SEO, B. S. 1990. *Fibricola seoulensis* Seo, Rim, and Lee, 1964 (Trematoda) and fibricoliasis in man. Seoul Journal of Medicine **31:** 61–96.

———, S. Y. CHO, S. T. HONG, S. J. HONG, AND S. H. LEE. 1981. Studies of parasitic helminths of Korea V. Survey on intestinal trematodes of house rats. Korean Journal of Parasitology **19:** 131–136.

———, S. H. LEE, S. T. HONG, S. J. HONG, C. Y. KIM, AND H. Y. LEE. 1982. Studies on intestinal trematodes in Korea V. A human case infected by *Fibricola seoulensis* (Trematoda: Diplostomatidae). Korean Journal of Parasitology **20:** 93–99.

———, H. J. RIM, AND C. W. LEE. 1964. Studies on the parasitic helminths of Korea. 1. Trematodes of rodents. Korean Journal of Parasitology **2:** 20–26.

SHOOP, W. L. 1989a. Systematic analysis of the Diplostomidae and Strigeidae (Trematoda). Journal of Parasitology **75:** 21–32.

———. 1989b. Experimental human infection with *Fibricola cratera* (Trematoda: Neodiplostomidae). Korean Journal of Parasitology **27:** 249–252.

J. Parasitol., 80(4), 1994, p. 663–666

Dynamics of Parasitic Infections at Four Sites within Lesser Snow Geese (*Chen caerulescens caerulescens*) from the Breeding Colony at La Pérouse Bay, Manitoba, Canada

Michael Clinchy* and Ian K. Barker†, Biology Department, Queen's University, Kingston, Ontario, Canada K7L 3N6; and †Department of Pathology, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada N1G 2W1. *Present address: Department of Zoology, University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z4

ABSTRACT: We enumerated parasite burdens within the blood, gizzard, ceca, and kidneys of adult female lesser snow geese *Chen caerulescens caerulescens* collected from the breeding colony at La Pérouse Bay, Manitoba, Canada, in 1989. We observed 5 species of nematodes, 1 species of digenean, 1 species of protozoan, and an unidentified microfilaria in these geese. We compared parasite burdens between geese collected during the incubation (2–14 June) and brood-rearing (1–5 August) periods. There was a significant decrease in the prevalence and intensity of the gizzard nematode *Amidostomum spatulatum* and a significant increase in the prevalence of the renal coccidium *Eimeria truncata* between the 2 collection periods. We suggest that the changes concerning *A. spatulatum* reflect transmission conditions some 6 months earlier when the geese were on the wintering grounds. Changes involving *E. truncata* reflected transmission conditions within the previous month. Consequently, it would appear that breeding colonies are the foci for transmission of *E. truncata,* a significant pathogen of adults and goslings.

Gajadhar, Cawthorn et al. (1983a) reported that in Saskatchewan, Canada the prevalence of coccidia *Eimeria* sp. within the kidneys of adult lesser snow geese *Chen caerulescens caerulescens* is generally much greater during the autumn migration (August to October) than the spring migration (April to June). There are to date no published reports on the dynamics of *Eimeria* sp. infections in lesser snow geese from the northern breeding colonies, the migratory destination. This is surprising because renal coccidia are significant pathogens of waterfowl (Gajadhar, Wobeser, and Stockdale, 1983b) and could be an important factor limiting snow goose populations, especially through adverse effects on newly hatched goslings. Here we compare parasite burdens within the blood, gizzard, ceca, and kidneys of adult female lesser snow geese collected during the incubation and brood-rearing periods from the northern breeding colony at La Pérouse Bay, Manitoba, Canada (58°4′N, 94°4′W). Examinations were restricted to these 4 sites within the host as we were primarily concerned with parasites likely to affect host reproduction (see Clinchy and Barker, 1994).

The breeding colony at La Pérouse Bay has been the location of a long-term study on the ecology of lesser snow geese since 1968. General field methods regarding the collection of data on snow goose ecology at La Pérouse Bay are described in Finney and Cooke (1978). Fifty-five adult female lesser snow geese were collected at La Pérouse Bay during the summer of 1989. Thirty-five females were killed with shotguns during the incubation period from 2 to 14 June. Twenty females were live-trapped and given lethal injections during mass leg-banding drives during the brood-rearing period between 1 and 5 August. Adult geese are easily captured in Au-

gust since they undergo a complete molt of their flight feathers and are unable to fly.

We collected blood samples and removed the gizzard, both ceca, and the kidneys from each of the birds. The gizzard, ceca, and kidneys were frozen until they could be processed. The gizzards of 10 of the 20 females collected during the brood-rearing period were accidentally allowed to thaw and rot before they could be examined. Consequently, data concerning gizzard infections during the brood-rearing period are only available for 10 females (see Table I).

Blood smears were prepared from each of the birds within 30 sec of death (see Bennett, 1970). Smears were air-dried and then fixed in 100% methanol. Smears were later stained with Wright's solution and scanned for hematozoa. Scanning involved 30 fields at 40× power, using ordinary light microscopy. Examination of the gizzard followed the procedures of Tuggle and Crites (1984). A single 1-cm-thick transverse section was removed from both ceca at approximately the midpoint and fixed in 10% neutral buffered formalin (NBF) for histopathological examination. Each cecum was opened and the contents were scraped out using the edge of a microscope slide. Cecal contents were mixed with tap water and strained through a 250-μm mesh. Material retained in the mesh was rinsed into a dissecting dish and 5 drops of Lugol's iodine solution were added. After 20 min, 3 drops of 10% aqueous sodium thiosulfate solution were added and the contents of the dish were immediately examined for helminths using a dissection microscope. The left kidney from each bird was fixed in 10% NBF while the right kidney was preserved in a 2.5% aqueous potassium dichromate solution. Four, 5-μm-thick, hematoxylin and eosin-stained transverse sections of the left kidney were examined microscopically for the presence of coccidia, or associated pathology, or both. The right kidney was examined for oocysts of renal coccidia using simple flotation (Gajadhar, Cawthorn et al., 1983a).

Using the standardized Morista index of dispersion (Krebs, 1989), we found that for several of the species of parasites we observed that the distribution among hosts deviated significantly from randomness. Consequently, nonparametric statistics were used to compare parasite burdens between geese collected during the incubation and brood-rearing periods. Application of statistical procedures followed Siegel and Castellan (1988). Differences in prevalence were compared using Fisher's exact test (Finney et al., 1963; Sokal and Rohlf, 1981). The Mann–Whitney *U*-statistic was used to assess differences in intensity. Overall, 14 comparisons were made. We used the Bonferroni procedure (Keppel and Zedeck, 1989) of dividing alpha (traditionally = 0.05) by

TABLE I. Site in host, prevalence, and intensity of parasitic infections in adult female lesser snow geese collected during incubation (2–14 June) and brood-rearing (1–5 August) periods from the La Pérouse Bay, Manitoba, Canada breeding colony in 1989.

Parasite species	Site in host	Prevalence*			Intensity†				
					Incubation		Brood-rearing		
		Incubation	Brood-rearing	*P*‡	Median	Range	Median	Range	*P*‡
Hematozoa									
Microfilaria (sp. ?)	Blood	0/35	1/20	>0.1	–	–	1	1	–
Nematodes									
Amidostomum anseris	Gizzard	24/35	4/10	>0.1	2	1–7	1	1–4	0.2735
Amidostomum spatulatum	Gizzard	35/35	5/10	0.0004	14	3–35	3	1–5	0.0007
Epomidiostomum crami	Gizzard	35/35	10/10	>0.1	14	2–39	11	2–36	0.6226
Heterakis dispar	Ceca	28/35	14/20	>0.1	5.5	1–518	25.5	2–78	0.0229
Trichostrongylus tenuis	Ceca	35/35	20/20	>0.1	67	1–242	97	9–260	0.1836
Digeneans									
Notocotylus attenuatus	Ceca	29/35	18/20	>0.1	16	1–220	18	1–284	0.8609
Protozoans									
Eimeria truncata	Kidneys	0/35	13/20	<0.0001	–	–	–	–	–

* Prevalence was compared using Fishers' exact test.
† Intensity was compared using the Mann–Whitney *U*-statistic.
‡ Critical $P \leq 0.0036$.

the total number of comparisons to determine the critical level of significance. Consequently, statistical significance was set at $P \leq 0.0036$.

We observed a single microfilaria in the blood of 1 of the female geese collected during the brood-rearing period (Table I). Six species of helminths (5 species of nematodes and 1 species of digenean) were found in the geese during both the incubation and brood-rearing periods (Table I). The median intensity, rather than the mean, is presented in Table I since the median is a better indicator of central tendency in nonrandom distributions (Sokal and Rohlf, 1981). We observed 1 species of protozoan, but only during the brood-rearing period (Table I). Protozoan intensity is not reported in Table I because the intensity of protozoan infections cannot be determined.

All of the species of parasites we observed have been reported previously in lesser snow geese (McDonald, 1969; Gajadhar et al., 1982). What has not previously been documented are the significant changes in prevalence and intensity occurring among some species of parasites during the relatively brief time spent by the geese at the northern breeding colonies. We observed a significant decrease in the prevalence and intensity of the gizzard nematode *A. spatulatum* and a significant increase in the prevalence of the renal coccidium *E. truncata,* in only a 2-mo period at the La Pérouse Bay breeding colony (Table I). The lack of statistical power resulting from our small sample sizes is the most parsimonious explanation for why we did not find such changes in the other species of parasites observed.

The level of infection (prevalence, or median intensity, or both) in the host population at time t reflects the history of transmission from time t − d to time t where d is the duration of infection (May and Anderson, 1979). When d is small the level of infection at time t is a good estimate of the level of transmission among hosts at time t. The duration of *E. truncata* infections is approximately 1 mo (Gajadhar et al., 1982), so the level of infection at any given time reflects the level of transmission over the last month. In contrast, the duration of *A. spatulatum* infections is likely 5–6 mo, based on studies involving *A. anseris* (Stradowski, 1977). Thus, the level of *A. spatulatum* infections during incubation most likely reflects the level of transmission 5–6 mo earlier on the wintering grounds, whereas the level of infection during the brood-rearing period reflects the level of transmission during the start of the northward migration. Consequently, if transmission is reduced during the northward migration, one would expect to see lower levels of infection during the brood-rearing period. A large number of factors accompanying the start of the northward migration could result in decreased transmission; for example, exposure to harsher climatic conditions or greater spacing between hosts.

The short duration of *E. truncata* infections means that changes in the level of infection at the breeding colony reflect changes in transmission at the colony. Once climatic conditions are suitable for survival and development of infectious stages in the external environment, they may begin to accumulate in high numbers in areas frequented by the now sedentary adult geese. As the season progresses, newly hatched goslings, lacking immunity to parasitic infection, will in turn become infected and ultimately contribute further to infection pressure on the adult goose population. The combination of high host densities, low host mobility, and a large pool of newly susceptible hosts would appear to provide the ideal conditions by which breeding colonies act as foci for the transmission of *E. truncata* (Pellerdy, 1974).

Eimeria truncata is the most significant parasite pathogen facing lesser snow geese. *Eimeria truncata* is a frequent cause of death of lesser snow goose goslings (Rainnie, 1983; Clinchy, 1990) and is known to kill adult Canada geese (Hanson et al., 1957) as well as adults and goslings of several other species of geese (Gajadhar, Wobeser, and Stockdale, 1983b). If as we suggest, breeding colonies are the foci for transmission of *E. truncata,* then *E. truncata* has the potential to be a significant factor in limiting snow goose populations, especially through effects on gosling survival.

Dr. F. Cooke, Queen's University, provided partial funding and the facilities at La Pérouse Bay. Thanks to Dr. D. J. Rainnie, Atlantic Veterinary College, University of Prince Edward Island, for a copy of his thesis and help at the outset. Dr. B. Hunter, Ontario Veterinary College, University of Guelph, assisted with the hematology. Thanks to Dr. R. Greenwood, Queen's University, Dr. R. Miller, Ontario Veterinary College, University of Guelph, and Dr. J. C. Fenwick, University of Ottawa, for laboratory facilities and technical assistance. Three anonymous reviewers provided many helpful comments on an earlier draft. Funding was provided in part by a grant to M.C. from the University Research

Support Fund of the Canadian Wildlife Service. M.C. received a graduate fellowship from Queen's University and generous discretionary funds from Beryl and John Clinchy.

LITERATURE CITED

BENNETT, G. F. 1970. Simple techniques for making avian blood smears. Canadian Journal of Zoology **48:** 584–586.

CLINCHY, M. 1990. Parasitic infections of lesser snow geese (*Chen caerulescens caerulescens*) from an arctic breeding colony: Implications for snow goose demography. M.Sc. Thesis. Queen's University, Kingston, Ontario, Canada, 102 p.

———, AND I. K. BARKER. 1994. Effects of parasitic infections on clutch size of lesser snow geese from a northern breeding colony. Canadian Journal of Zoology (in press).

FINNEY, D. J., R. LATSCHA, B. M. BENNETT, P. HSU, AND E. S. PEARSON. 1963. Tables for testing significance in a 2 × 2 contingency table. Cambridge University Press, Cambridge, U.K., 103 p.

FINNEY, G. H., AND F. COOKE. 1978. Reproductive habits in the snow goose: The influence of female age. Condor **80:** 147–158.

GAJADHAR, A. A., R. J. CAWTHORN, AND D. J. RAINNIE. 1982. Experimental studies on the life cycle of a renal coccidium of lesser snow geese (*Anser c. caerulescens*). Canadian Journal of Zoology **60:** 2085–2092.

———, ———, G. A. WOBESER, AND P. H. G. STOCKDALE. 1983a. Prevalence of renal coccidia in wild waterfowl in Saskatchewan. Canadian Journal of Zoology **61:** 2631–2633.

———, G. A. WOBESER, AND P. H. G. STOCKDALE. 1983b. Coccidia of domestic and wild waterfowl (Anseriformes). Canadian Journal of Zoology **61:** 1–24.

HANSON, H. C., N. D. LEVINE, AND V. IVENS. 1957. Coccidia (Protozoa: Eimeriidae) of North American wild geese and swans. Canadian Journal of Zoology **35:** 715–733.

KEPPEL, G., AND S. ZEDECK. 1989. Data analysis for research designs: Analysis of variance and multiple regression/correlation approaches. W. H. Freeman and Co., New York, 594 p.

KREBS, C. J. 1989. Ecological methodology. Harper Collins Publishers, New York, 654 p.

MAY, R. M., AND R. M. ANDERSON. 1979. Population biology of infectious diseases: Part II. Nature **280:** 455–461.

MCDONALD, M. E. 1969. Catalogue of helminths of waterfowl (Anatidae). U.S. Department of the Interior: Bureau of Sport Fisheries and Wildlife. Special Scientific Report: Wildlife, No. 126, Washington, D.C., 692 p.

PELLERDY, L. P. 1974. Coccidia and coccidiosis, 2nd ed. Verlag Paul Parey, Berlin, 959 p.

RAINNIE, D. J. 1983. Diseases of lesser snow geese (*Anser caerulescens caerulescens*) on a breeding colony. M.Vet.Sci. Thesis. University of Saskatchewan, Saskatoon, Saskatchewan, Canada, 62 p.

SIEGEL, S., AND N. J. CASTELLAN, JR. 1988. Nonparametric statistics for the behavioural sciences, 2nd ed. McGraw-Hill Book Co. Inc., New York, 399 p.

SOKAL, R. R., AND F. J. ROHLF. 1981. Biometry, 2nd ed. W. H. Freeman and Co., San Francisco, 859 p.

STRADOWSKI, M. 1977. Duration of prepatent, patent and postpatent periods of the *Amidostomum anseris* (Zeder, 1800) infection in domestic geese. Acta Parasitologica Polonica **24:** 249–258.

TUGGLE, B. J., AND J. L. CRITES. 1984. The prevalence and pathogenicity of gizzard nematodes of the genus *Amidostomum* and *Epomidiostomum* (Trichostrongylidae) in the lesser snow geese (*Chen caerulescens caerulescens*). Canadian Journal of Zoology **62:** 1849–1852.

DATE OF PUBLICATION

Volume 80, No. 4, was mailed 25 August 1994