THE DISTRIBUTION AND ABUNDANCE OF PARASITES IN HARVESTED WILDLIFE FROM THE CANADIAN NORTH:

A review

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Abstract

Parasites are key components of Arctic ecosystems. The current rate of climate and landscape changes in the Arctic is expected to alter host-parasite interactions, creating a significant concern for the sustainability of Arctic vertebrates. In addition to direct effects on host populations, changes in parasite loads on wildlife can have significant impacts on the people who depend on these organisms for food. Parasites play important roles in maintaining ecosystem stability through the regulation of host populations, and can provide unique insights into ecosystem structure. The present review examines the literature on the parasites of harvested wildlife in the Canadian North, including studies in the Yukon, Northwest Territories, Nunavut, northern Quebec, and Newfoundland and Labrador. For host species with higher mobility, we included records from other regions, such as Greenland, Russia, and the Canadian Subarctic, when no parasitological studies were available for the Canadian North. In addition, we searched databases of the Parasite Collection at the Canadian Museum of Nature and the United States Parasite Collection for records from the Canadian North. We found records for 248 species of macroparasites in vertebrate species of country food of animal origin in the Canadian North, including flatworms, roundworms, thorny-headed worms, ticks, lice, fleas, flies, and tongue worms. This review highlights the need to extend the study of the parasites that infect the primary species of harvested wildlife in the Canadian North. More detailed information on parasite communities is particularly important as climate and landscape change raises the possibility that new parasite species will colonize the region. Building a DNA barcode library for the parasites from country food in the area will facilitate their identification and monitoring.

Résumé

Les parasites sont des éléments clés des écosystèmes arctiques. Le rythme actuel des changements climatiques et des changements dans le paysage dans l'Arctique devrait modifier les interactions hôte-parasite, ce qui crée une préoccupation importante pour la viabilité des vertébrés arctiques. En plus des effets directs sur les populations hôtes, les changements dans les charges parasitaires sur la faune peuvent avoir des répercussions importantes sur les personnes qui dépendent de ces organismes pour se nourrir. Les parasites jouent un rôle important dans le maintien de la stabilité de l'écosystème grâce à la régulation des populations hôtes et peuvent fournir des informations uniques sur la structure de l'écosystème. Le présent examen porte sur la documentation sur les parasites de la faune récoltée dans le Nord canadien, y compris des études réalisées au Yukon, dans les Territoires du Nord-Ouest, au Nunavut, dans le Nord du Québec et à Terre-Neuve-et-Labrador. Pour les espèces hôtes à plus grande mobilité, nous avons inclus des données provenant d'autres régions, comme le Groenland, la Russie et la région subarctique canadienne, alors qu'aucune étude parasitologique n'était disponible pour le Nord canadien. De plus, nous avons fait des recherches dans les bases de données de la collection de parasites du Musée canadien de la nature et de la collection de parasites des États-Unis pour y trouver des données sur le Nord canadien. Nous avons trouvé des données sur 248 espèces de macroparasites chez des espèces de vertébrés servant d'aliments traditionnels dans le Nord canadien, y compris des vers plats, des vers ronds, des acanthocéphales, des tiques, des poux, des puces, des mouches et des linguatules. Cet examen met en évidence la nécessité d'étendre l'étude des parasites qui infectent les principales espèces sauvages récoltées dans le Nord canadien. Des informations plus détaillées sur les communautés de parasites sont particulièrement importantes, car le changement climatique et le changement du paysage évoquent la possibilité que de nouvelles espèces de parasites colonisent la région. La construction d'une bibliothèque de codes à barres de l'ADN pour les parasites provenant d'aliments traditionnels dans la région facilitera leur identification et leur surveillance.

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Introduction

Parasites are an important component of Arctic ecosystems, influencing the health and sustainability of wildlife populations and the people who depend on them (Hoberg et al. 2003; Davidson et al. 2011). Beginning in the 1940s, a succession of parasitologists and ecologists have explored parasitism in the Arctic, advancing understanding of the structure and function of host-parasite systems in this setting. In recent years, the recognition of rapid climate change in the North has stimulated increased effort (Kutz et al. 2012).

The current rate of climate and landscape change in the Arctic is expected to alter host-parasite interactions, creating a significant concern for the sustainability of Arctic vertebrates (Hoberg et al. 2008; Kutz et al. 2009; Polley et al. 2010). In addition to direct effects on host populations, changes in the parasite loads carried by wildlife can significantly impact the people who depend on these organisms for food. Parasites can affect the quality, quantity, and safety of meat or other animal products consumed by humans, and changes in parasite biodiversity and the associated disease processes can influence the levels and sustainability of host populations (Davidson et al. 2011).

Although often portrayed negatively, parasites play an important role in maintaining ecosystem stability through the regulation of host populations, and provide unique insights into the historical and current status of ecosystems. Parasites can, for example, provide information on the presence of direct or indirect interactions among species present in the ecosystem as well as information about the host habits (Hoberg 2010). Healthy ecosystems typically have a high diversity of parasites, reflecting the number of definitive (ultimate) and intermediate host species and vectors. As a result, the detection of a "normal" complement of parasites can be indicative of a healthy ecosystem. Conversely, the detection of "new" (invasive) parasites or very few parasite species can suggest otherwise (Hudson et al. 2006).

To use parasites as indicators of environmental health and to track or predict changes in parasitism and animal health, comprehensive data on parasite diversity, distributions, and life cycles are essential (Hoberg et al. 2003; Hoberg and Brooks 2008; Hoberg et al. 2008). Although considerable progress has been made in defining the diversity and ecology of parasites found in/on Arctic vertebrates (Rausch 1974; Hoberg et al. 2012a), there remain substantial knowledge gaps.

Methodology

The present review considers all available literature on the parasites of country food of animal origin in the Canadian North, defined as the land- and ocean-based territory of Canada that lies north of the southern limit of discontinuous permafrost, from northern British Columbia in the west to northern Labrador in the east (IPY, 2007–2008). We consulted three academic databases, Web of Science, JSTOR, and Google Scholar, with the search words parasite + arctic + Canada; further searches were conducted with the scientific and common names of the hosts + parasite. Studies out of the defined geographic range or without parasite identification to family or lower level were excluded. We also revised the cited literature of the publications found in the searches. For host species with high mobility, we included records from other regions, such as Alaska, Greenland, Iceland, Russia, and the Canadian Subarctic, when no parasitological studies have been conducted in the Canadian North. In addition, the databases of the Canadian Museum of Nature Parasite Collection and the United States Parasite Collection were searched for records of the host species in the Yukon, Northwest Territories, Nunavut, northern Quebec, and Newfoundland and Labrador; only records within the Canadian North were considered.

We considered vertebrate species regularly hunted for food in the Canadian North (Table 1). We also considered the wolf (*Canis lupus*) and wolverine (*Gulo gulo*), although rarely consumed, because they are reservoirs of parasites that transmit to humans and are frequently hunted for their fur. For parasite nomenclature, we followed the Encyclopedia of Life (http://eol.org) and specialized literature for each taxon.

Results

We found records for 248 species of macroparasites in vertebrate species of harvested wildlife in the Canadian North (Appendix 1, https://www.polardata.ca/pdcsearch/?doi_id=12962). Of these, 185 species were recorded within the Canadian North, and 63 were recorded outside this region; the 63 recorded outside this region were parasitizing species (mainly birds) that are also distributed in the Canadian North but have not been studied for parasites. The record includes platyhelminths (flatworms of the classes Monogenea, Digenea, and Cestoda); nematodes (roundworms); acanthocephalans (thorny-headed worms); acari (ticks); insects (lice, fleas, and flies); and pentastomids (tongue worms). The most diverse groups are roundworms and tapeworms (Cestoda), with 80 and 78 species respectively. Birds are the group of vertebrates with the largest number of recorded parasite species, with 115; although many of these taxa were extraterritorial, they are also likely to occur in the Canadian North because of the high mobility of their hosts. Mammal and fish parasite records comprise 88 and 59 species respectively. It is interesting that no parasites have been documented for the Arctic hare, *Lepus arcticus* (Table 1). Among the 248 species of parasites, only 133 are represented by voucher specimens in existing collections. Importantly, no vouchers are available for parasites of polar bears or walruses from the Canadian North. Conversely, there are numerous records in these collections for species that have not been reported in the literature (Appendix 2, https://www.polardata.ca/pdcsearch/?doi_id=12962).

Table 1: Number of macroparasite species known from species of harvested wildlife in the Canadian North.

Host species	# of parasite species						
	P	N	A	C	Ac	I	TOTAL
Fish							
Salvelinus alpinus (Arctic char)	21	8	4	2			35
Salvelinus namaycush (Lake trout)	9	2		1			12
Coregonus clupeaformis (Whitefish)	8	2		2			12
Boreogadus saida (Polar cod)	11	4	2	1			18
Arctogadus glacialis (Arctic cod)	2 (2)	2 (2)	1 (1)				5 (5)
Birds							
Cepphus grylle (Black guillemot)	2 (1)					3	5 (1)
Uria aalge (Common murre)	11	6			2	4 (1)	23 (1)
Anas acuta (Northern pintail)	7 (6)	2 (2)					9 (8)
Anser albifrons (Greater white-fronted goose)	2 (2)						2 (2)
Anser caerulescens (Snow goose)	5 (1)	5				1	11 (1)
Anser rossii (Ross's goose)					1 (1)		1 (1)
Branta canadensis (Canada goose)	6 (5)	5 (4)			1 (1)	2	14 (10)
Branta bernicla (Brant goose)	2 (2)	1 (1)				1	4 (3)
Clangula hyemalis (Long-tailed duck)						1	1
Cygnus colombianus (Tundra swan)	2 (2)	1 (1)			1 (1)	4 (2)	8 (6)
Histrionicus histrionicus (Harlequin duck)	3 (3)						3 (3)
Somateria spectabilis (King eider)	6 (6)	1 (1)	1			1	9 (7)
Gavia pacifica (Pacific loon)	4 (4)						4 (4)
Gavia stellata (Red-throated loon)	4 (4)	1					5 (4)
Gavia adamsi (Yellow-billed loon)	2 (2)						2 (2)
Lagopus lagopus (Willow ptarmigan)	7 (6)	6 (5)			5 (5)	7 (5)	25 (21)
Lagopus muta (Rock ptarmigan)	6 (6)	3 (3)				2	11 (9)
Mammals							
Rangifer tarandus (Caribou)	7	15			3	2	27
Ovibos moschatus wardi (Muskox)	5	12					17
Vulpes lagopus (Arctic fox)	4	4					8
Canis lupus (Wolf)	12	5					17
Gulo gulo (Wolverine)		1					1
Ursus arctos horribilis (Grizzly bear)	2	5					7
Ursus maritimus (Polar bear)	2	3					5
Cystophora cristata (Hooded seal)		3					3
Erignathus barbatus (Bearded seal)		3				1	4
Pagophilus groenlandicus (Harp seal)	1	7					8
Phoca vitulina (Harbour seal)	1 (1)	8 (2)	1 (1)			1 (1)	11 (5)
Pusa hispida (Ringed seal)	5	9	3			1	18
Odobenus rosmarus (Walrus)		2					2
Delphinapterus leucas (Beluga whale)	2	5					7
Monodon monoceros (Narwhal)		1					1

Fishes

The Arctic char (*Salvelinus alpinus*) is the fish species with the largest number (35) of known parasite species (Table 1). Reflecting its anadromous nature, these parasites include some species acquired in the marine environment and others in fresh water. However, its high diversity of parasites also reflects the fact that the Arctic char is, by far, the most intensively studied fish species in the Arctic. Other Arctic fish species are known to host from 5 to 18 parasite species.

Several of these species are of zoonotic importance. Larvae of roundworms in the genus *Contracaecum* and other related genera live in mesenteries and body cavity of fish. However, once a fish is dead, they rapidly migrate into the muscle, reducing the quality of the meat, and some species represent a potential source of infection for humans if they ingest raw, smoked, or undercooked fish (McCarthy and Moore 2000). Although in most cases the infection is asymptomatic, patients may experience nausea, vomiting, diarrhea, abdominal pain, and hypersensitivity reactions (Jenkins et al. 2013). In the same way, larval tapeworms of the genus *Diphyllobothrium* live in the muscle or viscera of fish and are transmitted to their definitive host when ingested. In the wild, the definitive hosts are polar bears, marine mammals, and other carnivores, but humans can be infected by zoonotic diphyllobothriid tapeworms if they eat raw or undercooked fish (Desdevises et al.

1998). Diphyllobothrosis is rarely associated with clinical disease and is not considered a major public health problem in Canada (Jenkins et al. 2013). High infection levels with *Diphyllobothrium* species can also inhibit gonadal development in fish, reducing their reproductive potential (Gallagher et al. 2009).

Monogenean and copepod parasites on fish gills can cause delays in growth and sexual maturation as well as hypoxia in heavy infections (Gallagher, et al. 2009; Winger et al. 2008). Although no epizootic events caused by *Tetraonchus* spp. or *Salmincola* spp. have been reported in the Canadian North, these species are present in this area, and it is important to be aware of their potential effects on fish populations.

Birds

A total of 99 species have been documented in Arctic birds, although 55 of these records are extraterritorial (Appendix 1, https://www.polardata.ca/pdcsearch/?doi_id=12962). The list is dominated by tapeworms and roundworms of the digestive tract, and no parasites of zoonotic importance have been reported. Mortality events in geese have been documented in other regions, in which heavy infections with roundworms of the upper digestive tract (*Echinuria uncinata*) in Poland (Cornwell 1963), heartworms (*Sarconema eurycea*) in the United States (Holden and Sladen 1968), or schistosomes (*Anserobilharzia brantae*) in southern Ontario (Wojcinski et al. 1987) were reported, and might have contributed to mortality. A negative correlation between parasite community burden and host fitness parameters has contributed to cyclic declines in willow ptarmigan (*Lagopus lagopus*) populations in Norway (Holmstad et al. 2005). The flea *Ceratophyllus vagabundus* had a negative impact on reproductive success in geese colonies in Nunavut (Harriman and Alisauskas 2010), and may be a vector for bacterial diseases for Arctic wildlife (Mascarelli et al. 2015). The parasite fauna on guillemots and murres has been intensively studied in the Arctic and used as a model for host-parasite coevolution (Hoberg 1986) and as markers of ecological change (Muzaffar et al. 2005). Considering the migratory behaviour of ducks and geese, it is important to monitor their parasite fauna, as they might introduce emerging pathogens (Amundson et al. 2016).

Mammals

The caribou, *Rangifer tarandus*, and muskoxen, *Ovibos moschatus*, both harbour diverse parasite assemblages, 27 and 17 species respectively. These parasites include various taxonomic groups, including digeneans, tapeworms, roundworms, flies, and mites, although the roundworms are most diverse. Nematodes of the subfamily Trichostrongylinae (*Ostertagia*, *Marshallagia*, and *Teladorsagia*) are common parasites of the abomasum (the fourth stomach compartment in ruminants), where they can cause serious effects on nutrition when present in high numbers. However, these two ungulate species are most seriously impacted by internal parasites, such as the lungworms (*Dictyocaulus*, *Varestrongylus*, *Protostrongylu*s, and *Umingmakstrongylus*) or the muscle-dwelling worms (*Parelaphostrongylus*). Infection with these parasites can affect respiratory function and interfere with neurological or muscular function, increasing susceptibility to predation (Kutz et al. 2012).

Caribou and muskoxen are natural intermediate hosts for the tapeworms *Echinococcus canadensis*, *Taenia hydatigena*, and *T. krabbei*, which complete their life cycle in canids (dogs, foxes, and wolves) and release their eggs with the feces of the definitive host. *Taenia hydatigena* and *T. krabbei* have not been reported as a cause of zoonoses (various diseases that can be transmitted from animals to humans); in contrast, *Echinoccocus canadensis* is the cause of a recurrent zoonosis in the Arctic. People, like caribou and muskoxen, get infected when eggs of this tapeworm are accidentally ingested (Jenkins et al. 2013).

Crustaceans of the subclass Pentastomida are parasites of the nasal cavity of vertebrates. *Linguatula arctica* is a common parasite of the nasal cavity of caribou in particular; this species has a direct life cycle, but the eggs are expelled with mucus and ingested by other ungulates when grazing. There has been no report of serious effects on infected animals (Kutz et al. 2012).

Parasitic flies commonly attack caribou; larvae of *Hypoderma tarandi* (warbles) and *Cephenemyia trompe* (nose bots) can cause damage by burrowing into the skin or growing in the nasal cavity respectively. Harassment by these parasitic dipterans can reduce feeding time and lead to diminished feed intake, reduced summer weight gain, decreased lactation, lower calf weight, and poorer overall condition, which may influence reproductive success. There is an increasing concern about *Hypoderma tarandi* causing a zoonosis, as it can cause migratory dermal swellings and ophthalmomyasis interna (invasion of the eye) in humans, often causing loss of the eye (Lagacé-Wiens et al. 2008; Kan et al. 2013). Mites of the genus *Chorioptes* have been reported to cause epidermal and dermal inflammatory lesions in the outer ear canal of caribou and hair loss on the legs of muskoxen, reducing the overall condition of the animals (Kutz et al. 2012).

Wolves (*Canis lupus*) and Arctic foxes (*Vulpes lagopus*) harbour 17 and 8 species of parasites respectively, with tapeworms and roundworms being most diverse. Digeneans of the genus *Alaria* have been recorded from the boreal ecozone only, as their life cycle involves intermediate hosts (amphibians) that are not yet present in the Arctic. *Echinococcus multilocularis* and *E. canadensis* have particularly important implications for human health. These tapeworms use foxes, wolves, and dogs as their definitive hosts; *E. multilocularis* uses rodents (voles and lemmings) as an intermediate host, while *E. canadensis* uses cervids (moose and caribou) (Jenkins et al. 2013). People get infected when they accidentally ingest eggs that have been shed in carnivore feces, developing cystic echinococcosis (usually in the lungs and liver) or alveolar echinococcosis (usually in the liver), which may be fatal if not detected and treated early (Jenkins et al. 2013; Gesy et al. 2014). Echinococcosis, or hydatid disease, can be asymptomatic for several years until cysts grow enough to trigger clinical signs — abdominal pain and nausea if the liver is the affected organ, or cough, chest pain, and shortness of breath if the lungs are affected (WHO 2018). Feeding dogs with the viscera of infected caribou or moose can facilitate human infection, given the closeness of dogs to humans. Molecular studies have revealed several strains of *E. canadensis* (G8 and G10) and *E. multilocularis* (Asian, European, and North American strains) in North America, which is important because there may be differences in their levels of infectivity and pathogenicity for humans (Thompson et al. 2006; Gesy et al. 2014).

Toxascaris leonina is an intestinal roundworm of canids and felids that has a direct life cycle and is not considered zoonotic; the zoonotic canine ascarid Toxocara canis appears to have low prevalence in the Canadian North (Jenkins et al. 2013). Other important parasite species recorded from foxes, wolves, and wolverines are roundworms of the genus T*richinella*. These roundworms possess a unique life history, as a single vertebrate species serves as both definitive and intermediate host. Adults live in the intestine, where females produce larvae that migrate to the skeletal muscle. Transmission to other species, including humans, can occur when the original host is eaten. The genus *Trichinella* includes nine species and three genotypes (Krivokapich et al. 2012); only T. nativa (T2) and genotype T6 have been reported from northern Canada (Larter et al. 2011). These roundworms have been recorded from many vertebrate species in the Arctic, including carnivores (polar and grizzly bears, Arctic fox, wolf, and dog) and pinnipeds (walrus and ringed seal) (Appendix 1, https://www.polardata.ca/pdcsearch/?doi_id=12962). People get infected through the consumption of raw or undercooked meat from an infected animal, producing trichinellosis, which causes edema, fever, rash, and myalgia. Outbreaks of human trichinellosis remain a public health concern in the Canadian North (Jenkins et al. 2013).

Few parasitological studies have been conducted with bears in the Canadian North, and some of the studies in polar bears are from captive specimens. Seven parasite species have been recorded from grizzly bears and five from polar bears (four of these from captive specimens). The tapeworm Diphyllobothrium ursi completes its life cycle in the intestine of bears after they feed on fish, the intermediate host. Humans can accidentally be infected with this species by consuming raw or undercooked fish (Jenkins et al. 2013). *Trichinella* spp. roundworms (*T. nativa* and genotype T6) are common in both grizzly and polar bears in the Canadian North (Brown et al. 1949; Choquette et al. 1969; Gajadhar and Forbes 2010; Jenkins et al. 2013; Larter et al. 2011; Rah et al. 2005; Smith 1978; Thorshaug and Rosted 1956), and at least one human outbreak has been linked to the consumption of grizzly bear (Houzé et al. 2009).

The ringed seal has considerably more species of parasites (18) than the other seal species, which have from 3 to 11 species (Table 1). Among the parasite species are the heartworms (*Acanthocheilonema spirocauda*) and the lungworms (*Otostrongylus circumlitus* and *Parafilaroides hispidus*), which can cause damage to the lungs in heavy infections, especially to seal pups (Measures and Gosselin 1994; Ondreka 1989). Both tapeworms and roundworms occur in the intestinal tract as *Anisakis* sp., *Contracaecum osculatum* and *Pseudoterranova* *decipiens*. Larvae of these ascarids are transmitted by fish, and humans can become infected by consuming raw or undercooked fish (Jenkins et al. 2013).

Sucking lice (family Echinophthiriidae) are mostly specialized on seals. *Echinophthirius horridus*, in particular, is found on many seal species in the Northern Hemisphere, including the ringed seal. It is most prevalent on young animals because of their higher body temperature and thinner skin. There is evidence that this ectoparasite is the intermediate host for the heartworm *Acanthocheilonema spirocauda*, which often has serious consequences for young seals (Geraci et al. 1981; Leidenberg et al. 2007).

At least 16 species of parasites (tapeworms, roundworms, and acanthocephalans) have been reported from walrus in the Bering Strait (Rausch et al. 2007). However, few studies have been completed in the Canadian North, where only two species of parasites have been recorded, an ascarid, *Pseudoterranova decipiens*, from the stomach and *Trichinella* sp. in muscle. This latter species has caused several outbreaks of trichinellosis in humans after eating walrus meat (Jenkins et al. 2013).

The beluga whale hosts at least seven species of parasites in the Canadian North, five roundworms and two digeneans. No negative effects have been linked to the presence of these parasites, even from heavy infections of the lungworm *Pharurus pallasii* (Houde et al. 2003). The ascarids recorded from beluga whale stomachs (*Anisakis simplex*, *Contracaecum osculatum*, and *Pseudoterranova decipiens*) are caused by the ingestion of fish. Humans can be infected with Anisakis sp. and *Contracaecum* sp. by eating raw or undercooked fish, but there is no evidence of zoonotic infection with *Pseudoterranova*. The only parasite species recorded for the narwhal is the lungworm *Halocercus monoceris*, which caused the death of a specimen collected at Baffin Island after it had been held captive in the Vancouver Aquarium (MacNeill et al. 1975).

Community considerations

This review highlights the need to extend the study of the parasites that infect the primary animal species of country food in the Canadian North. Although some host species (Arctic char and caribou) have been intensively investigated, most have received little attention. For example, there are no records of parasites from the Arctic hare, and information on parasite assemblages for many birds (ducks, geese, and ptarmigan) is only available for other regions. More detailed information on parasite communities is particularly important as climate change raises the possibility that new parasite species will colonize the region. For example, the winter tick (*Dermacentor albipictus*) is an abundant and serious pest of moose (*Alces alces*) in southwestern Canada, causing anemia and hair loss (Samuel 1989). The northernmost distribution of *D. albipictus* was documented just south of 60º N (Wilkinson 1967); in recent years a range expansion to the Arctic, presumably induced by climate warming and/or anthropogenic translocation, has been documented (Kutz et al. 2009). This is of particular interest because caribou and moose are highly susceptible to winter ticks, and in captive conditions, infections can be severe (Welch et al. 1990).

Another example is the lone star tick (*Amblyomma americanum*), which primarily parasitizes deer, but also a wider variety of mammals and a wide variety of birds. This tick may transmit various bacterial infections (Kollars et al. 2000) and causes an allergy to red meat (Commins et al. 2013). This species of tick was formerly restricted to the eastern United States and northern Mexico, but its range is expanding north and west in the US (Scott et al. 2001). It is improbable that this temperate tick species will establish in the Arctic in the near future.

To address the current information gap, it is essential to assemble a comprehensive inventory of the parasite fauna for the most important food species in the North. Studies then need to be expanded to obtain baseline information on the prevalence and abundance of each parasite species on each host species. This information will make it possible to monitor long-term trends in parasite populations, which in turn make it possible to anticipate epizootic or zoonotic outbreaks that could seriously affect their host species and take preventive actions (Brooks et al. 2004). In the past, it was difficult to accurately identify very many parasite species, because the distinguishing morphological characters are not present in all parasite stages, and this requires technical expertise, which is increasingly unavailable. In some cases, accurate identification of a parasite is of high importance because of differential ability to infect and cause disease in humans (e. g., differences among species and strains of the tapeworm genus Echinococcus). Because of such factors, it is essential to employ an identification method that is fast and accurate, a need that is met by DNA barcoding (Hebert et al. 2003). Once the reference barcode for a species is established, identifications can be made by simply comparing DNA sequences from newly collected material with the references, in most cases. There are some cases where intraspecific variation or lack of variation in the particular fragment of DNA used as the standard barcode (for animals, frequently the COI mtDNA locus) can obscure the results; in these cases, sequencing of additional fragments may solve this problem (if sufficient sequence databases exist). Building a DNA barcode library for the parasites from wildlife harvested in the Canadian North will also contribute to voucher collections and sequence databases, providing better coverage of Canadian biodiversity.

Conclusions

Parasites are key components of ecosystems and sentinels of environmental change. Nevertheless, there are large gaps of knowledge about parasites of wildlife harvested as country food in the Canadian North, especially for some species of fish, birds, and carnivores. Documenting and monitoring the presence and distribution of parasites in the Canadian North will be of great value in the development of effective action plans for coping with emerging infectious diseases linked to climate change. The early detection of a novel parasite in an ecosystem or an abrupt fluctuation in the population of a common parasite species gives important insights, not only about one host species, but also about the intermediate host populations, including trophic relationships. Detection is a key step towards mitigation of the effects of climate and landscape change on parasite communities in the Canadian North.

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