeon have been missing almost totally from the river. Sturgeon also accumulate Hg (Tiaptirgianov, 2016).

Reservoir water level fluctuations are a driver of bank erosion. Combined with permafrost thaw, these fluctuations may lead to increased levels of Hg in the stream. Mustonen (2009) reports that some subsistence fishermen have associated 'glowing fish' with Hg and other releases from the dams.

In the Kolyma communities, reservoirs are also associated with increased flooding. Before the construction of the dams, Kolyma communities used to expect a flood every 25 to 30 years. Now, flooding occurs every other year. Elders have also observed air humidity and water regime changes adding to bank erosion, another potential driver of Hg.

Artisanal and small-scale gold mining (ASGM), industrial gold mining, and Gulag mining operations and related Indigenous health impacts

As in Southern Sakha-Yakutia, artisanal and small-scale gold mining (ASGM) is prominent in the Kolyma region. ASGM operations most likely still use Hg to process gold amalgam; they then release Hg directly into the river after processing.

Obrist et al. (2017) determine that this is the single largest sourcing of Hg globally. This practice is officially illegal, a ban on mercury-use in ASGM having come into force in 1988 (Order #124 of the USSR State Committee on Precious Metals in Tiaptirgianov, 2016), but implementation has been critically slow (Romanov et al., 2018). The release of other chemicals (including cyanide and other hazardous materials) have also impacted Kolyma River water quality, and mining operations have led to an observed darkening of the waters. This change in water color is detectable both by Indigenous harvesters close to the mining sites as well as from aerial and satellite imagery. There are also industrial-scale gold mining operations in the upper parts of the Kolyma River. Mines have released, and continue to release, both Hg and other contaminants into the river.

Historically, 'artisanal' mining in the region relied on prisoners, who used shovels and other handheld equipment to attempt to find gold, silver and tin. Since the first efforts to industrialize the region in the 1930s, hundreds of forced labor camps and mining sites have been built along the Kolyma. The separation of gold from Hg at such sites has relied on regal water (a mixture of nitric acid and hydrochloric acid), cyanide and other acids. The left-over material (tailings) and wastewaters are then released into the Kolyma. Romanov et al. (2018:42) highlight the ASGM in Magadan as a major source of Hg. According to a report on implementing federal decisions in the ASGM sector (Magadan, 2014) there is 2.5 million m^3 of mining waste in Magadan, which contains an estimated 48 tonnes of Hg from 'traditional gold mining'.

The 1988 ban on the use of Hg in ASGM, unfortunately, has not prevented the use of Hg in many sites across Siberia. As Magadan (2014) shows, the amount of Hg already present in the environment is in the tens of tonnes, even in official reporting. These older mine tailing sites will continue to leach Hg into nearby waters (including, potentially, into groundwater). Such was the case with the Karamkenski gold processing plant. In 2009, the tailing pond of this plant (now closed) burst, resulting in the release of waste containing cyanide (and also, therefore, Hg) into the Khasyn River (not in the Kolyma Basin; Magadan, 2014). This led to the government taking measures to restore the Karamkenski site in 2017; these measures were, according to official reports, 93.5% successful (Magadan, 2017). No independent survey of the site has been conducted, nor are there verifiable public records of present or historic levels of Hg at the site or in the Khasyn River.

In the 2020s, the most prominent area for ASGM is the Magadan Oblast (or region), where gold mining remains a strategic resource (Romanov et al., 2018). Service huts and operational bases are accessible using *traktornaya* (ATV trails) out into the wilderness.

Forest fires in the Kolyma Basin are frequent and increase humus loading into the river. This is affecting the accumulation of methylmercury to predators and ultimately to humans. Short summers on the Kolyma leave a lot of aquatic vegetation that rots on the river. This, in itself, causes natural chemical and water-quality changes; added methylmercury creates an overall situation which, due to its complexity, is hard to assess, but its effects include the lowering of pH in the waters of the river (Mattsson, 2020).

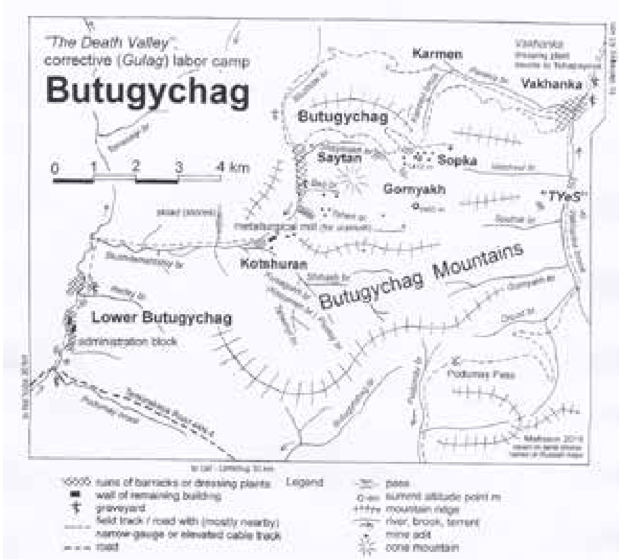

Figure EA10. Map of Butugychag uranium mining site showing nearby tributaries of the Kolyma River. Source: Jorma Mattsson, Snowchange Cooperative, 2022.

In the tributaries of the lower Kolyma, two industrial companies, Kinross Gold Mining Company and Polymetal, carry out industrial-scale gold mining: this occurs mainly in Omolon and in Anyui, Chukotka. Chukotka has also seen an increase since 2018 in ASGM activities, but the scale of these operations is hard to assess.

Based on regional research trips and analysis, we have determined that artisanal gold mining continues in close proximity to the Kolyma 1 hydroelectric power station (see also Romanov et al., 2018). Evidence of gold mining has also been detected on the Lednikoviy, Obo, Kango, Datshnyi and Olen rivers. All of these sites are a further source of the Hg in the Kolyma 1 reservoir, around which there are also many gold mining camps (see Figure EA10).

Of special importance in the mining history of the Kolyma Basin is the Butugychag site in the Upper Kolyma, north of the town of Magadan. Butugychag was a major source of uranium for the Soviet Union. In the 1940s and 1950s, uranium was harvested by Gulag prisoners in Butugychag without any protective gear. Prisoners and guards alike died within months of starting work on the site. While the area is today off limits, reindeer herders have reported that reindeer are losing hair from their feet close to Butugychag. Uranium mine tailings are known to contain Hg; the site should, therefore, be considered in an overall assessment of Hg loading in the Kolyma Basin.

Mercury loading from permafrost melt

Eagle-Smith et al. (2018) state that the entire Arctic area, and especially the Indigenous communities who live there, are vulnerable to Hg pollution. This is due to their dependence on fishing, not only for food security but also for cultural and social reasons. According to Eagle-Smith et al. (2018), global climate change — including permafrost thaw events — may be a major driver of releases of Hg into river systems.

Differentiation of the sources of Hg release via bank erosion and linking these releases to impacts on Indigenous health may be impossible. A solution may rest in a basin-wide survey of drivers of Hg for the Kolyma, including sedimentation, and by furthering our understanding of exactly what happens to sediments when drivers associated with hydroelectric power production and permafrost melt events increase.

Official regional reports

Positioning Indigenous-related case studies in a dialogue with regional governmental monitoring data can provide partial answers, as well as points of divergence and convergence. Tiaptirgianov (2016) has produced a monograph on Sakha-Yakutia which has been summarized above. A recent governmental monitoring report on the environmental protection in Sakha-Yakutia (Sakha, 2017) states that in waters of the Lower Kolyma near the Kolymskoe settlement, the average annual Hg amounts for 2016 and 2017 were within threshold value limits (see above regarding regional 'thresholds'). The report also states that Hg levels have been diminishing in water samples taken from the lower part of the river. In the delta area, according to the report, the loading from both the hydroelectric power stations and gold mining has lessened and Hg has, therefore, most likely sedimented. We have assessed that permafrost erosion events may be the largest single driver of Hg releases towards the delta. However, Tiaptirgianov (2016) points to the sediment leaching and continually raised Hg levels also in the lower part of Kolyma.

In the case of the Magadan region, official reports state that it is mainly the soils of urban areas that have been monitored for Hg (Magadan, 2018:41). Specific ecological restoration measures undertaken after accidents have also been identified (Magadan, 2017). It is worth noting that in the 2018 report on the ecological situation in Magadan, the section on the quality of regional water resources does not mention Hg (Magadan, 2018:24). However, in the sector specific reports (e.g., those devoted to mining) Hg is associated with older mining tailings (Magadan 2014, 2017). Remedial actions are prioritized for sites closest to human settlements.

The inconsistent way in which the presence of Hg is addressed in official reporting points to a large gap in either monitoring capacity (lack of resources), misreporting, or the ignoring of Hg for other reasons. This is especially the case for ASGM activities. Land use and industrial activities are certain to be drivers of Hg in Magadan (with impacts across a range of scales) but are mostly missing from the monitoring data. One exception is the 2014 report, where the past tailings are identified as a major source (Magadan, 2014).

Looking further afield at Hg reporting in neighboring regions beyond the Kolyma catchment, a comparative view emerges. Kamchatka (2018:91) links Hg releases to wastewater issues. Interestingly, AO Kamgold, a gold company operating on the peninsula, includes Hg as one of the monitored indicators in the discharge waters. This may be at least partly attributed to the large presence of Hg in natural soils. Additionally, Kamchatka (2018) mentions that reports from the company AO Ametistovoe also includes an analysis of Hg in the 'clean' rivers Ichigin-Unneivayam and Tklavayam, and on equally clean smaller brooks (Pryamoy, Rudnyy and Severnyy). The sources and amounts of Hg in these reports cannot be confirmed independently.

Khabarovsk (2018:209) has identified Hg pollution as an ecological problem in Khabarovsky Kray. This is especially true in the case of the area around the former Amursky cellulose-cardboard factory. The former factory is included in the federal program *Chistaya Strana* (Clean Country), which helps regions deal with pollution which has accumulated in the environment as a result of historic industrial development projects. The program has allocated federal subsidies to demolish the Amursky factory's chlorine department and to undertake remedial measures to address polluted sites.

None of the regional environmental reports from Eastern Siberia and the Russian Far East which were surveyed for this case study (i.e., from Sakha, Magadan, Kamchatka and Khabarovsk regions) had a special section on Hg. Instead, Hg was mentioned in different sections of the reports. The sections that most often mentioned Hg were sections on air, soil and water monitoring and waste handling. Mercury reporting in these reports is somewhat partial and inconsistent. Since the reports do not clearly mention all the substances they have measured and tend to report only the indicators that exceed threshold limit values, it is impossible to say based on those reports whether Hg is measured but not reported (since the concentration is not deemed to exceed threshold limit values), or if it is not measured at all.

Clearly, Hg has not been taken to be especially important in the monitoring reports of either private companies or state environmental agencies. However, all reports mentioned Hg every now and then, even though, in some reports, Hg features more prominently than in others (Tiaptirgianov, 2016). However, mercury-containing waste has started to become an important subject for all the regions mentioned in this case study. This may be due to heightened awareness of Hg waste resulting from educational campaigns about Hg in light bulbs. Romanov et al. (2018) note that ASGM is not prohibited in the Minamata Convention on Mercury and point to how this affects the way it is addressed by the regional authorities and in monitoring. On the federal level, evidence of the monitoring of Hg also remains elusive.

Tiaptirgianov (2016) has assessed the health implications of Hg levels for the Indigenous communities living on the Kolyma. The recommendation is currently that, when fish is consumed from the river, only the filet should be eaten (and this as rarely as possible) because the levels of Hg (often exceeding the maximum allowed levels of 0.6 mg/kg), lead and cadmium exceed safe levels in fish caught from the Kolyma.

Tiaptirgianov (2016) points to the backlog of Hg loading (historic Hg loading which continues to affect the environment) from a century of mining activities and how this continues to influence fish health. Indigenous observations of abnormalities have also become more common on the Kolyma (Mustonen, 2009 reports alterations in the smell, taste and coloring of the fish; see also Tiaptirgianov, 2016 for summaries of abnormalities in the river itself). However, Tiaptirgianov's recommendations are those of a single researcher; to date, none of these recommendations or observations have been implemented or had any visible effect on regional policy.

Discussion and Conclusions

Kolyma is a lifeline and home to many Indigenous Peoples of Eastern and Northeastern Siberia, including the Even, Chukchi, Evenki, Koryak and the Yukaghir. All of these Indigenous Peoples are dependent on the river for fish, which is not only consumed as food but important for cultural and spiritual well-being.

The Kolyma Basin has been affected by large-scale industrial developments that have sourced Hg to the river for a century (Tiaptirgianov, 2016). This includes the hydroelectric dams Kolyma 1 and Kolyma 2 (the latter currently under construction), artisanal and small-scale gold mining (ASGM) both past and present, and industrial mining operations, including secondary drivers of Hg levels in the environment such as the uranium mined in Butugychag. Ongoing changes to Hg levels in the basin include additional sourcing from the impacts of climate change, including permafrost thaw and flooding (Tiaptirgianov, 2016; Eagle-Smith et al., 2018).

Community-based observations undertaken along the Kolyma River have detected direct impacts of Hg (e.g., changes in fish smell, taste and health) and indirect impacts (e.g., ethical and cultural) through Indigenous Knowledge regarding Hg. Mercury is very challenging to monitor directly and exclusively using CBM methods. Individual researchers like Tiaptirgianov (2016) have begun to offer a system-wide ecological view, but much work remains, both in terms of collecting Indigenous observations and in linking these observations with systematic monitoring of the sources and impacts of Hg in the Kolyma Basin.

These same issues and research needs are also present in the neighboring Chukotka region. Chuvan Yuri Borisovich Diachkov from the village of Markovo in Chukotka has been concerned about the impact of gold mining on the river and local people (in Mustonen and Mustonen, 2016). He described how, after gold had been dredged in Chukotka, thousands of barrels of waste were left behind, leaving the rivers polluted. He added that local people have benefited very little from the industrial development in the region.

Yevgeny Remkylen (in Mustonen and Mustonen, 2016) also noted that when the mining companies dredged nearby rivers in their search for gold, they did so without consulting the local population at all. This resulted in the disappearance of fish spawning areas in the upper reaches of the rivers and the destruction of many areas previously used as important reindeer pastures.

For this case study, we have combined data from regional environmental reports, remote sensing and satellite analysis, and a limited literature review. In summary, Hg monitoring remains critically insufficient for ASGM activities. Indigenous observations, where available, have not led to action. This is in spite of the fact that some government reports do identify the backlog of mining tailings as a source of Hg (Magadan, 2014) and the fact that other reports (Magadan, 2017 and Khabarovsk, 2018) discuss Hg releases from industrial factories and sites. The Magadan government has taken remedial and restorative actions, at least officially, after the tailings pond burst at the Karamkenski site. Such events, however, have not been thoroughly followed-up on; the state of these sites, and the Hg levels at these sites, today represents a research gap that will need to be addressed in future.

A thorough, formal assessment of the impacts of Hg on Kolyma Indigenous communities is highly recommended. Tiaptirgianov (2016) is a very important starting point for baseline measurements and in mapping a system-wide ecological view. A large environmental monitoring program which includes historic events whose Hg emissions are having, most likely, an ongoing impact (such as the Karamkenski event, not in the Kolyma Basin) and an analysis of Hg loading in predator and other fish, should be the first priority.

Secondly, any future assessment program should also include a study of environmental and community health developed in consultation with local communities to ensure that free, prior and informed consent has been obtained; research into links between land/river drivers and ocean drivers of Hg, especially on the delta area, should also be undertaken; an assessment of how much Hg is being released from a range of 'natural' sources (e.g., permafrost; see Obrist et al., 2017, as well as riverbanks and soils) and human sources (hydroelectric dams, sediment loading and mining operations past and present; see Tiaptirgianov, 2016) should also be carried out. The implementation of the Minamata Convention on Mercury and the inclusion of ASGM in regional environmental monitoring, if this can be determined to have been properly sourced, is considered an important early step towards a more wide-ranging future program.

EA Case Study 5: References

British Admiralty Charts, 1948. Siberian coastal charts 1:2,830,000 by U.S.S.R. Government charts and sketch surveys to 1947 (soundings in fathoms).

Eagle-Smith, C. et al., 2018. Modulators of mercury risk to wildlife and humans in the context of rapid climate change. Ambio, 47:170-197.

Hsu-Kim H. et al., 2018. Challenges and opportunities for managing aquatic mercury pollution in altered landscapes. Ambio, 47:141-169.

Kamchatka, 2018. The Report on the Current State of Environment in Kamchatka Kray in 2018 ДОКЛАД О СОСТОЯНИИ ОКРУЖАЮЩЕЙ СРЕДЫ В КАМЧАТСКОМ КРАЕ В 2018 ГОДУ.

Khabarovsk, 2018: The State Report on the Current State and Protection of Environment of Khabarovsk Kray Государственный доклад о состоянии и об охране окружающей среды Хабаровского края в 2018.

Magadan, 2014. Passport of the State Programme "Nature Resources and Ecology of the Magadan Region", approved on 30.4.2014 by the Government of Magadan Region. Available at: https://minprirod.49gov.ru/common/download.php?file=2_366_30.04.2014_1.pdf&obj=document

Magadan, 2017. Report on the Actions of Implementing Federal Actions of Natural Resources and Ecology.Пояснительная записка о результатах реализации мероприятий государственной программы министерством природных ресурсов и экологии Магаданской области в 2017 году.

Magadan, 2018. The Report on Ecological Situation in Magadan Oblast. ДОКЛАД ОБ ЭКОЛОГИЧЕСКОЙ СИТУАЦИИ В МАГАДАНСКОЙ ОБЛАСТИ В 2018 ГОДУ.

Mattsson, J., 2020. Regional Report of Kolyma Basin 2020. An unpublished regional environmental report. Snowchange Cooperative.

Mustonen, 2009. Karhun väen ajast-aikojen avartuva avara. Joensuu: University of Joensuu.

Mustonen, T. and Mustonen, K., 2016. Life in the Cyclic World – Traditional Knowledge Compendium of Eurasia. Snowchange Cooperative, Finland.

Mustonen and Shadrin, 2021. The River Alazeya: Shifting Socio-Ecological Systems Connected to a Northeastern Siberian River. ARCTIC, 74 (1):67-86. Available at: https://doi.org/10.14430/arctic72238

Obrist, D. et al., 2017. Tundra uptake of atmospheric elemental mercury drives Arctic mercury pollution. Nature, 547 (7662):201-204.

Romanov, A., Ignatieva, Y. and Morozova, I., 2018. Mercury Pollution in Russia: Problems and Recommendations. GEF (Global Environment Facility (GEF). Available at: http://www.ecoaccord.org/pop/Rtutnoe_zagryaznenie_English_25-08.pdf

Sakha, 2017. The State Report on the Current State and Protection of Environment of the Republic of Sakha (Yakutia) Госдоклад о состоянии и охране окружающей среды РС(Я).

Semenov, V., 2007. The Yukaghirs (Film). Yakutsk.

Tiaptirgianov, M., 2016. Fish of freshwater bodies of Yakutia (systematisation, ecology, impact of anthropogenic factors), Yakutsk. 2016. ТЯПТИРГЯНОВ Матвей Матвеевич. РЫБЫ ПРЕСНОВОДНЫХ ВОДОЕМОВ ЯКУТИИ (систематика, экология, воздействие антропогенных факторов), Якутск 2016.

EA Case Study 6. Yiengra: artisanal gold mining and Evenki taiga nomadism

Author: Tero Mustonen, Snowchange Cooperative

Introduction

In this case study, Indigenous observations of health and well-being are discussed in the context of artisanal gold mining and Hg. For this case study, we focus on the community of Yiengra and its surrounding nomadic reindeer camps located in the southern Sakha-Yakutian taiga of Eastern Siberia in Russia.

The Indigenous Evenki of Yiengra have faced the pressure of displacement since the days of their first encounters with Russians in the early 17th century, and the community was forcibly resettled in the 1920s. Under the Soviet regime and during the post-Soviet years, Evenki lands and waters became the target of expansive industrial operations. Coal mining, gold digging, hydropower construction, energy pipelines and many other infrastructure projects have all made their mark on the landscape. This expansion widely and thoroughly altered the post-Ice Age landscapes of the southern Sakha-Yakutia. The Soviet Union established the village of Yiengra in the catchment area of the Yiengra River in 1926; the village is located on a point along the traditional nomadic routes of the Evenki.

The Evenki have settled over a vast geographic range in East Siberia, Russia's Far East, Northern China and Mongolia (Mertens, 2015). It is estimated that the entire Evenki community currently has approximately 36 000 members and about 7000 speak the Evenki language. Their traditional livelihoods have revolved around nomadic reindeer herding, hunting and fishing.

Neryungrinsky, the administrative area, is a southern region of the Republic of Sakha (Yakutia) in the Russian Federation. It is located close to the Chinese border. The population of the district is about 75 000, and most residents live in urban areas. Neriungri, the administrative center of the district, is also the center for coal-mining operations. The district produces 75% of the 10 million tons of coal that is produced in Sakha annually (Newell, 2004; Araseyenin, 2007).

The area is part of the continental climate zone. Coniferous trees, such as Siberian larch, as well as birch trees cover much of the taiga. Mountains and large hills dominate the landscape, with shallow rivers flowing in the valleys. For example, the Aldan River catchment area, a sub-catchment of the Lena River, is located in the district. Winters are usually very cold with small amounts of snowfall. Temperatures can plummet down to -50°C and below. Springtime is often short with snowmelt already well under way in April. Summers are continental and hot. Autumn (i.e., often September or October) brings the first frosts.

Salmonid fish, such as trout, grayling and whitefish, occupy the lakes and rivers. This is reflected in many Evenki place names around Yiengra (Lavrillier, 2006, and see the Evenki Atlas; ELOKA and Snowchange, 2020). The Evenki place significant value on local trout as a culturally important species. The Evenki have long used salmonid fish as bioindicators to assess the degradation of river health and change over time (Mustonen, 2009; ELOKA and Snowchange, 2020).

While the traditional Evenki trades of hunting, fishing and reindeer herding resemble those of other similar cultures in Eurasia (Klokov, 2016), Evenki practices are distinct. For example, reindeer are ridden and not eaten, nomadic routes are smaller in scale, traditional calendars are observed, and the taiga is ordered into 'human' and natural, remote zones.

The Yiengra River, the main catchment area addressed in this case study (see Figure EA11), is the center of Evenki seasonal

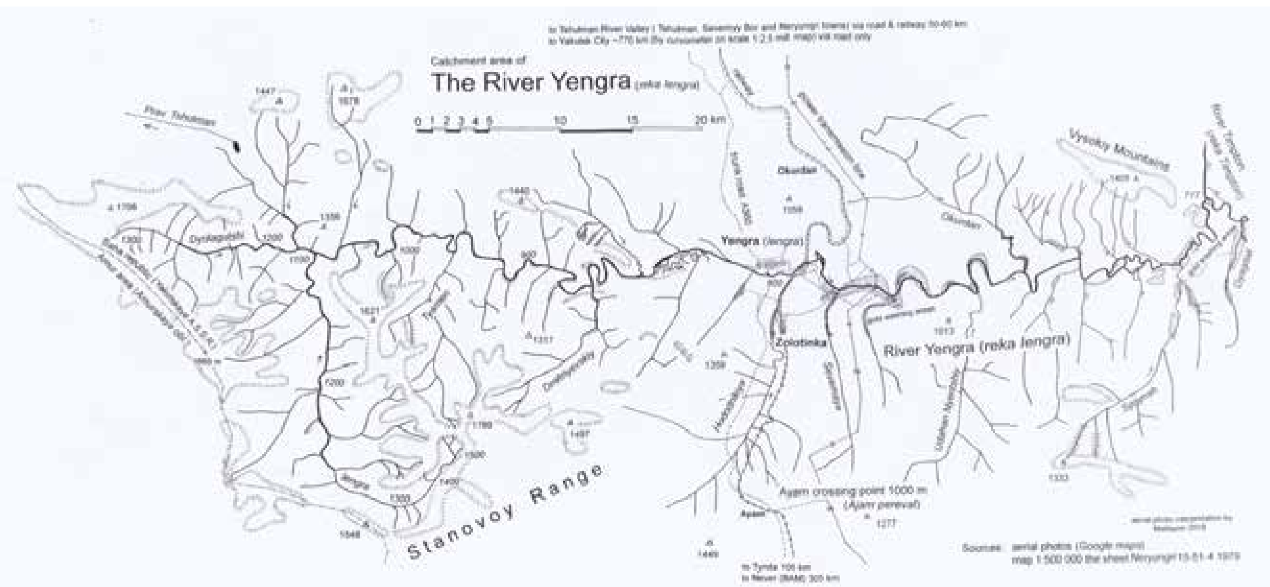

Figure EA11. Map of the Yiengra River catchment area and the village of Yiengra. Source: Jorma Mattsson, Snowchange Cooperative, 2022.

life. The Evenki are dependent on the river for drinking water (for reindeer and humans), transportation, and, in some cases, small-scale cultural fisheries.

The river catchment is also utilized by artisanal gold miners (Figure EA12). Mercury (Hg) and other chemicals, such as cyanide, are often released into waterways from small-scale gold mining operations. Mercury is used in artisanal practice to separate gold particles from sediment. The resulting amalgam is often burned to remove the Hg (Mustonen and Lehtinen, 2020), resulting in airborne pollution to nearby lands and waters. This technique is a source of Hg pollution to the Yiengra River; adjacent mining operations are also a direct source of Hg pollution. Mercury entering the waterways is transformed into methylmercury. Other chemicals also affect human and animal health along the Yiengra. Lastly, many of the riverbanks have been churned up, turned upside down, and greatly damaged as a result of the digging, affecting water quality and sedimentation patterns.

Methods

Mercury is naturally present in the boreal environment. When soils are altered — often through human disturbances such as burning, ditching, and mining — Hg embedded in the soils travels downstream and reacts with water due to microbial actions.

When it comes to Evenki observations of the impact of Hg on the Yiengra River catchment area, we are able to draw on 16 years of community-based observations, aquatic mapping and geographical analysis to identify the main artisanal mining sources of Hg. This has included working with Evenki co-researchers in reindeer camps (Mustonen, 2009; Mustonen and Lehtinen, 2020) between 2004 and 2020, field visits to river sites, and oral history documentation and mapping in the village of Yiengra.

The most significant source of Hg in the Yiengra River is artisanal and small-scale (ASGM) gold mining (Romanov et al., 2018). The actual gold mining is conducted by local and private operators, which are hard to monitor and track. Despite the national ban on unlicensed mining activities put in place in 1988 by the Soviet Union (see also Romanov et al., 2018), in practice, small-scale gold mines have been part of the landscape along the Yiengra for decades. What individual licenses and permits may allow varies and, as such, the industry is hard to control.

Additionally, we have reviewed the official monitoring reports from the government of Sakha-Yakutia to position the fieldwork alongside regional monitoring of Hg and to assess the effectiveness of this monitoring. The regional maximum allowed level of Hg in waters and fish has been set at 0.6 mg/kg by the regional authorities. Artisanal gold mining is not limited to the Yiengra; it is also present in the larger Aldan River catchment, for instance on the Timpton River.

Results

Gold mining on the Yiengra River is mostly artisanal (Romanov et al., 2018) and therefore affects smaller streams and old-growth forests of the taiga (Mustonen and Lehtinen, 2020)

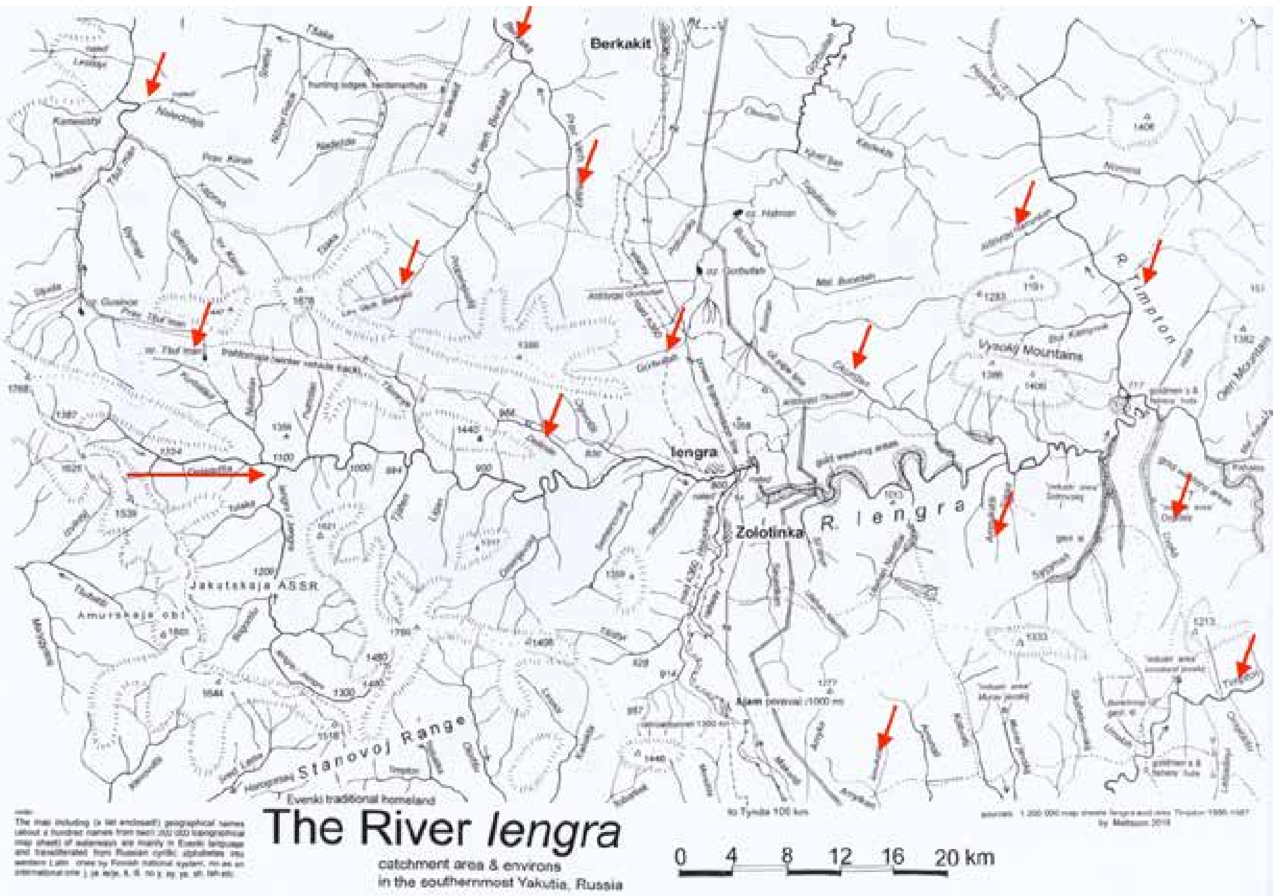

Figure EA12. Regional map of the Yiengra River and surrounding catchment areas. Gold mining areas are marked on the map (shaded areas). Red arrows point to sites of importance to the Evenki where environmental change is taking place (as of 2004–2020). Not all of this change is related to gold mining and may also be related to climate change impacts. Source: Jorma Mattsson, Snowchange 2022.

but has cumulative impacts on the main streams as well. This artisanal mining activity releases Hg, cyanide and other chemicals and hazardous materials into the rivers.

One Evenki reindeer herder in a leading position summarized the impact of gold mining on reindeer life during the oral history work (Mustonen, 2009):

> *"Reindeer do drink water, and now it is dirty. They make it dirty when they dig and wash gold. Look at Timpton river, it looks like tea with milk. Everything is poisoned there. There is not fish, nothing. So reindeer drink such water, and they get sick or even die. And [their] food [is] lichen. We have to change our route regularly, so that reindeer would get fresh food. But our territory is small, and everything around is dug up. So the reindeer are forced to graze and trample at the same spots."*

The Evenki have conducted their own observational assessment of change by reviewing historic place names, especially those related to aquatic ecosystems. In this oral history example, reindeer herder Vladimir Kolesov discusses place names and recent changes:

> *"We have two middle-sized rivers. It is enough for us. I cannot always even say why a river has the name it has. Kenerkit. Kener is a fishtrap. There are a lot of places in this river where one could place a fishtrap. A river called Kenerkit. Gonam is a long and meandering river. It was named Gonam. Or Takrekam, it is like this, twisting like a worm. It is like a lake, all shores are muddy. There are a lot of small rivers. My campsites are Kurekati-river, Kalbati, Turkit. There is Daban. Delinde refers to fishing, Nirunda. There is Davenda, from [the] word dva – artificial. These exist. Nirunda. It is a grayling river. There is Delinde. It is a river for trout. It used to be. These names are old. The names persist, but … all that is left is the name - due to the pollution from the gold mining."* (Mustonen, 2009).

Hydronyms, place names that reflect water bodies or their attributes, such as lakes and rivers, contain descriptions of the different elements and characteristics of water flow, depth, meanders, and points of safe crossing. Evenki campsites have traditionally been located at sites that provide a source of freshwater for both people and reindeer. At some of these locations, the river does not freeze in the winter due to the speed of water flow (Mustonen and Lehtinen, 2020).

At other locations, river ice compresses as a result of the deep freeze, and the river subsequently releases ice blocks as the tension breaks. These ice blocks are used as drinking water in the winter. Lavrillier (2006) points to the central role of rivers as winter highways for reindeer travel; as such, locations are often described not by using cardinal points (i.e., north, south, east and west) but rather through descriptions of riverbanks, streams and other aquatic features of travelled terrains.

Some place names are also layered; they reflect the Sakha arrivals and mixing of toponyms with the original Evenki ones. Relations and conflicts between these peoples have been encoded in these toponyms. An example of Evenki place names demonstrates the ecological connection between the Evenki language and the landscape.

According to Vladimir Kolesov, hunting and fishing grounds have been affected too:

> *"I hunt between Timpton and Gonam. In my area, [the] largest changes have taken place [at] the shoreline of large rivers. Along the shores of large rivers, the changes have been bigger than for example on mountains. Gonam is a large river, and crossing it used to be very difficult, but now it is possible [in] many places. It is becoming more shallow. In my area it is like milk. Water is the same colour as tea with milk. [The] largest changes have taken place along the big rivers. Maybe this is because of gold digging. They dig for gold. I cannot say that this would have an impact on climate, but on reindeer yes. Local environment, yes, it impacts a lot. I remember when we used to be close to lakes, we used to eat ducks for the whole summer, different kinds. Completely white and then silvery. They flew past*

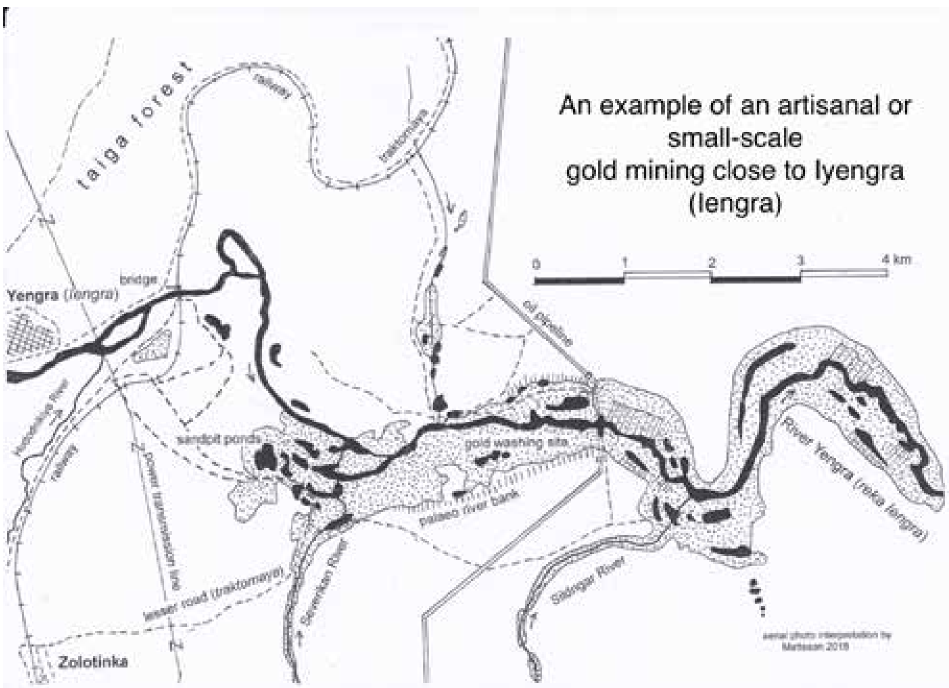

Figure EA13. Map of artisanal or small-scale gold mining sites to the west of Yiengra village. Source: Jorma Mattsson, Snowchange Cooperative.

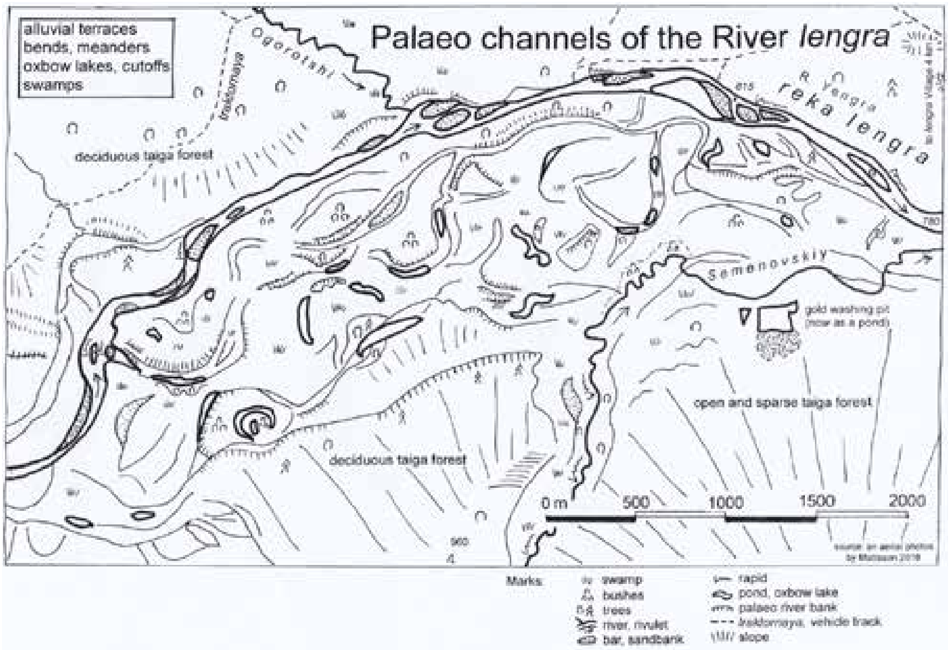

Figure EA14. Map of the western (upper) part of the Yiengra River and catchment area. Historic gold mining sites (over twenty-years-old) are now ponds, visible on the lower right-hand section of the map. Source: Jorma Mattsson, Snowchange Cooperative.

and nested here also. Incubated and geese incubated also. Now there are very few of those birds. There is no fish either, numbers have gone down also. Birds fly [to] some other places. There is no food and they change the place and the route. Well, where can you hide from civilisation? Nowhere" (Mustonen, 2009).

In this close-up map of artisanal gold digging, west of the village of Yiengra on the river (Figure EA13), we can see the scale of the mining operations and their impacts. Both the Yiengra and Sildngar rivers have been polluted. The mining sites and tailing pools are right next to the main river itself. This means that the release of Hg and other chemicals is directly affecting these waters. While point specific data are unavailable, an official environmental protection report for the state of Sakha (Sakha, 2017) records that 56% to 87% of water samples taken from the river Aldan (a major river downstream from Yiengra) had elevated levels of Hg (i.e., above maximum allowable levels). As point specific data have not been publicly released, determining the exact amounts of Hg in the water of these rivers would require sampling at the pollution sources.

Additionally, the banks of the rivers are churned up by mining operations, adding to organic loading and alterations in fish spawning locations, river depth and water quality. In certain places where the river meanders or the flow of water slows, Hg and other chemicals have most likely accumulated in the sediment. Past impacts of gold mining are visible as new 'pools' on the Western side of the Yiengra River catchment area, as in the map below (Figure EA14).

The cumulative impacts of historic land-use changes — especially those associated with the industrial megaprojects of the 2000s and 2010s — are as immense as they are difficult to assess. Artisanal gold mining and the resulting Hg loading is also hard to detect using only Indigenous Knowledge and observations. What emerges from the community-based monitoring (CBM) work and the Evenki oral histories is a distinct impact on reindeer and other animals that are using the affected waters. Understanding the specific role of Hg in these pollution events will require additional limnological and sampling studies.

We positioned the Evenki observations in a dialogue with official reporting on lakes and rivers by the Republic of Sakha (Yakutia) Ministry of Ecology, Nature Use and Forestry (Sakha, 2017). Official reporting has been compiled in the State Report on the Current State and Protection of Environment of the Republic of Sakha (Sakha, 2017). Mercury is one of the chemical elements that has been analyzed for water monitoring in the report. The presence of Hg is mentioned only for some rivers. The Aldan River basin, where Yiengra is located, has been categorized as class 3b: very polluted (using national indicators, see more in Sakha, 2017). Copper, phenol and Hg were higher than the national threshold limit value (TLV). Overall, Hg pollution resulting from surface waters of the Aldan River is said to have decreased in recent years (Sakha, 2017). However, to determine whether or not the level of Hg is now within maximum allowed levels in fish (less than 0.6 mg/kg) and in waters will require further sampling and monitoring efforts.

One of the major drivers of Hg in the region is the city of Tommot on the Aldan River, outside the area we are focusing on in this case study. In water samples taken 0.5 km upstream of Tommot, concentrations of Hg above the TLV were detected in 63% of samples (Sakha, 2017). The Yiengra, Timpton and Chulman rivers were classified as 3a or 3b (very polluted, see Sakha, 2017). The governmental report also points to the need for monitoring Hg below artisanal mining areas, but no specific data are mentioned. For example, the report states that the gold-mining company OOO Progress possesses a table of data showing the concentration of pollutants in company wastewater. While Hg is in the table, it is always marked as 'non-reported' (see Sakha, 2017:406).

Available regional data converges with Indigenous observations in defining the Yiengra, Timpton and Chulman rivers as polluted. Lack of data contributes to a large divergence between reported impacts of artisanal mining operations and observations of impacts by the Evenki. This is partly a result of understaffing at the Ministry of Ecology and the incapacity of monitoring staff to trace past and present loading on the Yiengra River.

In summary, mining, energy and infrastructure projects have thoroughly altered the Evenki land and lifescapes (i.e., emotions, health, socio-economic circumstances, cultural norms, and behaviors) in the following ways (see also Newell, 2004; Mustonen, 2009; Yakoleva, 2011; Sidortsov et al., 2016):

- Major hydrological regimes and aquatic ecosystems have been fundamentally transformed by mining operations and hydropower construction.
- Smaller streams and old-growth (naturally developed) forests have been contaminated by oil pipelines, as well as Hg releases and land churning by artisanal gold mining.
- Changes in forest cover, fish stocks, water color and quality have, in turn, thoroughly affected fishing livelihoods, household catches and reindeer herding.
- Mammals, birds and other fauna that are dependent on post-Ice Age, pristine, old-growth taiga forests have suffered and retreated elsewhere, making hunting and subsistence economies harder to maintain.
- Major transport corridors have cut across and divided up the taiga around Yiengra.
- The wastewater releases from the city of Neriungri may be an additional source of alarm, with regard to Hg in particular.

Discussion and Conclusions

The Evenki of Yiengra are one of the taiga Indigenous Peoples who continue to maintain their seasonal rounds, knowledge and land use in Eastern Siberia. This case study has focused on observations of impacts to their life from artisanal gold mining, which is known to be a major driver of Hg at the local as well as global scale (i.e., also in Africa, Asia and Latin America).

Mustonen and Lehtinen (2020) argue that Indigenous communities who are still practicing their nomadic way of life are intimately dependent on healthy terrestrial and aquatic ecosystems; the health of the environment is integral to the functioning of their socio-ecological systems. Sixteen years of CBM work with the Evenki has resulted in the mapping of gold mining sites and in the production and collection of descriptions of the following: impacts of Hg and other pollutants on reindeer and wildlife health; loss of fisheries and access to clean waters; alterations to waterways and their depth, water color, and accessibility; and the ethno-psychological impacts of alterations to the Evenki home area.

The Evenki have negotiated these impositions by recommending alternative locations for gold digging to limit the damage to their reindeer pastures, rivers and sacred places. The results of these local-scale adaptations vary. Positioning Evenki knowledge of Hg and its impacts alongside available science data (e.g., Sakha, 2017) reveals several points of convergence, including the fact that both the science and Evenki knowledge identify the Aldan Basin, in which the Yiengra River is located, as polluted. Divergence emerges with regard to the scale of the pollution described, the specificity as to how amounts of Hg are detected, and the long-term impacts of Hg on the river system. Further description and investigation into these points of divergence will have to wait for further collaborative studies.

The late reindeer herder Vladimir Kolesov recorded, in an oral history, how Evenki relations with their home area show how disturbance, loss and change are interconnected across both natural and human systems in a complex, intertwined whole:

> *"We say: Earth mother. If we go past large rivers, we hang a piece of cloth there. Close to the mountains we do that too. We hang a piece of cloth there. You are not allowed to leave pieces of firewood lying around. It is not allowed to cut more wood than what is needed. When you are someplace, for example hunting, don't leave pieces of wood crosswise. Everything needs to be in order. Don't throw bones around. I make a shelter, and all bones are put there. So that nothing is out of order. It is also because the reindeer come and bite the bones and suffocate.*
> *Clean and safe. To keep the reindeer from harm.*
> *You fish only as much as you need. If the next day you need more, you go fishing again then.*
> *If no one would buy the sable skins, it would not be hunted as much. If you need a hat, it is only then you're allowed to hunt. If there was no need, it would not be killed. This goes for all of the animals I think.*
> *And trees too. If you need wood for sleds, then you take but otherwise no. If there is no need, nothing will be cut"*
> (Mustonen, 2009).

Ultimately, the question of Hg loading on the Yiengra River is a debate between two human systems each of which possesses a very different kind of power — Evenki self-governance, built and continuing to build on Indigenous ways of being, and Soviet and Russian artisanal extraction of natural resources.

EA Case Study 6: References

Araseyenin, B., 2007. Jakutija – Istoriko-Kulturnii Atlas (Sakha Historical-Cultural Atlas). Yakutsk: Institute of Humanities.

ELOKA and Snowchange, 2020. Online Atlas of the Evenki of Iyengra, version 2.0. Exchange for Local Observations and Knowledge of the Arctic (ELOKA) and Snowchange Cooperative. Available at: www.evenki-atlas.org

Klokov, K., 2016. Reindeer herders' Communities of the Siberian Taiga in changing social contexts. Sibirica, 15 (1):81-101.

Lavrillier, A., 2006. S'orienter avec les rivières chez les Évenks du Sud-Est sibérien (Rivers as a spatial, social and ritual system of orientation among the Evenks of southeastern Siberia). Études mongoles et sibériennes, centrasiatiques et tibétaines, 36-37:95-138.

Mertens, K., 2015. Mobility and economy of the Evenkis in Eastern Siberia. Master of Arts in Anthropology Thesis. Boise State University. Boise State University Theses and Dissertations. 1049. Available at: https://scholarworks.boisestate.edu/td/1049

Mustonen, T., 2009. Karhun väen ajast-aikojen avartuva avara. Tutkimus kolmen euraasialaisen luontaistalousyhteisön paikallisesta tiedosta pohjoisen ilmastonmuutoksen kehyksessä (Peoples of the Bear: an inquiry into the local knowledge of three Eurasian subsistence communities in the context of northern climate change). Unpublished doctoral dissertation. University of Joensuu, Finland.

Mustonen, T. and Lehtinen, A., 2020. Lived Displacement among the Evenki of Yiengra. International Journal of Critical Indigenous Studies, 13(1):16-44.

Newell, J., 2004. Russian Far East – a reference guide for conservation and development. McKinleyville, CA: Daniel & Daniel Publishers. 466pp.

Romanov, A., Ignatieva, Y. and Morozova, I., 2018. Mercury Pollution in Russia: Problems and Recommendations. GEF (Global Environment Facility (GEF). Available at: http://www.ecoaccord.org/pop/Rtutnoe_zagryaznenie_English_25-08.pdf

Sakha, 2017. The State Report on the Current State and Protection of Environment of the Republic of Sakha (Yakutia) Госдоклад о состоянии и охране окружающей среды РС(Я). Available at: https://minpriroda.sakha.gov.ru/spravki-o-sostojanii-okruzhajuschej-sredy/spravka-o-sostojanii-okruzhajuschej-sredy-za-2017-god

Sidortsov, R., Ivanona, A. and Stammler, F., 2016. Localizing governance of systemic risks: a case study of the power of Siberia pipeline in Russia. Energy Research and Social Science, 16:54-68.

Yakovleva, N.,2011. Oil pipeline construction in Eastern Siberia: implications for Indigenous people. Geoforum, 42 (6):708-719.