



Limia mandibularis, a new livebearing fish (Cyprinodontiformes: Poeciliidae) from Lake Miragoane, Haiti

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Abstract

Limia mandibularis, a new livebearing fish of the family Poeciliidae is described from Lake Miragoane in southwestern Haiti on Hispaniola. The new species differs from all other species in the genus *Limia* by the presence of a well-developed lower jaw, the absence of preorbital and preopercular pores, and preorbital and preopercular canals forming an open groove each. The description of this new *Limia* species from Lake Miragoane confirms this lake as an important center of endemism for the genus with a total of nine described species so far.

Key words: Caribbean, jaw, morphology, endemism, preopercular canal

Resumen

Limia mandibularis, una nueva especie de pez vivíparo de la familia Poeciliidae que habita en el Lago Miragoane en el suroeste de Haití en La Española, es descrita en el presente trabajo. Esta nueva especie puede ser diferenciada de otras del género *Limia* por la presencia de una mandíbula muy desarrollada, la ausencia de poros preorbitales y preoperculares, observándose solamente un canal preorbital y preopercular abierto. La descripción de esta nueva especie que habita en el Lago Miragoane confirma a este lago como un importante centro de endemismo para el género con un total de nueve especies descritas hasta el momento.

Palabras clave: Caribe, mandíbula, morfología, endemismo, canal preopercular

Introduction

Livebearing fishes of the family Poeciliidae are the dominant group of freshwater fishes in terms of species richness and abundance in the insular Caribbean. However, species composition is highly variable among islands. For instance, the two bigger Antilles (Cuba and Hispaniola) show a contrasting pattern of species diversification. In Cuba, for instance, four genera: *Gambusia* Poey, *Limia* Poey, *Girardinus* Poey and *Quintana* Hubbs (the last two endemic to Cuba) are represented (Ponce de León & Rodríguez, 2010). On the other hand, the genera *Gambusia*, *Limia* and *Poecilia* Bloch & Schneider are widespread on Hispaniola. Specifically, the genus *Limia* is the most speciose of the family in the entire geographic region with 21 species currently known from Hispaniola, Cuba, Jamaica, and Grand Cayman. Although *Limia* is considered a freshwater fish genus, some species are tolerant to varying salinity levels and may be even found in hypersaline coastal lagoons (Haney & Walsh, 2003; Weaver *et al.*, 2016a). However, most of the species occur in inland waters including species locally distributed in mountain streams. Most of the recent studies aimed to determine the origins of this genus in the Caribbean, agree on the South American derivation of *Limia* fishes via dispersal or vicariance (Hrbek *et al.*, 2007; Palacios *et al.*, 2016; Weaver *et al.*, 2016b; Reznick *et al.*, 2017)

Hispaniola is considered to be the center of endemism for *Limia* since at least 18 species are known from this island whereas only one endemic species is reported from Cuba, Jamaica, and Grand Cayman each (Chambers, 1987; Burgess & Franz, 1989; Hamilton, 2001; Weaver *et al.*, 2016b). A notable radiation is particularly observed in Lake Miragoane located in southwestern Haiti where eight endemic species are currently reported. This species flock includes five species described by Rivas (1980) (*L. grossidens*, *L. fuscomaculata*, *L. garnieri*, *L. immaculata*, and *L. miragoanensis*), *L. ornata* and *L. nigrofasciata* both described by Regan (1913), as well as *L. islai* which was recently described by Rodriguez-Silva & Weaver (2020). According to Rivas (1980), the genus *Limia* can be separated in two distinct groups that he interpreted as different subgenera: *Odontolimia* and *Limia*. The diagnosis of the two subgenera is essentially based on the number of preopercular pores, and also the number and shape of teeth of outer and inner rows. Based on Rivas' (1980) classification, the subgenus *Odontolimia* is composed of six species: *L. grossidens*, *L. fuscomaculata*, *L. garnieri*, *L. immaculata*, *L. miragoanensis* and *L. ornata*, all endemic to Lake Miragoane; and the subgenus *Limia* currently comprises fifteen species: *L. melanonotata* Nichols & Myers, *L. perugiaae* (Evermann & Clark), *L. zonata* (Nichols), *L. versicolor* (Günther), *L. pauciradiata* Rivas, *L. yaguajali* Rivas, *L. sulphurophila* Rivas, *L. dominicensis* (Valenciennes), *L. nigrofasciata* Regan, *L. rivasi* Franz and Burgess, *L. tridens* (Hilgendorf) and *L. islai* Rodriguez-Silva & Weaver, all endemic to Hispaniola. The other three species are *L. vittata* (Guichenot) endemic to Cuba and the sister species *L. caymanensis* Rivas & Fink endemic to Grand Cayman, and *L. melanogaster* (Günther) endemic to Jamaica.

In this paper we describe a new species of *Odontolimia* from specimens collected at the north shore of Lake Miragoane in southwestern Haiti on Hispaniola. We examined meristic and morphological characters to formally describe this new livebearing fish. Lake Miragoane is one of the few places in the Neotropics that holds a high biodiversity of endemic livebearing fishes and is also a geographic area that deserves more scientific work in light of the serious conservation challenges facing Haiti's biodiversity (Hedges *et al.*, 2018).

Materials and methods

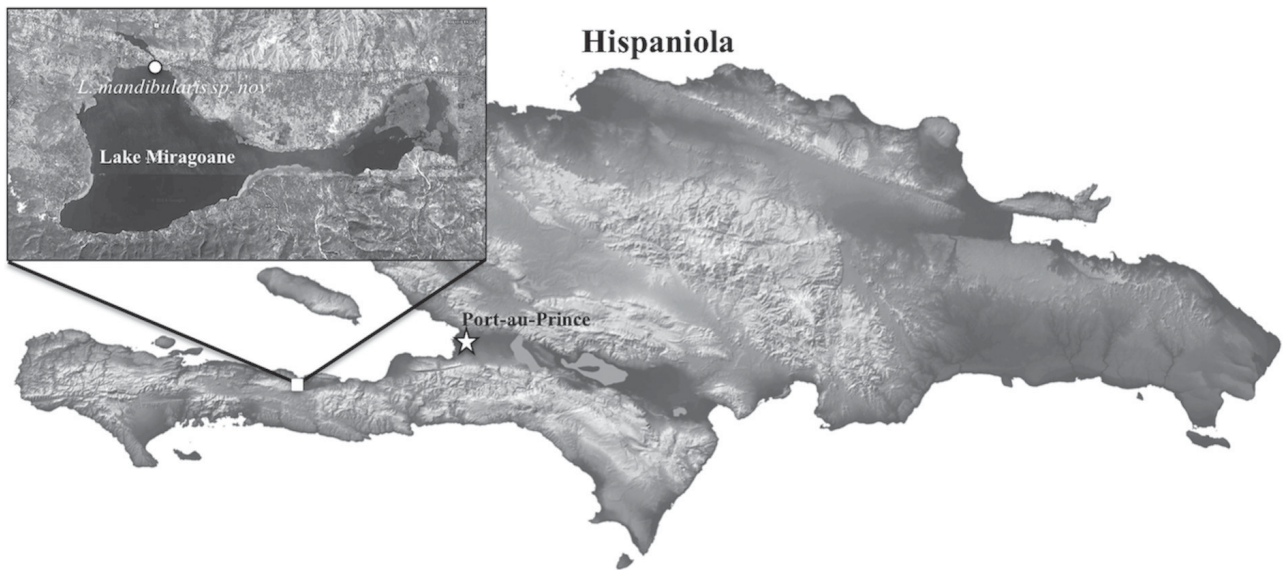


FIGURE 1. Map showing the collection locality for *Limia mandibularis* **sp. nov.** Enlargement shows greater details of Lake Miragoane in Haiti, with the type locality for *Limia mandibularis* (white circle) at the north bight of the lake.

Species description was performed from wild caught specimens collected in June 2019 in Lake Miragoane, Haiti (Fig. 1). Fish were collected with the authorization of the Ministry of Environment of Haiti as part of a survey of the native freshwater fish fauna of the lake. A total of 12 specimens (2 males and 10 females) were examined under an Olympus SZX7 stereomicroscope with direct and transmitted light and magnification 50X. Characters used by Rivas (1980) in the description of five *Limia* species from Lake Miragoane in Haiti were measured in all specimens. We followed the methodologies described by Rivas (1963, 1978), Chambers (1987) and Rauchenberger (1989) for identification and counting of gonopodium elements. Three additional gonopodial characters for males (segments distal to ray 3 keel, ray 4 grooved segments, and segments distal to ray 5 keel) were included in the species descrip-

tion according to Chambers (1987). Scale counts were done according to Miller (1948). Morphometric measurements were taken using a DigitalAid caliper (to the nearest 0.1 mm). Proportional body and fin measurements were avoided in species description since these characters can be affected by several environmental factors (Hubbs & Springer, 1957; Rivas, 1963; Rivas & Fink, 1970). One male and one female were cleared and stained using the protocol of Taylor & Van Dyke (1985) for description of the gonopodium tip in males and also to describe the morphology of the lower and upper jaws. Nomenclature used for osteological features of the jaws was according to Hernandez *et al.* (2009) and Dial *et al.* (2017).

Institutional abbreviations used: OMNH, Sam Noble Museum of Natural History, University of Oklahoma. MNHNSD, Museo Nacional de Historia Natural “Prof. Eugenio de Jesús Marcano”, Santo Domingo, Dominican Republic.

***Limia mandibularis*, sp. nov.**

(Figs. 2-6, Tables 1 and 2)

Holotype. OMNH 86828, adult male 35.5 mm SL (Fig. 2), Lake Miragoane, Haiti; coordinates 18°25'33.2" N, 73°02'56.9" W; R. Rodriguez-Silva, P. Torres-Pineda, J. Josaphat, and P. Michard Beaujour, June 5, 2019



FIGURE 2. *Limia mandibularis* sp. nov., holotype OMNH 86828, adult male 35.5 mm SL (top) and paratype OMNH 86829, adult female 41.0 mm SL (bottom).

Paratypes. Same origin, date and collectors as holotype. OMNH 86829, 1 female, 41.0 mm SL (Fig. 2); OMNH 86831, 1 male, 38.5 mm SL and 1 female, 41.5 mm SL (cleared and stained specimens); OMNH 86832, lot of 5 females, 36.0-41.5 mm SL; MNHNSD.22.10426, 1 female, 39.5 mm SL; MNHNSD.22.10427, 1 female, 33.0 mm SL; MNHNSD.22.10428, 1 female, 33.0 mm SL.

Diagnosis. *Limia mandibularis* **sp. nov.** is uniquely diagnosed by the presence of a well-developed lower jaw due to the presence of an elongate anguloarticular bone (Fig. 3). The new species can also be identified by the lack of preorbital and preopercular pores and by the presence of single preorbital and preopercular canals forming open grooves (Fig. 4). *Limia mandibularis* **sp. nov.** can be further distinguished by the combination of the following characters: dorsal fin with 8 rays and its origin is slightly behind of the origin of the anal fin in females; 13 predorsal scales; caudal fin symmetrical and truncate or slightly convex; no crossbars, spots or blotches on body in both sexes. See additional comments in the Discussion below.

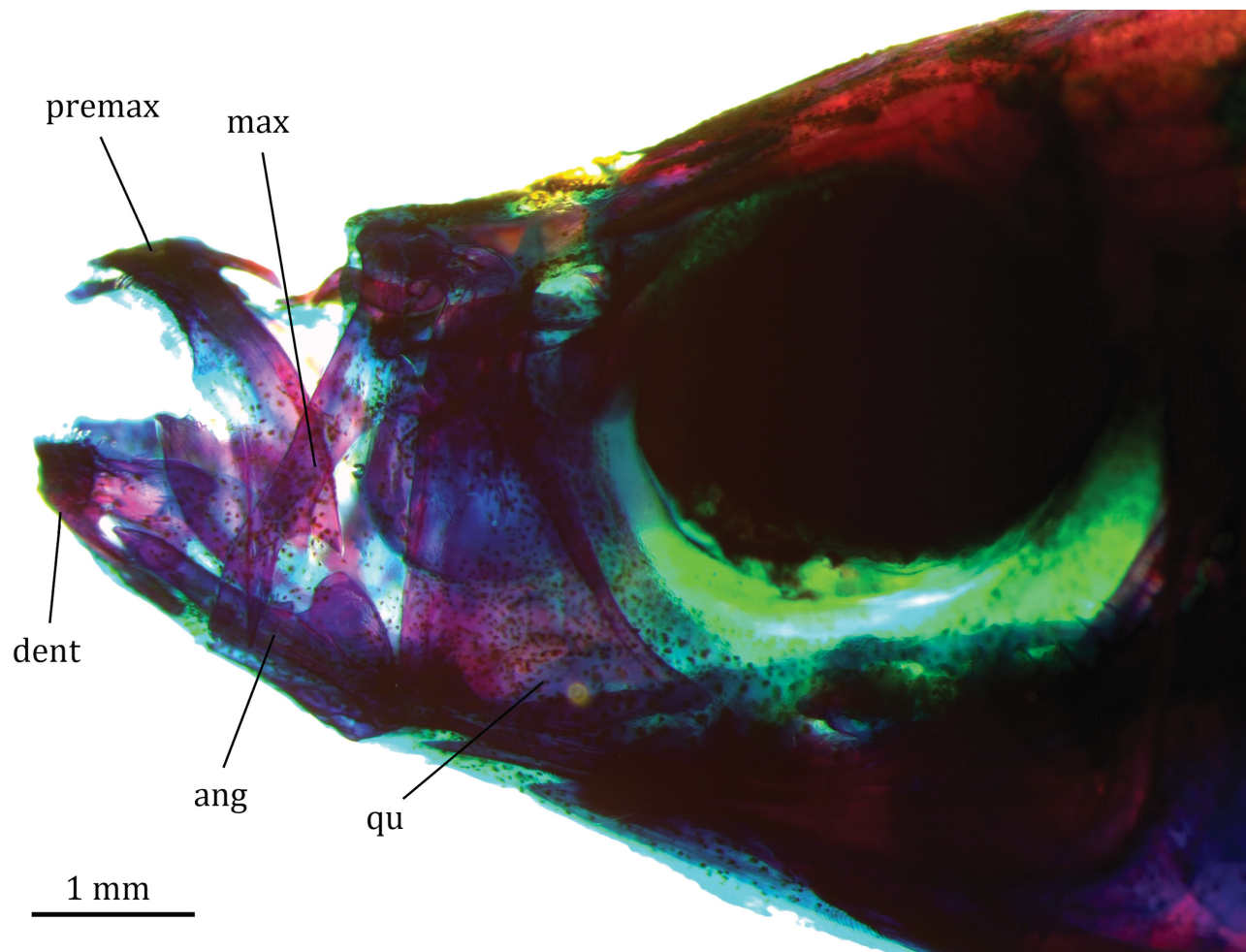


FIGURE 3. Mouth of a cleared specimen of *Limia mandibularis* **sp. nov.** (OMNH 86831, female, 41.5 mm SL) showing the peculiar arrangement of bones of the upper and lower jaws. Premax: premaxillar, max: maxilla, dent: dentary, ang: anguloarticular, qu: quadrate

Description. Elongate body with deep caudal peduncle. Post-anal region moderately compressed towards caudal peduncle. Dorsal profile slightly concave from snout tip to posterior edge of eye; convex from middle of eye to origin of dorsal fin; slightly concave or straight from dorsal fin origin to caudal fin. Ventral profile convex with distinctive protuberance in the lower jaw area that is formed by the joint of anguloarticular and quadrate bones (quadrato-mandibular joint). Post-anal profile slightly concave or straight (Fig. 2). Gonopodial segments of ray 4p serrae 11 (Fig. 5). Predorsal scales 12 to 13 (usually 13) and lateral scales 26 to 28 (usually 26). Dorsal fin with 8 rays (Table 1). Caudal fin with 15 to 17 rays (usually 16), truncate or slightly convex, and symmetrical in both sexes. Mouth wide and superiorly oriented. Teeth of outer row conical in upper and lower jaws. Vertebral column with 30 vertebrae.

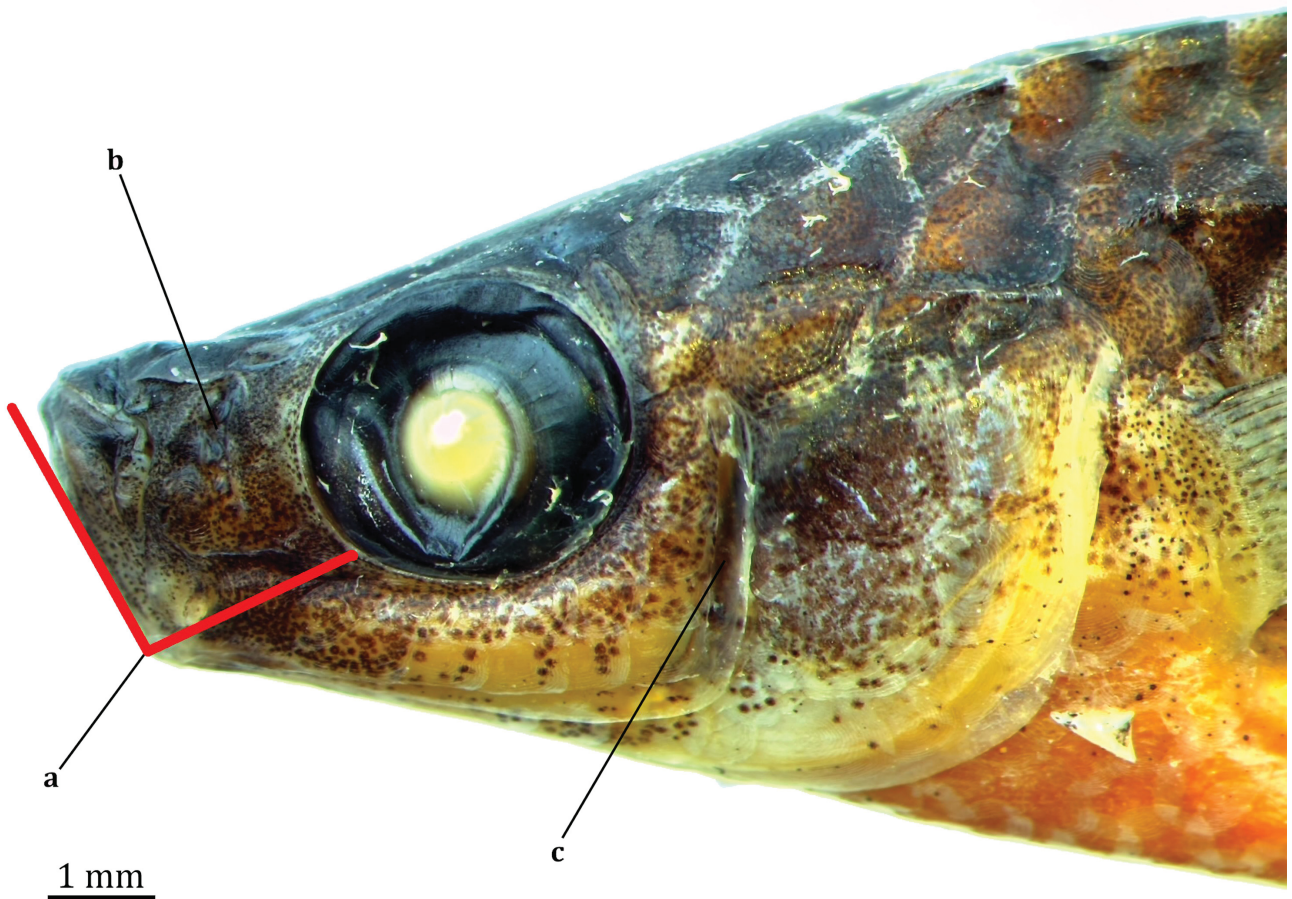


FIGURE 4. Head of *Limia mandibularis* **sp. nov.** showing the protuberance in the lower jaw (**a**), the single preorbital canal forming an open groove (**b**) and the single preopercular canal forming an open groove (**c**). Red lines show the quadrato-mandibular joint forming nearly a right angle between the front of the mouth and the inferior edge of the eye globe.

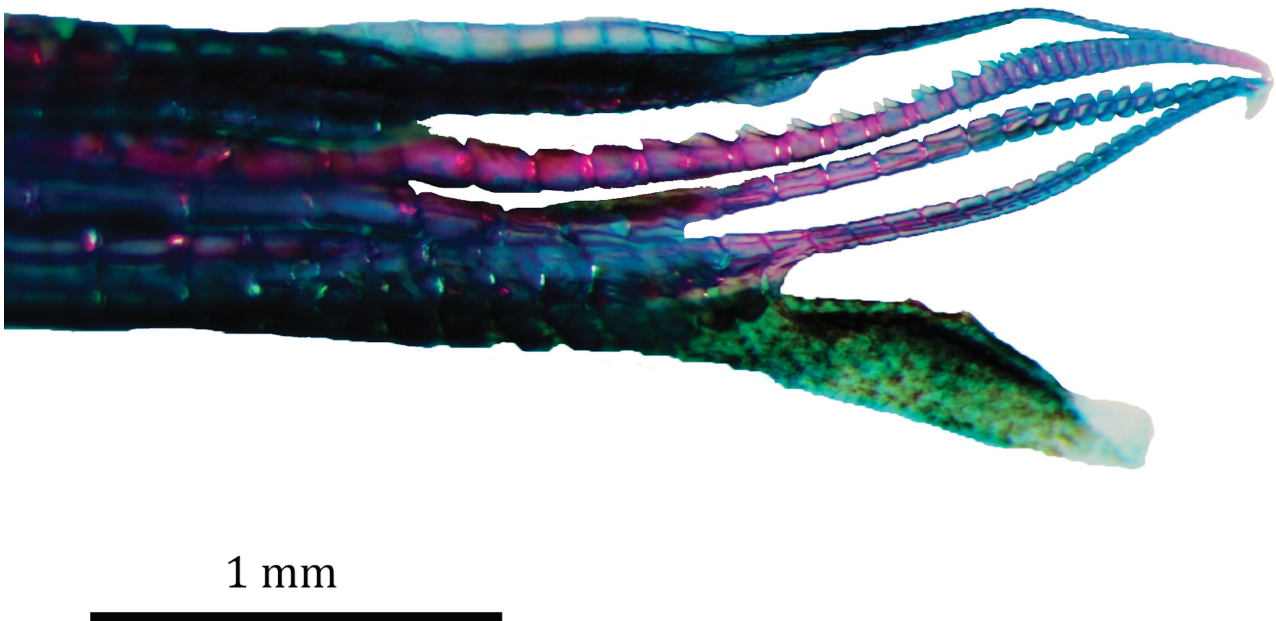


FIGURE 5. Cleared and stained gonopodium tip of *Limia mandibularis* **sp. nov.**, paratype OMNH 86831, adult male, 38.5 mm SL.

TABLE 1. Counts for holotype and paratypes of *Limia mandibularis* sp. nov. Values in parentheses indicate the number of specimens examined with that count.

Counts	Holotype	Paratypes (N=11; 1 male and 10 females)		
Dorsal rays	11	11 (11)		
Branched caudal rays	16	15 (3)	16 (6)	17 (2)
Pectoral rays	16	15 (8)	17 (3)	
Anal rays	-	7 (9)	8 (1)	
Segments distal to ray 3 keel	19	21 (1)		
Ray 4a grooved segments	18	17 (1)		
Ray 4p serrae	11	11 (1)		
Segments distal to ray 4p serrae	14	16 (1)		
Segments distal to ray 5 keel	18	20 (1)		
Lateral scales	28	26 (6)	27 (3)	28(2)
Pre-dorsal scales	13	12 (5)	13 (6)	
Pre-orbital pores	0	0 (11)		
Pre-opercular pores	0	0 (11)		
Teeth of outer row (upper jaw)	24	24 (7)	28 (3)	30 (1)
Teeth of outer row (lower jaw)	30	30 (5)	36 (4)	38 (2)

Color of preserved specimens. Dorsal and middle portion of body dark, with noticeable reticulated pattern due to black pigmentation on edges of scales. Ventral region of body and scales of the hypural area with tannish coloration, much darker below pectoral fins. All fins hyaline (Fig. 2).

Color in live specimens. Yellowish background towards dorsal region of body, darker in snout and above opercula. Ventral region with silver coloration. No distinctive features like spots, bars or blotches on body or fins in both sexes (Fig. 6).



FIGURE 6. Female of *Limia mandibularis* sp. nov (48.5 mm SL) showing coloration in a live specimen.

Distribution and ecological notes. *Limia mandibularis* **sp. nov.** is only known from the north bight of Lake Miragoane in Haiti. The lake seems very isolated in terms of connectivity with other water bodies as we did not see any tributary river or stream, but only mountain springs that lead to the lake. Our observations agree with the classification of Curtis & Hodell (1993) of the lake as an endorheic drainage. The species herein described was collected in a clear water path with slow current exiting the lake. Water temperature was 29.9 °C and water conductivity was 321 microS/cm on the collecting date (June 5th, 2019). The area is characterized by the presence of muddy bottoms and some semi-submerged and submerged vegetation growing near the banks (Fig. 7). *Limia mandibularis* was sympatric with *Gambusia beebei*, five other *Limia* species (*L. miragoanensis*, *L. immaculata*, *L. nigrofasciata*, *L. garnieri* and *L. islai*), *Nandopsis haitiensis* and two species of African cichlids introduced in the lake (*Oreochromis aureus* and *Tilapia* sp.).

Etymology. The specific epithet *mandibularis*, from the Latin *mandibula* (jaw), is in reference to the well-developed lower jaw, a character that distinguishes the species. The vernacular name “Jawed Limia” is proposed for this species, due to the distinct protuberance that can be seen in the lower jaw.



FIGURE 7. Habitat where *Limia mandibularis* **sp. nov.** was collected. The locality is found at the north end of Lake Miragoane and corresponds with locality represented by the white circle in Figure 1.

Discussion

Lake Miragoane represents a remote and isolated area located in the southwestern extreme of Hispaniola. The high number of endemic livebearing fish species that can be found in the lake makes it remarkably important for the study of the origin and evolution of freshwater fishes in the Antilles (Vergara, 1992; Weaver *et al.*, 2016b). However, there seem to be no published scientific studies conducted since 1980 involving the freshwater fish fauna living in that lake. The recent descriptions of *L. islai*, and now *L. mandibularis* both from Lake Miragoane, add two important species records to the impressive biodiversity of the genus *Limia* on Hispaniola. It seems that the degree of isolation

of Lake Miragoane, coupled with the early colonization of southwestern Hispaniola by the *Limia* lineage (Weaver *et al.*, 2016b), are key factors that may explain the radiation of *Limia* species in the lake.

According to the gonopodial characters examined, the species herein described should be placed in the genus *Limia* (sensu lato) since the subdistal segments of ray 3 of gonopodium lack spines or processes. In addition, the distal arc of ray 5a curves sharply towards ray 4p (Fig. 5) and the number of segments distal to ray 4p serrae are 14 or more (Table 1) (Rivas, 1978; Chambers, 1987). Following Rivas' (1980) criteria, *L. mandibularis* may be considered as belonging to the subgenus *Odontolimia* due to the presence of a preopercular canal forming an open groove and also the conical shape of teeth of the outer row in both jaws. However, the numbers of teeth in upper and lower jaws are slightly greater than those reported by Rivas (1980) when diagnosing this subgenus (Table 1).

The new species differs from all the other members of the genus *Limia* by the very distinctive shape of the mouth, which is a diagnostic feature of the new species. *Limia mandibularis* has a superiorly oriented mouth with the junction of the anguloarticular and quadrate bones forming a distinguishing protuberance. This characteristic quadrato-mandibular joint makes the front of the snout very steep, approximately forming a right angle with the inferior edge of the eye when the mouth is closed (Fig. 4). The lack of distinctive color markings on body or fins in both sexes is also another feature that distinguishes the new species from other congeners except *L. immaculata*. However, the body shape is different between *L. mandibularis* and *L. immaculata* with the new species having a more elongate body compared to *L. immaculata*. In addition, the two species can also be distinguished by the position of the dorsal fin in relation to the anal fin in females. The origin of dorsal fin is slightly behind of the origin of anal fin in *L. mandibularis* while in *L. immaculata* the origin of the dorsal fin of females is above origin of the anal fin. *Limia mandibularis* also differs from all other species in the genus, except *L. fuscomaculata*, by having single preorbital and preopercular canals forming open grooves (Fig. 4). Nevertheless, *L. mandibularis* has a truncate or slightly convex and symmetrical caudal fin, not mottled or speckled (Fig. 6), versus a very convex, asymmetrical and mottled caudal fin in *L. fuscomaculata*.

TABLE 2. Measurements of morphological variables of *Limia mandibularis* **sp. nov.** Table shows values for the holotype, and range, mean and standard deviation (SD) for the paratypes. All measurements are given in millimeters

Measurements	Holotype	Range	Mean	SD
Standard length	35.5	33.0–41.0	37.6	
Body depth	9.0	7.0–10.0	8.9	1.0
Snout to dorsal-fin origin	21.5	20.5–25.5	22.9	1.8
Snout to anal-fin origin	15.5	15.5–24.0	20.4	2.9
Snout to pectoral-fin origin	10.5	10.5–13.5	11.8	1.1
Snout to pelvic-fin origin	14.0	13.0–18.0	16.0	2.0
Caudal peduncle depth	6.0	5.0–6.0	5.8	0.4
Caudal peduncle length	9	8.0–11.0	9.2	0.9
Head length	9.5	8.0–12.0	10.1	1.1
Eye diameter	3.5	3.0–3.5	3.4	0.2

The presence of some phenotypic plasticity among the species occurring in Lake Miragoane cannot be ruled out. This has been shown in other *Limia* species such as *Limia vittata* in Cuba (Howell-Rivero, 1946; Vergara, 1992; Ponce de Leon & Rodriguez, 2010) where populations show differences in coloration depending on the geographic area. However, we propose that the new species described in this study stands out as valid species due to the presence of remarkable and unique characters with potential adaptive value. Particularly, the well-developed and anteriorly projected lower jaw of *L. mandibularis* may offer some advantages or specializations in relation to diet. The degree of trophic specializations existing in the genus *Limia* needs further research, as it could be another factor in determining the high radiation observed in this genus on Hispaniola and particularly in Lake Miragoane. Trophic adaptations have been shown to drive speciation in many cichlids species of African lakes (Takahashi & Kobl-müller, 2011; Winkelmann *et al.*, 2013). Although most species of Cyprinodontiformes (Teleostei) are considered “midwater omnivores” (Motta *et al.*, 1995; Mansfield & Macardle, 1998), this general classification does not take into account species-specific trophic morphology and behaviors, which in fact are really diverse within the group (Hernandez *et al.*, 2009). In the case of *Limia* species, no previous studies have been done reporting the role of food

resources and anatomical feeding specializations in the diversification of this livebearing fish genus. Preliminary data of gut content analyses show that *Limia* species may have some degree of specialization or preference for certain food items (Rodríguez-Silva and Schlupp, in preparation).

The description of this new species from Lake Miragoane raises some conservation concerns in relation to the freshwater fish fauna of the lake. Local human communities living in the surroundings rely on water from the lake for daily use including drinking water, taking baths, washing clothes, and also washing cars and motorcycles. Particularly the last two activities mainly done by groups of young men on the banks of the lake just on Route Nationale 2, might represent a threat to aquatic life because water and detergent used to wash the cars go right into the lake. In addition, the presence of some invasive species (i.e. *Oreochromis aureus*, *Tilapia* sp.) that can prey upon endemic species of smaller sizes, such as livebearing fishes, can turn into a significant threat to the native freshwater fish fauna.

Comparative material: *Limia grossidens*: USMN 220523 (1, holotype); *Limia fuscomaculata*: USMN 220525 (1, holotype), USMN 220526 (1, paratype); *Limia garnieri*: USMN 220527 (1, holotype); *Limia immaculata*: USMN 220529 (1, holotype), USMN 220530 (1, paratype); *Limia miragoanensis*: USMN 220531 (1, holotype); *Limia pauciradiata*: USMN 220533 (1, holotype); *Limia yaguajali*: USMN 220535 (1, holotype); *Limia sulphurophila*: USMN 220537 (2, paratypes); *Limia rivasi*: USMN 232484 (2, paratypes); *Limia nigrofasciata*: USMN 78243 (3), USMN 78245 (4); *Limia versicolor*: USMN 88338 (5); *Limia ornata*: USMN 164769 (2); *Limia zonata*: USMN 89002 (2); *Limia melanogaster*: USMN 102200 (3); *Limia dominicensis*: USMN 120359-60 (2), USMN 132111 (4); *Limia perugiae*: USMN 382409 (3); *Limia vittata*: USMN 167692 (4), USMN 331925 (3); *Limia tridens*: USMN 305527 (1); *Limia melanonotata* USMN 305523 (3), USMN 122629 (2); *Limia nigrofasciata*: BMNH 1913.7.25.15 (1, syntype), *Limia nigrofasciata*: BMNH 1913.3.6.21 (1, syntype); *Limia ornata*: BMNH 1912.9.4.12-14 (1, syntype); *Limia islai*: OMNH 86867 (1, holotype).

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