

Health and Environmental Security in a Warming Arctic

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Introduction – A Warming Arctic

The Arctic is warming faster than any other region on Earth, with the rate of warming being two to three times greater than the global average (AMAP, 2024). Warming is shifting habitats northward, disrupting wildlife and altering ecosystem dynamics. Rapid warming is dramatically transforming the Arctic environment, from vanishing sea ice to thawing permafrost to more extreme weather (Pecl et al., 2017). As the Arctic warms, permafrost (permanently frozen ground) is thawing, releasing greenhouse gases like methane and carbon dioxide, which further amplify warming. An unexplored vulnerability for the Arctic region now and in the immediate future is the rapid thawing of permafrost due to climate change, with concomitant emerging risks to human and animal health (Hedlund et al., 2014). Permafrost contains a vast microbial diversity, including bacteria, viruses, and fungi that have been frozen for millenia. As permafrost thaws, these microbes can become active again, potentially causing new or re-emerging infectious diseases in humans and animals (Caruso & Rizzo, 2025, Findlay, 2025). The risk is particularly high for zoonotic diseases, as thawing permafrost alters the habitats and migration patterns of wildlife that can serve as disease reservoirs (Parkinson & Evengård, 2009).

Recognizing permafrost thaw as one of the greatest vulnerabilities in the Arctic is crucial for mobilizing the resources and partnerships needed to address this urgent challenge (Ramage et al., 2021). By working across disciplines and knowledge systems, and by centering the voices of Arctic

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communities, more effective strategies should be developed for monitoring, mitigating, and adapting to the far-reaching impacts of permafrost thaw in the rapidly changing North.

What Is Arctic Environmental Security?

Arctic Environmental Security comprises three realms: ecological security, human security, and defense security that interact within the larger framework of a Tripartite Environmental Security concept for the polar regions (Causey & Greaves, 2021; Causey et al., 2022; 2024). This has major implications for ecosystems, infrastructure, food security, and ways of life – especially for Indigenous communities. Due to varying definitions and perspectives, there have been multiple perspectives with a lack of a collective understanding of the components and their interactions (Bazeley et al., 2014; Heininen, 2021).

Environmental change in habitat and species distribution may directly affect food and water security, including changing distributions of traditional subsistence food items (Huntington et al., 2018; Medeiros et al., 2017; Natcher et al., 2016) that will challenge local adaptation to change. This weakening of the internal structure of environmental interconnections may be conceptualized as a weakening of “ecosystem health” or ecological complexity. Still, direct measurement of change has vexed environmental ecologists from the onset of focused study (Klubnikin & Causey, 2002; 2005).

Environmental security in the rapidly changing Arctic requires managing rising geopolitical tensions, understanding and adapting to climate change impacts, protecting ecosystems and biodiversity amidst natural resources exploration, extraction, and competition; ensuring sustainable industrial development, tackling industrial contaminants, bolstering food security, and building resilient infrastructure (Heininen, 2021). Improving scientific research, Indigenous knowledge co-production, and international cooperation will be critical in all of these areas. Human security is contextual, determined by local people and local communities. Thus, local knowledge and local contexts are informed—a concept evident and important in the Arctic and polar regions (Huntington & Pungowiyi, 2009). Bazeley et al. (2014) describe human security as providing “...a framework in which local peoples can identify issues and solutions that will increase their security, and many policies, pathways, and options become available.”

The analog and integral interacting component to Environmental Security is the One Health paradigm, where human public health, environmental health, and animal health are interdependent (Dudley et al., 2015; Ruscio et al., 2015). While it is a relatively new concept of how public health can be understood and directed, key aspects of One Health have already been encompassed and utilized by Indigenous people throughout the Arctic. A very concise review of how the intersection of these three components may affect the environmental security of the Arctic and its inhabitants is given by Berner et al. (2024):

Operationalising One Health requires application of the One Health paradigm to the issues to be addressed. It requires the development of metrics to monitor trends in recognised threats, to detect emerging ones, and evaluate the results of mitigation and adaptation strategies. The strategy should take advantage of Indigenous and local knowledge, as well as scientific application of technology, where appropriate. In the circumpolar north, where many community challenges are climate-sensitive, a One Health approach may help in developing an effective

and sustainable response. In the European Union, the One Health approach has been the basic element of the new funding calls together with community-based participatory elements of including local and Indigenous populations. Communities benefit from a well-functioning system for systematically monitoring trends in environmental change and diseases or other threats to wildlife, such that residents and jurisdictional health systems can respond effectively. This may include physical monitoring, for example concerning shoreline erosion or permafrost temperature; as well as biomonitoring to collect evidence of subsistence animal exposure to zoonotic diseases and contaminants.

The Role of Climate in Disease Emergence in the Arctic

A changing Arctic environment is expected to have significant impacts on the emergence, transmission, and distribution of infectious diseases in the region. As permafrost thaws due to rising temperatures, ancient bacteria, fungi, and viruses that have been trapped for thousands of years could be released. Some of these microbes might be capable of infecting humans or animals, potentially causing new diseases or the re-emergence of previously eradicated ones (Parkinson & Evengård, 2009; Waits et al., 2018).

Further, as described in Berner et al. (2024):

Climate change is predicted to be one of the most influential factors in the emergence of infectious diseases and will have both direct and indirect impacts on human health, especially in relation to infectious diseases...Higher sea and land temperatures can increase growth rates of pathogens and animals, including insect vectors. Changes in climatic factors can expand or compress a disease vector's geographic range, change the seasonality of vector-borne diseases, increase/decrease its population size, and alter vector species and individuals' ability to survive the winter.

Specific examples of diseases that could be impacted include zoonotic diseases like rabies and tularemia can spillover to new species hosts, and to humans. Tularemia, a fatal infection caused by the bacteria *Francisella tularensis*, recently spilled over to beluga whales in Cook Inlet, Alaska, and to a human case in Anchorage, Alaska (Rouse et al., 2025). Other severe disease risks from ancient Arctic permafrost reservoirs include anthrax, caused by *Bacillus anthracis*, a fatal disease of herbivores that can spill over to humans. Indeed, an intense outbreak of anthrax occurred in reindeer (*Rangifer tarandus*) in the Yamal Peninsula of Siberia in 2016, with over 6% incidence in a herd population of 41,000 head, and 2,350 recorded animal deaths (case fatality rate, 89%) (Liskova et al., 2021). The cause and route of exposure in the 2016 Yamal reindeer outbreak is unclear; however, climatic factors including exposure to anthrax spores in thawing permafrost, and cessation of reindeer vaccination some years prior, may have contributed (Liskova et al., 2021). There were 36 human cases in reindeer herding communities, one of which was fatal.

Reindeer and their North American cousin the caribou, found in herds in Alaska and northern Canada in a total population of more than 500,000 head, exhibit a wide-ranging migratory behavior across a melting Arctic. Consequently, they are an important subsistence food source for Indigenous peoples, and can serve both as a sentinel species and potential hosts of anthrax and other exotic diseases – notably, brucellosis (*Brucella* spp.), Q fever (*Coxiella*), and erysipelas

(typically caused by *Erysipelothrix rhusiopathiae*; in some human cases by group A *Streptococcus*). Moreover, herbivores in Alaska (caribou, moose, musk ox, and buffalo) are potential hosts of novel *Mycobacteria* spp. found in the environment, including *M. bovis*, that can occasionally cross species barriers. Alaska already suffers from endemic *M. tuberculosis*, a *Mycobacteria* well-adapted to humans, and has noted *M. bovis* cases (Inman et al., 2025). The potential for ancient strains of these exotic bacterial infections to spread from carcasses (whether contemporary or thawed out of permafrost) to animals or humans is a serious challenge to biosecurity in the Arctic regions.

Changing climate is also altering bird migration patterns, which could introduce new avian-borne diseases to the Arctic. One severe disease that has spread to Alaska and the Arctic, and indeed to seven continents, by migratory birds is highly pathogenic avian influenza (HPAI). HPAI is fatal in some wild bird species, and can spillover to cause severe or fatal infections in poultry and mammals (Ahlstrom et al., 2024). Marine mammals (northern fur seals) in the Bering Sea have died from HPAI exposure; and terrestrial mammals in Alaska including foxes and bears are thought to have been exposed by predatory and scavenging behavior (Stimmelmayer et al., 2024; 2024; Sobolev et al., 2024; Beckmen et al., 2025).

Climate change is disrupting traditional food sources and water supplies in the Arctic, as ecosystems change and infrastructure is damaged by thawing permafrost (Cavicchioli et al., 2019). This could lead to malnutrition and waterborne diseases, especially given inadequate sanitation infrastructure often found in Arctic communities that are of higher vulnerability to infections (Eichelberger et al., 2021). Vector-borne diseases like Lyme, malaria, and West Nile virus also might emerge (Hueffer, 2015). For example, the range of the *Ixodes* tick, which can carry Lyme disease, is projected to expand as the Arctic warms (Berner et al., 2024; Omazic et al., 2019).

Wildlife and Human Health Interactions in the Arctic

Migrating animals are expected to play a significant role in the spread and emergence of infectious diseases in the Arctic as the climate warms. As migratory birds and mammals alter their routes and timing in response to changing Arctic conditions, they could introduce novel pathogens from lower latitudes into the Arctic (Altizer et al., 2011). Warmer temperatures are allowing mosquitoes, ticks, and other disease-carrying arthropods to expand their ranges northward (Kutz et al., 2014). Migratory birds can transport these vectors long distances and introduce them to new areas in the Arctic. As noted above for HPAI, migratory birds are known to carry influenza viruses and could potentially spread new strains to Arctic bird populations and then to other wildlife or humans. Migratory animals can serve as reservoir hosts for zoonotic pathogens, amplifying them in the environment. As Arctic habitats change and migratory patterns shift, this could bring infected animals into closer contact with other wildlife species and humans, facilitating disease spillover events (Pecl et al., 2017). Diseases like HPAI and exotic bacterial infections (noted above) could potentially spread in this way (Descamps et al., 2017; Ahlstrom et al., 2024; Beckmen et al., 2025). Altered migration timing and routes could affect the dynamics of established host-pathogen systems in the Arctic. For example, changes in caribou migration in response to earlier spring snowmelt could affect their exposure to parasites and diseases (Pearce et al., 2015). Shifts in the population density and distribution of migratory species could also influence disease transmission dynamics.

Many Arctic communities, particularly Indigenous ones, have limited access to healthcare services. Damage to infrastructure from thawing permafrost and coastal erosion could further disrupt healthcare delivery and disease surveillance efforts. This could make it harder to detect and respond to infectious disease outbreaks. Enhanced surveillance, research into climate-disease relationships, and strengthening of public health systems will be critical to mitigating and adapting to these emerging infectious disease risks in a changing Arctic (Johnson et al., 2015).

Traditional Arctic Indigenous peoples, including the Inuit, Aleut, and other groups in Alaska, Canada, Greenland and Russia, have lived for centuries in close connection with the land and animals. Over time, they have developed a wealth of traditional knowledge about health and disease (Ford et al., 2020). A deep understanding of the Arctic environment, weather patterns, animal migrations and other ecological factors can provide insights relevant to the emergence and spread of infectious diseases (Kipp et al., 2019; Krawchuck & Tracz, 2021). However, much of this traditional knowledge has been eroded due to colonization, suppression of Indigenous practices, and loss of Elders who carry this knowledge. In recent years there has been growing research interest in better understanding and applying Indigenous knowledge to inform culturally-grounded approaches to infectious disease control in the Arctic (Latulippe & Klenk, 2020; Petrusek MacDonald et al., 2015; UNESCO 2019). Partnerships should focus on bringing together Indigenous traditional knowledge and Western scientific knowledge to develop a more holistic understanding of climate change impacts and potential solutions (Johnson et al. 2015, Pearce et al. 2015). This requires building trust, respect, and mutual understanding between Indigenous knowledge holders and researchers (Redvers et al., 2020).

The Arctic Council has emphasized the need for a "One Health" approach that integrates human, animal and environmental health surveillance to detect emerging disease risks in the Arctic. For example, they have highlighted the potential for pathogens to be released from thawing permafrost as the Arctic warms. Notably, new technologies for remote sensing such as drone-based data collection, and metagenomics for agnostic microbial detection from environmental, animal, human or food samples, can function as knowledge-multipliers to provide data-rich insights for identification of novel emerging pathogens across vast Arctic environments (Atkinson et al., 2021; Rouse et al., 2025). Arctic states maintain essential cooperation on biosecurity threats through informal channels and other international forums (Nicol & Heininen, 2014). For example, the Sustaining Arctic Observing Networks (SAON) initiative, which is not directly part of the Council, will continue to promote some coordination on public health surveillance. Longstanding scientific data sharing on issues like animal disease outbreaks must continue and expand. as the need becomes increasingly urgent.

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