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Unexplored diversity of the mesophotic echinoderm fauna of the Easter Island ecoregion

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Abstract

The Easter Island Ecoregion (EIE) is one of the most remote marine areas of the world and encompasses a vast and fragile ecosystem including oceanic islands and seamounts. In March 2016, a remotely operated vehicle was used to explore a subsurface peak off Easter Island (27.23° S, 109.48° W) and a seamount (26.92° S, 110.26° W), respectively located 10 km southwest and 98 km west of the island. More than 950 echinoderms were observed in the five hours of video recorded during the seven dives conducted at depths between ~160 and ~280 m. The communities of echinoderms observed at these depths markedly differed from those reported for shallower waters near Easter Island. Of the 20 morphospecies reported in the present study, only five were previously reported in the EIE. One species, six genera, and three families were reported for the first time in this area, and two new genera were discovered and described. A preliminary biogeographic analysis suggests affinities between the observed echinoderms and those of the West Pacific. These findings highlight the uniqueness of these assemblages, and therefore the importance of considering them in the establishment of effective management strategies of these communities, which are within the Rapa Nui Marine Protected Area created in 2017.

Keywords: benthos; biodiversity; biogeography; invertebrates; oceanic island; Marine Protected Area; South Pacific, Rapa Nui.

INTRODUCTION

Oceanic islands and seamounts are considered fragile environments that harbor faunas highly vulnerable to anthropogenic activities (e.g. extensive fisheries, mining) and climate change (Ramirez-Llodra et al. 2011). Two of the most remote inhabited oceanic islands of the world are Rapa Nui (Easter Island) and Motu Motiro Hiva (Salas y Gómez Island). These islands, with their surrounding seamounts, form the Easter Island Ecoregion (EIE) (Spalding et al. 2007), which extends eastward from the East Pacific Rise to $\sim 104^{\circ}\text{W}$ along the $\sim 2500\text{-km}$ -long Salas y Gómez Ridge. The isolated location of the EIE makes it a perfect area to study the colonization and dispersion of benthic species across the South Pacific Ocean (Glynn et al. 2007; Schlacher et al. 2010; Kvile et al. 2014); however, faunal studies of the southeastern Pacific seamounts and islands remain scarce (i.e. only 10 biological oceanographic expeditions between 1905 and 2010) compared to other areas of the South and North Pacific (Fernández and Hormazábal 2014; McClain and Lundsten 2015). Most of these studies are from the seamounts east of the EIE (i.e., those of the Nazca Ridge and eastern Salas y Gómez Ridge) that were surveyed on one American and several Russian expeditions between 1970 and 1990 in international waters at 160 to 3000 m depth (Parin et al. 1997). Those studies described benthic communities of more than 22 seamounts located from $\sim 101^{\circ}\text{W}$ to 80°W , where echinoderms were one of the most abundant and speciose groups, with a high endemism rate (i.e. 42% in echinoids; Parin et al., 1997). Therefore, echinoderms have been used as target groups for biogeographical studies of the Nazca Ridge (Mironov et al. 2006).

In the EIE, 32 species of echinoderms have been reported from shallow-water areas off Rapa Nui and Salas y Gómez (Ziesenhenné 1963; Fell 1974; Fernández et al. 2014). However, benthic communities of the mesophotic zone are poorly documented compared to their shallow-water counterparts. The mesophotic zone, characterized by low-light penetration, extends from $\sim 30\text{ m}$ depth to the limits of photosynthetically dependent biota (generally 150 m). Located in the middle of the South Pacific Gyre, the EIE is characterized by ultraoligotrophic waters and consequently high water clarity that allow for unusually high light penetration to deeper depths (often $>50\text{ m}$ depth) (Fernández and Hormazábal 2014). For example, sufficient light penetration has been documented for euphotic conditions to exist to up to 170 m depth (Claustre et al. 2007; Ras et al. 2008) and light-dependent fauna (e.g., crustose coralline algae) have been observed to $\sim 280\text{ m}$ (Easton et al., 2019). Therefore, mesophotic communities can persist in this region to over 100 m deeper than their typical depths extent of 150 m. Mesophotic ecosystems could act as potential biodiversity reservoirs with higher rates of

endemism and coral coverage and may be able to maintain a healthier status than their shallower counterparts (Soares et al. 2018).

To fill this knowledge gap on the mesophotic echinoderm communities of the EIE, we conducting remotely operated vehicle (ROV) surveys at ~160-280 m depth. The objectives of this study were (i) to describe the echinoderm community at two sites of the EIE and (ii) to explore biogeographic affinities between the observed assemblages and those of the eastern and western South Pacific. Considering the higher degree of endemism reported for the deep communities of the Nazca Ridge and EIE (Friedlander et al. 2013; Easton et al. 2017) and the distance (i.e., isolation) among potential mesophotic habitats in the EIE, we expect similar high rates of endemism in the EIE mesophotic echinoderms. We hypothesize that fauna will be more similar to that of tropical West Pacific species than those of the Eastern Pacific as found for shallow-water and deep-sea studies of southeast Pacific fauna (Fell 1974; Parin et al. 1997). The observed echinoderm distribution patterns will contribute to our understanding of how benthic communities have colonized and dispersed through the southern Pacific Ocean.

MATERIAL AND METHODS

The present study considered the exploration of two sites, locally known as Pukao and Apolo (Fig. 1). Pukao is a seamount located 98 km west of Rapa Nui, with its summit at ~150 m depth (26.92° S, 110.26° W). Although this seamount has been sporadically fished by locals (using hand lines) in recent years, it is considered to be relatively pristine. Apolo is a subsurface peak on the southwestern slope of Rapa Nui, located 13 km offshore, with its summit at ~165 m depth (27.23° S, 109.48° W). This topographic high is an ancestral fishing ground that has been heavily fished since the early 1960s by line-and-hook techniques. Surveys were conducted in January 2014 and March 2016 at Apolo and Pukao, respectively, with a Comander MKII ROV (Mariscope Meerestechnik, Kiel, Germany) operated from local fishing boats. The ROV was equipped with two laser pointers separated by 10 cm and a front-pointing, at an angle of 45°, HD video camera (Panasonic SD 909), recording with a resolution of 1920×1080 pixels at 30 fps. While conducting video transects, the ROV was driven about 50 cm above the seafloor, resulting in an image frame size of about 80 × 60 cm. To document morphological characters of sessile and slow-moving fauna, such as echinoderms, at a higher resolution, the ROV was set on the ground and the camera was zoomed in on the characters of interest. Because the ROV was deployed from small fishing boats and was not equipped with a tracking system, the transect tracks were non-linear with potentially intersecting paths. Therefore, counts were made conservatively to minimize the potential for double counts associated with these issues.

Videos were reviewed at half their normal speed in GOM Player 2.3.19 (GOM & Company), and digital frames of morphospecies were extracted. Classification was accomplished by the use of an extensive review of echinoderm literature (e.g. Clark, 2012;; Friedlander et al., 2013; Fernández et al., 2014) and reports, such as the Hawaii Undersea Research Laboratory Identification Guide (<http://www.soest.hawaii.edu/HURL/animals/id/echinoderms/>) and Ocean Biogeographic Information System (OBIS, 2018, Intergovernmental Oceanographic Commission of UNESCO. www.iobis.org), from the EIE and other Pacific areas. Because classifying echinoderms from images and videos can be difficult because of a lack of visible diagnostic characters, specimens were identified to the lowest possible taxon (generally genus or family) and individuals with no evident external differences were assigned to the same morphospecies. We omitted all echinoderm observations (i.e. blurry images or distant targets) that did not provide taxonomical information. Scientific names followed those on the WoRMS database (WoRMS Editorial Board, 2018, World Register of Marine Species. Available from <http://www.marinespecies.org> at VLIZ. doi:10.14284/170). Morphospecies were identified and those not recorded in the literature were described and compared to morphologically similar species.

RESULTS AND DISCUSSION

A total of seven transects (two at Apolo and five at Pukao) were performed, capturing more than five hours of bottom-time video, between 160 and 280 m depth (Table 1, Fig.1). The seafloor was generally sandy with sparse rocks; however, the summit of Pukao and Apolo had rocky outcrops. On sandy areas, other fauna included some stomatopods and patches of whip corals and rhodoliths, with small fishes observed in association with the structure they provided. On the rock outcrops, the community was mainly composed of subtropical fishes, encrusting algae, and patches of whip corals. A total of 960 echinoderms, distributed in four classes, were observed (Fig. 2a): Echinoidea (71.6% of the total observations), Asteroidea (25.0%), Ophiuroidea (3.2%), and Holothuroidea (0.2%). No members of Crinoidea were observed. Of the 960 individuals, 178 were observed at Apolo (90.4% were Echinoidea and 9.6% Asteroidea; Fig. 2b) and 782 individuals were observed at Pukao (67.3% Echinoidea, 28.5% Asteroidea, 4% Ophiuroidea, and 0.2% Holothuroidea; Fig. 2c). Of the 960 observations, 600 were sufficiently well imaged to assign them to morphospecies. Twenty morphospecies were recognized (Table 2); ten occurred at both sites, nine only at Pukao, and one only at Apolo. Of the 20 morphospecies, 12 were echinoids (Table 2). One morphospecies of echinoid, classified as “Black Diadematidae,” could only be assigned to family level and was not imaged in

sufficient detail to further describe it. Echinoid morphospecies were assigned to four families: Diadematidae, which is the echinoid family best represented in the studied area, with six morphospecies (Table 2), Cidaridae with three morphospecies, Toxopneustidae with two morphospecies, and Clypeasteridae represented by one morphospecies. Diadematidae was the most speciose family, but also the best represented, with >370 observations, whereas the Cidaridae, Toxopneustidae and Clypeasteridae had >140, 4, and 3 observations, respectively. The remaining eight morphospecies were asteroids (Table 2). Goniasteridae were the most readily observed and abundant family of asteroids, with ~70 individuals in three morphospecies. Members of the Ophidiasteridae were the second most abundant family with 17 observations, followed by Oreasteridae, Astropectinidae, Asteriidae and Asterodiscidae with 14, 7, 3 and 3 observations, respectively.

Over 25 ophiuroid and two holothurian specimens were observed but none of the images allowed assignment of individuals to species. Ophiuroids were observed on whip corals and small rocks between 160 and 240 m depth on Pukao seamount (Table 2) but none of the frames captured complete specimens (only the arms were observed), thus precluding any reliable classification. The observed holothurians were too distant to allow identification down to family.

Morphospecies descriptions and distributions

CLASS ECHINOIDEA Leske, 1778

According to the literature, only 11 species of echinoids have been reported for the EIE (Fell 1974; Larraín 1995; Boyko 2003; Fernández et al. 2014). Of the 12 morphospecies described in this study, only four of them (*C. reticulatus*, *P. Indiana*, *T. gratilla*, black diadematidae) were previously reported for the EIE. The remaining eight echinoid morphospecies have not previously been reported for the region.

Family Clypeasteridae L. Agassiz, 1835

This family is a cosmopolitan group with more than 13 species reported for the South Pacific (Ghiold 1989). The highest species richness has been reported for the Indo-Pacific region, with ten species in the Hawaiian Islands and nine on the Mascarene Islands (Ghiold 1989). Only one species, *Clypeaster reticulatus*, is known from the EIE.

***Clypeaster reticulatus* (Linnaeus, 1758) - Fig. 3 a, b - Table 2**

Three specimens of *C. reticulatus* were observed at 220 m depth on the Pukao seamount. The presence of *C. reticulatus* on Rapa Nui was first reported by Fell (1974) based on one specimen sampled during the DOWNWIND Expedition (1958, station-76) between 40 and 100 m. Its

distribution extends from southeast African waters through the Indo-Pacific to Rapa Nui at 0 - 125 m depth (Rowe & Gates, 1995; Mooi & Munguia, 2014;). The observed specimens at 220 m depth on the Pukao seamount increase the known depth range of this species. *Clypeaster isolatus* (Table 2, Fig. 3C), distinguished from *C. reticulatus* by the open distal end of the petal, has been reported on seamounts ~800 km east of Rapa Nui (Serafy 1971) and on the Desventuradas Islands (Mecho pers. obs.), but *C. reticulatus* has not been reported at these eastern localities, suggesting that the EIE is the easternmost distribution of *C. reticulatus*.

Family Toxopneustidae Troschel, 1872 - Fig. 4 a, b - Table 2

Two species belonging to this family are reported for the EIE (Fell 1974; Zigler et al. 2012), *Pseudoboletia indiana* (Michelin, 1862) and *Tripneustes gratilla* (Linnaeus, 1758), both are common Indo-Pacific species from shallow waters (<100 m depth) (Clark 2012). In the present study, both species were observed at 160 m depth; three specimens of *T. gratilla* on Pukao and one specimen of *P. indiana* on Apolo. *Tripneustes gratilla* was reported with a maximum depth of 75 m (Toha et al. 2017), so this report extends its known depth range by 85 m. *Pseudoboletia indiana* is absent from most EIE databases (i.e. review from Fernández et al., 2014, OBIS database), but it was not only observed in the present study but specimens from Rapa Nui were also used for a molecular study of the genus (Zigler et al. 2012), so it likely abundant near Rapa Nui.

Family Cidaridae Gray, 1825

Only one species of this family has been reported for Rapa Nui, the Indo-Pacific pencil sea urchin, *Phyllacanthus imperialis* (Lamarck, 1816) (Fernández et al. 2014). Another cidarid species *Stereocidaris nascaensis* Allison, Durham & Mintz, 1967 has been reported east of the EIE from the Nazca Ridge seamounts and the Desventuradas Islands and is considered endemic to the Desventuradas Ecoregion (Allison et al. 1967). These two species were not observed during our study but the following three cidarid morphospecies were reported for the EIE for the first time.

Cidaridae sp. A – cf. *Stylocidaris* Fig. 5 a, b - Table 2

Six specimens were observed between 220 -240 m depth on the southern side of Pukao. This morphospecies is characterized by a pure white test and green primary spines. Secondary spines are mostly white. Similarities between the present morphospecies and the cosmopolitan genus *Stylocidaris* include slender primary spines ending in a fine point and well-separated areoles (Schultz 2015). Several *Stylocidaris* species are reported at similar depths in the west Pacific

Ocean. For example, *Stylocidaris conferta* and *S. reini* are known from the southwest Pacific at 135 – 550 m and 100 – 840 m, respectively (Table 2) and are morphologically consistent with the observed specimens (white test, primary spines slender and uniform in color). However, although the observed specimens are morphologically consistent with these species, ROV image quality was insufficient to visualize characteristic details (e.g. apical system, ambulacra, interambulacra, secondary spines) used for species-level assignment.

Cidaridae sp. B – Fig. 5 c - Table 2

One specimen with a brown test, green primary spines, and a large apical disc was observed at Pukao seamount on a rocky outcrop at 160 m depth. This species is not consistent with any known species from the EIE or adjacent areas; moreover, the quality of the images obtained did not allow assignment of this specimen to a genus.

Cidaridae sp. C — cf. *Prionocidaris* Fig. 5 d, e - Table 2

More than 130 specimens with a dark-reddish test and red primary spines, most of them stout and pointing up, were observed, often in large groups on sandy bottoms (e.g. more than 60 specimens grouped, Fig. 5e) close to rocky outcrops on Pukao at 160 m depth. A pattern of ornamentation is distinguishable at the base of the spines. Strong similarities to the genus *Prionocidaris*, present in the South Pacific waters, include long and relatively slender primary spines, short neck short, shaft ornamented in rows of modest thorns, and flattened secondary spines (Schultz 2015). Several species of this genus have been reported for the North Pacific (i.e. *P. thomasi* and *P. hawaiiensis* at 150 – 400 m and 75 – 600 m depth, respectively) and Australian waters (i.e. *P. callista* at 20 – 65 m). The observed specimens are morphologically consistent (i.e., (no light color spots on the collar of the primary spines, dark test, secondary spines long, slender and flattened) with *P. baculosa*, which also has a similar depth range (<200 m) and in the western Pacific but morphological characters necessary to confirm this classification were not apparent in the images.

Family Diadematidae Gray, 1855

Three species of Diadematidae have been reported for the EIE (Fernández et al. 2014), *Diadema savignyi* (Audouin, 1809), *D. paucispinum* A. Agassiz, 1863, and *Lissodiadema lorioli* Mortensen, 1903. The morphospecies Black Diadematidae observed in this study could coincide with *D. savignyi* or *D. paucispinum*. None of the other five morphospecies of Diadematidae reported in the present study is consistent with the three species reported for the EIE.

Diadematidae cf. *Diadema palmeri* – Fig. 6 a - f - Table 2

More than 50 specimens with a reddish-purple coloration, with white bands in the median areas of the interambulacral, were observed at 160 -180 m on Pukao and Apolo on hard substrate. The color pattern is in accordance with the color patterns described for *D. palmeri* Baker, 1967, which has cream-colored, triangular-shaped naked median areas on the interambulacra and a reddish test with lilac lines radiating down each side of the naked median areas (Coppard and Campbell 2006). *Diadema palmeri* is the only species of this genus with a reddish test and is known from Australian and New Zealand tropical and subtropical waters and to 200 m depth, but it is usually found shallower (10 – 50 m, Schultz 2015). A morphologically similar *Diadema* sp. was imaged in Hawaiian waters between 100 and 200 m depth by the Hawai'i Undersea Research Lab (*HURL* – specimen R- 187- d1- 00558). Other morphological characters are not visible in the images to confirm this classification, which would expand the distribution of this species throughout the subtropical and tropical Pacific to at least the EIE.

Diadematidae sp. A – Fig. 7 a - e - Table 2

Over 80 specimens of this morphospecies were reported on sandy areas from Apolo and Pukao at 160 – 240 m depth. Specimens are characterized by pale pink tests of more than 5 cm with burgundy spines. Spines are slender and quite abundant, and a swollen, whitish-translucent periproctal cone with a white ring was observed on all the individuals. Specimens presented an active behavior, moving energetically. Confusion with genus *Aspidodiadema* is possible but unlikely because the flattened test, spine position, and the shallow depth of the observed specimens are inconsistent with the genus *Aspidodiadema*, which is characterized by a spherical test and is considered a deep-sea species (Wilson et al. 1985). A morphologically similar *Diadema* sp. was imaged by the Hawai'i Undersea Research Lab (*HURL* – specimen R- 187- d1- 01705) for Hawaiian waters between 100 and 200 m depth. No other morphologically similar species are known to which a comparison can be made to identify a potential sister species or assign this morphospecies to genus (Coppard and Campbell 2006).

Diadematidae sp. B – Fig. 8 a - c - Table 2

More than 70 specimens of this morphospecies were observed on Apolo and Pukao at 160 – 180 m depth on sand or rock outcrops. All specimens had a swollen, whitish-translucent periproctal cone with a white ring and had a pattern of alternating pink-purple and broad white bands in the median areas of the interambulacra. It has been described for several echinoderm species that specimens living in the deeper part of their range of distribution could present paler patterns of coloration than their shallower counterparts (Mecho et al. 2014), so these specimens

may belong to one of the two previous morphospecies. However, in the present case, the differences in color pattern, depth, and substrate where they were observed are substantial enough for us to consider them as a separate morphospecies (i.e.).

Diadematidae sp. C – Fig. 9 a - Table 2

A specimen was observed at 240 m depth on a rock on Pukao. It presented few secondary spines on the aboral side surrounding the swollen, whitish-translucent periproctal cone with a white ring. Compared with the other morphospecies, this morphospecies has less obvious ambulacral areas longer and more scarce primary spines. These morphological differences and its presence at a deeper depth range led us consider it a different morphospecies than those previously described.

Diadematidae sp. D – Fig. 9 b, c - Table 2

More than 70 specimens with grey tests were observed at ~160 m depth on rock outcrops on Apolo and Pukao. This morphospecies differs from the previous morphospecies of the family by presenting shorter and stronger spines, a test more visible through the spines, and no anal cone. Three color patterns were observed; black primary spines, grey primary spines, and black and grey primary spines. Observed specimens could be confused with *Echinostrephus aciculatus* A. Agassiz, 1863, a species reported in Rapa Nui (Fernández et al. 2014); however, *E. aciculatus* morphological characters, bathymetric range, and behavior are not in accordance with our samples. *Echinostrephus aciculatus* is a rock burrowing urchin that is distributed from 0-50 m depth (Fernández et al. 2014) and has a large periproct and stronger and shorter spines than Diadematidae sp. D. None of the specimens from the present study were observed inside burrows, but instead were observed on the rock surface.

CLASS ASTEROIDEA de Blainville, 1830

Six species of asteroids are known for the EIE (Fernández et al. 2014). The present study reports eight morphospecies of which only *Ophidiaster easterensis* has been previously reported on EIE. The other seven are first records for the area, and two are likely new genera.

Family Asterodiscididae Rowe 1977

This family comprises four genera with wide tropical and sub-tropical Indo-Pacific distributions (Rowe 1977, 1985); however non have been reported for the southeast Pacific (Marsh 1974; Parin et al. 1997; Yanez et al. 2009). Therefore, this report is the first for this family in the EIE.

Asterodiscididae sp. – Fig. 10 - Table 2

Three specimens were observed on Pukao and Apolo between 160 and 180 m depth. This species was distinguished by the prominent conical spines emerging from the central region on the disk surface, the enlarged penultimate plates on the arm tips and by the brilliant orange color (Rowe 1977). Although images were insufficient for positive identification to genus, specimens were morphologically consistent with Asterodiscididae. The specimen could belong to one of several genera, including *Amphiaster*, *Paulia*, *Asteodiscides*, are present in the South Pacific or to an undescribed new genus.

Family Oreasteridae Fisher, 1911

Oreasteridae is a tropical family mostly distributed in Indo-Pacific waters (Clark 2012). The observed specimen may belong to the genera *Pentaceraster* Doderlein 1916 or *Protoreaster* Doderlein 1916 because these genera present the largest specimens of the family. These genera have not been reported for the southeast Pacific, according to Clark (2012). This report for the family is the first for the EIE.

Oreasteridae cf. new genus and species. – Fig. 11 a - h - Table 2

This morphospecies is tentatively suggested to be a new genus and species of Oreasteridae. However, conclusive determination cannot be made without specimen collection and examination. Fourteen individuals were observed between 160 and 180 m depth on sandy-bottoms of Pukao. All the specimens were white in color, with a darker brown on primary radial and interrational disk spines as well as on distal carinal plates on the arms (Fig. 11 a - h). Sometimes specimens were observed camouflaged on sandy sediment with rodoliths (e.g. Fig. 11 h).

This species is comparable to similar oreasterids, , such as *Pentaceraster* or *Protoreaster* in lacking a strongly arched disk and having a triangular arm shape. However, the observed specimens differ from known species of *Pentaceraster* and *Protoreaster lincki* (Blainville, 1830) in lacking spines on either the superomarginal or inferomarginal series. Likewise, strongly developed and/or elevated disk spines are absent from this species compared to all known species of *Pentaceraster* or *Protoreaster*. The lack of pronounced spines on the disk and marginal plates as well as its distinct white color further distinguishes this species from the other prominent southwest Pacific oreasterids, such as *Pentaceraster cumingi* (Gray, 1840), which is orange and has well-developed spination on the disk and marginal spines.

Family Ophidiasteridae Verrill, 1870

This family is distributed in Indo-Pacific and Atlantic waters and has more than 27 genera and 106 species (Mah and Blake 2012). The following three species have been described for the EIE: *Leiaster coriaceus* Peters, 1852, *Linckia multifora* (Lamarck, 1816) and *Ophidiaster easterensis* Ziesenhenne, 1963. Only the latter was observed in this study.

Ophidiaster easterensis Ziesenhenne, 1963 – Fig. 12 a - b - Table 2

Seventeen specimens were observed between 160 – 180 m depths on rocks. This species has been described as an endemic to Rapa Nui (Ziesenhenne 1963). According to Ziesenhenne, *O. easterensis* is more morphologically similar to *O. agassizi* Perrier, 1881 (endemic from Juan Fernández Islands) than any other species of genus *Ophidiaster*. Specimens present the typical *Ophidiaster* characteristics of being an orange-tan color and having five fingerlike rays with a relatively small disk.

Family Goniasteridae Forbes, 1841

The family Goniasteridae is one of the most diverse families of the class Asteroidea (Mah and Blake 2012), having 65 genera and 256 species. None of the genera have been reported for the EIE; the closest records are from the seamounts ~1500 km east of Rapa Nui (Parin et al., 1997) and from the Pitcairn islands (i.e. *Neoferdina cumingi* (Gray, 1840) (Marsh 1974). Based on color and plate pattern, three morphospecies were recognized in the present study.

Goniasteridae sp. A – Fig. 13 a - c - Table 2

More than 50 specimens were observed at 160 – 220 m depth on Pukao and Apolo. This morphotype has triangular arms with tapering arm tips, a thick disk and a deep-orange red color and is similar in appearance to *Anthenoides* (Fig. 13b, c), a genus widely occurring in tropical Atlantic and Pacific but never previously reported in the EIE.

Goniasteridae sp. B – Fig. 13 a - d - e -Table 2

Two specimens of a second morphospecies were observed at Pukao at 160 – 180 m depth. These specimens are similar to *Ogmaster* and *Goniodiscaster*, are an orange-white color, have >20 marginal plates (Fig. 13de), and have elongate arms and broad interradsial arcs with a distinct abactinal disk plate pattern. One individual was more orangish beige with > 30 marginal plates (Fig. 13d). The differences in color and marginal plate number were insufficient to consider them different species because these differences may be associated with size differences. None of the suggested genera have been reported for the EIE or the Salas y Gómez Ridge (Parin et al. 1997; Fernández et al. 2014).

Goniasteridae sp. C. cf. new genus and species – Fig. 14 a - c - Table 2

More than 20 specimens were observed from 160 to 280 m depth on rocky areas of Pukao and Apolo. This species has a pentagonal body form with approximately 11 to 16 marginal plates per interradius and weakly curved interrarial arcs. The abactinal surface presents relatively low tabular plates, each with a flat-topped, coarse granular surface. Marginal plates are strongly convex with deep indentions between them. Abactinal surface is orange with yellow radial regions. The strongly convex marginal plates are bright orange to yellow with deep-orange regions between them. Although this species is similar to several other pentagonal goniasterids, the most similar is *Ceramaster australis* H.E.S. Clark, 2001 from the New Zealand region; however, *C. australis* has less strongly convex marginal plates and abactinal plates that contrast in morphology and shape with the observed specimens. In addition, this species morphologically differs substantially from other Pacific *Ceramaster* species. Further examination is necessary to classify this specimen but the observed differences suggest it is likely a representative of an new undescribed goniasterid genus.

Family Asteroiidae Gray, 1840

The family Asteroiidae consists of 35 genera and 178 species that are distributed globally (Mah and Blake 2012) and are morphologically diverse. For example, species may have from 5 to 15 arms, depending of the species, with the dorsal skeleton of arms being reticulate and having spines forming distinct longitudinal series (Mortensen 1927). Only one species has been reported from the EIE, the endemic sea star *Astrostele paschae* (H.L. Clark, 1920).

Sclerasterias sp. – Fig. 15 - Table 2

Three specimens of this morphospecies were observed on Apolo and Pukao at 160 – 220 m depth. This species shows the distinctive carinal and marginal spination observed in the widely occurring asteroid *Sclerasterias*. Ludwig, 1905, recorded one species, *S. alexander*, from the Baja California region but specimen collection necessary assign the observed specimens to species. This report is the first for this genus in the EIE.

Family Astropectinidae Gray, 1840

Two species of this family have been reported for the EIE area, *Astropecten polyacanthus* Müller & Troschel, 1842, an Indo-Pacific species with cream and brown colors (Marsh 1974), and *Astropecten triseriatus fijiensis* John, 1948, a rare species known from Fiji islands based on dry specimens and collected from Rapa Nui in 1973 (Marsh 1974; Castilla and Rozbaczylo 1987).

Although those species have been reported for the EIE, the number of studied specimens is extremely scarce and the definitive classification remains doubtful (Marsh 1974).

Astropectinidae sp. cf. *Ctenophoraster* Fig. 16 a - c - Table 2

Seven specimens of an intense orange astropectinid were observed at 160 m depth on Pukao. This morphospecies have distinct elongate, triangular arms as well as acute interradii and a moderately sized disk. The body shape of this species is observed in several astropectinid genera but its shape is most comparable to *Ctenophoraster*, which would be a new record for the area, or *Astropecten*. Two species have been reported for areas neighboring the EIE; *C. marquesensis* Marsh, 1974 from the Marquesas Islands, and *C. hawaiiensis* Fisher, 1906 from Hawaii Islands. Astropectinids burrow into weakly unconsolidated sediment where they hide, living concealed below the surface (Jangoux 1982). In some cases, they also burrow and swallow sediment as a means of finding food, including bivalves or snails. It is unclear how this behavior differs for species occupying relatively coarse sediment as this species does. Nevertheless, sediment on the abactinal surface of this species suggests that it had been recently buried.

EIE echinoderm diversity

As reported for other echinoderm assemblages of seamount (Parin et al. 1997; Stock 2004; Clark 2012) and mesophotic coral reef communities (Samadi et al. 2008) in the southeast Pacific, the classes Echinoidea, Asteroidea and Ophiuroidea dominated the Pukao and Apolo assemblages, whereas crinoids and holothuroids are less abundant or absent. This pattern contrasts with other geographical areas such as the coral triangle, specifically the Philippines and Honduras (Roatan), where crinoids are one of the most abundant groups of echinoderms in the mesophotic zone and echinoids are scarce (QUOTE). Six Ophiuroidea species have been previously reported for the Rapa Nui (Fernández et al. 2014); however, video observations did not allow any reliable assignment of our observations because none of the frames recorded an entire specimen, only portions of the arms (Table 2). Likewise, observations of Holothuroidea were too distant to assign them to genus but, taking into account the morphology, specimens belong to the family Holothuriidae Burmeister, 1837 (Table 2). Five holothurians species previously reported for the EIE belong to this family (Fernández et al. 2014). A classification to species level without specimens is not feasible. Holothuroids have usually been reported in the southeast Pacific near island shorelines (Codocero 1974; Shiell and Knott 2010) but have been reported as scarce from the southeast Pacific seamounts at deep mesophotic depths (e.g. Parin et al. 1997, who excluded them in the species list because of their scarce number). The absence of crinoids in our samples (on both, sediment and rocky areas) is in accordance with the review

of Fernández et al., 2014, that indicated crinoids were not reported for the area. This lack of observations could be because of a sampling bias due to shallow-water crinoids being nocturnal (Clark 2012).

Some families observed in the present study, i.e., Diadematidae, Toxopneustidae, and Oreasteridae, are among the most common ones reported for other mesophotic communities (i.e. west Pacific waters; Clark, 2012). Of the 20 morphospecies reported in this study, 15 were not previously reported for the EIE. In addition, several families, i.e., Oreasteridae, Goniasteridae and Asterodiscididae, have never been reported for the EIE. Numerous morphospecies have also not been reported for neighboring areas, such as Pitcairn (Friedlander et al. 2014) or Desventuradas Islands (Parin et al. 1997), emphasizing how limited our basic knowledge of this group is for not only the EIE but also the southeast Pacific. Studies undertaken on other EIE fauna (e.g. fishes, macroalgae) likewise revealed several potential new species and first records for the region (Easton et al., 2017; Santiañez et al., 2018), supporting our observations that several of the reported morphospecies may not only be new records for the region but also could be potential new genera and species. Moreover, when comparing echinoderm assemblages reported from shallow EIE waters (<30 m) (Fernández et al. 2014) with our results for mesophotic depths (160 – 280 m), we observed only five concordant species: *Clypeaster reticulatus* (Linnaeus, 1758), *Tripneustes gratilla* (Linnaeus, 1758), *Pseudoboletia indiana* (Michelin, 1862), *Ophidiaster easterensis* Ziesenhenné, 1963 and “Black Diadema.” This high dissimilarity between shallow and deep mesophotic species has also been described in other taxa (i.e. fishes and coral) but this pattern was unknown for echinoderms because, except for isolated species reports (e.g., Rocha et al. 2018), the present study is one of the first mesophotic echinoderm reports for the EIE.

Bathymetric and Biogeographic patterns

Of the 20 morphospecies reported herein, only five were among the 32 species previously reported for the EIE (Marsh 1974; Zigler et al. 2012; Fernández et al. 2014), suggesting that the echinoderm assemblage from the deep mesophotic zone (160 – 280 m) off Rapa Nui is distinct from assemblage known from the shallow-water communities (0 – 50 m). Seven echinoid and three asteroid morphospecies as well as all holothurians were exclusively observed at 160-180 m, whereas three echinoid morphospecies were only reported at 220-280 m. One species of echinoid and three asteroid and ophiuroid species were detected along the entire bathymetric range studied (160 – 280 m). These patterns suggests a that echinoderm assemblages transition with depth but a sampling gap at 50 – 150 m exists and more data are required to understand these transitions and the factors (e.g., light, temperature) governing them.

From a geographical perspective, few concordances were observed between the species reported herein and species from adjacent areas, such as Pitcairn Islands (Paulay 1989; Irving and Dawson 2012; Friedlander et al. 2014) and the Desventuradas Islands (Friedlander et al. 2016; Mecho et al. in prep). Of the 32 species of shallow-water echinoderm species reported for Rapa Nui in Fernández et al., 2014, two are cosmopolitan species, 21 have Indo-Pacific distributions, and four are Pacific-wide species, two are exclusively from Polynesian waters, and three are endemic to the EIE. Although we could not assign most of the morphospecies to species level, we could identify sister species for 14 of the 20 morphospecies (Table 2). Of these sister species, eleven have western-Pacific and three have eastern-Pacific distributions. Thus, the observed echinoderm assemblages have more affinities with western and north Pacific genera (i.e. *Diadema* cf. *palmeri*, *Stylocidaris*) than to eastern Pacific counterparts (i.e. *Stereocidaris*, *Scrippsechinus*, *Brissopsis*). Such affinities to western Pacific taxa are also suggested for shallow-water species (Zigler et al. 2012, Liggins, Gleeson, & Riginos, 2014, Fernández et al., 2014). The number of presumed sister species from the western Pacific (see Table 2) suggests a pattern of a common ancestor with a range from the western Pacific to the EIE followed by subsequent speciation due to isolation, resulting in a high number of endemic species with affinities to the western Pacific fauna. Echinoid species reported along the eastern extent of more than 2000 km of the Easter Seamount Chain (i.e. *Stereocidaris nascaensis*, *Scrippsechinus fisheri* and *Clypeaster isolatus*) have not been observed in the EIE at similar depths (Allison et al. 1967; Parin et al. 1997); their westernmost distribution is ~800 km east of Rapa Nui. This absence of shared species between the EIE and eastern extent of the Easter Seamount Chain suggests a faunal break at ~101°W (east of Salas y Gómez Island). This pattern of no overlapping of mesophotic species between these regions and between the EIE and Pitcairn reinforces the hypothesis proposed by Mironov and Detinova in Parin et al., 1997, based on deep-sea species, that Salas y Gómez and Rapa Nui belong to a separate ecoregion (i.e., the EIE). Although the data herein support this hypothesis, additional data are needed to further evaluate this hypothesis and to define the boundaries of the EIE because limited data exist for comparisons at these depths across the southeast Pacific. Nevertheless, this report is an important first step that could provide key information to elucidate several unresolved questions. For example, the knowledge of echinoderm communities from south Pacific seamounts and islands could be an important factor to understand the history of how benthic communities have been colonized, dispersed, and isolated as well as are currently connected throughout the southern Pacific Ocean. This information is especially critical to inform management of the recently created (by the Chilean government in late 2017) large protected area, which includes the no-take the Motu Motiro Hiva Marine Park around Salas y Gómez Island

and a marine protected area of multiple uses that encompasses the entire jurisdictional zone surrounding Rapa Nui and Salas y Gómez Island.

Compliance with ethical standards

We declare that all applicable international, national and/or institutional guidelines for sampling videos and organisms for the study have been followed and all necessary approvals have been obtained. Finally, the authors declare that they have no conflict of interests.

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Figure 1. Study area where ROV dives (black points) were conducted in the Easter Island Ecoregion at Apolo (D 1-2) and Pukao (D 3-7).

Figure 2. Percentage of faunal observations at each seamount per class for (a) total observations (n= 960), (b) Apolo (n= 178), and (c) Pukao (n= 782). Ast: Asteroidea; Ech: Echinoidea; Hol: Holothuroidea; Oph: Ophiuroidea.

Figure 3. (a, b) 2 specimens of *Clypeaster reticulatus* at 220 m depth on Pukao seamount; (c) *Clypeaster isolatus* Desventuradas Island (Cruise CIMAR 22 October 2016).

Figure 4. (a) Regular echinoid *Pseudoboletia indiana* at 160-m depth on southern slope of Apollo peak; (b) *Tripneustes gratilla* at 160-m depth on Pukao seamount.

Figure 5. (a, b) Cidaridae sp. A - cf. *Stylocidaris*. Specimens at 220 and 240 m depth on Pukao seamount; (c) Cidaridae sp. B. One specimen from Pukao seamount observed at 160 m depth on the rocky wall; (d-e) Cidaridae sp. C - cf. *Prionocidaris*. Specimens observed at 160 m depth on Pukao sandy bottoms.

Figure 6. (a - f) Diadematidae cf. *Diadema palmeri*. Specimens were observed between 160 and 180 m depth, on both, Pukao and Apolo rocky areas.

Figure 7. (a - e) Diadematidae sp. A. Specimens were observed between 160 and 240 m depth, on both, Pukao and Apolo, exclusively on sandy bottoms.

Figure 8. (a - c) Diadematidae sp. B. Specimens were observed between 160 and 180 m depth, on both, Pukao and Apolo, on sand and hard bottoms.

Figure 9. (a) Diadematidae sp. C observed at 240 m depth on Pukao seamount; (b, c) Diadematidae sp. D. Specimens were observed at 160 m depth on the rocky walls of Pukao and Apolo.

Figure 10. Specimen of Family Asterodiscididae. The specimen presented the characteristic conical spines, the enlarged penultimate plates on the arm tips and a brilliant orange color.

Figure 11. (a - h) Family Oreasteridae, tentatively identified as a new genus and species. Several white specimens were observed with different patterns of dark brown spines. Specimens were observed between 160 and 180 m depth in sandy areas of the Pukao seamount.

Figure 12. (a - b) *Ophidiaster easterensis* Ziesenhenne, 1963. Specimens were observed between 160 and 180 m depth on rocks and rocky walls of the Pukao seamount and Apolo area

Figure 13. (a) Goniasteridae sp. A and sp. B.; (b, c) Goniasteridae sp. A with orange-beige color similar to *Anthenoides* sp.; (d, e) Goniasteridae sp. B cf. *Ogmaster* or *Goniodiscaster* sp. with orange-white color, a reticulate pattern of abactinial plates and 20 marginal plates. Scale bar 2.5 cm. Specimens were observed between 160 and 220 m depth on both Apolo and Pukao areas.

Figure 14. (a - c) Goniasteridae sp. C. Suggested new genus and species, presenting characteristic convex marginal plates. Specimens were observed at 160 and 280 m depth on rocky areas from Pukao and Apolo.

Figure 15. (a, b) *Sclerasterias* sp.. Specimens were observed at 160 and 220 m depth on sandy areas from Pukao and Apolo.

Figure 16. (a - c) *Astropectinidae* sp. cf. *Ctenophoraster*. Specimens were observed at 160 depth at Pukao on sandy bottoms.

Table 1: Average depth (m), time on bottom (min), and initial Latitude and Longitude of the seven ROV dives conducted in the Easter Island Ecoregion.

Dive	Seamount	Date	Depth	Time	Latitude	Longitude
1	Apolo	03/2016	280	30	27.2381° S	109.4861° W
2	Apolo	03/2016	160	20	27.2345° S	109.4840° W
3	Pukao	03/2016	160	72	26.9203° S	110.2664° W
4	Pukao	03/2016	180	68	26.9240° S	110.2674° W
5	Pukao	03/2016	240	48	26.9319° S	110.2762° W
6	Pukao	03/2016	220	35	26.9369° S	110.2648° W
7	Pukao	03/2016	160	34	26.9190° S	110.2687° W

Table 2: Morphospecies observed on the seven ROV dives conducted in the Easter Island Ecoregion. P= Pukao; A= Apolo; N= number of observed specimens; SS= sister species in the closest geographical range; X= not applicable.

Morphospecies	Area	Depth (m)	Bottom	N	EIE Report	Sister Species (SS)	SS distribution
CLASS ECHINOIDEA							
<i>Clypeaster reticulatus</i> – Fig. 3 a, b	P	220	sand	3	Reported	<i>C. isolatus</i>	Nazca Ridge
<i>Pseudoboletia indiana</i> – Fig. 4 a	A	160	sand	1	Reported	<i>P. maculata</i>	Western Pacific
<i>Tripneustes gratilla</i> – Fig. 4 b	P	160	sand	3	Reported	<i>T. kermadecensis</i>	Western Pacific
Cidaridae sp.A– cf. <i>Stylocidaris</i> Fig. 5 a, b	P	220-240	sand	6	First record Genus	<i>S. conferta</i> and <i>S. reini</i>	Western Pacific
Cidaridae sp. B –Fig. 5 c	P	160	rock wall	1	x	x	x
Cidaridae sp. C –cf. <i>Prionocidaris</i> –Fig. 5 d, e	P	160	sand	± 130	First record Genus	<i>P. baculosa</i> , <i>P. callista</i> <i>P. thomasi</i> , <i>P. hawaiiensis</i>	West Pacific
Diadematidae cf. <i>Diadema palmeri</i> – Fig. 6 a-f	P-A	160-180	rock	± 50	First record Species	<i>D. palmeri</i>	South-West Pacific
Diadematidae sp. A – Fig 7 a-e	P-A	160 -240	sand	±80	x	x	x
Diadematidae sp. B – Fig. 8 a-c	P-A	160-180	sand	±70	x	x	x
Diadematidae sp. C– Fig. 9 a	P	240	rock	1	x	x	x

Diadematidae sp. D– Fig. 9 b, c	P-A	160	rock wall	±70	x	x	x
Black diadematidae	P-A	160-180	sand	±100	Reported	x	x
CLASS ASTERIOIDEA							
Asterodiscidae sp. – Fig 10	P-A	160-180	rock	3	First record Family	<i>Amphaster, Paulia, Asteodiscides?</i>	Indo-Pacific
Oreasteridae cf. New genus and species – Fig. 11 a-h	P	160-180	sand	14	First record Family	<i>Pentaceraster – Protoreaster??</i>	West Pacific
<i>Ophidiaster easterensis</i> – Fig. 12 a, b	P-A	160-180	rock	17	Reported	<i>O. agassizi</i>	Eastern Pacific
Goniasteridae sp. A cf. <i>Anthenoides</i> sp. – Fig. 13 a-c	P-A	160-220	sand	±50	First record Family and Genus	Several species	West Pacific and Hawaii
Goniasteridae sp. B cf <i>Ogmaster</i> or <i>Goniodiscaster</i> – Fig. 13 a-d,e	P	160-220	sand	2	First record Family and Genus	<i>O. capella; G. rugosus, G. integer</i>	West Pacific
Goniasteridae cf. C. New genus and species – Fig. 14 a-c	P-A	160-280	rock wall	±20	First record Family and Genus	<i>Ceramaster australis?</i>	West Pacific
<i>Sclerasterias</i> sp. – Fig. 15 a, b	P-A	160-220	sand	3	First record Genus	<i>Sclerasterias</i> sp.	South East Pacific
Astropectinidae sp. cf. <i>Ctenophoraster</i> – Fig. 16 a, b	P	160	sand	7	First record Genus	<i>C. marquesensis</i>	Marquese Islands
CLASS OPHIUROIDEA	P	160-240	whip corals	±20	x	x	x
CLASS HOLOTHUROIDEA	P	160	sand	2	x	x	x