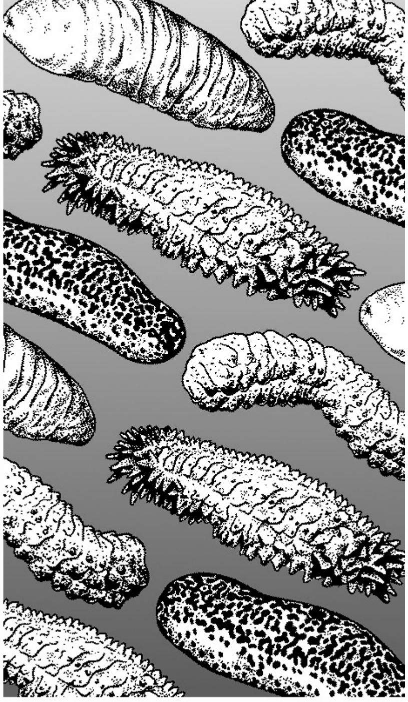

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Editorial

This 41th issue of the SPC *Beche-de-Mer Information Bulletin* includes 16 original articles and scientific observations from a wide variety of regions around the world. We first want to express our congratulations to Dr Marie Bonneel, Dr Cathy Hair and Dr Hocine Benzait who recently received their PhDs. Dr Bonneel received her PhD from the University of Mons in Belgium, and her dissertation is titled "Sea cucumbers as a source of proteins with biomimetic interest: Adhesive and connective tissue – stiffening proteins from *Holothuria forskali*". Dr Hair received her PhD from James Cook University in Australia, and the title of her dissertation is "Development of community-based mariculture of sandfish, *Holothuria scabra*, in New Ireland Province, Papua New Guinea". Dr Benzait received his PhD from the Université de Mostaganem in Algeria, and his dissertation is titled "Ecologie, dynamique de la population et reproduction d'*Echinaster sepositus*, *Ophioderma longicauda* et de *Parastichopus regalis* au niveau de la côte de Mostaganem".

The first article by Simone et al. (p. 3) recalls that at the last meeting of the Conference of the Parties to CITES in August 2019, three species of teatfish were included in CITES Appendix II. This inclusion has opened the door for potential new species listings.

The next four articles are original research contributions. Two articles are from Murphy et al. One (p. 5) provides updated conversion ratios for beche-de-mer species in Torres Strait, Australia. These values are useful for stock assessments, management and monitoring of the beche-de-mer fishery in Australia. In their second article (p. 8), the authors show the results of a field survey of eastern Torres Strait where they used a remotely operated vehicle to survey sea cucumbers. Ram et al. (p. 12) investigates the effect of salting time on the collagen content of the body wall of *Holothuria scabra*. They observed that after 72 hours of salting, collagen fibers are almost totally destroyed and disappear from the body wall of sandfish. The analysis of *Parastichopus regalis*'s digestive content, by Elakkermi et al. (p. 15), reveals that it includes mostly fine sedimentary particles and that a very small part is composed of foraminiferans, annelids, fragments of mollusc shells, sponge spicules, echinoderm ossicles, diatoms and cyanobacteria.

The next three articles concern field observations. Tanita et al. (p. 19) observed several juvenile teatfish showing intermediate ventral colour morphs and provide illustrations of these variations. Schagerström and Sundell (p. 22) and

Christophersen (p. 25) describe the biology of *Parastichopus tremulus* whose distribution is in the northeast Atlantic Ocean, mainly along the Norwegian and Swedish coasts. This species shows significant potential as a commercial product for the Chinese market. Mulochau et al. (p. 37) provide us with some extraordinary photos of a green turtle looking for and eating *Synapta maculata* in seagrass and coral blocks at Reunion Island.

Two articles follow, and relate past stories about sea cucumbers. I first describe the history of *Holothuria scabra* aquaculture in Madagascar and talk about the history behind the creation of Indian Ocean Trepang, which is becoming one of the largest sandfish aquaculture companies in the world (p. 40). Solís-Marín et al. (p. 46) then tells us an extraordinary story where sea cucumber ossicles were found in a ritual deposit of consecration, found 2 m below the monolith of the Earth goddess Tlaltecuhtli (Mexico). They have identified vestiges of 20 species of echinoderms, including five species of sea cucumbers.

Sea cucumber crimes in India and Sri Lanka are analysed by Bondaroff (p. 55). Similarly, Rodriguez-Forero (p. 66) explains the situation in Colombia, and the interest in developing a blue economy programme in that country. Mezali et al. (p. 69) show us the results of a survey in Algeria for analysing consumer behaviour to introduce sea cucumbers on the local Algerian market.

González-Wangüemert (p. 79) describes WANGUMAR, a new consultancy company linked to sea cucumber fisheries and aquaculture in the Mediterranean and northeast Atlantic regions. Lovatelli (p. 81) announces the second edition of the global guidebook for identifying commercially exploited sea cucumbers, and kindly invites people to contribute to it.

Also included in this issue are various communications (p. 79) about publications and PhD dissertations. This issue is the first where we present English and French sections. The article by Simone et al. in English, also appears in French (p. 73). Finally, Sohou et al. (p. 75) give us, for the first time, information on sea cucumber fishing in Benin (West Africa).

I deeply thank Kim Des Rochers for her editing and proofreading work on the articles in English.

Igor Eeckhaut

Sea cucumbers – mysterious offerings to Mexica gods

Francisco Alonso Solís-Marín,[1] Leonardo López Luján,[2] Andrea Alejandra Caballero-Ochoa,[3] Carlos Andrés Conejeros-Vargas,[4] Tayra Parada Zárate[4] and Belem Zúñiga-Arellano[2]

Abstract

Tenochtitlan offerings (AD 1325–1521) were buried by the Mexica priests inside religious buildings and under the plaza floors in order to consecrate the enlargements of their temples, to commemorate special festivities, or to appease their gods. Each one of these offerings contained all kinds of gifts, including raw minerals, plants, animals, human remains and artifacts. In the last 10 years, and thanks to the careful recovery and analysis of all kinds of materials found at the bottom of the offerings, we have identified vestiges of 20 species of echinoderms: 6 species of starfish, 1 species of brittle star, 8 species of sea urchins and 5 species of sea cucumbers (*Neothyone gibbosa*, *N. gibber*, *Pachythyone lugubris*, *Neopentamera anexigua* and *Isostichopus fuscus*). The latter species were identified from dermal ossicles found at the lowest level of ritual deposit of consecration (offering 126), found 2 m below the monolith of the Earth goddess Tlaltecuhtli. Spatial analysis of the offering made it clear that the Mexica priests distributed the gifts in a patterned way to create a cosmogram; that is, a miniature model of a large section of the universe according to the prevailing religious conceptions.

Key words. Zooarchaeology, Tenochtitlan, Mexico City, ossicles, faunal remains, religious ceremonies

Like many Mesoamerican cultures, the Mexicas used to bury rich offerings in their main places of religious worship. In general, they did so on the occasion of significant events for the State, such as the construction and remodelling of religious buildings, the opening of sculptural monuments, the end of time cycles, the rites of passage of the sovereigns, war victories and natural catastrophes. Animal remains are a common feature of archaeological discoveries from around the world and are present in different cultures and periods of time. Archaeozoology is defined as the study of faunal remains left behind when an animal dies on an archaeological site, and includes bones, shells, hair, scales, proteins, and sometimes DNA (Kalof 2012).

Tenochtitlan offerings (AD 1325–1521) were buried by the Mexica priests inside religious buildings and under plaza floors. Each of these offerings contained all kinds of gifts, including raw minerals, plants, animals, human remains and artifacts (López Luján 2005). In terms of animals, archaeologists and biologists have identified the remains of more than 500 species associated with Tenochtitlan's Templo Mayor, corresponding to six different phyla: Porifera, Cnidaria, Echinodermata, Arthropoda, Mollusca and Chordata, the latter with six classes (Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves and Mammalia). There is a clear predominance of species endemic to regions quite far away from the Basin of Mexico, where Tenochtitlan is located. These were imported by the Mexicas from practically all corners of the empire and beyond, and from contrasting ecosystems such as tropical forests, temperate zones, marine environments, estuaries, coastal lagoons and mangrove swamps. The scarcity of edible species reveals the clear interest on the part of priests in those animals that were attributed with profound religious or cosmological significance (López Luján et al. 2014). In the last 10 years, and thanks to the careful recovery and analysis of all kinds of materials found at the bottom of the offerings, we have identified vestiges of 20 species of echinoderms (Table 1).

In 2010, a group of researchers from the Institute of Marine Sciences and Limnology (ICML) at the Universidad Nacional Autónoma de México (UNAM), and the Templo Mayor Project (PTM), Instituto Nacional de Antropología e Historia, began a fruitful collaboration to study marine organisms, and specifically echinoderms, that had been recovered during archaeological excavations carried out at the base of the main pyramid of Tenochtitlan. These materials, of incalculable scientific value, come from the ritual deposits buried by the Mexicas in the 15th and 16th centuries inside religious

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Table 1. Species of echinoderms found in the offerings of the Templo Mayor, Tenochtitlan (modern Mexico City).

Class Asteroidea
Astropecten regalis Gray, 1840
Astropecten duplicatus Gray, 1840
Luidia superba A.H. Clark, 1917
Phataria unifascialis (Gray, 1840)
Nidorellia armata (Gray, 1840)
Pentaceraster cumingi (Gray, 1840)
Class Ophiuroidea
Ophiothrix rudis Lyman, 1874
Class Holothuroidea
Neopentamera anexigua Deichmann, 1941
Neothyone gibbosa Deichmann, 1941
*Neothyone gibbe*r (Selenka, 1867)
Pachythyone lugubris (Deichmann, 1939)
Isostichopus fuscus Ludwig, 1874
Class Echinoidea
Eucidaris thouarsii (L. Agassiz & Desor, 1846)
Toxopneustes roseus (A. Agassiz, 1863)
Echinometra vanbrunti A. Agassiz, 1863
Clypeaster speciosus Verrill, 1870
Encope laevis H.L. Clark, 1948
Mellita notabilis H.L. Clark, 1947
M. quinquiesperforata (Leske, 1778)
Meoma ventricosa grandis Gray, 1851

buildings and under the plaza floors of their sacred precinct. It is still possible to detect them because they were protected inside ashlar boxes covered with slabs, or in cavities dug in the construction fill and then sealed with slabs or stucco floors.

In the first phase, our team – comprising biologists, restorers and archaeologists – focused our efforts on the analysis of the remains of starfish (class Asteroidea) and brittle stars (class Ophiuroidea), which are observed in the excavation as concentrations of disarticulated calcareous plates. After a long learning process and multiple comparative examinations, we were able to identify six species of starfish, of which five came from the northeastern Pacific (*Luidia superba*, *Astropecten regalis*, *Phataria unifascialis*, *Nidorellia armata*, *Pentaceraster cumingi*) and one from the Atlantic (*A. duplicatus*), together with a brittle star from the Pacific (*Ophiothrix rudis*) (Martín-Cao-Romero et al. 2017; López Luján et al. 2018; Zúñiga-Arellano et al. 2019). The surprising results of this work were soon made known through conferences for the general public, presentations at specialist meetings, museographic and photographic exhibitions, as well as in a series of popular and scientific publications. For the second phase, we focused on the remains of echinoderms, mainly on those belonging to the class Echinoidea. In this case, we were able to identify eight species (*Echinometra vanbrunti*, *Eucidaris thouarsii, Toxopneustes roseus*, *Clypeaster speciosus*, *Encope laevis*, *Mellita notabilis, M. quinquiesperforata* and *Meoma ventricosa grandis*). All but one (*M. quinquiesperforata*) have a northeastern Pacific distribution (Zúñiga-Arellano et al. 2019). The third and most recent phase of research is still in process but has already yielded important results. This phase is focused on sea cucumbers (class Holothuroidea). So far, we have identified five species that we will report for the first time in this work.

Methodology

Sea cucumber ossicles were found at the lowest level of offering 126, an ashlar box found 2 m below the monolith of the Earth goddess Tlaltecuhtli (AD 1486–1502) (Figs. 1–3). After being described in their original contexts, all of these microscopic holothurian remains were collected using Eppendorf tubes, labelled, and recorded in a database. Later, they were carefully isolated, cleaned and dried in the laboratory, then placed in a scanning electron microscope (SEM) sample holder, sputter coated with gold 2.5 kV in the ionizer Polaron E3000 for 3 min, and photographed using a Hitachi S–2460N SEM. The examined material is deposited in the Museo del Templo Mayor in Mexico City. They were then separated according to their differential morphology. We distinguished various shapes (buttons, tables, and rods) of the ossicles, which enabled us to begin the genus and species identifications using taxonomic keys such as those of Deichmann (1941, 1958). We compared our archaeological remains to those found in modern specimens collected in Mexican waters and stored in the National Echinoderm Collection (NEC) ICML, UNAM.

Results

Systematics

Five species of sea cucumber were found in offering 126 at the Templo Mayor of Tenochtitlan (modern Mexico City):

Phylum Echinodermata Bruguière, 1791

Class Holothuroidea

Order Dendrochirotida Grube, 1840

Family Sclerodactylidae Panning, 1949

Genus *Neothyone* Deichmann, 1941

Neothyone gibbosa Deichmann, 1941

Neothyone gibber (Selenka, 1867)

Genus *Pachythyone* Deichmann, 1941

Pachythyone lugubris (Deichmann, 1939)

Genus *Neopentamera* Deichmann, 1941

Neopentamera anexigua Deichmann, 1941

Order Aspidochirotida Grube, 1840

Family Stichopodidae Haeckel, 1896

Genus *Isostichopus* Deichmann, 1958

Isostichopus fuscus Ludwig, 1874

Neothyone gibbosa Deichmann, 1941

Figure 1. Earth goddess monolith on offering 126, located at the old Mayorazgo de Nava Chavez urban ground, Mexico City. (Scan 3D by Saburo Sugiyama, courtesy of the Templo Mayor Project)

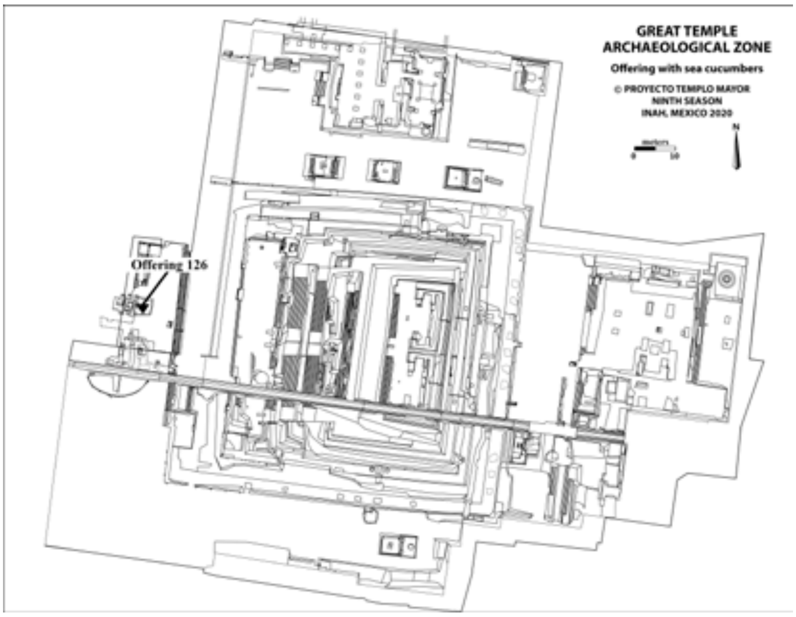

Figure 2. Map of offering 126 at the archaeological zone in the Templo Mayor.

Figure 3 Offering 126 was the ritual deposit for the consecration of the monolith of Tlaltecuhtli. (Courtesy of Templo Mayor Project)

Fig. 4A, 1–4.

Description. When adult, body size varies from 2 to 5 cm. U-shaped body, with the posterior end smaller than the anterior. Thin and rough skin due to the presence of a large number of spicules, tube-like feet covering the entire body. Dark grey to reddish, with darker tentacles.

Description of the archaeological elements. Eroded knobbed buttons from the body wall (Fig. 4A, 1, 2, 4), supporting table from a tube foot (Fig. 4A, 3).

Geographic and bathymetric distribution. From Baja California Sur, Sonora, Sinaloa, Guerrero, Mexico (Fig. 5); El Salvador; Costa Rica; Ecuador to Peru. From 0 to 50 m depth.

Habitat. This species is usually found in cavities or crevices within hard substrates such as large rocks, associated with pieces of dead coral and under large stones that move very little. This species practically never moves and lives aggregated in small populations.

Neothyone gibber (Selenka, 1867)

Fig. 4B, 1-5.

Description. When adult, body size varies from 4.5 to 8.0 cm. U-shaped body, with rounded ends, thick and rough skin due to the large number of spicules present, tube feet more abundant in the terminal areas of the body. Yellowish to white skin, with brown stripes along the body. Front end and tentacles are brown or slightly purple.

Description of the archaeological elements. Eroded supporting tables from tube feet (Fig. 4B, 1, 2, 4), body wall knobbed buttons (Fig. 4B, 3, 5).

Geographic and bathymetric distribution. From Baja California Sur through Guerrero and Oaxaca, Mexico (Fig. 5), to Isla de Lobos de Afuera, Peru. From 0 to 50 m depth.

Habitat. Usually found in hollows of hard substrates such as rocks, associated with pieces of dead corals and in some areas with little a sand. They hide under stones of different sizes.

Pachythyone lugubris (Deichmann, 1939)

Fig. 4C, 1–2.

Description. Adults reach a total length of from 2 to 5 cm. U-shaped body, thin skin, with numerous tube feet covering the entire body, those on the ventral surface larger than those on the dorsal area. With yellow to brown colourations.

Description of the archaeological elements. Eroded supporting table from a tube foot (Fig. 4C, 1) and knobbed button from the body wall (Fig. 4C, 2).

Geographic and bathymetric distribution. From Bahia Magdalena and "Isla Cerros", Baja California, through Baja California Sur, to Oaxaca, Mexico (Fig. 5). From 18 to 73 m depth.

Habitat. The species inhabits crevices within hard substrates such as large rocks and under large stones. The species is practically sessile. As they grow, they tend to erode the substrate to increase the size of the void.

Neopentamera anexigua Deichmann, 1941

Fig. 4D, 1–2.

Description. Body size from 0.5 to 2.0 cm. Body slightly curved, anterior region with the tentacles smaller than the posterior region, thin and flexible skin, abundant tube feet on the ventral surface. Dark skin and white tube feet. The tentacle area is orange or light brown. **Description of the archaeological elements**. Eroded knobbed button from the body wall (Fig. 4D, 1) and smooth supporting table from a tube foot (Fig. 4D, 2).

Geographic and bathymetric distribution. From Baja California, through Baja California Sur, Jalisco to Guerrero, Mexico (Fig. 5). From 8 to 12 m depth.

Habitat. This species is usually found in hollows of hard substrates such as rocks, associated with pieces of dead corals and in some areas with a little sand. They hide under stones of different sizes.

Isostichopus fuscus Ludwig, 1874

Fig. 4E, 1–3.

Description. Adults reach a size of 20 to 28 cm total length. Flat shape ventral side with convex dorsal surface, very robust body with thick edges, mouth directed to the substrate, soft and hard skin, feet on the dorsal surface with the appearance of thick warts, feet on the ventral surface soft and thin. Colour from dark to light brown and greenish in some specimens. Dorsal podia may have lighter shades.

Description of the archaeological elements. Eroded ossicles of the body with C-shaped body (Fig. 4E, 1), table (Fig. 4E, 2) and perforated plate from the body wall (Fig. 4E, 3).

Geographic and bathymetric distribution. From Baja California Sur to Oaxaca, Mexico, through the Revillagigedo Archipelago (Fig. 5), and Central America to the Galapagos Islands, Ecuador. From 0 to 37 m depth.

Habitat. This species is usually found on hard substrates such as large rocks covered by algae and other organisms associated with coral reef systems. In some cases, it hides under stones during the day.

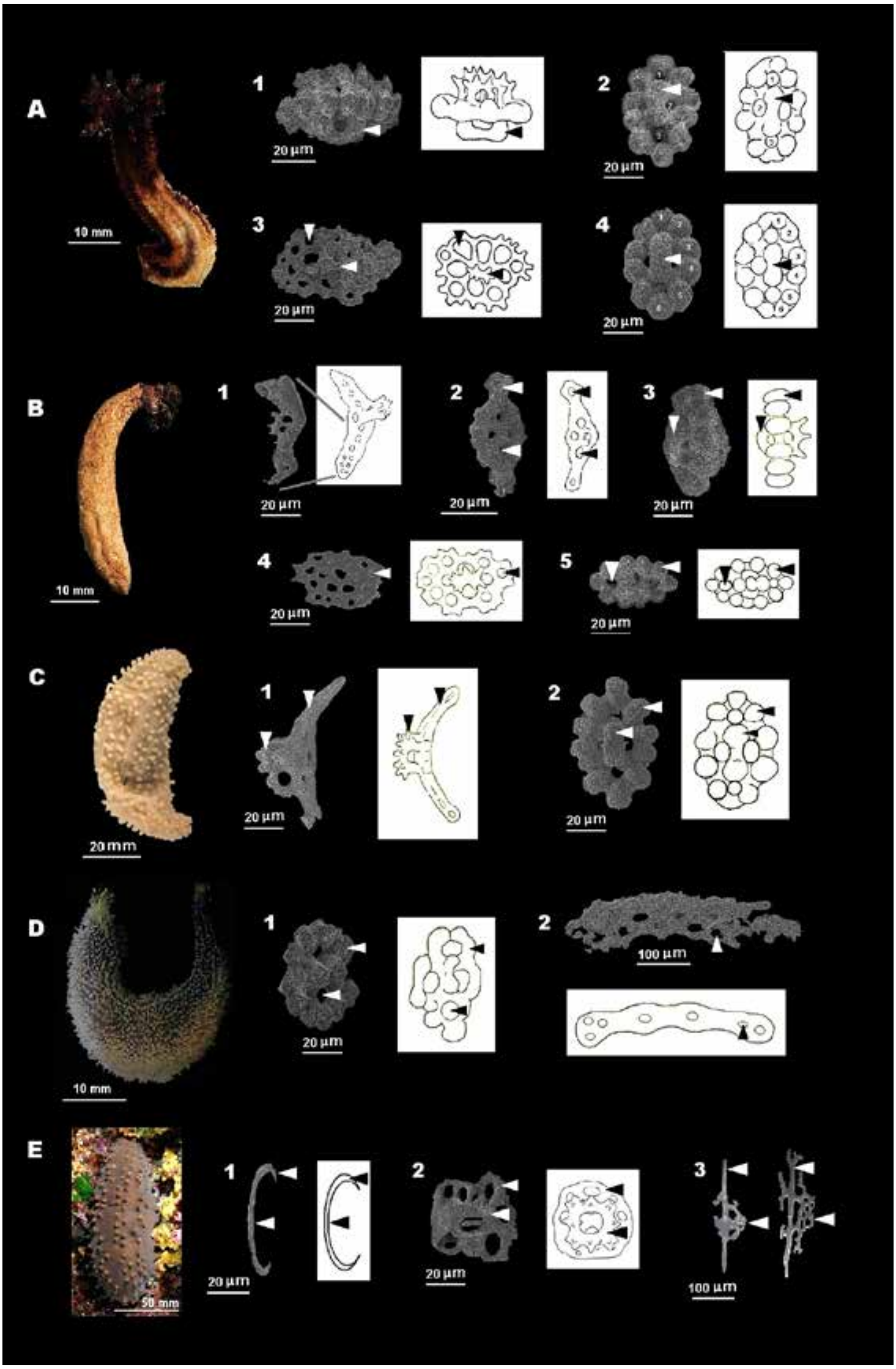

Figure 4. A) *Neothyone gibbosa* Deichmann, 1941. 1. Lateral view of a knobbed button showing the inner handle. 2. Knobbed button. 3. Table. 4. Knobbed button. B) *Neothyone gibber* (Selenka, 1867). 1. Fragment of a supporting table from a tube foot. 2. Supporting table from a tube foot. 3. Knobbed button. 4. Table. 5. Knobbed button. C) *Pachythyone lugubris* (Deichmann, 1939). 1. Lateral view of a supporting table from a tube foot. 2. Knobbed button from body wall. D) *Neopentamera anexigua* Deichmann, 1941. 1. Knobbed button from the body wall. 2. Smooth supporting plate from a tube foot. E) *Isostichopus fuscus* Ludwig, 1874. 1. "C" shaped body. 2. Table. 3. Perforated plate from the body wall. Archaeological elements are represented by SEM photographs, linear drawings were taken from Deichmann (1941, 1958) for comparison.

Discussion

Spatial analysis of the offering made it clear that the Mexica priests distributed the gifts in a patterned way to create a cosmogram, that is, a miniature model of a large section of the universe according to prevailing religious concepts. In the bottom of the box, they first deposited thousands of disarticulated bones and defleshed anatomical segments belonging to mammals, birds and reptiles, according to the detailed study of the bioarchaeologist Ximena Chávez. They then completely covered that first level, which could be described as "skeletal", with a second level of "aquatic" symbolism, made up of very numerous and varied marine animals. They immediately formed a third level with flint knives strung on copal bases. According to the archaeologist Alejandra Aguirre, these represent – through masks, attire and ornaments – a contingent of dead warriors, one a god of rain and another of wind. Finally, in the fourth and uppermost of the levels, the priests represented the Earth's surface with a sawfish rostrum (symbol of the primeval telluric monster) and with seven basalt images of the god of fire, marking with them the three stones of the hearth in the navel of the world and the four cardinal directions. At the same level they arranged gifts of copal, as well as a bowl and a ceramic pot painted blue, the latter full of seeds.

One of the things that amazes us the most about offering 126 is its unusual biodiversity. At the bottom of the box, according to the identification by Ximena Chávez and the mastozoologist Montserrat Morales, there were bones belonging to seven taxa of mammals (28 wolves, 19 lynxes, 15 pumas, 3 jaguars, 1 ocelot, 1 Florida rabbit, 1 deer mouse), birds (5 golden eagles, 4 American owls, 2 red falcons, 1 red-tailed hawk, 1 chicken hawk, 2 quails) and one reptile (1 rattlesnake). At the intermediate levels, all sorts of marine organisms were concentrated. According to the ichthyologist Ana Fabiola Guzman, six Osteichthyes taxa were present there (two needlefish, two globe fish, two shoemaker fish, one cabrilla, one remora, one hunchback). Chondrichthiologists Oscar Uriel Mendoza and Nataly Bolaño concluded that there was only one taxon of cartilaginous fish (two sawfish). Regarding molluscs, the malacologist Belem Zúñiga reported 65 clam taxa (624 individuals), 60 snail taxa (833 individuals) and one polyplacophoran (96 individuals). For his part, marine biologist Pedro Medina recognised four taxa of cnidarians (four gorgonians, three brain corals, one deer horn coral, one elkhorn coral). Finally, with regard to echinoderms, we counted six taxa of starfish (13 individuals), one of regular sea urchin (seven individuals), two of non-regular sea urchins (four individuals), one of brittle star (one individual) and five of sea cucumbers (five individuals). We also detected remains of at least one Porifera taxon (one marine sponge).

The total numbers of the fauna recovered in offering 126 are overwhelming: a minimum of 1688 individuals belonging to no less than 167 taxa, 90.4% of which are of marine origin. Offering 126 possess a truly exhaustive list or complete inventory of the organisms that inhabit that "aquatic world" of absolute fertility that, in the Mexica worldview, is located just below and around the crust of the primeval telluric monster.

Incredible as it may seem, the discovery was made by analysing a sediment sample as small as 1 g under the stereomicroscope and the scanning electron microscope. There, dozens of spicules from the body walls of sea cucumbers appeared. These fragile calcium carbonate structures managed to survive to this day, although highly degraded, thanks to a combination of various environmental factors. During the excavation of offering 126, a flooded context was recorded, where the groundwater had not undergone seasonal level fluctuations that would have triggered leaching processes. The pH of the water was practically neutral (6.8–7.0) and temperature stable (17–19° C), to which we must add that there was a minimum amount of dissolved oxygen, and total darkness.

At present, specimens of these five species of sea cucumber are easy to collect near the beach, free diving no deeper than 20 m deep on the Mexican Pacific (Fig. 5). At the end of the 15th century, it is possible that sea cucumbers were moved to the imperial capital, particularly with ceremonial interest, such is the case of the large brown sea cucumber *Isostichopus fuscus*, which may have been transported live. This implies a minimum distance of 290 km from the coasts of the current Mexican state of Guerrero, which could have been covered by a carrier in 10 to 12 days, according to estimates by archaeologist Kenneth Hirth. The sea cucumbers could have been kept for a long time in the saltwater ponds that existed in the Moctezuma vivarium in Tenochtitlan, awaiting the arrival of the festivity in which they would be buried as an offering in the sacred enclosure. On the other hand, unlike the brown sea cucumber that lives on rocks on the shallow coast, the rest of the species were found buried alive between sand, corals or rocks. There is the possibility that these species were extracted indirectly as an accompanying fauna as they were associated with *Spondylus* shells or large coral heads, organisms that were also found in offering 126.

We obviously expect more discoveries in the near future. For now, it remains for us a lesson of this research phase that, during the process of archaeological exploration of the offerings, we must always recover all the sediments and store them as true treasures for our awaiting analysis.

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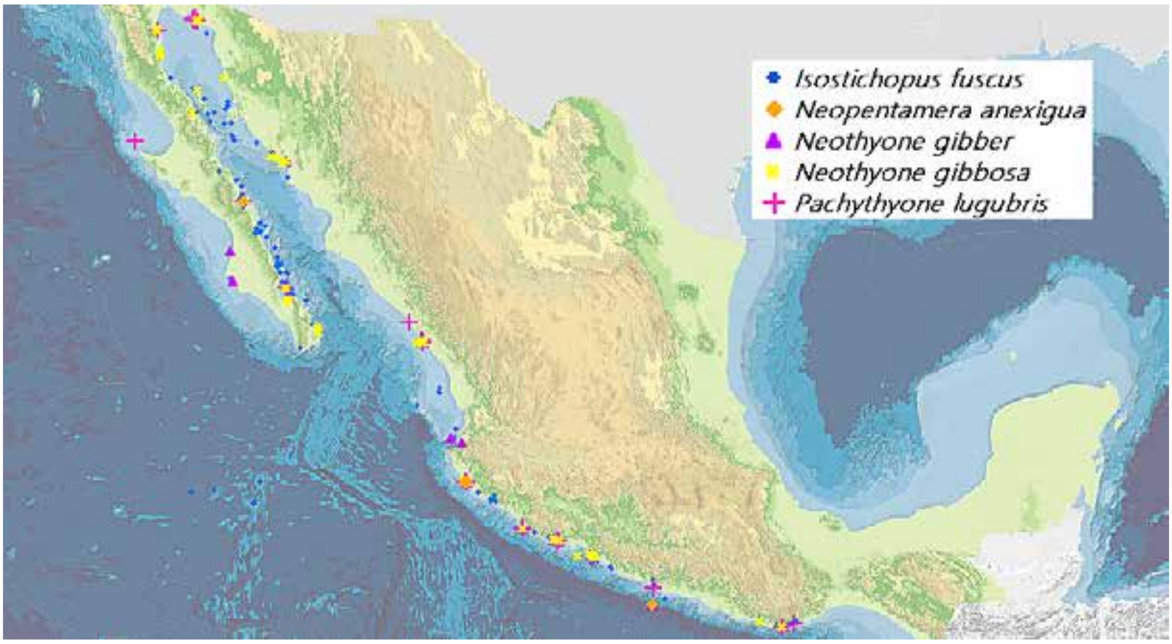

Figure 5. Distribution map of the sea cucumber species exhumed at offering 126 of the Templo Mayor. *Isostichopus fuscus*: blue rhombuses; *Neopentamera anexigua*: orange rhombuses; *Neothyone gibber*: purple triangles; *Neothyone gibbosa*: yellow circles; *Pachythyone lugubris*: purple crosses.

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