

Helminth Parasites of Freshwater Fishes of the Pánuco River Basin, East Central Mexico

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ABSTRACT: This study presents results from a survey of helminth parasites of fishes in the Pánuco River basin, in the states of San Luis Potosí, Hidalgo, Querétaro and Guanajuato, all in east central Mexico. Seventeen freshwater fish species ($n = 1,019$) were examined for helminths between May 1997 and September 1998. Thirty-one helminth species were collected: 11 allogenic species, mostly Nearctic in origin, and 20 autogenic species. Two anthropogenically introduced species were recorded. The most prevalent and widespread helminth taxon was *Posthodiplostomum minimum* (metacercariae). The helminth fauna of fishes of the Pánuco River is dominated by trematodes (12 species) and nematodes (11 species) accompanied by a few monogenean (4 species), cestode (3 species), and acanthocephalan (1 species) taxa. Most of the helminth taxa reported have been reported from other regions of Mexico. Thus, the helminth parasite fauna of fishes of the Pánuco River basin are not exclusive, including a primordially autogenic Neotropical species component mixed with a mainly allogenic, globally distributed Nearctic species component. The regional freshwater fish helminth fauna is associated with the ichthyofaunal composition of the basin. The nematode family Rhabdochonidae displays high species richness in this hydrological basin of Mexico.

KEY WORDS: Digenea, Monogenea, Cestoda, Nematoda, Acanthocephala, helminth parasites of freshwater fishes, Pánuco River basin, Mexico, survey.

The Pánuco River drainage basin is the fourth largest in Mexico (66,300 km²), and it drains portions of the states of Guanajuato, Estado de México, Querétaro, Hidalgo, San Luis Potosí, Veracruz, and Tamaulipas. The Pánuco River originates in the Sierra Madre Oriental Mountains and generally flows eastward. The longest arm of the river runs approximately 600 km from its origin to the Gulf of Mexico. It can be divided into 2 sections, the Upper and Lower Pánuco (Alto and Bajo Pánuco). The upper Pánuco includes the Metztitlan, Amajac, Tula, and San Juan del Río rivers, which are part of the Moctezuma subbasin of the Pánuco. The lower Pánuco includes the Estorax, Lower Amajac, Tempoal (formed by the union of the San Pedro, Atlapexco and Calabozo rivers), Tampaón (formed by the union of the Gallinas, Verde and Santa María rivers), Lower Moctezuma and Pánuco rivers. The

Tamesí River, which flows into the Pánuco from the north, is considered an independent subbasin (Tamayo, 1990).

The ichthyofauna of the Pánuco River consists of 51 primary and secondary species (Miller, 1986), or 74 species, if diadromous and peripheral species are included (Miller and Smith, 1986). Data from the National Mexican Freshwater Fish Collection (Colección Nacional de Peces Dulceacuícolas Mexicanos, Escuela Nacional de Ciencias Biológicas del Instituto Politécnico Nacional, México), includes reports of 46 species in 13 families of fish from the Pánuco, including 6 introduced species. Twenty species are considered endemic to the region: *Dionda ipni* and *Notropis sallei* (Cyprinidae); *Ictalurus mexicanus* (Ictaluridae); *Cualac tesellatus* (Cyprinodontidae), *Ataeniobius toweri* and *Xeenophorus captivus* (Goodeidae); *Gambusia atrora*, *Gambusia aurata*, *Gambusia vittata*, *Poecilia latipunctata*, *Xiphophorus montezumae*, *Xiphophorus nigrensis*, *Xiphophorus pygmaeus*, *Xiphophorus malinche*,

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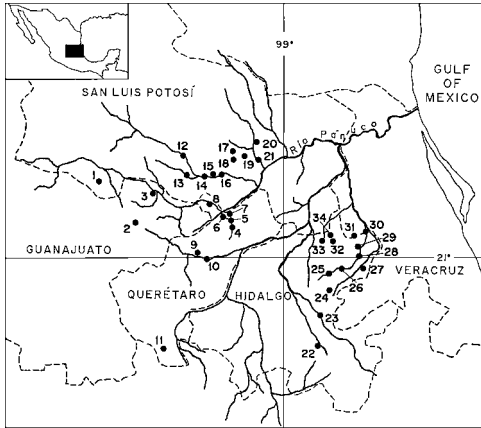


Figure 1. The Pánuco River basin of East Central Mexico, showing fish collection sites. Río Santa María: (1) Fracción Sánchez, (2) Río Manzanares, (3) Río Bagres, El Realito, (4) Río Jalpan, (5) Río Ayutla, (6) Río Santa María, (7) Arroyo Chubejé, (8) Río El Carrizal; Río Estórax: (9) Río Estórax, (10) Oasis, (11) Río Las Zúñigas; Río Verde: (12) La Planta, (13) Afluente Río Verde at La Plazuela, (14) El Rodeo, (15) Río Verde, (16) Pirihuán; Río Gallinas: (17) Arroyo Canoas, (18) Cascada Canoas, (19) Cascadas Tamasopo, Balneario las Cascadas, (20) El Rascón, (21) El Carpintero; Río Amajac: (22) Río Amajac, (23) Río Venados; Río Tempoal: (24) Arroyo Tenango, (25) Afluente Río Calnalí, (26) Afluente Río Atlapexco, (27) Río Calabozo, (28) Río Atlapexco, (29) Río Candelaria, (30) Río Tecoloco, (31) Afluente Río Tecoloco, (32) Río San Pedro, (33) Río Talol, (34) Afluente Río Acamoluco.

Xiphophorus cortezi, and *Xiphophorus birchmani* (Poeciliidae); and, *Cichlasoma bartoni*, *Cichlasoma pantosticum*, *Cichlasoma steindachneri*, and *Herichthys labridens* (Cichlidae). The basin is also home to exotic species such as Asian cyprinids (carps), African cichlids (tilapias), and *Micropterus salmoides* and *Lepomis macrochirus* (Centrarchidae) (Miller, 1986; Soria-Barreto et al., 1997).

No record of a helminth parasite from a fish of the Pánuco River basin exists. This report is the first survey of helminth parasites in fishes from this basin and provides information on the distribution, infection intensity, and prevalence of helminth parasites in the Pánuco River fish community.

MATERIALS AND METHODS

As part of an ongoing parasitological investigation into the helminth fauna of the freshwater fishes of Mexico, 1,019 fishes representing 17 species collected from the Pánuco River basin were examined for helminths between May 1997 and September 1998. The following fish species were examined (family and sample size follow each taxon parenthetically; taxa marked * are endemic to the Pánuco

River basin; taxa marked ** are endemic to the Lerma River basin and to high altitudes of the Pánuco River basin): *Astyanax mexicanus*, (Characidae, 226); *Archocentrus nigrofasciatus*, (Cichlidae, 24); *Herichthys cyanoguttatum**, (Cichlidae, 42); *H. labridens**, (Cichlidae, 73); *D. ipni**, (Cyprinidae, 83); *N. sallei***, (Cyprinidae, 26); *Goodea atripinnis*, (Goodeidae, 4); *I. mexicanus**, (Ictaluridae, 1); *G. vittata**, (Poeciliidae, 47); *Heterandria bimaculata*, (Poeciliidae, 3); *Poecilia mexicana*, (Poeciliidae, 265); *Poecilia sphenops*, (Poeciliidae, 28); *Poeciliopsis gracilis*, (Poeciliidae, 109); *Poeciliopsis infans***, (Poeciliidae, 40); *X. montezumae**, (Poeciliidae, 5); *Xiphophorus* sp.*, (Poeciliidae, 38); *Oncorhynchus mykiss* (Salmonidae, 5). We sampled sites in the main branches of the Pánuco River basin, the rivers Santa María, Estórax, Tempoal, Amajac, Gallinas, and Verde, in the states of Querétaro, Hidalgo, San Luis Potosí, and Guanajuato. All sampling sites were located in streams or portions of relatively large rivers. No lentic environment was sampled. Locality names and coordinates for each sampling point (Fig. 1) are: Río Santa María: Fracción Sánchez (21°47'10"N; 100°41'13"W), Río Manzanares (21°23'32"N; 100°22'56"W), Río Bagres, El Realito (21°31'39"N; 100°08'49"W); Río Jalpan (21°20'03"N; 99°31'49"W), Río Ayutla (21°23'45"N; 99°34'57"W), Río Santa María (21°23'37"N; 99°34'38"W), Arroyo Chubejé (21°11'25"N; 99°34'00"W), Río El Carrizal (21°25'54"N; 99°37'04"W); Río Estórax: Río Estórax (21°02'11"N; 99°50'45"W), Oasis (21°00'27"N; 99°42'43"W), Río Las Zúñigas (20°19'13"N; 100°08'38"W); Río Verde: La Planta (21°56'28"N; 99°58'45"W), Afluente Río Verde at La Plazuela (21°47'28"N; 99°55'31"W), El Rodeo (21°43'26"N; 99°46'14"W), Río Verde (21°42'2"N; 99°48'13"W), Pirihuán (21°43'04"N; 99°33'40"W); Río Gallinas: Arroyo Canoas (21°56'47"N; 99°23'47"W), Cascada Canoas (21°55'10"N; 90°30'34"W), Cascadas Tamasopo, Balneario las Cascadas (25°45'57"N; 99°23'46"W), El Rascón (21°59'06"N; 99°15'27"W), El Carpintero (21°53'57"N; 99°15'02"W); Río Amajac: Río Amajac (20°19'08"N; 98°44'17"W), Río Venados (20°30'52"N; 98°42'55"W); Río Tempoal: Arroyo Tenango (20°43'18"N; 98°38'34"W), Afluente Río Calnalí (20°53'36"N; 98°36'34"W), Afluente Río Atlapexco (20°54'57"N; 98°26'34"W), Río Calabozo (20°55'16"N; 98°17'27"W), Río Atlapexco (21°00'53"N; 98°20'24"W), Río Candelaria (21°04'59"N; 98°04'27"W), Río Tecoloco (21°11'16"N; 98°17'18"W), Afluente del Río Tecoloco (21°11'16"N; 98°18'20"W), Río San Pedro (21°10'17"N; 98°35'17"W), Río Talol (21°10'00"N; 98°36'56"W), Afluente Río Acamoluco (21°09'45"N; 98°33'28"W).

Fishes were captured using a DC backpack electrofishing device or by the techniques most appropriate for conditions at each site. All available habitats were sampled until continuing efforts failed to yield new species or changes in their relative abundance. Captured fishes were taken alive to the laboratory and examined within 24 hr. All the external surfaces, viscera, and musculature of each fish host were examined under a stereomicroscope, and all helminths observed were isolated and counted. Trematodes (adults and metacercariae), monogeneans, cestodes, and nematodes were fixed in hot 4% neutral formalin. Acanthocephalans were placed in distilled water, refrigerated overnight (6–12 hr) to evert the proboscis, and fixed in hot 4% formalin. Trematodes, monogeneans, cestodes, and acanthocephalans

were stained with Mayer's paracarmine or Ehrlich's hematoxylin, dehydrated using a graded alcohol series, cleared in methyl salicylate, and mounted entire. To study sclerotized parts of monogeneans, several specimens of each species were fixed according to Malmberg's semipermanent mount method (see Vidal-Martínez et al., 2001). Nematodes were cleared with glycerine for light microscopy and stored in 70% ethanol. Voucher specimens of all taxa have been deposited in the National Helminth Collection (Colección Nacional de Helminthos [CNHE]), Institute of Biology, Universidad Nacional Autónoma de México (UNAM), Mexico City, Mexico; in the Colección Parasitológica de la Universidad Autónoma del Estado de Morelos (COPA-UAEM); and in the United States National Parasite Collection (USNPC), Beltsville, Maryland, U.S.A.. Use of prevalence and mean intensity of infection are consistent with Margolis et al. (1982).

RESULTS

Thirty-one helminth species from 22 families were found infecting fishes of the Pánuco River basin. Twelve species of trematodes (5 adults and 7 metacercariae), 11 species of nematodes (7 adults and 4 larvae), 4 species of monogeneans, 3 species of cestodes (1 adult and 2 metacestodes), and 1 species of acanthocephalan (adult) were collected.

Five helminth species were widely distributed among Pánuco River basin fish species. Metacercariae of *Posthodiplostomum minimum* were the most widely distributed parasites, collected from 10 fish species representing 4 families. Larvae of *Contracaecum* sp. were collected from 7 fish species representing 4 families. The Asian fish tapeworm, *Bothriocephalus acheilognathi*, was collected from 6 fish species representing 2 families. Metacercariae of both *Clinostomum complanatum* and *Diplostomum* sp. were collected from 6 fish species representing 4 and 3 families, respectively.

Eighteen of the 31 helminth species recorded are autogenic, maturing in, and transported by fishes. Two additional helminth species are included as autogenics: the larvae of the nematode *Spiroxys* sp., maturing in reptiles, and the still unidentified larvae belonging to Pharyngodonidae that also probably matures in a reptilian host. Eleven of the 31 species mature in and are dispersed by birds.

Host species with the highest parasite species richness were *A. mexicanus* (14 helminth species), *P. mexicana* (13 species), and *H. labridens* (13 species). Other host species endemic to the Pánuco River harbored few helminth species in comparison. For example, 6 species were found in *Xiphophorus* sp., 4 in *D. ipni*, 3 in both *G. vittata* and *I. mexicanus*, 2 in *N. sallei*, and only 1 species in *X. montezumae*.

Faunal association and distribution arranged by host taxon are presented below. Parasites collected as larval forms are marked with an asterisk. Prevalence, mean intensity \pm SD, and range of intensity follow individual collection localities parenthetically as appropriate.

Family Characidae *Astyanax mexicanus*

This is a native species. An overall sample of 226 individuals was collected from 17 sites: Afluente Río Acamoluco (4), Afluente Río Tecoloco (36), Arroyo Canoas (2), Arroyo Tenango (10), Cascada Canoas (3), El Rascón (9), Fracción Sánchez (27), Oasis (12, 36), Río Amajac (1), Río Atlapexco (2), Río Calabozo (2), Río Candelaria (5, 6), Río El Carrizal (4), Río Estórax (5), Río Santa María (51), Río Tecoloco (8), and Río Venados (3).

Magnivitellinum simplex

Prevalence, intensity, and temporal distribution: August: Río Venados (3/3, 2.3 ± 2.3 , 1–5); October: Arroyo Canoas (1/2, 5); March: Río Atlapexco (1/2, 4), Afluente Río Acamaluco (2/4, 6 ± 6 , 2–10).

Site of infection: Intestine.

Voucher specimens: CNHE 4840.

Genarchella astyanactis

Prevalence, intensity, and temporal distribution: March: Afluente Río Tecoloco (4/36, 1 ± 0 , 1–1).

Site of infection: Intestine.

Paracreptotrematina aguirrepequenoi

Prevalence, intensity, and temporal distribution: May: Río Estórax (1/51, 1); November: Río Estórax (1/5, 2).

Site of infection: Intestine.

*Ascocotyle (Ascocotyle) tenuicollis**

Prevalence, intensity, and temporal distribution: November: El Rascón (5/9 6.8 ± 7.4 , 2–20).

Site of infection: Heart.

*Clinostomum complanatum**

Prevalence, intensity, and temporal distribution: November: Río El Carrizal (1/4, 4).

Site of infection: Body cavity.

Centrocestus formosanus*

Prevalence, intensity, and temporal distribution: August: Río Candelaria (4/6, 11 ± 13, 3–30).

Site of infection: Gills.

Diplostomum* sp.

Prevalence, intensity, and temporal distribution: November: El Rascón (1/9, 2).

Site of infection: Fins.

Uroleidoides strombicirrus

Prevalence, intensity, and temporal distribution: March: Río Candelaria (2/5, 1.5 ± 0.7, 1–2); May: Río Estórax (31/51, 3.7 ± 3.2, 1–17), Oasis (12/12, 9.7 ± 6, 4–25); August: Río Candelaria (2/6, 3 ± 2.8, 1–5); October: Fracción Sánchez (11/27, 2.9 ± 2.2, 1–8), Arroyo Canoas (1/2, 1), Cascada Canoas (1/3, 6); November: Río El Carrizal (2/4, 4.5 ± 0.7, 4–5), Río Estórax (2/5, 5 ± 4.2, 2–8), Oasis (14/36, 6.3 ± 6.0, 1–19).

Site of infection: Gills.

***Gyrodactylus* sp.**

Prevalence, intensity, and temporal distribution: May: Río Estórax (5/51, 2.6 ± 1.8, 1–5), Oasis (3/12, 3.7 ± 2.0, 2–6); November: Oasis (1/36, 2).

Site of infection: Gills.

Procamallanus (Spirocamallanus) neocaballeri

Prevalence, intensity, and temporal distribution: March: Río Calabozo (2/3, 1 ± 0, 1–1), Río Atlapexco (2/2, 1 ± 0, 1–1), Río Candelaria (2/5, 1.5 ± 0.7, 1–2), Río Tecoloco (3/8, 1.3 ± 0.6, 1–2), Afluente Río Tecoloco (9/36, 1 ± 0, 1–1), Afluente Río Acamoloco (2/4, 1.5 ± 0.7, 1–2); August: Río Candelaria (4/6, 2 ± 0.8, 1–3).

Site of infection: Intestine.

Voucher specimens: COPA-UAEM N-024.

Rhabdochona mexicana

Prevalence, intensity, and temporal distribution: May: Río Estórax (28/51, 1.7 ± 1.2, 1–6), Oasis (6/12, 4 ± 1.8, 1–2); October: Fracción Sánchez (7/27,

3.7 ± 2.3, 1–8), Cascada Canoas (1/3, 1); November: Oasis (25/36, 2.3 ± 2.2, 1–5), El Rascón (1/9, 1).

Site of infection: Intestine.

Voucher specimens: COPA-UAEM N-3886, N-3887.

Contracaecum* sp.

Prevalence, intensity, and temporal distribution: March: Río Tecoloco (3/8, 2.7 ± 1.5, 1–4), Afluente Río Tecoloco (4/36, 1.8 ± 1.0, 1–3); October: Fracción Sánchez (1/27, 4); November: El Rascón (5/9, 56%, 4 ± 3, 2–9).

Site of infection: Mesentery.

Voucher specimens: COPA-UAEM N-021.

Pharyngodonidae* gen. sp.

Prevalence, intensity, and temporal distribution: March: Río Atlapexco (1/2, 4).

Site of infection: Intestine.

Spiroxys* sp.

Prevalence, intensity, and temporal distribution: May: Río Estórax (10/51, 1.5 ± 0.9, 1–4), Oasis (1/12, 2); October: Fracción Sánchez (2/27, 1 ± 0, 1–1).

Site of infection: Mesentery.

Voucher specimens: COPA-UAEM N-028.

Family Cichlidae
Herichthys cyanoguttatum

This species is endemic to the Pánuco River basin. An overall sample of 42 individuals was collected from 5 sites: Río Atlapexco (12), Río Candelaria (10), Río San Pedro (7), Río Talol (7), Río Tecoloco (6).

Crassicutis cichlasomae

Prevalence, intensity, and temporal distribution: March: Río Tecoloco (1/6, 1); September: Río Atlapexco (1/12, 4).

Site of infection: Intestine.

Centrocestus formosanus*

Prevalence, intensity, and temporal distribution: September: Río Atlapexco (1/12, 1), Río Talol (1/7, 2).

Site of infection: Gills

Clinostomum complanatum*

Prevalence, intensity, and temporal distribution:
March: Río Atlapexco (3/10, 0.5 ± 1 , 1–3);
September: Río Atlapexco (2/12, 6 ± 7 , 1–11), Río
Talol (3/7, 13 ± 20 , 1–37).

Site of infection: Mesentery.

Diplostomum sp.*

Prevalence, intensity, and temporal distribution:
September: Río Atlapexco (2/12, 1.5 ± 0.7 , 1–2).

Site of infection: Eyes.

Posthodiplostomum minimum*

Prevalence, intensity, and temporal distribution:
September: Río Atlapexco (3/12, 1.3 ± 0.6 , 1–2),
Río Talol (1/7, 4).

Site of infection: Body cavity.

Bothriocephalus acheilognathi

Prevalence, intensity, and temporal distribution:
September: Río Atlapexco (1/12, 1).

Site of infection: Intestine.

Neoechinorhynchus golvani

Prevalence, intensity, and temporal distribution:
March: Río Atlapexco (2/2, 5 ± 3 , 3–7).

Site of infection: Intestine.

Rhabdochona kidderi

Prevalence, intensity, and temporal distribution:
March: Río Atlapexco (7/10, 4.2 ± 3.6 , 1–10), Río
Tecoloco (2/6, 2.5 ± 0.7 , 2–3); August: Río San
Pedro (1/7, 1), Río Talol (1/7, 1); September: Río
Atlapexco (1/12, 1).

Site of infection: Intestine.

Contracaecum sp.*

Prevalence, intensity, and temporal distribution:
March: Río Atlapexco (2/10, 1.5 ± 0.7 , 1–2);
August: Río San Pedro (1/7, 1); September: Río
Atlapexco (4/12, 1.5 ± 1 , 1–3).

Site of infection: Mesentery, body cavity, liver.

Voucher specimens: COPA-UAEM N-041.

Herichthys labridens

This species is endemic to the Pánuco River basin. An overall sample of 73 individuals was collected from 10 sites: Afluente Río Atlapexco (10), Afluente Río Verde at La Plazuela (5), Cascada Canoas (4), Cascadas Tamasopo, Balneario Las Cascadas (6), El Carpintero (7), El Rascón (1), Río Atlapexco (10), Río San Pedro (1, 16), Río Talol (4, 8), Río Venados (1).

Crassicutis cichlasomae

Prevalence, intensity, and temporal distribution:
March: Río Atlapexco (4/10, 1.5 ± 0.6 , 1–2);
August: Río Talol (1/4, 1); November: Afluente Río
Verde at La Plazuela (4/5, 13.5 ± 13.7 , 2–32),
Cascadas Tamasopo, Balneario Las Cascadas (4/6,
 2.7 ± 3.5 , 1–8), El Carpintero (4/7, 3.5 ± 1.0 , 3–5).

Site of infection: Intestine.

Voucher specimens: CNHE 4834, 4835, 4836;
USNPC 94412, 94413.

Ascocotyle (Ascocotyle) tenuicollis*

Prevalence, intensity, and temporal distribution:
November: Cascadas Tamasopo, Balneario Las
Cascadas (4/6, 13 ± 26 , 3–40), El Carpintero (1/7,
244).

Site of infection: Heart.

Clinostomum complanatum*

Prevalence, intensity, and temporal distribution:
August: Río Talol (3/4, 1.3 ± 0.6 , 1–2); September:
Río San Pedro (14/16, 12 ± 17 , 1–5), Río Talol (7/8,
 18 ± 22 , 1–61).

Site of infection: Muscle, fins, gills, eyes.

Voucher specimens: USNPC 94409, 94410

Diplostomum sp.*

Prevalence, intensity, and temporal distribution:
September: Río San Pedro (2/16, 3 ± 0 , 3–3), Río
Talol (1/8, 12).

Site of infection: Eyes

Voucher specimens: CNHE 4921; USNPC 94411.

Posthodiplostomum minimum*

Prevalence, intensity, and temporal distribution: March: Río Atlapexco (1/10, 1); August: Río Talol (1/4, 1); September: Río San Pedro (2/16, 1.5 ± 0.7 , 1–2), Río Talol (2/8, 1.5 ± 0.7 , 1–2); November: Afluente Río Verde at La Plazuela (5/5, 65 ± 56 , 6–155), El Carpintero (4/7, 33 ± 27 , 7–71).

Site of infection: Liver, muscle.

Voucher specimens: CNHE 4843, 4844.

Uvulifer ambloplitis*

Prevalence, intensity, and temporal distribution: November: Cascadas Tamasopo, Balneario Las Cascadas (2/6, 2 ± 0 , 2–2), El Carpintero (1/7, 1).

Site of infection: Skin, scales.

***Sciadicleithrum* sp.**

Prevalence, intensity, and temporal distribution: March: Río Atlapexco (2/10, 1 ± 0 , 1–1); August: Río Talol (1/4, 2).

Site of infection: Gills.

Bothriocephalus acheilognathi

Prevalence, intensity, and temporal distribution: August: Río Talol (1/4, 1).

Site of infection: Intestine.

Tetrabothridae* gen. sp.

Prevalence, intensity, and temporal distribution: November: Cascada Canoas (1/4, 1).

Site of infection: Intestine.

Neoechinorhynchus golvani

Prevalence, intensity, and temporal distribution: March: Río Atlapexco (6/10, 4.8 ± 3.4 , 2–11).

Site of infection: Intestine.

Rhabdochona kidderi

Prevalence, intensity, and temporal distribution: March: Río Atlapexco (4/10, 3.2 ± 1.8 , 1–5), Río San Pedro (1/1, 5); August: Río Talol (3/4, 10 ± 7 , 6–18); September: Afluente Río Atlapexco (1/10, 1),

Río San Pedro (1/16, 1), Río Talol (1/8, 1); November: Cascada Canoas (1/4, 1), Afluente Río Verde at La Plazuela (1/5, 1), El Rascón (1/1, 1), El Carpintero (1/7, 1).

Site of infection: Intestine.

Contraecum* sp.

Prevalence, intensity, and temporal distribution: August: Río Talol (1/4, 1); September: Río San Pedro (2/16, 3.5 ± 3.5 , 1–6), Río Talol (2/8, 2.5 ± 2.1 , 1–4); November: Cascadas Tamasopo, Balneario Las Cascadas (4/6, 1.2 ± 0.6 , 1–2), El Carpintero (5/7, 1.4 ± 0.5 , 1–2).

Site of infection: Intestine, body cavity, mesentery, liver.

Eustrongylides* sp.

Prevalence, intensity, and temporal distribution: August: Río Venados (1/1, 1).

Site of infection: Mesentery.

Voucher specimens: COPA-UAEM N-039.

Archocentrus nigrofasciatum

This is an introduced species. A sample of 24 individuals was collected from 1 site: Río Atlapexco (24).

Clinostomum complanatum*

Prevalence, intensity, and temporal distribution: March: Río Atlapexco (1/24, 1).

Site of infection: Body cavity.

Diplostomum* sp.

Prevalence, intensity, and temporal distribution: March: Río Atlapexco (2/24, 1.5 ± 0.7 , 1–2).

Site of infection: Eyes.

Posthodiplostomum minimum*

Prevalence, intensity, and temporal distribution: March: Río Atlapexco (1/24, 1).

Site of infection: Muscle.

Neoechinorhynchus golvani

Prevalence, intensity, and temporal distribution: March: Río Atlapexco (7/24, 2.6 ± 1.3 , 1–5).

Site of infection: Intestine.

Rhabdochona kidderi

Prevalence, intensity, and temporal distribution:
March: Río Atlapexco (1/24, 1).

Site of infection: Intestine.

Family Cyprinidae
Dionda ipni

This species is endemic to the Pánuco River basin. An overall sample of 83 individuals was collected from 4 sites: Afluente Río Calnalí (15), Arroyo Tenango (45, 7), Río Amajac (14), Río Atlapexco (2).

Posthodiplostomum minimum*

Prevalence, intensity, and temporal distribution:
March: Arroyo Tenango (1/45, 2).

Site of infection: Muscle.

Uvulifer ambloplitis*

Prevalence, intensity, and temporal distribution:
March: Arroyo Tenango (1/45, 5); September 1998, Arroyo Tenango (5/7, 7.2 ± 4.4 , 3–13).

Site of infection: Skin.

Bothriocephalus acheilognathi

Prevalence, intensity, and temporal distribution:
August: Río Amajac (9/14, 5 ± 5 , 1–15).

Site of infection: Intestine.

Voucher specimens: CNHE 4935.

Rhabdochona canadensis

Prevalence, intensity, and temporal distribution:
March: Arroyo Tenango (21/45, 2.6 ± 1.9 , 1–7).

Site of infection: Intestine.

Notropis sallei

This species is endemic to the Lerma River basin and high altitudes of the Pánuco River basin. An overall sample of 26 individuals was collected from 3 sites: Afluente Río Acamolucó (2), Río Las Zúñigas (7), Río San Pedro (5, 12).

Posthodiplostomum minimum*

Prevalence, intensity, and temporal distribution:
August: Río San Pedro (4/12, 31 ± 32 , 2–66).

Site of infection: Muscle.

Bothriocephalus acheilognathi

Prevalence, intensity, and temporal distribution:
October: Río Las Zúñigas (1/7, 1).

Site of infection: Intestine.

Voucher specimens: CNHE 4849.

Rhabdochona canadensis

Prevalence, intensity, and temporal distribution:
October: Río Las Zúñigas (1/7, 2).

Site of infection: Intestine.

Family Goodeidae
Goodea atripinnis

This is a native species. A sample of 4 individuals was collected from 1 site: Río Estórax (4).

Rhabdochona lichthenfelsi

Prevalence, intensity, and temporal distribution:
November: Río Estórax (1/4, 7).

Site of infection: Intestine.

Family Poeciliidae
Gambusia vittata

This species is endemic to the Pánuco River basin. A sample of 47 individuals was collected from 1 site: Río Verde (47).

Posthodiplostomum minimum*

Prevalence, intensity, and temporal distribution:
August: Río Verde (8/47, 2.1 ± 1.6 , 1–5).

Site of infection: Mesentery, fat, liver, muscle.

Voucher specimens: CNHE 4847.

Bothriocephalus acheilognathi

Prevalence, intensity, and temporal distribution:
August: Río Verde (7/47, 1.6 ± 0.8 , 1–3).

Site of infection: Intestine.

Voucher specimens: CNHE 4936.

Heterandria bimaculata

This is a native species. A sample of 3 individuals was collected from 1 site: Afluente Río Calnalí (3). No parasite was found.

Poecilia mexicana

This is a native species. An overall sample of 265 individuals was collected from 20 sites: Afluente Atlapexco (6), Afluente Río Acamolucó (10), Arroyo Canoas (16), Arroyo Tenango (18), El Carpintero (3, 8), La Planta (37), Río Amajac (8), Río Atlapexco (10), Río Bagres, El Realito (27), Río Calabozo (9), Río Candelaria (13, 15, 8), Río El Carrizal (2), Río Estórax (3), Río Jalpan (9), Río San Pedro (12, 2, 4), Río Santa María (4), Río Talol (13), Río Tecolucó (11, 2), Río Venados (14), Río Verde (1).

Saccocoelioides cf. sogandaresi

Prevalence, intensity, and temporal distribution: March: Río Tecolucó (2/11, 2.5 ± 0.7 , 2–3); August: Río Amajac (4/8, 2.5 ± 1.3 , 1–4); October: La Planta (6/37, 1 ± 0 , 1–1); November: Río Verde (1/1, 22).

Site of infection: Intestine.

Apharyngostrigea sp.*

Prevalence, intensity, and temporal distribution: August: Río Candelaria (1/13, 12).

Site of infection: Body cavity.

Voucher specimens: CNHE 4930.

Centrocestus formosanus*

Prevalence, intensity, and temporal distribution: September: Río Candelaria (2/8, 14 ± 18 , 1–27).

Site of infection: Body cavity.

Voucher specimens: CNHE 4933.

Clinostomum complanatum*

Prevalence, intensity, and temporal distribution: November: Río Jalpan (5/9, 13 ± 14 , 4–37).

Site of infection: Muscle.

Diplostomum sp.*

Prevalence, intensity, and temporal distribution: September: Afluente Río Atlapexco (1/6, 4), Río Talol (1/13, 15).

Site of infection: Eyes.

Voucher specimens: CNHE 4922.

Posthodiplostomum minimum*

Prevalence, intensity, and temporal distribution: March: Río Calabozo (2/9, 3 ± 2.8 , 1–5), Río Candelaria (1/15, 2), Río Tecolucó (7/11, 1.4 ± 0.8 , 1–3), Río San Pedro (3/12, 2.3 ± 2.9 , 1–6); August: Río Amajac (4/8, 4 ± 1.2 , 3–5), Río Venados (2/14, 1.5 ± 0.7 , 1–2), Río Candelaria (2/13, 2.5 ± 2.1 , 1–4), Río San Pedro (2/2, 11 ± 14 , 1–21); September: Arroyo Tenango (6/18, 2.8 ± 1.8 , 1–5), Afluente del Río Atlapexco (2/6, 2 ± 1.4 , 1–3), Río San Pedro (3/4, 1.3 ± 0.6 , 1–2), Río Talol (3/13, 16 ± 27 , 1–44); October: La Planta (15/37, 46 ± 81 , 1–295), Arroyo Canoas (2/16, 2 ± 1 , 1–3), El Carpintero (6/8, 3 ± 3 , 1–9); November: El Carpintero (1/3, 1).

Site of infection: Liver, mesentery, fat, body cavity, muscle, kidney, eyes, intestine.

Voucher specimens: CNHE 4845, 4846.

Uvulifer ambloplitis*

Prevalence, intensity, and temporal distribution: August: Río Venados (1/14, 3); September: Arroyo Tenango (3/18, 1.3 ± 0.6 , 1–2); October: Arroyo Canoas (5/16, 24 ± 31 , 20–77).

Site of infection: Skin.

Bothriocephalus acheilognathi

Prevalence, intensity, and temporal distribution: March: Afluente Río Acomalucó (1/10, 1); August: Río Venados (1/14, 1); October: Río Bagres, El Realito (1/27, 1).

Site of infection: Intestine.

Voucher specimens: CNHE 4937.

Glossocercus auritus*

Prevalence, intensity, and temporal distribution: March: Río Calabozo (1/9, 1).

Site of infection: Fat.

Capillaria cyprinodonticola

Prevalence, intensity, and temporal distribution: March: Río Candelaria (2/15, 8 ± 8 , 2–14); August: Río Candelaria (4/13, 10 ± 15 , 1–32); September: Río Candelaria (2/8, 3 ± 2.8 , 1–5), Río San Pedro (3/4, 7 ± 5 , 4–12), Río Talol (2/13, 3.5 ± 2.1 , 2–5).

Site of infection: Intestine, liver.

Rhabdochona lichtenfelsi

Prevalence, intensity, and temporal distribution:
May: Río Estórax (1/3, 3).

Site of infection: Intestine.

Contraecum sp.*

Prevalence, intensity, and temporal distribution:
March: Río Calabozo (2/9, 1 ± 0, 1–1), Río Tecoloco (3/11, 1 ± 0, 1–1); October: La Planta (1/37, 1), Arroyo Canoas (1/16, 2), El Carpintero (3/8, 2 ± 1, 1–3).

Site of infection: Mesentery, liver, body cavity.

Eustrongylides sp.*

Prevalence, intensity, and temporal distribution:
October: La Planta (5/37, 1 ± 0, 1–1).

Site of infection: Body cavity.

Spiroxys sp.*

Prevalence, intensity, and temporal distribution:
May: Río Estórax (1/3, 6); October: Río Bagres, El Realito (1/27, 1).

Site of infection: Body cavity.

Poecilia sphenops

An overall sample of 28 individuals was collected from 3 sites: El Rascón (2), Río Ayutla (21), Río El Carrizal (5). No parasite was found.

Poeciliopsis gracilis

An overall sample of 108 individuals was collected from 6 sites: Afluente Río Acomoluco (2), Río Atlapexco (14), Río Candelaria (10, 4, 54), Río San Pedro (2, 9), Río Santa María (2), Río Tecoloco (11).

Saccocoelioides cf. sogandaresi

Prevalence, intensity, and temporal distribution:
March: Río Tecoloco (6/11, 3.8 ± 1.9, 1–6), Río San Pedro (2/9, 1 ± 0, 1–1).

Site of infection: Intestine.

Apharingostrigea sp.*

Prevalence, intensity, and temporal distribution:
August: Río Candelaria (1/54, 1).

Site of infection: Body cavity.

Voucher specimens: CNHE 4931.

Centrocestus formosanus*

Prevalence, intensity, and temporal distribution:
August: Río Candelaria (3/54, 10 ± 7.5, 2–15);
September: Río Atlapexco (2/14, 33 ± 35, 8–58).

Site of infection: Gills.

Diplostomum sp.*

Prevalence, intensity, and temporal distribution:
March: Río Tecoloco (1/11, 1); September: Río Atlapexco (1/14, 13).

Site of infection: Eyes.

Posthodiplostomum minimum*

Prevalence, intensity, and temporal distribution:
March: Río Tecoloco (1/11, 5), Río San Pedro (1/9, 1).

Site of infection: Fat.

Contraecum sp.*

Prevalence, intensity, and temporal distribution:
March: Río Tecoloco (1/11, 1).

Site of infection: Body cavity.

Spiroxys sp.*

Prevalence, intensity, and temporal distribution:
September: Río Atlapexco (1/14, 1).

Site of infection: Intestine.

Poeciliopsis infans

This species is endemic to the Lerma River basin and high altitudes of the Pánuco River basin. A sample of 40 individuals was collected from 1 site: Río Manzanares (40). No parasite was found.

Xiphophorus montezumae

This species is endemic to the Pánuco River basin. A sample of 5 individuals was collected from 1 site: El Carpintero (5).

Contraecum sp.*

Prevalence, intensity, and temporal distribution:
October: El Carpintero (3/5, 1 ± 0, 1–1).

Site of infection: Mesentery, liver.

***Xiphophorus* sp.**

This species is endemic to the Pánuco River basin. An overall sample of 38 individuals was collected from 3 sites: Arroyo Tenango (33), Río Atlapexco (1), Río Candelaria (4).

Saccocoelioides* cf. *sogandaresi

Prevalence, intensity, and temporal distribution: March: Arroyo Tenango (1/33, 1).

Site of infection: Intestine.

Centrocestus formosanus*

Prevalence, intensity, and temporal distribution: March: Río Atlapexco (1/1, 25).

Site of infection: Gills.

Voucher specimens: CNHE 4934.

Posthodiplostomum minimum*

Prevalence, intensity, and temporal distribution: March: Arroyo Tenango (1/33, 1), Río Atlapexco (1/1, 12), Río Candelaria (1/4, 1).

Site of infection: Muscle, eyes, fat.

Uvulifer ambloplitis*

Prevalence, intensity, and temporal distribution: March: Arroyo Tenango (1/33, 1).

Site of infection: Skin.

***Dactylogyridae* gen. sp.**

Prevalence, intensity, and temporal distribution: March: Arroyo Tenango (2/33, 1.5 ± 0.7 , 1–2).

Site of infection: Gills.

Rhabdochona xiphophori

Prevalence, intensity, and temporal distribution: March: Arroyo Tenango (4/33, 1.2 ± 0.5 , 1–2).

Site of infection: Intestine.

Family Ictaluridae
Ictalurus mexicanus

This species is endemic to the Pánuco River basin. One individual was collected from 1 site: Afluente Río Verde at La Plazuela (1).

Clinostomum complanatum*

Prevalence, intensity, and temporal distribution: October: Afluente Río Verde at La Plazuela (1/1, 2).

Site of infection: Body cavity.

Posthodiplostomum minimum*

Prevalence, intensity, and temporal distribution: October: Afluente Río Verde at La Plazuela (1/1, 22).

Site of infection: Intestine.

Contracaecum* sp.

Prevalence, intensity, and temporal distribution: October: Afluente Río Verde at La Plazuela (1/1, 1).

Site of infection: Mesentery.

Family Salmonidae
Oncorhynchus mykiss

This is an exotic, anthropogenically introduced species. A sample of 5 individuals was collected from 1 site: Arroyo Chubejé (5). No parasite was found.

DISCUSSION

Trematode and nematode species dominate the helminth fauna of Pánuco River fishes: monogeneans and cestodes are less abundant and acanthocephalans are rare. This pattern is similar to that reported for other river basins in Mexico (for examples see Salgado-Maldonado, Cabañas-Carranza, Soto-Galera, et al., 2001; Salgado-Maldonado et al., 2004). Most helminth species in the Pánuco are not unique to the basin. Sixty-two percent (19 species) of all helminths infecting Pánuco River basin fishes are also found in Balsas River basin fishes and 55% (17 species) in the Grijalva-Usumacinta system (Salgado-Maldonado, Cabañas-Carranza, Caspeta-Mandujano, et al., 2001). Forty-eight percent (15 species) have also been recorded from the cenotes of the Yucatan Peninsula (Moravec, Vivas-Rodríguez, Scholz, Vargas-Vazquez, Mendoza-Franco, and Gonzalez-Solís, 1995; Moravec, Vivas-Rodríguez, Scholz, Vargas-Vazquez, Mendoza-Franco, Schmitter-Soto, et al., 1995; Scholz et al., 1995a, b; Scholz et al., 1996). Only *P. aguirrepequenoi* and *R. xiphophori* have been collected solely from the Pánuco River basin. The helminth parasites of the endemic fishes *D. ipni*, *G. vittata*, *H. cyanoguttatum*, *H. labridens*, *I. mexicanus*, *N. sallei*, *X. montezumae*, *Xiphophorus* sp., include at least 50% generalist and allogenic species, as well as the exotic cestode, *B. acheilognati*.

The helminth fauna of Pánuco River fishes

includes Neotropical, Nearctic, and Mexican transition zone components. The distinctive Neotropical element includes *C. cichlasomae*, *M. simplex*, *G. astyanactis*, *S. cf. sogandaresi*, *P. aguirrepequeñoi*, *Sciadicleithrum* sp., *U. strombicirrus*, *P. (S.) neocaballeroi*, *R. mexicana*, *R. xiphophori*, and *N. golvani*. The Pánuco River helminth community also includes widely distributed Nearctic species such as *P. minimum*, *C. complanatum*, *R. kidderi*, and *C. cyprodonticola*. *Rhabdochona lichtenfelsi* is a member of the Mexican transition zone previously reported only from the Mexican Highland Plateau (Salgado-Maldonado, Cabañas-Carranza, Soto-Galera, et al., 2001 and references cited therein). Two human-introduced species are also present: *C. formosanus*, infecting 5 fish species, and *B. acheilognathi*, infecting 6 fish species.

The distribution of American characid and cichlid specialist parasites closely follows that of their hosts. In fact, the Neotropical composition of the helminth fauna correlates with the Neotropical origin of the cichlid and characid fish species in the Pánuco River. These fish families have a very distinctive helminth fauna, including the cichlid specialists *C. cichlasomae*, *Sciadicleithrum* sp., *R. kidderi*, and *N. golvani*. Although the typical host of *R. kidderi* is *Rhamdia guatemalensis* (Pimelodidae: Siluriformes), it has been reported from *Ogilbia pearsei* (Bythitidae: Gadiformes) (Moravec, 1998). We included it as a cichlid specialist because of its close association with cichlids throughout its geographic range (Salgado-Maldonado, Cabañas-Carranza, Caspeta-Mandujano, et al., 2001; Salgado-Maldonado, Cabañas-Carranza, Soto-Galera, et al., 2001; Salgado-Maldonado et al., 2004). Characid specialists include *M. simplex*, *G. astyanactis*, *P. aguirrepequeñoi*, *U. strombicirrus*, *P. (S.) neocaballeroi*, and *R. mexicana*. *Gyrodactylus* sp. is included in this group on the basis of its close association with characids (Jiménez-Guzmán, 1973; Caballero-Deloya, 1977; Scholz, Vargas-Vázquez, and Salgado-Maldonado, 1995; Caspeta-Mandujano et al., 2000). More characid specialists were collected in this study than cichlid specialists, even though the characids were represented by a single species, *A. mexicanus*. Characids are widely distributed in the Americas (776 species from 152 genera [Nelson, 1994]). Of these, 5 genera and 9 species are common in the streams and rivers of Mexico (Espinosa-Pérez et al., 1993), facilitating the dispersal and distribution of their parasites. Altogether, cichlid and characid specialists comprise 33% of the helminths collected in this study and 98% of the Neotropical helminths

reported from the Pánuco River basin. The presence of these groups combined with the paucity of helminths exclusive to the Pánuco River basin underlies the similarity in helminth composition between the Pánuco and other basins of Mexico.

Although cichlids originated in Africa, the genus *Cichlasoma* stems from Central America and has diversified within the Grijalva-Usumacinta system. The family includes 65 nominal species in Central America and Mexico (Eschmeyer, 1990) with some species dispersing to the southern United States (Darlington, 1957; Díaz-Pardo, 1974). In the continental waters of Mexico, cichlid diversity decreases as latitude increases. In the Grijalva-Usumacinta system, in the states of Campeche, Tabasco, and northern Chiapas, 33 cichlid species are present. In neighboring basins that drain into the Gulf of Mexico, such as the Papaloapan and Coatzacoalcos rivers in the state of Veracruz, there are only 12 cichlid species (Díaz-Pardo, 1974). In the more northerly Pánuco River only 5 native and 3 introduced cichlid species are recorded (Miller, 1986; Soria-Barreto et al., 1997). Lack of cichlid diversity on the Pacific coast drainages is more stark: only *C. istlanum* and *C. nigrofasciatum*, an introduction, are found in the Balsas River basin. Limited and discontinuous cichlid distributions and large variation in population abundance constitute limiting factors for the dispersal of cichlid parasites.

Nematodes are believed to be the major helminth component in Neotropical fish communities (Moravec, 1998). Five species of *Rhabdochona* were collected in this study: *R. canadensis* from cyprinids, *R. kidderi* from cichlids, *R. lichtenfelsi* from goodeids, *R. mexicana* from characids, and *R. xiphophori* from poeciliids. The species richness of the Rhabdochonidae is a product of the diversity of the basin's ichthyofauna. Characids, goodeids, poeciliids, and cichlids all inhabit the Pánuco River basin, facilitating species of *Rhabdochona* associated with hosts in each family. Similarly, the Ayuquila River, Jalisco is inhabited by a variety of characid and poeciliid fishes and contains 4 *Rhabdochona* species (Salgado-Maldonado et al., 2004). In contrast, characids and poeciliids are absent from the Lerma-Santiago basin and Rhabdochonid richness is lower (Salgado-Maldonado, Cabañas-Carranza, Soto-Galera, et al., 2001). These patterns support the hypothesis that host specificity plays an important role in determining regional faunistic composition of helminth communities.

The data presented herein document a parasite fauna of fishes from the Pánuco River basin that

combines an autogenic Neotropical component with an allogenic globally distributed Nearctic species component. This parasite fauna is not exclusive to the Pánuco River basin but reflects similar patterns across Mexico.

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