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FRESHWATER SHRIMP OF THE GENUS *MACROBRACHIUM* (DECAPODA: PALAEMONIDAE) FROM THE BAJA CALIFORNIA PENINSULA, MÉXICO

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A B S T R A C T

Freshwater decapods like the palaemonid river shrimp have received little attention in the Baja California Peninsula, México. From the first formal report in 1878 to now, only three *Macrobrachium* species have been reported (*M. americanum*, *M. digueti*, and *M. tenellum*) from the peninsula in only three basins. We made a taxonomic study of freshwater shrimp, which included an extensive field survey at 81 sites distributed on both the Pacific and the Gulf of California slopes and a revision of material from the area that had been deposited in scientific collections. We report six species of *Macrobrachium* by adding *M. hobbsi*, *M. michoacanus*, and *M. olfersii*. We also discuss some aspects of the diversity and conservation of these species in the peninsula and provide an identification key for the *Macrobrachium* shrimp of northwestern México.

Introduction

The Baja California Peninsula in northwestern México is the second longest and believed to be the most geographically isolated peninsula in the world (Durham and Allison, 1960). Surrounded by the Gulf of California (Sea of Cortés) and the Pacific Ocean, it extends about 1500 km from the México-U.S.A. border in the north to Cabo San Lucas in the south. Its average width is about 70 km. The peninsula is politically divided into two Mexican states, Baja California and Baja California Sur, with the interstate border at the 28°N parallel. The peninsula has a wide range of climatic conditions, though arid conditions are predominant. The general physiography is characterized by outstanding mountainous chains, which extend along the peninsula, with numerous basins and coastal plains on both the Gulf of California and the Pacific slopes. There are no permanent rivers, but freshwater springs, intermittent creeks, and small water bodies occur forming unique oasis ecosystems (Arriaga and Rodríguez-Estrella, 1997).

Maya et al. (1997) recognized 184 oases in the peninsula, but only 77 were recorded to have surface water. Besides the presence of freshwater (surface or interstitial soil water), the oases are characterized by the assemblage of species representing biogeographic relicts of subtropical mesophilic communities surrounded by the typical vegetation of the Sonoran Desert (Grismer, 1994). The vegetation and fauna, such as arachnids, amphibians, reptiles, birds, and mammals, have been studied in representative oases (Arriaga and Rodríguez-Estrella, 1997). However, freshwater crustaceans like the palemonid river shrimp have received little attention.

Palaemonids are among the most abundant and diverse shrimp that inhabit seawater and freshwater in both tropical and temperate waters (Wicksten, 1983). The genus *Macrobrachium* is well known because of the number of species, wide geographic distribution, and commercial importance (Holthuis, 1952; Villalobos, 1982). The species of *Macrobrachium* have a primary tropical distribution (Hedgpeth, 1949; Jayachandran, 2001). In the American continent, they have been reported from the Illinois River basin, USA (Bowles et al., 2000) to Argentina (Rodríguez De La Cruz, 1965; Acuña, 2002) and from the Gulf of California to Perú (Holthuis, 1952; Wicksten and Hendrickx, 2003).

The genus *Macrobrachium* is distinguished from other palaemonid genera by the following morphological traits; carapace with a projecting rostrum, mandibles with molar process furnished with a triarticular palp, first pair of pereiopods chelate and slender and as long as the carapace, second pair chelate and often in males longer than the entire body, posterior three pairs of pereiopods simple, telson triangular, terminating in a single tip (Bate, 1868; Holthuis, 1952; Mossolini and Bueno, 2003). They also have hepatic and antennal spines and two pairs of spines on the dorsal surface of telson (Hedgpeth, 1949; Holthuis, 1952). Holthuis (1952) concluded that only a few characteristics are available for identification of the species of *Macrobrachium* and that females often differ strongly from males. Villalobos (1982) proposed that the best identification characteristics are the shape of the rostrum and the chelae of the male's second pair of pereiopods.

The presence of freshwater shrimp in the Baja California Peninsula was first annotated in 1780 by the Jesuit priest Del Barco (León-Portilla, 1988). However, the first formal record was given by Lockington (1878), who reported *Macrobrachium tenellum* (Smith, 1871) (cited as *Palaemon longipes*) from the oasis of Mulegé. From the same oasis Bouvier (1895) also reported *M. americanum* Bate, 1868 (cited as *Palemon jamaicensis*) and *M. tenellum* (cited as *P. forceps*) and described a new species, *M. digueti* (Bouvier, 1895) (cited as *Palaemon digueti*). Holthuis (1952),

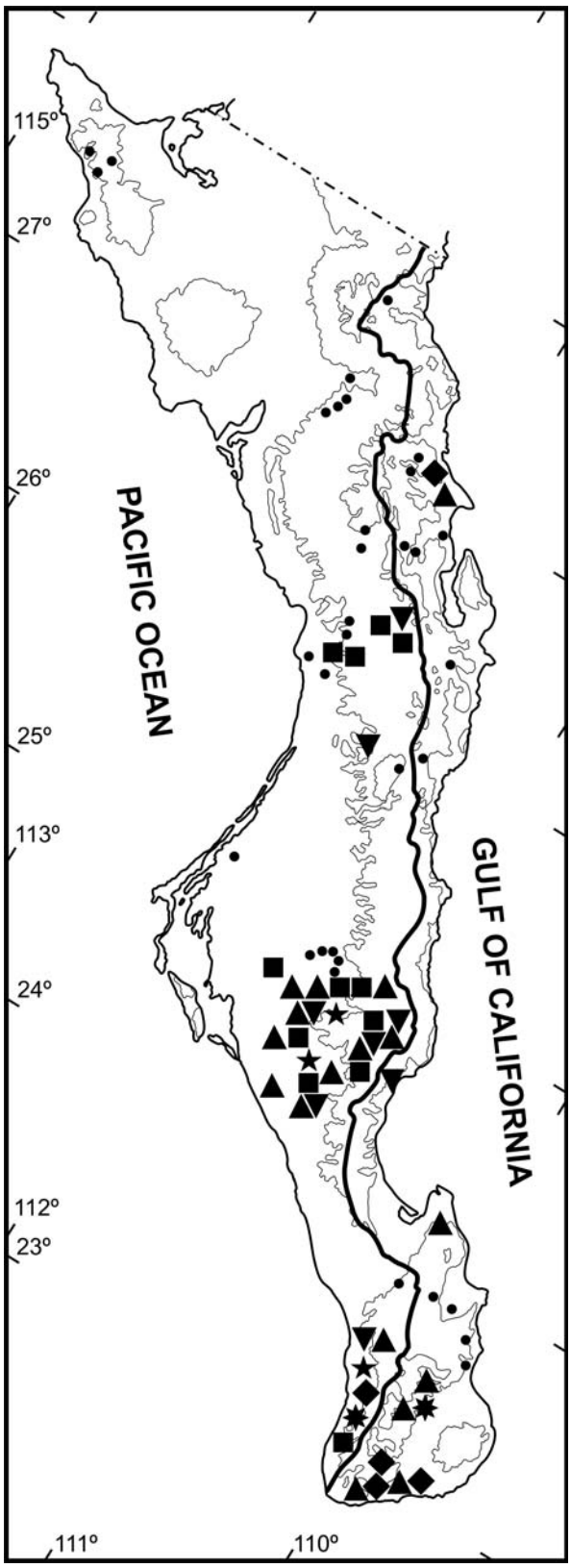

Fig. 1. Distribution of *Macrobrachium* species in the state of Baja California Sur, México (Southern Baja California Peninsula). *Macrobrachium americanum* (triangle), *M. digueti* (eight tip-star), *M. hobbsi* (square), *M. michoacanus* (five tip-star), *M. olfersii* (inverted triangle), and *M. tenellum* (rhombus). Black dots indicate approximate locations of sampling sites with no shrimp found. The thick line indicates the separation of the Pacific and Gulf of California slopes.

Rodríguez De La Cruz (1968), Ríos (1989), Wicksten and Hendrickx (1992, 2003), and Hendrickx (1994), listed from the Baja California Peninsula the three species already recorded by Bouvier (1895).

We made a taxonomic study that included an extensive field sampling on both the Pacific and the Gulf of California slopes and a revision of voucher specimens from the area that had been deposited in scientific collections. In this work we report six species of the genus *Macrobrachium* for the peninsula and discuss some aspects on the diversity and conservation of these species in the region. We also provide an identification key for *Macrobrachium* of northwestern México.

Materials and Methods

Sampling

Shrimp were captured using different fishing gear (hand net, casting net, gill net, and minnow traps baited with fish meat). In most of the sampling sites, water characteristics such as temperature, total dissolved solids (TDS) (Hach model 44600), and pH (ORION 230A) were measured at the time of sampling. The geographic position of each sampling site was determined using a GPS (Garmin 12XL). The specimens collected were placed in plastic bags, anaesthesized with ice, and fixed with 100% ethanol.

Study Area

The Baja California Peninsula was separated from the mainland by tectonic movements between the Pacific and the North American plates along the San Andreas fault, with the gradual separation occurring over the last 4 to 5 million years (Stock and Hodges, 1989). Today the northern part of the peninsula is dominated by high granitic mountains (Sierra Juárez and Sierra San Pedro Mártir) and the central region is characterized by repeating layers of volcano-clastic sandstones and conglomerates (Sierra de La Giganta). Granitic rocks and higher elevations (Sierra de La Laguna) appear again in the southern Cape region (Durham and Allison, 1960). The Baja California Peninsula has a heterogeneous array of landscape and vegetation, from coniferous and tropical deciduous forest in the mountains to xeric desert scrub in low arid plains (Riddle et al., 2000). On the western side of the peninsula the topographic altitude decreases gradually from the mountains to the coast to extensive sedimentary alluvial plains, whereas on the eastern side the distance from the mountain to the coast is shorter, often with abrupt escarpments (Grismer, 2002). Because of its historic geology with complex tectonic movements including uplifts and submergences, plus the ecological transformations produced by the geographic isolation and desertification, the peninsula now has a peculiar environmental diversity with the climate being characterized by relatively high annual mean temperatures (19 to 22°C) and a low annual rainfall (100 to 300 mm) (Grismer, 2002).

A total of 81 sites were sampled (see Appendix) with 71 in the state of Baja California Sur (Fig. 1) and distributed along 20 basins and four hydrological regions. The remaining seven sites are in the state of Baja California and distributed along four basins and two hydrological regions.

Identification of Material

Anatomical nomenclature used in this work is according to McLaughlin (1980). Additional terms are defined as follows (Fig. 2):

Fixed finger: Nonjointed projection of the propodus (manus or palm) of the cheliped.
Gaping fingers: Cutting edges of fixed finger and dactylus are arched, thus there is a clear space between them.
Closed fingers: Cutting edges of fixed finger and dactylus are straight, thus there is no a clear space between them.
Spine: A stout, sharp process, found mostly on the carapace, pereiopods, chelae, and telson.
Spinules: Slender small spines, found mostly on the pereiopods and chelae.
Tubercle: Small rounded prominence, found mostly on the pereiopods and chelae.
Pubescence: Small and numerous seta-like structures.

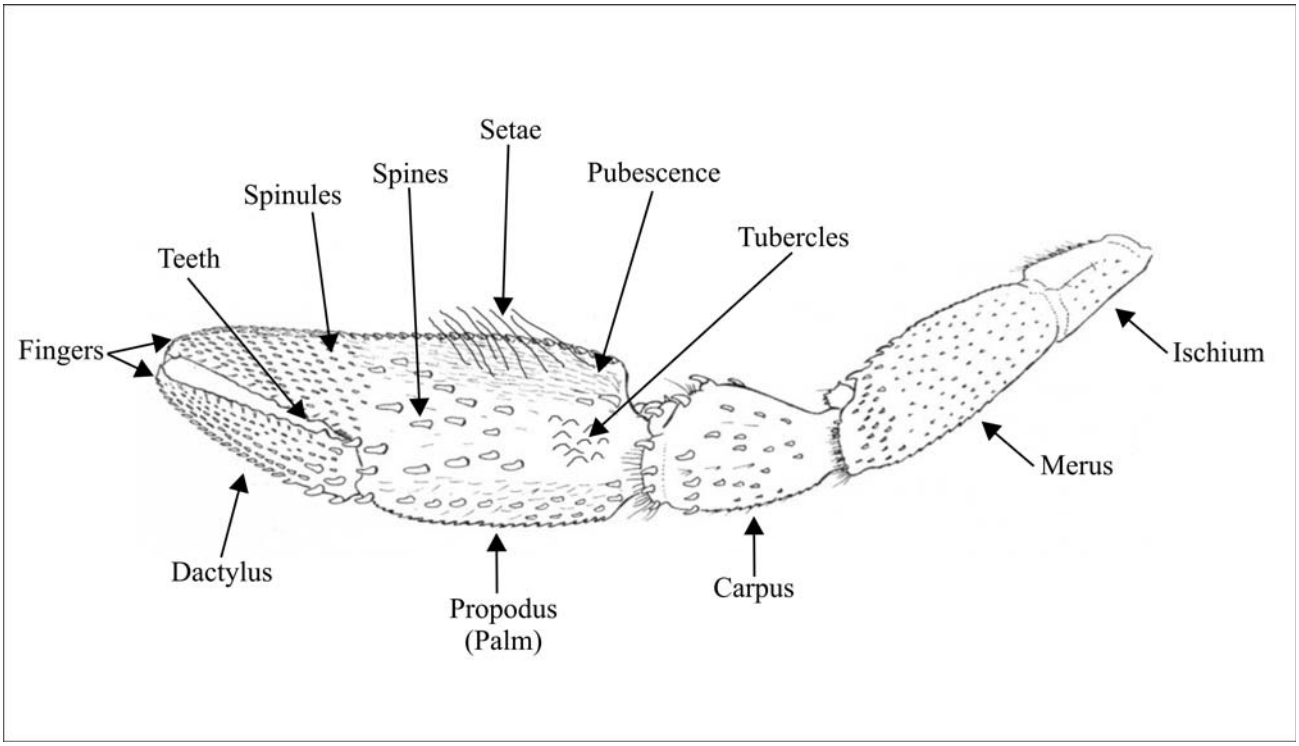

Fig. 2. Schematic representation of the appendage with the largest chela of the second pair of pereiopods of the genus *Macrobrachium* showing the main structures useful for species identification (modified from Villalobos and Nates, 1990).

Teeth: As described by McLaughlin (1980), but also as conspicuous protuberances found sometimes along the cutting edge of one or both fingers of the chela.
Denticles: Small teeth found along the cutting edge of one or both fingers of the chela.
Chelae unequal: Right and left chela are different in size and-or in shape.
Chelae subequal: Right and left chela are similar in size and shape.

In the laboratory, the material was sorted according to gender. Males were distinguished by the presence of the appendix masculina on the second pleopods. The following measurements were obtained: total length (TL) (from tip of rostrum to posterior end of telson) and length of merus, carpus, palm (length and height), and dactylus of the larger chela of the second pair of pereiopods. The number of teeth on both margins of the rostrum was recorded. A data base with all morphometric and meristic data was deposited in the Crustacea collection at Centro de Investigaciones Biológicas del Noroeste, S.C., La Paz, Baja California Sur, México (CIB). Specimens were identified using the keys for the species of *Macrobrachium* proposed by Holthuis (1952) and Wicksten (1989) and the original descriptions of the species. All collected material was deposited in the Crustacea collection at CIB. The material of *Macrobrachium* was also revised in the scientific collections at Universidad Nacional Autónoma de México, Colección Nacional de Crustáceos; Instituto de Biología, México City (CNCR); Colección de Crustáceos, Instituto de Ciencias del Mar y Limnología, Mazatlán (EMU); Universidad Autónoma de Baja California, Facultad de Ciencias, Colección de Crustáceos (UABC); and the crustacean collection of the Muséum National d' Histoire Naturelle, Paris (MNHN).

Presentation of the Taxonomic Account

The taxonomic account includes: 1) species name, author, and year of description; 2) synonymy, restricted to names used for Mexican specimens (for a complete synonymy see Holthuis, 1952); 3) type locality; 4) diagnosis; 5) distribution in the Baja California Peninsula, including data on water characteristics and on the co-occurrence of the species with other congeneric forms; 6) distribution in México (following a north-south order); 7) general distribution; 8) remarks; and 9) material examined, indicating the country, state, site, collection date, senior collector's name, catalog code, and number of males and females with total length measurements (when the specimen was complete). For comparative purposes, specimens of three *Macrobrachium* species not found in the Baja California Peninsula were also examined and included in the sections of their geminated species.

SYSTEMATICS

Palaemonidae Rafinesque, 1815
Macrobrachium Bate, 1868
Macrobrachium americanum Bate, 1868
(Fig. 3)

Macrobrachium americanum Bate, 1868; Holthuis, 1952; Rodríguez De La Cruz, 1968; Wicksten, 1983, 1989; Ríos, 1989; Wicksten and Hendrickx, 1992, 2003; Villalobos-Hiriart et al., 1993; Hendrickx, 1994.

Palemon jamaicensis Herbst; Bouvier, 1895.

Type Locality.—Lago Amatitlán, Guatemala.

Diagnosis.—Rostrum strong, arched over orbital margin, curved upward at tip; it reaches the end joint of antennular peduncle; dorsal margin with 10 to 12 teeth of which three to four are placed behind orbital margin; ventral margin with two to four teeth. Second pair of pereiopods with subequal chelae and gaping fingers; carpus almost twice as long as high and shorter than merus. Whole chela covered with spinules. Palm elongated, fingers slightly shorter than palm. Fingers with single strong tooth on cutting edge; tooth of fixed finger on first third of cutting edge, dactylus with tooth in the middle; two to four proximal denticles on both fingers.

Distribution in the Baja California Peninsula.—This common species was previously reported from Mulegé, La Paz, and Cabo San Lucas (Bouvier, 1895; Holthuis, 1952). We found it on the Pacific slope in the basins

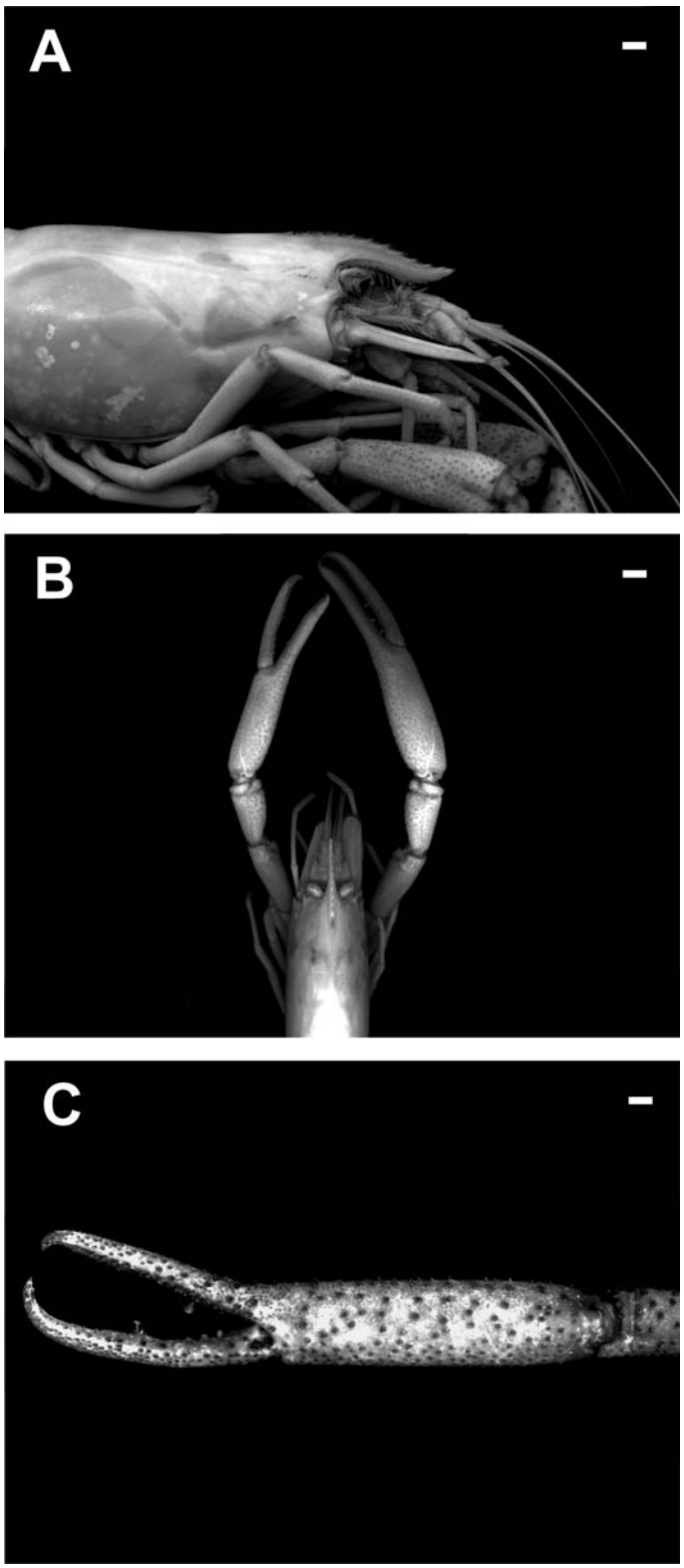

Fig. 3. Adult males of *Macrobrachium americanum* Bate, 1868. A, Rostrum in right lateral view; B, Anterior region in dorsal view; C, Largest chela of the second pair of pereiopods in inner view. All figures from CIB 814. Scale bars = 10 mm.

Santa Rita, Las Pocitas, Todos Santos, and Plutarco Elías Calles, and on the Gulf of California slope in the basins of Mulegé, El Coyote, San Bartolo, and San José del Cabo. Specimens were found in waters with TDS 0.34 to 1.5 g/L, pH 6.7 to 8.3, and temperatures 23.9 to 34.5°C. *Macrobrachium americanum* was found often co-ocurring with the other five species found in the peninsula. An assemblage of four species (*M. americanum*,

M. digueti, *M. hobbsi*, and *M. michoacanus*) was recorded at the Los Potreros site.

Distribution in México.—BAJA CALIFORNIA SUR (see above). SONORA: Guaymas (Holthuis, 1952), Río Yaqui, and Río Mayo (Rodríguez De La Cruz, 1968). SINALOA: El Rosario, Río El Fuerte, Río Presidio, Río Quelite (Holthuis, 1952; Rodríguez De La Cruz, 1968; Hendrickx, 1994), and Mazatlán. NAYARIT: Isla María Magdalena, and Isla María Cleofas (Holthuis, 1952; Hernández and Martínez, 1992), Río Santiago, and Jalcocotán. JALISCO: Río Santiago, and Río Ameca (Holthuis, 1952), Chamela, Cuitzmala, and Puerto Vallarta. COLIMA: Río Armería (Holthuis, 1952). MICHOACÁN: La Villita, and Mexcaltitlán. GUERRERO: Bahía Petatlán (Holthuis, 1952), and Río Murga. OAXACA: Pochutla, Salina Cruz, Río Valdeflores, Tuxtepec, Mixtequita dam, and Tehuantepec. CHIAPAS: Mal Paso dam, and Río El Naranjo.

General Distribution.—Baja California Peninsula to Perú, Cocos Island, and Galápagos Islands (Holthuis, 1952; Wicksten and Hendrickx, 1992, 2003).

Remarks.—Similar to *Macrobrachium carcinus* (Linnaeus, 1758), *M. americanum* is one of the largest species of the genus and its size may help to distinguish it from other species (Holthuis, 1952). The largest specimen in our study was found at Rancho Tres Pozas (Santa Rita basin) at 246-mm TL. Small specimens may be confused with males of *M. occidentale* or *M. heterochirus* (Wiegmann, 1836), but *M. americanum* can be distinguished by its subequal chelae, the form and size of the carpus, and by the rostral length. The Atlantic geminated species of *M. americanum* is the big claw river shrimp *M. carcinus* (Holthuis, 1952) that has been reported from the Florida to Brazil (Bowles et al., 2000). Differences among specimens is not easy to detect, however Holthuis (1952) noted that *M. carcinus* is sligthly larger than *M. americanum* and that the carpus length is more than twice as long as high in *M. carcinus*, whereas in *M. americanum* the same characteristic is not more than twice as long as high. In our revision of 86 voucher specimens, we noted that proportions on the carpus as previously established by Holthuis are consistent, so this characteristic may help us to separate both species. Color in life for *M. carcinus* is dark brown with lighter mottling on the sides and tan stripes laterally. Chelipeds are dark green to blue with dark tubercles and orange articulations (Bowles et al., 2000). In *M. americanum* the body is yellow-brown with tan stripes laterally from the carapace to telson and the periopods with blue articulations. In adults, the fingers of the second pair of chelipeds are dark with some little specimens showing the terminal third of the fingers in white.

After the Holthuis (1952) review, there was only one record of *M. americanum* for the peninsula reported by Ríos (1989), who found it at Mulegé. The new records from the Pacific slope basins such as Santa Rita, Las Pocitas, Los Potreros, and Todos Santos extend the geographical distribution of the species to the west side of the peninsula. The collections from the Santa Rita basin represent its northernmost records in the Pacific slope. Álvarez-Ruiz et al. (1996) cited Chirichigno et al. (1982) as reporting *M. americanum* from Isla Cedros, Baja California, México. However Chirichigno et al. (1982) only mentioned that this species may be located in the fishery zone 77A, which comprises an enormous area from Baja California to Oaxaca, but did not give any particular data from Isla Cedros. Records of this species from Mexican islands are those from Isla María Magdalena and Isla María Cleofas, Nayarit (Holthuis, 1952; Hernández and Martínez, 1992).

Material Examined.—*Macrobrachium americanum*: MÉXICO: BAJA CALIFORNIA SUR: Mulegé dam, 28.02.2004, A. Maeda, CIB 803, 1 female; Guadalupe dam, C. Méndez, CIB 860, 2 specimens; Las Paredes, 30.05.2004, L. Hernández, CIB 804, 1 male (139.5 mm); San Juanito Nuevo, 22.09.2004, L. Hernández, CIB 866, 1 specimen; Rancho Tres Pozas, 30.05.2004, L. Hernández, CIB 805, 2 males (134 and 246 mm); Merecuaco, 16.05.1998, G. Ruiz-Campos, UABC 003, 1 male (115 mm); Corral de Piedra, 29.05.04, L. Hernández, CIB 806, 1 male (121.3 mm); El Caracol, 29.05.2004, L. Hernández, CIB 807, 1 male (151.1 mm) and 1 female (151 mm); Poza de La Matanza, 29.05.2004, L. Hernández, CIB 808, 1 male (152 mm); Santa Fe, 26.02.2004, L. Hernández, CIB 867, 1 specimen; Las Vinoramas, 21.11.2003, A. Maeda, CIB 809, 1 female (59.2 mm); Las Vinoramas, 03.12.2003, L. Hernández, CIB 810, 2 males (63 and 69.8 mm); Todos Santos, 26.02.2004, L. Hernández, CIB 811, 1 male (145 mm); La Poza, 10.07.2005, L. Mercier, CIB 861; 1 specimen; Agua Caliente, 13.12.2003, A. Maeda, CIB 812, 1 female (70 mm); Rancho San Antonio, 08.09.2004, L. Hernández, CIB 813, 1 female (129.4 mm); Los Potreros, 06.10.2002, A. Maeda, CIB 814, 1 female (144.5 mm, ovigerous); Los Potreros 24.07.2003, L. Hernández, CIB 815, 2 females (109.6 and 112 mm, ovigerous); Poza de Santa Rosa, 14.12.2003, A. Maeda, CIB 816, 2 females (131.7 and 68 mm); San José del Cabo estuary, 26.11.2004, L. Hernández, CIB 862, 1 specimen. SINALOA: Mazatlán, 10.09.1973, D. Peláez, CNCR 199, 1 specimen; EMU 0268, 3 specimens. NAYARIT: Río Santiago, 07.07.1991, C. Rosales, CNCR 11499, 1 specimen; Jalcocotán, 13.09.2003, L. Hernández, CIB 853, 5 males (104 to 185.5 mm), 1 female (118 mm), and 1 ovigerous female (132.9 mm). JALISCO: Puerto Vallarta, 17.09.1973, A. Jiménez, CNCR 202, 1 specimen; Chamela, 31.08.1992, CNCR 1619, 1 specimen. COLIMA: Río Armería, 12.09.1973, CNCR 200, 2 specimens. MICHOACÁN: La Villita, 28.09.1973, A. Villalobos, CNCR 205, 2 specimens; La Villita, CNCR 13685, 1 male (190 mm). GUERRERO: Río Murga, 08.05.1984, A. Villalobos, CNCR 2624, 5 juveniles; Río Murga, 21.05.1984; A. Villalobos, CNCR 2663, 3 specimens; Río Murga, 23.09.1986; J.C. Nates, CNCR 3116, 2 males (118.4 and 95 mm), 1 female (ovigerous). OAXACA: Río Valdeflores, 24.05.1961, A. Villalobos, CNCR 198, 1 specimen; Salina Cruz, 11.09.1973, I. Larios, CNCR 201, 1 specimen; Tuxtepec, 13.09.1973, A. Villalobos, CNCR 204, 4 specimens; Mixtequita dam, 21.12.1955, A. Villalobos, CNCR 208, 2 specimens. CHIAPAS: Mal Paso dam, 12.09.1973, C. Beutelspacher, CNCR 203, 4 specimens; Río El Naranjo, 06.09.2002, E. Soto, CNCR 22021, 1 male (69.8 mm). *Macrobrachium carcinus*: MÉXICO: MNHN 1222, 1 specimen (172 mm); MNHN 989, 1 specimen; CNCR 13332, 2 males (118.4 and 140.1 mm); CNCR

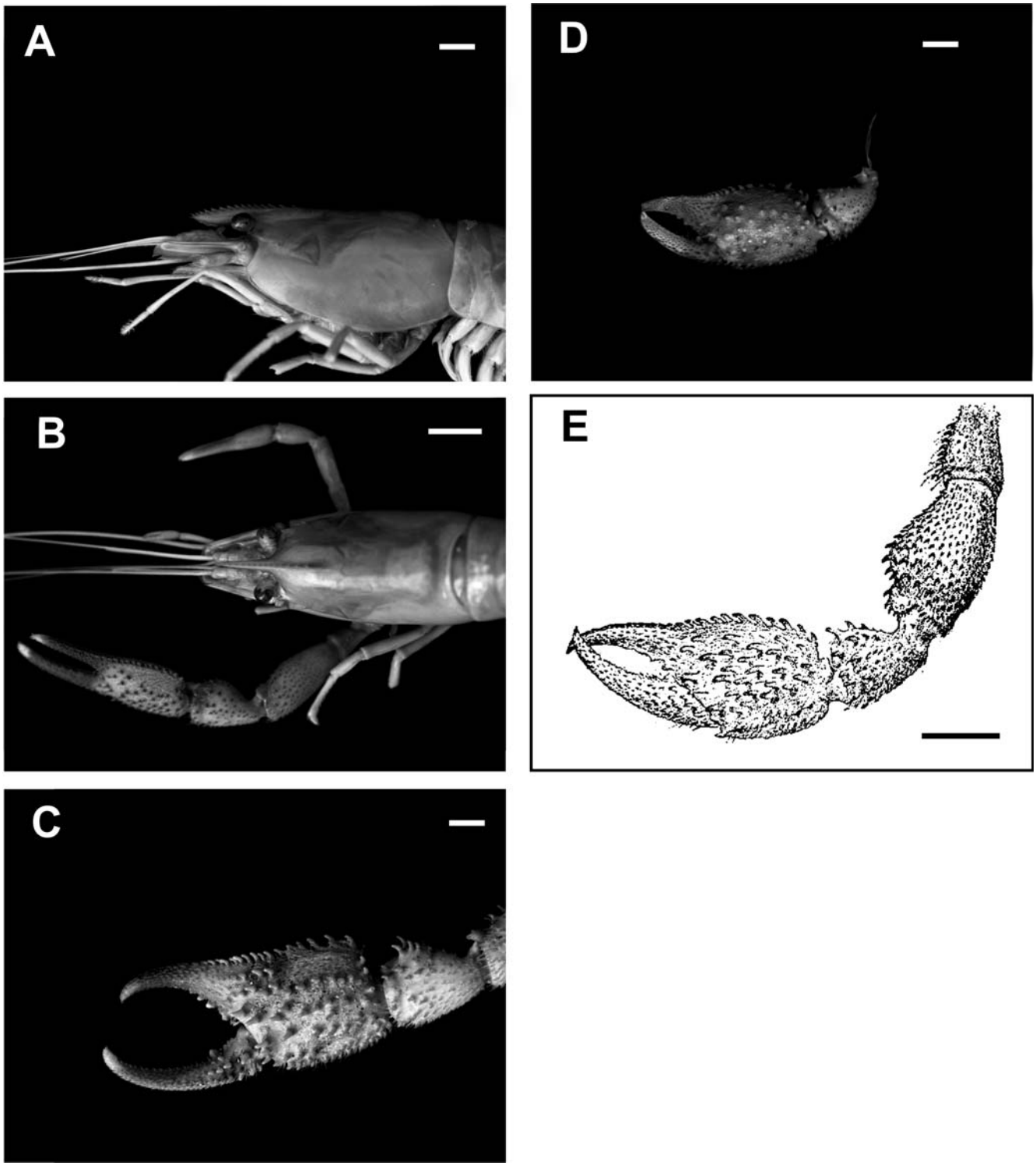

Fig. 4. Adult males of *Macrobrachium digueti* (Bouvier, 1895). A, Rostrum in left lateral view; B, Anterior region in dorsal view; C-D, Largest chela of the second pair of pereiopods in lateral view. A and C from CIB 801, B from CIB 817, D from MNHN 1235, and E from Bouvier (1895). Scale bars = 10 mm.

13667, 2 females (133.9 and 141.4 mm); CNCR 13676, 1 female (143.9 mm); CNCR 16494, 1 male (61 mm); CNCR 17174, 1 female (110.6 mm); CNCR 17380, 2 females (151.3 and 159.4 mm); CNCR 17401, 1 male (228.5 mm); CNCR 17403, 1 male (216.3 mm); CNCR 18648, 3 males (125.7 to 206.2 mm) and 1 male (174.5 mm).

Macrobrachium digueti (Bouvier, 1895)
(Fig. 4)

Palaemon digueti Bouvier, 1895.

Macrobrachium digueti (Bouvier, 1895); Holthuis, 1952; Rodríguez De La Cruz, 1968; Wicksten, 1983, 1989; Ríos, 1989; Wicksten and Hendrickx, 1992, 2003; Villalobos-Hiriart et al., 1993; Hendrickx, 1994; Román et al., 2000.

Macrobrachium acanthochirus Villalobos, 1967; Villalobos, 1968; Villalobos and Nates, 1990; Wicksten, 1989; Wicksten and Hendrickx, 1992, 2003; Villalobos-Hiriart et al., 1993; Román et al., 2000.

Type Locality.—Mulegé, Baja California Sur.

Diagnosis.—Rostrum straight, reaching last joint of antennular peduncle; dorsal margin with 13 to 16 teeth, four to six placed behind orbital margin; ventral margin with three to five teeth. Second pair of pereiopods with unequal chelae and gaping fingers; carpus and merus globose at middle section. Largest chela with palm almost as long as high, with spines on dorsal margin and external side. Palm with scarce pubescence, without setae. Fixed finger with up to four teeth on proximal half of cutting edge. Dactylus with a stout tooth, and up to four denticles on proximal part of cutting edge.

Distribution in the Baja California Peninsula.—*Macrobrachium digueti*, previously collected from Mulegé, La Paz, and Cabo San Lucas (Bouvier, 1895; Holthuis, 1952; Hendrickx, 1994), was found only at two sites, one in Boca de la Sierra, Santiago basin in the Gulf of California slope and the other in Los Potreros, Plutarco Elías Calles basin on the Pacific slope. Specimens were found in waters with TDS 0.18 to 1.5 g/L, pH 7.8 to 8.8, and temperature 25.3 to 33.7°C. We found this species co-occurring with three congeners at Los Potreros. Previously, Bouvier (1895) reported this species along with *M. americanum* and *M. tenellum*.

Distribution in México.—BAJA CALIFORNIA SUR (see above). SONORA: Río Yaqui and Río Mayo (Rodríguez De La Cruz, 1968). SINALOA: Laguna Caimanero and Río Baluarte (Wicksten and Hendrickx, 2003). NAYARIT: Colomó. JALISCO: Cuitzmala and Río Los Cuartones. COLIMA: Tecomán, and Puerto Juárez. MICHOACÁN: Mexcaltitlán, Río Murga, and La Villita. GUERRERO: Acapulco (Wicksten and Hendrickx, 2003). OAXACA: Valdeflores.

General Distribution.—Baja California Peninsula to Perú (Holthuis,1952; Wicksten and Hendrickx, 1992, 2003).

Remarks.—Villalobos (1968) indicated that the description of this species given by Holthuis (1952) does not correspond to the original species of Bouvier (1895) and we agree with this assessment. Holthuis (1952, plate 26) described the largest second chela of *Macrobrachium digueti* as ''The second legs are very unequal in shape and size in the adult male. The fingers in the larger chela are as long as the palm; they are curved and gape. The cutting edges of both fingers bear in the extreme proximal part one large tooth, behind which 1 or 2 much smaller teeth are placed. The cutting edge distally of the large teeth is provided with teeth 9 to 12 in number, which are placed up to the tips of the fingers. Tufts of hair are implanted along the cutting edges. The rest of the fingers is naked and is densely covered with spinules. The palm has a distinct, large thickly pubescent area at each of the lateral surfaces''. These features do not correspond to those of the original description given by Bouvier (1895), who wrote ''sa grande pince est plus courte, plus large et complètement dépourvue de longues soies raides entre les doigts béants, enfin on n'observe pas de longs poils duveteux sur la face externe de cette pince et le épines de la face interne sont moins nombreuses que dans le *P. spinimanus* et plus irrégulièrement disposées'' (its second large chela is shorter, higher, and completely without large setae between the fingers, finally we do not observe large setae over the external face of the chela and the spines of the internal face are less numerous than in *P. spinimanus* and more irregularly disposed). According to Holthuis (1952), *Palemon spinimanus* is a synonym of *Macrobrachium faustinum* (De Sassure, 1857). L. Hernández in Paris revised a lot (MNHN 1235) labeled as Syntype of *P. Digueti*, Mulegé, 1895. This lot contained 16 specimens (39.5 to 56.4 mm), most of them incomplete. One incomplete appendage still having carpus, propodus, and dactylus seems to correspond to that described and figured by Bouvier (1895) (Fig. 4E). Bouvier's measurements were -longueur de la pince 38 mm; largeur maximum 16 mm; longueur de doigt mobile 22 mm- (length of the chela 38 mm, maximum height 16 mm; length of the mobile finger 22 mm). The chela examined by L. Hernández had similar values with a carpus length of 12.7 mm, palm length 20.1 mm, and dactylus length 20.3 mm. The remaining 16 specimens were determined by L. Hernández as *Macrobrachium hobbsi* Nates and Villalobos, 1990.

Macrobrachium acanthochirus Villalobos, 1967 was described from two lots, one from specimens collected in Tecomán, Colima and the other from Río Valdeflores, Oaxaca. Villalobos (1968) was not sure about the validity of this species, even proposing that it could be better assigned as a subspecies of *M. digueti*. Upon the morphological examination of 28 voucher specimens (see below the material examined), the similar proportion values of the carpus length/palm length, and palm length/palm high shown by specimens of both nominal taxa (Table 1), the overlap distribution of both forms along the Pacific slope, we concur that *M. acanthochirus* should remain as a synonym of *M. digueti*.

Macrobrachium digueti is similar to *M. olfersii* (Wiegmann, 1836), however in *M. digueti* there is no pubescence but scarce setae on the second large chela, whereas in *M. olfersii* the chela characteristically has copious setae and pubescence. Though *M. digueti* has only a few teeth on the proximal part of the cutting edge of both fingers, *M. olfersii* has more than five teeth along the cutting edge of both fingers.

Macrobrachium digueti is rare in the Baja California Peninsula. We found no specimens at the type locality, the oasis of Mulegé. Ríos (1989) did not find any specimens at Mulegé during four years of monitoring. This suggests that the species has been extirped from the type locality. Our collection at Los Potreros represents the first record of the species on the Pacific slope of the Baja California Peninsula.

Material Examined.—*Macrobrachium digueti*: MÉXICO: BAJA CALIFORNIA SUR: Mulegé, 1894, L. Diguet, MNHN 1235, 1 second largest chela of a male (Syntype); Mulegé, CNCR 10619, 4 specimens; Boca de la Sierra, 08.09.2004, L. Hernández, CIB 801, 2 males (78.6 and 70 mm); Los Potreros, 06.10.2002, A. Maeda, CIB 802, 1 male (79.4 mm); Los Potreros, 06.10.2002, A. Maeda, CIB 817, 1 female (81.3 mm); San José del Cabo, 19.09.1946, I.

Table 1. Morphometric data of the largest chela of the second pair of periopods and rostral teeth of *Macrobrachium digueti* males from several Mexican locations. CaL, carpus length; PL, palm length; PH, palm high; DL, dactylus length; CL, carapace length (all in mm).

Specimen	CaL	PL	CaL/PL	PH	PL/PH	DL	Rostral teeth	CL	Reference
Holotype from Mulegé, Baja California Sur	—	—	—	16	—	22	14-16	28	Bouvier, 1895
Syntype from Mulegé, Baja California Sur (MNHN 1235)	12.7	20.1	0.63	16.2	1.2	20.3	—	—	this study
Male from Tecomán, Colima (cited as *M. acanthochirus*)	11.4	14	0.81	13.2	1.06	16.5	13 (5)/4	28.9	Villalobos, 1967
Male from Tecomán, Colima (CNCR 328, labeled as holotype of *M. acanthochirus*)	10.4	15.7	0.66	13.3	1.18	16.7	13 (5)/4	20	this study
Male from Valdeflores, Oaxaca (cited as *M. acanthochirus*)	10.3	14.5	0.71	12	1.2	15	—	27	Villalobos, 1967
Male from Los Potreros, Baja California Sur (CIB 802)	10.3	12.6	0.79	10.1	1.24	13.4	15 (4)/3	27.3	this study
Male from Colomó, Nayarit (CIB 866)	14.1	20.6	0.68	18.9	1.08	23.7	14 (6)/4	29	this study
Male from Río Murga, Guerrero (CNCR 3538, labeled as *M. acanthochirus*)	10.7	18.1	0.59	17.2	1.08	19.9	14 (5)/5	24.4	this study

Bonet, CNCR 235, 1 male (77 mm); San José del Cabo, 10.09.1946, F. Bonet, CNCR 236, 3 specimens. SINALOA: Río Baluarte, EMU 0840, 3 females (62 to 74 mm). NAYARIT: Colomó, 13.08.2003 L. Hernández, CIB 866, 5 specimens (75 to 91 mm). JALISCO: Cuitzmala, 04.02.1983, J.C. Nates, CNCR 2723, 1 male (65.1 mm, labeled as *M. acanthochirus*); Cuizmala, 20.02.1984, J.C. Nates, CNCR 3121, 9 specimens (40 to 87 mm); Río Los Cuartones, 01.03.1992, A. Novelo, 1 male, CNCR 13372 (labeled as *M. acanthochirus*). COLIMA: Tecomán, 18.01.1943, F. Bonet, CNCR 328, 1 male (62 mm) (labeled as holotype of *Macrobrachium acanthochirus* Villalobos, 1967); Puerto Juárez, 23.06.1986, R. Navarro, 1 female, CNCR 20804 (labeled as *M. acanthochirus*). MICHOACÁN: Mexcaltitlán, 31.07.1984, J.C. Nates, 12 males, CNCR 3536 (labeled as *M. acanthochirus*); Río Murga, 28.07.1984, CNCR 3538 (labeled as *Macrobrachium* sp.); La Villita, 15.12.1994, CNCR 12986, 2 specimens. GUERRERO: Acapulco, 13.08.1973, W. López, CNCR 141, 1 male (59 mm, labeled as *M. acanthochirus*); OAXACA: Valdeflores, 25.05.1962, A. Villalobos, CNCR 331, 2 specimens (labeled as *M. acanthochirus*).

Macrobrachium hobbsi Nates and Villalobos, 1990 (Fig. 5)

Macrobrachium hobbsi Nates and Villalobos, 1990; Villalobos and Nates, 1990; Villalobos-Hiriart et al., 1993; Wicksten and Hendrickx, 2003.

Type Locality.—Río El Naranjo, Chiapas.

Diagnosis.—Rostrum straight, reaching last joint of antennular peduncle; dorsal margin with 13 to 16 teeth, four to six placed behind orbital margin; ventral margin with two to four teeth. Second pair of pereiopods with unequal chelae and closed fingers. Carpus shorter than palm length, subequal to merus length. Palm with spinules covered with pubescence. Palm about two times or more long as high. Adult specimens of the species are small (< 100 mm).

Distribution in the Baja California Peninsula.—First records of the species in the peninsula. It was collected on the Pacific slope at La Purísima, Santa Rita, Las Pocitas, and Plutarco Elías Calles basins, and on the Gulf of California slope in the basin of Mulegé. Specimens were found in waters with TDS 0.29 to 1.09 g/L, pH 6.7 to 8.9, and temperatures 22.1 to 32.5°C. We found this species co-ocurring with the other five species found in the peninsula.

Distribution in México.—Endemic to México from Guerrero to Chiapas and Veracruz (Villalobos and Nates, 1990; Wicksten and Hendrickx, 2003) and from the west and east sides of the Baja California Peninsula, and in Nayarit. BAJA CALIFORNIA SUR (see above). NAYARIT: Río Huaynamota and Los Salazares. GUERRERO: Río Murga (Villalobos and Nates, 1990). OAXACA: Río Astuta (Villalobos and Nates, 1990). CHIAPAS: Río Lagartero, Arroyo Ocuilapa, Río Cintalapa, Río Chacamax (Villalobos and Nates, 1990), Río Grande, and Río Urbina. VERACRUZ: Río La Palma (Villalobos and Nates, 1990).

Remarks.—Large specimens of *Macrobrachium hobbsi* may be confused with *M. olfersii* (Wiegmann, 1836). One important difference between the two species noted by Villalobos and Nates (1990) is the absence of space in the cutting edges of both fingers of the second largest chela in *M. hobbsi*. The second pair of chelae are subequal in shape but not in size, whereas in *M. olfersii* the second large chelae are unequal.

Macrobrachium hobbsi is an amphiamerican species with a wide distribution in Baja California Sur and occurs on both the Pacific and Gulf of California slopes. Ojo de Agua in the La Purísima basin is the northernmost site of the species distribution. There is an apparent distribution gap of the species between the Baja California Peninsula and the Río Huaynamota, Nayarit.

Material Examined.—*Macrobrachium hobbsi*: MÉXICO: BAJA CALIFORNIA SUR: Mulegé, 1895, MNHN 1235, 16 specimens (39.5 to 56.4 mm) (labeled as *M. Digueti*); Ojo de Agua, 01.07.2004, G. Ruiz-Campos, UABC 009, 4 males (59 to 68 mm) and 9 females (69 to 91 mm); Ojo de Agua, 14.07.2004, L. Hernández, CIB 818, 3 males (64.4 to 79.3 mm) and 1 ovigerous female (61.5 mm); San Isidro dam, 15.07.2004, L. Hernández, CIB 819, 5 males (49.3 to 69.8 mm) and 4 specimens; La Purísima, 01.07.2004, G. Ruiz-Campos, UABC 008, 10 specimens (56.2 to 73.2 mm); La Purísima, 02.07.2004, G. Ruiz-Campos, UABC 006, 3 males (72.5 to 77.2 mm); San Juanico road, 14.07.2004, L. Hernández, CIB 820, 1 male (53 mm); San Pedro de la Presa, 30.05.2004, L. Hernández, CIB 821, 3 females (53.5 to 68.4 mm) and 8 specimens; San Basilio, 30.05.2004, L. Hernández, CIB 822, 3 males (47 to 72.8 mm) and 9 specimens; Las Paredes, 30.05.2004, L. Hernández, CIB 823, 8 males (46.2 to 56 mm) and 51 specimens of juveniles and females; Merecuaco, 16.05.1998, G. Ruiz-Campos,

UABC 002, 7 specimens (43.6 to 69.2 mm); Paso Iritú, L. Hernández, CIB 824, 3 males (42.1 to 52.1 mm); El Caracol, 29.05.2004, L. Hernández, CIB 825, 3 males (50 to 63.2 mm TL), and 7 specimens; El Colorado, 02.03.2004, L. Hernández, CIB 826, 1 male (67.2 mm and 6 females; Los Potreros, 06.10.2002, A. Maeda, CIB 827, 7 males, and 2 females (52.3 and 63.6 mm); San Pedro de la Soledad, 25.11.2004, L. Hernández, CIB 828, 1 female. NAYARIT: Río Huaynamota, 03.07.1991, A. Cantú, CNCR 13357, 1 male (69.2 mm); Los Salazares, 14.08.2003, L. Hernández, CIB 854, 2 males (65.2 and 66.8 mm) and 4 ovigerous females. CHIAPAS: Río Grande, 14.02.1985, J.L. Villalobos, CNCR 5605, 3 males (68.9 to 79.7 mm); Río Urbina, 10.06.2002, CNCR 13335, 1 female (54.3 mm); El Naranjo, J.C. Nates, CNCR 2939 (Holotype), 1 male (67.5 mm).

Macrobrachium michoacanus
Nates and Villalobos, 1990
(Fig. 6)

Macrobrachium michoacanus Nates and Villalobos, 1990; Villalobos and Nates, 1990; Villalobos-Hiriart et al., 1993; Wicksten and Hendrickx, 2003.

Type Locality.—Río Mexcalhuacán, Michoacán.

Diagnosis.—Rostrum straight, reaching last joint of antennular peduncle; dorsal margin with 14 to 15 teeth, five to six behind orbital margin; ventral margin with three to four teeth. Second pair of pereiopods with unequal chelae and closed fingers. Merus about 1.5 times longer than carpus. Palm with spines distributed on lateral surface, scarce pubescence on lateral ventral area, and less than two times as long as high.

Distribution in the Baja California Peninsula.—First records of the species for the peninsula. *Macrobrachium michoacanus* was collected on the Pacific slope in Las Pocitas and Plutarco Elías Calles basins. Specimens were found in waters with TDS 0.71 to 3.56 g/L, pH 7.4 to 9.3, and temperatures 22.1 to 31.3°C. This species was co-occurring with the other five congeneric species.

Distribution in México.—Endemic to México, from Jalisco to Oaxaca (Villalobos and Nates, 1990; Wicksten and Hendrickx, 2003). Also found on the west side of the Baja California Peninsula. BAJA CALIFORNIA SUR (see above). JALISCO: Río Cuitzmala (Villalobos and Nates, 1990), Chamela, and Río Las Aletas. MICHOACÁN: Morelos dam, Río Chucatitlán, and Río Papoyutla (Villalobos and Nates, 1990). GUERRERO: Río Murga, Río Aguas Blancas, Mexcalhuacán (Villalobos and Nates, 1990), Río Salitrera, and La Villita. OAXACA: Río Valdeflores (Villalobos and Nates, 1990; Wicksten and Hendrickx, 2003), and Río Galván.

Remarks.—This species is similar to *M. digueti*, but it can be distinguished by the shape of the cutting edges of the finger of the second mayor chela as noted by Villalobos and Nates (1990). *Macrobrachium michoacanus* has closed fingers on the second large chela, whereas *M. digueti* has gaping fingers. The differences between *M. michoacanus* and the other species with closed fingers, *M. hobbsi*, are in the palm. The first species has spines on the palm and the length of the palm is less than twice the high, whereas the second species has spinules and pubescence on the palm and the palm length is at least two times longer than high.

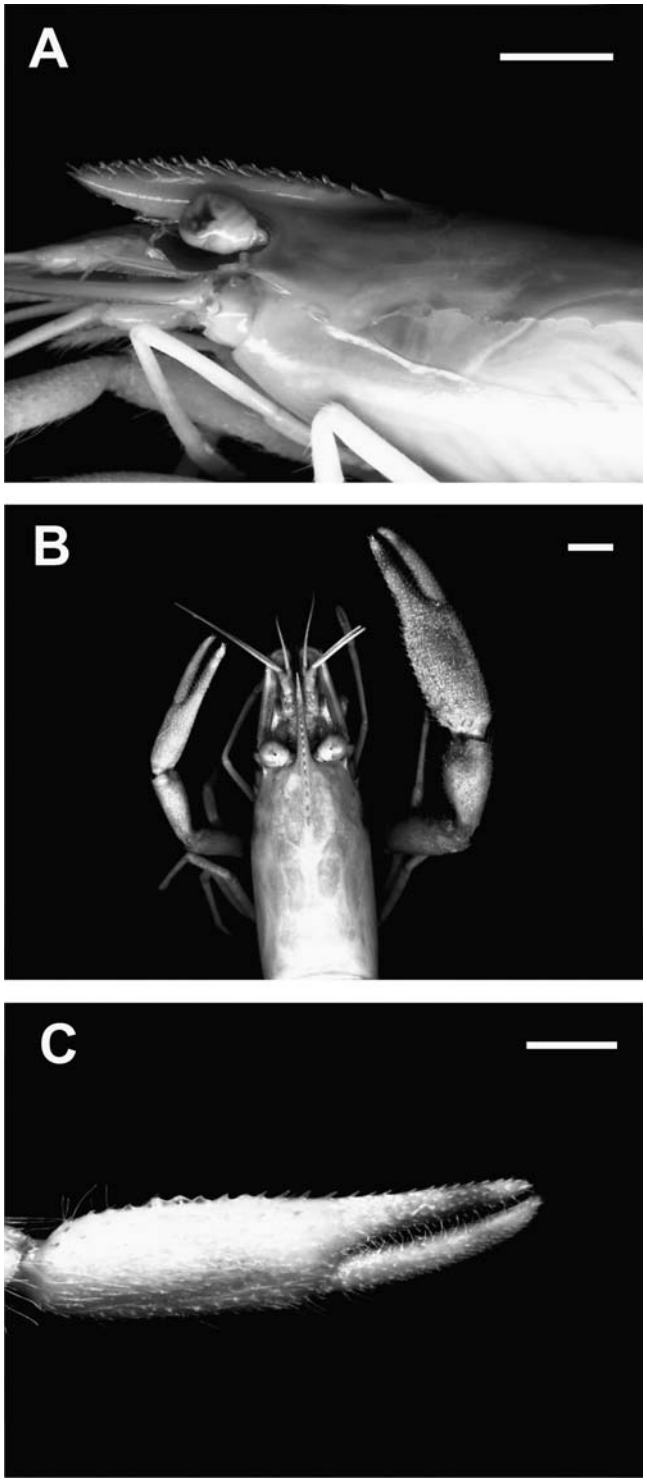

Fig. 5. Adult males of *Macrobrachium hobbsi* Nates and Villalobos, 1990. A, Rostrum in left lateral view; B, Anterior region in dorsal view; C, Largest chela of the second pair of pereiopods in lateral view. A and B from CIB 824, and C from CIB 828. Scale bars = 10 mm.

Las Cuevas in Las Pocitas basin of the Pacific slope of the Baja California Peninsula is the northernmost boundary of the

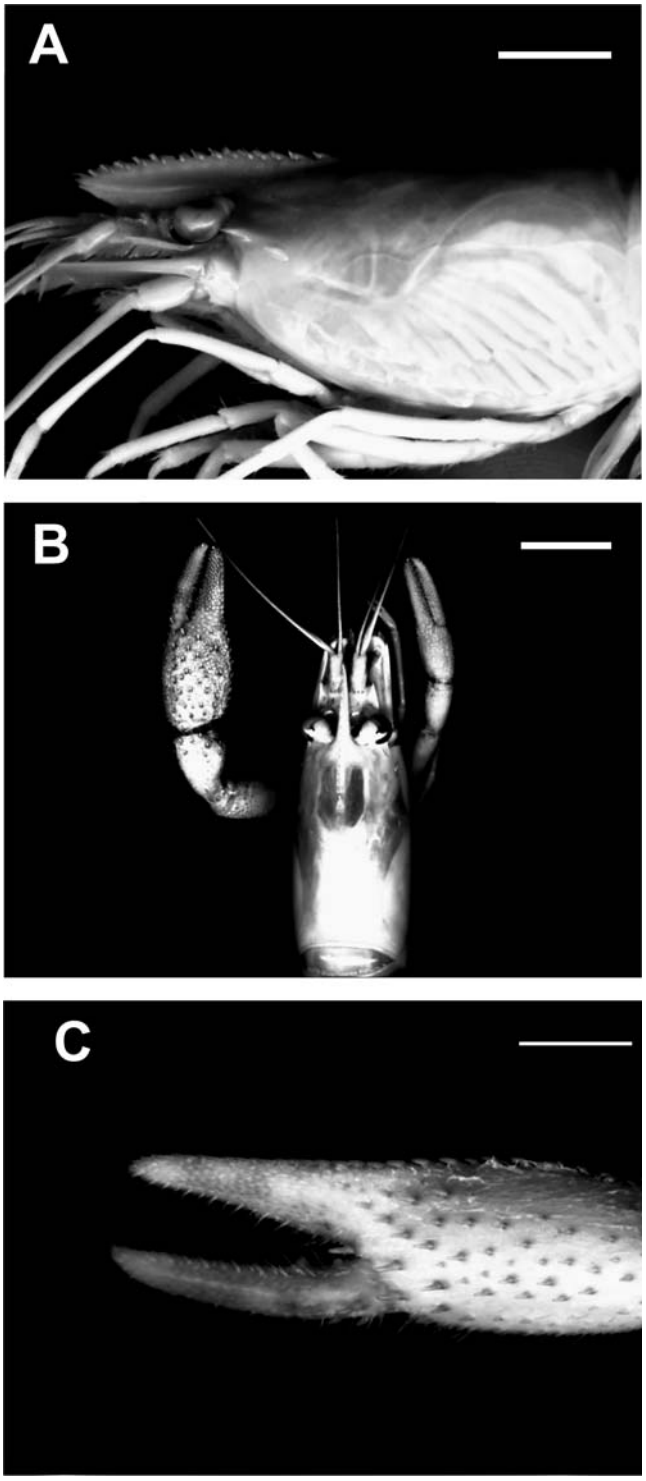

Fig. 6. Adult males of *Macrobrachium michoacanus* Nates and Villalobos 1990. A, Rostrum in left lateral view; B, Anterior region in dorsal view; C, Largest chela of the second pair of pereiopods in lateral view. A from CIB 829, and B and C from CIB 831. Scale bars = 10 mm.

species distribution. The species was not found along the Gulf of California slope. There is an apparent gap in the distribution of the species between the Baja California Peninsula and the northernmost record at Río Cuitzmala, Jalisco.

Material Examined.—*Macrobrachium michoacanus*: MÉXICO: BAJA CALIFORNIA SUR: San Basilio, 15.05.1998, G. Ruiz-Campos, UABC 001, 5 males (51.5 to 75.2 mm) and 2 females; Rancho Las Cuevas, 30.05.2004, L. Hernández, CIB 829, 2 males (57.9 and 74.2 mm); Paso Iritú, 16.05.1998, G. Ruiz-Campos, UABC 004, 9 males (39.7 to 70.3 mm) and 13 females (34 to 65 mm); El Cardalito, 19.11.2003, A. Maeda, CIB 830, 1 ovigerous female (59.4 mm); Los Potreros, 24.07.2003, A. Maeda, CIB 831, 1 male (45.6 mm) and 2 other males. JALISCO: Chamela, 25.07.1998, C. Sánchez, CNCR 191, 2 specimens; Chamela, 19.06.1991, C. Sánchez, CNCR 192, 3 specimens; Chamela 12.09.1991, G. Casas, CNCR 196, 1 specimen; Puerto Vallarta, Las Aletas stream, 17.09.1973, A. Jiménez, CNCR 195, 1 specimen. GUERRERO: La Villita, 28.09.1973, A. Villalobos, CNCR 209, 3 specimens; Mexcalhuacán, 31.06.1984, J.C. Nates, CNCR 3550, 1 male (56 mm) (Holotype); Río Salitrera, Zihuatanejo, 22.07.1987, J.P. Gallo, CNCR 13292, 1 male (17.1 mm) and 1 ovigerous female. OAXACA: Río Galván, 31.05.1995, J.P. Gallo, CNCR 13293, 1 male (84.7 mm).

Macrobrachium olfersii (Wiegmann, 1836) (Fig. 7)

Palaemon olfersii Wiegmann, 1836.
Macrobrachium olfersii (Wiegmann, 1836); Hedgpeth, 1949; Villalobos, 1968; Villalobos-Hiriart et al., 1993; Hernández-Aguilera et al., 1996; Wicksten and Hendrickx, 2003.
Macrobrachium olfersi (Wiegmann, 1836); Holthuis, 1952; Villalobos, 1968.

Type Locality.—Not assigned. The original material was reported from a Brazilian shore.

Diagnosis.—Rostrum straight, reaching third joint of antennular peduncle; dorsal margin with 12 to 16 teeth, three to six placed behind orbital margin; ventral margin with one to five teeth. Second pair of pereiopods with unequal chelae and gaping fingers; carpus shorter than palm length and about as long as the merus; palm about 1.5 times long as high, with setae and pubescence on the lateral side; dactylus length slightly shorter than palm length; cutting edges of fingers with numerous denticles and dense hairs.

Distribution in the Baja California Peninsula.—Our collections represent the first records of the species for the peninsula. *Macrobrachium olfersii* is the second amphiamerican species recorded in the peninsula. It was found mainly on the Pacific slope in the basins of La Purísima, Santo Domingo, Santa Rita, Las Pocitas, Todos Santos, and Plutarco Elías Calles. On the Gulf of California slope the species was found only in the Alfredo V. Bonfil and San José del Cabo basins. Specimens were found in waters with TDS 0.26 to 0.61 g/L, pH 8.1 to 8.4, and temperatures 19.1 to 34.8°C. This species was co-occurring with other four congeners.

Distribution in México.—BAJA CALIFORNIA SUR (see above). SINALOA: Río Baluarte (Wicksten and Hendrickx, 2003). NAYARIT: Los Salazares, Río Santiago, and Arroyo Bogadero. MICHOACÁN: Mexcaltitán, and San Nicolás

creek. GUERRERO: Morelos dam, and Zihuatanejo. OAXACA: Río Tehuantepec. CHIAPAS: El Naranjo (Wicksten and Hendrickx, 2003), and Río Novillero. VERACRUZ: Río Tamazunchale (Holthuis, 1952).

General Distribution.—This species is distributed in the Pacific slope from the Baja California Peninsula to El Naranjo, Chiapas (Wicksten and Hendrickx, 2003) and in the Atlantic slope from Saint Agustin, Florida to Santa Catherina, Brazil (Bowles et al., 2000; Wicksten and Hendrickx, 2003).

Remarks.—One of the most evident features that distinguishes *M. olfersii* from other *Macrobrachium* species was noted by Boone (1931), who reported that this species has a dense brush of setae on the dorsal surface of the palm of the second large chela. It also has several denticles along the cutting edges of the fingers. *Macrobrachium hancocki* Holthuis, 1950 is one of the species similar to *M. olfersii*. We can separate them because the former species has only one proximal tooth on the cutting edges of the fingers and there is a pubescent area on the palm uncovered by spines (Holthuis, 1952). Another species similar to *M. olfersii* is *M. faustinum* (De Sassure, 1857). We can separate them using the ratio length/height of the palm. In *M. faustinum* the ratio is almost 2, whereas in *M. olfersii* is about 1.5. La Purísima basin is the northernmost boundary of the species in the entire Pacific slope.

Material Examined.—*Macrobrachium olfersii*: MÉXICO: BAJA CALIFORNIA SUR: Ojo de Agua, 15.07.2004, L. Hernández CIB 868, 1 specimen; La Purísima, 14.07.2004, G. Ruiz-Campos, UABC 007, 1 male (85.4 mm); San Javier dam, 15.07.2004, L. Hernández, CIB 869, 2 specimens; San Juanito Nuevo, 23.09.2004, L. Hernández, CIB 832, 1 male (55 mm); Rancho Tres Pozas, 23.09.2004, L. Hernández, CIB 833, 6 males (61 to 69 mm) and 24 specimens; El Cardalito, 19.11.2003, A. Maeda, CIB 834, 8 males (40.6 to 52.6 mm); El Mechudo, CIB 859, J.L. León, 4 specimens; Todos Santos, 26.02.2004, A. Maeda, CIB 835, 1 male (65.2 mm) and 1 ovigerous female (46.6 mm); Todos Santos, 26.11.2004, CIB 836, L. Hernández, 1 male (57 mm) and 1 ovigerous female (59 mm); Arroyo San José, 26.11.2004, L. Hernández, CIB 837, 3 males (45 to 63 mm); Poza de Santa Rosa, 14.12.2003, A. Maeda, CIB 838, 5 males (36.9 to 73.9 mm), 25.11.2004, L. Hernández, CIB 839, 3 males (57.3 to 65.8 mm). NAYARIT: Los Salazares, 14.08.2003, L. Hernández, CIB 840, 3 males (50.8 to 61.8 mm); Río Santiago, Espinosa, CNCR 11208, 1 male (78.7 mm); Arroyo Bogadero, 14.07.1991, A. Cantú, CNCR 11488, 2 males (70 and 72 mm); Arroyo Bogadero, 14.07 1991, A: Cantú, 3 males CNCR 11489. MICHOACÁN: Mezcaltitán, 13.08.2003, CNCR 22237, 1 male (56.4 mm); San Nicolás creek, 07.04.1987, J.C. Nates, CNCR 13304, 3 males (37.4 to 43.8 mm) and 1 female (51.1 mm). GUERRERO: Morelos dam, Zihuatanejo, 18.04.1974, Martínez, CNCR 259, 7 males (50 to 59.4 mm). OAXACA: Río Tehuantepec, 17.04.1974, R. Ortiz, CNCR 256, 1 specimen. CHIAPAS: Río Novillero, 06.10.2002, CNCR 22023, 1 male (42.8 mm). *Macrobrachium faustinum*: FRANCE: ÎLE DE LA GUADELOUPE: Riviere Corossol, MNHN 3654 6 males (65.8 to 83.3 mm).

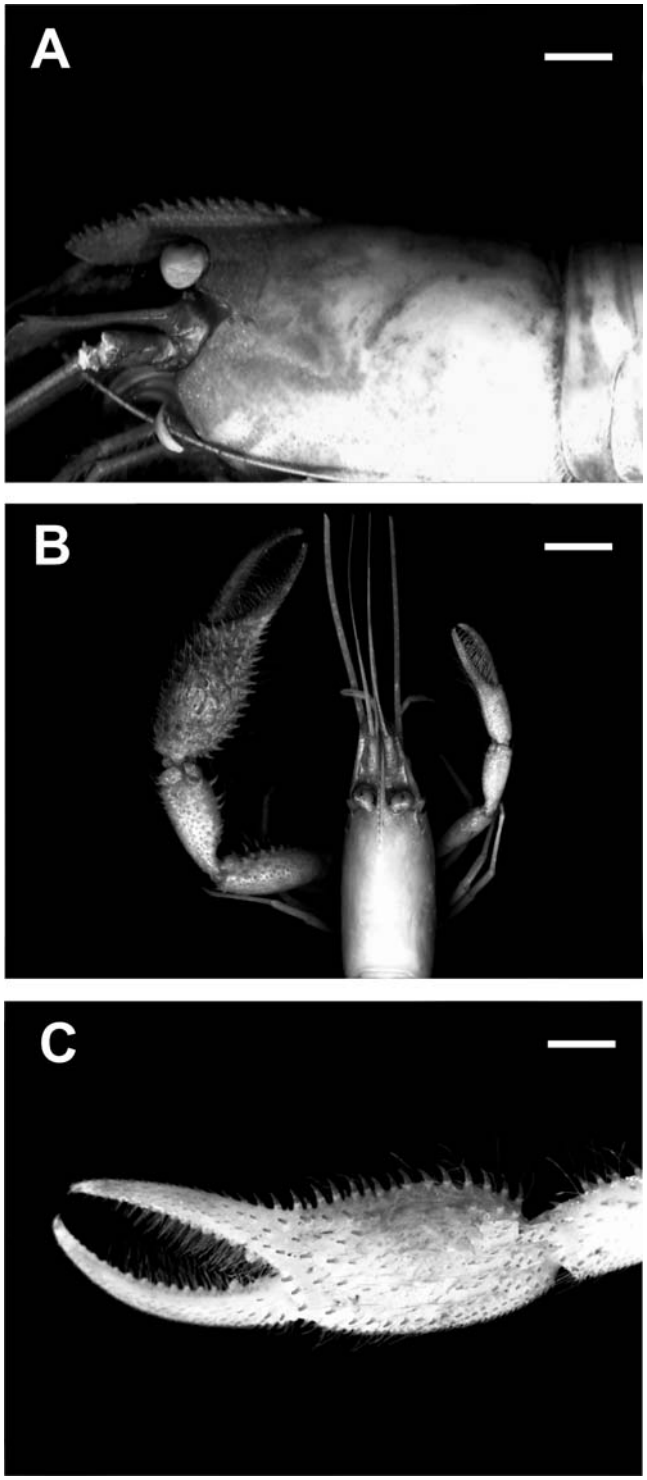

Fig. 7. Adult males of *Macrobrachium olfersii* (Wiegmann, 1836). A, Rostrum in left lateral view; B, Anterior region in dorsal view; C, Largest chela of the second pair of pereiopods in inner view. A and B from CIB 832, and C from CIB-834. Scale bars = 10 mm.

Macrobrachium tenellum (Smith, 1871) (Fig. 8)

Palaemon tenellus Smith, 1871.
Palaemon forceps M. Edwards; Bouvier, 1895.
Palaemon longipes Lockington, 1878.

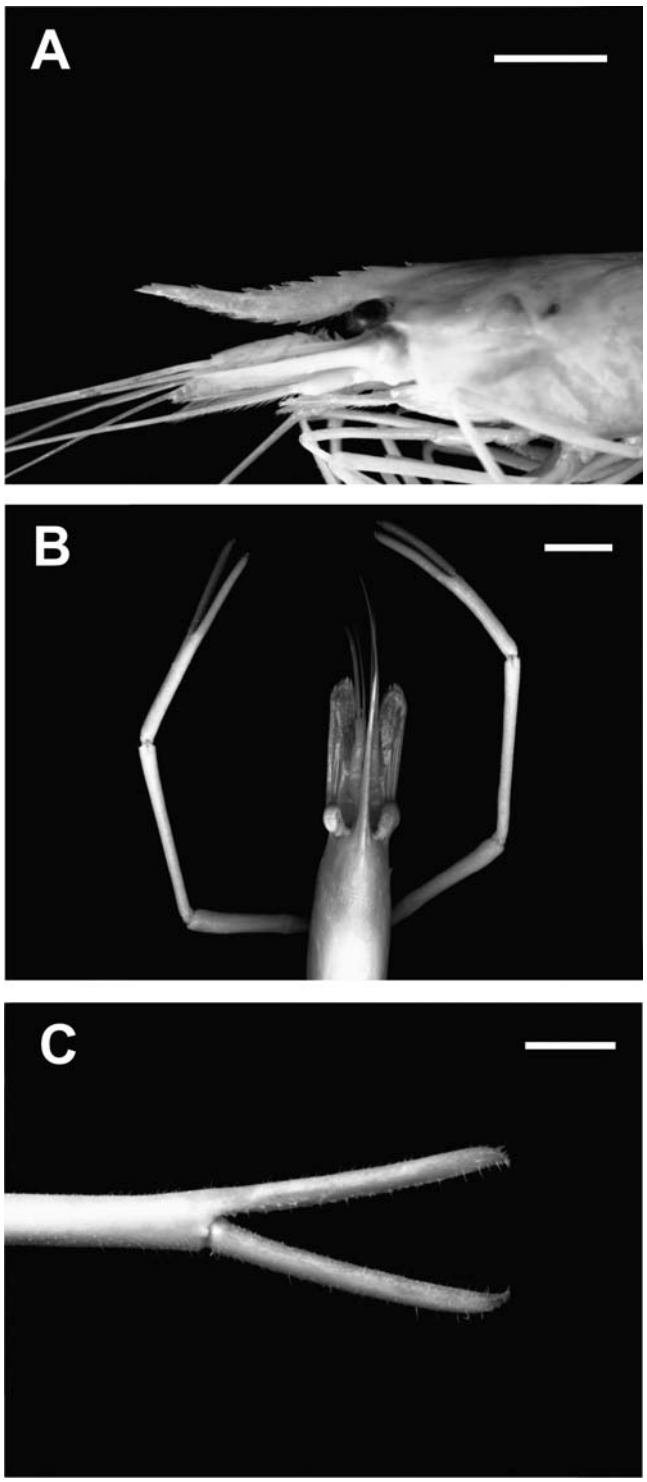

Fig. 8. Adult males of *Macrobrachium tenellum* (Smith, 1871). A, Rostrum in left lateral view; B, Anterior region in dorsal view; C, Right chela of the second pair of pereiopods in lateral view. A from CIB 841, B and C from CIB 844. Scale bars = 10 mm.

Macrobrachium tenellum (Smith, 1871); Holthuis, 1950, 1952; Rodríguez De La Cruz, 1968; Román-Contreras, 1979, 1991; Wicksten, 1983, 1989; Ríos, 1989; Wicksten and Hendrickx, 1992, 2003; Villalobos-Hiriart et al., 1993.

Type Locality.—Polvón, Nicaragua.

Diagnosis.—Rostrum very long, far in advance of the antennular peduncle; distal half curved upward with a terminal dent that looks like a bifid tip; dorsal margin with eight to 11 teeth, seven or eight placed over proximal half; only one tooth placed behind posterior orbital margin; ventral margin with five to seven teeth. Second pair of pereiopods with subequal chelae and closed fingers; carpus longer than merus length and palm length; fingers straight, slender, naked, or with scarce pubescence.

Distribution in the Baja California Peninsula.—*Macrobrachium tenellum* was previously reported in the peninsula only on the Gulf of California slope from the Mulegé and San José del Cabo basins (Lockington, 1871; Bouvier, 1895; Holthius, 1952). We found this species on the Pacific slope in the basins of Santa Rita, Las Pocitas, and Todos Santos. Specimens were collected in waters with TDS 0.52 to 1.58 g/L, pH 6.7 to 8.9, and temperatures 17.3 to 33.7°C. This species co-occurred with the other five species of the peninsula.

Distribution in México.—BAJA CALIFORNIA SUR (see above). SINALOA: Mazatlán, Laguna Caimanero, and El Rosario (Rodríguez De La Cruz, 1968; Wicksten, 1983), Escuinapa, Estero Botadero, and Estero Urías. NAYARIT: Colomó, Mezcaltitán, and San Blas. JALISCO: Río Cuitzmala. MICHOACÁN: Río Balsas and Arroyo Playa Azul. GUERRERO: Laguna de Coyuca, Laguna Tres Palos (Román, 1979), Zihuatanejo, and Laguna Coyula. OAXACA: Bahía Tangola Tangola (Holthuis, 1952). CHIAPAS: Río Coatán.

General Distribution.—From the Baja California Peninsula to Perú (Holthuis, 1952; Wicksten, 1983; Wicksten and Hendrickx, 1992, 2003).

Remarks.—*Macrobrachium tenellum* is easy to distinguish from its congeners of the Pacific slope. This species has the second pair of pereiopods with subequal chelae, a large rostrum upcurved at the distal half, with a terminal dent that looks like a bifid tip. Among adult males, we observed some specimens with very large second pereiopods with dense pubescence on the chelae and fingers. We compared 190 specimens of *M. tenellum* with 60 specimens of its geminated species *M. acanthurus* (Wiegmann, 1836) of the Atlantic slope. The differences are in the longest and upcurved rostrum of *M. tenellum* and the presence of one dorsal spine of the rostrum behind the orbital margin. The color in life for *M. acanthurus* is pale yellow-brown, chelipeds are dark green becoming blue distally, and the midrib of the rostrum is red (Bowles et al., 2000). In our observations *M. tenellum* has a translucent body with little red spots on lateral abdomen. Chelae are yellow-brown.

The northernmost boundary of *M. tenellum* in the Baja California Peninsula is at Merecuaco in the Santa Rita basin of the Pacific slope and in Mulegé on the Gulf of California slope.

Material Examined.—*Macrobrachium tenellum*: MÉXICO: BAJA CALIFORNIA SUR: Mulegé, 1894, L. Diguet, MNHN 6476, 9 specimens (58.7 to 112.2 mm) and 5 ovigerous females (74 to 80.2 mm) labeled as *M.*

acanthurus; Mulegé, 1894, L. Diguet, MNHN 6377, 12 specimens (77 to 107 mm) and 2 ovigerous females (73.8 and 79.8 mm) labeled as *M. acanthurus*; Mulegé, 08.07.1999, G. Ruiz-Campos, UABC 005, 1 male (91.5 mm), 7 females (50.5 to 67.9 mm), and 1 ovigerous female (72.8 mm); Mulegé, 28.02.2004, A. Maeda, CIB 841, 11 specimens; Mulegé, 21.09.2004, L. Hernández, CIB 842, 2 males (77.2 and 91.8 mm) and 4 ovigerous females (58 to 68.5 mm); Mulegé, 11.11.2004, L. Hernández, CIB 843, 3 males (95.5 to 130.4 mm) and 5 females (56 to 72.6 mm); Rancho Las Cuevas, 30.05.2004, L. Hernández, CIB 844, 4 males (86 to 111.3 mm); Merecuaco, L. Hernández, CIB 845, 4 males (84.6 to 110 mm) and 1 female (68.9 mm); Corral de Piedra, 29.05.2004., L. Hernández, CIB 846, 1 male (88.2 mm) and 4 females (63 to 73.7 mm); El Caracol, 29.05.2004, L. Hernández, CIB 847, 11 males (58.3 to 85.6 mm), 8 females (45 to 67.3 mm), and 8 specimens; Santa Fe, 02.03.2004, L. Hernández, CIB 848, 11 specimens (18.8 to 33.3 mm); La Poza, 10.07.2005, L. Hernández, CIB 856, 4 males (28.5 to 30.3 mm) and 2 females (28.8 and 30.2 mm); San Pedrito, 09.07.2005, L. Mercier, CIB 858, 11males (49 to 72 mm) and 4 females (42.2 to 47.7 mm); San José del Cabo, 08.09.2004, L. Hernández, CIB 849, 9 males (57.7 to 111.5 mm) and 7 females (64.7 to 72.2 mm). SINALOA: Escuinapa, 25.03.1974, Díaz, CNCR 185, 2 specimens; Estero Botadero, 25.03.1974, CNCR 296, 1 male (88.6 mm); Laguna Caimanero, CNCR 1665, 2 males (71 and 104.8 mm); Estero Urías, 25.10.1973, D. Peláez, CNCR 2593, 1 female (76.8 mm). NAYARIT: Colomó, 13.08.2003, L. Hernández, CIB 850, 1 male (115.3 mm) and 1 female (82.1 mm); Mezcaltitán, L. Hernández, CIB 851, 8 males (112.9 to 128.5 mm) and 15 females (90 to 92 mm ovigerous); San Blas, 26.03.1974, G. Gaviño, CNCR 2594, 1 male (88.7 mm). JALISCO: Río Cuitzmala, 02.04.1984, A. Villalobos CNCR 13395, 2 males (18.5 and 50.9 mm); Cuitzmala, 15.05.1994, H. Espinosa, CNCR 13429, 1 female (51.4 mm). MICHOACÁN: Mouth of Río Balsas (between Michoacán and Guerrero), 20.09.1976, C. Martínez, CNCR 305, 1 male (82.3 mm); Mouth of Río Balsas, 30.09 1976, CNCR 1819, 1 specimen; Arroyo Playa Azul, 06.03.1983, A. Villalobos, CNCR 20701, 2 males (56.5 and 102.3 mm). GUERRERO: Laguna de Coyuca, J. Cabrera, CNCR 186, 4 specimens; Laguna de Coyuca, 26.05.1976, A. Enhir, CNCR 2219, 1 specimen; Zihuatanejo, 05.12.1976, CNCR 1804, 2 females (60 and 62.6 mm); Laguna Coyula, 09.05.1984, A. Villalobos, CNCR 2627, 1 male (75.1 mm). OAXACA: Puerto Escondido, 30.10.1991, C. Rosales, CNCR 13367, 1 male (113.2 mm) and 1 female (94.6 mm). CHIAPAS: Río Coatán, 03.10.1970, CNCR 295, O. Gutiérrez, 1 male (119.2 mm). *Macrobrachium acanthurus*: MÉXICO: 26.12.1894, MNHN 339 65, 1 specimen; CNCR 207, 1 male (59 mm), and 2 females (46.7 and 48.8 mm); CNCR 13290, 2 specimens; CNCR 13336, 4 males (66.7 to 106 mm); CNCR 16489, 2 males (82.2 and 110.8 mm); CNCR 16493, 1 specimen; CNCR 16514, 4 males (64 to 80 mm); CNCR 16579, 1 ovigerous female (47.9 mm); CNCR 17077, 1 male (58.9 mm), and 2 ovigerous females (46.7 and 48.8 mm); CNCR 17086, 2 males (71.7 and 72 mm); CNCR 17105, 7 males (28 to 45.8 mm), and 2 ovigerous females (44.1 and 48 mm); CNCR 17117, 1 male (96.6 mm), and 3 females (81.4 to 91.4 mm); CNCR 17138, 4 males (50 to 75 mm), and 1 ovigerous female (57.5 mm); CNCR 17146, 3 males (66.7 to 93 mm), and 3 females (53.7 to 67.1 mm); CNCR 17335, 4 males (104 to 115.4 mm); CNCR 17337, 3 males (107 to 134.3 mm); CNCR 17344, 2 males (131.6 and 135.5 mm); CNCR 21699, 6 males (77.7 to 107.6 mm).

Discussion

Jayachandran (2001) recently proposed the division of the genus *Macrobrachium* into two subgenera. The subgenus *Macrobrachium* includes those species with the second pair of pereiopods with equal or subequal chelae and the tip of telson reaching or passing the distal end of the lateral uropodal spine, and the subgenus *Allobrachium* includes those species with the second pair of pereiopods with unequal chelae and the tip of telson not reaching the distal end of the lateral uropodal spine. The materials examined by us are not consistent with the extension of the telson as mentioned by Jayachandran (2001). We do not accept this subgeneric division until a molecular analysis has been made and demonstrates that the division proposed using the types of chelae is phylogenetically supported.

The total number of the species of *Macrobrachium* recorded from México is 17. Those distributed for the Mexican Pacific slope are *M. americanum*, *M. digueti*, *M. hobbsi*, *M. michoacanus*, *M. occidentale*, *M. olfersii*, and *M. tenellum* (Villalobos-Hiriart et al., 1993; Román et al., 2000; Wicksten and Hendrickx, 2003) and those of the Mexican Atlantic slope are *M. acanthurus*, *M. acherontium* Holthuis, 1977, *M. carcinus*, *M. heterochirus*, *M. hobbsi*, *M. nattereri* (Heller, 1862), *M. olfersii*, *M. quelchi* De Man, 1900, *M. totonacum* Mejía, Álvarez and Hartnoll, 2003, *M. tuxtlaense* Villalobos and Álvarez, 1999, *M. vicconi* Roman, Ortega and Mejía, 2000, and *M. villalobosi* Hobbs, 1973 (Rodríguez De La Cruz, 1968; Álvarez et al., 1996; Villalobos-Hiriart et al., 1993; Villalobos and Álvarez, 1999; Román et al., 2000; Mejía et al., 2003). Our results give relevant information on the species diversity existing in the Baja California Peninsula. Of the seven species of *Macrobrachium* of the Mexican Pacific slope, six (86%) occur in the Baja California Peninsula. This is an outstanding number considering that its oases have a total area of only about 75 km^2 (Maya et al., 1997) and that these oases are fragile habitats in a desert ecosystem with a limited volume of surface water. The basins of the Baja California Peninsula with the highest species diversity are in the Pacific slope: Plutarco Elías Calles and Las Pocitas with five species each, and Santa Rita with four species.

The northernmost record of the genus *Macrobrachium* along the Pacific slope of the Baja California Peninsula is in the La Purísima basin where *M. hobbsi* and *M. olfersii* were found. The northernmost record of the genus in the Gulf of California slope of the peninsula is in Mulegé basin where *M. americanum* and *M. tenellum* were found. However the general northernmost boundary of the genus in the whole Pacific slope is Guaymas, Sonora (27°55′N, 110°52′W)

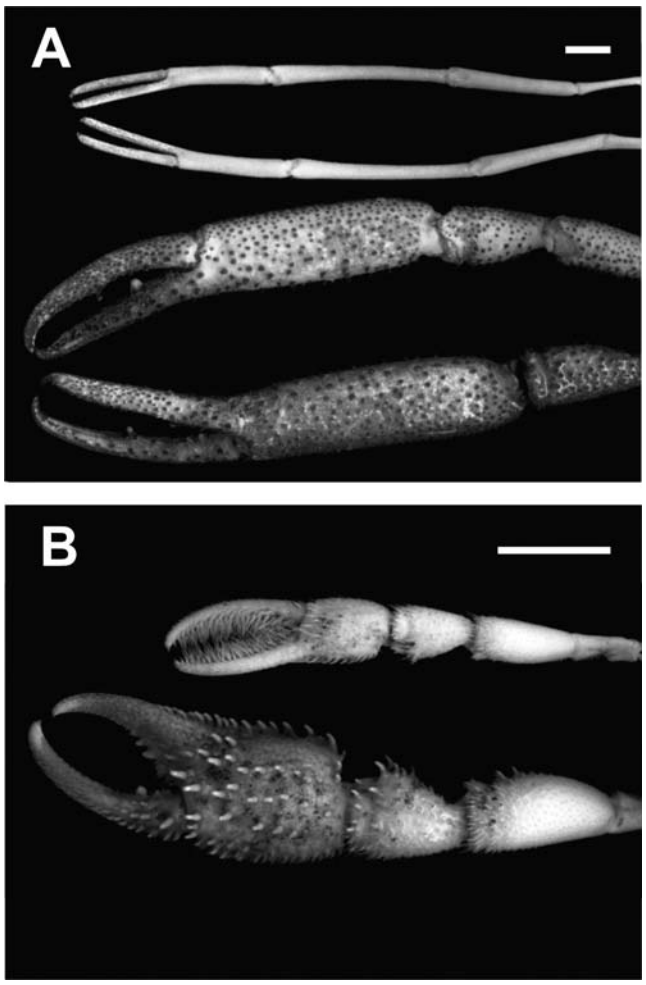

Fig. 9. Types of chelae of the second pair of pereiopods in adult males of *Macrobrachium*. A, Subequal type; B, Unequal type. Scale bars = 10 mm.

where *M. americanum* and *M. tenellum* occur (Wicksten, 1983, 1989; Wicksten and Hendrickx, 2003).

Native fish and reptiles of the Baja California Peninsula are considered to have a vicarious origin (Follett, 1960; Grismer, 1994; Castro-Aguirre et al., 1999). We suggest the same for the freshwater decapods. Thus the populations of *Macrobrachium* of the peninsula may represent relict strains of species distributed in mesophilic environments during the formation and separation of the peninsula since the Miocene. Of the six species occurring in the peninsula, four (*M. americanum*, *M. digueti*, *M. olfersii*, and *M. tenellum*) have a wide distribution on the Pacific slope of North and South America, so they are also found in one or two of the mainland states of Sonora and Sinaloa on the east coast of the Gulf of California (Wicksten and Hendrickx, 2003). The other two species are endemic to México and show distributional gaps worth being studied: *M. hobbsi* and *M. michoacanus* are present in the peninsula, but in the mainland they are distributed from Nayarit and Jalisco to southern states of Chiapas and Oaxaca (Villalobos and Nates, 1980; Wicksten and Hendrickx, 2003). Relict populations of the seventh species of the Mexican Pacific slope, *M. occidentale*, may also be present in the peninsula, but additional monitoring is required to test this hypothesis.

According to Wilcove et al. (1998), the greatest threats to biodiversity are habitat destruction (degradation or loss) and introduction of nonnative (alien, exotic) species. The species of *Macrobrachium* in the peninsula of Baja California are mainly threatened by the modification of the habitat and the introduction of exotic species. Half of the sites we sampled have been altered by water extraction for human use. In 12 of these sites the water is impounded and controlled by dams. In most of the 33 sites with shrimp, the native aquatic community has been modified by the introduction of exotic and invasive fish as tilapia and guppy (Ruiz-Campos et al., 2002, 2004). In the oasis of San Ignacio, no species of *Macrobrachium* were found but an exotic crayfish species was present (a study of exotic crustaceans in the Baja California peninsula is in progress and will be published elsewhere).

The Australian crayfish *Cherax quadricarinatus* (Von Martens, 1868) has been introduced into the Baja California Peninsula for aquaculture. The only active farm for this species uses outdoor tanks and is in the El Carrizal basin, which is situated between two basins rich in native species of *Macrobrachium* (Todos Santos and Las Pocitas basins). Lodge et al. (2000) have reported that invariably *C. quadricarinatus* escapes from outdoor aquaculture facilities, so there is a high risk that this Australian crayfish will reach and become established in the oases. *Cherax quadricarinatus* is considered an invasive and aggressive animal that may compete with and replace local freshwater shrimp (Williams et al., 2001). Some countries and states of the USA have taken legal measures to avoid the introduction and culture of this alien animal into their territories (Lodge et al., 2000). Because the control or elimination of alien species is a difficult or impossible task, local, state, and federal Mexican authorities should give attention to this threat by implementing effective measures of control and-or prohibiting the introduction and use of alien invasive species in the Baja California Peninsula. Immediate measures of protection should be given to those basins with shrimp but still free of exotic species, such as Alfredo V. Bonfil, El Coyote, and Plutarco Elías Calles, especially the last one, which is the refuge of five of the six species of *Macrobrachium*.

Nothing is known about the conservation status and dynamics of the populations of *Macrobrachium* in the Baja California Peninsula. Studies on these are imperative to establish a sustainable management proposal. The local population in the San José del Cabo, Plutarco Elías Calles, and Las Pocitas basins use these animals as food without any official regulation, and this may be an important additional pressure to these shrimp populations.

The comparison of historical records (Bouvier, 1895; Ríos, 1989) with those of this study indicates that *Macrobrachium digueti* has been extirpated from its type locality, the Mulegé oasis, which is considered one of the oases along the peninsula most impacted by humans. The anthropogenic modification of the oases is putting the survival of native flora (León and Domínguez, 2006) and fauna (Ruiz-Campos et al., 2002, 2004) at risk. The identification of proper biotic and

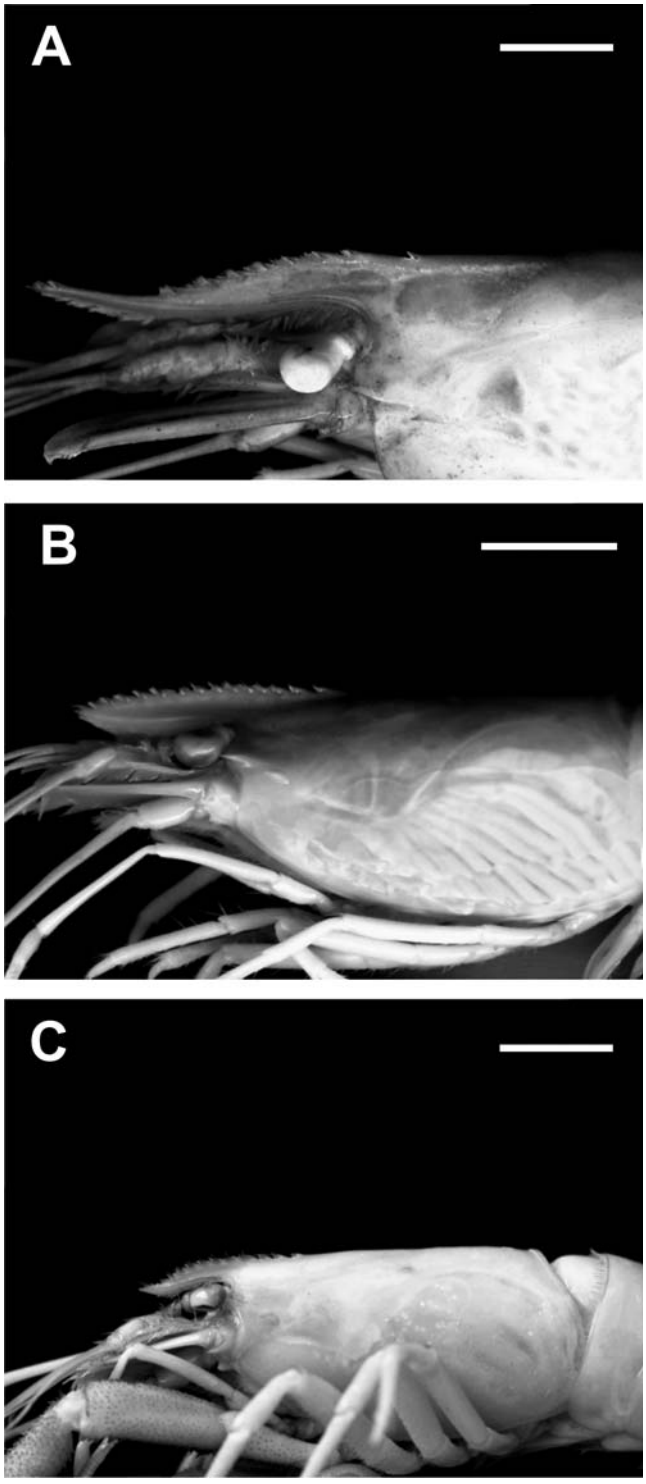

Fig. 10. Types of rostra in adult males of *Macrobrachium*. A, Large type, longer than the antennular peduncle; B, Straight type; C, Arched type. Scale bars = 10 mm.

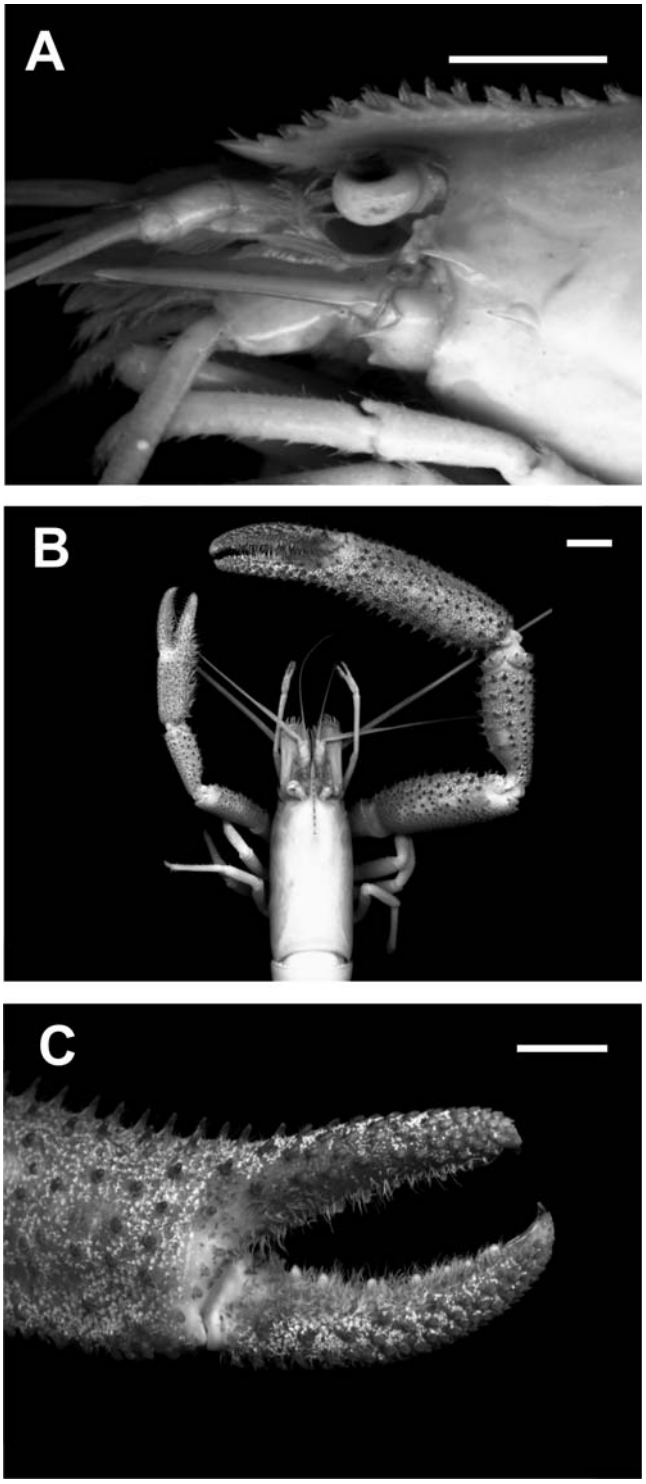

Fig. 11. Adult males of *Macrobrachium occidentale* (Wiegmann, 1836). A, Rostrum in left lateral view; B, Anterior region in dorsal view; C, Largest chela of the second pair of pereiopods in lateral view. All figures from CIB 863. Scale bars = 10 mm.

abiotic indicators of the ecological integrity of the oases is urgently needed. Freshwater shrimp of the oases are resource-limited and process-limited organisms because their survival primarily depends on the existence of surface water (resource) and on the stational refilling of the water bodies (ecological process). These characteristics, according to the criteria for the selection of indicator species (Carignan and Villard, 2002), make the various species of *Macrobrachium* potential indicators to monitor the ecological integrity of these oases.

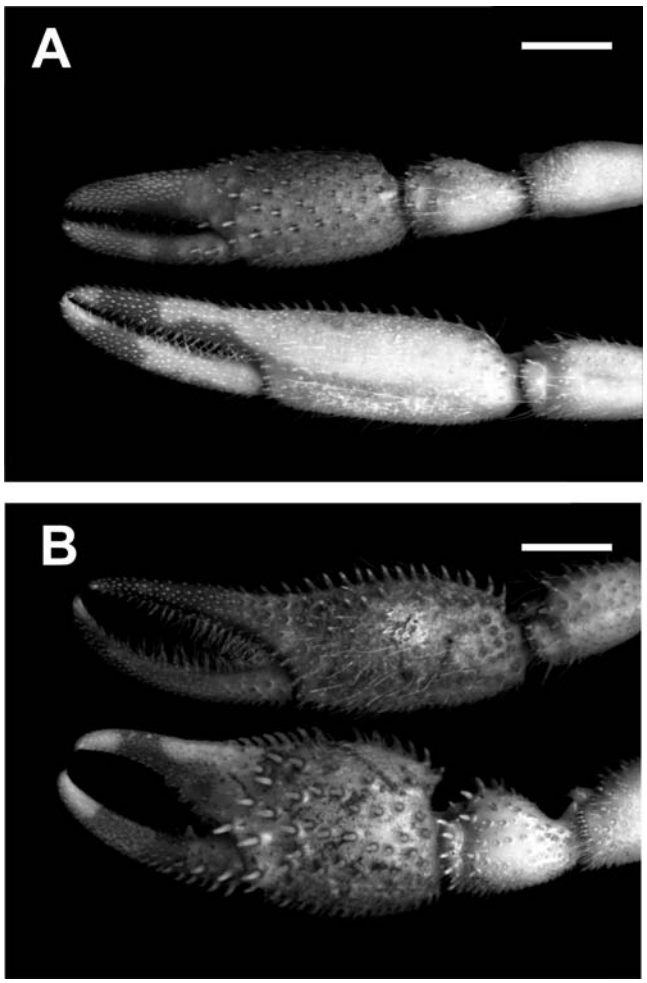

Fig. 12. Types of fingers in adult males of *Macrobrachium*. A, Closed fingers; B, Gape fingers. Scale bars = 10 mm.

Key to the Species of *Macrobrachium* of Northwest México

1a. Second pair of pereiopods with chelae subequal (Fig. 9A): 2
1b. Second pair of pereiopods with chelae unequal (Fig. 9B): 3
2a. Rostrum arched (Fig. 10C), reaching almost the distal joint of the antennular peduncle; second pair of pereiopods with carpus shorter than half of palm; cutting edge of fixed finger with a tooth in the proximal third; dactylus with one tooth in the middle of the cutting edge: . . . . . *Macrobrachium americanum* Bate, 1868 (Fig. 3).
2b. Rostrum extending beyond distal margin of antennular peduncle, distal half up curved (Fig. 10A); second pair of pereiopods with carpus almost twice as long as the palm: . . . . . *Macrobrachium tenellum* (Smith, 1871) (Fig. 8).
3a. Rostrum short and arched (Fig. 10C), not far than the second joint of the antennular peduncle; second pair of pereiopods with carpus longer than half of palm; cutting edges of fingers with hairs covering the 5 to 8 denticles: . . . . . *Macrobrachium occidentale* Holthuis, 1950 (Fig. 11).
3b. Rostrum straight (Fig. 10B), reaches at least the second joint of the antennular peduncle: 4
4a. Second pair of pereiopods with closed fingers (Fig. 12A): 5
4b. Second pair of pereiopods with gaping fingers (Fig. 12B): 6
5a. Largest chela of the second pair of pereiopods with evident pubescence over the palm; palm about twice as long as high; carpus as long as merus: . . . . . *Macrobrachium hobbsi* Nates and Villalobos, 1990 (Fig. 5).
5b. Largest chela of the second pair of periopods with scarce pubescence over the palm; palm less than 1.5 times long as high; merus longer than carpus: . . . . . *Macrobrachium michoacanus* Nates and Villalobos, 1990 (Fig. 6).
6a. Largest chela of the second pair of periopods with carpus shorter than palm, and about as long as the merus, pubescence and setae over the palm; cutting edges of fingers with 9 to 12 teeth; carpus shorter than palm, and about as long as the merus: . . . . . *Macrobrachium olfersii* (Wiegmann, 1836) (Fig. 7).
6b. Largest chela of the second pair of periopods with scarce pubescence and without setae; cutting edges of dactylus with up to 4 proximal teeth; carpus shorter than merus: . . . . . *Macrobrachium digueti* (Bouvier, 1895) (Fig. 4).

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Appendix: Sampled Sites

The sampled sites are organized below according to the political state and the hydrological regions and basins of the Baja California Peninsula given by INEGI (1995). For each site, its name and coordinates are given. Data on the general condition of the habitat and water characteristics are given only for those sites where *Macrobrachium* were found. For previous reports of fish and water characteristics of the sites see Ruiz-Campos et al. (2002).

State of Baja California Sur

I. Pacific slope

1. Hydrological region RH2: Baja California Centro Oeste (Vizcaíno)
1.1. Punta Eugenia basin
1.1.1. Arroyo San José de Castro, 27°32′19.7″N, 114°28′20.7″W.
1.1.2. Arroyo San Cristóbal (north), 27°31′10.5″N, 114°34′36.5″W.
1.1.3. Arroyo Rancho Nuevo, 27°28′42.6″N, 114°32′21″W.
1.2. San Ignacio basin
1.2.1. San Ignacio, 27°18′N, 112°53′W.
1.2.2. San Joaquín, 27°11′N, 112°51′W.
1.2.3. El Sauzal, 27°10′N, 112°52′W.
1.2.4. San Zacarías, 27°08′N, 112°54′W.
2. Hydrological region RH3: Baja California Sur-Oeste (Magdalena)
2.1. La Purísima basin
2.1.1. Poza en La Tasajera, 26°21′17.4″N, 111°49′59.1″W.
2.1.2. Arroyo La Tasajera, 26°20′46″N, 111°47′12″W.
2.1.3. Ojo de Agua, 26°19′36.4″N, 111°58′40″W. Freshwater spring and the main water source of the basin. Palms and acacias surround the spring and the bottom was muddy. Part of the water is taken for agricultural and domestic use. The water characteristics were TDS 0.4 g/L, pH 7.9, and temperature 31.4°C.
2.1.4. San Isidro dam, 26°14′19.7″N, 112°08′04″W. Dam at La Purísima creek with a sandy bottom and a surface area of about 0.5 km^2. The water is taken for domestic use, agriculture, and orchards. The water characteristics were TDS 0.4 g/L, pH 8.4, and temperature 27.7°C.
2.1.5. Carambuche dam, 26°12′58″N, 112°01′12″W. Dam at La Purísima creek with a sandy bottom. The water is taken for domestic use, agriculture, and orchards. There are some houses and farms near the stream. The water characteristics were TDS 0.6 g/L, pH 9.0, and temperature 26.8°C.
2.1.6. La Purísima, 26°10′58″N, 112°05′18″W. Freshwater pond at La Purísima creek with a sandy bottom and a surface area of about 0.5 km^2. The pond is surrounded by palms and orchards. The water is taken for domestic use, agriculture, and orchards. The water characteristics were TDS 0.4 g/L, pH 7.9, and temperature 31.4°C.
2.1.7. San Juanico road, 26°09′32″N, 112°07′42″W. Intermittent freshwater pond at La Purísima creek with sandy bottom. The water characteristics were TDS 1.0 g/L, pH 8.9, and temperature 30°C.
2.1.8. Arroyo San Gregorio, 26°05′09.8″N, 112°13′31.4″W.
2.1.9. San José de Comondú, 26°03′32″N, 112°07′42″W.
2.1.10. San Miguel de Comondú, 26°01′57″N, 111°49′58″W.
2.2. Santo Domingo basin
2.2.1. San Javier, 25°52′07″N, 111°32′49″W. Small dam in a mountainous area (about 1000 m above sea level). The bottom is sandy with gravel. The surface area is about 20 m^2 and is surrounded by acacias and other riparians. No living shrimp were collected, but some exhuviae were found. The water characteristics were TDS 0.3 g/L, pH 7.8, and temperature 33°C.
2.2.2. Rancho Los Dolores, 25°49′53.1″N, 111°31′06.9″W.
2.2.3. Poza de las Bramonas, 25°08′53.8″N, 112°02′35.3″W.
2.3. Santa Rita basin
2.3.1. Presa Ihuajil, 24°58′22″N, 111°23′37″W.
2.3.2. Rancho San Lucas, 24°57′44″N , 111°20′17″W.
2.3.3. Rancho Frijolito, 24°57′29″N, 111°19′06″W.
2.3.4. Misión San Luis Gonzaga, 24°54′34″N, 111°17′21″W.
2.3.5. Rancho Las Cuedas, 24°53′59″N, 111°14′58″W.
2.4. Las Pocitas basin
2.4.1. Presa de Guadalupe, 24°53′36″N, 110°03′07″W. Dam over the creek with granitic bottom surrounded by palms and other riparian vegetation. The water surface area was about 2500 m^2. The water is used for orchards in a small ranch. No water characteristics were taken in this site.
2.4.2. San Pedro de la Presa, 24°50′43″N, 110°59′32″W. Dam over the creek with granitic bottom surrounded by palms. The water surface area was about 100 m^2. The water is used for orchards and agriculture. The water characteristics were TDS 0.2 g/L, pH 8.1, and temperature 31°C.
2.4.3. San Basilio, 24°50′13″N, 111°04′37″W. Freshwater intermittent pond over the creek. The bottom was sandy without surrounding vegetation. The water is used for farm animals. The water characteristics were TDS 0.9 g/L, pH 7.4, and temperature 31.3°C.
2.4.4. Las Paredes, 24°49′55.3″N, 110°48′25.2″W. Permanent small fall, surrounded by rocks and bottom with gravel. The water surface area was about 20 m^2. The water is used for domestic activities. The water characteristics were TDS 0.3 g/L, pH 7.3, and temperature 26.1°C.
2.4.5. San Juanito Nuevo, 24°49′40.4″N, 111°06′19.1″W. Permanent freshwater pond with sandy bottom, surrounded by riparian plants. The water area was about 10 m^2. The water is taken for domestic use and farm animals. The water characteristics were TDS 0.3 g/L, pH 8.4, and temperature 34.8°C.
2.4.6. Rancho Las Cuevas, 24°49′00″N, 110°52′47.7″W. Permanent freshwater pond with rocky bottom, surrounded by rocks and riparian vegetation. The water surface area was about 30 m^2. The water is taken for domestic and farm animals. The water characteristics were TDS 0.5 g/L, pH 8.1, and temperature 30°C.
2.4.6. Rancho Tres Pozas, 24°48′58″N, 111°07′33″W. Three freshwater ponds over the creek, with rocky bottom with gravel. The water is taken for domestic use and farm animals. The water characteristics were TDS 0.3 g/L, pH 8.3, and temperature 34.5°C.
2.4.7. Rancho Merecuaco, 24°48′25″N, 111°09′03″W. Small freshwater pond over the intermittent sandy creek with no surrounding vegetation. The water surface area was 10 m^2. The water is used for domestic activities. The water characteristics were TDS 0.7 g/L, pH 8.9, and temperature 24.3°C.
2.4.8. Presa Vieja, 24°48′18.6″N, 111°32′52.6″W.
2.4.9. Paso Iritú, 24°46′55″N, 111°09′02″W. Rustic dam surrounded by riparian vegetation. The bottom was sandy with gravel. The water surface area was about 20 m^2. The water is taken for domestic use. The water characteristics were TDS 0.7 g/L, pH 9.3, and temperature 28.5°C.
2.4.10. Corral de Piedra, 24°44′16.3″N, 110°55′59.8″W. Freshwater permanent pond with a sandy bottom and with gravel. The water surface area was about 20 m^2. The water is used for domestic activities. The water characteristics were TDS 0.8 g/L, pH 8.1, and temperature 24°C.
2.4.11. El Caracol, 24°31′22″N, 111°00′08″W. Freshwater spring with sandy bottom surrounded by palms and riparian vegetation. The water surface area was about 20 m^2. The water characteristics were TDS 0.6 g/L, pH 6.7, and temperature 31.5°C.
2.4.12. La Matanza, 24°28′47″N, 111°03′40.8″W. Freshwater pond with sandy bottom. The water surface area was about 10 m^2 and the water is used for domestic activities and orchards. The water characteristics were TDS 0.9 g/L, pH 7.4, and temperature 30°C.
2.4.13. Arroyo Las Pocitas, 24°24′10″N, 111°06′12″W.
2.4.14. El Colorado, 24°24′07.9″N, 111°06′09.7″W. Freshwater pond surrounded by riparian vegetation. The bottom was sandy and the water surface area was about 8 m^2. The water is used for farm animals. The water characteristics were TDS 3.5 g/L, and temperature 22.1°C.
2.4.15. El Cardalito, 24°23′23.5″N, 111°07′01.9″W. Intermittent freshwater pond over the creek, with sandy bottom. There was some riparian vegetation. The water characteristics were TDS 0.6 g/L, and temperature 19°C.
2.4.16. Santa Fe, 24°16′44.2″N, 111°14′01.5″W. Intermittent freshwater pond over the sandy creek. The pond is located about 8 km from the estuary. The water characteristics were TDS 1.1 g/L, and temperature 22.7°C.
2.5. Todos Santos basin
2.5.1. Todos Santos, 23°28′35.6″N, 110°12′41.4″W. Permanent freshwater pond that has been altered by urban and agricultural activities. There is a net of channels for agriculture and orchards. The surrounding vegetation is composed mainly by palms and giant reeds. The site was visited twice. The water characteristics were TDS 0.1 g/L, pH 6.9, and temperature 25.5°C on 26 February 2004 and TDS 0.3 g/L, pH 7.3, and temperature 26.6°C on 26 November 2004.
2.5.2. Todos Santos channels, 23°27′N, 110°13′W. Net of water channels for orchards. The water characteristics were TDS 0.3 g/L, pH 8.9, and temperature 26.8°C.

2.5.3. La Poza, 23°26′13.4″N, 110°14′17.3″W. Estuarine pond surrounded by palms and giant reeds. The water surface area was about 80 m^2. The water characteristics were TDS 0.3 g/L, pH 8.9, and temperature 23.5°C.
2.5.4. San Pedrito, 23°23′28″N, 110°12′40″W. Estuarine pond surrounded by palms and giant reeds. The bottom was sandy and the water is used for local agriculture. The water surface area is about 200 m^2. The water characteristics were TDS 2.0 g/L, pH 7.3, and temperature 25°C.
2.6. Plutarco Elías Calles basin
2.6.1. Los Potreros, 23°17′N, 110°01′W. A series of intermittent ponds at Los Potreros creek, surrounded by riparian vegetation and some palms. The bottom is granitic with sand and gravel. The water is taken for domestic use and agriculture. The water characteristics were TDS 0.42 g/L, and temperature 32.6°C.
2.6.2. San Pedro de la Soledad, 23°14′33.6″N, 109°59′29.2″W. Permanent freshwater pond at Los Potreros creek with riparian vegetation and some palms. The bottom was sandy and muddy. The water characteristics were TDS 0.3 g/L, pH 8.0, and temperature 25.8°C.
2.7. Migriño basin
2.7.1. Arroyo San Cristóbal (south), 22°57′N, 109°59′W.

II. Gulf of California slope

3. Hydrological region RH5: Baja California Centro-Este (Santa Rosalía)
3.1. Las Vírgenes basin
3.1.1. Rancho San Gregorio, 27°40′35″N, 113°01′02″W.
3.2. Santa Rosalía basin
3.2.1. Arroyo San Luciano, 27°19′06″N, 112°14′36″W.
3.3. Santa Águeda basin
3.3.1. Santa Águeda, 27°15′39.4″N, 112°21′01.3″W.
3.4. San Marcos basin
3.4.1. San José de Magdalena, 27°04′08″N, 112°12′07″W.
3.5. Mulegé basin
3.5.1. Mulegé, 26°53′N, 111°57′W. Historic oasis located two kilometers inland from the coastal mangrove. At the site there is an old dam that contains a permanent water pond surrounded by a forest of palms and giant reeds. The bottom was sandy-muddy and the water is used for domestic activities and agriculture. The city of Mulegé is growing around the oasis, so probably this is the most altered oasis along the eastern Baja California Peninsula because of urban impact and increasing water use. This site was sampled three times during February and September 2004 and April 2005. The water characteristics were TDS 1.1 g/L, pH 8.0, and temperature 20.5°C on 28 February 2004, TDS 1.2 g/L, pH 7.7, and temperature 31°C on 21 September 2004, and TDS 1.2 g/L, pH 8.1, and temperature 22.2°C on 08 April 2005.
3.5.2. La Trinidad, 26°45′10.6″N, 112°07′39.6″W.
3.5.3. San Narcisito, 26°44′43.3″N, 112°08′48.3″W.
3.5.4. San Miguel, 26°42′40.5″N, 112°18′15.8″W.
3.5.5. Arroyo San Martín, 26°38′14″N, 112°17′27″W.
4. Hydrological Region RH6: Baja California Sur-Este (La Paz)
4.1. El Rosarito basin
4.1.1. El Bombedor, 26°23′11.7″N, 111°36′01″W.
4.2. Alfredo V. Bonfil basin
4.2.1. El Mechudo, 24°48′N, 110°40′W. Intermittent freshwater pond. Apparently, the site has not been altered by human activities. No data on water characteristics.
4.3. El Coyote basin
4.3.1. Las Vinoramas, 24°11′N, 110°11′W. Intermittent creek with sandy bottom and patches of rocky bottom. There are palms and riparian vegetation surrounding the creek. The water is taken for domestic activities and orchards. The water characteristics were TDS 1.5 g/L, and temperature 24°C.
4.4. Los Planes basin
4.4.1. Arroyo San Antonio, 23°48′30.7″N, 110°03′19.8″W.
4.4.2. Arroyo Hondo, 23°48′01.7″N, 110°09′01.4″W.
4.4.3. Arroyo Buenos Aires, 23°41′13.5″N, 109°43′51.1″W.
4.5. San Bartolo basin
4.5.1. Arroyo Las Cuevas, 23°32′20.7″N, 109°40′24.2″W.
4.5.2. Arroyo San Jorge, 23°28′19″N, 109°48′30″W.
4.5.3. Agua Caliente, 23°26′N, 109°47′W. Small dam containing a freshwater pond formed by a hot spring. The bottom was sandy with gravel and the water surface area was about 300 m^2. The water characteristics were TDS 0.1 g/L, and temperature 25.5°C.
4.6. San José del Cabo basin
4.6.1. Boca de la Sierra, 23°23′10″N, 109°49′11″W. Permanent freshwater pond in a granitic cannyon. The bottom was sandy but there were gravel patches. The water surface area was about 250 m^2 and the water is taken for domestic use and agriculture. The water characteristics were TDS 0.1 g/L, pH 7.6, and temperature 25.3°C.
4.6.2. Arroyo La Tinaja, 23°21′59″N, 109°45′29″W.
4.6.3. Rancho San Antonio, 23°19′53″N, 109°50′20.9″W. Rustic dam containing a freshwater pond with sandy bottom, surrounded by riparian vegetation. The water is taken for domestic use and farm animals. The water characteristics were TDS 0.3 g/L, pH 8.2, and temperature 27.2°C.
4.6.4. Presa de San Lázaro, 23°07′14.3″N, 109°48′59.3″W.
4.6.5. Arroyo San José, 23°03′41.8″N, 109°41′01.6″W. Intermittent freshwater creek starting in the Sierra San Fernando (about 1, 550 m above sea level) and ending at the San José del Cabo estuary after about 70 km. The vegetation surrounding the creek is composed by palms and mesquite. The water is taken for domestic use, orchards, and hotel services. The water characteristics were TDS 0.2 g/L, pH 8.1, and temperature 24°C.
4.6.6. Poza de Santa Rosa, 23°03′32″N, 109°41′28″W. Permanent freshwater pond at the San José creek, with sandy bottom surrounded by palms, giant reeds, and grass. An urban area is around the stream. The water characteristics were TDS 0.2 g/L, pH 8.1, and temperature 23.9°C.
4.6.7. San José del Cabo estuary, 23°03′13.2″N, 109°40′32.8″W. Permanent freshwater spring surrounded by a forest of palms, giant reeds, and grass. The water is taken for agriculture. The water surface area was about 1.4 km^2. This site was sampled three times during December 2003 and September and November 2004. The water characteristics were TDS 0.5 g/L, and temperature 24°C on 14 December 2003, TDS 1.5 g/L, and temperature 33.7°C on 8 September 2004, and TDS 1.4 g/L, and temperature 17.3°C on 26 November 2004.
State of Baja California

Pacific slope

1. Hydrological region RH1: Baja California Noroeste (Ensenada)
1.1. Río Tijuana-Arroyo de Maneadero basin
1.1.1. Arroyo El Descanso, 32°12′09.3″N, 116°54′47.8″W.
1.1.2. Arroyo San Carlos, 31°47′51.6″N, 116°30′02.4″W.
1.2. Arroyo Las Ánimas-Arroyo de Santo Domingo basin
1.2.1. Arroyo Las Ánimas, 31°37′00″N, 116°26′00″W.
1.2.2. Arroyo Santo Tomás, 31°32′12.9″N, 116°39′28″W.
1.2.3. Arroyo San Telmo, 30°56′29.5″N, 116°14′57.6″W.
1.3. Arroyo Escopeta-Cañón San Fernando basin
1.3.1. Rancho Los Aguajes, 30°31′33.3″N, 115°39′09.2″W.
2. Hydrological region RH2: Baja California Centro-Oeste (Vizcaíno)
2.1. Arroyo Santa Catarina-Arroyo Rosarito basin
2.1.1. Arroyo Cataviña, 29°43′37″N, 114°42′45.9″W.

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