



Arctic Vulnerability: Examining Biosecurity Risks Amidst Climate Change

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M. P. Poto supervised the first draft of this research and provided insights on how to refine and shape this project idea into educational and research content.

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Abstract Building on the objectives of a working paper, this chapter explores the intricate relationship between the Arctic Circle, climate change, and One Health. The Arctic is exceptionally susceptible to climate change, warming three times faster than the global average, leading to increased melting of snow, ice sheets, and permafrost. These changes heighten the vulnerability of flora, fauna, and Indigenous communities that thrive in this ecosystem. Additionally, thawing permafrost releases numerous toxins and revives dormant microorganisms, increasing biosecurity risks to human, animal, and plant health. Urgent enhancement of health surveillance is essential to identify and contain potential zoonotic disease outbreaks promptly. Informed by the One Health approach which emphasises the interconnection of environmental, animal, and human well-being, this working paper aims to enrich existing literature by systems mapping diverse One Health surveillance systems in this region. The overarching goal is to improve public health outcomes in the Arctic Circle by fostering transdisciplinary collaborations and addressing challenges associated with implementing the One Health framework in this vast and unique landscape. Aligned with the United Nations 2030 Agenda for Sustainable Development, emphasising transformative actions for planet protection, this paper advocates for the successful integration of the One Health framework to improve the holistic health of the ecosystem. In doing so, it supports ecological education and contributes to the overall goal of safeguarding the planet.

Keywords Sustainability · Research · One Health · Arctic

I INTRODUCTION: OVERVIEW OF THE WORKING PAPER AND CASE STUDY

Human-induced climate change is irreversibly transforming the world, and these effects are even more accelerated in the Arctic Circle where warming temperatures are melting snow, icesheets, and permafrost that

have protected and supported this environment for centuries.¹ Unfamiliar transformations of the ecosystem are increasing the vulnerability of the flora, fauna, and Indigenous residents who live in this region, and compromising their ability to adapt and thrive. Thawing permafrost is concerning because biogeochemical toxins that have laid frozen for millennia are now being reintroduced into the environment.² Additionally, microorganisms adapted to extreme temperatures are also being revived, posing potential threats to the region's ecosystem.³ The focused case study elaborates on this phenomenon and expands on the biosecurity risks to human, animal, and plant health. To mitigate these risks, there is an urgent need to enhance health surveillance in this region so that zoonotic disease outbreaks can be quickly identified and contained.

An important component of an efficient and successful health surveillance programme for the Arctic is the One Health framework.⁴ This framework recognises that the health of the people, animals, and ecosystem are intimately interconnected and that holistic strategies need to be embraced for building resistance against the devastating effects of climate change and to restore balance and well-being to this region. Although research in this field is gaining traction, there is currently a knowledge gap on what the existing pathways for human, animal, and environmental disease surveillance are within the various countries in the Arctic Circle. This is largely because of the geopolitical vastness of this region, as well as complex challenges associated with implementing the framework.⁵ In the capacity of a working paper, the goal is to enrich the existing literature by systems mapping the diverse One Health surveillance systems currently in place. Through the creation of a comprehensive visual representation of these systems, the aim is to promote the One

¹ For more detailed look at climate change statistics in the Arctic, see Norsk Polar Institute. Climate Change in the Arctic. Available at <https://www.npolar.no/en/themes/climate-change-in-the-arctic/#toggle-id-1>, last access 28 October 2023.

² See Miner, K. R., D'Andrilli, J., Mackelprang, R., Edwards, A., Malaska, M. J., Waldorp, M. P. & Miller, C. E. (2021). Emergent biogeochemical risks from Arctic permafrost degradation. *Nature Climate Change*, 11, 809–819.

³ Ibid. (see footnote 1).

⁴ For more information on the One Health approach, see Reynolds, A., Kutz, S., & Baker, T. (2022). A holistic approach to one health in the Arctic. In M. Tryland (Ed.), *Arctic One Health*. Cham: Springer.

⁵ Ibid. (see footnote 2).

Health approach in the region. This involves identifying opportunities for transdisciplinary collaborations and elucidating strategies for successful integration to improve public health outcomes in the Arctic Circle.

2 BACKGROUND

2.1 *Arctic Circle and the Arctic Council*

The Arctic Circle denotes an area of exceptional natural beauty and harsh environmental circumstances. It is an imaginary line that circles the Earth at roughly 66.5 degrees latitude north (precise coordinates vary depending on the Earth's axial tilt). Geographically, the Arctic Circle passes through several countries and regions, including parts of Norway, Sweden, Finland, Russia, the United States (Alaska), Canada, Greenland, and Iceland. The vast region encircled by the Arctic Circle is home to a multitude of ecosystems ranging from the Arctic Ocean to frozen tundra and icy landscapes, all of which support unique and resilient plant and animal life. Apart from its geographical relevance, the Arctic Circle bears cultural, ecological, and geopolitical significance. These northern regions have been home to generations of Indigenous peoples who have adapted their ways of life to meet the unique opportunities and challenges presented by the Arctic environment.

The Arctic Council which was originally established to protect the environment and people of this region, consisting of eight Arctic states (Canada, Finland, Denmark, Iceland, Norway, the Russian Federation, Sweden, and the United States) and six permanent participants as represented by the Indigenous Peoples of the Arctic.⁶ Regional diplomacy was severely impacted by the invasion of Ukraine by the Russian Federation in 2022 which directly resulted in the suspension of Russia from the Council and, motivated the historically neutral countries of Finland and Sweden to join the North Atlantic Treaty Organization (NATO).⁷ These fractured political relationships add a layer of complexity and constraint to the

⁶ More information on the Arctic Council can be accessed online at <https://arctic-council.org/about>, last access 28 November 2023.

⁷ McVicar, D. (2022). How the Russia-Ukraine war challenges Arctic governance. Council on Foreign Relations. <https://www.cfr.org/blog/how-russia-ukraine-war-challenges-arctic-governance>, last access 27 November 2023.

climate-change-related biogeochemical transformation that this region is currently undergoing.

2.2 *Effects of Climate Change on the Arctic Ecosystem*

The Arctic region is extremely sensitive to global warming, making it a key reference point for studying the effects of climate change on Earth.⁸ Traditionally, the Arctic has been covered in snow, ice, and permafrost, forming a reflective surface that collectively deflects 80% to 90% of the sun's radiation through the albedo effect.⁹ This phenomenon helps preserve cooler temperature ranges in the region. With the acceleration of global warming, there is a melting of these elements, leading to the expansion of land and water areas that absorb heat, thereby contributing to Arctic heating. In fact, it is warming three times faster than the global average, and it is predicted that within the next three decades, summers in the Arctic will become completely ice-free leading to irreversible consequences both locally and globally.¹⁰ This has profound implications for the delicate ecological balance that exists between the flora, fauna, and Indigenous Peoples of this region.

The Arctic tundra biosphere is characterised by a region of low-growing, treeless vegetation that is cold-resistant, extending from the Arctic Ocean in the North to the boreal forests in the South. Historically, extreme living conditions in the Arctic region have been inhospitable to most life forms and only the sturdiest of species have evolved and adapted to this unique ecosystem. Recent decades of global warming, accompanied by the rapidly melting sea ice evoked physical and biological changes in this region resulting in “the greening of the Arctic”.¹¹ These developments along with human influences through transportation networks, are

⁸ For more detailed look at climate change statistics in the Arctic, see Norsk Polar Institute. Climate Change in the Arctic. Available at <https://www.npolar.no/en/themes/climate-change-in-the-arctic/#toggle-id-1>, last access 28 October 2023.

⁹ To read more about albedo effect, see NSIDC. Sea Ice. <https://nsidc.org/learn/parts-cryosphere/sea-ice/quick-facts-about-sea-ice>, last access 28 October 2023.

¹⁰ On the key trends and impacts of climate change in the arctic, see the following policy brief: Arctic Monitoring and Assessment Programme. (2021). *Arctic Climate Change Update 2021: Key Trends and Impacts*. <https://oarchive.arctic-council.org/server/api/core/bitstreams/952ce558-b096-458c-9bed-89e1cc9129ba/content>.

¹¹ Frost, G. V., Macander, M. J., Bhatt, U. S., Berner, L. T., Bjerke, J. W., Epstein, H. E., Forbes, B. C., Goetz, S. J., Lara, M. J., Phoenix, G. K., Serbin, S. P., Tømmervik,

encouraging the influx of non-native plant life into the Arctic environment. This, in turn, enables the migration of alien animal species and insects to the tundra, significantly impacting the ability of indigenous species to survive and flourish in this area.¹² Arctic biosecurity issues are further amplified because these intruders carry new parasites and diseases that pose a threat to existing biodiversity and place numerous species at immediate risk of disease and extinction.¹³

For centuries, the Indigenous people of the Arctic have thrived in this region, forming deep connections with its various elements such as the land, water, snow, ice, animals, and plants. The delicate balance of this interconnected system is disrupted when any one component is affected. Recent climate changes have wreaked havoc within this intricate ecosystem, severely impacting the traditional knowledge and practices that have been passed down through generations.¹⁴ These practices are mostly weather- and environment-sensitive, both of which have become erratic due to global warming. Daily activities like hunting, fishing, and reindeer herding have become riskier as journeys over sea ice are now more unpredictable, with thawed and frozen water bodies coexisting in close proximity.¹⁵ Similarly, the availability of traditional foods such as

H., Walker, D. A., & Yang, D. (2022). Arctic Report Card: Update for 2022. NOAA, 1. <http://doi.org/10.25923/g8w3-6v31>.

¹² For more details on the zoonotic diseases, see Waits, A., Emelyanova, A., Oksanen, A., Abass, K., & Rautio, A. (2018). Human infectious diseases and the changing climate in the Arctic. *Environmental International*, 121(1), 703–713.

¹³ To explore the impact of climate change on polar ecology, see Rew, L. J., McDougall, L., Alexander, J. M., Daehler, C. C., Essl, F., Haider, S., Kueffer, C., Lenoir, J., Milbau, A., Nuñez, M. A., Pauchard, A., & Rabitsch, W. (2020). Moving up and over: Redistribution of plants in alpine, Arctic, and Antarctic ecosystems under global change. *Arctic, Antarctic, and Alpine Research*, 52(1), 651–665. <http://doi.org/10.1080/15230430.2020.1845919>.

¹⁴ For more in-depth analysis on the relationship between Indigenous peoples in the Arctic and climate change, see Almonte, M. P. (2023). Vulnerability in the Arctic in the context of climate change and uncertainty. The Arctic Institute. <https://www.thearcticinstitute.org/vulnerability-arctic-context-climate-change-uncertainty/>, last access 30 November 2023.

¹⁵ Ibid. (see footnote 12).

berries, herbs, whales, seals, etc. is also negatively influenced by temperature changes and Arctic greening which further cripples the ability of Indigenous residents to live healthy lives.¹⁶

2.3 *One Health*

To protect the holistic health of the region, an innovative approach needs to be embraced. One Health is a comprehensive and coordinated strategy that aims to optimise the health of people, animals, and ecosystems in a sustainable way by acknowledging and respecting the deep interconnections that exist between them.¹⁷ One Health is particularly suitable for the vastness of the Arctic region since it recognises the importance of working at the local, regional, national, and global levels, rather than a siloed approach.¹⁸ Furthermore, the interconnectedness between people, animals, and their ecosystems constitutes a worldview that is reflective of and in alignment with Indigenous teachings and experiences.¹⁹ The Arctic Council's Sustainable Development Working Group along with multinational stakeholders such as The Canadian Arctic One Health Network²⁰ and others, have been promoting One Health initiatives in this region. The goal is realised by establishing a platform for transdisciplinary communication and collaboration among experts in human, animal, and environmental sciences, as well as other stakeholders, including policy-makers. The primary objective is to monitor and mitigate public health threats arising from the transmission of diseases among humans, animals, plants, and the environment. The challenges to implementing One Health in this region arise from the complex geopolitical relationships that exist within the vast Circumpolar North.

¹⁶ Ibid. (see footnote 12).

¹⁷ See World Health Organization. (2017). One Health. <https://www.who.int/news-room/questions-and-answers/item/one-health>, last access 29 November 2023.

¹⁸ See Centers for Disease Control and Prevention. (2023). One Health Basics. <https://www.cdc.gov/onehealth/basics/index.html>, last access 5 December 2023.

¹⁹ The parallels between Indigenous worldview and One Health framework are further elaborated in Hueffer, K., Ehrlander, M., Etz, K., & Reynolds, A. (2019). One health in the circumpolar North. *International Journal of Circumpolar Health*, 78(1), 1607502. <https://doi.org/10.1080/22423982.2019.1607502>.

²⁰ More on The Canadian Arctic One Health Network can be accessed on <https://arcticnet.ulaval.ca/project/the-canadian-arctic-one-health-network/>, last access 30 November 2023.

3 CASE STUDY

3.1 *Thawing Permafrost and Arctic Biosecurity*

Rising temperatures from global warming are contributing to the accelerated and erratic thawing of the region's permafrost which is a layer of soil that has remained frozen for at least two consecutive years. It functions as an extensive reservoir for biological, chemical, and radioactive materials that have been preserved for millions of years.²¹ In fact, permafrost has been labelled as one of the most significant carbon reservoirs on Earth. With continued thawing, primitive, extreme-temperature resistant microorganisms are reawakened, potentially impacting the health of the arctic ecosystem, increasing the risk of zoonotic diseases, and posing an immediate biosecurity risk to plant, animal, and human health in this region and beyond.²²

What is particularly concerning to researchers is that even small pockets of permafrost contain a substantial variety of active, unknown microbial and viral species which cripples the ability of scientists to perform risk assessments because of the vast expanse of this region.²³ Most viruses and bacteria found in permafrost so far mostly infect non-human hosts, such as plants and microorganisms. Even though the chances of human transmissions are statistically low, exposure of naïve immune systems to even one of these pathogens is deeply concerning because of the catastrophic potential to initiate a novel pandemic.²⁴ This scenario has been candidly labelled by the World Health Organization (WHO) as Disease

²¹ For an insightful article that elaborates on the mechanisms behind permafrost melting and their potential impact on Arctic ecosystem, see Miner, K. R., D'Andrilli, J., Mackelprang, R., Edwards, A., Malaska, M. J., Waldorp, M. P., & Miller, C. E. (2021). Emergent biogeochemical risks from Arctic permafrost degradation. *Nature Climate Change*, *11*, 809–819.

²² Ibid. (see footnote 19).

²³ Further information on biosecurity risks can be accessed on National Academies of Sciences, Engineering, and Medicine. (2020). *Understanding and Responding to Global Health Security Risks from Microbial Threats in the Arctic: Proceedings of a Workshop*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/25887>.

²⁴ Fears, R. (2020). Arctic warming and microbial threats: Perspectives from IAP and EASAC following an international academies' workshop. The InterAcademic Partnership. <https://www.interacademies.org/59586/Arctic-warming-and-microbial-threats>, last access 28 November 2023.

X.²⁵ Disease X is included to signify an unidentified pathogen with the potential to trigger a severe global epidemic.

Moreover, genomic testing on human and animal mummies that have resurfaced from ancient burial grounds because of melting permafrost, have revealed genetic material capable of causing historically destructive pandemics such as the smallpox and influenza ones. An outbreak of Anthrax in reindeer herds in the Yamal Peninsula in the Russian Federation in 2016 was attributed to the exposure of herds to Anthrax spores from thawing permafrost.²⁶ This outbreak resulted in the death of more than 2,000 reindeer and one child. Our experience with the recent Coronavirus pandemic and the ability of pathogens to transcend species and international borders is a stark reminder of the devastating global repercussions of local epidemics. As elaborated above, the effects are even more immediate for the Indigenous peoples of the Arctic, whose lives and livelihoods are impacted daily by the effects of global warming and the resulting biogeochemical threats that fill their environment.

3.2 *The One Health Approach*

The One Health approach is a vital element for developing an effective and successful health surveillance programme in the Arctic.²⁷ This approach recognises and emphasises the interconnectedness of people, animals, and the environment, understanding that the health of one is intricately linked to the health of others. By considering these elements as an integrated whole, the One Health approach provides a comprehensive framework for understanding and addressing health challenges in complex ecosystems like the Arctic. While research in the One Health field is gaining momentum, there exists a notable gap in understanding

²⁵ See World Health Organization. (2022). *WHO to identify pathogens that could cause future outbreaks and pandemics*. WHO. <https://www.who.int/news/item/21-11-2022-who-to-identify-pathogens-that-could-cause-future-outbreaks-and-pandemics>, last access 27 November 2023.

²⁶ For more on Anthrax outbreak in the Arctic, see Stella, E., Mari, L., Gabrieli, J., Barbante, C., & Bertuzzo, E. (2020). Permafrost dynamics and the risk of anthrax transmission: A modelling study. *Scientific Reports*, 10 (16460).

²⁷ For more information on One Health strategy in the Arctic, see Ruscio, B. A., Brubaker, M., Glasser, J., Hueston, W., & Hennessy, T. W. (2015). One Health—A strategy for resilience in a changing arctic. *International Journal of Circumpolar Health*, 74, 27913.

and establishing the existing pathways for human, animal, and environmental disease surveillance specifically tailored to the Arctic region. The unique environmental conditions, the presence of Indigenous communities, and the distinct wildlife in the Arctic necessitate a specialised and integrated surveillance system. Understanding these pathways is crucial for identifying potential health threats and ensuring a timely and effective response to emerging issues.

The current lack of integration in disease surveillance pathways poses challenges to public health in the Arctic. Bridging this gap requires a systematic approach to mapping and understanding the existing One Health surveillance systems in place. This working paper aims to contribute to the scientific literature by undertaking a comprehensive system mapping exercise. By delineating the structures and functions of various One Health surveillance systems currently operational in the Arctic, the paper aims to provide insights into the strengths, weaknesses, and potential areas for improvement. Such an analysis is essential for fostering collaboration between diverse disciplines, facilitating knowledge exchange, and ultimately enhancing the overall effectiveness of One Health in the Arctic region. The findings and recommendations from this working paper could inform future strategies for health surveillance, contribute to policy development, and strengthen the resilience of Arctic communities against emerging health challenges.

4 CONCLUSION

Climate change has destabilised the Arctic landscape, and its effects are threatening to impact the health and well-being of humans, animals, and the environment. The consequences of health risks, affecting both Arctic populations and those beyond, underscore the need for extensive and varied collaborations among stakeholders. These collaborations aim to deepen our fundamental understanding of emerging health threats and foster the creation of joint initiatives that reduce vulnerabilities for human and animal communities, as well as the environment. Recognising the interconnected existence of these elements, it is necessary to amplify the health surveillance programmes within the Arctic to recognise zoonotic outbreaks and to facilitate immediate response to contain them. Through systems mapping, this research will aim to create a visual representation of health surveillance within the region so it can facilitate more meaningful transdisciplinary collaborations.

Emphasising and fortifying ties with Indigenous communities in the Arctic is crucial for biosecurity initiatives. These communities hold invaluable knowledge and spiritual connections deeply ingrained in the region. Incorporating their insights into health surveillance efforts is not just essential but also a matter of respect, considering their traditional lifestyles and expertise in navigating the land and sea. Indigenous communities serve as vital stewards of the Arctic environment, and their perspectives can greatly enhance our understanding of the intricate dynamics at play.

The United Nations 2030 Agenda for Sustainable Development emphasises the necessity for global communities to dedicate themselves to transformative actions aimed at safeguarding the planet. This chapter seeks to further the Agenda 2030 by actively advocating for the One Health approach in the Arctic region and beyond. Incorporating the One Health approach as a strategy to strengthen biosecurity in the Arctic region simultaneously contributes to several Sustainable Development Goals (SDGs) and draws attention to the interconnectedness of the goals themselves, such as SDG 3 Good Health and Well-Being, SDG 13 Climate Action, SDG 14 Life below water, SDG 15 Life on land, SDG 16 Peace, justice, and strong institutions, and SDG 17 Partnerships for the goals.^{28,29} Mitigating the negative effects that the changing Arctic environment has on the health of humans and animals requires action across multiple levels of government and transdisciplinary collaboration between various stakeholders³⁰ to better protect the natural ecosystems that constitute the Arctic region.³¹ Improving the health of the environment consequently improves the health of humans and animals, and instilling an awareness of the risks that environmental degradation plays

²⁸ Hossain, K. (2022). Climate change challenges in the Arctic. In *The Palgrave Handbook of Global Sustainability*. Palgrave Macmillan.

²⁹ For an overview of The 2030 Agenda for Sustainable Development, see <https://www.un.org/development/desa/jpo/wp-content/uploads/sites/55/2017/02/2030-Agenda-for-Sustainable-Development-KCSD-Primer-new.pdf>, last access 28 November 2023.

³⁰ Sjöberg, Y., Bouchar, F., Gartler, S., Bartsch, A., & Zona, D. (2023). Focus on Arctic change: Transdisciplinary research and communication. *Environmental Research Letters*, 18, 010201.

³¹ Ruscio, B. A., Brubaker, M., Glasser, J., Hueston, W., & Hennessy, T. W. (2015). One Health—A strategy for resilience in a changing arctic. *International Journal of Circumpolar Health*, 74(1), 27913.

on human and animal health has the potential to create a more sustainable human society that makes decisions with a mindset that embodies the characteristics of the One Health approach.

Using this as an example and moving beyond the Arctic, this chapter demonstrates how holistic, transdisciplinary frameworks such as One Health can promote and facilitate effective responses to sustainability challenges while also respecting Indigenous populations and other communities who are disproportionately affected by the changing climate (i.e., low-lying coastal communities).³² Further, it commits to endorse ecological education on this subject, ultimately contributing to the overarching goal of safeguarding the planet. Although One Health has been conceptualised as an approach specific to optimising health and protecting people and animals from biosecurity and other public health threats, it can be translated into an ecological approach to climate education—one that recognises the interconnectedness of all life forms.³³ Expanding climate education programmes to include topics embodied within One Health such as good governance, public health, systems thinking, and the interconnections between humans, animals, plants, and nature can foster future generations who approach global health and climate change challenges with a holistic, transdisciplinary focus that protects human and non-human communities from harm.³⁴

³² Sjöberg, Y., Bouchard, F., Gartler, S., Bartsch, A., & Zona, D. (2023). Focus on Arctic change: Transdisciplinary research and communication. *Environmental Research Letters*, 18, 010201, cit.

³³ On the One Health approach applied to research and education in the Arctic, see Tryland, M. (Ed.). (2022). *Arctic One Health: Challenges for Northern animals and people*. Springer Nature.

³⁴ Windsor, S., Maxwell, G., & Antonsen, Y. (2022). Incorporating sustainable development and inclusive education in teacher education for the Arctic. *Polar Geography*, 45(4), 246–259.

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