Range extension of helminth parasites of *Profundulus* spp. (Teleostei: Profundulidae) from southern Mexico and Central America

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**ABSTRACT:** In this paper we provide new records and range extensions for four intestinal helminth species parasites of profundulid fishes. Our data extends the known geographical distribution of these species from Guerrero, southern Mexico to nuclear Central American countries and southward to Honduras. Three of the helminth species here studied are specific to profundulids, the digenean *Paracreptotrema profundulusi* and the nematodes *Spinitectus humbertoi* and *Rhabdocochna salgadoi*. Our data confirm that these species are distributed only with profundulids and within the geographical range of this fish family. Therefore, the data presented in this study partially contributes to empirically support the idea that each fish family has "its own" suite of parasites that are not shared with other fish families, and that freshwater fish parasites are distributed within the limits of the range of the fish family.

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The knowledge about taxonomic composition and geographical distribution of helminth parasites of freshwater fishes of Mexico has undergone a dramatic development during recent years (Luque and Poulin 2007; Scholz and Choudhury 2014). An accepted generalization about the helminth parasite fauna of freshwater fishes of Mexico states that the assemblages of helminth parasites of each fish family includes a suite of specialist helminths, and that this suite is characteristic for each given family (Vidal-Martínez and Kennedy 2000; Pérez-Ponce de León and Choudhury 2005; Salgado-Maldonado et al. 2005; Salgado-Maldonado 2006, 2008). Although generalist helminths can be shared between non related host species, the specialist helminths are not shared between fish species of different families. The helminth fauna of some freshwater fish families such as Cichlidae, Poeciliidae and Goodeidae, are relatively well known (Salgado-Maldonado 2006; Salgado-Maldonado and Quiroz-Martínez 2013 and references cited therein). But other freshwater fish families such as Profundulidae have been seldom examined for parasites.

The cyprinodontid family Profundulidae Hoedeman & Bronner (Teleostei) is a lineage with a limited geographical distribution that extends from southern Mexico to Central America (Miller 1955; Matamoros and Schaefer 2010; Matamoros et al. 2012); it is a low diversity group, and comprises a single genus *Profundulus* Hubbs, 1924 which currently has eight valid species (Matamoros and Schaefer 2010; Matamoros et al. 2012). *Profundulus* is one of the distinctive elements of the endemic fauna of Central America and Mexico (Miller 1955). The species of *Profundulus* originated in Central America have probably been in the region since the Pliocene and perhaps even the Miocene (Miller 1955). The family is distributed from the State of Guerrero, Mexico to the Río Nacaome in the Honduran Pacific versant, and from the Petlapa River sub-basin (Río Papaloapan drainage basin) in the boundary between the states of Oaxaca and Puebla to the Río Ulúa, Honduras on the Atlantic slope (Miller 1955; Martínez-Ramírez et al. 2004; Matamoros et al. 2012). Most species of *Profundulus* have restricted distributional ranges they are found only in a few adjacent river systems (Matamoros et al. 2012). These fishes are small, generally between 41 to 103 mm length (Matamoros et al. 2012) (Figures 1–5). Species of this genus typically inhabit mountains streams; they are found at altitudes ranging from 10 to 2300 m above sea level (a.s.l.) (Martínez-Ramírez et al. 2004), but they are most abundant at altitudes between 300 to 1500 m a.s.l. Very often, at higher elevations they constitute the only native fishes in Central American streams.

Two congeneric digenetic species have been recorded in fishes of this genus: *Paracreptotrema blancoi* Choudhury, Pérez, Brooks & Daverdin, 2006, and *Paracreptotrema profundulusi* Salgado-Maldonado, Caspeta-Mandujano,

The aim of this contribution is to report new localities that represent range extensions for four species of helminth parasites of Profundulus spp. These new records are the result of survey work performed in the Mexican states of Guerrero, Oaxaca, and Chiapas, as well as in the Central American countries of Guatemala, El Salvador, and Honduras.

As part of a study of helminth parasites of profundulid fishes of Mexico and Central America, 435 Profundulus spp. were examined for helminths during February, March, and May 2013 in 14 Mexican localities, and 215 additional Profundulus spp. were examined in May, 2014 from nine localities in Central American countries (Table 1; Figures 6–9). Here, we treat Profundulus balsanus, Profundulus sp. 1 and Profundulus sp. 2 as three nominal taxa, based on the molecular results of Doadrio et al. (1999) in which they determined that these groups were distinctive organismal taxonomic units, however, we recognize that more taxonomic work needs to be done in order to formally elevate these taxa to the species level.

Fishes were caught using an electrofishing device and deep-nets, transported live to the laboratory and examined for helminths within 24 hours post-capture. Fishes were examined under a dissecting microscope, and helminths were fixed and processed using standard helminthological procedures (Salgado-Maldonado et al. 2005). Vouchers of the helminth species were deposited in the "Colección Nacional de Helmintos (CNHE)", at the Instituto de Biología, Universidad Nacional Autónoma de México.

Details for all localities (i.e., latitude and longitude, and
Table 1. Study sites and date of collections (first column, correlative number of localities as located in the map Figure 6).

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>LOCALITY</th>
<th>COORDINATES</th>
<th>ALTITUDE (m)</th>
<th>DATE</th>
</tr>
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<tbody>
<tr>
<td>1 Profundulus balsanus</td>
<td>Río La Laca (Rio Papagayo basin), Guerrero</td>
<td>17°4′09.3″ N, 98°39′55.7″ W</td>
<td>1394</td>
<td>March 2013</td>
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<td>2 Profundulus balsanus</td>
<td>Río Cahiapan, Guerrero</td>
<td>17°1′6.9″ N, 99°35′04.7″ W</td>
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<td>3 Profundulus balsanus</td>
<td>Río Tamarindo (Río Nespa basin), Guerrero</td>
<td>17°0′36.5″ N, 99°06′0.8″ W</td>
<td>417</td>
<td>March 2013</td>
</tr>
<tr>
<td>4 Profundulus balsanus</td>
<td>Río del Aguacate, (Río Manialtepec basin), Oxaca</td>
<td>16°0′7.19″ N, 97°9′22.8″ W</td>
<td>482</td>
<td>Feb 2013</td>
</tr>
<tr>
<td>5 Profundulus oaxacae</td>
<td>creek Los Sabinos (Río Atoyac-Verde basin), Oxaca</td>
<td>16°25′39.9″ N, 97°34′28.9″ W</td>
<td>1106</td>
<td>Feb 2013</td>
</tr>
<tr>
<td>6 Profundulus punctatus</td>
<td>Río Chacabula (Río Astata basin), Oxaca</td>
<td>15°5′54.8″ N, 95°56′0.3″ W</td>
<td>207</td>
<td>Feb 2013</td>
</tr>
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<td>7 Profundulus sp. 1</td>
<td>Río Chiquaquatlta (Río Atoyac-Verde basin), Oxaca</td>
<td>17°0′30.30″ N, 97°5′32.52″ W</td>
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<td>8 Profundulus sp. 2</td>
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<td>16°5′34.50″ N, 96°12′27.42″ W</td>
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<td>9 Profundulus candalarius</td>
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<td>16°3′1′22.2″ N, 92°25′10.7″ W</td>
<td>1924</td>
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<td>10 Profundulus candalarius</td>
<td>Río Grande de Comitán, Chiapas</td>
<td>16°1′46.9″ N, 92°0′7.21″ W</td>
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<td>May 2013</td>
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<td>11 Profundulus hildebrandi</td>
<td>Creek at ECOSUR, San Cristóbal de las Casas, Chiapas</td>
<td>16°4′27.3″ N, 92°3′56.4″ W</td>
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<td>May 2013</td>
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<td>12 Profundulus hildebrandi</td>
<td>Creek at Teopisca, Chiapas</td>
<td>16°3′13.7″ N, 92°2′34.9″ W</td>
<td>1794</td>
<td>May 2013</td>
</tr>
<tr>
<td>13 Profundulus labialis and Profundulus punctatus</td>
<td>Río at rancho San Antonio, Chiapasán, Chiapas</td>
<td>16°58′30.9″ N, 93°0′43.4″ W</td>
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<td>May 2013</td>
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<tr>
<td>14 Profundulus labialis</td>
<td>Creek Tres Picos, Copainalá, Chiapas</td>
<td>17°0′3′28.3″ N, 93°1′10.7″ W</td>
<td>325</td>
<td>May 2013</td>
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<tr>
<td>15 Profundulus labialis and Profundulus punctatus</td>
<td>Río Nandail mi, Chipa de Corso, Chiapas</td>
<td>16°4′18.4″ N, 92°5′32.4″ W</td>
<td>486</td>
<td>May 2013</td>
</tr>
<tr>
<td>16 Profundulus punctatus</td>
<td>Arroyo Ojo de Agua, El Canelar, La Frailesca, Chiapas</td>
<td>16°3′2′08″ N, 92°5′50.2″ W</td>
<td>466</td>
<td>May 2013</td>
</tr>
<tr>
<td>17 Profundulus guatemalensis</td>
<td>Río Ní, Guatemala</td>
<td>14°3′55.4″ N, 91°4′25.4″ W</td>
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<td>May 2014</td>
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<tr>
<td>18 Profundulus guatemalensis</td>
<td>Río El Cantil (Río Guacalate basin), Guatemala</td>
<td>14°2′1′22.6″ N, 90°4′30.4″ W</td>
<td>563</td>
<td>May 2014</td>
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<td>19 Profundulus guatemalensis</td>
<td>Creek El Platanar (Río Guacalate basin), Guatemala</td>
<td>14°3′56.8″ N, 90°4′37.9″ W</td>
<td>1628</td>
<td>May 2014</td>
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<td>20 Profundulus guatemalensis</td>
<td>Río Cauta (Río Lempa basin), El Salvador</td>
<td>13°4′62.6″ N, 89°5′1′40.8″ W</td>
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<td>May 2014</td>
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<td>21 Profundulus guatemalensis</td>
<td>Río Cuaca (Río Lempa basin), El Salvador</td>
<td>13°4′46.1″ N, 89°4′41.6″ W</td>
<td>450</td>
<td>May 2014</td>
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<tr>
<td>22 Profundulus kreiseri</td>
<td>Quebrada Los Tecomates (Río Lempa basin), El Salvador</td>
<td>14°1′8′11.3″ N, 89°9′0′40.8″ W</td>
<td>983</td>
<td>May 2014</td>
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<tr>
<td>23 Profundulus kreiseri</td>
<td>Río Noosalpa (Río Lempa basin), El Salvador</td>
<td>14°1′7′23.2″ N, 89°9′0′10.7″ W</td>
<td>1040</td>
<td>May 2014</td>
</tr>
<tr>
<td>24 Profundulus portillorum</td>
<td>Creek at Ojijona, Fco. Morazán (Río Nacaome basin), Honduras</td>
<td>13°5′43.7″ N, 87°1′7′40″ W</td>
<td>1391</td>
<td>May 2014</td>
</tr>
<tr>
<td>25 Profundulus portillorum</td>
<td>Lepaterique, Fco. Morazán (Río Nacaome basin), Honduras</td>
<td>14°0′3′42.9″ N, 87°2′58.6″ W</td>
<td>1462</td>
<td>May 2014</td>
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<tr>
<td>26 Profundulus portillorum</td>
<td>Lepaterique, Fco. Morazán (Río Nacaome basin), Honduras</td>
<td>14°0′4′14.4″ N, 87°2′5′6.9″ W</td>
<td>1656</td>
<td>May 2014</td>
</tr>
</tbody>
</table>

**Records from localities listed below were taken from literature (Salgado-Maldonado et al. 2011):**

- **Profundulus balsanus**: Piedra Labrada (Río Papagayo basin), Guerrero, 18°5′8.54″ N, 99°14′12.2″ W, 419
- **Profundulus balsanus**: Río La Soledad Carrizo (Río Atoyac-Verde basin), Oaxaca, 16°25′0.4″ N, 97°40′12.9″ W, 733
- **Profundulus balsanus**: Río San José de las Flores (Río Atoyac-Verde basin), Oaxaca, 16°24′21.5″ N, 97°42′22.6″ W, 619
- **Profundulus balsanus**: Río Santa Cruz Flores Magón (Río Atoyac-Verde basin), Oaxaca, 16°21′6″ N, 97°45′38.3″ W, 275
- **Profundulus balsanus**: Río Pichuaca (short river opening to Pacific Ocean), Oaxaca, 16°0′34.2″ N, 97°24′18.1″ W, 139
- **Profundulus balsanus**: Río La Reforma (Río Manialtepec basin), Oaxaca, 16°0′33.5″ N, 97°0′4′16.6″ W, 517
- **Profundulus balsanus**: Río Pueblo Viejo (Río Colotepec basin), Oaxaca, 16°0′6′22.3″ N, 97°0′3′47.8″ W, 522
- **Profundulus balsanus**: Río Santa María Huatulco (Río Colotepec basin), Oaxaca, 15°50′14.2″ N, 96°1′30.8″ W, 199
- **Profundulus oaxacae**: Río Macuta, (Río Atoyac-Verde basin), Oaxaca, 16°1′38.6″ N, 95°49′36.6″ W, 772
- **Profundulus punctatus**: Ojo de Agua Creek (Río Tehuantepec basin), Oaxaca, 16°5′35.6″ N, 96°2′57.3″ W, 1152
Salgado-Maldonado et al. | Range extension of helmint parasites of Profundulus spp.

Drainage basins) referred for each data record are found in Table 1.

**Paracreptotrema blancoi** Choudhury, Pérez-Ponce de León, Brooks & Daverdin, 2006

The specimens were identified as *P. blancoi* according to the original description (Choudhury et al. 2006), and the work by Salgado-Maldonado et al. (2011). These digenea have a spinose body, widest in midregion, with rounded ends, oral sucker and acetabulum well developed, with oral sucker smaller than ventral sucker; intestinal bifurcation in forebody, caeca blind, reaching around testes, two testes symmetrical; well developed cirrus sac containing saciform seminal vesicle, pars prostatic, ejaculatory duct, and unarmed cirrus; median genital pore located near intestinal bifurcation; vitellarium follicular extending from the level of esophagus to level of testes; excretory vesicle I-shaped, in hindbody (Figure 10). Measurements of 10 gravid specimens: total length 0.505–0.982 (mean 0.732) mm, maximum width 0.262–0.445 (mean 0.341) mm, oral sucker length × width 0.095–0.120 (0.116) × 0.107–0.120 (0.122) mm, acetabulum length × wide 0.217–0.287 (0.239) × 0.212–0.287 (0.239) mm, pharynx length × wide 0.042–0.080 (0.056) × 0.050–0.080 (0.065) mm, eggs (n = 15 measured) 50–64 (56) × 25–36 (29) μ.

*Paracreptotrema blancoi* was first recorded from poeciliids (Teleostei, Poeciliidae) in Costa Rica by Choudhury et al. 2006. Salgado-Maldonado et al. (2011) reported this species from profundulids from southern Mexico locations, including: from *P. balsanus* from the Río Papagayo, at Piedra Labrada, Guerrero; and Río La Soledad Carrizo, Río San José de las Flores, Río Santa Cruz Flores Magón, Oaxaca; and also from the Río Pichuca, Río La Reforma, Río Pueblo Viejo, and Río Santa María Huatulco, Oaxaca. Specimens of *P. blancoi* were also found in *P. oaxacae* collected at Río Macuta, Oaxaca, and in *P. punctatus* collected Ojo de Agua Creek and Río Templo, Oaxaca.

**New records:** Profundulus balsanus Río Caohapán, and Río Tamarindo, Guerrero; Río del Aguacate, Oaxaca; Profundulus oaxacae, arroyo Los Sabinos, Oaxaca; Profundulus punctatus, Río Chacalapa, Oaxaca; Río Nandalumi, Chiapas; Profundulus sp. 2, Río Chico, Oaxaca; Profundulus guatemalensis, Río Nil, and Río El Cantil, Guatemala; Profundulus kreiseri Río Caica, and Quebrada Los Teocamates, El Salvador. Voucher specimens, catalog number CNHE 9286.
the caeca extend beyond the testes in *P. profundulus* and do not extend beyond the level of the testes in *P. blancoi*. In the same way, the vitelline follicles are denser and extend until post-testicular area in *P. profundulus*, as opposed to *P. blancoi* where vitelline follicles reach only to anterior edge of the testes. Moreover, the uterus of *P. profundulus* is mostly pretesticular, forming short transversal loops over the testes, well separated from posterior body end. On the contrary, the uterus of *P. blancoi* projects a loop between the testes, and in many specimens eggs can be observed at the posterior body end (compare Figures 10 and 11). Measurements of 10 gravid specimens: total length 0.725–0.775 (mean 0.758) mm, maximum width 0.357–0.387 (mean 0.367) mm, oral sucker length × wide 0.122–0.150 (0.133) × 0.147–0.160 (0.149), acetabulum length × wide 0.162–0.217 (0.189) × 0.175–0.237 (0.203), pharynx length × wide 0.045–0.050 (0.048) × 0.055–0.062 (0.056) mm, eggs (n = 14 measured) 50–67 (58.9) × 25–37 (29.2) µ.

*Paracreptotrema profundulus* was first reported from the intestine of *Profundulus punctatus* from Río Templo, Oaxaca, and from *P. balsanus* from Ojo de Agua Creek, and Río San José de las Flores, Oaxaca.

**New records:** *Profundulus balsanus* Río La Laca, Río Cahoapán, and Río Tamarindo, Guerrero; *Profundulus labialis* Arroyo Rancho San Antonio, Arroyo Tres Picos, and Río Nandalumi, Chiapas; *Profundulus punctatus*, Río Chacalapa, Oaxaca; Arroyo Rancho San Antonio, Chiapas; *Profundulus* sp. 1 Río Chicaguaxtla, Oaxaca; *Profundulus guatemalensis*, Río Nil, and Río El Cantil, Guatemala; *Profundulus kreiseri* Río Cauta, Río Cauca, and Río Nonoapa, El Salvador. Voucher specimens, catalog number CNHE 9289.

**Spinitectus humbertoi** Caspeta-Mandujano & Moravec, 2000

The specimens were identified as *S. humbertoi* according to the original description by Caspeta-Mandujano and Moravec (2000). They are small, whitish nematodes, having characteristic transverse denticulate rings of spines on the body. Rings of spines interrupted at anterior end of body by two lateral, one dorsal and one ventral longitudinal lines, dividing each ring into four distinctly separated dorsal and ventrolateral sectors. Rings of spines more or less regularly spaced. First ring consisting of a total of 36–38 spines, 0–10 spines placed in each of the four sectors, in both males and females. Cephalic end rounded, with two slightly elevated lateral pseudolabia. Excretory pore just posterior to the seventh ring of spines. Male, four pairs of preanal papillae arranged in two couples, six pairs of postanal papillae; left spicule slender, right spicule longer than wide. Length of males 2.96 to 3.20 mm, females 3.67 to 4.29 mm; eggs oval, smooth, containing larvae, 0.033 × 0.019 mm (Figure 12).

*Spinitectus humbertoi*, was first reported from *Profundulus labialis* from Río Papagayo, Guerrero (Caspeta-Mandujano and Moravec, 2000).

**New records:** *Profundulus balsanus* Río La Laca, Río Cahoapán, and Río Tamarindo, Guerrero; *Profundulus labialis* Arroyo Rancho San Antonio, Arroyo Tres Picos, and Río Nandalumi, Chiapas; *Profundulus punctatus*, Río Chacalapa, Oaxaca; Arroyo Rancho San Antonio, Chiapas; *Profundulus* sp. 1 Río Chicaguaxtla, Oaxaca; *Profundulus guatemalensis*, Río Nil, and Río El Cantil, Guatemala; *Profundulus kreiseri* Río Cauta, Río Cauca, and Río Nonoapa, El Salvador. Voucher specimens, catalog number CNHE 9289.


Ojo de Agua, Chiapas; Profundulus sp. 1 Río Chicaguaxtla, Oaxaca; Profundulus sp. 2, Río Chico, Oaxaca; Profundulus guatemalensis, Río Nil, Guatemala; Profundulus kreiseri Río Nonoalpa, and Quebrada Los Tecomates, El Salvador; Profundulus portillorum Leparterique, Honduras. Voucher specimens, catalog number CNHE 9290.

In this paper, we provide new records and range extensions for four intestinal helminth parasites species of profundulid fishes. Our data extends the geographically known distribution of these species from Guerrero, southern Mexico to nuclear Central American countries, reaching their southernmost distribution in the Río Nacaome in Honduras.

The digenean P. blancoi was recorded along Profundulus spp. subgenus Profundulus ("punctatus" group sensu Miller, 1955), including P. balsanus, P. guatemalensis, P. kreiseri, P. punctatus, and P. oxaecae, from rivers of South Mexico in the states of Guerrero, Oaxaca, and Chiapas, to Guatemala and El Salvador. Paracreptotrema blancoi was originally reported from a poeciliid fish from the Área de Conservación Guanacaste in the Pacific versant of Costa Rica (Choudhury et al. 2006). This original and only record in a poeciliid fish prevents the qualification of this species as a specialist of profundulids. Therefore, the geographic distribution of P. blancoi extends from Guerrero, Mexico, southward to the Pacific slope of Costa Rica. The congeneric species P. profundulasi is known only from profundulids; it is indeed a specialist of this family as far as the available or current data has shown. Based on our results, this species is geographically limited to southern Mexico, specifically to Guerrero and Oaxaca. It parasitizes only Profundulus species of the subgenus Profundulus ("punctatus" group), including P. balsanus, P. oxaecae, Profundulus sp. 2 and P. punctatus.

As far as the current available data has demonstrated both nematode species are strictly specific to profundulid fishes: Spinitectus humbertoi parasitizes P. balsanus, P. labialis, P. guatemalensis, P. kreiseri, P. punctatus, and Profundulus sp. 1 from the south Mexican states of Guerrero, Oaxaca, and Chiapas to Guatemala and El Salvador. The species with the most widespread distribution range recorded in our sampling was R. salgadoi that was present in most profundulid species examined including P. balsanus, P. candalarius, P. guatemalensis, P. kreiseri, P. labialis, P. oxaecae, P. portillorum, P. punctatus, and Profundulus sp. 1 and Profundulus sp. 2 extending its geographical distribution along the entire range of the host fish family, from Guerrero, Oaxaca and Chiapas in Mexico to El Salvador and Honduras.

Concerning the helminth parasites of freshwater fishes of Mexico, each fish family has its own assemblage of specialist parasites, that are not shared with fishes from other families; these specialist species disperse along with the host family (Salgado-Maldonado, 2006, 2008), meaning that the suite of helminths characteristic to each fish family, is geographically distributed within the limits of the range of the distribution of the fish family. Data presented in this work partially contributes additional empirical support to these ideas, because, three of the helminth species here studied are specialist of profundulids, the trematode P. profundulasi and the nematodes S. humbertoi and R. salgadoi. Our data clearly show that these species are distributed with the Profundulidae, and within the geographical range of this fish family. These specialist species seem to use species Profundulus available in a given locality, but no other sympatric fish species. However, current available data does not allow the classification of the other digenetic species, P. blancoi. During the present survey, this species was recorded only from profundulid fish, even when sympatric poeciliids, as for example Poeciliopsis pleurospilus, or Poecilia mexicana, were examined from the same locality.

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Salgado-Maldonado, G., J.M. Caspeta-Mandujano, and E. Martínez-


**Authors’ contribution statement:** GSM, JMCM and EFMF collected the data and identified the helminth species; WAM, EMR and EVV collected and identified the fish species; GSM and WAM made the analysis and wrote the paper.

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