New records of marine decapods and stomatopods in Área de Conservación Guanacaste (ACG): four years of marine biodiversity inventorying

Rita Vargas-Castillo 1,3 and Jorge Cortés 1,2,3*

Abstract

The marine area of Área de Conservación Guanacaste (ACG) contains a 43,000 ha formal marine protected area, a 732 ha special management zone in Bahía Santa Elena, and 150 km of wild protected coastline. In an effort to broaden the biodiversity knowledge of all marine taxa present in the area, an inventory was started in 2015 (BioMar-ACG Project). This initiative is being funded by the Guanacaste Dry Forest Conservation Fund (GDFCF) in collaboration with government staff at ACG, and is carried out by Centro de Investigación en Ciencias del Mar y Limnología (CIMAR, Center for Research in Marine Science and Limnology) and Museo de Zoología (Zoology Museum), both from Universidad de Costa Rica (UCR). After four years of the project, 2650 specimens of marine decapod crustaceans and stomatopods have been collected, belonging to 209 species, out of which 99 are new records for ACG, four may be new species and nine (Cyrtoplax panamensis, Glyptoxanthus labyrinthicus, Pachyches marcorzpees, Petrolithes donadio, Pylopagurus holmesi, Synalpheus pinkfordi, Typton granulosus, Zenopontonia soror, Neogonodactylus pumilus) are new records for Costa Rica. With this contribution the total number of decapods (257 spp.) and stomatopods (14 spp.) for ACG is 271 species, more than half the species reported for Costa Rica, and more than a quarter of all crustaceans reported for the eastern tropical Pacific. The high concentration of species in ACG may be attributed to the diversity of habitats, the seasonal upwelling and to the recent sampling efforts. In only four years, the BioMar-ACG has increased the number of species in these groups of crustaceans by 37% over the past 85 years of previous studies in the ACG.

Keywords: Decapods, Stomatopods, Biodiversity, Inventory, ACG

Introduction

The first study of marine decapods of Costa Rica was completed by Faxon (1895), and on stomatopods by Schmitt (1940) and Reaka and Manning (1980). Compilations of the biodiversity of marine decapod crustaceans and stomatopods in Costa Rica began with a publication by Moran and Dittel (1993), with an annotated list of anomuran and brachyuran crabs from the Pacific and Caribbean coasts. Castro and Vargas (1996) published an annotated list of decapods and stomatopods from Golfo Dulce, while Vargas and Cortés (1997) a list of stomatopods of the country. Afterwards, two other compilations on crustaceans were published for Penaeoidae, Sergestoidea, Caridea, Astacidea, Thalassinidea and Palinura in the Caribbean (Vargas and Cortés 1999a) and in the Pacific (Vargas y Cortés 1999b). Vargas and Cortés (2006) published a compilation of the Infraorder Anomura. Some years later, compilations were published in the book “Marine Biodiversity of Costa Rica, Central America” (Wehrtmann and Cortés 2009), which examines all groups of marine organisms reported for Costa Rica. Chapters include all crustacean groups known to be present in this country on the Pacific and Caribbean, including the best-known taxa: stomatopods (35 spp.)
Área de Conservación Guanacaste (ACG) includes several terrestrial National Parks and Reserves and a Marine Sector that is 43,000 ha and 150 km of protected coastline (http://www.acguanacaste.ac.cr/acg/que-es-el-acg). It is one of the best-studied conservation areas in Central America, but previous biological research has

| Code | Collection sites                                                                 | Type of environment                                           |
|------|----------------------------------------------------------------------------------|---------------------------------------------------------------|
| BEH  | Bahía El Hachal                                                                 | Intertidal zone                                               |
| BEJ  | Bajo El Jardín                                                                  | Reef and algae covered coralline rocks                       |
| BEM  | Bajo El Machetazo                                                               | Rocky bottom and small loose rocks                           |
| BET  | Bajo El Tigre                                                                   | Rocky bottom and small loose rocks                           |
| BEV  | Bajo El Viejón                                                                  | Rocky bottom and small loose rocks                           |
| BEJ  | Bajo El Jardín                                                                  | Rocky bottom and small loose rocks                           |
| BSE  | Bahía Santa Elena, Pintadero, Playa Cocos                                       | Rocky bottom and small loose rocks                           |
| BLC  | Bajo Las Chavelas                                                               | Rocky bottom and small loose rocks                           |
| BLM  | Bajo Los Mogotes                                                                | Rocky bottom and small loose rocks                           |
| BRR  | Bajo La Rajada                                                                  | Rocky bottom and small loose rocks                           |
| BLS  | Bajo La Salvadita                                                               | Rocky bottom and small loose rocks                           |
| BMu  | Bajo Los Muñecos                                                                | Rocky bottom and small loose rocks                           |
| BPi  | Bajo Pintadero                                                                   | Rocky bottom and small loose rocks                           |
| BPo  | Bajo Pochote                                                                    | Rocky bottom and small loose rocks                           |
| BRo  | Bajo Rojo                                                                       | Rocky bottom and small loose rocks                           |
| BTh  | Bahía Thomas                                                                    | Floating oyster baskets, rocky beach, rocky beach with sponges, live and dead Pocillopora |
| Cua  | Bahía Cuajiniquil, Playa Cuajiniquil                                            | Sand and mud bottoms                                         |
| IDa  | Isla David                                                                      | Rocky intertidal zone and reefs                               |
| IDa  | Isla David                                                                      | Rocky bottom and small loose rocks                           |
| IGo  | Isla Golondrina                                                                 | Pavona clavus reef, dead coral                               |
| Ip   | Isla Pelada                                                                     | Rocky intertidal zone, rocks covered with algae               |
| ISJ  | Esquina Conchal, Playa del Maíz, Playa Cactus, Isla San José                   | Rocky intertidal zone and dead Pocillopora                   |
| ISP  | Arrecife al NE de Isla San Pedrito, arrecife muerto San Pedrito, San Pedrito    | Coral reef and dead coral                                    |
| Jun  | Playa Junquillal, Junquillal esquina norte; Isla Junquillal, Junquillal, Esquina del Tamarindo | Rocky intertidal zone, polychaete reef, and Pocillopora        |
| Mat  | Matapalito                                                                      | Coral reef, dead coral and rocky-sandy bottom                 |
| MCu  | Manglar en Bahía Cuajiniquil, Manglar 3 Bocas, Manglar 4 × 4 Cuajiniquil         | Mangrove, mud, rubble with sponges and algae                 |
| MSE  | Manglar Santa Elena                                                             | Mangrove, muddy flats                                        |
| Mue  | Muelle lado derecho, muelle lado izquierdo, Cástula, Tiza, Hielera               | Rocky intertidal and subtidal zones, sandy bottom, rubble    |
| PCI  | Piedra Claudio                                                                  | Rocky bottom and small loose rocks with barnacles             |
| PCo  | Playa Corona                                                                    | Rocky intertidal zone                                        |
| Pd1  | Puerta de Iglesia, Isla San José                                               | Rocky bottom                                                 |
| PGs  | Playa Potrero Grande, Estero de Potrero Grande                                 | Rocky intertidal zone, sandy beach, estuary, mangrove        |
| PMa  | Playa Macaya                                                                    | Rocky intertidal zone, subtidal live coral                   |
| PPo  | Punta Pochote                                                                   | Dead corals                                                  |
| Pre  | Playa Respingue                                                                 | Rocky intertidal zone                                        |
| PSe  | Piedra Seca                                                                     | Rocky bottom and small loose rocks with barnacles             |
| 2MM  | Arrecife 2MM                                                                    | Coral reef                                                   |
Table 2 New records of marine decapods and stomatopods from Área de Conservación Guanacaste after four years of the BioMar-ACG project. In bold type: new records for Costa Rica (Continued)

| Taxon | Locality |
|-------|----------|
| 34) Goniopsis pulchra (Lockington, 1877) | MCu |
| Family Hippolytidae | |
| 35) Thor alpicola Wicksten, 1987 | BTh, BRo, ISJ, Jun, Cue, PGr |
| 36) Thor sp. nov. | PSe |
| Family Hymenoceridae | |
| 37) Hymenocera picta Dana, 1852 | BTh, 2MM |
| Family Inachidae | |
| 38) Coryphyna vestitus (Stimpson, 1871) | BTh, BEJ, BLM, Cua, Jun, Cue, PCi |
| Family Leucosiidae | |
| 39) Peneponia tournesi Bell, 1855 | Koa |
| 40) Ultia elliptica Stimpson, 1871 | BTh, ISJ |
| Family Menipidae | |
| 41) Menippe obtusa Stimpson, 1859 | Mue |
| Family Ocypodidae | |
| 42) Leptusca beebri (Crate, 1941) | Cua, Mue, PGr |
| 43) Leptusca musicus (Rathbun, 1914) | PGr |
| 44) Uca princeps (Smith, 1870) | Mue, PGr |
| 45) Uca styllina (H. Milne Edwards, 1852) | Mue |
| 46) Ucides occidentalis (Ortmann, 1897) | Mue, PGr |
| Family Oxidae | |
| 47) Euclannus xantheus (Stimpson, 1860) | BTh, BEm, ISJ, Mue |
| 48) Oxius perlitus Stimpson, 1860 | Koa, ISJ |
| Family Palaemonidae | |
| 49) Pagonus namades Hagg & Harvey, 1991 | Mue |
| 50) Phithomurix roseus (Benedict, 1892) | BTh |
| 51) Pylacinus holmesi Schmitt, 1921 | Koa, ISJ |
| Family Palaemonidae | |
| 52) Ascidonia pusilla (Holthius, 1951) | BTh |
| 53) Harpiliopsis depressa (Stimpson, 1860) | BTh, ISJ, Mue, PGr, PRe, PRe |
| 54) Palaemon ritteri Holthius 1895 | BTh, Koa, ISJ, Mue, PGr, PRe |
| 55) Palaemonella holmesi (Benedict, 1892) | BTh, BEm, BLo, BEV, ISJ, Mue, Mue |
| 56) Pontonia maculata Guerin-Méneville, 1855 [in Guerin-Méneville, 1855–1856] | BTh, BEJ, Bro, BEV, ISJ, BEm, Mue |
| 57) Pseudocauterina elegans Holthius, 1951 | BTh, BEm, BLo, BEV, ISJ, Mue |
| 58) Pseudoveleronia latifrons (Holthius, 1951) | BTh, BEJ, BLo, BEV, ISJ, Mue |
| 59) Typton granulosus Ayon-Parente, Hendrick & Galvan-Villa, 2015 | BTh, BEJ, BEV, ISJ, Mue, Mue |
| 60) Zemopontonia soror (Benedict, 1892) | BTh, BEm, ISJ, Mue |

Family Panopeidae | |
| 61) Acantholobulus mirafloresensis (Abele & Kim, 1989) | BTh, BEm, ISJ, Mue, PGr |
| 62) Lophopanopeus maculatus Rathbun, 1898 | ISJ |
| 63) Panopeus purpureus Lockington, 1877 | BTh, Cua, Mue, PGr |
| 64) Pironoiafla clistia Smith, 1870 | Mue, PGr |

Family Panopinae | |
| 65) Heterocrypsa colombiana Garth, 1940 | Cua, Mue |
Table 2 New records of marine decapods and stomatopods from Área de Conservación Guanacaste after four years of the BioMar-ACG project. In bold type: new records for Costa Rica (Continued)

| Taxon | Locality |
|-------|----------|
| 66) Pandalus interruptus (Stimpson, 1860) | BTh |
| Family Pandalidae | |
| 67) Penaeus stylostris Stimpson, 1871 | BTh |
| 68) Penaeus vannamei Boone, 1931 | BTh |
| Family Penaeidae | |
| 69) Pilumnus iliosus Smith, 1869 | BTh, BEV, MCu, Mue |
| 70) Pilumnus stimpsoni Miers, 1886 | BLM, BRo, BLS, BEv, ISJ, Mue, ISJ, Gdo, |
| BTh | ISP, Mue, PSe |
| Family Pilumnidae | |
| 71) Pinnixa sp. indet | Jun |
| 72) Pinnixa sp. indet | Mue |
| 73) Pinnotheres sp. indet | PGr |
| 74) Turnidithrix sp. indet | BTh |
| Family Pinnotheridae | |
| 75) Pismus immaculatus Lamarck, 1818 | BTh, PBe, PGr |
| Family Porcellanidae | |
| 76) Megalobrachium erasum (Glassell, 1936) | BTh, Cua |
| 77) Neopenaeosoma mexicanum (Streets, 1871) | Jun, PGr |
| 78) Pachycheles calcaratus Haig, 1960 | Jun |
| 79) Pachycheles marcetzenmis Glassell, 1936 | BTh |
| 80) Pachycheles spinidactylus Haig, 1957 | ISJ, Jun, JMM |
| 81) Petrolisthes donadio Hiller & Werding, 2007 | BTh, BLM, ISJ, Jun, Mat, Mue, PSe, PRo |
| Family Paguroidea | |
| 82) Polyonyx confinis Haig, 1960 | Jun, Mue |
| 83) Uloosa perplexa Glassell, 1938 | BLM |
| Family Pinnotheridae | |
| 84) Acherous tuberculatus Stimpson, 1860 | BTh, ISJ, MSE |
| Family Pseudosquillidae | |
| 85) Processa perviana Wickstien, 1983 | Cua, ISJ, Mue |
| Family Pseudosquillidae | |
| 86) Cyrtoplax panamensis Ziesenhenne in Garth, 1940 | MSE |
| Family Raninidae | |
| 87) Raninoides benedicti Rathbun, 1935 | PGr |
| Family Rhynchocinetidae | |
| 88) Cretorhinus sp. nov. | BTh |
| Family Sesarmidae | |
| 89) Sesarma sulcatum Smith, 1870 | MCu |
| Family Spongidae | |
| 90) Terebido digitatus Latreille, 1828 | BEH, BTh, IDa, Jun, Mat, PMA |
| Family Upogebiidae | |
| 91) Upogebia titillie Williams, 1986 | BTh, BSE,Jun, Mue |
| Family Xanthidae | |
| 92) Glyptoxanthus labyrinticus (Stimpson, 1860) | BLS |
| 93) Liponesthes laticorne Rathbun, 1898 | BEl, BEM, BEV, BLM, BPr, PCh, BTh, BEV, BBL, BLS, BPr, BRe, BSe, PSe |
| 94) Lipkemedaus spinulifer (Rathbun, 1898) | BTh, BEM, BEV, BLM, BPr, PCh, BTh, BEV, BBL, BLS, BPr, BRe, BSe, PSe |

Methodology

Sixty sites were visited in ACG, from Punta Descartes to Islas Murciélago (Table 1), including rocky beaches (most common) and muddy beaches, shallow and deep reefs, shallow and deep rocky areas, estuaries, mangroves and areas deeper than 45 m. The location, geographic coordinates, depth and substrate type were registered.

In the rocky beaches during low tide, rocks were lifted to collect the organisms that live beneath them and the substrate was dug up to collect the organisms that live buried in the sediments. In the muddy beach areas, organisms were also collected from the mud. To collect the organisms that live within coral reefs, an indirect method was used: dead coral rocks were brought to the surface and broken apart to collect the organisms that mutually live inside. A similar method was used areas of rocky ocean floor, where collected specimens were brought to the surface. In the mangroves, specimens

Stomatopoda

| Taxon | Locality |
|-------|----------|
| 95) Platypodia bella (Stimpson, 1860) | BTh, BEM, BRe, Cua, ISJ, ISJ, Gdo, ISJ, Jun, MCu, Mue, PGr |
| Family Gonodactylidae | |
| 96) Neogonodactylus pumilus (Manning, 1970) | ISJ |
| 97) Neogonodactylus stanschi (Schmitt, 1940) | BEV, Mat |
| Family Squillidae | |
| 98) Cladopus dubia (H. Milne Edwards, 1837) | BTh |
| 99) Metacarpita stanschii Manning, 1970 | MSE |

focused primarily on the terrestrial part. In order to expand the knowledge of marine biodiversity in this region, the project entitled “Marine Biodiversity of Área de Conservación Guanacaste” (BioMar-ACG) was launched in 2015. The project has been funded by the Guanacaste Dry Forest Conservation Fund (GDFCF), and carried out by the Centro de Investigación en Ciencias del Mar y Limnología (CIMAR) and Museo de Zoología, both from Universidad de Costa Rica (UCR) (Cortés & Joyce in prep). The project has also received necessary support from the government staff of ACG, local marine “parataxonomists” supported by GDFCF and private foundations.

Following the compilation on marine biodiversity in ACG published by Cortés (2017), this paper presents an update of the inventory of marine decapod crustaceans and stomatopods, with new records for ACG as well as new records for the country. This is the result of work from mid 2015 to early 2019 by the BioMar-ACG project.
were collected during walks in the forest and intertidal zone, and they were taken from the roots and ground. Using a shovel, the substrate was dug up and sifted to look for those organisms that live buried in the mud. In the external part of the mangrove, a similar process was followed, but also fallen leaves and tree trunks were examined for organisms. Deep dredging sampling (down to 50 m depth) was carried out with a Van Veen dredge with a $25 \times 25$ cm opening. Other organisms were manually collected during dives, and some samples of crustaceans were associated with octocorals.

Collected specimens were placed in plastic containers with a net and then submerged in a bucket filled with seawater. Afterwards, the organisms were photographed in an improvised lab, a code was assigned to each specimen, a preliminary identification was provided and a sample of tissue was taken for barcoding. Once this process was finished, the organisms were sent to the

Fig. 1 New records of crustaceans for Costa Rica, with their BioMar-ACG sample code: (a) Cyrtoplax panamensis, 17-BMACGRV-02644-ACG001862; (b) Glyptoxanthus labyrinthicus, 16-BMACGRV-02104-ACG005676; (c) Neogonodactylus pumilus, 16-BMACGRV-02407-ACG006086; (d) Pachyches marcortezensis, 15-BMACGRV-00507-ACG006967; (e) Petrolisthes donadio, 16-BMACGRV-02177-ACG009006; (f) Pylopagurus holmesi, 16-BMACGRV-02414-ACG007167; (g) Synalpheus pinkfloydi, 16-BMACGRV-02245-ACG003908; (h) Typton granulosus, 16-BMACGRV-01941-ACG001783, and (i) Zenopontonia soror, 15-BMACGRV-00590-ACG009037
Zoology Museum at Universidad de Costa Rica, where a definite identification was provided and the samples were catalogued and stored. The names of the species used are as in WoRMS (http://www.marinespecies.org).

**Results and discussion**

By early 2019, 2650 specimens have been collected (Table 2), corresponding to 209 species, 99 of which are new records for ACG, four could be new undescribed species, and nine are also new records for Costa Rica: *Cyrtoplax panamensis* (Fig. 1a), *Glyptoxanthus labynthicus* (Fig. 1b), *Neogonodactylus pumilus* (Fig. 1c), *Pachyches marcortezensis* (Fig. 1d), *Petrolisthes donadio* (Fig. 1e), *Pylopagurus holmesi* (Fig. 1f), *Synalpheus pinkfloydi* (Fig. 1g), *Typton granulosus* (Fig. 1h) and *Zenopontonia soror* (Fig. 1i). Cortés (2017) reported 172 species from ACG, 162 decapods and 10 stomatopods. In this study 209 species have been collected so far, 200 decapods and 9 stomatopods. Of the decapod species reported by Cortés (2017), 57 species of decapods and 5 species of stomatopod have not been collected yet. These belong mainly to organisms commonly found at depths greater than 40 m, that were collected by dredging. Taking this into account, the total number of species found in the area is 271, which includes 257 decapods and 14 stomatopods. During the last four years since the BioMar-ACG project started, 99 new records have been added to the known species from ACG (Table 2) This represents an increase of 37% over the almost 85 years of previous studies in the region.

The number of species of decapods and stomatopods reported for ACG (271) is the highest number found in Costa Rica and among the highest reported in the eastern tropical Pacific ETP (Table 3). The ETP extends from the Gulf of California to southern Ecuador and include several oceanic islands (Robertson and Kramer 2009). ACG has more than half the species reported for Costa Rica and about a quarter of decapods and stomatopods crustaceans reported for the ETP (Boschi 2000; Cortés et al. 2017) (Table 3). The high diversity of decapods and stomatopods at ACG may be due to the diversity of habitats: beaches of different wave and sediment regimes, islands and continental shorelines, mangrove forests, seagrass beds, coral reefs (live and dead), intertidal and submerged rocky platforms, sandy and muddy bottoms and deep areas (Cortés 2017). The region is exposed to season upwelling, with temperatures ranging from 15° to 30 °C (Cortés et al. 2014). And finally, the sampling effort makes a difference in how many species are reported from an area, as demonstrated in this paper.

Up to now 60 sites have been sampled, with many more still to explore, such as the coastal area of Peninsula Santa Elena, south of Playa Naranjo and offshore, as well as some habitats such as sandy beaches, and deep rocky and muddy bottoms. Definitely more species of decapods and stomatopods will be found increasing the biodiversity of crustaceans in Área de Conservación de Guanacaste.

**Resumen**

El sector marino del Area de Conservación Guanacaste (ACG) posee 43,000 ha y 150 km de costa, en su mayoría poco estudiada. En un esfuerzo por conocer mejor la biodiversidad de todos los taxones marinos presentes en el área, se inicio en el 2015 un inventario (Proyecto BioMar-ACG). Esta iniciativa está siendo sustentada por la Guanacaste Dry Forest Conservation Fund (GDFCF) y desarrollada por el Centro de Investigación en Ciencias del Mar y Limnología (CIMAR) y el Museo de Zoología, ambos de la Universidad de Costa Rica (UCR).

| Table 3 Richness of stomatopods and decapods in the eastern tropical Pacific (ETP) |
|-----------------------------------|-----------|-----------|-----------|----------------------|
| **Stomatopoda**                  | **Decapoda** | **Total** | **References**                       |
| México                            | 28        | 1029<sup>a</sup> | **878** | Hendrickx 2005a, 2005b; M.E. Hendrickx, personal communication, 2019 |
| Eastern Pacific                   | 53        | 825<sup>b</sup>  | **878** | Boschi 2000; Cortés et al. 2017; Salgado-Barragán & Hendrickx 2010 |
| Costa Rica                        | 29        | 437        | **466** | Vargas 2009; Vargas & Wehrtmann 2009 |
| Colombia                          | 11        | 378        | **389** | Lemaître & Álvarez-León 1992; López & Jairnes 2014 |
| ACG, Costa Rica                   | 14        | 257        | **271** | This study |
| Oaxaca, México                    | 15        | 197        | **212** | Bastida-Zavala et al. 2013 |
| Galápagos, Ecuador                | 5         | 205        | **210** | Hickman & Zimmermn 2000 |
| Clipperton, France                | 4         | 190        | **194** | Poupin et al. 2009 |
| Isla del Coco, Costa Rica         | 6         | 139        | **145** | Vargas-Castillo & Wehrtmann 2008; Cortés 2012 |
| Bahía Culebra, Costa Rica         | 3         | 99         | **102** | Cortés et al. 2012 |
| Golfo Dulce, Costa Rica           | 2         | 71         | **71**  | Morales-Ramirez 2011; Castro & Vargas 1996 |

<sup>a</sup>Includes pelagic and deep and shallow water species (M.E. Hendrickx, personal communication, 2019)

<sup>b</sup>Includes only shallow water species
Transcurridos cuatro años del proyecto, se han recolectado 2650 especímenes de crustáceos decápodos y estomatopodos marinos pertenecientes a 209 especies, de las cuales 99 son nuevas para el ACG, cuatro podrían ser nuevas especies para la ciencia y nueve (Cyrtolax pana-
mensis, Glytoxanthus labrinthicus, Pachycheles marco-
zentis, Petrolithes donadio, Pyllogopus holmesi, 
Synalpheus pinkfloydii, Typton granulosus, Zenopontonia 
soror y Neogonodactylus pumilus) son ampliaciones de 
ámbito y nuevos informes para el país. Con esta contribu-
ción aumenta el número de decápodos a 257 spp. y de 
estomatopodos a 14 spp. para un total de 271 spp. para 
ACG. Esto es más de la mitad las especies conocidas de 
estos grupos para Costa Rica y más una cuarta parte de las 
especies conocidas para el Pacífico Tropical. En 
cuatro años el proyecto BioMar-ACG ha aumentado el 
número de especies de decápodos y estomatopodos del 
ACG en 37% más que lo que se conocía a partir de estu-
dios en los últimos 85 años.

Conclusions
The model for marine biodiversity inventory developed 
with the BioMar-ACG project, the partnership between 
government, academia, private funding and local para-
taxonomists, accelerates the rate of species discovery 
and reporting. It also makes species information and 
project results available in an open access format. In 
only for years of the project the number of decapods 
and stomatopods of ACG increased by 37% over the past 
85 years of previous studies, for a total of 271 species. 
This number represents more than half the species re-
ported for Costa Rica, and more than a quarter of all 
decapods and stomatopods reported for the eastern 
tropical Pacific.

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Authors’ contributions
RV collected and identified the specimens, wrote a first draft of the 
manuscript. JC, conceived the main project, helped with logistics and 
and obtaining the funds, wrote some sections of the paper, helped prepared the 
images and the final draft of the paper. All authors read and approved the 
final manuscript.

Authors’ information
Rita Vargas: Collection Manager and curator of Crustaceans of the Zoology 
Museum of the University of Costa Rica.

Jorge Cortés: Senior researcher at the Center for Research in Marine Science 
and Limnology, and professor at the School of Biology, both at the 
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Availability of data and materials
Data will be made available in the project website. The specimens are 
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Competing interests
The authors declare that they have no competing interests.

Author details
1Museo de Zoología, Universidad de Costa Rica, San Pedro, San José 
11501-2060, Costa Rica. 2Centro de Investigación en Ciencias del Mar y 
Limnología (CIMAR), Universidad de Costa Rica, San Pedro, San José 
11501-2060, Costa Rica. 3Escuela de Biología, Universidad de Costa Rica, San 
Pedro, San José 11501-2060, Costa Rica.

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References
Bastida-Zavala JR, del S G-MM, Rosas-Alquicica EF, López-Pérez RA, Benítez-
Villalobos F, Menzag-Hernando JF, Torres-Huerta AM, Montoya-Máquez A, 
Barrientos-Luján NA. Marine and coastal biodiversity of Oaxaca, Mexico. 
Check List. 2013;9:329–90.
Boschi E. Species of decapod crustaceans and their distribution in the American 
marine zoogeographic provinces. Rev Invest Des Pesc. 2000;131–63.
Castro M, Vargas R. Annotated list of species of marine crustaceans (Decapoda 
and Stomatopoda) from Golfo Dulce, Costa Rica. Rev Biol Trop. 1996;44(Suppl 
3):87–95.
Cortés J. Marine biodiversity of an eastern tropical Pacific oceanic island, Isla del 
Coco. Costa Rica Rev Biol Trop. 2012;60(Suppl 3):131–85.
Cortés J. Marine biodiversity baseline for Area de Conservación Guanacaste, Costa 
Rica: published records. ZooKeys. 2017;652:129–79. https://doi.org/10.3897/ 
zookeys.652.10427.
Cortés J, Enochs IC, Sibaja-Cordero J, Hernández L, Álvarez JJ, Breedy O, Cruz-
Barraza JA, Esquivel-Garrote O, Fernández-García C, Hernissoil A, Kaiser KL, 
Medina-Rosas P, Morales-Ramírez A, Pacheco C, Pérez-Matus A, Reyes-Bonilla 
H, Riosmena-Rodríguez R, Sánchez-Noguera C, Wieters E, Zapata FA. Marine 
biodiversity of eastern tropical Pacific coral reefs. In: Glynn PW, Manello D, 
Enochs I, editors. Coral reefs of the eastern Pacific: persistence and loss in a 
dynamic environment. Dordrecht: Springer Science+Business Media; 2017. p. 
203–50.
Cortés J, Sampa-Villareal J, Beemer A, Seasonal phenology of Sargassum 
leembranni J. Agardh (Fucales, Heterokontophyta) in an upwelling area of 
the eastern tropical Pacific. Aquat Bot. 2014;119:105–10.
Cortés J, Vargas-Castillo R, Nava-Ruiz J. Marine biodiversity of Bahía Culebra, 
Guanacaste, Costa Rica: published records. Rev Biol Trop. 2012;60(Suppl 
2):39–71.
Faxon W. Reports on an exploration off the west coast of México, Central and 
South America, and off the Galápagos Islands by the U.S. Fish Commission 
Steamer “Albatross,” during 1891. XV. The stalk-eyed Crustacea. Mem Mus 
Comp Zool. 1895:292.
Faxon W. Reports on an exploration off the west coast of México, Central and 
South America, and off the Galápagos Islands by the U.S. Fish Commission 
Steamer “Albatross,” during 1891. XV. The stalk-eyed Crustacea. Mem Mus 
Comp Zool. 1895;18:292.
Hendrickx ME. Chapter 10. Crustacea 2: Stomatopoda. In: Hendrickx ME, Brusca 
RC, Findley LT, editors. A distributional checklist of the macrofauna of the 
Gulf of California, Mexico. Tucson, Arizona; Part I. Invertebrates. Arizona-
Sonora Desert Museum; 2005a. p. 127–95.
Hendrickx ME. Chapter 14. Crustacea 6. Decapoda: Dendrobranchiata, Caridea, 
Palaemonidae, Stomatopoda, Anomura & Brachyura. In: Hendrickx ME, Brusca 
RC, Findley LT, editors. A distributional checklist of the macrofauna of the Gulf of California, 

Page 7 of 8
Vargas-Castillo and Cortés Marine Biodiversity Records (2019) 12:21

https://doi.org/10.3897/

zookeys.652.10427.

https://doi.org/10.3897/
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zookeys.652.10427.

zookeys.652.10427.

zookeys.652.10427.

zookeys.652.10427.

zookeys.652.10427.
Mexico, Tucson, Arizona: Part I. Invertebrates. Arizona-Sonora Desert Museum; 2005b. p. 159–94.
Hickman CP, Zimmerman TL. A field guide to the crustaceans of Galápagos. Lexington, Virginia: Galápagos Marine Life Series, Sugar Spring Press; 2000.
Lemaitre R, Álvarez-León R. Crustáceos decápodos del Pacífico colombiano: Lista de especies y consideraciones zoogeográficas. An Inst Inv Mar Punta Betín. 1992;21:33–76.
López RH, Jaimes JC. Aspectos de la distribución larval de Stomatopoda (Crustacea) en aguas superficiales del pacífico colombiano. Rev UDCA Actual Divulg Cient. 2014;17:227–36.
Morales-Ramírez A. La diversidad marina del Golfo Dulce, Pacífico sur de Costa Rica: amenazas a su conservación. Biotecnología. 2011;24:9–20.
Moran DA, Dittel AL. Anomuran and brachyuran crabs of Costa Rica: annotated list of species. Rev Biol Trop. 1993;41:599–617.
Poupin J, Bouchard J-M, Albenga L, Cleva R, Hermoso-Salazar M, Solis-Weiss V. Les crustacés décapodes et stomatopodes, inventaire, écologie et zoogéographie. In: Charpy L (ed) Clipperton, environnement et biodiversité d’un microcosme océanique. Patrim Nat. 2009;68:163–216.
Reaka ML, Manning RB. The distributional ecology and zoogeographical relationships of stomatopod Crustacea from Pacific Costa Rica. Smithsonian Contr Mar Sci. 1980;129–225.
Robertson DR, Cramer KL. Shore fishes and biogeographic subdivisions of the tropical eastern Pacific. Mar Ecol Prog Ser. 2009;380:1–17.
Salgado-Barragán J, Hendrickx ME. Clave ilustrada para la identificación de los estomatópodos (Crustacea: Holoarcanida) del Pacífico oriental. Rev Mex Biodiv. 2010;81:51–549.
Schmitt WL. The stomatopods of the west coast of America based on collections made by the Allan Hancock expeditions, 1933–38. Allan Hancock Pac Exp. 1940;5:129–225.
Vargas R, Cortés J. Biodiversidad marina de Costa Rica: Orden Stomatopoda (Crustacea: Holoarcanida). Rev Biol Trop. 1997;45:1531–9.
Vargas R, Cortés J. Biodiversidad marina de Costa Rica: Orden Crustacea: Decapoda (Peneoidea, Sergestoidea, Stenopodidae, Caridea, Thalassinidea, Palinura) del Caribe. Rev Biol Trop. 1999a;47:877–85.
Vargas R, Cortés J. Biodiversidad marina de Costa Rica: Crustacea: Decapoda (Peneoidea, Sergestoidea, Caridea, Astacidea, Thalassinidea, Palinura) del Pacífico. Rev Biol Trop. 1999b;47:887–911.
Vargas R, Cortés J. Biodiversidad marina de Costa Rica: Crustacea: Infraorden Anomura. Rev Biol Trop. 2006;54:461–88. https://doi.org/10.15517/rbt.v54i2.13894.
Vargas R, Wehrtmann IS. Decapods crustaceans. In: Wehrtmann IS, Cortés J, editors. Marine biodiversity of Costa Rica, Central America. Dordrecht: Springer & Business Media Bv; 2009. p. 193–7. https://doi.org/10.1007/978-1-4020-8278-8_17.
Vargas-Castillo R, Wehrtmann IS. Stomatopods and decapods from Isla del Coco, Pacific Costa Rica. Rev Biol Trop. 2008;56(Suppl 2):79–97.

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