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Research Article

First *in situ* observations of the benthic-demersal fauna on the upper continental slope off Punta Pichalo (19°36'S), northern Chile

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ABSTRACT. An autonomous lander equipped with a video camera (dropcam) was used for *in situ* observations of the bento-demersal macrofauna on the upper continental slope off Punta Pichalo in northern Chile, an area of permanent coastal upwelling processes, located ~70 km north of Iquique. The lander was deployed at nine stations and between 227 and 798 m of depth. According to morphological characteristics, 34 operational taxonomic units (OTUs) were identified to the lowest taxonomic level; 24 belonged to macroinvertebrates and 10 to fishes. Macroinvertebrates comprised 9 OTUs of crustaceans, seven cnidarians, and six echinoderms. Fishes included 3 OTUs of the order Chondrichthyes, 3 belonging to macrourid. Perciformes, Anguilliformes, and Alepocephaliformes were represented by one OTU each. Also, we observed one species of lanternfish (Myctophidae). Apart from the brachyuran decapod *Lophorochinia parabranchia* Garth, 1969 and euphausiids, all species were observed at depths greater than 560 m. The presence of one individual identified as the granulate dogfish *Centroscyllium granulatum* Günther, 1887 extended the known distribution range of this species about 1000 km to the north. Images taken at 795 m showed *Bathyraja peruana* McEachran & Miyake, 1984. Our study suggests that the upper continental slope of northern Chile harbors nearly undiscovered biodiversity, worth to be studied more intensively to complete the comparable sparse knowledge about marine biodiversity and species distribution at the continental margin in front of Chile.

Keywords: underwater imagery; benthic-demersal; biodiversity; deep-sea; continental slope; northern Chile

INTRODUCTION

Continental slopes extend from the shelf break at about 200 m down to the continental rise at ~1000 m and form part of the deep sea (Thistle 2003). Although waters deeper than 200 m represent over 50% of the earth's surface (Webb et al. 2010), the biodiversity of the oceans' deeper parts bottom-living fauna is sparsely known compared to shallow coastal waters around the world (Costello et al. 2018). However, novel technologies such as remotely operated vehicles facilitate exploration, especially deep-sea (Appeltans & Webb 2014, Costello et al. 2018). Studies of deep-sea fishes and invertebrates in Chilean waters were concentrated either on the seamounts around the oceanic islands or between central and central-southern Chile. The important publications and catalogs written in the past about the fishes of Chile, starting with Fowler (1945a,b), Mann (1954), then Pequeño (1989, 1997), and later Hüne (2019), mentioned the lack of knowledge about the fish fauna of northern Chile, including some studies dedicated to fishes of southern Chile, such as Zama & Cárdenas (1984). Only some prospective studies, dedicated generally to fisheries, included samples of fishes and invertebrates from northern Chile (Yáñez et al. 1974), as some few cruises were carried out between Arica and Mocha Island (Kong & Meléndez 1991) and in the area between Arica and Antofagasta (Palma 1993, Sielfeld et al 1995, Sielfeld & Vargas 1996). All other studies about the

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fish an also invertebrate fauna of the deep sea in the southeast Pacific in front of Chile were concentrated in the oceanic sectors, especially along the Nazca and Salas and Gomez ridges, mainly due to collections of Russian expeditions made between 1959 and 1975 (Parin et al. 1973, Grossman 1978), and later between 1979 and 1987 (Parin et al. 1997). A more recent study repre-sented the German-Chilean Expedition PUCK (SO-156) in 2001, exploring depths between 100 and 4600 m, including some sampling in front of Antofagasta and Iquique in northern Chile (Quiroga et al. 2009, Sellanes et al. 2010, Melo et al. 2007). However, apart from the international cruises mentioned above and some sporadic sampling of benthic deep-sea invertebrates during other international cruises, such as the R/V Anton Bruun Expedition in 1966 (Mc Lean & Andrade 1982), information about the benthic invertebrates of the continental slope in the northernmost part of Chile is limited and is based mainly on historical data. The "Mar-Chile II" Expedition in 1962 investigated the seafloor on the upper slope between Arica (18°30'S) and Punta Patache (1°S), detecting a significant increase of biodiversity below the oxygen minimum zone (OMZ) at 200 m (Gallardo 1963). About 30 years later, the composition of benthic-demersal fishes was studied in the same area, identifying different assemblages of fishes distributed at different depth strata down to 1000 m (Sielfeld & Vargas 1996). Nearly all investigations of the deep-sea benthos off Chile used traditional gears such as dredges and bottom Agassiz trawls, except the PUCK (SO-156) Expedition, using additional underwater video using a remotely operated vehicle (ROV). Underwater imagery was also used to document the seafloor of the Atacama trench during the 2018 cruises Atacamex and RV Sonne SO261 (Purser et al. 2019), and recently in January 2022, a manned submersible explored the abyssal of the Atacama trench. However, the upper continental slope off northern Chile was excluded from these recent studies.

The present study was conducted at the continental margin off Punta Pichalo, considered one of two locations in northern Chile with nearly permanent and comparable strong upwelling processes (Barahona & Gallegos 2000). Since the "Mar-Chile II" Expedition results indicated a comparable rich fauna below 200 m depth, upwelling of well-oxygenated water masses on the slope may explain why benthic biodiversity on the continental margin is higher as on the seafloors of the OMZ. On the other hand, coastal upwelling is typical for several locations along the Chilean coast forming part of the Humboldt Current System (HCS), one of the most productive marine ecosystems on the planet (Thiel et al. 2007). Despite their ecological importance, none of these highly productive coastal areas is considered a marine protected area (MPA). However, during the past years, national authorities and NGOs considered the coast north and south of Punta Pichalo as a priority site for marine conservation due to the extraordinary diversity and abundance of sea mammals, sea birds, and rich pelagic fauna of coastal fishes and invertebrates. Successful marine conservation planning must consider any ecological and spatial connectivity between ecosystems due to vertical and horizontal movements of animals (Carr et al. 2017). The present study formed part of a general investigation of the marine biodiversity conducted between 2017 and 2019 for a proposal to suggest the area around Punta Pichalo as a future MPA. In this context, the goal of the present study was to complete existing inventories of the benthic fauna of the area with the first *in situ* observations from the upper continental slope using underwater video images. In Chile, this technology was applied successfully in the past years to describe the benthic-demersal fauna of other deep-sea habitats such as the seamounts around the oceanic islands in the southeastern Pacific (Friedlander et al. 2013, Easton et al. 2017, Tapia et al. 2021b).

MATERIALS AND METHODS

Study area

The study area was located in northern Chile, between 19°29'-19°39'S and 70°20'-70°30'W, about 10 nm north and 5 nm south of Punta Pichalo (19°36'S). Punta Pichalo is a land tip close to the small port of Pisagua in northern Chile, located about 70 km north of Iquique (Fig. 1), and nearly permanent and comparable strong upwelling processes characterize the environmental conditions of that area (Barahona & Gallegos 2000). Due to the Equatorial Subsurface Water (ESSW) (Silva et al. 2009), a southward flow of waters with low oxygen concentrations and high salinity occurs between 100 and 300 m deep (Nekrasov 1994, Gallardo et al. 2013). According to Blanco et al. (2001), water temperature in this area fluctuates between 5 and 10°C, and salinity is above 34. The locations for *in situ* observations were selected off the coastline proposed as a future MPA given the special geomorphology of the seafloor in front of Punta Pichalo. Close to the land tip, the shelf margin is only 2 nm away from the coast and separated by a ridge with about 500 m depth, allowing to cover different depth strata within a comparatively small area. On the other hand, the selected points correspond to stations sampled during the "Mar-Chile II" Expedition in 1962.

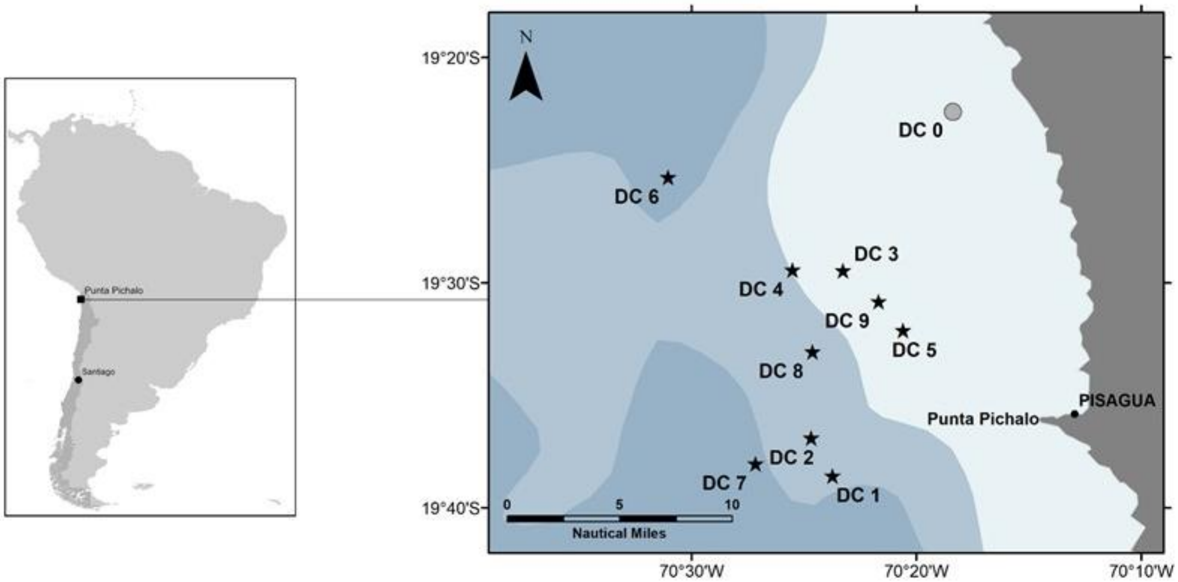

Figure 1. The study zone shows the dropcam deployments locations off Punta Pichalo, northern Chile, during 2019 and one test launch during 2018 (grey circle). The bathymetric colored chart was extracted and adapted from the bathymetric data viewer of NOAA (https://maps.ngdc.noaa.gov/viewers/bathymetry/).

Dropcam

The video images from the seafloor were obtained by deploying an autonomous camera lander system (dropcam) manufactured by Mariscope Meerestechnik, Kiel, Germany (Fig. 2). The lander system consisted of a steel frame carrying an underwater camera housing equipped with a GoPro Hero 4 camera. A pair of lights and a battery housing providing the energy for these lights were also attached. An upper buoy was attached to the top of the frame to allow the lander to return from the seafloor whenever a bottom weight was placed under the frame and dropped. The bottom weight entailed a 22 kg block of concrete attached below the frame with a galvanic timed releaser (GTR). GTRs are automatically dissolving hooks using two dissimilar metals that corrode during a predictable time when exposed to the seawater. For this study, the hooks constructed by International Fishing Devices (Florida, USA) released the bottom weight after approximately 2 h. The descent speed of the dropcam was 0.7 m s^{-1}, and the ascents were slightly slower due to the strong positive buoyancy of the system. After popping up on the surface, the lander was detected visually by the strong yellow color of the buoy and a reflecting signal flag attached to the top of it. Additionally, acoustic detection was provided by a handhold radio receiver device with an antenna (Staba XR100), allowing to receive pings emitted by a small radio transmitter located on top of the buoy (Wichmann Technik, Germany). The geographic positions of all deployments were registered on a laptop equipped with the GPS Pro Trackmaker navigation software (version 4.9) connected to a Garmin 18 USB antenna device.

***In situ* observations**

The dropcam was deployed at nine locations located about 5 nm north and south of Punta Pichalo in depths between 227 m on the edge of the continental platform and 799 m at the upper slope (Table 1). Since the lander did not have a depth recording device, the depths reached by the equipment were calculated as estimated depths (ED) considering the sinking speed of the equipment calibrated against data obtained with an echosounder (Garmin Fishfinder GPSMap 527xs echosounder) in water depths down to 500 m, including a test dive in 2018. The lander's mean sinking speed was 0.6492 m s^{-1} (± 0.0242 standard deviation, SD; n = 4). Additionally, these depths were compared with data indicated on the Bathymetric Data Viewer published by the US National Centre for Environmental Information of the National Oceanic and Atmospheric Administration (NOAA). As shown in Table 1, the variation between all data was less than 30 m (Table 1). The high-resolution underwater video was recorded with a GoPro4 Camera in a resolution of 2.7 K (2704×15200 pixels and 60 frames per second). The underwater camera housing was mounted at 15° inclination on one side of the frame with 50 cm between the camera and the seafloor when the lander was on the ground. At this distance, the area covered by the camera's objective

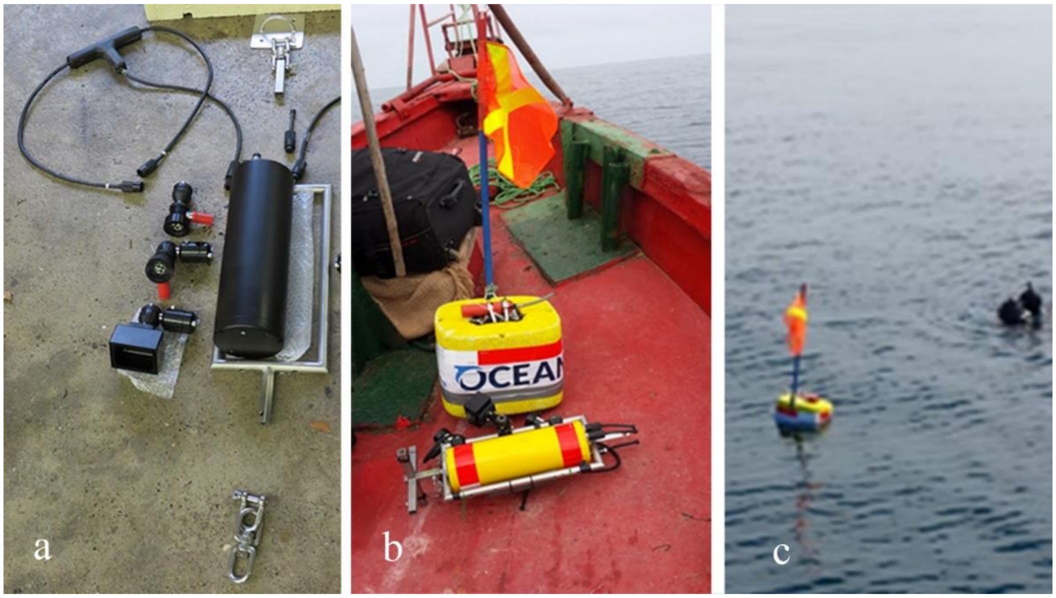

Figure 2. Autonomous camera lander system (dropcam). a) Assemblage of the system as used in the present study with battery housing, one set of cables, one pair of LED lights, and one camera housing, b) system with a top buoy on deck (without clump weight), c) on the water surface after popping up from the ground.

Table 1. Station list of nine dives of a dropcam off Punta Pichalo in northern Chile during 2019, including one test dive in 2018 (*). Bottom depths at each dive are indicated as estimated depths (ED). Depths indicated by depth elevation models (DEM) published by NOAA (https://maps.ngdc.noaa.gov/viewers/bathymetry/) were also given, and the last column shows echosounder depths (ES) measured at four reference stations.

Station	Date	Latitude	Longitude	Depth (m)		
				ED	DEM	ES
DC0*	05-05-2018	19°S 22' 22.1"	70°W 18' 23.7"	84	92	100
DC1	07-10-2019	19°S 38' 34.8"	70°W 23' 42.0"	686	680	
DC2	07-10-2019	19°S 36' 54.0"	70°W 24' 39.6"	517	522	
DC3	08-10-2019	19°S 29' 27.6"	70°W 23' 14.6"	430	451	430
DC4	08-10-2019	19°S 29' 25.8"	70°W 25' 29.2"	560	583	
DC5	08-10-2019	19°S 32' 07.4"	70°W 20' 34.1"	227	216	210
DC6	09-10-2019	19°S 25' 19.2"	70°W 31' 01.2"	797	780	
DC7	09-10-2019	19°S 38' 02.4"	70°W 27' 07.2"	700	705	
DC8	10-10-2019	19°S 33' 03.6"	70°W 24' 36.0"	580	576	
DC9	10-10-2019	19°S 30' 50.4"	70°W 21' 39.6"	363	350	320

corresponded to a maximum area of 2.5 m^2 of the seafloor (2.1 m width × 1.2 m length), depending on the visibility at the seafloor, which at all stations was limited by a varying density of fast floating debris. The video footage at all stations comprised 120 min of video from the ground.

Image processing

All underwater videos were analyzed at half their normal speed or framewise in the GOM Player Plus 2.3.55 (GOM & Company; https://www.gomlab.com/), and digital frames with a size of 2704×1520 pixels were extracted to identify all species encountered on the seafloor or swimming over the seabed below the camera. The qualitative image analyses considered all individuals of macroinvertebrates and fishes seen on the seafloor or swimming about 1 m above the ground. Species identification was done to the lowest possible taxonomic level and assigned to morphospecies according to external morphological characteristics. Invertebrates were classified using general literature about marine species from Chile (Reyes & Hüne 2015) and specific literature for crustaceans (Retamal 1993, 1994, Retamal & Moyano 2010). Fishes were identified according to literature about the deep-sea fish and demersal fish fauna of Chile (Kong & Meléndez 1991, Sielfeld et al. 1995, Sielfeld & Vargas 1996), specific literature about sharks (Compagno 1984, Meléndez & Meneses 1989, Lamilla & Bustamante 2005, Ebert & Mostarda 2016), macrourids (Pequeño 1971) and gadiform fishes in general (Cohen et al. 1990). Morphometrical measurements were applied to identify some fish to the species level. Dogfishes belonging to the genus *Centroscyllium* can be distinguished by measuring the length of the caudal peduncle (Ebert & Mostarda 2016). Rattail fish species fishes belonging to the genus *Trachyrhynchus* were distinguished by comparing the proportions measured for the distance from the orbit to the tip of the snout with the total length of the head.

RESULTS

Over 18 h of underwater video were recorded when the camera lander was on the seafloor, with an average of 1 h and 58 min on each station. At all nine stations, the visibility was affected by floating debris, with decreasing density of the particle flow towards greater depth. Soft sediments were observed at all depths; however, at two stations (DC9 and DC3), large boulders covered by a thick layer of soft sediment were visible.

The *in situ* observations at all stations together revealed the presence of 34 morphospecies, composed of 24 invertebrates and 10 fishes (Table 2). Invertebrates were represented mainly by crustaceans, echinoderms, cnidarians, and crustaceans with nine species were the most diverse taxonomic group. It was not possible to identify invertebrates at the species level. However, the videos revealed the first *in situ* images of the oxyrhynchus crab *Lophorochinia parabranchia* Garth, 1969 from northern Chile (Fig. 3c), observed at two stations (cf. Table 2). At 430 m depth, five crabs (corresponding to a density of ~2 ind m^{-2}) were filmed moving slowly around in front of the camera during the time (73 min) when the equipment stayed on the ground. Only one crab appeared at 580 m, crossing the seafloor during a time-lapse of about 90 s at the end of the video. Its carapace was covered entirely with barnacles and fluffy greenish substances, whereas all crabs filmed at 430 m had carapaces of clean and uncovered surfaces.

Crustaceans were filmed swimming a few centimeters above the ground (euphausiids, two comparable large morphospecies of copepods and mysids) or moving across the seafloor (cf. Table 1). Echinoderms with six morphospecies were the second most diverse group of taxa among the invertebrates, with two morphospecies each of asteroids and ophiurids (Fig. 3d) one morphospecies of a crinoid. Sessile invertebrates were represented by whip corals (Pennatulacea), probably one species, forming comparable dense banks at 580 and 686 m (Fig. 3a). Four different morphospecies of medusozoa jellyfish were filmed floating close above the ground. Sea anemones (Actiniaria) were represented by only one morphospecies, characterized by long and tiny tentacles of brown color.

Fishes comprised 10 species of seven different orders (Squaliformes, Rajiformes, Anguilliformes, Osmeriformes, Myctophiformes, Gadiformes, and Perciformes). Apart from one unidentified species belonging to the family Macrouridae, all other individuals were identified at least to genus level. Squaliformes were represented by *Centroscyllium granulatum* Günther, 1887, and one species of the genus *Etmopterus*. The granular dogfish *C. granulatum* (Fig. 3e) was identified according to the caudal peduncle, which is, according to Ebert & Mostarda (2016), much longer than in *C. nigrum*. Lantern sharks of the genus *Etmopterus* are characterized by dark spots on the body and pelvic fins. However, the exact identification of the species requires analysis of the teeth, which was not possible since the images allowed only a lateral and dorsal view of this shark. The third species of elasmobranchs was the skate *Bathyraja peruana*, filmed at 797 m.

The most frequent species of fishes were a driftfish of the genus *Cubiceps* (Perciformes, Nomeidae), documented at five stations but only at greater depths (517 to 700 m). One of the deepest records of fishes was one specimen of a lanternfish belonging to the genus *Diogenichthys* as indicated by the strong luminous plates, its small head, and compressed body, compared to other Myctophidae with luminous plates on the subcaudal glands as described for members of the genus *Protomyctophum*, *Lobianchia*, some *Lampanyctus* and *Lampadena*. Our specimen shows that a very strong illuminating gland is typical for male lanternfishes.

One species of the genus *Serrivomer* represented Anguilliformes, most probably the thread sawtooth eel *S.* cf. *bertini* (Fig. 3f). However, the exact identification of this species is based on the shape of the mouth roof bone (Eschmayer et al. 1983). On the other hand, *S. bertini* is the only species of sawtooth eels registered frequently in the continental waters of Chile (Parin 1971, Kong & Meléndez 1991). In contrast, all other species of the genus have been registered so far around the oceanic islands of Rapa Nui (Easter Island), the Juan Fernandez Archipelago (Sielfeld & Kawaguchi 2004a), and Desventuradas Islands (Sielfeld &

Table 2. Composition of 34 morphospecies filmed with a dropcam on the seafloor between the continental shelf margin and upper slope off Punta Pichalo in northern Chile. The data are ordered by increasing depth from the shelf towards the slope. OBS: observation indicates where each species was observed (B, on the bottom; F, swimming a few centimeters above the ground; BP, benthopelagic, swimming about 1-2 m above the seabed). Frequencies of occurrence are given for each species as the sum of presence per station (ΣF), and species richness at each station is given separately for invertebrates and fishes as the number of all morphospecies filmed at each station (ΣR).

	Depth [m]		227	363	430	517	560	580	686	700	797	
Invertebrates	Morphospecies	OBS	DC5	DC9	DC3	DC2	DC4	DC8	DC1	DC7	DC6	ΣF
Cnidaria	Pennatulacea sp.	B						1	1			2
	Medusozoa sp.1 (red)	F				1	1		1			3
	Medusozoa sp.2	F				1			1			2
	Medusozoa sp.3 (Siphonophorae)	F									1	1
	Medusozoa sp.4	F									1	1
	Actinaria sp.1	F								1		1
Cephalopoda	Octopus sp.1	B					1					1
Polychaeta	Polychaeta sp.1	B						1		1		2
	Polychaeta sp.2 (white)	B						1				1
Crustacea	Copepoda sp.1	F									1	1
	Copepoda sp.2	F						1			1	2
	Mysidacea sp.	F						1			1	2
	Euphausiacea sp.	F		1		1	1					3
	Anomura sp. (squat lobster)	B							1			1
	Lophorochinia parabranchia	B			1			1				2
	Brachyura sp.1	B					1					1
	Brachyura sp.2	B					1					1
	Caridea sp.	B									1	1
Echinodermata	Ophiuroidea sp.1	B							1		1	2
	Ophiuroidea sp.2	B									1	1
	Ophiuroidea sp.3	B								1		1
	Asteroidea sp.1	B								1		1
	Asteroidea sp.2	B								1		1
	Crinoidea sp.	B								1		1
	Total of species (invertebrates)/station	ΣR	0	1	1	3	5	6	5	6	8	
		Station	DC5	DC9	DC3	DC2	DC4	DC8	DC1	DC7	DC6	
Pisces	Morphospecies	Depth (m)	227	363	430	517	560	580	686	700	797	ΣF
Squaliformes	*Centroscyllium granulatum*	BP				1						1
Squaliformes	*Etmopterus* sp.	B			1	1	1				1	4
Rajiformes	*Bathyraja* cf. *peruana*	B									1	1
Anguiliformes	*Serrivomer* cf. *bertini*	B				1	1	1	1			4
Perciformes	*Cubiceps* sp.	B				1	1	1	1	1		5
Myctophidae	*Diogenichthys* sp.	B									1	1
Macrouridae	*Trachyrhynchus villegai*	B		1			1					2
Macrouridae	Macrouridae (Macrourinae) indet.	B						1		1		2
Macrouridae	*Trachyrhynchus helolepis*	B		1				1				2
Alepocephaliformes	*Alepocephalus* sp.	B					1				1	2
	Total of species (fishes)/station	ΣR	0	2	1	4	5	4	2	2	4	
	Total (invertebrates and fishes)	ΣR	0	3	2	7	10	10	7	8	12	

Kawaguchi 2004b). In the present study, *S.* cf. *bertini* appeared at four stations of greater depths (517 to 686 m).

Rattail fishes of the subfamily Trachyrincinae (Macrouridae) were represented by two species of the genus *Trachyrhinchus*, *T. helolepis* Gilbert, 1892 (Fig. 3g) and *T. villegai* Pequeño, 1971 (Fig. 3h). Both species were filmed at 226 m, the shallowest registers of fishes in this study (cf. Table 2). At greater depths, macrourid fishes were represented by one member of the family Alepocephalidae, identified as one of two for the area known species of the genus *Alepocephalus* through its comparable short pectoral fins.

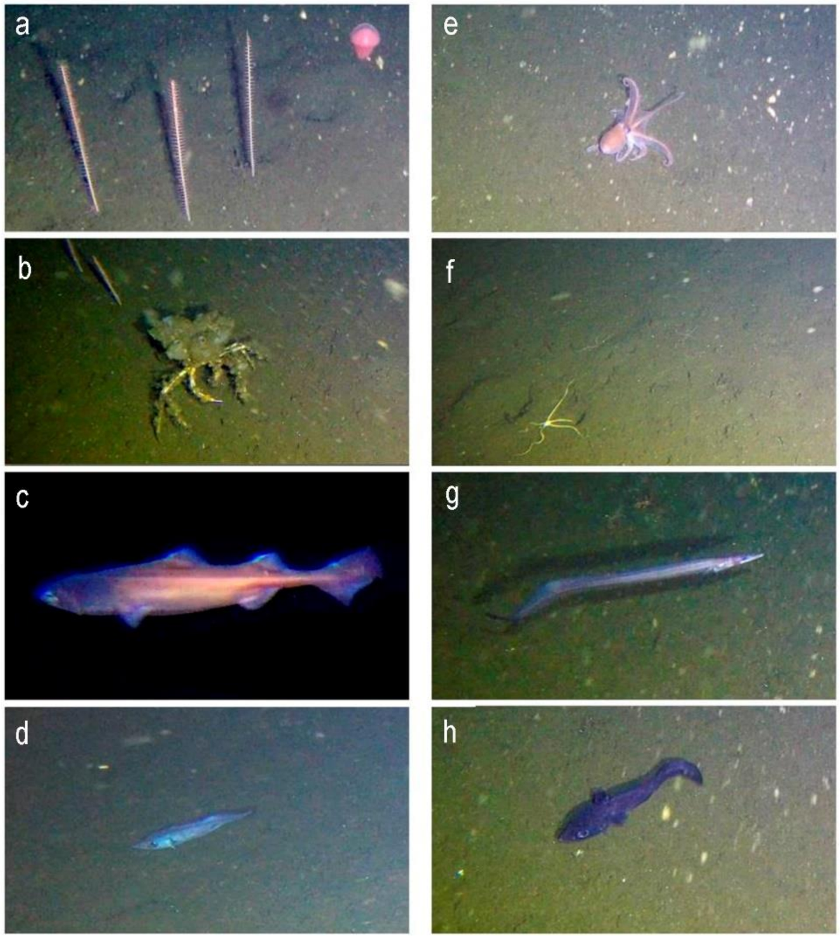

Figure 3. Dropcam recorded images of selected morphospecies off Punta Pichalo, northern Chile. a) Sea pens Penatulacea (DC8-580 m), b) crab *Lophorochinia parabranchia* walking among sea pens (DC1-686 m), c) granulate dogfish *Centroscyllium granulatum* (DC2-517 m), d) rattail *Trachyrhinchus helolepis* (DC8-580 m), e) octopus (DC4-560 m), f) brittle star (DC8-580 m), g) sawtooth eel *Serrivomer* cf. *bertini* (DC1-686 m), h) *Trachyrincus villegai* (DC8-580 m). Photo credits: Matthias Gorny, Oceana.

Species richness (measured as the number of species per station) varied between 2 and 11 species per station (mean 8 ± 3.7), increasing significantly at depths below 500 m (Fig. 4). Fishes were most diverse at 517, and 560 m depth, whereas the most diverse fauna of invertebrates, was observed at the deepest station at 797 m. Except for the two specimens of rattail fishes, the brachyuran crabs and krill, no other species were observed in the 200 to 500 m depth strata.

DISCUSSION

The present study represents the first visual documentation from the upper continental slope in northern Chile. The register of 34 morphospecies filmed during 18 h at nine fixed points of the seafloor represents a notable result. The surface observed at each video station is smaller than surfaces usually sampled with any traditional towed bottom gear. On the other hand, 21 deployments of a dropcam with ~39 h of video footage between 150 to 1850 m at the Salas and Gomez Ridge resulted in the record of 14 species of invertebrates and 27 species of fishes (Friedlander et al. 2013), slightly more than we observed in half of the time. However, most of our observations were made on soft bottoms, whereas most of the Salas and Gomez Ridge videos were from hard substrates.

The low species number of invertebrates and fishes in the depth strata between 200 and 500 m confirmed the results of the few former studies in this part of northern Chile, observing an increasing diversity down the slope (Gallardo 1963). Samples taken during the "Mar-Chile II" Expedition between 133 and 268 m on a transect perpendicular to the coast off Punta Pichalo

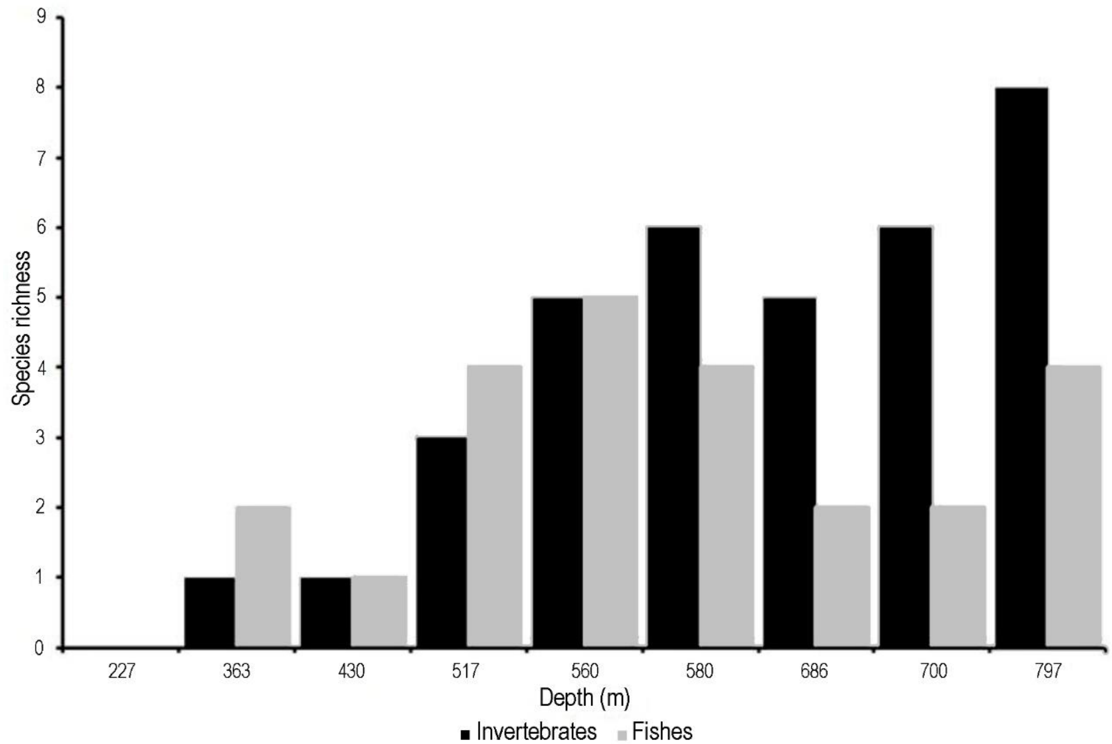

Figure 4. Bar chart of the species richness (number of species per station), visually documented at nine stations off Punta Pichalo, northern Chile. The number of species observed at each station increased significantly at depths >500 m. Fishes were most diverse between 500 and 600 m in depth and less diverse than invertebrates at greater depths.

comprised only a few polychaetes and amphipods. On the other hand, a sample from 552 m, taken in 1962, only 2 nm away from DC8, yielded pennatulaceans, crustaceans, echinoderms, polychae-tes, and bivalves (Gallardo 1963), a very similar composition as in the videos. Unfortunately, the "Mar-Chile II" data represents the only published information about benthic invertebrates of the upper shelf in northern Chile since results from two expeditions in 1988 and 1989 (executed by an FAO/PNUD program) were available only in internal project reports (Palma 1993). According to these unpublished data, sampling with bottom gears between Arica and Antofagasta and between 30 and 900 m revealed at some stations lots of echinoderms (sea urchins, sea stars, and brittle stars) and also several specimens of the crab *Lophorochinia parabranchia* (Palma 1993). Based on these samples, Retamal & Moyano (2010) indicated that *L. parabranchia* is distributed between 18 and 34°S, and according to Garth & Haig (1971), the bathymetric range of this crab is 200 to 700 m. Since after 1989, no other sampling happened in the area, the dropcam footages represent the only existing actual data about the species composition of benthic invertebrates on the upper slope of northern Chile.

All images were affected by particle flow of dissolved organic matter, resulting in a loss of sharpness, complicating a more detailed identification of the species. Studies on the demersal and mesopelagic fish fauna carried out between 18°24' and 24°S indicated the existence of different assemblages of demersal fishes, separated by bathymetric strata above and below 200 m of depth, and most probably caused by the different concentrations of oxygen and salinity (Sielfeld & Vargas 1996). However, particle flow and density decreased with increasing depths and north of Punta Pichalo. Upwelling processes of water masses from the deeper slope were probably stronger north of Punta Pichalo than in the bottom topography. According to Barbieri et al. (1995), north off Punta Pichalo, upwelling occurs nearly constantly with varying intensities throughout the year. One of the strongest of six upwelling zones between 18 and 24°S during the El Niño 1998 event (Barahona & Gallegos 2000). The impoverished fauna of bottom-living invertebrates described for many parts of the shelf and shelf margin in northern and central Chile is related to the OMZ, and typical for the HCS and influenced by the Equatorial Subsurface Water (ESSW), a water mass with high salinity and low concentration of oxygen, flowing northwards between 100 and 500 m (Thiel et al. 2007, Blanco et al. 2011). The composition of demersal fishes on the videos varied with depth, but most of the species (5) occurred at 560 m. Sielfeld & Vargas (1996) described the presence of different assemblages of demersal fishes, distributed between three different depth strata (200-500, 500-700, and 700-1000 m), mainly composed of the deepwater conger *Xenomystax atrarius* (Congridae), and the macrourids *Coryphaenoides ariommus* and *Trachyrhynchus helolepis*. In the present study, macrourids were filmed between 200 and 500 m. Interestingly the dropcam registered two species of Chondrichthyes at 797 m, whereas Sielfeld & Vargas (1996) mentioned the absence of elasmobranchs in hauls between 700 and 1000 m.

For some of the filmed species, the known bathymetric range was also extended as for *T. helolepis*, filmed at 363 m, above the known minimum depth of 500 m (Kong & Melendez 1991). The granulate dogfish *Centroscyllium granulatum* was registered in the southeast Pacific only south of 33°S and in depths between 262 and 480 m (Bustamante et al. 2014), and is considered a vulnerable species according to the IUCN Red List (Kyne et al. 2020). Thus, the visual record of *C. granulatum* off Punta Pichalo extends the known geographical distribution range by nearly 4° of latitude towards the north (~1000 km) and the vertical range to depths greater than 500 m. However, several specimens of *C. granulatum* appeared during the FAO/PNUD 1988/89 expeditions in trawl catches off Punta Pichalo in 470 and 700 m (Palma 1993), indicating that this shark is common in northern Chile. The other shark observed in the videos was identified as a member of the genus *Eptmopterus*. So far, all species of this genus were registered further south between central Chile and Patagonia (Reyes & Hüne 2006) or far off the coast on the seamounts of the Nazca Ridge (Parin et al. 1997, Compagno et al. 2005, Oñate & Pequeño 2005). The register of *Bathyraja peruana* off Punta Pichalo is the northernmost for this species in Chile and the deepest record in Chilean waters, according to Bustamante et al. (2014), indicating the presence of *B. peruana* in the area between 29 and 39°S and the depth range with 243-484 m.

The present study covered the depth strata between 200 and 800 m, which is considered an important transition zone between the shelf and the deeper slope fauna (Brown & Thatje 2014). Improving knowledge about the biodiversity of these less explored depths is important. Data on species composition, diversity, and geographic distribution of marine species is a central issue in understanding marine ecosystems' ecological patterns, especially considering that climate change already alters these ecological patterns on a global scale. Recently, visual registers of invertebrates and fishes significantly improved the knowledge about Rapa Nui (Easter Island) and Desventuradas Ecoregions marine biodiversity (Friedlander et al. 2013, Mecho et al. 2019, Tapia et al. 2021b). They are enforcing the creation of large MPAs around Rapa Nui and Desventuradas islands to configure management plans to administrate the conservation of the recently created marine parks (Aburto et al. 2020). In this sense, the present study supports the ongoing attempts of the Chilean government to increase the MPAs by adding coastal waters to the existing large oceanic marine parks (Aburto et al. 2020). A few years ago, the local government in the Tarapaca Region, together with the NGO Oceana, scientists, and local stakeholders, planned to decree the area south and north of Punta Pichalo and the Pisagua Bay as a coastal marine protected area (CMPA) of multiple uses. One of the critical points to designing such MPAs is to define the limit toward the open sea. A comparable high diversity on the upper continental slope and shelf margin represent an important argument for decision-makers to extend these areas towards the continental slope. Coastal ecosystems are linked by species migration with the deeper habitats on the continental slope (Brown & Thatje 2014, O'Leary & Roberts 2018). Octocorals such as the sea pens filmed about 12 nm away from the coast are accepted as species of high importance for marine conservation due to the associated fauna (Greathead et al. 2015) and considered as important for the sustainability even of nearby shallow coastal marine ecosystems (Bastari et al. 2018). In this sense, our findings may contribute to any future conservation plans for the area around Punta Pichalo, allowing us to protect widely distributed and vulnerable species, such as macrourid deep-sea fishes, elasmobranchs, and typical deep-sea corals.

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