RESEARCH ARTICLE

# Svalbard rock ptarmigan: a first glimpse into parasite infections

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## Abstract

Natural ecosystems are under stress due to climate change and impacts are especially prominent at high latitudes. Manifestations of these changes include northward shifts in the distribution of birds, phenological mismatches, improved survival of parasites in the environment and the arrival of new parasite vectors and intermediate hosts. We collected baseline data on parasite infections in the Svalbard rock ptarmigan (*Lagopus muta hyperborea*), which is endemic to two High Arctic archipelagos, by sampling 10 birds caught in September–October 2015 in Van Mijenfjorden, Spitsbergen. Five species were found, three endo- and two ectoparasites. The endoparasites included a nematode, *Heterakis* sp. (prevalence 10%), and two species of *Eimeria*, all with direct life cycles. The *Eimeria* species are provisionally called *Eimeria* sp. A and sp. B (prevalence 50% and 20%; mean intensity 1560 and 1850 oocysts per g faeces, respectively). Both show morphological similarities with known rock ptarmigan eimeriids, but further taxonomic research is needed to describe their phylogenetic relationships. The two ectoparasites, the ischnoceran chewing lice *Goniodes lagopi* and *Lagopoecus affinis*, both showed 90% prevalence and a mean intensity of 18.3 and 5.6, respectively. The eimeriids are host specific, and the chewing lice are common parasites of closely related grouse species. On the basis of our knowledge of rock ptarmigan parasites, *Heterakis* sp. is considered a generalist parasite. The parasite fauna of the Svalbard rock ptarmigan is impoverished compared with conspecific populations in other Arctic locations, such as Iceland and Greenland.

## Introduction

Infectious diseases caused by viruses, microparasites (bacteria, protozoans and fungi) and macroparasites, such as helminths, are important factors in the population dynamics of some avian species, including grouse (Hudson et al. 1998; Holmstad et al. 2005; Stenkewitz 2017). Two grouse species—rock ptarmigan (*Lagopus muta*) and willow ptarmigan (*Lagopus lagopus*; both Galliformes: Phasianidae: Tetraoninae)—inhabit tundra, heathland and scrub habitats within the Arctic and the Subarctic (Fuglei et al. 2020; Montgomerie & Holder 2020). These regions are under stress due to climate change (IPCC 2021). The High Arctic Svalbard archipelago is one of the fastest-warming locations on Earth. Here the ambient temperature has increased 3–5 °C over the last 50 years, particularly in winter (Nordli et al. 2020). One manifestation of increased temperatures is a shift northward in the distribution and numbers of wild birds, and these new species potentially

bring with them assemblages of pathogens foreign to the local faunas (Van Hemert et al. 2014). Ectoparasites of migrant birds in Svalbard have been studied, but few species have been observed (Gwiazdowicz et al. 2012; Descamps 2013; Pilskog et al. 2014; Elsterová et al. 2015). In one of these studies, average winter temperature was a major determinant of tick infestations among Arctic seabirds in Svalbard (Descamps 2013).

The Svalbard rock ptarmigan (*Lagopus muta hyperborea*) is endemic to the Norwegian archipelago of Svalbard and the nearby Russian group of islands, Franz Josef Land (Løvenskiold 1964; Uspenskiy & Tomkovich 1987). Rock ptarmigan likely colonized these archipelagos at the end of the Last Glacial Period, i.e., or less than 12 Kya, from either the Siberian mainland or Greenland (Sahlman et al. 2009). The subspecies *hyperborea* is unique among rock ptarmigan in many respects because it has several morphological and physiological adaptations to Arctic conditions (Mortensen et al. 1983; Stokkan et al. 1995;

Appenroth et al. 2021). These unique traits reflect adaptations of sedentary species to the High Arctic environment, where selective forces include harsh climate, sparse vegetation, two-and-a-half-months of polar night and a structurally simple food-web characterized, among others, features, by the absence of small mammals and specialist predators like the gyrfalcon (*Falco rusticolus*; Strøm & Bangjord 2004; Ims et al. 2013; Descamps et al. 2017).

The Svalbard rock ptarmigan occurs at moderate densities compared to other ptarmigan distribution ranges (Fuglei et al. 2020). In Svalbard, it has been monitored since 2000, and numbers were low until 2013 (1–3 territorial males per km² in spring), but since then increased and now vary between three and five territorial males per km² (Pedersen et al. 2012; Marolla et al. 2021). There are no indications of cyclic dynamics, but temporal fluctuations are partly driven by interannual variation in ROS (Hansen et al. 2013) and milder winter temperatures (Marolla et al. 2021). ROS events may result in basal ice covering important feeding plants, leading to food shortage and subsequent population reductions (Hansen et al. 2013), while increased winter temperatures may improve overall survival (Marolla et al. 2021) and at present appear to outweigh the negative effect of ROS.

The vulnerability of the rock ptarmigan to climate changes is expected to increase pressure on individuals and populations. In this context, the general health status of the Svalbard rock ptarmigan may be compromized by the increased likelihood of infections by macro- and microparasites. This will be facilitated by: (a) an increase in the local availability of parasites through the arrival of new avian host species and an increase in local populations of migratory species (Madsen et al. 2017); (b) the effect of increased ambient temperature on the development and survival of parasites and parasite eggs and larvae in the environment (Descamps 2013); and (c) the colonization of new parasite vectors and intermediate hosts (Henttonen et al. 2001).

In total, 40 parasite species are known for the rock ptarmigan across its range (Skirnisson et al. 2012). Of those parasites, seven ectoparasites can be considered host specific for grouse (Tetraoninae), including three chewing lice (Ischnocera: *Goniodes lagopi* and *Lagopoecus affinis* and Amblycera: *Amyrsidea lagopi*), three Astigmata feather mites (Psoroptidia: *Tetraolichus lagopi*, *Strelkoviacarus holoaspis* and *Metamicrolichus islandicus*) and one Prostigmata quill mite (Syringophilidae: *Mironovia lagopus*). *Eimeria* (Apicomplexa: Eimeriidae) endoparasites are generally considered to be host specific (Duszynski et al. 2018). Where *Eimeria* infections in rock ptarmigan have been studied, two *Eimeria* species are usually found in the different component communities (Levine 1953; Skirnisson & Thorarinsdottir 2007; Matsubayashi et al. 2018). In total, seven *Eimeria* species

associated with rock ptarmigan have been described (Skirnisson et al. 2012); however, taxonomic research using traditional and molecular techniques is needed to describe the phylogenetic relationships among ptarmigan eimeriids. The only extant observations of Svalbard rock ptarmigan parasites are for the ischnoceran chewing lice *G. lagopi* and *L. affinis* (Mehl et al. 1982). Known pathogenic parasites of rock ptarmigan are *Eimeria* spp. (causing coccidiosis), the nematodes *Trichostrongylus tenuis* (causing strongylosis) and *Aonchotheca caudinflata* (as *Capillaria caudinflata*, causing capillariosis) and the epidermoptid feather mite *M. islandicus* living on or within the skin, causing mange (Mironov et al. 2010; Stenkewitz 2017).

Our aim is to describe for the first time the parasite fauna of the Svalbard rock ptarmigan. On the basis of existing knowledge (i.e., Bochkov & Skirnisson 2011; Skirnisson et al. 2012), we expected to find a number of host-specific parasite species with direct life cycles, like chewing lice (Phthiraptera), feather mites (Psoroptidia), quill mites (Syringophilidae) and different species of *Eimeria*. However, because of the simple terrestrial ecosystem in Svalbard, we did not expect to find any variety of host generalists with complex life cycles, like trematodes and cestodes or vector-borne epidermoptid astigmatan parasites such as *Myialges borealis*.

## Materials and methods

Svalbard is an isolated archipelago in the Arctic Ocean between 74°N and 81°N and 10°E and 35°E (Fig. 1). The total area is approximately 63 000 km², of which approximately 60% is covered by glaciers, 25% is barren ground and 15% is vegetated land (Johansen et al. 2012). The vegetation is dominated by prostrate dwarf shrub tundra with wetlands, various heath, snow-bed and ridge vegetation (Walker et al. 2005). The climate is influenced by the warm North Atlantic Current, resulting in a warmer and wetter climate compared to other areas at similar latitudes (Cottier et al. 2005; David & Krishnan 2017). Mean air temperature in winter (December–February) was -13.9 °C and in summer (June–August) 4.5 °C, and mean precipitation was 51 mm in winter and 52 mm in summer, as measured at the Svalbard Airport meteorological station from 1971 to 2000 (Hanssen-Bauer et al. 2019). A warming of 3–5 °C was observed between 1971 and 2017, with the largest increase in winter and the smallest in summer (Hanssen-Bauer et al. 2019; Nordli et al. 2020).

### Ptarmigan sample

Ten Svalbard rock ptarmigan, one adult and four juvenile males, and one adult and four juvenile females, were shot

**Fig. 1** The rock ptarmigan subspecies *Lagopus muta hyperborea* is confined to the archipelagos of Svalbard and Franz Josef Land, in the Arctic Ocean. The collection site, Van Mijenfjorden, is marked with a yellow dot. Svalbard is 700 km from mainland Norway, 500 km from Greenland and 1590 km from Iceland.

in the hunting season during the period 10 September to late October 2015 in Van Mijenfjorden, Spitsbergen, Svalbard (77.858°N, 15.661°E). After the hunt, birds were stored collectively, so we could not control for transmission of ectoparasites between birds. We sexed the birds using both the loral stripe and size and colour of the combs (Montgomerie & Holder 2020), and age was determined on the basis of pigmentation of the primaries (Weeden & Watson 1967; Parker et al. 1985). During dissection, sex and age were confirmed by inspection of the gonads and by the presence or absence of the bursa Fabricii. Two age classes were recognized: juveniles (birds hatched in 2015, ca. 3 months old) and adults (birds hatched in 2014 and earlier, 15 months or older).

### Collection and quantification of endoparasites

The gut was removed during dissection and separated into the following parts for parasite assessment: (a) oesophagus and crop along with trachea and associated connective tissue; (b) proventriculus and gizzard; (c) duodenum; (d) small intestine; (e) caeca, separated left and right; and (f) rectum and cloaca. The rectum was cut open and its contents collected, whereas the different parts of the alimentary tract were placed in plastic bags and frozen for later analysis.

To detect and estimate infection intensity, a previously frozen faecal sample was collected from the rectum of each bird and examined by using a modified McMaster method (Anonymous 1986; Rommel et al. 2000). From each bird, 0.5 g faeces were mixed with 14.5 ml of water in a centrifugation tube and sedimented at 800 g for 2 min. The supernatant was decanted, and the tube refilled with the flotation medium Parasitosol (Meku®), with a specific density of 1.26 g/ml. After thorough mixing of the sediment in the tube with the floatation medium, part of the sample was transferred with a pipette into two McMaster counting chambers, and the number of eggs or oocysts was counted under a microscope at 125× magnification. The counts were multiplied by 50 to give an estimate on the number of eggs or oocysts per g faeces of the host.

Adult worms were searched for in the alimentary tract. The different parts of the alimentary tract—duodenum, small intestine and caeca—were cut open separately and the contents washed over a 150 µm sieve. After gentle washing with water, the content of the sieve was poured into a Petri dish and examined for helminths under a stereoscope. Worms were identified, counted and then fixed in 70% ethanol. The identification of nematodes was based on Rommel et al. (2000). Further, we searched for nematodes in the oesophagus, crop, proventriculus, gizzard and under the koilin lining of the gizzard.

### Collection and quantification of ectoparasites

A handheld vacuum cleaner (Princess turbo tiger, type 2755) was used to collect external parasites. The vacuum was modified for this purpose: the nozzle (4 × 1.5 cm) was connected to an external collection chamber fitted with a circular sack-like filter (92 cm$^2$; 2–30 µm pore diameter). Each bird was vacuumed systematically, being entirely vacuumed in 1–2 minutes. Thereafter, the filter was placed in a plastic bag and preserved in a freezer (-20 °C) until analysis.

At the time of analysis, the content of the vacuum filter (feathers, skin particles, blood flakes, parasites, etc.) was poured into an open 400 ml glass jar. Approximately, 100 ml of water was used to gently rinse the filter and collected in the glass jar. Seven drops of Triton® X-100 were added to the water to reduce adhesive forces and promote the settling of particles. Feathers were removed from the mixture and discarded after being rinsed further with water over the jar. After gently stirring, to remove air bubbles and particles from the surface, the contents
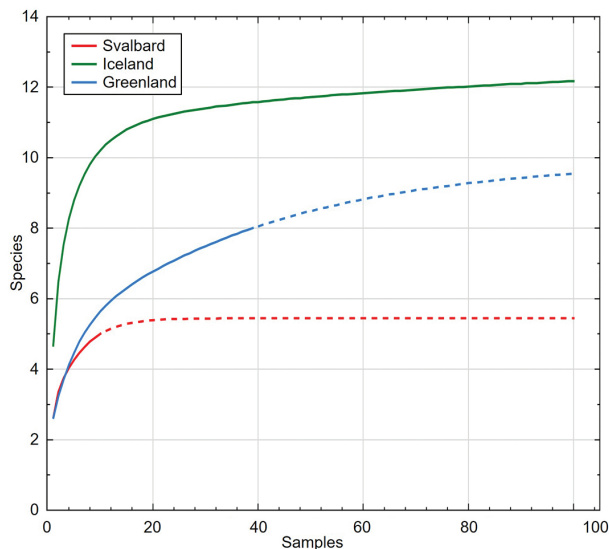
**Fig. 2** Rarefaction curves for rock ptarmigan parasite communities in Svalbard, Iceland and Greenland. The curves for Svalbard (*n* = 10 hosts) and Greenland (*n* = 39 hosts) were extrapolated (broken lines) to 100 hosts.

were left to settle for several hours. Parasites were collected from the sediment at the bottom of the jar under a stereoscope at 10× to 35× magnification and preserved in 70% ethanol.

The bare skin of each bird was visually inspected for signs of mange, an indicator of skin mite infestations (see figure 4.2 by Stenkewitz 2017). Also, the rectrices were examined for feather holes, indicating the presence of the chewing louse *A. lagopi* (see figure 2 by Stenkewitz 2017). In addition, seven wing feathers per bird were examined for quill mites (Skirnisson & Nielsen 2019). The identification of the chewing lice *G. lagopi* and *L. affinis* was based on Timmermann (1950).

### Statistical analysis

Quantitative data included the total number of worms and indexes of abundance for the two eimeriids (OPG) and two chewing lice species (number vacuumed). Descriptive statistics—prevalence of infection, mean intensity of infection and discrepancy index—were calculated for each parasite species. All calculations were done using the software Quantitative parasitology 3.0 (Rozsa et al. 2000). The prevalence of infection is expressed as percentage (%) of hosts infected with the parasite; mean intensity of infection is the mean number of parasites per host based on infected individuals only. The discrepancy index ranges from 0 to 1; high values indicate aggregated distribution and low values a uniform distribution. The Sterne method was used to calculate the 95% confidence

limits for prevalence and the bootstrap method for confidence limits for mean intensity and the discrepancy index.

We did a rarefaction curve for the Svalbard data set using the software EstimateS and extrapolated the curve by 90 hosts (Colwell 2013). The rarefaction curve is a plot of the number of species (here parasites) against the number of samples (here hosts). This curve is created by randomly re-sampling the pool of *N* samples several times and then plotting the average number of species found on each sample. For comparison, we used curves derived for rock ptarmigan—1140 hosts and 13 parasite species—in Iceland (Nielsen et al. 2020) and Greenland—39 hosts, extrapolated by 61 hosts, eight parasite species (Karl Skírnisson & Ólafur K. Nielsen, unpubl. data). Parasites for these two-time series were collected and analysed in an identical way to the Svalbard data set. Two species were omitted from the Iceland samples for the rarefaction curve: *Ornithomya chloropus* (Diptera: Hippoboscidae) and *Ceratophyllus gallinae* (Siphonaptera: Ceratophyllidae). The reason for this is their ephemeral characteristics, and even if present in the environment they would not have been registered in either Svalbard or Greenland samples because of the timing of the sampling effort.

## Results

### Parasite richness

Five species of parasites were found, three endoparasites and two ectoparasites (Table 1). Prevalence was high for four of the species and the rarefaction curve rose steeply and then plateaued. The comparison with Iceland and Greenland rarefaction curves (Fig. 2) suggests an impoverished parasite community for the Svalbard rock ptarmigan, especially compared to Iceland.

### Endoparasites

Two species of *Eimeria* were recorded; until further analyses we call them *Eimeria* sp. A and *Eimeria* sp. B. Genetical analysis of these species is underway (Matsubayashi et al. in press). *Eimeria* sp. A is elongated in shape (Fig. 3a) and morphologically close to *E. muta*, which parasitizes rock ptarmigan in Iceland (Skirnisson & Thorarinsdottir 2007), and *E. uekii*, which parasitizes rock ptarmigan in Japan (Kamimura & Kodama 1981). *Eimeria* sp. B is spherical (Fig. 3b) and morphologically similar to *E. rjupa*, which parasitizes rock ptarmigan in Iceland (Skirnisson & Thorarinsdottir 2007), and *E. raichoi*, which parasitizes rock ptarmigan in Japan (Matsubayashi et al. 2018). The average length × width of 17 elongated oocysts of *Eimeria* sp. A was 23.7 × 15.4 μm (range

**Table 1.** Summary statistics of the endoparasites (*Eimeria* sp. A and sp. B and *Heterakis* sp.) and ectoparasites (*Goniodes lagopi* and *Lagopoecus affinis*) from the sampled Svalbard rock ptarmigan (*Lagopus muta hyperborea*; n = 10).

| Parasite species | No. infected hosts | Prevalence (%) | 95% cl[a] | Mean intensity[b] | 95% cl[a] | Discrepancy index | 95% cl[a] |
|---|---|---|---|---|---|---|---|
| *Eimeria* sp. A | 5 | 50 | 22–78 | 1560 | 540–2620 | 0.641 | 0.483–0.818 |
| *Eimeria* sp. B | 2 | 20 | 4–55 | 1850 | – | 0.784 | 0.545–0.818 |
| *Heterakis* sp. | 1 | 10 | 1–45 | 1 | – | 0.818 | – |
| *Goniodes lagopi* | 9 | 90 | 55–100 | 18.3 | 10.1–27.3 | 0.424 | 0.294–0.630 |
| *Lagopoecus affinis* | 9 | 90 | 55–100 | 5.6 | 3.1–9.7 | 0.444 | 0.333–0.692 |

[a] Confidence limits. [b] Mean intensity of *Eimeria* sp. A and sp. B is based on oocysts per gram of faeces.
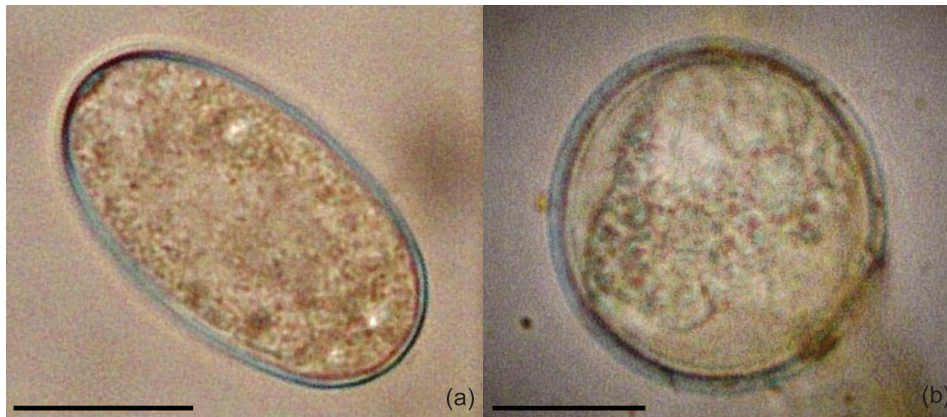


**Fig. 3** Unsporulated eimeriids (Coccidia: Eimeria) from frozen faeces of Svalbard rock ptarmigan (*Lagopus muta hyperborea*). (a) *Eimeria* sp. A. (b) *Eimeria* sp. B. Scale bars 10 μm.

18–30 × 13–18); average width/length ratio 1.53. Average length × width of 19 spherical oocysts of *Eimeria* sp. B. was 22.6 × 20.5 μm (range 19–25 × 19–23); average width/length ratio 1.10. The prevalence and mean intensity of *Eimeria* sp. A and *Eimeria* sp. B were 50% and 20% and 1560 and 1850 OPG, respectively (Table 1). Both species showed an aggregated distribution (dispersion index 0.641 and 0.818 for sp. A and sp. B, respectively). Neither of the two adult birds had *Eimeria* infections. The only helminth found was a single female of *Heterakis* sp. in the caeca of a juvenile bird (10% prevalence; Table 1). Using the McMaster method, we found a single *Heterakis* sp. egg in the same individual that hosted the female worm.

### Ectoparasites

Two species of ectoparasites were found: the ischnocerans *G. lagopi* and *L. affinis* (Fig. 4, Table 1). The prevalence of both species was 90%, and the mean intensity was 18.3 and 5.6 for *G. lagopi* and *L. affinis*, respectively. Both species were less aggregated within the host population than the two eimeriids (Table 1). Only one bird—a juvenile—was free of ischnocerans, but both adults examined were infected with both *G. lagopi* and *L. affinis*.

### Discussions

Our study is the first to describe the parasite fauna of the Svalbard rock ptarmigan. Five parasite species were found, three endoparasites and two ectoparasites. This suggests an impoverished parasite community for the Svalbard rock ptarmigan compared to other ptarmigan populations. The sample size was limited to just 10 birds, which is too small to fully describe species richness of the parasite community of this subspecies (Walther et al. 1995). Also, the birds collected for the study were collectively stored during the hunt, allowing ectoparasites to transfer between individuals. These shortcomings should be kept in mind when interpreting the data.

Ptarmigan (*Lagopus*) evolved in North America and comprise three species: rock ptarmigan, willow ptarmigan and white-tailed ptarmigan (*Lagopus leucura*). The rock ptarmigan and willow ptarmigan have a Holarctic distribution, but the white-tailed ptarmigan is confined to the Nearctic. The ancestral *Lagopus* diverged from other tetraonids ancestral to *Tetrao*, *Lyrurus* and *Falcipennis* some 7–10 million years ago (Persons et al. 2016). We assume that the interaction between the rock ptarmigan and its coterie of host-specific parasites has a long history of
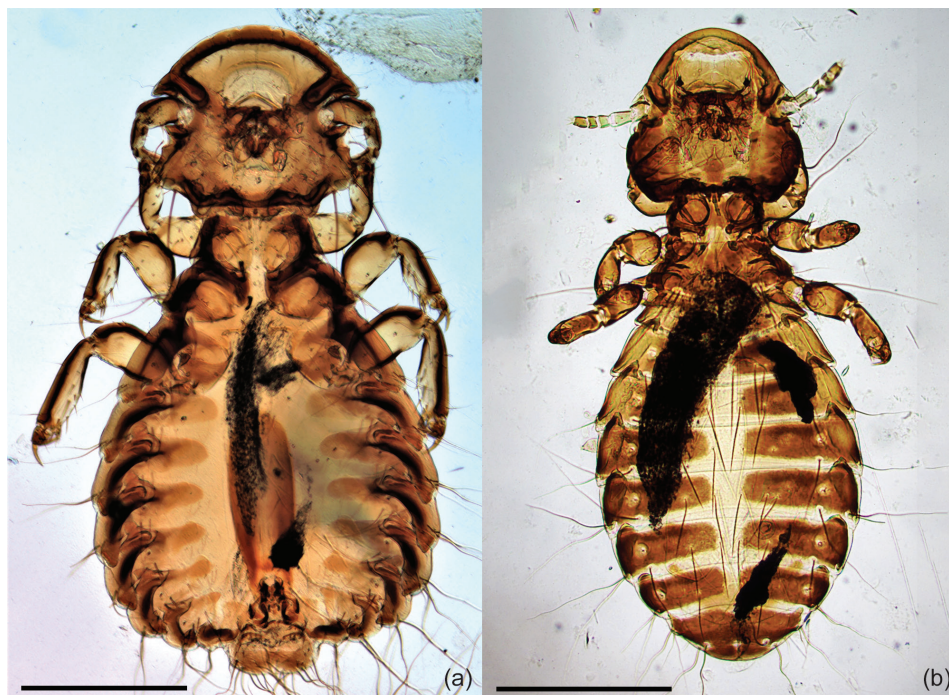
**Fig. 4** Two ischnoceran chewing lice (Phthiraptera) found in the plumage of the Svalbard rock ptarmigan (*Lagopus muta hyperborea*). (a) *Goniodes lagopi*, male. (b) *Lagopoecus affinis*, female. Scale bars 500 μm.

coevolution going back to the grouse heartland in North America. This has probably not been a 'closed system' but has instead frequently involved host switching during periods of sympatry among different grouse species, as has been suggested for chewing lice (Sweet et al. 2020).

Of the five parasite species found, four were host specific: two ischnoceran chewing lice and two species of *Eimeria*. We expected to find more host-specific species, including one amblyceran chewing louse and some species of feather mites and quill mites (Skirnisson et al. 2012; Skirnisson & Nielsen 2019). This impoverished parasite community could reflect a founder effect (ptarmigan colonists not infected by those parasites), local extinction of parasites following settlement or small sample size of hosts examined in our study. Also, the helminth fauna, which are generalist parasites, was meagre. The absence of generalist parasites may simply reflect their general scarcity within rock ptarmigan habitats in Svalbard. We could not identify to species the single *Heterakis* sp. female found. The nematode *H. gallinarum* is a known parasite of rock ptarmigan in both the Palearctic and the Nearctic (Skirnisson et al. 2012). It is a generalist known to parasitize many different types of host, including ducks and geese, and we consider that this case from Svalbard of *Heterakis* sp. probably represents an instance of host switching. Potential reservoir hosts for parasites of ptarmigan in Svalbard are waterfowl (Anseriformes) and shorebirds, terns and gulls (Charadriiformes).

The impoverished parasite community prompts questions about the source and timing of rock ptarmigan colonizing Svalbard. The glaciation of Svalbard suggests that the rock ptarmigan settled in Svalbard sometime after the end of the Last Glacial Period, about 12 000 years ago (see Sahlman et al. 2009 and references therein). The Svalbard rock ptarmigan belongs to the so-called *rupestris* group (Vaurie 1965), so the settlers must have come from the Nearctic (Greenland) or Siberia. Sahlman et al. (2009) concluded, on the basis of genetic analysis, that the most likely source of the founders was Siberia rather than Greenland. We can assume that the founder population of Svalbard rock ptarmigan carried the nine host-specific parasites (two eimeriids, three feather mites, one quill mite and three chewing lice) that rock ptarmigan in Greenland (Karl Skírnisson & Ólafur K. Nielsen, unpubl. data) and Siberia (Smith et al. no date; Price et al. 2004; Mironov et al. 2010) have. Considering the high prevalence of some of those parasites, like the feather mite *S. holoaspis* (Nielsen et al. 2020), in rock ptarmigan outside of Svalbard, we suggest that the history of rock ptarmigan parasites in Svalbard has been characterized by local extinction rather than founder effect. Further, host-switching has been rare and that probably reflects the harsh conditions that prevail in Svalbard. This is in a stark contrast to the situation in Iceland, which was colonized by rock ptarmigan at the same time as Svalbard. In Iceland, the host-specific

parasite fauna has prevailed and there are also several cases of host-switching (Skírnisson et al. 2012; Karl Skírnisson & Ólafur K. Nielsen, unpubl. data).

Any changes in abundance and diversity of pathogens, parasites and vectors may have management and conservation implications for a species isolated for millennia on remote islands (Paxton et al. 2016). The rapid increase in average temperature and precipitation during all seasons in Svalbard (Nordli et al. 2020) may provide novel environments for new species of parasites and vectors to colonize Svalbard. For instance, at present, average winter temperature is a major determinant of prevalence for the tick *Ixodes urea,* parasitizing the Svalbard Brünnich's guillemot (*Uria lomvia* [Charadriiformes]), where 1 °C increase in average winter temperature led to a 5% increase in tick prevalence (Descamps 2013). There are no indications that the health status of the Svalbard rock ptarmigan has been challenged by changes in parasite prevalence or communities because of climate change. The population is presently increasing, as warmer winters seem to be improving survival rates (Marolla et al. 2021).

## Conclusions

Although limited by a very small sample size, this study indicates a highly impoverished parasite fauna composed mainly of a few host-specific species, three of which are endoparasites and two ectoparasites. We interpret this to reflect local extinctions of host-specific fauna following settlement, combined with the low availability of generalist parasites in rock ptarmigan habitats in Svalbard. Our understanding of the origin and evolution of the Svalbard rock ptarmigan could be enhanced by genetic studies of the eimeriids and chewing lice in Svalbard and comparing them with likely source populations in Siberia or Greenland.

Our study provides baseline data on the parasite community for comparison with future studies. To fully explore the component parasite community of rock ptarmigan in Svalbard a bigger sample (50–100 ptarmigan hosts) is needed. The rock ptarmigan is a game bird in Svalbard and the annual harvest ranges from 700 to 2000 birds (Marolla et al. 2021), a relatively convenient source of birds for parasite analysis.

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## Disclosure statement

The authors declare no conflicts of interest.

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