

THE GUEST PLAYING HOST: COLONIZATION OF THE INTRODUCED MEDITERRANEAN GECKO, *HEMIDACTYLUS TURCICUS*, BY HELMINTH PARASITES IN SOUTHEASTERN LOUISIANA

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ABSTRACT: Parasite surveys of exotic hosts offer the opportunity to examine parasite colonization on different scales (i.e., host individual, host population, host species, and new geographic locality). Ten helminths (*Macracanthorhynchus ingens*, *Mesocostoides lineatus*, *Oochoristica javaensis*, *Haematoloechus varioplexus*, *Mesocoelium monas*, *Telorchis corti*, *Cosmocercoides variabilis*, *Oswaldocruzia leidy*, *Skrjabinoptera* sp., and a larval acuariid nematode) were recovered from the exotic Mediterranean gecko *Hemidactylus turcicus*, in southeastern Louisiana. Only 1 exotic parasite, *O. javaensis*, colonized a new geographic locality, but 7 local helminths colonized a new host species. Helminth communities of *H. turcicus* were similar in structure to what has been hypothesized or observed for lizards. Thus, communities were composed of generalists and were depauperate (i.e., colonization of individual geckos or host populations was rare for most of the helminths); however, there was significant variation in community structure among local habitats. Although the gecko's behavioral and physiological attributes predict colonization by monoxenous helminths, only 2, *C. variabilis* and *O. leidy*, were recovered. Eight heteroxenous helminths, 2 of which (the acuariid and *O. javaensis*) were the most widely distributed and abundant, were the better colonizers. The gecko's generalist diet may have exposed it to a diverse parasite fauna and thus been important in determining the helminths that could colonize.

Helminth component communities of the introduced Mediterranean gecko *Hemidactylus turcicus* were examined from 6 locations in southeast Louisiana. *Hemidactylus turcicus* is an Old World gecko that is found naturally around the Mediterranean regions of Africa, Asia, Europe, into Somalia, and western India (Conant and Collins, 1991). It was first reported in the United States from Florida in 1915 (Stejneger, 1922) and was first collected from Louisiana in 1949 (Etheridge, 1952). It has since extended its distribution throughout the southern United States (Conant and Collins, 1991). Because life history characteristics of *H. turcicus* have been well documented in its introduced range (Rose and Barbour, 1968; Selcer, 1986; Saenz, 1996), hypotheses for determinants of parasite colonization and community structure, especially those from studies on reptile hosts (Aho, 1990), could be examined in relation to host ecology. In this report, host or parasite attributes that may have facilitated parasite colonization, and thus ultimately affected the composition of the component communities, are discussed.

MATERIALS AND METHODS

Habitat descriptions

Mediterranean geckos were collected from 6 localities in southeastern Louisiana between July and October 1998 (Fig. 1). Bayou Segnette State Park (BSS) is located in Westwego (29°53.18'N, 90°9.80'W), has 234 ha of bottomland hardwood forest and marsh, but also contains several buildings and paved parking lots. Fairview–Riverside State Park (FRS) has bottomland hardwoods and campsites interspersed among pine trees; the 40-ha park borders the Techefunct River in Madisonville (30°24.55'N, 90°8.41'W). Fontainebleau State Park (FON) is located on the north shore of Lake Pontchartrain in Mandeville (30°20.41'N, 90°2.24'W) and consists of 1,136 ha of bottomland hardwoods and pine forest; however, buildings and paved parking lots are dispersed throughout the park. Mediterranean geckos were collected from small isolated buildings located within the state parks. The state parks were open to the public year-round, and vegetation within all of the parks was secondary growth.

The remaining 3 locations, unlike the state parks, were located in the middle of urbanized areas, where buildings and other human structures predominated over vegetated habitats. Vegetation that was present was constantly altered via human landscaping. At Louisiana State University

(LSU) in Baton Rouge (30°24.92'N, 91°10.81'W), geckos were collected from Foster Hall and several contiguous buildings. Surrounding vegetation consisted of open lawns and a few trees. Metairie (MET) (30°0.76'N, 90°8.90'W) collections were from 6 neighboring private residences. Within this residential neighborhood, adjacent houses are not separated by more than 3 m and vegetation is primarily limited to flower gardens, open lawns, and dispersed trees. Collections from Southeastern Louisiana University (SLU) in Hammond (30°30.67'N, 90°27.98'W) were from adjacent buildings on the southeastern edge of campus. Surrounding vegetation was sparse and similar to that of the collection area around LSU; however, undeveloped areas of secondary growth were located next to this portion of campus.

Host and parasite collection

For each location, sampling was spread out over the 4 mo to avoid temporal heterogeneity among locations. Seasonal or yearly fluctuations, however, cannot be accounted for from this sampling period. Geckos were hand collected from dusk to midnight while foraging along walls or while still in daytime refuges. All geckos were kept alive in an ice chest at 7 C until necropsied, and examined within 72 hr to minimize parasite loss. Geckos were killed using an overdose of ether and the body cavity, musculature, and all internal organs were examined for helminth parasites. Trematodes were heat-killed under a floating coverslip by passing them over an open flame and cestodes were killed with hot water (90 C). Acanthocephalans, trematodes, and cestodes were fixed and stored in acetic acid–formalin–alcohol, stained in Semichon's acetocarmine, dehydrated in ethanol, cleared in xylene, and mounted in Canada balsam. Nematodes were fixed with Berland's solution (1 part formalin: 9 parts acetic acid), stored in 70:5% ethanol:glycerin, and mounted in glycerol for examination. Voucher specimens of all species were deposited in the United States National Parasite Collection (90314–90348), Beltsville, Maryland.

Data analysis

The use of ecological terms is in accordance with Bush et al. (1997). All statistical tests were conducted with SYSTAT 9.0 (SPSS, 1999) statistical package. Statistical tests for patterns of association with prevalence and comparisons of abundance or intensity among localities were carried out separately for each helminth species that had a prevalence of at least 20% from 2 or more habitats. Individuals for which sex had not been determined were not used in these analyses. Patterns of association between prevalence and sex or prevalence and location were tested with contingency table analysis using the Pearson chi-square statistic. Analysis of covariance (ANCOVA) with snout–vent length (SVL) as the covariable was used to test for differences in abundance or intensity. The models tested the main effects of location and sex and the interaction between location and sex. Because abundance and intensity data were not normally distributed, these data and SVL were ranked transformed. This allowed parametric multiple

Received 29 January 2001; revised 29 May 2001; accepted 1 June 2001.

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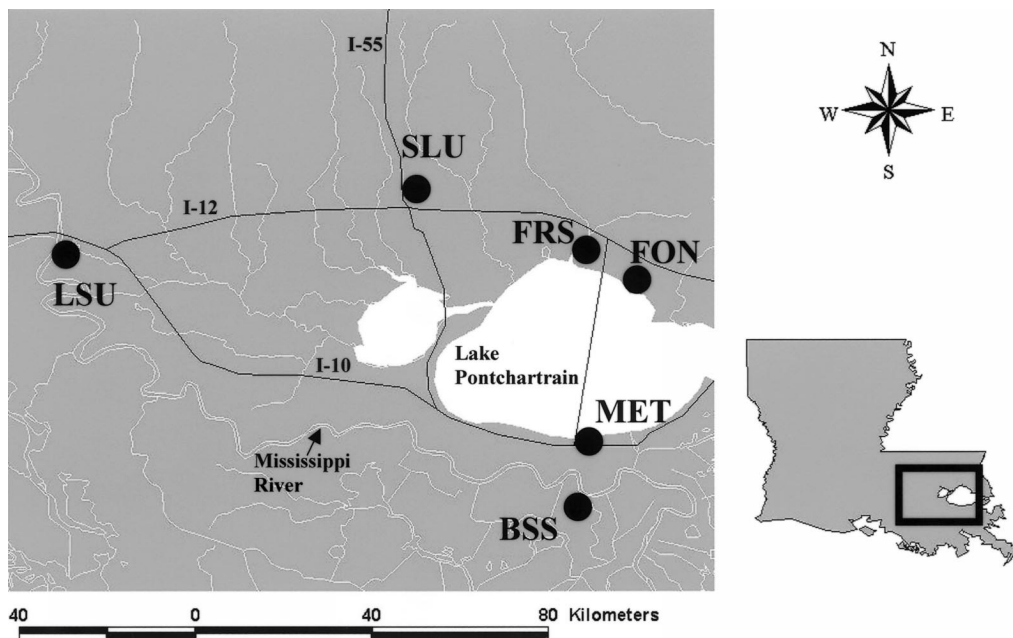


FIGURE 1. Map showing the 6 collection locations of *Hemidactylus turcicus* in southeastern Louisiana. BSS, Bayou Segnette State; FON, Fontainebleau State Park; FRS, Fairview–Riverside State Park; LSU, Louisiana State University; MET, Metairie; SLU, Southeastern Louisiana University.

comparisons to be made among locations (Conover and Iman, 1981). Kruskal–Wallis tests were also conducted on the main effects of location and sex to check for agreement in statistical tests. Statistical significance was determined at $P < 0.05$.

Differences for mean infracommunity richness (i.e., number of helminth species per host individual) among locations were tested with ANCOVA (SVL = covariable); these data were ranked transformed. To compare helminth richness at the component level while correcting for host sampling size, curves of cumulative helminth species versus number of hosts sampled were generated for each locality. Means ± 1 SD of species accumulation were calculated after host sampling order was randomized 5,000 times; EstimateS ver. 5 (Colwell, 1997) was used for these calculations. By rarefying host sample sizes based on the curves, helminth richness among locations could be qualitatively compared. Richness analyses included unsexed geckos.

RESULTS

From the 6 localities, 217 Mediterranean geckos (107 males, 100 females, and 10 not sexed) were collected. One species of Acanthocephala, *Macracanthorhynchus ingens* (Von Listow, 1879); 2 species of Cestoda (*Mesocostoides lineatus* (Goeze, 1782) and *Oochoristica javaensis* Kennedy, Killick, and Beverly-Burton, 1982); 3 species of Trematoda (*Haematoloechus varioplexus* Stafford, 1902; *Mesocoelium monas* (Rudolphi, 1819); and *Telorchis corti* Stunkard, 1915); and 4 species of Nematoda (*Cosmoceroides variabilis* (Hardwood, 1930); *Oswaldocruzia leidy* Steiner, 1924; *Skrjabinoptera* sp.; and a larval acuariid) were found (Table I). Ranges and species identifications for *H. varioplexus* and *M. monas* were based on the redescription and synonymies of Kennedy (1981) and Nasir and Diaz (1971), respectively. The only parasite considered introduced was *O. javaensis* (see Criscione and Font, 2001a, 2001b), and because the other helminths have been recorded from resident hosts in Louisiana or adjoining states, they were regarded as local species. Accurate assessment of *Skrjabinoptera* sp. and the acuariid, however, is not possible until adults

are obtained for specific identification. All helminths represent new records for *H. turcicus*, with the possible exception of *Skrjabinoptera* sp. To the authors' knowledge, this is also the first report of a *Haematoloechus* spp. infecting a nonanuran host. Prior to this study, only 7 helminth species were reported from *H. turcicus* in its native range and 6 in its introduced range (Table II).

A total of 137 (63%) Mediterranean geckos (61 males, 74 females, and 2 not sexed) was infected. Of these, 85 were single-, 48 were double-, and only 4 were triple-species infections. When geckos from all 6 localities are combined ($n = 217$), the 3 parasites with the greatest mean abundance (± 1 SE) were the acuariid larva (7.51 ± 1.65), *M. lineatus* (3.96 ± 2.62), and *O. javaensis* (2.28 ± 0.59). *Mesocostoides lineatus*, however, was found only at BSS, whereas the acuariid and *O. javaensis* were found at 5 of the 6 locations; the remaining 7 helminths all had a mean abundance of < 1 (Table I).

With the exception of *O. javaensis*, the acuariid, and *O. leidy*, helminths were restricted to 3 or fewer habitats; however, *O. leidy* had $< 3\%$ prevalence in 3 of its 4 locations (Table I). By far, the most widely distributed and abundant helminths recovered were the acuariid and *O. javaensis*. After removal of unsexed geckos, sample sizes for tests of prevalence, abundance, and intensity at BSS, FRS, LSU, MET, and SLU were 54, 31, 41, 33, and 33, respectively. There was no association between sex and prevalence, but there was an association between location and prevalence for both the acuariid and *O. javaensis*, ($\chi^2 = 53.1$ and 41.9 , respectively, $df = 4$, $P < 0.0001$). In the abundance and intensity tests for the acuariid and abundance for *O. javaensis*, the use of the covariable, SVL, was effective ($P < 0.05$). There were no sex effects, but there were significant location effects for acuariid abundance ($F_{4, 181} = 40.5$, $P < 0.0001$) and intensity ($F_{4, 92} = 18.3$, $P < 0.0001$) and

TABLE 1. Site of infection, mean abundance, prevalence, and intensity range for helminths of *Hemidactylus turcicus* from southeastern Louisiana.

Helminth	Site*	BSS (n = 58)	FON (n = 19)	FRS (n = 32)	LSU (n = 42)	MET (n = 33)	SLU (n = 33)
Acanthocephala							
<i>Macracanthorhynchus ingens</i> (cystacanth)	SK	—	0.21 ± 0.12 [†] 1.33 ± 0.33 [‡] 15.8§, 1–2	—	—	—	—
Cestoda							
<i>Mesocestoides lineatus</i> (tetrathyridia)	BC, MF	14.81 ± 9.72 122.7 ± 72.3 12.1, 6–534	—	—	—	—	—
<i>Oochoristica javaensis</i> #	SI	0.10 ± 0.06 C 1.5 ± 0.5 6.9, 1–3	—	0.25 ± 0.19 C 2.67 ± 1.67 9.4, 1–6	5.69 ± 2.16 A 9.96 ± 3.56 57.1, 1–79	3.42 ± 1.93 AB 7.06 ± 3.83 48.5, 1–64	3.88 ± 1.81 BC 16 ± 5.83 24.2, 2–42
Trematoda							
<i>Haematoloechus varioplexus</i>	LU	0.02 ± 0.02 1 1.7, 1	—	—	—	0.03 ± 0.03 1 3, 1 0.06 ± 0.04 1 6.1, 1	—
<i>Mesocoelium monas</i>	SI	—	—	—	—	—	—
<i>Telorchis corti</i>	SI	0.02 ± 0.02 1 1.7, 1	—	—	—	—	—
Nematoda							
Acuariid larvae#	PS	1.29 ± 0.40 C 3.75 ± 0.97 B 34.5, 1–19	—	1.84 ± 0.42 B 3.11 ± 0.55 B 59.4, 1–10	9.07 ± 1.99 AB 12.29 ± 2.46 A 73.8, 1–67	33.49 ± 9.29 A 38.1 ± 10.29 A 87.9, 1–223	0.3 ± 0.22 C 2.5 ± 1.5 B 12.1, 1–7
<i>Cosmoecerooides variabilis</i>	LI	0.03 ± 0.02 1 3.4, 1	0.21 ± 0.16 2 ± 1 10.5, 1–3	0.06 ± 0.04 1 6.3, 1	—	—	—
<i>Oswaldoeruzia leidy</i>	SI, ST	0.12 ± 0.09 3.5 ± 1.5 3.4, 2–5	0.26 ± 0.15 1.67 ± 0.33 15.8, 1–2	0.03 ± 0.03 1 3.1, 1	0.02 ± 0.02 1 2.4, 1	—	—
<i>Skrijabinoptera</i> sp.	SI, S	0.12 ± 0.06 1.4 ± 0.25 8.6, 1–2	—	0.06 ± 0.06 2 3.1, 2	—	0.15 ± 0.15 5 3, 5	—

* Site abbreviations: BC, body cavity; LI, large intestine; LU, lung; MF, muscle fascia of intestines; PS, peritoneum of stomach; SK, between skin and muscle; SI, small intestine; ST, stomach.
[†] Mean abundance ± 1 SE.
[‡] Mean intensity ± 1 SE.
[§] Prevalence as a percentage.
^{||} Intensity range.
[#] Letters denote statistical similarity based on Bonferroni corrected pairwise comparisons for *O. javaensis* abundance and acuariid abundance and intensity. Data were ranked transformed and did not include unsexed geckos. See text for sample sizes used in these analyses.

TABLE II. Helminths reported from *Hemidactylus turcicus* in its native and introduced ranges.

Helminth	Location	No. infected/ no. examined	Reference
Native range			
Cestoda			
<i>Nematotaenia tarentolae</i>	Spain	1/3	Roca and Lluch (1986)
Trematoda			
<i>Lecithodendrium</i> sp.	Egypt	1/5	Groschaft and Moravec (1983)
Nematoda			
<i>Pharyngodon laevicauda</i>	Turkey	43/79	Tinar (1982)
<i>Pharyngodon inermicauda</i>	Egypt	Not given	Al-Deen et al. (1995)
<i>Pharyngodon mamillatus</i>	Egypt	Not given	Al-Deen et al. (1995)
<i>Spauligodon auziensis</i>	Egypt	Not given	Al-Deen et al. (1995)
<i>Spauligodon paratectipenis</i>	Spain	2/3	Roca and Lluch (1986)
Introduced range			
Nematoda			
<i>Ascarops</i> sp.	Texas	9/98	McAllister et al. (1993)
<i>Skrjabinoptera phrynosoma</i> *	Cuba	1/9	Coy Otero and Baruš (1979)
<i>Spauligodon californiensis</i> *	Cuba	3/9	Coy Otero and Baruš (1979)
<i>Cyrnea</i> sp.	Cuba	1/9	Coy Otero and Baruš (1979)
Pentastomida			
<i>Raillietiella frenatus</i> *	Texas, Florida	210/480	Pence and Selcer (1988)
<i>Raillietiella teagueselfi</i> *	Texas	17/86	Riley et al. (1988)

* Helminths regarded by the authors as being nonnative to that location.

O. javaensis abundance ($F_{4, 181} = 14.3$, $P < 0.0001$). For *O. javaensis*, there was no significance for intensity. Kruskal–Wallis tests agreed with all of the above tests. When there was statistical significance, MET and LSU consistently had higher values of prevalence, ranked abundance, and ranked intensity for the acuariid and *O. javaensis*; BSS was always on the lower end of these measures (Table I). FRS and SLU exhibited intermediate patterns depending on the parasite in question (Table I). FON was not included in the analyses because of the absence of the acuariid and *O. javaensis*; however, the small sample size may have precluded detection, especially if prevalence was low.

Mean infracommunity richness for all samples combined (0.89 ± 0.06 , $n = 217$) was higher (1-sample *t*-test, $P < 0.0001$)

TABLE III. Mean infracommunity richness (MIR), total richness (TR), and mean component richness (MCR) for 19 and 28 hosts sampled. MCR values were generated from the species accumulation curves.

Location	MIR*	TR	MCR \pm 1 SD	
			19 hosts	28 hosts
BSS (58)†	0.72 \pm 0.12 BC	8	5.31 \pm 1.20	6.34 \pm 1.06
FON (19)	0.42 \pm 0.12 BC	3	3.00 \pm 0.00	N/A‡
FRS (32)	0.81 \pm 0.12 B	5	4.11 \pm 0.80	4.80 \pm 0.40
LSU (42)	1.33 \pm 0.10 A	3	2.44 \pm 0.50	2.73 \pm 0.44
MET (33)	1.49 \pm 0.12 A	5	3.99 \pm 0.76	4.68 \pm 0.51
SLU (33)	0.36 \pm 0.11 C	2	1.98 \pm 0.16	2.00 \pm 0.00

* There was a location effect on MIR ($F_{5, 210} = 15.78$, $P < 0.0001$); letters denote statistical similarity based on Bonferroni corrected pairwise comparisons.

† Number of Mediterranean geckos used in richness analyses for each location; includes unsexed geckos.

‡ N/A, not applicable.

than the mean for lizards (0.63), but within the range (0–2.5; see Aho, 1990). There was a significant difference, however, in mean infracommunity richness among locations, with MET and LSU having higher values than the other habitats (Table III). Qualitatively, the total number of helminth species was also different among locations, with BSS having the most species (Table III). This is supported by the fact that the order of habitats from greatest to least richness (BSS, FRS, MET, FON, LSU, then SLU) remained constant even after host sampling size was rarefied to 19 or 28 (Table III).

DISCUSSION

Aho (1990) concluded that helminth communities of amphibians and reptiles are highly variable, depauperate, and not responsive to food web dynamics, and they would be dominated by monoxenous helminths. He considered low host vagility and ectothermy to be the primary causes of a depauperate helminth fauna and that local habitats and host dietary patterns increased variability among host populations. Attributes of the Mediterranean gecko, such as being an ectotherm (Slade et al., 1994) and having limited movement (Rose and Barbour, 1968; Selcer, 1986; Trout and Schwaner, 1994), indicate that its populations would be comprised of helminth communities that were similar in structure to those hypothesized by Aho (1990). Examination of these data at the hierarchical levels of parasite colonization proposed by Bush et al. (1997) (i.e., host individual, host population, or new host species) provided support or contradicted hypotheses about helminth communities of lizards.

At the level of host individual, geckos were mostly infected with heteroxenous and not monoxenous helminths (Table I).

Limited movement, shared daytime refuges, and shared nesting sites (Selcer, 1986) should predispose individual geckos to monoxenous parasites (Aho, 1990). These factors, however, did not facilitate colonization of the 2 helminths with direct life cycles (*C. variabilis* and *O. leidy*); the other 8 helminths were acquired via ingestion of infected intermediate hosts. The broad diet of *H. turcicus* (Saenz, 1996) is an attribute that could have exposed the gecko to a diverse parasite fauna (Kennedy et al., 1986). In southeastern Louisiana, food web dynamics are important in determining the helminths that colonize *H. turcicus*. Colonization of individual hosts, however, was infrequent for most of the helminths, as indicated by their low prevalence (Table I). Moreover, the overall infracommunity richness (0.89) was relatively low and within the range reported for lizards (Aho, 1990). The decreased ability to infect individuals should lead to a depauperate helminth community in a host population (Holmes and Price, 1986). In general, this was observed for the helminth communities of *H. turcicus*, but there was significant variation in richness, prevalence, and abundance among the 6 locations.

It should be noted that parasite colonization of a host population could occur without colonization of a new habitat. Such was the case with the local helminths infecting the introduced gecko. Alternatively, an exotic parasite that is maintained in its exotic host and does not establish in local hosts would have colonized a new external habitat. Exposure to new environmental conditions directly or indirectly via a host poses obstacles to the establishment of a parasite population; therefore, colonization of a geographic location, not mentioned by Bush et al. (1997), should be regarded as another level of parasite colonization. To facilitate discussion of variation among the habitats and because colonization of a host population and geographic location can occur simultaneously, both levels were concurrently addressed.

For lizards, local habitat has an apparent effect on helminth community composition (Bundy et al., 1987; Dobson and Pacala, 1992; Biserkov and Kostadinova, 1998; Goldberg et al., 1998). In the present study, habitat also appeared to influence the colonization of helminths among the local populations of *H. turcicus*. In general, richness was greater in the state parks (BSS, FRS, and FON), but for the acuariid or *O. javaensis*, there was higher prevalence and abundance in urbanized habitats (LSU, MET, and SLU). There was not a distinct dichotomy, however, for helminth community organization between parks and urbanization. For example, MET had high richness, and prevalence for the acuariid was high at FRS but low at SLU. Although mechanisms were not examined, supracommunity dynamics may be important for richness and abundance, such that habitats with more definitive or intermediate host species could support a greater pool of helminth species available to colonize *H. turcicus* (Holmes, 1979; Bush et al., 1993). Although speculative, the parks were likely to harbor more reptile and amphibian species (for sympatric reptile and amphibian species see Dundee and Rossman, 1989) and, thus, may explain why helminth richness was relatively high. Also, spatial constraints of the habitats may have affected prevalence and abundance patterns by altering the frequency of contact between the gecko and intermediate hosts. More research will be needed to establish determinants of community organization within each habitat.

Colonization among host populations or new habitats will

also be dependent on the life cycle of the parasite. Dobson and May (1986) stated that monoxenous parasites are more likely to colonize new habitats because they do not require intermediate hosts. Again, the present results contradict the predictions in that 2 heteroxenous parasites, the acuariid and *O. javaensis*, have colonized 5 of the 6 locations. Colonization of new habitats could have been facilitated by intermediate hosts with broad distributions (Kennedy, 1993) or a parasite's lack of intermediate host specificity; however, the natural intermediate host for either helminth is unknown. It should be noted that the flour beetle *Tribolium castaneum* is a suitable intermediate host for *O. javaensis* in the laboratory (Criscione and Font, 2001b); therefore, coleopterans, which have been reported in the diet of *H. turcicus* (Saenz, 1986), could be natural intermediate hosts. Additionally, *O. javaensis* may have an increased chance of being introduced to new localities because it infects a family of hosts, Gekkonidae (Kennedy et al., 1982), that has taken advantage of anthropogenic effects to colonize new habitats.

No helminths reported from the native range of *H. turcicus* (Table II) were recovered in the present study. Interestingly, the pentastomes recovered in the introduced range (Table II), like *O. javaensis*, were regarded as exotic species originating from the Old World despite not being reported from *H. turcicus* in its native range (Pence and Selcer, 1988; Riley et al., 1988). This may be because Old World surveys have yet to detect these helminths, or possibly, *H. turcicus* has acquired these helminths in introduced ranges that overlap with other geckos harboring these helminths. Additionally, the helminth richness of *H. turcicus* in its introduced range is greater than that in its native range; however, the small sample sizes in the native range surveys preclude definitive comparison and assessment of causal mechanisms.

Seven local helminths have colonized a new host species *H. turcicus*, hence the characterization of a guest playing host. When considering that the gecko has acquired local parasites, some of which are considered to be predominantly anuran parasites (*C. variabilis*, *H. varioplexus*, and *O. leidy*), the results of this study provide support for the notion of reptile and amphibian parasites tending to be generalists (Aho, 1990). Although reptile and amphibian parasites may be poor colonizers of individuals, generalist life history strategies, as demonstrated by these results, allow reptiles and amphibian helminths to be exceptionally good colonizers of new host species. Also, because there are no naturally occurring members of the Family Gekkonidae in Louisiana, colonization of *H. turcicus* by native parasites would be a result of ecological factors rather than host phylogenetic determinants (Brooks, 1980; Bush et al. 1990).

ACKNOWLEDGMENTS

We thank the people associated with the Louisiana State Parks for permitting us to collect in their parks and extend our gratitude to B. Nickol and I. de Buron for identifying *M. ingens* and R. Overstreet for identifying the acuariid larvae. In addition, we are grateful to B. Horne, M. Mire, A. Vincent, and J. Willis for their assistance in the field.

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