

First record and description of *Panulirus pascuensis* (Reed, 1954) first stage phyllosoma in the plankton of Rapa Nui

By Meerhoff Erika*, Mujica Armando, García Michel,
and Nava María Luisa

Abstract

Among the most striking crustaceans from Rapa Nui Island (27° S, 109°22' W) is the endemic lobster *Panulirus pascuensis*, commonly known as the spiny lobster. This species is also present in Pitcairn Island and the Salas y Gomez ridge. The larvae of this species pass through different phyllosoma stages until metamorphosis, in which they molt to puerulus, a transitional stage adapted to benthic life. This species is an important fishery resource for the inhabitants of Rapa Nui. However, there are several gaps in the biological knowledge of this species, including its ontogeny. We sampled zooplankton to obtain first stage *P. pascuensis* phyllosoma during three oceanographic campaigns around Rapa Nui (April 2015, September 2015 and March 2016), individuals were encountered between the surface and 200 m depth with an abundance of 1.3 indiv/1000 m³. These individuals, along with laboratory hatched phyllosoma, allowed us to describe the morphology of this larval stage. The *P. pascuensis* stage I phyllosoma were observed in fall, suggesting that the larval development would be synchronized with the productivity cycle in the region of Rapa Nui, where maximum chlorophyll concentration is observed during the austral winter.

*Corresponding Author E-mail: erikameerhoff@udec.cl

This **early view** paper has been peer-reviewed and accepted for publication in *Pacific Science*. However, it has not been copy-edited nor has it undergone typesetting for *Pacific Science*. The final published paper will look different due to formatting changes, but scientific content will remain the same.

Introduction

The island of Rapa Nui (also known as Easter Island) is part of the Marine and Coastal Protected Area called Coral Nui Nui, Motu Tautara and Hanga Oteo submarine Parks (Sierralta et al. 2011). Due to the distance that separates the island from other areas of shallow water, its small size and the lack of habitat diversity, the marine fauna is not very diverse (Fraser & Randall 1986) but presents high levels of endemism (Randall 1976, Rehder 1980). The endemism is the highest found in submarine mounts, even surpassing hydrothermal vents (Richer de Forges *et al.* 2000). Retamal and Moyano (2010) found that Rapa Nui is zoo-geographically isolated from other regions in Chile, and constitutes an area of endemism for decapods at the family, genus and species level. The decapods from Rapa Nui and Salas y Gomez Island correspond in part to fauna distributed along the occidental region of the tropical Indo-Pacific (Retamal 2004).

Among the most striking crustaceans from Rapa Nui is the endemic lobster *Panulirus pascuensis*, commonly known as the spiny lobster. Females carry eggs that hatch into pelagic larvae known as phyllosomas. These increase their swimming capacities during the larval development until metamorphosis, when larvae molt transforming into the puerulus stage, which is adapted to benthic life (Phillips et al. 2013). This species is an important fishery resource for the inhabitants of Rapa Nui (Boyko 2003), and historically has been important in the diet of the residents, even featuring as part of the mythology and culture of Rapa Nui. More recently, extraction has affected its abundance, and the size of individuals has been reduced, suggesting possible overexploitation (CORFO 1978, FAO 2007). There are several gaps in the biological knowledge of this species, including its ontogeny. There are no records of *Panulirus pascuensis* phyllosoma larvae in the previous oceanographic research in the area (Vereschaka 1990, 1995; Parin et al. 1997, Rivera & Mujica 2004). Even when scientific aquaculture of *P. pascuensis* was

attempted on the island, phyllosomas were not obtained (Navarrete 2002). The objective of this study was to identify and describe the *P. pascuensis* phyllosoma, as well as the depth at which it is found in plankton.

Materials and methods

Zooplankton sampling was conducted in the coastal zone around Rapa Nui during oceanographic campaigns in April 2015, September 2015 and March 2016. The sampling was conducted with a Tucker trawl net with a 300 μm mesh size and 0.25 m² mouth area (in April 2015, Apolo Transect, figure 1) and a 300 μm mesh Bongo net (April 2015 SE transect, Omohi; September 2015 Apolo Transect, Omohi Transect and Motu Tautara station and March 2016 Apolo Transect, Omohi Transect and Motu Tautara station). Since phyllosoma larvae are often more abundant at nighttime in the upper layer of the water column, suggesting a diurnal vertical migration behavior (Palma et al. 2011), we conducted epineustonic coastal sampling at night as well as during the day in April 2015, but subsequently only during the day in September 2015 and March 2016. The night sampling was conducted over the course of three consecutive nights at the end of March 2015. The trawls and the epineustonic sampling were performed at a constant velocity of 2 knots and the volume filtered was estimated using a mechanical flowmeter (Sea Gear). Zooplankton samples were preserved in ethanol (96%), and identified under a magnifying glass (50 x) at the laboratory of Universidad Católica del Norte. The hydrographic characterization of the water column was conducted using a set of CTD profiles (Seabird 18). In addition to tows, we also installed light traps with the objective of improving the chances of collecting phyllosoma and puerulus which may be attracted to light sources. The light traps were designed based on Sigurdsson et al. (2014) and Porter et al. (2008) (Figure 2). Two moorings with two light traps each were installed at 5 and 15 m depth near the coast of Rapa Nui (Motu

Tautara, figure 1) for a period of 12 hrs over the course of 3 nights in April 2015. White led lights were used in the traps.

To supplement phyllosoma from sampling in March 2016 two female lobsters were held in captivity at the laboratory on the island to directly obtain phyllosoma when they hatched. Females were kept in marine water at constant temperature (23°C), and fed with tuna fish until the larval hatched. The females were then released in the ocean. The morphology of the larvae was described based on 20 phyllosoma larvae hatched at the laboratory and two individuals obtained in the zooplankton trawls. Identification of the phyllosoma followed Rivera and Mujica (2004), as well as international taxonomic keys (Lewis 1951, Abrunhosa et al. 2008, Martin et al. 2014).

Results

The phyllosoma of the endemic lobster *P. pascuensis* were found in very low abundances in the plankton around Rapa Nui. One first stage phyllosoma was found in the diurnal zooplankton samples between the surface and 200 m of depth around the submarine seamount Apolo in April 2015, with an abundance of 1.3 indiv/1000 m³ (density based on one individual found in the zooplankton). The environmental characteristics of the water column in April 2015 were: a mean temperature of 21.2 °C, a mean salinity of 35.7 ‰, and 4.94 ml/L dissolved oxygen. In March 2016, another first stage phyllosoma was found in the diurnal zooplankton (one individual) between the surface and 80 m depth near the coast of Rapa Nui (station Motu Tautara). No phyllosoma larvae were encountered in the epineustonic samples or in the light traps. No other larval stages of *P. pascuensis* were found in the zooplankton.

The phyllosoma found in the plankton corresponded morphologically to the *P. pascuensis* phyllosoma that hatched in the laboratory. Of the two females we kept in the laboratory, only one

succeeded in hatching the larvae. The female lobster participates actively in liberating the naupliosoma larvae (figure 3b), which molt and become the first phyllosoma (figure 3c) (Dupré 2000).

Panulirus pascuensis phyllosoma description

The size and morphology of the observed larvae indicate that they correspond to the first phyllosoma stage. The cephalon is pear-shaped, with a maximum width (1.00 mm) less than its length (1.27 mm), features that correspond to the description of phyllosoma of the *Panulirus* genus (figure 3c and d) (Rivera & Mujica 2004). The eye stalk is undivided and terminates with a prominent eye. The total length of the eye stalk and eye is similar to the cephalic length (1.25 mm). The length of the antennae is approximately the same as the eye stalk, with a lateral process along the internal margin and two small apical setae. Antennulae are non-segmented, thinner and longer than the antenna with small apical setae (figure 3d).

The first pair of maxillipeds is small, non-segmented, uniramous with small distal setae. The second pair is also uniramous, with five segments. In the fourth segment there is a fine long subdistal spine that surpasses the distal extreme of the fifth segment, which is short with an apical spine nearly as long as the segment. The third pair of maxillipeds is long, and uniramous with five segments. The third segment has a small subdistal spine, while the fourth has two long spines that surpass the fifth segment, which has an apical spine. The first pereopod is biramous and the exopodite is composed of three segments with long setae along the external margin and the tip of the terminal segment. While the endopodite has five segments with fine lateral setae in the fourth and fifth segment and a wider seta at the tip of the terminal segment. The third pereopod has a developing exopodite with fine distal setae and an endopodite with five segments. The fourth and fifth segments have fine setae with one wider, slightly curved claw-shaped seta on the tip of the fifth segment. Phyllosoma have a short (0.39 mm) non-segmented

abdomen, similar in length to the first segment of the third pereopod with a small terminal neckline and a short fine spine at each distal apex.

Discussion

This is the first time *P. pascuensis* phyllosoma of planktonic origin have been found and also the first time phyllosoma of this species hatched in the laboratory. The first stage phyllosoma were found in the plankton near the coast of Rapa Nui and the Apolo sea mount, which is a lava platform at 150 m depth located 7 nautical miles southwest of Rapa Nui (Hernández et al. 2015). The presence of Apolo may modify local oceanic currents and retain fish larvae and eggs in this area (Meerhoff et al. submitted). Additionally, during April 2015 a maximum fluorescence of 0.4 mg/m³ was recorded at a depth of 170 m, indicating an increase in phytoplankton primary productivity in this region (Yannicelli, unpublished data).

Since it is known that larval tows present some limitations, for example they work particularly well at sampling slow and abundant planktonic organisms, but they are less efficient at sampling strong-swimming or scarce organisms (Pineda et al. 2010), we also installed light traps. Light traps have been used to catch spiny lobster larvae in the tropics and recently used to catch European and Norwegian lobster larvae (Sigurdsson et al. 2014). Lobster pueruli exhibit a strong attraction to bright lights at night (Serfling and Ford, 1975) and nocturnal illumination of the collectors resulted in increased catches of the puerulus larvae of the western rock lobster *Panulirus longipes* (Phillips 1975). We found neither phyllosoma nor puerulus in the light traps. However, this may be due to the low frequency of deployment of the traps in the field.

Phyllosoma of other *Panulirus* species migrate vertically in the water column, for example *Panulirus cygnus* undergoes a diurnal vertical migration off the coast of Australia with the early stages (I to III) occurring at the surface at night regardless of moonlight intensity (Rimmer and Phillips 1979). However, we did not find phyllosomas in the epineustonic night

samples that could support this behavior in *P. pascuensis*. This result may be due to our sampling methods, for example Rivera and Mujica (2004) suggested that the lack of captures of *P. pascuensis* phyllosoma around Rapa Nui may be due to its great motility that could allow it to avoid nets. Another explanation could be that in this oligotrophic area, where the vertical distribution of pigment concentrations typically exhibits a deep maximum at or below 100 m (von Dassow and Collado 2014), the phyllosoma larvae would remain at depths where the food is concentrated.

The lobster females captured for experimental purposes were obtained on March 18th 2016 and presented eggs after the date of closure for the fishery season (November 1st to March 1st, SERNAPESCA). This suggests that the reproductive season may have been extended due to El Niño in 2016. El Niño 2015/2016 was a strong event (<https://www.climate.gov/news-features/blogs/enso/april-2016>) with sea surface temperature (SST) around Rapa Nui above the maximum monthly mean (http://coralreefwatch.noaa.gov/vs/timeseries/polynesia.php#easter_island). More studies are needed to explore if the fishery season should be adapted to annual variability.

The *P. pascuensis* phyllosoma were observed in fall, suggesting that the larval development may be synchronized with the productivity cycle in the region of Rapa Nui, where a clear annual chlorophyll cycle is observed with maximum concentration during the austral winter (Andrade et al. 2014). The spawning of the California spiny lobster (*Panulirus interruptus*) also occurs in late summer and early autumn (Koslow et al. 2012). This study and description of the phyllosoma of *P. pascuensis* is a contribution to the knowledge of the ontogeny of this species, and to future investigations of the connectivity between Rapa Nui and the Motu Motiro Hiva marine park around Salas y Gómez Island (26°28'S, 105°21'W).

Finally, despite the fact that in Rapa Nui there are two other species of lobster, we did not find phyllosoma larvae of *Parribacus perlatus* or *Scyllarides roggeveeni*. The phyllosoma of *Parribacus* sp. and *Scyllarides* sp. are morphologically different from *Panulirus* sp. (Rivera and Mujica 2004), with the particular shape of the cephalon and the well-developed and setous exopodites at the second and third maxillipeds being the main features that distinguish these genera (Rivera & Mujica 2004).

Acknowledgements

This research was financed by the Chilean Millennium Initiative (NC120030) grant. EM also acknowledges the support from Postdoctoral-FONDECYT Chile N° 3150419. the authors acknowledge the Chilean Navy at Rapa Nui for their collaboration in sampling aboard the Tokerau and Matatoa, as well as ORCA diving center for the deployment of the light traps. EM also acknowledges Juan Serratos for his support during sampling in September and Trevor Walter for editing. the authors also acknowledge Carolina Paz Concha Molina from CFRD University of Concepcion for her contribution with the drawing.

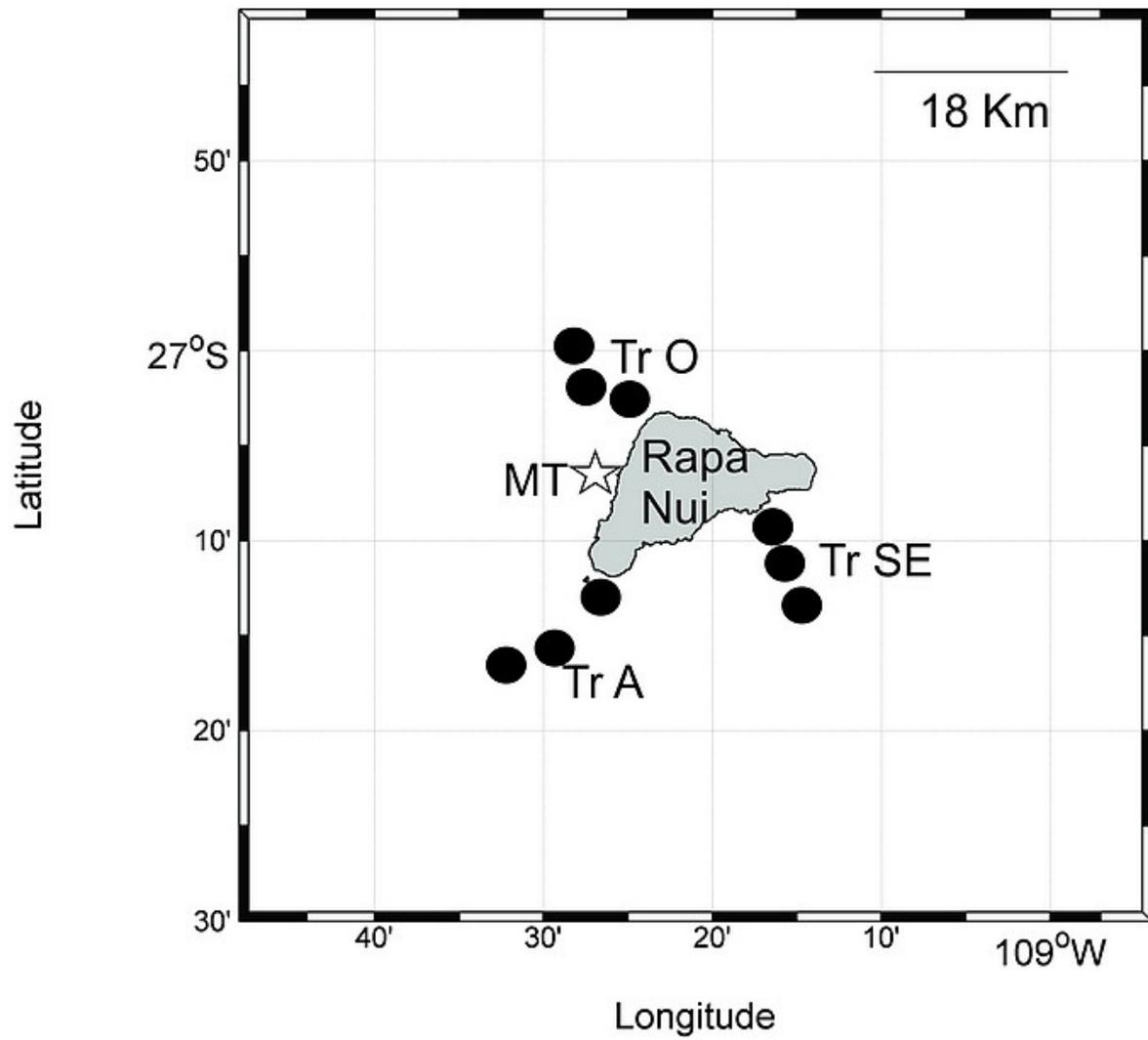


Figure 1. Study area, Tr A: Mount Apolo transect, Tr SE: southeast transect, Tr O: Omohi transect, MT: Motu Tautara station.

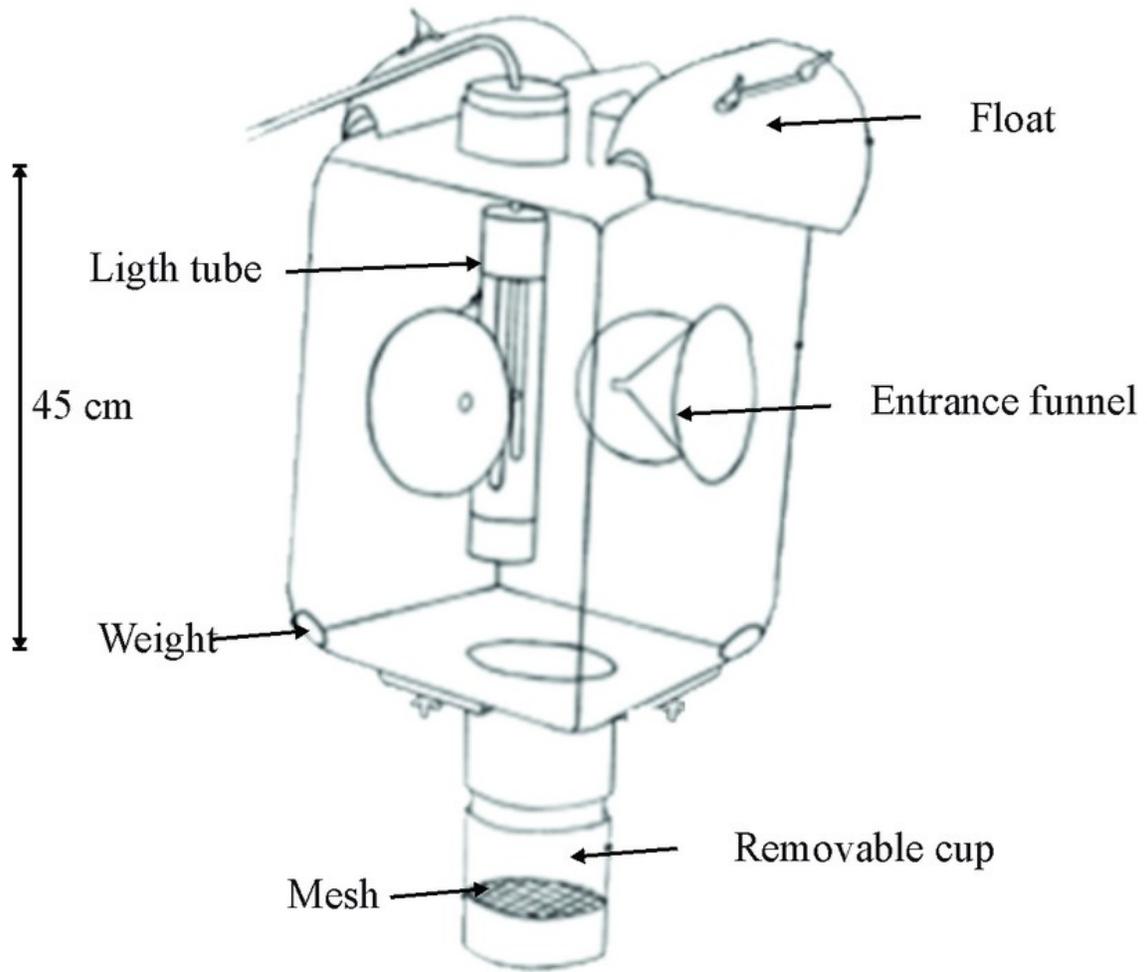


Figure 2. Light trap collector design installed on the coast of Easter Island in April 2015 (from Porter et al. 2008).

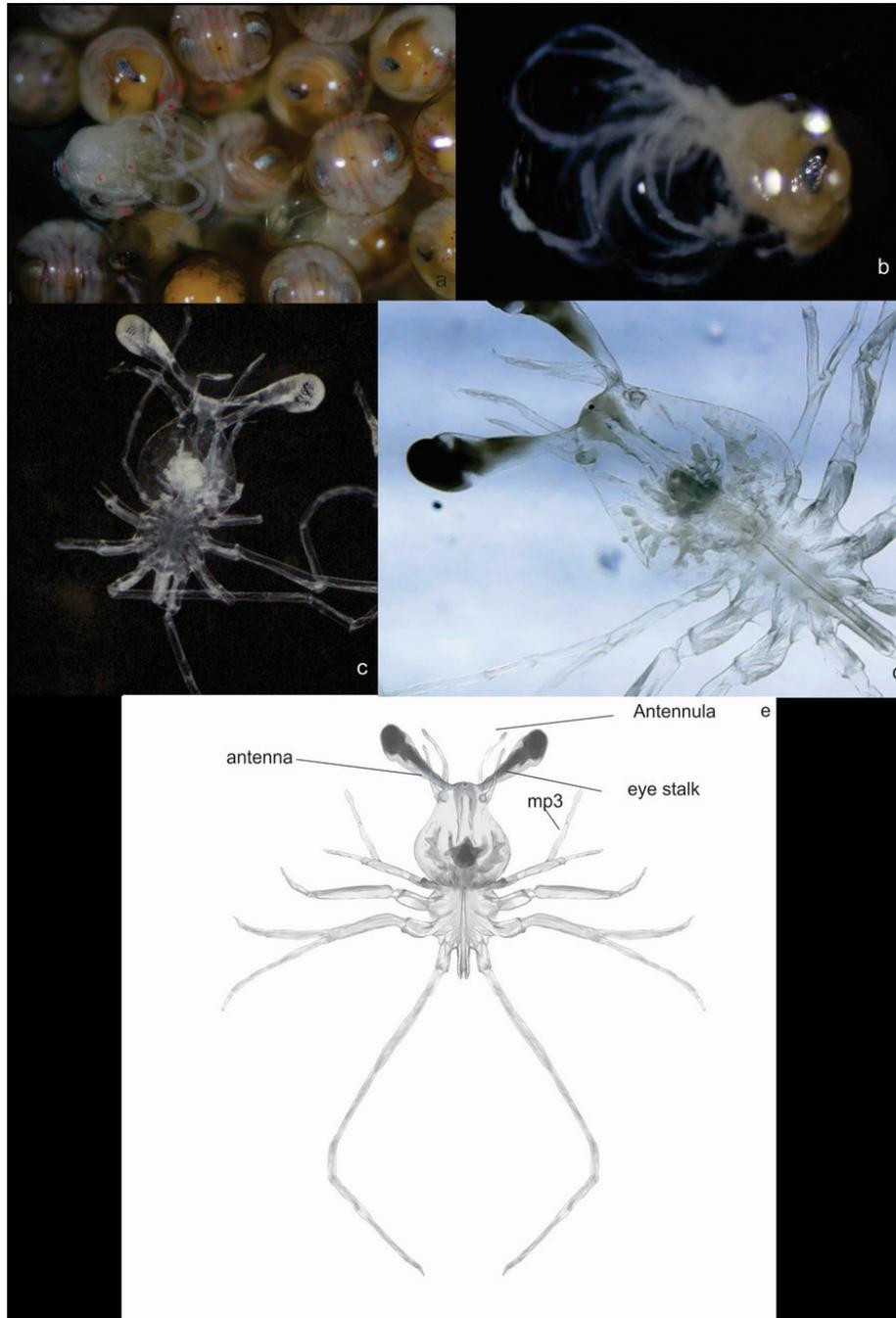


Figure 3. Photo of a) *Panulirus pascuensis* eggs, b) recently hatched naupliosoma (bar=0.84 mm) c) phyllosoma (I stage, from zooplankton tow, bar= 1.25 mm), d) detail of the *P. pascuensis* phyllosoma where the antenna and antennule are observed (from larvae hatched at laboratory, bar=1.25mm).e) schematic drawing of the phyllosoma (mp3: third maxilliped).

Literature Cited

- Abrunhosa FA, Santiag AP, Abrunhosa, JP. 2008. The early phyllosoma stages of spiny lobster *Panulirus echinatus* Smith, 1869 (Decapoda: Palinuridae) reared in the laboratory. *Braz. J. Biol.*, 68: 179-186
- Andrade I, Hormazábal S, Correa-Ramírez M. 2014. Time-space variability of satellite chlorophyll-a in the Easter Island Province, southeastern Pacific Ocean. *Lat. Am. J. Aquat. Res.*, 42: 871-887
- Boyko CB. 2003. The Endemic Marine Invertebrates of Easter Island: How Many Species and for How Long?, pp 155-175. In: Easter Island Scientific Exploration into the World's Environmental Problems in Microcosm. Loret J, Tanacredi JT Eds. Springer Science+Business Media New York
- Costello C, Rassweiler A, Siegel DA, De Leo G, Micheli F, Rosenberg A. 2010. The value of spatial information in MPA network design. *PNAS* 107: 18294–18299
- Cowen RK, Sponaugle S. 2009. Larval Dispersal and Marine Population Connectivity. *Annu Rev Mar Sci* 1: 443-466
- Dupré E. 2000. Reproducción, muda y desarrollo de la langosta de Juan Fernández, *Jasus frontalis*, en estanques de cultivo. *Invest. Mar.*, Valparaíso, 28: 165-174
- FAO. 2007. Informe del quinto Taller Regional sobre la Evaluación y la Ordenación de la Langosta Común del Caribe. Merida, Yucatan, Mexico, 19-29 de septiembre de 2006. FAO Fisheries Report/FAO Informe de Pesca. No. 826. Rome, Roma, FAO. 99p
- Fraser TH & Randall JE. 1986. A New Species of the Cardinalfish Genus *Apogon* from Easter Island, *Copeia*, 3: 641-645

- Hernández S, García M, Gaymer CF, Friedlander AM. 2015. First Records of Striped Boarfish *Evistias acutirostris* and Ornate Butterflyfish *Chaetodon ornatissimus* from Easter Island. *Pac Sci* 69, 525–529
- Koslow JA, Rogers-Bennett K, Neilson DJ. 2012. Lobster phyllosoma abundance linked to warm conditions CalCOFI Rep., Vol 53
- Lewis JB. 1951. The phyllosoma larvae of the spiny lobster *Panulirus argus*. *B Mar Sci Gulf and Caribbean* 1: 89-103
- Martin JW, Olesen J, Hoeg JJ. 2014. Atlas of crustacean larvae. Martin JW, Olesen J, Hoeg JJ (Eds.) John Hopkins University Press, Baltimore, USA 370 pp
- Meerhoff E, Ramos M, Yannicelli B, Varela C, Bravo L. Meroplankton distribution in the Rapa Nui ecoregion of the South Pacific Ocean, implications for larval connectivity between islands. *Deep Sea Res* (in review)
- Navarrete C. 2002. Informe final FIC: Pesquería sustentable de la langosta de isla de Pascua. 152 pp
- Palma AT, Caceres-Montenegro I, Bennett RS, Magnolfi S, Henriquez LA, Guerra JF, Manríquez K, Palma E. 2011. Near-shore distribution of phyllosomas of the two only lobster species (Decapoda: Achelata) present in Robinson Crusoe Island and endemic to the Juan Fernández archipelago. *Rev Chil Hist Nat* 84: 379-390
- Parin N, Mironov A, Nesis K. 1997. Biology of Nazca and Sala y Gómez submarine ridges, an outpost of the Indo-West Pacific fauna in the Eastern Pacific Ocean: composition and distribution of the fauna, its communities and history. *Adv. Mar. Biol.*, 32: 147-230

- Phillips BF. 1975. Effect of Nocturnal Illumination on Catches of the Puerulus Larvae of the Western Rock Lobster by Collectors Composed of Artificial Seaweed. *Aust. J. mar. Freshwat. Res.* 1975, 26, 41 1-14
- Phillips BF, Melville-Smith R, Kay MC, Vega-Velazquez A. 2013. *Panulirus* Species In: Lobsters: biology, management, aquaculture and fisheries (second edition). Phillips BF (Ed). Department of Environment & Agriculture Curtin University, Western Australia 503 pp
- Pineda J, Porri F, Starczak V, Blythe J. 2010. Causes of decoupling between larval supply and settlement and consequences for understanding recruitment and population connectivity. *J Exp Mar Biol Ecol* 392: 9-21
- Porter SS, Eckert GL, Byron CJ, Fisher JL, 2008. Comparison of light traps and plankton tows for sampling brachyuran larvae in an Alaskan fjord. *J Crustacean Biol* 28, 175-179
- Randall JF. 1976. The endemic shore fishes of the Hawaiian Islands, Lord Howe Island and Easter Island. *Colloque Commerson 1973, ORSTOM Trav Doc, 7: 49-73*
- Rehder HA. 1980. The marine mollusks of Easter Island (Isla de Pascua) and Sala y Gomez. *Smithsonian Contr. Zool.*, 289:1-167
- Retamal MA. 2004. Decapods of the Chilean oceanic islands: Easter and Salas y Gomez. *Cien. Tec. Mar.* 27: 55-68
- Retamal MA & Moyano HI. 2010. Zoogeografía de los crustáceos decápodos chilenos marinos y dulceacuícolas. *Lat. Am. J. Aquat. Res* 38: 302-328
- Richer de Forges B, Koslow JA & Poore GCB. 2000. Diversity and endemism of the benthic seamount fauna in the southwest Pacific. *Nature*, 405: 944–947
- Rimmer DW, Phillips BF. 1979. Diurnal migration and vertical distribution of phyllosoma larvae of the Western Rock Lobster *Panulirus cygnus*. *Mar Biol* 54:109-124

- Rivera J, Mujica A. 2004. Larvas phyllosoma (Decapoda, Palinuridae y Scyllaridae) de las islas oceánicas chilenas. Invest. Mar., Valparaíso, 32: 99-111
- Serfling AS, Ford RF. 1975. Ecological studies of the puerulus larval stage of the California spiny lobster, *Panulirus interruptus*. Fish B-NOAA 73, 360:377
- Sierralta L, Serrano R, Rovira J, Cortes C (Eds.), 2011. Las áreas protegidas de Chile, Ministerio del Medio Ambiente, 35 pp
- Sigurdsson GM, Morse B, Rochette R. 2014. Light traps as a tool to sample pelagic larvae of American lobster (*Homarus americanus*). J Crustacean Biol 00, 1-7
- Vereschaka AL. 1990. Pelagic decapods from seamount of Nazca and Sala-I-Gomez ridges. En: A.N. Mironov & J.A. Rudjacov (eds.). Plankton and benthos from the Nazca and Sala-y-Gomez submarine ridges. Trud. Inst. Okeanol, Acad. Sci., Moscow, 124: 129-15
- Vereschaka AL. 1995. Macroplankton in the nearbottom layer of continental slopes and seamounts. Deep-Sea Res., 42(9): 1639-1668
- von Dassow P, Collado S. 2014. Biological oceanography, biogeochemical cycles, and pelagic ecosystem functioning of the east-central South Pacific Gyre: Focus on Easter Island and Sala-y-Gómez Island. Lat. Am. J. Aquat. Res. 42, 703-742.