Argulus ambystoma, a New Species Parasitic on the Salamander *Ambystoma dumerilii* from México (Crustacea: Branchiura: Argulidae)[1]

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ABSTRACT. **A new species of *Argulus* is described based on 18 specimens taken from the salamander ("achoque" or "ajolote") *Ambystoma dumerilii* Dugès, collected in Lake Pátzcuaro, Michoacán, México. Diagnostic characters include the shape of the respiratory areas, number of sclerites in suction cup rods, and structures on the legs of males. Females are heavily stippled, whereas males have a very distinctive pigment pattern consisting of abundant melanophores covering the testes dorsally and two dark, inverted triangular patches on the carapace dorsally. The new species is similar to the North American species, *A. versicolor*, *A. americanus*, *A. maculosus*, and *A. diversus*. A single, dorsal pore was observed on each caudal ramus using scanning electron microscopy; these pores have not been reported previously in the Branchiura.**

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INTRODUCTION

Ten species of *Argulus* Müller have been collected in México, Central America, and the West Indies. The widespread exotic, *Argulus japonicus* Thiele, was found on aquarium fishes, *Carassius auratus* (Linné) and *Astronotus ocellatus* (Agassiz), in Puerto Rico (Bunkley-Williams and Williams 1994), and Vargas and Fallas (1976) found *A. japonicus* on *Carassius* sp. in Costa Rica in 1972 and 1973. *Argulus dactylopteri* Thorell was described from specimens collected from the gills of *Dactylopterus volitans* (Linné) in the West Indies (Thorell 1865, 1867); neither Cressey (1982) nor Pineda and others (1995) mentioned *A. dactylopteri*. Wilson (1902) gave the locality for *A. dactylopteri* as the East Indian Ocean from the branchial cavity of *D. volitans*, whereas Yamaguti (1963) cited Europe and *Dactylopterus* sp. If the type locality of *A. dactylopteri* is somewhere other than the Atlantic Ocean or Mediterranean Sea, the host would not be *D. volitans* but a species of *Dactyloptena* (see Eschmeyer 1997). Only six species of *Argulus*, *A. chromidis* Krøyer; *A. flavescens* Wilson; *A. megalops* Smith; *A. mexicanus* Pineda, Páramo, and Del Rio; *A. melanostictus* Wilson; and *A. rhamdiae* Wilson have been found in México (Wilson 1936; Causey 1960; Olson 1972; Cressey 1982; Fucugauchi and others 1988; Pineda and others 1995; Suárez-Morales and Gasca 1997; Suárez-Morales and others 1998). In addition, an unidentified species of *Argulus* was reported from *Potamarius nelsoni* (Evermann and Goldsborough) by Pineda-López and others (1985).

The species described herein was collected from Lake Pátzcuaro (Lago de Pátzcuaro) in Central México, State of Michoacán. Both the invertebrate and vertebrate faunas of the lake have been investigated; however, the genus *Argulus* has not been recorded as a component of the fauna (Ueno 1939; Ancona and others 1940; Brehm 1942; Tressler 1954; Brandon 1970; Barbour 1973; Rosas and others 1985; Chacón-Torres and others 1991; Osorio-Sarabia and others 1986; Pérez-Ponce de León and others 1994; Peresbarbosa-Rojas and others 1994; Espinosa-Huerta and others 1996; Peresbarbosa-Rojas and others 1997). A number of endemic taxa exist in Lake Pátzcuaro including several fishes (*Chirostoma patzcuaro* Meek, *C. e. estor* Jordan, *C. a. attenuatum* Meek), a crayfish (*Cambarellus patzcuarensis* Villalobos), and the salamander host of the new argulid (*Ambystoma dumerilii* (Dugès)) (Brandon 1970; Barbour 1973; Hobbs 1989).

MATERIALS AND METHODS

Three males and two females were examined using scanning electron microscopy (SEM). Preparation procedures were modified slightly from those of Rupp (1990). All specimens were initially preserved and stored in 70% ethanol (EtOH, J. A. Beatty pers. comm.). Specimens were dehydrated in an EtOH series consisting of 80% (5 min), 90% (5 min), 100% (1st, 5 min; 2nd, 10 min), then immediately critical point dried (CO_2), mounted on metal stubs with carbon paint, allowed to dry overnight in an oven (60° C), and sputter coated with gold/palladium. Specimens were stored in an oven at 60° C between uses. Some specimens were coated up to three times and were examined in a Hitachi S570 Scanning Electron Microscope at 15kV. Six females and seven males (including the holotype, all adult) were examined under dissecting and compound microscopes in a watchglass or temporary slide mount (with 70% EtOH/glycerin). The holotype and allotype were photographed using a camera tube on a light microscope. In addition, some counts and measurements were taken from 3 male and 2 female specimens later used for SEM. All measurements were made using an ocular micrometer, and measurements reported in the description are arranged as follows: range (mean, holotype) with allotype values substituted in the case of females. Values for the right and left sides refer to the right and left of the specimen in dorsal view. Type specimens were deposited in the National Museum of Natural History, Washington, DC (USNM), and specimens of *Argulus americanus* Wilson (USNM 274331, 274332), *A. diversus* Wilson (USNM

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32823, 32824), *A. maculosus* Wilson (USNM 12226, 74329), and *A. versicolor* Wilson (USNM 74321; MCZ 19604, 19607) were examined by light microscopy for comparative purposes (MCZ, Museum of Comparative Zoology, Harvard University, Cambridge, MA).

RESULTS

Family Argulidae Rafinesque, 1815
Argulus Müller, 1785
Argulus ambystoma, new species

Material Examined

Holotype: adult male, 3.48 mm total length, USNM 282782, Lake Pátzcuaro, Michoacán, México. Allotype: adult female, 4.18 mm total length, USNM 282783, collected with holotype. Paratypes: 5 adult males, 4 adult females, USNM 282784, collected with holotype; 4 adult males, 3 adult females (used for SEM or cleared, not retained), collected with holotype (host collected by J. Arnett; *Argulus* collected from hosts, *Ambystoma dumerilii* (Dugès), by J. A. Beatty and R. A. Brandon on 27 May 1981).

Diagnosis

Respiratory areas with a smaller, oblong "area" situated anterior to and abutting or nearly contacting a larger posterior "area"; respiratory areas outlined with melanophores and very distinct; caudal rami near posterior end of abdomen in anal sinus; paired postantennal spines with reduced anterior spine and stout posterior spine; males with 43-56 support rods per suction cup; females with 45-54 support rods per suction cup; usually 3 to 4 sclerites per rod in males and 4 to 5 sclerites per rod in females; basal plate of second maxilla with three stout, digitate spines; first two pairs of legs each with a recurved flagellum on dorsal surface; coxae of second legs of males with bilobate structure posteroventrally, scales on lobes distally; third legs of males with paddle-like extension issuing anterodistally from the coxae, extending over bases.

Description

Total length (mm) 3.26-3.72 (3.53, 3.48) in males, 4.06-5.85 (4.92, 4.18) in females. Carapace ovoid to circular, narrower anteriorly. Carapace length (mean of both sides, mm) 2.16-2.47 (2.33, 2.26) in males, 3.20-3.97 (3.57, 3.22) in females. Maximum carapace width (mm) 2.13-2.57 (2.41, 2.38) in males, 3.21-4.15 (3.66, 3.30) in females. Carapace extending to middle of third legs or posterior edge of third legs/anterior margin of abdomen in males. Carapace extending to middle of third legs or posterior of fourth legs/anterior of abdomen in females, varies considerably in females. Females without eggs in carapace alae. Carapace in males with inverted, dark, triangular patch of melanophores on dorsal surface of both left and right alae (much more apparent at lower magnifications) as well as scattered melanophores on alae and diffuse pigment scattered on cephalic region. Females with numerous scattered melanophores on carapace; inverted, triangular patches not as apparent in females (Fig. 1). Small pores and sensilla (Fig. 2) scattered on dorsal surface and margins of carapace. Smaller type of sensillum present on anterior margin (between sinuses) of cephalic region, abundant in interspaces between larger sensilla. Pair of compound eyes anteriorly with diameters (left and right eyes, μm) 170-210 (187, left: 170 and right: 180) (n = 18 eyes) in males, 200-240 (224, left: 230 and right: 210) (n = 14 eyes) in females. Transverse distance between eyes (μm) 390-440 (419, 410) in males, 510-650 (604, 570) in females. Nauplius eye with one anterior and two posterior ocelli, pigment between ocelli forming a dark, prominent "Y" or "V." Sclerotized dorsal ridges forked anterior of eyes, inner branches longer and less developed than outer branches. Bifurcation of dorsal ridges usually more obvious in males and sometimes appears absent in females. Ventrally, carapace with small, posteriorly-projecting spines along outer margin, more numerous anterior of respiratory areas with a few rows extending along outer margin of carapace and respiratory areas to level of second legs. Respiratory areas consist of smaller, oblong "area" situated anterior to and abutting or nearly contacting larger posterior "area"; respiratory areas distinct, outlined with melanophores (Fig. 3).

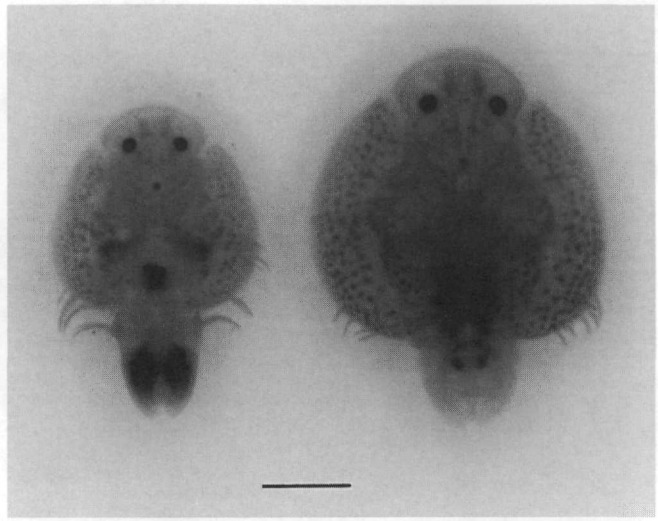


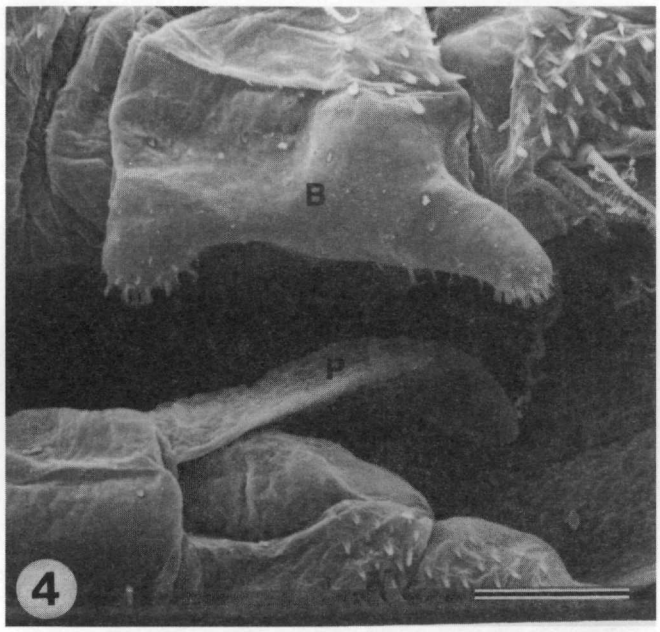
FIGURE 1. *Argulus ambystoma*, new species, dorsal view, male (holotype, left) and female (allotype, right) (scale bar = 1.0 mm).

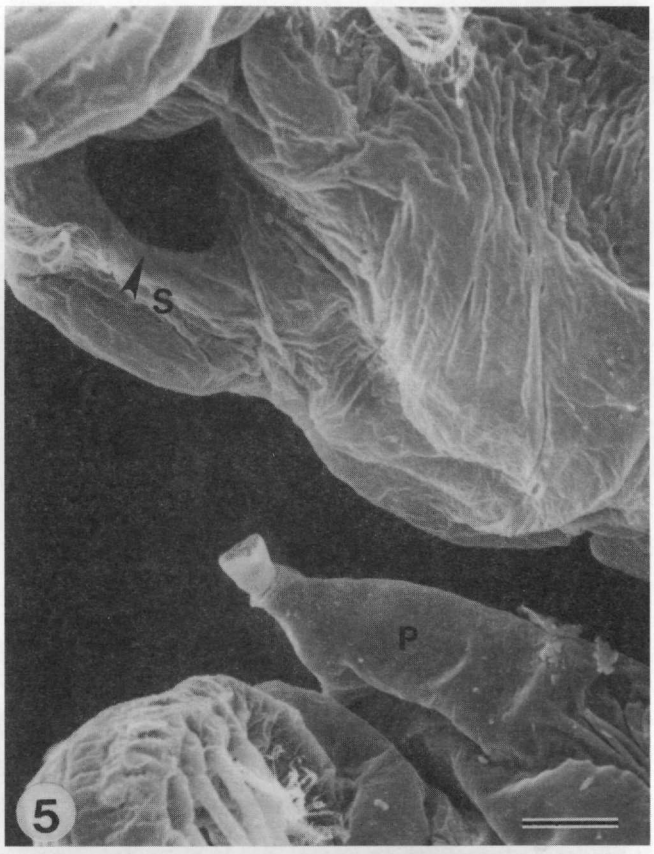
Thorax dorsoventrally compressed, indistinctly segmented with two pairs of posteriorly-projecting spines ventrally. Spines digitate, rounded distally, the anterior pair (accessory spines) larger than posterior pair (postmaxillary spines). Accessory spines situated between basal segments of second maxillae; postmaxillary spines positioned farther apart than accessory spines. Thorax with coarse-pectinate scales scattered on ventral surface. Four pairs of biramous swimming legs composed of a precoxa, coxa, basis, exopod, and endopod; with plumose setae on all exopods, endopods, coxae, and bases. First two pairs of legs each with a recurved flagellum on dorsal surface. Flagella laterally compressed, bearing plumose setae. Endopods of first pair of legs three-segmented, bearing three "setae" or "spines" at distal end. Endopods of second pair of legs unsegmented. Endopods of third and fourth pairs of swimming legs

FIGURES 2-3. *Argulus ambystoma*, new species. 2) Sensillum on dorsal surface of carapace (scale bar = 5.0 μm); 3) Shape of respiratory areas (right ala of female) (scale bar = 1.0 mm).

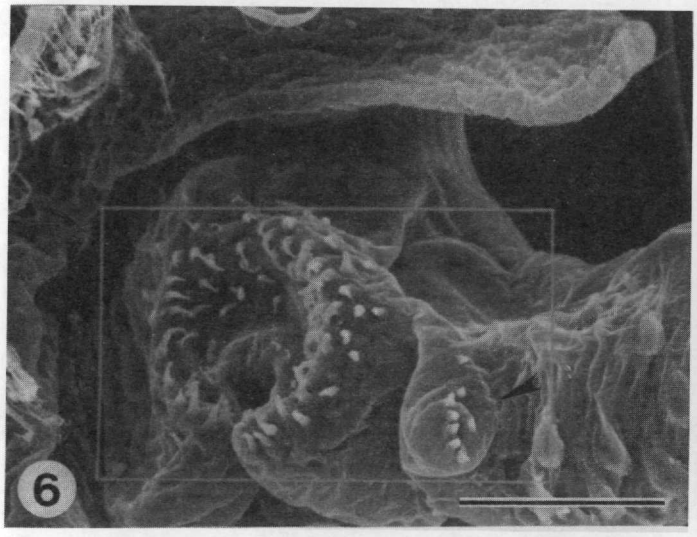
two-segmented. Second, third, and fourth legs of males with accessory sexual structures. Coxae of male second legs with a bilobate structure posteroventrally, with scales on lobes distally (Fig. 4). Third legs each with paddle-like extension issuing anterodistally from the coxae, extending over bases (extending beyond distal margin of bases in larger males) (Fig. 4) and a hyaline, bubble-like area ("socket") on posterior of bases with opening of socket dorsally (Fig. 5). Dorsal surface of basis of third leg with conical pit ("pocket") ringed with papillae and minute pores; posterior wall of pocket split completely; opening of pocket leads to opening of socket below it. Paddle-like structure of coxa extends over pocket. Adjacent to pocket is a small, fleshy lobe tipped with papillae; lobe appears to be at base of exopod rather than on basis (Fig. 6). Bases of fourth legs each with large peg, sclerotized at its base; a smaller peg (dorsal to larger peg) and small sclerotized hump with minute spines ventral to larger peg (Fig. 5). Distal end of peg with notch on ventral surface and bearing blunt "tentacles" along its rim and numerous forked "tentacles" in concavity (Fig. 7). Precoxae + coxae of fourth legs of males and females with posterior boot-shaped natatory lobes fringed with plumose setae and bearing scattered, coarse-pectinate scales; distal end of lobes extend beyond middle of bases but not beyond distal end of bases. Dorsal surface of all legs with fine-pectinate scales (Fig. 8), including dorsal surfaces of exopods and endopods. Ventral surfaces of all leg segments, including endopod, with coarse-pectinate scales (Fig. 9); ventral surface of exopod with fine-pectinate scales (Fig. 8). Sensilla and pores scattered on ventral surfaces of legs, pores also on dorsal surfaces of legs (Fig. 8).

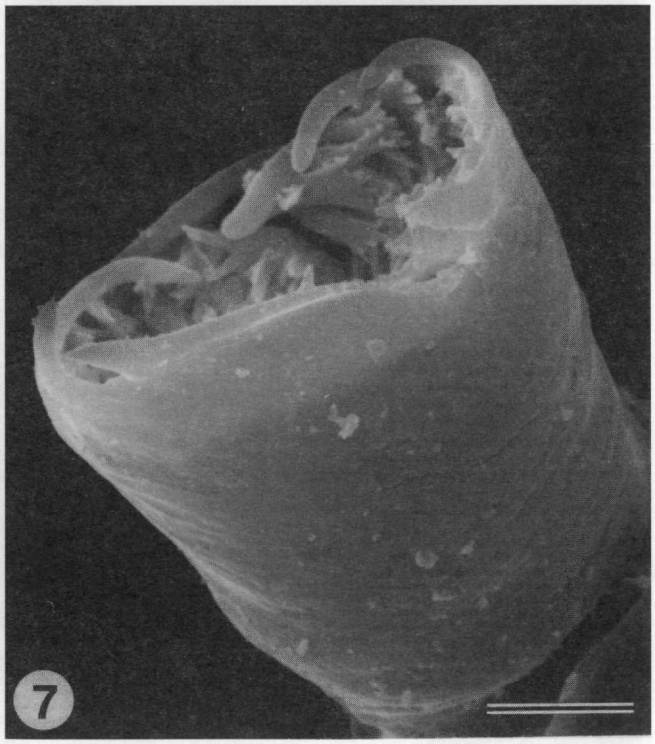
Abdomen bilobate, with pair of caudal rami near posterior end in anal sinus. Abdomen length (mm) 1.13-1.30 (1.21, 1.19) in males, 0.95-1.31 (1.14, 1.01) in females; maximum width (mm) 0.94-1.06 (1.00, 0.97) in males, 1.07-1.40 (1.26, 1.12) in females. Anal sinus length (μm) 180-220 (202, 180) in males, 350-430 (392, 350) in females. Male abdomen with spine-covered crests at each anterior corner (Fig. 10b), narrower than female abdomen, which is rounded at anterior corners (Fig. 10a). Small, lateral spines along most of edge of abdomen in both sexes. Each caudal ramus with five stout, naked "setae" (possibly not true setae) and dorsal pore just anterior of "setae" (Figs. 11, 12). Some of the "setae" extend beyond posterior margin of abdomen in males but not in females. Paired spermathecae of female brownish, round to oval, located anteriorly on abdomen. Pair of papillae on female abdomen anteroventrally, with small spines on ventral surface of papillae. Male abdomen with prominent black patches over testes dorsally (Fig. 1) and fewer, scattered melanophores ventrally over testes. Pores scattered on dorsal and ventral surfaces of abdomen, but only one short, sensillum observed dorsally





FIGURES 4-7. *Argulus ambystoma*, new species. 4) Bilobed structure (B) on posteroventral surface of coxa of second leg and paddle-like structure (P) extending from the anterodistal margin of the coxa of the third leg of male (ventral view of left, second, and third legs) (scale bar = 100.0 µm); 5) Socket (S) and peg (P) on third and fourth legs, respectively, of male (dorsal view) (scale bar = 50.0 µm); 6) Conical pit or "pocket" (with papillae and pores) and fleshy lobe (with papillae, indicated by arrow) located anterodorsally on basis of the third leg of male (dorsal view) (scale bar = 50.0 µm); 7) Tip of peg on basis of fourth leg of male (dorsal view) (scale bar = 5.0 µm).



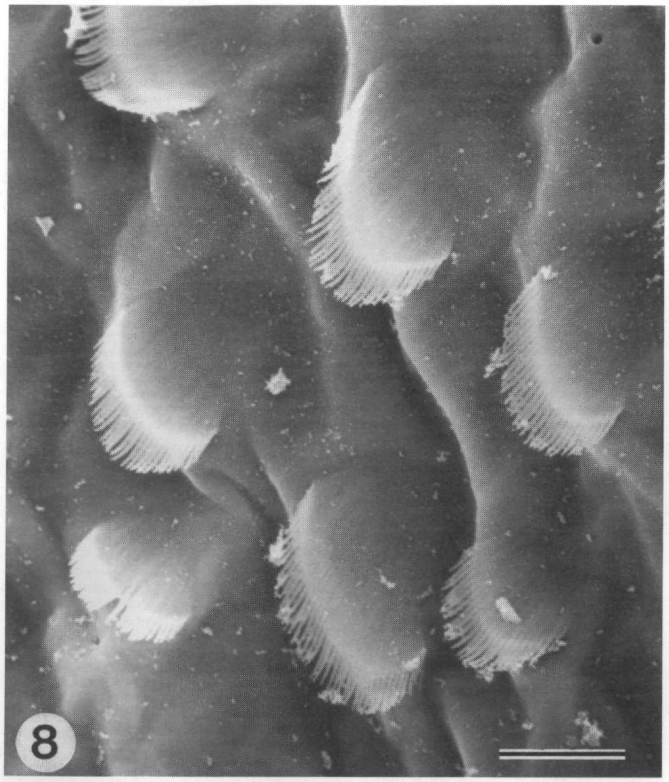


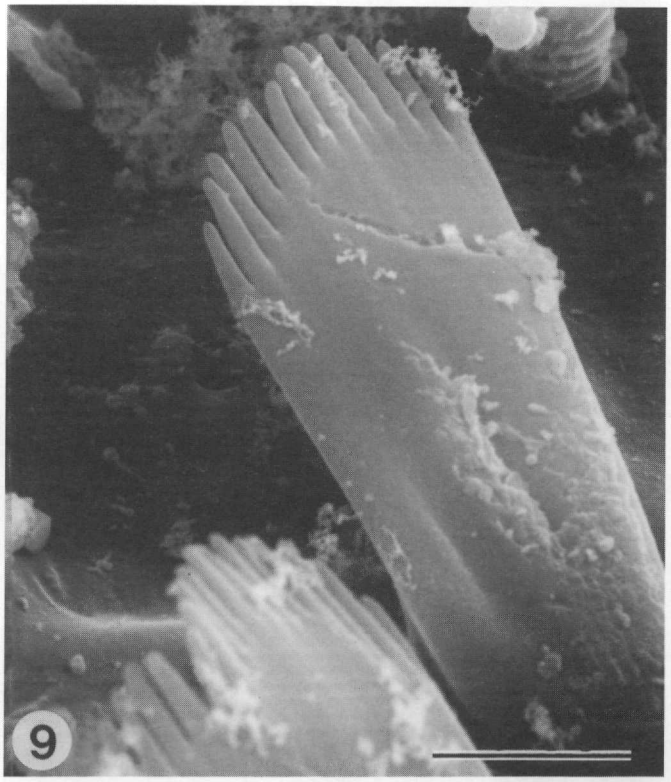
on a male's abdomen.

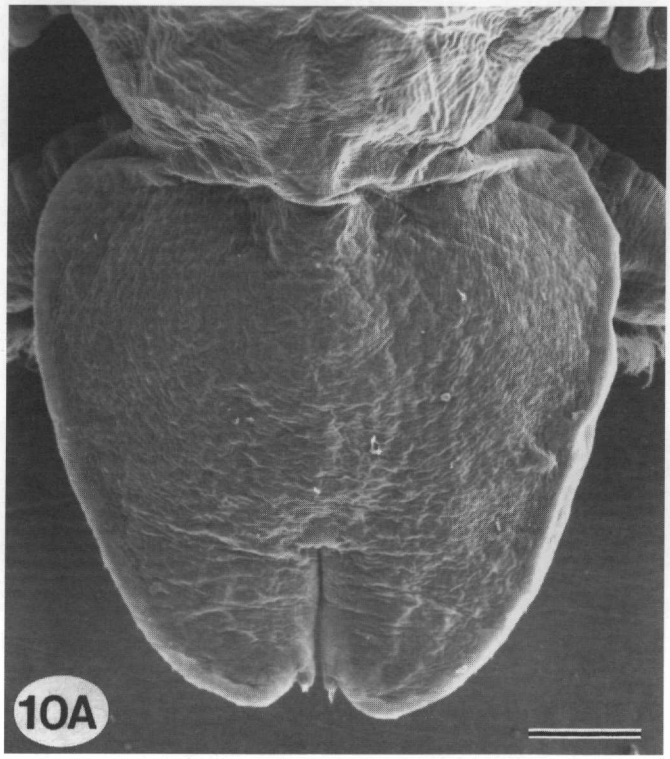
First antennae composed of four segments: first segment sclerotized, large, with stout posteriorly-projecting posterior spine; second segment sclerotized with hump anteriorly, a smaller, posteriorly-projecting medial spine and large recurved terminal spine; third segment fleshy, cylindrical and smaller with large, stout seta distally that projects ventrally and several smaller setae; fourth segment fleshy, small, with few setae distally (Fig. 13). Second antennae with five fleshy segments; basal segment with posteriorly-projecting posterior spine. First two segments rounded, bulbous; remaining three thin, cylindrical. All segments of second antennae with several setae that project distally (Fig. 13). Paired postantennal spines consist of reduced anterior spine and stout posterior spine (Fig. 13). Posterior first antennal spines and

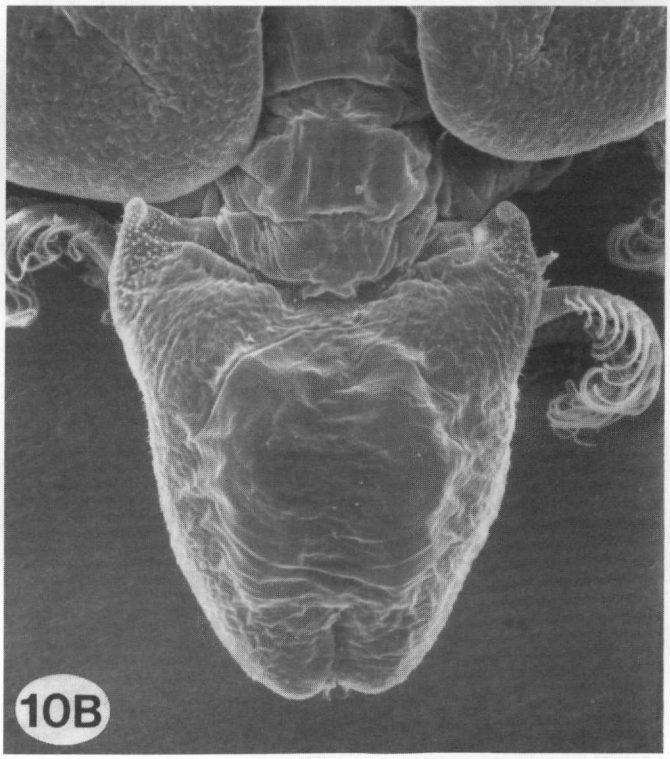
postantennal spines more robust in females than in males. Reduced anterior postantennal spines vary in degree of development, sometimes partially hidden by posterior first antennal spines.

First maxillae modified into suction cups in adults. First maxillae inner diameter (μm) 290-320 (303, left: 300 and right: 290) (n = 15, left and right) and outer diameter (μm) 430-490 (460, left: 450 and right: 450) (n = 15) in males, inner diameter (μm) 500-620 (564, left: 500 and right: 500) (n = 11, left and right) and outer

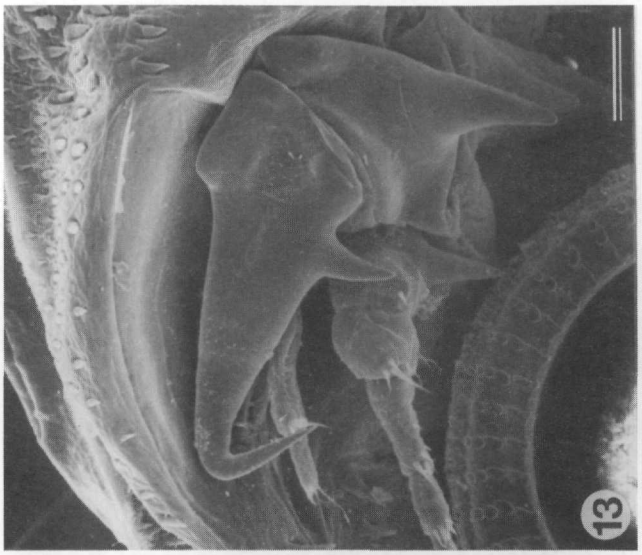


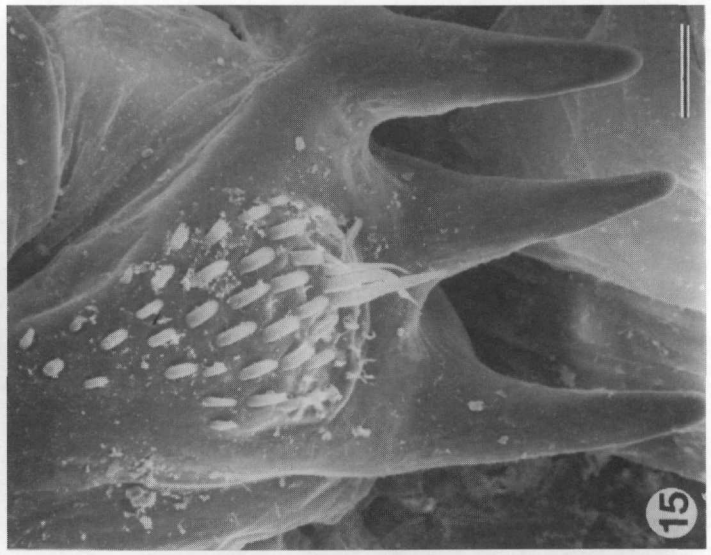


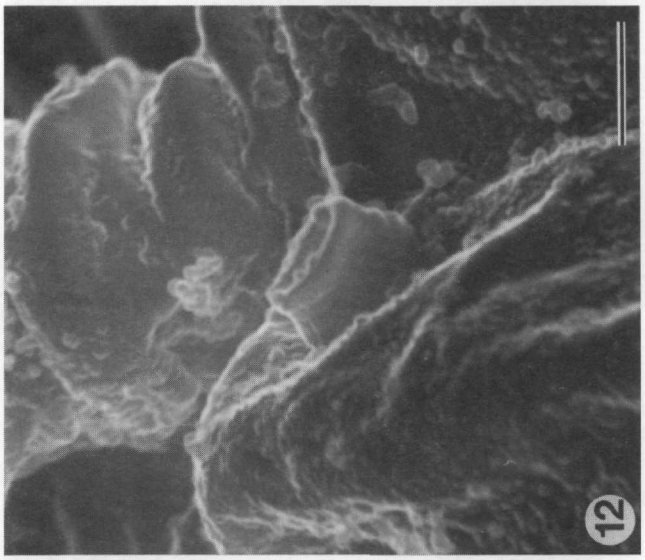


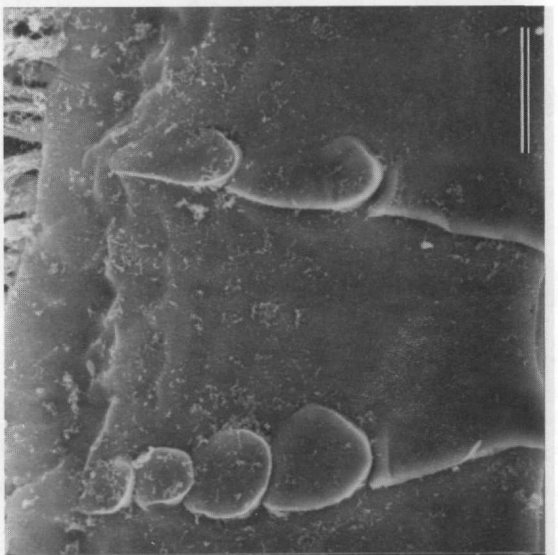


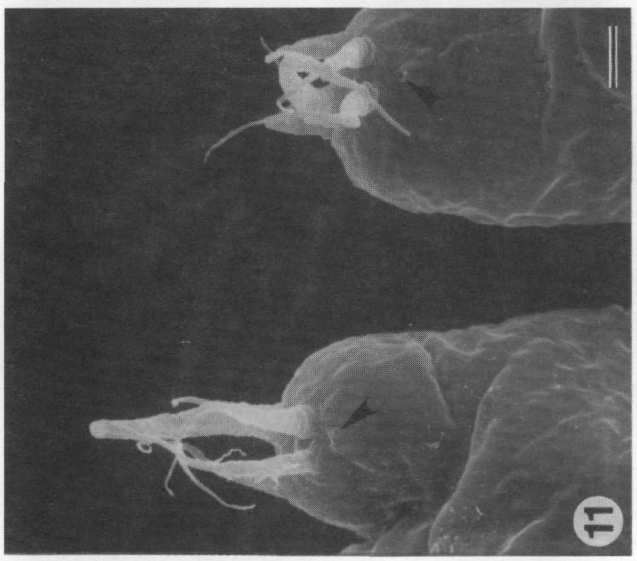
FIGURES 8-10. *Argulus ambystoma*, new species. 8) Fine-pectinate scales on dorsal surface of exopod base; two pores are visible also (scale bar = 10.0 μm); 9) Example of a coarse-pectinate scale (on basal plate) (scale bar = 5.0 μm); 10A) abdomen of female, 10B) abdomen of male, showing sexual dimorphism (dorsal view). The male abdomen has anterolateral crests with small spines, whereas the female abdomen is rounded anterolaterally and lacks the spines (scale bar 0.25 mm).











FIGURES 11-15. *Argulus ambystoma*, new species. 11) Caudal rami located on posterior of abdomen (dorsal view, female). Arrows indicate locations of pores (scale bar = 10.0 µm); 12) Example of the pore located posterodorsally on each caudal ramus (scale bar = 1.0 µm); 13) First and second antennae and postantennal spines (female). The fifth segment of the second antenna is partially out of the frame (scale bar = 100.0 µm); 14) Suction cup (first maxilla) support rods displaying variation in number and shapes of sclerites (female) (scale bar = 20.0 µm); 15) Basal plate (first segment of second maxilla) showing the three spines projecting posteriorly (female) (scale bar = 50.0 µm).

diameter (µm) 700-850 (787, left: 700 and right: 720) (n = 9) in females. Number of support rods (left and right suction cups) in males 43-56 (49.9, left: 50 and right: 52) and in females 45-54 (49.5, left: 47 and right: 52) (see Table 1). Number of sclerites per support rod in males 1-5 (3.3, holotype: mean: 3.4, range: 3-4) (n = 589 rods) and in females 1-7 (4.6, allotype: mean: 4.9, range: 3-7) (n = 445 rods). Number of sclerites variable with position

on suction cup, shape of sclerites variable. Usually 3 to 4 sclerites per rod in males, 4 to 5 sclerites per rod in females (Figs. 13, 14); lower counts, such as one, usually due to missing sclerite(s), uncommon. Proximal sclerite usually rod- or vase-shaped, longer than other sclerites, which may be barrel-shaped to teardrop-shaped, slightly imbricated to offset, barely connecting with adjacent sclerites, and diminishing in size distally.

Second maxillae five-segmented with broad basal plate bearing three digitate spines; spines narrower, rounded distally. Outer two spines closer together than median spine and innermost spine; outermost spine slightly shorter than remaining two spines. Basal plate with elevated pad bearing coarse-pectinate scales and about three stout, simple setae that extend over base of median posterior spine (Figs. 9, 15). Bidentate to multidentate spines and coarse-pectinate scales clustered in distinct patches on ventral surfaces of last four segments. Two stout, simple setae on second segment, one on third and fourth segments posterodistally. Distal segment with two sharp claws (usually appearing offset and not side-by-side) and blunt, elongate lobe positioned above claws, short sensillum at tip of lobe.

Mouth tube short, lacking armature, not reaching thoracic accessory spines. Labium with three to four rows of small, embedded scales below mouth; short sensilla scattered on remainder of labium. Pair of serrated mandibles inside mouth tube. Preoral stylet present.

Etymology

The specific name is derived from the name of the host genus, *Ambystoma* (gender neuter), as a noun in apposition to the generic name, *Argulus* (gender masculine).

Remarks

Argulus ambystoma is most similar to *A. versicolor*, *A. americanus*, *A. maculosus*, and *A. diversus*, but can be distinguished from them by the shape and position of the respiratory areas and the secondary sexual modifications on the legs of males. The paddle-like structure on the third leg of male *Argulus ambystoma* resembles those of males of *A. americanus* and *A. diversus*. The number of suction cup rod sclerites also distinguishes *A. ambystoma* from both *A. maculosus* and *A. americanus* (usually 2-3 and 2 sclerites per rod in the latter two species, respectively). *Argulus ambystoma* is similar to *A. versicolor* in number and shape of sclerites in suction cup rods, but can be distinguished readily by the shape and position of the respiratory areas and pigmentation of the carapace (refer to Wilson 1902, 1904; Yeatman 1965 for figures of other species; except, note that at least some of the illustrations of *A. versicolor* in Yeatman do not apply to that species).

DISCUSSION

Only rarely have *Argulus* been recorded as parasites of amphibians (for example, Goin and Ogren 1956; Bower-Shore 1940; Sauer 1977; Cuvier 1798 in Wilson 1902; Lemos de Castro and Gomes-Corrêa 1985; Clark 2001). The first record of *Argulus* from *Ambystoma dumerilii* was obtained when salamanders were purchased from local fishermen at Lake Pátzcuaro to study their life history (R. Brandon pers. comm.; Brandon 1970). Salamanders harboring *Argulus* were captured in August 1968 (1 female) and December 1968 (1 female and 1 male), but the parasites were not noticed until April and May 1969, indicating that they were too small to observe easily when the salamanders were initially brought into the lab or that the species is cryptic on its host. Either may be the case, but the parasites were hidden among the gills of its host and were observed on the heads of salamanders in the evening only after the lights had been off for some time (R. Brandon pers. comm.). Also, when the lights were turned on, the parasites quickly moved toward the gills (R. Brandon pers. comm.). These observations support the cryptic nature of this argulid on *Ambystoma dumerilii* and may be the reason the species was not noticed until recently. None of the specimens collected by R. Brandon in 1969 could be located. The second record of *Argulus* on *Ambystoma dumerilii* resulted in the collection of the material used for the description; R. Brandon received some *A. dumerilii* from the Cincinnati Zoo and collected the *Argulus* from these animals. An additional observation of *Argulus* around the gills and on the head of wild caught *A. dumerilii* was supplied by S. Randal Voss (pers. comm.) in 1996.

TABLE 1

First maxillae support rod counts for male and female Argulus ambystoma, *new species (holotype and allotype counts in bold).*

	Male (n = 7)							Female (n = 6)					
Left Suction Cup	49	47	46	48	**50**	53	53	53	**47**	45	49	52	46
Right Suction Cup	48	51	43	50	**52**	52	56	48	**52**	–[a]	49	50	54
	Mean = 49.9; Range = 43-56							Mean = 49.5; Range = 45-54					
	Mean = 49.7; Range = 43-56 (male and female)												

[a]Structure missing.

The number of suction cup rods is a useful taxonomic character that rarely has been included in descriptions or redescriptions. A neglected aspect of suction cup sclerites has been variability within a species and on a single suction cup. Rizvi (1970) examined suction cup rods of *Argulus foliaceus* (Linné), and rod number was 40 to 51 (10 specimens). *Argulus japonicus* suction cup rod numbers varied from 38-50 with a mean of 44.6 (12 specimens), and asymmetry (left/right) was observed in all 12 individuals (Hsiao 1950). Pilgrim (1967) examined *A. japonicus* from New Zealand and reported a range of 44-50 suction cup rods with a mean of 45.9 (4 specimens, 7 suction cups). Suction cup rods of 15 *Argulus matuii* Sikama (29 suction cups) ranged from 75-83 in males and 81-95 in females with symmetry occurring in only three individuals (Sikama 1938). *Argulus ambystoma* suction cup rods ranged from 43 to 56 with a mean of 49.7 (13 specimens, 25 suction cups), and only one individual was not asymmetrical (Table 1). Variation in both sclerite number and shape has been noted by a few authors, depending on the position of rods in a suction cup (Fryer 1959; Rushton-Mellor and Boxshall 1994; Avenant-Oldewage and Oldewage 1995). Variation in sclerite number and shape also occurs in *A. ambystoma* and other North American *Argulus* spp. (pers. observ.). In *A. ambystoma* higher numbers of sclerites per rod usually occur in the anterolateral (outer) section of a suction cup rim, and the sclerites tend to be more bulbous or round anterolaterally, whereas sclerite numbers are lower posteriorly and on the inner margin, and sclerites tend to be more rod-like and slender; Fryer (1959) found the same trend in *Argulus ambloplites* Wilson. One female *A. ambystoma* had one long, unsegmented rod and a two-segmented rod, both spanning the entire width of the suction cup rim. Intraspecific variation in the length of the carapace alae also can be found among *Argulus* spp. (Meehean 1940; Fryer 1982), and *A. ambystoma* exhibited such variation.

Number of setae (or "spines") on the endopod of the first leg and number of "setae" on the caudal rami may be useful characters for taxonomy or systematics. Sikama (1938) indicated that three "spines" were present at the tip of the endopod in *Argulus matuii* (see his Fig. 11). Rushton-Mellor and Boxshall (1994) indicated that two setae were present on the last segment of the endopod of the first leg of *Argulus foliaceus* in the first developmental stage, whereas three setae were present in all later stages. *Argulus japonicus* has three setae at the tip of the endopod of the first leg, and three setae are present in the first naupliar stage according to Tokioka (1936). *Argulus stizostethii* Kellicott, *A. flavescens*, *A. rhipidiophorus* Monod, and *A. major* Wang also have the three setae (Kellicott 1880; Suárez-Morales and others 1998; Monod 1931; Wang 1960); *Argulus ambystoma* possesses the three setae as well, at least in adults. Benz and others (1995) stated that two spines were present at the tip of the endopod of *A. melanostictus*, as did Dana and Herrick (1837) for *A. catostomi* Dana and Herrick, but there are three setae in these species as well (pers. observ.). Three setae are difficult to observe because one seta is often hidden by the other two setae. *Argulus ambystoma*, *A. americanus*, *A. maculosus*, *A. versicolor*, *A. diversus*, *A. stizostethii*, *A. flavescens*, *A. foliaceus*, *A. meehani* Cressey, and *A. chesapeakensis* Cressey all have five "setae" on the caudal rami (this study; Shimura and Asai 1984; Yeatman 1965; Kellicott 1880; Suárez-Morales and others 1998; Leydig 1889; Cressey 1971), whereas *A. ellipticaudatus* Wang and *A. melanostictus* apparently have only four (Wang 1960; Benz and others 1995), *A. foliaceus* (3rd stage) has four (Rushton-Mellor and Boxshall 1994), and *A. japonicus* (1st stage) has three (Tokioka 1936).

The pocket on the third leg of male *A. ambystoma* is similar to the pocket of male *A. appendiculosus* Wilson shown by Sutherland and Wittrock (1986). Male *A. versicolor* and *A. americanus* also have pockets similar to those of the above-mentioned species (pers. observ.).

Sensilla of *Argulus* rarely have been mentioned or figured in the literature. Leydig (1889) and Debaisieux (1953) illustrated the type of sensillum shown herein (Fig. 2) as well as other sensilla found on *A. foliaceus*. Madsen (1964:22-23) mentioned the sensilla ("hairs") found on the rim of the carapace, anterior rim of head, and dorsal surface of carapace and stated that the sensilla were probably rheotactical. Smaller sensilla are abundant in the interspaces between the larger sensilla and have been figured most often on nauplius stages (Tokioka 1936; Rushton-Mellor and Boxshall 1994). Linnenbach and Hausmann (1983) included a photomicrograph of sensilla on *Argulus* sp., and sensilla and various scale types of *A. foliaceus* were shown in SEM micrographs by Lange and Sundermann (1990). Sutherland and Wittrock (1986:410) reported only sensory pits on the dorsal surface of the carapace of *A. appendiculosus*, hence there may be some taxonomic value in the distribution or presence/absence of sensilla as shown among the Copepoda (for example, Fleminger 1973). No pores or sensilla were observed on the dorsal surface of the thorax of *A. ambystoma* in this study.

The dorsal pores on the caudal rami have not been reported previously in the genus *Argulus* nor in any other member of the Branchiura, but similar pores on the ventral surface of the caudal rami of *Unicolax collateralis* Cressey and Boyle Cressey (Copepoda: Bomolochidae) were shown by Cressey and Boyle Cressey (1980, their Fig. 113e); however, they did not mention the pore specifically. The function of these pores is unknown. A small cyst measuring 160 μm was extracted from the left ala of the carapace of the holotype, but its identity has not been determined; another cyst may exist in the coxa of the right, second leg of a female individual, but no attempt was made to extract or positively identify the object. Lesions characteristic of crustacean shell disease were present on two males and three females.

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LITERATURE CITED

Ancona I, Batalla MA, Caballero E, Hoffmann CC, Llamas R, Martin del Campo R, Ochoterena I, Rioja E, Roca J, Samano A, Vega C, Villagran F. 1940. Prospecto biológico del Lago de Pátzcuaro [six papers and bibliography on Lake Pátzcuaro]. Anales del Instituto de Biología, Universidad Nacional Autónoma de México 11:417-513.

Avenant-Oldewage A, Oldewage WH. 1995. A new species of *Argulus* (Crustacea: Branchiura) from a bony fish in Algoa Bay, South Africa. South African J Zoology 30:197-9.

Barbour CD. 1973. A biogeographical history of *Chirostoma* (Pisces: Atherinidae): a species flock from the Mexican Plateau. Copeia 1973:533-56.

Benz GW, Otting RL, Case A. 1995. Redescription of *Argulus melanostictus* (Branchiura: Argulidae), a parasite of California grunion (*Leuresthes tenuis*: Atherinidae), with notes regarding chemical control of *A. melanostictus* in a captive host population. J Parasitology 81:754-61.

Bower-Shore C. 1940. An investigation of the common fish louse, *Argulus foliaceus* (Linn.). Parasitology 32:361-71.

Brandon RA. 1970. Size range, size at maturity, and reproduction of *Ambystoma* (*Bathysiredon*) *dumerilii* (Dugès), a paedogenetic Mexican salamander endemic to Lake Pátzcuaro, Michoacán. Copeia 1970:385-8.

Brehm V. 1942. Plancton del Lago de Pátzcuaro. Revista de la Sociedad Mexicana de Historia Natural 3:81-3.

Bunkley-Williams L, Williams EH Jr. 1994. Parasites of Puerto Rican freshwater sport fishes. Puerto Rico Dept of Natural and Environmental Resources and Mayaguez Dept of Marine Sciences, Univ of Puerto Rico, San Juan. 168 p.

Causey D. 1960. Parasitic Copepoda from Mexican coastal fishes. Bull of Marine Science of the Gulf and Caribbean 10:323-37.

Chacón-Torres A, Pérez Mungía R, Muzquiz Iribe E. 1991. Biología Acuática 1. Síntesis Limnológica del Lago de Pátzcuaro, Michoacán, México. Sría. de Difusión Cultural Editorial Universitaria, Universidad Michoacana de San Nicolás de Hidalgo. 48 p.

Clark VC. 2001. Natural History Notes: *Rana heckscheri* (River Frog). Ectoparasites. Herpetological Review 32:36.

Cressey RF. 1971. Two new argulids (Crustacea: Branchiura) from the eastern United States. Proceedings of the Biological Society of Washington 84:253-8.

Cressey RF. 1982. Branchiura. In: Hurlbert SH, Villalobos-Figueroa A, editors. Aquatic Biota of Mexico, Central America and the West Indies. San Diego (CA): San Diego State Univ Pr. p 196-7.

Cressey RF, Boyle Cressey H. 1980. Parasitic copepods of mackerel- and tuna-like fishes (Scombridae) of the world. Smithsonian Contributions to Zoology 311:1-186.

Dana JD, Herrick EC. 1837. Description of the *Argulus Catostomi*, a new parasitic Crustaceous animal, (with figures). Amer J Science and Arts 31:297-308 + I pl.

Debaisieux P. 1953. Histologie et histogenèse chez *Argulus foliaceus* L. (Crustacé, Branchiure). Cellule 55:245-90.

Eschmeyer WN. 1997. A new species of Dactylopteridae (Pisces) from the Philippines and Australia, with a brief synopsis of the family. Bull of Marine Science 60:727-38.

Espinosa-Huerta E, García-Prieto L, Pérez-Ponce de León G. 1996. Helminth community structure of *Chirostoma attenuatum* (Osteichthyes: Atherinidae) in two Mexican lakes. Southwestern Naturalist 41:288-92.

Fleminger A. 1973. Pattern, number, variability, and taxonomic significance of integumental organs (sensilla and glandular pores) in the genus *Eucalanus* (Copepoda, Calanoida). Fishery Bull 71:965-1010.

Fryer G. 1959. A report on the parasitic Copepoda and Branchiura of the fishes of Lake Bangweulu (northern Rhodesia). Proceedings of the Zoological Soc of London 132:517-50.

Fryer G. 1982. The parasitic Copepoda and Branchiura of British freshwater fishes: a handbook and key. Freshwater Biol Assn Scientific Publ No. 46, Cumbria, UK. 87 p.

Fucugauchi Suárez del Real MG, García Magaña L, Brito Arjona B del R. 1988. Análisis previo de la parasitofauna de peces de la Laguna del Rosario, Huimanguillo, Tabasco. Divulgación Científica (Diciembre 1988):319-35.

Goin CJ, Ogren LH. 1956. Parasitic copepods (Argulidae) on amphibians. J Parasitology 42:172.

Hobbs HH Jr. 1989. An illustrated checklist of the American crayfishes (Decapoda: Astacidae, Cambaridae, and Parastacidae). Smithsonian Contributions to Zoology 480:iii + 1-236.

Hsiao SC. 1950. Copepods from Lake Erh Hai, China. Proceedings of the United States National Museum 100:161-200.

Kellicott DS. 1880. *Argulus Stizostethii*, N.S. Amer J Microscopy and Popular Science 5:53-8 + I unnumb. pl.

Lange J, Sundermann G. 1990. Die karpfenlaus *Argulus* im rasterelektronenmikroskop. Mikrokosmos 79(3):65-9.

Lemos de Castro A, Gomes-Corrêa MM. 1985. *Argulus hylae*, espécie nova de Argulidae parasita de girino. In: XII Congresso Brasileiro de Zoologia, Resumos. 27 de Janeiro a I de Fevereiro de 1985, Universidade Estadual de Campinas, Campinas, S.P. p 52 [abstract].

Leydig F. 1889. Ueber *Argulus foliaceus*. Neue mittheilung. Archiv für Mikroskopische Anatomie 33:1-51 + 5 pl.

Linnenbach M, Hausmann K. 1983. Die karpfenlaus *Argulus*: Ein ektoparasit an fischen mit interessanten feinstrukturen. Mikrokosmos 72:70-4.

Madsen N. 1964. The anatomy of *Argulus foliaceus* Linné with notes on *Argulus coregoni* Thorell and *Argulus africanus* Thiele. Part 1. Integument, central nervous system, sense organs, praeoral spine, and digestive organs. Lunds Universitets Årsskrift. N.F. Avd. 2, Bd 59, Nr 13:1-32.

Meehean OL. 1940. A review of the parasitic Crustacea of the genus *Argulus* in the collections of the United States National Museum. Proceedings of the United States National Museum 88(3087):459-522.

Monod Th. 1931. Sur quelques Crustacés aquatiques d'Afrique (Cameroun et Congo). Revue de Zoologie et de Botanique Africaines 21:1-36.

Olson AC Jr. 1972. *Argulus melanostictus* and other parasitic crustaceans on the California grunion, *Leuresthes tenuis* (Osteichthyes: Atherinidae). J Parasitology 58:1201-4.

Osorio-Sarabia D, Pérez-Ponce de León G, Salgado-Maldonado G. 1986. Helmintos de peces del Lago de Pátzcuaro, Michoacán I: Helmintos de *Chirostoma estor* el "pescado blanco." Taxonomía. Anales del Instituto de Biología, Universidad Nacional Autónoma de México (Serie Zoologia) 57:61-92.

Peresbarbosa-Rojas E, Pérez-Ponce de León G, García Prieto L. 1997. Helminth community structure of some freshwater fishes from Pátzcuaro, Michoacán, México. Tropical Ecology 38:129-31.

Peresbarbosa-Rojas E, Pérez-Ponce de León G, García Prieto L. 1994. Helmintos parásitos de tres especies de peces (Goodeidae) del Lago de Pátzcuaro, Michoacán. Anales del Instituto de Biología, Universidad Nacional Autónoma de México (Serie Zoologia) 65:201-4.

Pérez-Ponce de León G, Mendoza GB, Pulido FG. 1994. Helminths of the charal prieto, *Chirostoma attenuatum* (Osteichthys: Atherinidae), from Pátzcuaro Lake, Michoacán, México. J Helminthological Soc of Washington 61:139-41.

Pilgrim RLG. 1967. *Argulus japonicus* Thiele, 1900 (Crustacea: Branchiura) - A new record for New Zealand. New Zealand J Marine and Freshwater Research 1:395-8.

Pineda R, Páramo S, Del Rio R. 1995. A new species of the genus *Argulus* (Crustacea: Branchiura) parasitic on *Atractosteus tropicus* (Pisces: Lepisosteidae) from Tabasco, Mexico. Systematic Parasitology 30:199-206.

Pineda-López R, Carballo Cruz V, Fucugauchi Suárez de Real MG, García Magaña L. 1985. Metazoarios parásitos de peces de importancia comercial de la Región de los Ríos, Tabasco, México. Usumacinta, Gobierno del Estado de Tabasco 1: 197-270.

Rizvi SSH. 1970. Studies on the structure of the sucker and seasonal incidence of *Argulus foliaceus* (L., 1758) on some freshwater fishes (Branchiura, Argulidae). Crustaceana 17:200-6.

Rosas I, Mazari M, Saavedra J, Báez AP. 1985. Benthic organisms as indicators of water quality in Lake Pátzcuaro, México. Water, Air, and Soil Pollution 25:401-14.

Rupp MB. 1990. An abbreviated method for preparing *Ixodes damini* ticks for scanning electron microscopy observation. J Electron Microscopy Technique 15:99-100.

Rushton-Mellor SK, Boxshall GA. 1994. The developmental sequence of *Argulus foliaceus* (Crustacea: Branchiura). J Natural History 28:763-85.

Sauer F. 1977. Die karpfenlaus als parasit an lurchen. Mikrokosmos 66:19-20.
Shimura S, Asai M. 1984. *Argulus americanus* (Crustacea: Branchiura) parasitic on the bowfin, *Amia calva*, imported from North America. Fish Pathology 18:199-203.
Sikama Y. 1938. On a new species of *Argulus* found in a marine fish in Japan. J Shanghai Sci Institute (Section III) 4:129-34 + pls. XI-XII.
Suárez-Morales E, Gasca R. 1997. *Argulus flavescens* (Crustacea: Arguloida), parásito de *Sphoeroides testudineus* (Osteichthyes: Tetraodontidae) en Quintana Roo, México. Revista de Biología Tropical 45:1270-2.
Suárez-Morales E, Gasca R, Kim I-H, Castellanos I. 1998. A new geographic and host record for *Argulus flavescens* Wilson, 1916 (Crustacea, Arguloida), from southeastern Mexico. Bull Marine Sci 62:293-6.
Sutherland DR, Wittrock DD. 1986. Surface topography of the branchiuran *Argulus appendiculosus* Wilson, 1907 as revealed by scanning electron microscopy. Zeitschrift für Parasitenkunde 72:405-15.
Thorell T. 1865. Om *Argulus dactylopteri*, en ny vestindisk hafsargulid. Öfversigt af Konglika Vetenskaps-Akademiens Förhandlingar 1864(10):609-14 + pl. 16.
Thorell T. 1867. On *Argulus dactylopteri*, a new marine argulid from the West Indies. Annals and Magazine of Natural History (Series 3) 19:45-9.
Tokioka T. 1936. Larval development and metamorphosis of *Argulus japonicus*. Memoirs of the College of Science, Kyoto Imperial Univ (Series B) 12:93-114.
Tressler WL. 1954. Fresh-water Ostracoda from Texas and Mexico. J Washington Acad Sci 44:138-49.
Ueno M. 1939. Zooplankton of Lago de Pátzcuaro, Mexico. Annotationes Zoologicae Japonenses 8:105-14.
Vargas VM, Fallas BF. 1976. Brote de argulosis por *Argulus japonicus* Thiele, 1900 (Crustacea: Branchiura) en Costa Rica. Resúmenes de Trabajos Libres. IV Congreso Latinoamericano de Parasitología, IV Congreso Centroamericano de Microbiología y Parasitología, and III Congreso Nacional de Microbiología y Parasitología, San José, Costa Rica, 7-11 Diciembre 1976, Federación Latinoamericana, de Parasitólogos Asociación Costarricense de Microbiología y Parasitología, Impreso en la Oficina de Publicaciones de la Universidad de Costa Rica, San José. p 105 [abstract A-13].
Wang K-N. 1960. Two new species of *Argulus* from fresh-water fishes in China. Acta Zoologica Sinica 12:242-7 + 2 pls.
Wilson CB. 1902. North American parasitic copepods of the family Argulidae, with a bibliography of the group and a systematic review of all known species. Proceedings of the United States National Museum (1903) 25:635-742.
Wilson CB. 1904. A new species of *Argulus*, with a more complete account of two species already described. Proceedings of the United States National Museum 27:627-55.
Wilson CB. 1936. Copepods from the cenotes and caves of the Yucatan Peninsula, with notes on cladocerans. Carnegie Institution of Washington, Publ No. 457:77-88.
Yamaguti S. 1963. Parasitic Copepoda and Branchiura of fishes. New York: Wiley Interscience Publ. 1104 p.
Yeatman HC. 1965. Redescription of the freshwater branchiuran crustacean, *Argulus diversus* Wilson, with a comparison of related species. J Parasitology 51:100-7.

Note added in proof:

Argulus americanus, *A. diversus*, and *A.* sp. were reported recently from river frog tadpoles (*Rana heckscheri*) in Florida and South Carolina by Clark (2001) and Wolfe and others (2001).

Clark VC. 2001. *Rana heckscheri* (river frog). Ectoparasites. Herpetological Review 32:36.
Wolfe BA, Harmes CA, Groves JD, Loomis MR. 2001. Treatment of *Argulus* sp. infestation of river frogs. Contemporary Topics in Laboratory Animal Science 40: 35-6.