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Parasitic Nematodes of Freshwater Fishes from Two Nicaraguan Crater Lakes

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ABSTRACT: During November–December 2003, 44 fishes belonging to 6 endemic cichlid taxa (*Amphilophus citrinellus* "short", *Amphilophus citrinellus* "chancho", *Amphilophus amarillo*, *Amphilophus sagittae*, *Amphilophus xiloaensis*, and *Parachromis managuensis*) and 8 specimens of *Gobiomorus dormitor* were collected from 2 crater lakes in Nicaragua: Lake Apoyo and Lake Xiloá. Helminthological examination revealed 8 nematode species, 3 adults and 5 larval stages. *Rhabdochona* (*Rhabdochona*) *kidderi* was the only nematode present in both bodies of water; *Procamallanus* (*Spirocamallanus*) *rebecae* and *Paracapillaria teixeirafreitasi teixeirafreitasi* were restricted to Lakes Apoyo and Xiloá, respectively. *Procamallanus* (*S.*) *rebecae* and *Contracaecum* sp. type 2 were the most prevalent and abundant species found in Lakes Apoyo and Xiloá, respectively. Specimens exhibited morphometric variability in comparison to nematodes collected from fishes in southern Mexico. All nematode species have been previously reported from the same or phylogenetically related host species in freshwater habitats in southern Mexico and the Atlantic coast of Nicaragua. All species represent new geographical records, whereas nematodes from *A. c.* "short", *A. c.* "chancho", *A. sagittae*, *A. xiloaensis*, *A. amarillo*, and Spiruridae gen. sp. and *Contracaecum* sp. type 1 in *G. dormitor* are new host records. The nematode fauna of cichlid and eleotrid fishes from the Atlantic and Pacific coasts of Nicaragua is similar to that from southeastern Mexico.

KEY WORDS: Nicaragua, crater lakes, Nematodes, Cichlids, Eleotrids, Xiloá Lake, Apoyo Lake.

Despite the rich faunal diversity of tropical America, studies on the helminth parasites of fishes have mostly been carried out in South America and southern Mexico. In Central America, investigations were conducted by Caballero and Brenes (1957), Bravo-Hollis and Arroyo (1962), Watson (1976), Aguirre-Macedo et al. (2001a, b), Vidal-Martínez et al. (2001a), Choudhury et al. (2002), Mendoza-Franco et al. (2003, 2004), and Scholz et al. (2004), particularly with fish samples collected from the Atlantic coast of Nicaragua.

During November–December 2003, the helminth communities of the *Amphilophus citrinellus* (Günther, 1864) species complex in Lakes Xiloá and Apoyo were studied. Both localities represent deep crater lakes located at the center of the volcanic chain of the Pacific region of Nicaragua. In these water bodies, a rapid allopatric and intralacustrine speciation might be taking place within the *A. citrinellus* species complex (McKaye et al., 2002; Stauffer and McKaye, 2002). In Lake Apoyo, 1 species and 3 forms can be recognized: *Amphilophus zaliosus* (Barlow, 1976), *Amphilophus citrinellus* "chancho", *Amphilophus citrinellus* "short", and *Amphilophus citrinellus* "Apoyo Amarillo" (McKaye et al., 2002). Whereas in Lake Xiloá, *Amphilophus amarillo* Stauffer and McKaye, 2002, *Amphilophus sagittae* Stauffer and McKaye, 2002, and *Amphilophus xiloaensis* Stauffer and McKaye, 2002, have been reported. As a part of the parasitological examinations, we report the results of the taxonomic evaluation of parasitic nematodes and their infection parameters.

MATERIALS AND METHODS

A total of 52 fish, 44 belonging to 6 endemic cichlid taxa (*Amphilophus citrinellus* "short", *A. citrinellus* "chancho", *A. amarillo*, *A. sagittae*, *A. xiloaensis*, and *Parachromis managuensis* [Günther, 1867]), and 8 eleotrid fishes (*Gobiomorus dormitor* Lacepède, 1800) were collected from 2 localities: Lake Apoyo (12°14′47″N, 86°20′29″W) and Lake Xiloá (12°13′18″N, 86°19′14″W). Scuba divers collected fishes using small harpoons. Fish were examined for helminth parasites using standard helminthological procedures (Vidal-Martínez et al., 2001b). Autogenic parasites are those that complete their life cycles in aquatic environments, and allogenic parasites complete their life cycle in terrestrial hosts, usually birds and mammals (Esch et al., 1988). The term specialist refers to the presence of a parasite species in a particular host family, Cichlidae in this study. Generalist parasites have the ability to infect hosts in different families. All nematodes collected were fixed in 4% hot formalin with physiological saline (0.7%) or hot ethanol 70% and mounted in temporary preparations using a mixture of glycerine and water in different concentrations (1:10, 1:5, 1:2). Measurements are given in millimeters.

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Table 1. Infection parameters of nematodes parasitizing 7 freshwater fish taxa (*Amphilophus citrinellus* "short", *Amphilophus citrinellus* "chancho", *Amphilophus sagittae*, *Amphilophus amarillo*, *Amphilophus xiloaensis*, *Gobiomorus dormitor*, and *Parachromis managuensis*) from 2 crater lakes in Nicaragua.

Site and host*	N	Nematode taxon†	Prevalence (mean intensity ± SD)	Source§	Fidelity‖
Lake Apoyo					
A. citrinellus "short"[1]	23	*Rhabdochona* (*Rhabdochona*) *kidderi*‡	4 (2 ± 0.4)	1	1
		Procamallanus (*Spirocamallanus*) *rebecae*‡	17 (2 ± 1)	1	1
A. citrinellus "chancho"[2]	2	*P.* (*S.*) *rebecae*‡	100 (8 ± 9.2)	1	1
P. managuensis[2]	5	*P.* (*S.*) *rebecae*	20 (1 ± 0.4)	1	1
G. dormitor[2]	3				
Lake Xiloá					
A. sagittae[3,4]	11	*Contracaecum* sp. type 2 L‡	91 (11 ± 16)	2	2
A. amarillo[4,5]	2	*R.* (*R.*) *kidderi*‡	50 (3 ± 2)	1	1
		Contracaecum sp. type 2 L‡	50 (18 ± 13)	2	2
		Acuariidae gen. sp. L‡	50 (1 ± 0.7)	2	2
A. xiloaensis[5]	1	*Contracaecum* sp. type 2 L‡	100 (2 ± 2)	2	2
		Goezia sp. L‡	100 (13 ± 13)	2	2
G. dormitor[2]	5	*Paracapillaria teixeirafreitasi teixeirafreitasi*	40 (7 ± 4.4)	1	1
		Spiruridae gen. sp. L‡	20 (5 ± 2.2)	2	2
		Contracaecum sp. type 1 L‡	20 (2 ± 1)	2	2
		Contracaecum sp. type 2 L	20 (4 ± 1.8)	2	2

* Digestive tract contents: [1] filamentous algae, micromollusks (*Pyrgophorus coronatus*), copepods, ostracods, chironomids, scales and vertebrae of fish; [2] fish remains; [3] fish fry; [4] fish eggs; [5] mollusks.

† All nematodes reported from Lake Apoyo were taken from the intestine. All nematodes reported from Lake Xiloá were taken from the mesenteries except *Rhabdochona* (*Rhabdochona*) *kidderi* and *Paracapillaria teixeirafreitasi teixeirafreitasi*, which occurred in the intestine and stomach, respectively.

‡ New host record.

§ Population seed source: 1, autogenic; 2, allogenic.

‖ Host fidelity: 1, host specialist; 2, host generalist.

RESULTS

Eight nematode taxa, 3 adult (autogenic and specialists) species and 5 larval (allogenic and generalists) taxa, were collected (Table 1). Some patterns were evident despite small sample sizes. Number of nematode species was higher in Lake Xiloá in spite of the low number of fishes examined (N = 19) in comparison with fishes collected in Lake Apoyo (N = 33). *Rhabdochona* (*Rhabdochona*) *kidderi* was the only nematode present in both water bodies, while *Procamallanus* (*Spirocamallanus*) *rebecae* and *Paracapillaria teixeirafreitasi teixeirafreitasi* were restricted to Lakes Apoyo and Xiloá, respectively. No larval nematodes occurred in fishes from Lake Apoyo (Table 1). The generalist larvae of *Contracaecum* sp. type 2 were the only nematode species present in the 2 fish families examined from Lake Xiloá (Cichlidae and Eleotridae). *Procamallanus* (*S.*) *rebecae* and *Contracaecum* sp. type 2 were the most prevalent and abundant species found in Lakes Apoyo and Xiloá, respectively (Table 1).

Morphometric variability was evident in comparison between nematodes collected from fishes in southern Mexico. Mature males of *P.* (*S.*) *rebecae* showed similar body measurements to those from previous studies (Moravec et al., 1995a), although buccal capsule (0.049–0.072 vs. 0.084–0.105) and spicule lengths (right spicule 0.26–0.30 vs. 0.48–0.52, left spicule 0.23–0.26 vs. 0.26–0.31) were shorter in specimens of this survey. Moreover, gravid females were smaller in fishes from Nicaragua (8.33–8.88 vs. 12.35–20.68) (Table 2).

A similar pattern was found in mature individuals of *P. t. teixeirafreitasi* whose body measurements during this survey were like those of specimens earlier described by Moravec et al. (1995a) (males: 3.28–3.87 vs. 2.95–3.26; females: 4.07–6.19 vs. 4.18–4.95). However, lengths of spicules varied between specimens from Mexico and Nicaragua, being slightly larger in nematodes from Central American fishes (0.17–0.26 vs. 0.14–0.18) (Table 3).

On the other hand, males of the species *R.* (*R.*) *kidderi* from Mexico (Moravec et al., 1995a) were larger than those reported from Nicaragua (5.64–8.70 vs. 3.64–3.68, respectively; Table 4). The length of their left spicule was also smaller (0.24–0.47 vs. 0.65–1.16) in the 2 specimens measured. In specimens from both surveys, the length of spicules

Table 2. Comparative morphometric values for adults of *Procamallanus* (*Spirocamallanus*) *rebecae* from Nicaragua and southern Mexico.

Characteristic	♂	♂*	♀	♀*
N	4	36	4	36
Total length	7.68–12.03	8.98–10.91	8.33–8.88	12.35–20.68
Buccal capsule length	0.049–0.072	0.084–0.105	0.053–0.068	0.099–0.110
Muscular esophagus	0.34–0.38	0.32–0.41	0.29–0.38	0.43–0.59
Glandular esophagus	0.46–0.68	0.51–0.70	0.45–0.54	0.70–1.12
Nerve ring	0.22–0.23	0.25–0.27	0.18–0.22	0.30–0.34
Tail	0.19–0.22	0.28–0.33	0.17–0.19	0.35–0.45
Vulva	—	—	4.37–5.09	6.77–10.65
Spicules, right	0.26–0.30	0.48–0.52	—	—
Spicules, left	0.23–0.26	0.26–0.31	—	—

* Data from Moravec et al. (1995a).

represents 1% of total body length. The unique juvenile female found in Nicaragua cannot be compared with those gravid females recovered from other studies. The difference in the body measurements of adult males could be considered to be within the intraspecific variability that is found among specimens collected from the same host species but from distant localities and/or as an effect of the low number of individuals available for measurement. Larval stages reported in this work also showed morphometric variability; however, it is impossible to compare them because body variation might be a consequence of the diverse degree of development and age of infection of each species.

Few nematode species found during this investigation were previously reported from the same host species or from phylogenetically related fishes in freshwater habitats from southern Mexico and the Atlantic coast of Nicaragua. Most species represented new host records (Table 1).

Table 3. Comparative morphometric values for adults of *Paracapillaria teixeirafreitasi teixeirafreitasi* from Nicaragua and southern Mexico.

Characteristic	♂	♂*	♀	♀*
N	5	36	5	36
Total length	3.28–3.87	2.95–3.26	4.07–6.19	4.18–4.95
Muscular esophagus	0.11–0.14	0.16–0.18	0.13–0.16	0.17–0.20
Glandular esophagus	2.26–2.56	1.95–2.09	2.25–3.26	2.18–2.62
Nerve ring	0.06–0.07	0.06–0.07	0.04–0.07	0.058–0.068
Vulva	—	—	2.42–3.53	2.19–2.63
Spicules, right	0.17–0.26	0.14–0.18	—	—
Egg length	—	—	0.044–0.054	0.050
Egg width	—	—	0.022–0.026	0.020–0.023

* Data from Moravec et al. (1995a).

Table 4. Comparative morphometric values for adults of *Rhabdochona* (*Rhabdochona*) *kidderi* from Nicaragua and southern Mexico.

Characteristic	♂	♂*	♀	♀*
N	2	36	1	36
Total length	3.64–3.68	5.64–8.70	2.03	6.42–9.26
Muscular esophagus	0.19–0.24	0.30–0.36	0.16	0.30–0.36
Glandular esophagus	0.89–0.92	1.27–2.10	0.62	1.14–1.66
Nerve ring	0.14–0.15	0.16–0.22	0.11	0.17–0.20
Tail	0.15–0.16	0.15–0.25	0.12	0.11–0.17
Vulva	—	—	—	2.52–3.63
Spicules, right	0.040–0.068	0.075–0.087	—	—
Spicules, left	0.24–0.47	0.65–1.16	—	—

* Data from Moravec et al. (1995a).

DISCUSSION

Analysis of the nematode fauna of cichlid and eleotrid fishes studied showed low species richness with the presence of only 1 or 2 specialist nematode genus per fish family, *Procamallanus* and *Rhabdochona* in cichlids and *Paracapillaria* in eleotrids. Camallanids seem to be a common component of the digestive tract of tropical freshwater fish, e.g., *P.* (*S.*) *rebecae* has been frequently reported in cichlids, whereas *P.* (*S.*) *neocaballeroi* was found in pimelodid and characid fishes from the Yucatán Peninsula (Moravec et al., 1995a). On the other hand, capillariid nematodes often occur in eleotrid fish inhabiting the Pacific and Atlantic coasts of Mexico (Moravec et al., 1995a, 1999). The presence of *P. t. teixeirafreitasi* in eleotrid hosts from Lake Xiloá (Pacific coast of Nicaragua) suggests that this nematode is specific to *G. dormitor* in both coasts (Atlantic and Pacific) of the Americas.

Larvae of *Contracaecum* sp. type 2 were the most frequent and abundant nematode species in both fish families studied. Larval nematodes belonging to this genus are know for being present in different families of freshwater fish and is the most commonly collected larval nematode from Mexican cichlids (Moravec et al., 1995a, b; Salgado-Maldonado et al., 1997) and eleotrids (Jiménez-García, unpublished data). The relatively high values of prevalence and abundance of *Contracaecum* sp. type 2 in fishes might be related with its capability of being transmitted by ingestion of different prey (intermediate hosts), whether infected microcrustaceans or fishes (Moravec, 1998). Despite the wide capability of dispersion and its generalist status, *Contracaecum* spp. were absent from Lake Apoyo. Lack of availability of paratenic and intermediate hosts, as well as lake geology and/or differential use of the lake might explain the absence of *Contracaecum* in Lake Apoyo. The high abundance of *Contracaecum* sp. type 2 from Lake Xiloá, located only to 28 km from Apoyo, was surprising, considering that *A. citrinellus* "short", one of the most abundant cichlid forms in Apoyo, includes microcrustaceans in its diet (Table 1).

Despite the low number of *G. dormitor* examined from both lakes, presence of *P. t. teixeirafreitasi* and *Contracaecum* larvae from Lake Xiloá may be related to the abundance of suitable crustaceans and fishes acting as paratenic or intermediate hosts of these nematodes, and/or to the relatively high rate of fish exposure to infected intermediate hosts. Although McKaye et al. (1979) mentioned that this fish species shows piscivorous feeding habits in Lake Xiloá, *P. t. teixeirafreitasi* in *G. dormitor* is transmitted by a flexible feeding behavior depending on the availability of food items (vertebrate or invertebrates), or perhaps by accidental ingestion of invertebrates during grazing activities. For example, occurrence of the metacercariae of *Oligogonotylus manteri* (prevalence 50%; mean intensity 43 $\pm$ 97) in the stomach of *G. dormitor* (N $=$ 6) from Yucatán provides evidence that this fish species is eating mollusks (*Pyrgophorus coronatus*) of less than 1 cm total length (Jiménez-García, unpublished data).

This study of helminths from 2 crater lakes, in conjunction with previous studies from Central America (Aguirre-Macedo et al., 2001a, b), demonstrate a similarity between the nematode fauna of fishes from the Atlantic coast of Nicaragua and southeastern and southern Mexico. Morphometric variation of nematodes recovered from Nicaraguan fishes could be related to phenotypic variability found within the *A. citrinellus* species complex (see Stauffer and McKaye, 2002).

This survey increases the knowledge about the helminth parasites of freshwater fishes in Nicaragua, and it is clear that more samples from different localities and regions of Central America should be obtained in order to understand the biogeographical patterns of the parasites and their hosts in tropical America.

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