

Helminth parasites of freshwater fishes, Nazas River basin, northern Mexico

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ABSTRACT: This paper represents the first study of the helminth parasites of freshwater fishes from the Nazas River basin in northern Mexico. Between July 2005 and December 2008, 906 individual fish were collected and examined for helminth parasites in 23 localities along the river basin. Twenty-three species of fish were examined as a part of this inventory work. In total, 41 helminth species were identified: 19 monogeneans, 10 digeneans, seven cestodes, one acanthocephalan, and four nematodes. The biogeographical implications of our findings are briefly discussed.

INTRODUCTION

Freshwater fish helminth parasites are undoubtedly the most well-known group among vertebrate parasites in Mexico. This group of parasites has been studied in Mexico since the decade of the 1930's (Pérez-Ponce de León *et al.* 1996). Recently, Luque and Poulin (2007) suggested that Mexico stands out as a hotspot of parasite diversity for freshwater fishes. Still, the helminth fauna of freshwater fishes from northern river basins in Mexico is poorly known (Garrido-Olvera *et al.* 2006; Pérez-Ponce de León *et al.* 2009). Recently, we started collecting samples in that part of the country with the main objective of completing the inventory, mostly by considering Nearctic freshwater fishes such as cyprinids, catostomids, ictalurids and centrarchids (Lee *et al.* 1980), which constitute the most abundant and most species-rich host species in River basins in northern Mexico (Espinosa-Pérez *et al.* 1993). The first results of that survey work were published by Pérez-Ponce de León *et al.* (2009) who described the endohelminth fauna of freshwater fishes from the upper Mezquital River basin. In this paper, we present the results of the survey work we conducted in freshwater fishes of the Nazas River basin, an interesting area from the biogeographical point of view that represents an interior (closed) basin that runs from the Sierra Madre Occidental down to the lowlands of the Meseta del Norte.

MATERIALS AND METHODS

The Nazas River is an endorreic River basin located in the north of Mexico and it extends along the states of Coahuila and Durango. It is only 560 Km in length, but irrigates an area of 71,906 km² in the middle of the deserts of Coahuila and Durango states (Figure 1). The Nazas is also nurtured by the San Juan, Ramos, Potreritos, del Oro, Nazas, Santiago, Tepehuanes and Peñón Blanco Rivers. The River starts at the Mexican Sierra Madre Occidental and drains through state of Durango into the now dry Laguna

del Mayran, in state of Coahuila (Castañeda-Gaytán *et al.* 2005; Návar *et al.* 2006).

Between July 2005 and December 2008, 906 individual fish belonging to 23 species were collected in 23 localities along the Nazas River drainage, with sample sizes per species varying from 2 to 145 specimens (Figure 1; Table 1). Fish were collected under the Cartilla Nacional de Colector Científico de Flora y Fauna Silvestre (FAUT-0057 issued to G.P.P.L.). Fish were collected with seine nets and electrofishing, and were kept alive and studied for helminths no more than 4 hours after capture. All internal organs were analyzed separately in Petri dishes with 0.65 % saline under the stereoscope. Gills from each host were also obtained and placed in tap water to search for monogeneans. Monogeneans were fixed in glycerin ammonium-picrate (GAP) in order to study their sclerotized structures. After the morphological evaluation, specimens fixed with GAP were remounted in Canada balsam following Ergens (1969); some specimens were fixed in hot formaline 4 %, stained with Gomori's trichrome and mounted in Canada balsam to study their internal organs. Endoparasites were removed to a Petri dish with saline 0.65 %, prior to fixation. Digeneans and cestodes were fixed with hot (steaming) 4 % formalin. Acanthocephalans were maintained at 4 °C for 12 hours in distilled water, and then fixed in 70 % ethanol. Nematodes were fixed with hot (steaming) 4 % formalin or 70 % ethanol. All helminths were processed following standard procedures. Identification was made using specialized literature, and representative specimens of all helminth species were deposited at the Colección Nacional de Helminthos, Instituto de Biología, Universidad Nacional Autónoma de México (UNAM), Mexico City (CNHE).

RESULTS AND DISCUSSION

In total, 41 helminth species were found, representing 26 genera and 17 families. Of the 41 species we record herein, 19 were monogeneans, 10 digeneans, seven

cestodes, one acanthocephalan, and four nematodes. The systematic position of each helminth species is presented next, with information related with host (s), locality(s) and

were collected for DNA work or scanning electron microscopy are referred as “MW”. Some specimens were not collected and are referred as “NC”.

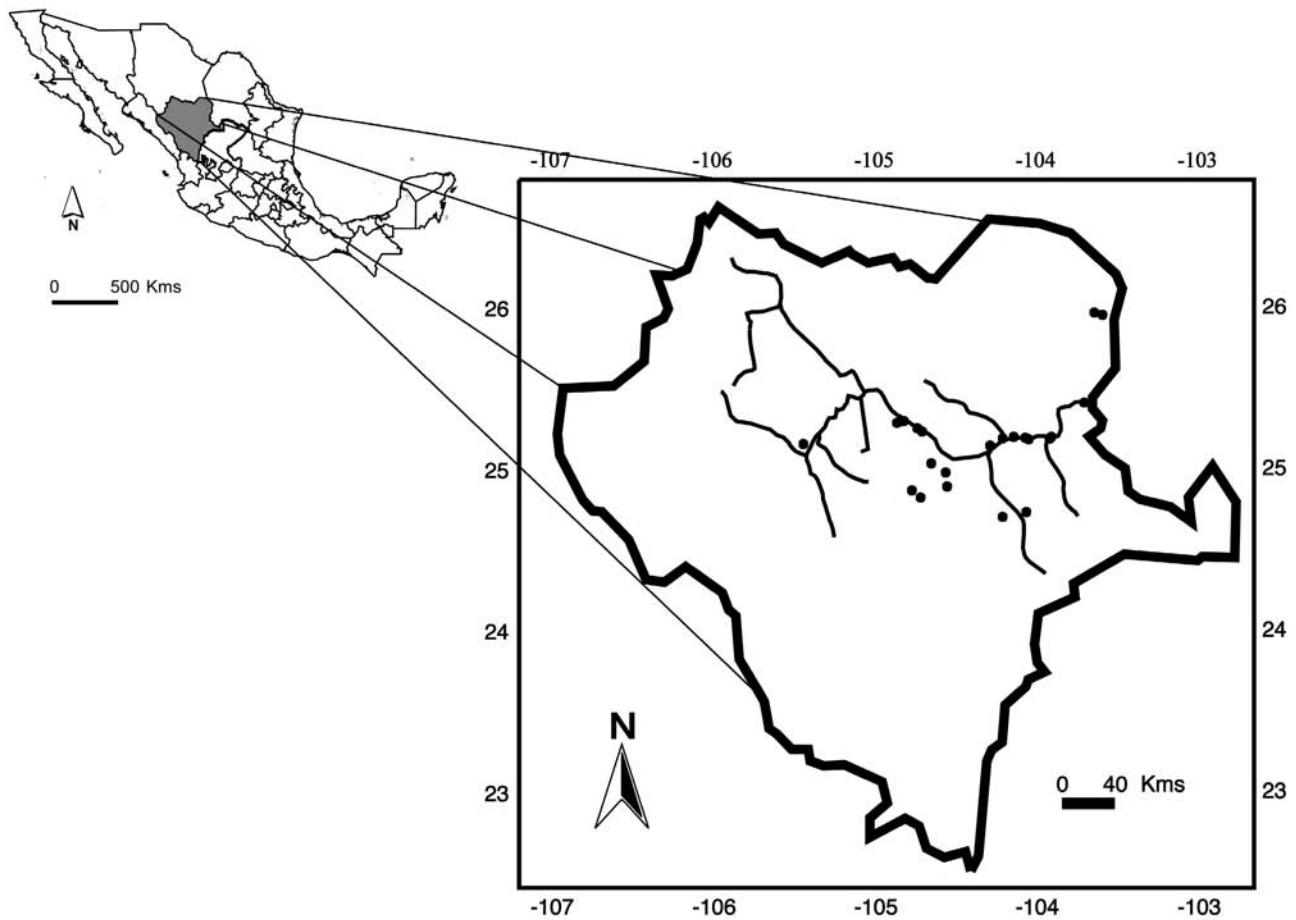


FIGURE 1. Map of the Mexican Republic showing the localities where fish were sampled along the Nazas River basin in state of Durango.

TABLE 1. Species of freshwater fishes analyzed in this survey, with host name and sample size per locality.

| Locality | Host species | Sample size |
|--|--|-------------|
| 1 Balneario “la Concha”, Peñón Blanco | <i>Astyanax mexicanus</i> De Filippi, 1853 | 6 |
| | <i>Cyprinodon nazas</i> Miller, 1976 | 32 |
| | <i>Poeciliopsis gracilis</i> Heckel, 1848 | 6 |
| 2 Camino a San Rafael Jicorica | <i>Astyanax mexicanus</i> | 3 |
| | <i>Campostoma ornatum</i> Girard, 1856 | 1 |
| | <i>Catostomus nebuliferus</i> Garman, 1881 | 3 |
| | <i>Cyprinella garmani</i> Jordan, 1885 | 4 |
| | <i>Gila conspersa</i> Garman, 1881 | 12 |
| | <i>Lepomis megalotis</i> (Rafinesque, 1820) | 9 |
| | <i>Notropis chihuahua</i> Woolman, 1892 | 12 |
| | <i>Notropis nazas</i> Meeke, 1904 | 15 |
| | <i>Pimephales promelas</i> Rafinesque, 1820 | 5 |
| | <i>Rhinichthys cataractae</i> Valenciennes, 1842 | 15 |
| 3 Charco las pitahayas, poblado Las Higueras | <i>Ictalurus pricei</i> Rutter, 1896 | 4 |
| | <i>Lepomis macrochirus</i> Rafinesque, 1819 | 7 |
| | <i>Gila conspersa</i> | 1 |
| | <i>Oreochromis nilotica</i> Linnaeus, 1758 | 1 |
| | <i>Pimephales promelas</i> | 2 |
| | <i>Poeciliopsis gracilis</i> | 9 |
| 4 Canal de Riego, poblado Dolores Hidalgo | <i>Carassius auratus</i> Linnaeus, 1759 | 1 |
| | <i>Notropis chihuahua</i> | 2 |
| | <i>Poeciliopsis gracilis</i> | 4 |
| 5 El Palmito | <i>Campostoma ornatum</i> | 4 |

| Locality | Host species | Sample size |
|---|---|-------------|
| | <i>Codoma ornata</i> Girard 1856 | 1 |
| 6 Poza en el Arroyo Torreones | <i>Notropis nazas</i> | 10 |
| | <i>Astyanax mexicanus</i> | 10 |
| | <i>Codoma ornata</i> | 15 |
| | <i>Gila conspersa</i> | 30 |
| | <i>Ictalurus pricei</i> | 1 |
| 7 Puente en carretera Peñón Blanco-Yerbaniz | <i>Notropis chihuahua</i> | 5 |
| | <i>Campostoma ornatum</i> | 37 |
| | <i>Catostomus nebuliferus</i> | 11 |
| | <i>Codoma ornata</i> | 23 |
| | <i>Cyprinella garmani</i> | 3 |
| | <i>Cyprinus carpio</i> | 1 |
| | <i>Gila conspersa</i> | 50 |
| | <i>Notropis nazas</i> | 6 |
| | <i>Pimephales promelas</i> | 2 |
| 8 Puente Lajas I, poblado de San Juan Francisco Lajas | <i>Astyanax mexicanus</i> | 3 |
| | <i>Catostomus nebuliferus</i> | 1 |
| | <i>Gila conspersa</i> | 39 |
| 9 Puente Lajas II, poblado de San Juan Francisco Lajas | <i>Astyanax mexicanus</i> | 12 |
| 10 Río Covadonga, poblado de Peñón Blanco | <i>Astyanax mexicanus</i> | 4 |
| | <i>Campostoma ornatum</i> | 20 |
| | <i>Catostomus nebuliferus</i> | 19 |
| | <i>Codoma ornata</i> | 22 |
| | <i>Etheostoma pottsi</i> Girard, 1859 | 20 |
| | <i>Gila conspersa</i> | 51 |
| | <i>Notropis nazas</i> | 17 |
| 11 Río Nazas, poblado de San Rafael Jicorica | <i>Ictalurus cf. pricei</i> | 3 |
| 12 Río Nazas, puente Nazas, Poblado de Nazas | <i>Gila conspersa</i> | 2 |
| | <i>Ictalurus cf. pricei</i> | 1 |
| | <i>Notropis nazas</i> | 26 |
| | <i>Pimephales promelas</i> | 11 |
| | <i>Poeciliopsis gracilis</i> | 2 |
| | <i>Oreochromis niloticus</i> | 1 |
| 13 Río Nazas, puente en carretera Rodeo-Hidalgo de Parral, desviación a Abasolo | <i>Lepomis macrochirus</i> | 7 |
| | <i>Notropis nazas</i> | 3 |
| | <i>Pimephales promelas</i> | 21 |
| 14 Río San Juan en "El Cuarto" | <i>Astyanax mexicanus</i> | 10 |
| | <i>Campostoma ornatum</i> | 16 |
| | <i>Catostomus nebuliferus</i> | 5 |
| | <i>Codoma ornata</i> | 40 |
| | <i>Cyprinodon nazas</i> | 1 |
| | <i>Gila conspersa</i> | 32 |
| | <i>Poeciliopsis gracilis</i> | 1 |
| 15 Canal de riego, Tlahualillo 1 | <i>Lepomis macrochirus</i> | 2 |
| 16 Canal de riego, Tlahualillo 2 | <i>Lepomis macrochirus</i> | 4 |
| 17 Presa Francisco Zarco | <i>Cyprinus carpio</i> Linnaeus, 1758 | 5 |
| | <i>Ictalurus cf. pricei</i> | 5 |
| | <i>Ictalurus punctatus</i> Rafinesque, 1818 | 5 |
| 18 Puente Carretera Paso Nacional | <i>Campostoma ornatum</i> | 2 |
| | <i>Catostomus nebuliferus</i> | 1 |
| | <i>Ictalurus pricei</i> | 2 |
| | <i>Lepomis macrochirus</i> | 4 |
| | <i>Notropis nazas</i> | 2 |
| | <i>Pimephales promelas</i> | 11 |
| | <i>Pomoxis annularis</i> Rafinesque, 1918 | 4 |
| 19 Río Nazas, poblado de Santa Rita | <i>Astyanax mexicanus</i> | 22 |

| Locality | Host species | Sample size |
|--|---|-------------|
| | <i>Carassius auratus</i> | 1 |
| | <i>Micropterus salmoides</i> Lacepède, 1802 | 2 |
| | <i>Pimephales promelas</i> | 3 |
| | <i>Poeciliopsis gracilis</i> | 1 |
| | <i>Pomoxis annularis</i> | 1 |
| | <i>Oreochromis nilotica</i> | 1 |
| 20 Río Nazas, salida de Presa Francisco Zarco, camino Graceros-Las Pirañas | <i>Pomoxis annularis</i> | 16 |
| 21 Río Nazas, bomba de agua en Ciudad Lerdo | <i>Astyanax mexicanus</i> | 20 |
| | <i>Cyprinus carpio</i> | 20 |
| | <i>Micropterus salmoides</i> | 20 |
| 22 Río en el Pueblo Emilio Carranza | <i>Astyanax mexicanus</i> | 26 |
| | <i>Catostomus nebuliferus</i> | 1 |
| | <i>Cyprinella garmani</i> | 10 |
| | <i>Lepomis macrochirus</i> | 11 |
| | <i>Micropterus salmoides</i> | 11 |
| | <i>Notropis nazas</i> | 8 |
| 23 Río Ramos, poblado el Olote | <i>Catostomus nebuliferus</i> | 16 |
| | <i>Ictalurus cf. pricei</i> | 19 |

PHYLUM Platyhelminthes Gegenbaur, 1859

CLASS Trematoda Rudolphi, 1808

ORDER Plagiorchiida La Rue, 1957

FAMILY Allocreadiidae Looss, 1902

Allocreadiidae gen. sp. (adult)

Host and localities: *Codoma ornata* Río Covadonga, poblado de Peñón Blanco (CNHE 6706)

FAMILY Clinostomatidae Lühe, 1901

Clinostomum complanatum (Rudolphi, 1814) Braun, 1899 (metacercariae)

Hosts and localities: *Astyanax mexicanus* Río San Juan en "El Cuarto" (CNHE 6315); *Catostomus nebuliferus* Río Covadonga, poblado Peñón Blanco (MW); *Etheostoma pottsi* Río Covadonga, poblado de Peñón Blanco (CNHE 6316); *Lepomis macrochirus* Canal de riego, Tlahualillo 2 (CNHE 6314); *Micropterus salmoides* Río en el Pueblo Emilio Carranza (CNHE 6225); *Notropis chihuahua* Camino a San Rafael Jicorica (MW); *Poeciliopsis gracilis* Charco las pitahayas, Las Higueras (MW).

FAMILY Gorgoderidae Loos, 1901

Phyllodistomum lacustri (Loewen, 1929) Lewis, 1935 (adult)

Hosts and localities: *Ictalurus cf. pricei* Río Ramos, poblado el Olote (CNHE 5932), Río Nazas, poblado de San Rafael Jicorica (CNHE MW); *Ictalurus pricei* Poza en el Arroyo Torreones (MW).

FAMILY Heterophidae Odhner, 1914

Centrocestus formosanus (Nishigori, 1924) Price, 1932 (metacercariae)

Hosts and localities: *Astyanax mexicanus* Balneario "La

Concha", Peñón Blanco (MW), Río Covadonga, Peñón Blanco (CNHE 6485); *Lepomis macrochirus* Canal de riego en Tlahualillo 1 (MW); Heterophidae gen. sp. (metacercariae) Host and locality: *Astyanax mexicanus* Río Nazas, Ciudad Lerdo (MW).

FAMILY Macroderoididae McMullen, 1937

Magnivitellinum simplex Kloss, 1966 (adult)

Host and locality: *Astyanax mexicanus* Río Covadonga, Peñón Blanco (CNHE 6311-6313).

Alloglossidium corti Lamont, 1921 (adult)

Hosts and localities: *Ictalurus cf. pricei* Camino a San Rafael Jicorica (CNHE 6239); *Ictalurus pricei* Charco las pitahayas, Las Higueras (CNHE 6647-6748).

FAMILY Diplostomidae Poirier, 1886

Diplostomum sp. (metacercariae)

Hosts and locality: *Pimephales promelas* Río Nazas, Poblado de Nazas (MW).

Posthodiplostomum minimum (Lutz, 1928) Dubois, 1970 (metacercariae)

Hosts and localities: *Astyanax mexicanus* Camino a San Rafael Jicorica (MW); *Campostoma ornatum* Camino a San Rafael Jicorica (MW), Puente carretera Peñón Blanco-Yerbaniz (CNHE 6333), Río Covadonga, Peñón Blanco (6318), Puente carretera Paso Nacional-Lázaro Cárdenas (CNHE 6327), Río San Juan en "El Cuarto" (6324); *Codoma ornata* Puente carretera Peñón Blanco-Yerbaniz (CNHE 6320-6321), Río Covadonga, Peñón Blanco (6325-6326, 6328), Río San Juan en "El Cuarto" (6329); *Cyprinella garmani* Puente carretera Paso Nacional-Lázaro Cárdenas (CNHE 6330-6331); *Gila conspersa* Poza en el Arroyo Torreones (MW), Camino a San Rafael Jicorica (CNHE 6613), Puente carretera Peñón Blanco-Yerbaniz (CNHE 6332), Río Covadonga, Peñón Blanco (6317), Río San Juan en "El Cuarto" (6223); *Ictalurus punctatus* Presa Francisco Zarco

(CNHE 6319); *Lepomis macrochirus* Charco las pitahayas, Las Higueras (CNHE 6646), Canal de riego, Tlahualillo 2 (CNHE 6337), *Río en el Pueblo Emilio Carranza* (CNHE 6222, 6224, 6524); *Lepomis megalotis* Río Nazas, poblado de San Rafael Jicorica (CNHE 6641); *Notropis chihuahua* Canal de Riego, poblado Dolores Hidalgo (MW), Camino a San Rafael Jicorica (not collected); *Notropis nazas* Camino a San Rafael Jicorica (MW), Río Covadonga, poblado de Peñon Blanco (not collected), Río Nazas, Poblado de Nazas (6295); *Pimephales promelas* Río Nazas, Poblado de Nazas (6236), Río en el Pueblo Emilio Carranza (6334), Camino a San Rafael Jicorica (MW), Puente carretera Paso Nacional-Lázaro Cárdenas (CNHE 6325), Charco las pitahayas, Las Higueras (MW), Río Nazas, puente en la carretera Rodeo-Hidalgo de Parral, desviación al poblado de Abasolo (CNHE 6237-6238); *Pomoxis annularis* Río Nazas, salida de la Presa Francisco Zarco (CNHE 6322-6323); *Rhinichthys cataractae* Camino a San Rafael Jicorica (MW).

Uvulifer sp. (metacercariae)

Host and locality: *Campostoma ornatum* Río Covadonga, poblado de Peñon Blanco (CNHE 6483); *Gila conspersa* Río Covadonga, Peñón Blanco (6484); *Notropis nazas* Río Nazas, Poblado de Nazas (CNHE 6505), Río Covadonga, poblado de Peñon Blanco (MW).

CLASS Monogenea Carus, 1863

ORDER Dactylogyridea Bychowsky, 1937

FAMILY Dactylogyridae Bychowsky, 1933

Cleidodiscus bedardi Mizelle, 1936 (adult)

Host and locality: *Lepomis macrochirus* Río Nazas, puente en la carretera Rodeo-Hidalgo de Parral, desviación a Abasolo (CNHE 6363).

Onchocleidus spiralis (Mueller, 1937) Mizelle and Huges, 1938

Host and locality: *Lepomis macrochirus* Río Nazas, puente en la carretera Rodeo-Hidalgo de Parral, desviación a Abasolo (CNHE 6512).

Ligictaluridus mirabilis Muller, 1937 (adult)

Host and locality: *Ictalurus cf. pricei* Río Nazas, poblado de San Rafael Jicorica (CNHE 6478, 6506);

Ligictaluridus pricei Muller, 1936 (adult)

Hosts and localities: *Ictalurus cf. pricei* Río Nazas, poblado de San Rafael Jicorica (CNHE 6482, 6507), Río Nazas, Poblado de Nazas (CNHE 6481, 6508).

Characithecium costaricensis (Price and Bussing, 1967) Mendoza-Franco, Reyna, and Torchin, 2009 (adult)

Host and locality: *Astyanax mexicanus* Puente Lajas II. (MW).

"*Urocleidoides*" *strombicirrus* (Price and Bussing, 1967) Kritsky and Thatcher, 1974 (adult)

Host and locality: *Astyanax mexicanus* Puente Lajas II (CNHE 6510-6511).

FAMILY Dactylogyridae Yamaguti, 1963

Dactylogyryrus anchoratus (Dujardin, 1845) Wagener, 1857 (adult)

Host and locality: *Carassius auratus* Canal de Riego, en poblado Dolores Hidalgo (CNHE 6359).

Dactylogyryrus dulceiti Bychowsky, 1936 (adult)

Host and locality: *Carassius auratus* Canal de Riego, en poblado Dolores Hidalgo (CNHE 6360).

Dactylogyryrus extensus Mueller and Vam Cleave, 1932 (adult)

Host and locality: *Cyprinus carpio* Pozo San Fernando (CNHE 6951),

Dactylogyryrus sp 1 (adult)

Hosts and localities: *Gila conspersa* Poza en el Arroyo Torreones (CNHE 6952), Puente Lajas I (CNHE 6953).

Dactylogyryrus sp. 2 (adult)

Hosts and localities: *Gila conspersa* Poza en el Arroyo Torreones (CNHE 6954), Puente Lajas I (CNHE 6955); *Notropis nazas* Río Nazas, Poblado de Nazas (NC).

Cichlidogyryrus sclerosus Paperna y Thurston, 1969 (adult)

Host and locality: *Oreochromis nilotica* Río Nazas, Poblado de Nazas (CNHE 6956)

FAMILY Gyrodactylidae Van Beneden and Hesse, 1863

Gyrodactylus spathulatus Mueller, 1936 (adult)

Hosts and localities: *Catostomus nebuliferus* Río Ramos, poblado el Olote (MW); *Gila conspersa* Puente Lajas I (MW), Poza en el Arroyo Torreones (NC); *Ictalurus cf. pricei* Río Nazas, Poblado de Nazas (NC).

Gyrodactylus sp. 1 (adult)

Host and locality: *Gila conspersa* Puente Las Lajas I (CNHE 6957).

Gyrodactylus sp. 2 (adult)

Host and locality: *Catostomus nebuliferus* Río Ramos, poblado el Olote (CNHE 6958)

Gyrodactylus sp. 3 (adult)

Host and locality: *Notropis nazas* Río Nazas, Poblado de Nazas (CNHE 6959).

Gyrodactylus sp. 4 (adult)

Hosts and localities: *Campostoma ornatum* Río Nazas, puente en la carretera Rodeo-Hidalgo de Parral, desviación a Abasolo (MW); *Pimephales promelas* Río Nazas, puente en la carretera Rodeo-Hidalgo de Parral, desviación a Abasolo (NC).

Gyrodactylus sp. 5 (adult)

Host and locality: *Astyanax mexicanus* Poza en el Arroyo Torreones (NC), Puente Lajas II (CNHE 6960).

Gyrodactylus sp. 6 (adult)

Host and locality: *Lepomis macrochirus* Río Nazas, puente

en la carretera Rodeo-Hidalgo de Parral, desviación a Abasolo (CNHE 6513).

CLASS Cestoda Rudolphi, 1808

ORDER Caryophyllidea van Beneden in Carus, 1863

FAMILY Lytocestidae Hunter, 1927

Khawia sinensis Hsu, 1935 (adult)

Host and locality: *Cyprinus carpio* Presa Francisco Zarco (6515-6516).

FAMILY Caryophyllaeidae Leuckart, 1878

Caryophyllidea gen. sp.

Host and locality: *Notropis nazas* Río en el Poblado Emilio Carranza (CNHE 6797).

Isoglaridacris sp. (adult)

Host and locality: *Catostomus nebuliferus* Río Covadonga, poblado Peñón Blanco (CNHE 6802)

ORDER Proteocephalidea Mola, 1928

FAMILY Proteocephalidae La Rue, 1911

Corallobothrium fimbriatum Essex, 1927 (adult)

Hosts and localities: *Ictalurus cf. pricei* Presa Francisco Zarco (CNHE 6517); *Ictalurus pricei* Puente carretera Paso Nacional-Lázaro Cárdenas (MW).

Megathylacoides giganteum Essex, 1928 (adult)

Hosts and localities: *Ictalurus cf. pricei* Río Ramos, poblado el Olote (MW), Río Nazas, poblado de San Rafael Jicorica (not collected), Presa Francisco Zarco (6519); *Ictalurus pricei* Puente carretera Paso Nacional-Lázaro Cárdenas (MW); *Ictalurus punctatus* Presa Francisco Zarco (CNHE 6520).

ORDER Pseudophyllidae Carus, 1863

FAMILY Bothriocephalidae Blanchard, 1849

Bothriocephalus acheilognathi Yamaguti, 1934 (adult)

Hosts and localities: *Astyanax mexicanus* Puente Lajas I (CNHE 6439), Río Covadonga, Peñón Blanco (MW), Río Nazas, Ciudad Lerdo (CNHE 6452), Río San Juan en "El Cuarto" (MW); *Campostoma ornatum* Río Covadonga, Peñón Blanco (6352), Río San Juan en "El Cuarto" (6343); *Codoma ornata* Poza en el Arroyo Torreones (CNHE 6433, 6449), Puente carretera Peñón Blanco-Yerbaniz (CNHE 6395-6396), Río Covadonga, Peñón Blanco (6394), Río San Juan en "El Cuarto" (6349-6350); *Cyprinella garmani* Camino a San Rafael Jicorica (not collected), Puente carretera Peñón Blanco-Yerbaniz (not collected), Puente carretera Peñón Blanco-Yerbaniz (CNHE 6341, 6514), Río en el Pueblo Emilio Carranza (6219); *Cyprinus carpio* Presa Francisco Zarco (6340, 6342), Río Nazas, Bombas de agua en Ciudad Lerdo (6338); *Gila conspersa* Camino a San Rafael Jicorica (not collected), Puente Lajas I (CNHE 6436-6438, 6447), Río Nazas, Poblado de Nazas (6426, 6454),

Poza en el Arroyo Torreones (CNHE 6430-6432, 6457-6458), Puente carretera Peñón Blanco-Yerbaniz (CNHE 6220, 6351), Río Covadonga, Peñón Blanco (6216, 6353-6355), Río San Juan en "El Cuarto" (6215, 6345-6347); *Lepomis macrochirus* Puente carretera Paso Nacional-Lázaro Cárdenas (MW); *Notropis chihuahua* Camino a San Rafael Jicorica (not collected), Poza en Arroyo Torreones (CNHE 6434), Canal de Riego, poblado Dolores Hidalgo (CNHE 6427-6428); *Notropis nazas* El Palmito (MW), Río Covadonga, poblado de Peñón Blanco (6218, 6397, 6456), Río en el Poblado de Emilio Carranza (6217), Río Nazas, Poblado de Nazas (CNHE 6429); *Pimephales promelas* Puente carretera Paso Nacional-Lázaro Cárdenas (CNHE 6339, 6451), *Río Nazas* en Sta. Rita (not collected), Camino a San Rafael Jicorica (not collected), Río Nazas, Poblado de Nazas (CNHE 6425), Río Nazas, puente en carretera Rodeo-Hidalgo de Parral, desviación a Abasolo (CNHE 6435); *Poeciliopsis gracilis* Río San Juan en "El Cuarto" (CNHE 6348, 6455).

ORDER Cyclophyllidae van Beneden in Brun, 1900

FAMILY Dilepididae Railliet and Henry, 1909

Neovalipora sp. (cysticercoid)

Host and locality: *Ictalurus cf. pricei* Presa Francisco Zarco (CNHE 6530).

PHYLUM Acanthocephala Rudolphi, 1808

CLASS Palaeacantocephala Meyer, 1931

ORDER Polymorphida Petrochenko, 1956

FAMILY Polymorphidae Meyer, 1931

Polymorphus sp. (cystacanth)

Hosts and localities: *Astyanax mexicanus* Río Nazas, Ciudad Lerdo (CNHE 6929-6930); *Micropterus salmoides* Río en el Pueblo Emilio Carranza (NC), Río Nazas, Ciudad Lerdo (CNHE 6928).

PHYLUM Nematoda Rudolphi, 1808

CLASS Secernentea Von Linstow, 1905

ORDER Ascaridida Skrjabin and Schulz, 1938

FAMILY Anisakidae (Railliet and Henry, 1912) Skrjabin and Karokhin, 1945

Contraecaecum sp. (larvae)

Hosts and localities: *Astyanax mexicanus* Río Nazas, Emilio Carranzas (CNHE 6388-6389); *Cyprinella garmani* Camino a San Rafael Jicorica (CNHE 6728); *Gila conspersa* Camino a San Rafael Jicorica (MW); *Ictalurus cf. pricei* Presa Francisco Zarco (CNHE 6392-6393); *Ictalurus pricei* Charco las pitahayas, Las Higueras (CNHE 6726), Puente carretera Paso Nacional-Lázaro Cárdenas (MW); *Ictalurus punctatus* Presa Francisco Zarco (CNHE 6387); *Pomoxis annularis* Río Nazas, salida de la Presa Francisco Zarco

(CNHE 6386).

FAMILY Gnathostomidae Railliet, 1895

Spiroxys sp. (larvae)

Hosts and localities: *Astyanax mexicanus* Puente Lajas I (CNHE 6382), Puente Lajas II (NC); *Campostoma ornatum* Puente carretera Peñon Blanco-Yerbaniz (MW); *Cyprinodon nazas* Río San Juan en "El Cuarto" (MW); *Gila conspersa* Puente carretera Peñon Blanco-Yerbaniz (not collected), Puente Las Lajas I (CNHE 6380-6381, 6450), Poza en el Arroyo Torreones (CNHE 6384-6385); *Notropis chihuahua* Poza en el Arroyo Torreones (CNHE 6383); *Notropis nazas* Puente carretera Peñon Blanco-Yerbaniz (MW);

ORDER Spirurida Chitwood, 1933

FAMILY Rhabdochoniidae (Travassos, Artigas and Pereira, 1928) Skrjabin, 1946

Rhabdochona canadensis Moravec and Arai, 1971 (adult)
Hosts and localities: *Campostoma ornatum* Puente carretera Peñon Blanco-Yerbaniz (MW); *Codoma ornata* Puente carretera Peñon Blanco-Yerbaniz (MW), Río Covadonga, Peñon Blanco (MW), Poza en el Arroyo Torreones (CNHE 6698-6699); *Cyprinella garmani* Camino a San Rafael Jicorica (MW); *Gila conspersa* Puente carretera Peñon Blanco-Yerbaniz (MW), Río Covadonga, Peñon Blanco (NC), Puente Las Lajas I (CNHE 6701); *Notropis chihuahua* Camino a San Rafael Jicorica (NC); *Notropis nazas* Puente carretera Peñon Blanco-Yerbaniz (MW), Río Covadonga, poblado de Peñon Blanco (CNHE 6705); Pimephales promelas Río Nazas, puente en la carretera Rodeo-Hidalgo de Parral, desviación al poblado de Abasolo (CNHE 6700).

Rhabdochona catostomi Kayton, Kritsky, and Tobias, 1979 (adult)

Hosts and localities: *Catostomus nebuliferus* Puente carretera Peñon Blanco-Yerbaniz (CNHE 6702), Río Covadonga, poblado Peñon Blanco (CNHE 6704), Río Ramos, poblado el Olote (CNHE 6703).

Host-Parasite List.

The host-parasite list is presented below in alphabetical order by fish family. In each host species sample size as the sum of all the sampled localities is presented. The list of helminth species per host species is ordered by helminth parasite group, and within each helminth group, in alphabetical order.

Catostomidae

Catostomus nebuliferus (n = 58)
Digenea
Clinostomum complanatum
Monogenea
Gyrodactylus spathulatus
Gyrodactylus sp. 2
Cestoda
Isoglaridacris sp.
Nematoda
Rhabdochona catostomi

Centrarchidae

Lepomis macrochirus (n = 37)
Digenea
Centrocestus formosanus
Clinostomum complanatum
Posthodiplostomum minimum
Cestoda
Bothriocephalus acheilignathi
Monogenea
Cleidodiscus bedardi
Gyrodactylus sp. 6.
Onchocleidus spiralis.
Lepomis megalotis (n = 9)
Digenea
Posthodiplostomum minimum
Micropterus salmoides (n = 33)
Digenea
Clinostomum complanatum.
Acanthocephala
Polymorphus sp.
Pomoxis annularis (n = 21)
Digenea
Posthodiplostomum minimum
Nematoda
Contracaecum sp.

Characidae

Astyanax mexicanus (n = 135)
Digenea
Centrocestus formosanus
Clinostomum complanatum
Heterophyidae gen. sp.
Magnivitellinum simplex
Posthodiplostomum minimum
Cestoda
Bothriocephalus acheilognathi
Monogenea
Characithecium costaricensis
Gyrodactylus sp. 5
Acanthocephala
Polymorphus sp.
Nematoda
Contracaecum sp.
Spiroxys sp.

Cichlidae

Oreochromis niloticus (n = 3)
Monogenea
Cichlidogyrus sclerosus

Cyprinidae

Campostoma ornatum (n = 80)
Digenea
Posthodiplostomum minimum
Uvulifer sp.
Monogenea
Gyrodactylus sp. 4
Urocleidoides strombicircus
Cestoda
Bothriocephalus acheilognathi
Nematoda
Rhabdochona canadensis

Spiroxys sp. (N).

Carassius auratus (n = 2)

Monogenea

Dactylogyrus anchoratus

Dactylogyrus dulketi

Codoma ornata (n = 101)

Digenea

Posthodiplostomum minimum

Cestoda

Bothriocephalus acheilognathi

Nematoda

Rhabdochona canadensis

Cyprinella garmani (n = 19)

Digenea

Posthodiplostomum minimum

Cestoda

Bothriocephalus acheilognathi

Nematoda

Contracaecum sp.

Rhabdochona canadensis

Cyprinus carpio (n = 26)

Cestoda

Bothriocephalus acheilognathi

Khawia sinensis

Gila conspersa (n = 217)

Digenea

Posthodiplostomum minimum

Uvulifer sp.

Monogenea

Dactylogyrus sp. 1.

Dactylogyrus sp. 2.

Gyrodactylus spathulatus

Gyrodactylus sp. 1.

Cestoda

Bothriocephalus acheilognathi

Nematoda

Contracaecum sp.

Rhabdochona canadensis

Spiroxys sp.

Notropis chihuahua (n = 19)

Digenea

Clinostomum complanatum

Posthodiplostomum minimum

Cestoda

Bothriocephalus acheilognathi

Nematoda

Rhabdochona canadensis

Spiroxys sp.

Notropis nazas (n = 87)

Digenea

Posthodiplostomum minimum

Uvulifer sp.

Monogenea

Dactylogyrus sp. 2.

Gyrodactylus sp. 3.

Cestoda

Bothriocephalus acheilognathi

Caryophyllidea gen. sp.

Nematoda

Rhabdochona canadensis

Spiroxys sp.

Pimephales promelas (n = 55)

Digenea

Diplostomum sp.

Posthodiplostomum minimum (D).

Monogenea

Gyrodactylus sp. 4

Cestoda

Bothriocephalus acheilognathi

Nematoda

Rhabdochona canadensis (N).

Rhinichthys cataractae (n = 15)

Digenea

Posthodiplostomum minimum (D).

Cyprinodontidae

Cyprinodon nazas (n = 33)

Nematoda

Spiroxys sp. (N).

Ictaluridae

Ictalurus cf. pricei (n = 9)

Digenea

Alloglossidium corti

Phyllodistomum lacustri.

Monogenea

Gyrodactylus spathulatus.

Ligictaluridus mirabilis

Ligictaluridus pricei

Cestoda

Corallobothrium fimbriatum

Megathylacoides giganteum

Neovalipora sp.

Nematoda

Contracaecum sp.

Ictalurus pricei (n = 7)

Digenea

Alloglossidium corti

Phyllodistomum lacustri

Cestoda

Corallobothrium fimbriatum

Megathylacoides giganteum

Nematoda

Contracaecum sp.

Ictalurus punctatus (n = 6)

Digenea

Posthodiplostomum minimum

Cestoda

Megathylacoides giganteum

Nematoda

Contracaecum sp.

Percidae

Etheostoma pottsi (n = 20)

Digenea

Clinostomum complanatum

Poeciliidae

Poeciliopsis gracilis (n = 20)

Digenea

Clinostomum complanatum

Cestoda

Bothriocephalus acheilognathi

This list of helminth species we present herein represents the continuation of our efforts to describe the biodiversity of this group of parasites in their freshwater fish hosts in Mexico. The inventory is not complete yet, but we are targeting River basins in the northern parts of the country, which still remain the less explored regions for helminth parasites (Pérez-Ponce de León and Choudhury 2005). In this case, we adopted a geographical region approach to conduct the survey work by considering 23 localities along the Nazas River basin. We surveyed 23 host species which account for most of the species found along the River basin (see Miller *et al.* 2005). These host species represent 18 genera and nine families. Most of the freshwater fish fauna in the basin are typically Nearctic elements, i.e., minnows (cyprinids), catfishes (ictalurids), darters (etheostomids), suckers (catostomids), sunfishes and basses (centrarchids). These fishes account for 19 of the 23 studied species.

In total, in this survey work we recorded 41 species of helminths, and since the region was previous unexplored, this accounts for 74 and 71 new locality and new host records, respectively. The monogeneans *Gyrodactylus spathulatus*, *Dactylogyrus dulceiti*, *D. anchoratus*, *Cleidodiscus bedardi*, *Ligictaluridus pricei*, as well as the cestodes *Khawia sinensis* and *Isoglaridachris* sp., are recorded for the first time in Mexico. All these species, however, have been previously recorded in other North American freshwater fishes (see Margolis and Arthur 1979; McDonald and Margolis 1995; Hoffman 1999). The unidentified species of monogeneans and caryophyllideans await further taxonomic work, and they represent new records for the country (and most likely they represent new species) that will be described in a separate paper.

Some studies (e.g. Pérez-Ponce de León and Choudhury 2002; 2005; Aguilar-Aguilar *et al.* 2008) have corroborated the fact that the historical biogeography of the parasites is closely link to that of their hosts, leading to the prediction made by Pérez-Ponce de León and Choudhury (2005) that the parasite fauna is largely circumscribed by higher levels of monophyletic host taxa, especially to the level of fish family. Our inventory work in the Nazas River basin provides further empirical evidence to corroborate that prediction. In a recent study of the helminth parasite fauna in freshwater fishes from a nearby basin, the Mezquital River, Pérez-Ponce de León *et al.* (2009) found no support for that prediction by analyzing the faunal composition of the parasite fauna in typically Nearctic fish groups such as cyprinids and catostomids. The Nazas River basin shows no connection with River basins from central areas of Mexico, as the Mezquital River does. In this context, findings made through this survey work allowed us to increase not only the sample size, but also the species diversity for nearctic fish families, particularly the cyprinidae. In the former study, only three species of cyprinids (with 123 individuals), and only one species of catostomid (with five individuals) were collected. Here, we increased our sampling effort and the same catostomid species was sampled, albeit with 58 specimens, while 10 species of cyprinids were collected, accounting for 597 specimens. In this case, typical Nearctic helminth species that are part of the biogeographical core fauna of both, catostomids and cyprinids, were found. In catostomids,

the nematode *Rhabdochona catostomi* and one species of caryophyllidean tapeworm were recorded, while in cyprinids, an allocreadiid digenean, the caryophyllidean *Khawia sinensis*, monogeneans of the genera *Dactylogyrus* and *Gyrodactylus*, and the nematode *Rhabdochona canadensis* were collected. Further evidence was found by analyzing other freshwater fishes, such as ictalurids which harbored at least six members of the biogeographical core fauna, including the digeneans *Phyllodistomum lacustri* and *Aloglossidium corti*, two species of monogeneans of the genus *Ligictaluridus*, and the tapeworms *Magathylacoides giganteum*, and *Corallobothrium fimbriatum*. The centrarchids also harbored at least two species of monogeneans commonly found in members of the fish group in other parts of North America, north of Mexico, *Cleidodiscus bedardi* and *Onchochelidus spiralis*.

In contrast, larval forms were found in most host species and in particular, three of them were found as generalist parasites, occurring in a large proportion of the analyzed hosts. That is, the metacercariae of *P. minimum* and *C. complanatum*, and the larval nematode *Contraecaecum* sp. A fourth species, the Asian tapeworm, *B. acheilognathi*, which represents an introduced species, was also commonly found in most host species. Overall, the aforementioned species were found in 13, six, six, and 11 of the 23 species studied in this survey, respectively. More importantly, these helminths were recovered from four to six of the nine families to which fish are allocated which further demonstrates its generalist character (Pérez-Ponce de León *et al.* 1996; 2007; Rojas-Sánchez and García-Prieto personal communication; Hernández-Mena and Osorio-Sarabia personal communication).

A lower proportion of larval helminths in comparison to adults was found in our study. This seems to be a striking result when compared with other freshwater fish parasite surveys in other regions of Mexico, at both regional (basin) and local scales. In this study, 10 out of the 41 recorded species were larval forms (25 %). All these larval forms (metacercariae, 3rd stage larvae, cystacanths, or cysticercoids), with the exception of *Spiroxys* sp. which is a parasite of turtles, develop to the adult stage in fish-eating birds. In other studies, the percentage of larval forms tends to be higher, with 33 %, 42 %, 43 % or 44 % for the Papaloapan, Pánuco, Ayuquila, and Mezquital River basins, respectively (Salgado-Maldonado *et al.* 2004a, 2004b, 2005; Pérez-Ponce de León *et al.* 2009). This clearly may be the result of a sampling artifact, due to the fact that monogeneans were not studied in detail in the aforementioned surveys, which is not unexpected since their collection may result a time consuming activity due to their small size and need for proper fixation. On the other hand, it has been suggested that digeneans and nematodes represent the most species-rich groups in the parasite fauna of freshwater fishes of Mexico (Salgado-Maldonado *et al.*, 2005). In our study, however, monogeneans accounted for the greatest species richness, with 19 recorded species, while digeneans and nematodes had 10 and four species, respectively. A larger proportion of monogeneans in our samplings increase the proportion of adult helminth parasites. Whether this trend is the result of a sampling artifact due to the paucity of studies on monogeneans in freshwater fishes of Mexico, or it is related to the fact

that Nearctic components of the parasite fauna include more species of monogeneans such as *Dactylogyrus* spp. and *Gyrodactylus* spp (see Hoffman 1999), needs to be determined with more survey work in northern regions of Mexico. Although, recent studies by monogenean taxonomists have demonstrated that the species richness of this parasitic group in freshwater fishes of Mexico is increasing very rapidly (see Kritsky and Mendoza-Franco 2003; Mendoza-Palmero and Aguilar-Aguilar 2008; Mendoza-Franco *et al.* 2009; Mendoza-Palmero *et al.* 2009). From a biogeographical perspective, it is also possible that the Nearctic freshwater fish host a larger proportion of adult helminth parasites than larval forms. Our data seems to support that contention, however, a comparative analysis needs to be conducted to corroborate that observation, and to determine if this may rule out as a general pattern or if it is only found for some particular host groups such as ictalurids. For instance, Rosas-Valdez and Pérez-Ponce de León (2008) compared the helminth parasite fauna of ictalurids (a Nearctic element) and heptapterids (a Neotropical element) in Mexico. These authors found that the former harbors 33 adults and 18 larvae along its distributional range, while heptapterids are parasitized by 20 adults and 32 larvae.

Much has been accomplished in the last few years in terms of survey work on the helminth parasite fauna of freshwater fishes in Mexico. Still, inventory work is required in other northern portions of the country, but the information gathered thus far allow us to seek for general patterns about the way this host-parasite association is established, addressing the evolutionary and biogeographical factors that determine such association.

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