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Short Communication

First report of sea cucumber species (Holothuroidea: Holothuriidae) in Matanchén Bay, México

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ABSTRACT. Sea cucumbers (holothuroids) play a major role in coastal environments; their detritivore conduct favors oxygen penetration in the sediments and the disposal of pathogens on the sea floor. This study determined holothuroid diversity in the rocky intertidal zone of Matanchén Bay, Mexico. Sampling campaigns were carried out in January, March, May, and July 2018. Linear transects (10 m length and 1 m width) perpendicular to the coastline in rocky areas (0-3 m depth) were established, where the density (ind m^{-2}) and proportion (%) of sea cucumbers were estimated. Organisms were photographed, examined live, and preserved in 70% alcohol for subsequent identification utilizing ossicle characterization. Our results show the presence of four sea cucumber species: *Holothuria* (*Halodeima*) *inornata* Semper, 1868, *Holothuria* (*Selenkothuria*) *lubrica* Selenka, 1867, *Holothuria* (*Selenkothuria*) *portovallartensis* Caso, 1954, and *Holothuria* (*Mertensiothuria*) *viridiaurantia* Borrero-Pérez & Vanegas-González, 2019. The average density per species was 0.208, 0.108, 0.017, and 0.025 ind m^{-2}, respectively; each species' proportion was 58.1, 30.2, 4.7, and 7.0%, respectively. Due to the above values, we found that the number and spatial distribution of sea cucumber species vary in Matanchén Bay.

Keywords: Holothuroidea; holothuroids; intertidal zone; diversity; density; Matanchén Bay, México

Sea cucumbers (holothuroids) inhabit a wide range of habitats, from shallow coastal sandbanks to abyssal trenches (Jamieson et al. 2011). Most species are distributed in the benthos, residing on sandy shores, between rocks, seagrass, and coral reefs (Santos-Beltrán & Salazar-Silva 2011), usually presenting scarce movement. Currently, holothuroids are exploited for human consumption and pharmaceutical use, being commercialized globally, especially in Asian countries such as Japan and China (Solís-Marín et al. 2009). In Mexico, holothuroids are considered to be overexploited, which has reduced their fisheries significantly, generating control measures against their exploitation (Espinoza-Tenorio et al. 2012). *Isostichopus fuscus* and *Holothuria inornata* have been cataloged as depleted. They are included in NOM-059-ECOL-2001, which has resulted in the search for other sea cucumber species and areas for their exploitation, including Jalisco, Nayarit, Sinaloa, and Sonora (Espinoza-Tenorio et al. 2012). Consequently, expanding the knowledge of this group of echinoderms is important, which will contribute to building the groundwork and understanding of holothuroid distribution for management purposes.

In contrast with the Gulf of California, where targeted sea cucumber fisheries have been recorded (Salgado-Rogel et al. 2009), there are no reports of sea cucumber fisheries for the State of Nayarit, even though

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the presence of holothuroids on its coasts is evident. For instance, out of the 68 sea cucumber species reported in the Mexican Pacific, 10 are registered in Isabel Island, Nayarit (Ríos-Jara et al. 2008), while for Bahía Banderas, Nayarit, Santos-Beltrán & Salazar-Silva (2011) reported 12 species. The coasts of Nayarit are close to the entrance of the Gulf of California, hence, dominated by the effects of the Gulf Currents (cold water) and the North-Equatorial current (warm water) (Pantoja et al. 2012). These oceanographic conditions granted the coasts of Nayarit exceptional physico-chemical and biological characteristics, which are not displayed in the north and south Mexican Pacific, where the greatest number of studies of echinoderms of Mexico have been developed. According to Spalding et al. (2007), coastal zones should be classified into ecoregions, as they reflect a good spatial resolution for species, allowing comparisons with the conditions of other biogeographic regions. In this case, our assessment was conducted in Matanchén Bay, Nayarit, located within the Cortezian marine ecoregion, with conditions similar to those of the Magdalena transition and the Mexican Tropical Pacific. Therefore, our hypothesis suggests that the sea cucumber species found in Matanchén Bay are similar to those of the latter two marine ecoregions.

The state of Nayarit accounts for two bays with rocky intertidal zones: Jaltemba Bay and Matanchén Bay; therefore, this study used the latter as a proxy. Matanchén Bay is located in the municipality of San Blas, Nayarit, Mexico, in the intermediate zone of the state. This bay has a coastline extension of 15.7 km, with beaches varying between rocky and sandy areas. The climate in this area is warm subhumid with rains in summer, and the temperature ranges from 22-30°C (Cepeda-Morales et al. 2017). For sampling, we subdivided Matanchén Bay into three sites (Playa las Islitas, Mal Paso, and Plaza Aticama) with rocky shores to ensure the presence of holothuroids.

Playa las Islitas (21°30'43"N, 105°14'59"W) is located in the northernmost area of this study, which was delimited by a polygon of 203×50 m, parallel and perpendicular, respectively, to the coastline. This site is shaped by pocket beaches separated by cliffs and rocky formations. A fine texture characterizes the sand in this site with a greyish color, and the coastline manifests a soft surf. Mal Paso (21°29'16"N, 105°11'52"W) comprises a rocky area, in this study, encompassed by 350×50 m, parallel and perpendicular, respectively, to the coastline. It is shaped by an extension of rocks located at higher depths, accompanied by small extensions of macroalgae forests (mainly *Padina caulescens*) and a continuous current derived from the north. Finally, Plaza Aticama (21°28'39"N, 105°12'10"W) is a coastal zone situated in the Aticama community, with substantial extensions of rocky areas in the sampling site, which in this study was delimited within a polygonal extent of 370×200 m, parallel and perpendicular, respectively, to the coastline. Plaza Aticama is an area dominated by the macroalgae *P. caulescens*.

Sampling was carried out in January, March, May, and July of 2018 in the three sampling sites of Matanchén Bay. Specimens were collected along five linear transects of 10 m length and 1 m width (transect area of 10 m^2) per site, which were placed perpendicularly to the coastline and inside the intertidal zone during low tide to optimize sampling effort. At each site, specimens were quantified, photographed (FINEPIX XP90), and deposited in sea water supplied by a magnesium chloride 30 g L^{-1} dissolved solution to relax the specimens, following Heasman et al. (1995). Samples were transported (transportation period lasted between 15-30 min) to the laboratory of Producción de Alimento Vivo of Escuela Nacional de Ingeniería Pesquera. Later, photographed and transferred into three fiberglass tanks of 100 L capacity with filtered seawater (1 µm), continuous aeration, and a normal circadian cycle. The population density was estimated for each sampling site during the sampling period using the following formula: $D = N_i/A_t$, where N_i is the total number of individuals per transect surface area, and A_t is the total area (m^2) of each sampled transect.

The US National Research Council's technique guidelines for the care and use of laboratory animals were followed for manipulation and specimen preservation. Morphological revision of each specimen was conducted *in vivo*, where the specimens were photographed. Each individual was submerged in a 10% formol solution followed by submersion in 40% alcohol. Fragments of 0.5 cm were extracted with a scalpel from the mid-ventral region for ossicle observation and identification. Each fragment was deposited in 15 mL test tubes and treated with 6% sodium hypochlorite for tissue degradation. After 5 min, samples were prepared for observation in a compound microscope (Optika E-pL) attached to a camera (P'Tikam B5), where ossicles were photographed. Subsequently, organisms were stored for posterior analyses. Species were identified using the taxonomical keys assembled by Solís-Marín et al. (2009) and Santos-Beltrán & Salazar-Silva (2011) and described by Semper (1868).

In this study, the holothuroid biodiversity of Matanchén Bay was analyzed in three sampling sites.

Table 1. *Holothuria* spp. distribution, density (ind m^{-2}), and proportion at three sampling sites in Matanchén Bay, Nayarit. -: not registered. Values are means ± standard deviations; values with different superscripts within a column are significantly different ($P < 0.05$).

Species	Sampling site	Month				Density (ind m^{-2})	Proportion (%)
		Jan	Mar	May	Jul		
Holothuria inornata	Las Islitas	17	2	-	3	$0.208^{a} \pm 0.14$	58.1^{a}
	Mal Paso	8	2	-	20		
	La Plaza Aticama	-	6	25	40		
Holothuria lubrica	Las Islitas	30	10	-	1	$0.108^{a} \pm 0.08$	30.2^{b}
	Mal Paso	5	5	20	-		
	La Plaza Aticama	-	4	-	1		
Holoturia viridiaurantia	Las Islitas	-	-	-	13	$0.017^{b} \pm 0.01$	4.7^{c}
	Mal Paso	-	-	-	-		
	La Plaza Aticama	-	-	-	-		
Holoturia portovallartensis	Las Islitas	-	-	-	5	$0.025^{b} \pm 0.04$	7.0^{c}
	Mal Paso	-	-	-	-		
	La Plaza Aticama	-	-	-	-		

All individuals belonged to the genus *Holothuria*, and four species were identified morphologically: *Holothuria* (*Halodeima*) *inornata* Semper, 1868, *Holothuria* (*Selenkothuria*) *lubrica* Selenka, 1867, *Holothuria* (*Selenkothuria*) *portovallartensis* Caso, 1954, found at all sampling sites, and *Holothuria* (*Mertensiothuria*) *viridiaurantia* Borrero-Pérez & Vanegas-González, 2019 only found in Playa las Islitas. This latter site showed the highest diversity and density of species, with slight variations among sampling months (Table 1).

Holothuria inornata: the specimens collected were 30-35 cm of relaxed length. The body shape was cylindrical, with ambulacral cylindrical feet scattered in the dorsal area. The dorsal surface presented small reddish papules in six rows; three polian vesicles, table-shaped and bar-shaped ossicles were observed mostly on the ventral side of the body. Regarding the dorsal region, abundant table-shaped ossicles were present (Fig. 1). Under these observations, and following the taxonomical keys, the specimens were identified as *H. inornata*.

Holothuria lubrica: the specimens collected were 5-15 cm of relaxed length. The body shape was long and cylindrical, covered with scattered brown colored and yellow pigments papillae. A calcareous ring built by radial high and robust V-shaped structures with 20 plate-shaped tentacles with dark green ambulacral feet shaped in longitudinal bands, small and abundant bar-shaped spiny ossicles assembled in a C resembling structure (Fig. 2). Under these observations, and with the support of the taxonomical keys, the specimens were identified as *H. lubrica*. This species was present at all three sampling sites; previous evaluations of the Mexican Pacific reveal its presence in intertidal zones with a broad distribution in Isla Isabel, Mexico (Ríos-Jara et al. 2008), which is the closest assessed zone (76 km) to Matanchén Bay. The proximity to the Gulf of California and the current recirculation processes that concur in this area induce conditions that allow the presence of species such as *H. lubrica*, which occurs extensively along the Gulf of California, Jalisco, Guerrero, and Oaxaca (Santos-Beltrán & Salazar-Silva 2011).

Holothuria portovallartensis: this species was found in Playa las Islitas. The body was subcylindrical with 12 tentacles, inconspicuous dorsal papillae, and ambulacral feet showing three bands in their structure. Barely visible radii and triradiate and placoid bar-shaped ossicles (Fig. 3). Under the previously mentioned information and guided by the taxonomical keys, the specimens were identified as *H. portovallartensis*. This species was only observed in Playa Las Islitas, situated in the northernmost region of Matanchén Bay, closer to the mouth of the Gulf of California. Additionally, water input from the outlet of San Cristobal River, located 1200 m from this beach, could have promoted diversity variations when comparing this site with the other two evaluated sites. According to Domínguez-Godino & González-Wangüemert (2019), environmental shifts in the seawater modify the physiological development of holothuroid species, which in this case could explain the higher diversity and lower abundance levels in this

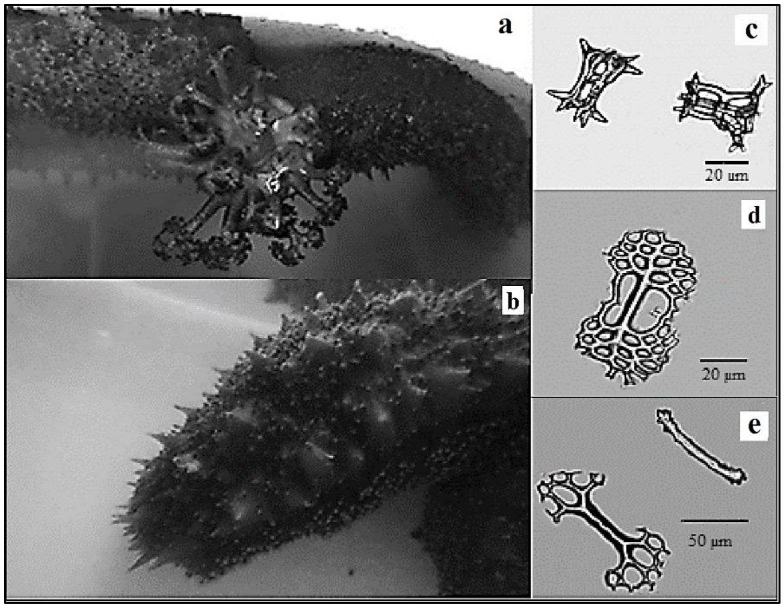

Figure 1. a) *Holothuria inornata*, 20 well-defined plate-shaped tentacles with divisions, b) ventral region of the specimen with reddish conical papillae, c) table-shaped ossicles observed from the dorsal region, d) table-shaped ossicles, e) bar-shaped and plate-shaped ossicles.

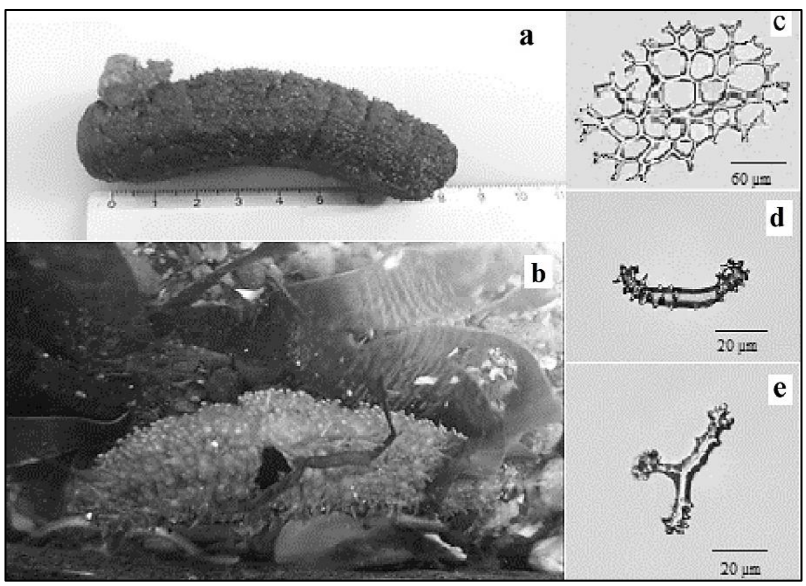

Figure 2. a-b) *Holothuria lubrica*, 20 terminal tentacles are shown. Three different ossicle configurations: c) terminal plates, d) spiny bar-shaped with an E-resembling structure, e) bifurcated bar-shaped ossicle.

sampling site. In agreement with Santos-Beltrán & Salazar-Silva (2011), the closest area where *H. portovallartensis* has been found is Banderas Bay, México, with no previous records in the studied area.

Holothuria viridiaurantia: according to our assessment of the three sampling sites, specimens of this species were only found in Playa las Islitas in July. Specimens collected were 13 cm relaxed in length. The body shape was cylindrical with short and thick papillae with reddish terminations, a simple calcareous ring, two polian vesicles, and a single madreporite. Regular ossicles include circular tables with six to eight elongated orifices and ambulacral feet with an end plate (Fig. 4). These characteristics follow the identification

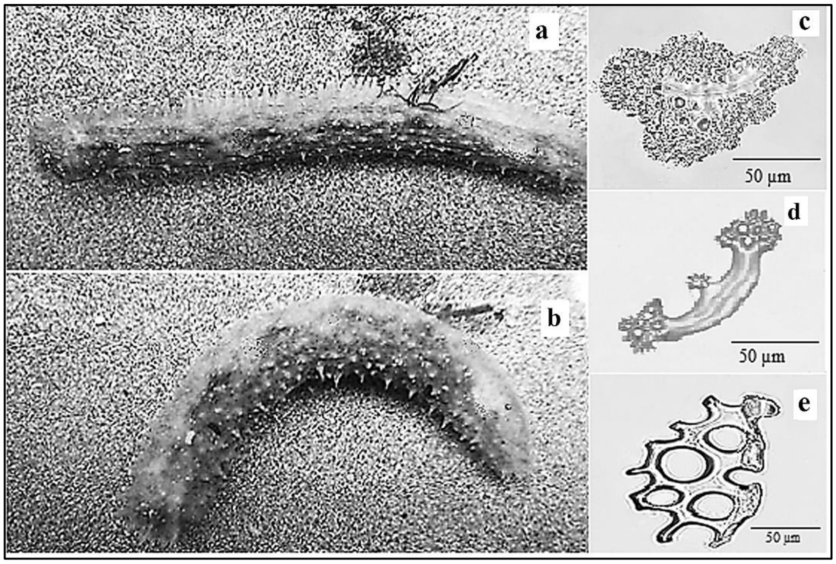

Figure 3. a-b) Live *Holothuria portovallartensis* specimen (15 cm total length), c) triradiate bar-shaped ossicles, d) placoid rod ossicles, e) flattened bar-shaped ossicles, perforated plates with irregular edges.

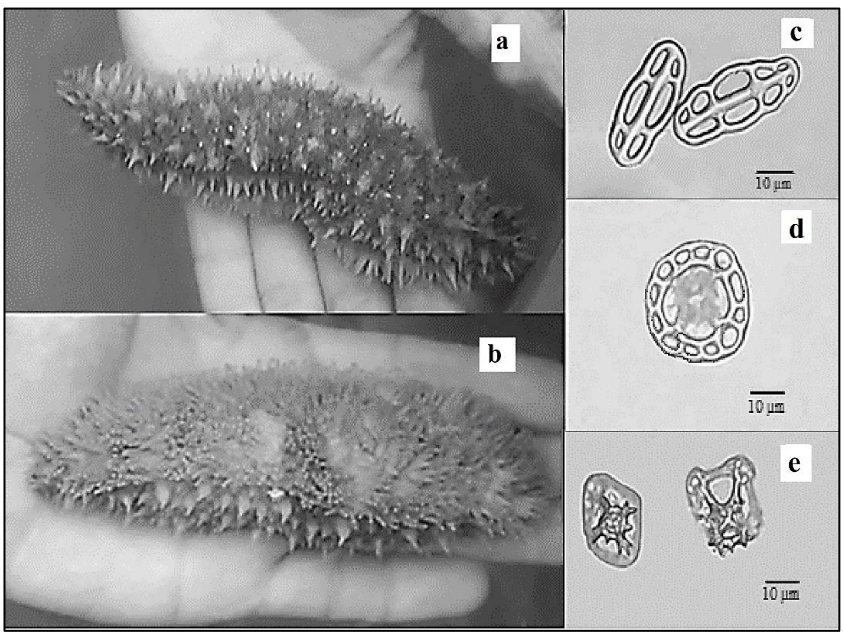

Figure 4. a) Dorsal view of *Holothuria* (*Mertensiothuria*) *viridiaurantia* (13 cm total length), b) ventral view, c) button-shaped elongated ossicles throughout the entire body, d) lower view of a table-shaped ossicle, e) upper view of table-shaped ossicle.

guide described by the taxonomical keys, and the specimens were identified as *H. viridiaurantia*.

Although the distance between the three sampling sites was short (<6.3 km in a straight line), the presence of different species was evidenced, being Playa las Islitas where the greatest diversity was observed. Our results show that four different species of holothuroids can be found in Matanchén Bay. As in this case, some habitat variations generate spatial differences in populations, which has been reported by Eriksson et al. (2012). The greatest diversity of species in Playa las Islitas occurred during July, and additionally, *H. viridiaurantia* and *H. portovallartensis* were found exclusively at this site. The high diversity levels in

Playa las Islitas may be related to the peculiar characteristics of the oligotrophic water in this area. These hydrographic conditions are intensified during July by the presence of organic matter and nutrients dissolved in the water input from the San Cristóbal River caused by the rainy season, as previously mentioned by Pérez-Maqueo et al. (2011). Claereboudt & Al-Rashdi (2011) stated that *H. viridiaurantia* is favored by higher nutrient levels in the water. Since these enhance marine diatom's growth and other essential food supplies, it could have prompted the presence of *H. viridiaurantia* in Playa las Islitas and its absence in the rest of Matanchén Bay. In addition, other conditions such as the sediment input from the mouth of the San Cristobal River, sunlight, temperature, and nutrient availability may have promoted algal growth and, consequently, sea cucumber species to thrive (Huettel et al. 2014, González-Gándara et al. 2015). Furthermore, the presence of sandy zones between coralline and rocky areas favors the occurrence of irregular echinoids and holothuroids, which is related to the feeding habits of both groups, as they depend upon filtration methods or sand foraging to acquire their food (González-Gándara et al. 2015).

The conditions and diversity of Mal Paso and La Plaza Aticama share similarities in their rocky areas and water currents, which directly influence the observed species of both sites. Heterogeneity is a general characteristic of marine assemblages and could explain the aggregation of the species found in these sites, as Shiell & Knott (2010) reported. Matanchén Bay (all sampling sites included) is found in an oceanic transition zone, where species from the Mexican north and south Pacific converge, with mixed subtropical temperature conditions throughout summer and autumn (Padilla-Pérez et al. 2017). These conditions provide a heterogeneous cover for corals, rocks, and sandy areas, which allows the settling and recruitment of larvae for different marine invertebrate species. In contrast with our research, a previous study (i.e. Ríos-Jara et al. 2008) assessing the sea cucumber diversity in Isabel Island, the closest surveyed zone to Matanchén Bay, did not record *H. inornata*, *H. viridiaurantia*, and *H. portovallartensis*. Moreover, the second closest site to our study area where the sea cucumber diversity was characterized in Bandera Bay, Nayarit, where the four holothuroid species identified here were recorded and other sea cucumber species (Santos-Beltrán & Salazar-Silva 2011).

This research provides the first results of the four holothuroid species inhabiting the intertidal zone of Matanchén Bay, Nayarit, which was identified as *Holothuria* (*Halodeima*) *inornata*, *Holothuria* (*Selenkothuria*) *lubrica*, *Holothuria* (*Selenkothuria*) *portovallartensis* and *Holothuria* (*Mertensiothuria*) *viridiaurantia*. Although this study was restricted to three rocky intertidal areas of Matanchén Bay, a typical habitat for sea cucumbers, we increased the knowledge of biogeographic aspects associated with the species evaluated. Furthermore, their taxonomic richness and distribution will contribute to establishing the foundations for management plans and fishery regulations to protect this resource.

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