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"It's Always a Learning Process": A Preliminary Study of Traditional Food Safety Knowledge and Practices in Kotzebue, Alaska

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ABSTRACT. In Kotzebue, Alaska, traditional Qikiqtaġruŋmiut food practices help reduce risks of food-borne diseases from locally harvested foods. Changes to climate and societal change affecting food systems may introduce new pathogens (e.g., avian influenza, neurotoxins from harmful algal blooms) to local food resources or increase the potential for known pathogens to cause illness (e.g., *Clostridium botulinum*, *Brucella* spp., *Toxoplasma gondii*). To learn more about local concerns and knowledge, we first discussed the topic with five knowledgeable Elders, then conducted formal interviews with five Qikiqtaġruŋmiut, from young adults to Elders, selected for experience gathering, processing, and preparing traditional foods. We also reviewed published literature, selected through keyword searches, on our topic to provide a preliminary assessment of how current practices reduce or exacerbate risks from food-borne pathogens. We found that traditional practices, such as inspecting animals and foods, freezing, drying, and cooking, among others, remain effective for reducing some risks, if those practices are followed carefully. We also found that some emerging pathogens (e.g., harmful algal bloom toxins) are likely to evade detection or mitigation using traditional practices, and thus may be a priority for monitoring and raising awareness. Further steps to reducing the risks from food-associated diseases include emphasizing the importance of sustaining Qikiqtaġruŋmiut knowledge and practices as the basis for food safety in the community and supporting mutual learning between traditional food practitioners, wildlife veterinarians, and public health officials. We believe our findings have relevance to other northern communities with similar food resources and practices.

Keywords: Qikiqtaġruŋmiut; Iñupiat; Indigenous; zoonotic disease; climate change; pathogens; hunting; traditional food system

RÉSUMÉ. À Kotzebue, en Alaska, les pratiques alimentaires traditionnelles des Qikiqtaġruŋmiuts aident à atténuer les risques de maladies d'origine alimentaire provenant des aliments récoltés à l'échelle locale. Les changements d'ordre climatique et sociétal ayant des incidences sur les systèmes alimentaires pourraient entraîner l'émergence de nouveaux agents pathogènes (par exemple, la grippe aviaire ou des neurotoxines produites par la prolifération d'algues nuisibles) dans les ressources alimentaires locales, ou encore, augmenter la possibilité que des agents pathogènes connus provoquent des maladies (par exemple, *Clostridium botulinum*, *Brucella* spp., *Toxoplasma gondii*). Pour en savoir plus sur les préoccupations et les connaissances des gens de la région, nous avons d'abord discuté du sujet avec cinq aînés bien informés, puis nous avons réalisé des entrevues structurées avec cinq Qikiqtaġruŋmiuts, allant de jeunes adultes à des aînés, choisis en fonction de leur expérience en récolte, en transformation et en préparation d'aliments traditionnels. Nous avons également étudié la littérature publiée sur le sujet, en utilisant des termes de recherche pour effectuer une première évaluation de la manière dont les pratiques actuelles réduisent ou exacerbent les dangers associés aux agents pathogènes dérivés des aliments. Nous avons remarqué que les pratiques traditionnelles, comme l'inspection, la congélation, le séchage et la cuisson des animaux et des aliments, entre autres, contribuent encore tout de même à la réduction de certains risques, à condition de les appliquer correctement. Nous avons également constaté que les pratiques traditionnelles ne permettent vraisemblablement pas de détecter ou d'atténuer certains agents pathogènes émergents (par exemple, les toxines produites par la prolifération d'algues nocives). Par conséquent, il est important de privilégier la sensibilisation de la population à ces agents pathogènes et de lui montrer comment les repérer. Parmi les autres mesures à prendre pour réduire les risques de maladies d'origine alimentaire, mentionnons l'accent mis sur l'importance de maintenir les connaissances et les pratiques des Qikiqtaġruŋmiuts, qui constituent un fondement de la salubrité alimentaire dans la communauté, ainsi que la promotion de l'échange de connaissances entre les adeptes de la

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nourriture traditionnelle, les vétérinaires spécialisés en faune sauvage et les responsables de la santé publique. Nous croyons que nos constatations sont pertinentes pour d'autres communautés nordiques dont les ressources et les pratiques alimentaires sont similaires.

Mots-clés : Qikiqtaġruŋmiut; Iñupiat; autochtone; maladie zoonotique; changement climatique; agents pathogènes; chasse; système alimentaire traditionnel

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INTRODUCTION

In common with Indigenous peoples elsewhere, the Qikiqtaġruŋmiut, the Iñupiat of Kotzebue, Alaska (Fig. 1), have thrived on locally harvested foods for millennia (Whiting, 2006; ICC-Alaska, 2015). These foods are nutritious and provide extensive cultural, social, and spiritual benefits as well (Branch, 2015; ICC-Alaska, 2015). This pattern continues today. Harvest surveys in 1986 and 2002–04 show total wild food harvests of up to about 180 kg (400 lbs) per person and up to about 2250 kg (5000 lbs) per Tribal member household (Georgette and Loon, 1993; Whiting, 2006). The main species harvested include caribou (*Rangifer tarandus*), bearded seal (*Erignathus barbatus*), sheefish (*Stenodus leucichthys*), and chum salmon (*Oncorhyncus keta*), as well as a wide variety of other fish and animals, including several bird species (Georgette and Loon, 1993; Whiting, 2006; Mikow and Kostick, 2016). Harvest levels vary from year to year but have remained in a similar range throughout this period, suggesting a high degree of continuity of participation in the traditional food system.

Consuming food is also a common pathway of human exposure to pathogens (Morya et al., 2020). To reduce the risk of food-borne disease and related hazards, the Qikiqtaġruŋmiut rely on traditional practices. These practices cover health assessment, handling of animals, and preparation of food items (Table 1), similar to those documented elsewhere (Spray, 2002; Ostertag et al., 2018; Martinez-Levasseur et al., 2020). In Kotzebue, as in the rest of Alaska, colonization and modernity have hampered the transmission of Indigenous Knowledge and practice from one generation to the next and undermined confidence in the efficacy of traditional ways in contrast to external knowledge and assessment systems (Demientieff et al., 2023). There is thus a pressing local need to understand, appreciate, and sustain traditional practices regarding food safety. The Native Village of Kotzebue, the Tribal government for the Qikiqtaġruŋmiut, was motivated to collaborate on this study because of concerns about the safety of traditional foods, especially in light of information about new pathogens, such as highly pathogenic avian influenza and neurotoxins associated with harmful algal blooms, as well as concern about the potential loss of Indigenous Knowledge associated with food safety.

Some work has been done in Alaska and northern Canada to document and analyze traditional food practices (Shaffer et al., 1990; Forbes et al., 2003; Leclair et al., 2004; Food Safety Network, 2009; Andersen-Ranberg et al., 2024). "Traditional practices" here refers to the knowledge and skills associated with longstanding relationships with lands, waters, and species of the region, sometimes modified with modern technology and ways of life. Such research is valuable for external audiences, such as wildlife veterinarians and public health experts, so that they can understand in greater detail how traditional practices help protect people from food-borne illness, and also which pathogens may evade traditional detection, mitigation, and avoidance mechanisms.

This work is especially relevant as social and environmental conditions change. Climate change is linked to, or expected to cause, increases in prevalence and northward expansion of pathogens and their vectors. Other effects in the Arctic include the emergence of novel disease risks or re-emergence of known pathogens. Pathogens of concern include bacteria such as *Bacillus anthracis*, *Brucella* spp., *Clostridium botulinum*, *Erysipelothrix rhusiopathiae, Francisella tularensis,* and *Pasteurella multocida* subsp. *multocida*; viruses such as rabies virus, avian influenza, West Nile virus, Hantaviruses, and tick-borne encephalitis viruses; and parasites such as *Echinococcus* spp., *Leptospira* spp., *Giardia* spp., *Cryptosporidia* spp., *Umingmakstrongylus pallikuukensis*, *Elaphostrongylus rangiferi,* and *Toxoplasma gondii* (Burek et al., 2008; Ytrehus et al., 2008; Laaksonen et al., 2010; Slenning, 2010; Davidson et al., 2011; Kutz et al., 2012, 2015; Hueffer et al., 2013; Parkinson et al., 2014; Hollmén and Franson, 2015; Atwood et al., 2017; Tryland et al., 2018; Yoder, 2018; Sanderson and Alexander, 2020). Many of these pathogens have zoonotic risk. Unfortunately, good baseline data on most of these pathogens is lacking in Arctic Alaska. Elsewhere in the Arctic however, warming weather patterns have dramatically altered the distribution and ecology of several wildlife pathogens, some with zoonotic potential (Ytrehus et al., 2008, Laaksonen et al., 2010; Kutz et al., 2013, Tschritter et al., 2024).

Societal change can also alter awareness of, and exposure to, food-borne pathogens through changes to diets and loss of Indigenous Knowledge (Huntington et al., 2021; Demientieff et al., 2023). Without understanding traditional practices for wildlife health assessments and food preparation in the context of specific pathogens of concern in a region, it is difficult for those involved with food safety assessments, including health professionals, to evaluate the risks from the potential spread of new pathogens and from changing patterns of hunting, fishing, gathering, and preparing local foods.

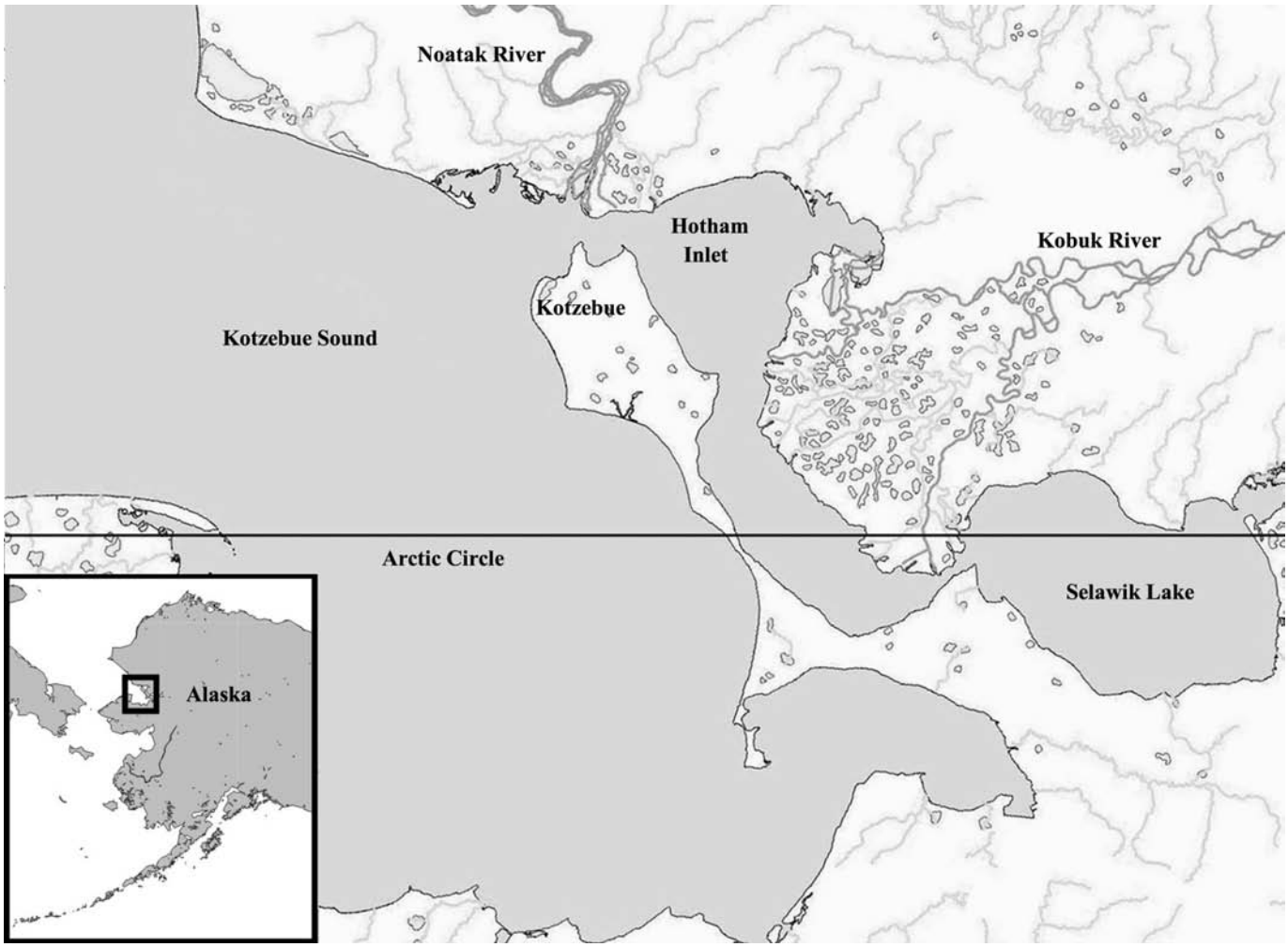


FIG. 1. Map of Kotzebue and the surrounding region.

We present findings from an initial effort in Kotzebue to document Qikiqtaġruŋmiut concerns and practices related to food safety. Our project was exploratory, aiming to assess interest in the topic among residents of Kotzebue and identify promising directions for further research. Our study adds a specific local perspective to previous work on the topic. We also summarize findings from a literature survey about wildlife-associated pathogens and food processing practices. Thus, we lay the foundation for further evaluation of specific risks by presenting an introduction to the types of pathogens known to be present in the Kotzebue area or of concern due to their presence in the Arctic. The discussion explores the potential for connecting Iñupiaq and veterinary knowledge about animal health and food safety for the benefit of those who produce and consume Iñupiaq foods and those who study and work on animal health. This work is intended to explore shared pathways for addressing current and future traditional food safety in our study community and other communities reliant on local food harvest. Public health considerations are beyond the scope of this paper but will be highly relevant to future studies to ensure careful consideration of risk and benefits and the need for effective communication concerning the vital and sensitive topic of food safety in the context of traditional practices. While this study focuses on Kotzebue due to the strong research record of the Native Village of Kotzebue and longstanding relationships among those involved in the project, our expectation is that the topic and our overall approach will be of interest to any communities and areas that have strong traditional food systems.

METHODS

The project began with discussions among members of the core research team (AW, TH, KBH, and HPH) and is based on extensive collaborations among them. Recognizing a shared interest in the topic of food safety, the core team secured a planning grant from the U.S. National Science Foundation. The plan was to have Indigenous Knowledge holders living in Kotzebue share food practices with the team to better understand how food safety is thought about and addressed in practical terms. Indigenous Knowledge is built from experience, shared through stories and example, and refined through generations of practice (Noongwook et al., 2007). We began with four open-ended conversations

TABLE 1: Summary and assessment of traditional methods of reducing risks from foodborne pathogens.

	Steps of Food Harvest and Production					
	Assessment of animal before harvesting	External assessment of carcass	Internal assessment of carcass	Processing and storage	Preparation and consumption	Notes
Traditionally used indicators	Odd behavior, injuries, poor body condition	Wounds, skin lesions, poor body condition	Abnormalities in liver or lungs, visible lesions or parasites, foaming when tissues are cut, odd smells, odd feel to tissues (e.g., slimy)	Odd appearance, odd smell, odd feel	Odd appearance, odd smell, odd taste, odd feel	Traditional ways have helped reduce risk for generations
Potential for Pathogen Exposure	(none)	Contact pathogens (e.g., seal finger, tularemia, leptospira)	Contact pathogens (e.g., seal finger), airborne pathogens	Pathogen growth (e.g., botulism, mold, from poor storage methods). Pathogens unaffected by drying (*E. coli*, Salmonella, etc.)	Ingestion of pathogens	New pathogens (e.g., HABs) may evade traditional methods
Potential for Reducing Risk	Avoiding badly diseased animals	Avoiding animals with obvious problems	Avoiding animals with systemic problems, avoiding tissues with site-specific problems	Destruction of pathogens affected by drying, freezing	Destruction of pathogens affected by cooking	Careful attention to traditional ways will help; shortcuts may not
Potential for Increasing Risk	(none)	(none)	(none)	Creating conditions for pathogens to thrive (poor processing or storage methods)	Introduction of new pathogens (e.g., *E. coli*) from poor hygiene	Shortcuts and failure to follow traditional practices may create problems
Consequences of a False Negative (failing to identify a pathogen)	Taking a sick animal that does not show signs of illness	Cutting up a diseased animal	Taking food with pathogens	Storing food with pathogens or in ways that increase pathogenicity or do not destroy them	Ingesting pathogens	Unnecessary exposure to pathogens; can also result from new pathogens that traditional ways do not detect or avoid
Consequences of a False Positive (identifying a pathogen when none exists)	Avoiding an otherwise healthy animal	Leaving otherwise healthy food in the field	Leaving otherwise healthy food in the field	Loss of otherwise healthy food	Loss of otherwise healthy food	Loss of opportunity, switch to less healthy diet

with five community members selected by the Native Village of Kotzebue for their experience with traditional food systems. These individuals are Pete Schaeffer, Bobby Schaeffer, John and Pearl Goodwin (who were interviewed together), and one who preferred to remain anonymous, all of whom are Tribal Elders and grew up learning and practicing traditional food harvesting and processing methods. The insights gathered were further enhanced by the experiences of project co-leader and lead author AW, who has participated in traditional food systems in Kotzebue for over 35 years. The purpose of these conversations was to start a broader discussion about food safety and learn what concerns Kotzebue residents had, as well as to explore topics they saw as important and related to food safety.

Following the initial conversations, the core team determined that there was strong interest in continuing research about food safety. We also identified an opportunity to involve Qikiqtaġruŋmiut committed to the well-being of their community and interested in taking part in a research project. Accordingly, we worked with Aqqaluk Trust to support the involvement of co-authors CAN and LAB. Aqqaluk Trust is a subsidiary of NANA Regional Corporation, created under the 1971 Alaska Native Claims Settlement Act, providing scholarships and internships for local youth.

Aqqaluk team member CAN conducted five semi-directed interviews (i.e., interviews without specific questions, but instead, using a list of general topics to discuss in conversation; Huntington, 1998) with six people who live in or near Kotzebue, including three men and three women, ranging in age from young adults to Elders. These individuals are Shylena Lie, Lance Kramer, Alice Adams, Pete and Agnik Schaeffer, and one who preferred to remain anonymous. They were selected because they are heavily involved in the traditional food system and include both men and women, as well as older and younger persons. Interviews focused on food handling and preparation methods, topics that were identified as important in the earlier conversations. Co-author CAN had relatively little experience conducting interviews, so a

narrower focus also helped keep the conversation on track and ensure major topics were covered. Following the interviews, CAN prepared transcripts, which are the source of the quotes in our results section. We did not attempt a comprehensive documentation of all food handling methods, but instead present a basic overview to indicate some of the ways Iñupiat in Kotzebue assess food safety, and the practices they use that may affect exposure to pathogens and associated risks. Additionally, CAN wrote about her experience on the project, an excerpt of which is included in the discussion section as an illustration of the benefit of including younger community members in projects of this kind.

The project was approved by the Native Village of Kotzebue Tribal Council (Resolution 20-021), the sovereign government of the Tribal community. The project was also reviewed and approved by the Institutional Review Board of the University of Alaska Fairbanks (IRB # 2102361-3). Interviews were conducted following the principle of free, prior, and informed consent (United Nations, 2007). Participants were free to decline to be interviewed, to withdraw from the project at any time, and to decide if they wanted to remain anonymous; to be named in the acknowledgments section; or to be co-authors of this paper. Participants were also paid for their time in accordance with Native Village of Kotzebue policy and practice.

In addition to the interviews, the core team also spoke with a public health official from Maniilaq Association, the regional Tribal health and social services organization, and personnel at the local offices of the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service. These conversations were held in the offices or facilities of each organization and related directly to the professional duties of the individuals involved. The discussions confirmed the importance of the topic and provided valuable insight into day-to-day interactions agency personnel have with local hunters and food preparers. Discussions with officials also revealed their interest in, experiences with, and concerns about monitoring wildlife health and the potential for future partnerships.

We also performed a literature review about pathogens and traditional practices through Google Scholar. Some of the keywords used included: Native food practices, Arctic; wildlife disease, arctic; wildlife disease, Arctic Alaska; climate change and wildlife disease; Alaska wildlife disease; traditional Alaska food and public health; zoonoses; food safety Inuit; traditional food handling; Inupiaq/Inuit; food safety; Alaska Native subsistence foods safety; Inuit traditional practices in food handling disease; and safe preparation and storage of Inuit subsistence foods. Further searches were conducted on specific pathogens identified in the initial search; these are listed in Tables 2 and 3.

The positionality of the authors is as follows: AW began the Environmental Program for the Native Village of Kotzebue in 1997 and has been its director since then. AA, LK, SL, and AS are individuals experienced in all aspects of traditional food safety and include Qikiqtaġruŋmiut Elders. CAN is a young Iñupiaq from Kotzebue with strong interest in the well-being of her culture and community, committed to learning. LAB is Iñupiaq from Buckland and focuses on creating opportunities for young people to engage with their language and culture. TH is a non-Native marine ecologist and veterinary epidemiologist with over 20 years' experience working in Alaska and the Arctic on wildlife health, including One Health and community-based research. KBH is a non-Native veterinary pathologist originally from the Midwest of the U.S. with over 30 years' experience in Alaska, specializing in wildlife health, sometimes in collaboration with Tribal organizations and individuals. HPH is a non-Native social scientist from the Northeast of the U.S., married to KBH, and has over 30 years' experience working in and with Alaska Native and other Arctic Indigenous communities, particularly concerning aspects of human–environment interactions.

RESULTS

Interviews

The traditional food production system has numerous steps in which the health of animals and the suitability of food items are evaluated (Table 1). Here, we summarize information from the interviews, with selected quotes to illustrate the ways participants describe their practices.

Before taking an animal, hunters have a variety of methods for assessing its suitability. These methods begin with watching the animal to see if it displays any odd behavior or has any signs of ill health. "Odd behavior" is difficult to describe, but relies on deep familiarity with the animals and extensive experience recognizing behavioral anomalies. Signs of ill health also include visible wounds or lesions, as well as signs of emaciation. Hunters acknowledge, however, that one cannot always detect signs of ill health before butchering begins. Elders report noticing an increase in poor health indices (e.g., thinner blubber stores). They ascribe these changes in part to environmental change and in part to greater disturbance by humans: "I know if [caribou] are sick, they're just super skinny. You can see the back rump bones" (Alice Adams).

Hunters expressed being risk averse, in that signs of abnormality are taken seriously, and animals will be avoided if there is any doubt. If fish or animals are discovered to be unhealthy for human consumption during butchering, they will typically be discarded. "I usually throw it away. I mean if we're on the beach I usually just toss it back in the water with fish" (Shylena Lie).

> The other year I had to throw a big chunk of ugruk [bearded seal] blubber because it was just too hard for me to work on it. From what I heard it might have been in a fight or something. I'm not going to risk me or my family, not knowing if they [the pathogens] survived the boiling water.
>
> Alice Adams

TABLE 2. Examples of foodborne pathogens in the Arctic (a) associated with some of the species harvested by Qikiqtaġruŋmiut, (b) posing a risk during various steps of food processing, and (c) intended to illustrate a range of pathogens and exposure pathways.

Pathogen	Host species	Gross pathologic indicators	Significant diagnostic samples	Diagnostic techniques to confirm in animals	Reported human disease	Recommended food handling / preparation	References
Anisakid nematodes	Fish, birds	Larvae in muscle and coelomic cavity of fish	Muscle of fish	In animals, visualization of larvae in stomach, muscle or abdominal cavity; in people	Gastritis with ulcerative lesions of stomach wall	Freeze or cook	Jenkins et al., 2013; Keatts et al., 2021
Avian influenza	Birds, especially waterfowl, carnivores (polar bear, fox)	None to perhaps reddened swollen brain (mammals) or pneumonia	lung, choanal/nasal rectal/cloacal material; brain (mammals),	Polymerase chain reaction (PCR)	Rare, but concerns with highly pathogenic avian influence (HPAI) (H5N1) conjunctivitis to encephalitis	Use gloves; cook well	Elsmo et al., 2023; Graziosi et al., 2024; Stimmelmayer et al., 2024
Brucella spp.	Polar bears (serology increasing over time)	Unknown	Unknown	Histopathology, immunohistochemistry, bacterial culture, PCR, and serology, PCR and sequencing to determine type and zoonotic potential PCR	Unknown	Cook meat, viscera, and bone marrow thoroughly; Avoid lesions, reproductive tract fluids. Wear gloves – pathogen enters through broken skin.	Atwood et al., 2017
B. pinnipedialis	Eared seals (fur seals, sea lions)	Placentitis	Placenta	"	Unknown - possible zoonotic disease	"	Duncan et al., 2014
B. pinnipedialis	Seals, beluga	None	—	"	None known	"	Nymo et al., 2011 (review); 2018 (Alaska true and eared seals); Waltzek, 2012 (review); Tryland et al., 2014 (marine mammals); Whatmore et al., 2017; Foster et al., 2018 (Bearded seal); Thompson et al., 2022
B. ceti	Cetaceans	None to Blubber and liver abscesses; Skin lesions, Swollen brain, swollen or discolored placenta, abortion, pneumonia, peritonitis, osteomyelitis, endocarditis, epididymitis	Brain, blubber lesions, repro tract, liver lesions, affected joints	"	Neurobrucellosis - intracerebral granulomas, spinal osteomyelitis	"	Guzmán-Verri et al., 2012.
B. suis serovar 4	Caribou, muskox	Swollen and deformed joints, Swollen testes, abortions	Joint fluid, reproductive tissues, placenta	"	Abortion, arthritis, undulant fevers (very rare)	"	Tomaselli et al., 2019 (Muskoxen)

TABLE 2. Examples of foodborne pathogens in the Arctic (a) associated with some of the species harvested by Qikiqtaġruŋmiut, (b) posing a risk during various steps of food processing, and (c) intended to illustrate a range of pathogens and exposure pathways – *continued*:

Pathogen	Host species	Gross pathologic indicators	Significant diagnostic samples	Diagnostic techniques to confirm in animals	Reported human disease	Recommended food handling / preparation	References
Clostridium botulinum type E	Primarily marine mammals and fish	Indicators of putrefaction	Aged traditional foods, stranded marine mammals, traditional dried fish	Botulinum toxin detection, using the standard mouse bioassay	Botulism (double vision, nausea, vomiting, dry and sore throat, followed by paralysis of the motor nerves, with respiratory insufficiency and paralysis)	Proper food handling during butchering (avoid contact with soil/rocks), storage temperature during aging: <36˚F (2˚ Celsius), avoiding producing anaerobic conditions during processing (sealed plastic containers).	Shaffer et al., 1990; McLaughlin et al., 2004; Austin and Leclair, 2011; Leclair et al., 2013; Tryland et al., 2014
Diphyllobothrium spp.	Piscivorous birds, humans, and mammals	Worms in the intestines	Muscle (larvae); feces (eggs)	diagnoses based solely on eggs in fecal samples of definitive hosts; PCR to ID genus	Pernicious anemia	Cook fish well / freeze several days <–10˚C	Jenkins et al., 2013
Echinococcus granulosus	Canid definitive host (dog, fox, wolf); herbivore intermediate (moose, caribou); egg contamination of water	Small parasites in GI of canids; fluid-filled (hydatid) cysts in caribou and moose lungs	Feces	Canids – fecal and ID; PCR to ID genus	Cystic echinococcosis; cysts in the liver and lungs, rarely brain- coughing, anorexia, fever, shortness of breath, chest, or abdominal pain, and functional neurological deficit	Do not feed cysts to dogs; deworm dogs; good hygiene when handling food	Jenkins et al., 2013
Echinococcus multilocularis (restricted to northern hemisphere)	Canid definitive host (dog, fox, wolf); rodents intermediate; egg contamination of water	Small parasites in GI of Canids; Fluid filled cysts in rodent livers	Feces – Canids	Canids – fecals and ID; PCR to ID genus	Alveolar echinococcosis; multilocular hydatid cysts in liver - looks like invasive neoplasm	Deworm dogs; good hygiene when handling food	Jenkins et al., 2013
Erysipelothrix rhusiopathiae	Many, especially muskoxen, cetaceans	Erysipelas: skin lesions, endocarditis, septicemia	All	Culture and/or PCR	Low risk of erysipeloid = skin lesions, endocarditis, septicemia	Hot water, soap, and gloves if there is broken skin	Waltzek et al., 2012; Kutz et al., 2015; Mavrot et al., 2022
Francisella tularensis	Primarily hares, beavers, muskrats	None to spots on the liver and spleen, +/- lungs	Liver, spleen	PCR, culture	Local skin infection to regional swollen lymph nodes to pneumonia to septicemia	Hot water, soap, and gloves when processing carcass; cooking wells	Desvars et al., 2014
Leptospira spp.	Contaminated water, urine of seals, beluga whale, other carnivores, Caribou and moose	None to spotted or swollen kidneys	Kidney, urine	PCR, serology	Asymptomatic to jaundice, renal failure, and bleeding	Hot water, soap, and gloves when processing carcass; cooking kidney and liver well	Waltzek, 2012 (review); Tryland et al., 2014 (marine mammals); Pijnacker et al., 2016; Stimmelmayer and Sheffield, 2022

TABLE 2. Examples of foodborne pathogens in the Arctic (a) associated with some of the species harvested by Qikiqtaġruŋmiut, (b) posing a risk during various steps of food processing, and (c) intended to illustrate a range of pathogens and exposure pathways – *continued*:

Pathogen	Host species	Gross pathologic indicators	Significant diagnostic samples	Diagnostic techniques to confirm in animals	Reported human disease	Recommended food handling / preparation	References
Mycobacterium tuberculosis complex	Polar bears, seals, moose	Polar bears – unknown; seal – infrequent; chronic skin lesions, granulomatous pneumonia, disseminated infection	Lung, liver, lymph nodes, muscle	PCR, culture, serology	Tuberculosis – pneumonia or cutaneous; unknown human disease risk with arctic variant	Hot water, soap, gloves when processing carcass; cooking well	Tryland, 2000; Forde et al., 2012; Waltzek et al., 2012; Barnett et al., 2013; Tryland et al., 2014; Keatts et al., 2021; Tschritter et al., 2024
Mycoplasma spp.	Seals, cetaceans	Usually none in the animal. In rare cases pneumonia	Diseased lung	Mycoplasma culture	Seal finger, Blubber finger – painful local infection on the hands, arthritis, abscesses	Hot water, soap, and gloves if there is broken skin	Tryland et al., 2014; Westley et al., 2016
Toxoplasma gondii	Polar bears (serology increasing over time), Beluga, seals, caribou, +/- waterfowl.	None to possible abortion (caribou)	Muscle, heart, liver, brain	PCR	Asymptomatic infections and mild influenza-like illness to severe ocular and neurological lesions, especially in congenitally infected children, abortion	Wash hands and utensils thoroughly; tissue cysts in meat are destroyed by heating meat to an internal temperature of 67˚C. Conversely, freeze meat at –8 ˚C (18˚F) for three days, –7˚C (20˚F) for at least 17 days, or –1˚C (30˚F)	Hill and Dubey, 2002; Food Safety Network, 2009; Forbes et al., 2009; Jenkins et al., 2013; CDC, 2018; Reiling and Dixon, 2019; Stimmelmayer and Sheffield, 2022; Rode et al., 2024
Trichinella nativa	Walrus, bears, other carnivores	None	Muscle	Tongue or diaphragm – Digestion method or PCR	Edema, fever, rash, and myalgia, persistent diarrhea	Meat must be cooked to an internal temperature of 71˚ C (160˚ F). Traditional fermentation may destroy cysts. Freezing does not destroy	Prestrud et al., 1993; Tryland, 2000; Forbes et al., 2003; LeClair et al., 2004; Rah et al., 2005; Davidson et al., 2008; Gajadhar et al., 2009; Jenkins et al., 2013

TABLE 3: Examples of potential risk reduction using traditional food safety practices, with regard to selected pathogens.

	Steps of Food Production					
Potential for reducing risk of exposure to:	Assessment of animal before harvesting	External assessment of carcass	Internal assessment of carcass	Processing and storage	Preparation and consumption	Notes
Brucella	Badly swollen joints or testes, aborted fetus	Swollen joints or testes	Avoid swollen or inflamed joints, reproductive organs	Wear gloves when processing meat	Cook thoroughly	
Trichinella	None – no behavioral effects	None – no visible effects	None – no gross lesions or visible organisms	None	Meat must be cooked to an internal temperature of 71˚ C (160˚ F). Traditional fermentation may destroy cysts. Freezing does not destroy cysts.	Traditional practices of thoroughly cooking bear meat make are highly effective
Botulinium	None – a found dead animal has a higher risk	For an animal found dead, bloating and other signs of rot may also indicate C. botulinum.	None – botulism develops during processing	Proper processing and storage are essential. Avoid contact with soil/ rocks. storage temperature during aging: <36˚ F (2˚ Celsius), avoiding producing anaerobic conditions during processing (sealed plastic containers.	While the botulinum spores can survive in boiling water, the toxin is heat-labile, meaning that it can be destroyed at high temperatures. Heating food to a typical cooking temperature of 176˚F (80˚C) for 30 minutes or 212˚F (100˚C) for 10 minutes before consumption can greatly reduce the risk of foodborne illness as the toxin is heat labile. This will not destroy the spores. (WHO, 2023)	Traditional practices are effective, but deviation from those practices can create high risk
HAB neurotoxins	Only if the animal is acutely affected and behaving oddly	None – no visible signs or effects	None – no gross lesions or visible effects	None – HAB neurotoxins are not affected by processing or storage methods	Non – HAB neurotoxins are not affected by cooking	Only laboratory testing can detect HAB neurotoxins. If detected, the only option is to avoid the contaminated food.

Once an animal is taken, there are a variety of processing and storage steps that may be carried out, depending on species and foodstuffs being made, before human consumption occurs. When temperatures are above freezing, animals need to be gutted right away after harvest. During processing for storage, people continue to look for abnormal or distasteful signs, smells, or feel of the various foods. Rendering oil from blubber without cooking is done carefully and cleanly in a cooler area, avoiding water contamination and stirring several times a day (Fig. 2). Drying fish and meat is similarly labor intensive, requiring careful attention to keep flies away, even in places protected by a screen or netting, and periodically turning the pieces over to ensure overall even drying. One participant mentioned a scolding from an Elder for being away from the drying meat long enough to take a shower. Each fish or piece of meat must be inspected and taken care of. Failure to keep insects off can lead to meat that is infested with maggots and unfit for consumption, as some participants have experienced. When meat is drying and aging, the surface will get hard and may turn green. Food preparers will use a washcloth and vinegar to wipe off the green material.

> So when we're processing it, anything that we store away, we always clean it beforehand. And then like with caribou, we'll hang it to make it soft. When I am processing my seal oil I make sure that it's not too hot when we are rendering. It could be on a porch or something, or in a cooler area, or in the shop. You have to stir it multiple times a day. When meat starts to turn green on the outside, you've got to check it multiple times a day. But as soon as it starts turning green, we were taught to use a washcloth and white distilled vinegar and water and wipe it off and keep doing that. You check it like two three times a day and make sure we clean off any [insect] eggs or anything like that.
>
> Shylena Lie



FIG. 2. Seal oil making, illustrating the adaptation to new methods and knowledge to include cleanliness, stirring, and aerobic conditions to produce seal oil that is safe for human consumption. Note the jars of finished (rendered) seal oil next to the bucket with rendering blubber. Photo courtesy of the Native Village of Kotzebue.

The dried crust can be cut away before storage. If cysts or other problems are found, they can sometimes be cut out, though the rest of the piece of meat or fish must be examined carefully. Fish may also be smoked.

Aging of meat and fish (often called fermenting, though technically the process is not fermentation) was formerly more common, and many Elders especially continue to enjoy fermented foods. Similar to rendering of blubber, fermentation requires an appropriate location and temperature, and careful tending to ensure the aging is proceeding properly. Smell and appearance are among the indicators used, along with taste from trying a small sample.

Freezing meat and fish also requires attention so that the items freeze quickly and completely. Fish or pieces of meat placed together will not freeze quickly and will likely stick to each other, making a frozen bundle, so they must be kept separate until frozen. When hunting in winter, directly after harvest and while skinning, pieces of meat can be left separate in the snow to cool before transport or storage. If the carcass is left whole with skin on, it needs to be gutted, and the cavity allowed to cool, or it will begin to spoil and start to smell unpleasant.

> Even out there in the fall time, you have to cool the caribou meat off before you put them [away] and lay them on together. Because the meat is just too warm, and you know how bacteria can grow. Always tend the fish and always tend the meat when they're drying because there may be worms growing in there. You always have to tend every part of the fish even if you have a hundred hanging. You touch every one of those hundred fish to make sure that there's nothing in there. Those bugs even always lay on the places you never know to find them.
>
> Alice Adams

Storage methods include drying, freezing, fermenting, storing in oil, canning, and combinations of these methods. Some storage methods have changed over time. For example, the siġḷuaq (ice cellar, a cavity dug into the permafrost, which will remain below freezing year-round) has been replaced, in part, by electric freezers. As well, less food is required overall since hunters no longer need to maintain dog teams, which have been replaced by snow machines. Today, frozen meat and fish are often wrapped in cellophane or vacuum packed to ensure freshness: "We just have a system where we wrap them in that kind of the cellophane wrap that you can get, Saran Wrap basically, and then you can vacuum seal them" (Lance Kramer). Canning was not a common practice formerly and today is not as common as freezing or drying, though some hunters and their families still can food. Dried meat, fish, and greens may be stored in seal oil, which not only preserves them but also adds the taste of the oil, a much-desired condiment. Salting barrels of fish was a common practice for most of the 20th century but has fallen out of use, in large part due to a major decrease of permanent residence camps and, to a lesser degree, because of generational change in traditions and tastes. Today, most people live in Kotzebue and have easy access to electricity and freezers to store fish in.

> So storing the dried meat or greens [e.g., willow (*Salix* spp.) leaves] or maktak [the skin and blubber of a whale] or just other foods such as that, as long as it's properly dried and stored in the oil, it's got a long shelf life. Today it's so much different without using the oil for what we used it for back then. It's like a preservative. We're mostly storing it today in freezers.
>
> Anonymous

Elder participants spoke about the former practice of storing food in sealskin pokes (Fig. 3), containers made by keeping the sealskin intact, sewing up any openings, then using the mouth or neck hole for filling and emptying, with a plug made to seal it. Pokes made from spotted seals (*Phoca largha*) could contain hundreds of pounds of meat. Stored in a siġḷuaq, the meat would remain tasty for a long time. One Elder remembers well the mouth-watering aromas coming from a poke that was opened. Using pokes and retrieving food from the siġḷuaq, however, was hard work and resulted in cold hands. One Elder remembers his grandmother retrieving food from the siġḷuaq during winter, returning with blue hands that hurt and had to be warmed carefully in cool water.

> We used to use all natural stuff. Some of us had wooden barrels that we'd put the meat in, but most of the time it was stored in the sealskin pokes. We had a storage cottage that was about eight feet high, so in the fall time we rolled the full pokes up and into it.
>
> Pete and Agnik Schaeffer

Preparation methods include rendering fat into oil, boiling, roasting, frying, and cooking into stews and soups. Many foods, such as caribou, fish, and maktak are



FIG. 3. A seal skin poke, traditionally used to store oil and meat. Gladys Knight Harris Collection. Circa 1949.

eaten raw, frozen, or fermented. At this stage, too, people pay attention to the look, smell, and feel of the foods to confirm they are suitable for consumption. "And I saved the [bearded seal] flippers for my papa. He ferments them. I've tried that. That's not my cup of tea. But I'll save them" (Shylena Lie).

When people notice abnormalities, they share information about them with family and friends in person, by telephone or radio, or by social media, in order to reinforce existing knowledge or to document and try and understand novel or unknown food safety issues: "I ask my boys, I let them see. And if we start talking about that in general with other people, you know, we share information" (Alice Adams). At times, people may seek opinions from others known to be knowledgeable about wildlife and traditional foods, and occasionally from wildlife authorities, such as local offices of the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service. Social media is a common means of sharing and asking for information and advice, allowing individuals to reach a larger group of potential respondents within and beyond their community.

> I think the easiest way nowadays is social media, but fortunately I haven't had too many instances where we've had to harvest anything unhealthy, so I haven't really had to post or anything, but I do see a lot of people posting whenever they do come across it.
>
> Shylena Lie

In response to a specific question in the interviews, several participants said they would be interested in a cell phone app that would help them share and receive information about food abnormalities.

Of great interest and concern to many of those interviewed is the need for intergenerational learning. The older participants have seen major transitions in the community, from dog teams to snow machines, from a primarily subsistence economy to one where cash and wages predominate, the loss of Iñupiaq fluency among a majority of the population, less attention to minimizing unnecessary disturbance to animals and the environment, and more. Younger participants are aware of these shifts and recognize what has been lost, as well as what is still practiced. In addition to retaining a vibrant and vital cultural heritage, some participants recognized a practical need for traditional skills as a backup, should modern materials and foods become unavailable for any reason. Activities and materials that would foster intergenerational interactions and learning would be welcome in the community. Some participants stated that an emphasis on traditional food safety knowledge and practice could help address this need.

> I see some people still taking their families out and for me it was my biggest thing to make sure my kids know how to survive. They know they can go get the fish, they know they can go get the berries and the greens, they know what part of the country they can go out to. I think we are delaying passing on knowledge and we're losing a lot of time before we can give anything to our younger generation, those that are willingly wanting to just step in and cut even if you make all the mistakes. It's always a learning process and I'm still learning every season.
>
> Alice Adams

Literature Review

The literature survey of wildlife-associated pathogens of public health consequence identified several known pathogens in species harvested in Kotzebue, as well as some pathogens that pose a potential risk in the future due to climate-related factors, such as extended host range, increased survival of pathogens in the environment due to higher temperatures and changing precipitation patterns. A few of these pathogens and associated human diseases include *Brucella* spp. (brucellosis), *Bacillus anthracis* (anthrax), *Clostridium botulinum* type E (botulism), *Echinococcus spp.*, *Erysipelothrix rhusiopathiae* (erysipelas), *Francisella tularensis* (tularemia), *Leptospira* spp. (leptospirosis), *Mycoplasma* spp. (seal finger), rabies virus, *Toxoplasma gondii*, *Trichinella* spp. in mammals, avian influenza virus in birds and mammals, and *Diphyllobothrium* spp. and *Anisakis* spp. in fish (Table 2 and references therein). Public health recommendations for many of these pathogens involved cooking to certain

temperatures and pressures, as well as clean food handling practices and using gloves (Table 2). Many of these recommendations do not take into account, or even run counter to, often preferred methods of consumption, which may involve eating foods raw, dried, smoked, or fermented.

Combining Indigenous and veterinary knowledge creates opportunities for holistic understanding, timely observations, and future monitoring of wildlife health in the context of traditional use and preparation of wild game (Peacock et al., 2020). There have been several studies, primarily in Canada, working with Indigenous hunters on how they assess health of the animals, as well as methods of food preparation (Spray, 2002; Food Safety Network, 2009; Ostertag et al., 2018; Waugh et al., 2018) and reviews of such studies (Stimmelmayr and Sheffield, 2022; Andersen-Ranberg et al., 2024).

Similar to our findings, an Inuvialuit community assessed the health of harvested belugas by external appearance and behavior, as well as internal characteristics, such as blubber thickness and quality, meat quantity and quality, abnormalities in the liver, heart and lungs, and smell (Ostertag et al., 2018). Preferred methods of food preparation were similar to those described by our interviewees, including cooking, fermenting, drying, half drying and rendering; pickling, salting or brining; and storage in pokes and cold cellars (Spray, 2002; Food Safety Network, 2009; Waugh et al., 2018). In each case we reviewed in the literature, country food harvesters were aware of the risk of botulism, especially with putrefied or fermented food, and how to avoid it.

Understanding how Indigenous Peoples process their traditional foods can assist veterinarians and public health professionals in communicating the degree of risk for food-borne disease. Some researchers have documented traditional food processing (Spray, 2002; Stimmelmayr and Sheffield, 2022). Shaffer et al. (1990) investigated how traditional processing of food may affect the risk from pathogens. Among their findings was that using plastic air-tight containers while aging seal oil and other products increases risk of botulism. Some studies have shown that aged, dried, and smoked foods offer resistance to, and sometimes destroy, *Toxoplasma gondii* and *Trichinella* (Forbes et al., 2009; Stimmelmayr and Sheffield, 2022). However, as a food preservation method, drying is generally less effective for inactivation of food-associated enzymes, microbes, and parasites (Beuchat et al., 2013; Stimmelmayr and Sheffield, 2022). For example, *E. coli* 0157:H7, *Listeria monocytogenes*, and *Salmonella* spp. are resistant to drying and have been found in jerky and some fermented meat preparations (Beuchat et al., 2013). Many of these studies also give a host of information about the positive health benefits of traditional foods.

DISCUSSION

Safe consumption of local food relies on being able to identify risks and take appropriate measures to reduce those risks. The traditional methods for doing so in Kotzebue have worked well since time immemorial, though some risk is always present. Food-borne pathogens still afflict people, causing conditions such as seal finger, toxoplasmosis, brucellosis, trichinosis, and botulism. For some pathogens, such as botulism, cases can be caused by modern materials and practices, such as the use of air-tight containers or storing foods in warmer temperatures than were traditionally maintained, creating an anaerobic environment in which botulinum toxin can develop (Shaffer et al., 1990; Chiou et al., 2002; Food Safety Network, 2009). Other risks may increase in the future if novel pathogens spread into the area. Nonetheless, two highly important steps in reducing the risk of foodborne pathogens are to continue to use traditional methods of assessing animal health and food safety and consider public health recommendations. Our results demonstrate the opportunities offered by the traditional system to assess healthfulness food items, and its procedures for diminishing the viability of pathogens and exposure to them among food handlers and consumers.

Recognizing the robustness of the traditional system, insights from veterinary science should be applied where possible within that system. For example, awareness of visible symptoms of an emerging disease can allow hunters to look for those symptoms, in addition to the ones they already monitor for, relying on their own experience and acumen. Similarly, some cultural practices, such as consuming raw and raw-frozen foods, may expose Iñupiat to pathogens, including *Trichinella* spp., *Vibrio parahemolyticus, Toxoplasma gondii*, *Francisella tularensis*, *Brucella* spp., and others that would be mitigated by thorough cooking (Table 2, which includes fish and wildlife harvested by Qikiqtaġruŋmiut). Nonetheless, providing only advice to cook foods thoroughly runs counter to cultural norms and can have the unintended effect of reducing confidence in external advice concerning food safety. Educating public health individuals about cultural preferences may also help in developing culturally appropriate recommendations, for instance, related to relative risk rather than thoroughness of cooking. Working within the traditional system can help strengthen that system, rather than implying that hunters require external help or that external experts always know better. As noted earlier, traditional systems have been systematically undermined by colonization. Greater efforts may be needed within the community to sustain Indigenous Knowledge and practices regarding food safety, and could include documentation of the details of traditional methods concerning food. This effort should be the priority and should be community led.

Co-author Naylor's experience on the project speaks to the importance of local leadership and involvement, not just for ensuring the accuracy of the research, but also

TABLE 4. Potential for sustaining traditional methods and for mutual learning between traditional methods and veterinary pathology.

	Steps of Food Production					
	Assessment of animal before harvesting	External assessment of carcass	Internal assessment of carcass	Processing and storage	Preparation and consumption	Notes
What can be done to sustain traditional methods?	Hands-on experience, documentation of traditional practices, informal and formal educational opportunities for those with less experience to learn from those with more experience. Details in the processing are very important (e.g., frequent stirring of seal oil as it renders)					Such efforts would be aimed at community members
What veterinary pathologists can learn from traditional practitioners?	Details of what hunters look for, frequency of specific conditions, what decisions are made on the basis of the observations			Details of food handling, to assess the potential for reducing or introducing risk		To help veterinary pathologists and others better assess risk, based on actual practices
What traditional practitioners can learn from veterinary pathologists?	Additional signs of ill health that hunters may not already be aware of		Additional signs, and also any risks from contact with pathogens	Potential adjustments to further reduce risk (e.g., frequency of stirring seal oil as it renders, cooking)		To include relevant veterinary knowledge into the traditional system

for increasing awareness and interest among community members. As she wrote after conducting interviews in the second phase of the project:

> Through this research, we aimed to respect and preserve the valuable wisdom of the people in our communities concerning food safety, and contribute to the broader understanding of Indigenous food practices. I found this research utterly fascinating and I was deeply intrigued by the captivating stories about how we used to store food. The traditional methods of freezing, drying, and fermenting were not just interesting, but they also filled me with a profound respect for our ancestors. For example, the use of a seal's stomach to store the oil and niqipiaq (Native food) for the year was a practice that truly fascinated me. Even though we don't practice storing our food in the stomach, we still hold the same level of caution in storing our food. It's truly amazing how these techniques have been passed down through generations, and they play a crucial role in preserving the quality and safety of our native foods. I was truly captivated by the valuable wisdom and insights surrounding food safety practices within our community.

In addition, comparing traditional methods with current veterinary understanding of animal-borne pathogens can also help assess risks and develop mitigation strategies. Two approaches are promising here. First, we can examine specific pathogens and assess the likelihood that traditional methods will mitigate the risk to human health (Table 3). For example, *Brucella* suis biovar 4 in caribou causes visible signs of ill health in an animal in later stages of disease, which will then be avoided, reducing the risk of human exposure. Or, in the case of *Trichinella* in polar bears, the traditional practice of cooking polar bear meat (Dupouy-Camet et al., 2017) thoroughly reduces the risk of trichinosis in humans. Similarly, traditional avoidance of polar bear liver removes the risk of hypervitaminosis A (Rodahl and Moore, 1943; Senoo et al., 2012). Likewise, frequent stirring, avoiding an anaerobic environment, and keeping blubber cool during rendering has likely protected people traditionally from botulism. Such an assessment of pathogens and food practices can help identify where risks are greatest and thus focus attention on specific aspects of food safety. Doing so can also avoid unnecessary scares concerning food safety, for example when traditional practices already mitigate risks from a pathogen whose presence has been recently discovered by veterinarians or scientists. Additionally, creating shared approaches to monitoring wildlife health can increase an understanding of emerging disease risks (Tomaselli et al., 2018; Tomaselli et al., 2019; Stimmelmayr and Sheffield, 2022).

Second, we can consider traditional methods for assessing animal health and food safety and assess the likelihood that those methods will detect pathogens of concern. For example, generalized infections like tularemia and brucellosis, as well as some parasites, often manifest in lesions or other abnormalities in the liver, which hunters examine carefully already as an indicator of systemic health problems in an animal. The results of this second step can be used to identify additional measures to be taken to promote food safety and perhaps avoid unnecessary disposal of otherwise healthy food items. For example, hunters can be encouraged to continue to examine livers, and those involved in food storage and preparation can be encouraged to pay careful attention to traditional practices rather than taking shortcuts (e.g., using readily available but air-tight containers). Both approaches can help promote mutual learning among practitioners of traditional food safety systems, wildlife veterinarians, and other outside experts (Table 4).

These steps will not, however, address all risks of food-borne illness. Early stages of systemic infections, such as tularemia and brucellosis, may show few to no visible lesions. Some pathogens, such as some viral agents (including highly pathogenic avian influenza), and toxins generated by harmful algal blooms (such as paralytic shellfish toxin) may not produce visible signs of ill-health in wildlife and may not be mitigated by traditional or any other

food preparation techniques (Stimmelmayr and Sheffield, 2022). These pathogens require special attention from the community, veterinarians, wildlife biologists, and public health officials. A systematic assessment of risk based on understanding of both the pathogens and traditional practices can help focus attention where it is needed and reinforce the importance of traditional practices. Further work should also include attention to communication and public health to avoid confusing messages and ensure attention is being given to pathogens and exposures that are priority concerns.

In conclusion, while much work has been done on Arctic wildlife health (Nymo et al., 2011; Elmore et al., 2012; Hueffer et al., 2013; Kutz et al., 2013; Desvars et al., 2015; Kutz and Tomaselli, 2019; Giacinti et al., 2022), less work has been done to document, in detail, traditional food handling and preparation practices in Arctic Alaska, or assess the degree to which those practices reduce the risks from pathogens (Andersen-Ranberg et al., 2024). There is thus a major imbalance in the relative availability of Indigenous and veterinary knowledge, which inhibits mutual understanding and learning. In this paper, we have explored this gap and attempted to show both why and how it might be filled. By calling attention to this topic, our team of Qikiqtaġruŋmiut and visiting researchers hopes to spur further collaborations that can support an effective response to rising concerns about existing and emerging pathogens in Arctic Alaska and beyond, to sustain Iñupiaq and other Indigenous cultural practices and knowledge, and to promote continuation of a vital and healthful way of life.

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REFERENCES

Andersen-Ranberg, E., Nymo, I.H., Jokelainen, P., Emelyanova, A., Jore, S., Laird, B., Davidson, R.K., et al. 2024. Environmental stressors and zoonoses in the Arctic: Learning from the past to prepare for the future. Science of the Total Environment: 176869. https://doi.org/10.1016/j.scitotenv.2024.176869

Atwood, T.C., Duncan, C., Patyk, K.A., Nol, P., Rhyan, J., McCollum, M., McKinney, M.A., et al. 2017. Environmental and behavioral changes may influence the exposure of an Arctic apex predator to pathogens and contaminants. Scientific Reports 7: 13193. https://doi.org/10.1038/s41598-017-13496-9

Barnett, J.E.F., Booth, P., Brewer, J.I., Chanter, J., Cooper, T., Crawshaw, T., Davison, N.J., et al. 2013. Mycobacterium bovis infection in a grey seal pup (*Halichoerus grypus*). Veterinary Record 173(7): 168. https://doi.org/10.1136/vr.101480

Beuchat, L.R., Komitopoulou, E., Beckers, H., Betts, R.P., Bourdichon, F., Fanning, S., Joosten, H.M., and TerKuile, B.H. 2013. Low-water activity foods: Increased concern as vehicles of foodborne pathogens. Journal of Food Protection 76(1):150–172. https://doi.org/10.4315/0362-028X.JFP-12-211

Branch, K. 2015. Sigluaq. Kotzebue, Alaska: Maniilaq Association. https://www.maniilaq.org/sigluaq/

Burek, K.A., Gulland, F.M., and O'Hara, T.M. 2008. Effects of climate change on Arctic marine mammal health. Ecological Applications 18(sp2):S126–S134. https://doi.org/10.1890/06-0553.1

CDC (Centers for Disease Control and Prevention). 2018. Parasites—Toxoplasmosis (*Toxoplasma* infection): Prevention & control. Centers for Disease Control and Prevention. https://www.cdc.gov/parasites/toxoplasmosis/prevent.html

Chiou, L.A., Hennessy, T.W., Horn, A., Carter, G., and Butler, J.C. 2002. Botulism among Alaska natives in the Bristol Bay area of southwest Alaska: a survey of knowledge, attitudes, and practices related to fermented foods known to cause botulism. International Journal of Circumpolar Health 61(1):50–60. https://www.tandfonline.com/doi/abs/10.3402/ijch.v61i0.17405

Davidson, R.K., Handeland, K., and Kapel, C.M.O. 2008. High tolerance to repeated cycles of freezing and thawing in different *Trichinella nativa* isolates. Parasitology Research 103:1005–1010. https://doi.org/10.1007/s00436-008-1079-0

Davidson, R., Simard, M., Kutz, S.J., Kapel, C.M.O., Hamnes, I.S., and Robertson, L.J. 2011. Arctic parasitology: Why should we care? Trends in Parasitology 27(6):239–245. https://doi.org/10.1016/j.pt.2011.02.001

Demientieff, L.X., Rasmus, S., Black, J.C., Presley, J., Jauregui-Dusseau, A., Clyma, K.R., and Jernigan, V.B.B. 2023. Supporting traditional foodways knowledge and practices in Alaska Native communities: The Elders Mentoring Elders Camp. Health Promotion Practice 24(6):1101–1104.
https://doi.org/10.1177/15248399231190365

Desvars, A., Furberg, M., Hjertqvist, M., Vidman, L., Sjöstedt, A., Rydén, P., and Johansson, A. 2015. Epidemiology and ecology of tularemia in Sweden, 1984–2012. Emerging Infectious Diseases 21:32–39.
https://doi.org/10.3201/eid2101.140916

Duncan, C.G., Tiller, R., Mathis, D., Stoddard, R., Kersh, G.J., Dickerson, B., and Gelatt, T. 2014. *Brucella placentitis* and seroprevalence in northern fur seals (*Callorhinus ursinus*) of the Pribilof Islands, Alaska. Journal of Veterinary Diagnostic Investigation 26(4):507–512.
https://doi.org/10.1177/1040638714532647

Dupouy-Camet, J., Bourée, P., and Yera, H. 2017. *Trichinella* and polar bears: A limited risk for humans. Journal of Helminthology 91(4):440–446.
https://doi.org/10.1017/S0022149X17000219

Elmore, S.A., Jenkins, E.J., Huyvaert, K.P., Polley, L., Root, J.J., and Moore, C.G. 2012. *Toxoplasma gondii* in circumpolar people and wildlife. Vector-Borne and Zoonotic Diseases 12(1):1–9.
https://doi.org/10.1089/vbz.2011.0705

Elsmo, E.J., Wünschmann, A., Beckmen, K.B., Broughton-Neiswanger, L.B., Buckles, E.L., Ellis, J., Fitzgerald, S.D., et al. 2023. Highly pathogenic avian influenza A (H5N1) virus clade 2.3.4.b: Infections in wild terrestrial mammals, United States in 2022. Emerging Infectious Diseases 29(12):2451–2460.
https://doi.org/10.3201/eid2912.230464

Food Safety Network. 2009. Safe preparation and storage of Aboriginal traditional/country foods: A review.
https://ncceh.ca/sites/default/files/Aboriginal_Foods_Mar_2009.pdf

Forbes, L.B., Measures, L., Gajadhar, A., and Kapel, C. 2003. Infectivity of *Trichinella nativa* in traditional northern (country) foods prepared with meat from experimentally infected seals. Journal of Food Protection 66(10):1857–1863.
https://doi.org/10.4315/0362-028x-66.10.1857

Forbes, L.B., Measures, L., and Gajadhar, A. 2009. Infectivity of *Toxoplasma gondii* in northern traditional (country) foods prepared with meat from experimentally infected seals. Journal of Food Protection 72(8):1756–1760.
https://doi.org/10.4315/0362-028x-72.8.1756

Forde, T., Orsel, K., De Buck, J., Côté, S.D., Cuyler, C., Davison, T., Elkin, B., et al. 2012. Detection of Mycobacterium avium subspecies paratuberculosis in several herds of Arctic Caribou (*Rangifer tarandus* spp.). Journal of Wildlife Diseases 48(4):918–924.
https://doi.org/10.7589/2011-09-261

Foster, G., Nymo, I.H., Kovacs, K.M., Beckmen, K.B., Brownlow, A.C., Baily, J.L., Dagleish, M.P., et al. 2018. First isolation of *Brucella pinnipedialis* and detection of *Brucella* antibodies from bearded seals *Erignathus barbatus*. Diseases of Aquatic Organisms 128(1):13–20.
https://doi.org/10.3354/dao03211

Gajadhar, A.A., Pozio, E., Gamble, H.R., Nöckler, K., Maddox-Hyttel, C., Forbes, L.B., Vallee, I., Rossi, P., Marinculić, A., and Boireau, P. 2009. *Trichinella* diagnostics and control: Mandatory and best practices for ensuring food safety. Veterinary Parasitology 159:197–205.
https://doi.org/10.1016/j.vetpar.2008.10.063

Georgette, S., and Loon, H. 1993. Subsistence use of fish and wildlife in Kotzebue, a northwest Alaska regional center. Technical Paper No. 167. Juneau: Alaska Department of Fish and Game, Division of Subsistence.
https://www.adfg.alaska.gov/techpap/tp167.pdf

Giacinti, J.A., Parmley, E.J., Reist, M., Bayley, D., Pearl, D.L., and Jardine, C.M. 2022. Canadian wildlife health surveillance—Patterns, challenges and opportunities identified by a scoping review. Facets 7(1):25–44.
https://doi.org/10.1139/facets-2021-0027

Graziosi, G., Lupini, C., Catelli, E., and Carnaccini, S. 2024. Highly pathogenic avian influenza (HPAI) H5 clade 2.3. 4.4 b virus infection in birds and mammals. Animals 14(9): 1372.
https://doi.org/10.3390/ani14091372

Guzmán-Verri, C., González-Barrientos, R., Hernández-Mora, G., Morales, J.-A., Baquero-Calvo, E., Chaves-Olarte, E., and Moreno, E. 2012. *Brucella ceti* and brucellosis in cetaceans. Frontiers in Cellular and Infection Microbiology 2: 3.
https://doi.org/10.3389/fcimb.2012.00003

Hill, D., and Dubey, J.P. 2002. *Toxoplasma gondii*: Transmission, diagnosis and prevention. Clinical Microbiology and Infection 8(10):634–640.
https://doi.org/10.1046/j.1469-0691.2002.00485.x

Hollmén, T.E., and Franson, J.C. 2015. Infectious diseases, parasites, and biological toxins in sea ducks. In: Savard, J.-P.L., Derksen, D., Esler, D., and Eadie, J.M., eds. Ecology and conservation of North American sea ducks. Studies in Avian Biology 46. Boca Raton, Florida: CRC Press. 97–129.

Hueffer, K., Parkinson, A.J., Gerlach, R., and Berner, J. 2013. Zoonotic infections in Alaska: Disease prevalence, potential impact of climate change and recommended actions for earlier disease detection, research, prevention and control. International Journal of Circumpolar Health 72(1).
https://doi.org/10.3402/ijch.v72i0.19562

Huntington, H.P. 1998. Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge. Arctic 51(3):237–242.
https://doi.org/10.14430/arctic1065

Huntington, H.P., Raymond-Yakoubian, J., Noongwook, G., Naylor, N., Harris, C., Harcharek, Q., and Adams. B. 2021. "We never get stuck": A collaborative analysis of change and coastal community subsistence practices in the northern Bering and Chukchi Seas, Alaska. Arctic 74(2):113–126.
https://doi.org/10.14430/arctic72446

ICC-Alaska. 2015. Alaskan Inuit food security conceptual framework: How to assess the Arctic from an Inuit perspective. Technical Report. Anchorage: Inuit Circumpolar Council-Alaska.
https://iccalaska.org/wp-icc/wp-content/uploads/2016/05/Food-Security-Full-Technical-Report.pdf

Jenkins, E.J., Castrodale, L.J., de Rosemond, S.J., Dixon, B.R., Elmore, S.A., Gesy, K.M., Hoberg, E.P., et al. 2013. Tradition and transition: Parasitic zoonoses of people and animals in Alaska, northern Canada, and Greenland. Advances in Parasitology 82:33–204.
https://doi.org/10.1016/b978-0-12-407706-5.00002-2

Keatts, L.O., Robards, M., Olson, S.H., Hueffer, K., Insley, S.J., Joly, D.O., Kutz, S., et al. 2021. Implications of zoonoses from hunting and use of wildlife in North American Arctic and boreal biomes: Pandemic potential, monitoring, and mitigation. Frontiers in Public Health 9: 627654.
https://doi.org/10.3389/fpubh.2021.627654

Kutz, S., and Tomaselli, M. 2019. "Two-eyed seeing" supports wildlife health. Science 364(6446):1135–1137.
https://doi.org/10.1126/science.aau6170

Kutz, S.J., Ducrocq, J., Verocai, G.G., Hoar, B.M., Colwell, D.D., Beckmen, K.B., Polley, L., Elkin, B.T., and Hoberg, E.P. 2012. Parasites in ungulates of Arctic North America and Greenland: A view of contemporary diversity, ecology, and impact in a world under change. Advances in Parasitology 79:99–252.
https://doi.org/10.1016/b978-0-12-398457-9.00002-0

Kutz, S., Ducrocq, J., Cuyler, C., Elkin, B., Gunn, A., Kolpashikov, L., Russell, D., and White, R.G. 2013. Standardized monitoring of *Rangifer* health during International Polar Year. Rangifer 33(2):91–114.
https://doi.org/10.7557/2.33.2.2532

Kutz, S., Bollinger, T., Branigan, M., Checkley, S., Davison, T., Dumond, M., Elkin, B., et al. 2015. *Erysipelothrix rhusiopathiae* associated with recent widespread muskox mortalities in the Canadian Arctic. Canadian Veterinary Journal 56(6):560–563.
https://pmc.ncbi.nlm.nih.gov/articles/PMC4431149/

Laaksonen, S., Pusenius, J., Kumpula, J., Venalainen, A., Kortet, R., Oksanen, A., and Hoberg, E. 2010. Climate change promotes the emergence of serious disease outbreaks of filarioid nematodes. EcoHealth 7:7–13.
https://doi.org/10.1007/s10393-010-0308-z

Leclair, D., Forbes, L.B., Suppa, S., Proulx, J.F., and Gajadhar, A. 2004. A preliminary investigation on the infectivity of *Trichinella* larvae in traditional preparations of walrus meat. Parasitology Research 93(6):507–509.
https://pubmed.ncbi.nlm.nih.gov/15278445/

Leclair, D., Fung, J., Isaac-Renton, J.L., Proulx, J.-F., May-Hadford, J., Ellis, A., Ashton, E., et al. 2013. Foodborne botulism in Canada, 1985–2005. Emerging Infectious Diseases 19(6): 961.
https://doi.org/10.3201/eid1906.120873

Martinez-Levasseur, L.M., Simard, M., Furgal, C.M., Burness, G., Bertrand, P., Suppa, S., Avard, E., and Lemire, M. 2020. Towards a better understanding of the benefits and risks of country food consumption using the case of walruses in Nunavik (Northern Quebec, Canada). Science of the Total Environment 719: 137307.
https://doi.org/10.1016/j.scitotenv.2020.137307

Mavrot, F., Aleuy, O.A., Forde, T., and Kutz, S.J. 2022. Erysipelas in Arctic and northern regions. In: Tryland, M., ed. Arctic one health: Challenges for northern animals and people. Springer International Publishing. 363–375.
https://doi.org/10.1007/978-3-030-87853-5_16

McLaughlin, J.B., Sobel, J., Lynn, T., Funk, E., and Middaugh, J.P. 2004. Botulism type E outbreak associated with eating a beached whale, Alaska. Emerging Infectious Diseases 10(9): 1685.
https://doi.org/10.3201/eid1009.040131

Mikow, E.H., and Kostick, M.L. 2016. Subsistence wildlife harvests in Kotzebue, Alaska, 2013–2014. Special Publication No. 2016-02. Fairbanks: Alaska Department of Fish and Game, Division of Subsistence.
https://www.adfg.alaska.gov/download/Special%20Publications/SP2_SP2016-002.pdf

Morya, S., Amoah, A.E.D.D., and Snaebjornsson, S.O. 2020. Food poisoning hazards and their consequences over food safety. In: Chowdhary, P., Raj, A., Verma, D., and Akhter, Y., eds. Microorganisms for sustainable environment and health. 383–400. https://doi.org/10.1016/B978-0-12-819001-2.00019-X

Noongwook, G. The Native Village of Savoonga, The Native Village of Gambell, Huntington, H.P., and George, J.C. 2007. Traditional knowledge of the bowhead whale (*Balaena mysticetus*) around St. Lawrence Island, Alaska. Arctic 60(1):47–54. https://doi.org/10.14430/arctic264

Nymo, I.H., Tryland, M., and Godfroid, J. 2011. A review of *Brucella* infection in marine mammals, with special emphasis on *Brucella pinnipedialis* in the hooded seal (*Cystophora cristata*). Veterinary Research 42: 93. https://doi.org/10.1186/1297-9716-42-93

Nymo, I.H., Rødven, R., Beckmen, K., Larsen, A.K., Tryland, M., Quakenbush, L., and Godfroid, J. 2018. *Brucella* antibodies in Alaskan true seals and eared seals—Two different stories. Frontiers in Veterinary Science 5: 8. https://doi.org/10.3389/fvets.2018.00008

Ostertag, S.K., Loseto, L.L., Snow, K., Lam, J., Hynes, K., and Gillman, D.V. 2018. "That's how we know they're healthy": The inclusion of traditional ecological knowledge in beluga health monitoring in the Inuvialuit Settlement Region. Arctic Science 4(3):292–320. https://doi.org/10.1139/as-2017-0050

Parkinson, A.J., Evengard, B., Semenza, J.C., Ogden, N., Børresen, M.L., Berner, J., Brubaker, M., et al. 2014. Climate change and infectious diseases in the Arctic: Establishment of a circumpolar working group. International Journal of Circumpolar Health 73(1): 25163. https://doi.org/10.3402/ijch.v73.25163

Peacock, S.J., Mavrot, F., Tomaselli, M., Hanke, A., Fenton, H., Nathoo, R., Aleuy, O.A., et al. 2020. Linking co-monitoring to co-management: Bringing together local, traditional, and scientific knowledge in a wildlife status assessment framework. Arctic Science 6(3):247–266. https://cdnsciencepub.com/doi/full/10.1139/as-2019-0019

Pijnacker, R., Goris, M.G., te Wierik, M.J., Broens, E.M., van der Giessen, J.W., de Rosa, M., Wagenaar, J.A., et al. 2016. Marked increase in leptospirosis infections in humans and dogs in the Netherlands, 2014. Eurosurveillance 21(17): 30211. https://doi.org/10.2807/1560-7917.es.2016.21.17.30211

Prestrud, P., Stuve, G., and Holt, G. 1993. The prevalence of *Trichinella* sp. in Arctic foxes (*Alopex lagopus*) in Svalbard. Journal of Wildlife Disease 29(2):337–340. https://doi.org/10.7589/0090-3558-29.2.337

Rah, H., Chomel, B.B., Kasten, R.W., Hew, C.H., Farver, T.B., Follmann, E.H., Garner, G.W., and Amstrup, S.C. 2005. Serosurvey of selected zoonotic agents in polar bears (*Ursus maritimus*). Veterinary Record: Journal of the British Veterinary Association 156(1):7–13. https://doi.org/10.1136/vr.156.1.7

Reiling, S., and Dixon, B. 2019. *Toxoplasma gondii*: How an Amazonian parasite became an Inuit health issue. Canada Communicable Disease Report 45(7-8):183–190. https://pmc.ncbi.nlm.nih.gov/articles/PMC6615440/

Rodahl, K., and Moore, T. 1943. The vitamin A content and toxicity of bear and seal liver. The Biochemical Journal 37(2):166–168. https://doi.org/10.1042/bj0370166

Rode, K.D., Van Hemert, C., Wilson, R.R., Woodruff, S.P., Pabilonia, K., Ballweber, L., Kwok, O., and Dubey, J.P. 2024. Increased pathogen exposure of a marine apex predator over three decades. PLoS ONE 19(10): e0310973. https://doi.org/10.1371/journal.pone.0310973

Sanderson, C.E., and Alexander, K.A. 2020. Unchartered waters: Climate change likely to intensify infectious disease outbreaks causing mass mortality events in marine mammals. Global Change Biology 26(8):4284–4301. https://doi.org/10.1111/gcb.15163

Senoo, H., Imai, K., Mezaki, Y., Miura, M., Morii, M., Fujiwara, M., and Blomhoff, R. 2012. Accumulation of vitamin A in the hepatic stellate cell of Arctic top predators. The Anatomical Record 295(10):1660–1668. https://doi.org/10.1002/ar.22555

Shaffer, N., Wainwright, R.B., Middaugh, J.B., and Tauxe, R.V. 1990. Botulism among Alaska Natives: The role of changing food preparation and consumption practices. Western Journal of Medicine 153(4):390–393. https://pubmed.ncbi.nlm.nih.gov/2244373/

Slenning, B. 2010. Global climate change and implications for disease emergence. Veterinary Pathology Online 47(1):28–33. https://doi.org/10.1177/0300985809354465

Spray, Z. 2002. Alaska's vanishing Arctic cuisine. Gastronomica 2(1):30–40. https://doi.org/10.1525/gfc.2002.2.1.30

Stimmelmayr, R., and Sheffield, G. 2022. Traditional conservation methods and food habits in the Arctic. In: Tryland, M., ed. Arctic one health: Challenges for northern animals and people. New York: Springer Nature. 469–504. https://doi.org/10.1007/978-3-030-87853-5

Stimmelmayr, R., Rotstein, D., Torchetti, M.K., and Gerlach, R. 2024. Highly pathogenic avian influenza virus A (H5N1) clade 2.3.4.4b infection in free-ranging polar bear, Alaska, USA. Emerging Infectious Diseases 30(8):1660–1663. https://doi.org/10.3201/eid3008.240481

Thompson, L.A., Goertz, C.E., Quakenbush, L.T., Burek Huntington, K., Suydam, R.S., Stimmelmayr, R., and Romano, T.A. 2022. Serological detection of marine origin *Brucella* exposure in two Alaska beluga stocks. Animals 12(15): 1932. https://doi.org/10.3390/ani12151932

Tomaselli, M., Gerlach, C., Kutz, S., Checkley, S., and the community of Iqaluktutiaq. 2018. Iqaluktutiaq voices: Local perspectives about the importance of muskoxen, contemporary and traditional use and practices. Arctic 71(1):1–14. https://journalhosting.ucalgary.ca/index.php/arctic/article/view/67735/51631

Tomaselli, M., Elkin, B., Kutz, S., Harms, N.J., Nymo, H.I., Davison, T., Lelerc, L.-M., Branigan, M., Dumond, M., and Tryland, M. 2019. A transdisciplinary approach to *Brucella* in muskoxen of the western Canadian Arctic 1989–2016. EcoHealth 16(3):488–501. https://doi.org/10.1007/s10393-019-01433-3

Tryland, M. 2000. Zoonoses of Arctic marine mammals. Infectious Disease Review 2(2):55–64.

Tryland, M., Nesbakken, T., Robertson, L., Grahek-Ogden, D., and Lunestad, B. 2014. Human pathogens in marine mammal meat—A northern perspective. Zoonoses and Public Health 61(6):377–394. https://doi.org/10.1111/zph.12080

Tryland M., Ravolainen, V., and Øhnvik Pedersen, Å. 2018. Climate change—Potential impacts on pasture resources, health and diseases of reindeer and caribou. In: Tryland, M., and Kutz, S., eds. Reindeer and caribou: Health and disease, 1st ed. Boca Raton, Florida: CRC Press. https://doi.org/10.1201/9780429489617

Tschritter, C.M., van Coeverden de Groot, P., Branigan, M., Dyck, M., Sun, Z., Jenkins, E., Buhler, K., and Lougheed, S.C. 2024. The geographic distribution, and the biotic and abiotic predictors of select zoonotic pathogen detections in Canadian polar bears. Scientific Reports 14: 12027. https://doi.org/10.1038/s41598-024-62800-x

United Nations. 2007. United Nations Declaration on the Rights of Indigenous Peoples. https://www.un.org/development/desa/Indigenouspeoples/wp-content/uploads/sites/19/2018/11/UNDRIP_E_web.pdf

Waltzek, T.B., Cortés-Hinojosa, G., Wellehan J.F.X., Jr., and Gray, G.C. 2012. Marine mammal zoonoses: A review of disease manifestations. Zoonoses and Public Health 59(8):521–535. https://doi.org/10.1111/j.1863-2378.2012.01492.x

Waugh, D., Pearce, T., Ostertag, S.K., Pokiak, V., Collings, P., and Loseto, L.L. 2018. Inuvialuit traditional ecological knowledge of beluga whale (*Delphinapterus leucas*) under changing climatic conditions in Tuktoyaktuk, NT. Arctic Science 4(3):242–258. https://doi.org/10.1139/as-2017-0034

Westley, B.P., Horazdovsky, R.D., Michaels, D.L., and Brown, D.R. 2016. Identification of a novel *Mycoplasma* species in a patient with septic arthritis of the hip and seal finger. Clinical Infectious Diseases 62(4):491–493. https://doi.org/10.1093/cid/civ875

Whatmore, A.M., Dawson, C., Muchowski, J., Perrett, L.L., Stubberfield, E., Koylass, M., Foster, G., et al. 2017. Characterisation of North American *Brucella* isolates from marine mammals. PLoS One 12(9): e0184758. https://doi.org/10.1371/journal.pone.0184758

Whiting, A. 2006. Native Village of Kotzebue Harvest Survey Program 2002–2003–2004: Results of three consecutive years cooperating with Qikiqtagrugmiut to understand their annual catch of selected fish and wildlife. Kotzebue: Native Village of Kotzebue. https://www.kotzebueira.org/wp-content/uploads/Kotzebue-IRA-Harvest-Report-2006-03-24.pdf

Yoder, S. 2018. Assessment of the potential health impacts of climate change in Alaska. State of Alaska Epidemiology Bulletin 20(1). https://epi.alaska.gov/bulletins/docs/rr2018_01.pdf

Ytrehus, B., Bretten, T., Bergsjø, B., and Isaksen, K. 2008. Fatal pneumonia epizootic in musk ox (*Ovibos moschatus*) in a period of extraordinary weather conditions. EcoHealth 5:213–223. https://doi.org/10.1007/s10393-008-0166-0