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Helminth community structure in two species of arctic-breeding waterfowl

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ABSTRACT

Climate change is occurring rapidly at high latitudes, and subsequent changes in parasite communities may have implications for hosts including wildlife and humans. Waterfowl, in particular, harbor numerous parasites and may facilitate parasite movement across broad geographic areas due to migratory movements. However, little is known about helminth community structure of waterfowl at northern latitudes. We investigated the helminth communities of two avian herbivores that breed at high latitudes, Pacific black brant (*Branta bernicla nigricans*), and greater white-fronted geese (*Anser albifrons*), to examine effects of species, geographic area, age, and sex on helminth species richness, aggregation, prevalence, and intensity. We collected 83 and 58 black brant and white-fronted geese, respectively, from Arctic and Subarctic Alaska July–August 2014. We identified 10 known helminth species (*Amidostomum anseris*, *Amidostomum spatulatum*, *Drepanidotaenia lanceolata*, *Epomidiostomum crami*, *Heterakis dispar*, *Notocotylus attenuatus*, *Tetrameres striata*, *Trichostrongylus tenuis*, *Tschertkovilepis setigera*, and *Wardoides nyrocae*) and 1 previously undescribed trematode. All geese sampled were infected with at least one helminth species. All helminth species identified were present in both age classes and species, providing evidence of transmission at high latitudes and suggesting broad host susceptibility. Also, all but one helminth species were present at both sites, suggesting conditions are suitable for transmission across a large latitudinal/environmental gradient. Our study provides important baseline information on avian parasites that can be used to evaluate the effects of a changing climate on host-parasite distributions.

1. Introduction

Rapid climate change makes northern latitudes a potential hotspot of change in parasite communities (Polley et al., 2010). In particular, birds host numerous parasites that may negatively affect body condition (Calvete and Estrada, 2003; Souchay et al., 2013), reproduction (Holmstad et al., 2005; Amundson and Arnold, 2010), and survival (Wobeser, 1997). Further, migratory birds are important vehicles for parasite movement across broad geographic areas under suitable environmental conditions and intermediate host availability (Hoberg et al., 2008; Koprivnikar and Leung, 2015). Infected birds may disperse parasites that are now able to complete their life cycles in a warmer Arctic, with implications for other suitable host species and young-of-the-year with naïve immune systems.

Common helminths of birds include nematodes (i.e., round worms), trematodes (i.e., flukes or flatworms), and cestodes (i.e., tapeworms). For most nematode species, definitive hosts are infected through direct uptake of eggs or larvae passed from feces of infected definitive hosts (Cole and Friend, 1999). Conversely, cestodes and trematodes require at least one intermediate host to complete their life cycle. Eggs and larvae passed from a definitive host are consumed by the intermediate host where they develop into an infective stage. Definitive hosts then consume intermediate hosts to complete the cycle (Cole and Friend, 1999). Factors affecting helminth transmission and persistence include: soil and water temperature, rainfall and humidity, and availability of intermediate and definitive hosts (Poulin, 2006; Dudley et al., 2015). Helminth transmission, then, is driven by whether the environment can support different parasite life stages, especially those directly exposed to ambient conditions (e.g., nematode eggs on

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soil). Thus, parasites and intermediate host populations will likely have complex responses to climate change. Several studies suggest helminth transmission and prevalence will increase with climate change as temperatures 1) change ecological barriers among parasites and hosts (e.g., glacier melt facilitating movement between previously isolated populations of hosts; Kutz et al., 2014), 2) increase growing season length leading to greater transmission opportunity and promotion of intermediate host populations (Plante and Downing, 1989; Elgmork, 2004), and 3) shorten larval development periods (Pietrock and Marcogliese, 2003). However, not all helminths may respond favorably to a warmer Arctic; high temperatures may also decrease helminth transmission (Penner, 1941; Kutz et al., 2014)).

Helminth diversity, prevalence, and infection intensity may vary by host age, sex, and species because of differences in exposure and transmission rates. Host distribution, behavior, habitat use, diet, sexual selection, body size, and immune function all affect exposure and transmission rates among suitable hosts (Gregory et al., 1991). Young birds may have higher exposure to parasites than adults due to different diets (e.g., greater insect consumption in young waterfowl; Street, 1978). Further, young birds often have underdeveloped or naïve immune systems and may be more susceptible to parasitic infection than adults (Cooper and Crites, 1976). Males may have greater helminth burdens than females because of costs associated with testosterone production or developing secondary sex characteristics (e.g., colorful plumage; Poulin, 1996; Hillgarth and Wingfield, 1997; Møller et al., 1999). Additionally, larger birds both among and within species (e.g., adults, males), consume more forage and are thereby more likely to encounter infected intermediate hosts and consume infected feces (Poulin, 1998; Robinson et al., 2008).

Waterfowl, especially, harbor a wide variety of parasites (Ballweber, 2004) usually with unknown implications to hosts. In some cases, helminths have been shown to contribute to negative population-level effects including mass die-offs (Cornwell, 1963; Sandland et al., 2013). Further, studies suggest wide variation in helminth infection dynamics among guilds at high latitudes. Sea ducks that consume mostly marine and benthic invertebrates typically have high helminth diversity (e.g., 31 helminth species; Skirnisson, 2015) and intensity (e.g., 240,000 worms of a single taxon; Galaktionov 1996). Conversely, avian herbivores like geese generally have somewhat lower helminth diversity and infection intensities (e.g., 3–4 cestode species of up to 175 worms; Schiller, 1954); partly because they only opportunistically consume the aquatic invertebrates that typically serve as intermediate hosts (Sedinger and Raveling, 1984; Budeau et al., 1991).

Despite their potential consequences on host populations, very little is known regarding helminth infection characteristics and transmission in waterfowl breeding at high latitudes. Therefore, we investigated the gastrointestinal helminth communities of two avian herbivores, Pacific black brant (hereafter; brant), and greater white-fronted geese (*Anser albifrons*; hereafter white-fronted geese), breeding at two sites in Subarctic (brant) and Arctic (brant and white-fronted geese) Alaska to examine geographic, species, age, and sex variation in helminth species richness, aggregation, prevalence, and intensity. Additionally, we examined whether parasite abundance was associated with host mass to assess one potential consequence of infection.

We examined several theories regarding variation in helminth infection characteristics: First, we hypothesized that shorter growing seasons and lower maximum temperature in the Arctic would reduce diversity and abundance of some helminths through regulation of intermediate host diversity and population size. Second, we expected greater nematode, lower trematode, and similar cestode prevalence and infection rates in brant than white-fronted geese. Colonially-breeding brant forage on primarily well-developed grazing lawns of salt-tolerant sedges such as *Carex subspathacea* or *Puccinellia phryganodes*. For these plants, repeated regrazing results in higher forage quality. Thus, brant frequently forage in previously grazed habitats, which facilitates contact with fecal material, increasing exposure to direct-cycle nematodes. Conversely, non-colonial white-fronted geese feed more on freshwater sedges such as *Carex aquatilis* in a manner that does not promote higher quality forage (i.e., consuming leaf tips and not the entire plant) and thus, are less likely to regraze specific areas. Common trematodes of waterfowl (e.g., Strigeatoidea, Echinostomida; McDonald, 1969) often rely on freshwater gastropods as first and sometimes second intermediate hosts (Sorensen and Minchella, 2001) that are more likely to occur in less saline habitats frequented by white-fronted geese (Ezzat, 1961; Skala et al., 2014). Therefore, we hypothesized white-fronted geese would have greater prevalence and intensity of trematodes than brant. Cestode intermediate hosts are likely copepods or other microcrustaceans tolerant of salinity (Castro, 1996, Chen et al., 2006) and we did not expect interspecific variation in exposure to cestodes. We also predicted goslings would have lower prevalence rates and helminth diversity than adults because of their smaller body size and lack of exposure to parasites prior to the breeding season (i.e., cross over). However, we predicted goslings would be less immuno-competent and thus suffer higher infection intensities than adults. Lastly, we predicted males would have higher helminth infections and diversity than females because of larger body size and subsequently greater food intake.

2. Methods

2.1. Study area

We collected birds in two important waterfowl breeding areas in Alaska; the Yukon-Kuskokwim Delta (YKD; 61° N 164° W), and the Arctic Coastal Plain (ACP; 70° N 154° W) (Fig. 1). In both areas, waterfowl are distributed along coastal habitat characterized by low elevation short-grass tundra with numerous wetlands. The YKD and ACP vary in breeding season climate; the onset of the growing season is on average 2 weeks later and maximum summer temperatures are ~7 °C lower on the ACP (Meteoblue v 1.08; Cano-Cruz and López-Orozco, 2015). Waterfowl species composition is similar between the two breeding areas; from 1988 to 2014, 18 of 24

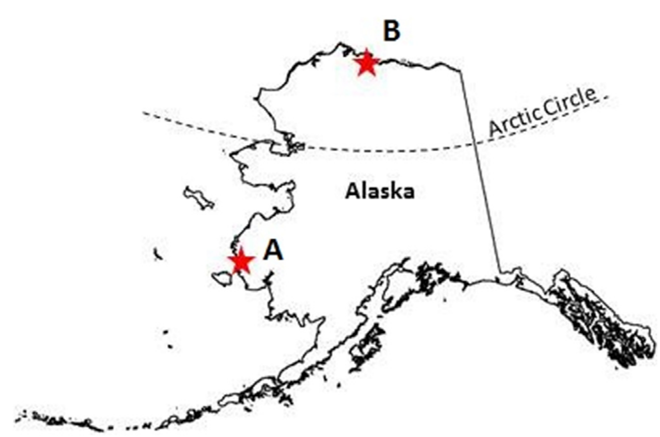

Fig. 1. Study sites in Alaska where Pacific black brant and greater white-fronted geese were collected for helminth examination in 2014; A) Yukon-Kuskokwim Delta (61° N 164° W) in Subarctic western Alaska and B) the Arctic Coastal Plain (70° N 154°) in Arctic Alaska.