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Gnathostoma procyonis From South Georgia and North Florida Raccoons

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ABSTRACT: From 2004 to 2006, 511 raccoons collected by the United States Department of Agriculture Wildlife Services as part of a study to evaluate the effects of mesomammalian predator removal on bobwhite-quail reproduction, were examined for the presence of *Gnathostoma procyonis*, a nematode that parasitizes the stomach of its definitive host, the raccoon. One hundred forty-one raccoons (27.6%) contained *G. procyonis*, with males being equally infected (27.5%) as females (27.8%). Mean intensity did not differ significantly between sexes (males—mean = 2.88, range 1–17; females—mean = 2.78, range 1–10) or between collection sites. A significant seasonal prevalence of *G. procyonis* was noted with a peak in March (43.3%, n = 120) and a minimum in September (5.4%, n = 37). Both collection sites exhibited significant seasonal decreases in *G. procyonis*, but were not significantly different from each other. There was no cumulative seasonal pattern in mean intensity of *G. procyonis*, and no seasonal pattern at either collection site. Host weight was not related to either *G. procyonis* prevalence or mean intensity. Host removal did not have an apparent effect on prevalence or mean intensity of *G. procyonis*.

The parasite fauna of the raccoon (*Procyon lotor*) has been well documented. Many studies have focused on regional or local evaluations of populations of raccoons for entire parasite fauna (Ingram, 1941; Harkema and Miller, 1964; Johnson, 1970; Bafundo et al., 1980; Richardson et al., 1992), typically incorporating less than 150 animals from a broad geographic area. Few studies have focused on individual sites and individual parasite species, with the primary exception being specific analyses for *Baylisascaris procyonis*, due to its human health implications (Birch et al., 1994; Sorvillo et al., 2002; Eberhard et al., 2003).

Gnathostoma procyonis Chandler (1942) is a nematode parasite in the stomach of raccoons. The life cycle of *G. procyonis* involves copepods as first intermediate hosts, fish as second intermediate hosts, and cold-blooded vertebrates such as snakes, frogs, turtles, and alligators, as paratenic hosts (Ash, 1960, 1962a, 1962b). In the definitive host, ingested larvae migrate to the tissues for a brief period, then return to the stomach to reach adult stage 3–6 mo postinfection (Ash, 1962b). Adults produce large nodules in the stomach wall and may induce tissues changes described as neoplasms (Chandler, 1942; Jordan and Hayes, 1959; Ash, 1962b). Females produce eggs that must reach water to embryonate.

From 2001 to 2006, the United States Department of Agriculture–Georgia Wildlife Services (USDA-GWS), in association with the University of Georgia (Athens, Georgia), Auburn University (Auburn, Alabama), Tall Timbers Research Station (Leon County, Florida), and the Jones Ecological Research Center (Mitchell County, Georgia), lethally removed mesomammalian nest predators of bobwhite quail from 4 sites in north Florida and south Georgia to determine whether spring and summer trapping to remove predators would provide landowners a means of enhancing quail production and populations on their land. Beginning in 2003, Valdosta State University (Valdosta, Georgia) and the author became involved with this study and, in 2004, began examining collected raccoons for the presence of *G. procyonis*.

Objectives of this study were to determine prevalence and intensity of *G. procyonis* in raccoons from each study site, and to identify any seasonal or host sex relationship in worm prevalence and abundance. Secondary objectives included analysis of the effect host removal may have on parasite prevalence and abundance.

Raccoons examined were collected between February/March and September, 2004–2006, from Pinebloom Plantation (PB—84°14′30″N, 30°39′32″W), Mitchell County, Georgia and from Tall Timbers Research Station (TTRS—84°19′21″N, 31°24′18″W), Leon County, Florida. Raccoons were trapped with leg-hold or live traps (then killed by gunshot), or were shot by spotlighting at night by USDA–GWS. Approximately 125 traps were placed each night at a variety of locations on each site for an average of 25,625 trap-nights per year at each collection site. Whole animals were immediately frozen and transported to Valdosta State University, Valdosta, Georgia, and remained frozen until necropsy. Raccoons were thawed and weighed; the stomachs were removed and opened longitudinally with scissors, and contents were screened through a No. 14 Tyler standard sieve. The internal lining of the stomach was visually examined and screened contents were visually examined for *G. procyonis* and examined with the aid of a dissecting microscope. Collected nematodes were fixed and stored in ethanol–glycerine solution in sealed vials until definitive identifications could be performed. Nematodes were identified with the use of standard parasitological keys. Representative *G. procyonis* specimens were deposited in the U.S. National Parasite Collection in Beltsville, Maryland, and were given accession numbers 099371.00, 099372.00, and 099373.00.

TABLE I. Distribution of raccoons examined/collected, 2004–2006.*

	2004			2005			2006		
	F	M	T	F	M	T	F	M	T
Pinebloom	40	74	114	27	60	87	42	74	116
Tall Timbers	29	50	79	21	38	59	17	39	56
Total examined	69	124	193	48	98	146	59	113	172
Total collected	98	177	275	77	149	226	81	176	257

* (F = female, M = male, T = total).

Ecological terms as related to parasites are used as defined by Bush et al. (1997). Data analysis was performed with the use of JMP IN v. 5.1.2. Individual yearly analysis was performed with the use of linear regression and host sex, and between-year comparisons were made with the use of Wilcoxon signed-rank tests. Statistical significance in all cases was considered at $P < 0.05$.

In total, 758 raccoons were collected by the USDA-GWS from 2004 to 2006 at the 2 research sites (Table I). Of these, 511 were examined for the presence of *G. procyonis* and 141 (27.6%) were infected. There were no significant differences in the number of raccoons collected between years ($P > 0.74$) or between years at particular sites (TTRS—$P > 0.58$ and PB—$P > 0.82$).

A significant seasonal decrease in prevalence of *G. procyonis* occurred from February/March to September (Fig. 1) in each year (2004—$P < 0.008$; 2005—$P < 0.04$; 2006—$P < 0.0008$) and when seasonal data are considered cumulatively from 2004 to 2006 ($P < 0.0003$). Significant seasonal prevalence decreases occurred (Fig. 1) at both Pinebloom ($P < 0.007$) and Tall Timbers ($P < 0.0003$) and there was a significant difference in overall infection prevalence between sites (PB = 23.90%, TTRS = 33.51%, $P < 0.04$). There was no detectable trend in infection prevalence (2004—29.02%; 2005—37.67%; 2006—17.34%) between years ($P > 0.61$).

Mean intensity of *G. procyonis* among 141 infected raccoons was 2.84 (females—mean = 2.78, range 1–10; males—mean = 2.88, range 1–17). There was no significant seasonal pattern (Fig. 2) in mean *G. procyonis* intensity at individual sites (PB—$P > 0.05$; TTRS—$P > 0.57$), in either host sex (female—$P > 0.67$; male—$P > 0.50$), in any particular year (2004—$P > 0.07$; 2005—$P > 0.35$; 2006—$P > 0.96$), or when data are considered cumulatively from 2004 to 2006 ($P > 0.95$). There was no significant difference in mean *G. procyonis* intensity between collection year ($P > 0.30$), between sexes ($P > 0.15$), or between collection sites ($P > 0.71$).

Prevalence and mean intensity of *G. procyonis* was greatest in raccoons weighing 5.0–5.9 kg (36.0% and 3.22, respectively) as only 3

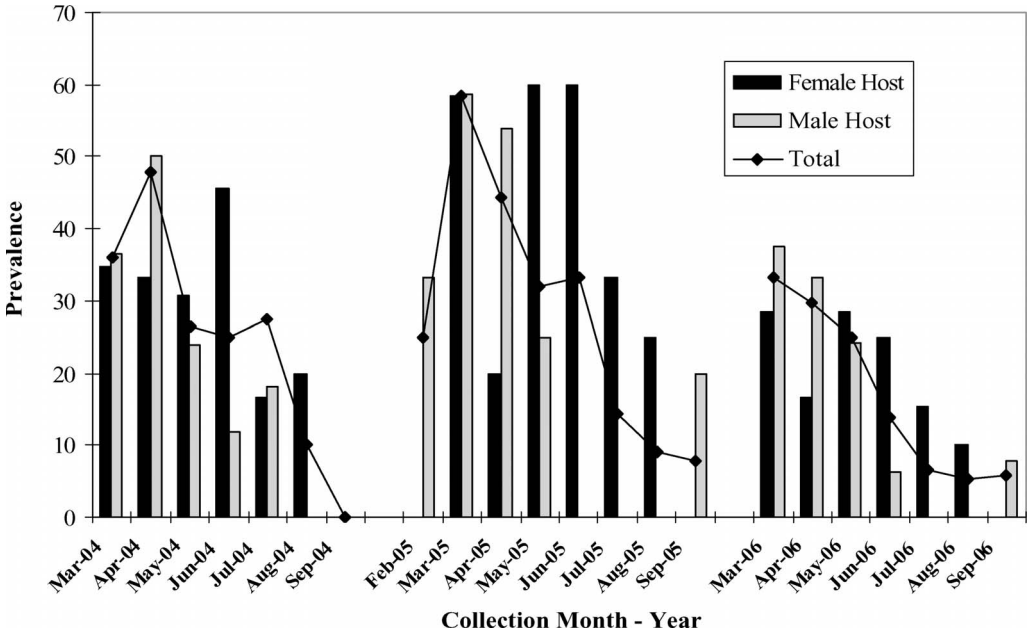

FIGURE 1. Prevalence of *Gnathostoma procyonis* from south Georgia and north Florida, 2004–2006.

negative animals in the 6.0–6.9-kg group were examined, and only 1 positive animal, which contained 7 *G. procyonis*, was found in the 1.0–1.9-kg group (Fig. 3). Neither prevalence ($P > 0.33$) nor mean intensity ($P > 0.42$) showed a significant trend with regard to weight of the host.

The author became involved opportunistically with the predator removal study and agreed to necropsy all collected predators in exchange for sample collection privileges. Few studies have evaluated seasonal prevalence of parasites of raccoons, typically due to low numbers of replicates in a given time period. This study afforded the opportunity to evaluate a large number of animals from 2 locations over 3 yr.

Each study site encompassed roughly 1,600 ha and collection of raccoons each year appeared to be thorough and extensive. One might expect an overall decline in the host population or change in host density. However, even with a relatively similar trapping effort each year, similar numbers of raccoons were collected (Table I). Maintaining a stable population despite intense harvesting efforts may be accomplished by an increase in reproduction, producing more juveniles to replace animals being lost, or increased immigration into the population by animals colonizing newly vacant areas, or both. The data suggest immigration may be the primary cause of new individuals in the raccoon population at each site, as few juveniles were captured at either location and many pregnant or lactating females were killed each spring/summer, resulting in the loss of litters. It thus appears there was a substantial pool of animals in the surrounding habitat available to immigrate in and replace removed individuals.

Overall prevalence of infection was 27.6% and overall mean intensity of *G. procyonis* was 2.82 (range 1–17). These values compare favorably to past studies and suggest that *G. procyonis* is more common in the southern and eastern United States (Table II). A few animals were found to have empty nodules, and these were considered to be negative. These nodules may have been regressing and healing, as noted by Ash (1962b) and Johnson (1970). In retrospect, further documentation of these empty nodules may have provided critical information in regard to seasonal prevalence of *G. procyonis*.

Chandler (1942) and Johnson (1970) each reported significantly lower prevalences of *G. procyonis* in summer and a peak in winter. Ash (1962b) suggested no apparent seasonal prevalence of *G. procyonis* in

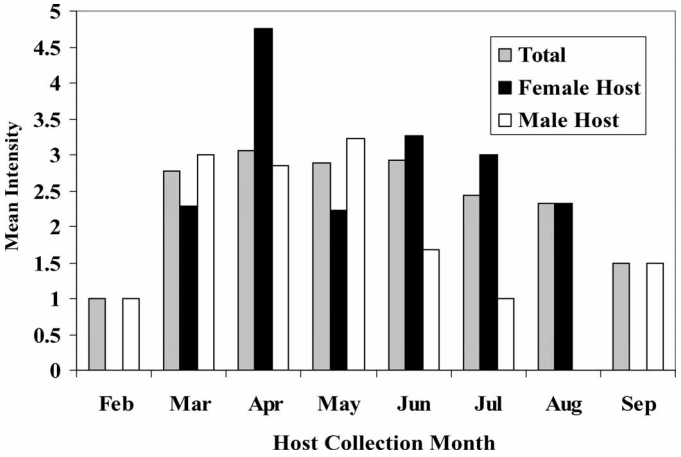

FIGURE 2. Mean intensity of *Gnathostoma procyonis* from south Georgia and north Florida, 2004–2006.

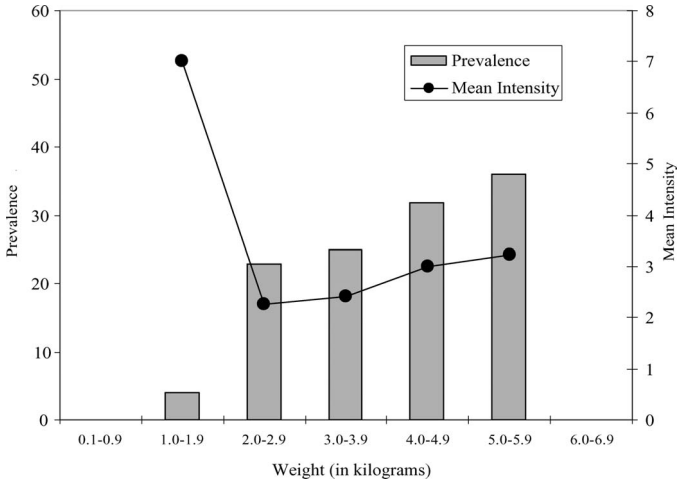

FIGURE 3. Prevalence and mean intensity of *Gnathostoma procyonis* by weight classification.

TABLE II. Past occurrences of *Gnathostoma procyonis*.

State	Prevalence	Range	Citation
AL	38.6% (59/153)	Not reported	Johnson, 1970
AR	6.7% (2/30)	0–1	Richardson, 1992
GA	4.0% (4/100)	Not reported	Jordan and Hayes, 1959
GA*	10.0% (1/10)	0–1	Schaffer et al., 1981
GA	31.3% (10/32)	0–57	Price and Harman, 1983
GA/NC*	46.1% (6/13)	0–13	Schaffer et al., 1981
IL	5.6% (2/36)	Not reported	Barnstable and Dyer, 1974
IL	0.0% (0/245)	0	Snyder and Fitzgerald, 1985
IL	11.7% (7/60)	Not reported	Birch et al., 1994
KS	0.0% (0/128)	0	Robel et al., 1989
KY	27.1% (19/70)	0–30	Cole and Shoop, 1987
SC	6.3% (1/16)	0–1	Harkema and Miller, 1962
SD	0.0% (0/250)	0	Boddicker and Progulske, 1968
TN	9.1% (23/253)	0–13	Bafundo et al., 1980
TN/KY	1.4% (2/145)	0–4	Smith et al., 1985
TN/VA*	0.0% (0/20)	0	Schaffer et al., 1981
WV*	0.0% (0/10)	0	Schaffer et al., 1981
Canada	0.0% (0/56)	0	Hoberg and McGee, 1982

* From this study, only raccoons considered ''resident,'' i.e., not translocated, are presented.

Louisiana in a study of 31 adult raccoons. No corroboration concerning winter prevalence can be made, because no winter trapping occurred as part of the predator removal study. Evidence presented here does support the concept of a winter/spring peak and fall minimum, as suggested by Chandler (1942) and Johnson (1970). I have no explanation for the apparent difference in prevalence between the 2 sites (PB = 23.90%, TTRS = 33.51%). Tall Timbers Research Station has constant research activities performed throughout the Station and is much more intensively managed than Pinebloom. This may have had some effect on the first intermediate, second intermediate, and paratenic host population, leading to increased potential transmission opportunities for *G. procyonis*.

Although not statistically significant, there appears to be an upward trend in prevalence and mean intensity of *G. procyonis* in raccoons with regard to weight classification (Fig. 3). However, low replicate numbers at both ends of the weight classifications may have influenced statistical results. Indeed, if those questionable values (0.1–0.9- and 6.0–6.9-kg classifications and 7.0 mean intensity value) are eliminated, statistically significant increases ($P < 0.05$) in both *G. procyonis* prevalence and mean intensity are noted with regard to host weight. The life cycle of *G. procyonis* is such that raccoons are infected by ingesting either fish or 1 of the other paratenic hosts (Ash, 1960, 1962a). Newly weaned raccoons are perhaps just beginning to utilize these food items and may not come into contact with *G. procyonis* until their second year, or later.

Findings that no significant changes occurred in regard to prevalence or mean intensity from 2004 to 2006 suggest that no critical minimum host threshold (Anderson and May, 1979, 1981) was reached by removal of raccoons to affect *G. procyonis* numbers. Although large numbers of potential hosts were removed from the host population, this apparently did not affect parasite prevalence or mean intensity. Experimental analysis is warranted to further analyze the relationship between *G. procyonis* and its definitive host.

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