HELMINTH PARASITE COMMUNITIES OF *CHARACODON AUDAX* AND *C. LATERALIS* (PISCES: GOODEIDAE), ENDEMIC FRESHWATER FISHES FROM DURANGO, MEXICO

ANDRÉS MARTÍNEZ-AQUINO, GUILLERMO SALGADO-MALDONADO,* ROGELIO AGUILAR-AGUILAR, GUILLERMINA CABAÑAS-CARRANZA, AND CARLOS MENDOZA-PALMERO

Universidad Nacional Autónoma de México, Instituto de Biología, Laboratorio de Helmintología, A.P. 70-153, C.P. 04510, México, D.F., Mexico
**Correspondent: gsalgado@mail.ibiologia.unam.mx*

ABSTRACT—We examined *Characodon audax* ($n = 30$) and *C. lateralis* ($n = 27$) (Pisces: Goodeidae), endemic freshwater fishes from Durango, Mexico. We recorded 8 helminth species, and metacercariae of *Posthodiplostomum minimum* had the highest prevalence and highest mean intensity of infection. Specialist species included *Salsuginus* sp. (an undescribed monogenean) and the intestinal trematode *Margotrema bravoae*. These 3 species and larvae of the nematode *Spiroxys* sp. were the most frequent and abundant species. The remaining species were rare and found at low mean intensities. Intestinal helminth communities were comprised primarily *M. bravoae*, though most host intestines were free of macroscopic parasites. These data confirm the depauperate nature of the helminth communities of Goodeidae fish species in Nearctic Mexico. Helminth host specificity is suggested as an important factor for explaining the observed richness, and host feeding habits and local habitat characteristics are suggested as the main factors contributing to the variability observed in community composition and richness.

RESUMEN—Examinamos *Characodon audax* ($n = 30$) y *C. lateralis* ($n = 27$) (Pisces: Goodeidae), especies de peces dulceacuícolas endémicas de Durango, México. Registramos 8 especies de helmintos, y la metacercaria de *Posthodiplostomum minimum* fue la especie dominante y alcanzó las mayores intensidades de infección. Especies especialistas incluyeron *Salsuginus* sp. (un monogeneo no descrito) y el trematodo intestinal *Margotrema bravote*. Estas 3 especies y la larva del nematodo *Spiroxys* sp. fueron las más frecuentes y abundantes. Las demás especies fueron raras y se presentaron en bajas intensidades promedio. Las comunidades de helmintos intestinales fueron constituidas principalmente por *M. bravoae*, aunque la mayoría de los intestinos resultaron vacíos de parásitos macroscópicos. Los datos confirman la naturaleza pobre de las comunidades de helmintos parásitos de los Goodeidae del Neártico de México. La especificidad hospedaria se sugiere como un factor importante para explicar la riqueza observada y los hábitos alimenticios del hospedero y las características locales del hábitat se sugieren como los factores principales que contribuyen a la variabilidad observada en la composición y riqueza de la comunidad.

Freshwater fish species of the family Goodeidae (Pisces: Cyprinodontiformes) include those in the subfamilies Empetrichtynae and Goodeinae (Webb et al., 2004). The Goodeinae includes 17 genera and 36 species, which are primarily restricted to the Mexican Highland Plateau (Berra, 2001; Webb et al., 2004). Several Goodeinae species have been examined to date for helminth parasites (Salgado-Maldonado et al., 2001*a*, 2001*b*, 2004*a*; Martínez-Aquino et al.,

2004; Mejía-Madrid et al., 2005; Pineda-López et al., 2005). Data on the helminth parasites of the Goodeinae can be useful in addressing questions about the composition, ecology, zoogeography, origin, and evolution of helminth communities in freshwater fish from the Mexican Highland Plateau and other Nearctic areas of Mexico.

The genus *Characodon* Günther (Goodeinae) includes 2 species, *C. audax* Smith and Miller and *C. lateralis* Günther, currently restricted to small springs in the states of Coahuila and Durango in northern Mexico. These species are currently listed as at risk (Contreras-Balderas et al., 2003), and a third species, *C. germani* Jordan and Evermann, formerly found in the Nazas River basin of Coahuila, Mexico, is now considered extinct (Espinosa-Pérez et al., 1993). The present report provides data on the helminth communities of both extant species of *Characodon* from their current distribution area, including taxonomic composition, richness, and diversity characteristics.

Samples were taken in November 2003 from 2 freshwater springs in the state of Durango, Mexico. Thirty *C. audax* specimens were caught using gill nets in the El Toboso spring (24°16′45″N, 104°34′41″W) and 27 *C. lateralis* specimens were collected from Abraham González spring (24°12′45″N, 104°31′48″W). These springs are independent, approximately 9 km apart, but belong to the same watershed. Fish specimens were taken live to the laboratory and examined within 24 h after capture using standard procedures. All the external surfaces, mouth, gills, and eyes, as well as body cavity and viscera, including liver, kidney, gut, mesenteries, and musculature of each host were examined under a stereomicroscope. All helminths encountered in each fish were counted and then fixed with hot 4% formalin. Monogeneans, digeneans, and cestodes were stained with Meyer's paracarmine or Ehrlich's haematoxylin, dehydrated using a graded alcohol series, cleared in methyl salicylate, and whole-mounted. Nematodes were cleared with glycerin for light microscopy and stored in 70% ethanol. Voucher specimens of all taxa were deposited in the Colección Nacional de Helmintos (CNHE), Instituto de Biología, Universidad Nacional Autónoma de México (UNAM), Mexico City.

Terminology of parasite infections follows definitions given by Bush et al. (1997), i.e., prevalence (% infected) and mean intensity of infection (mean number of parasites per infected fish).

Analyses were carried out at the component community level (i.e., all the helminths in all of the individuals of each species of *Characodon*), and at the infracommunity level (i.e., all the helminths in each individual) (Holmes and Price, 1986). A species richness sample effort curve was used to determine if sample size was sufficient to produce an accurate estimate of the pool of helminths parasitizing *C. audax* and *C. lateralis* from each locality (Salgado-Maldonado et al., 2004*b*). A cumulative species curve was plotted and the observed values fitted to the Clench model to assess an asymptotic trend (Clench, 1979). The nonparametric species richness estimator bootstrap was calculated from the observed data to extrapolate the number of missing species at the component community level (Poulin, 1998). Helminth species were separated as dominant (high prevalence and abundance) and rare (low prevalence and abundance) after an Olmstead-Tukey corner test of association (Steel and Torrie, 1981). Moreover, numerical dominance at the component community and infracommunity levels was determined using the Berger-Parker dominance index (Southwood, 1978). Infracommunities were described by the mean number of parasite species per fish, the mean number of helminth individuals per fish, and the mean value of the Brillouin diversity index per fish. Infracommunities within individual fish were compared qualitatively within localities using the Jaccard similarity index, and quantitatively using the Morisita-Horn index, as calculated in Magurran (1998). All correlations were carried out using Spearman's Rank test.

Total lengths of the examined *C. audax* ranged from 27 to 79 mm (mean 39 ± 9.7 *SD*), and those of the examined *C. lateralis* ranged from 25 to 49 mm (mean 36 ± 6.4 *SD*). Examination of the gonads indicated that all collected host specimens were sexually mature adults. A total of 1,713 individuals from 8 helminth species were collected from *C. audax*, while only 11 nematode larvae of one species were collected from *C. lateralis*.

The helminth species recovered from *C. audax* included an undescribed monogenean species, *Salsuginus* sp.; the adult digenean *Margotrema bravoae* Lamothe-Argumedo, 1970; metacercariae

TABLE 1—Number of individuals, prevalence (% infected), mean intensity of infection (MI), and site of infection for helminth parasites of 2 *Characodon* species (Pisces: Goodeidae) from 2 springs in Durango, Mexico.

	C. audax (n = 30) El Toboso			*C. lateralis* (n = 27) Abraham González		
Helminth (site of infection[1])	n	%	MI ± *SD*	n	%	MI ± *SD*
Adult trematodes						
Family Allocreadiidae						
Margotrema bravoae (i)	35	63.3	1.8 ± 1.2			
Metacercariae						
Family Clinostomidae						
Clinostomum complanatum (l, m)	2	6.7	1			
Family Diplostomidae						
Posthodiplostomum minimum (1, m)	1,609	100	53.6 ± 41.2			
Monogenea						
Family Dactylogyridae						
Salsuginus sp. (g)	24	43.3	1.8 ± 0.9			
Metacestodes						
Caryophylloidea gen. sp. (m)	10	20	1.7 ± 0.8			
Larval nematodes						
Family Anisakidae						
Contracaecum sp. (l, m)	4	6.7	2.0 ± 1.4			
Family Camallanidae						
Serpinema trispinosum (s)	1	3.3	1			
Family Gnathostomatidae						
Spiroxys sp. (bc)	28	50	1.9 ± 1.5	11	29.6	1.4 ± 1.0

[1] bc = body cavity; g = gills; i = intestine; l = liver; m = mesentery; s = serosa.

of *Clinostomum complanatum* (Rudolphi, 1814) and of *Posthodiplostomum minimum* (MacCallum, 1921); an unidentified metacestode of the order Caryophylloidea; and larvae of the nematodes *Contracaecum* sp., *Serpinema trispinosum* (Leidy, 1852), and *Spiroxys* sp. Two of these helminth species, *Salsuginus* sp. and *M. bravoae*, are considered goodeid specialists, the latter being the only helminth species found in the intestine of this fish species. Larvae of *Spiroxys* sp. were the only species collected from *C. lateralis*. Infection sites of each helminth species, number of helminths recovered, prevalence, and mean intensity are shown in Table 1.

Based on the cumulative species curve and the nonparametric species richness estimator value for *C. audax* and *C. lateralis* (bootstrap = 8.7 and 1.8, respectively), the inventory presented here for both species can be considered nearly complete. The richness estimator suggested one more species remains to be found at the component community level for each fish species.

The Olmstead-Tukey corner test showed 4 of the 8 helminth species from *C. audax* to be frequent and abundant. The metacercariae of *P. minimum* was the most abundant, accounting for 94% of the collected individual helminths, and was the dominant species in the component community (Berger-Parker index = 0.94). The data indicated that *Salsuginus* sp., as well as *M. bravoae* and *Spiroxys* sp., were frequent (prevalence > 40%) and abundant (mean intensity > 1.8). The remaining species were rare, infrequent, and of low mean intensity (Table 1).

All *C. audax* hosts were infected with at least one helminth species, with the number of helminth species per host ranging from 1 to 6. Six hosts had just one helminth species, 3 had 2 species, 13 had 3, 4 had 4, 3 had 5, and one had the maximum of 6. Total number of helminth individuals of all species per host varied from 1 to 152, with a mean (± *SD*) number of helminth individuals per host of 57.1 ± 42.4. Mean number of species per host was 2.9 ± 1.3. The Brillouin index varied from 0.05 to 1.1, with a mean diversity value of 0.3 ± 0.3. The Berger-Parker dominance index values varied from 0.4 to 1, with a mean of 0.9 ± 0.1. The metacercariae of *P. minimum* was the most abundant species occurring in 100% of the hosts. One of 3 host

intestines was free of large parasites, because only 19 of the 30 hosts examined had the intestinal helminth *M. bravoae*.

The helminth infracommunities of *C. audax* from El Toboso spring displayed a relatively medium level of similarity. The corresponding Jaccard index varied from 0.1 to 1 (mean of 0.5 ± 0.2 *SD*) and the Morisita-Horn index varied from 0.7 to 1 (mean of 0.96 ± 0.06 *SD*). Not surprisingly, the infracommunities of *C. lateralis* from Abraham González spring had low comparative similarity because 19 of these hosts were helminth-free, while the rest were only infected by *Spiroxys* sp. Low similarity was also observed when comparing component communities between *C. audax* and *C. lateralis* (Jaccard index = 0.1; Morisita-Horn index = 0.02).

No differences were observed in helminth species prevalences, mean intensity, or richness between host sexes for any of the recorded helminth species. No significant correlation was observed between host size and total number of individual helminths, though a significant correlation between richness and fish size ($r = 0.2$, $t_{0.05(1)}$, $\alpha = 1.08 < 1.7$) was recorded.

The data presented here constitute a complete helminthological record for *C. audax*. All the helminths identified in the present study, except *S. trispinosum*, have been recorded previously in goodeids from other bodies of water in Mexico (Pérez et al., 2000; Salgado-Maldonado et al., 2001*b*, 2004*a*; Martínez-Aquino et al., 2004; Pineda-López et al., 2005). The nematode *S. trispinosum* parasitizes freshwater fishes in several Neotropical basins of Mexico (Aguilar-Aguilar et al., 2003), though the present finding constitutes its first record from a Nearctic locality, though with minimum abundance.

The present data confirm that host specificity is important for explaining helminth community composition, because 25% of the taxa recorded (2 of 8) are specialists to goodeid fishes. Most of the species, however, were generalists. This pattern has been recorded previously for the helminth communities of Mexican freshwater fish species (Salgado-Maldonado and Kennedy, 1997; Salgado-Maldonado et al., 2001*a*, 2001*b*, 2004*a*, 2004*b*; Martínez-Aquino et al., 2004; Sánchez-Nava et al., 2004), and it suggests opportunistic colonization of available habitats by generalist parasites with a wide distribution range, generally transported by piscivorous birds.

The helminth communities of the 2 *Characodon* species studied here are depauperate and dominated by single generalist helminth species. Indeed, the intestines of both host species were either free of parasites or contained only a single helminth species at low densities. Reports exist of rich helminth communities parasitizing freshwater Neotropical fishes in Mexico (Salgado-Maldonado and Kennedy, 1997; Vidal-Martínez et al., 1998; Vidal-Martínez and Kennedy, 2000), but the present findings confirm the generally impoverished nature of helminth communities in the Nearctic freshwater fish of Mexico (Pérez et al., 2000; Martínez-Aquino et al., 2004). This suggests that different processes operate in the Nearctic and Neotropical areas of Mexico. However, a dominance pattern exerted by a single helminth species is common to fish in both the Neotropical and Nearctic areas of Mexico, notwithstanding community richness. *Posthodiplostomum minimum* is one of the most abundant and widely distributed helminth species on the Mexican Highland Plateau and in Mexico overall (Salgado-Maldonado et al., 2001*a*).

Although both of the host species examined in this study inhabited localities forming part of the same watershed, their helminthological communities were different. These differences can be at least partially explained by the feeding habits of each species because 4 of the 8 helminth species recorded from *C. audax* infect their host through its food. *Characodon audax* is an omnivorous species (pers. observ.), while *C. lateralis* is an herbivorous species (Fitzsimons, 1972), meaning it is potentially less exposed to intermediate hosts. Other important factors contributing to the observed differences in community composition must be related to habitat characteristics, such as availability of appropriate intermediate hosts, as well as habitat and host population sizes.

Thus, the data presented here confirm the depauperate and dominated nature of helminth communities in the Goodeinae fish species of Nearctic Mexico. Helminth host specificity is an important factor explaining the observed richness, and the data suggest host feeding habits and local habitat characteristics are the main factors contributing to the observed variability in community composition and richness.

This study was supported by Project no. CN-02-82 from UC MEXUS-Consejo Nacional de Ciencia y

Tecnología (CONACyT), Mexico to GSM. We thank E. Ávila-Luna (Instituto de Ecología, UNAM) for suggestions to get the hosts; E. Soto-Galera (Instituto Politécnico Nacional, México) and J. Lyons of Wisconsin Department of Natural Resources for identification of hosts; and N. Mercado-Silva, H. L. Bart Jr., and M. Cabañas for technical assistance in the field. This study is part of a Bachelor thesis of the first author. Special thanks to 2 anonymous reviewers for their suggestions to improve the manuscript.

Literature Cited

Aguilar-Aguilar, R., R. Báez-Valé, C. Mendoza-Palmero, G. Salgado-Maldonado, and G. Barrios-Quiroz. 2003. Nuevos registros de *Serpinema trispinosum* (Leidy, 1852) (Nematoda: Camallanidae) para México. Universidad y Ciencia 19:62–65.

Berra, T. M. 2001. Freshwater fish distribution. Academic Press, San Diego, California.

Bush, A. O., K. D. Lafferty, J. M. Lotz, and A. W. Shostak. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. Journal of Parasitology 65:667–669.

Clench, H. K. 1979. How to make regional lists of butterflies: some thoughts. Journal of the Lepidopterological Society 33:215–231.

Contreras-Balderas, S., P. Almada-Villela, M. L. Lozano-Vilano, and M. E. García-Ramírez. 2003. Freshwater fish at risk or extinct in Mexico. Reviews in Fish Biology and Fisheries 12:241–251.

Espinosa-Pérez, H., M. T. Gaspar-Dillanés, and P. Fuentes-Mata. 1993. Listados Faunísticos de México III. Los peces dulceacuícolas mexicanos. Instituto de Biología, Universidad Nacional Autónoma de México, México.

Fitzsimons, J. M. 1972. A revision of two genera of goodeid fishes (Cyprinodontiformes, Osteichthyes) from the Mexican Plateau. Copeia 1972:728–756.

Holmes, J. C., and P. W. Price. 1986. Communities of parasites. In: J. Kikkawa and D. J. Anderson, editors. Community ecology patterns and processes. Blackwell Scientific Publications, Oxford, United Kingdom. Pages 187–213.

Magurran, A. 1988. Ecological diversity and its measurement. Croom Helm, London, United Kingdom.

Martínez-Aquino, A., G. Salgado-Maldonado, R. Aguilar-Aguilar, G. Cabañas-Carranza, and M. P. Ortega-Olivares. 2004. Helminth parasites of *Chapalichthys encaustus* (Pisces: Goodeidae), an endemic freshwater fish from Lake Chapala, Jalisco, Mexico. Journal of Parasitology 90:889–890.

Mejía-Madrid, H., O. Domínguez-Domínguez, and G. Pérez. 2005. Adult endohelminth parasites of Goodeinae (Cyprinodontiformes: Goodeidae) from México with biogeographical considerations. Comparative Parasitology 72:200–211.

Pérez, P. G., L. García-Prieto, V. León-Régagnon, and A. Choudhury. 2000. Helminth communities of native and introduced fishes in Lake Pátzcuaro, Michoacán, México. Journal of Fish Biology 57:303–325.

Pineda-López, R., G. Salgado-Maldonado, E. Soto-Galera, N. Hernández-Camacho, A. Orozco-Zamorano, S. Contreras-Robledo, G. Cabañas-Carranza, and R. Aguilar-Aguilar. 2005. Helminth parasites of viviparous fishes in Mexico. In: H. J. Grier and M. C. Uribe, editors. Viviparous fishes. New Life Publications, Homestead, Florida. Pages 437–456.

Poulin, R. 1998. Comparison of three estimators of species richness in parasite component communities. Journal of Parasitology 84:485–490.

Salgado-Maldonado, G., G. Cabañas-Carranza, E. Soto-Galera, J. M. Caspeta-Mandujano, E. Mayén-Peña, D. Brailovsky, and R. Báez-Valé. 2001*a*. Helminth parasites of freshwaters fishes of the Balsas River drainage basin of southwestern Mexico. Comparative Parasitology 68:196–203.

Salgado-Maldonado, G., G. Cabañas-Carranza, E. Soto-Galera, J. M. Caspeta-Mandujano, R. G. Moreno-Navarrete, P. Sánchez-Nava, and R. Aguilar-Aguilar. 2001*b*. A checklist of helminth parasites of freshwater fishes from the Lerma-Santiago river basin, México. Comparative Parasitology 68:204–218.

Salgado-Maldonado, G., and C. R. Kennedy. 1997. Richness and similarity of helminth communities in the tropical cichlid fish *Cichlasoma urophthalmus* from the Yucatán Peninsula, Mexico. Parasitology 114:581–590.

Salgado-Maldonado, G., N. Mercado-Silva, G. Cabañas-Carranza, J. M. Caspeta-Mandujano, R. Aguilar-Aguilar, and L. I. Iñiguez-Dávalos. 2004*a*. Helminth parasites of freshwater fishes of the Ayuquila River, Sierra de Manantlán Biosphere Reserve, west central Mexico. Comparative Parasitology 71: 67–72.

Salgado-Maldonado, G., F. Moravec, G. Cabañas-Carranza, R. Aguilar-Aguilar, P. Sánchez-Nava, R. Báez-Valé, and T. Scholz. 2004*b*. Helminth parasites of the tropical gar, *Atractosteus tropicus* Gill from Tabasco, Mexico. Journal of Parasitology 90: 260–265.

Sánchez-Nava, P., G. Salgado-Maldonado, E. Soto-Galera, and B. Jaimes-Cruz. 2004. Helminth parasites of *Girardinichthys multiradiatus* (Pisces: Goodeidae) in the Upper Lerma River sub-basin, Mexico. Parasitology Research 93:396–402.

Southwood, T. R. 1978. Ecological methods, second edition. Chapman and Hall, London, United Kingdom.

Steel, R. G. D., and J. H. Torrie. 1981. Principles and procedures of statistics: a biometrical approach, second edition. McGraw-Hill International Book Company, London, United Kingdom.

Vidal-Martínez, V. M., and C. R. Kennedy. 2000. Potential interactions between the intestinal hel-

minthes of the cichlid fish *Cichlasoma synspilum* from southeastern Mexico. Journal of Parasitology 86:691–695.

Vidal-Martínez, V. M., C. R. Kennedy, and M. L. Aguirre-Macedo. 1998. The structuring process of the macroparasite community of an experimental population of *Cichlasoma urophthalmus* through time. Journal of Helminthology 72:199–207.

Webb, S. A., J. A. Graves, C. Macías-García, A. E. Magurran, D. Ó. Foighil, and M. G. Ritchie. 2004. Molecular phylogeny of the livebearing Goodeidae (Cyprinodontiformes). Molecular Phylogenetics and Evolution 30:527–544.

Submitted 13 July 2005. Accepted 28 April 2006.
Associate Editor was Gary Garrett.