



New host and locality records of freshwater fish helminth parasites in river basins north of the Transmexican Volcanic Belt: another look at biogeographical patterns

Nuevos registros de hospedero y localidad de helmintos parásitos de peces dulceacuícolas en cuencas hidrológicas al norte del Cinturón Volcánico Transmexicano: otra revisión a los patrones biogeográficos

Gerardo Pérez-Ponce de León^{1✉}, Berenit Mendoza-Garfias¹, Rogelio Rosas-Valdez¹ and Anindo Choudhury²

¹Departamento de Zoología, Instituto de Biología, Universidad Nacional Autónoma de México. Apartado postal 70-153, México D. F., México.

²Division of Natural Sciences, St. Norbert College, 100 Grant Street, DePere, Wisconsin 54115, USA.

✉ ppdleon@ibiologia.unam.mx

Abstract. Freshwater fish helminths have been studied for more than 80 years in Mexico, and currently the inventory of this parasite fauna is nearing completion. Between 1999 and 2006, we studied 958 freshwater fishes belonging to 34 species in 36 localities distributed along 9 states of the Mexican Republic, north of the Transmexican Volcanic Belt. In total, 25 helminth taxa were found, including 9 digeneans, 6 nematodes, 4 monogeneans, 5 cestodes, and 1 acanthocephalan. Of the 25 species of helminths, 12 were found as larval stages while 13 were found as adults. A large number of hosts (582, i.e., 60.7%) were uninfected with helminth parasites. The data we present here is then used in combination with other recently published parasite surveys conducted in northern Mexico to revise our understanding of the biogeographical patterns of the freshwater fish parasite fauna in an area inhabited predominantly by Nearctic freshwater fishes.

Key words: helminths, Monogenea, Digenea, Nematoda, Acanthocephala, Northern Mexico, new host records, new locality records.

Resumen. Los helmintos parásitos de peces de agua dulce de México han sido estudiados por más de 80 años y en la actualidad, el inventario está cerca de ser completado. Entre 1999 y 2006, se estudió un total de 958 peces de agua dulce pertenecientes a 34 especies en 36 localidades distribuidas en 9 estados de la República Mexicana, al norte del Cinturón Volcánico Transmexicano. En total, se encontraron 25 taxa de helmintos, incluyendo 9 digéneos, 6 nemátodos, 4 monogéneos, 5 céstodos y 1 acantocéfalo. De las 25 especies de helmintos, 12 se registraron como estadios larvarios y 13 como adultos. Una proporción muy alta de hospederos estuvieron libres de infección por helmintos (582/958, 60.7%). Los datos que aquí se presentan son usados junto con otros trabajos de inventario realizados en el norte de México que fueron recientemente publicados para revisar los patrones biogeográficos de la fauna helmintológica que parasita a peces dulceacuícolas en un área que está habitada principalmente por elementos neárticos.

Palabras clave: helmintos, Monogenea, Digenea, Nematoda, Acanthocephala, norte de México, nuevos registros de hospedero, nuevos registros de localidad.

Introduction

Freshwater fishes comprise a group of hosts with the largest number of papers published thus far describing the diversity and species richness of the helminth parasite fauna in Mexico (Pérez-Ponce de León and Choudhury,

2010; Pérez-Ponce de León et al., 2011). Recently, Pérez-Ponce de León and Choudhury (2010) proposed that the inventory of this group of parasites in freshwater fishes in its traditional approach is nearing completion in Mexico, and addressed some strategies to complete such a task, by targeting particular localities (in the northern parts of the country), and particular hosts groups (e.g., cyprinids and poeciliids), parallel with the use of a DNA-based approach to establish more robust criteria for species delimitation.

These authors also addressed that these approaches should be combined with other sources of information such as morphology, host association and geographical distribution, which may allow us to recognize and delimit putative cryptic species.

In order to fulfill the expectation of completing the inventory, we have conducted extensive sampling work in different areas of northern Mexico during the past years. Even though most of the data we gathered in that part of the country do not constitute formal survey work, with well-defined sampling sizes for hosts in each locality, a good deal of information has been accumulated thus far by studying individual hosts from several river basins in the northern parts of the country. The main objective of this paper is to present new host and locality records of the helminth parasite fauna of several freshwater fish species occurring in some localities of northern Mexico, north of the so-called Transmexican Volcanic Belt, a biogeographical province that has been recognized as a part of the transitional zone between the Nearctic and Neotropical biogeographical regions (Morrone, 2005). The data we present here is then used in combination with other recently published parasite surveys conducted in northern Mexico (e.g., Pérez-Ponce de León et al., 2009, 2010; Méndez et al., 2010; Aguilar-Aguilar et al., in press) to revise our understanding of the biogeographical patterns of the freshwater fish parasite fauna in an area inhabited predominantly by Nearctic freshwater fishes. This in turn will hopefully allow us to assess hypotheses and predictions regarding the patterns and processes (Pérez-Ponce de León and Choudhury, 2005): 1) that the adult parasite fauna in freshwater fishes is largely circumscribed by higher levels of monophyletic host taxa (families, orders, etc.), resulting in the presence of a biogeographical core parasite fauna, and 2) that areas with similar fish composition have more similar parasite faunas.

Materials and methods

Between 1999 and 2006, 958 freshwater fishes belonging to 34 species in 21 genera and 8 families were studied for helminths. These freshwater fishes were collected in 36 localities distributed along 9 states of the Mexican Republic (Fig. 1), mostly corresponding to the Nearctic biogeographical region. In terms of distribution along biogeographical provinces, following Morrone (2005), fishes were collected in river basins mainly located in 4 provinces from Northern Mexico, included within the Nearctic dominion, the Sonora, Mexican Altiplano, Sierra Madre Occidental, and Tamaulipas provinces (Morrone, 2005). Surveys of particular river basins included within such provinces have been published elsewhere (Pérez-

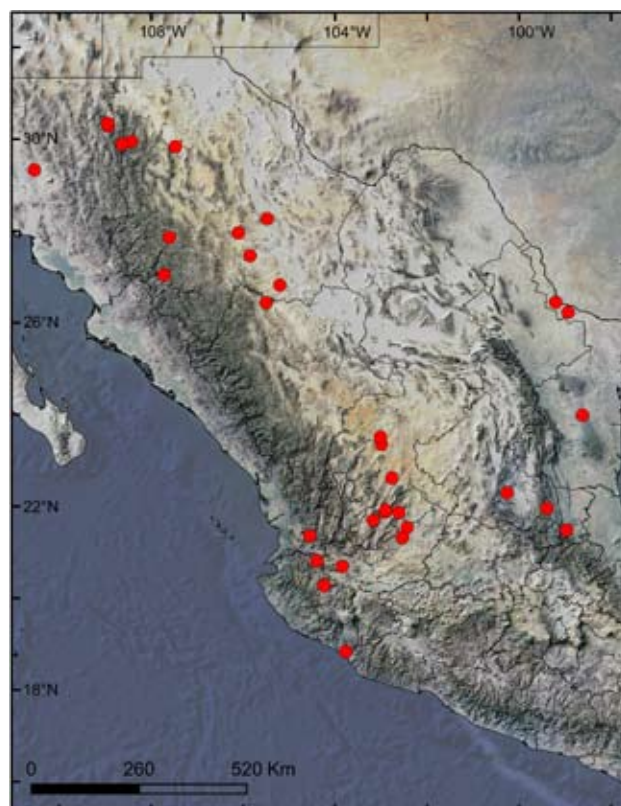


Fig. 1. Map of northern Mexico showing the sampled localities reported in this study along different river basins.

Ponce de León et al., 2009, 2010; Aguilar-Aguilar et al., in press). Localities included in this survey mainly correspond with the following river basins: Santiago, Mayo-Yaqui, Conchos, Aguanaval, Pánuco, Soto La Marina, and Bravo river basins (see Miller et al., 2005).

Freshwater fishes were collected by using seine nets and electrofishing. For parasitological examination, fishes were maintained alive until they were examined. They were killed by pithing and immediately studied for helminths. Helminths were separated in Petri dishes with 0.6% saline, and studied under the stereomicroscope. All helminths were washed in 0.6% saline and fixed either for morphological study (in 4% steaming formalin) or for DNA extraction (in 100% ethanol). For morphological study, helminths were stained with Mayer's paracarmine or Delafield's haematoxylin. Platyhelminths and acanthocephalans were mounted as permanent slides in Canada balsam; nematodes were cleared with lactophenol. Voucher specimens were deposited at the Colección Nacional de Helmintos (CNHE), Instituto de Biología, Universidad Nacional Autónoma de México (accession numbers in the host-parasite list, results section). Specimens for molecular work were kept in the

refrigerator at 4° C. Likewise, hosts were deposited at the Colección de Peces, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán (CPUMSNH).

Results

In this survey, isolated records of helminth parasites of freshwater fishes are presented from 958 individual fish belonging to 34 species. These freshwater fishes were collected in 36 localities of northern Mexico. A total of 25 helminth taxa were found, with digeneans as the most diverse helminth group, with 9 species. The results of this survey work are presented in Table 1, in the form of a host parasite list. The list is organized alphabetically by state of the Mexican Republic. Within each state, particular localities are listed alphabetically, with sampling size in parenthesis followed by the number of uninfected hosts per locality. In each locality, analyzed hosts (with sampling size) are presented also in alphabetical order by host family. For each host, the helminth species followed by the accession number to the CNHE are presented. In those cases where no accession number is included, specimens were fixed either for scanning electron microscopy study, or for DNA extraction.

Discussion

In this survey 958 individuals representing 34 species of freshwater fishes were collected from 36 localities of northern Mexico and studied for helminth parasites. Interestingly, 582 (60.7%) were uninfected with helminth parasites. In total, 25 helminth taxa were found, including 9 digeneans, 6 nematodes, 4 monogeneans, 5 cestodes, and 1 acanthocephalan. Of the 25 species of helminths, 12 were found as larval stages while 13 were found as adults. With the single exception of the nematode *Spiroxys* sp., all the other larval forms complete their life cycles in fish-eating birds that fed upon fish. The adult tapeworm *B. acheilognathi* represents an introduced species. This tapeworm, along with the metacercariae of *P. minimum* are the most common helminth species since they were found in 16 and 12 of the fish species examined in this survey work, respectively. This result is not unexpected, since this represents a general pattern as shown in other surveys, where both species are commonly found infecting freshwater fishes (e.g., Pérez-Ponce de León et al., 2009, 2010). With the exception of the cestode *Bothriocephalus* cf. *cuspidatus*, parasitizing *Lepomis macrochirus* in Chihuahua, and the caryophyllidean cestodes that are being studied in detail by Dr. Tomas Scholz at the Institute of Parasitology, Czech Republic, all the other species have been previously recorded in freshwater fishes in Mexico.

The cestode *Bothriocephalus* c.f. *cuspidatus* seems to represent an undescribed species of *Bothriocephalus* that is commonly found in centrarchids in Eastern USA, and is being described by one of us (Choudhury, pers comm.), but still it represents the first record in Mexico. Likewise, in this survey, 50 new host, and 25 new locality records, are presented. Interestingly, the helminth fauna of 7 host species (*Carpionotus carpio*, *Catostomus bernardini*, *C. plebeius*, *Dionda erymizonops*, *Gila minckleyi*, *Notropis tropicus* and *Thampichthys dicromus*) was studied for the first time. Only 4 out of the 34 examined species were negative to the presence of helminth parasites, i.e., *Carpionotus carpio*, *Catostomus* sp., *Gambusia* sp., and *Poecilia* sp.

The new data obtained through this survey from "isolated" samplings, along with other more formal inventories published in the last 3 years (Pérez-Ponce de León et al., 2009, 2010, Méndez et al., 2010; Aguilar-Aguilar et al., in press) conducted in Durango, Baja California Sur and Coahuila, respectively, provide further support to the idea that the inventory of the Mexican freshwater fish helminth fauna in its traditional form is nearing completion (Pérez-Ponce de León and Choudhury, 2010). All the data we have accumulated from northern areas of Mexico brings the percentage of fish species studied so far for helminth parasites to almost 60%. Apparently, it did not seem to matter whether we examined host species that were previously studied for helminthes or not; we were unable to find any new species, and basically most records correspond to species previously reported as part of the Mexican helminth fauna.

Similar results were found by other authors studying particular areas of northern Mexico. For instance, Méndez et al. (2010) studied 471 fishes corresponding to 9 freshwater fish species from 13 oases and other water bodies of Baja California Sur, in the peninsula of Baja California. In that survey authors collected 24 helminth parasite species, most of them as larval stages. Interestingly, while all were new records for that area of Mexico, all of them were previously recorded in other parts of the country. Likewise, Aguilar-Aguilar et al. (in press) recently studied 570 fish, representing 17 fish taxa, from 26 sampling sites in Cuatro Ciénegas basin and neighboring areas, in Coahuila State, northeastern Mexico; 25 helminth taxa were identified and, with the exception of the acanthocephalan *Leptorhynchoides thecatus* and the digenean *Microphallus* cf. *opacus* (which were recorded in Mexico for the first time), all the other helminths had been previously found in other localities of Mexico.

With the information we gathered in this survey from northern Mexico, we were able to address again the predictions made by Pérez-Ponce de León and Choudhury

Table 1. List of the helminth parasite fauna recovered from freshwater fishes in several localities of northern Mexico. Uninfected host species in each sampling site are indicated under the symbol †. Each host species marked in bold

Aguascalientes (21)

Río Gil (21°51'41.21" N, 102°37'3.50" W) (21 revised / 17 uninfected)

Cyprinidae: *Yuriria alta* (21): *Bothriocephalus acheilognathi* (CNHE 7425), *Posthodiplostomum minimum* (CNHE 7422).

Chihuahua (451)

Bocoyna (27°51'30.32" N, 107°36'3.01" W) (15/6)

Cyprinidae: *Campostoma ornatum* (5): *Clinostomum marginatum* (CNHE 8074), *Diplostomum* sp., *Posthodiplostomum minimum*; *Codoma ornata* (8): *Bothriocephalus acheilognathi*, *Clinostomum marginatum*, *Posthodiplostomum minimum*; *Gila minacae* (2): *Posthodiplostomum minimum*.

Buenaventura (29°50'16.94" N, 107°28'24.86" W) (73/38)

Catostomidae: *Catostomus plebeius* (9) †; Cyprinidae: *Cyprinella lutrensis* (38): Acuariidae gen. sp. (CNHE 7221), *Bothriocephalus acheilognathi* (CNHE 7394), *Margotrema bravoae* (CNHE 7402), *Rhabdochona canadensis*; *Pimephales promelas* (26): *Bothriocephalus acheilognathi* (CNHE 7403), *Clinostomum marginatum* (CNHE 7379), *Posthodiplostomum minimum* (CNHE 7380, 7381), *Eustrongylides* sp. (CNHE 7212)

El Colorado (29°56'51" N, 108°25'28" W) (22/17)

Characidae: *Astyanax mexicanus* (19): *Bothriocephalus acheilognathi* (CNHE 7401); Cichlidae: *Oreochromis* sp. (3): *Posthodiplostomum minimum* (CNHE 7375).

Meoqui (28°15'51.00" N, 105°28'37.53" W) (74/33)

Characidae: *Astyanax mexicanus* (30): *Contracaecum* sp. (CNHE 7216), *Eustrongylides* sp. (CNHE 7220), *Procamallanus* (*Spirocamallanus*) *neocaballeroi* (CNHE 7206); Catostomidae: *Catostomus plebeius* (10): *Polymorphus brevis* (CNHE 7384); Cyprinidae: *Notropis chihuahua* (9): *Bothriocephalus acheilognathi* (CNHE 7409), *Diplostomum* sp. (CNHE 7390), *Contracaecum* sp. (CNHE 7217); Poecilidae: *Gambusia senilis* (25): *Clinostomum marginatum*, *Diplostomum* sp. (CNHE 7382), *Eustrongylides* sp. (CNHE 7218, 7219), *Polymorphus brevis* (CNHE 7383), *Posthodiplostomum minimum* (CNHE 7391).

Río Batopilas (27°02' 27.8" N, 107°43'11.28" W) (12/4)

Catostomidae: *Catostomus bernardini* (3): *Rhabdochona* sp.; Cyprinidae: *Gila minacae* (9): *Rhabdochona* sp.

Río Primero (26°48'54.2" N, 105°12'12.9" W) (113/47)

Characidae: *Astyanax mexicanus* (2): *Procamallanus* (*Spirocamallanus*) *neocaballeroi* (CNHE 7209); Catostomidae: *Moxostoma austrinum* (4): *Rhabdochona ovifilamenta* (CNHE 7211); Centrarchidae: *Lepomis macrochirus* (3): *Bothriocephalus* cf. *cuspidatus* (CNHE 7400); Cyprinidae: *Campostoma ornatum* (12): *Bothriocephalus acheilognathi* (CNHE 7392), *Posthodiplostomum minimum* (CNHE 7387), *Rhabdochona canadensis* (CNHE 7207); *Cyprinella lutrensis* (14): *Bothriocephalus acheilognathi* (CNHE 7396); *Cyprinella panarcys* (27): *Eustrongylides* sp. (CNHE 7213), *Posthodiplostomum minimum* (CNHE 7371); *Gila pulchra* (14): *Bothriocephalus acheilognathi* (CNHE 7397), *Posthodiplostomum minimum* (CNHE 7386), *Rhabdochona canadensis* (CNHE 7210); *Notropis chihuahua* (11): *Bothriocephalus acheilognathi* (CNHE 7393), *Rhabdochona canadensis* (CNHE 7208); *Pimephales promelas* (26): *Bothriocephalus acheilognathi* (CNHE 7395), *Posthodiplostomum minimum* (CNHE 7369, 7370)

Satevó (27°57'19.57" N, 106°6'2.78" W) (66/32)

Characidae: *Astyanax mexicanus* (18) †; Cyprinidae: *Codoma ornata* (34): *Bothriocephalus acheilognathi* (CNHE 7406), *Clinostomum marginatum* (CNHE 7377, 7388), *Posthodiplostomum minimum* (CNHE 7376); *Gila* sp. (3): *Bothriocephalus acheilognathi* (CNHE 7407), *Clinostomum marginatum*, *Posthodiplostomum minimum* (CNHE 7371); *Notropis chihuahua* (11): *Clinostomum marginatum* (CNHE 7378).

Villa de Zaragoza (27°27'32" N, 105°50'48" W) (76/52)

Cyprinidae: *Cyprinella lutrensis* (30): *Bothriocephalus acheilognathi* (CNHE 7404); *Notropis chihuahua* (30): *Bothriocephalus acheilognathi*, *Diplostomum* sp. (CNHE 7385), *Rhabdochona canadensis*; *Codoma ornata* (16): *Ornithodiplostomum* sp. (CNHE 7373), *Posthodiplostomum minimum* (CNHE 7374).

Durango (63)

Villa de Ocampo (26°26'08" N, 105°29'55" W) (63/45)

Catostomidae: *Moxostoma austrinum* (5); *Rhabdochona ovifilamenta* (CNHE 7205); Cyprinidae: *Campostoma ornatum* (3) †; *Codoma ornata* (23); *Bothriocephalus acheilognathi* (CNHE 7399), *Posthodiplostomum minimum* (CNHE 7372); *Dionda episcopa* (32); *Bothriocephalus acheilognathi* (CNHE 7398), *Rhabdochona canadensis*.

Jalisco (64)

Río Atengo (20°16'41.9" N 109°14'11.3" W) (5/3)

Catostomidae: *Moxostoma austrinum* (5); Caryophyllidea gen. sp.

Río Chiquito (20°48'28.20" N, 104°23'57.16" W) (15)

Cyprinidae: *Yuriria alta* (15); *Posthodiplostomum minimum* (CNHE 7419), *Bothriocephalus acheilognathi* (CNHE 7403).

Río Verde, Belem (21°32'13.7" N, 102°25'57.7" W) (3/2)

Cyprinidae: *Yuriria alta* (3); *Posthodiplostomum minimum* (CNHE 7420)

Santa Rosa (21°41'29.9" N 103°10'17.7" W) (30/30)

Poeciliidae: *Poecilia* sp. (30) †.

Teuchitlán (20°41'20.6" N 103°50'29.9" W) (3/3)

Poeciliidae: *Poecilia* sp. (3) †

Tributario Río Verde (21°18'52" N, 102°32'27.7" W) (8/1)

Cyprinidae: *Yuriria alta* (8); *Bothriocephalus acheilognathi* (CNHE 7430), *Posthodiplostomum minimum* (CNHE 7421)

Nayarit (54)

La Cofradía (21°21'33.4" N 104°32'59.2" W) (20/19)

Cyprinidae: *Algansea avia* (20); *Spiroxys* sp. (CNHE 5859)

Santa María del Oro (21°21'37.1" N 104°32'55.15" W) (34/34)

Cyprinidae: *Azteculea sallaei* (34); *Bothriocephalus acheilognathi* (CNHE 7423), *Posthodiplostomum minimum* (CNHE 7417), *Ligula intestinalis* (CNHE 7426).

San Luis Potosí (105)

El Aguaje (22°17'42.3" N, 100°15'37.1" W) (19/16)

Characidae: *Astyanax mexicanus* (3) †; Cichlidae: *Herichthys* sp. (6); *Clinostomum marginatum*; Cyprinidae: *Thampichthys dichromus* (4); *Bothriocephalus acheilognathi* (CNHE 7432); Poeciliidae: *Poecilia mexicana* (6) †

El Trampolín (21°57'10.8" N, 99°23'18.7" W) (51/47)

Characidae: *Astyanax mexicanus* (6); *Contraecum* sp.; Cichlidae: *Herichthys* sp. (10); *Clinostomum marginatum* (CNHE 7416); Cyprinidae: *Dionda* sp. (10), *Bothriocephalus acheilognathi* (CNHE 7431); Poeciliidae: *Poecilia mexicana* (25); *Clinostomum marginatum* (CNHE 7412).

Huichihuayán (21°28'47.7" N, 98°58'1.5" W) (45/24)

Characidae: *Astyanax mexicanus* (19); *Creptotrematina aguirrepequeñoi* (CNHE 7411), *Prosthenthera obesa* (CNHE 7410); Cyprinidae: *Dionda erymizonops* (6) †; *Notropis tropicus* (5); *Bothriocephalus acheilognathi* (CNHE 7414); Poeciliidae: *Gambusia* sp. (7) †; *Poecilia mexicana* (8); *Saccocoelioides* cf. *sogandaresi* (CNHE 7413), *Posthodiplostomum minimum* (CNHE 7415).

Sonora (24)

Mesa Tres Ríos (29°53'21.7" N, 108°38'3.3" W) (8/1)

Catostomidae: *Catostomus* sp. (4); *Clinostomum marginatum* (CNHE 8075); Cyprinidae: *Campostoma ornatum* (1); *Clinostomum marginatum* (CNHE 8076); *Codoma ornata* sp. (1); *Uvulifer ambloplitis*; *Gila* sp. (2); *Clinostomum marginatum* (CNHE 8077)

Río Bavispe al norte de Huachinera (30°16'59.3" N, 108°56'7.8" W) (6/5)

Catostomidae: *Catostomus* sp. (4) †; Cyprinidae: *Campostoma ornatum* (1); *Clinostomum marginatum* (CNHE 8078, 8230); *Gila* sp. (1) †

Río Bavispe en el puente, sur de Bacerac 30°20'36.9" N, 108°56'52.9" W (4/1)
Catostomidae: <i>Carpioides carpio</i> (1) †; Cyprinidae: <i>Compostoma ornatum</i> (2): <i>Clinostomum marginatum</i> (CNHE 8079); <i>Gila minacae</i> (1): <i>Clinostomum marginatum</i> (CNHE 8080)
Río Sonora (29°19'25.83" N, 110°32'14.12" W) (1/1)
Catostomidae: <i>Catostomus bernardini</i> (1) †
Unión de dos ríos (29°53'21.7" N, 108°38'3.3" W) (5/4)
Cyprinidae: <i>Campostoma ornatum</i> (2): <i>Clinostomum marginatum</i> ; <i>Codoma ornata</i> (3) †
Tamaulipas (46)
Presa Falcón (26°26'34" N, 99°12'05" W) (17/10)
Centrarchiidae: <i>Micropterus salmoides</i> (3) †; Cichlidae: <i>Herichthys</i> sp. (4): Proteocephalidea gen. sp.; Clupeidae: <i>Dorosoma anale</i> (5): <i>Mazocraeoides olentangiensis</i> (CNHE 3393), Proteocephalidea gen. sp., <i>Pseudanthocotyloides banghami</i> (CNHE 7428); Scianidae: <i>Aplodinotus grunniens</i> (5): <i>Diplostamenides spinicirrus</i> (CNHE 7429).
Presa Marte R. Gómez (26°13'26.01" N, 98°55'52.9" W) (24/21)
Centrarchiidae: <i>Micropterus salmoides</i> (7): <i>Contracaecum</i> sp. (CNHE 4990), <i>Hysterothylacium</i> sp.; Characidae: <i>Astyanax mexicanus</i> (13): <i>Hysterothylacium</i> sp.; Cichlidae: <i>Herichthys</i> sp. (4) †
Río Soto La Marina (23°58'57" N, 98°37'01" W) (5/4)
Characidae: <i>Astyanax mexicanus</i> (5): <i>Microcotyle</i> sp. (CNHE 7427).
Zacatecas (130)
Huejuquilla (21°21'33.4" N, 104° 32' 59.2" W) (30/29)
Cyprinidae: <i>Algansea monticola</i> (30): <i>Posthodiplostomum minimum</i>
Presa El Tesorero (21°21'33.4" N 104°32'59.2" W) (20/18)
Cyprinidae: <i>Algansea monticola</i> (20): <i>Bothriocephalus acheilognathi</i>
Río Florido (23°20'45.66" N, 102°59'34.03" W) (15/13)
Cyprinidae: <i>Cyprinella</i> sp. (15): <i>Bothriocephalus acheilognathi</i>
Río Juchipila, Jalpa (22°36'57.2" N, 102°45'39.5" W) (29/8)
Cyprinidae: <i>Yuriria alta</i> (35): <i>Posthodiplostomum minimum</i> (CNHE 7418), <i>Bothriocephalus acheilognathi</i> (CNHE 7424)
Río Juchipila, Tabasco (21°52'27.8" N, 102°54'53.6" W) (14/14)
Catostomidae: <i>Moxostoma austrinum</i> (14) †
Río Juchipila, Tenanguillo (21°54'57.8" N, 102°54'11.54" W) (5/5)
Catostomidae: <i>Moxostoma austrinum</i> (5) †
Río de Medina (23°30'25.5" N, 103°00'47.6" W) (17/12)
Cyprinidae: <i>Cyprinella</i> sp. (17): <i>Bothriocephalus acheilognathi</i>

(2005) regarding the biogeographical patterns of the freshwater fish helminth fauna in Mexico and we found that goodeids, atherinopsids, cichlids, ictalurids, cyprinids, centrarchids, catostomids, characids, heptapterids, and poeciliids have their characteristic parasite core fauna. For instance, we examined species of cyprinids that were not studied before. Cyprinids comprise a typical Nearctic component that extends their distributional range into central Mexico along the Transmexican Volcanic Belt, with high levels of endemisms in river basins of the north and central plateau. We found the same species there that are found in cyprinids in other parts of the country,

i.e., the cestode *Bothriocephalus acheilognathi*, the digeneans *Uvulifer ambloplitis*, *Clinostomum marginatum*, *Posthodiplostomum minimum*, and the nematode *Rhabdochona canadensis*. Our new data allowed us also to corroborate that limited host sharing occurs across higher phylogenetic host groups (families) even in areas where fishes co-occur. Centrarchids, cyprinids, catostomids and ictalurids (Nearctic fauna) maintain their own helminth fauna even in localities where all of them co-occur, such as the Nazas and the Conchos river basins in Durango and Chihuahua, respectively. For example, in these areas of northern Mexico, centrarchids (black basses and sunfishes)

are infected with the monogenean *Cleidodiscus bedardi*, the dinereans *Crepidostomum cooperi* and *C. cornutum*, and the cestode *Bothriocephalus* cf. *cuspidatus*; while ictalurids (catfishes) harbored *Phyllodistomum lacustri*, *Megathylacoides giganteum*, *Corallobothrium fimbriatum*, and *Alloglossidium corti*. All these helminth species are common in areas where those species are naturally distributed in other parts of North America, and even in Mexico (see Hoffman, 1999, Rosas-Valdez and Pérez-Ponce de León, 2008).

We have gathered empirical evidence to support the contention that the inventory of the helminth parasites of the Mexican freshwater fish fauna, in its traditional way, is nearing completion (Pérez-Ponce de León and Choudhury, 2010). We posit that only detailed molecular work with target species will demonstrate hidden diversity through the recognition of cryptic species and potential complexes of unique entities, in what has been thought to be a single species. Documented examples of this scenario can be seen in detail in Martínez-Aquino et al., (2009), Razo-Mendivil et al., (2010), and Rosas-Valdez et al., (2011), but needless to say, cases of cryptic diversity are increasingly evident in the freshwater fish helminth fauna, as a result molecular tools will need to become commonplace in future taxonomic and survey work.

Acknowledgements

We would like to thank the following people for their help during field work: Rodolfo Pérez, Omar Domínguez, Alejandro Varela, Elizabeth Martínez, Jacqueline Bravo and Rosario Briosio. We thank Rodolfo Pérez and Omar Domínguez for the taxonomic determination of the hosts; to Lorena Garrido-Olvera for the taxonomic determination of some of the nematodes collected in this study and Carlos Gómez Hinostrosa for preparing Figure 1. The study was funded by grants from Conacyt (No. 83043) and PAPIIT-UNAM (IN202111) to G.P.P.L.

Literature cited

- Aguilar-Aguilar, R., A. Martínez-Aquino, H. Espinosa-Pérez and G. Pérez-Ponce de León. Helminth parasites of freshwater fishes from Cuatro Ciénegas, Coahuila, in the Chihuahuan desert of Mexico: Inventory and biogeographical implications. Integrative Zoology (in press).
- Hoffman, G. L. 1999. Parasites of North American freshwater fishes, 2nd ed. Cornell University Press, Ithaca. 537 p.
- Martínez-Aquino, A., M. E. Reyna-Fabián, R. Rosas-Valdez, U. Razo-Mendivil, G. Pérez-Ponce de León and M. García-Varela. 2009. Detecting a complex of cryptic species within *Neoechinorhynchus golvani* (Acanthocephala: Neoechinorhynchidae) inferred from ITS's and LSU rDNA gene sequences. Journal of Parasitology 95:1040-1047.
- Méndez, O., G. Salgado-Maldonado, J. M. Caspeta-Mandujano and G. Cabañas-Carranza. 2010. Helminth parasites of some freshwater fishes from Baja California Sur, Mexico. Zootaxa 2327: 44-50.
- Miller, R. R., M. L. Minckley and S. M. Norris. 2005. Freshwater fishes of Mexico. The University of Chicago Press, Chicago. 490 p.
- Morrone, J. J. 2005. Hacia una síntesis biogeográfica de México. Revista Mexicana de Biodiversidad 76:207-252
- Pérez-Ponce de León, G. and A. Choudhury. 2005. Biogeography of helminth parasites of freshwater fishes in Mexico: the search for patterns and processes. Journal of Biogeography 32:645-659.
- Pérez-Ponce de León, G. and A. Choudhury. 2010. Parasite Inventories and DNA-based Taxonomy: Lessons From Helminths of Freshwater Fishes in a Megadiverse Country. Journal of Parasitology 96:236-244.
- Pérez-Ponce De León, G., R. Rosas-Valdez, B. Mendoza-Garfias, R. Aguilar-Aguilar, J. Falcón-Ordaz, L. Garrido-Olvera and R. Pérez-Rodríguez. 2009. Survey of the endohelminth parasites of freshwater fish in the upper Mezquital River Basin, Durango State, Mexico. Zootaxa 2164:1-20.
- Pérez-Ponce de León, G., R. Rosas-Valdez, R. Aguilar-Aguilar, B. Mendoza-Garfias, C. Mendoza-Palmero, L. García-Prieto, A. Rojas, R. Briosio-Aguilar, R. Pérez-Rodríguez and O. Domínguez-Domínguez. 2010. Helminth parasites of freshwater fishes in the Nazas River Basin, Northern Mexico. Check List: Journal of Species Lists and Distribution 6:26-35.
- Razo-Mendivil, U, E. Vázquez-Domínguez, R. Rosas-Valdez R, G. Pérez-Ponce de León and S. A. Nadler. 2010. Phylogenetic analysis of nuclear and mitochondrial DNA reveals a complex of cryptic species in *Crassicutis cichlasomae* (Digenea: Apocreadiidae), a parasite of Middle-American cichlids. International Journal for Parasitology 40:471-486.
- Rosas-Valdez, R. and G. Pérez-Ponce de León. 2008. Composición taxonómica de los helmintos parásitos de ictalúridos y heptaptéridos (Osteichthyes: Siluriformes) de México, con una hipótesis de homología biogeográfica primaria. Revista Mexicana de Biodiversidad 79:473-499.
- Rosas-Valdez, R., A. Choudhury and G. Pérez-Ponce de León. 2011. Molecular prospecting for cryptic species in *Phyllodistomum lacustri* (Platyhelminthes, Gorgoderidae). Zoologica Scripta 40:296-305.