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## Diversity of deep-sea fishes of the Easter Island Ecoregion

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## ABSTRACT

The Easter Island Ecoregion is in the center of the South Pacific gyre and experiences ultra-oligotrophic conditions that could make it highly susceptible to global change and anthropogenic activities, so it is imperative that these regions are characterized and studied so that conservation and sustainable management strategies can be developed. From the few studies from the region, we know that the coastal areas are relatively depauperate and have relatively high rates of endemism. Here, we present a brief report from the first video observations from this region of the deep-dwelling fishes from ROV exploration of benthic communities from 157 to 281 m and baited drop-camera videos from 150 to 1850 m. We observed a total of 55 fish species from the ROV and Drop-Cam surveys; nine could not be assigned family level or lower, 26 were observed in the ROV surveys, 29 were observed in the Drop-Cam surveys, nine were observed with both survey methods, at least six species are potentially new to science, and nine species were observed at deeper depths than previously reported. These new reports may be indicative of the unique oceanographic conditions in the area and the relative isolation of the communities that have provided opportunity for the evolution of new species and favorable conditions for range expansion. In contrast, these new reports may be indicative of the severe undersampling in the south Pacific at mesopelagic depths. The prevalence of potentially new species suggests that the region likely harbors a wealth of undiscovered biodiversity.

## 1. Introduction

The Easter Island Ecoregion (EIE) consists of Easter Island, Salas y Gómez, and the nearby seamounts. These islands and seamounts are part of a ~ 4000 km chain of seamounts (Salas y Gómez and Nazca Ridges) that formed from the movement of the Nazca plate over the Easter Island hotspot, currently located somewhere between Easter Island and Salas y Gómez (Ray et al., 2012; Vezzoli and Acocella, 2009). Easter Island (27°09'S, 109°22'W) is considered the most-isolated inhabited island on Earth (Loret and Tanacredi, 2003; Mieth and Bork, 2005; Santelices and Abbott, 1987), located ~ 2000 km east of the nearest inhabited island, Pitcairn, and ~ 3700 km west of continental Chile. Because of its remoteness, relative isolation, and limited resources to support scientific studies, knowledge on the diversity of fishes was limited prior to the mid-1980s. Studies at Salas y Gómez, which lies 400 km to the east, are even more limited. The waters surrounding Salas y Gómez are part of the Motu Motiro

Hiva Marine Park, established by the Chilean government in October 2010. The area experiences ultra-oligotrophic conditions, but with increased nutrients at Salas y Gómez relative to Easter Island (Andrade et al., 2014). Since the 1980s, the known diversity of Easter Island shore and epipelagic fishes expanded from less than 30 species to 171 species; however, these fauna are considered depauperate in comparison to other islands, which have ~10-fold more fish species (Randall and Cea, 2010).

Of the 171 species known from the island (Randall and Cea, 2010), 141 occur at depths less than 200 m. Of these fishes, ~26.3% are locally endemic and an additional ~14% are regionally endemic (Friedlander et al., 2013; Randall and Cea, 2010). Of those species reported from depths to 200 m, their reports primarily come from scuba surveys and observations to ~40 m and catches by artisanal fisherman in the coastal and offshore waters (DiSalvo et al., 1988; Hubbard and Garcia, 2003; Randall and Cea, 2010; Zyllich et al., 2014). Because offshore artisanal fisheries focus on top predators (e.g., tunas and jacks) and use a

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traditional line method instead of trawls, relatively few species are known from depths greater than 40 m.

The only studies in the area of deep-dwelling fishes were a series of expeditions by Russian scientists in the 1970s and 1980s to explore the seamount communities of the Nazca Ridge and eastern Salas y Gómez Ridge (Parin, 1991; Parin et al., 1997). From the resulting data, the authors made several preliminary conclusions that require further studies for verification. (1) An apparent biogeographic discontinuity occurs at  $\sim 83^\circ$  W and may be maintained by the Humboldt Current serving as a barrier. (2) As observed for shallow-water fishes, a high percentage ( $\sim 44\%$ ) of deep-sea fishes appear to be locally or regionally endemic. (3) The EIE should be considered a separate ecoregion from the surrounding ones, including the Nazca and eastern Salas y Gómez Ridges. (4) The benthopelagic communities studied are more similar to the west Pacific than to the continental east Pacific despite their relative proximity to continental Chile.

Because the EIE is near the center of the South Pacific Gyre and is surrounded by ultra-oligotrophic waters that could limit the available energy to support biomass at depth, the region is more susceptible to climatic and anthropogenic disturbances and likely has a slow recovery time after disturbances (Andrade et al., 2014). Susceptibility to disturbances and productivity may vary at various time scales due to oceanographic and other environmental conditions that can vary, in turn, intra-annually in association with season and eddies and inter-annually in association with El Niño Southern Oscillation (ENSO) (Andrade et al., 2014; Mucciarone and Dunbar, 2003).

The diversity and abundance of coastal fishes has declined since the 1980s, with some fishes, including endemics, being rare or not observed in more recent surveys (Friedlander et al., 2013; Randall and Cea, 2010; Wieters et al., 2014). This decline potentially could be due to changes in environmental conditions and benthic community structure and the effects of increased fishing pressure due to increasing tourism and consequent demand for fish (DiSalvo et al., 1988; Zyllich et al., 2014). Similarly, catch of commercially important fishes has begun to level off or decline over the last 20 years (Zyllich et al., 2014). Under these changing conditions, it is important to catalogue the diversity and distribution of species of Easter Island to inform local and national communities for planning management and conservation strategies. In addition, Parin et al. (1997) could not investigate the seamounts and islands within the Chilean EEZ, so they were unable to determine whether the pattern of apparent trends of longitudinal transitions in community composition and high levels of endemism continued along the Salas y Gómez Ridge into the EIE. To help begin to fill the knowledge gap for the EIE, we report the biodiversity of benthopelagic fishes observed in videos from a remotely-operated vehicle (ROV) deployed at 155–280 m of the southwest coast of Easter Island at an ancestral fishing ground, locally called “Apolo,” as well as those fishes observed in videos from baited drop cameras deployed in 2011 at 150–1850 m off the coasts of Salas y Gómez and Easter Island and at two seamounts between these islands. We then compare our observations to the available literature on the distributions and depth ranges of the identified species.

## 2. Methods

### 2.1. Study site

Easter Island is a triangular-shaped island consisting of three volcanoes, Rano Kau, Terevaka, and Poike, with one located at each of the three corners of the island. Rano Kau forms the southwest corner of the island and has a subsurface peak  $\sim 13$  km offshore at  $\sim 150$  m depth, where the local Rapanui fishermen have a historic fishing ground called Apolo (Fig. 1). Three exploratory surveys were performed at Apolo on 1 October 2014 with a ROV Comander MK2 (Mariscope Meerestechnik, Kiel, Germany) equipped with a HD Camcorder (Panasonic SD 909). Bottom time for each survey varied

from 12 to 32 min and depths ranged from 157 to 281 m (Table 1). The distance between the HD camera and the seafloor varied between several centimeters and about 1 m, and the camera was positioned in front of the ROV with a fixed angle of 15 degrees towards the bottom, with two laser pointers fixed to indicate a distance of 10 cm.

Up to three baited, deep-ocean Drop-Cams (Turchik et al., 2015), developed by the National Geographic Society, were simultaneously deployed at a total of 20 stations along the island slopes of Salas y Gómez and Easter Island or the slopes of two seamounts west of Salas y Gómez at 150–1850 m (Table 2, Fig. 2). These Drop-Cams have a 12-megapixel Sony Handycam HDR-XR520V encased in a borosilicate glass sphere rated to 12,000 m. Depending on the angle of the substrate, the viewing area per frame was 3–6 m<sup>2</sup>. Each camera was baited with frozen fish and deployed for  $\sim 5$  h. For some deployments, the lights, a high-intensity LED array directed using external reflectors, were not turned on until up to  $\sim 4$  h after deployment. Depth was measured with an external pressure sensor, and communication with the sealed cameras was through a waterproof bulkhead connector. The Drop-Cams were positively buoyant, resulting in an ascent rate of 0.5 ms<sup>-1</sup> and weighted with a 22 kg external weight, resulting in a descent rate of 1.5 ms<sup>-1</sup>. The weight was released by burn wire, activated using onboard battery voltage, and the Drop-Cams were located for recovery by communication of an onboard VHF transmitter and locating antennae, with backup location via communication with the ARGOS satellite system.

### 2.2. Video analyses

ROV videos were first analyzed frame-by-frame with Adobe Premiere Pro CS5 (Adobe Systems Incorporated, San Jose, CA) by a single observer and then by the same observer at 0.2 $\times$  speed with GOM Player 2.2 (GOMlab, Gretech Corporation, Seoul, Korea) to quantify the maximum number (NMax) of individuals of each species per frame for each 3-minute segment of video, starting when the seafloor became visible. ROV videos were watched a third time by a 2-person team of observers to confirm species identifications and counts of individuals. Drop-Cam videos were watched by a two-person team at normal speed with GOM Player 2.2 to quantify the NMax per frame for each 3-minute segment of video for each species. Frame grabs of representatives of each species were taken with Adobe Premiere and GOM Player for archival and identification purposes. Individuals were identified to the lowest possible taxonomic level using the Hawaii Underwater Research Laboratory (HURL) database (HURL, 2013), FishBase (Froese and Pauly, 2011), and regional guides and reports of trawl data from Salas y Gómez and Nazca Ridge (Dyer and Westneat, 2010; Parin, 1991; Parin et al., 1997; Randall and Cea, 2010).

### 2.3. Nomenclature and species assignment

We acknowledge the inherent difficulties in identifying individuals to species level from video footage and therefore all species assignments are made to the lowest possible taxon in which we had reasonable confidence. For this reason, we likely underestimated the number of species, especially for those morphologically similar taxa that often have overlapping geographic ranges (e.g., Macrouridae). We used information on the known ranges, the original descriptions, and reports of revisions to aid us in assigning individuals to species and to discuss potentially conflicting data, including differences in color, among reports to help fill gaps in primary literature on biogeographic ranges and color variation within species. In this study, we used nomenclature accepted by FishBase (Froese and Pauly, 2011) and accepted species names were verified using WoRMS (WoRMS Editorial Board, 2016); however, lack of clarity in several species names warrants discussion.

The following species were reported in Randall and Cea (2010) under synonymous names: *Cheilodactylus plessisi* (as *Goniistius*

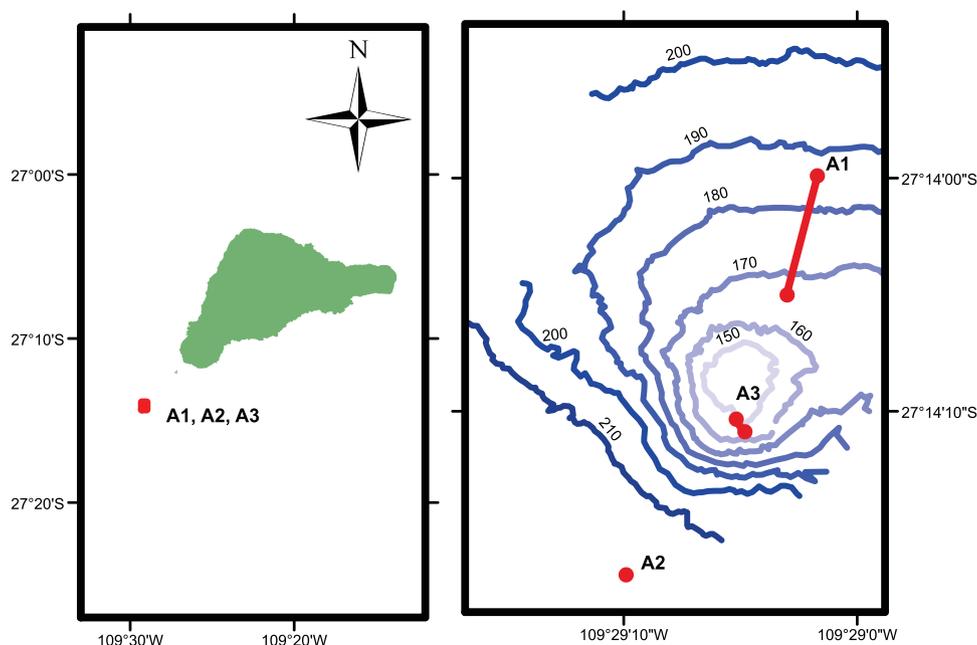


Fig. 1. Location of the three ROV transects at Apolo, the subsurface peak off the southwest coast of Easter Island.

Table 1

Location and duration information for the three exploratory ROV transects done at the Apolo fishing ground on 1 October 2014.

Transect name	Depth (m)	Bottom time (min)	Starting latitude	Starting longitude	Ending latitude	Ending longitude
Apolo-1	171–175	~12 min	27°13'59.9\"S	109°29'01.7\"W	27°14'05.5\"S	109°29'02.0\"W
Apolo-2	277–281	~32 min	27°14'17.0\"S	109°29'09.9\"W	27°14'17.0\"S	109°29'09.9\"W
Apolo-3	157–167	~20 min	27°14'4.1\"S	109°29'02.3\"W	27°14'17.6\"S	109°28'54.6\"W

Table 2

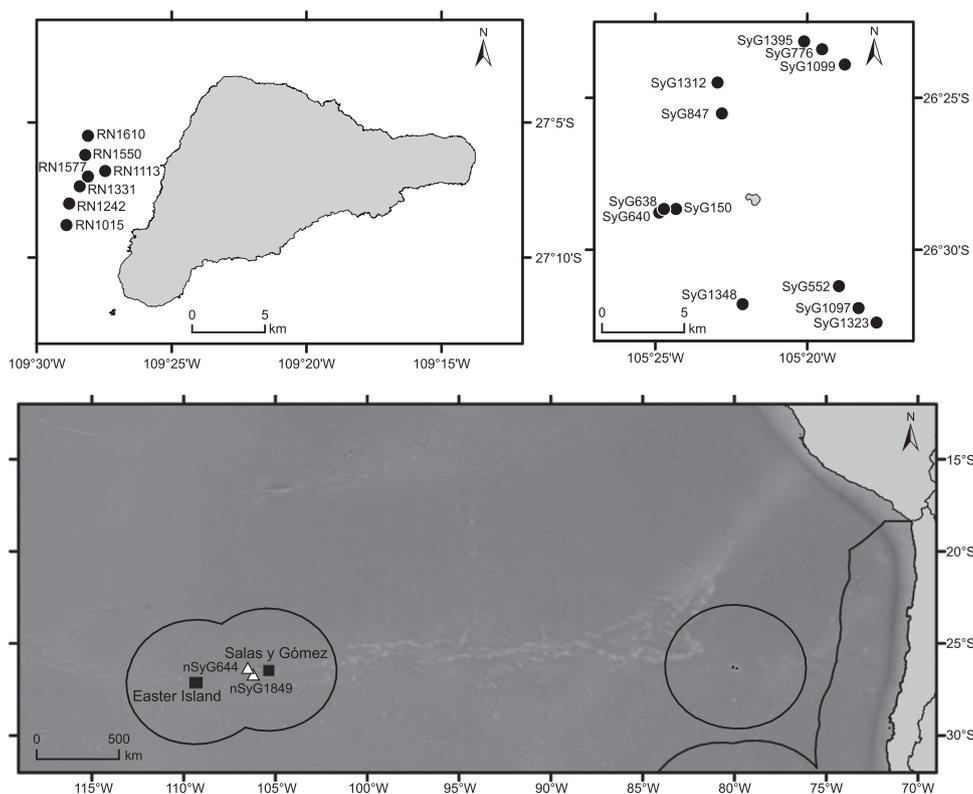
Station information for the Drop-Cam deployments. SyG=deployments on the island slope of Salas y Gómez. nSyG=deployments along the slope of seamounts near Salas y Gómez. RN=deployments on the slope of Easter Island (also known as Rapa Nui). Camera number indicates which of the three Drop-Cams was used.

Station	Location	Depth (m)	Latitude	Longitude	Video time (min)	Date (2011)	Camera number
SyG150	SyG	150	26°28.66' S	105°24.301' W	300	22-Feb	1
SyG552	SyG	552	26°31.197' S	105°18.947' W	135	26-Feb	3
SyG638	SyG	638	26°28.653' S	105°24.71' W	300	22-Feb	3
SyG640	SyG	640	26°28.772' S	105°24.859' W	300	22-Feb	2
nSyG644	nSyG	644	26°21.98' S	106°35.48' W	105	28-Feb	2
SyG776	SyG	776	26°23.4' S	105°19.5' W	105	25-Feb	2
SyG847	SyG	847	26°25.52' S	105°22.8' W	35	24-Feb	1
SyG1097	SyG	1097	26°31.912' S	105°18.302' W	35	27-Feb	1
SyG1099	SyG	1099	26°23.9' S	105°18.75' W	105	25-Feb	3
RN1113	RN	1113	27°6.799' S	109°27.469' W	76	2-Mar	3
RN1242	RN	1242	27°8' S	109°28.8' W	105	3-Mar	1
SyG1312	SyG	1312	26°24.5' S	105°22.94' W	35	24-Feb	2
SyG1323	SyG	1323	26°32.393' S	105°17.716' W	35	27-Feb	2
RN1331	RN	1331	27°7.369' S	109°28.402' W	76	2-Mar	2
SyG1348	SyG	1348	26°31.783' S	105°22.122' W	65	23-Feb	3
SyG1395	SyG	1395	26°23.15' S	105°20.1' W	105	25-Feb	1
RN1550	RN	1550	27°6.2' S	109°28.2' W	195	4-Mar	3
RN1577	RN	1577	27°7' S	109°28.1' W	105	3-Mar	3
RN1610	RN	1610	27°5.5' S	109°28.1' W	195	4-Mar	2
nSyg1849	nSyG	1849	26°43.831' S	106°16.87' W	105	28-Feb	1

*plessisi*), *Pseudocaranx dentex* (as *P. cheilio*), and *Etelis carbunculus* (as *E. marshi*). In the case of *Goniistius plessisi*, Randall and Cea (2010) recognized generic-level morphological and genetic differences that have yet to be officially revised (Burrige and White, 2000; Randall, 1983). *Pseudocaranx cheilio* has conflicting reports on its validity due to differences in gill raker counts of Easter Island specimens relative to Hawaiian specimens (Randall and Cea, 2007). The Catalogue of Fishes (Eschmeyer, 2015) considers it a valid species; however, it is a synonym of *P. dentex* in WoRMS and Fishbase. See

Supplementary material for additional discussion of nomenclature issues for *E. marshi* and morphological differences between *Antigonia capros*, *Pristilepis oligolepis*, and *Priacanthus nasca* and morphologically similar species in the area.

A preliminary report of 21 species from these Drop-Cam videos were reported in Friedlander et al. (2013); however, many of their preliminary identifications differ from this report, including *Squalus mitsukurii*, Congridae, *Glossanodon* cf. sp., *Synodus isolatus*, *Coelorinchus* sp., *Plectranthias parini*, *Priacanthus nasca*,



**Fig. 2.** Location of the Drop-Cam deployments near Salas y Gómez and Easter Island (black circles) and the seamounts (white triangles) between the islands. See Table 1 for station information and deployment details.

*Amphichaetodon melbae* (see Table 4a in Friedlander et al. 2013). Here, we report the list of species observed during this study with notes on the differences between the preliminary reports and this brief report. For *S. mitsukurii*, recent work suggests that the species present in our study area is part of the *S. mitsukurii* species group, but we have insufficient data to assign it to species or to determine whether it is potentially a new species (see Section 3.3.1). For *Glossanodon* cf. sp. (our unidentified species 7, Table 3), we did not assign it to a specific taxon due to the small size of the specimen and poor image quality. For *Coelorinchus* sp., individuals were not sufficiently close to the camera to assign individuals below the level of family, Macrouridae. For *Plectranthias parini*, *Priacanthus nasca*, and *Amphichaetodon melbae*, we assigned them respectively to *Tosanoides* sp., *Cookeolous japonicus*, and *Prognathodes* sp. on the basis of their morphology. For example, the *Tosanoides* sp. is distinct from *P. parini* in several aspects, including color pattern, size, and fin shape. Finally, it appears that individuals of Halosauridae and Synphobranchidae were assigned to either Congridae or Nettastomatidae in the preliminary reports; one unidentified fish at 1099 m could be a Congridae but video quality was insufficient to assign that individual definitively to family.

### 3. Results and discussion

#### 3.1. Species assignments

We observed a total of 55 fish species from the ROV and Drop-Cam surveys. Of these species, nine could not be assigned family level or lower; however, color patterns and general shape allowed us to determine that they are morphologically distinct from the other 46. Due to the uncertainty in assigning those individuals to taxon, we only considered the 46 species we could assign to family level or lower for the remaining results. From ~64 min of total bottom recording time from the ROV videos, we assigned individuals to 26 putative taxa. In ~42 h (2517 min) of total video time from the Drop-Cams, we assigned

individuals to 29 putative taxa. Of the 46 putative taxa, nine were observed with both survey methods, ROV and Drop-Cam (Table 3). In addition, *Beryx splendens* and *B. cf. splendens* were observed respectively in the Drop-Cam and ROV surveys, and both taxa could be *B. splendens*.

At least one species of *Rexea* was observed from 552–847 m at Salas y Gómez and a neighboring seamount (Table 3, Fig. 3F). Species known from the area are *R. brevilineata* and *R. antefurcata*. Distinguishing characters between these species include the length of the upper lateral line, squamation patterns, maximum size, and differences in fin coloration patterns (Nakamura and Parin, 1993). These features were not sufficiently clear in the videos to confidently assign individuals to one of these two species; however, the known geographic range, the apparent size of individuals, and the depth at which they were observed is more consistent with *R. antefurcata* (Froese and Pauly, 2011; Nakamura and Parin, 1993; Parin et al., 1997). For example, the smaller *R. brevilineata* has only been reported from 81 °W to 90 °W (more than 15° east of Salas y Gómez) at depths of 180–440 m, whereas, the generally larger *R. antefurcata* has been reported from 83°W to 143°E at depths of 160–920 m.

Individuals of cf. *Synphobranchus affinis* (Fig. 3G) could not be assigned confidently to species, and even to a genus, as most of their diagnostic characteristics were not visible from videos and they are notoriously difficult to identify even with specimens in hand (Sulak and Shcherbachev, 1997). For those individuals that were close enough to the camera to observe the head morphology, the morphology was consistent with *Synphobranchus* (Sulak and Shcherbachev, 1997). Therefore, we tentatively assigned all individuals to cf. *Synphobranchus affinis*, which is known from 290–2400 m, with most observations at 500–1500 m (Froese and Pauly, 2011; Sulak and Shcherbachev, 1997); however, we only observed individuals at depths greater than 1000 m despite their apparent abundance at 250–750 m at the seamounts to the east (Parin et al., 1997). It is possible that some of the individuals may belong to one of the other two species of

**Table 3** Maximum number per frame (Nmax) of each species of fish per ROV transect and Drop-Cam deployment, with transects and deployments ordered from the shallowest to the deepest. Station names include the location abbreviation (see Table 2) followed by the depth of the deployment. SyG1097 is excluded from this table because no fishes were observed. A-1, A-2, and A-3 are ROV transects 1–3 at Apolo. Easter Island endemics are indicated respectively by (E) after the species name. See Tables 1 and 2 for station localities and deployment information.

Family	Species	SyG 150	A-3 157	A-1 171	A-2 277	SyG 552	SyG 638	SyG 640	SyG 644	nSyG 644	SyG 776	SyG 847	SyG 1099	RN 1113	RN 1242	SyG 1312	SyG 1323	RN 1331	SyG 1348	SyG 1395	RN 1550	RN 1577	RN 1610	nSyG 1849
Hexanchidae	<i>Hexanchus griseus</i> <sup>a</sup>					1	1	1	2															
Squalidae	<i>Squalus cf. mitsukurini</i>																							
Chimaeridae	<i>Hydrolagus cf. trolli</i> <sup>a,b</sup>													1	1	1	1	1	1	2	2	1		1
Halosauridae	Halosauridae sp.																							
Muraenidae	<i>Gymnothorax bathophilus</i>	2																						
Synphobranchidae	<i>cf. Synphobranchus affinis</i>																							2
Nettastomatidae	Nettastomatidae sp.																							1
Sternopychidae	<i>Argyripnus</i> sp.					1	1																	
Synodontidae	<i>Synodus cf. isolatus</i>	2	1																					
Polymixiidae	<i>Polymixia salagomezensis</i>								1	2														
Moridae	<i>Laemonema</i>					1																		
Moridae	<i>Antimora rostrata</i>																							
Macrouridae	Macrouridae sp. 1																							
Macrouridae	Macrouridae sp. 2																							
Holocentridae	<i>Pristilepis oligolepis</i>																							
Holocentridae	<i>Sargocentron wilhelmi</i> (E)																							
Berycidae	<i>Beryx splendens</i> <sup>a</sup>																							
Berycidae	<i>cf. Beryx splendens</i> <sup>a</sup>																							
Berycidae	<i>Beryx splendens</i> <sup>a</sup>																							
Berycidae	<i>cf. Beryx splendens</i> <sup>a</sup>																							
Berycidae	<i>Antigonia capros</i>																							
Autostomidae	<i>Autostomus chinensis</i>																							
Scorpaenidae	<i>Scorpaenoides engleri</i> (E)																							
Scorpaenidae	<i>Scorpaena ongila</i>																							
Serranidae	<i>Caprodon longimanus</i>	1																						
Serranidae	<i>Plectranthias parini</i>																							
Serranidae	<i>Tosanoides</i> sp. <sup>a,b</sup>	8	56 <sup>d</sup>	32 <sup>d</sup>	2																			
Serranidae	<i>cf. Grammatonotus</i> sp. <sup>a,b</sup>																							
Serranidae	<i>Cookeolus japonicus</i>	1																						
Priacanthidae	<i>Priacanthus nasca</i> (E)																							
Priacanthidae	Emmelichthyidae sp.	2																						
Emmelichthyidae	<i>Parapristipomoides squamimaxillaris</i>	8																						
Lutjanidae	<i>Etelis carbunculus</i>	2																						
Lutjanidae	<i>Prognathodes</i> sp. <sup>a,b</sup>	1																						
Chaetodontidae	<i>Eviptis acutirostris</i>	1																						
Pentaceroptidae	<i>Pseudocaranx dentex</i>	1																						
Carangidae	<i>Seriola lalandi</i>	4																						
Carangidae	<i>Cheilodactylus plessisi</i>	1																						
Cheilodactylidae	<i>Chromis</i> sp. <sup>a,b</sup>	2	15	11																				
Pomacentridae	<i>Bodianus unimaculatus</i>	2	1	3 <sup>c</sup>																				
Labridae	<i>Pseudolabrus semifasciatus</i> (E)																							
Labridae	<i>Suezichthys</i> sp. <sup>a,b</sup>	1																						
Labridae	Unidentified <i>Suezichthys</i> sp. <sup>a,c</sup>	1																						
Labridae	<i>Paraperis</i> sp. <sup>a,b</sup>																							
Pinguipedidae	<i>Rexea</i> sp.																							
Gempylidae	<i>Runettus pretiosus</i>																							
Gempylidae	<i>cf. Rexea</i>																							
Ostraciidae	<i>Lactoria diaphana</i>																							
Unidentified 1	Unidentified 1																							

(continued on next page)

Table 3 (continued)

Family	Species	SyG	A-3	A-1	A-2	SyG	SyG	SyG	SyG	nSyG	SyG	SyG	RN	SyG	RN	SyG	RN	SyG	RN	SyG	RN	SyG	RN	nSyG
Unidentified 2	Unidentified 2	150	157	171	277	552	638	640	644	644	776	847	1099	1113	1242	1312	1323	1331	1348	1395	1550	1577	1610	1849
Unidentified 3	Unidentified 3			1																				
Unidentified 4	Unidentified 4			1																				
Unidentified 5	Unidentified 5				1																			
Unidentified 6	Unidentified 6		1																					
Unidentified 7	Unidentified 7					1																		
Unidentified 8	Unidentified 8						1																	
Unidentified 9	Unidentified 9												1											

<sup>a</sup> First confirmed report from the Easter Island Ecoregion.

<sup>b</sup> Potentially a new species on the basis of distinct coloration and, in some cases, fin shape in comparison to known species.

<sup>c</sup> This report is a new maximum depth for this species.

<sup>d</sup> Count may include juveniles of the *Chromis* species.

<sup>e</sup> This potential species could be either the female or male of the above *Suezichthys* sp. nov. or a separate new species of *Suezichthys*.



**Fig. 3.** Representative images of select fishes from the Drop-Cam videos deployed in the Easter Island Ecoregion. (A) *Gymnothorax bathyphilus*. (B) *Parapristipomoides squamimaxillaris*. (C) *Polymixia salagomeziensis*. (D) *Laemonema* sp. (E) *Antimora rostrata*. (F) *Rexea* sp. (G) cf. *Synaphobranchus affinis*. (H) cf. *Synaphobranchus affinis* consuming loose bait. (I) Halosauridae sp. (J and K) *Hydrolagus* cf. *trolli*. (L) *Squalus* cf. *mitsukurii*. Photo credit: Eric Berkenpas, National Geographic.

Synaphobranchidae, *Ilyphis blachei* and *Simenchelys parasiticus*, which were reported from the area by Parin et al. (1997).

Due to the small size of individuals and their generally large distance from the cameras, we could not assign Macrouridae individuals to any of the known species from the area. In one video, we did observe one individual with a different body shape, so at least two species of Macrouridae were present. Similarly, we were unable to assign the individuals of Nettastomatidae and Halosauridae (Fig. 3I) to species due to lack of visible diagnostic characters. Other species in these families known from similar depths along the Salas y Gómez Ridge are *Nettastoma falcinaris*, *Aldrovandia affinis*, and *A. phalacra* (Froese and Pauly, 2011; Parin et al., 1997).

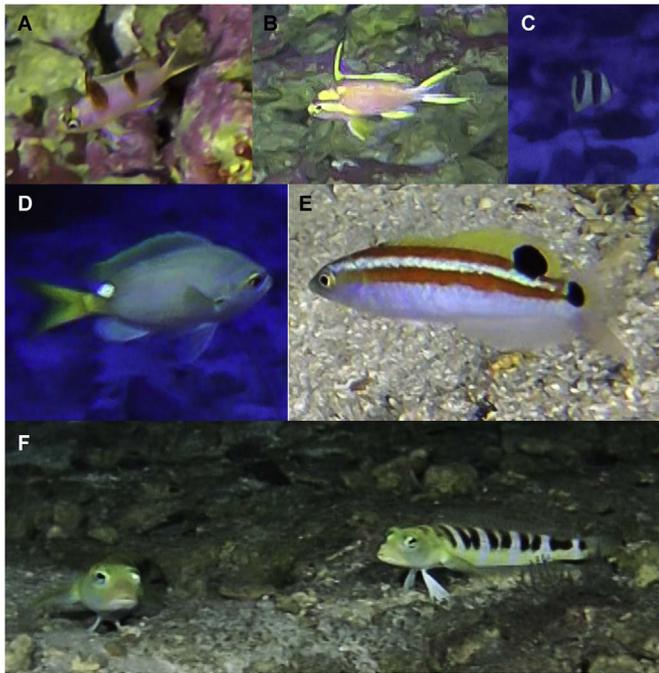
### 3.2. Biodiversity and abundance

The ~10-fold lower diversity of fishes at Easter Island compared to other oceanic islands (Randall and Cea, 2010) may be due to its relatively young age (< 2 my), its distance from source populations, and the ultra-oligotrophic conditions. These same factors may also contribute to the relatively high percentage of local and regional endemics, which is among the largest percentages in the world. With such high rates of endemics, Easter Island harbors unique biodiversity and may have a limited ability to recover from disturbances due to

ultra-oligotrophic conditions and the limited number of populations and ranges of each species.

This report expands the total number of known shorefishes (found at depths < 200 m) from 141 to 145 and the total number of known species from Easter Island by at least seven, from 171 to 178, including five deep-dwelling species observed at depths > 200 m. Therefore, this report increased the known species for the island by ~4%; which we believe is an underestimate as we observed several individuals that we were unable to identify but that were distinct from species known from the island. On the basis of these observations, we suggest that Easter Island and the surrounding seamounts harbor many undiscovered species, especially at depths > 60 m. Further, with high rates of apparent endemism and, therefore, potentially high rates of speciation, this area may provide researchers with an ideal environment to study speciation and connectivity patterns among seamounts that are not strongly influenced by coastal inputs and coastal and boundary currents.

Most species observed in the ROV videos had relatively low abundances and were often observed in a single transect. Several species were observed in relatively high abundance (NMax > 10): *Seriola lalandi*, *Chromis* sp. nov., *Antigonina capros*, and the new species of *Tosanoides*. Of these, only *S. lalandi* is commercially important (Zylich et al., 2014). Due to the noise and lights of the



**Fig. 4.** Images of potentially new species of fishes observed in the ROV videos from Apolo. (A) Female of *Tosanoides* sp. (B) Male of *Tosanoides* sp. (C) *Prognathodes* sp. (D) *Chromis* sp. (E) *Suezichthys* sp. (F) *Parapercis* sp. Photo credit: Matthias Gorny, Oceana Chile. (For visualization of the references to color in the text, the reader is referred to the web version of this article).

ROV, some species may have been attracted to or frightened away from the ROV. Jacks, such as *S. lalandi*, and *A. capros* appear to be attracted by the noise or lights of the ROV, whereas *Parapercis* sp., *Tosanoides* sp., and some unidentified fishes would swim away and hide as the ROV approached. Therefore, relative abundances could differ by the sampling location and due to behavioral differences in response to the ROV.

The diversity and abundance of fishes we observed during only ~64 min of video recording on bottom at Apolo were relatively high considering the declining diversity and abundance of fishes at dive depths over the last 50 years (DiSalvo et al., 1988; Friedlander et al., 2013; Hubbard and Garcia, 2003). During surveys at 10 stations around Easter Island in the austral summer of 2011, only 41 species of fishes were recorded in four days of diving (~12 h of total bottom time) (Friedlander et al. 2013). Mesophotic reefs have been found to have higher percentages of endemism (Kane et al., 2014) and relatively few fish species in common with adjacent shallow-water communities; however, the prevalence of new depth reports suggests at least some species dominant in shallow waters also live at mesophotic depths, so additional studies are necessary to better understand depth patterns (Kahng et al., 2014; Kahng et al., 2010). The general trends from the few studies at mesophotic depths are that fish richness and abundance declines with depth, especially for herbivores, and that higher abundance and richness are correlated with greater structure associated with steep topography and greater abundance of crevices and corals (see Kahng et al., 2014; Kahng et al., 2010). The relatively high diversity and abundance we observed may, likewise, be associated with structure and the abundance of whip corals, crevices, and rocky structures present. Further studies are necessary to uncover depth patterns in the mesophotic waters of Easter Island and how these habitats compare to other mesophotic habitats.

Compared to the known diversity (> 170 species) of the deep, benthopelagic fishes from 22 seamounts of the Nazca and Salas y Gómez Ridges (Parin, 1991; Parin et al., 1997), relatively few species were identified from the baited Drop-Cams. The relatively low percentage of species we identified is not surprising considering the limits of

this technology relative to trawling. With the exception of six potentially new species (see Section 3.3.1), all of the taxa we identified have been reported from the South Pacific, including from the EIE and the adjacent Salas y Gómez and Nazca Ridges (see, e.g., Parin, 1991; Parin et al., 1997).

Like Parin et al. (1997), we found apparent breaks in fish compositions with depth (Table 3). These breaks are between 150 m and 550 m and between 850 to 1100 m (Table 3), which are comparable to those reported in Parin et al. (200–300 m, 500–600 m, and 700–800 m). In addition, species-composition changes with longitude led Parin et al. to conclude that the EIE was separate from that of the surrounding area, including the Nazca Ridge and eastern extent of the Salas y Gómez Ridge. To determine whether these breaks are real or an artifact of limited sampling and the difference in depth among stations, we will need future studies as we could not statistically compare communities among islands or with depth because of differences in depth among survey locations, a lack of replication among similar depths and locations, and differences in survey methods and the associated biases. For example, Drop-Cams were baited and therefore were biased towards scavengers and species associated with structure provided by the rocky outcrops in some videos, and ROV surveys were biased towards the peak of an area known to have high productivity.

Of 171 species identified by Parin et al. (1997), 44.4% were new to science and the largest percentage (42.8%) were related to Indo-Pacific species instead of to eastern Pacific species. In comparison, we determined ≥ 15% of the 46 species observed in the ROV and Drop-Cam videos were new reports for the southeast Pacific and potentially new to science. As we identified several potentially new species from our relatively limited video footage, we suspect that the EIE and the Salas y Gómez and Nazca Ridges harbor a substantial amount of undiscovered biodiversity and therefore future studies should be done in these regions and adjacent areas in the south Pacific so that we can have a better understanding of the biodiversity and connectivity among the seamounts in this area.

### 3.3. New records

#### 3.3.1. Potentially new species

At least six species are potentially new to science or, at least, have unique color and/or fin patterns in comparison to the closely related species known from adjacent areas (Fig. 4). Potentially new species were assigned to the following taxa: *Tosanoides*, *Chromis*, *Grammatonotus*, *Parapercis*, *Suezichthys*, and *Prognathodes*. In addition, *S. cf. mitsukurii* and *Hydrolagus cf. trolli* may be new species (Table 3, Fig. 3J–L).

Although we assigned individuals to potentially new species on consensus of expert opinions, we acknowledge the difficulty in assigning individuals to a genus or subfamily from video alone and emphasize that these identifications are tentative until specimens can be collected to confirm identifications. Further, determining whether species are truly endemic to Easter Island or the region requires more extensive sampling. Due to a lack of sampling in this area, it is premature to hypothesize whether these potentially new species are endemic or whether they reflect an overall lack of sampling at mesopelagic and greater depths, especially in the South Pacific.

The potential new species of *Tosanoides* has a distinct color pattern in comparison to known *Tosanoides* species. We observed two distinct patterns for this species (Fig. 4A and B). The less abundant and larger individuals (likely males) are light pink or purple with bright yellow fins and two broad, bright yellow stripes separated by a thin purple stripe on the dorsal portion of the head, with the lower yellow stripe extending down towards the pectoral fin. The smaller individuals (probably females) are pale pink or purple with pale yellow fins and two broad orangish bands extending from the midline up into the dorsal fin. Some individuals with the orange bands had a yellow and purple banding pattern on the front-dorsal region of their head,

possibly indicating that these individuals are in the process of changing from female to male as is common in Anthiinae. Individuals were also observed at Salas y Gómez at 150 m and were observed hiding in holes at 277–281 m and swimming among whip corals in groups as large as ~60 individuals at 157–175 m at Easter Island. Other Anthiines are known to aggregate in large numbers, live at similar depths, be sexually dichromatic and dimorphic, and be protogynous hermaphrodites.

The potential new species of *Chromis* was observed at 150–175 m, which is comparable to several *Chromis* spp. with depth maxima of 150–210 m (Froese and Pauly, 2011). This species has a bright yellow body and caudal fin and the other fins are lighter yellow to bluish grey (Fig. 4D). They have one or two white spots, one bright spot dorsally at the base of the caudal fin and another lighter spot medially at the base of the dorsal fin. They were observed in large groups of several dozens, generally swimming a meter or more above the seafloor. Along with the potentially new *Tosanoides*, this *Chromis* species is one of the most abundant species observed at ~150 m at Easter Island and Salas y Gómez (Table 3).

The potential new species of *Grammatonotus* was observed at 277–281 m, where the habitat was rocky with an abundance of crevices in which the individuals would hide when the ROV approached. This habitat and depth range, the overall body and fin shape, and the relative size of the eyes are consistent with other species in this genus; however, genus-level diagnostic characters require specimens to be collected, and this genus is believed to need taxonomic revision (Mundy and Parrish, 2004). Due to the scarcity of specimens and observations of species in this genus, living color of many species are unknown and new species reports have been made from comparisons of video observations to published descriptions and images (Mundy and Parrish, 2004; Prokofiev, 2006, 2015). Other species are known to have yellowish bodies and pink, blue, and /or lavender fins or markings; however, none of the reported color patterns are consistent with the individuals we observed (Katayama et al., 1982; Mundy and Parrish, 2004; Prokofiev, 2006, 2015). This species has a bright yellow body and bright purple fins, with outer rays of the caudal fin produced into filaments.

The potential new species of *Paraperis* species was observed at 277–281 m on a rocky bottom, which is within the known range of congeners. Due to differences in coloration (Fig. 4F), we could not confidently assign this individual to a known species. The only known species from the area is *P. dockinsi*, which is considered endemic to the Juan Fernandez Archipelago (Dyer and Westneat, 2010; Froese and Pauly, 2011; Rosa and Rosa, 1997) despite Parin et al. (1997) reporting specimens from 180–290 m at two seamounts of the Salas y Gómez and Nazca Ridges. The specimens we observed have distinct coloration patterns in comparison to *P. dockinsi*, and it is unclear whether the specimens from the seamounts explored by Parin et al. (1997) differed in coloration as well. Although minor variation in color pattern within species has been observed (Ho and Causse, 2012; Randall, 2008), this genus is not known to have substantial within-species color variation, excluding sexual dimorphism (Imamura and Yoshino, 2007), and morphological revision of populations with distinct color patterns has revealed additional morphometric and meristic differences resulting in revisions of species (Randall, 2008). Further, two morphotypes of *P. sexfasciata* were found to be genetically distinct with variation among morphotypes being consistent with inter-species differences (Kai et al., 2004). Specimens are necessary to resolve whether coloration differs along the geographic range of this species and whether observed color patterns are indicative of species-level differences.

The potential new species of *Suezichthys* was observed at 157–281 m (Fig. 4E), which is consistent with the depth range of some congeners (Froese and Pauly, 2011). This genus has not been reported for Easter Island and the first-ever report of this genus in the eastern Pacific is of *S. rosenblatti*, which was found at 10–33 m at Juan Fernandez Archipelago and San Felix Island (Russell and Westneat, 2013). The individuals in this report have a distinct color pattern in

comparison to *S. rosenblatti*; however, the pattern is similar to the Indo-Pacific coastal species *S. devisi*. The species in this report and *S. devisi* have two orange lateral stripes in the same location and a black spot dorsally on the caudal peduncle; however, the spot on the caudal peduncle is considerably smaller on *S. devisi*. The species in this report, unlike *S. devisi*, has a small, black spot ventrally on the dorsal fin and a much larger spot posteriorly on the bright yellow, dorsal fin.

Finally, a potential new species of *Prognathodes* was observed at 157–175 m (Fig. 4C), which is within the known range of congeners. It is similar but distinct from that of the undescribed *Prognathodes* sp. “basabei” found along the Hawaiian archipelago. It is the first report of this genus at Easter Island.

Recent revisions of *Squalus* spp., especially those formally considered *S. mitsukurii*, have led to the conclusion that *S. mitsukurii* is likely restricted to the western North Pacific and is not a circumglobal species with a patchy distribution as previously thought (see Froese and Pauly (2011), White and Iglésias (2011)). Further, geographic variability in reproductive and growth parameters and recent taxonomic work suggest that *S. mitsukurii* is a species complex and several populations currently reported as *S. mitsukurii* are likely new and probably endemic species in their respective regions (Cotton et al., 2011; Graham, 2005; Last et al., 2007). Additional taxonomic work is needed to identify the number of species in this complex as well as their geographic and depth ranges and whether the individuals in this study were the same as the two individuals of an undescribed new species of *Squalus* collected 8 mi SW of Easter Island at 200–400 m (Randall and Cea, 2010). Individuals in this study were observed at 552–644 m, which is consistent with *Squalus* cf. *mitsukurii* species (Graham, 2005).

*Hydrolagus* cf. *trolli* may be a new species as reported by Friedlander et al. (2013); however, we were unable to eliminate or confirm the identification of the observed individuals as *H. trolli*. Few species of *Hydrolagus* are known from the eastern South Pacific and only three, *H. macrophthalmus*, *H. melanopasma*, and *H. trolli*, are known from Chile (Bustamante et al., 2014). The individuals we observed were distinct in color pattern, lateral line pattern, and fin shape from the first two species. The individuals we observed were more similar to *H. trolli*; however, we chose not to assign the individuals as we could not see sufficient diagnostic features and the report of *H. trolli* was not determined from analysis of a specimen but from reported morphometrics of a specimen originally assigned to a different species (Bustamante et al., 2012).

### 3.3.2. New depth reports

Nine species were observed at deeper depths than previously reported. Two species with notably deeper ranges than previously reported are *Etelis carbunculus* and *Polymixia salagomeziensis*. *Etelis carbunculus* was observed at 638 m, which is deeper than the reported range of 90–400 m (Froese and Pauly, 2011). *Polymixia salagomeziensis* (Fig. 3C), which differs in several morphological characters, including distinct color patterns from the only other known species of the genus from the area, *P. yuri* (Kotlyar, 1982, 1991, 1993), was observed at 644 and 776 m, which is considerably deeper than the previous report of 330 m (Parin et al., 1997) but similar to maximum depths (550–770 m) for other species in this genus (Froese and Pauly, 2011). See Supplementary Material for discussion of the depth range expansions for the other seven species: *Aulostomus chinensis*, *Cheilodactylus plessisi*, *Lactoria diaphana*, *Plectranthias parini*, *Bodianus unimaculatus*, *Sargocentron wilhelmi*, and *Scorpaena orgi-la*. In addition to these nine new depth reports, *Evistias acutirostris* was recently registered for Easter Island (Hernández et al., 2015), with this study being one of two documented observations for the island.

Some of these new depth reports are indicative of the limited sampling efforts below 40 m at Easter Island and general under-sampling at mesopelagic depths, especially in the south Pacific (Kahng et al., 2010). The prevalence of new depth reports could also

be indicative of the unique oceanographic conditions of the area and depauperate faunal assemblages that allow species to expand their ranges to take advantage of open niches as well as deeper chlorophyll maxima and deeper aphotic and disphotic conditions associated with ultra-oligotrophic waters and local oceanographic regimes (e.g., central-gyre downwelling, eddies, and island- and seamount-influenced currents).

#### 4. Conclusion

These surveys of the deep-dwelling fishes of the EIE revealed apparent breaks in fish communities between 150 m and 550 m and between 850 to 1100 m, which are comparable to breaks in fish communities observed by Parin et al. (1997) for seamounts of the Nazca and eastern Salas y Gómez Ridges. Our surveys expanded the known depth ranges of nine species and the known species for the region by ~4%. Many of the previously unrecorded fishes, including six potential new species, were observed at mesopelagic depths (150–280 m). The abundance of new reports from this study emphasizes the lack of knowledge available for deep-dwelling fish species, especially for the southeast Pacific, including the EIE. In addition, these new reports may be indicative of the relative isolation of the island and/or unique oceanographic conditions that may have provided favorable conditions for range expansion and the evolution of new species. The data obtained from these surveys is the first step in establishing a baseline for conservation and sustainable management planning, for understanding the effects of natural and anthropogenic disturbances on these communities, and for testing biogeographical hypotheses, including whether latitudinal or longitudinal breaks in species' ranges exist among similar communities in the Pacific and the extent and pathway of connectivity among them.

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#### Appendix A. Supplementary materials

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.dsr2.2016.12.006>.

#### Appendix B. Supplementary materials

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.dsr2.2016.12.006>. These data include Google maps of the most important areas described in this article.

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