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Gut Helminths of Two Species of Light Geese in Illinois

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by

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Abstract

Parasite burdens in lesser snow geese (*Chen caerulescens caerulescens*) and Ross's geese (*Chen rossii*) migrating through central Illinois were determined and compared to documented parasite burdens on the breeding grounds in northern Canada and the wintering grounds in southern Texas. The digestive tracts of 48 snow geese (38 lesser snow geese and 10 Ross's geese) were collected from 4 February to 3 March, 2012, in Raymond, Illinois. Eight helminth taxa (two species of Trematoda, four species of Nematoda, and two species of Cestoda) were recovered. Five of the eight helminth taxa were common in both species of host, while *Hymenolepis* species "B," *Zygocotyle lunata*, and *Echinostoma revolutum* were only found in lesser snow geese. Prevalence of the eight helminth taxa ranged from 2.1% in *Zygocotyle lunata* to 97.7% in *Epomidiostomum* sp. and mean intensities ranged from 1.00 in *Echinostoma revolutum* to 22.89 in *Trichostrongylus tenuis*. Helminthes with direct life cycles had higher prevalences than helminthes with indirect life cycles. *Trichostrongylus tenuis* infections expressed higher prevalence and mean intensity in Ross's geese than lesser snow geese and higher mean intensity in juvenile than adult Ross's geese. The prevalence of *Heterakis dispar* was higher in adult birds than juveniles in pooled hosts. *Amidostomum* sp., and *Epomidiostomum* sp. were seen to mimic documented burdens on the wintering and breeding grounds, while *Heterakis dispar* and *Trichostrongylus tenuis* seemed to fluctuate throughout the migration.

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Introduction

Snow geese, commonly known as light geese, are subdivided into three groups. These include two closely related subspecies lesser snow geese (*Chen caerulescens caerulescens*) and greater snow geese (*Chen caerulescens atlantica*), and the closely related species Ross's geese (*Chen rossii*). Physiologically, these species are very similar, although they do express different physical characteristics. Ross's geese are the smallest of the three species, exhibiting a smaller body, neck, and bill. Lamellae, serrations along the outer edge of the jaws, are characteristic of lesser and greater snow geese, but are absent in Ross's geese (Alisauskas 2001). Lesser snow geese show a variation in plumage color, which gives rise to the blue goose (Cooke et al. 1975). Color phases are a form of polymorphism, which are commonly seen in artic waterfowl (Cooch 1961). Plumage variation is absent in greater snow geese and very rare in Ross's geese. Greater snow geese leave their northern breeding grounds and follow the Atlantic coastline down the United States. Because greater snow geese are not commonly found in Illinois; they were not included in this study. Ross's and lesser snow geese migrate through the Mississippi flyway of the United States to their wintering grounds in southern Texas, Louisiana, and Mexico (Abraham et al. 2005, Bêty et al. 2004).

Lesser snow geese and Ross's geese migrate together and inhabit the same breeding grounds. Most of the breeding snow geese pairs are found in the Northwest Territories, Canada (Ankney 1977). Breeding grounds for snow geese are typically on flat delta basins within 5 miles of salt water (Cooch 1961). Both lesser snow geese and Ross's geese primarily consume green vegetation and grain while foraging in fields during their spring and fall migrations (Ankney 1977). Snow geese feed heavily during their spring migration to build a nutrient reservoir that will last throughout the laying process (Shutler et al. 2012).

Waterfowl, including snow geese, are infected with a wide range of parasites throughout their range. Lesser snow geese and Ross's geese have been reported to be infected with the nematodes *Amidostomum, Epomidiostomum*, *Trichostrongylus tenuis, Heterakis dispar*, and the protozoan *Eimera truncata* while at the breeding grounds in northern Canada (Clinchy & Barker 1994). Forbes et al. (1999) reported that the most abundant helminth infections were *H. dispar* and *T. tenuis* throughout their range. They were present in 51% and 46% of all hosts sampled, and had a mean abundance of 15 worms and 11 worms, respectively. The trematode, *Echinostoma trivolvus*, exhibited a mean abundance of 0.37 and a mean intensity of 2.3 within snow geese during their spring migration and on the wintering grounds (Forbes et al. 1999). The trematodes, *Echinostoma revolutum* and *Zygocotyle lunata*, common waterfowl parasites, were also reported on the wintering grounds (Buscher 1965, Purvis et al. 1997).

Large wintering flocks of lesser and Ross's snow geese have been documented in southern Texas, Louisiana, and Mexico (Fedynich et al. 2005). Gizzard nematodes of the genera *Amidostomum* and *Epomidiostomum* were reported causing lesions under the lining of the gizzard from a wide range of wintering waterfowl species in southern Texas (Purvis 1997). Wintering Ross's geese in southern Texas have been reported to carry heavy infections of *T. tenuis* and *H. dispar* as well (Fedynich et al. 2005). Purvis et al. (1997) reported that 43% of all lesser snow geese sampled were infected with *T. tenuis*, while 57% were infected with *H. dispar*.

Hosts collected in the coastal habitat of the breeding grounds exhibited higher parasite burdens then hosts collected farther inland, away from coastal marshes (Mellor et al. 2006). *Trichostrongylus tenuis* and *Amidostomum* infections in juvenile Ross's geese showed a higher mean intensity than in adult hosts (Fedynich et al. 2005). Juvenile snow geese were infected with higher amounts of *T. tenuis* than adults while migrating to the breeding grounds (Forbes et al. 1999).

Parasitic life cycles can be either direct or indirect. In a direct life cycle, which only requires one host, the parasite is transmitted to the definitive host through an infective larvae stage typically while feeding. An indirect life cycle is more complex; the parasite is transmitted to the definitive host through a series of intermediate hosts. *Amidostomum* sp., *Epomidiostomum* sp., *Trichostrongylus tenuis,* and *Heterakis dispar* are nematodes that have a direct life cycle (Cole and Friend 1999, Forbes et al. 1999, Hudson et al. 1992). *Echinostoma revolutum* and *Zygocotyle lunata* are digenetic trematodes that use an indirect life cycle with the main difference being the number of intermediate hosts used throughout their life histories (Huffman et al. 1991, Kanev 1994).

The objective of this study was to document parasite burdens in the light goose population while they are on their spring migration to their breeding grounds in northern Canada. The close anatomical and physiological resemblance of the two species of light geese found in Illinois would suggest that Ross's and lesser snow geese would be susceptible to the same parasites. Correlations of parasite burdens and host sex, age, and species were examined to determine if infection rates differed between host species. Parasite infections recorded in snow geese while in Illinois were compared to documented parasite burdens on the breeding grounds in northern Canada and the wintering grounds in southern Texas.

Materials & Methods

Snow geese (*Chen caerulescens caerulescens* and *Chen rossii*) were collected during the spring 2012 conservation hunting season between 4 February and 3 March. All 48 specimens, 38 lesser snow geese and 10 Ross's geese, were hunter-harvested birds collected approximately 5 km southwest of Raymond, Illinois, within the boundaries of the Mississippi flyway. The collection site was a pond with a maximum depth of approximately 1 meter surrounded by cattle pasture on all sides. All samples were migrants on their spring migration to the breeding grounds.

Within 12 hours of collection, the intestines, cecum, and gizzard were removed from the body cavity and frozen until dissection. Hosts were classified as adults or juveniles based on plumage. Sex of each host was determined by the presence or absence of male reproductive organs.

Samples were allowed to thaw at 4^0C for 24 hours prior to dissection. Intestinal tracts were divided into 6 anatomical regions (anterior 1/3, middle 1/3, and posterior 1/3 of the small intestine, cecum, large intestine, and gizzard). Each section of the intestine and cecum was opened longitudinally, the contents were removed and the mucosal surface was examined for helminths. Sedimentations of gastrointestinal contents were performed to collect any worms present in the lumen contents. Gastrointestinal contents were mixed with saline in a dissection dish and examined for parasites using a dissection microscope. The gizzard was cut open and the contents were washed into a dissection dish using deionized water for examination under a dissection microscope. Epithelial linings inside the gizzard were peeled off and examined for the presence of helminths. Lesions on the surface of the epithelial lining were common indicators of parasite burden within the gizzard.

Platyhelminths were fixed in AFA, stained in acetocarmine followed by an alcohol dehydration series, then cleared in hemo de and mounted in permount. Nematodes were fixed in glycerin ETOH and mounted in glycerin jelly. Specimens were identified using available keys (McDonald 1974, 1981).

Prevalence (percentage of hosts infected with a particular species), mean abundance (number of parasites per host, including uninfected hosts), and mean intensity (number of parasites per infected host) were determined for each parasite species. Prevalence data was treated as a single variable test (the number of geese infected or uninfected per helminth taxa) and analyzed by a chi-squared test. Abundance and mean intensity data were analyzed using an analysis of variance (ANOVA) or student's t test.

Results

A total of 1,342 helminths were collected from 48 specimens, 38 lesser snow geese and 10 Ross's geese, during this study. Eight helminth taxa (two species of Trematoda, four species of Nematoda, and two species of Cestoda) were recovered from gastrointestinal tracts (Table 1). Five of the eight helminth taxa were common in both species of hosts, while *Hymenolepis* species B, *Zygocotyle lunata,* and *Echinostoma revolutum* were only found in lesser snow geese.

Prevalence of the eight helminth taxa ranged from 2.1% in *Zygocotyle lunata* to 97.7% in *Epomidiostomum* sp. and mean intensities ranged from 1.00 in *Echinostoma revolutum* to 22.89 in *Trichostrongylus tenuis* (Table 2). The most prevalent parasites were the gizzard nematode *Epomidiostomum* sp. and the caecal nematodes *Heterakis dispar* and *Trichostrongylus tenuis*. *Epomidiostomum* sp. was found in 42 out of 43 (97.7%) hosts and exhibited a mean intensity of 9.14. In almost every infection, *Epomidiostomum* caused lesions in the mucosal lining of the gizzard. *Heterakis dispar* was found in the ceca of 23 out of the 48 (47.9%) hosts and exhibited a mean intensity of 3.17. *Trichostrongylus tenuis* infections occurred in 75% of all hosts sampled with a mean intensity of 22.89. Only two other parasite species were seen with prevalence > 30%. *Amidostomum* sp., a nematode found under the mucosal lining of the gizzard, was found in 15 of the 43 hosts and showed a mean intensity of 2.00. *Hymenolepis* species A, a tapeworm found in the anterior and middle one-third of the small intestine, was found in 22 of the 48 hosts. Because I was unable to locate all scolices and the fact that individual worms broke during freeze and thaw cycles, mean intensities were unable to be calculated for species of Cestoda. The other three helminth species, *Hymenolepi*s species B, *Echinostoma revolutum,* and *Zygocotyle lunata*, were rare among hosts, with prevalences < 6.5%.

Only *T. tenuis* showed a significant difference in prevalence between host species, being more common in Ross's geese (p=0.04, Fig. 1). Prevalence of *Heterakis dispar* was significantly higher in adults than juveniles in combined hosts (p=0.01, Fig. 2). There was no significant difference in prevalence of any worm based on the sex of the host (P>0.05). Analysis of mean intensities for each helminth taxa showed no significant difference between the sex of the host (Fig. 3), but mean intensity of *T. tenuis* was significantly higher in Ross's geese (p=0.04, Fig. 4). *Trichostrongylus tenuis* infections also exhibited a significantly higher mean intensity in juvenile Ross's geese (50.5) than adult Ross's geese (20.5) (p=0.02, Fig. 5).

Heterakis dispar had a prevalence of 47.9 % with a mean intensity of 3.2 (Table 2). *Amidostomum* sp. exhibited a prevalence of 35% with a mean intensity of 2 (Table 2). *Trichostrongylus tenuis* infections were found in 75% of all hosts sampled and was seen to express a mean intensity of 22.9 (Table 2). *Epomidiostomum* sp. infected 42 out of the 43 (97.9%) hosts sampled with a mean intensity of 9.1 (Table 2). A high percentage of uninfected hosts produced skewed distribution abundance patterns, typical of many parasites, in *Heterakis dispar* (Fig. 6A) and *Amidostimum* sp (Fig. 6B). *Trichostrongylus tenuis* also showed a skewed distribution, but the high mean intensity is reflected in the longer tail (Fig. 6C). Conversely, a high prevalence, and therefore few uninfected hosts, in *Epomidiostomum* sp. produced a more normal abundance distribution, which is less typical of parasite distributions (Fig. 6D).

Discussion

Light geese migrating through Illinois were infected with a diverse assemblage of parasitic helminths. Of the eight helminth taxa recovered, six were generalist parasites, infecting numerous species of waterfowl including lesser snow geese and Ross's geese (Buscher 1965, Clinchy & Barker 1994, Fedynich et al. 2005, Mellor & Rockwell 2006, Purvis et al., 1997, Tuggle & Crites 1984). This lends support to my hypothesis that these similar hosts would share paratistes. *Hymenolepis* species B, *Zygocotyle lunata*, and *Echinostoma revolutum* were only found in lesser snow geese in this study (albeit at low levels), however, indicating that these worms were more host specific. It is unclear how much of this is because of the small sample size of Ross's geese, as *Z. lunata* and *Echinostoma* have been previously reported from Ross's geese (Fedynich et al. 2012).

Parasitic helminthes have either a direct lifecycle (requiring a single host to complete development) or an indirect lifecycle (requiring at least 2 hosts). Parasite assemblages in light geese were dominated by nematodes with direct life cycles. Specifically, *Amidostomum* sp., *Epomidiostomum* sp., *Trichostrongylus tenuis,* and *Heterakis dispar* utilize a direct life cycle and were far more prevalent than species with an indirect life cycle. All the parasites utilizing an indirect life cycle, except *Hymenolepis* species A, had a prevalence of less than 8%. While migrating through the Midwest, snow geese primarily feed on grasses and various types of waste grain such as corn and soybeans (Alisauskas et al. 1988). Thus, they might be more likely to ingest infective parasite larvae of a direct life history directly from the ground, than eat an infected intermediate host such as an insect or snail. Arguably, both species of snow geese have a greater exposure rate to parasites using a direct life history.

Trichostrongylus tenuis is a small bursate nematode found in the caeca of numerous species of domestic and migratory waterfowl. It has a direct life cycle, in which infective larvae are ingested and a short life span (Hudson et al. 1992). In this study, *T. tenuis* showed a higher prevalence and mean intensity in Ross's Geese than in lesser snow geese, and higher mean intensity in juvenile Ross's than adults. Fedynich et al. (2005) reported similar findings. *Trichostrongylus tenuis* infections were similar among age classes of lesser snow geese in this study, but have been documented to exhibit higher mean intensities in juveniles than adults (Forbes et al. 1999). Interspecific differences might be an artifact of this study, but the age-dependent differences probably have an immunological explanation. It is common for initial infections to be the most successful, before the immune system can fight them off (Soulsby 1982). The size of immune defense organs such as the spleen and the bursa of Fabricius in birds has been associated with the ability to defend against parasite infections (Møller & Erritzøe 1998).

The abundance curve for *T. tenuis*, with many uninfected individuals would model a parasite that infects young animals and is cleared and produces some immunologic resistance to reinfection. Conversely, the *Epomidiostomum* sp. abundance curve showed few uninfected hosts. This might be more reflective of a longer-lived parasite that persists as hosts age, thus infecting more animals and increasing prevalence. The mean intensity in adults was not higher than in juveniles however, so seemingly infected birds do not accumulate more worms. The ability of an existing infection to provide protection from new infections (premunition or concomitant immunity) is well documented (Roberts & Janovy 2009).

Table 3 shows parasite infections within light geese recovered in Illinois to documented parasite burdens in birds resident on the breeding grounds in northern Canada (Clinchy & Barker

1994), resident on the wintering grounds along the southern coast of the United States (Purvis et al. 1997) and over the course of their northward migration (Forbes et al., 1999). Because snow geese were collected during their spring migration to the breeding grounds, I assumed that parasite infections recovered in Illinois would be similar to when they arrive on the breeding grounds or when they leave the wintering grounds.

Of the eight helminth species recovered in Illinois, four species of nematodes, *Amidostomum* sp., *Epomidiostomum* sp., *Heterakis dispar,* and *Trichostrongylus tenuis*, were common on both the breeding and wintering grounds (Clinchy & Barker 1994, Purvis et al. 1997). Prevalence and mean intensity of *Amidostomum* sp. and *Epomidiostomum* sp. were similar in resident snow geese on the breeding grounds and wintering grounds (Clinchy & Barker 1994, Purvis et al. 1997). The prevalence of *Trichostrongylus tenuis* and *Heterakis dispar* was generally lower on the wintering grounds than on the breeding grounds (Clinchy & Barker 1994, Purvis et al. 1997). The development and survival of infective larvae of *Trichostrongylus tenuis* decreases at low temperatures (Shaw et al. 1989). The corresponding drop in density of infective larvae within the feeding environment of southward-migrating snow geese limits the number of new infections and might explain the decrease in prevalence. Over the course of their northern migration to the breeding grounds, the prevalence of *T. tenuis* ranged from 16.1% to 79.3% (Forbes et al., 1999). The time required for *T. tenuis* eggs to fully develop into infective L3 larvae is 7 days (Hudson et al. 1992). Because these hosts are not resident in one area, the eggs of *T. tenuis* do not have enough time to develop into infective stages before the hosts move on. Successive waves of birds may then be exposed to infective larvae from previous birds, but this random exposure might explain the fluctuating prevalence of *T. tenuis* during the spring migration.

Amidostomum sp. was present in 35% of all snow geese sampled in Illinois, with an average of 2.00 worms per infected host. This was similar to the documented 40% prevalence with an average of 2 worms on the breeding grounds and 45% prevalence with an average of 3 worms on the breeding grounds. *Epomidostomum* showed up in nearly 100% of all hosts sampled with a mean intensity greater than 9 in all three locations.

Of the geese sampled in Illinois, 48% of all hosts were infected with 3.2 individuals of *Heterakis dispar*. The prevalence of *H. dispar* within Illinois fell within wide the ranges of documented prevalence on the wintering grounds (57% to 72%; Forbes et al. 1999, Purvis et al. 1997) and on the breeding grounds (12% to 70%; Clinchy and Barker 1994, Forbes et al. 1999). Mean intensity of *H. dispar* was greater than 29 worms in resident birds on the breeding grounds. It was only 5.5 in resident birds on wintering grounds, however, and similar to a value of 3.2 seen in birds migrating through Illinois. Birds seem to lose *H. dispar* infections along the length of their northerly migration, and then infections increase in resident birds.

The prevalence of *Trichostrongylus tenuis* infections in snow geese during their spring migration fluctuated from 14.8% to 79.3% with an average prevalence of 46% (Forbes et al. 1999), while 43% of all hosts sampled on the wintering grounds were infected (Purvis et al. 1997). The prevalence of *T. tenuis* infections in Illinois (75%) was closer to that when they left the breeding grounds than when they arrived on the breeding grounds, and the mean intensity recorded in Illinois (22.9) resembled the documented mean intensity from resident birds on the wintering grounds (24.7). Birds seem to lose *T. tenuis* infections between Illinois and the breeding grounds, then as with *H. dispar*, infections increase in resident birds.

The trematodes, *Echinostoma revolutum* and *Zygocotyle lunata*, were recovered within the gastrointestinal tracts of snow geese on the wintering grounds in southern Texas, while

Echinostoma trivolvus was documented within lesser snow geese on their spring migration north (Forbes et al. 1999, Purvis et al. 1997). Documented prevalences of these species ranged from 0 to 64.3%, with the highest percentages being observed while snow geese are on the breeding grounds and on the wintering grounds (Forbes et al. 1999, Purvis et al. 1997). The prevalence of trematodes in Illinois was lower than that recorded from resident birds on breeding and wintering grounds. The increased number of marshes, bays, and potholes available on the breeding grounds and the wintering grounds might be directly related to the number of intermediate hosts in the environment and might explain the high documented prevalences of trematodes in the most northern and southern regions. It would be particularly interesting to compare these trematode burdens in adults birds to newly hatched goslings that feed preferentially on invertebrates.

The snow geese that were sampled while migrating through Illinois on their spring migration were infected with common waterfowl parasites, which were documented on both the breeding grounds in northern Canada and on the wintering grounds along the southern coast of the United States. Different patterns were seen, with some parasites like the gizzard worms persistently high in all locations while *H. dispar* and *T. tenuis* infections fluctuating throughout the year.

Conclusions

The major conclusions of this study are as follows:

(1) Eight helminth taxa (4 nematodes, 2 trematodes, 2 tapeworms) were recovered in snow geese within Illinois.

(2) Helminths with direct life histories expressed a higher prevalence than helminths with indirect life histories.

(3) *Trichostrongylus tenuis* infections expressed higher prevalence and mean intensities in Ross's geese than lesser snow geese and higher mean intensity in juvenile Ross's geese than adult Ross's geese.

(4) *Heterakis dispar* prevalence was significantly higher in adult birds than juveniles in pooled hosts.

(5) Different patterns were seen. Gizzard worms were consistently high in all locations while *H. dispar* and *T. tenuis* infections varied throughout.

Table 1. List of helminth species found in each species of snow geese in Illinois during the spring conservation season.

Species of Helminth	Lesser Snow Goose	Ross's Goose
Nematoda		
Epomidiostomum sp.	X	X
Amidostomum sp.	X	X
Heterakis dispar	X	X
Trichostrongylus tenuis	X	X
Trematoda		
Echinostoma revolutum	X	
Zygocotyle lunata	X	
Cestoda		
Hymenolepis species A	X	X
Hymenolepis species B	X	

Table 2. Mean intensity and prevalence of helminths from snow geese collected in Illinois during the spring conservation season.

	Lesser Snow Goose	Ross's Goose	Total Geese
	MI ± SE* (P*)	MI ± SE P	MI ± SE P
Species			
Nematoda			
Amidostomum sp.	2.154 ± 0.451 (38.2%)	1.000 ± 0 (22.2%)	2.000 ± 0.402 (34.9%)
Epomidiostomum sp.	9.706 ± 1.441 (100%)	6.000 ± 1.868 (88.9%)	9.143 ± 1.225 (97.7%)
Heterakis dispar	3.611 ± 0.589 (47.4%)	1.600 ± 0.245 (50%)	3.174 ± 0.494 (47.9%)
Trichostrongylus tenuis	19.192 ± 3.081 (68.4%)	32.500 ± 6.824 (100%)	22. 889 ± 3.059 (75.0%)
Trematoda			
Echinostoma revolutum	1.000 ± 0 (7.9%)	- (0%)	1.000 ± 0 (6.3%)
Zygocotyle lunata	28.000 ± 0 (2.6%)	- (0%)	28.000 ± 0 (2.1%)
Cestoda			
Hymenolepis species A	(52.6%)	(20%)	(45.8%)
Hymenolepis species B	(5.3%)	(0%)	(4.2%)

MI ± SE*= Mean Intensity ± standard error
P*=Prevalence.
4 of 38 Lesser and 1 of 10 Ross's geese were not examined for gizzard worms

Table 3. Documented helminth infections (mean intensity, and prevalence) recorded from snow geese, on the wintering grounds, in Illinois, and on the breeding grounds.

Species	Wintering Grounds (MI)* P*	In Illinois (MI) P	Breeding Grounds (MI) P
Cestoda			
Drepanidotaenia sp.	**A.** (1.0) 28.6% **B.** 13.9%	—	**B.** 1.2%
Microsomacanthus sp.	**A.** (5.0) 14.3%	—	—
Retinometra sp.	**A.** (1.0) 42.9%	—	—
Sobolevicanthus gracilis	**B.** 37.6%	—	**B.** 0
Hymenolepis Species A	—	45.8%	—
Hymenolepis Species B	—	4.2%	—
Nematoda			
Amidostomum sp.	**A.** (3.1) 45.5%	(2.0) 34.9%	**C.** (2) 40%
Epomidiostomum sp.	**A.** (15.9) 95.5%	(9.1) 97.9%	**C.** (14) 100%
Heterakis dispar	**A.** (29.5) 57.1% **B.** 72.3%	(3.2) 47.9%	**B.** 12.2% **C.** (5.5) 70%
Trichostrongylus tenuis	**A.** (24.7) 42.9% **B.** 62.8%	(22.9) 75%	**B.** 28.1% **C.** (67) 100%
Trematoda			
Echinostoma revolutum	**A.** (7.5) 28.6%	(1.00) 6.3%	—
Zygocotyle lunata	**A.** (1.0) 14.3%	(28.00) 2.1%	—
Echinostoma trivolvus	**B.** 16.8%	—	**B.** 16.5%

MI*= Mean Intensity; P*=Prevalence

A= Purvis et al. 1997 — Resident birds

B= Forbes et al. 1999 — Birds leaving wintering; Birds arriving on breeding

C= Clinchy & Barker 1994 — Resident birds

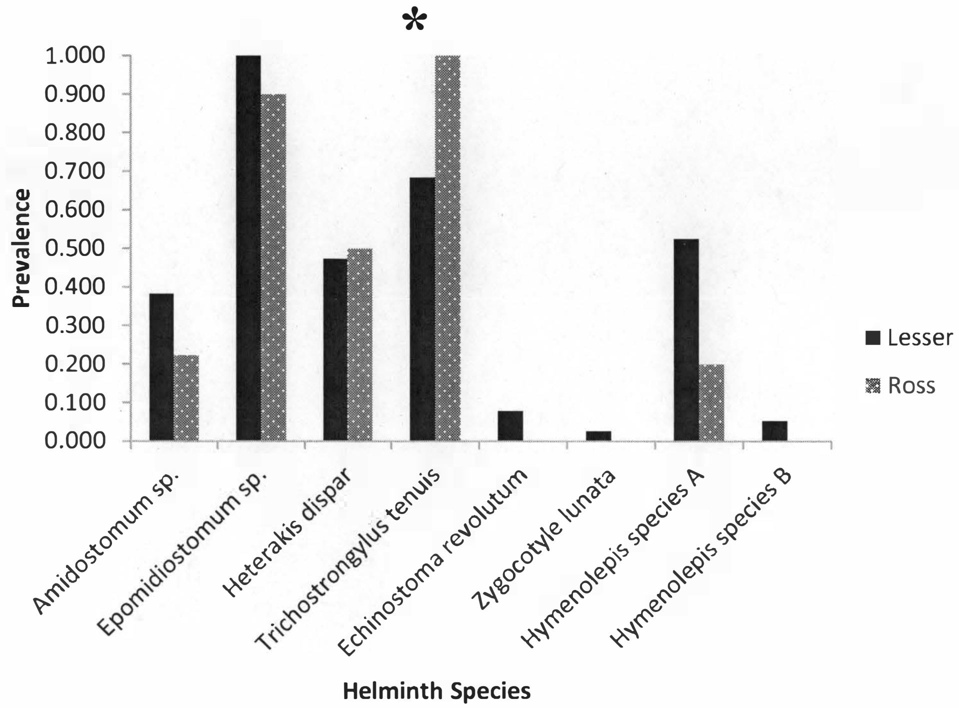

Figure 1. Prevalence of eight helminth taxa recovered from two species of snow geese in Illinois during the 2012 spring conservation season in Raymond, Illinois. The prevalence of *Trichostrongylus tenuis* in Ross's geese was higher than that of lesser snow geese (p=0.04).

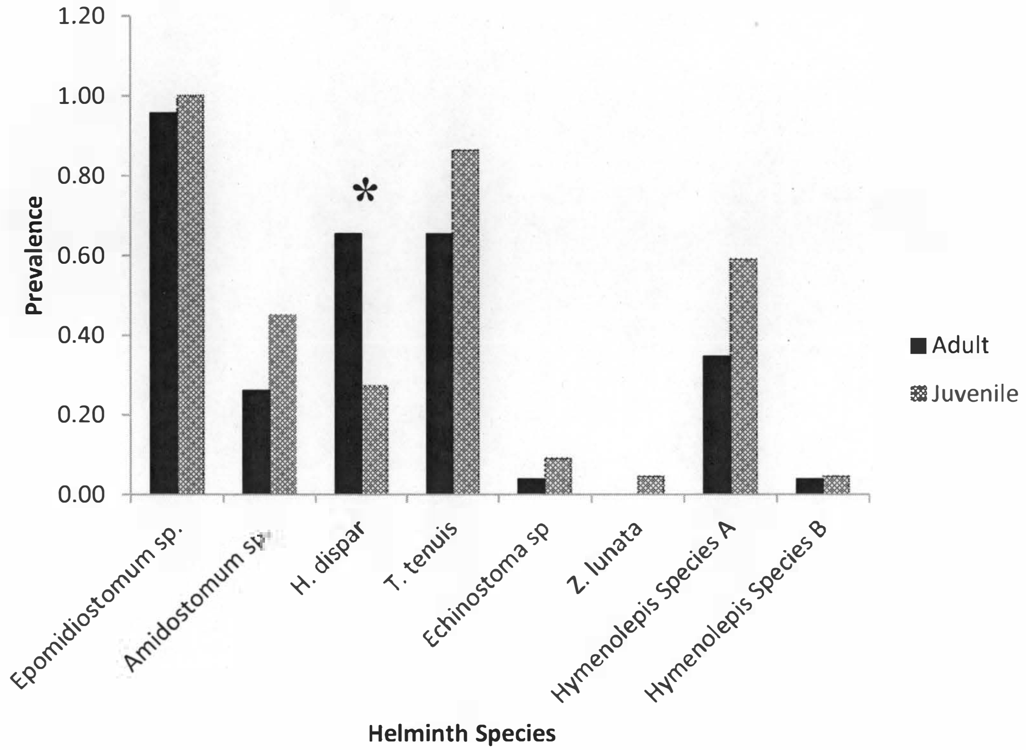

Figure 2. Prevalence of eight helminth taxa recovered from snow geese in Illinois based on age. The prevalence of *Heterakis dispar* in adult snow geese was higher than that of juvenile geese (p=0.01).

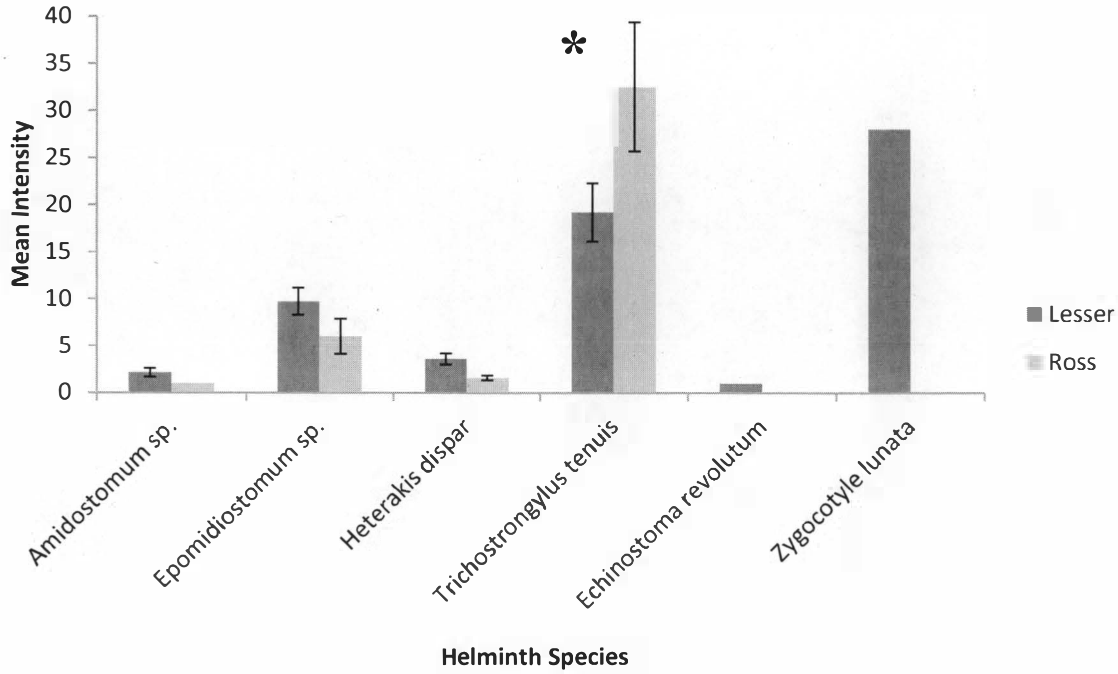

Figure 3. Mean intensity of six helminth taxa ± one standard error recovered from two species of snow geese during the 2012 spring migration in Raymond, Illinois. *Hymenolepis* species A and B were excluded due to the inability to determine an accurate mean intensity for each. *Trichostrongylus tenuis* was the only species that showed a difference among species (p=0.04).

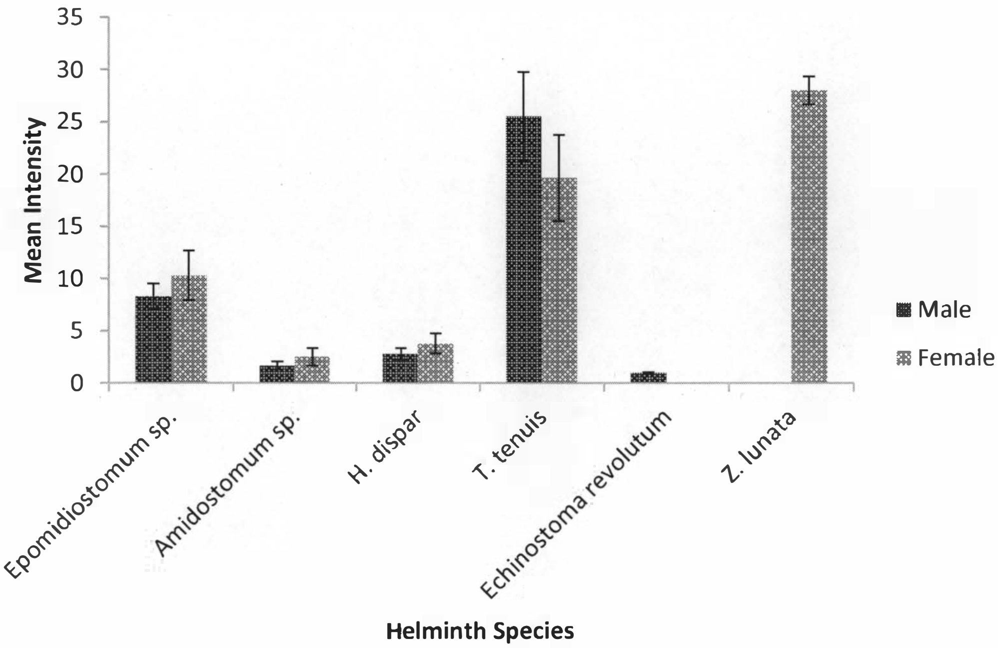

Figure 4. Mean intensities ± one standard error of helminth taxa recovered from snow geese in Illinois divided by sex of host. *Hymenolepis* species A and B were excluded due to the inability to determine an accurate mean intensity for each. No differences were observed among the six helminth taxa based on sex of host.

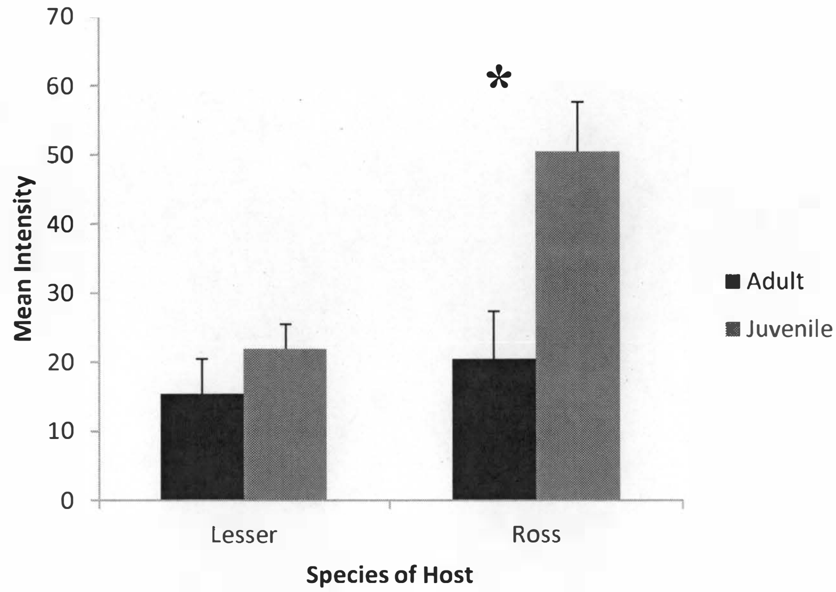

Figure 5. Mean intensities ± one standard error of *Trichostrongylus tenuis* infections based on age of host within two species of light geese found in Illinois during the spring 2012 conservation season. Juvenile Ross's geese exhibited higher mean intensities than adult Ross's geese ($p=0.02$).

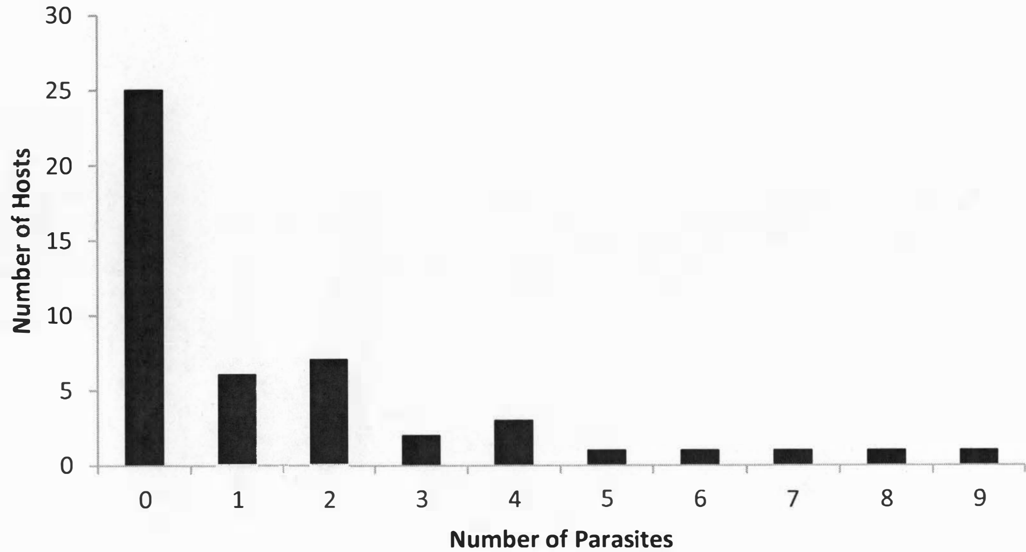

Figure 6A.

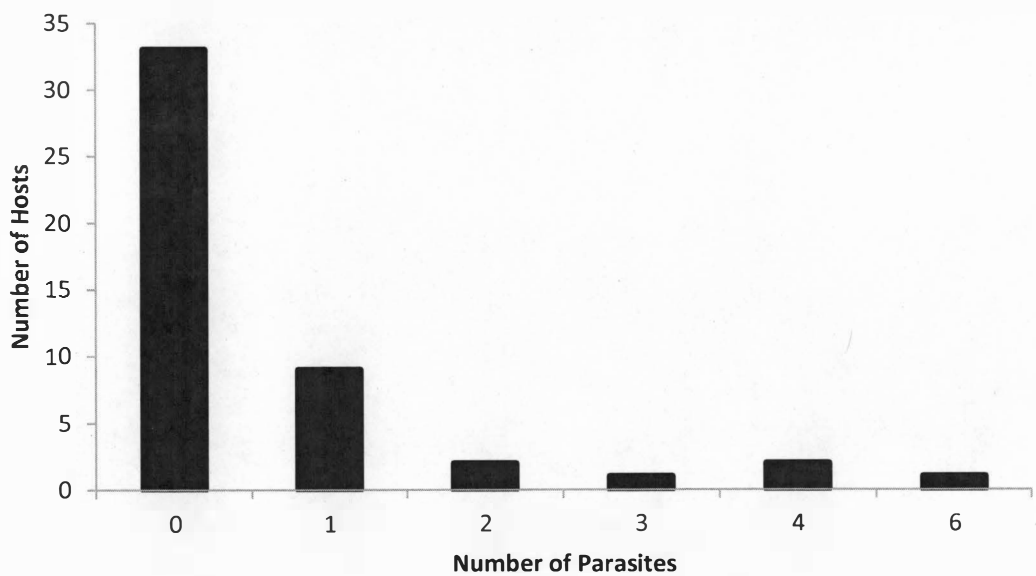

Figure 6B.

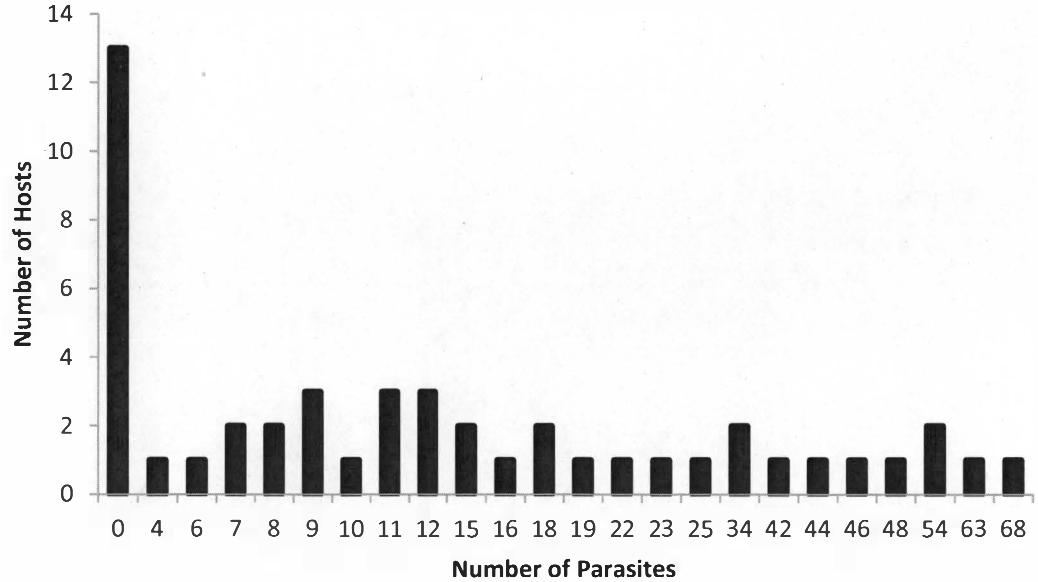

Figure 6C.

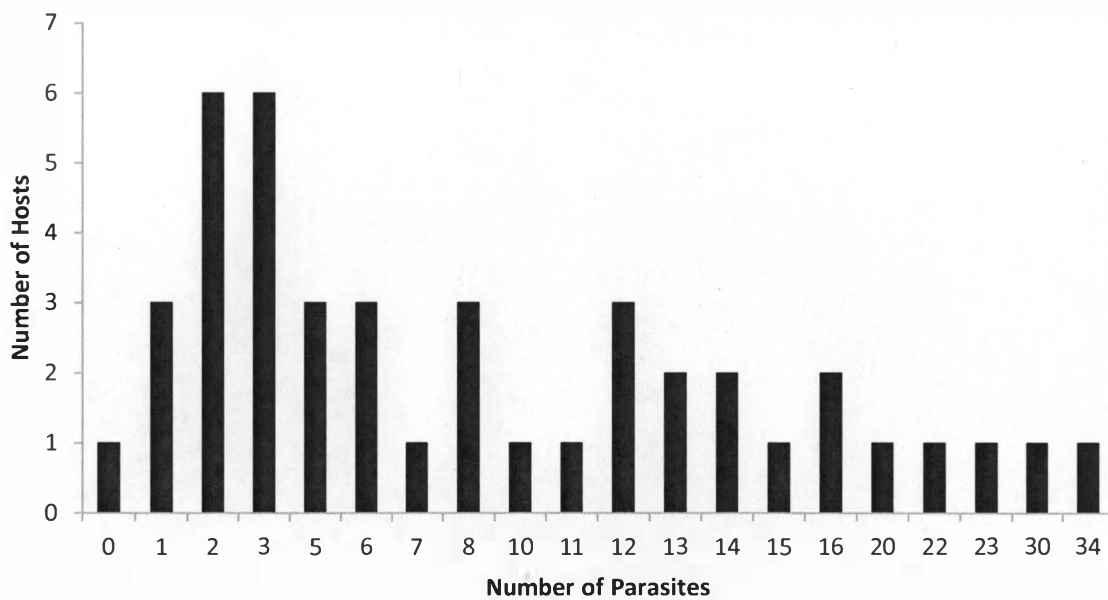

Figure 6D.

Figure 6. Abundance curves showing differences in distributions among the four parasitic nematode species: *Heterakis dispar* (A), *Amidostomum* sp. (B), *Trichostrongylus tenuis* (C), and *Epomidiostomum* sp. (D).

Literature Cited

Abraham, K. F., Jefferies, R. L., and Alisauskas, R. T. The dynamics of landscape change and snow geese in mid-continent North America. Global Change Biology, 11 (2005): 841-855.

Alisauskas, R.T. The Status of Ross's Geese. U.S. Fish and Wildlife Service and Canadian Wildlife Service, (2001): 5-9.

Alisauskas, R. T., Ankney, C. Davison, and Klaas, Erwin E. Winter diets and nutrition of midcontinental lesser snow geese. Journal of Wildlife Management, 52 (1988): 403-414.

Ankney, C. D. Feeding and digestive organ size in breeding lesser snow geese. The Auk, 94 (1977): 275-282.

Bêty, J., Giroux, J. F., and Gauthier, G. Individual variation in timing of migration: causes and reproductive consequences in greater snow geese (*Anser caerulescens atlanticus*). Behavioral Ecology and Sociobiology, 57 (2004): 1-8.

Buscher, H. N. Dynamics of the intestinal helminth fauna in three species of ducks. Journal of Wildlife Management, 29 (1965): 772-781.

Clinchy, M., and Barker, I. K. Dynamics of parasite infections at four sites within lesser snow geese (*Chen caerulescens caerulescens*) from the breeding colony at La Perouse Bay, Manitoba, Canada. Journal of Parasitology, 80 (1994): 663-666.

Cole, R. A., and Friend, M. Parasites and Parasitic Diseases (Field Manual of Wildlife Diseases). Zoonotics and Wildlife Disease, 15 (1999):

Cooch, G. Ecological aspects of the blue-snow goose complex. The Auk, 78 (1961): 72-89.

Cooke, F., MacInnes, C.D., and Prevett, J.P. Gene flow between breeding populations of lesser snow geese. The Auk, 92 (1975): 493-510.

Fedynich, A. M., Finger, R. S., Ballard, B. M., Garvan, J. M., and Mayfield, M. J. Helminths of Ross's and greater white-fronted geese wintering in south Texas, U.S.A. Comparative Parasitology, 72 (2005): 33-38.

Forbes, M.R., Alisauskas, R. T., and McLaughlin, J. D. Explaining Co-occurrence among helminth species of lesser snow geese (*Chen caerulescens*) during their winter and spring migration. Oecologia, 120 (1999): 613-620.

Hudson, P. J., Newborn, D., and Dobson, A. P. Regulation and stability of a free-living host-parasite system: *Trichostrongylus tenuis* in red grouse. I. monitoring and parasite reduction experiments. Journal of Animal Ecology, 61 (1992): 477-486.

Huffman, J. E., Sabol, C., and Fried, B. Infectivity, growth, survival, and pathogenicity of *Zygocotyle lunata* (Trematoda) in experimental rodent hosts. Journal of Parasitology, 77 (1991): 280-284.

Kanev, I. Life-cycle, delimitation and redescription of *Echinostoma revolutum* (Froelich, 1802)(Trematoda: Echinostomatidae). Systematic Parasitology, 28 (1994): 125-144.

McDonald, M. E. Key to Nematodes Reported in Waterfowl. US Government Printing Office. (1974).

McDonald, M. E. Key to Trematodes Reported in Waterfowl. US Department of Interior, Fish and Wildlife Service. (1981).

Møller, A. P., and Erritzøe, J. Host immune defense and migration in birds. Evolutionary Ecology, 12 (1998): 945-953.

Mellor, A. A., and Rockwell, R. F. Habitat shifts and parasite loads of lesser snow geese (*Chen caerulescens caerulescens*). Ecoscience, 13 (2006): 497-502.

Purvis, J. R., Gawlik, D. E., Dranen, N. O., and Silvy, N. J. Helminths of wintering geese in Texas. Journal of Wildlife Disease, 33 (1997): 660-663.

Roberts, L. S., and Janovy Jr., J. Foundations of Parasitology.8th ed. McGraw Hill (2009).

Shaw, J. L., Moss, R., and Pike, A. W. Development and survival of the free-living stages of *Trichostrongylus tenuis*, a caecal parasite of red grouse *Lagopus lagopus scoticus.* Parasitology, 99 (1989): 105-113.

Shutler, D., Alisauskas, R. T., and McLaughlin, J. D. Associations between body composition and helminths of lesser snow geese during winter and spring migration. International Journal of Parasitology, 42 (2012): 755-760.

Soulsby, E.J. L., Helminths, Arthropods, and Protozoa of Domesticated Animals. 7th ed. Lea and Febiger, (1982).

Tuggle, B. N., and Crites, J. L. The prevalence and pathogenicity of gizzard nematodes of the genera *Amidostomum* and *Epomidiostomum* (Trichostrongtylidae) in the lesser snow goose (*Chen caerulescens caerulescens*). Canadian Journal of Zoology, 62 (1984): 1849-1852.