

## One health in the circumpolar North

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### ABSTRACT

The North faces significant health disparities, especially among its many Indigenous peoples. In this article we discuss historical, environmental, and cultural variables that contribute to these disparities and propose a One Health approach to address them in a holistic and culturally appropriate manner. The One Health paradigm recognizes the interdependence among the health and well-being of people, animals and the environment. As such, the framework aligns well with many Indigenous world views. This proactive, interdisciplinary, constructivist, and collaborative approach promise earlier detection of risks and threats, as well as more effective responses, in part by engaging community level stakeholders in all stages of the process. In the far North, humans, especially Indigenous peoples, continue to live closely connected to their environment, in settings that exert significant impacts on health. In recent decades, rapid warming and elevated contaminant levels have heightened environmental risks and increased uncertainty, both of which threaten individual and community health and well-being. Under these circumstances especially, One Health's comprehensive approach may provide mitigating and adaptive strategies to enhance resilience. While many of the examples used in this manuscript focus on Alaska and Canada, the authors believe similar conditions exist among the indigenous and rural residents across the entire Circumpolar North.

### ARTICLE HISTORY

Received 15 January 2019

Revised 4 April 2019

Accepted 9 April 2019

### KEYWORDS

One health; Arctic

### One health introduction and definition

Efforts to improve human health have varied, but many focus on individual patients and react to physical disease. While this approach has done much to advance health research and, in turn, health outcomes, a more holistic perspective on health that focuses on living in balance with the natural world has emerged with the potential to improve human health more broadly. The One Health paradigm defines health as more than the absence of disease, recognizing the interrelationships among human, animal and environmental welfare, and striving for the *well-being* of all three through the coordinated efforts of multiple sectors, including various scales of governance, medical professionals, scientists, and community members (One Health Initiative; World Health Organization; European Union).

The well-being of the One Health triad [1] of human, animal, and environmental health also impacts other parts of systems involving individuals, including the well-being of communities and their ability to sustain themselves. In the circumpolar North, where subsistence lifestyles tie the people closely to one another and to the land, this model lends itself especially well to exploring

questions of health outcomes, particularly now as rapid climate change dramatically alters the land and seascapes, endangering traditional lifeways, individual lives, and community sustainability [2]. The U.S. Global Change Research Program's (USGCRP's) *Fourth National Climate Assessment* stresses the impacts of climate change on Indigenous peoples' health, stating: "Indigenous health is based on interconnected social and ecological systems that are being disrupted by a changing climate. As these changes continue, the health of individuals and communities will be uniquely challenged by climate impacts to lands, waters, foods, and other plant and animal species. These impacts threaten sites, practices, and relationships with cultural, spiritual, or ceremonial importance that are foundational to Indigenous peoples' cultural heritages, identities, and physical and mental health" [3].

The burden of health-related climate change impacts is and will continue to be unevenly distributed. Whereas wealthier industrial regions of the world generate the overwhelming majority of greenhouse gases, negative health impacts of warming will fall disproportionately in poor countries and regions [4–8]. The Arctic exemplifies this paradox: the pace of warming is twofold greater than the rest of the planet, even though minimal production of greenhouse gases takes place in the region [2,3].

## One health's potential for enhancing well-being in the North

Research conducted within a broad spectrum of disciplines affirms the interdependence of climate change impacts on physical, biological and social processes in the Arctic and the need for holistic approaches to understand and address these impacts [9,10]. The preponderance of Indigenous peoples in large areas of the far North also contributes to the paradigm's salience in the region. The linkage of human health to environmental and animal health corresponds with a holistic world-view and definitions of health and well-being in many Indigenous cultures [11–13]. As Moerlein and Carothers discovered through their ethnographic research in the Inupiat villages of Noatak and Selawik, Alaska in 2010 and 2011, although they sought to limit discussions to their observations of environmental changes, “informants consistently discussed wide-ranging shifts in ecological, social, cultural, political, and economic realms as they are experienced together” [10]. Similarly, in northern Labrador, Inuit focus groups described the effects of reliable sea ice on health, including mental/emotional, cultural, spiritual, social, physical, and economic well-being [14]. And a study of Nunavut Inuit youth perspectives on health, well-being and happiness tied these conditions closely to environmental health and their ability to maintain subsistence lifeways that tie them closely with family and community members and with their culture [15]. These responses indicate a worldview in these communities that aligns with One Health. Importantly, the coordinated, holistic One Health paradigm can enhance surveillance capacity to detect health threats early and increase understanding of their relationship with climate change [2]. Furthermore, the subsistence lifestyle discussed below inherently uses a One Health approach without using that western terminology.

In June 2015, the Arctic Council's two health-related expert groups – the Sustainable Development Working Group's (SDWG's) Arctic Human Health Expert Group (AHHEG) and the Arctic Monitoring and Assessment Program's (AMAP's) Human Health Assessment Group (HHAG) jointly identified One Health as a vital initiative for collaboration. Several conference workshops and other forums focusing on the challenges and opportunities presented by operationalizing One Health in the Arctic followed. In May 2017, at the Arctic Council's Ministerial Meeting in Fairbanks, the Ministers endorsed the project with the following objective: “To operationalize a One Health approach in the Arctic by forging co-equal, inclusive collaborations across multiple scientific disciplines and Arctic communities, to enhance resiliency of the Arctic inhabitants through an enhanced understanding of climatic change impacts on health risks to

people, animals, and the environment” [16]. The endorsement of Operationalizing One Health in the Arctic by the region's foremost intergovernmental forum illustrates its view of the relevance of this holistic paradigm, especially as climate change poses unprecedented threats to the region's ecosystem and the health of its peoples.

## Northern priorities within the One Health triad

### *The environment – the changing arctic*

Rapid environmental change in the North increases both the advisability and the urgency of taking a One Health approach to health and well-being in this region. The critical lead time afforded by close monitoring of conditions by residents of specific localities, and the coordination of various actors and entities with knowledge and resources, can enhance prevention, response and adaptation [2]. Recent climate change impacts on the northern environment include melting sea ice, rising sea levels, increasing storm surges, flooding, salination of ground water, ocean acidification, increased precipitation, thawing permafrost, less predictable river ice conditions, shifting vegetation patterns, and more wildfires [17–20]. These conditions increase hazards associated with subsistence activities in a region that experiences significantly elevated unintentional injury mortality, with even higher rates among Indigenous individuals [18]. Uncertainty associated with the unpredictability of weather and environmental conditions, and in turn heightened risks, contribute to increased stress levels in northern communities [21–23]. The USGCRP's Fourth National Climate Assessment observes: “The impacts of climate change will likely affect all aspects of Alaska Native societies, from nutrition, infrastructure, economics, and health consequences to language, education, and the communities themselves” [3].

Ecological impacts of warming include alterations in terrestrial and marine animal migration and distribution patterns [2], that undermines subsistence practices. Moreover, scientists anticipate the emergence of infectious diseases and insect vectors not previously seen at high latitudes [24,25]. In many areas provision of safe water and sanitation services is increasingly challenging, which raises the risk of infectious diseases [21,26–28]. In some cases, whole villages face the prospect of relocation due to coastal erosion [29,30].

Since the 1970s, contaminants from the industrialized world have entered the Arctic food web, where through the processes of bioaccumulation and biomagnification, they endanger the health and well-being of Indigenous peoples who depend heavily on marine species [31–35]. In addition to the direct and indirect impacts of such contamination on the health of individual humans, the

knowledge of such threats to human health and to the future of Indigenous peoples and cultures contributes to mental stress [23]. Some scholars, including the historian John McCannon, have used the term “Arcticide” to describe the cumulative effects of these threats to the Arctic environment [36].

Together these developments imperil the physical, mental and social well-being of residents of the entire circumpolar North, along with traditional lifeways and community life, by disrupting the intimate relationships among people, animals and the environment. Indigenous peoples throughout the circumpolar North, except in Fenno-Scandinavia, have lower life expectancies than their respective national averages [18]. These disparities are thought to reflect harsh Arctic environments, dangers associated with subsistence lifestyles, and residual impacts of colonial histories on physical and mental health and well-being. The One Health approach to researching and managing these issues provides a pathway to mitigate health disparities, especially in remote communities with limited infrastructure where dependence on the intricate balance of multiple systems correlates closely with health [37].

### **Zoonotic diseases**

The One Health approach also furthers Western scientific knowledge of disease in a physical sense, most notably perhaps in the field of zoonotic diseases. While species richness is relatively low at high latitudes, including the diversity of infectious agents, zoonoses present significant challenges to health in the North. Examples of zoonotic diseases of concern to public health officials include brucellosis, toxoplasmosis, trichinellosis, protozoan infections, echinococcosis, tularemia, anthrax and rabies [38]. Logistical impediments, including limited transportation infrastructure and extreme weather conditions in remote communities, pose challenges to surveillance and outreach concerning harvesting-related risks associated with these diseases. Climate change imposes the risk of newly invasive diseases such as those borne by ticks and other vectors that may have enhanced survival and proliferation potential as the Arctic warms. Across the Circumpolar North, the thawing of permafrost may also enhance the risk of exposure to pathogens such as anthrax and influenza. The 2016 death of a child associated with an anthrax outbreak in a reindeer herd in the Yamal region of Russia could be an example of how climate change may influence exposure to zoonotic disease threats [39,40].

Coordination among subject matter experts including wildlife biologists, infectious disease researchers, local knowledge holders, and public health officials in both human and veterinary medicine would help address these issues more effectively [38]. A holistic approach could

enhance public health responses across disciplines, especially given the uncertainty associated with predicting changes in infectious disease dynamics in the complex system of the infectious disease triad of host, pathogen, and environment in a rapidly changing North [41]. One Health provides a functional framework for coordination and collaboration across professional specialities [42].

### **Human mental and social health and well-being**

Including the social environment in the One Health paradigm in the North facilitates addressing human health and well-being more holistically at both the individual and community level. The 2004 Arctic Climate Impact Assessment states: “It is more likely that populations living in close association with the land, in remote communities, and those that already face a variety of health-related challenges will be most vulnerable to future climate changes” [17]. The US Global Change Research Group’s 2018 assessment declares: “Climate change creates new risks and exacerbates existing vulnerabilities in communities across the USA, presenting growing challenges to human health and safety, quality of life, and the rate of economic growth” [3].

Numerous indicators reflect the elevated mental health stress that northern Indigenous peoples experience, including higher numbers of self-reported poor mental health days for Alaska Native adults, compared with the U.S. average [43], higher rates of sexual and domestic violence [44], and most strikingly, elevated rates of suicide [18,45]. As leading circumpolar health experts write in the *Circumpolar Health Atlas*: “Circumpolar peoples are subject to immense mental stress as their communities undergo profound social and cultural changes. Particularly for Indigenous peoples, the second half of the twentieth century has been a period when the traditional life irrevocably gave way to modern ‘Western’ lifestyles” [18].

This rapid socio-economic and cultural change of the past three quarters of a century radically altered the social fabric of Indigenous communities. Migrants inadvertently brought infectious diseases that killed large numbers of Indigenous individuals, sometimes nearly destroying whole communities. Christian missionaries introduced a new world view, implicitly and/or explicitly devaluing traditional ways of knowing and being, while they also brought medical care, sanitary practices, and social services that saved lives and improved some health outcomes. Meanwhile, assimilationist educational policies, including English-only rules and boarding schools, deprived Indigenous individuals, families and communities of fluency in their native languages and much other cultural knowledge [46], resulting in what is now called historical trauma [47].

World War II and Cold War construction projects, along with the arrival of government services and transfer payments, generated sweeping socioeconomic changes to rural Alaska and northern Canada in the mid-twentieth century [48]. In the 1950s the Canadian government encouraged nomadic Inuit to settle in hamlets with offers of housing, education and healthcare [49]. Employment opportunities drew people from subsistence activities, increasing sedentarism and less healthy diets, while the cash flow enhanced access to alcohol. Transfer payments and education and employment opportunities for both women and men encouraged a shift from subsistence to wage labour, all of which altered gender relations, with males experiencing more negative effects of acculturative stress, including loss of identity and self-esteem [18,50,51]. Social pathologies, including alcohol abuse, sexual and domestic violence, and suicide skyrocketed in the wake of these developments [45,48,50,52].

In Alaska, suicide rates among Alaska Natives, especially men aged 15–34 years, rose rapidly in the 1960s, the decade following statehood, when infrastructure development and the infusion of federal transfers altered the economic landscape [52]. The 20<sup>th</sup> century spike in Alaska Native suicides emerged among Inuit across the Arctic approximately a decade after the period of mid-twentieth century “active colonialism” in each region, when government-sponsored programs dramatically altered traditional lifeways [45]. Today’s strikingly high suicide rates among young men differ starkly from the rare historical occurrences of suicide by older men in failing health. Of the current pattern among the Inuit, Canadian researcher Jack Hicks writes: “The young Inuit men at greatest risk appear to be those who are situated somewhere between the historical Inuit ‘life script’ and the emerging urban Inuit ‘life script’, in communities and families where unemployment and social dysfunction are more common” [45].

High levels of mental stress can also be seen in the rates of sexual and domestic violence in Alaska and northern Canada, that far exceed national averages [53,54]. Many historical, social and economic forces are thought to contribute to such violence. The role of Adverse Childhood Experiences (ACEs) in mental and physical health problems later in life is well recognized [55] and contributes to the cyclical affects of violence in the home that are well documented in the North [45]. The common factor of alcohol consumption by both perpetrators and victims complicates reporting and prosecution [44,45,56–59]. Climate change-related disruptions to traditional lifeways and to family and community life can be expected to exacerbate mental stress that contributes to such violence [21]. Among other effects, Indigenous peoples’ strong attachment to place can lead to elevated anxiety and sense of loss when displacement occurs [7,60].

Foreseeable mental health impacts of climate change include: stress on individuals, families and communities related to increased exposure to physical dangers; increased depression, distress, anxiety, and hopelessness; as well as rising rates of alcohol/drug use, violence, and suicide ideation owing to uncertainties and threats to traditional lifeways and food security. Likely indirect effects of climate change on mental health and well-being include the disruption of economic and social networks, mass migration, and the relocation of houses, buildings and even whole villages [22]. On the other hand, close interpersonal, family and community ties provide a source of strength in the face of such challenges. Community-based research on alcohol abuse and suicide in Alaska Native communities identified an inter-related individual, family and community traits that contribute to resilience associated with lower rates of alcohol abuse and suicide [61]. The proactive capacity of the One Health paradigm to anticipate these myriad, interrelated effects of climate change, and integrate them to address mental and community health challenges in the North will be a potent factor in this model’s potential to build effective management strategies for these issues.

One example of operationalising One Health in indigenous communities is the health indicators developed by the Swinomish Indian Tribal Community [11] to assess human health outcomes in a more culturally appropriate way. An example of effective local collaboration that aligns well with One Health is the *coordinated community response*, or Duluth Model, which has shown promise in reducing domestic and sexual violence in Alaskan communities [44,62]. The victim-centred concept integrates the efforts of first responders, other service providers, and advocates to encourage reporting and reduce domestic violence. Many Alaskan and northern Canadian localities lack the public safety and medical personnel required to provide such integrated responses, however, which illustrates the need for financial support from national and subnational governments to respond effectively to these and other threats to health and well-being.

### One health in the subsistence context

In this manuscript, subsistence refers to reliance on hunting, fishing, and gathering to obtain a significant portion of one’s food, shelter, clothing, or livelihood. For cultural and nutritional reasons, and due to limited transportation infrastructure and economic opportunities, people continue to live off the land, or live a subsistence lifestyle, in many communities in the far North [63,64]. In many regions, subsistence foods provide a large proportion of caloric intake [65]. Especially in Indigenous communities,

subsistence practices hold deep cultural meaning. As Aqqaluk Lyngge of Greenland, President of the Inuit Circumpolar Conference (ICC), remarked in 1999: “indeed, hunting, fishing and gathering food is central to all Indigenous peoples’ survival” [63]. This view of subsistence captures the centrality of peoples’ connection to the land, water, and animals to their health and well-being, and to community well-being.

While subsistence continues to play a vital role in individual nutrition and well-being, and in community food security through traditional sharing practices, multiple forces currently threaten subsistence lifestyles. The cash economy may pose the greatest threat in the early 21<sup>st</sup> century. Taking part in subsistence activities requires participation in the cash economy, if not by the hunter, fisher or gatherer, then by a family member, to purchase implements such as transportation and hunting equipment, as well as fuel. Meanwhile, wage employment limits the time available to participate in subsistence activities. Therefore, modernity creates a paradox for many subsistence communities: Technology, such as transportation, rifles, and ammunition, has made harvesting resources more efficient, but participating in the cash economy hinders full participation in such culturally and nutritionally important activities owing to the demands it places on the individual’s time and location [10,66]. Spending less time “on the land” leads to loss of traditional subsistence skills and knowledge, and it weakens intergenerational bonds [10,67]. Moerlein and Carothers found that residents of Noatak and Selawik in northwest Alaska perceived socio-economic changes as a greater threat to subsistence practices and traditional lifeways than environmental change, although they viewed the multiple forces of change holistically [10].

The impacts of socio-economic change on subsistence practices may be more visible, but environmental change and contamination of traditional foods increasingly threaten traditional lifeways in the North. Climate change alters availability and access to subsistence resources. Climate change impacts are more extreme at high latitudes, with the North showing an average temperature increase 2.5 times the rate of more temperate regions [68]. Indigenous hunters have identified changing marine ice, river ice, and trail conditions as significant impediments to safety and successful subsistence hunting, and in general as a threat to the availability of subsistence resources [21,23]. Furthermore, a warming climate threatens some resource processing and storage practices such as fermenting fish and meat, and storage of food in ice cellars. Thawing permafrost can render traditional ice cellars unusable, leading to food spoilage with obvious food safety and associated health implications, all of which threatens traditional subsistence cultures [69].

Pollution from industrial production in more southern, populated regions not only contributes to climate change but also releases substances that contaminate resources in far northern communities. Through global atmospheric and oceanographic processes, especially long-lived contaminants accumulate in subsistence resources. The levels of contamination vary greatly by region and among species, as they feed at various levels of the food web. In the Canadian Arctic, the contaminants of greatest concern in subsistence foods are the persistent organic pollutants chlordane and toxaphene, and PCBs, along with mercury and naturally occurring radionuclides [70]. Bowhead whales show relatively low levels of contaminants, whereas narwhales and other marine mammals that feed at higher levels of the food web have high concentrations of persistent contaminants such as mercury in their tissues [71–74]. Arctic residents who consume higher proportions of terrestrial and freshwater foods accrue the highest levels of radionuclides [75]. Developing human fetus is at greatest risk from these persistent contaminants [70].

This variability and the resulting uncertainty for consumers regarding the safety of these resources pose challenges in communicating associated health threats to communities [70]. The risk of contaminated traditional foods leads not only to direct health consequences through consumer exposure to contaminants, but also to fear of using traditional resources and food insecurity, and to consumption of lower quality store-bought food, which engenders broader health consequences. Commercially produced foods, especially those available in remote northern regions, tend to be less nutritious and have high levels of added sugars and unhealthy fats. Among Arctic residents, days with consumption of subsistence foods have significantly less consumption of fat, saturated fat, sucrose and total carbohydrate than days when subsistence foods are not consumed [70]. Higher consumption of non-traditional foods, as well as the more sedentary lifestyle that corresponds with movement away from traditional subsistence practices, has been linked to health problems such as obesity, diabetes, colorectal cancer, cardiovascular disease, and developmental disorders [65,70,76,77] and to nutritional deficiencies. For example, in the Yukon–Kuskokwim Delta of Alaska, a retrospective study of banked samples from young Alaska Native women taken from 1960 to 2010 showed a significant decline in plasma vitamin D concentrations associated with a drop in the consumption of traditional marine foods [78–80]. The prevalence of lifestyle-associated diseases has been increasing in remote communities throughout the circumpolar North. Given the health benefits of traditional foods and the wide variability of toxins

whose harmful effects could outweigh the nutritional value of specific foods, carefully crafted messaging should be targeted toward specific regions and demographic groups, for instance, women of childbearing age.

Finally, a regulatory threat to subsistence exists throughout the circumpolar North. Many hunting and fishing regulations are based on materialistic and individualistic notions of rights that ignore cultural practices such as sharing and the importance of subsistence in maintaining intergenerational bonds [63]. Some of these regulatory defects or incongruities are beginning to be addressed through co-management approaches towards subsistence resources. However, competition for limited resources between Indigenous and non-Indigenous northerners, as well as inequitable political influence in many northern regions, can leave Indigenous interests under-represented and thereby threaten Indigenous life-ways and community well-being. The One Health paradigm, in fully engaging Indigenous perspectives and Indigenous knowledge, and in considering both individual and community well-being, holds potential for generating regulatory policies that enhance, rather than threaten, the well-being of northern peoples, animals, and the environment.

### Current one health efforts in the north

The Sustainable Development Working Group of the Arctic Council recently provided an overview of some One Health activities in the North [16]. That document lists several international efforts to advance a One Health agenda in the North. Recent activities include the Joint Arctic Council Health Expert Groups Meeting in Oulu, Finland in 2015; the AHHEG One Health Session in Anchorage, Alaska, USA, in 2016; the Circumpolar Arctic Fulbright Conference in Hanover, New Hampshire, USA, in 2016; the Arctic Science Summit Week in Fairbanks, Alaska, USA, in 2016; the Alaska Forum on the Environment in Anchorage, Alaska, USA, in 2017; and a survey on One Health among stakeholders in healthcare-related fields [16]. In addition to these activities, a One Health working group holds bimonthly meetings to allow interested parties to exchange ideas and news on One Health with a circumpolar focus [42].

In May 2017, in conjunction with the Arctic Council ministerial meeting in Fairbanks Alaska, the UAF Department of Veterinary Medicine sponsored a workshop entitled “One Health Concerns in a Changing Arctic.” Organizers sought to engage participants in developing demonstration projects grounded in research objectives and collaborations established at the workshop and to form working groups to develop local, regional, and circumpolar networks to address key One Health concerns in

the Arctic [81]. Community members, One Health professionals and researchers, and government officials from all eight Arctic nations attended. Participants identified five overarching research objectives, including:

- (1) Development of veterinary care capacity in rural communities
- (2) Development of youth educational programs under the One Health paradigm
- (3) Development of pathways for local community engagement in natural resource management decisions
- (4) Identification of the effects of environmental change on food security and health of Indigenous communities and societies
- (5) Identification of effects of environmental change on future sustainability of subsistence ways of life in the Arctic [81].

This workshop exemplifies how stakeholders from the local to international level can be engaged to identify and address significant concerns by developing roadmaps towards building collaborative research and management plans.

The Hub Outreach Program (HOP) in the Yukon–Kuskokwim delta of Alaska is an example of how the outcomes of this workshop have been operationalized. Due to geographic isolation, this area has no access to veterinary care and has a significant dog overpopulation problem, Rabies and echinococcus are endemic there and the incidence of dog bites has been declared a public health concern by the Alaska Native Tribal Health consortium. Historically these problems were addressed by shooting unconfined dogs, Dogs have always been an integral part of Yup’ik culture and this practice has resulted in psychological stress in those shooting the dogs as well as those hearing the shots (Personal communication Mike Williams Sr Yup’ik elder from Akiak July 2017). The HOP program partners veterinarians, local health-care providers, community leaders, university researchers, and private industry to address the physical and mental health disparities arising from the dog overpopulation by providing free spays, neuters, vaccinations, and parasite control administered by a veterinarian living in Bethel and serving the nearly 50 communities of the region. Program leaders are collecting data to determine the cost-benefit ratio of supporting this program versus paying for the consequences of its absence. This data will be presented to local tribal organizations, health-care consortiums and state health agencies to build sustainable support for the program which could be a model for similar communities across Alaska, Canada, Greenland, and Russia.

The University of Alaska Fairbanks (UAF) plans a follow-up to its 2017 workshop in March 2020. Thus far, globally, One Health initiatives have emphasized climate change impacts on zoonotic diseases and large-scale agriculture, while regionally they have focused on climate-change effects on ecological systems and traditional lifeways. Notably, UAF's One Health initiative not only focuses on the north/Arctic but also recognizes the effects of ecological change on individual and community health and well-being, especially of Indigenous peoples. The March 2020 workshop will reflect this mission. One Health meetings have also recently been held in Canada (Saskatoon, June 2018) and Finland (February 2019), where scientists presented on One Health issues spanning zoonotic disease, food security, contaminant biomonitoring, and mental and behavioural health.

Apart from research and public health efforts, One Health also can fill a vital role in education. The Biomedical Learning and Student Training (BlaST) program takes a One Health approach to engage students from rural and Alaska Native backgrounds in biomedical research [82,83]. By making biomedical research relevant to students from remote communities through linking human, environmental and animal health, the program has successfully integrated students from diverse backgrounds in meaningful research experiences that increase science self efficacy and student interest in biomedical careers, including individuals from backgrounds currently under-represented in the biomedical workforce (Cotter et al. submitted for peer review). BlaST illustrates how, in the North especially, One Health's linkage of human, animal, and environmental health can open pathways to careers in science that students recognize as relevant to themselves and their communities.

### **One health's role in resilience, adaptation, and mitigation of changes in the arctic**

For millennia, Indigenous peoples have subsisted in Arctic settings, surviving in the world's most challenging environments, based on their intimate knowledge of land and seascapes, and their ability to adapt to change. Responding to the unprecedented pace, scope, and complexity of the current threats to northern communities' health and well-being, however, requires the integration of local and outside expertise, along with outside financial and technical resources. Key strengths of the One Health approach are its interdisciplinarity and engagement of multiple scales of governance and Indigenous knowledge to identify problems and conceive of solutions; as well as the potential it offers to generate effective localized responses

that are informed and supported by state, national and international expertise and resources. The collaboration and exchange of information among experts and stakeholders has synergistic effects, advancing knowledge and fostering resiliency and adaptation [2]. Climate change interventions have thus far focused primarily at the national and state levels of governance; increased surveillance in localities will foster community-based adaptations [2,18,84,85] and enhance local agency. Not only does the integration of Indigenous knowledge rely on local capacities to adapt to climate change impacts, but it leads to more effective and culturally appropriate responses, and thereby enhance individual and community well-being [85]. Moreover, the local capacities, or social capital, generated through such efforts can have far-reaching positive impacts on the community [84]. As the USGCRP points out regarding Alaska: "Flexible, community-driven adaptation strategies would lessen [climate change] impacts by ensuring that climate risks are considered in the full context of the existing sociocultural systems" [3].

### **One health in future policy formulation and implementation**

A One Health approach to policy development that begins in the community, asking local residents to define the situation to be managed from their perspective and builds out, engaging stakeholders for contributions in their respective areas of expertise is needed to address health problems in the North. This holistic, "bottom-up" model integrates traditional ways of knowing with Western knowledge. In this framework, One Health provides a constructivist, integrative operational approach for studying problems and building resilient and adaptive strategies to manage them. We posit this approach, which gives the communities most affected a primary role in the process, will provide the best opportunity for proactively addressing health concerns facing the circumpolar North, in contrast to the common historical tack of reacting to symptomatic outcomes.

### **Conclusion**

The circumpolar North has experienced previously unprecedented rates of environmental, socio-economic, and cultural change over the past half-century. These changes have been associated with significant challenges to the health of the people, animals and environment of this region. Understanding and managing these developments will require a holistic, integrated approach that recognizes the inseparable and interdependent nature of the One

Health triad. Through synergy between Indigenous and Western knowledge systems, and the incorporation of community input throughout the process, the One Health approach may provide the best means of building adaptive, resilient, and effective strategies for mitigating the negative influences associated with these challenges and promoting a sustainable future for northern ecosystems and the people and animals residing within them.

## Disclosure statement

No potential conflict of interest was reported by the authors.

## Funding

This work was supported by the National Institute of General Medical Sciences [UL1GM118991]; National Institute of General Medical Sciences [RL5GM118990]; National Institute of General Medical Sciences [TL4GM118992].

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