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GASTROINTESTINAL HELMINTHS IN RACCOONS IN TEXAS

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ABSTRACT: Raccoons (n=590) were collected from October 1999 to August 2003 from 35 counties across Texas, and gastrointestinal tracts were examined for helminth parasites. Prevalence was calculated and differences in mean abundance were examined among habitat ecoregions, age classes, and between sexes. Twenty different species of helminths (13 nematodes, two cestodes, two acanthocephalans, and three trematodes) were positively identified in the gastrointestinal tracts of 590 raccoons in Texas. Five of the 20 helminth species collected (*Physaloptera rara*, *Placoconus lotoris*, *Molineus barbatus*, *Atriotaenia procyonis*, and *Macracanthorhynchus ingens*) had a prevalence >20%. The total number of individuals of these five species (n=22,777) accounted for over 86% of the total number of individuals of all helminth species (n=26,426) collected. Subsequent analyses were based on these five helminths. Mean abundance differed among habitat ecoregions, age classes, and between sexes for all five parasites evaluated. This study is the most comprehensive statewide survey ever done of gastrointestinal helminths of raccoons across Texas. The five most prevalent helminths identified have all been reported in at least one previous survey, indicating that these parasites are not new to Texas and that raccoons are not naïve to the effects these parasites have on them. It may be helpful to wildlife rehabilitators, trappers, wildlife biologists, and other professionals to be aware of parasite abundance in raccoons from different areas of the state, as frequent human–raccoon interactions occur, and some of these parasites could be harmful to humans and domestic animals.

Key words: Gastrointestinal parasites, helminths, *Procyon lotor*, raccoon, Texas.

INTRODUCTION

Raccoons (*Procyon lotor*) are found throughout the United States. They have adapted well to living in proximity to humans and can readily be found in urban and suburban environments as well as in rural communities. Because raccoons are omnivorous and live in a variety of habitats, they are host to a variety of gastrointestinal helminths and have been the subject of many helminth surveys across the US. However, many of these surveys are regional in nature or are based on small sample sizes (Bafundo et al., 1980; Smith et al., 1985; Snyder and Fitzgerald, 1985; Birch et al., 1994; Ching et al., 2000). Even surveys conducted in larger regions, such as the southeastern US, only reported parasite occurrences in translocated and resident raccoons from 1–4 counties in each of five states (Schaffer et al., 1981), or only reported sample sizes of 6–209 from each of five states (Harkema and Miller, 1964). Past surveys of raccoons in Texas have also been regional in nature, concentrating on eastern, central, or southern parts of the state (Chandler, 1942; Schaffer et al., 1981; S. C. Waring and D. D. Dingley unpubl. in Kazacos and Boyce, 1989; Kerr et al., 1997). In addition, no recent surveys of raccoon parasites have been conducted in the extreme southern regions of the US, and no comprehensive, statewide survey of gastrointestinal helminths of raccoons has been reported for Texas.

Factors such as host habitat use and diet can influence helminth communities. Use of multiple habitats by hosts often results in a helminth community dominated more by host generalists than by the host specialists that tend to dominate helminth communities of hosts using a narrow range of habitat types (Gaston et al., 1997). From another perspective, helminth species that use a variety of intermediate hosts (which can occur in a variety of

habitats) will also occur in a variety of habitats, and helminth species that use one intermediate host, or use only one mode of transmission (which can occur in a narrow range of habitats), will also occur in a narrow range of habitats (Price, 1990; Gaston et al., 1997).

The two objectives of this study were to 1) determine prevalence of gastrointestinal helminths from raccoons in Texas, and 2) determine differences in mean abundances of gastrointestinal helminths from raccoons in Texas among habitat ecoregions, among age classes, and between sexes.

MATERIALS AND METHODS

Raccoon collection was a cooperative effort among many individuals and organizations and took place from October 1999 to August 2003. Generally, raccoons were collected with similar intensity across Texas; however, some areas were revisited to improve sample sizes within ecoregions. Although urbanization levels differ among ecoregions, we sampled fairly equally among urban, suburban, and rural areas within each ecoregion. Raccoons were obtained from across Texas primarily by trapping with Havahart® traps (Forestry Suppliers, Inc., Jackson, Mississippi, USA) and also by collecting animals from municipal animal damage control offices and Wildlife Damage Management Services offices, picking up recently killed (within 24 hrs) hit-by-vehicle animals and by collecting hunter-shot animals. Captured animals were killed with a .22-caliber rifle shot. Both collection and use of animals in this study were approved by the Texas A&M University–Kingsville Animal Care and Use Committee (ACUC# 1-97-36). The sex and weight of each animal was recorded, when possible, and trapping or collecting locations of raccoons were noted, when possible, by either global positioning system coordinates or nearest street address. Raccoons were eviscerated and viscera were frozen at −10 C until necropsy. The gastrointestinal tracts (esophagus, stomach, small intestine, large intestine, and rectum) were examined from all 590 raccoons collected.

A lower canine tooth was extracted from each raccoon, when possible, for age determination (Johnston et al., 1987). No differences were observed among year classes in adult raccoons; therefore, adults were grouped and analyses were conducted among age class. Raccoons were placed into age classes with pups being any raccoon <3.5 mo of age (no permanent lower canine tooth eruption), juveniles being any raccoon 3.5 mo to 1 yr old (permanent lower canine eruption but root was hollow), and with adults being any raccoon older than 1 yr (lower canine root not hollow; Johnston et al., 1987).

At the time of examination, gastrointestinal tracts were separated with the esophagus and stomach as one section and the small intestine, large intestine, and rectum as another section. Both sections were dissected longitudinally, mucosa scraped, and contents washed using a washing and sedimentation process in conical glasses. Washed sediment was examined with a dissecting microscope. Helminths were collected, identified, quantitated, fixed, and stored in 70% ethanol containing 8% glycerin. Nematodes and acanthocephalans were identified in lactophenol wet mounts, when necessary; cestodes and trematodes were identified in wet mounts, if possible (Yorke and Maplestone, 1962; Levine, 1968; Dunn, 1969; Schmidt, 1970; Petrochenko, 1971; Anderson et al., 1974; Chabaud, 1974, 1978; Hartwich, 1974; Peter and Quentin, 1976; Lichtenfels, 1980; Anderson and Bain, 1982; Durette-Desset, 1983; Schmidt, 1986; Bowman, 1987; Anderson, 2000). Otherwise, they were stained using Semichon's acetocarmine and placed into Canada balsam permanent mounts. Representative specimens of all helminths from this study were deposited in the United States National Parasite Collection (Beltsville, Maryland 20705, USA; Accession #94951–94985).

Additional data, including habitat ecoregions, was obtained for each raccoon location. Because our survey was statewide, we chose the coarse scale of ecoregions, rather than a finer scale, to minimize breakdown of categories during analyses. The habitat ecoregion map was obtained from the Texas Parks and Wildlife Department webpage (Accessed 1 October 2001) (Fig. 1). Climatic and physical characteristics of each habitat ecoregion were summarized (Table 1).

Prevalence of helminths was calculated. Because frequency distributions of helminth populations were usually overdispersed, abundance values were rank-transformed prior to statistical analyses. Because raccoons were collected throughout different times of the year, habitat ecoregions and seasons were examined for interaction effects using a general linear model (GLM) on rank-transformed values. Seasons were designated as "warm season" (March–October) or "cool season" (November–February) because Texas

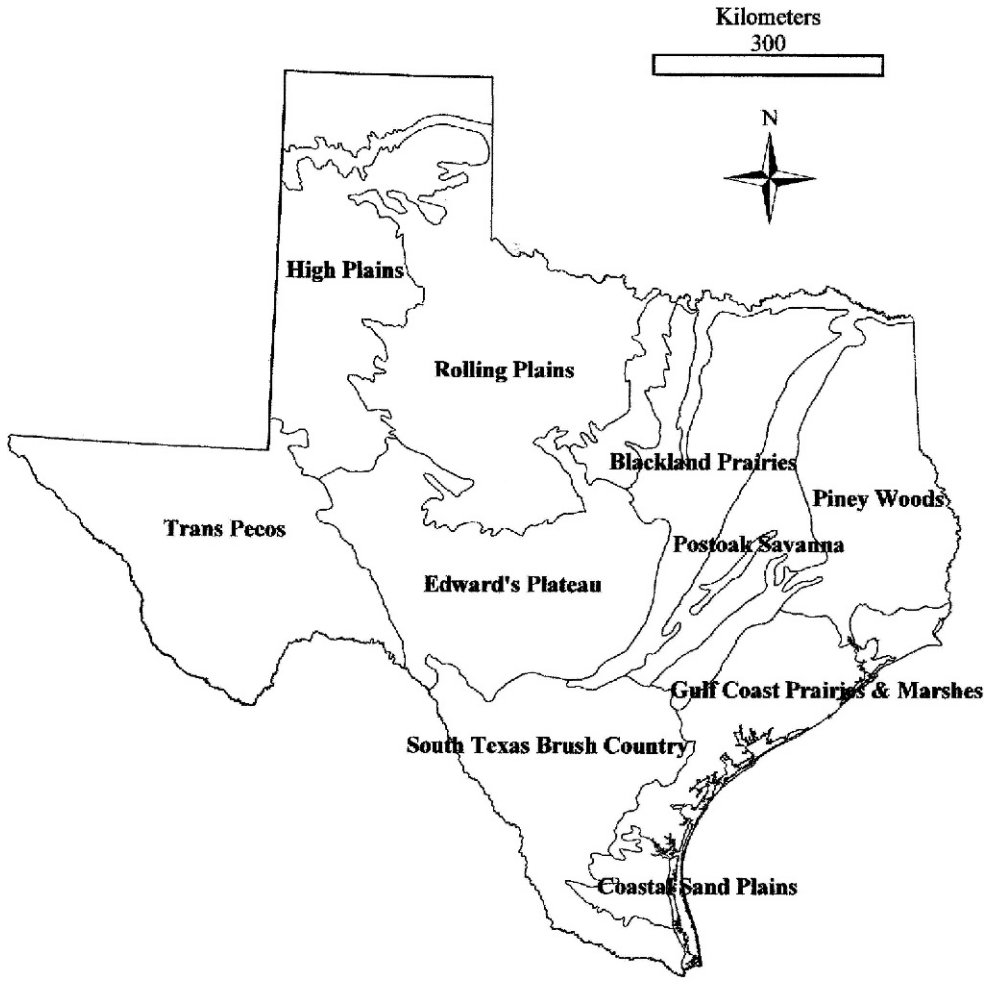

FIGURE 1. Habitat ecoregions of Texas as obtained from Texas Parks and Wildlife Department. www.tpwd.state.tx.us/nature/tx-eco95.htm. Accessed: 1 October 2001.

is in a warm-temperate–subtropical zone and, in general, does not experience four seasons (Hatch et al., 1990). If no interactions between habitat ecoregions and seasons occurred, mean abundance (±SE) was examined among habitat ecoregions using an analysis of variance (ANOVA) on rank-transformed values. Differences in mean abundance (±SE) were examined among age classes using an ANOVA on rank-transformed values and between sexes using a *t*-test on rank-transformed values. A post hoc means separation test (Tukey method) was also reported, when appropriate. Statistical significance was inferred at $P<0.05$. These statistical procedures were conducted using the Statistical Package for the Social Sciences (SPSS; SPSS Inc., Chicago, Illinois, USA, 2001). The terms 'prevalence' and 'abundance' used to describe helminth infections follow the definitions of Bush et al. (1997).

RESULTS

Twenty different helminths species (13 nematodes, two cestodes, two acanthocephalans, and three trematodes; exclusive of unknown specimens) were found in gastrointestinal tracts (and, in the case of *Heterobilharzia* sp., in surrounding abdominal mesenteric venules) of 590 raccoons in

TABLE 1. Summary of climatic and physical characteristics of the 10 ecoregions of Texas.[a]

Ecoregion	Million hectares	Annual precipitation (cm)	Frost-free days	Topography	Elevation (m)	Major soil textures	Month of peak precipitation (secondary peak)
Piney Woods	6.06	102–142	235–265	Nearly level to gently undulating	61–213	Sands or sandy loams	Even distribution
Gulf Coast Prairies & Marshes	4.59	66–142	245–320	Nearly level	0–76	Sands and sandy loams; clays in river bottoms	September (May)
Coastal Sand Plains	0.96	50–76	300–340	Nearly level	0–46	Sands	September (May)
South Texas Brush Country	6.83	46–76	260–340	Nearly level to rolling	0–305	Clays and clay loams	September (May)
Postoak Savanna	5.26	76–114	235–280	Nearly level to gently rolling	91–244	Uplands: sandy loam or sands; Bottomlands: sandy loams to clays	May (September)
Blackland Prairies	6.39	76–114	230–280	Nearly level to rolling	76–213	Clays interspersed with sandy loams	May (September)
Edward's Plateau	8.90	30–81	220–260	Deeply dissected hilly, stony plain	366–914	Shallow clays or coarse sands	May (September)
Trans Pecos	9.63	20–46	220–245	Mountain ranges, rough, rocky land, flat basins, and plateaus	762–2,667	Varied—loams to sands	July, August, September (November)
Rolling Plains	11.18	46–71	185–235	Nearly level to rolling	305–914	Coarse sands to tight clays	May (September)
High Plains	8.77	36–53	180–220	Nearly level high plateau	914–1,372	Clays to sands	May (September)

[a] Adapted from Godfrey et al., 1973; Hatch et al., 1990; and Smith and Campbell, 1996.

TABLE 2. Overall prevalence and mean abundance of gastrointestinal helminths in 590 raccoons in Texas collected across the state from October 1999 to August 2003.

Parasite	Host NI/NE[a]	Parasite prevalence (%)	Parasite abundance ($\bar{x}$±SE)
Nematoda			
Physaloptera rara	340/590	57.6	7.6±0.8
Gnathostoma procyonis	17/590	2.9	0.1±0.0
Gongylonema sp.	3/590	0.5	0.0±0.0
Placoconus lotoris	275/590	46.6	16.8±1.9
Molineus barbatus	176/590	29.8	7.2±2.4
Toxascaris leonina	1/590	0.2	0.0±0.0
Baylisascaris procyonis	32/590	5.4	0.4±0.1
Lagochilascaris sp.	3/590	0.5	0.1±0.1
Synhimanthus sp.	5/590	0.8	0.0±0.0
Aonchotheca putorii	16/590	2.7	0.1±0.0
Pharyngodon sp.[b]	1/590	0.2	0.0±0.0
Syphacia sp.[b]	1/590	0.2	0.0±0.0
Cruzia americana	1/590	0.2	0.0±0.0
unknown Oxyuroidea[b,c]	3/590	0.5	0.0±0.0
Cestoda			
Atriotaenia procyonis	122/590	20.7	7.8±1.8
Mesocestoides lineatus	20/590	3.4	1.5±0.9
unknown Cestoda[c]	42/590	7.1	0.3±0.1
Acanthocephala			
Macracanthorhynchui ingens	240/590	40.7	2.6±0.3
Moniliformis sp.[b]	8/590	1.4	0.1±0.1
Trematoda			
Pharyngostomoides sp.[d]	3/590	–	–
Heterobilharzia sp.[e]	10/590	1.7	0.1±0.1
Grysoma singularis	3/590	0.5	0.1±0.1
unknown Trematoda[c]	4/590	0.7	0.0±0.0

[a] NI/NE = Number of hosts infected/number of hosts examined.

[b] From raccoon prey species.

[c] Not identified due to damaged specimens or lack of identifying features.

[d] Did not collect or count.

[e] Found in the abdominal mesenteric venules.

Texas and were positively identified (Table 2). *Pharyngostomoides* sp. specimens were collected from three raccoons for identification purposes only and were not collected or quantitated in other raccoons; therefore, the prevalence and mean abundance of this helminth were not reported. Prevalence and mean abundances of all other helminth species collected from study raccoons are listed in Table 2.

Unknown species of Oxyuroidea, Cestoda, and Trematoda specimens are listed in Table 2, but these specimens were not positively identified because they were highly damaged or lacked identifying features such as a head. Five of the 20 helminth species collected from 590 raccoons in Texas had prevalence >20% (Table 2). The total number of individuals of these species (n=22,777) accounted for over 86% of the total number of individuals of all helminth species (n=26,426) collected. The remaining 15 helminth species were deleted from subsequent analyses, all of which are based on the five predominant helminth species (*Physaloptera rara* [*P. rara*], *Placoconus lotoris* [*Pl. lotoris*], *Molineus barbatus* [*M. barbatus*], *Atriotaenia procyonis*, and *Macracanthorhynchus ingens* [*Ma. ingens*]).

Abundance

Generally, due to lower raccoon densities in western Texas, raccoon sample sizes varied among ecoregions, although raccoon trap effort in our study was similar in all ecoregions of Texas. Trap effort suggests that, in general, raccoon density decreased from eastern Texas to western Texas. The overall mean abundance for *P. rara*, *Pl. lotoris*, *M. barbatus*, *Ma. ingens*, and *A. procyonis* was 7.6±0.8, 16.8±1.9, 2.6±0.3, 7.2±2.4, and 7.8±1.8, respectively (Table 2). The GLM used to examine habitat ecoregions and seasons detected no interaction effects on parasite abundance for four helminths species examined (*P. rara*: $F_{5,540}=1.317$, $P=0.255$; *M. barbatus*: $F_{5,540}=0.577$, $P=0.718$; *Ma. ingens*: $F_{5,540}=0.763$, $P=0.576$; *A. procyonis*: $F_{5,540}=1.106$, $P=0.356$). *Placoconus lotoris* abundance was related to an interaction effect between habitat ecoregion and season ($F_{5,540}=3.031$, $P=0.010$). Within ecoregions, *Pl. lotoris* abundance significantly differed between seasons only in the South Texas Brush Country ecoregion ($F_{1,90}=55.121$, $P<0.0001$), with the warm season having a higher mean abundance than the cool season. Within both warm and cool seasons, *Pl. lotoris* abundance significantly differed among ecoregions (Table 3). Mean abundance of *Pl. lotoris* during the warm season was highest among Piney Woods and the Gulf Coast Prairies and Marshes ecoregions and was similar to Coastal Sand Plains ecoregion ($F_{8,418}=35.013$, $P<0.0001$) (Table 3). Mean abundance of *Pl. lotoris* during the cool season was higher among Gulf Coast Prairies and Marshes and the Coastal Sand Plains ecoregions than other ecoregions ($F_{6,111}=33.035$, $P<0.0001$) (Table 3).

Mean abundance differed among habitat ecoregions for all four remaining species of helminths examined ($P<0.0001$; Table 4). Mean abundance of *P. rara* within the Trans Pecos ecoregion was greater than the Gulf Coast Prairies and Marshes, Postoak Savanna, Blackland Prairie, Coastal Sand Plains, Edward's Plateau, and Rolling Plains ecoregions (Table 4). Mean abundance of *M. barbatus* was highest in Blackland Prairies ecoregion and was similar to Gulf Coast Prairies and Marshes and the Postoak Savanna ecoregions. Piney Woods ecoregion also was similar to Gulf Coast Prairies and Marshes ($F_{9,558}=26.830$, $P<0.0001$) (Table 4). Mean abundance for *Ma. ingens* differed among ecoregions ($F_{9,558}=5.133$, $P<0.0001$) (Table 4), with Rolling Plains ecoregion having a higher mean abundance than Postoak Savanna, Blackland Prairie, and Edward's Plateau ecoregions. Mean abundance among ecoregions differed for *A. procyonis* ($F_{9,558}=3.538$, $P<0.0001$), with Rolling Plains ecoregion having a higher mean abundance than the Postoak Savanna ecoregion (Table 4).

Mean abundance differed among age classes for all five species of helminths examined (*P. rara*: $F_{2,587}=13.817$, $P<0.001$: *Pl. lotoris*: $F_{2,587}=25.833$, $P<0.001$; *M. barbatus*: $F_{2,587}=26.211$, $P<0.001$; *Ma. ingens*: $F_{2,587}=7.424$, $P=0.001$; *A. procyonis*: $F_{2,587}=6.522$, $P=0.002$) (Table 5). Mean abundance of *P. rara* and *Ma. ingens* each differed, with pups having a lower mean abundance than juveniles and adults. *Placoconus lotoris* and *M. barbatus* each differed, with pups and juveniles having a lower mean abundance than adults. Mean abundance for *A. procyonis* differed, with pups having a lower mean abundance than adults (Table 5).

Mean abundance differed between sexes for all five species of helminths examined (*P. rara*: $t=2.956$, 565 df, $P=0.003$; *Pl. lotoris*: $t=-2.747$, 565 df, $P=0.006$; *M. barbatus*: $t=-2.029$, 565 df, $P=0.043$; *Ma. ingens*: $t=2.746$, 565 df, $P<0.0001$; *A. procyonis*: $t=0.357$, 565 df, $P=0.006$) (Table 6). *Physaloptera rara*, *Ma. ingens*, and *A. procyonis* each had a higher mean abundance in female raccoons than in males, but *Pl. lotoris* and *M. barbatus* had higher mean abundances in male raccoons than in females (Table 6).

TABLE 3. Mean abundance ($\bar{x}\pm$SE) of *Placoconus lotoris* in 545 raccoons in Texas collected during warm and cool seasons across the state from October 1999 to August 2003 and compared to habitat ecoregions.

	Locality[a]											
	PW	GCPM	CSP	STBC	PS	BP	EP	TP	RP	HP		
	NI/NE[b]	NI/NE	NI/NE	NI/NE	NI/NE	NI/NE	NI/NE	NI/NE	NI/NE	NI/NE		
Season	$\bar{x}\pm$SE	$\bar{x}\pm$SE	$\bar{x}\pm$SE	$\bar{x}\pm$SE	$\bar{x}\pm$SE	$\bar{x}\pm$SE	$\bar{x}\pm$SE	$\bar{x}\pm$SE	$\bar{x}\pm$SE	$\bar{x}\pm$SE	F[c,d]	*P*
Warm (Mar–Oct)	55/63	99/126	5/6	12/23	23/41	29/50	3/57	0/0	3/59	0/2	35.013	<0.0001
	27.1±6.4	43.6±6.3	5.2±2.1	4.5±1.9	13.3±4.2	22.5±8.7	0.2±0.1	–	0.1±0.1	0.0±0.0		
	A[e]	A	AB	B	B	B	C		C	ABC		
Cool (Nov–Feb)	0/0	11/14	5/6	2/68	7/12	0/3	0/6	0/9	0/0	0/0	33.035	<0.0001
	–	17.6±5.2	34.8±12.5	0.1±0.1	4.5±1.7	0.0±0.0	0.0±0.0	0.0±0.0	–	–		
		A	A	B	C	BC	B	B				

[a] PW = Piney Woods; GCPM = Gulf Coast Prairies & Marshes; CSP = Coastal Sand Plains; STBC = South Texas Brush Country; PS = Postoak Savanna; BP = Blackland Prairies; EP = Edward's Plateau; TP = Trans Pecos; RP = Rolling Plains, and HP = High Plains.

[b] NI/NE = Number of hosts infected/number of hosts examined.

[c] Analysis was conducted on rank abundance.

[d] Warm season: $F_{8,418}$; cool season: $F_{6,111}$.

[e] Mean abundance values with the same letter for each parasite are not different ($P>0.05$) using Tukey method.

TABLE 4. Mean abundance ($\bar{x}$±SE) of four predominant gastrointestinal helminths in 568 raccoons in Texas collected across the state from October 1999 to August 2003 and compared to habitat ecoregions.

	Locality[a]											
	PW	GCPM	CSP	STBC	PS	BP	EP	TP	RP	HP		
	NI/NE[c]	NI/NE	NI/NE	NI/NE	NI/NE	NI/NE	NI/NE	NI/NE	NI/NE	NI/NE		
Parasite[b]	$\bar{x}$±SE	$\bar{x}$±SE	$\bar{x}$±SE	$\bar{x}$±SE	$\bar{x}$±SE	$\bar{x}$±SE	$\bar{x}$±SE	$\bar{x}$±SE	$\bar{x}$±SE	$\bar{x}$±SE	$F_{9,558}$[d]	*P*
P. rara	50/63	83/149	9/15	77/102	30/53	23/53	14/63	9/9	37/59	2/2	11.214	<0.0001
	8.7±2.3	5.7±1.1	6.6±2.9	10.2±1.3	11.9±6.0	5.4±1.8	1.4±0.6	37.7±20.2	9.1±2.5	16.5±6.5		
	ADE[e]	B	BCD	AD	BE	BC	C	A	BD	ABC		
M. barbatus	45/63	84/149	0/15	13/102	10/53	21/53	2/63	0/9	0/59	0/2	26.830	<0.0001
	12.4±4.8	8.8±1.9	0.0±0.0	1.9±0.7	5.2±3.4	31.6±25.1	0.1±0.1	0.0±0.0	0.0±0.0	0.0±0.0		
	A	AB	D	D	CD	BC	D	CD	D	ACD		
Ma. ingens	28/63	74/149	4/15	54/102	13/53	12/53	16/63	1/9	28/59	2/2	5.133	<0.0001
	1.5±0.5	3.2±0.6	0.4±0.2	3.3±0.8	0.9±0.4	1.1±0.4	1.0±0.3	0.1±0.1	6.4±2.1	2.0±1.0		
	AB	A	AB	A	B	B	B	AB	A	AB		
A. procyonis	15/63	32/149	1/15	14/102	21/53	17/53	6/63	1/9	7/59	1/2	3.538	<0.0001
	10.3±4.2	3.9±1.7	0.1±0.1	10.3±7.2	10.9±4.9	7.4±3.1	0.4±0.2	0.2±0.2	18.0±9.7	7.0±7.0		
	AB	AB	AB	B	A	AB	B	AB	B	AB		

[a] PW = Piney Woods; GCPM = Gulf Coast Prairies & Marshes; CSP = Coastal Sand Plains; STBC = South Texas Brush Country; PS = Postoak Savanna; BP = Blackland Prairies; EP = Edward's Plateau; TP = Trans Pecos; RP = Rolling Plains; and HP = High Plains.

[b] *P. rara* = *Physaloptera rara*; *M. barbatus* = *Molineus barbatus*; *Ma. ingens* = *Macrocanthorhynchus ingens*; *A. procyonis* = *Atriotaenia procyonis*.

[c] NI/NE = Number of hosts infected/number of hosts examined.

[d] Analysis was conducted on rank abundance.

[e] Mean abundance values with the same letter for each parasite are not different ($P>0.05$) using Tukey method.

TABLE 5. Mean abundance of the five predominant gastrointestinal helminths in 590 raccoons in Texas collected across the state from October 1999 to August 2003 and compared to raccoon age.

	Raccoon age class								
	Pup		Juvenile		Adult				
Parasite[a]	*n*	x̄±SE	*n*	x̄±SE	*n*	x̄±SE	df	F[b]	*P*
P. rara	9	2.1±1.0 A[c]	62	10.4±2.4 B	269	7.5±1.0 B	2,587	13.817	<0.001
P. lotoris	4	0.9±0.8 A	21	9.2±2.8 A	250	19.8±2.3 B	2,587	25.833	<0.001
M. barbatus	0	0.0±0.0 A	7	1.4±1.2 A	169	9.0±3.1 B	2,587	26.211	<0.001
Ma. ingens	5	0.3±0.2 A	43	2.0±0.4 B	192	2.9±0.4 B	2,587	7.424	0.001
A. procyonis	2	0.8±0.6 A	11	0.7±0.3 AB	109	9.9±2.3 B	2,587	6.522	0.002

[a] *P. rara = Physaloptera rara; P. lotoris = Placoconus lotoris; M. barbatus = Molineus barbatus; Ma. ingens = Macrocanthorhynchus ingens; A. procyonis = Atriotaenia procyonis.*

[b] Analysis was conducted on rank intensity.

[c] Mean abundance and mean intensity values with the same letter for each parasite and characteristic are not different (P>0.05) using Tukey method.

DISCUSSION

Parasites are associated with certain habitat ecoregions. This is related, in part, to the types of intermediate hosts and the habits of definitive hosts involved. For example, helminths such as *Physaloptera* spp., *Atriotaenia* spp., and *Macracanthorhynchus* spp. use intermediate hosts that include beetles, mites, millipedes, crickets, and cockroaches. These intermediate hosts are common in most types of habitats and, therefore, one would expect the associated helminths to occur in definitive hosts from a variety of habitats as well. We expected mean abundances to be similar among all ecoregions for *P. rara*, *Ma. ingens*, and *A. procyonis*. In our study, however, this statistically was not the case: abundance exhibited similar trends with these three parasites. In urban areas, raccoons often exploit garbage as a nontypical food source and, because urbanization levels are different among ecoregions, this may have caused biases in parasite abundance. However, we sampled fairly equally among urban, suburban, and rural areas within each ecoregion and do not believe this bias occurred with our study.

For *P. rara*, mean abundance among ecoregions varied from arid regions (Trans Pecos, High Plains) to humid, riparian areas

TABLE 6. Mean abundance of the five predominant gastrointestinal helminths in 590 raccoons in Texas collected across the state from October 1999 to August 2003 and compared to raccoon sex.

	Raccoon sex						
	Female		Male				
Parasite[a]	*N*	x̄±SE	*n*	x̄±SE	df	*t*[b]	*P*
P. rara	187	9.8±1.5 A[c]	145	5.9±0.9 B	565	2.956	0.003
Pl. lotoris	125	12.6±2.0 A	144	20.9±3.1 B	565	−2.747	0.006
M. barbatus	77	4.4±0.9 A	95	10.7±5.0 B	565	−2.029	0.043
Ma. ingens	137	3.7±0.6 A	92	1.4±0.2 B	565	3.534	<0.0001
A. procyonis	73	9.6±2.4 A	45	5.8±2.8 B	565	2.746	0.006

[a] *P. rara = Physaloptera rara; Pl. lotoris = Placoconus lotoris; M. barbatus = Molineus barbatus; Ma. ingens = Macrocanthorhynchus ingens; A. procyonis = Atriotaenia procyonis.*

[b] Analysis was conducted on rank intensity.

[c] Mean abundance values with the same letter for each parasite and characteristic are not different (P>0.05) using Tukey method.

(Postoak Savanna, South Texas Brush Country). *Macracanthorhynchus ingens* had similar results, with high mean abundances occurring in arid regions (Rolling Plains) as well as in humid, coastal, or riparian regions (Gulf Coast Prairies and Marshes, South Texas Brush Country). *Atriotaenia procyonis* also had a similar trend in mean abundances of the parasite occurring in a variety of habitat ecoregions. Even though our results deviated from what was expected, they supported the idea that *P. rara*, *Ma. ingens*, and *A. procyonis* occur in a variety of ecoregions and that their mean abundance is dependent on habitat type; the regions with the highest abundance varied in habitat type (e.g., from arid to riparian). Small sample sizes could have contributed to this deviation from the expected result. We recognize that ecoregions represent a coarse scale, but if a finer scale had been used, trends might have washed out with an increased number of categories. We conducted a statewide survey; thus, the scale was coarse to minimize breakdown of categories.

Parasites such as *Pl. lotoris* and *M. barbatus* do not have intermediate hosts and usually infect the definitive hosts by skin penetration (Marquardt et al., 2000). They are most prevalent in moist habitats where the definitive host population is concentrated or congregated (Marquardt et al., 2000). We expected *Pl. lotoris* and *M. barbatus* to have higher mean abundances in eastern, coastal, and central parts of Texas because these areas are less arid and have more of the surface water where raccoons congregate. Our results supported this for *Pl. lotoris*. For *M. barbatus*, we also found significantly higher mean abundances occurring where surface water is more available.

We also expected younger animals to have higher mean abundances because, with increased age, they develop an immune response to parasite infections (Kazacos, 2001). Although more animals in the population may be infected, they generally have a lower number of parasites per individual (i.e., lower mean abundance). Younger animals have not developed this immune response, and therefore, usually have higher parasite abundances. Our study showed a significant trend to the opposite in parasite mean abundance for *P. rara*, *Pl. lotoris*, *M. barbatus*, *A. procyonis*, and *Ma. ingens*. No parasite exhibited the expected trend wherein pups and juveniles have higher mean abundances than adults. This opposite trend may be explained in that raccoon populations are naïve to infections of some parasites. If adult raccoons had not been exposed to these parasites as pups or juveniles, then adult raccoons may not have had a chance to build an immune response to the parasites, allowing adults to have parasite abundances at levels comparable to juveniles. This opposite trend may also be explained by small sample sizes. Another possible explanation for this opposite trend could be if the pups and juveniles had a higher occurrence of pathology; this would lead to a higher occurrence of death and illness, thus making them less likely to be captured and sampled. Although not specifically addressed by our study, no gross lesions or perforations were observed in the mucosal lining of gastrointestinal tracts of any pup, juvenile, or adult raccoon.

We expected mean abundances to be similar between female and male raccoons. Mean abundances showed differences between females and males for the five parasites examined. The cause of these differences in mean abundance is unknown. We expected equal opportunities in the environment for females and males to become infected with any parasite. There is no apparent age bias between females and males. Differences may have resulted because male raccoons generally have a larger home range than females (Gehrt, 2003) and may become exposed to more potential parasites, or because of a sex bias in diet (i.e., lactating females may have a different diet from males or nonlactating females).

Our study has been the most comprehensive statewide survey of gastrointesti-

nal helminths of raccoons ever performed in Texas. Other studies have been conducted, but these studies were only regional or countywide surveys in Texas (Chandler, 1942; Schaffer et al., 1981), or were conducted in other states (Harkema and Miller, 1964; Bafundo et al., 1980; Smith et al., 1985; Snyder and Fitzgerald, 1985; Birch et al., 1994; Ching et al., 2000). We wanted to determine if our survey results were reasonably comparable to previous Texas surveys, and Schaffer et al. (1981) was the most recent survey with which we could compare our results. It is important to note that Schaffer et al. (1981) only examined 37 raccoons from Brown County, Texas (North–Central Texas), whereas we examined 590 raccoons from 35 counties across Texas. Because their study was only conducted from one county, and our survey was statewide, differences noted could be regional. Some differences occur when comparing prevalence of Schaffer et al. (1981) with prevalence from our survey and when comparing the species of helminths found in the two studies. Schaffer et al. (1981) reported a 22% prevalence of *Heterobilharzia americana*, which was much higher than our prevalence of 1.7%. A possible explanation for this difference is that we were examining intestinal lumen contents and *H. americana* is a parasite of the mesenteric venules. We did not specifically examine the mesentery for this parasite, and its occurrence in our samples is probably because the parasite was scraped from the mesentery when the intestinal lumen was being scraped. Other species found in both surveys, but with differing prevalence, were *A. procyonis* (Schaffer et al., 1981 reported 92%; our study reported 20.7%), *Mesocestoides* sp. (Schaffer et al., 1981, 11%; our study 3.4%), *Ma. ingens* (Schaffer et al., 1981, 24%; our study 40.7%), *P. rara* (Schaffer et al., 1981, 84%; our study 57.6%), and *Pl. lotoris* (Schaffer et al., 1981; 11%; our study 46.6%). Prevalence for *M. barbatus* was similar between surveys (Schaffer et al., 1981, 27%; our study 29.8%). Helminth species found in our study that were not reported by Schaffer et al. (1981) include *Gnathostoma procyonis*, *Gongylonema* sp., *Baylisascaris procyonis*, and *Synhimanthus* sp. In addition, Schaffer et al. (1981) reported finding *Pharyngostomoides* spp., which is consistent with our report, although prevalence could not be compared.

Two helminths found in our study were identified as parasites of raccoon prey species (*Pharyngodon* sp. and *Syphacia* sp.), and the unknown species of Oxyuroidea is also suspected as being from a prey species. *Pharyngodon* sp. is a parasite of reptiles, and the stomach contents of the raccoon with this parasite included the remains of a snake. *Syphacia* sp. is a parasite of rodents, and although the raccoon with this parasite did not have rodent remains in the stomach contents, rodents are a common prey item of raccoons. Cystacanths consistent with *Moniliformis* sp. larvae were found in the stomach and are suspected of being from a prey species as well. *Moniliformis* spp. are also parasites of rodents.

Lagochilascaris spp. are parasites of felids and opossums (*Didelphis virginiana*) and are considered to be accidental parasites of raccoons (Craig et al., 1980). This parasite has been previously reported in raccoons by Craig et al. (1980). They reported finding *Lagochilascaris major* in a granulomatous mass embedded in the mesentery between the stomach and duodenum, with no apparent tract into the gastrointestinal lumen. The three raccoons in our study that harbored *Lagochilascaris* sp. were all from the same area (Cass County, Texas, near Texarkana), and all specimens were found in the stomach lumen.

The five most prevalent helminths identified in our study have all been reported in at least one previous survey (Chandler, 1942; Schaffer et al., 1981), indicating that these parasites are not new to Texas and that the raccoon population

in Texas is not naïve to the effects these parasites have on them. Differences in parasite abundance were as expected across different habitat ecoregions. It may be helpful to wildlife rehabilitators, trappers, wildlife biologists, and other professionals to be aware of parasite abundance in raccoons from different areas of the state, because frequent human–raccoon interactions occur, and some of these parasites could be harmful to humans and to domestic animals (i.e., *Pl. lotoris*, *G. procyonis*, *B. procyonis*, and *Mesocestoides* spp.) (Marquardt et al., 2000; Kazacos, 2001).

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