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GIZZARD NEMATODES OF CANADA GEESE WINTERING IN SOUTHERN ILLINOIS

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ABSTRACT: Gizzards from 64 hunter-shot Canada geese (*Branta canadensis*) were collected in southern Illinois (USA) in December 1991 and January 1992 to determine the prevalence and intensity of gizzard nematodes. Three species of gizzard nematodes were recovered: *Amidostomum anseris*, *Amidostomum spatulatum*, and *Epomidiostomum crami*. The prevalence of infection was 98%. Mean intensity was 17.8 nematodes per host and was significantly greater for immature geese (40.3 nematodes/host) than for adult geese (10.9 nematodes/host). The intensity of both *A. anseris* and *E. crami* was greater in immature geese, but even the most heavily infected birds did not display serious lesions. Despite a dramatic increase in the population of geese, mean intensity in adult geese was similar to mean intensity reported from earlier studies at the same site. Mean intensity in immature geese in 1991 and 1992 was greater than in earlier studies.

Key words: *Amidostomum* spp., *Epomidiostomum* spp., Canada goose, *Branta canadensis*, Mississippi Valley population.

INTRODUCTION

Gizzard worms (*Amidostomum* spp. and *Epomidiostomum* spp.) are nematode parasites that have a wide geographic distribution and infect many species of waterfowl (McLaughlin and McGurk, 1987). Although they are common parasites in waterfowl, gizzard nematodes are not considered an important cause of mortality. Nevertheless, they may cause serious disease in Canada geese (*Branta canadensis*) if geese are malnourished and crowded on wintering grounds (Herman et al., 1955).

Gizzard nematodes have at least two characteristics that could pose a hazard to Canada geese and their populations. First, lesions these nematodes produce may impair the ability of geese to digest food (Herman and Wehr, 1954). Second, the nematodes have a short (6 day) and direct life cycle (Leiby and Olsen, 1965) and can infect geese on wintering grounds (Herman and Wehr, 1954).

Our objectives in this study were to determine the prevalence and intensity of gizzard nematodes in Canada geese wintering in southern Illinois (USA), compare the prevalence and intensity of infections among hosts of different age classes and sex, and compare our results with those of earlier studies from the same location (Hanson and Gilford, 1961; Tuggle, 1982; D. Roby, unpubl.). We suspected parasite transmission might have increased because the Mississippi Valley population increased from 150,000 geese in the 1940's (Reeves et al., 1968) to almost one million geese in 1990 (A. Woolf, unpubl.) without an increase in winter habitat.

MATERIALS AND METHODS

We collected gizzards from hunter-shot Canada geese at a cleaning station approximately 3.2 km east of Ware, Union County, Illinois (37°27'N, 89°23'W). We only accepted geese that were shot near the Union County Conservation Area and were limp and warm at the time hunters submitted them for cleaning. We determined the age class and sex of these geese from plumage characteristics and cloacal morphology (Hanson, 1962). We separated gizzards from surrounding tissue, weighed them, and noted their general condition. Afterwards, we placed them on ice and then stored them at −20 C until they were examined for parasites.

We thawed gizzards at 16 C and examined them within 12 hr by cutting each one open and flushing it with tap water. The gizzard contents and its internal surface were then examined at 5× for nematodes. Afterwards, the epithelium was scraped away from underlying tis-

sues and examined again. The koilin layer of the gizzard was peeled from underlying tissues and both were examined. The gizzard muscle was examined intact, and after it was cut into sections.

We noted gross appearance of the gizzards and recorded the location and the number of nematodes present. We identified all nematodes to species and sex (McDonald, 1974) at the same time. Nematodes were considered immature if they were females and lacked eggs or males and lacked sperm. Later, we fixed and stored nematodes in glycerine alcohol. Representative specimens of male and female *Epomidiostomum crami* (accession numbers: 84049, 84050), *Amidostomum anseris* (84051, 84052), and *A. spatulatum* (84053, 84054), were deposited in the U.S. National Parasite Collection (Beltsville, Maryland, USA).

Data from this study were compared to data on gizzard nematodes in Canada geese wintering in southern Illinois during the winters of 1988 and 1989 (D. Roby, unpubl.), 1979 to 1981 (Tuggle, 1982), and 1950 to 1953 (Hanson and Gilford, 1961). Gizzards were examined in a similar manner in all studies.

We analyzed the data set from the winter of 1991 to 1992 to examine factors affecting gizzard nematode distribution in Canada geese. Our null hypotheses were that the prevalence and intensity of gizzard nematodes were independent of host sex, host age class, and the occurrence of other gizzard nematode species. The prevalence of infections was examined by a series of 2 × 2 contingency tables; each species of gizzard nematode was treated separately. Results with a probability ($P < 0.05$) were considered significant. Data sets from other years were examined by the same methods.

Because nematode intensity in Canada geese from 1988 and 1989 (D. Roby, unpubl.) and 1991 to 1992 differed ($P < 0.05$) from a normal distribution, we relied on non-parametric analysis of intensity whenever possible. Nonparametric methods are "not concerned with specific parameters (such as the mean in analysis of variance) but only with the distribution of the variates" (Sokal and Rohlf, 1981). We use the term intensity to refer to the distribution of intensities in the host population. Other use of terms follows established guidelines (Margolis et al., 1982). We used Wilcoxon two-sample rank sum tests (Brown and Hollander, 1977) to compare the intensity among geese age classes or sexes. We used Spearman's rank correlation (Brown and Hollander, 1977) to determine if the intensity of gizzard nematode species were independent of each other.

We also compared our data to those from geese collected in previous winters. Our null hypotheses were that the prevalence and intensity of gizzard nematodes were independent of year collected. Again, the prevalence of infections was examined by a series of 2 × 2 contingency tables. Unfortunately, most between-study comparisons of intensity could not take advantage of non-parametric statistics because the original data were not available. Therefore, we made comparisons using mean intensity and measures of variance to compute z-scores (Brown and Hollander, 1977). In the compared studies, no relationship was found between host sex and gizzard infections, but a relationship ($P < 0.05$) was found between host age and infections. Therefore, host age was controlled in all statistical analyses and host sex was ignored.

We collected 64 gizzards from hunter-shot Canada geese between 21 December 1991 and 20 January 1992. Because sex or age was not determined for some hosts, gizzards from only 47 specimens were included in analyses that depended on host sex or age class. In statistics referring to combined data, data from the other 17 gizzards were added to the total of all immature and adult geese.

RESULTS

Three species of nematodes infected the 64 gizzards we examined: *Amidostomum anseris, Amidostomum spatulatum,* and *Epomidiostomum crami* (Table 1). We recovered 1,112 nematodes; most were in the gizzard epithelium ($n = 567$) or beneath the koilin pads ($n = 521$). Twenty nematodes were in the gizzard lumen; four were in the muscle. Only 4% of the *A. anseris* in adult geese were mature compared to almost 40% in immature geese (chi-square = 53.2, $P = 0.005$). Conversely, 80% of *A. spatulatum* in adult geese were mature compared to 62% in immature geese (chi-square = 11.5, $P = 0.05$).

The prevalence of *A. spatulatum* was greater in adult geese than immature geese (chi-square = 3.9, $P < 0.05$) (Table 2). Dual infections of *A. anseris* and *E. crami* were observed more often than expected (chi-square = 5.75, $P < 0.05$) and intensity of the two species was highly correlated ($r = 0.56$, $P < 0.0005$). The intensity of gizzard nematodes (all species) was not independent of age class ($W^* = 2.03$, $P < 0.05$); immature geese harbored more nematodes than adults. The median of in-

TABLE 1. Species, sex, and stage of development of gizzard nematodes recovered from 64 Canada geese collected during the winter of 1991 to 1992 in southern Illinois.

	Immature nematodes			Adult nematodes			
	Male	Female	All	Male	Female	All	Totals
Amidostomum anseris	74	100	174	168	267	435	609
Amidostomum spatulatum	114	176	290	76	28	104	394
Epomidiostomum crami	1	2	3	42	47	89	92
Unknown	5	4	9	4	4	8	17

tensity values in immature geese was 16 (range, 2 to 215) compared to 8.5 in adults (range, 2 to 28). Finally, the intensities of *A. anseris* and *E. crami* were not independent of age class; immature geese harbored more of each species than adult geese did ($W^* = 2.58$, $P < 0.01$ and $W = 118$, $P < 0.005$, respectively).

As in the data from 1991 to 1992, the prevalence of *A. anseris* was higher in immature geese than adult geese during 1979 to 1981 and 1952 to 1953 (chi-square = 7.14, $P < 0.01$; chi-square = 5.37, $P < 0.05$) (Table 3). Also similar to the 1991 to 1992 data, the prevalence of *A. spatulatum* was greater in adult geese in 1978 to 1981 (chi-square = 6.08, $P < 0.05$). The intensity of *A. anseris* and intensity of gizzard nematodes (all species) were not independent of age class during 1979–81; immature geese carried more nematodes than adults in both cases ($Z = 2.5$, $P < 0.01$; $Z = 2.5$, $P < 0.01$).

Intensity and prevalence of infections also differed among these studies. First, mean intensity of gizzard nematodes was higher in immature and lower in adult geese in 1991 to 1992 than in 1979 to 1981 ($Z = 1.71$, $P < 0.05$; $Z = 2.03$, $P < 0.05$, respectively). Mean intensity of *A. spatulatum* was also higher in immature and adult geese from 1991 to 1992 than in 1979 to 1981 ($Z = 1.89$, $P < 0.05$; $Z = 3.77$, $P < 0.001$, respectively). No statistical comparison of intensity using data from the 1950's was possible because no measure of variation was reported with the data. Nonetheless, prior to this study, the highest mean intensity in immature geese from southern Illinois was reported in 1951 to 1952.

Changes in the prevalence of gizzard nematodes in Canada geese from the Union County Conservation Area have occurred since the first study in the area. The prevalence of *A. anseris* increased dramatically after 1951. The prevalence of *A. anseris* was highest in 1979 to 1981 for both immature (compared to 1952 to 1953, chi-square = 38.4, $P < 0.001$) and adult geese (compared to 1952 to 1953, chi-square = 44.1, $P < 0.001$). Furthermore, prevalence of gizzard nematode infections (all species) was nearly 100% for all geese in all studies after 1953. *Amidostomum spatulatum* and *E. crami* first were discovered at this site during the 1979 to 1981 study and their prevalence was higher in immature geese by 1991 to 1992 (chi-square = 4.04, $P < 0.05$; chi-square = 4.62, $P < 0.05$). Among adult geese, *A. spatulatum* also was more prevalent in the 1991 to 1992 study (chi-square = 7.17, $P < 0.01$).

DISCUSSION

We could not reject the hypothesis that gizzard nematode abundance is equal in male and female geese. Male and female geese collected in 1991 to 1992 differed in intensity of infections, but not significantly. Differences in prevalence between the sexes were not significant either. Earlier workers also failed to detect differences in intensity or prevalence between male and female geese (Tuggle, 1982; Hanson and Gilford, 1961). The consistent inability to detect differences between infections in

TABLE 2. Mean intensity and prevalence of gizzard nematode infections in adult and immature Canada geese collected during 1991 to 1992 in southern Illinois.

	Immature geese			Adult geese			Totals
	Males	Females	All	Males	Females	All	
Number collected	10	5	15	15	17	32	64
Amidostomum anseris							
Intensity	12.0 ± 9.1[a]	76.3 ± 93.4	33.4 ± 58.6	3.0 ± 3.2	8.0 ± 8.0	5.1 ± 6.1	13.1 ± 31.6
Prevalence (%)	80	80	80	80	53	66	73
Amidostomum spatulatum							
Intensity	13.2 ± 14.8	5.3 ± 3.0	10.3 ± 12.3	6.9 ± 5.7	7.4 ± 5.8	7.2 ± 5.7	7.2 ± 7.6
Prevalence (%)	70	80	73	100	88	94	86
Epomidiostomum crami							
Intensity	6.8 ± 7.7	3.0 ± 2.0	5.6 ± 6.5	2.0 ± 0.0	2.9 ± 2.1	2.7 ± 1.8	3.4 ± 4.1
Prevalence (%)	60	60	60	13	41	25	42
All species							
Intensity	22.9 ± 29.4	83.8 ± 96.4	40.3 ± 57.2	9.6 ± 5.7	12.0 ± 8.9	10.9 ± 7.5	17.8 ± 29.4
Prevalence (%)	100	80	93	100	100	100	98

[a] Mean ± standard error.

TABLE 3. Mean intensity and prevalence of gizzard nematode infections in adult and immature Canada geese collected in southern Illinois, 1950 to 1989.

	1950 to 1951[a,d]		1951 to 1952[a,d]		1952 to 1953[a,d]		1979 to 1981[b]		1988 to 1989[c,e]	
	Adult	Immature	Adult	Immature	Adult	Immature	Adult	Immature	Adult	Immature
Number	16	6	149	279	93	96	48	48	130	6
Amidostomum anseris										
Intensity	5.2	11.5	7.6	19.3	5.7	7.1	4.7 ± 3.3[b]	11.2 ± 17.8	NR[g]	NR
Prevalence (%)	44	100	25	34	19	45	81	98	NR	NR
Amidostomum spatulatum										
Intensity	0.0	0.0	0.0	0.0	0.0	0.0	3.1 ± 1.8	3.2 ± 3.0	NR	NR
Prevalence (%)	0	0	0	0	0	0	69	43	NR	NR
Epomidiostomum crami										
Intensity	0.0	0.0	0.0	0.0	0.0	0.0	2.1 ± 1.5	3.4 ± 2.8	NR	NR
Prevalence (%)	0	0	0	0	0	0	33	29	NR	NR
All species										
Intensity	5.2	11.5	7.6	19.3	5.7	6.9	13.7 ± 18.1	9.6 ± 5.7	14.1 ± 11.1	11.3 ± 9.3
Prevalence (%)	44	100	25	34	19	96	98	100	99	100

[a] Hanson and Gilford (1961).
[b] Tuggle (1982).
[c] Roby (unpubl. data).
[d] No measure of variation reported with the data on intensity.
[e] Gizzard worms were not identified to species.
[f] Mean ± standard error.
[g] NR, not reported.

male and female geese is evidence that the sex of the host does not affect risk of infection.

The intensities of *A. anseris* alone, and all gizzard nematodes collectively, were higher in immature geese in all years that geese were collected except 1952 to 1953. In addition, the prevalence of *A. anseris* often was greater in immature geese than in adult geese. Similarly, more *E. crami* infected immature geese than adult geese in the 1991 to 1992 sample. Although the prevalence of *A. spatulatum* was higher in adults, it too had a slightly higher intensity in immature geese. Consequently, host age appeared to be an important determinant of gizzard nematode prevalence and intensity in geese, but its effect depended upon the species of gizzard nematode.

The relationship between host age and prevalence and intensity may depend on one or more mechanisms. *Amidostomum anseris* may be more abundant in immature geese because they are exposed to greater numbers of infective larvae than adult geese, or adults develop an immunity to hyperinfections, or other parasites infecting adult geese displace *A. anseris*. If the first mechanism is operating, something must reduce the intensity of infections in adults: either heavily infected geese die before becoming adults or the gizzard nematodes die before geese become adults. In experimental infections, the number of eggs in the feces of infected geese declined after 18 mo (Cowan, 1955). The lack of serious lesions in geese heavily infected with *A. anseris* does not provide evidence to support these nematodes as a cause of host mortality. If the second mechanism is operating, it should be more difficult to infect adult geese than to infect immature geese. The low percentage of mature *A. anseris* in adult geese was evidence consistent with the second mechanism. If the third mechanism is operating, statistical analyses should show a negative relationship between *A. anseris* and another parasite. Intensity of *A. anseris* and *A. spatulatum* was negatively correlated, but not significantly.

The abundance of *A. spatulatum* may depend upon different mechanisms than *A. anseris* since its pattern of occurrence differed. This parasite had a significantly higher prevalence in adult geese, but its intensity was slightly higher in immature geese. Furthermore, more of the parasites in adult geese were larvae (80% versus 62% in immature geese), but the percentages of adult geese having infections with mature parasites were similar (63% vs. 67%). We find it difficult to propose a single mechanism that might account for these differences.

Based on our data and comparisons with earlier studies, we believe gizzard nematodes posed little threat to the Canada goose population in 1991 to 1992. Although the Mississippi Valley population of Canada geese was at a historic high, there was no evidence of a proportionate increase in parasites. Yearly variations in mean intensity from 1950 to 1951 and 1952 to 1953 were as great as the variation between all the studies. The mean intensity of infections in adults was consistently low. Furthermore, the lack of serious lesions and the good condition of heavily infected geese is evidence that these infections usually are well tolerated. Even the most heavily infected gizzard possessed an intact lining, functional koilin pads, and contained food or grit.

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