A new record of the Haematophagic Praobdellidae Leech (Hirudinida) in the Peninsular Ranges of Baja California, México, and a Leech distribution review

William H. Clark^{1,2} & Peter Hovingh^{3*}

¹Museo de Artrópodos de CICESE, Departamento de Biología de la Conservación, Centro de Investigación Cíentifica y de Educación Superior de Ensenada, Carretera Ensenada-Tijuana No. 3918 Codigo Postal 22860, Ensenada, Baja California, México

²Orma J. Smith Museum of Natural History, The College of Idaho, Caldwell, ID 83605 4432; e-mail: clarkfam1@mindspring.com

³721 Second Avenue, Salt Lake City, UT 84103; e-mail: phovingh@xmission.com

*Corresponding author

ABSTRACT	A Praobdellidae leech and its palm oasis environment is described from Baja California, Mex-
	ico. This leech is tentatively identified as Pintobdella cajali Caballero, 1932 by somite annu-
	lation and reproductive tract. Praobdellid records were noted in literature and museum from
	Baja California Sur and Arizona. Six leech species are noted from the Peninsula Range in
	southern California (five species) and Baja California (one species), five taxa in the Gila River
	drainage of Arizona and New Mexico, one species from Sonora, and three species from
	Sinaloa illustrating the effects of the region's aridness and/or the paucity of leech surveys in
	northwestern Mexico.

KEY WORDS Hirudinida; Praobdellidae; arid environments; palm oasis; Baja California.

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INTRODUCTION

The North American Hirudiniformes leeches include the haematophagic Macrobdellidae and Praobdellidae and the macrophagus Haemopidae, the Haemopid being distinguished from the haematophagic leeches by the massive penile sheath (Sawyer, 1986). Herein we describe a leech from Baja California (the Baja leech), an area most isolated from both northern and southern Hirudiniformes. This leech was collected March 1, 2000 as a part of the Franco and de la Cueva (2001) research studies on the biodiversity importance of the palm oases south and east of the Sierra San Pedro Martir. They were not able to list invertebrates found in the oases in such a short chapter. Arriaga & Rodríguez (1997) produced the most comprehensive overview of the palm oases in Baja California Sur, with the invertebrate chapter (Jimenez et al., 1997), not listing any leeches. This Baja leech was dissected some 20 years ago and determined not to be *Haemopis marmorata* (the only leech in Death Valley, California), *H. lateromaculata* of western United States (Hovingh, 2006, 2020), or *H. caballeroi* from Federal District, Mexico (Richardson, 1971), based on the absence of the massive male penile sheath. This cold case is now reinvestigated and reported herein. Since the leech site is geographically, geologically,

and hydrologically isolated and unique, a physical description of the Peninsular Ranges is described below. The discussion addresses the arid environment of the Peninsular Range, northwestern Mexico, and southwestern United States, and the presence of leeches.

MATERIAL AND METHODS

Study area

The granitic Peninsular Ranges stretches 1500 km from southern California Transverse and Sierra Nevada Ranges to the tip of Baja California, including the Palomar, San Jacinto, Cuyamaca, and Laguna Ranges (Big Laguna Lake elevation 1825 m.s.l.) east of San Diego, California and the Sierra de Juárez and Sierra San Pedro Mártir (elevation to 3078 m m.s.l.) in northern Baja California. The geology is a result of Farrallon Pacific Plate subduction ending 30 Ma, followed by the western North America Basin and Range extensions (Martin-Barajas, 2014).

The Late Miocene <12 Ma extension resulted in subsidence of Sonora and southern California and Arizona, allowing marine incursion into the narrow zone forming the Gulf of California (7 Ma). The Pacific Plate is moving northwest (12 to 6 Ma) relative to the continental plate by the San Andreas fault system, placing Baja California within the Pacific Plate. The Peninsular Ranges have gradual slopes to the Pacific and steep escarpments to the Gulf of California, similar to the Sierra Nevada Range in California.

The Yaqui-Papigóchic River, Yaqui-Aqua Prieta River, and Magdelina-El Cumaro River in northwestern Mexico and the Colorado-Gila Rivers in southwestern United States are major rivers flowing into the Gulf of California. River paleoconnectivty occurred between the Rio Grande River (Gulf of Mexico) and southern California via the Gila River of southern New Mexico and Arizona, allowing aquatic fauna interbasin transfers of fish, mollusk, and leeches between the southern Great Plains and the Pacific Coast drainages (Taylor, 1985; Hershler et al., 2002; Reheis et al., 2008; Hovingh et al., 2008; Hovingh, 2020). The present Colorado River drainage is a result of impoundments and stream captures upstream of the Grand Canyon, through flowing the Grand Canyon (6 Ma), the impoundments below Grand Canyon (5.6–5 Ma), breaching these impoundments, and entering the Gulf 5.5 Ma (Reheis et al., 2008). The Grand Canyon, itself, is a major barrier for mollusk and leech upstream dispersal, and the Green and Colorado Rivers in Utah lack leeches. During the Pleistocene, the ocean was 120 km lower, with the Colorado River outflows extending 125 km further into the Gulf to 31° N latitude with broad coastal flats extending to 30° N.

Methods

The two leech specimens were observed swimming and collected with an insect net in the water column pool (Fig. 1) by W.H. Clark, J. Dominguez, and E. Franco. The specimens were relaxed with nicotine in water and later preserved in 70% ethyl alcohol. Voucher specimens were deposited in the Orma J. Smith Museum of Natural History, The College of Idaho, Caldwell 83603 (CIDA 107400, dissected specimen) and the Museo de Artropodos del Centro de Investigación Cientifica y de Educación Superior de Ensenada (CICESE), Ensenada, Baja Califonia, Mexico (MABC-060-001, whole specimen, formerly CIDA 107401).

Water quality variables were measured with a Yellow Springs Instrument Company Environmental Monitoring Systems Model 6 (Yellow Springs Instrument Company 2000). Measurements were taken in mostly standing water at a depth of approximately 30 cm. The instrument was field calibrated prior to use and checked following use.

The area precipitation was measured with three battery powered Rain $Wise_R$ tipping bucket rain gauges. One gauge is located in an arroya at Ralph and Pat Scoonmaker's house at Rancho Santa Inez. Two gauges near Rancho Santa Inez were located near our study site in the Catavina boulder field, with more open aspects. These are the closest precipitation gauges to the Santa Maria area and are about 15 air km distant, west of Santa Maria.

RESULTS

Site Description

Misión Santa Maria ruins (Geolocate 29.74743°N, 114.55430°W) was built between two

palm oases in the Santa Maria arroyo eastward of Santa Inez and Cataviña and draining to Arroya San Francisquito and Gonzaga Bay (Gerhard & Gulick, 1967). The Jesuit Padres established this mission in 1767 for the Cochimí Indians. After seven months. the Jesuits were expelled from the western hemisphere, whereby the Franciscan Padres in 1768 occupied the site until 1769 before transferring their operation to San Fernando de Velicatá mission near El Progresso. Rancho Santa Inez in 1950 built a "road", often washed out with monsoons, from Santa Inez 14.5 miles to the mission and then towards the Gulf coast at Punta Final, largely following the Santa Maria arroyo. The road was never completed due to the sheer cliffs and boulders in the area. Murvosh and Allen (1994) suggest that there is permanent water in this arroyo but did not actually visit the area.

Baja California palm oases are mesic habitat islands restricted to permanent or shallow ground water, with most (171 out of 184) occurring in the southern half of the peninsula (Grismer, 2002; León de la Luz, 2014). The Misión Santa Maria in Arroya de Santa Maria occurs within the San Felipe Desert region of the Sonoran Desert Biotic Province, receiving five cm average rainfall and is the driest region of the peninsula (Roberts, 1989). The mesic microhabitat is dominated by the palms Brahea armata (Blue Fan Palm, the dominant palm at Santa Maria) and the Washingtoni filifera (California Fan Palm), Juncus, sedges, and cattail Typha domingensis (Grismer & McGuire, 1993). The riparian zone is considered the moist soil region during the driest season March to July (León de la Luz, 2014). The semipermanent water can be utilized by Hyliola cadaverina (formerly Hyla) and Bufo punctatus amphibians (Grismer, 2002) with two amphibian species noted in Santa Maria arroya, and the mammals (suggested to be involved with the fan palm seed dispersal) foxes, coyotes, lynx, pumas, bighorn sheep and mule deer (Wehncke et al., 2009), as well as livestock (cattle, horses, and mules impacts noted in Santa Maria arroya) first introduced by the missionaries from the mainland Mexico (Crosby, 1994; Vernon, 2002).

The collection of two leeches was made at 1700 h, 1 March 2000, below Misión Santa Maria (Latitude 29.7433°N, Longitude 114.5500° W), 540 m altitude (Figs. 1, 2). Shaded air temperature at the time of collection was 15.8 °C. The pool habitat was clear. The granitic stream bed is rocky, with boulders. Field water quality measurements taken at a depth of approximately 30 cm were as follows: temperature 14.59 °C, dissolved oxygen 6.66 mg/L (66.3 % saturation), pH 7.56, and specific conductance of 1418 mS/cm. The arroyo is very rocky and full of large boulders.

Stream flow in these arroyos depends on variable precipitation in the watershed of interest. Our rain gauge at Rancho Santa Ines recorded 2.5 cm of precipitation during the time period between 20 March 1999 and March 2000. The mean precipitation from the two rain gauges near Rancho Santa Ines was 6.5 cm from 20 March 1999 through 29 February 2000. No leeches were found in the Santa Maria area on a return visit in May 2020. Stream flow was much reduced than what we encountered in 2000.

Specimen descriptions

EXTERNAL MORPHOLOGY. Two specimens: length 29, 30 mm, mid body width 6.0 mm, posterior sucker width 5.0 mm. The sucker width to total body length ratio was 0.17, much larger than comparable ratios of *Haemopis caballeroi* (0.12), *H. marmorata* (0.08), and *H. lateromaculata* (0.11) (Klemm, 1985 from illustrations; Richardson, 1971). Body length and width measurements are dependent on the state of relaxation and the post relaxation contraction. The ventrum is lighter than the dorsum, both being plain and without patterns.

The meristic characteristics were similar to *Haemopis* (Mann, 1954), with uniform annular widths and differing from the uniquely variable annular widths of *H. caballeroi* (Richardson, 1971). The presence of sensillae on *a2* throughout the length marked the body somites, with somite annulation being I - III uniannulate, somites IV and V biannulate, somites VI - VII triannulate, somite VIII tetraannulate, and somites IX - XXIII quinqueannulate, and the posterior somite annulation being XXIV tetraannulate, XXV triannulate, XXVI biannulate, and XVII uniannulate with the anal opening at segment XXVII/sucker (Mann, 1954; Sawyer, 2019).

Five pair of parabolic placed eyes occur on somites II to VI (Mann, 1954). The male and female gonopores occurred at XI *b5/b6* and XII *b5/b6*, respectively, separated by 5 annuli. Whitened

nephridiopores occur on the posterior side of b2 annuli on somites VIII to XXIV as noted by Mann (1954) for *Haemopis*. The mouth had three jaws without teeth (at 40x).

INTERNAL MORPHOLOGY. Specimen CIDA 107400 was dissected to examine the reproductive organs. The diminutive reproductive organs occurred within segments XI and XIII (Fig. 3). The vagina occurred within XIII b1/b2 and XIII a2, with paired oviducts arching anteriorly and lateral to XII/XIII and posteriorly to the paired ovisacs in XIII b2. The prostate occurred between XII b2 and XIII b2 and XIII b2. The prostate occurred between XII b2 and XIII b2 and XIII b2. The prostate occurred between XII b2 and XII b2. More thorough anatomical analysis including the testisac positions, the position and number of crop caeca, and the male and female reproductive ducts would be enhanced with histological serial sectioning.

TAXONOMY. The initial external appearance of the Baja leech suggested *Haemopis*. However, the

internal organs revealed the lack of the Haemopid massive penile sheath and the presence of the penil sheath and the ovisac posterior to Segment XII, and the absence of Macrobdellid external ventral copulatory glands, thus eliminating for consideration the North American Haemopis, Macrobdella, and Philobdella (Klemm, 1985), and with diminutive male and female reproductive organs. Soós (1969) reviewed the Hirudiniformes, Richardson (1969) examined a specimen Pintobdella cajali Caballero, 1934 provided by C.E. Cabellero, and Sawyer (1986) reviewed the morphology of Pintobdella cajali and Limnobdella mexicana Blanchard, 1893 from Mexico. These two genera have been classified in the subfamily Macrobdellinae (Sawyer, 1986), the family Semiscolecidae (Phillips & Siddall, 2009) and the family Praobdellidae (Phillips et al., 2010; Oceguera-Figueroa & León-Règagnon, 2014).

The western hemisphere Praobdellids have gonopore separations of five annuli, similar to the



Figure 1. Pool habitat of Praobdellidae collected near Misión Santa Maria, Baja California, Mexico. The photograph was taken late afternoon. Note the stones in the pool bottom and vegetative reflections.

Eurasian and north African sister genus *Limnatis*, whereas the African *Praobdellida* species has gonopore separations of seven or more annuli (Sawyer, 1986). The absence of teeth was noted for the Asian Praobdellid *Dinobdella ferox* (Sawyer, 1986) and two populations of *Haemopis marmorata* in the western United States Bonneville Basin and Snake River drainage (Hovingh, 2020), with Sawyer (2019) noting possible artifactual loss of teeth during preservation. The position and structure of testisacs and the thin walled non-muscular tortuous sperm ducts (Richardson, 1969), the position and structure of oviducts, the teeth, and the position and number per segment of the crop caeca were not detected.

Pintobdella cajali and *Limnobdella mexicana* were distinguished by their segments, the *P. cajali* having 15 five-annulated segments with XXV being triannulated, while *L. mexicana* having 16 five-annulated segments with XXV being tetraannulated (Richardson, 1969). The linear mid-dorsal position

of the male and female reproductive organs (Fig. 3) were similar to *P. cajali*, as shown in Richardson (1969: figure 1C) and by Sawyer (1986: figure 17.15 D), and distinguished from the lateral forms of *L. mexicana* (Richardson, 1969: figure 1D; Sawyer, 1986: figures 17.15 C). The pigmentation on the Baja form is without linear ventral patterns, and contrasts with the *L. mexicana* of Oceguera-Figueroa & León-Règagnon (2012, figure 1C). By these above criteria, the Baja leech is *P. cajali*.

The *Pintobdella* and *Limnobdella* taxon have been problematic. Ringuelet (1982) recognized the genus *Limnobdella* with five species including *L. chiapasensis*, and *Pintobdella* with one species *P. cajali*. Phillips et al. (2010) recognized *L. chiapasensis* as *P. chiapasensis*. Oceguera-Figueroa and León-Règagnon (2014) recognized *L. mexicana* as valid, and invalidated and reclassified *L. tehuacanea*, *L. olivacea*, *L. profundisulcata*, and *P. cajali* as *L. mexicana*. This current study identified *P. cajali* by criteria Richardson (1969) and Sawyer



Figure 2. Palm oasis near Misión Santa Maria, Baja California, Mexico. The pools containing Praobdellidae are located in the lower left of the photograph.

Figure 3. The noted reproductive organs of the Baja California Praobdellid leech. Male reproductive organs: E, the paired epididymis; \eth , the gonopore; P, the prostate. The female reproductive organs: \heartsuit , the gonopore (ventral to the prostate); V, vagina with paired ovisacs.

(1986), and is distinguishable from *L. mexicana* with respect to segmentation, pigmentation, and reproductive organ alignments.

The family Praobdellidae consists of two clades: the *Limnobdella* and *Limnatis* clade and the *Tyrannobdella*, *Pintobdella*, *Myxobdella*, and *Dinobdella* clade (Phillips et al., 2010). Two species are recognized in Mexico: *Limnobdella mexicana* Blanchard, 1893 and *Pintobdella chiapasensis* (Phillips et al., 2010; Oceguera-Figueroa & León-Règagnon, 2014). Richardson (1969) and Sawyer (1986) distinguished *L. mexicana* and *P. cajali* by morphological features as segmentation, reproductive organs, and the number of crop caeca per somite.

DISTRIBUTION. The distribution of Praobdellid leeches in Mexico extended south of latitude 23°N (at San Jose, Tamaulipas (22.41767°N, 99.06334°W, Discover Life GBIF 137388656) (Oceguera-Figueroa & León-Règagnon, 2014). The Misión Santa Maria leech at 29.74°N extends the range northward. Oceguera-Figueroa and León-Règagnon (2014) noted no freshwater leeches in Baja California, while Ringuelet (1982) noted *Limnobdella mexicana* at Santa Agueda (27.5990° N, 112.3554° W) whose spring water has been piped to the coastal mining town of Santa Rosalìa (Gerhard & Gulick, 1967). The eastern hemispheric *Limnatis* (?) was collected from Tucson, Arizona, 26 June 1917 (USNM 00037507), determined not to be *Haemopsis* (Hovingh, 2020), and suggested Praobdellid occurrence in the United States, arriving by movement of livestock to Tucson.

The Praobdellid are semipermanent parasites feeding on mammalian membranous tissues (Sawyer, 1986; Phillips et al., 2010) and amphibians (*Limnotis* Sawyer, 1986). Their location in Baja California and possibly Arizona would suggest movement within their livestock host from mainland sites of Mexico or even from the eastern hemisphere. Sawyer (1986: 452) noted *Dinobdella ferox* transport by deer from the Molucca Islands via Amsterdam to the London Zoo.

DISCUSSION

The North American leech distribution can be explained by three hypothesis:

(1) Aquatic fauna Neogene paleo-connectivity that also explains the present distribution of fish, mollusk and leech species (Taylor, 1985; Hershler et al., 2002; Reheis et al., 2008; Hovingh, 2020). The leech Mooreobdella microstoma distribution overlaps two major western North American paleoconnectivity patterns: the Idaho Snake River drainage to southern California, and the Great Plains Rio Grande drainage and the Gila River to southern California (Hovingh et al., 2008; Hovingh, 2020). Leech access to Baja California from southern California and Arizona could occur through suitable habitats during the Pleistocene glacial periods with the 120 m lower sea levels, with cooler temperature, and more precipitation, or before the 7 Ma peninsular isolation by the San Andreas fault system.

(2) Haematophagic leech distribution transported on their avian (*Theromyzon*) and mammalian (*Placobdella kwetlumye*) hosts, surviving their hosts transport, and surviving the terminal aquatic habitat with varying water quality, quantity, and



temperature in the arid western North America. The eastern haematophagic turtle/mammal leech *Placobdella rugosa* was found in 1917 west of the continental divide in southeastern Arizona at a cavalry military base, most likely transported via horses and cattle from the Great Plains (Hovingh, 2020).

(3) The haematophagic Praobdellid leech, living semi-permanently within membranous tisssue of their mammalian hosts (Sawyer, 1986; Phillips et al., 2010), most likely were transported into arid region of the Santa Maria Misión oasis and Santa Agueda by infested livestock, and maintained in part by amphibian hosts. The Praobdellid leeches are most likely the only leech species to occupy aquatic habitats of Baja California, as the Peninsular Range geography and arid environments prevent aquatic paleo-connectivity for even the *Theromyzon* or *Placobdella* leeches.

Five leech species have been collected from the Peninsular Range in southern California, suggesting aquatic fauna paleo-connectivity with the Colorado River or coastal California (Hovingh, 2020). Two recent collections (since 2000 C.E.) include Helobdella robusta in the Cuyamaca Range (1425 m m.s.l.) within the San Diego River drainage, and the endemic leech Erpobdella anoculata in the Laguna Range 1825 m m.s.l. of the Tijuana River basin (Hovingh, 2020), the latter first collected in 1889 by C.R. Orcutt, a San Diego botanist specializing in Mexico, Central America, and the Carribean Islands. Three historically collected leech species in 1875 by E. Palmer, a botanist and archeologist collector of Mexico, United States, and South America include Erpobdella punctata and Helobdella stagnalis (a species under taxonomic revision) near Campo in the Tijuana River drainage and Helobdella papillata collected at Spring Station in the Jucumba Mountains along the old (1870) Highway 80 turnpike (Verrill, 1875; Siddall & Borda, 2003), with drainage to the Colorado Desert and Colorado River, sites without any leeches in the 1990's surveys.

Of the 13 leech species found in Gila River (excluding the Salt River tributary) drainage of southern Arizona and New Mexico, five taxa occur in the hot desert biome 1125 to 1750 m msl: *Mooreobdella microstoma* (a widespread United States species), *Motobdella sedonensis gila*, *Helobdella stagnalis* (species undetermined), *H. papillata*, and *H. robusta* (Hovingh, 2020). *Motobdella s. gila* were found in the Mexican drainage basin of Agua Priete/Yaqui River drainage and Helobdella robusta in Magdelina-El Cumaro River drainage, both in Arizona. Mooreobdella ochoterenai was noted in Sonora and Sinaloa and Haementeria officinalis and Helobdella elongata noted in Sinaloa, with no freshwater leeches occurring in Baja California (Oceguera-Figueroa & León-Règagnon, 2014). Limnobdella mexicana was noted in Baja California at Santa Agueda (Ringuelet, 1982). These limited Mexican leech occurrences suggests an absence of leech surveys in northern Mexico similar to the paucity of leeches in the intermountain United States in 1986 (Hovingh, 1986), or the regional aridness and water development and human consumption as in the United States. Limnatis, USNM 00037507, 26 June 1917, Tucson, Arizona, served by the Santa Cruz River flowing north from the Sonora border to the Gila River, may be a northern record for the Praobdellid species.

Fresh-water Praobdellidae leeches were found in Baja California, Mexico. Little is known of their prevalence, distribution, and ecology in the Sonoran and Baja California deserts. Praobdellid leech transport and life history mostly within livestock protects this leech from the arid environments. This contrasts with the more northerly Haemopid, Erpobdellid, and Glossiphonid leeches, unlikely to be found in lower elevation permanent waters of the Sonoran desert, and would be limited to the upper reaches of suitable aquatic habitats in the Baja California Sierra de Juárez Range south of the California border. The Sierra San Pedro Martir Range may be beyond the paleoconnectivity reaches of these northerly leeches, and are probably excluded from Baja California south of Sierra de Juarez Range.

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