Permafrost Matters

Time to React

“Permafrost Matters” offers a glimpse into the changing world of permafrost, drawing from the stories, maps, and graphics presented in the Arctic Permafrost Atlas.

PERMAFROST MATTERS

G·R·I·D ARENDAL
A UNEP Partner

IASC

NUNATARYUK

This project is funded by the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 773421

Pacific Ocean
Bering Sea
180°
135°W
Anadyr
Magadan
UNITED STATES
Fairbanks
Whitehorse
Yukon
Kolyma
CHINA
Yakutsk
Chukchi Sea
Mackenzie
East Siberian Sea
Beaufort Sea
Lena
Yellowknife
Laptev Sea
CANADA
Arctic Ocean
RUSSIA
North Pole
Norilsk
Yenisei
Hudson Bay
Kara Sea
Novy Urengoy
Chisasibi
Baffin Bay
Iqaluit
KALAALLIT NUNAAT (GREENLAND)
60°W
Surgut
Vorkuta
Ob
Barents Sea
Naryan-Mar
75°N
30°E
Nuuk
0°
Alta
Murmansk
Happy Valley-Goose Bay
Norwegian Sea
Kiruna
Rovaniemi
Labrador Sea
Arctic Circle
SWEDEN
FINLAND
ICELAND
NORWAY
60°N

Modelled permafrost coverage

- Continuous (>90%)
- Discontinuous (50–90%)
- Sporadic (10–50%)
- Subsea permafrost
- Glacial ice

SOURCES: OVERDUIN *ET AL.* (2019); OBU *ET AL.* (2019). BY LEVI WESTERVELD | GRID-ARENDAL (2023)

Life on Frozen Ground

Permafrost is ground that remains frozen for at least two years and occurs in Earth's coldest reaches. Most of the world's permafrost is found in the northern hemisphere, and in the Arctic, it underlies about 15 per cent of the exposed land area. It is also present in vast areas below the seabed. Subsea permafrost occurs in the Arctic continental shelves in a large swath extending offshore the Russian coast from the Barents Sea to the Chukchi Sea and beyond to the Alaskan and north-western Canadian continental shelves.

Communities within this area are known as permafrost settlements. There are currently 1,162 permafrost settlements in the Arctic. Almost 90 per cent of them have less than 5,000 inhabitants, but most people in this region, approximately 4 million, live in the larger 123 settlements that range in population size from 5,000 to 360,000. Most of the large settlements, 85 per cent, are found in the Russian Arctic.

People have lived in the Arctic for thousands of years, adapting to life in this harsh environment and passing their knowledge onto successive generations. Today, approximately 5 million people reside in the Arctic circumpolar permafrost area. Indigenous Peoples and local communities depend on permafrost for more than just stabilising buildings and other infrastructure. Many still live traditional or semi-traditional lifestyles, where they depend on hunting, fishing, and gathering to support themselves, their families, and their communities. Knowing and understanding the characteristics of permafrost is vital for their needs.

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Arctic permafrost settlements

Continuous Discontinuous Sporadic

NOTE: Only settlements with a population over 5,000 are labelled.

Each circle represents a settlement

RUSSIAN FEDERATION 3.77 million permafrost settlement population (92.05%) 608 settlements

Bilibino, Churapcha, Mayya, Pokrovsk, Amga, Ytyk-Kyuyol, Mokhsogollokh, Ust-Nera, Borogontsy, Chulman, Namtsy, Zhatay, Berdigestyakh, Verkhnevilyuysk, Udachny, Vilyuysk, Aykhal, Mirny, Tazovskij, Nyurba, Tura, Suntar, Urengoj, Salekhard, Kharp, Pangody, Nadym, Monchegorsk, Olenegorsk, Vorkuta, Kola, Murmashi, Nikel, Zapoljarnyj, Iskatelei, Severnyj, Vorgashor, Kogalym, Kirovsk, Pokachi, Beloyarskiy, Solnechny, Bely Yar, Megion, Nyagan, Lyantor, Khanty-Mansiysk (99 000), Tommot, Olyokminsk, Aldan, Yar-Sale, Dudinka, Neryungri, Labytnangi, Novy Urengoy (113 000), Norilsk (178,000), Anadyr, Fyodorovskiy, Magadan (93,000), Nizhn Kuranakh, Lensk, Nizhnevartovsk (275,000), Nojabrysk (107 000), Muravlenko, Fyodorovskiy, Beryozovo, Raduzhny, Tarko-Sale, Goubkinski, Priobye, Purpe, Nizhnesortymskiy, Poykovskiy, Naryan-Mar, Barsovo, Neftejugansk (126 000), Igrim

Yakutsk has a population of 308,000. and is the largest city on continuous permafrost. Of the other 394 permafrost settlements in the Sakha Republic, 91% are located on continuous permafrost.

Murmansk (298,000)

With a population of 361,000, **Surgut** is the largest permafrost settlement in the Arctic. 60% of the Arctic permafrost population lives on sporadic permafrost.

U.S. 154,000 (3.8%) 152

Bethel, Badger, Fairbanks, Chena Ridge, College

CANADA 94,000 (2.3%) 82

Iqaluit, Yellowknife

KALAALLIT NUNAAT (GREENLAND) 45,000 (1%) 58

Sisimiut, Nuuk

SWEDEN 19,000 (0.5%) 5

Kiruna

NORWAY 12,000 (0.3%) 9

ICELAND 1,300 (0.03%) 3

FINLAND 500 (0.01%) 2

SOURCE: RAMAGE *ET AL.* (2021). BY LEVI WESTERWELD | GRID-ARENDAL (2023)

Influenced by Ice

While permafrost itself is largely unseen, there are numerous unique landscape features and processes associated with permafrost environments. The top layer of soil that thaws and refreezes every year is called the active layer. This layer plays a crucial role in Arctic ecosystems as this is where most hydrological, biogeochemical, and soil processes happen.

Ice-wedge polygons are common in lowland tundra landscapes (A). They form as a result of water infiltrating the soil and freezing year after year, pushing the soil laterally to create these striking geometric features. Thawing permafrost can also create thermokarst basins, or thaw lakes, which are important for Arctic wildlife (B).

Standing at 49 metres in height and a width of 300 metres at the base, Ibyuk is the tallest pingo in Canada and second tallest in the world. It formed about 1,300 years ago in a drained lake bottom (C). Like most pingos, it is the result of water in the permafrost freezing, generating upward pressure and pushing the soil into a dome-like feature.

Besides vast amounts of organic carbon, permafrost may have trapped other substances such as contaminants and pathogens too. As temperatures increase and permafrost thaws, these can be remobilised, potentially exacerbating climate warming and threatening human health and well-being.

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SOURCE: MODIFIED FROM VIEIRA *ET AL.* (2019). BY LEVI WESTERVELD | GRID-ARENDAL (2023)

Moving Grounds

In the far reaches of the Arctic, permafrost is not only shaping but also holding together the landscape and coastlines, locking the soil together in an icy embrace and making it play a crucial role in preventing erosion. However, as global temperature rises and permafrost thaws, the once solid ground becomes unstable. Hillsides may collapse and slide downslope as “retrogressive thaw slumps”, and depressions formed in the terrain can create new lakes, ponds, and wetlands.

The presence of ground ice makes Arctic coastlines more vulnerable to erosion. The loss of permafrost can lead to the crumbling and slumping of coastal areas, causing land to fall into the ocean. Coastal erosion is so severe in some locations that whole communities need relocating.

A striking feature of permafrost thaw is the appearance of “retrogressive thaw slumps” (A). These depressions are caused by the rapid thaw and erosion of ice-rich permafrost and can be found along coastlines, riverbanks, and hill slopes. As the ice melts, a slurry of water and sediments moves downslope and the slump retreats – or retrogresses – inland (B), while meltwater and rain create a drainage system that carries sediments further to the coast (C). The high sediment supply released into the sea affects the availability of light for marine organisms (D).

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SOURCE: MODIFIED FROM VIEIRA ET AL. (2018) | BY LEVI WESTERVELD | GRID-ARENDAL (2023)

Rivers Run Through It

Rivers and river deltas play a vital role in Arctic ecosystems. While the Arctic Ocean accounts for about 1 per cent of the Earth's ocean volume, it receives more than 10 per cent of all global river discharge.

Permafrost underlies a substantial part of the catchment of all Arctic rivers, both big and small, thus, largely controlling the hydrology of the area. Ice in deltas and riverbanks affects erosion and sedimentation processes, as well as the seasonal flow of water into the Arctic Ocean.

As permafrost thaw intensifies, enhanced river discharge and erosion brings more organic matter (dark colours) and fine sediments (bright colours) into the ocean (A). Increased dark organic matter absorbs more heat, warming the surface waters. More suspended material increases turbidity leading to less light penetration, affecting primary production. Combined with increased precipitation in the Arctic, more riverine transport in summer and early autumn can be expected. These changes in hydrology will have a profound impact on the terrestrial ecosystems, as well as the freshwater balance.

The Arctic Ocean is currently a large carbon sink, meaning it takes up carbon from the atmosphere and stores it in the water column or buries it in the sea floor sediments. Greater inputs of organic carbon to the ocean can change this, leading to an increased carbon flux or exchange from the ocean to the atmosphere.

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SOURCE: SATELLITE IMAGE OF A PART OF THE LENA RIVER DELTA IN NORTH-EASTERN SIBERIA, RUSSIA, COPERNICUS SENTINEL-2, 2020-09-10, LEVI WESTERVELD | GRID-ARENDAL (2023)

Terra Infirma

Permafrost has always presented engineering challenges. Houses, industrial facilities, roads, and transportation networks all need a stable surface on which to function. For the people living and working on permafrost this is nothing new. Over generations, innovative approaches have been developed to adapt to the harsh environments, such as building houses on piles or constructing above-ground pipelines to prevent damage from the annual thawing of permafrost's active layer.

As permafrost degrades, it is becoming more challenging to construct long-lasting, stable structures as permafrost is increasingly neither permanent nor stable. This may come at a heavy cost: the economic impacts of infrastructure damage in Arctic permafrost regions are estimated to be more than USD 276 billion over the next 40 years.

Like so many communities in the Arctic, Paulatuk heavily relies on air transportation, which is available all year-round. Built on permafrost and less than 100m from the shoreline, Paulatuk's airport is particularly vulnerable to the impact of permafrost thaw, coastal erosion, and flooding (A). It has experienced rapid coastal erosion up to 80 centimetre per year.

Paulatuk's infrastructure, including houses, are built over ice-wedge polygons which are particularly vulnerable to permafrost thaw (B). At the airport, the runway generates disturbances in the permafrost and prevents drainage of meltwater from ice wedge polygons in the spring, creating ponds (C).

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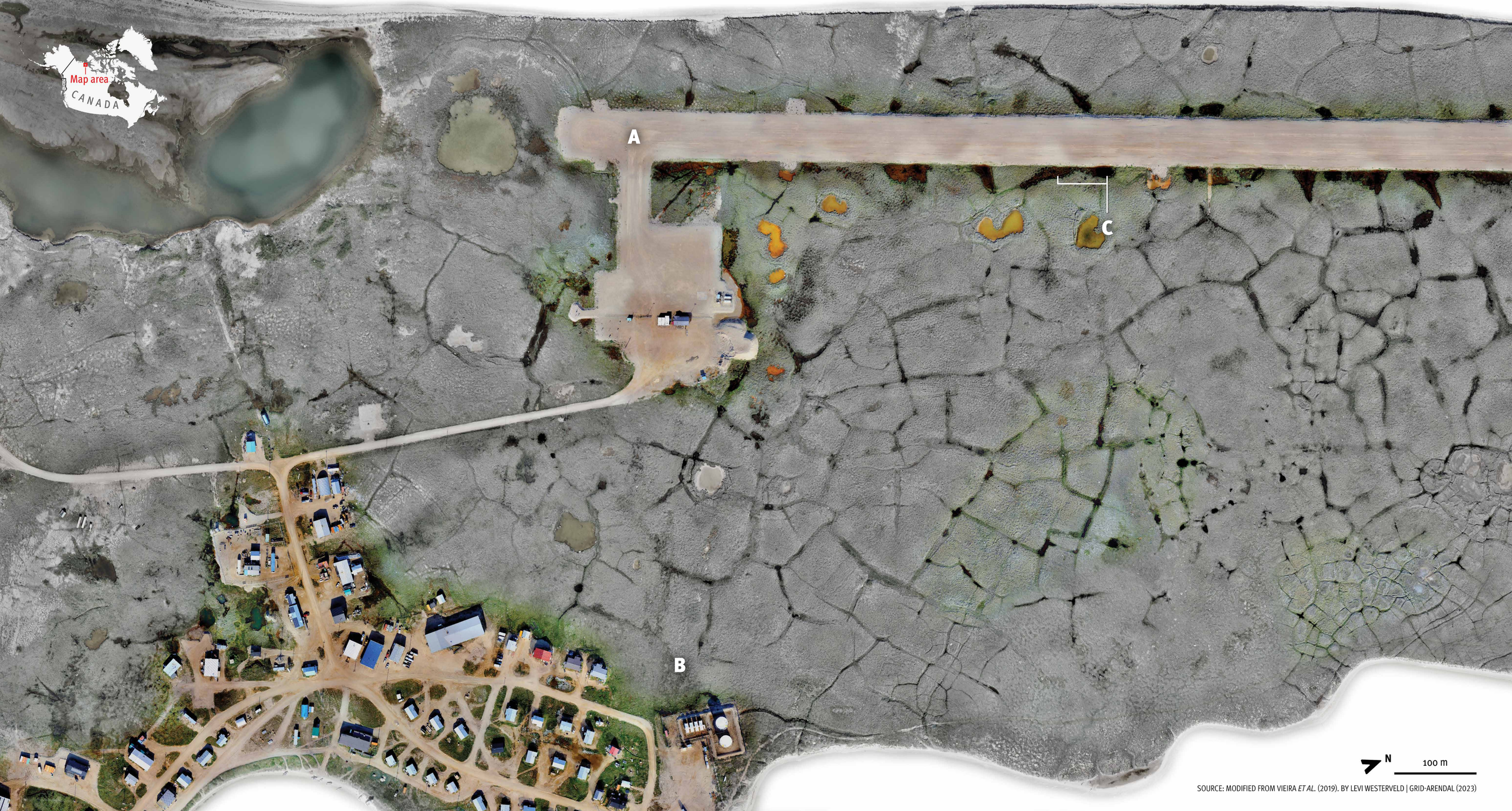

SOURCE: MODIFIED FROM VIEIRA *ET AL.* (2019). BY LEVI WESTERVELD | GRID-ARENDAL (2023)

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Lying beneath the surface of the land and the ocean, permafrost is seldom visible to us. Yet it is comparable in size to other components of the cryosphere, rivalling Antarctica in spatial extent.

The presence of permafrost influences everything, from Arctic landscapes and human settlements to the global climate system. Rising temperatures are causing dramatic transformations in permafrost. The once reliably frozen ground is now thawing, resulting in significant impacts to ecosystems, infrastructure, and the lives and livelihoods of Arctic people.

Permafrost soils may also have an outsized effect on our climate. As one of the largest carbon stores in the world, thawing permafrost has the potential to unleash a staggering 50 to 200 billion tons of carbon dioxide equivalent into the atmosphere. Such a substantial release of emissions could considerably accelerate global warming, jeopardising our ability to stay within the 1.5°C target established by the Paris Agreement and further increase the challenges we face as a global society. Adaptation costs for communities built on permafrost could skyrocket to USD 276 billion by mid-century.

The time for action is now!

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I have three siblings and we live in Aklavik, a hamlet with a population of approximately 500 located in the Inuvik region of the Northwest Territories, Canada. The village is situated along the Peel River, providing our community with all the water we use for drinking, showering, and washing.

Being located on permafrost means Aklavik has had to adapt in many ways.

There is no road to get in or out of Aklavik. Instead, boats are used in the summer as a mode of transportation across the Mackenzie Delta. In the winter, snowmobiles and trucks can be driven on the ice road. But with climate change, these landscapes are changing. I go out with my friends to check our traps and it is really cold out, and then suddenly we are sinking in slush. It's very unpredictable.

Reflecting on the impacts of permafrost thaw on my community, it's clear that people here know very little. It wasn't part of my high school curriculum, for example. I feel it is not treated as a priority for people to know about. I think a little more education on the topic would be beneficial for our community. Afterall, it is literally right under our feet.

Jessi Pascal

Environmental Coordinator at Gwich'in Renewable Resources Board, Aklavik, Canada

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I was born in 1967 in the village of Nelemnoye in the Upper Kolyma region of the Sakha Republic (Yakutia). I am both a researcher focusing on the history and culture of Indigenous minorities of the Russian North, and the Chairman of the Council of Elders of the Yukaghir people.

Changes in climate limit our traditional fishing and hunting practices.

Autumn sea-ice fishing, which historically would start around the end of October, can no longer take place, or has become very dangerous, as any ice is still quite thin then. Hunting practices have been similarly affected. Musk deer hunting usually takes place in November when the animals migrate from their summer to winter pastures. But as the ice road is no longer accessible this early, traditional hunting grounds are impossible or very dangerous to access.

As the number of fishers and hunters dwindle, more people are now scavenging for mammoth tusks and bones, which can fetch high prices on the black market. These appear at the tundra's surface as permafrost thaws. But scavenging mammoth tusks is against traditional beliefs. Traditionally, we associate mammoths and their spirits with the underworld. Bad things come from there. In the past, remains of mammoths mostly appeared during floods and on eroding riverbanks, so they are associated with such events. When these tusks and bones resurface in the tundra, a door is opened between the underworld and the middle world where people live.

■ **Vyacheslav Shadrin**
Chair of Council of Yukaghir Elders, Nelemnoye, Russia

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