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Comparative review of One Health and Indigenous approaches to wildlife research in Inuit Nunangat

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ABSTRACT

There is increasing interest in One Health and Indigenous methodologies and approaches in wildlife research, but they are not widely used research applications in the Arctic. Both approaches are wide in scope and originate from different knowledge systems but are often compared synonymously. We review the literature of overlap between the term One Health and Inuit Qaujimajatuqangit (Inuit Indigenous Knowledge) throughout Inuit Nunaat on wildlife research. Three databases (SCOPUS, Web of Science, and BIOSIS) were used to find English language articles and books within the bounds of Inuit Nunaat. While One Health and Inuit Qaujimajatuqangit research approaches share synergies, they are fundamentally disparate owing to their differences in epistemology, including views on the natural environment and wildlife management. We describe current examples of One Health being operationalized in Inuit Nunaat and identify potential to address larger and more complex questions about wildlife health, with examples from terrestrial and marine Arctic wildlife. Both Indigenous methodologies and One Health naturally have a human component at their core, which seamlessly lends itself to discussions on wildlife management, as human actions and regulations directly impact environment and wildlife health.

Positionality statement

Before we begin this paper, we need to place ourselves in the context of this work. As knowledge is bound to place for many Indigenous peoples, we would be remiss not to acknowledge our places. Enooyaq Sudlovenick, is Inuk from Nunavut. With her mother's family being Inuit from the north Baffin region, stretching from Pond Inlet, Somerset Island, and Taloyoak. Her father's side are Inuit from Inukjuak, Nunavik, Quebec, whose parents were relocated from the coast of Hudson Bay to Resolute Bay. Because of their upbringing and values, they prioritized hunting and camping for all their children. The author team is strengthened by the guidance from Dr. Emily Jenkins and Dr. Lisa Loseto, all whose mentorship, relations with Inuit Nunaat, and knowledge allow spaces for different knowledges to come together. Dr. Jenkins currently resides on Treaty 6 territory (Saulteax, Cree), the homeland of the Métis Nation in Saskatchewan, and is the co-lead for the University of Saskatchewan One Health Signature Area. Dr. Loseto resides in Treaty 1 territory (Anishnaabeg, Cree, Ojibway-Cree, Dakota, and Dene Peoples, and the homeland of the Red River Métis.

1. Introduction

Wildlife population and health research across the circumpolar north is challenging largely due to the remoteness and high operational costs. With the rapidly changing environment, new information is needed to make informed decisions on wildlife health, management, and food safety [1–4]. Climate change and associated impacts are already evident throughout the Arctic and warming has been at least double that of other areas of the globe. One Health is a term that embodies the concept that intersections of science between human, environment, and animal health overlap [5]. The majority of One Health papers focused on the Arctic highlight climate change [6–8], as it is expected to motivate scientific research for the foreseeable future. Dramatic changes to Arctic

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ecosystems such as warmer temperatures, increase in mean annual precipitation, and decreased snow cover are expected to continue [4].

Arctic wildlife, both terrestrial and marine, can act as sentinels for the environment and human health [9,10]. Sentinel species reveal information about their habitat and food webs providing a pulse on environment health and if interventions should be considered [10,11]. This is often the case for contaminant and pathogen monitoring [12,13]. While the Arctic contains few direct and local contamination sources, many contaminants have been observed in Arctic species at high concentrations [12,14] and in the people that live there [15,16]. For pathogens, prevalence of diseases and parasites in certain wildlife, such as Arctic foxes (*Vulpes* spp.), can give indication of prevalence and circulation in the larger ecosystem [13,17]. There is a sense of urgency in wildlife health research to better define methods, particularly if they are used in sentinel species that guide management and potentially impact human health [18].

Holistic approaches to studying wildlife health include One Health approaches and Indigenous Methodologies. The concept of One Health recognizes the connections among human, animal, and environmental health, and has been gaining much attention in recent scientific, veterinary, and medical communities [19]. And One Health methodologies can be described as the implementation of the One Health concept, which is the aim of this paper. There has also been much interest in introducing Indigenous Knowledges and Methodologies into western science frameworks. Indigenous Methodologies are derived from Indigenous Knowledges and values, just as One Health approaches are derived from Western research and knowledges. Evidence of this interest can be seen in terms such as 'adopting a One Health approach' and 'incorporate Indigenous Knowledge' which are peppered through the literature and in scientific conferences [20–22].

This paper reviews the current literature of these two approaches in Arctic wildlife research to explore parallels, divergences, and intersections of these two methodologies. We will identify gaps and opportunities of these two similar but distinct epistemologies, or systems and ways that meaning is made [23]. First, we separately review Indigenous Knowledge and Methodologies, specifically Inuit Knowledges, and then One Health approaches to wildlife health research in Inuit Nunaat (Inuit Homelands). Then, we review the literature that combines both One Health and Indigenous Methodological approaches. Finally, we present future directions in research on Arctic wildlife, including co-production of knowledge and co-management.

2. Methods

A comparative review provides the opportunity to compare two concepts or methodologies. Two simple search strings were used to identify the key literature published in the intersection between One Health approaches across Inuit Nunaat, and Inuit Qaujimajatuqangit in wildlife research. Two separate search strings were used. One search was conducted to isolate any literature on Inuit Knowledges and methodologies in wildlife research with the following search string: ("*Inuit Qaujimajatuqangit*" OR *Inuit* OR *Eskimo* OR *arctic*). The second search used the following search string: *("one health") AND (Inuit OR Eskimo OR arctic)*. These outputs then comprised the overlap between One Health and Inuit knowledges of the paper that examined the cross over between the two concepts.

2.1. Selection criteria

The databases used for the search included SCOPUS, Web of Science Core Collection, and BIOSIS in October 2023. The literature identified through the search were subject to the following criteria:

- Only those in English,
- Full text available,
- articles, books, and grey literature.
- Used the term Indigenous in terms of Peoples and not in the context of original (i.e indigenous plants)

The studies that met these criteria were reviewed. In addition, any references within these identified papers and any that the author's had prior knowledge about. These papers were stored in Mendeley.

3. Results & discussion

While the search strings were relatively narrow, the search criteria extended into the "article title, abstract, and keywords" in all the databases. As a result, this search string was wide enough to include many One Health approaches and Indigenous literature on the global scale, which are reflected throughout this paper. As the number of papers in the Arctic utilizing One Health approaches are few, and smaller still in Inuit Nunaat, which encompasses only part of the wider Arctic, examples from outside of Inuit Nunaat were drawn on to strengthen some points. As we compare One Health approaches, interventions, projects, and approaches to Indigenous Knowledges and Methodologies, we will use the terms "One Health Approaches" and "Indigenous Approaches" going forward.

3.1. Inuit Qaujimajatuqangit and Inuvialuit knowledge

Indigenous perspectives and Knowledge across the Arctic vary over geographic space and time, which is to be expected considering the differences in culture, language, histories, social and economic situations. Indigenous researchers themselves have their own practices in applying their home tribal or territorial epistemologies into their world [24]. The relations to homelands, languages, and culture are different across nations and individuals. It follows then, that there is no one set of standards or framework for Indigenous research, and this paper will focus on research conducted in Inuit Nunaat as defined by Inuit Tapiriit Kanatami, the national Inuit Governing body in Canada.

Historically, the term Traditional Ecological Knowledge (TEK) was used when any Indigenous Knowledges (IK) were recorded for data or 'facts' pertaining to individual wildlife species [25]. The term Inuit Qaujimajatuqangit (IQ), which can translate roughly to Inuit Knowledge and societal values, was first described in 1998 in Igloolik at the Nunavut Social Development Commissioner conference [26]. Where IK is an umbrella term for all Indigenous Knowledges across the globe, IQ is Inuit specific. IQ is defined as "Inuit ways of living and knowing for a good life" [27] and encompasses not only information about animals, but includes language, culture, and the environment [25,26]. Over time, IQ has remained a distilled collection of biophysical information that can be selectively diluted for research purposes [26]. It is important to note that the term IQ is used in Nunavik and Nunavut, but in the Inuvialuit Settlement Region (ISR) of Canada, it is more appropriately known as Inuvialuit Knowledge, and in Alaska, Inupiaq and Yupik Knowledge. Using the appropriate regional term signifies respect of the distinct groups and understanding that Indigenous Peoples are not a monolithic group across the Arctic.

The book 'Inuit Qaujimajatuqangit' by Karetak et al. [27] outlines four Inuit laws or principles:

1. Working for common good and not being motivated by personal interest or gain,
2. Living in respectful relationships with every person and thing that one encounters,
3. Maintaining harmony and balance; and
4. Planning and preparing for the future.

Inuit are a heavily wildlife-focused culture, and before European contact, were mostly meat-eating people. Considering the short summers and limited opportunity to harvest berries and edible plants. Because of this, it has always been of the utmost importance to ensure

that wildlife and the environment around us was understood and to take only what was needed. These principles guide sustainable wildlife management practices, where "hunters have ensured and taught young hunters to take only what they need " [28], for lean days are often ahead. Conservation has been a part of Inuit teachings handed down through generations [27]. Karetak's book also highlights that wildlife must be treated with respect and kindness and it is Inuit responsibility to protect and conserve nature and wildlife, this is also known as environmental stewardship.

3.1.1. Wildlife research in the Arctic

While there are many examples of different approaches of combining IQ and Western Science, it is never 'one size fits all'; i.e., a framework for the Inuvialuit Settlement Region may not work in Nunavut, and vice versa. It is also important to recognize that IQ and Western science knowledge systems are often working with different temporal scales [29]. Where Inuit Knowledge is passed down through generations, western science typically works in recent history, around 30–50 years in Inuit Nunaat [29].

While not all research aims to inform management bodies, many research activities and IQ documentations across Inuit Nunaat often do [29–31]. Kaplan and McCay [32] adeptly wrote "regulations have impacts on human communities, but regulators and managers have not been held accountable for the social, cultural, and economic pressures that result." Early wildlife research could be described as using unethical research practices and have left a legacy of negative views on research across Inuit Nunaat [33,34]. Many Indigenous Peoples still view western science as a power structure more than a knowledge system [32,35–37]. Understanding these legacies and mending relationships can unlock effective research partnerships and prevent further damaged relationships and contribute towards reconciliation across Inuit Nunaat [32,33].

Fortunately, there has been a strong resurgence of Indigenous research methods and epistemologies throughout Canada. In Inuit Nunaat, a call for equitable and ethical inclusive research approaches can be seen in ITK's National Inuit Strategy on Research [38], ICC's Circumpolar Inuit Protocols for Equitable and Ethical Engagement [39], and the Nunavut Wildlife Management Board, which envisions "conservation [of] wildlife through the application of Inuit Qaujimajatuqangit and scientific knowledge" (www. nwmb.com/en). Co-management systems to conserve wildlife for current and future uses is also explicitly required under treaties and modern land claims across Canada today, such as the Inuvialuit Final Agreement and the Nunavut Land Claim Agreement. Both of these Land Claims are legislated between the Government of Canada and the respective regional Inuit governance bodies [40,41]. These Land Claims outline many Inuit rights including the right to wildlife co-management systems within the Land Claim area. If these rights are not upheld by the Government of Canada than these grievances are investigated and settled in the court systems of Canada. There are also several Inuit-specific research methodologies and approaches that have emerged across Inuit Nunaat, including the Piliriqatigiinniq model in health research [42], The Kitchen Consultation Model for political consultations [43], The Qaggiq Model for education [44], the Alaskan Inuit food security conceptual framework [45], and the Sikumiut model for non-Indigenous allies to co-develop research [46]. While these models and frameworks will not be explored in detail here, all these models place Inuit are in decision-making positions and ensure that "there is more to incorporating IQ in research than mining Inuit for data " [47]. The Ikaarvik group of Inuit youth across Nunavut also have presented a set of recommendations for southern-based (non-Arctic residents) researchers to conduct work in a respectful and meaningful way [47]. These recommendations call for a "balance between the tools, technologies, and methods of science, and the knowledge, customs, and values of IQ", called ScIQ. This includes being present and respectful in communities and for researchers to self-monitor their own attitudes, intentions, and motivations as diligently as the data that they are collecting [42].

3.1.2. Considerations for IQ/IK approaches in wildlife research

There are some considerations when working with IQ or any Indigenous Knowledges. Indigenous scholars such as Mi'kmaq Elder Dr. Albert Marshall caution that there are those out there that "just make it up" and may not be authentic representations of the community [48]. This highlights the need for validation through multiple knowledge holders, and thoughtful partnerships with local organizations of interest who could guide researchers. These partnerships depend on the nature of the work (wildlife or trappers vs. health or veterinary focused). He also emphasizes that each Elder and knowledge holder has an area of expertise, and no single person knows everything, necessitating clear and transparent methodologies. Finally, he stressed that Traditional Knowledge is something gained over a lifetime of nourishing the relationship and culture, and cannot be gained over a few years like a university degree.

Some older papers caution against the inclusion of IK at all [49], suggesting that Traditional Knowledge does not follow a scientific method or undergo 'independent and blind repetition of inquiry' [31]. These sentiments are largely held by fields outside the qualitative and social sciences. While there are good intentions to foster research relationships through inclusion of IQ and IK, it is best practice to seek input from social scientists to design studies that look to understand people or how policies impact people, since qualitative research is an entirely separate field of research from natural sciences and Veterinary Medicine in which One Health origins from [50–52]. Qualitative researchers also tend to have better understandings of existing power and colonial dynamics involved in interviewing Inuit and Indigenous peoples [22,52,53]. Including IQ in a meaningful way means a considerable investment of time and money, since repeat and long visits are required to determine the study question, design, collection, and results processing [22]. This necessitates larger teams comprised of both natural and social scientists, along with community-based researchers and Indigenous Knowledge holders at the earliest possible stage of the project, even if the objectives appear to be purely in the natural or physical sciences. These trust-building processes prior to research activities can be time intensive, but once research relationships are established, the research opportunities and projects often grow and branch out in directions that yield positive impacts in research and in the community.

3.1.3. Co-management applications

Studies that have variably blended western science and Indigenous Knowledges and approaches to different degrees to monitor Arctic marine mammals that typically fall within co-management frameworks, described in Table 1. There are successful examples where Indigenous Knowledges are meaningfully incorporated into wildlife monitoring and management systems and include the Ekwo Naxoese K'e Boots on the Ground Programme involving the Tlicho government in the Northwest Territories, Canada, which monitors the dwindling Bathurst Caribou herd [54]. This example of co-management fosters healthy relationships between biologists, governments, and Indigenous Peoples. So, when "controversial control measures like hunting bans are proposed, it is more acceptable by both the scientific and Indigenous communities" [54]. Monitoring programs that are developed with local boards, knowledge holders and/or community members are on the rise [55]. A series of individual interviews with local knowledge holders, government workers, and health care representatives in Rigolet, Nunatsiavut concluded that any successful monitoring program (wildlife, environmental, human health etc.) is composed of many specialties and team members, including academics in social science and epidemiology, public health sector, government of Nunatsiavut, and computer scientists [28]. While this 'integrated monitoring system' program is specific to Labrador it could serve as a model for other regions.

Table 1
Examples of marine mammal research projects combining Western Science and Indigenous Knowledge (modified from Moore and Hauser, 2019) beyond sampling. Partnerships with local communities can take on different forms and can be expressed in a number of separate papers that all stem from one overarching project. ISR (Inuvialuit Settlement Region).

Project	Species	Region	Framework	References
Eastern Beaufort Sea Beluga research	Beluga	ISR	Longstanding partnerships with regional & local Inuvialuit organizations with co-management rights & transparent research objectives.	[129–135]
Eastern Hudson Bay Beluga	Beluga	Nunavik	Community partnerships identify and co-interpret data. Co-management.	[136–138]
Polar Bear Harvest Monitoring – Total Allowable Harvest	Polar Bear	Nunavut, ISR, Nunavik	Co-management. Sampling of each bear and tag system to monitor population metrics (age, length, sex, location, and contaminants).	[139,140]

3.2. One Health

The core principle of One Health is that the three domains of animal, environment, and humans cannot operate as individual silos when faced with serious or complex issues, such as the threat of Emerging Infectious Diseases (EIDs), climate change, and pollution among other 'wicked' problems. There are many definitions of One Health but a common thread is that all three domains together are more than the sum of their parts, and it is important to understand the relationships among these complex, non-linear, and interconnected systems to improve the health of all three components [56]. The term One Health has its origins in veterinary medicine [57], with other fields having different terms for similar concepts, such as EcoHealth, Planetary Health, or Systems Thinking (Fig. 1), they all encompass concepts and frameworks to explore the interconnections between two or three of these domains. EcoHealth is a term where the system approaches to health include bringing people into ecology, ecology into health, and health into community well-being [18]. Finally, One Health has been criticized as another western methodology that places humans above the environment and animals [52,58]. And the distinction of the three separate entities of human, environment, and animals "actually reveals the foundational conceptualization of bounded, separate and coherent identities." [52].

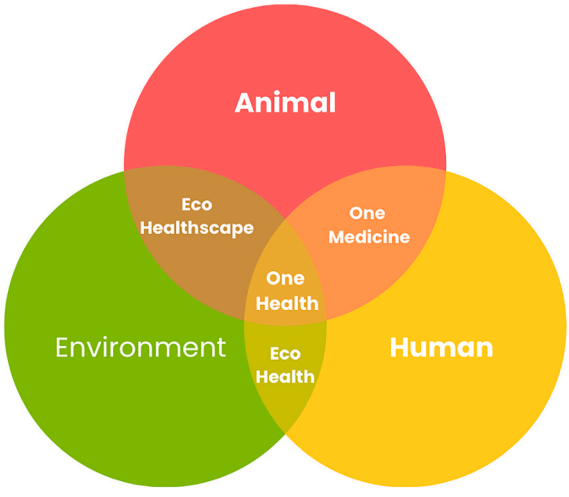

Fig. 1. The fields of research across the three domains. EcoHealthscape is the complex interactions among constituent species and their landscape (Stephen, 2021., One Medicine, bringing together human and animal medicine).

Perhaps due to its origins in animal health, One Health practitioners largely consist of veterinary scientists and biologists who study pathogens, with less representation from human and environmental health sciences [5,59]. One Health is still highly focused on infectious diseases, especially in domestic animals [8,52,59–61]. More recent One Health literature emphasizes a more holistic approach, recognizing that health is more than absence of disease [60], and that approaches to EIDs must consider complex and potential causative factors like ecology, biodiversity loss, invasive species, and conservation issues [62].

A systematic review by Schurer et al. [63] of the term 'One Health' found that most publications included only two of the three sectors defined by One Health, and proposed that studies limited to the animal and human health interface should instead be dubbed "One Medicine". The environment domain is often underrepresented across the literature [59,64,65]. Because of this non-standardized definition, several frameworks have been provided to give guidance for projects adopting One Health approaches. One such framework from Davis et al. [5] provides a very detailed (4 pages) checklist for every step of the research process (COHERE checklist), and even states that those studies which do not incorporate all three sectors should not claim to be One Health.

We favour a less restrictive definition of One Health that provides more flexibility [66] and recognizes efforts to move away from the reductionist, single hazard, or single species, approaches [60]. We also recognize efforts to develop and maintain cross-sectorial collaborations as valuable and critical to long-term success [60]. One such collaboration can be seen from the Arctic Council's Arctic and Monitoring Assessment Program (largely focused on the effects of contaminants on human health) and Sustainable Development Working Group (focused on economy, environment, and social conditions of human populations) who have identified One Health as a key initiative for collaborations [6] and developed strategies to assess the potential for disease emergence in the changing Arctic [3]. One Health provides a functional framework for coordination and collaborations across specialties and is meant to work across different levels of government and organization for successful implementation [6].

3.2.1. Arctic wildlife and One Health

Much of the One Health literature in the Arctic, including in Inuit Nunaat, affirm that the circumpolar north is an ideal field for One Health approaches to succeed [3,6,8,67]. First, the strong and intricate connections to the environment and wildlife in the northern communities remain relatively intact compared to much of the world [68]. Wildlife harvesting not only provides nutrition but is key to cultural and spiritual well-being to Indigenous Peoples, including Inuit [7,69,70]. However, harvesting wildlife is also considered a risk factor for exposure to various pathogens such as food borne parasites and zoonoses such as *Trichinella* or rabies [8,68,71]. Neglected infections of poverty, commonly known as neglected tropical diseases, disproportionately affect Inuit, including parasitic foodborne infections from the consumption of infected wildlife, including polar bears, walruses, and seals [72]. However, it is an oversimplification to attribute this to poverty, but instead should recognize unique drivers of socioeconomic and health disparities in the Arctic as compared to the global situation.

Secondly, the Arctic is a key model system for One health approaches because of the magnitude and impacts of climate change and globalization that disproportionately impact the Arctic ecosystem and people [8]. Ecological perturbation as a result of globalization and new shipping routes increases the potential of "pathogen pollution" from lower latitudes [8]. Because of lack of baseline data, it will be hard to detect subtle shifts in the ecology of hosts, vectors, and pathogens in the Arctic [8]. Wildlife acts as sentinels of both public health threats and changing climate, and are therefore key One Health indicators [10]. Two

prominent areas of study in the One Health literature in the Arctic are pathogens and contaminants in wildlife.

3.2.2. Pathogens in arctic wildlife

A number of reviews in the literature determined that most papers that mention 'One Health' are in the fields of microbiology, parasitology, infectious disease, then general science, in order [19,59]. Keatts et al. [73] identified 25 pathogens of zoonotic potential among all Canadian and Alaskan studies. These included bacterial, parasitic, and viral diseases from wildlife. One of the conclusions was that EIDs are not likely to emerge in the Arctic because of the extreme temperatures, photoperiod, relatively low biodiversity, and density [73,74]. Conversely, the Arctic can be viewed as extremely vulnerable to the introduction and establishment of novel pathogens, such as SARS CoV2, and the Alaskapox virus first described in October 2020 with unknown zoonotic origin [75]. Climate change may also drive increases in endemic diseases, such as an increase in *Erysipelothrix rhusiopathiae* in muskoxen in Canada [76], re-emergence of Anthrax from permafrost-preserved reindeer carcasses [77,78], and increased exposure of wildlife, like polar bears, to terrestrial pathogens as sea ice melts and they spend more time on land [79]. Transmission of endemic diseases may also increase as infected animals survive longer under milder winter conditions, and act as a reservoir of disease [7]. Risk of spillover of zoonoses from wildlife to humans also increases with wildlife-human interactions, which includes ecosystem encroachment of humans on the landscape, wildlife trade, and land use changes [73]. Additionally, climate change could see pathogens and their vectors, such as ticks, moving further north, and their population impacts are not yet understood [78,80]. The loss of protective traditional and local knowledge could also increase zoonotic risk, decrease food and land safety, and lead to meat wastage as experience is not passed on to the newer generations [73].

In addition to wildlife, most of the literature on zoonotic diseases and One Health in the Arctic and sub-Arctic focuses on free-roaming dogs [81,82]. Schurer et al. [81] studied five pathogens in local dogs and volunteers in northern Saskatchewan and found relatively high seroprevalence in a local Indigenous community. The arctic rabies virus variant (ARVV) [17] is naturally occurring in arctic fox and follows a 3–4-year cycle in many areas of the Arctic, where outbreaks threaten people, sled dogs, and wildlife [17,83]. Few human cases have been reported, most of which are in Russia [17,83], but there is likely an under-reporting of incidents. There have been many studies in northern Canada and risks of introducing rabies to rural Australia that follow a One Health approach to tackling the rabies prevalence in Indigenous communities (see Aenishaenslin et al. 2014 for a review) [64,84]. Climate change is hypothesized to impact/reduce fox prey and drive foxes onto land, thereby bringing foxes to communities more frequently [85].

Many pathogens endemic in the Arctic follow complex life cycles that necessitate One Health approaches, such as zoonotic pathogens *Trichinella, Toxoplasma*, and *Brucella* [86–88]. The zoonotic muscle dwelling roundworm *Trichinella* transmits among terrestrial carnivores, polar bear, and walrus in the Arctic, and causes large food borne outbreaks when infected wildlife is harvested. This parasite has been flagged in numerous review papers throughout Inuit Nunaat [86,88,89]. The protozoan parasite *Toxoplasma* originates from felines in more temperate regions of the world and is carried to the Arctic through marine currents, freshwater, and migratory wildlife, and is an important parasite in Arctic peoples [72] and exposure has been reported in Arctic marine mammals, such as in beluga whales [90,91], ringed seals [68], and polar bears [92]. Other papers also encourage the One health approach for study of zoonotic bacteria *Brucella* [93,94] in marine mammals, along with emerging pathogens including morbillivirus, herpesvirus, and influenza viruses that could affect animal and human health [57,95]. Many papers encourage the use of One Health to study pathogens and contaminants, but few offer implementation of ongoing research or surveillance programs.

3.2.3. Contaminants in arctic wildlife

Environmental contaminants such as mercury and PCBs accumulate in tissues of arctic animals high on the trophic level [8,96]. This is particularly an issue for arctic marine mammals which rely on blubber for a rich energy source and to keep warm [7,97], and carnivores, like foxes and polar bears that feed on them [13,98]. There are several contaminants that are lipophilic (fat-loving) and can be readily stored in blubber, such as POPs [7]. Polar bears are particularly vulnerable to contaminants as they rely on seal blubber as their main energy source [14,99]. Contaminant offloading from mothers to cubs has been recorded [100], where as much as 70% of the female's burden can be transferred to the cub in lactation. Secondary effects of contaminant exposure from POPs, PCB congeners, and mercury include suppressed immune functions such as humoral cell-mediated systems, leading to increased disease burdens [8,14,101]. These POPs and mercury also act as endocrine disruptors because of their structural similarity to endogenous compounds [7], which then have downstream health impacts such as reproductive success [102]. From a population conservation perspective, these contaminants that reduce fertility and survival of cubs are important to monitor in the Arctic [7,101]. One paper even suggested that Inuit alternate their food choice away from marine mammals in favour of anadromous arctic char because mercury concentrations were lower in fish [103].

Arctic top predators or those on a high trophic level, including polar bears, are not only sentinels for environmental contamination, but also serve as sources of human exposure since they provide a food source to Inuit [7]. Arctic peoples are exposed to high level of industrial contaminants because of atmospheric and oceanic transport and studies have found high level of mercury and PCBs in Indigenous harvesters [8], such as in East Greenland where Inuit have four times the level of PCBs and POPs than West Greenland [104]. Mercury exposure in people has been associated with neuro-endocrine and immune health problems in Faroe Islands, West Greenland, and Canada [7,69]. Contaminants research lends itself to One Health approaches and interventions as they are closely tied with the environment and human influences and health impacts, and because they may interact with the complex dynamics and composition of pathogens [7].

3.2.4. Human component

One Health must continue to engage with societal and human health connections, recognizing that human activities impact the flow of parasitic infections [62], and that humans are indeed part of the development, maintenance, and resilience of ecological systems. When pathogens move from wildlife to humans, or humans to wildlife, this is often referred to as spillover and spill back [62]. The leading cause of such events is thought to be human activities as a result of socioeconomic factors (crowding), harvesting wildlife, and even tourism [62,68]. Zoonotic disease impacts are heavier on the global poor, which causes disproportionate suffering [57,105]. Halliday et al. [105] outlined pathogens (brucella, leptospirosis etc.) and diagnosis issues in Tanzania, Africa, where many communities in poverty are overlooked in global disease control. Because One Health includes human health, it also touches on health care and equity. This includes access to health care and proper diagnosis, which can be difficult in rural and remote areas, including Inuit Nunaat, and where wild game is consumed more often than in urban populations. Socio-ecological factors impact zoonotic disease emergence [105]. Most of the fundamental social and environmental determinants of health (water security, biodiversity, social justice, equitable access to resources) are considered beyond the scope of One Health approaches even though they have large impacts on human health and sustainable development goals [60]. One Health approaches seeks to narrow the gap between research and implementation, informing policymakers and addressing socio-economic factors that affect the health of people, animals, and the environment

[59].

4. One Health and Indigenous approaches to wildlife research: differences and synergies

Our synthesis above provides contexts and the encompassing approaches of One Health and Inuit Qaujimajatuqangit in wildlife research, we asked if there was a body of literature that combines the two knowledge sources? Before answering this, a clarification should be addressed. There are many that would argue that while the term One Health is relatively new, the concept of more holistic research that goes beyond the typical boundaries of siloed research is not. Many Indigenous Methodologies and approaches are based on relationality, where everything is connected. Such examples can be seen in Kincentric ecology described by Salmon [106] from Rarámuri, Anishinaabe Aki (Aki meaning Earth but acknowledges Anishinaabe teachings) [107] and many more [24,36,108]. This distinction between the concept and term One Health should be made here, as the following discussion is based on the term One Health, which derives from western scientific framework discussed earlier.

While One Health is not a new concept, the inclusion of IQ, or any Indigenous Knowledges and approaches, in One Health research is. A systematic review by Riley et al. [64] of One Health and global Indigenous Peoples with a wide search string (included EcoHealth, Planetary Health, and One Welfare) found only 24 references in the literature, half of which included all three sectors of One Health, and no evidence for a One Health model in Indigenous communities globally. Our review yielded 40 papers but expanded to some regions outside of Inuit Nunaat to include northern regions of the prairie provinces in Canada, explored below. The increase in papers is likely due to the increase in volume of literature in recent years around One Health approaches being implemented in Indigenous communities in Canada and abroad.

Hillier et al. [19] conducted a systematic review of literature to determine which topics were addressed in One Health projects with Indigenous communities, and what engagement processes if any were used looked like. Of 20 papers, 15 were focused on zoonotic diseases, and 6 of those were circumpolar Arctic focused, which is relatively large considering the population size of the Arctic compared to other regions. This review also criticizes that the One Health interventions are purely a Western methodology with western definitions of health. Some recent literature documented Indigenous Knowledges in a wildlife health assessment and compared the knowledge that Inuit participants had shared in the study to that of a One Health approach, rather than recognizing it as demonstrating Indigenous worldviews [109]. These two papers touch on the similarities of One Health and Indigenous ways of understanding health and wellness, but their differences are not explored.

We argue that the very structure and priorities around One Health approaches and Indigenous Knowledges and approaches are fundamentally different. While they are two separate worldviews, One Health could potentially act as a bridge between Indigenous and western sciences [66]. One Health, in its current state in the literature, is largely under the western paradigm with a human centric worldview [110]. Any research or management that separates land or marine use and wildlife health are at odds with many Indigenous People's perspectives because of the interconnections between the environment, social health, and individuals [66].

To effectively bring the two methodologies together would require honouring the principles of Indigenous approaches by including Indigenous Peoples and their voices in the research, including them as researchers, as authors, and decisionmakers in wildlife research and conservation. The involvement of Indigenous Peoples in local research is key for both effectiveness and sustainability of One Health interventions in these communities [64]. This relationship between One Health and Arctic Indigenous Peoples was explored in Hueffer et al. [6] where they outlined the potential of One Health and their current activities in the circumpolar north, and compiled a list of community priorities. Their conclusion was that One Health appraoches are most likely to succeed with a bottom-up model, where locals define their priorities.

5. Recommendations going forward: wildlife research

> "Innovative and disruptive approaches are needed to address shared health threats such as climate change, urbanization, and pollution, because business as usual is insufficient to inspire the necessary actions to protect the health of one species without risking the health of another." -Dr. Craig Stephen [111].

As explored in this paper, wildlife research and inclusion of IQ is complex and variable owing to contrasts between Indigenous and western worldviews in wildlife management and co-management approaches across Inuit Nunaat. Historically, the general model of western wildlife management has been the practice of manipulating populations, habitats, and human interaction with wildlife [112]. Below, we explore the several examples of successful wildlife management system that adopt a co-management framework. Additionally, we argue that One Health approaches may continue to fall short of its full potential without the careful inclusion of social sciences, as human and social behaviours continue to impact animal and environmental health [64]. There is a wealth of literature that stresses the need for social science research team members on One Health projects [50,51,113]. Not only is human behaviour at the center of many One Health issues and interventions, but facilitating these intervention goals and evaluating their successes requires understanding of social science and qualitative methods [50,114]. Transparent decision-making and communication are also important in achieving One Health goals. Input from social science or ethical practices to ensure equity of local stakeholders should continue to be sought to plan and implement prevention programs and management interventions [63], examine policies and practices that are designed to mitigate wildlife decision and their impact, and facilitate co-management consensus [50].

5.1. *Wildlife research frameworks and co-management*

There are many successful frameworks that exemplify that cooperative research is key to improving relationships between stakeholders and regulators that ultimately lead to successful management of pathogens and wildlife regulations. Across Inuit Nunaat harvesting wildlife is tightly linked to the intricate socio-ecological fabrics of communities, and they cannot easily be separated, or managed without proper care. Local investment and know-how across Inuit Nunaat must be acknowledged and integrated to address shared priorities for sustainable and healthy wildlife populations. Wildlife co-management that includes Indigenous organizations fuels action, where local people feel empowered and heard, and are more likely to keep acting for the communal benefit and goals.

Ethical and equitable partnerships between communities and researchers and associated institutions are important for effective adaptation. Directives from external governments and organizations onto Indigenous Peoples and way of life are less likely to be implemented successfully [115]. For example, when the International Whaling Commission attempted to cease all whale hunting without distinguishing commercial whaling from subsistence harvest, this led to the formation of the Alaska Eskimo Whaling Commission (AEWC) [116] and the Alaska Beluga Whale Committee (ABWC) [37]. The AEWC, consisting of the National Oceanic and Atmospheric Administration (NOAA) and 11 communities along Alaska's coast, have co-managed bowhead whales since 1977. The ABWC formed in 1988 based on the success of the AEWC and have mainly focused on research of local beluga stocks. Both commissions still run many programs and employment opportunities today to increase knowledge on bowhead and beluga whales and to promote co-management and research practices that include both Indigenous

Knowledges and western science to assess beluga population estimates and trends, harvest levels, migration, and stock identity [37,117]. True co-management ensures communities are included in the research and decisions as early as possible, by identifying questions and concerns together, which leads to sustained local investment and collaborative partnerships and programs [68]. One Health approaches would benefit from co-management approaches that begin at the community level, as holistic 'bottom-up' models, that ideally include both Indigenous and Western methods and knowledge [6].

Working across different disciplines with such large goals calls for large interdisciplinary research teams. After all, One Health consists of at least three separate disciplines, and veterinarians and biologists require expertise from other fields and support from local government/management. Social scientists are key parts of research teams, pairing qualitative research methods with Indigenous research methods and documenting Inuit Knowledge, including in wildlife health. Natural scientists must go beyond seeking 'TEK information that benefits and conforms to Western science and existing management structures' [118,119]. Indeed, many of the most notable and successful projects occurring across Inuit Nunaat have had large teams with social scientists in their ranks and many co-authors, such as the Arctic Corridors and Northern Voices project [120], SmartIce Project [121], and beluga research in the ISR [122,123]. All these projects include social science components, long lasting relationships with local organizations or 'champions', and engage Inuit in mutual decision-making processes. But as important as local empowerment and engagement is, the "current threat to the Arctic now requires the integration of local and outside expertise, and with outside financial and technical resources" [6]. Arctic wildlife research occurs in remote areas, and requires external resources to support these large teams, as well as local expertise to conduct any wildlife research safely and effectively.

A possible collaborative framework could include a local (Indigenous) knowledge broker, or a local 'champion' [114], who is positioned to merge these two ways of knowing and can connect researchers with the right people within communities. As more researchers take interest in the Arctic, local communities become overwhelmed with research requests and proposals. A local champion could coordinate projects and connections. This could look different in each region and community depending on the need, where a central facility with staff coordinates more remote locations. A local ground-up wildlife health monitoring program in the Sahtu Region of Northwest Territories [114] had a framework that was envisioned as a 4-legged stool that rests on collaboration, funding, education, and information and analysis, all topped by a local champion to facilitate communication. Another example can be seen in the British Columbia First Nations Health Authority which created a First Nations Chief Medical Officer with the roles to:

a) See and hear (gather info and data from various sources to understand health of First Nations people in BC),
b) Report (share this story of health), and.
c) Guide by Two-Eyed Seeing leadership [124].

Similarly, Stephen and Oura [125] suggest the next steps in the One Health approach are to start building leadership in One Health, capacities, and mentorships to enact real and sustained approaches to health. One Health centers of research are emerging across the globe to build these capacities, including University of Alaska Fairbanks (UAF) with specific aims for promoting wellbeing in the north (https://uaf.edu/onehealth/). Centers and programs like those at UAF can be tailored to the specific needs and priorities of the region. This could also serve to adapt to local priorities and languages, as there is often a "gap between a person's experience of a given reality and science's explanation of that same reality - where we need lay epidemiology to understand what people are experiencing and understanding (or Inuktitut terms) and to communicate risk factors" [54]. Where lay epidemiology refers to terminology that is accessible to general non-scientific audiences. Social science can fill the human dimension portion of One Health, and incorporate local and Indigenous knowledge adhering to IQ principles [27].

The inclusion of social sciences, co-management frameworks, and the consideration of equity and socioeconomics that impact people's decisions into the typical One Health framework are on the steps to ethical and effective wildlife research across Inuit Nunaat (Fig. 2). Without these supporting structures (as seen in the figure), the large and difficult questions that One Health often tackles may not be sustainable, particularly in Indigenous communities. Wildlife research and management are tightly linked in Inuit Nunaat and several options and frameworks that have worked elsewhere have been presented.

6. Concluding remarks

While the term One Health recognizes that the health of animals, humans, and the planet are connected, and is moving closer to the concept of relationality, it does not stem from the same origins as Indigenous approaches. Their epistemologies and methodologies come from different places. However, they both underscore that to understand something, we must consider all relations and connections. One Health approaches asks us to spend less time on exploring or experimenting on the causal pathways and more time on understanding relationships and interactions of systems [126]. Indigenous approaches, or more specifically, Inuit Qaujimajatuqangit, provides guidance through Inuit worldview to maintain balance in nature and recognize the connections between everything. Integrating One Health and Indigenous Knowledges into wildlife research and management requires nothing less than a fundamental shift in how we see ourselves as part of the world [127,128]. Health risks are increasing as the climate changes, including EIDs, contaminant exposure, natural disasters, and decreased access to resources and healthcare [56]. Ultimately Arctic wildlife can act as sentinels for human and environmental health [10,13]. As environmental changes continue to occur including climate change, pathogen northward movement, and shifting ocean oscillating currents, all research projects will have to recognize the importance of environmental drivers and the need for holistic concepts of research which can be seen to a degree in One Health approaches but also in Indigenous approaches in research projects. To date One Health is encouraged and lauded for its holistic approaches, but there is much room to grow and facilitate its application to Arctic wildlife research. With the urgent changes to the Arctic environment, it will require contributions from larger research teams that include social sciences and investing in local engagement to create effective policies for wildlife research and co-

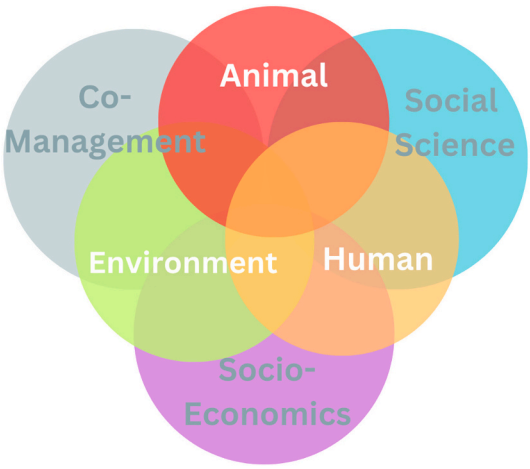

Fig. 2. A One Health Framework re-worked to include socioeconomics, co-management and social science.

management to take hold across Inuit Nunaat.

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E. Sudlovenick: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. **E. Jenkins:** Supervision, Validation, Visualization, Writing – review & editing. **L. Loseto:** Conceptualization, Funding acquisition, Project administration, Supervision, Visualization, Writing – review & editing.

Declaration of competing interest

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No data was used for the research described in the article.

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