

## Morphology of stomatopod larvae from National Parks: Sistema Arrecifal Veracruzano and Arrecife Puerto Morelos, Mexico

Sergio Cházaro-Olvera<sup>1</sup>  [orcid.org/0000-0002-0667-0043](https://orcid.org/0000-0002-0667-0043)

Manuel Ortiz<sup>1</sup>

Ignacio Winfield<sup>1</sup>

Rafael Robles<sup>2,3</sup>  [orcid.org/0000-0003-0531-5557](https://orcid.org/0000-0003-0531-5557)

Diego Alfonso Torres-Cabrera<sup>1</sup>

**1** Laboratorio de Crustáceos, Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México Código Postal 54090. Tlalnepantla, Estado de México, México.

**SCO** E-mail: [chazaro@campus.iztacala.unam.mx](mailto:chazaro@campus.iztacala.unam.mx)

**MO** E-mail: [ortiztouzet@yahoo.com](mailto:ortiztouzet@yahoo.com)

**IW** E-mail: [ignacioc@unam.mx](mailto:ignacioc@unam.mx)

**DATC** E-mail: [d13g0sg3n14l@hotmail.com](mailto:d13g0sg3n14l@hotmail.com)

**2** Laboratório de Bioecologia e Sistemática de Crustáceos, Departamento de Biologia da Faculdade de Filosofia Ciências e Letras de Ribeirão Preto, Universidade de São Paulo. Av. Bandeirantes, 3900. 14040-901 Ribeirão Preto, São Paulo, Brazil.

**3** Current affiliation: Facultad de Ciencias Químico Biológicas, Universidad Autónoma de Campeche. Avenida Agustín Melgar S/N, Colonia Buenavista. San Francisco de Campeche, Campeche, México.

**RR** E-mail: [roblesrafaelr@gmail.com](mailto:roblesrafaelr@gmail.com)

**ZOOBANK** <http://zoobank.org/urn:lsid:zoobank.org:pub:B74D8730-7DBA-4FF6-9E98-92980D1DEAF0>

### ABSTRACT

The present study provides information on the morphology of stomatopod larvae found in two different reef systems which are also considered national parks: the Sistema Arrecifal Veracruzano (SAVNP) and Arrecife Puerto Morelos (APMNP). Zooplankton samples were collected at 26 stations of the SAVNP and four stations of the APMNP. Stomatopod larvae were identified and classified by their larval stage. We found representatives of three stomatopod superfamilies: the superfamily Gonodactyloidea Giesbrecht, 1910 was represented by *Neogonodactylus oerstedii* (Hansen, 1895), *Neogonodactylus wennerae* Manning and Heard, 1997, and Pseudosquillidae genus and species indeterminate; the superfamily Lysiosquilloidea Giesbrecht, 1910 was represented by Lysiosquilloidea genus and species indeterminate, *Lysiosquilla* sp., *Lysiosquilla scabricauda* (Lamarck, 1818) and *Nannosquilla adkisoni* Camp and Manning, 1982; the superfamily Squilloidea was represented by larvae of *Alima neptuni* (Linnaeus, 1768), *Squilla* spp., and *Squilla empusa* Say, 1818. We were able to identify and describe four stages of larval development for

#### CORRESPONDING AUTHOR

Sergio Cházaro-Olvera  
[chazaro@campus.iztacala.unam.mx](mailto:chazaro@campus.iztacala.unam.mx)

**SUBMITTED** 21 March 2017

**ACCEPTED** 7 August 2017

**PUBLISHED** 15 March 2018

**DOI** 10.1590/2358-2936e2018005



All content of the journal, except where identified, is licensed under a Creative Commons attribution-type BY.

**Nauplius, 26: e2018005**

representatives of these superfamilies. This is the first study describing several stages of larval development of different species of the stomatopods from the Gulf of Mexico and Caribbean Sea.

## KEY WORDS

Crustaceans, Stomatopoda, larval stages, zooplankton, coral reefs.

## INTRODUCTION

The order Stomatopoda Latreille, 1817 consists of 481 species distributed in the tropical, subtropical and temperate regions of the world (Reaka *et al.*, 2009). During their development, stomatopods pass through different larval stages and could form part of both zooplankton and benthos (Ahyong *et al.*, 2014).

Four morphological types of stomatopod larvae are known: antizoea and pseudozoea are early larval stages, while erichthus and alima are late larval stages (Ahyong, 2004; Schram *et al.*, 2013). These forms do not necessarily have to be sequential. To date, three alternative sequences of larval development have been identified: antizoea/erichthus, pseudozoea/erichthus, and pseudozoea/alima (Ahyong *et al.*, 2014). The antizoea, the type in which the lysiosquilloids (and probably erythrosquilloids) hatch, is characterized by the presence of sessile eyes, antennules with a flagellum, five pairs of biramous thoracic appendages called maxillipeds (which are the most important differential characters among stomatopods), and the absence of appendages on the pleon. The carapace has a fixed spinous rostrum and covers most of the pleon except the last two or three pleomeres (Ahyong *et al.*, 2014). Squilloids, gonodactyloids, parasquilloids and some eurysquilloids hatch as pseudozoea. This larva is characterized by having pedunculated composite eyes, biflagellate antennules, two pairs of uniramous thoracic appendages (maxillipeds 1 and 2), and four (squilloids) or five pairs of biramous swimmers (pleopods). Both, antizoea and pseudozoea of gonodactyloids, parasquilloids and eurysquilloids develop into an erichthus larva type. This larva presents the second maxilliped as a rapacious claw, with some teeth in the occlusal margin of the dactyl; maxillipeds 3–5, pereopods and uropods are absent and present one or two intermediate denticles on the telson. Finally, squilloid pseudozoea develops into alima type larva, being unique for the squilloids. This larva differs from the erichthus by presenting a ventral spine on the

antennular segment and four or more intermediate denticles on the telson (Ahyong *et al.*, 2014).

Of the approximately 500 species of stomatopods described so far, no more than 10% of the larval stages can be identified worldwide (Diaz, 1998; Haug *et al.*, 2016). Moreover, there are only a few studies where the complete larval development of stomatopod larvae has been described (Manning and Provenzano, 1963; Pyne, 1972; Provenzano and Manning, 1978; Greenwood and Williams, 1984; Hamano and Matsuura, 1987; Morgan and Goy, 1987). Likewise, partial larval series are known for a limited number of species (Gurney, 1946; Alikunhi, 1967; Michel, 1968; 1970; Michel and Manning, 1972; Shanbhogue, 1975; Rodrigues and Manning, 1992; Ahyong, 2002; Veena and Kaladharan, 2010; Feller, 2013; Antonio-Bueno, 2015). This lack of information is due in part to the complexity of the larval development of stomatopods, where the initial stages are propelagic and the late stages are planktic (pelagic) (Hamano and Matsuura, 1987). First, the female mantis shrimp will provide maternal care by using her maxillipeds to clean the eggs and circulate water around them; after hatching of the larvae, the female will continue protecting the newly hatched larvae and physiological adaptations make the early larval stages stay within the cave with the parental female, thus the first stages may be overlooked (Wortham-Neal, 2002). Maintaining an ovigerous female in captivity until hatching is by itself a difficult task, add to that the behavior of the parental female who will hide in a cave with the eggs first and later with the larvae and the task becomes almost impossible (Pyne, 1972). Besides changes on physiology, ethology and ecology of the larvae described above, the time of development is very large, from 35 days to nine months, depending on the species. No wonder why the most common way of describing stomatopod larvae is by collecting planktic stages, with the unintended consequences of describing only the later stages of development (Ahyong *et al.*, 2014).

Thus, the objective of this study was to provide additional information on the morphology of the planktonic larvae, at different stages of development, of some of the stomatopod species found in the southwestern Gulf of Mexico and the Mexican Caribbean, specifically on the Sistema Arrecifal Veracruzano and Arrecife Puerto Morelos.

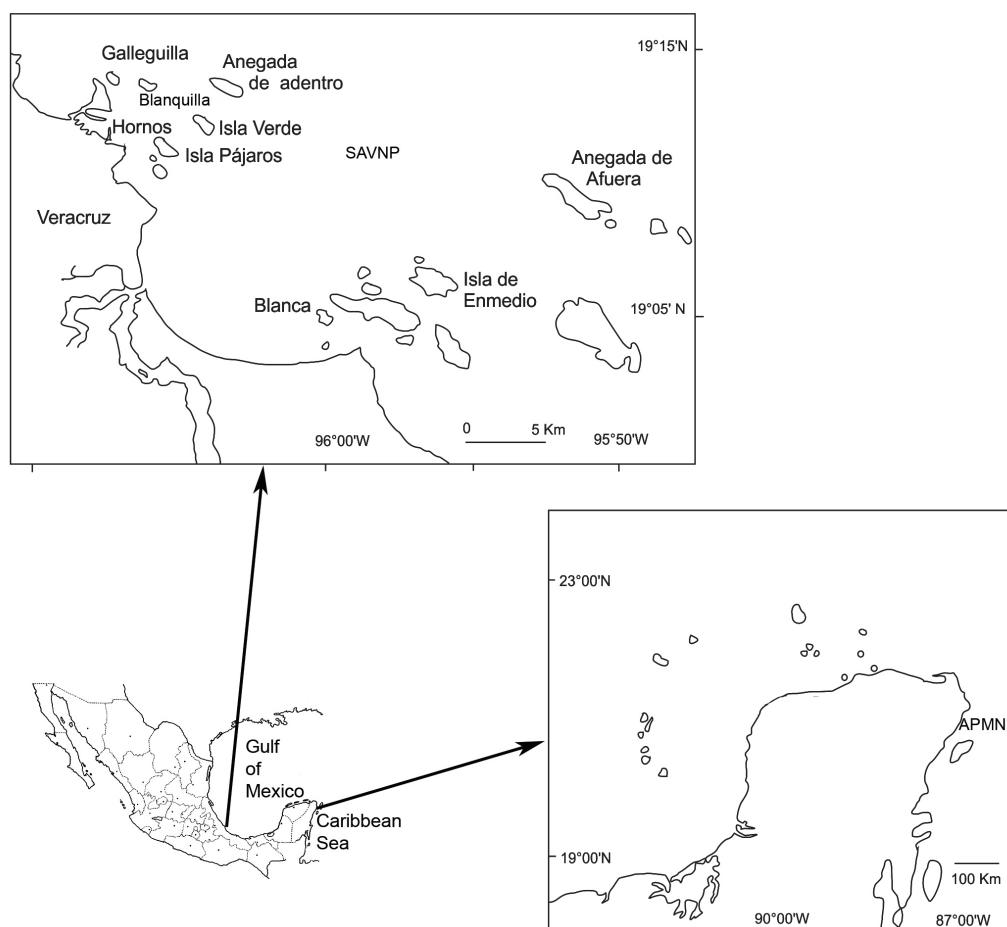
## MATERIAL AND METHODS

The Sistema Arrecifal Veracruzano (SAVNP) is a coral reef system located in the northwest sector of the Bay of Campeche, in the polygon delimited by  $19^{\circ}00'00'' - 19^{\circ}16'00''\text{N}$  and  $95^{\circ}45'00'' - 96^{\circ}12'00''\text{W}$ . It is formed by 23 coral reefs distributed in a northern group and a southern group, separated by the mouth of the Jamapa River (Granados *et al.*, 2007). The Arrecife Puerto Morelos National Park (APMNP) is part of the Mesoamerican Reef System which is in Puerto Morelos, Quintana Roo ( $20^{\circ}54'16''\text{N}$   $86^{\circ}49'39''\text{W}$ ). The reef lagoon is connected to the open sea by two entrances.

The bottom of the lagoon is covered with calcareous sand and stabilized by seaweed grasslands; patches of corals have colonized some areas becoming coral reef communities (Humann, 2002; Álvarez-Cadena *et al.*, 2007) (Fig. 1).

Field work on SAVNP: zooplankton samples were collected at 26 stations of the SAVNP. Trawls were made in the surface layer of the water column using conical plankton nets with a mesh light of  $330\ \mu\text{m}$  during five minutes, at a speed of three knots. The material was fixed in a 70% solution of ethanol and put in plastic containers previously labeled, and transferred to the Ecology Laboratory of the Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México (UNAM).

Field work in APMNP: two types of sampling were carried out: light traps were placed on three piers of the docking area of the Institute of Marine Sciences and Limnology during three nights, covering a 12 h cycle; these cycles were initiated at 18:00 h and stopped



**Figure 1.** Location of sampling sites at the national parks Sistema Arrecifal Veracruzano (SAVNP) and Arrecife Puerto Morelos (APMNP).

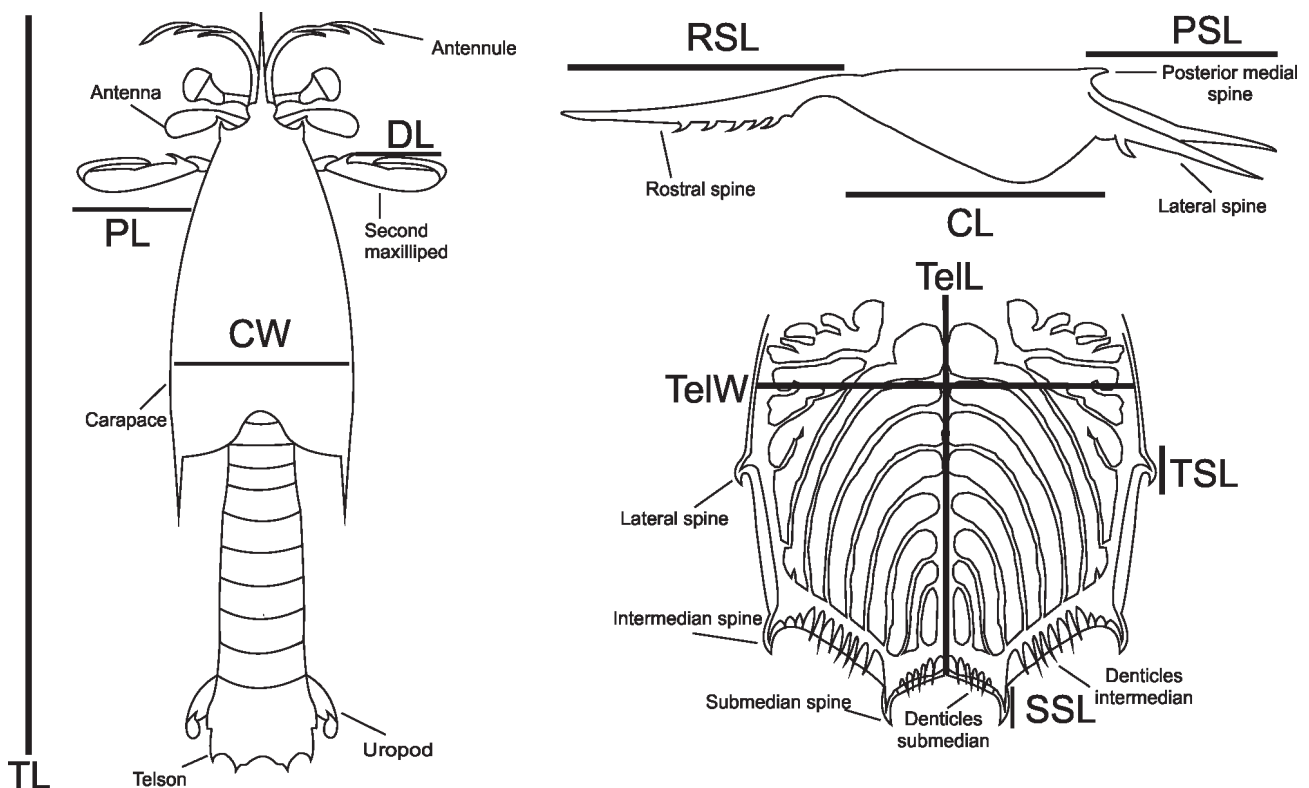
at 6:00 h of the next day on June 6, 7 and 8 on phase new moon. All traps had white light of 38 lumens. These traps were constructed with plastic boxes 0.4 m long, 0.25 m wide and 0.30 m high; a 40 mm diameter inlet holes were made in the upper part of each side of the box.

The contents were collected manually and concentrated in 500 ml plastic bottles at the end of the sampling period. The second sampling point was at the site called Rodman, where the sample was obtained in a coral stand at a depth of 20 m with SCUBA self-contained diving equipment. The substrate was placed in plastic bags for further review. All samples were preserved with 70% alcohol.

Samples were sorted out using a Motic SMZ-168 microscope at the Crustacean Laboratory. Identification of the larvae followed current literature [Manning (1969; 1995), Michel and Manning (1972); Rodrigues and Manning (1992); Ahyong *et al.* (2014); and Antonio-Bueno (2015), for larvae of stomatopods in general; Townsley (1953), for *Lysiosquilloidea* Giesbrecht, 1910, *Lysiosquilla* Dana, 1852 and *Pseudosquilloidea* Manning, 1977; Manning (1962) and

Fornshell (2012), for *Alima* Leach, 1817; Pyne (1972) and Diaz (1998) for *Squilla* Fabricius, 1787; Morgan and Provenzano (1979), for *Squilla empusa* Say, 1818; Morgan and Goy (1987), for *Neogonodactylus wennekeri* Manning and Heard, 1997; Provenzano and Manning (1978), for *Neogonodactylus oerstedii* (Hansen, 1895); García-Calzada (2013), for *Nannosquilla adkisoni* Camp and Manning, 1982 and *Lysiosquilla scabricauda* (Lamarck, 1818)]. The larvae were deposited in the National Collection of Crustaceans (CNCR) of the Institute of Biology of the Universidad Nacional Autónoma de México (UNAM).

Measurements of larvae and abbreviations: carapace length (CL), carapace width (CW), dactyl length (DL), posterolateral spines length (PSL), propodus length (PL), rostral spine length (RSL), telson lateral spines length (TSL), telson length (TelL), telson submedian spines length (SSL), telson width (Telw), and total length (TL) (Fig. 2). We also counted the number of spines and denticles of the different structures. Images of the larvae were taken using a Leica DM750 microscope equipped with an Omax 14MP USB 3.0 digital camera.



**Figure 2.** Stomatopod larvae. General morphology, structures and measurements. TL, total length; CL, carapace length; CW, carapace width; RSL, rostral spine length; PSL, posterolateral spines length; PL, propodus length; DL, dactyl length; TelL, telson length; Telw, telson width; TSL, telson lateral spines length; SSL, telson submedian spines length.

## RESULTS

We collected 1759 stomatopod larvae belonging to three superfamilies, six families, seven genera and 10 species. The superfamily Gonodactyloidea Giesbrecht, 1910 was represented by *Neogonodactylus oerstedii*, *N. wennerae* and Pseudosquilloidea genus and species indeterminate. The superfamily Lysiosquilloidea was represented by Lysiosquilloidea genus and species indeterminate, *Lysiosquilla* sp., *L. scabricauda*, and *Nannosquilla adkisoni*. Representatives of the superfamily Squilloidea Latreille, 1802 were also present as larvae of *Alima neptuni* (Linnaeus, 1768), *Squilla* spp., and *S. empusa*. Overall, we found larvae of nine stomatopod species at the SAVNP and of four at the APMNP. All morphological measurements are shown on [Tab. 1](#) and [Tab. 2](#).

*Taxonomic account and larval description.*

### Superfamily Gonodactyloidea Giesbrecht, 1910

#### Family Gonodactylidae Giesbrecht, 1910

##### *Neogonodactylus oerstedii* (Hansen, 1895)

Stage II: Pseudozoaea (CNCR32467)  
([Fig. 3A](#))

*Description.* Carapace lobate, short. Rostrum short, usually not surpassing peduncle of antennule (A1), with single posterior medial spine. Posterolateral spines short, extending to first or second pleonite, bearing thin proximal spine. Propodus of second maxilliped broadened, smooth, with mobile dactyl. Telson straight, bearing three pairs of articulated lateral spines, a pair of fixed posterolateral spines and 10–12 small denticles on either side of midline.

*Habitat.* Benthic, among coral rubbles.

*Location.* APMNP.

Stage III: Erichthus (CNCR32468)  
([Fig. 3B](#))

*Description.* Carapace lobate, short. Rostrum small, reaching base of flagellum of A1, lacking ventral spines,

posterolateral spines extend to second pleonite, bearing proximal small spine. Second maxilliped well developed, propodus broadened, smooth; mobile dactyl. Telson straight, bearing three pairs of fixed lateral spines and pair of posterolateral spines, bearing 10–12 denticles intercalated with small spines in between.

*Habitat.* Pelagic.

*Location.* SAVNP.

Stage IV: Erichthus (CNCR32469)  
([Fig. 3C](#))

*Description.* Carapace longer than width, reaching first or second pleonite; bearing well-developed supraorbital spines. Rostrum relatively short, surpassing flagellum of A1, armed with 3–5 ventral spines. Posterolateral spines reaching fourth pleonite, bearing small proximal spine. First maxilliped with eight aesthetascs and strong seta on dactyl. Second maxilliped well developed, propodus with 14–16 denticles on inner margin; dactylus with distal portion of cutting edge as small saw. Telson straight, bearing three pairs of fixed lateral spines and pair of posterolateral spines, bearing 10–12 denticles on either side of midline.

*Habitat.* Pelagic.

*Location.* SAVNP.

Stage VI: Erichthus (CNCR32470)  
([Fig. 3D](#))

*Description.* Carapace longer than width, extending to first pleonite, bearing well-developed supraorbital spines. Rostrum not exceeding flagellum of A1. Posterolateral spines reaching third pleonite, with small proximal spine. Propodus of second maxilliped armed with at least 10–13 small denticles, long sharp proximal spine, dactyl with basal bulge. Telson straight, bearing three pairs of fixed lateral spines and pair of strongly elongated lateral spines; bearing 22 denticles on each side of midline. Uropods fully developed.

*Habitat.* Pelagic.

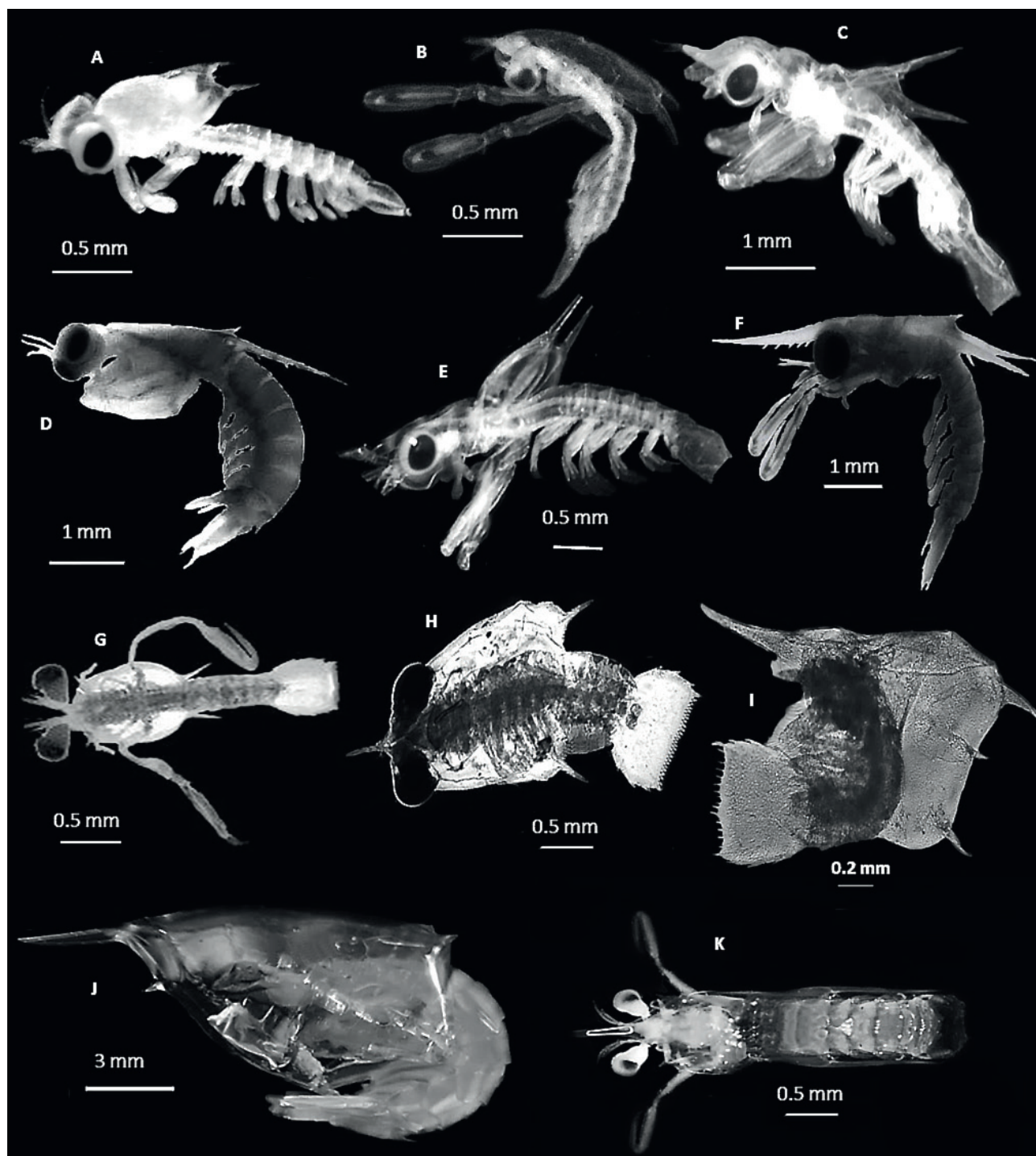
*Location.* SAVNP.

**Table 1.** Stomatopod larvae collected at the national parks Sistema Arrecifal Veracruzano (SAVNP) and Arrecife Puerto Morelos (APMNP) organized by species, larval stage, and type of larva. IN, indeterminate; X, presence; (-), absence. TL, total length; CL, carapace length; CW, carapace width; RSL, rostral spine length; posterolateral spines length (PSL).

Species	Type of larva	Stage	Number	SAVNP	APMNP	TL	RSL	CL	CW	PSL
<i>Neogonodactylus wennerae</i>	Erichtus	IV	56	X	-	4.08 ± 0.11	0.75 ± 0.09	1.49 ± 0.06	0.95 ± 0.03	0.53 ± 0.02
<i>N. wennerae</i>	Erichtus	VIII	4	X	-	7.75 ± 0.25	1.10 ± 0.11	2.26 ± 0.02	1.18 ± 0.32	1.07 ± 0.01
<i>Neogonodactylus oerstedii</i>	Pseudozoea	II	415	-	X	2.08 ± 0.11	0.17 ± 0.29	0.94 ± 0.06	0.55 ± 0.03	0.23 ± 0.02
<i>N. oerstedii</i>	Erichtus	III	719	X	-	2.25 ± 0.02	0.17 ± 0.01	0.96 ± 0.02	0.58 ± 0.02	0.27 ± 0.01
<i>N. oerstedii</i>	Erichtus	IV	503	X	-	4.06 ± 0.08	0.74 ± 0.09	1.59 ± 0.13	0.99 ± 0.08	0.63 ± 0.08
<i>N. oerstedii</i>	Erichtus	VI	5	X	-	6.04 ± 0.06	1.78 ± 0.09	2.22 ± 0.14	1.19 ± 0.053	1.05 ± 0.06
Pseudosquillaeae genus and species indeterminate	Erichtus	IN	8	X	-	2.45 ± 0.05	0.27 ± 0.02	0.95 ± 0.02	0.51 ± 0.06	0.21 ± 0.02
Lysiosquilloidea genus and species indeterminate	Antizoea	IN	8	X	-	3.71 ± 0.06	0.51 ± 0.041	2.01 ± 0.06	1.11 ± 0.06	0.36 ± 0.02
<i>Lysiosquilla</i> sp.	Antizoea	IN	1	X	-	2.97	0.78	1.29	0.62	0.33
<i>Lysiosquilla scabricauda</i>	Erichtus	IN	1	X	-	26.11	3.6	11.8	6.5	0.3
<i>Nannosquilla adkisoni</i>	Erichtus	IN	2	-	X	17.75 ± 0.01	3.78 ± 0.07	10.16 ± 0.07	2.73 ± 0.04	6.8 ± 0.01
<i>Alima neptuni</i>	Alima	IV	8	X	-	8.41 ± 0.08	0.79 ± 0.06	2.61 ± 0.09	0.97 ± 0.09	0.37 ± 0.04
<i>A. neptuni</i>	Alima	IX	3	X	-	43.4 ± 0.04		16.5 ± 0.031	6.2 ± 0.06	2.1 ± 0.03
<i>Squilla</i> sp. 1	Alima	IX	4	X	X	27.48 ± 1.51	2.35 ± 0.50	42.65 ± 0.65	6.16 ± 0.01	2.26 ± 0.07
<i>Squilla</i> sp. 2	Alima	II	1	X	-	4.62	0.68	1.63	0.84	0.39
<i>Squilla empusa</i>	Alima	I	3	X	-	2.81 ± 0.07	0.31 ± 0.01	0.91 ± 0.03	0.61 ± 0.02	2.26 ± 0.07
<i>S. empusa</i>	Alima	II	5	X	-	4.73 ± 0.07	0.55 ± 0.05	1.71 ± 0.01	0.86 ± 0.05	0.43 ± 0.06
<i>S. empusa</i>	Alima	III	8	X	-	6.72 ± 0.05	1.35 ± 0.09	1.99 ± 0.04	1.28 ± 0.05	0.92 ± 0.06
<i>S. empusa</i>	Alima	IX	5	-	X	18.23 ± 0.07	3.63 ± 0.08	5.29 ± 0.09	3.49 ± 0.07	2.44 ± 0.09

**Table 2.** Stomatopod larvae collected at the national parks Sistema Arrecifal Veracruzano (SAVNP) and Arrecife Puerto Morelos (APMNP) organized by species, larval stage, and type of larva. PL, propodus length; DL, dactylus length, TelL, telson length (TelL); Telw, telson width; TSL, telson lateral spines length; SSL, telson submedian spines length.

Species	Type of larva	Stage	PL	DL	TelL	TelW	TSL	SSL
<i>Neogonodactylus wennerae</i>	Erichtus	IV	1.44 ± 0.02	0.75 ± 0.03	0.75 ± 0.06	0.62 ± 0.03	0.06 ± 0.01	
<i>N. wennerae</i>	Erichtus	VIII	1.19 ± 0.01	1.16 ± 0.01	1.16 ± 0.01	1.16 ± 0.01	0.21 ± 0.01	
<i>Neogonodactylus oerstedii</i>	Pseudozoea	II	0.44 ± 0.02	0.35 ± 0.03	0.5 ± 0.06	0.42 ± 0.03	0.06 ± 0.01	
<i>N. oerstedii</i>	Erichtus	III	0.49 ± 0.07	0.36 ± 0.06	0.56 ± 0.09	0.45 ± 0.08	0.06 ± 0.01	
<i>N. oerstedii</i>	Erichtus	IV	1.06 ± 0.11	0.73 ± 0.06	0.78 ± 0.04	0.68 ± 0.06	0.06 ± 0.01	
<i>N. oerstedii</i>	Erichtus	VI	1.16 ± 0.01	0.98 ± 0.05	0.96 ± 0.05	0.95 ± 0.05	0.15 ± 0.01	
Pseudosquillaeae genus and species indeterminate	Erichtus	IN	0.62 ± 0.06	0.48 ± 0.02	0.46 ± 0.05	0.36 ± 0.08	0.03 ± 0.01	
Lysiosquilloidea genus and species indeterminate	Antizoea	IN			0.69 ± 0.05	0.92 ± 0.01	0.12 ± 0.01	
<i>Lysiosquilla</i> sp.	Antizoea	IN			0.64	0.62	0.19	
<i>Lysiosquilla scabricauda</i>	Erichtus	IN			2.27	5.9	0.09	
<i>Nannosquilla adkisoni</i>	Erichtus	IN	1.95 ± 0.02	1.55 ± 0.02	1.27 ± 0.01	2.12 ± 0.02	0.18 ± 0.02	0.17 ± 0.02
<i>Alima neptuni</i>	Alima	IV	1.99 ± 0.08	1.08 ± 0.03	0.98 ± 0.03	0.43 ± 0.03	0.11 ± 0.01	0.11 ± 0.01
<i>A. neptuni</i>	Alima	IX			8.7 ± 0.07	3.6 ± 0.032	0.43 ± 0.03	0.33 ± 0.01
<i>Squilla</i> sp. 1	Alima	IX	4.78 ± 0.18	3.05 ± 0.23	3.65 ± 0.07	3.15 ± 0.05	0.52 ± 0.03	0.41 ± 0.09
<i>Squilla</i> sp. 2	Alima	II	1.37	0.68	0.83	0.66	0.04	
<i>Squilla empusa</i>	Alima	I	0.77 ± 0.01	0.45 ± 0.07	0.45 ± 0.07	0.42 ± 0.02	0.07 ± 0.01	
<i>S. empusa</i>	Alima	II	1.21 ± 0.01	0.92 ± 0.05	0.81 ± 0.05	0.56 ± 0.06	0.08 ± 0.01	
<i>S. empusa</i>	Alima	III	1.56 ± 0.02	1.12 ± 0.06	1.09 ± 0.07	0.84 ± 0.05	0.11 ± 0.02	
<i>S. empusa</i>	Alima	IX	3.83 ± 0.01	2.66 ± 0.07	2.98 ± 0.05	2.98 ± 0.05	0.42 ± 0.05	0.26 ± 0.08



**Figure 3.** Stomatopod larvae collected at the national parks Sistema Arrecifal Veracruzano (SAVNP) and Arrecife Puerto Morelos (APMNP). A, *Neogonodactylus oerstedii* (Hansen, 1895), stage II pseudozoaea; B, *N. oerstedii*, stage III erichthus; C, *N. oerstedii*, stage IV erichthus; D, *N. oerstedii*, stage VI erichthus; E, *Neogonodactylus wenerae* Manning and Heard, 1997, stage IV erichthus; F, *N. wenerae*, stage VIII erichthus; G, Pseudosquillidae genus and species indeterminate, stage VI erichthus; H, Lysiosquilloidea genus and species indeterminate, antizoea; I, *Lysiosquilla* sp., antizoea; J, *Lysiosquilla scabricauda* (Lamarck, 1818), erichthus; K, *Nannosquilla adkisoni* Camp and Manning, 1982, erichthus.

***Neogonodactylus wennerae*  
Manning and Heard, 1997**

Stage IV: *Erichthus* (CNCR32471)  
(Fig. 3E)

*Description.* Carapace longer than width, extending to first or second pleonite; with well-developed posterolateral spines. Rostrum surpassing A1 flagellum, armed with 3–5 ventral spines. Posterolateral spines extend to fourth pleonite, bearing small proximal spine. First maxilliped dactyl with six aesthetascs, single strong seta. Second maxilliped well developed; propodus armed with three spines and 19–22 denticles; dactyl bearing 7–10 small setae. Telson straight, bearing three pairs of fixed lateral spines and pair of posterolateral spines; bearing 10–12 denticles on either side of midline.

*Habitat.* Pelagic.

*Location.* SAVNP.

Stage VIII: *Erichthus* (CNCR32472)  
(Fig. 3F)

*Description.* Carapace longer than width, extending to first pleonite; with well-developed posterolateral spines. Rostrum reaching beyond flagellum of A1, armed with six ventral spines. Posterolateral spines extending to fourth pleonite, having small proximal spine. Second maxilliped well-developed; propodus with 28–30 denticles and well developed spines; dactyl bearing 9–10 short setae. Telson straight, bearing three pairs of fixed lateral spines and pair of strongly elongated posterolateral spines, bearing 22 denticles on each side of midline. Uropods well developed.

*Habitat.* Pelagic.

*Location.* SAVNP.

**Family Pseudosquillidae Manning, 1977**

**Genus and species indeterminate**

Stage (Indeterminate): *Erichthus* (CNCR32473)  
(Fig. 3G)

*Description.* Carapace short, extending to fourth pleonite, slightly wider at base, bearing fine pairs of marginal spines, presenting pair of anterolateral spines. Rostrum relatively long reaching base of flagellum of A1, lacking ventral spines. Posterolateral spines reaching last pereonite, bearing well-developed proximal spine. Second maxilliped well developed, broadened propodus with 15–17 denticles and mobile dactyl. Telson straight, bearing three pairs of fixed lateral spines and pair of lateral spines; bearing seven denticles on either side of midline.

*Habitat.* Pelagic.

*Location.* SAVNP.

**Superfamily Lysiosquilloidea Giesbrecht, 1910**

**Genus and species indeterminate**

Stage (Indeterminate): Antizoea (CNCR32474)  
(Fig. 3H)

*Description.* Carapace globular, not widening at base of posterolateral spines, slightly rectangular. Rostral spine as long as half length of carapace; lacking ventral spines. Posterolateral spines strong and slightly curved, middle spine present; pereopods well-developed. Second maxilliped not well differentiated. Telson straight bearing three spines on margin and well-developed lateral spine on each side, with 12 spines on each side of midline.

*Habitat.* Pelagic.

*Location.* SAVNP.

***Lysiosquilla* sp.**

Stage (Indeterminate): Antizoea (CNCR32475)  
(Fig. 3I)

*Description.* Carapace globular, widening at base of anterolateral spines, slightly triangular. Rostral spine as long as half length of carapace; lacking ventral spines, bearing strong and slightly curved posterolateral spines;



middle spine present. Pereopods well developed. Second maxilliped not well differentiated. Telson straight bearing three lateral spines; posterior margin bearing well-developed posterolateral spine on each side, with four short submedian spines, followed by long and two short spines on each side of midline; cleft present at midline.

*Habitat.* Pelagic.

*Location.* SAVNP.

***Lysiosquilla scabricauda* (Lamarck, 1818)**

Stage (Indeterminate): *Erichthus* (CNCR32476)  
(Fig. 3J)

*Description.* Carapace extremely large, extending to third pleonite, rectangular, with very short anterolateral and posterolateral spines. Rostrum long, as long as half length of carapace; with three ventral spines, widened at base, triangular in shape. Pleon thick, last 2 pleomeres present spinules on posterolateral margin. Second maxilliped well developed; propodus with nearly 50 minute denticles; dactylus unarmed. Telson straight lacking well-differentiated median carina. Uropods well developed.

*Habitat.* Benthic, seagrass.

*Location.* Isla Sacrificios, SAVNP.

**Family Nannosquillidae Manning, 1980**

***Nannosquilla adkisoni* Camp and Manning, 1982**

Stage (Indeterminate): *Erichthus* (CNCR32477)  
(Fig. 3K)

*Description.* Carapace longer than wide, with pair of small anterolateral spines. Rostrum half length of carapace, without ventral spines. Extremely long posterolateral spines reach beyond telson. Second maxilliped bearing 25–28 denticles; dactyl bearing six teeth. Spines of basal prolongation of uropod of same size. Telson straight with three movable spines on posterior margin, large lateral spines and eight denticles on each side of midline, with 2–9 spines between each

pair of denticles. Uropods well developed, with spines on exopod.

*Habitat.* Benthic, among rubbles.

*Location.* APMNP.

**Superfamily Squilloidea Latreille, 1802**

**Family Squillidae Latreille, 1802**

***Alima neptuni* (Linnaeus, 1768)**

Stage IV: *Alima* (CNCR32478)  
(Fig. 4A)

*Description.* Carapace three times longer than width, extending to middle of fourth pereonite, with pair of small anterolateral spines, bearing pair of posterolateral spines reaching base of sixth pereonite, presenting small spinule and small spine proximally; margin of carapace convex. Rostrum small, reaching half of A1. Second maxilliped with proximal spine; propodus eight times as long as wide, distal portion of upper margin pectinate with 28–29 denticles; dactylus bearing three teeth. Telson convex, twice as long as wide, bearing eight intermediate and 12 submedian denticles on either side of midline.

*Habitat.* Pelagic.

*Location.* SAVNP.

Stage IX: *Alima* (CNCR32479)  
(Fig. 4B)

*Description.* Carapace three times longer than wide, extending to sixth pereonite; bearing strong anterolateral spines that reach eighth pereonite; posterolateral spines much less pronounced than anterolateral ones; bearing small dorsal spine; margin of carapace strongly convex, armed with 12 spines. Antennules, maxillipeds and pleopods well developed. Second maxilliped with spine on basal portion, propodus eight times as long as wide, dorsodistal margin pectinate with 30–32 denticles; dactylus bearing six teeth. Telson convex, twice as long as wide, bearing intermediate, submedian and lateral spines, all with movable apices, bearing

18 intermediate denticles between lateral spine and submedian, and 14 denticles between submedian spine and intermediate spine.

*Habitat.* Pelagic.

*Location.* SAVNP.

### ***Squilla* sp. 1**

Stage IX: Alima (CNCR32480)  
(Fig. 4C)

*Description.* Carapace three times longer than width, reaching sixth pereonite, concave margin with nine spines on each side, presenting pair of anterolateral spines, pair of short posterolateral spines extending to fifth pereonite, with small dorsal spine. Antennules, maxillipeds and pleopods well developed. Second maxilliped with spine on basal portion, propodus eight times as long as wide, distal portion of upper margin pectinate with 28–29 denticles; dactyl smooth. Telson concave, ornamented with defined medium carina, presents 10 intermediate denticles and 18 submedian spines on each side of midline.

*Habitat.* Pelagic

*Location.* SAVNP and APMNP.

### ***Squilla* sp. 2**

Stage II: Alima (CNCR32481)  
(Fig. 4D)

*Description.* Carapace triangular, slightly convex, with three pairs of spines on posterolateral margin, presenting pair of anterolateral spines, pair of extremely long posterolateral spines reaching middle of telson, bearing proximal spine at base. Rostrum long, twice as long as A1, lacking ventral spines. Second maxilliped elongate; propodus with strong terminal tooth followed by seven denticles on inner margin; dactylus with distal portion of cutting edge as small saw. Telson concave, slightly longer than wide, with six intermediate denticles and nine submedian denticles on either side of midline.

*Habitat.* Pelagic.

*Location.* SAVNP.

### ***Squilla empusa* Say, 1818**

Stage I: Alima (CNCR32482)  
(Fig. 4E)

*Description.* Carapace slightly longer than broad, moderately globose; convex margin armed with four ventral spines on each side; with pair of anterolateral spines and dorsal medial spine. Rostrum extending slightly beyond flagellum of A1; lacking ventral spines. Posterolateral spines armed with ventral spine extending to fourth pleonite. Second maxilliped large; propodus with strong terminal tooth followed by 18 to 19 denticles on inner margin; dactylus with distal portion of cutting edge as small saw. Telson concave, bearing four pairs of intermediate and 15 submedian denticles covered with spinules.

*Habitat.* Pelagic.

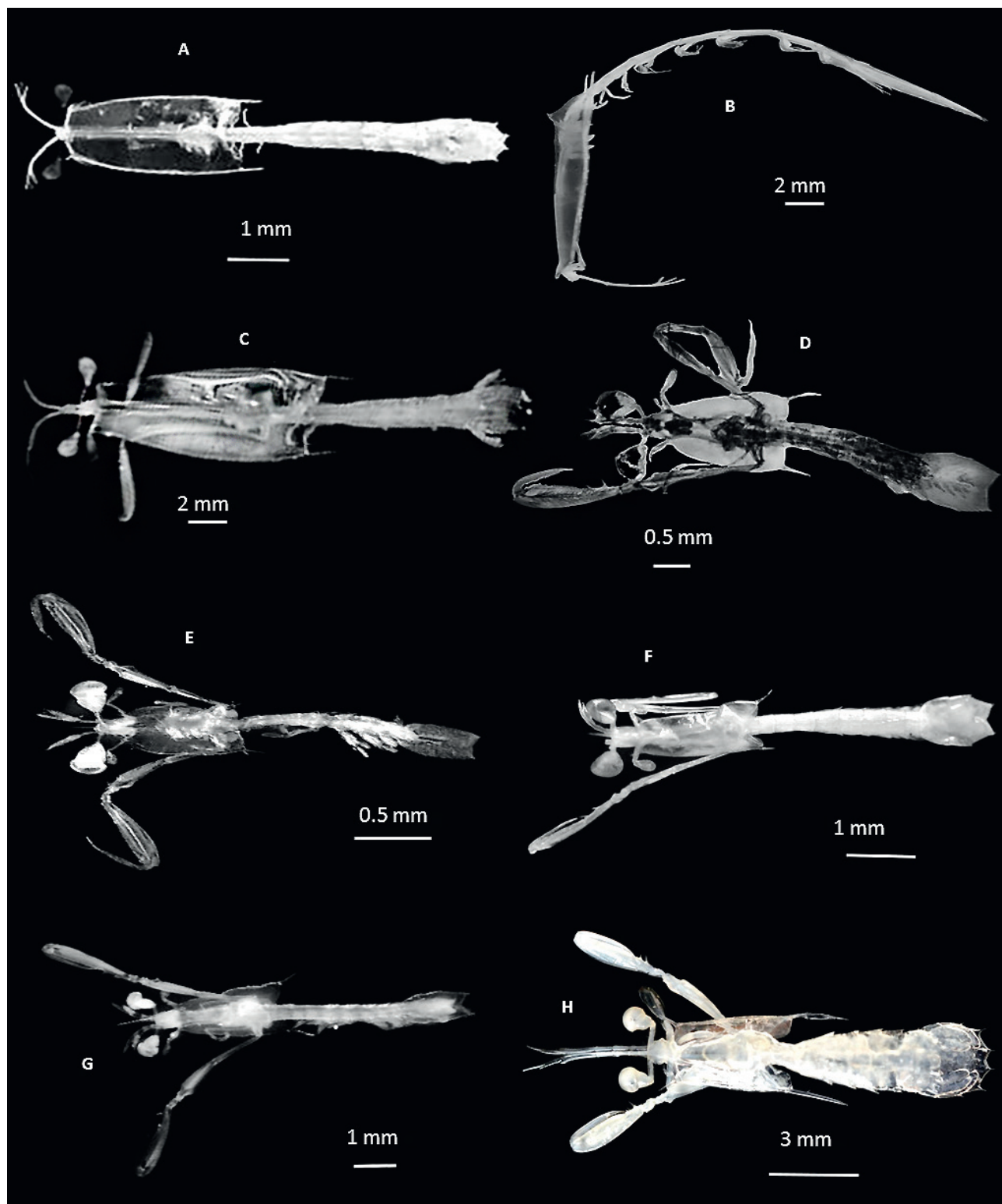
*Location.* SAVNP.

Stage II: Alima (CNCR32483)  
(Fig. 4F)

*Description.* Carapace longer than wide and moderately globose; convex margin armed with four ventral spines on each side; bearing pair of anterolateral spines and dorsal medial spine. Rostrum reaching beyond flagellum of A1; bearing four ventral spinules. Posterolateral spines armed ventrally with spine extending to base of telson. Second maxilliped elongate; propodus bearing proximal tooth followed by another large tooth and 19–20 denticles along inner margin; dactylus with distal portion of cutting edge as small saw. Telson concave, bearing four pairs of intermediate and 15 submedian denticles covered with spinules.

*Habitat.* Pelagic.

*Location.* SAVNP.



**Figure 4.** Stomatopod larvae collected at the national parks Sistema Arrecifal Veracruzano (SAVNP) and Arrecife Puerto Morelos (APMNP). A, *Alima neptuni* (Linnaeus, 1768), stage IV alima; B, *A. neptuni* stage IX alima; C, *Squilla* sp. 1, stage IX alima; D, *Squilla* sp. 2, stage II alima; E, *Squilla empusa* Say, 1818, stage I alima; F, *S. empusa*, stage II alima; G, *S. empusa*, stage III alima; H, *S. empusa*, stage IX alima.

Stage III: Alima (CNCR32484)  
(Fig. 4G)

*Description.* Carapace longer than wide, trapezoid, convex margin armed with two anterior and three posterior ventral spinules on each side, with pair of anterolateral spines and one dorsal medial spine. Rostrum long, twice as long as A1; bearing more than four ventral spines. Posterolateral spines armed ventrally with spine extending to end of telson. Second maxilliped large; propodus bearing 24–26 denticles, basis bearing proximal spine well developed; dactylus with distal portion of cutting edge as small saw. Telson concave with 8–10 pairs of intermediate denticles and 15–27 submedian denticles covered with spinules.

*Habitat.* Pelagic.

*Location.* SAVNP.

Stage IX: Alima (CNCR32485)  
(Fig. 4H)

*Description.* Carapace longer than wide, trapezoid, convex margin armed with two anterior and three posterior ventral spinules on each side, bearing pair of anterolateral spines and one dorsal medial spine. Rostrum long, twice as long as A1, presenting 2–6 ventral spines. Posterolateral spines armed with ventral spinule extending to posterior part of telson. Maxillipeds, pereopods, pleopods and uropods well developed. Second maxilliped elongate; propodus with 71–92 denticles; dactylus smooth. Telson concave, with 8–10 pairs of intermediate denticles and 26–34 submedian denticles covered with spinules.

*Habitat.* Benthic, among rubbles.

*Location.* APMNP.

## DISCUSSION

The most recent account of species of adult stomatopods in the Gulf of Mexico and Caribbean Sea lists 45 species contained in four superfamilies and 11 families (Reaka *et al.* 2009; García-Calzada, 2013). Only four complete larval development of the 45 species found in the area have been described in laboratory

(Manning and Provenzano, 1963; Provenzano and Manning, 1978; Morgan and Provenzano, 1979; Morgan and Goy, 1987; Rodrigues and Manning, 1992). We found larval stages of nine of those species at the SAVNP and four at the APMNP. Although the number represents only a fifth of the total number of species reported for this area, it is remarkable since it is only the first study on the morphology of stomatopod larvae for the south of the Gulf of Mexico and the Caribbean Sea.

We were able to identify larvae of two of the seven species of *Neogonodactylus* Manning, 1995 present in the study area, *N. wenerae* and *N. oerstedii*, although we only found two and four stages of *N. wenerae* and *N. oerstedii*, respectively. The complete larval development has been described for both species from specimens cultured in laboratory conditions (Manning and Provenzano, 1963; Provenzano and Manning, 1978; Morgan and Goy, 1987). These two species present three propelagic and four pelagic stages (Morgan and Goy, 1987). From those we found a pseudozoea and five erichthus. To differentiate these two species in stage IV erichthus we used the number of aesthetascs on first maxilliped as a diacritic character; *N. wenerae* presents six aesthetascs, while *N. oerstedii* presents eight. These two species are a rare example of the complexity of the larval development of stomatopods. During their long larval development, which takes five weeks in laboratory conditions (Provenzano and Manning, 1978), their first three larval stages are propelagic and the other four are planktonic (Dingle 1969; Provenzano and Manning 1978). Distribution in the water column of these larval stages is not a mere accident; the propelagic larvae do not hunt, they are lecitotrophic.

In addition, they present two behaviors that make them unique among crustaceans, they are thigmokinetic and present negative phototaxis. Thus, they feed on embryonic material, hide from light and grab any solid that comes in contact with them (Dingle, 1969). The result is that they keep hiding under the protection of the mother (Dingle, 1969). Thus, our finding of one of these propelagic stages is remarkable since most of the time only the pelagic stages will be found. These pelagic stages change dramatically the morphology and habits of the larvae. For instance, they will become planktotrophic (will actively hunt), will be attracted

to light (positive phototaxis) and their thigmokinesis will be reduced (Dingle, 1969).

On the other hand, we were able to identify the larvae of *A. neptuni* because of the size and morphological characters of both the carapace and telson. Larva of this species was described based on plankton samples (Manning, 1962, as *A. hyalina* Leach, 1817). There are two species of *Alima* distributed in the West Atlantic, *A. neptuni* and *Alima hildebrandi* (Schmitt, 1940). The former has been found in the Gulf of Mexico and Florida Keys, besides some other localities in the West Atlantic, while the latter is considered to be of amphiatlantic distribution, although never found within the Gulf of Mexico (Reaka *et al.*, 2009). In this study *A. neptuni* was represented by two larval stages.

The superfamily Lysiosquilloidea was represented by larvae of an unidentified genus and species of Lysiosquilloidea and an unidentified species of *Lysiosquilla*; both were found in the stage of antizoea (first phase of the larval development). Thus, the morphological characters used for identification were referred to Townsley (1953), who reported biramous thoracic appendages, where propodus of the four thoracic appendages are rounded, broader than long, and more than twice the fifth appendage. The telson is straight. In addition, we also identified one of the last larval stages of *L. scabricauda*. The larva can be traced back to the adult based on characters of the telson, the shape of the corneas and the edge of pereonites as reported by García-Calzada (2013). The most current literature recognizes two species of *Lysiosquilla* within the Gulf of Mexico and adjacent waters (Reaka *et al.*, 2009). These are *Lysiosquilla campechiensis* Manning, 1962 and *L. scabricauda*. We were able to recognize one larvae of *L. scabricauda*. However, we were unable to identify a second larval specimen of *Lysiosquilla* sp. Since there are two other species of this genus distributed in the study area, it may well be that the second larva belongs to one of those species, or even to *Lysiosquillina glabriuscula* (Lamarck, 1818) that is also distributed within the Gulf of Mexico. However, Giesbrecht (1910) has described nine pelagic stages for *Lysiosquilla* sp. but the adult form was not described. For the time being we cannot place our larva in any of those species of *Lysiosquilla* or *Lysiosquillina glabriuscula*. We wait either for a complete description of the larval development based on larvae reared on laboratory conditions or for a DNA analysis allowing the identification of our specimen.

The characters of Pseudosquillidae fit the description of other members of this genus (Brooks, 1886; Townsley, 1953). The telson is nearly rectangular, with eight denticles between submedian denticles and the eyes are not borne on long stalks as in alima of *Squilla*. The second maxilliped has the propodus finely pectinated along the upper margin and a dactylus with a single spine; the carapace is trispinous anteriorly, posteriorly bearing two long spines reaching the second pleonite. Considering the adult distribution and the observed characters, this individual may correspond to a specimen of *Pseudosquilla ciliata* (Fabricius, 1787) in its early larval stages. However, we could not place it based only on morphological characters and it remains as Pseudosquillidae. It is noteworthy that Townsley (1953) has described seven larval stages for this species.

Morgan and Provenzano (1979) reported that *S. empusa* undergoes nine pelagic stages before attaining the postlarval stage. Likewise, the authors mentioned that larvae of *S. empusa* may be identified by the spinules of the carapace and the intermediate denticles of the telson; stages I and II possess four spinules on the lateral margin of the carapace and four intermediate denticles; the third to ninth stages are armed with six spinules on the lateral margin of the carapace; there are two anterior and three posterior spinules all ventrally directed, and one median spinule laterally directed; the telson of the stages third to ninth have 8 to 10 intermediate denticles. The species *Squilla* sp. 2 shows all the characters of the larvae alima like the ornamentation on the telson, characteristic of the genus. However, it does not correspond with the description of *S. empusa*, due to the shape of the carapace. In *Squilla* sp. 2 the carapace is triangular, with three pairs of spines on lateral margin; in contrast, the carapace of *S. empusa* is longer than wide and moderately globose and the lateral margin is armed with four ventral spines on each side. Likewise, the larvae alima of *Squilla* sp. 1 in stage IX is larger and wider than *S. empusa* in the same stage. There are also differences in the ornamentation of the second maxilliped and telson. Thus, we are certain that these two larval stages, *Squilla* sp. 1 and *Squilla* sp. 2, fit the general morphology of *Squilla*. However, at this time we are unable to identify to species level these two specimens that could belong to any of the three species distributed in the area of study, *Squilla chydrea* Manning 1962, *Squilla edentata edentata* (Lunz, 1937) or *Squilla rugosa* Bigelow, 1893.

This study shows how it is possible to identify the larvae collected in zooplankton samples, even with only a few studies available describing a small number of stomatopod species. At the same time, it also shows that our knowledge about stomatopod larvae is scarce. It should be noted that if larval descriptions are scarce, the knowledge about their ecology is almost nonexistent. Some of the reasons for this lack of information are due to the complexity of the life history of these critters, as discussed above. Most of the observed characters agree with the original descriptions, which allowed the identification at specific level, although some differences were found. In others studies, it has been reported that there is an important variability in the intraspecific morphological characters of larvae reared under controlled conditions. Likewise, there is an important morphological variation of a species found in different regions (Criales and Anger, 1986; Pechenik, 1999; González-Gordillo and Rodríguez, 2000). The variety in the morphology of these larvae clearly shows extreme adaptations that we still do not fully understand.

## ACKNOWLEDGEMENTS

The authors are grateful for the support of the funds granted for this research to the program PAPIIT grant number: IN220715 of the Universidad Nacional Autónoma de México (UNAM). Also to the authorities of SEMARNAT, CONANP and CONAPESCA-DGOPA (SAGARPA) for the permits granted (PPF/DGOPA-051/15). RR has a postdoctoral fellowship by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Brazil. We are also grateful to the anonymous reviewers who kindly improved the manuscript with their helpful comments.

## REFERENCES

- Ahyong, S.T. 2002. Stomatopoda (Crustacea) from the Marquesas Islands: results of MUSORSTOM 9. *Zoosystema*, 24: 347–372.
- Ahyong, S.T. 2004. Stomatopoda – mantis shrimps. p. 517–548. In: G. Poore (ed), *Marine Decapod Crustacea of Southern Australia*. Collingwood, CSIRO Publishing.
- Ahyong, S.T.; Haug, J.T. and Haug, C. 2014. Stomatopoda. p. 185–189. In: J.W. Martin, J. Olesen and J.T. Høeg (eds), *Atlas of Crustacean Larvae*. Baltimore, The Johns Hopkins University Press.
- Alikunhi, K.H. 1967. An account of the postlarval development, moulting and growth of the common stomatopods of the Madras coast. p. 824–939. In: *Proceedings of the Symposium on Crustacea*, Marine Biological Association of India. Mandapan Camp, Marine Biological Association of Indian.
- Álvarez-Cadena, J.N.; Ordóñez-López, U.; Almaral-Mendivil, A.R.; Ornelas-Roa, M. and Uicab-Sabido, A. 2007. Larvas de peces del litoral arrecifal del norte de Quintana Roo, Mar Caribe de México. *Hidrobiológica*, 17: 139–150.
- Antonio-Bueno, S. 2015. Distribución y abundancia de larvas del orden Stomatopoda (Crustacea) en el talud continental del sur del Golfo de México. Facultad de Ciencias, Universidad Nacional Autónoma de México, México, Tesis de licenciatura. 48p. [Unpublished]
- Bigelow, R.P. 1893. Preliminary notes on the Stomatopoda of the Albatross collections and other specimens in the National Museum. *The Johns Hopkins University Circular*, 12: 100–102.
- Brooks, W. K. 1886. Report on the Stomatopoda collected by H.M.S. "Challenger." Report on the scientific results of the voyage of H. M. S. Challenger: during the years 1873-76: under the command of Captain George S. Nares, R.N. F.R.S. and the late Captain Frank Tourle Thomson, R.N. *Zoology*. 16: 1-116.
- Camp, D.K. and Manning R.B. 1982. Five new species of *Nannosquilla* from the Northwestern Atlantic (Crustacea, Stomatopoda). *Smithsonian Contributions to Zoology*, 368: 1–15.
- Criales M.M. and Anger K. 1986. Experimental studies on the larval development of the shrimps *Crangon crangon* and *C. allmanni*. *Helgoländer Meeresunters*, 40: 241–265.
- Dana, J.D. 1852. Crustacea, Part I. U.S. Exploring Expedition during 1838-1842, under the command of Charles Wilkes, U.S.N. Vol. 13. Philadelphia, C. Sherman, 1618p.
- Diaz, G.A. 1998. Description of the last seven pelagic larval stages of *Squilla* sp. (Crustacea, Stomatopoda). *Bulletin of Marine Science*, 62: 753–762.
- Dingle, H. 1969. Ontogenetic changes in phototaxis and thigmokinesis in stomatopod larvae. *Crustaceana*, 16: 108–110. doi: 10.1163/156854068X00313
- Fabricius, J.C. 1787. *Mantissa insectorum*. Copenhagen, Christ. Gottl. Prof. vol. 1, xx + 48 pp.
- Feller, K.D.; Cronin T.W.; Ahyong, S.T. and Porter M.L. 2013. Morphological and molecular description of the late-stage larvae of *Alima* Leach, 1817 (Crustacea Stomatopoda) from Lizard Island, Australia. *Zootaxa*, 3722: 22–32.
- Fornshell, J.A. 2012. Key to marine arthropod larvae. *Arthropods*, 1: 1–12.
- García-Calzada, F. 2013. Actualización del inventario y riqueza específica de estomatópodos (Crustacea: Hoplocarida: Stomatopoda) de aguas someras (0–50 m) del noroeste de Yucatán y zonas aledañas. Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México, México, Tesis de licenciatura. [Unpublished]
- Giesbrecht, W. 1910. “Stomatopoda.” *Fauna und Flora Neapel*, Monograph, 33: vii, 1–239, 11 pls.
- González-Gordillo, J.I. and Rodríguez, A. 2000. Larval development of *Philocheras fasciatus* (Risso, 1816) (Decapoda,

- Caridea) reared in the laboratory, comparison with plankton larvae and occurrence of accelerated development. *Journal of Plankton Research*, 22: 1909–1924.
- Granados, B.A.; Abarca, A.L.G. and Vargas, H.J.M. 2007. Investigaciones Científicas en el Sistema Arrecifal Veracruzano. Universidad Autónoma de Campeche, 304p.
- Greenwood, J.G. and Williams, B.G. 1984. Larval and early postlarval stages in the abbreviated development of *Heterosquilla tricarinata* (Claus, 1871) (Crustacea, Stomatopoda). *Journal of Plankton Research*, 6: 615–635.
- Gurney, R. 1946. Notes on Stomatopod Larvae. *Proceedings of the Zoological Society of London*, 116: 133–175.
- Hamano, T. and Matsuura S. 1987. Egg size, duration of incubation, and larval development of the Japanese mantis shrimp in the laboratory. *Nippon Suisan Gakkaishi*, 53: 23–39.
- Hansen, H.J. 1895. Isopoden, Cumaceen und Stomatopoden der Plankton-Expedition. *Ergebnisse der Plankton-Expedition der Humboldt Stiftung*, 2: 1–105.
- Haug, C.; Ahyong S.T.; Wiethase, J.H.; Olesen, J. and Haug, J.T. 2016. Extreme morphologies of mantis shrimp larvae. *Nauplius*, 24: e2016020.
- Humann, P. 2002. Reef fish identification. Florida, Caribbean, Bahamas. 3<sup>rd</sup> ed. Jacksonville, Florida, New World, 481p.
- Lamarck, J.B.M. 1818. Histoire naturelle des animaux sans vertèbres. Tome cinquième. Paris, Deterville/Verdière, 612p.
- Latreille, P.A. 1802. Histoire Naturelle, Générale et Particulière des Crustacés et des Insectes: Ouvrage Faisant Suite aux Oeuvres de Leclerc de Buffon, et Partie du Cours Complet d' Histoire Naturelle Rédigé par C.S. Sonnini. 14 vols. Paris, F. Dufart.
- Leach, W. E. 1817–1818. A general notice of the animals taken by Mr. John Cranch, during the expedition to explore the source of the River Zaire. Appendix 4. p. 407–419 (1818), 1 unnumbered plate (1817). In: J.K. Tuckey (ed) Narrative of an expedition to explore The River Zaire, usually called the Congo, in South Africa, in 1816, under the direction of Captain J.K. Tuckey, R.N., to which is added the journal of Professor Smith, some general observations on the country and its inhabitants, and an appendix, containing the natural history of that part of the Kingdom of Congo through which the Zaire flows. London, John Murray.
- Linnaeus, C. 1768. Dissertatio academica sistens Iter in Chinam, Cons. Exper. Fac. Med. Ups. Moderante Viro Generosissimo D: no. Car. v. Linné. Publico examini submissa ab Andrea Sparman Uplando. In Auditorio Carol. Maj. d. xxx. Nov. Anni MDCCLXVIII. Upsalae, H.A.M.S. Joh. Edman, 16p. [published 30 November 1768].
- Lunz, G.R. 1937. Stomatopoda of the Bingham Oceanographic Collection. *The Bulletin of the Bingham Oceanographic Collection*, 5: 1–19.
- Manning, R.B. 1962. *Alima hyalina* Leach, the pelagic larva of the Stomatopod crustacean *Squilla alba* Bigelow. *Bulletin of Marine Science*, 12: 496–507.
- Manning, R.B. 1969. Stomatopod Crustacea of the Western Atlantic. *Studies in Tropical Oceanography*, 380p.
- Manning, R.B. 1977. A monograph of the West African Stomatopod Crustacea. *Atlantide Report*, 12: 25–181.
- Manning, R.B. 1980. The superfamilies, families, and genera of recent stomatopod crustacea, with diagnoses of six new families. *Proceedings of the Biological Society of Washington*, 93: 362–372.
- Manning, R.B. 1995. Stomatopod Crustacea of Vietnam: The legacy of Raoul Serène. *Crustacean Research*, The Carcinological Society of Japan, Tokyo. Special Number 4. 339p.
- Manning, R.B. and Heard R.W. 1997. Stomatopod crustaceans from the Carolinas and Georgia, southeastern United States. *Gulf Research Reports*, 9: 303–320.
- Manning, R.B. and Provenzano, A.J. 1963. Studies on development of Stomatopod Crustacea I. Early larval stages of *Gonodactylus oerstedii* Hansen. *Bulletin of Marine Science of the Gulf and Caribbean*, 13: 467–487.
- Michel, A. 1968. Drift of stomatopod larvae in Eastern Indian Ocean. *Cahiers Orstom Oceanographie*, 6: 13–41.
- Michel, A. 1970. Pelagic larvae and post-larvae of genus *Odontodactylus* (Crustacea: Stomatopoda) in south and equatorial tropical Pacific. *Cahiers Orstom Oceanographie*, 8: 111–126.
- Michel, A. and Manning, R.B. 1972. The pelagic larvae of *Chorisquilla tuberculata* (Borradaile, 1907) (Stomatopoda). *Crustaceana*, 22: 113–126.
- Morgan, S.G. and Goy, J.W. 1987. Reproduction and larval development of the mantis shrimp *Gonodactylus bredini* (Crustacea: Stomatopoda) maintained in the laboratory. *Journal of Crustacean Biology*, 7: 595–618.
- Morgan, S.G. and Provenzano, A.J. Jr. 1979. Development of pelagic larvae and post-larva of *Squilla empusa* (Crustacea, Stomatopoda), with an assessment of larval characters within the Squillidae. *Fishery Bulletin*, 77: 61–90.
- Pechenik, J.A. 1999. On the advantages and disadvantages of larval stages in benthic marine invertebrate life cycles. *Marine Ecology Progress Series*, 177: 269–297.
- Provenzano, A.J. Jr and Manning, R.B. 1978. Studies on development of stomatopod Crustacea II. The later larval stages of *Gonodactylus oerstedii* Hansen reared in the laboratory. *Bulletin of Marine Science*, 28: 297–315.
- Pyne, R.R. 1972. Larval development and behaviour of the mantis shrimp, *Squilla armata* Milne Edwards (Crustacea: Stomatopoda). *Journal of the Royal Society of New Zealand*, 2: 121–146.
- Reaka, M.L.; Camp, D.K.; Álvarez, F.; García, A.; Ortiz, M. and Vázquez-Bader, A.R. 2009. Stomatopoda (Crustacea) of Gulf of Mexico. p. 901–921. In: D.R. Felder (ed), Gulf of Mexico: Origin, Waters and Biota, Vol. 1, Biodiversity. College Station, Texas A&M University.
- Rodrigues, S.A. and Manning, R.B. 1992. First stage larva of *Coronis scolopendra* Latreille (Stomatopoda: Nannosquillidae). *Journal of Crustacean Biology*, 12: 79–82.

- Say, T. 1818. An account of the Crustacea of the United States. Part 7. *Journal of the Academy of Natural Sciences of Philadelphia*, 1: 374–401.
- Schmitt, W.L. 1940. The stomatopods of the west coast of America based on collections made by the Allan Hancock Expeditions, 1933–1938. *Allan Hancock Pacific Expeditions*, 5: 129–225.
- Schram, F.R.; Ahyong, S.T.; Patek, S.N.; Gree, P.A.; Rosario, M.V.; Bok, M.J.; Cronin T.W.; Mead, K.S.; Caldwell, R.L.; Scholtz, G.; Feller, F.D. and Abelló, P. 2013. Subclass Hoplocarida Calman, 1904: Order Stomatopoda Latreille, 1817. p. 179–355. In: F.R. Schram and J.C. Von Vaupel Klein (eds). *Treatise on Zoology – Anatomy, Taxonomy, Biology. Crustacea*, Vol. 4, part A. Leiden, Brill.
- Shanbhogues, S.L. 1975. Descriptions of stomatopod larvae from the Arabian Sea with a list of stomatopod larvae and adults from the Indian Ocean and a key for their identification part I. *The Marine Biological Association of India*, 17: 196–238.
- Townsley, S.J. 1953. Adult and larval stomatopod crustacean occurring in Hawaiian Waters. *Pacific Science*, 7: 399–437.
- Veena, S. and Kaladharan, P. 2010. Mantis shrimp larvae from the inshore waters of Visakhapatnam. *Marine Biodiversity Records*, 3: e126.
- Wortham-Neal, J.L. 2002. Reproductive morphology and biology of male and female mantis shrimp (Stomatopoda: Squillidae). *Journal of Crustacean Biology*, 22: 728–741.