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Editorial

This 43rd issue of the SPC *Beche-de-Mer Information Bulletin* includes 12 original articles and scientific observations from around the world.

The first article by Ducarme et al. (p. 4) describes the results of a one-year sea cucumber survey conducted in Vanuatu (South Pacific) during 2019/2020. Paderanga et al. (p. 11) give us information on the distribution and abundance of white teatfish in the area of Medano White Island Marine Fish Sanctuary in the Philippines. Three teatfish species were included in Appendix II of CITES in 2019, and Di Simone et al. (p. 17) explain the inclusion of three new species of *Thelenota*: *T. ananas, T. anax* and *T. rubralineata.*

The next article, presented by Christophersen et al. (p. 23), presents the results of initial studies on the reproduction of *Parastichopus tremulus* in captivity in Norway. The results concern broodstock holding, induced spawning, and gamete quality. Potential new biotechnological tools for improving hatchery production are also discussed.

Ma et al. (p. 32) report on unusually heavy, deformed individuals of *Cucumaria frondosa* harvested by bottom trawl off the coast of Newfoundland (eastern Canada) that displayed stones nestled inside their body cavity.

Two articles concern different projects related to the investigation of microplastics found in sea cucumbers: one is from Dettling et al. (p. 39) and the other from Mohsen (p. 43).

The next two articles are about sea cucumbers from the Mediterranean Sea. In the first, Khodja and Mezzali (p. 46) determine some biometric relationships of *Parastichopus regalis* that can be used for the management of its fishery before its launch. In the second, Sellem (p. 52) provides data on the abundance of sea cucumber species in a Mediterranean lagoon on the Tunisian coastline.

Concerning education and training, Indriana et al. (p. 57) explain the training that was offered in Lombok (Indonesia) to several groups concerning the farming of *Holothuria scabra*. Eeckhaut et al. (p. 63) announce the setting up a Certificate in the Science of Artisanal Mariculture and Village Farming, supported by Belgian and Malagasy universities. The Certificate will welcome 20 candidates annually, and the first courses will be in September 2024. The practice of four maricultures (holothuriculture, algoculture, spiruliculture and coralliculture) will be taught.

In the same field, Di Simone et al. (p. 66) introduce a new simplified identification guide with 56 species of sea cucumbers, protected and unprotected by CITES, and traded worldwide for food consumption. It is purposedly simplified for use by non-specialists, including enforcement authorities whose mission is to detect potentially illegal shipments.

Finally, observations of juvenile *Stichopus horrens* in Solomon Islands (Komatsu et al. p. 74) and of *Stichopus herrmanni* (Ducarme p. 76) are presented.

Also included in this issue are various communications (p. 79) about past and future congresses. In particular, Alessandro Lovatelli and Steve Purcell (p. 82) announce the arrival of the second edition of the FAO guide on the "Commercially important sea cucumbers of the World". This edition includes 84 species. The articles by Di Simone et al. in English, are also presented in French (p. 20 and 70).

Igor Eeckhaut

Cover picture: Juvenile sea cucumbers, *Holothuria scabra*, being reared in an earthen pond in west Lombok, Indonesia. ©Lisa F Indriana

Field inventory and population assessment of sea cucumbers from Vanuatu

Frédéric Ducarme,[1,*] Pascal Dumas[2] and Rocky Kaku[3]

Abstract

This contribution describes the results of a sea cucumber (Holothuroidea) survey that was conducted in Vanuatu (South Pacific) from 2019 to 2020. A field species inventory was undertaken around Efate Island during this period, of which outcomes are then compared with the results from the 2019–2020 sea cucumber monitoring surveys, implemented by the Vanuatu Fisheries Department under the current Vanuatu National Sea Cucumber Fishery Management Plan. The main result of this survey is the correct health of sea cucumber populations, both abundant and diverse, including threatened species. These results bring the total number of sea cucumbers in Vanuatu to 36, including 20 species of commercial interest and 5 species of conservation interest observed throughout the course of the study.

Keywords: Holothuroidea, Vanuatu, Melanesia, South Pacific, fisheries management, Echinodermata, marine biodiversity

Introduction

Vanuatu is an island country in the southwest Pacific Ocean, and part of the region known as Melanesia. It is located between New Caledonia to the southwest, Fiji to the east, and Solomon Islands to the north. It is one of the youngest countries in the world, gaining independence in1980, but also among the poorest in terms of market economy, and among the least known to science. Coastal fisheries, including for marine invertebrates, is widespread but mostly targeted at local consumption, hence making an important contribution to food security (Raubani 2007). Small-scale, commercial fishing targets a small variety of higher-value species, including trochus topshell (*Rochia nilotica*), lobsters (*Panulirus* spp.) and coconut crab (*Birgus latro*). While not consumed locally, sea cucumbers are also a major source of income for coastal communities. Vanuatu is known for having its official language, Bislama, based on a European word designating sea cucumbers (beche-de-mer), suggesting an ancient tradition of fishing and trade (Pakoa et al. 2014). Documented at least since the 19th century, this activity has progressively evolved from unregulated, artisanal harvesting, eventually tempered with several temporal or local bans and regulations (Kinch et al. 2008), to community-based fisheries management (Léopold et al. 2013b) and, more recently, towards a national fishery regulated under a fully integrated management strategy (Kaku et al. 2020).

The marine fauna of Vanuatu remains poorly known, the main recent scientific expedition being the MNHN (Muséum national d'Histoire naturelle) expedition to Espiritu Santo Island in 2006 (Bouchet et al. 2008), which did not include a dedicated study of echinoderms (Bouchet et al. 2011). However, the isolation and geological particularities of the country may entail a diverse and original fauna, potentially divergent from better-known neighbouring countries such as New Caledonia (Cherbonnier 1980; Conand 1989; Améziane 2007). This ecological originality especially comes from the lack of "classical" coral lagoons around most of the islands, due to the rapid uplift of the New Hebrides tectonic plate (Taylor et al. 2005).

The present study describes the result of a pilot sea cucumber survey that was conducted on the shores, reefs and shallow (< 40 m) bottoms of Efate Island (including its surrounding islets) during one year, from August 2019 to August 2020. The results are discussed in light of the countrywide sea cucumber population monitoring carried out over the same period by the Vanuatu Fisheries Department.

Methodology

A survey of the distribution and diversity of holothurians was carried out at more than 20 sites around Efate Island and its islets (Fig. 1). These sites included mangrove forests (Erakor Channel and "lagoons"), sand beds (Erakor Channel, Havannah Harbour, Port Villa seafront), muddy bottoms (Havannah Harbour, Mele Bay, Port Villa seafront), seagrass beds (Erakor Channel and "lagoons") and coral reefs (most other sites).

Sites were investigated using scuba or snorkel, depending on depth, down to 40 m. Most sites were surveyed several times during the year, at different hours of the day and night and across different seasons, in order to avoid sampling bias. More than 50 surveys were conducted, including more than10-night surveys and more than 20 dives deeper than 20 m, all longer than one hour. All surveys were carried out by examining the benthos using the "roving diver technique" (RDT) as described in Schmitt and Sullivan (1996) and Bourjon et al. (2018), searching under crevices and rocks,

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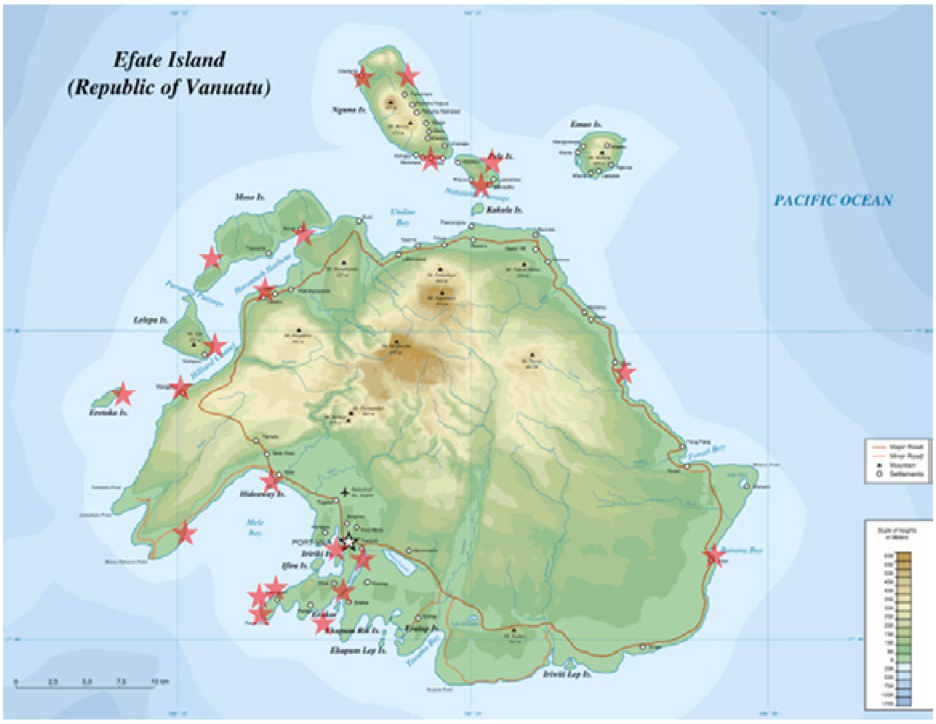

Figure 1. Location of main sampling stations (red stars) around Efate Island. Source: Wiki Commons

and identifying and photographing all sea cucumbers encountered. No specimens were sampled for this pilot study.

During this period (2019–2020), management surveys were implemented under the Vanuatu National Sea Cucumber Fishery Management Plan across six provinces of Vanuatu, recording specific abundances of commercial species. Target islands included Efate, Gaua, Santo, Maewo, Malekula, Maskelynes, Epi, Emau, Erromango and Tanna, along with associated islets (Fig. 2). All surveys were carried out by the Vanuatu Fisheries Department using a transect method, where all specimens observed within a geolocalised area, 100 m x 2 m corridor, were identified to species level and measured (body length and width). The number of transects ranged from 46 to 292 per site, depending on the depth and habitat of the sample station. Data were collected by walking, snorkelling or scuba diving. All surveys were limited to daytime.

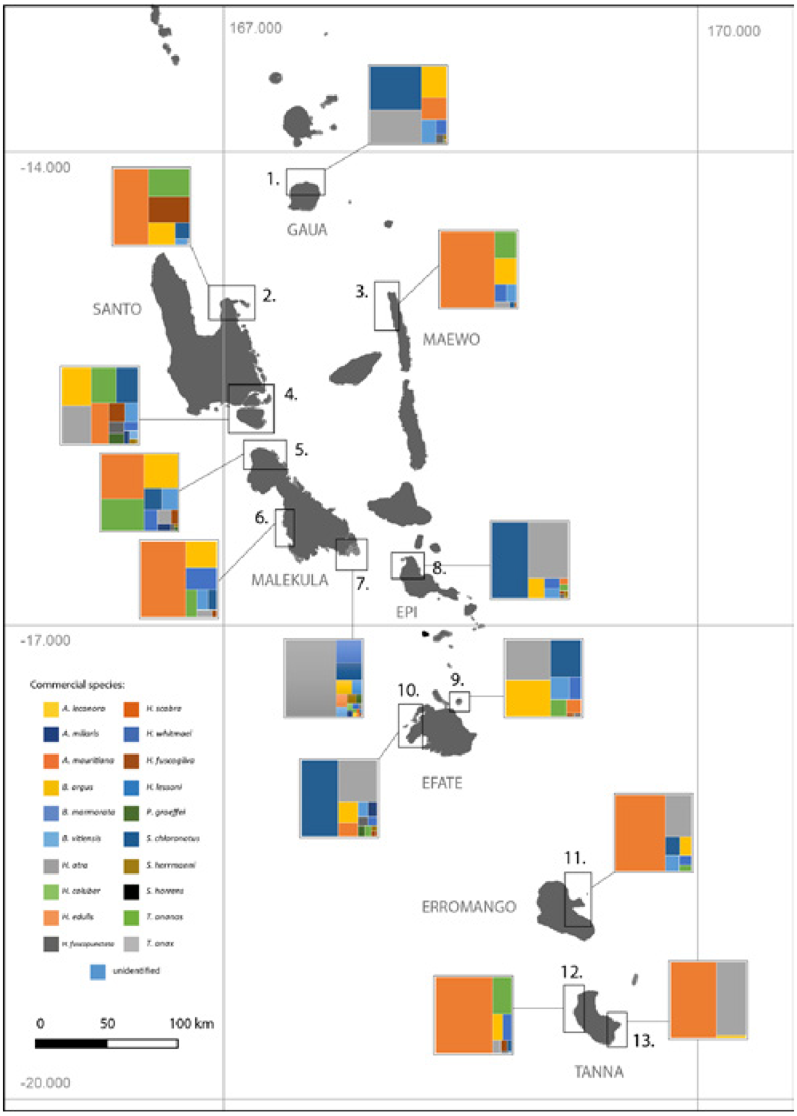

Figure 2. Species distribution patterns across the Vanuatu archipelago. Relative abundances of commercial holothurian species observed across 13 survey sites during the 2019–2020 surveys.

Results

Holothurian diversity

In total, 36 species of sea cucumbers were encountered during the scientific survey (Table 1), including 3 Apodida, 8 Synallactida (all belonging to the family Stichopodidae), and 24 Holothuriida (all belonging to the family Holothuriidae). It is worth noting that the species previously identified as *Actinopyga mauritiana* (an Indian Ocean endemic) appears to be its Pacific sister-species *Actinopyga varians*. Five species could not be identified beyond the genus level from the *in situ* observations, and are left as "sp." or "cf.".

Table 1. List of holothurians recorded during the Efate scientific surveys. Species are listed with relative abundances per benthos type (from 0 to 3 stars) along with commercial value and comments.

Order	Family	Species	Mangrove/ seagrass	Mud	Sand	Coral	Comments	Commercial value
Holothuriida	Holothuriidae	*Actinopyga lecanora*				*	Nocturnal	**
		Actinopyga miliaris				*	IUCN VU	**
		Actinopyga varians				*		**
		Bohadschia argus		*	***	***	Most abundant	**
		Bohadschia koellikeri			*			
		Bohadschia marmorata	***	*				*
		Bohadschia vitiensis	*		**			*
		Holothuria atra	*		*	*		*
		Holothuria cinerascens				*		*
		Holothuria coluber	*		*	*		*
		Holothuria difficilis				**		
		Holothuria edulis				*		*
		Holothuria fuscopunctata			*			**
		Holothuria hilla				*		*
		Holothuria impatiens				*		*
		Holothuria leucospilota				***		*
		Holothuria lineata				*		
		Holothuria pardalis				*		*
		Holothuria scabra	**	*			IUCN EN	***
		Holothuria whitmaei				*	IUCN EN	***
		Holothuria cf. verrucosa				*		
		Holothuria sp.				*		
		Labidodemas rugosum			*			
		Pearsonothuria graeffei				**		*
Synallactida	Stichopodidae	*Stichopus chloronotus*				**		***
		Stichopus herrmanni		**	*		IUCN VU	***
		Stichopus horrens				*	Nocturnal	**
		Stichopus cf. *monotuberculatus*				*	Nocturnal	**
		Stichopus pseudohorrens			*		Deeper (>30m)	*
		Stichopus vastus	*	*				*
		Thelenota ananas			*	*	IUCN EN	***
		Thelenota anax			*	*		*
Apodida	Chiridotidae	*Chiridota* sp.				*		
	Synaptidae	*Opheodesoma* sp. 1	*					
		Opheodesoma sp. 2			*			
		Synapta maculata	*					

In contrast, lower diversity was consistently recorded during the management surveys, with an average of 10 species observed per site out of 20 sites (ranging from 3 to 19 species per site, eventually including non-identified specimens) (Table 2).

Table 2. Occurrence of commercial holothurians across the Vanuatu archipelago. Reports of presence (+) or absence (-) of sea cucumber species recorded during the 2019–2020 management sea cucumber surveys.

Species	Gaua	Northeast Santo	West Maevo	South Santo	North Malekula	West Malekula	Maskelynes	West Epi	Emao	West Efate	East Erromango	West Tanna	South Tanna
Actinopyga lecanora	-	-	-	-	-	-	+	-	-	-	-	-	-
Actinopyga miliaris	-	-	-	-	-	-	+	-	+	+	-	+	-
Actinopyga varians	+	+	+	+	+	+	+	+	+	+	+	+	+
Bohadschia argus	+	+	+	+	+	+	+	+	+	+	+	+	-
Bohadschia marmorata	-	-	-	-	-	-	+	-	-	-	-	-	-
Bohadschia vitiensis	+	-	-	+	+	-	+	+	-	+	-	-	-
Holothuria atra	+	+	+	+	+	+	+	+	+	+	+	+	+
Holothuria coluber	-	-	-	-	-	-	+	-	-	-	-	-	-
Holothuria edulis	-	-	-	+	-	-	+	-	-	+	-	-	-
Holothuria fuscopunctata	+	-	-	+	+	-	+	+	-	+	-	+	-
Holothuria scabra	-	-	-	-	-	-	+	-	-	-	-	-	-
Holothuria whitmaei	+	-	+	+	+	+	+	+	+	+	+	+	+
Holothuria fuscogilva	-	+	-	+	+	+	+	-	-	-	-	+	-
Holothuria lessoni	-	-	-	-	-	-	+	-	-	-	-	-	-
Pearsonothuria graeffei	-	-	-	+	-	-	+	+	+	+	-	-	-
Stichopus chloronotus	+	+	+	+	+	+	+	+	+	+	+	-	-
Stichopus herrmanni	+	-	+	+	+	-	+	+	-	+	-	-	-
Stichopus horrens	-	-	-	-	-	-	+	-	-	-	-	-	-
Thelenota ananas	+	+	+	+	+	+	+	+	+	+	+	+	-
Thelenota anax	-	-	-	+	+	-	-	-	-	+	-	-	-
Non-identified species	+	+	+	+	+	+	+	+	+	+	+	-	-
Total nb. of species	10	7	8	14	12	8	20	11	9	14	7	8	3

Species in bold are high-value commercial species, and most are on the IUCN Red List.

Holothurian abundance

Five species accounted for 90% of abundances: *Holothuria atra, Actinopyga varians, Stichopus chloronotus, Bohadschia argus* and *Thelenota ananas.* Relative abundances highlighted contrasted patterns of species assemblages among islands, with some similarities, particularly across central sites 7–10 (south Malekula, north Epi, north and west Efate) and southern sites 11, 12 and 13 (Erromango and Tanna). Monitoring surveys highlighted the presence of potentially dense but highly localised populations of both high- and medium-value commercial species, including *S. chloronotus* (19.8% of total abundance), *A. varians* (22.4%), *B. argus* (8.4%) and *T. ananas* (4.4%). Overall, high- and medium-value species, respectively, accounted for 28.6% and 31.5% of total abundance.

Discussion

A first inventory of sea cucumbers from Vanuatu

The results show a diverse and seemingly healthy population of sea cucumbers, including some rare or endangered species. The taxonomic composition is typical of western Pacific Island countries (Clark and Rowe 1971; Kinch et al. 2008), and most species are also encountered in New Caledonia (Améziane 2007), apart from *Actinopyga varians* (identified as *A. mauritiana* in the source), *Bohadschia koellikeri, Holothuria lineata, H. whitmaei* (still merged in *A. nobilis* in the source), *Labidodemas rugosum*, *Stichopus herrmanni* (identified as *S. variegatus* in the source), *S.* cf. *monotuberculatus,* and *S. vastus*. *Holothuria lessoni*, recorded only outside of Efate, is also absent from Améziane's study (2007), but this species was described after this paper went out, and is often confused with *H. scabra*. This accounts for 38 shallow sea cucumber species recorded in Vanuatu, compared to 67 in New Caledonia (Conand 1989; Améziane 2007). Five species are reported on the International Union for Conservation of Nature "Red List" (Conand et al. 2014), including three species considered as endangered and two as vulnerable.

This result is consistent with other reports from neighbouring countries such as Fiji (with 27 known species according to Pakoa et al. 2013), even if most of the literature concentrates only on commercial species (such as Kinch et al. 2008).

Sea cucumber resources

Vanuatu has been a member of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) since 1989, applying international regulations on the trade of wild animals. The commercial fishery of sea cucumbers had been poorly regulated since independence (1980) and relied mostly on community-based fisheries management (Léopold et al. 2013b) until a global moratorium was put in place from 2008 to 2013. A major shift occurred in 2014, when scientific collaboration between Vanuatu and regional stakeholders led by IRD (French National Research Institute for Sustainable Development) led to a more comprehensive management framework (Léopold et al. 2013a and b). Based on an adaptive quota-based, co-management system, this approach was progressively updated and finally enforced under the 2019–2024 Vanuatu National Sea Cucumber Fishery Management Plan, with a first opening season starting in 2019 under strict control of the Vanuatu Fisheries Department (Kaku et al. 2020).

Among all the species recorded during this study, 7 are of high commercial value (Purcell et al. 2012; Di Simone et al. 2022), 7 are of medium value and 14 are of low value, although commercial values vary considerably with time and location (Conand 2018). The 10 remaining species are not subject to trade (too small, too rare, too difficult to reach or part of non-edible groups such as Apodida). At the country scale, abundance surprisingly did not correlate with commercial value: 60% of individuals recorded during the national management surveys belonged to species with high or medium market value. While the most expensive species such as "teatfishes" (*Holothuria whitmaei* and *H. fuscogilva*) and "sandfish" *H. scabra* remain rare (< 1.5% of total abundances), these still exhibited some localised dense populations (perhaps thanks to closure policies), and populations of other valuable species (e.g. *Stichopus chloronotus, Thelenota ananas, Bohadscia argus, Holothuria atra, Actinopyga varians,* 5–35% of total abundances) were eventually found with significant abundances in a number of sites across the archipelago.

These results are truly an encouraging sign in terms of biodiversity and harvest potential, especially in the current context of generalized overfishing of sea cucumbers. This suggests that the current commercial fishing pressure in Vanuatu may be (relatively) low compared to other countries such as the Maldives (Ducarme 2016) or, to a lesser extent, Fiji (Pakoa et al. 2013), and/or that the current updated management framework is working, despite sporadic reports of illegal poaching in Vanuatu (Fig. 3). This contrasts with reports from Kinch et al. (2008), who state that holothurian populations in Vanuatu back then as "depleted around the most populated areas" and then "barely recovered" five years later (Léopold et al. 2013a), suggesting positive effects from latter conservation policies. Whether or not this is sufficient to avoid the classical boom-and-bust cycle and ensure a sustainable exploitation of the resource on the longer term remains uncertain. This is particularly true given 1) the small-scale fragmentation of species distribution, which makes them particularly vulnerable to overharvest; and 2) the adverse effects of an ever-increasing demand for sea cucumber products from the Asian market, including rising fishing pressure and poaching in rural areas.

Figure 3. Seizure at the Port Vila airport of sea cucumbers illegally harvested during the fisheries moratorium, and bound for Asia. © IRD – P. Dumas

Sea cucumber aquaculture in Vanuatu

A small artisanal aquaculture of *Holothuria scabra* exists in Vanuatu (along with at least one hatchery), but little official information is available regarding it so far. Hatchlings are also imported from Australia by some Australian-based private companies (Kinch et al. 2008).

The government has made it a priority for the fisheries department to develop sea cucumber aquaculture in the future, in order to make it a valuable export product to Asia, which could provide to be an interesting economical sector for Vanuatu (Hamel et al. 2022).

Conclusion

Marine resources in Vanuatu appear to be in a reasonably good state at least with regards to sea cucumbers and despite growing demand and pressure. Although it is difficult to tell whether: 1) this is an effect good local enforcement and compliance of regulations; 2) to the still low and artisanal fishing pressure; or 3) other unsuspected drivers. The current state of this fishery seems currently sustainable under proper management rules, and compatible with the preservation of a healthy reef environment, which is paramount for such an isolated and vulnerable nation.

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Notes on the distribution and abundance of white teatfish – *Holothuria fuscogilva* Cherbonnier, 1980 – at White Island, Philippines

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Abstract

The white teatfish, *Holothuria fuscogilva*, is a vulnerable, commercially important sea cucumber in the Indo-Pacific region. Information on its distribution and abundance are important inputs for effective resource management. This study was conducted to locate white teatfish in the surrounding area of Medano White Island Marine Fish Sanctuary in Mambajao, Camiguin. In total, 21 white teatfish individuals weighing 0.6–2.1 kg were observed during 10 surveys from January 2020 to October 2020, and in November 2021. Density was found to be 2 individuals/ha. Knowing the occurrence of this species in the area is vital, considering that viable populations are only reported from Lopez Jaena, Misamis Occidental. The substrate of the area shows an overall distribution towards finer grain size, with coarse sand (53.17%) as the dominant substrate type and a low (4.7%±0.34%) organic matter content. Water salinity ranged from 35.8 ppt to 37.2 ppt, with a maximum water temperature of 28°C. There is no active collection or trading of white teatfish in the province; thus, the sanctuary and its surrounding area are a potential source of broodstock for the species. This note will serve as reference to strengthen protection inside the sanctuary and in its buffer zone. Meanwhile, white teatfish stock delineation in Mindanao is ongoing.

Keywords: Sea cucumber, broodstock, marine protected area, conservation, management

Introduction

The white teatfish (*Holothuria fuscogilva* Cherbonnier, 1980) is a commercially important sea cucumber species collected for its high nutritional value (Chen 2003, 2004) and varied applications: it is a luxury food item in some countries, particularly in Asia (Conand and Byrne 1995; Bordbar et al. 2011; Purcell et al. 2013), used as artificial feeds (Bakus 1973), in cosmetic products (Poh-Sze 2004; Conand 2005), and in traditional medicinal practices because it is supposedly effective against asthma, rheumatism, hypertension, impotence, constipation, and cuts and burns (Wen et al. 2010; Bordbar et al. 2011). Hence, the demand for this species has greatly increased, resulting in overexploitation of natural stocks in traditional fishing grounds in many areas (Guzmán et al. 2003; Conand 2004; Toral-Granda et al. 2008; Anderson et al. 2011; Eriksson and Byrne 2013).

The importance of high-valued sea cucumbers such as the white teatfish has prompted the Philippine government to conduct nationwide surveys to determine their population status, including that of De Guzman and Quiñones (2013), which established the presence of the species' viable populations in the Capayas Island Marine Sanctuary in Lopez Jaena, Misamis Occidental. This project brought about the implementation of two other projects on the development of captive breeding and hatchery technology for *Holothuria fuscogilva* from Lopez Jaena, Misamis Occidental in 2017, and the current project on the ecology, biology and genetic diversity of *H. fuscogilva* in Mindanao.[4] One of the objectives of the project is to map potential sites for sourcing white teatfish broodstock and determine their status. Captive breeding and restocking of hatchery-produced white teatfish juveniles in the wild is one plausible action to enhance the natural stocks.

Sexual maturity of white teatfish is attained when it is about 32 cm in length or 700 g in weight (Conand 1981). These body sizes may be applied when searching for sea cucumber broodstock. Adults are often found in deep areas of the reef, while juveniles can be found in shallow seagrass beds (Lumasag et al. 2017; De Guzman and Quinones 2013). However, this species is often found in low densities in the marine environment. Hence, establishing monitoring sites for ecological and biological studies is a challenge. The limited number of broodstock that could be available in a given sampled area is also a main concern of the hatchery component of the center. While the best quality, hatchery-grown individuals can be kept to become broodstock, this strategy requires long-term planning and considerable investment. In general, a significant portion of broodstock continues to come direct from wild-capture fisheries. Many hatcheries seek to obtain wild broodstock to diversify the genetic makeup of their stocks.

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The Medano White Island Marine Fish Sanctuary in Barangay Agoho, Mambajao, Camiguin Province was one of the areas in Mindanao that was surveyed, and where the surrounding area was found to have a potentially viable population of white teatfish. The 37.74 ha sanctuary was established through Municipal Ordinance No. 3, Series of 2000. Although there is no active collection or trading of white teatfish in Camiguin Province, there is also no available information on its population. Hence, this short article aims to present observations from an underwater survey in Camiguin Province, highlighting the possibility of the province being a potential source of broodstock.

Methodology

Study area

The Medano White Island Marine Fish Sanctuary in Barangay Agoho, Mambajao, Camiguin is located near an uninhabited sandbar within the municipality's designated White Island Marine Park, which is 1.4 km north of Camiguin Island in the Bohol Sea (Fig. 1). The exposed part of the island consists entirely of sand and has no fixed shape due to the tides and currents driven by monsoonal changes. The waters around White Island are known for strong currents due to the rising of the sandbar from the sea bottom, which causes the currents to flow swiftly around it. The sanctuary is a strip of protected area in the northeastern portion of the islet. Currents are strong on either side of the sanctuary, but conditions can be relatively calm in the middle.

Data collection and sampling

Ten surveys were intermittently conducted from January to October 2020 and in November 2021 to locate white teatfish in the surrounding areas of Medano White Island Marine Fish Sanctuary. Collected individuals were photographed using the Olympus Tough TG-5 underwater camera, after which they were measured in terms of their gravimetric body length, width and weight. The temperature and salinity of the water were analyzed *in situ*. Sediment samples were collected to a depth of 10 cm using a PVC corer with a diameter of 6 cm. For grain size analysis, 10 samples of clean sediments (each with 80–100 g dry weight) were subjected to dry sieving using a stack of Wentworth-grade sieves within the range of 4000–31 µm. Sieved samples were pooled (composite) and grain size classification was based on Wentworth (1922). A simple estimate of the organic content of sediments was derived from the mass of the loss on ignition combusted at 450°C in a muffle furnace (Eleftheriou 2013). Other sea cucumber species found in the surveyed site were also recorded and counted.

All sampled individuals were marked to avoid recapture by removing a small piece of skin tissue at the posterior dorsal portion of the body and released back to the general area where they were collected. No marked individuals were recaptured, implying that the survey area was within a larger area in which individuals of white teatfish moved around.

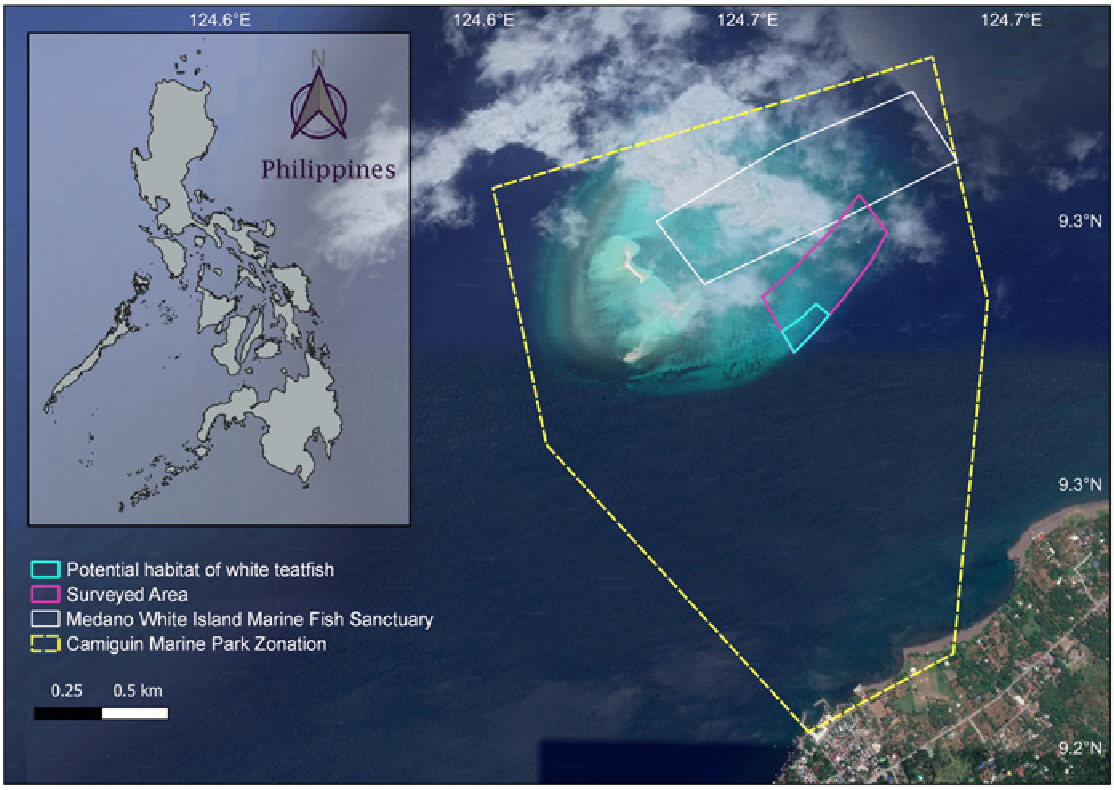

Figure 1. The geographic location of the surveyed area in Mambajao, Camiguin. Source: Adapted from Google Earth 2020

Results and discussion

An initial underwater scoping survey was conducted within a total area of 11 ha at a depth of 4–18 m that included the southern half of the sanctuary, and in which one individual of white teatfish of adult size was encountered (Fig. 2). This area was found to include zones where substrate conditions were unfavorable for white teatfish. Within this area, only 12.18%, or 1.34 hectares, were within the preferred habitat range of the species, which was where the individual was found. This area was a sandy slope of the south-southeastern part of the sanctuary at a depth of 6–11 m. Overall, the 10 intermittent surveys have a computed density of 2 individuals/ha. Although this figure is much lower than the density of 2130/ha reported for the Gulf of Aqaba in the Red Sea (Hasan and Johnson 2019) or 147 individuals/ha for Lopez Jaena in Misamis Occidental in the Philippines (De Guzman and Quinones 2021), it is comparable to those reported for Tubbataha at 1.04 individuals/ha (Dolorosa 2015) and Tonga at 1.66 individuals/ha (Shedrawi et al. 2020).

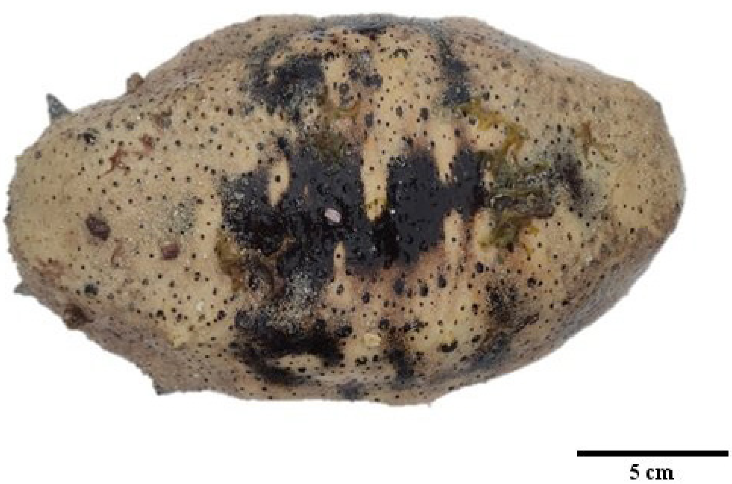

Figure 2. Dorsal view of a white teatfish, *Holothuria fuscogilva*, found in the surrounding area of Medano White Island Marine Fish Sanctuary. Image: EBGen Project

The gravimetric data from all the sampled white teatfish individuals showed a body length ranging from 24 cm to 49.5 cm, body width ranging from 10.5 cm to 19.2 cm, and weight ranging from 600 g to 2060 g (Table 1). Given these values, the white teatfish in Camiguin can be used as broodstock because size at first maturity reported for this species is about 32 cm in length and 700 g in weight (Conand 1981; Preston 1993; Leopardas et al. 2021). As to their gonadal maturity, Leopardas et al. (2021) reported that white teatfish in Laguindingan, Misamis Oriental were mostly mature in the month of May with relatively high gonad output. Accordingly, size at first maturity and the period of broodstock collection should also be considered in any initiatives to manage the sea cucumber resource.

The presence of adult and sub-adult white teatfish in deeper areas is expected because relatively larger individuals tend to be found in greater depths compared to juveniles, which in turn would be expected to be found in shallower seagrass beds (Conand 1981; Reichenbach 1999; Kinch et al. 2013). The same observation was also recorded for the orange-footed sea cucumber *Cucumaria frondosa* (Conand 1981; Hamel and Mercier 1996) which undergoes progressive migration from shallow reef areas to deeper exposed sandy areas as the organism sexually matures. Hence, the observation that white teatfish juveniles are mostly found in shallower protected areas such as seagrass beds and then slowly migrate to reef areas as they mature is indicative of an analogous migration pattern for this species. This notion is supported by Ramofafia et al. (2000), where sexually mature individuals of white teatfish were recorded in water depths ranging from 25 m to 35 m. Similarly, size-related migration has also been observed in *Stichopus hermanni* (Conand 1993).

The substrate where the white teatfish individuals were found showed an overall gradient towards finer grain size distribution, with coarse sands as the dominant substrate type (Fig. 3), and with a low organic matter content of 4.7% ± 0.34%. These characteristics of sediments are also observed in habitats of white teatfish in other parts of Mindanao. Although it is reported elsewhere that substrates of sea cucumbers can have organic matter levels as high as

Table 1. Gravimetric data of white teatfish (n = 21) assessed in the surrounding areas of Medano White Island Marine Fish Sanctuary.

Physical characteristics	Mean	± STDEV	± SEM	Min	Max
Length (cm)	34.12	6.15	1.34	24	49.5
Width (cm)	14.11	2.33	0.52	10.5	19.2
Weight (g)	1392.33	389.85	85.07	600	2060

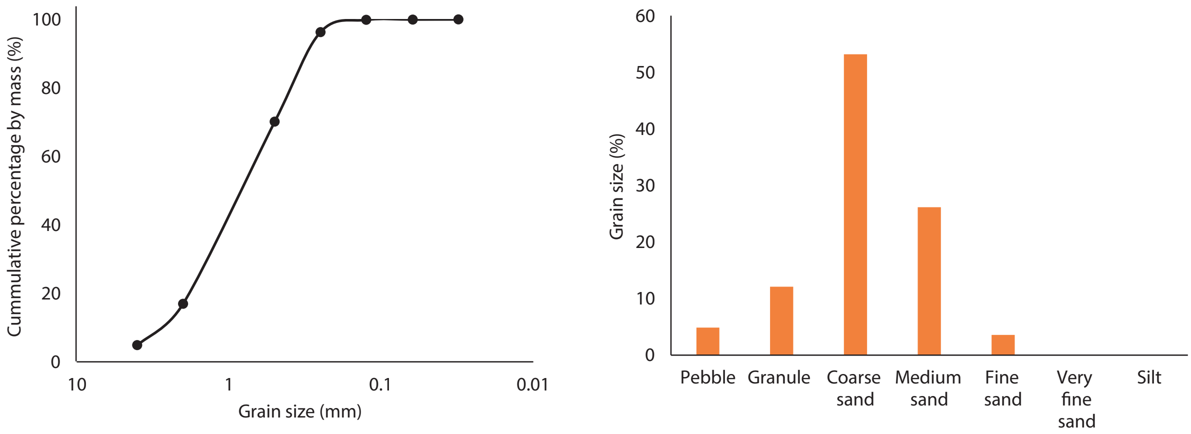

Figure 3. Grain size composition on the habitat in which white teatfish individuals were found at White Island, Camiguin.

30%, Mercier et al. (2000) reported that *Holothuroa scabra* prefers substrates with an organic matter content of less than 5%. Meanwhile, salinity in the area during sampling was 35.8–37.2 ppt, and water temperature was 28°C *in situ*. The findings were comparable to those of other reports on the habitat of the white teatfish across the Indo-Pacific, with the species commonly found to inhabit outer barrier reef slopes, reef passes and sandy areas in semi-sheltered reef habitats (Battaglene 1999; Asha and Muthiah 2002, 2005). Understanding the features of the sediment and water where white teatfish are found is essential since these factors can explain some variations in the growth and microhabitat preference of the species (Plotieau et al. 2014).

All white teatfish individuals recorded during the surveys were found in the surrounding area of Medano White Island Marine Fish Sanctuary. It is well recognized that marine protected areas play a key role in protecting many species from unregulated harvesting as well as in increasing species abundance in its adjacent areas through the spillover effect (Halpern 2003; Lubchenco et al. 2003; Norse et al. 2003; Russ et al. 2004). On the other hand, the rarity and dispersal of sea cucumbers in the different coastal habitats may be influenced by localized and/or climatic conditions, such as habitat types, shelter, sediment properties, and water depth. In terms of preference for microhabitat, seagrasses in general appear to provide sea cucumbers an appropriate substrate for larval settlement, burying actions, and water turbulence protection (Floren et al. 2021). Other factors affecting and regulating the distribution of sea cucumbers are coastal processes such as hydrodynamics, which influence the sediment granulometry and, thereby, define the niches of holothurians (Massin and Doumen 1986).

Recommendations

Given the occurrence of white teatfish, *Holothuria fuscogilva*, in the vicinity of the marine protected area, we recommend that the protection of the areas be strengthened, including that of the buffer zone. We also advocate for continued legal protection because the area could be a potential source of white teatfish broodstock for future captive breeding activities. Moreover, a more detailed survey is also necessary to fully understand the ecology, biology and genetics of the white teatfish in Camiguin vis-a-vis promoting public awareness of its importance en route to sustainable management and resource conservation.

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The listing of three new holothurian species in CITES Appendix II

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Introduction

The first listing of sea cucumbers in the CITES appendices dates back to 2003 with the addition of *Isostichopus fuscus* to Appendix III. This was followed in 2019 by the listing in Appendix II of three, easily identifiable, species: *Holothuria fuscogiva, H. nobilis* and *H. whitmaei* (Di Simone et al. 2021); and again, in November 2022, at the CITES Conference of the Parties (CoP 19 CITES) in Panama, with three new species added to Appendix II: *Thelenota ananas, T. anax* and *T. rubralineata*.

Sea cucumbers and CITES

The examination of sea cucumbers at CITES began in the early 2000s without being the subject of a proposal for listing in the Appendices during a CoP meeting. Ecuador included the Holothurians in the CITES Appendices in 2003 by requesting the inclusion of its national populations of *Isostichopus fuscus* in Appendix III. It was finally in Geneva, at the 18th CITES CoP, in 2019, that sea cucumbers were included in Appendix II, with three species of the genus *Holothuria* (*H. nobilis, H. whitmaei* and *H. fuscogilva*, the "teatfish") on an original proposal from France, supported by the European Union, and co-supported by the United States, Kenya, Senegal and the Seychelles (Di Simone et al. 2022). The CITES dynamics of sea cucumbers then changes dimension.

Listing proposal of Thelenota in Appendix II

At the 19th session of the CoP in Panama, the European Union co-sponsored by the United States and the Seychelles, again on an original proposal from France (Fig. 1), submitted a listing proposal in Appendix II of three additional species of sea cucumbers: the entire genus *Thelenota*. Exploitation rates of these species have increased rapidly over the last 25 to 50 years, and their life history characteristics, combined with their limited mobility and large size, made them particularly vulnerable to overexploitation. These three species are easily differentiated from other species due to their large papillae (Fig. 2). Many Parties expressed their support: Australia, Burkina Faso, Comoros, Fiji, Gabon, Ghana, India, Jordan, Liberia, Mauritania, Niger, Panama, United of Tanzania, Senegal, Sierra Leone, Somalia and Vanuatu, and Tonga. Maldives, Samoa, Sierra Leone, Vanuatu and the South Pacific Regional Environment Programme request technical and financial assistance from the Secretariat for the implementation of any listing, drawing particular attention to the need to support the making of non-detriment findings.

China, Indonesia, Japan, Papua New Guinea, and Solomon Islands oppose the proposal, pointing to the lack of stock assessments and scientific data, and believing that listing on the Appendix II would have negative consequences on the livelihoods of coastal communities.

Figure 1. Speech by France (Arnaud Horellou – French CITES Scientific Authority) under European delegation, at Committee I of COP19, in Panama.

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Figure 2. An adult specimen of *Thelenota ananas*, one of the most valuable and prized sea cucumber species (Purcell 2014).

Figure 3. Results of the vote for the adoption of proposal 42: Listing of the genus *Thelenota* in Appendix II of CITES, at Committee I of COP19, in Panama.

At the request of Japan, the proposal was put to the vote. With 97 Parties in favour, 16 against, and 16 abstentions (Fig. 3), the proposal was accepted with an entry into force of the listing in Appendix II delayed by 18 months. As well as the 12-month delayed entry into force of teatfish, this delay will allow range states of these species and importers to prepare for and effectively implement the listing, including the implementation adequate management, identification, monitoring and permitting procedures (Di Simone et al. 2019).

The international trade in these species is now regulated and controlled in accordance with the provisions of Appendix II: CITES permits and certificates will be required for international movements, attesting to the legality and sustainability of shipments. In the absence of these documents, the shipments must be seized as they are expected to be illegal trade (CITES Secretariat 2020). Appendix II controls and regulates trade to ensure that it is based on the management (methods and volumes) of sustainable takes. Transactions will also be tracked and compiled in the Parties' annual trade reports and recorded in the CITES trade database (CITES Secretariat 2020; Di Simone et al. 2021).

Perspectives

This new CITES listing of three additional sea cucumber species encourages potential new species listings in the future. According to Purcell et al. (2012), 58 species of sea cucumbers are traded worldwide. This number is increasing: species with high commercial value being rare or even depleted, fishing targets other species not yet or with low commercial value that were not listed before (Purcell et al. 2012; Di Simone et al. 2022). The new edition of the FAO book (Purcell et al. 2023) specifies this increase by identifying the new species concerned. Also, the identification guide for commercial sea cucumbers published at the end of 2022 (Di Simone et al. 2022) represents an important tool for implementing the listing of sea cucumbers since it facilitates controls and reporting.

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Figure 4. Invitation to the event "Thelenota" at COP19, 21 November 2022.

Inscription de trois nouvelles espèces d'holothuries à l'Annexe II de la CITES

Marie Di Simone,[1] Arnaud Horellou[1] et Chantal Conand[2]

Introduction

La première inscription des holothuries aux annexes CITES remonte à 2003 avec l'ajout d'*Isostichopus fuscus* à l'Annexe III. Elle a été suivie en 2019 par l'inscription à l'Annexe II de trois espèces facilement identifiables : *Holothuria fuscogiva, H. nobilis* et *H. whitmaei* (Di Simone et al. 2021) ; et, de nouveau, en novembre 2022, à la Conférence des Parties CITES (CoP 19 CITES) au Panama, avec trois nouvelles espèces ajoutées à l'Annexe II : *Thelenota ananas, T. anax* et *T. rubralineata*.

Historique des concombres de mer à la CITES

L'examen des holothuries à la CITES commence au début des années 2000, sans toutefois faire l'objet de proposition d'inscription aux annexes lors d'une CoP. L'Équateur fait entrer les holothuries aux annexes de la CITES en 2003 en demandant l'inscription de ses populations nationales *d'Isostichopus fuscus* à l'Annexe III. C'est finalement à Genève, à la 18ème CoP CITES, en 2019, que les holothuries entrent à l'Annexe II, avec trois espèces du genre *Holothuria* (*H. fuscogilva, H. nobilis et H. whitmaei,* les « holothuries à mamelles ») sur une proposition originale de la France, portée par l'Union Européenne, co-soutenue par les États-Unis d'Amérique, le Kenya, le Sénégal et les Seychelles (Di Simone *et al*. 2022). La dynamique CITES des concombres de mer change alors de dimension.

Proposition d'inscription des *Thelenota* à l'Annexe II

A la 19e session de la CoP au Panama, l'Union Européenne co-sponsorisée par les États-Unis et les Seychelles, à nouveau sur une proposition originale de la France (Figure 1), a présenté une demande d'inscription en Annexe II de trois espèces supplémentaires d'holothuries, l'ensemble du genre *Thelenota*. Les taux d'exploitation de ces espèces ont augmenté rapidement au cours des vingt-cinq à cinquante dernières années, et leurs caractéristiques biologiques, combinées à leur mobilité limitée et à leur grande taille, les rendent particulièrement vulnérables à la surexploitation. Ces trois espèces se différencient facilement des autres espèces en raison de leurs grandes papilles (Figure 2). Beaucoup de Parties ont exprimé leur soutien : l'Australie, le Burkina Faso, les Comores, les Fidji, le Gabon, le Ghana, l'Inde, la Jordanie, le Libéria, la Mauritanie, le Niger, le Panama, la République-Unie de Tanzanie, le Sénégal, la Sierra Leone, la Somalie et le Vanuatu, et Tonga. Les Maldives, le Samoa, la Sierra Leone, le Vanuatu et le Programme régional océanien de l'environnement (PROE) demandent au Secrétariat une assistance technique et financière pour la mise en œuvre de toute inscription, en attirant particulièrement l'attention sur la nécessité de soutenir l'élaboration d'avis de commerce non préjudiciable.

Figure 1. Prise de parole de la France (Arnaud Horellou – Autorité scientifique CITES France) sous délégation européenne, au Comité I de la COP19, au Panama.

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Figure 2. Un spécimen adulte de *Thelenota ananas*, une des espèces de concombres de mer les plus précieuses et les plus prisées (Purcell 2014).

Figure 3. Résultat du vote pour l'adoption de la proposition 42 : Inscription du genre *Thelenota* à l'annexe II de la CITES, au Comité I de la COP19, au Panama.

La Chine, l'Indonésie, le Japon, la Papouasie-Nouvelle-Guinée, les Îles Salomon s'opposent à la proposition, soulignant l'absence d'évaluations des stocks et de données scientifiques, et estimant que l'inscription à l'Annexe II entraînerait des conséquences négatives sur les moyens d'existence des communautés côtières.

A la demande du Japon, la proposition est mise aux voix. Avec 97 Parties pour, 16 contre, et 16 abstentions (Figure 3), la proposition est acceptée avec une entrée en vigueur de l'inscription à l'Annexe II retardée de dix-huit mois. Au mettre titre que l'entrée en vigueur retardée de 12 mois des holothuries à mamelles, ce délai permettra aux États de l'aire de répartition de ces espèces et aux importateurs de se préparer et appliquer efficacement l'inscription, notamment la mise en place de procédures adéquates de gestion, d'identification, de suivi et de délivrance de permis (Di Simone *et al*. 2019).

Désormais, le commerce international de ces espèces est réglementé et contrôlé conformément aux dispositions de l'Annexe II : des permis et certificats CITES seront nécessaires pour les mouvements internationaux, attestant de la soutenabilité de l'exploitation et de la légalité des envois. En l'absence de ces documents, les envois doivent être saisis car ils seront considérés comme du commerce illégal (CITES Secretariat 2020). L'Annexe II vise la surveillance et régulation du commerce afin de s'assurer que celui-ci s'appuie sur la gestion (méthodes et volumes) de prélèvements soutenables. Les transactions seront également suivies et compilées dans les rapports annuels sur le commerce des Parties et enregistrées dans la base de données sur le commerce CITES (CITES Secretariat 2020 ; Di Simone *et al*. 2021).

Perspectives

Cette nouvelle inscription de trois autres espèces d'holothuries à la CITES encourage de potentielles nouvelles inscriptions d'espèces dans le futur. D'après Purcell et al. (2012), 58 espèces d'holothuries sont commercialisées dans le monde. Ce nombre est en augmentation : les espèces avec une forte valeur commerciale étant rares, voire épuisées, la pêche cible d'autres espèces à faible valeur commerciale qui n'étaient pas répertoriés avant (Purcell et al. 2012 ; Di Simone *et al*. 2022). La nouvelle édition de l'ouvrage FAO (Purcell et al. 2023) précise cette augmentation en

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identifiant les nouvelles espèces concernées. Aussi, le guide d'identification des concombres de mer commercialisés publié fin 2022 (Di Simone *et al*. 2022) représente un outil important pour mettre en œuvre l'inscription des holothuries puisqu'il facilite les contrôles et le rapportage.

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Figure 4. Invitation à l'évènement 'Thelenota' de la COP19.

Realising the reproductive potential of *Parastichopus tremulus* in aquaculture

Gyda Christophersen,[1] Roger Meisal and Jan Sunde

Abstract

Presently, the sea cucumber *Parastichopus tremulus* is only caught as bycatch from nearshore trawl and pot fisheries because no targeted fishery is allowed in Norway. Due to an increasing market interest, however, the species has been identified as a potential aquaculture candidate. A viable sea cucumber aquaculture production relies on predictable yields of high-quality gametes and the subsequent growth, and survival rates, during the different life stages. Results from initial studies on the reproduction of *P. tremulus* in captivity related to broodstock holding, induced spawning and gamete quality are presented, and new biotechnological tools for improving hatchery production are discussed.

Keywords: Norwegian red sea cucumber, *Parastichopus tremulus*, aquaculture, reproduction, gamete quality, genome, fecundity, conditioning

Introduction

The Norwegian red sea cucumber, *Parastichopus tremulus*, is presently only caught as bycatch from near hore trawl and pot fisheries of fish and crustaceans. No targeted fishery is allowed in Norway unless an environmentally friendly bottom fishing gear can be used. Increased market interest has led to several initiatives with the purpose of exploiting this unused resource. Aquaculture is considered an option to develop a sustainable production of local sea cucumbers, but to reach this level, long-term research and development is needed. *Parastichopus tremulus* lives naturally in the cold temperate waters of the northeast Atlantic Ocean and is also documented from the Mediterranean Sea (Madsen and Hansen 1994; Ordines et al. 2019; Christophersen et al. 2021). Its distribution range is wide, both in terms of latitude (~25–75°N) and depth (20–3000 m) (Grieg 1921; Mortensen 1927; MNHN, Chagnoux S. 2023), suggesting a potential for influencing growth at the different development stages through the modification of environmental conditions and improved culture technology. Knowledge of the reproductive biology of a species is instrumental in designing breeding and aquaculture programmes. Also needed in order to achieve sustainable aquaculture independent of wild animals, is an understanding of the organism's complete life cycle – from spawning to reproductive age in a controlled environment. Predictable reproductive output and growth during the early life stages is crucial to advance the process. The rearing of *P. tremulus* is in its infancy, but spawning and larval production in the lab have successfully been repeated (Christophersen et al. 2020; Christophersen and Sunde 2021; Schagerström et al. 2021). There are many knowledge gaps related to reproduction potential and the possibilities of broodstock conditioning and induced gonad development in culture, for sea cucumbers in general, and for *P. tremulus*, in particular. Broodstock animals for aquaculture may either be collected from the wild within the spawning season, or at other times and maintained in the hatchery under conditions that stimulate gonadal maturation. The spawning season of *P. tremulus* is from June to August, and gonadal development has a clear seasonal pattern (Lönning 1976; Christophersen et al. 2020). The demographic and genetic population structure of *P. tremulus* is not yet known, further emphasising the need for studies related to life history parameters such as stage-specific growth, size at age, and timing of sexual maturity. These events are influenced by environmental and physical conditions. Attempts towards spat production of *P. tremulus* in our lab includes studies on broodstock in captivity, induced spawning, fecundity, and gamete quality. A next step will be the introduction of new biotechological and genetic tools that aid the development of a viable aquaculture industry.

Broodstock and spawning

Because *Parastichopus tremulus* mainly occurs in waters deeper than 100 m in Norway (Kjerstad et al. 2015), access to live and healthy individuals may be a challenge. We obtain our broodstock sea cucumbers from local fishermen trawling for shrimp (*Pandalus borealis*) or capturing the Norway lobster (*Nephrops norvegicus*) using pots in the fjords nearby Ålesund in western Norway (62°N, 6°E). The sea cucumbers are caught in depths of 100–300 m. Based on our initial work describing the annual reproductive cycle of our local *P. tremulus* where the highest gonad index (GI, % gonad wet weight of body wall wet weight) was registered in May (Christophersen et al. 2020), individuals are brought to the lab in the (Northern Hemisphere's) late spring–early summer for spawning in June and July. A lower GI was found in sea cucumbers kept for a longer time in the lab (from March) compared with individuals obtained shortly before spawning, suggesting that tank conditions influence gonadal maturation (Christophersen et al. 2020). The GI has, over the years, shown large variations between individuals and years, ranging from <0.5% to 23% at peak season.

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In trials comparing the effect of increased temperature, reduced salinity, or air exposure stress (Christophersen et al. 2021), we found that *P. tremulus* was most reliably induced to spawn by a heat shock method. With this method, the sea cucumbers are exposed to a temperature increase of 6°C above the holding temperature for one hour before being transferred to individual spawning containers (Fig. 1). This is also when we can determine the sex without sacrificing the sea cucumbers.

Based on the previously observed GI peak in May (Christophersen et al. 2020), we tried to induce spawning twice weekly, from the end of May to early July 2019 (Table 1). Previous studies have determined the natural spawning time as lasting from July to September in southern Norway (Lönning 1976). We successfully induced spawning in males after temperature stimulation from the end of May, whereas both females and males spawned towards the end of June to the beginning of July (Table 1). From these female spawning events, viable gametes that developed into larvae were produced.

The timing of the collection of broodstock from the wild is important. Liu et al. (2015) stated that it is crucial to collect broodstock when gonads are fully developed because the transfer to new environmental conditions in captivity may arrest the development of immature gonads. We suggest that *P. tremulus* broodstock should be collected no earlier than May. In our lab, spawning trials in subsequent years have confirmed that induced spawning is most successful around the time of midsummer, indicating that the spawning period of our local sea cucumber population is restricted to end of June and July. Sea cucumbers obtained from the sea in August and September may have gonad tissue but are usually in the spent stage or not willing to spawn. The proportion of individuals that actually spawn in captivity varies from season to season, as does the ratio of spawning males to females (Table 2). Thus, the predictability of spawning success in terms of getting large numbers of eggs and synchronous production of egg and sperm is still a gamble, depending on the material that can be obtained by local fishermen.

Figure 1. Spawning of *Parastichopus tremulus* in the Møreforsking lab. ©G. Christophersen

Table 1. Spawning of *Parastichopus tremulus* at different times during the expected spawning season.

Date of spawning	No. of individuals	No. of spawned males	No. of spawned females	Percentage spawned
29 May 2019	7	2	0	28.6
31 May 2019	7	1	0	14.3
04 June 2019	6	1	0	14.3
12 June 2019	8	4	0	50.0
18 June 2019	4	0	0	0
24 June 2019	12	4	3	58.3
01 July 2019	11	4	4	72.7

Table 2. Spawning success of *Parastichopus tremulus* induced to spawn in the lab in different years during the period from 20 June to 3 July.

	2017	2019	2020-1	2020-2	2021	2022-1	2022-2	2022-3
Broodstock group (#)	34	23	18	22	13	36	21	24
Spawned females (#)	4	7	4	4	2	6	5	4
Spawned males (#)	7	8	2	6	7	5	6	0
Spawned (%)	32	65	33	45	69	31	52	17

Broodstock maintenance and conditioning

Worldwide, hatchery production of sea cucumbers is largely based on the collection of broodstock from the wild during times close to the natural spawning period (Agudo 2006; Liu et al. 2015). Successful broodstock maintenance in captivity is needed in order to develop a sustainable aquaculture industry, independent of harvesting sea cucumbers from the wild. Methods of broodstock conditioning – to either enhance the maturation of gonads or to stimulate the rebuilding of spent gonads – will further contribute to predictable and potentially even out-of-season production. The onset and termination of the reproductive period may vary with latitude or from year to year, and is determined by a combination of endogenous and exogenous factors (Giese 1959; Sewell 1992; Mercier and Hamel 2009). Therefore, conditioning regimes must be developed that are specific to species and local stocks. The existing information on methods and conditions for broodstock maturation is limited to a few species, mainly *Holothuria scabra* and *Apostichopus japonicus* (Turner 2015; Hamel et al. 2022). Venâncio et al. (2021) has recently showed the importance of diet during conditioning and how this can be important for larval viability. It has been shown that it is possible to bring *A. japonicus* out of phase by manipulating environmental factors, resulting in a shift in the time of gonadal maturation by up to two months (Liu et al. 2015). From our experience with *P. tremulus*, we know that broodstock can survive in captivity for years, but it remains to see if it is possible to condition them to rebuild or mature their gonads in captivity. Others have faced challenges related to the development of adult sea cucumbers kept in captivity over time, such as reduced growth and fecundity with the number of days in captivity (Morgan 2000a; Venâncio et al. 2021). So far, our attempts to re-spawn broodstock held in captivity have not been too promising, but we believe there is a large room for improvements.

Parastichopus tremulus collected for spawning in one season were kept in flow-through holding tanks up to four years as potential broodstock. They were induced to spawn in 2017 and 2019 and kept under conditions with no extra feeding except for the organic matter in the unfiltered incoming seawater from 40 m depth. Trials of re-spawning these individuals in the 2020 and 2021 seasons gave no results in terms of spawning. Poor spawning results were also the case for re-spawning in 2021 of individuals originally taken in for spawning in 2020. In a group given supplemental *Sargassum*-based feed for two months before the attempt to re-spawn, spawning was unsuccessful; whereas in a group that was fed for the entire year resulted in one male spawning. In these preliminary trials, sea cucumbers were not sacrificed to assess gonad status. Accordingly, a new trial was carried out in 2022 with sea cucumbers fed all year and given different conditions from February until the end of June when dissection was performed. Three groups (n=10) were: 1) kept under the standard unfiltered seawater conditions and supplemented with *Sargassum*-based feed enriched with fish feed to increase the protein and lipid content; 2) kept in filtered seawater (1 µm) given *Sargassum* and fish feed; and 3) just *Sargassum*. Mean GI (% ± SD) was low for all groups: 0.68±0.482, 0.09±0.032 and 0.13±0.117 for groups 1, 2 and 3, respectively. In comparison, in 2022 the observed GI in sea cucumbers taken from the wild during the reproductive season was also <1% (0.61±0.683, n=25).

Fecundity and reproductive potential

The potential reproductive output in terms of gonad size and number of mature eggs varies individually in *P. tremulus* that are caught close to the natural spawning season. Very few broodstock individuals that have been dissected during the natural spawning season have had large amounts of gonad tissue (GI >10%), and the majority has a GI <4%. This could, of course, be due to a loss of gonad tissue during fishing and transport stress, but this is unlikely because we have seldom seen the expulsion of an entire gonad or gonad tissue fragments in our holding tanks. We must also consider that the individuals we have received may or may not be representative samples of the local population distribution of mature and immature sea cucumbers.

To investigate the spawning potential of *P. tremulus* we have made attempts to quantify the fecundity of individuals from induced spawning egg production and from counting remaining oocytes in samples of gonad tissue. Our observations after induced spawning estimate a release of approximately 100–200,000 eggs per female per spawning event (Table 3). This spawning output is probably a fraction of the potential egg production because gonads are not totally emptied during a single spawning event, as has been documented for other sea cucumber species (Sewell 1992; Morgan 2000a; Ramofafia et al. 2000). We have obtained viable eggs from repeated spawnings of the same female (Schagerström et al. 2021). To what extent *P. tremulus* performs multiple batch spawning in nature is unknown. Because we have observed more than one category of gonad developmental stage at the same time (reported in Christophersen et al. 2020), there is a possibility that our sea cucumbers are partial spawners (immature eggs are carried over to the next spawning season), which may complicate the estimation of fecundity.

To quantify the egg production potential, approximately three 0.01 g pieces of filled gonad tissue were sampled from seven females (Table 4). The gonad tissue samples were evaluated under a dissection microscope to confirm they were close to the mature stage. Eggs were separated from the tubules and each sample suspended in 6 mL from where the number of eggs in triplicate volumes of 1 mL was counted. Mean values were used in the calculations of total number of eggs per gonad, and per gram gonad, body wall or total wet weight of the individuals. The number of eggs per gram gonad ranged from 41 to 418,000, averaging 190,000. This is within the same range (50–500,000) as that produced (spawned) by individual *Holothuria scabra* (Morgan 2000a). Based on these estimates, and on the amount of gonad tissue observed in our lab over the years, the proportion of *P. tremulus* females that have the potential of producing millions of eggs seems to be limited, at least for our local population at 62°N. Figure 2 shows the mean number of eggs per gram of total and body wall wet weights. We found lower fecundity of *P. tremulus* than Whitefield and Hardy (2019) reported for *Apostichopus californicus* (≤1000 vs 2863 ± 1502 eggs per g total wet weight).

The relationship between number of eggs counted per gonad correlated well with gonad wet weight (Figure 3), but not with total wet weight of female individuals (R = 0.02; not shown).

Improving reproduction in captivity

For more developed aquaculture species such as fish, manipulation of environmental parameters and the use of hormonal implants have significantly increased the spawning season in captivity beyond that in nature. The development of these techniques has been essential for establishing profitable industrial aquaculture production of these species. Techniques for efficient reproduction in captivity thus seems crucial to establishing predictable production of juveniles and, thus, secure economic investment to develop industries. Several methods have been developed for other sea cucumbers that could potentially be adapted to improve reproduction of *P. tremulus*. As mentioned previously, common spawning induction protocols are often based on stressing the broodstock temporarily via environmental factors such as raised or lowered temperatures or by exposure to air. However, stress induced by these methods could potentially affect the short- or long-term health of broodstock, and might also be detrimental to the quality of the gametes obtained. Novel biochemical approaches targeting chemical signalling pathways that have been tested in the laboratory but not in aquaculture production systems, may have the potential to be more efficient without exposing the animal to unnecessary stress (see Eeckhaut et al. 2012; Hamel et al. 2022 for reviews). In order to have an industrial application, however, the effects of these compounds need to be tested for confirmation of their properties in each species.

Gamete quality and storage

When spawning was repeatedly induced in *P. tremulus* males twice a week by temperature shock, sperm initially showed poor motility from the time of the observed GI peak (May–June) (Christophersen et al. 2020). However, from the end of June onwards, quality improved significantly, and collected ejaculates consistently displayed vigorous movement and >90% motile sperm. After collection, sperm motility rapidly degraded and reached 0% within hours, even when stored on ice. From our experience, the relatively short motile period observed, coupled with asynchrony of male and female spawning observed in our laboratory, is a major obstacle to the reliable production of *P. tremulus* larvae and juveniles. Sperm often is either in

Table 3. Number of eggs spawned per female *Parastichopus tremulus*, 2019–2022.

Year	Female				
	1	2	3	4	5
2019	194,000	177,000	37,000	5000	
2020	82,800	101,200	240	120	260
2022	10,1578	58,500	833	3389	2400

Table 4. Metrics, gonad index and number of eggs (oocytes) in gonad for individual *Parastichopus tremulus*. Egg number is estimated as total number per ovary (average of three samples).

Individual #	Length (mm)	WW (g)	Body wall WW (g)	Gonad WW (g)	GI (%)	Egg number
1	190	273	166	0.98	0.59	188,644
2	302	356	181	0.25	0.14	37,128
3	220	221	122	0.06	0.05	15,269
4	220	383	177	2.97	1.68	393,903
5	218	238	144	1.00	0.69	133,006
6	202	200	105	1.73	1.65	359,169
7	182	259	157	2.24	1.42	577,508

WW: wet weight

excess or lacking, depending on the success rate and gender distribution of broodstock induced to spawn. However, sea cucumber sperm seemingly can be used for *in vitro* fertilisation even when harvested from dissected gonads (Shao et al. 2006). This has not yet been attempted for *P. tremulus*. Even though this technique could provide more reliable access to sperm for fertilisation and possibly reduce the total number of males needed, we do not consider this a sustainable model for hatchery production, because it requires sacrificing potentially, genetically valuable males. Development of additional methods that facilitate storage of gametes, both in the short or long term, is necessary to improve the efficiency of reproduction in captivity.

As with other externally fertilising marine organisms, sperm motility in holothuroids is initiated by changes in osmolarity upon release to the surrounding seawater (Yu et al. 2011). Motility can also be modulated by changes in pH, salinity and concentration of specific ions, as demonstrated in *Apostichopus japonicus* (Shao et al. 2006; Yu et al. 2011). Methods for short-term storage of sperm from other species have taken advantage of these properties to successfully develop buffer solutions that inhibit motility and prolongs the motile period and fertilising ability of the sperm. Although some progress has been made with regards to storage solutions for sperm from other echinoderm species (see review by Gwo 2000), little has been published on sea cucumber sperm storage. Sperm motility inhibition and re-activation has been demonstrated for *A. japonicus* sperm collected from gonads (Shao et al. 2006; Yu et al. 2011), and without any additional treatment, sperm excised from gonads could be stored in their original seminal fluid at 4°C and still be activated after one day (Shao et al. 2006). A cryopreservation protocol has been developed for *A. japonicus* sperm that is both simple and effective for hatchery applications (Shao et al. 2006; Xu et al. 2022) and, at present, seems to be the best option for the storage of *P. tremulus* sperm. Hopefully, more research efforts will be focused on adapting this method to new species, or developing new cryopreservation protocols. Sperm cryopreservation is not only a useful tool for aquaculture purposes, but has a particular important application to conservation of genetic resources from endangered sea cucumber stocks worldwide. In contrast to sperm, oocytes from dissected gonads of

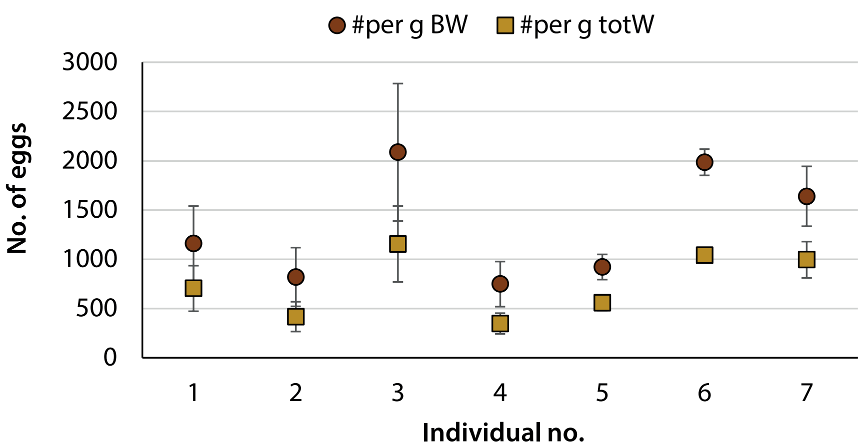

Figure 2. For the seven individuals, the average number of eggs (± SD) in gonads per gram of body wall and total wet weight of *Parastichopus tremulus*.

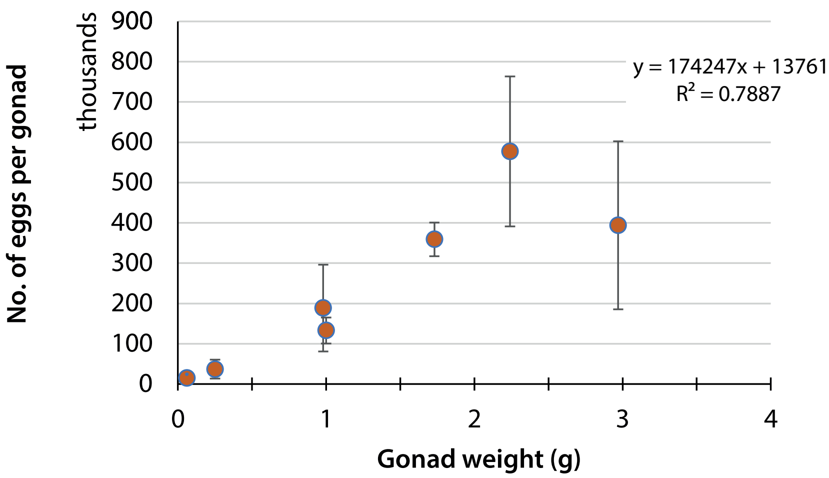

Figure 3. Relationship between gonad wet weight of seven individuals and the average number of eggs per gonad (± SD) in mature *Parastichopus tremulus*.

females can rarely be fertilised *in vitro*, although some promising efforts have been made towards achieving final oocyte maturation *in vitro* (see Léonet et al. 2009, 2019; Hamel et al. 2022; Eeckhaut et al. 2012 for reviews). So far, no trials have been carried out on *P. tremulus* oocytes.

We can speculate as to whether all sexually mature individuals of *P. tremulus* reproduce annually, or if gonad maturation happens over years, such as that described in the proposed tubule recruitment model of gonad development for *Apostichopus californicus* (Smiley and Cloney 1985). This model, however, does not seem to be applicable to all holothuroid species because gonad development may be different between closely related species and even within geographically separated populations of the same species (Sewell et al. 1997; Hamel et al. 2022). It has also been observed that variations in environmental factors from year to year impact the gonad maturation processes (Sewell and Bergquist 1990; Sewell et al. 1992). More thorough investigations into gonad development in *P. tremulus* over several years needs to be performed in order to gain a better understanding of this process and how it can be manipulated in captivity.

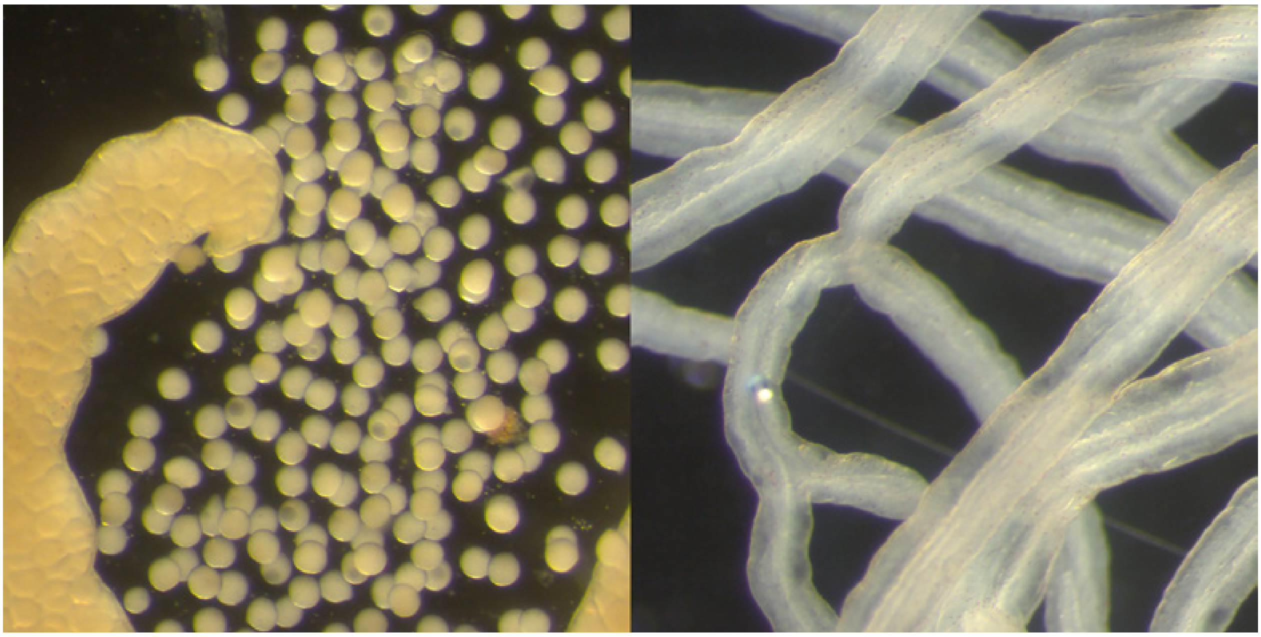

Figure 4. Female (left) and male (right) gonads of *Parastichopus tremulus*. @ G. Christophersen

Genome and genomic tools

Knowledge of the sequence, structure and genetic content of animal genomes is being used at an increasingly larger scale in breeding programmes to select for traits for improved animal health and to increase production (Rexroad et al. 2019). The first sea cucumber genome to be published was of *Apostichopus parvimensis* in February 2015. To date, 22 nuclear genomes of 21 different sea cucumber species are available at the National Center for Biotechnology Information (NCBI) in the database Genbank (search term "Holothuroidea"), including colour variants of *Apostichopus japonicus*, the most studied species (Jo et al. 2017; Zhang et al. 2017). None of the nuclear genomes are currently in NCBI RefSeq (a non-redundant database collection of reference sequences). However, of the 109 currently available mitochondrial genomes, encompassing 46 verified species, 29 can be found in RefSeq. Research interest in genome data from sea cucumbers seems to be accelerating because 18 of the nuclear genomes were submitted and or published between January 2021 and February 2023. There are currently no genome data available for *P. tremulus*. Only a few mitochondrial gene fragments such as the Cytochrome Oxidase subunit I (COI) that are typically used for species identification of eukaryotes are available in Genbank (https://www.ncbi.nlm.nih.gov) (Ratnasingham and Hebert 2007).

Thus far, the genome sequence of *Stichopus chloronotus* (unpublished direct submission, assembly accession GCA_021234535) is the only one that has achieved chromosome resolution on its assembly, all other sea cucumber assemblies are in the form of contigs or scaffolds and are, thus, considered draft genomes. This is also the case in general for most other genomes assembled today. Although there may be both inter- and intra-species variation in both ploidity and chromosome number in Holothuroidea, genomes are most consistently reported to be diploid, with 22 chromosome pairs (Colombera 1974; Okumura et al. 2008; Zhang et al. 2017). DNA sequencing technology is developing at a fast rate and has gone from being available exclusively at larger sequencing facilities, to currently being available in most research laboratories and even in the field. To answer some of the pressing questions regarding aspects of the biology and function of the red sea cucumber, Møreforsking has initiated work to sequence, assemble, and annotate the whole genome of *P. tremulus* using Nanopore sequencing (Oxford Nanopore Technology, Oxford, United Kingdom). The resulting genome will improve our understanding of this species and aid in the development of farming and breeding technologies, as well as enable bioprospecting of high-value compounds. So far, with the currently produced *P. tremulus* DNA sequence data, a low-quality assembly has been produced (Meisal, unpublished).

These data can already be used to search for answers to questions relating to the reproduction of *P. tremulus*. Due to the lack of external gender-specific characteristics in *P. tremulus*, determining the gender of potential broodstock before spawning is difficult. Techniques for gender identification could be developed based on *e.g.* gonad biopsy (Morgan 2000b; Pratas et al. 2017), but identification of gender-specific genes as previously described for *Holothuria scabra* and *Apostichopus japonicus* (Zixuan et al. 2023; Wei et al. 2021) would potentially be a good option when a reliable and inexpensive method becomes available.

Future possibilities to realise the reproductive potential

Reliable methods for spawning induction and gamete storage for *P. tremulus* are still being developed, but several promising strategies can be pursued to adapt protocols developed for other species for spawning induction, oocyte maturation and cryopreservation of sperm. By advancing the methods of conditioning to successfully manipulate maturation of gonads in captivity, opportunities lie ahead for the synchronous maturation and reliable spawning of males and females. This in turn will enhance larval yield, a prerequisite for predictable juvenile production.

In parallel to optimising methods for broodstock conditioning and reproduction, our ambition in the near future is to assemble the first complete *P. tremulus* genome. This will contribute to the relatively scarce information on holothuroid genetics, and hopefully lead to increased knowledge that will assist the development of new tools for aquaculture of emerging sea cucumber species.

Acknowledgement

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The enigma of stones found in the body cavities of sea cucumbers

Kevin C.K. Ma,[1]* Robert Trenholm,[1,2] Jean-François Hamel[3] and Annie Mercier[1]

Abstract

For the first time, industrial processors of the suspension-feeding sea cucumber *Cucumaria frondosa* (Holothuroidea: Dendrochirotida) have reported two individuals with pebbles or stones nestled inside their body cavities. The two sea cucumbers were harvested by bottom trawl off the coast of Newfoundland (eastern Canada) and later analysed. They measured 11.5 cm and 14.0 cm in length, respectively, and harboured stones weighing up 450 g (i.e. three to four times their whole wet weight). These individuals displayed a severely damaged or crushed aquapharyngeal bulb, open wounds through the integument, and other deformations. The absence of, or damage to, internal organs and the erosion of the podia rows pointed to severe trauma, rather than deliberate ingestion (i.e. gastrolith), as the cause of the phenomenon. Violent impact of metal gear components with stones present on the seafloor or in the trawl itself may forcibly push these stones into the sea cucumbers during harvesting. A concrete outcome is potential damage to industrial equipment used for processing these stone-bearing sea cucumbers. As the fishery intensifies, it is anticipated that harvested sea cucumbers harbouring stones may increase in frequency, raising questions around this harvesting method, and calling for ways to detect the presence of internal stones before processing.

Keywords: *Cucumaria frondosa*, Dendrochirotida, fishery, health, gastrolith, industrial processing, Northwest Atlantic

Introduction

The fishing gear presently used during the commercial fishery for *Cucumaria frondosa* in Newfoundland and Labrador is a form of bottom trawl, composed of a heavy steel front end (ironwork), chain grid, chaffing mat, and a braided polyethylene net bag drawn along the sea floor that captures benthic species into an attached net bag (Barret et al. 2007; Figure 1). Such trawls have been associated with low efficiencies for target size classes, high rates of bycatch, and substantial changes to the benthic habitat (Lambert et al. 2014; Pusceddu et al. 2014). Further, this method of harvesting sea

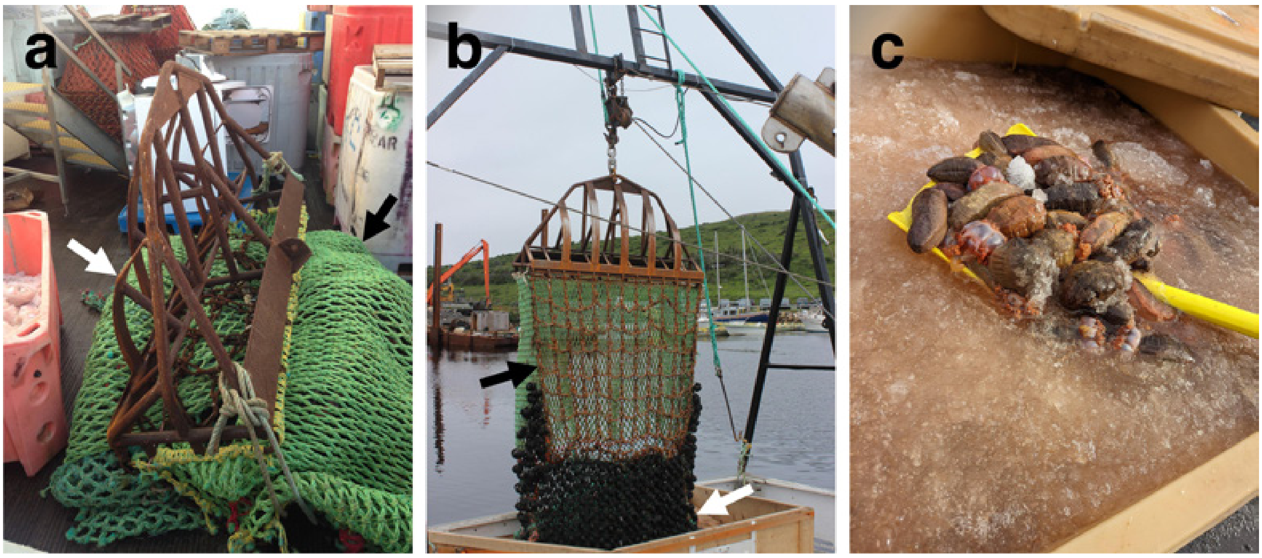

Figure 1. A Newfoundland sea cucumber bottom trawl, commonly referred to as a "drag" (a) placed on the ground of a wharf (white arrow indicates the steel front end and black arrow the green net bag), and (b) suspended in the air from a fishing vessel (black arrow indicates the chain grid and white arrow the chaffing mat), and (c) harvested sea cucumbers in a 1000-L insulated container packed with ice.
Photo credits: (a, b) R. Trenholm (photographed in November 2017 and July 2018); (c) K.C.K. Ma (September 2022).

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cucumbers contributes towards an inherently flawed high volume–low value model that has characterised the sea cucumber fishery in the eastern United States and Canada since it began in the 1980s, as described by Gianasi et al. (2021).

During production, landed sea cucumbers are typically handled and inspected to isolate any damaged and small individuals (though there is currently no official minimal size, those under ~10 cm are usually treated separately). In most high-volume production lines, standard-size individuals are processed by a (semi-) automated system that opens the body cavity and removes the viscera without further damaging the skin (integument) to produce butterfly cuts or cocoon cuts, depending on the equipment (Hossain et al. 2020).

The sea cucumber *C. frondosa* inhabits benthic environments that features some combination of gravely and rocky substrata (Gianasi et al. 2021). Like other sea cucumbers in the order Dendrochirotida, *C. frondosa* is a suspension feeder that gains sustenance from organic particulate matters (e.g. phytoplankton, microzooplankton) present in the water column (Hamel and Mercier 1998); it may also ingest larger organic particles (Gianasi et al. 2017) and small sand grains (Graham and Thompson 2009).

This paper documents and explores for the first time the presence of stones in the body cavities of adult *C. frondosa* captured by the trawl fishery. The location of the stones, the circumstances that may explain their presence, and the detrimental implications this phenomenon may have on processing equipment are presented and discussed.

Methods

Sea cucumbers were harvested between depths of 50 m and 100 m from the St Pierre Bank, off the south coast of Newfoundland (NAFO Subdivision 3Ps; Western Bed; south of 46°30'N and west of 56°28'W), during the 2022 fishing season. During post-harvest preparation for production at the Cape Broyle processing plant (eastern Avalon Peninsula) quality control found two uncharacteristic individuals of *C. frondosa*. One unusually heavy individual (14.0 cm in body length) was detected on 26 August 2022, and one misshapen individual (11.5 cm) on 5 October 2022. Digital still images and videos were taken and both individuals were dissected.

To contextualise how bottom trawling and post-harvest handling of sea cucumbers may be linked to the phenomenon as reported in this study, the steps involved were examined from past and recent interactions with the industry. Assessments of sea cucumber landings were conducted in 2017–2018 on the Burin Peninsula, including one in St Lawrence on 20 November 2017 and another at Fortune on 16–17 July 2018. Visits to the processing plant at Cape Broyle were conducted on 21 September and 15 October 2022 to gather additional information.

Results

Cucumaria frondosa *individual found in August*

The contracted body of the sea cucumber harbouring a large stone was approximately 8.3 cm wide and 14.0 cm long, and exhibited physical damage (Fig. 2). Most of the aquapharyngeal bulb (including the tentacles) was absent and anterior rows of podia were eroded (Fig. 2a). Perforation of the integument (i.e. an open wound towards the posterior end) partially revealed the stone and another wound (ventral side) exposed internal organ(s) (Fig. 2b). This perforation measured 1.9 cm in width and 2.6 cm in length. The individual was dissected longitudinally to fully reveal the stone, which was in the perivisceral cavity surrounded by muscle tissues. The stone was covered in crustose red algae, *Lithothamnion* sp. (Fig. 2c), and thus structurally abrasive. The stone had a Feret diameter of 8.0 cm (circumference of 22.1 cm), weighed 456 g, and had a total volume of 176 $cm^{3.}$

Cucumaria frondosa *individual found in October*

Excluding the aquapharyngeal bulb and tentacles, the deformed body of this individual was 3.1 cm wide and 3.3 cm long (Fig. 3a). The sea cucumber featured a large tissue pocket (about 4.1 cm in length) next to the extended aquapharyngeal bulb, which contained a stone. The stone was entirely enveloped by collagenous tissue and was partially visible through a perforation on the surface of this pocket, which measured about 1.6 cm in diameter (Fig. 3a). Upon dissection, the posterior portion of the integument was found to be folded inside the body cavity (Fig. 3b) and further examination revealed that the actual body length was 11.5 cm (Fig. 3c). The stone had a smooth surface (with no fouling organisms), and the Feret diameter was ~4.5 cm (weight and volume unknown; Fig. 3b, c).

Additional information about processing

During typical dockside offloading procedures (Fig. 4a), visible stones, debris and bycatch of other species are separated from sea cucumbers and set aside (Fig. 4b). Sea cucumbers are then placed in insulated containers (~1000 L) and transported to the processing plant (Fig. 1c). Small loose stones can still be found in the containers used during overland transport and, occasionally, some can be found still attached to sea cucumbers via their ambulacral podia. At the processing plant, inspections of sea cucumbers are performed prior to mechanical evisceration.

Operators and quality control personnel at the Cape Broyle processing plant had neither encountered nor been informed of any stone-bearing sea cucumbers before the ones documented in the present paper. However, loose stones hidden among the sea cucumbers were recovered from the processing plant (Fig. 4c), and an examination of these stones showed that a majority weighed between 0.5 g and 26.3 g (5.9 ± 4.9 g [mean ± SD]; n = 127). The largest loose stone detected during our visits to the plant weighed 111.7 g.

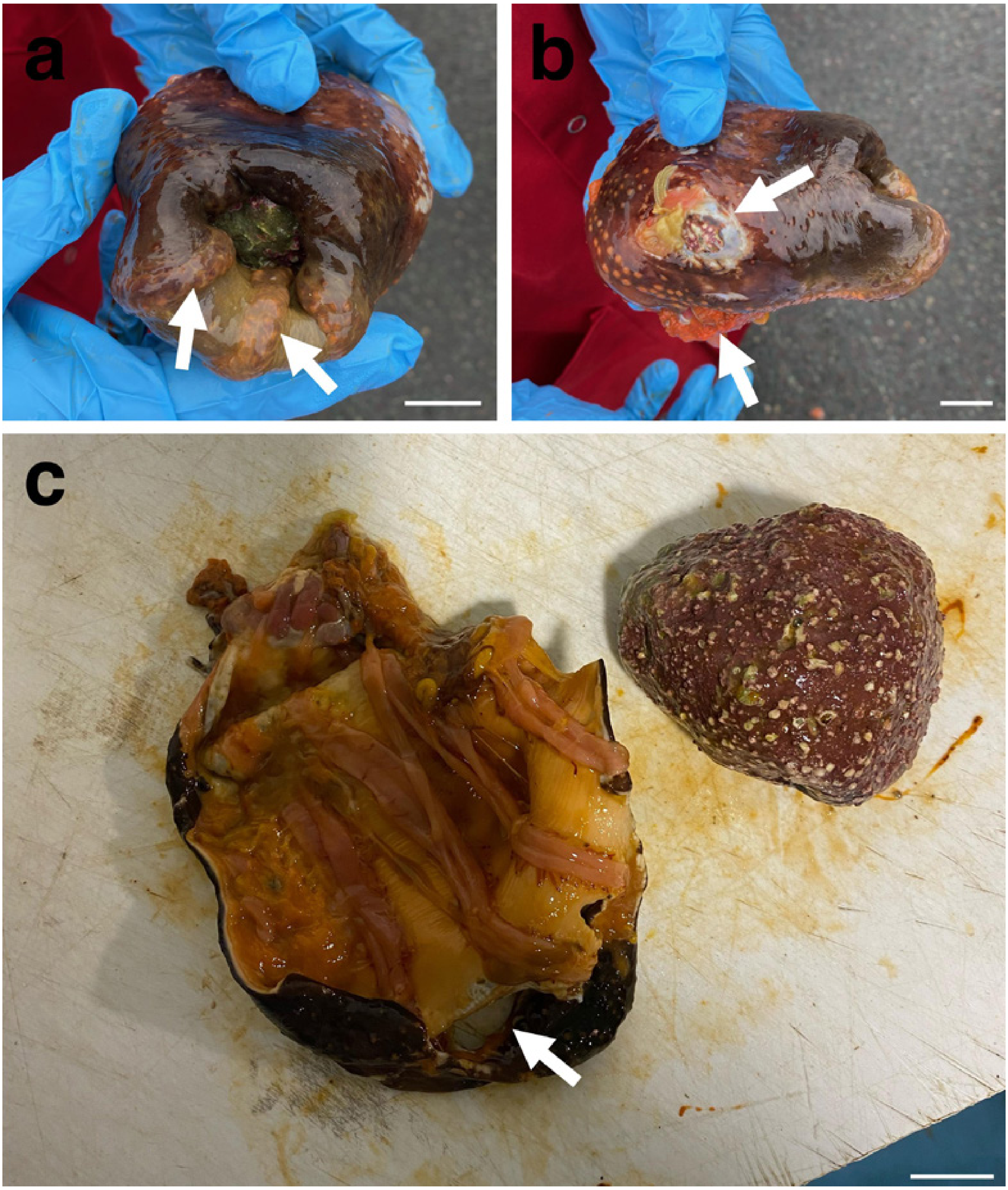

Figure 2. An individual of *Cucumaria frondosa* with a 456-g stone inside its body cavity that was harvested in late August 2022 off the south coast of Newfoundland, Canada: (a) ex situ anterior view with partial view of the stone and eroded rows of podia (white arrows), (b) ex situ side view with open wounds through its integument (white arrows), and (c) oblique view of the dissected individual and a fully revealed stone (to the right of the sea cucumber), providing an internal view of one of the wounds (white arrow). All scale bars represent ~2 cm. Photo credit: Quin-Sea Fisheries Ltd, a division of Royal Greenland

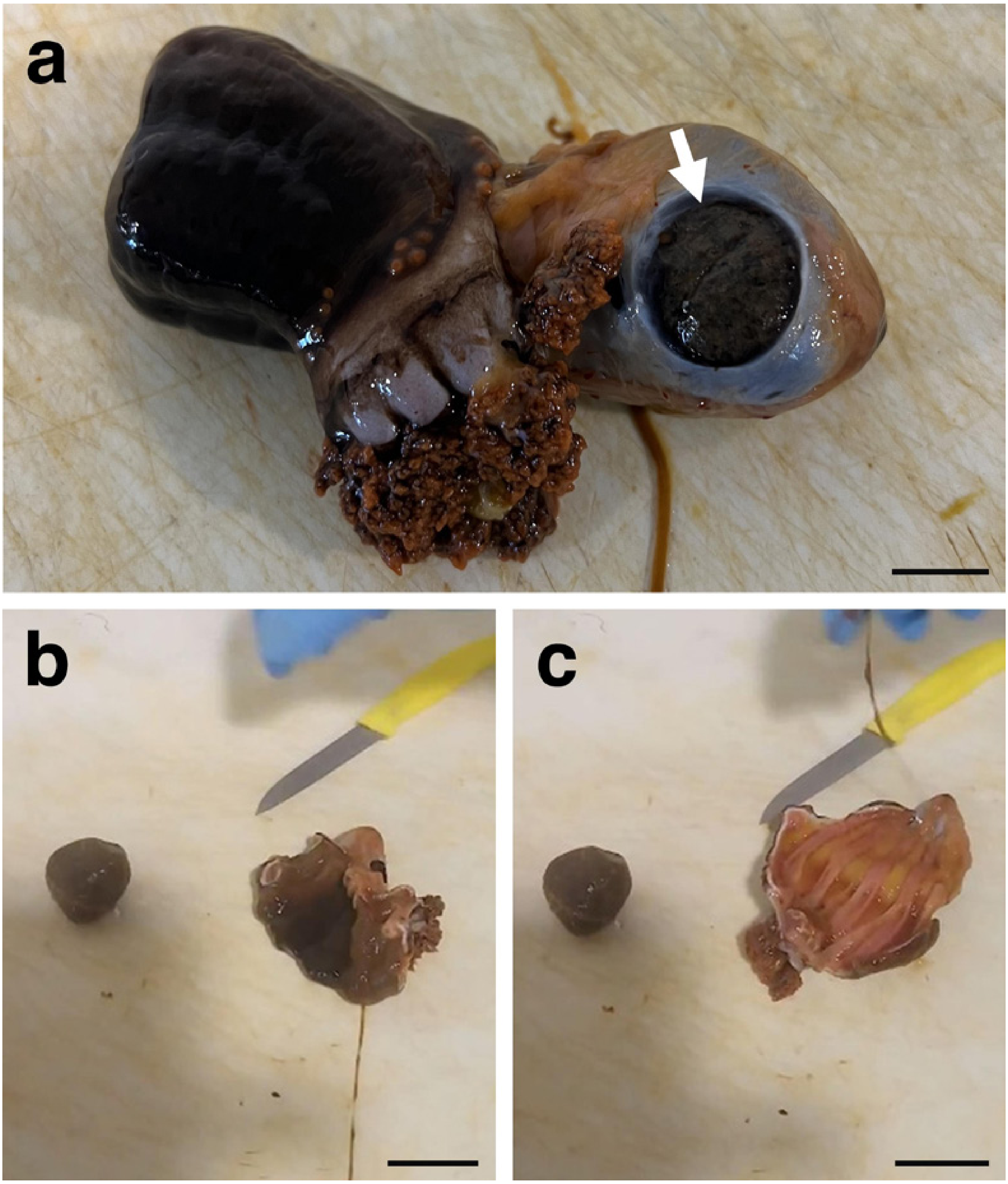

Figure 3. An individual of *Cucumaria frondosa* with a stone inside a pocket of collagenous tissue that was harvested in early October 2022 off the south coast of Newfoundland, Canada: (a) *ex situ* side view with partial view of the stone was visible through a perforation (white arrow), (b) oblique view of the dissected individual with the posterior portion of the integument folded inside the body and a fully revealed stone (to the right of the sea cucumber), and (c) oblique and internal view of the dissected individual with the integument unfolded. The scale bar represents ~1 cm in (a), and ~5 cm in (b) and (c).
Photo credit: Quin-Sea Fisheries Ltd, a division of Royal Greenland

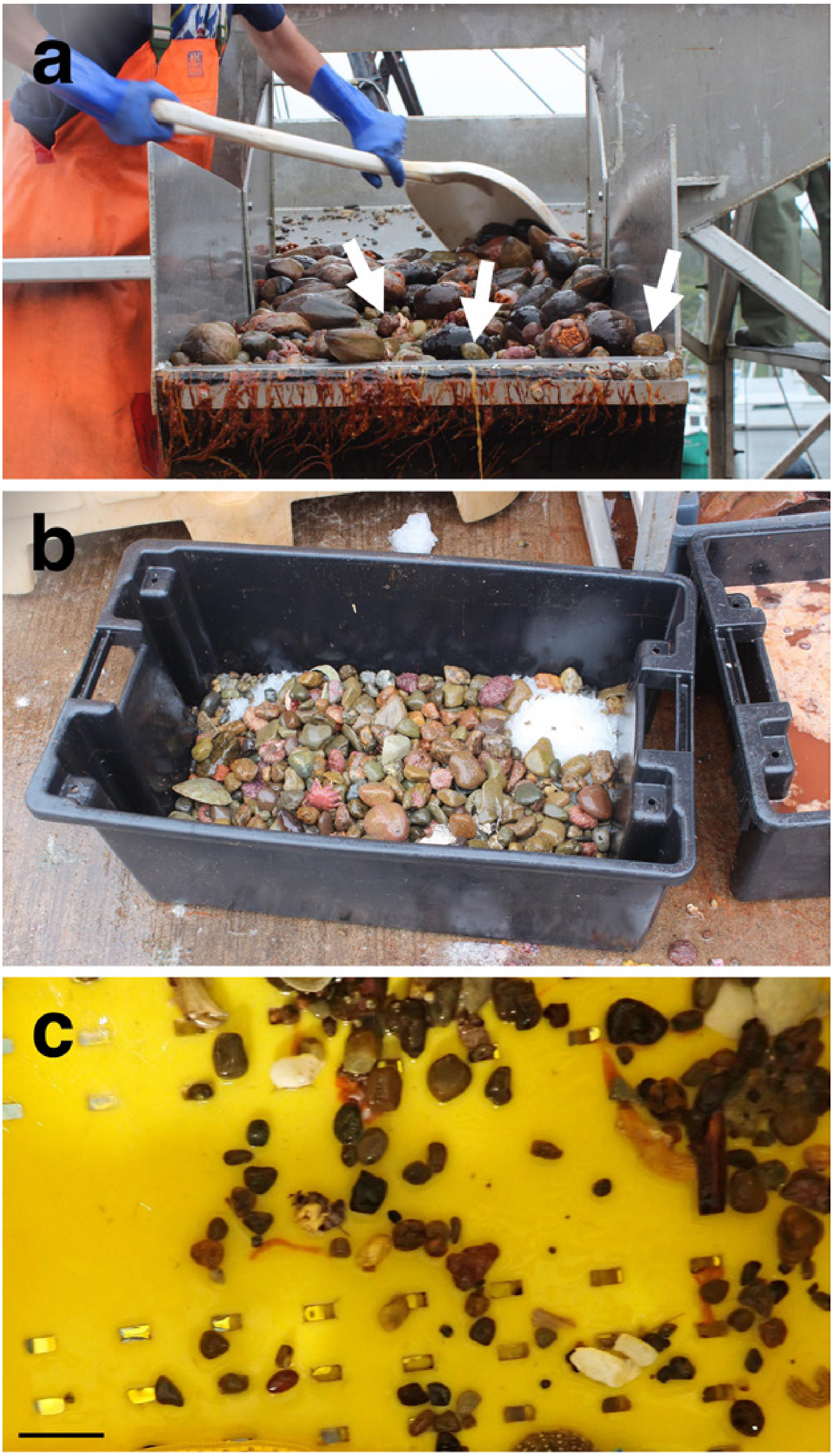

Figure 4. Field observations at: (a) the dockside where harvested sea cucumbers, loose stones, and bycatch were manually sorted (white arrows indicate stones); (b) the dockside where easily visible loose stones were set aside in a black container; and (c) the processing plant where leftover loose stones were set aside in a yellow container. The scale bar in (c) represents ~5 cm. Photo credits: (a, b) R. Trenholm (photographed in July 2018); (c) K.C.K. Ma (September 2022).

Discussion

The two sea cucumbers examined allowed us to document for the first time the occurrence of stones found inside freshly harvested individuals of the sea cucumber *C. frondosa*. The feeding habits of *C. frondosa* (and other species of dendrochirotids) made it unlikely that individuals would naturally or incidentally ingest stones, especially some as large as the ones found in the present study (relative to the size of the sea cucumber). Here, we determined that the stones were not swallowed but rather forcibly inserted into the body cavity (perivisceral coelom) of the sea cucumbers.

In contrast to most other commercial species of sea cucumber, *C. frondosa* does not eviscerate internal organs nor discharge Cuvierian tubules in response to stressors (Gianasi et al. 2021). Instead, it responds to stress and physical disturbance by contracting longitudinal and circular muscles, as well as longitudinal retractor muscles, such that an individual attains a firm ellipsoidal shape. Mutable collagenous tissue in the body wall often creates a firm dermis protecting the individual from punctures or predation (e.g. Mo et al. 2016; Motokawa 2019). In addition, *C. frondosa* can actively regulate its buoyancy (i.e. active buoyancy adjustment) through intake of seawater in its body cavity as a behavioural response to the presence of predators and other stressors (Hamel et al. 2019). Swollen individuals can tumble or float away, which augments dispersal potential for this otherwise sedentary benthic species (Hamel et al. 2019). A possible explanation for the presence of stones inside *C. frondosa* individuals could be the deliberate ingestion of substratum (i.e. gastrolith) as ballast to modulate the buoyancy response. However, the existence of this potential strategy was challenged by the current study, following informal discussions with processors and the examination of existing images and videos. Furthermore, while the occurrence of gastroliths for food processing and buoyancy is documented in other species (primarily in marine and terrestrial tetrapods; Taylor 1993; Rondeau and Gee 2005; Shuert and Mellish 2016), it has not been reported in sea cucumbers.

Overall, the finding of a stone inside *C. frondosa* was determined to be a non-natural phenomenon, possibly caused by bottom trawling during harvesting. This is supported by the serious injuries suffered by the sea cucumbers (e.g. open wounds, crushed and partially missing aquapharyngeal bulb), which were probably caused by contact with the bottom trawl towed along the seafloor. During harvesting, injuries (including blemishes) to sea cucumbers may also be inflicted by violent physical contact with stony bycatch. Conceivably, a sea cucumber could be forced beneath the drag and compressed against the seafloor, which could cause enough shear and force to press a stone into its body cavity; this sea cucumber could then be captured by a subsequent trawl. A possible but improbable consequence may be decreased fitness for individuals that would otherwise escape the trawl and heal their body wall around the stone. Yet, the exact chain of events during harvesting to produce the serious injuries that were reported here remains unconfirmed. Despite this, the August individual exhibited signs that the stone was forcibly inserted through the anterior end into the body cavity. While in motion, the stone covered with calcareous algae (rough surface) probably damaged the ambulacral podia rows on its way inside the perivisceral cavity of the sea cucumber. In contrast, the October individual presented signs that the stone was inserted through the posterior end, most probably at high velocity. The stone appeared to have invaginated the posterior portion of the integument through the body cavity and out the anterior end (next to the tentacles). A pocket of what remained of the collagenous tissue trapped the stone. Overall, damage to the tissues and internal organs (intestine, respiratory tree, and gonad) of both individuals suggests severe trauma associated with this phenomenon.

After about seven years of processing sea cucumbers, this was the first year the producers at the plant in Cape Broyle detected individuals containing stones (S. Botlagunta, pers. comm., 2022). Operators at another processing plant in Change Islands, Newfoundland and Labrador, Canada (near Fogo Island), have never reported any stone-bearing sea cucumbers since operations began around 2015 (S. Botlagunta, pers. comm., 2022). It thus remains uncertain if these observations were an isolated incidence or represent an ongoing impact of bottom trawling that was never previously discovered.

Although both cases were discovered by quality control personnel on the processing line at the earlier stages of production (i.e. before sizing and mechanical evisceration), they raised important concerns. Any stones (or other solid debris) hidden inside sea cucumbers can have detrimental consequences for industrial equipment, especially evisceration systems, at later stages of production (e.g. Singleton et al. 2016). Replacement parts to repair damaged blades of an evisceration system, such as those used at the plant in Cape Broyle to produce butterfly cuts, can cost between USD 150 and 200 per system (B. Payne, pers. comm., 2022).

It is likely that the presence of stones forced into the body of sea cucumbers is a more common phenomenon in trawl fishery than described here. Future investigations are needed to understand the exact causes and rate of incidence of this phenomenon, and to explore mitigation strategies to prevent any damage by undetected stones (hidden inside sea cucumbers).

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Can deep-sea holothurians from New Caledonia be used to monitor microplastic pollution?

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Introduction

Plastic production has increased exponentially since the early 1950s (Bergmann et al. 2015; Geyer et al. 2017). Plastics represent the vast majority of total marine litter (Barnes et al. 2009; Pham et al. 2014), and mostly stem from mismanaged land-based litter (Gallo et al. 2018). In 1972, Carpenter's seminal work first described the impact of plastics in the marine environment, showing their ingestion by fishes (Carpenter 1972). This work paved the way to a new field of research on the effects of anthropogenic litter on marine life (Bergmann et al. 2015). This research was first focused on macro-litter and the accumulated evidence of microplastic harm to a broad range of species (see Andrady 2011; Bergmann et al. 2015; Galloway et al. 2017; Courtene-Jones et al. 2022). Now, researchers have realised that this macrolitter only represents a fraction of all plastic pollution.

Most of the pollution is due to microparticles either produced as such, or resulting from the weathering and breakdown of larger plastics. Microplastics encompasses particles that are 1 µm to 5 mm in size (Koelmans et al. 2022). In 2004, Thompson and colleagues revealed that microplastics could be deleterious in many ways, as they could be easily ingested (Thompson et al. 2004). Their presence has since been documented in all marine ecosystems. In particular, microplastics can sink down to the seafloor due to a high density, or to mechanisms such as biofouling or marine snow. As such, several studies have shown that microplastics can accumulate in sediments, and that the deep-seafloor could constitute a major microplastics sink, rendering them bioavailable to benthic organisms (Woodall et al. 2014; Galloway et al. 2017; Courtene-Jones et al. 2019; Zhang et al. 2021).

Most holothurian species are benthic organisms found at all depths and latitudes (Purcell et al. 2016). A vast majority of species are deposit feeders (Slater and Chen 2015), with high bioturbation and sediment-filtering rates, between 9 and 82 kg per individual per year (Purcell et al. 2016; Williamson et al. 2021). Hence, we hypothesise that holothurians could be a relevant model organism to study microplastic pollution. Research in shallow-water ecosystems has already demonstrated the presence of microplastics in several species of holothurians such as *Apostichopus japonicus, Holothuria floridana and Cucumaria frondosa* (Graham and Thompson 2009; Renzi 2018; Mohsen et al. 2019; Plee and Pomory 2020; Bulleri et al. 2021; Coc et al. 2021).

Here, we present the objectives of a new project (Fig. 1) on holothurians, which are to:

- investigate the temporal trends of microplastic pollution using a time-series museum collection of deep-sea New Caledonia holothurians of the Muséum National d'Histoire Naturelle (Paris, France);
- determine the potential uptake and biodistribution of microplastics by holothurians, and investigate the physiological consequences via *in vivo* experiments; and
- develop ways to involve local New Caledonian citizens in our project.

Deep-sea holothurians from New Caledonia as an indicator of microplastic pollution – a study from the MNHN collections

Only a few studies have used time-series collections to investigate plastic accumulation within marine organisms such as in fish (Beer et al. 2018; Hou et al. 2021), plankton (Ostle et al. 2019), brittle stars and sea stars (Courtene-Jones et al. 2019). These studies reached contrasting conclusions showing that there has been an increase or saturation of microplastics found in these organisms. To our knowledge, no such study has been conducted in the Indo-Pacific, nor on holothurians.

The Muséum National d'Histoire Naturelle (MNHN) and the Institut de Recherche pour le Développement (IRD) have established a collection of deep-sea organisms sampled from 1976 to 2021, through several research cruise programmes: MUSORSTOM, Tropical Deep-Sea Benthos, and La Planète revisitée) (Richer De Forges et al. 2013). About 40 research cruises were conducted off New Caledonia at depths of 200 m and 2000 m and leading to the collection of more than a thousand holothurian specimens. These specimens are stored in the MNHN collections in ethanol, a solvent that does not alter plastics over time (Courtene-Jones et al. 2017).

Prior to using the specimens for microplastic analysis, this taxonomically understudied material will be identified by leading deep-sea taxonomists (morphology, barcoding).

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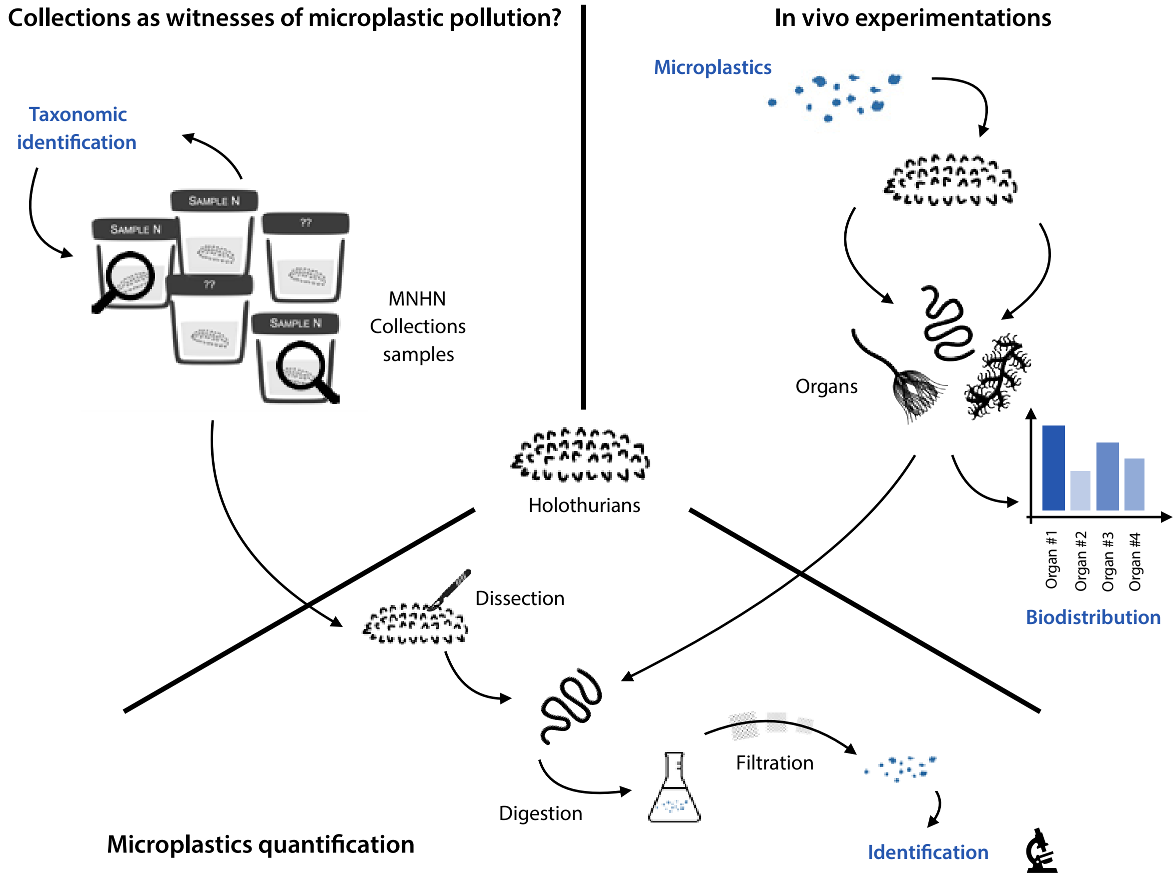

Figure 1. Graphical abstract summarizing the project.

Following identification, a representative subsample of specimens found at different locations and time will be analysed for microplastics. Microplastics will be extracted from the gastro-intestinal tract, the respiratory tree and the gonads. Results will include abundance, size, polymers and any potential trend.

Further development of the project will also address other marine invertebrates to obtain a broader and more relevant picture of the marine biota contamination throughout time. As suggested by Valente and collaborators, such an approach is necessary to obtain a representative insight on microplastic pollution of biota in a given location (Valente et al. 2022).

Biodistribution and impact on physiology: *in vivo* experiments

Concurrently, we aim to assess the biodistribution of microplastics in holothurians, through *in vivo* feeding experiments, as already tested by Mohsen (et al. 2019) and Iwalaye (et al. 2020). To validate the method, we will first use the shallow-water species *Holothuria forskali*, before using *Parastichopus regalis*, a deeper species that is more representative of the collection samples. Holothurians will be placed in closed-loop aquariums, with food supplemented in microplastics. We will then investigate microplastics uptake by holothurians. If microplastics are indeed uptaken by holothurians, we will assess their biodistribution within their internal organs. By knowing the organs in which microplastics tend to accumulate, we will focus on the more relevant organs to analyse in collections specimens.

After investigating microplastics uptake and biodistribution, we will further assess whether holothurian physiology is altered by the consumption of microplastics.

This work will be conducted in collaboration with the Marine Station of Concarneau in France.

Involvement of New Caledonian citizens in the project

Because the samples we are collecting are from New-Caledonia, we want to involve local communities in the project. At the project onset in September 2022, we carried out workshops in two secondary schools in Noumea (New Caledonia's capital), where students were introduced to marine biodiversity as well as plastic and microplastic pollution. Students were asked to impersonate researchers. Students had to choose a taxon that would be a good candidate, according to them, to study the impacts of plastic pollution. We then discussed their choice. This workshop was carried out with the Centre d'Initiation à l'Environnement de Nouvelle-Calédonie, a non-profit association promoting sustainable behaviour through sensitisation.

We have also started a dialogue with local institutions, notably with IRD researchers, as well as the Noumea Aquarium.

Finally, we took advantage of our time in Noumea to sample holothurians, to constitute a new batch of specimens from 2022. We will implement similar initiatives throughout the project.

Author information

The project will be carried out over a period of three years under the direction of Prof Sarah Samadi and Prof Jean-Baptiste Fini, both MNHN researchers. The experimental work will be carried out by Dr Claire Laguionie-Marchais, a postdoctoral researcher, and Valentin Dettling, a PhD candidate.

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Microplastics pathway in sea cucumbers: A perspective

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Plastics have become a major component of our life, mainly due to their durability (Thompson et al. 2009). Plastic production increased rapidly from the 1950s onward, with global production reaching about 368 million metric tons in 2019 (Shanmugam et al. 2020). The mismanagement of plastic waste has resulted in the accumulation of plastics in the ocean (Eriksen et al. 2014). Plastics degrade over time, resulting in the formation of tiny plastic particles called microplastics (5 mm–1µm) and nanoplastics (less than 1 µm) (Wayman and Niemann 2021). Microplastics can also be purposefully manufactured, such as microbeads, which are used for personal care products, and have been named as primary microplastics (Rochman 2018).

Marine microplastics are distributed throughout the ocean, from the Arctic to the Antarctic (Rochman 2018). These microplastics can have a significant ecological impact not only because of their original structure but also because of the chemicals applied to their final product, such as dibutyl phthalate and phthalates (Zimmermann et al. 2020). Furthermore, microplastics have raised concern because of the adsorbed chemicals and colonised microbes on their surface in the ocean (Barboza et al. 2018). The transport of microplastics in the ocean is dependent on their properties, among which the density, shape and size are considered to be major factors (Khatmullina and Chubarenko 2019). Microplastics may be ingested by marine organisms intentionally or unintentionally, according to an organism's feeding habits (Egbeocha et al. 2018).

Sea cucumbers are exposed to microplastics in water and sediment according to their behaviour. Deposit- and suspension-feeding sea cucumbers can ingest microplastics through the mouth (Graham and Thompson 2009). Sea cucumbers likely ingest microplastics unintentionally when they brush the surfaces to collect particles into their mouth. Microplastics with shapes that the tentacles can trap are likely to have the highest proportion of being ingested by sea cucumbers. It has been shown that dietary-ingested microplastics can be excreted from sea cucumbers through their faeces without evidence of transferring these microplastics through the intestinal epithelium (Fig. 1), as has been shown in the sea cucumber *Apostichopus japonicus* (Mohsen et al. 2020b). However, nanoplastics have been observed to cross the intestinal barrier in fish (Clark et al. 2022; Vagner et al. 2022), which is worthy of investigation in sea cucumbers (Fig. 1).

Microplastics are ubiquitous in seawater, and fresh water sea cucumbers can uptake microplastics during suspension feeding (Iwalaye et al. 2020; Mohsen et al. 2020a) or respiration (Mohsen et al. 2022b, 2020b). Microplastics in inhaled water can reach the perivisceral coelomic fluid of sea cucumbers and even breach the tissues of the respiratory tree (Mohsen et al. 2020b). However, these microplastics are excreted again by sea cucumbers when they are placed in clean seawater (i.e. sand-filtered seawater) (Fig. 1) (Mohsen et al. 2023). It is worth investigating whether these microplastics can be a vector for pollutants (e.g. heavy metals) or pathogens, and passed on to sea cucumbers (Fig. 1) because

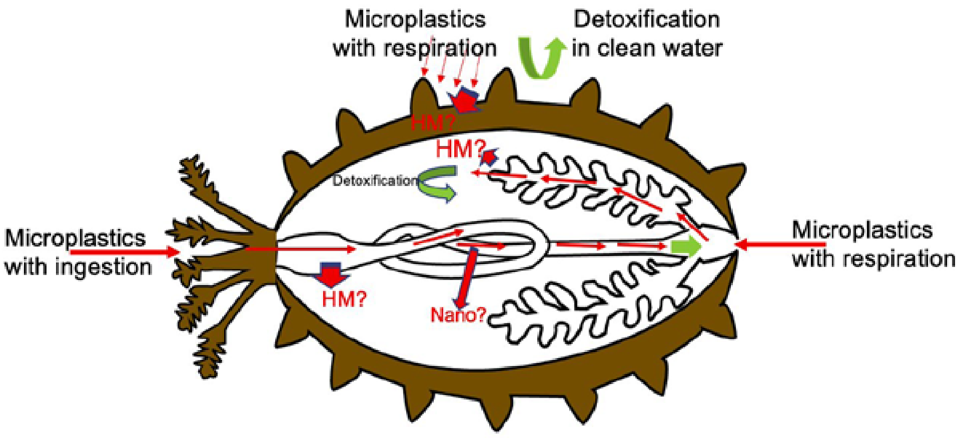

Figure 1. Microplastics pathway in sea cucumbers. Microplastics are taken up by sea cucumbers during feeding and respiration. These microplastics decrease in abundance when the sea cucumbers are transferred to clean seawater (i.e. filtered seawater). Polluted microplastics moving inside sea cucumbers can be vectors for transferring heavy metals (HM) or pathogens, which is worth future investigation. Also, the possibility of nanoplastics being transferred through the intestinal epithelium is worth investigating.

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microplastics adsorb a wide range of heavy metals (Mohsen et al. 2019) and potential pathogens (Mohsen et al. 2022a). Furthermore, microplastic transfer during the respiration of sea cucumbers can disturb their growth. Mohsen et al. (2023) showed in laboratory experiments that sea cucumbers exposed to microplastics two times and three times per week (thus had microplastics transferred in their coelomic fluid), had significantly affected growth rates over 60 days. It has been suggested that sea cucumbers should be farmed in areas where microplastic concentrations are low (Mohsen et al. 2023). Accordingly, microplastic abundance in the water should be added to water quality parameters for the healthy farming of high-quality sea cucumbers.

Although the microplastic pathway has been revealed in adult sea cucumbers, research on the microplastics and nanoplastics pathway in the larvae of sea cucumbers has not gained much attention. The uptake of 20-µm nanoplastics by larvae of the sea cucumber *Parastichopus californicus* has been demonstrated, and the uptake rate has been calculated (Hart 1991). However, the uptake and toxicity mechanism of nanoplastics is still not well understood, including the effect of different nanoplastic characteristics and their adsorbed pollutants or attached biofilm. Because sea cucumber larvae are useful in ecotoxicology and environmental risk assessment (Rakaj et al. 2021), microplastics and nanoplastics uptake and toxicology research on larvae is of potential value. The uptake and pathway research of microplastics and nanoplastics in sea cucumbers not only can clarify the fate and effects of emerging contaminants on these endangered species and echinoderms, but can also provide useful information about the physiology of sea cucumbers. For instance, when the deposit-feeding sea cucumber *Apostichopus japonicus* is exposed to microplastics in the water, it exhibits suspension-feeding behaviour (Mohsen et al. 2020a).

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Biometric study of the royal sea cucumber, *Parastichopus regalis* (Cuvier, 1817), from Algeria's west coast

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Abstract

The exploitation of sea cucumbers in Algeria began about 10 years ago, although it does not involve *Parastichopus regalis*, which is considered to be bycatch by professional fishermen despite its availability and its very high nutritional and economic value. The objective of this study was to determine some biometric relationships of *P. regalis* that can be used for managing its fishery before its launch. For this, 65 individuals were collected from 9 stations – corresponding to five regions of the Algerian west coast – and were measured and weighed. *Parastichopus regalis* presents a length-weight relationship of $W=0.429L^{1.784}$ considering the measured length and $W=0.371Le^{1.836}$ using the length estimated from the SLW index, which takes into account the length and width of individuals.

Keywords: sea cucumber, length-weight relationship, slw index, estimated length-weight relationship, Algeria

Introduction

In Algeria, the sea cucumber fishery is authorised but not their marketing. Exploitation began in 2013, and individuals are most often harvested by hand, snorkeling and sometimes by scuba diving then destined for illegal export (Mezali and Slimane-Tamacha 2020). However, this fishery does not target the species *Parastichopus regalis*, which is considered as bycatch and discarded at sea. This is done despite its availability along the Algerian coast, its nutritional quality suitable for human consumption, and its economic value (Ramón et al. 2010; Santos et al. 2015; Roggatz et al. 2018; Khodja et al. 2021; Khodja and Mezali 2022). These factors mean that the fishery of this species is promising, and must be launched by the authorities of fisheries sector, but not before measures for its management and sustainable exploitation are undertaken. This study aims to contribute to the knowledge of some biometric parameters of *P. regalis* that can be used for managing this fishery.

Methodology

The sampling of *P. regalis* was carried out at nine stations on the west coast of Algeria. In total, 65 individuals were collected from trawler bycatch (Fig. 1A and 1B) between June 2019 and January 2020 (Table 1). Each individual was measured (contracted length and width) with a tape measure (± 0.1 cm) and weighed on a balance (± 0.001 g). The thickness of the body wall was measured with a caliper (± 0.01 mm). A comparison of length and weight as a function of depth was performed using the Kruskal-Wallis H test because the data were not parametric. Dunn's multiple comparison post hoc test was used to determine the source of the significant differences.

Biometric relationships

The length (L) and width (l) of the individuals are related by a linear relation (Y= bX + a). The linear trendline was used to determine the regression coefficient "b" and the

Table 1. Characteristics of *Parastichopus regalis* sampling stations.

Stations	Geographic coordinates	Depth (m)	No. of individuals
Bahara Mostaganem	36°27.978'N, 0°38.431'E	73	21
Kharrouba Mostaganem 1	35°59.109'N, 0°01.089'E	68	3
Kharrouba Mostaganem 2	36°02.611'N, 0°01.823'W	117	5
Kharrouba Mostaganem 3	36°05.077'N, 0°00.490'E	225	13
Arzew	35°55.443'N, 0°16.166'W	77	12
Bouzedjar	35°38.068'N, 1°08.766'W	96	7
Beni-Saf 1	35°20.186'N, 1°21.456'W	36	1
Beni-Saf 2	35°25.160'N, 1°29.428'W	125	1
Ghazaouet	35°11.392'N, 2°05.491'W	113	2

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intercept "a". The isometry hypothesis (b = 1) was verified by the Student's t-test.

Length-weight and estimated length-weight relationships

To avoid deviations from accurate sea cucumber measurements due to body wall elasticity, the method described by Yamana and Hamano (2006) was used to obtain a more accurate size. This method combines length and width to produce the SLW index, which is the square root of the length multiplied by the width ($SLW=\sqrt{length \times width}$). Subsequently, the recalculated body length (Le) was estimated using the regression between L vs SLW, according to the following equation: Le = bSLW + a (Yamana and Hamano 2006; Poot-Salazar et al. 2014; Siddique and Ayub 2019). The length-weight relationships were estimated using the equation $Y= aX^b$, where "a" and "b" are coefficients, X is the length (L or Le), and Y is the weight (W). The isometry hypothesis (b = 3) was verified by the Student's t-test.

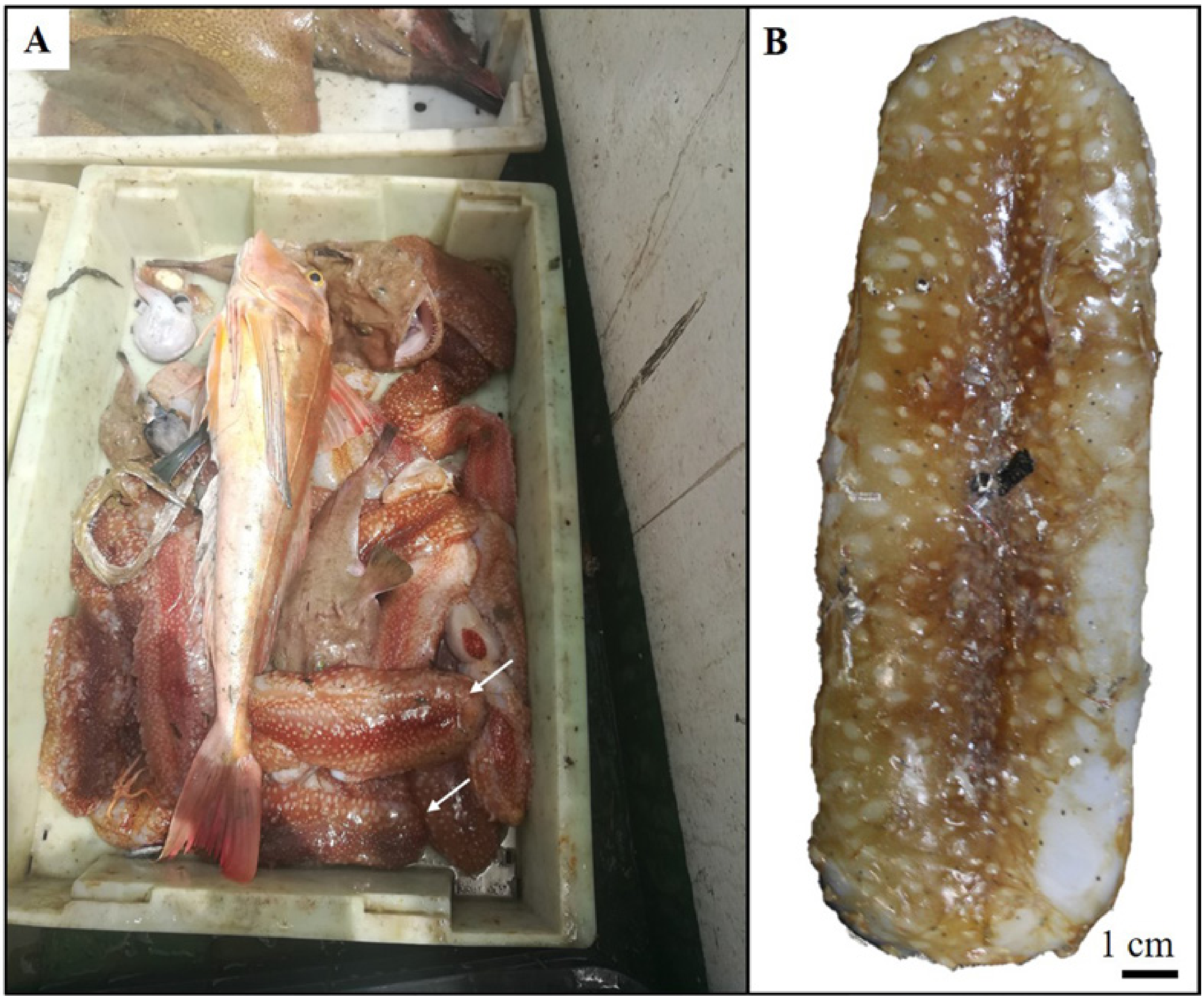

Figure 1. A. Trawler bycatch, including *Parastichopus regalis* (indicated by white arrows); B. dorsal side of *P. regalis*.

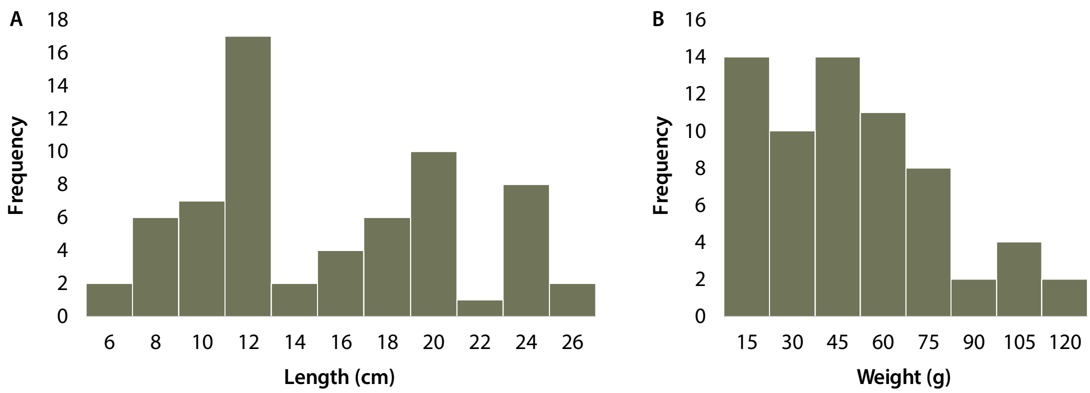

Figure 2. Length (A) and weight (B) frequency distribution of *Parastichopus regalis* from the Algerian west coast (n = 65).

Results and discussion

The individuals from the western Algerian coast (n = 65) have a mean length of 15.14 ± 5.51 cm, a mean width of 4.99 ± 1.22 cm, a mean weight of 61.55 ± 38.58 g, and a mean body wall thickness of 3.41 ± 1.55 mm. The length and weight frequency distributions of *P. regalis* are multimodal, with a major length modal class at 11–13 cm, and two major weight modal classes at 7.50–22.50 g and 37.50–52.50 g (Fig. 2A and 2B).

Table 2 summarises a comparison of the biometric measurements of *P. regalis* with other sea cucumber species of the same family. The mean length and weight values obtained in this study are lower than those obtained by Ramón et al. (2010) for the same species on the Spanish coast. This difference is probably due to the length measurement method used, which is the contracted length in the case of our study and the relaxed length in the case of the study of Ramón et al. (2010). Compared to some species of the Stichopodidae family from other regions (Mexico, Ecuador, Philippines), *P. regalis* from the Algerian west coast has the lowest value of mean length (Poot-Salazar et al. 2014; Dolorosa 2015; Pañola-Madrigal et al. 2017; Jesús-Navarrete et al. 2018; Ramírez-González et al. 2020).

These *P. regalis* length and weight values are also lower than those obtained for some other species of the genus *Holothuria* from Algeria's central and western coast (Mezali 1998; Mecheta and Mezali 2019).

Variation of the length and weight according to depth

A comparison of length and weight as a function of depth was performed using the Kruskal-Wallis non-parametric test. The results indicated that there was a significant difference, depending on depth whether for length (Kruskal-Wallis test = 32.654, $p < 0.05$) or for weight (Kruskal-Wallis test = 24.945, $p < 0.05$), between at least two depths. To determine the source of the differences, the Dunn post hoc test was applied, and the results are presented on the box plots by letters (Fig. 3). Different letters represent a significant difference ($p < 0.05$), while equal letters mean that there is no significant difference.

The Dunn test results for length (Fig. 3A) indicate that the station with a depth of 73 m (Bahara Mostaganem) is different from that of 225 m (Kharrouba Mostaganem 3) and 96 m (Bouzedjar). The latter also differs from that of 117 m (Kharrouba Mostaganem 2). For weight (Fig. 3B), the station with a depth of 117 m (Kharrouba Mostaganem 2) differs from those of 96 m (Bouzedjar), 113 m (Ghazaouet) and 225 m (Kharrouba Mostaganem 3).

The significant differences observed between the Mostaganem, Bouzedjar and Ghazaouet stations are probably due to the differences in region, however, considering the same region, namely Mostaganem, significant differences are found between stations at 73 m and 225 m for length, and 117 m and 225 m for weight. Although there is a difference between shallow and deeper depths, data are not sufficient for the same region to make a conclusion regarding the pattern of distribution of *P. regalis* individuals and whether, like other sea cucumbers, this species exhibits segregation between adults and juveniles, in which juveniles use shallow marine habitats and larger individuals move to deeper habitats (Reichenbach 1999; Mercier et al. 2000).

Biometric relationships

The biometric relationship between length and width (Fig. 4A) has a slope much higher than 1 ($p < 0.05$), indicating a positive allometry. Thus, the length grows four times faster than the width. The regression equation between L and SLW (Fig. 4B) used to generate the estimated length from the measured lengths and widths is Le = 2.102, SLW – 3.057 ($R^2 = 0.97$, $p < 0.05$).

Table 2. Biometric measurements of *Parastichopus regalis* compared to other sea cucumber species.

Species	L (cm)	l (cm)	T (mm)	W (g)	Region	References
Parastichopus regalis	15.14 ± 5.51	4.99 ± 1.22	3.41 ± 1.55	61.55 ± 38.58	West Algeria	Present study
	19.30 ± 4.30			177.20 ± 73.20	Spain	Ramón et al. (2010)
Isostichopus badionotus	22.61 ± 0.43				Mexico	Jesús-Navarrete et al. (2018)
	25.30 ± 5.20				Mexico	Poot-Salazar et al. (2014)
Isostichopus fusus	21.40 ± 6.00			375.60 ± 249	Mexico	Pañola-Madrigal et al. (2017)
	20.30 ± 5.00				Ecuador	Ramírez-González et al. (2020)
Stichopus chloronotus	24.10				Philippines	Dolorosa (2015)
Thelenota ananas	53.20				Philippines	Dolorosa (2015)
Thelenota anax	60.00				Philippines	Dolorosa (2015)

L = Length, l = width, T = body wall thickness, W = weight

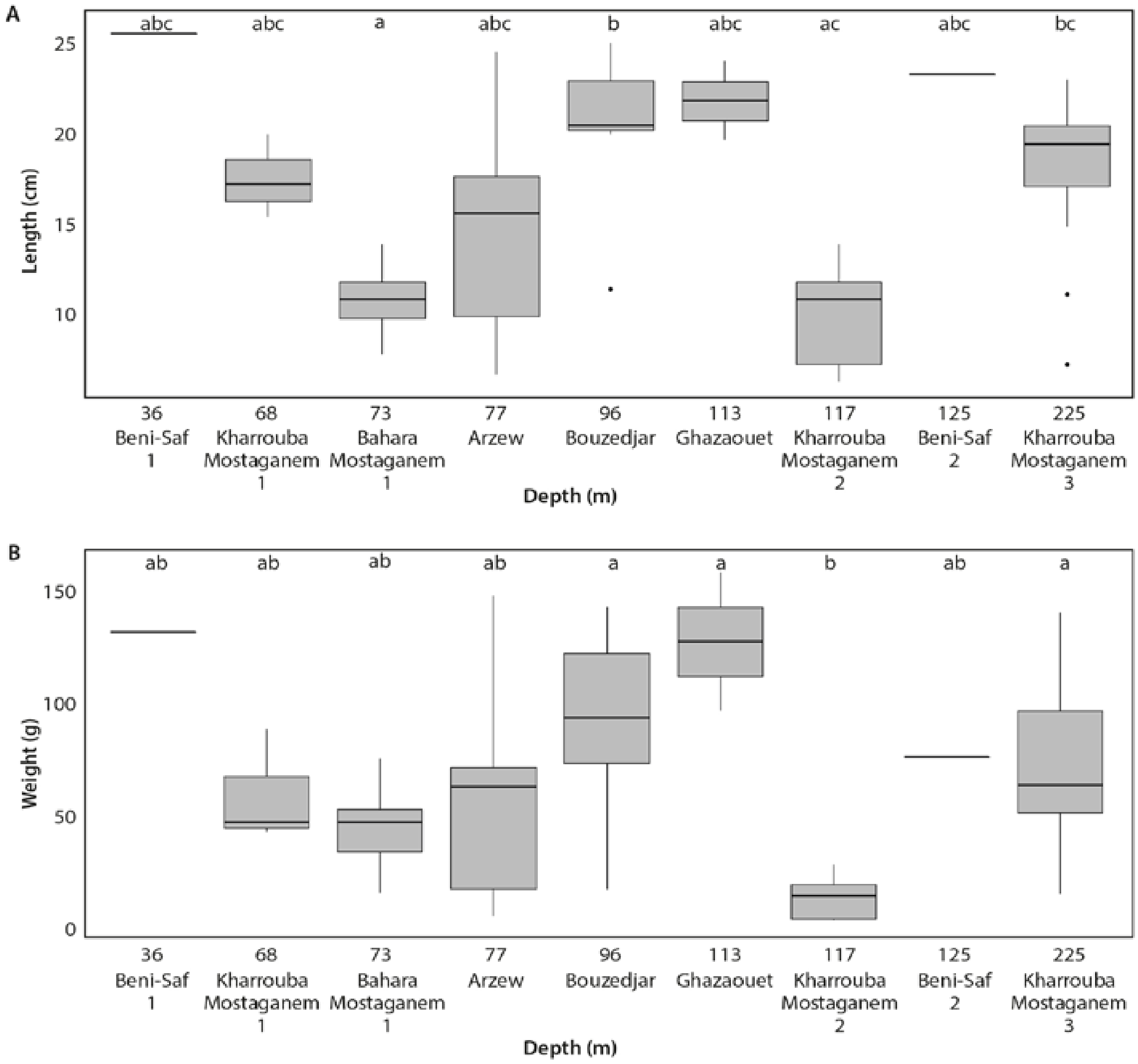

Figure 3. Box plots of length (A) and weight (B) of *Parastichopus regalis* categorised according to depth.

Length-weight relationships

The obtained "b" values are 1.784 and 1.836 for the length-weight relationship (Fig. 4C) and the estimated length-weight relationship (Fig. 4D), respectively. In both cases, the relationships are significantly different from 3 ($p < 0.05$), indicating a negative allometry, which means that the body length of the species grows faster than its weight. Using the estimated length derived from two measurements (length and width) rather than the measured length alone, improved the correlation coefficient and increased the regression coefficient "b", although the latter remains less than 3, indicating a negative allometry. These results are close to the results obtained for the same species on the Spanish coast (Ramón et al. 2010). Negative allometry is commonly observed in sea cucumber species of the same family as *P. regalis* or belonging to other families (Aydın 2020; Mezali 1998, 2001) in different regions of the world (Table 3), indicating that these species preferentially invest their resources in increasing their length rather than their body wall thickness (Pasquini et al. 2022).

Conclusion

Currently, *Parastichopus regalis* is nearly unexploited in Algeria. However, fishermen do not know the identity of the species when it is caught as bycatch, and often ask us questions in order to exploit it. We think that it will be the case in the future, especially given the signs of overexploitation being seen in other shallow-water sea cucumber species (genus *Holothuria*) in some areas. Although the exploitation of *P. regalis* remains nutritionally and economically beneficial, local authorities must initiate management programmes before launch an actual fishery in order to avoid destruction of the stock. On the other hand, it is important to beginwork on artificial reproduction in order to promote the farming sector of sea cucumbers with high aquaculture potential in integrated multitrophic aquaculture systems, with a view to rational industrialisation and marketing abroad.

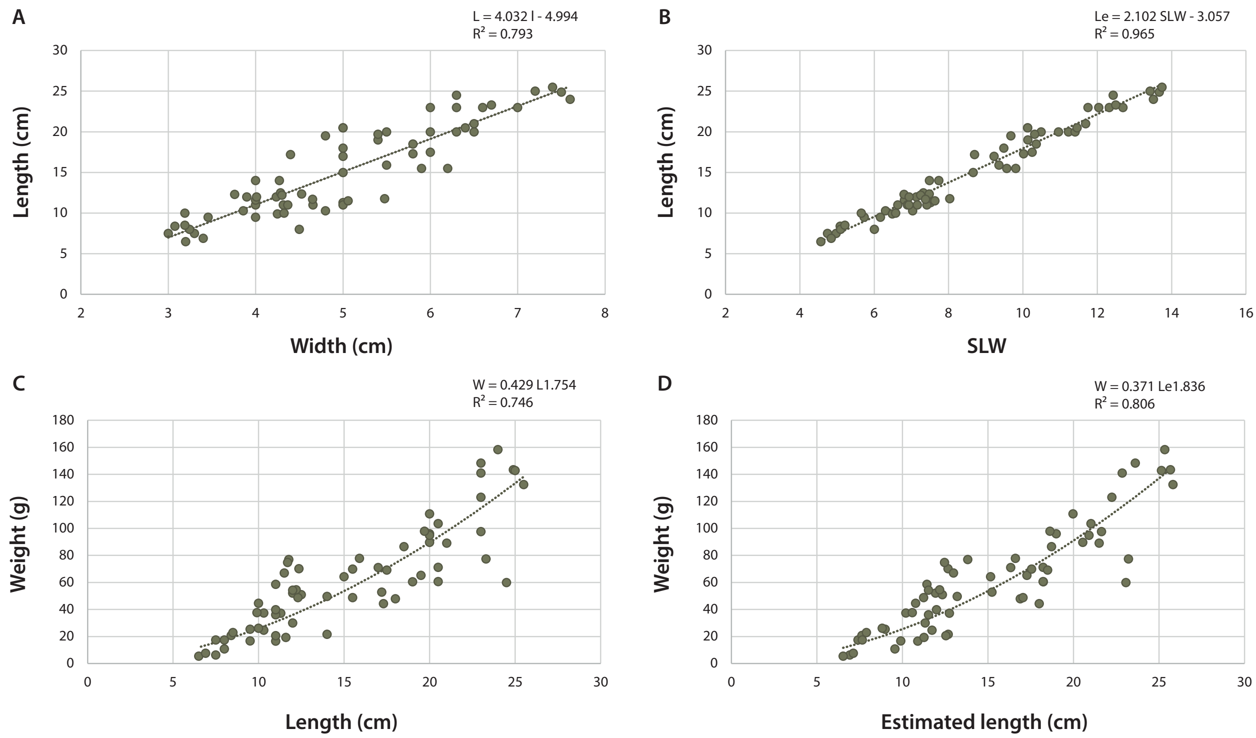

Figure 4. A. Biometric length-width relationship. B. Biometric length-SLW relationship. C. Length-weight relationship. D. Estimated length-weight relationship.

Table 3. Comparison of length-weight relationship parameters of sea cucumbers from different geographical regions.

Species	Model	a	b	R^2	Region	Reference
Parastichopus regalis	$W=aL^b$	0.429	1.784	0.746	West Algeria	Present study
	$W=aLe^b$	0.371	1.836	0.806	West Algeria	Present study
	$We=aL^b$	0.002440	2.112	0.83	Spain	Ramón et al. (2010)
Stichopus naso	$W=aL^b$	0.012	1.021	0.575	Sri Lanka	Veronika et al. (2018)
Thelenota ananas	$W=aL^b$	0.2247	2.1784	0.888	Seychelles	Aumeeruddy and Conand (2008)
Isostichopus fucus	$W=aL^b$	1.1421	1.8321	0.7141	Mexico	Herrero-Pérezrul and Reyes-Bonilla (2008)
Isostichopus badionotus	$W=aL^b$	2.8112	1.7411	0.7228	Mexico	Jesús-Navarrete et al. (2018)

L = length, Le = estimated length, W = weight, We = eviscerated weight

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Surveying and monitoring sea cucumber population densities in Bizerte Lagoon, Tunisia

Feriel Sellem[1]

Abstract

This work provides data on the abundance of sea cucumber species in a Mediterranean lagoon on Tunisia's northern coast. Assessments were conducted over a two year-year period in Bizerte Lagoon in an area divided into three stations and nine linear transects. Monitoring revealed that *Holothuria poli* and *Holothuria tubulosa* are the most common species. Data analysis showed that sea cucumber densities declined according to dates and stations, with some exceptions. A maximal density value of 96 individuals/100 m^2 was noted in October 2016, and a minimal of 13 individuals/100 m^2 was observed in October 2018. Analysis of variance revealed highly significant mean densities variation throughout the period of investigation. However, no significant mean density variation between stations is observed. In Bizerte Lagoon, the average density estimated for all species is 43.81 ± 23.72 individuals/100 m^2.

Keywords: sea cucumbers, density, Tunisia, lagoon, Mediterranean

Introduction

A sea cucumber fishery has appeared and developed in the northeast Atlantic Ocean and Mediterranean Sea. In the Mediterranean, the sea cucumber species particularly being targetted include *Holothuria poli, H. tubulosa, H. mammata, H. arguinensis and Parastichopus regalis* (Mohsen and Yang 2021).

Fishing for Mediterranean sea cucumber species has become attractive for international markets. Studies of the habitat, ecology and biology of these species are geographically limited, and concern mainly the northern basin (Dereli et al. 2016; González-Wangüemert et al. 2016). An illegal sea cucumber fishery exists, specifically in some parts of the southern Mediterranean. Most of the harvesting is carried out with no management plan in place, and exploitation seems to be uncontrolled. In the absence of measures, the stocks are threatened. This is the case for Tunisia, where sea cucumber harvesting has been carried out for years, without regulation (Sellem et al. 2017). Collections are mainly done by hand and or by snorkeling in shallow areas. In greater depths, gathering is done by scuba diving using small motorised boats. This illegal activity quickly developed along the coastline and the threat of loss of economically valuable species is real.

The objective of this study is to assess and compare the density and size distribution of sea cucumber populations in Bizerte Lagoon over a two-year period. Results will provide basic information on the ecology of species particularly those of commercial interest. This work provides also information on the state of the sea cucumber population in the lagoon, thus helping the authorities on the use of some data for management of this new fishery.

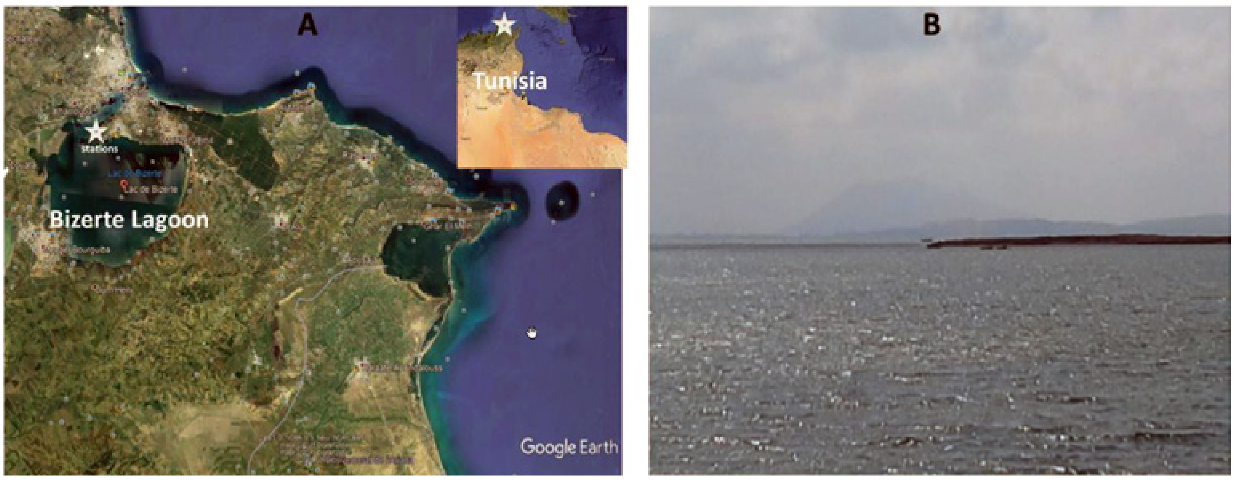

Figure 1. (A) Location of Bizerte lagoon, and sea cucumber survey area. (B) Study area. Photo by F. Sellem

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Methodology

The study was carried out in the northwestern part of Bizerte Lagoon (Fig. 1), which is an important socioeconomic area for the country. Coastal fishing and mollusc farming (mussels and oysters) are the main activities carried out by the neighboring community.

The assessment area was divided into three stations (st1, st2 and st3) about 150 m apart, and defined by geographical coordinates. The stations and their depths were checked using a GPS and a depth gauge. Measurements were performed by scuba diving. Each station was evaluated at the level of three rectangular linear transects (4 m x 25 m). All sea cucumbers found in the 100 m^2 area were counted. Total length of randomly selected samples of sea cucumber species (10–20 individuals) were measured. Finally, a sample of sea cucumbers was collected haphazardly for species identification. Substrate, vegetation and macrofauna were recorded simultaneously. In total, 36 surveys were carried out in October 2016, April 2017, March 2018 and October 2018 in nine transects (T1, T2, T3, T4, T5, T6, T7, T8 and T9) at an average depth of 6 m.

Data analysis

Holothuroidea species were identified following the guidelines of Tortonese (1965). All sea cucumbers collected during the monitoring are used to calculate specific abundance. Mean densities were evaluated for 100 m^2. One-way analysis of variation (ANOVA) was used to compare means. Measurements of total length of individuals were recorded to the nearest 0.5 cm, and sea cucumber size distributions were represented with intervals of 1 cm.

Results

Specific abundance

Throughout the monitoring period, 359 sea cucumber individuals were collected and used for systematic identification. The area of investigation was uniform and the stations had the same benthic habitat profile, with the substrate composed of sandy muddy substrates with fragments of mollusc shells and some stones. The seagrass *Cymodocea nodosa* was the main phanerogam encountered in addition to macroalgae, particularly *Caulerpa prolifera* and *Enteromorpha* sp.

All samplings from surveys revealed a high relative abundance of *Holothuria poli* (73.81%), followed by *Holothuria tubulosa* (16.71%) (Fig. 2). *Holothuria forskali* was also present (6.12%), while *H. sanctori* and *H. mammata* were scarce (< 1%).

Densities

In total, 1847 sea cucumber individuals were counted at all three stations in Bizerte Lagoon. In October 2016, 457 sea cucumbers were found, while in October 2018 only 224 individuals were counted (Table 1). However, sea cucumbers were totally absent in October 2016 and October 2018 at the same transects T6 and the same station 2.

The population densities of sea cucumbers varied from 0 to 94 individuals/100 m^2 by transect. The average was 51 individuals (SD ± 18)/100 m^2 for station 1, 35 individuals/(SD ± 25)/100 m^2 for station 2 and 44 individuals (SD ± 25)/100 m^2 for station 3. Finally, the average density estimated for all stations throughout the study period was 43.80 individuals (± 23.75 SD)/100 m^2 (Fig. 3).

Table 1. Density value by station (individuals/300 m^2) of sea cucumber species in Bizerte Lagoon.

Period	station 1	station 2	station 3
October 2016	166	87	204
April 2017	202	148	136
March 2018	137	165	378
October 2018	114	24	86
Total	**619**	**424**	**804**

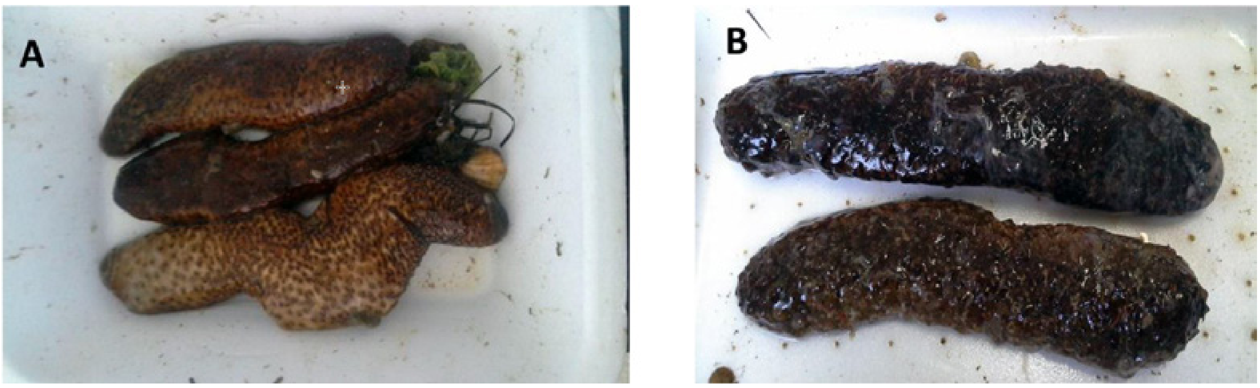

Figure 2. (A) *Holothuria poli* and (B) *Holothuria tubulosa* from Bizerte Lagoon. Photos by F. Sellem

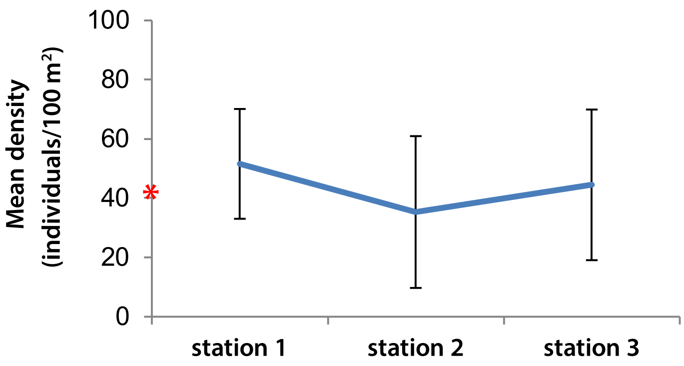

Figure 3. Mean density (individuals/100 m^2) of sea cucumber species from Bizerte Lagoon. Vertical bars represent standard deviation (SD).

The highest mean density of sea cucumbers was observed in October 2016 at station 3 (68 individuals ±24 individuals /100 m^2), while the lowest mean density was recorded in October 2018, also at station 3. No significant difference was observed between sea cucumbers densities at the level of the three stations (one-way ANOVA, $p=0.249$; $p>0.05$).

Average density regularly decreased with the time of the surveys (Fig. 4). Moreover, a significant difference was observed between the mean densities during the four periods ($p = 0.034$). Variations were observed between October 2016, April 2017, March 2018 and October 2018 ($p =$ 0.023, 0.008, 0.026). On the other hand, a decrease in mean density is not regular according to the stations (Fig. 5).

Average size of sea cucumbers

During the study period, 309 individuals were measured *in situ* and are represented by 1 cm length size classes (Fig. 6). The total length of the sea cucumbers recorded varied between 8 cm and 32 cm and the sea cucumber average size was (17.35 ± 4.53 cm). Average sizes were 18.14 cm (± 4.621) for station1, 16.77 cm (± 4.58) for station 2, and 16.95 cm (± 4.29) for station 3.

Regardless of the period, distribution was multimodal. All size classes are present in October 2016, although in April 2017, March 2018 and October 2018 the smallest and largest size classes were scarce or sometimes absent.

Discussion

This survey was carried out in order to determine sea cucumber density from Bizerte Lagoon over two consecutive years. The lagoon is characterised by a biodiversity of sea cucumber species, and *Holothuria poli* is the most abundant species (Sellem et al. 2019). Over the two-year period, the results showed a decrease in the average density of sea cucumbers. Mean densities do not vary significantly between stations, but significant variations are observed seasonally. In October 2016 the average density was 51 individuals/100 m^2 while in October 2018 it was 25 individuals/100 m^2.

In a previous study in the lagoon, Ben Mustapha and Hattour (2017) estimated a mean density of sea cucumbers species at 0.29 individual /m^2 in November 2014. In Bizerte Lagoon, the average density of sea cucumbers, all species combined, was determined to be 0.43 individual/m^2 (present study). These results confirm that the values recorded in the lagoon are homogeneous. Nevertheless. it was noticed that the average density recorded in October 2018 was the lowest among all the data collected in the lagoon. In the literature, on a larger geographical scale, reported densities seem to vary, although some fluctuations could arise due to different survey methods. On the Turkish coasts of the Aegean Sea, for example, Aydin (2019) found the total number of sea cucumbers per square meter of three species (*Holothuria tubulosa, H. poli, H. mammata*) to be equal to 1.91 individuals/m^2. But later in the same region area, Lok et al. (2022) found lower densities for *H. poli* and *H. tubulosa*, varying between 0.02 individual/m2 and 0.002 individual/m^2. In Mediterranean lagoon environments, sea cucumber density data are scarce. Gonzalez-Wanguemert et al. (2018) reports a high density of *H. poli* (reaching 4.32 individuals/m^2 on Isla del Ciervo) in Spain for the Mar Menor.

In conclusion, this work reveals the impact of the harvesting of sea cucumbers on their density. The question of this anarchic fishing deserves to be discussed by fisheries departments and fishermen in order to adopt a management plan, the provisions of which would contribute to the preservation of this resource. As with all management plans, the main aspects to be regulated should include sea cucumber fishing quotas, limits of fishing areas, time closures to allow sea cucumber reproduction, limits on the number of licenses issued, restrictions on the type of fishing equipment that can be used to harvest sea cucumbers, and landing control.

Acknowledgements

Many thanks to the diving teams for the National Institute of Marine Science and Technology, especially Othman A. and Harki M. who participated in collecting the data. Also, thanks to the fishermen and shipping agents of Bizerte who helped us to conduct the fieldwork.

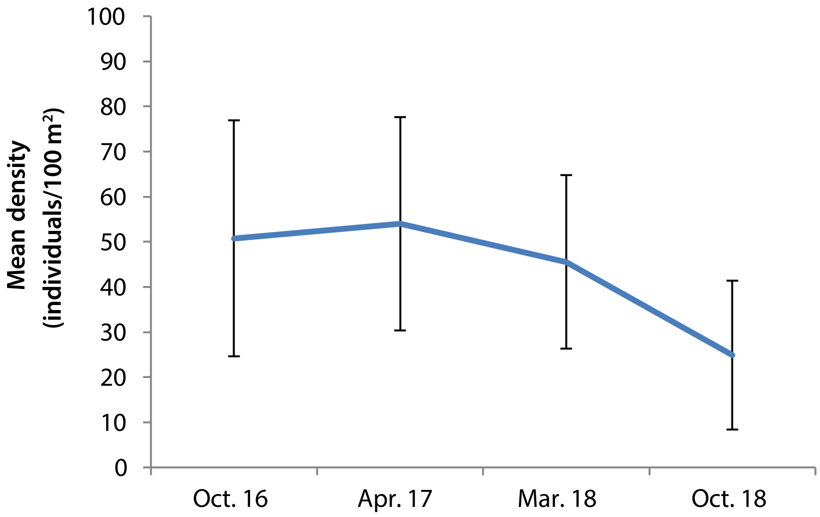

Figure 4. Mean density according to study period. Vertical bars represent standard deviation.

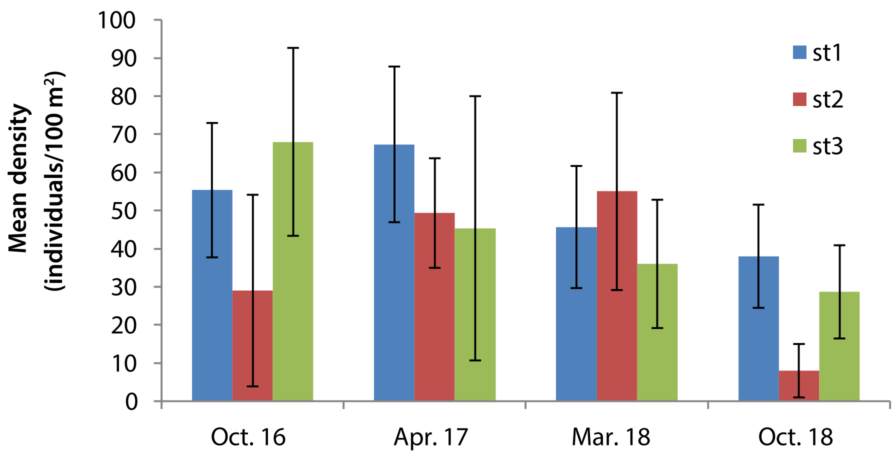

Figure 5. Mean density according to study station and period. Vertical bars represent standard deviation.

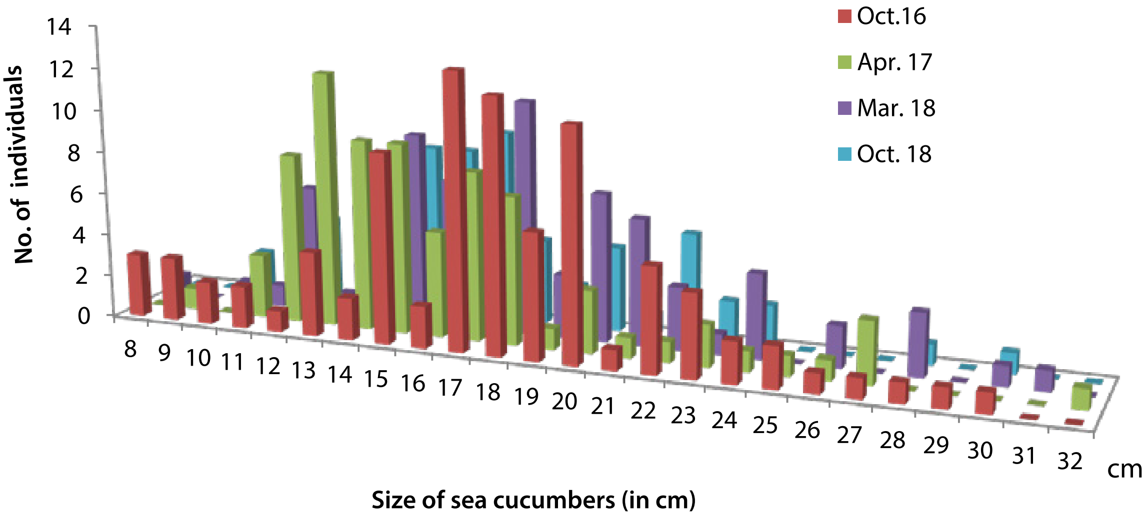

Figure 6. Size distribution of sea cucumbers from Bizerte Lagoon.

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Coastal community empowerment through grow-out of the sea cucumber *Holothuria scabra* in Lombok, Indonesia

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Abstract

Lombok Island in Indonesia has suitable areas for the development of sea cucumber aquaculture, particularly for the species *Holothuria scabra*. Training, workshops, and supervision concerning the grow-out system of juvenile *H. scabra* in ponds and sea pens are parts of coastal community empowerment. Groups of fishermen can learn how to improve pond conditions and place rearing cages in the sea to increase productivity. Understanding the characteristics of the habitat and environment is important for determining the locations of suitable juvenile *H. scabra* rearing locations, as well as overcoming obstacles encountered are needed to support grow-out implementation. Introducing sea cucumber commodities and educating coastal communities on how to maintain *H. scabra* juveniles are expected to enhance the knowledge of fishermen.

Keywords: sea cucumber, *Holothuria scabra*, Indonesia, community empowerment, grow-out

Introduction

In Lombok, West Nusa Tenggara Province in Indonesia, only a few types of fishery products – such as grouper fish, pomfret fish and seaweed (*Kappaphycus alvarezii* and *Euchema cottonii*) – are produced in marine aquaculture. Lobster farming has the potential to be developed in Lombok's waters, although more research is still required. Shrimp culture (*Litopenaeus vannamei*) has been managed in ponds in semi-intensive and intensive systems. Additionally, salt production, milkfish (*Chanos chanos*) and seaweed (*Gracilaria* sp.) have all been traditionally cultured in earthen ponds.

One sea cucumber of commercial importance is *Holothuria scabra*, also known as sandfish. The overexploitation of *H. scabra* is caused by a rise in its demand and a subsequent high harvesting rate (Conand 2017), resulting in *H. scabra* becoming an endangered species (Hamel et al. 2013). Sea cucumbers may contribute to the health of marine ecosystems through their ecological role in bioturbation, nutrient recycling, improved sediment and water chemistry, energy transfer along the food web, and ecosystem maintenance (Purcell et al. 2016).

In Indonesia, sea cucumbers are not popular as either food or as a cultivation commodity. However, Lombok Island has an opportunity to develop sea cucumber aquaculture because it has suitable areas, particularly for *H. scabra*. The introduction of *H. scabra* aquaculture would provide an alternative livelihood for coastal communities. Accordingly, improving community empowerment necessitates the transfer of knowledge through training, workshops and monitoring.

Sandfish (*H. scabra*) juveniles have been successfully produced at the Research Center for Marine and Land Bioindustry (BRIN) in north Lombok. Since 2011, the center has developed an aquaculture system that includes broodstock collection, spawning, larval rearing and juvenile growth. BRIN has disseminated information about sandfish aquaculture to fishermen's groups and stakeholders in coastal communities, especially around Lombok Island.

Dissemination of sea cucumber aquaculture information

Training sessions, workshops and supervision were conducted as part of the dissemination process, not only to transfer knowledge about *H. scabra* culture to stakeholders and fishermen's groups, but also to build capacity in coastal communities. Participants received fundamental information about the biology, life cycle, optimal habitat, cage construction, predators and rearing techniques of *H. scabra*.

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Training sessions and workshops were held near the location of a particular fishermen's group, and most fishermen were from east Lombok (Table 1). The first training session took place in north Lombok to train the Pada Girang fishermen's group. A second training session was held in east Lombok, with the fishermen's groups Optimis, Segare Lauk and Maju Bersama. Two fisher groups – Sunsak Bareng Maju and Tarah-Tarah Maju Sukses – participated in workshops in east Lombok.

After receiving juvenile sandfish and field equipment, fisher groups practiced rearing *H. scabra* in the field (Fig. 1 and Table 2). The group Taruna maintained early juveniles in an earthen pond during the nursery phase. Other groups reared juveniles in coastal areas and applied a sea pen-based system using bottom cages. Supervision was provided on an as-needed basis; groups were directed to build cages (or *hapas*) in the coastal area and to care for juveniles until they were ready to be harvested.

Table 1. Training sessions and workshops on the grow-out of *Holothuria scabra*.

Name of fishermen's group	Date		Number of participants
Training sessions			
Pada Girang	8 August 2019	BRIN, Teluk Kodek, North Lombok	6
Optimis, Segare Lauk, Maju Bersama	15 August 2019	LPSDN, Jerowaru, East Lombok	25
Workshops			
Sunsak Bareng Maju	27 September 2018	LPSDN, Jerowaru, East Lombok	20
Tarah-Tarah Maju Sukses	29 August 2019	Telone, Sekaroh, Jerowaru, East Lombok	25

BRIN = Badan Riset dan Inovasi Nasional (National Research of Innovation Agency)
LPSDN = Lembaga Pengembangan Sumberdaya Nelayan (Fisher Empowerment Institute)

Table 2. Fishermen's groups and their locations.

Name of group	(Sub-Village, Village, District, Regency)	Remarks
Pond		
Taruna	Labuan Tereng, Lembar, west Lombok	- Revitalization of two ponds for nursery - Application of nursery using floating cages - Nursery of 78,072 juveniles
Sea pens		
Pada Girang	Teluk Kombal, Pemenang Barat, Pemenang, north Lombok	- Construction of bottom cages of sizes 10 x 10 x 2.4 m and 15 x 15 x 2.4 m - 1000 juveniles
Optimis	Mandar, Seruni Mumbul, Pringgabaya, east Lombok	- Construction of bottom cages of sizes 5 x 5 x 2.4 m and 20 x 30 x 2.4 m - 1000 juveniles
Segare Lauk	Ujung Betok, Pemongkong, Jerowaru, east Lombok	- Construction of bottom cages of sizes 5 x 5 x 2.4 m and 20 x 30 x 2.4 m - 1000 juveniles
Maju Bersama	Pelebe, Ketapang Raya, Keruak, east Lombok	- Construction of bottom cages of sizes 5 x 5 x 2.4 m and 20 x 30 x 2.4 m - 1000 juveniles
Sunsak Bareng Maju	Sunut, Sekaroh, Jerowaru, east Lombok	- Construction of bottom cages of size 10 x 10 x 2.4 m - 5000 juveniles
Tarah Tarah Maju Sukses	Telone, Sekaroh, Jerowaru, east Lombok	- Construction of bottom cages of size 30 x 20 x 2.4 m - 5000 juveniles

Nursery in earthen pond in west Lombok

According to Partelow et al. (2018), the construction of ponds in west Lombok has not been ideal for aquaculture. The authors stated that through training, groups of fishermen may learn how to improve pond conditions to increase productivity. Ponds were formerly used for keeping milkfish *Chanos chanos*, but the yield was not ideal because dike conditions were not workable. The Taruna group, based in Lembar in west Lombok, focuses on nursery stage activities. They revitalised the ponds, constructed floating cages, and sorted and harvested *H. scabra* juveniles before releasing them on the coast.

In 2015, the Taruna group implemented an integrated multi trophic aquaculture (IMTA) system in their pond through the Lombok Marine Technopark scheme, funded by BRIN. *Holothuria scabra*, *Chanos chanos* and the seaweed *Gracilaria* sp. were maintained in a similar pond at the same time. In 2017, this group possessed earthen ponds of 400 m^2 and 225 m^2 and contemplated focusing on nursery rearing using floating cages (Fig. 2). The ponds have been revitalised by repairing sluice gates and dikes, removing sewage and predators, and draining and fertilising.

During the nursery process, post settlement of *H. scabra* produced larvae that were 5–10 mm in length, which were then reared in a floating cage (1 x 1 x 1 m) constructed of net mesh size 0.5 mm and 2-inch PVC pipes (Fig. 2). In 2019, 78,072 juveniles were maintained and reared to sizes 10–20 g and prepared for release into the sea. Occasionally, moss grew on the surface of the water and stuck to the cages; therefore, routine cleaning was required in order to promote the growth of juveniles.

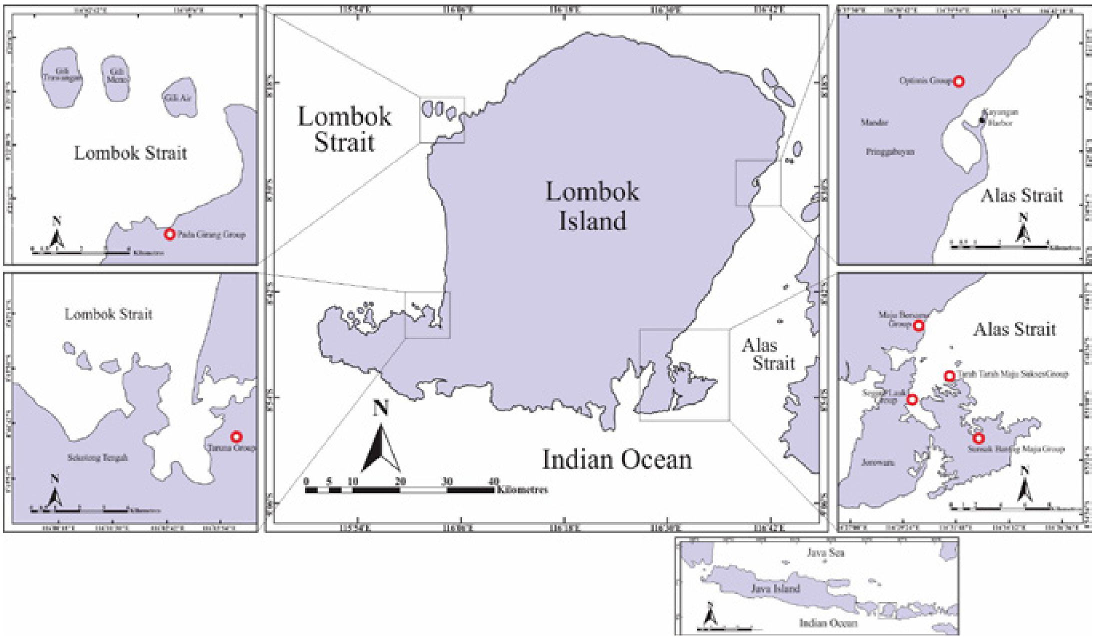

Figure 1. Location of the nursery and grow-out area for *Holothuria scabra* by fisher groups.

Figure 2. Juvenile sea cucumbers, *Holothuria scabra*, being reared in an earthen pond in west Lombok. ©Lisa F Indriana

Grow-out in north Lombok

The fisher group Pada Girang from Teluk Kombal in north Lombok, reared juveniles in Teluk Kombal waters, which is a natural habitat for sandfish due to its muddy-sand substrate and seagrass bed (Fig. 3). Two bottom cages with dimensions of 10 x 10 x 2.4 m and 15 x 15 x 2.4 m were installed, and 1000 juveniles were released in the cages. The fisher group faced an obstacle when big waves destroyed the cages, leading to predators (crabs) getting into the cages, and juvenile *H. scabra* escaping from the cages. The big cage was modified into 10 smaller bottom cages, each measuring 2 x 1 x 0.3 m in order to reduce wave damage. Another concern was that the density of the seagrass (*Syringodium* sp.) was too high, which prevented juveniles from reaching the substrate, thereby stunting their growth due to inadequate nourishment from the sediment.

Grow-out in east Lombok

Training and supervision were provided to local fishermen's groups in east Lombok to introduce juvenile grow-out in sea pens. In 2019, through the Prioritas Nasional project, 1000 juveniles of *H. scabra* (5–10 g) and numerous pieces of equipment – including a net with a mesh size of 3 mm, bamboo poles, pegs and snorkel masks – were distributed to three fishermen's groups –Optimis, Segare Lauk and Maju Bersama – to support the grow-out of juveniles in the sea.

Group Optimis is in Mandar, Seruni Mumbul in east Lombok. This group set up two small cages (5 x 5 x 2.4 m each) to grow juveniles with an initial weight of 10 g until they reached 50 g, and then transferred them to a larger cage (20 x 30 x 2.4 m) until they reached a harvestable size (Fig. 4).

The muddy sand substrate, surrounded by mangroves – the natural habitat of *H. scabra* – is characteristic of Seruni Mumbul. The primary constraints identified by the fisher group were predators. To address this issue, they added mesh extensions at the bottom of the cages to keep out crabs, and installed nylon nets on the top to keep out birds.

Group Segare Lauk is in Ujung Betok in east Lombok. This group installed a small cage (5 x 5 x 2.4 m) to maintain juveniles weighing 10–50 g before transferring them to a larger cage (20 x 30 x 2.4 m) until they reached commercial size (Fig. 5). During the rearing period, the group did not discover any problems. With characteristics such as a muddy-sand substrate, seagrass bed, mangroves, and calm coastal waters, the waters of Ujung Betok were suitable for the grow-out of juveniles.

In addition, Pelebe in east Lombok was where the group Tambak Maju Bersama was from. Like other groups, 1000 juveniles weighing 5–10 g were reared in small cages (5 x 5 x 2.4 m) before being transferred to large cages (20 x 30 x 2.4 m) until they reached a marketable size (Fig. 6). Conditions at Pelebe included calm water, a muddy-sand substrate, seagrass and macroalgae – an ideal habitat for rearing juveniles. However, juveniles were lost during the maintenance period, possibly due to predators.

The Sunsak Bareng Maju and Tarah Tarah Maju Sukses groups were in Sekaroh, east Lombok. These areas had

Figure 3. Bottom cages broken due to waves (above), and modified bottom cages (below) with the Pada Girang fisher group. © Sigit AP Dwiono


Figure 4. Bottom cages of the Optimi fisher group (left) and muddy sand substrate as the natural habitat of the sea cucumber *Holothuria scabra* (right). ©Sigit AP Dwiono


Figure 5. Bottom cage of the Segare Lauk group (left), and sea cucumber (*Holothuria scabra*) rearing in Ujung Betok (right). ©Sigit AP Dwiono

Figure 6. Bottom cage of the group Tambak Maju Bersama in Keruak, east Lombok. ©Sigit AP Dwiono


Figure 7. Bottom cages of the Sunsak Bareng Maju group in Sunut (left) and Tarah Tarah Maju Sukses group in Telone, east Lombok (right). ©Sigit AP Dwiono

particularly favourable habitat characteristics for *H. scabra* growth, including semi-closed bays, sluggish currents, a muddy-sand substrate, a variety of seagrasses and macroalgae species, and mangroves (Fig. 7).

Group Sunsak Bareng Maju distributed 5000 juveniles among five bottom cages, each 10 x 10 x 2.4 m. The problem was that the cages had been destroyed and needed to be rebuilt. Group Tarah Tarah Maju Sukses released 5000 juveniles in a bottom cage (30 x 30 x 2.4 m). To protect the juveniles from predators such as birds, the cage surface was covered with nylon mesh. Sea urchins (*Brissus* sp.) were discovered on the sea floor, a situation that could cause injuries to the skin of sea cucumbers. Mesh nets were installed on the bottom of the cage and then covered by sediment to overcome this circumstance.

Conclusions

Introducing sea cucumber commodities and educating coastal communities on how to maintain *Holothuria scabra* juveniles through training, workshops, and supervision is one strategy for empowering coastal communities. On this basis, it is envisaged that coastal communities will gain knowledge about proper farming techniques, which will allow them to earn supplemental revenue and increase their income.

Acknowledgments

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Certificate in the Science of Artisanal Mariculture and Village Farming

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Introduction

In Madagascar, our consortium, made up of universities (Universities of Toliara, Mons and Liège) and private partners (Indian Ocean Trepang, Ocean Farmers, Spirusud), has been supporting the development of artisanal mariculture and village farming for more than 20 years. Four types of mariculture were particularly developed: holothuriculture, algoculture, spiruliculture and coralliculture. The first one to be developed was holothuriculture. Today, sea cucumber farming is practiced on company farms (70% of production) and in village farming (30%) throughout Madagascar. Seaweed farming, which emerged after sea cucumber farming in Madagascar, consists of the cultivation of red macroalga, *Kappaphycus alvarezii*, which is exported to industrialised countries to extract carrageenan which is used in foods and cosmetics. It is totally practiced in a village farming situation. Spiruliculture is the cultivation of *Spirulina*, a cyanobacterium of the genus *Arthrospira*, exported for its nutritional benefits. It is carried out entirely on a company farm. Coral farming is an artisanal mariculture in the making, and involves the production of corals – most often for the aquarium trade.

The success of artisanal mariculture and village farming developed in Madagascar is internationally recognised (Eeckhaut 2022), and the demand to transfer these techniques to other countries is real and significant. To meet this demand, several actions have been carried out: 1) meetings and discussions during colloquium and conferences; 2) exhibitions of research work through publications; 3) occasional visits to Madagascar; and 4) consultancies carried out by the Malagasy-Belgian team to interested foreign entities. These actions have only had mixed impacts in developing countries. To date, they have not led to the development of autonomous private firms such as those in Madagascar, nor has there been any obvious positive effects on coastal villagers. This issue was addressed in focus group discussions and, after discussions with several countries requesting training techniques, the idea of providing training for best practices for mariculture and village farming is unanimously seen as an essential step in the solution to these problems.

As a result, our consortium is setting up a Certificate in the Science of Artisanal Mariculture and Village Farming, financed by Académie de Recherche et d'enseignement supérieur – Coopération au développement (Belgium). There are four main problems with transferring mariculture and village farming to other countries: biological, agronomic (fisheries engineering), economic and sociological. The training will, therefore, include these four themes. Instructors will provide expertise in biology, fisheries engineering, economics and the sociology of village farming. The Malagasy universities involved will be Tulear (Halieutic Institute and Marine Sciences) and Tamatave, and the Belgian universities will be the University of Mons and University of Liège. Because the private sector is important in the development of village farming, people from the private sector will be actively involved in teaching. Training will take place at the Institute of Fisheries and Marine Sciences at the University of Tulear (southwest Madagascar).

The Certificate

The Certificate in the Science of Artisanal Mariculture and Village Farming will welcome 20 candidates annually, with the first year of courses beginning in September 2024. Some of the participants will be scholarship holders from developing countries supported by ARES-CCD (28 countries supported), while the others will be candidates (from developing and developed countries) who will be self-financing. The scholarship application should be submitted by January 2024 to the Academic Committee (a website is under construction for applications). Candidates who successfully complete the training will have triple certification (i.e. a university certificate) from the University of Tulear, the University of Mons and the University of Liège.

The course will accept candidates with a Master's or Engineering degree. In special cases, if the Academic Committee considers that the application of a candidate who has neither a Master's nor Engineer degree is interesting, the activities of the candidate relating to training may give weight to their application. All applicants will be asked for a letter of support from an interested entity within their country.

All training will be conducted in English. The course will last one academic year, and consist of 60 credits. It will include four modules: 1) one concerning general information about aquaculture, 2) another focusing on the biology and engineering of the four artisanal maricultures, 3) a third relating to the sociology and economy of village farming, and the final module devoted to an end-of-study work. If some students are only interested in one type of mariculture

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2 Belaza Marine Station, Toliara, Madagascar
3 Institut Halieutique et des Sciences Marines, University of Toliara, Toliara, Madagascar
4 Institut Supérieur de Technologie Régional de la Côte-Est, Fénérive-Est, University of Toamasina, Toamasina, Madagascar
5 Laboratory of Evolutionary Ecology, FOCUS, University of Liège, Liège, Belgium
6 Indian Ocean Trepang, Toliara, Madagascar

(e.g. sea cucumber farming), the modules will be organised in such a way that the student can follow a practical course of two to three months that focuses on their chosen mariculture.

Students can view the theoretical courses remotely. To do this, video capsules will be produced by the instructors for all the theoretical courses and integrated into a flipped classroom system that also offers exercises and tests. Students will thus have the possibility of viewing these courses from Madagascar or abroad (mainly because of covid). Training will include as many practice sessions as possible. Practical training will take place in hatcheries, nurseries, pens at sea, and in target villages for the study of village farming. All necessary infrastructure will be accessible and usable at the Marine Station of Belaza[7] and in the neighbouring villages. To enable the acquisition of this knowledge and skills, theorical courses will be highlighted during the practical work carried out and during field visits. During this practical work, instruction will be totally interactive, with students handling the organisms of interest and being in some cases in contact with Malagasy mariculturists.

Modules, courses and expected skills

The four modules of the Certificate cover the following courses:

Module A "General courses": 1) Biology of Aquacultured Organisms; 2) Mariculture: generalities; 3) Diseases of organisms in the marine environment

Module B "Sociology and economy of mariculture and village farming": 4) Sociology of village farming; 5) Gender in artisanal mariculture; 6) Management and entrepreneurship related to artisanal mariculture; 7) Legislation relating to village farming

Module C "Biology and engineering of mariculture and village farming": 8) Aquaculture of integrated and multitrophic systems; 9) Sea cucumber farming; 10) Seaweed farming; 11) Coral farming; 12) Spiruliculture farming.

Module D "Certificate thesis": A research work at the end of the study will be required to estimate the level of competence reached by the students. Examples of possible certificate theses include: "Is the transposition of sea cucumber farming profitable in the Ouidah region in Benin? "What is the degree of acceptance of Haitian fishermen to becoming seaweed farmers? "How does the growth of *Seriatopora hystrix* (Scleractinia) vary with temperature conditions identical to those encountered in Vietnam?

The skills targeted at the end of the training will be:

1. Possess, in the field of artisanal mariculture sciences and village farming, highly specialised knowledge.

2. Be able to mobilise, articulate and enhance the knowledge and skills acquired in order to contribute to the conduct and implementation of a large-scale development in connection with artisanal mariculture and village farming.

3. Be able to organise and carry out research, development or innovation in order to address an unprecedented problem relating to artisanal mariculture and village farming.

4. Be able to communicate clearly, in a structured and reasoned manner, both orally and in writing, to an informed public, the principles underlying artisanal mariculture and village farming.

5. Be aware of and understand the biological, agronomic, social and economic problems inherent to these maricultures and to react accordingly if these problems arise in the countries or regions where the methods are transposed.

Sea cucumber aquaculture and farming: the targeted skills

People only interested in sea cucumber aquaculture and village farming will be able to follow a special module of approximately six weeks focused on these practices only. The expected skills acquired will be to know:

1. the biology of sea cucumbers and the stages of their production in aquaculture;

2. how to analyse the reproductive cycle of sea cucumbers;

3. the methods to increase the efficiency of breeders, including the maintenance of breeders, thermal shocks and *in vitro* fertilisation;

4. to raise embryos and larvae to post-metamorphic individuals in a hatchery;

5. to raise juveniles in a nursery, and adults at sea; and

6. the right steps in the formation of trepang (dried exported product).

[7] http://www.polyaquaculture.mg/

Figure 1. Signature of the agreement concerning the Certificate in the Science of Artisanal Mariculture and Village Farming. The president of the University of Tulear, Razafiharison Manantena (left), and the rector of the University of Mons, Philippe Dubois (right).

Figure 2. Inauguration, with personalities from the University of Mons, University of Tulear and the Indian Ocean Trepang company, of the Belaza Marine Station (Madagascar),which has become a Belgian-Malagasy university campus and where some of the Certificate courses will take place.

Identifying CITES-listed sea cucumbers: An identification guide

Marie Di Simone,[1] Arnaud Horellou,[1] Frédéric Ducarme[2] and Chantal Conand[2]

Introduction

CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, has the mission of preventing international trade from causing the extinction of a species, either by regulating or trade prohibition. In this context, from the end of the 1990s, groups of experts were formed to examine the issue of the trade in sea cucumbers (Bruckner 2006), the importance of which is similar to that of shark fins. However, no listing proposal has been submitted to the Conference of Parties for almost 20 years.

Finally, in 2019, sea cucumbers were included in CITES Appendix II, with three easily identifiable species – the "teatfish" from the subgenus *Holothuria* (*Microthele*) (Di Simone et al. 2021). This French proposal had been presented by the European Union, the United States, Kenya, Senegal and the Seychelles. This was the first proposal for sea cucumbers presented to a Conference of the Parties.

Difficulties in identifying sea cucumbers

After 17 years of unsuccessful attempts, this first CITES listing of sea cucumbers raises the question of the implementation of controls and reporting on a group little considered by non-specialists. Commercial data are most often reported by groups ("sea cucumber") rather than by species, preventing clear identification of the most popular species. Moreover, control authorities themselves are not competent and have no tools to differentiate goods containing sea cucumbers. The question arises as to how to certify that a package containing sea cucumbers is legal or not, if nobody is able to certify that they are not species that are currently listed on CITES. These animals, mainly exported to Asian markets, should be distinguished at the species level by fisheries officers, traders and other specialists to better target overexploited species.

Identifying sea cucumbers is a matter for specialists. Indeed, most works are based on spicules, small structures in calcium carbonate that require dissection and microscopy to be observed. In 2012, the Food and Agriculture Organization of the United Nations published the first edition of a guide to sea cucumbers of global commercial importance (Purcell et al. 2012). This guide identified 58 species that are significantly represented in international trade and mainly fished for in the Pacific and Indian oceans, bound for China and, to a lesser extent, Viet Nam. A new edition of the guide extends to other regions and other species, and is in the process of being published (Purcell et al. 2023). It allows an expert to identify the different species of sea cucumbers with laboratory criteria. These methods, however, are not compatible with the reality on the ground, especially with control authorities.

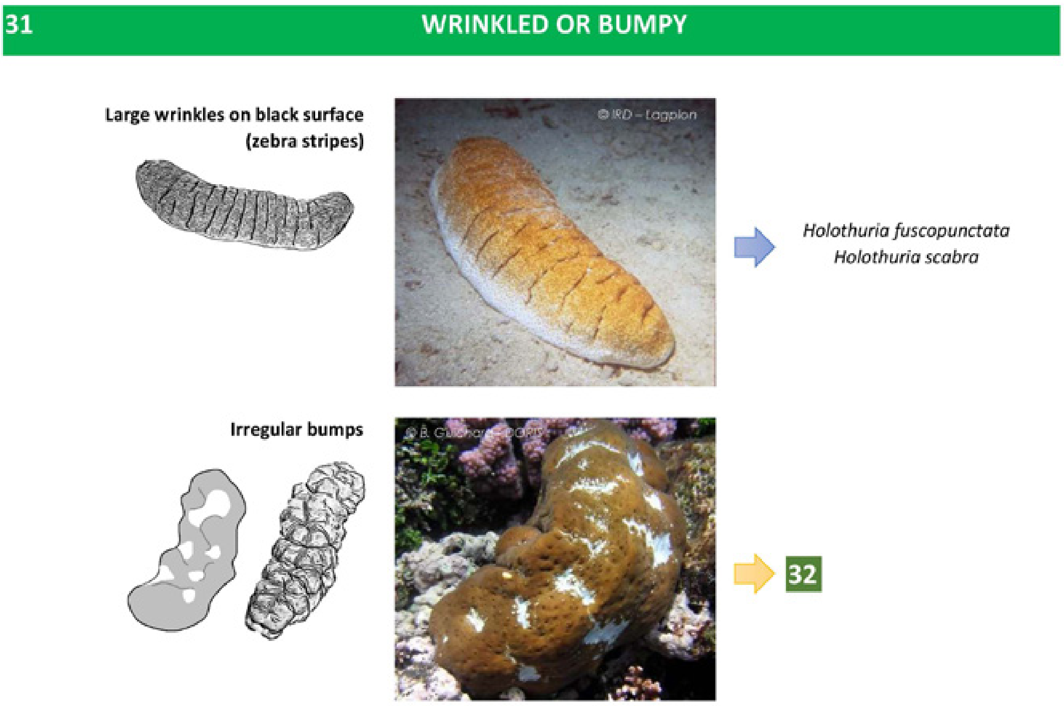

Figure 1. Excerpt from the identification key for live specimens of sea cucumbers. Source: Di Simone et al. 2022

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Realisation of a simplified identification guide on sea cucumbers

The French Scientific Authority for CITES[3] has therefore decided to produce a simplified identification guide, based on the FAO scientific guide, in a long-term vision on sea cucumbers, their trade and the constitution of more precise data (Di Simone et al. 2022). This guide presents 56 species of sea cucumbers, protected or not by CITES, traded worldwide, for food consumption. It is purposedly vulgarized and simplified for being used by non-specialists, including enforcement authorities whose mission is to detect what is potentially illegal.

This guide makes it possible to recognize traded species using two identification keys: one for live specimens (Fig. 1) and one for dried specimens (Fig. 2). Each species is described in the form of a sheet presenting the morphological and/or distinctive characteristics, as well as the description of the spicules for specialists (Fig. 3).

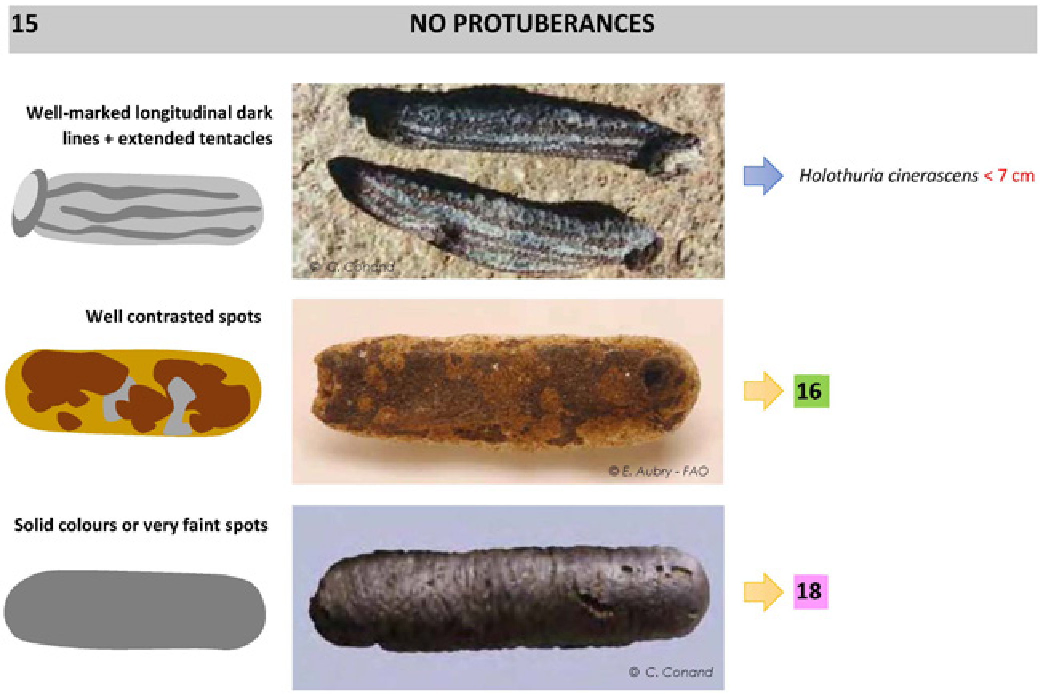

Figure 2. An excerpt from the identification key for dry specimens of sea cucumbers. Source: Di Simone et al. 2022

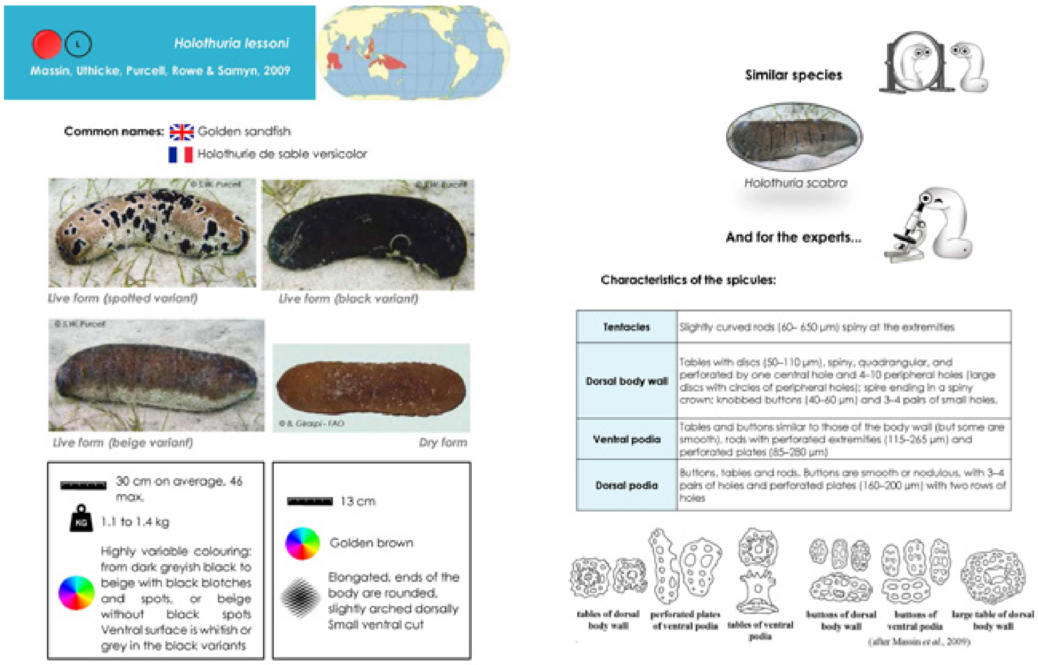

Figure 3. Example of a species sheet. Source: Di Simone et al. 2022

[3] Patrinat (Office français de la biodiversité, Centre national de la recherche scientifique, Muséum national d'Histoire naturelle, Institut de recherche pour le développement)

Figure 4. The cover of the sea cucumber identification guides in English, French, Spanish and Mandarin.

Permalinks to download the guide are given below:
English version: https://inpn.mnhn.fr/docs/CITES/Guide-identification-concombres-de-mer-2022-EN.pdf
French version: https://inpn.mnhn.fr/docs/CITES/Guide-identification-concombres-de-mer-2022-FR.pdf
Spanish version: https://inpn.mnhn.fr/docs/CITES/Guide-identification-concombres-de-mer-2022-ES.pdf
Chinese version: https://inpn.mnhn.fr/docs/CITES/Guide-identification-concombres-de-mer-2022-CN.pdf

In addition to being published in the three official languages of CITES (French, Spanish and English), the guide is also translated into Chinese. Given that the largest import market for sea cucumbers is, by far, China and its neighbouring countries, China is demanding that Mandarin be a new official language of CITES. And, also given that enforcement authorities require maximum efficiency, publishing this guide in Mandarin is important, both for the conservation of sea cucumbers and for the challenges of applying the Convention's commitments to China.

Support for CITES sea cucumber listing proposals

This guide also supports a long-term sea cucumber strategy. It is an important tool for implementing the CITES listing of teatfish and for future sea cucumber listings. It supported the proposal to include the genus *Thelenota* in Appendix II presented by France under the European delegation during CoP19, which took place in Panama in November 2022 (Di Simone et al. 2023). The proposal was accepted, and three additional species of sea cucumbers are now listed in CITES. All CITES authorities around the world, as well as the fisheries concerned, will have an obvious need for increased skills.

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Bruckner A. 2006. Proceedings of the CITES workshop on the conservation of sea cucumbers in the families Holothuriidae and Stichopodidae. Silver Spring, MD, USA: US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

Di Simone M., Conand C. and Horellou A. 2021. The listing of three sea cucumber species in CITES Appendix II enters into force. SPC Beche-de-mer Information Bulletin 41:3–4. https://purl.org/spc/digilib/doc/273hx

Di Simone M., Horellou A., Ducarme F. and Conand C. 2022. Identificaton guide. Commercial sea cucumbers. Paris: Patrimoine naturel. 227 p. https://inpn.mnhn.fr/docs/CITES/Guide-identification-concombres-de-mer-2022-EN.pdf

Di Simone M., Horellou A. and Conand C. 2023. The listing of three new holothurian species in CITES Appendix II. SPC Beche-de-mer Information Bulletin 43:17–19.

Purcell S.W., Samyn Y. and Conand C. 2012. Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes, No. 6. Rome: Food and Agriculture Organization of the United Nations. 150 p.

Purcell S.W., Lovatelli A., González-Wangüemert M., Solís-Marín F., Samyn Y. and Conand C. 2023. Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes, No. 11. Rome: Food and Agriculture Organization of the United Nations. 273 p.

Identifier les concombres de mer inscrits à la CITES : un guide d'identification

Marie Di Simone,[1] Arnaud Horellou,[1] Frédéric Ducarme[2] et Chantal Conand[2]

Introduction

La CITES, Convention sur le commerce international des espèces de faune et de flore sauvages menacées d'extinction, a pour mission d'éviter que le commerce international ne soit la cause de la disparition d'une espèce, soit par l'encadrement, soit par l'interdiction du commerce. Dans ce contexte, dès la fin des années 1990, des groupes d'experts se sont constitués pour se pencher sur la question des concombres de mer (Bruckner 2006), dont l'importance du commerce avoisine celui des ailerons de requins. Pour autant, aucune proposition d'inscription n'a été portée à la Conférence des Parties, pendant presque une vingtaine d'années.

C'est finalement en 2019 que les concombres de mer intègrent l'annexe II de la CITES, avec 3 espèces facilement identifiables : les holothuries à mamelles (Di Simone *et al.* 2021). Cette proposition française avait été présentée par l'Union Européenne, les Etats-Unis, le Kenya, le Sénégal et les Seychelles. Il s'agissait de la première proposition pour des holothuries, présentée à une conférence des Parties.

Difficultés d'identification des concombres de mer

Après 17 ans de tentatives infructueuses, cette première inscription d'holothuries à la CITES pose la question de la mise en œuvre des contrôles et du rapportage, sur un groupe peu considéré par les non spécialistes. Les données commerciales sont le plus souvent rapportées au groupe (« concombre de mer ») plutôt qu'à l'espèce, empêchant d'identifier clairement les espèces les plus prisées. Par ailleurs, les forces de contrôle elles-mêmes ne sont pas compétentes et n'ont aucun outil pour différencier les marchandises contenant des concombres de mer. Comment certifier qu'un colis contenant des concombres de mer est légal ou non, si on ne peut certifier qu'il ne s'agit pas des espèces actuellement inscrites à la CITES ? Ces animaux, principalement exportées vers les marchés asiatiques, devraient être distinguées au rang de l'espèce par les pêcheries, les négociants… pour mieux cibler les espèces surexploitées.

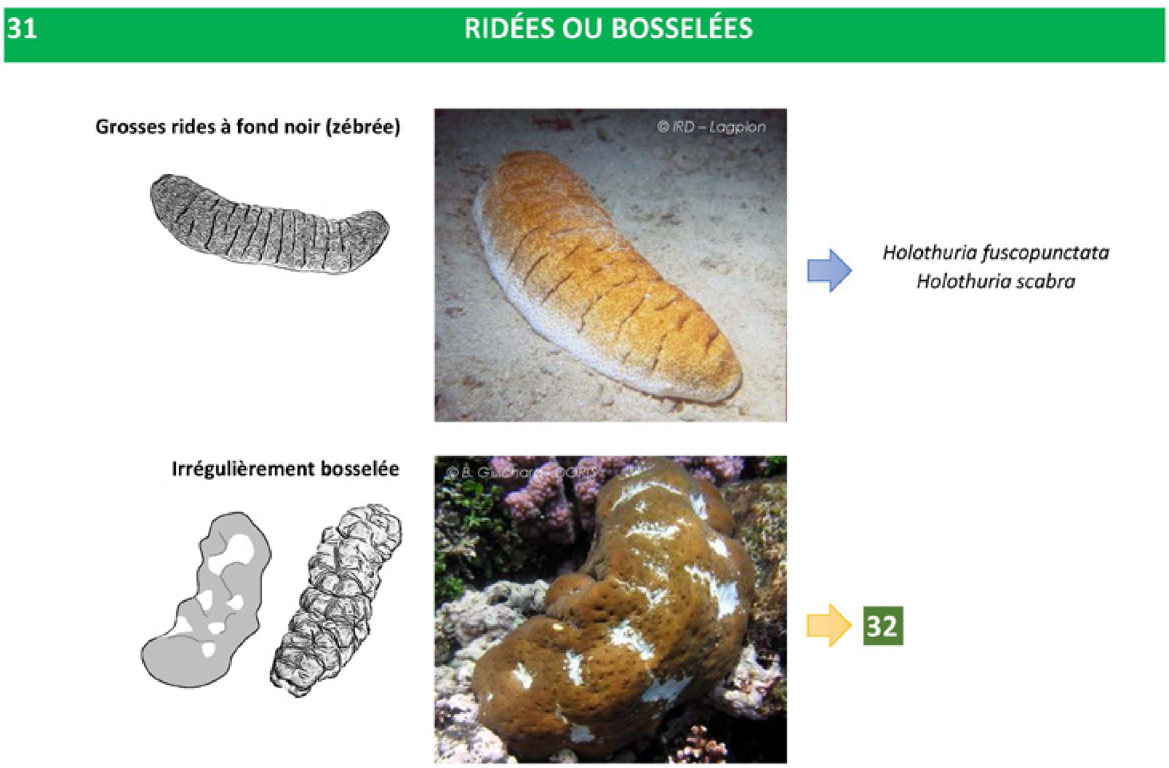

Figure 1. Extrait de la clé d'identification pour les spécimens vivants d'holothuries

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[2] Muséum national d'Histoire naturelle. Email: chantal.conand@mnhn.fr

Identifier les concombres de mer est une affaire de spécialistes. En effet, la plupart des ouvrages se basent sur les spicules, de petites structures en carbonate de calcium qui nécessitent dissection et microscopie pour être observées. En 2012, la FAO publie la première édition du guide des concombres de mer d'importance commerciale mondiale (Purcell *et al*. 2012). Ce guide identifiait 58 espèces significativement représentées dans le commerce international et principalement pêchées dans les Océans Pacifique et Indien, à destination de la Chine et dans une moindre mesure du Vietnam. Une nouvelle édition élargie à d'autres régions et d'autres espèces est en cours de publication (Purcell et al. 2023). Il permet à un expert d'identifier les différentes espèces de concombres de mer avec des critères de laboratoire. Ces méthodes ne sont pas compatibles avec la réalité du terrain, des douanes notamment.

Réalisation d'un guide simplifié d'identification sur les concombres de mer

L'Autorité Scientifique française pour la CITES, le Service Patrinat (OFB, CNRS, MNHN, IRD), a donc décidé de produire un guide simplifié d'identification, d'après le guide scientifique de la FAO, dans une vision à long terme sur les concombres de mer, leur commerce et la constitution de données plus précises (Di Simone *et al*. 2022).

Ce guide présente 56 espèces de concombres de mer, protégées ou non par la CITES, commercialisées dans le monde entier, pour la consommation alimentaire. Il a été conçu de manière volontairement vulgarisée, afin qu'il soit accessible à des personnes non spécialistes, dont les agents des forces de contrôle qui ont pour mission de détecter les possibles infractions.

Ce guide permet de reconnaître les espèces commercialisées à l'aide de deux clés d'identification : une pour les spécimens vivants (Figure 1) et une pour les spécimens séchés (Figure 2). Chaque espèce est décrite sous forme de fiche présentant les caractéristiques morphologiques et/ou distinctifs, ainsi que la description des spicules pour les spécialistes (Figure 3).

En plus d'être publié dans les trois langues officielles de la CITES (français, espagnol et anglais), le guide est également traduit en chinois. Dans un contexte où le premier marché importateur est, et de loin, la Chine et les pays voisins, où la Chine réclame que le Mandarin soit une nouvelle langue officielle pour la CITES, et où les flux de contrôles douaniers réclament une efficience maximale, l'édition de ce guide en Mandarin est importante, autant pour la conservation des concombres de mer que pour les enjeux d'application des engagements de la Convention par la Chine.

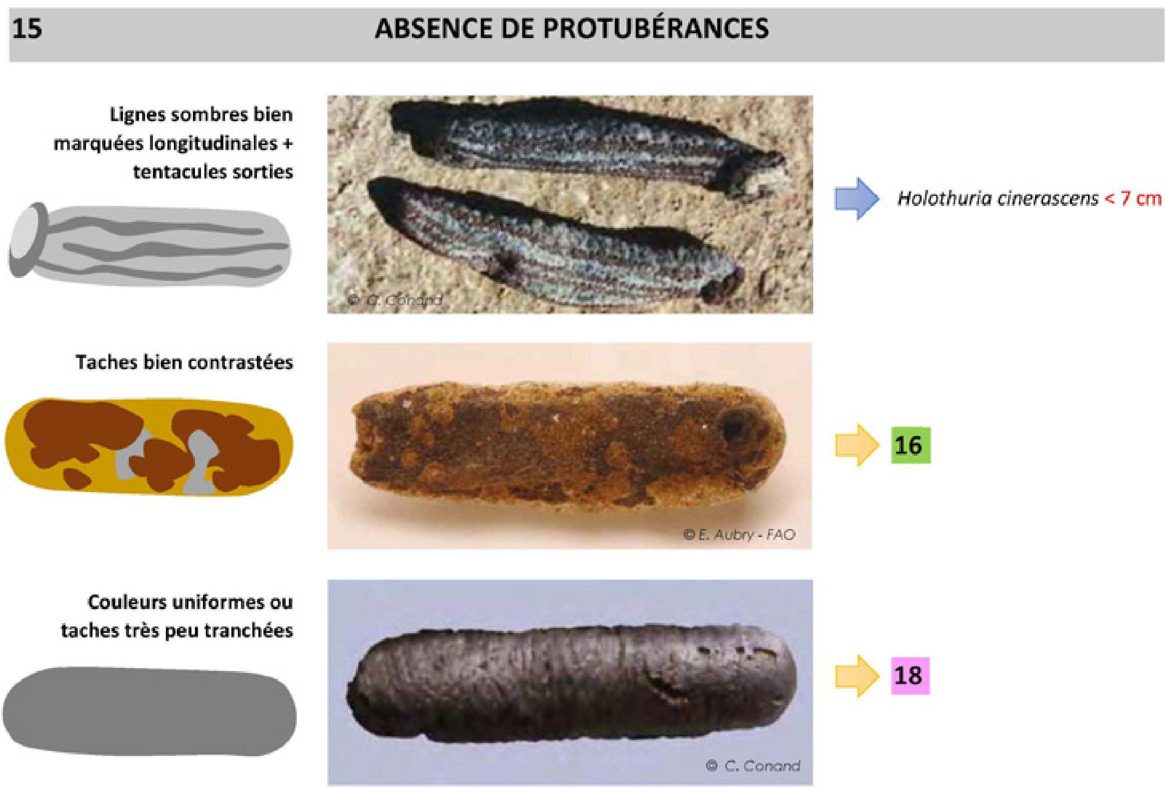

Figure 2. Extrait de la clé d'identification pour les spécimens séchés d'holothuries

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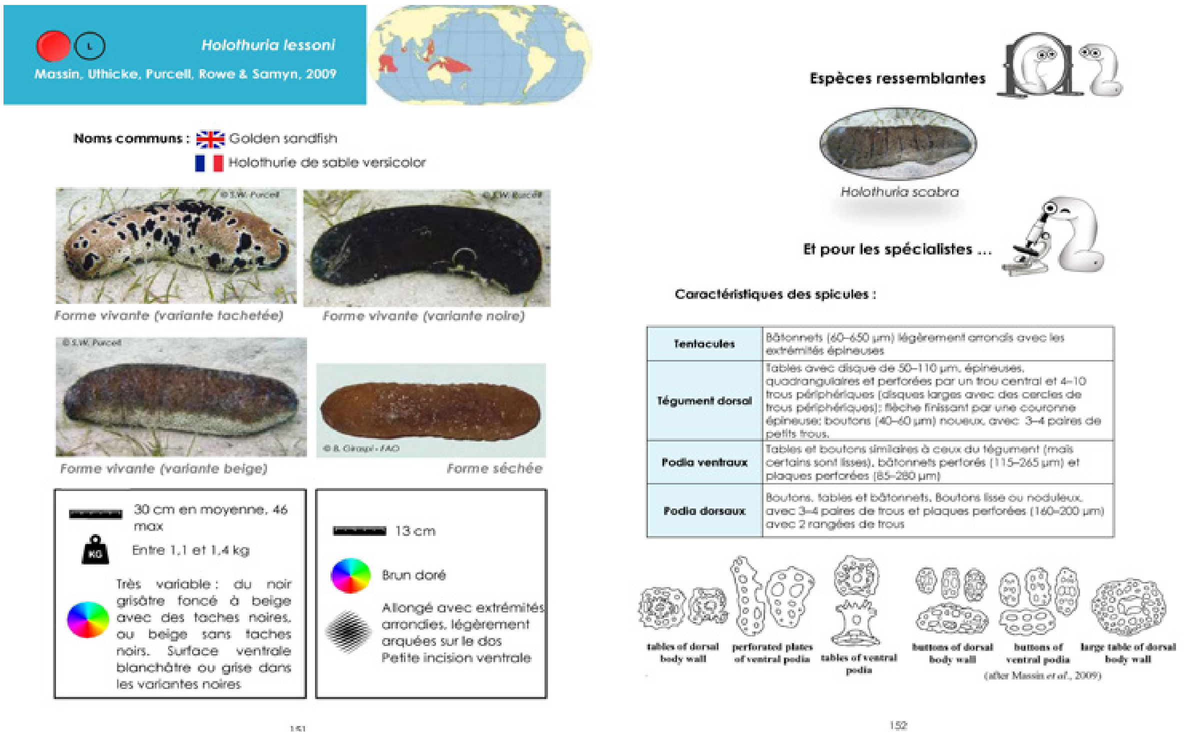

Figure 3. Exemple d'une fiche espèce

Appui aux propositions d'inscription des holothuries à la CITES

Ce guide constitue également le support d'une stratégie à long terme sur les concombres de mer. Il représente un outil important pour mettre en œuvre l'inscription des holothuries à mamelles à la CITES et pour de futures éventuelles inscriptions de concombres de mer. Il a appuyé la proposition d'inscription du genre *Thelenota* à l'Annexe II présentée par la France sous délégation européenne lors de la CoP19 qui a eu lieu au Panama en novembre 2022 (Di Simone et al. 2023). La proposition a été acceptée, trois espèces supplémentaires de concombres de mer entrent à la CITES. L'ensemble des autorités CITES du monde entier, ainsi que les pêcheries concernées, auront un besoin évident de montée en compétence.

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Di Simone M., Horellou A. et Conand C. 2023. Inscription de trois nouvelles espèces d'holothuries à l'Annexe II de la CITES. SPC Beche-de-mer Information Bulletin 43:20–22.

Di Simone M., Horellou A., Ducarme F. et Conand C. 2022. Guide d'identification - Concombres de mer commercialisés, Patrinat, France, 227 p. https://inpn.mnhn.fr/docs/CITES/Guide-identification-concombres-de-mer-2022-FR.pdf

Purcell S.W., Samyn Y. and Conand C. 2012. - Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes. No. 6. Rome, FAO. 150 pp. 30 colour plates

Purcell S.W., Lovatelli A., González-Wangüemert M., Solís-Marín F., Samyn Y and Conand C. 2023. Commercially important sea cucumbers of the world. *FAO Species Catalogue for Fishery Purposes.* No. 11. Rome, FAO 273 p. +viii.

Figure 4. Couvertures des quatre versions du manuel (anglais, français, espagnol et chinois).

Les liens permanents pour télécharger le guide sont indiqués ci-dessous :
Version française : https://inpn.mnhn.fr/docs/CITES/Guide-identification-concombres-de-mer-2022-FR.pdf
Version anglaise : https://inpn.mnhn.fr/docs/CITES/Guide-identification-concombres-de-mer-2022-EN.pdf
Version espagnole : https://inpn.mnhn.fr/docs/CITES/Guide-identification-concombres-de-mer-2022-ES.pdf
Version chinoise : https://inpn.mnhn.fr/docs/CITES/Guide-identification-concombres-de-mer-2022-CN.pdf

Observations of juvenile *Stichopus horrens* on the southeast coast of Guadalcanal, Solomon Islands

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Species: *Stichopus horrens*

Dates of observation: 17 October 2011 and 26 December 2011

Location: Within the moat in front of Hatare Community, Marau Sound, east Guadalcanal

Depth: ca. 0.3 m to 1 m, depending on the tide

Habitat: Underneath dead coral stones and rocks on the rocky sea bottom

Approximate sizes: 2–6 cm

Note: Juvenile *Stichopus horrens* were found underneath dead coral stones and rocks of various sizes within the area overlapping with the habitat of adults (Fig. 1A, B and D). One juvenile was found side by side with an adult (Fig. 1A). Cross sections of juveniles' bodies were quadrangular. The body walls of smaller individuals (< 3 cm) contained less pigment, with dark ring-like spots at the tips of papillae, and were more or less translucent, making the internal organs visible externally (Fig. 1A and B). The characteristics mentioned above closely resemble those of hatchery-produced juveniles of *S. horrens* (Fig. 1C). Figure 1D shows a larger juvenile (ca. 6 cm) of *S. horrens*. For comparison, hatchery-produced juveniles in similar sizes are shown in Fig. 1E, which were released in the same area, based on the information on juveniles' preferred habitat obtained by the present survey. This area has been selected as a government project site for the experimental release of hatchery-produced juveniles of *S. horrens*. This area was also chosen because the co-occurrence of juveniles and adults in the same habitat implies that released juveniles can complete their life cycle to the adult stage within this site (without long-range migration), which seems suitable for areal-based management by the local community.

Acknowledgements

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[4] Hatare Community MPA monitor members
[a] Project counterpart at the time of the survey
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Figure 1. A: Juvenile *Stichopus horrens* (within green circle) found underneath a dead coral stone side by side with an adult; B: another juvenile *S. horrens*; C: hatchery-produced *S. horrens* juveniles (< 3 cm) for comparison; D: larger wild juvenile of *S. horrens* (ca. 6 cm); E: hatchery-produced *S. horrens* released within the area where wild adults occur. Images ©Toru Komatsu

New observation of juvenile *Stichopus herrmanni* within a dense population of mixed ages in Vanuatu

Frédéric Ducarme[1]

Species: *Stichopus herrmanni* (Semper, 1868; syn. *S. variegatus*), also known as "curryfish".

Context: *Stichopus herrmanni* is one of the increasingly targeted beche-de-mer species in the Indo-Pacific (Purcell et al. 2012; Di Simone et al. 2022), and listed as Vulnerable (A2bd) by the International Union for Conservation of Nature since 2013 (Conand et al. 2014). Hence, improving the knowledge on its biology, particularly its ecology, reproduction and growth is paramount (Wolfe and Byrne 2017a). Although considered scarce in many areas, this species is also known to occur in high densities in some places, especially inside some marine protected areas (Eriksson et al. 2010).

Juvenile beche-de-mer (Holothuroidea) are rarely observed and particularly difficult to identify because many species exhibit very different morphologies and color patterns from the adults, hence constituting a challenge for scientists (Shiell 2004). Observations of large, single-species aggregations of individuals of mixed ages, sizes and morphological features can enable a better understanding of these variations and provide better *in situ* identification of isolated juveniles.

Place: This observation took place at the "waterfront" of Port Vila, the capital and main city of Vanuatu (South Pacific) during a survey of beche-de-mer (see Ducarme et al. 2023, p.4 in this issue). It was observed on the shallow reef at the north of Port Vila's main bay, about 100–300 m westof Kumul Highway, in depths of 1–3 m (approximate coordinates 17°43'56.2"S, 168°18'33.1"E). This area is considered polluted because it is in the center of a Port Vila with a population of 60,000 inhabitants. Port Vila has very little in the way of sewage treatment, and the water is often milky or murky. The bottom is a detritic sandy bay with dead coral, sparse live reef elements, and an irregular rubble matrix. The water receives a high nutrient input due to its proximity to the city and a small estuary. This site appears quite different from previously reported habitats for juveniles (i.e. seagrass beds) as reported on in Conand (1993), "coralline algae and associated bacterial films" in Eriksson et al. (2013) and "piecrust reef" in Wolfe and Desbiens (2022).

Date: 13 April 2020

Observation: A couple of hundred meters from the seashore at shallow depths, we observed a dense population of *Stichopus herrmanni* exhibiting many different sizes (hence ages), ranging from 6 cm to 40 cm in length. The smallest specimens had various mottled colour patterns, mostly yellowish-brown with dark or light areas, and black wrinkles. Juveniles also had more elevated papillae than adults (making them looking like species from the *Stichopus horrens* complex), with the same distinctive concentric wrinkles around them. The largest specimens tended to have the smoothest tegument, and uniform colouration. These observations are consistent with the appearance of juveniles reported from New Caledonia by Conand (1993) and Réunion Island by Bourjon and Morcel (2016).

The size of the smaller specimens suggests an age of one or two months if the growth rate of these are similar to the ones described by Hu and al. (2010), hence likely born from a summer spawning event, consistent with Conand (1993) and Wolfe and Byrne (2017b).

The co-occurrence of juveniles and large adults is surprising as this species is known to experience ontogenic migrations towards deeper waters (Conand 1993; Palazzo et al. 2016; Wolfe and Byrne 2017b). Some ecological parameters (such as food availability) may prevent this behaviour from occurring here.

This population was part of a densely populated ecosystem, including important populations of synaptids (*Synapta maculata* and *Opheodesoma* sp.), as well as other sea cucumber species (*Holothuria hilla* and *H. difficilis*, along with scarcer *H. atra*, *H. coluber* and *Chiridota* sp.). Apart from sea cucumbers, the bottom was also densely populated by other echinoderms, especially the sea urchins *Mespilia globulus, Parasalenia gratiosa* and *Laganum laganum*, and diverse ophiotrichid brittle stars. *Stichopus chloronotus* was not observed around the site, although this species was associated with juvenile *S. herrmanni* in Wolfe and Desbiens (2022).

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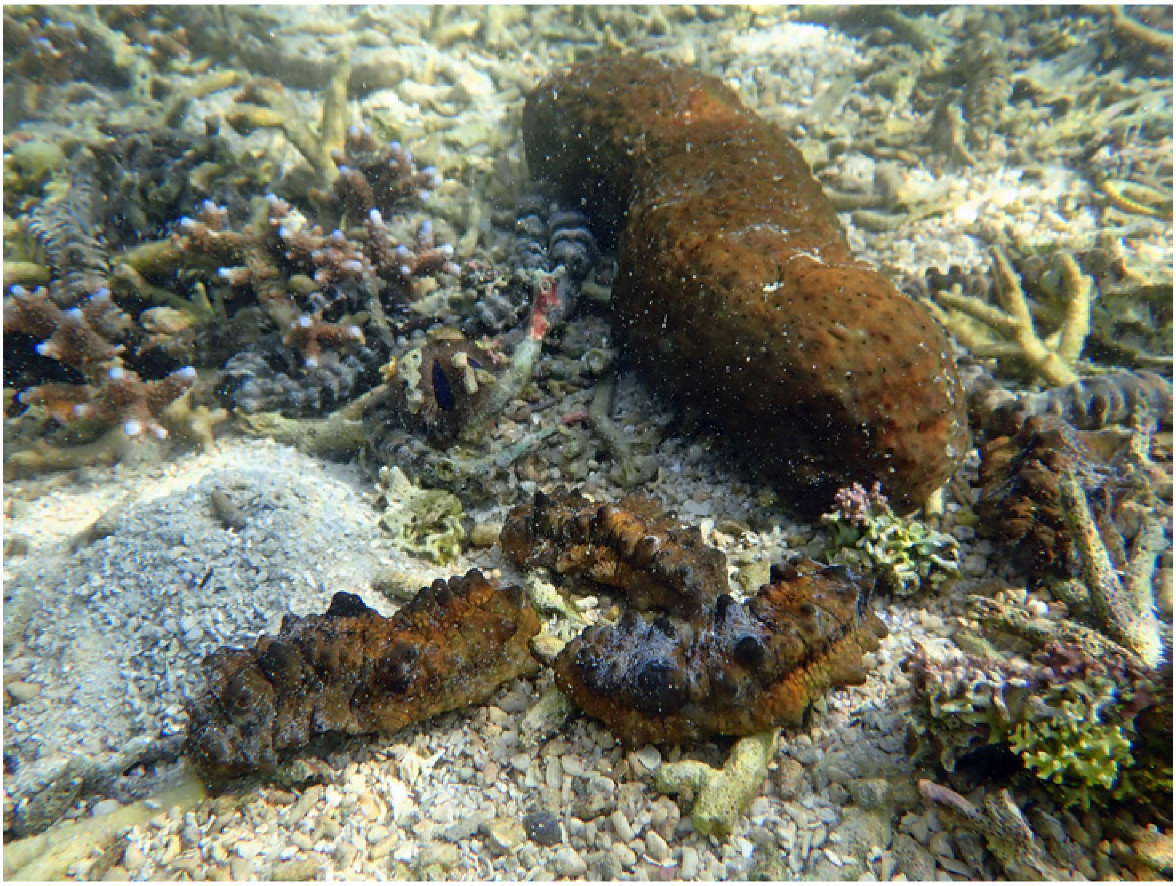
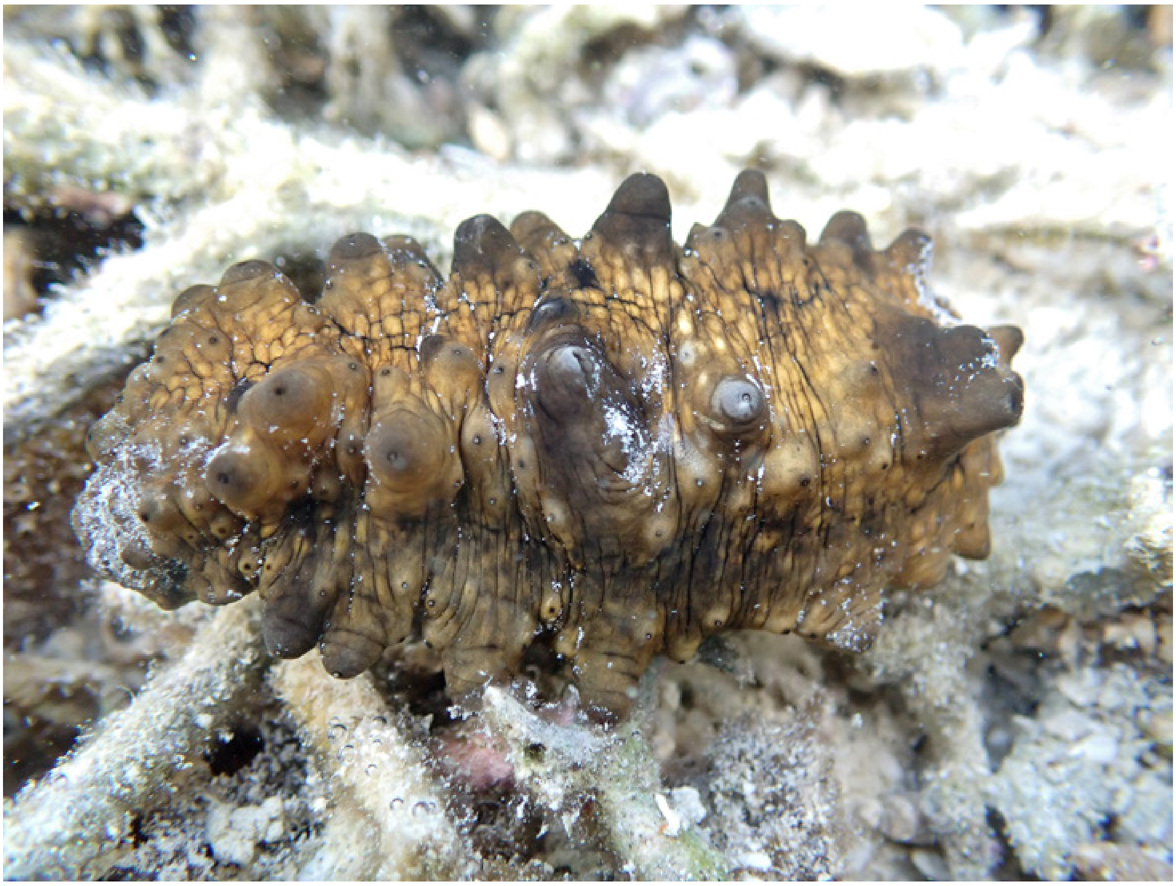


One large adult and four juvenile *Stichopus herrmanni*.



A small *Stichopus herrmanni*.

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COMMUNICATIONS

CONFERENCES

11th European Conference on Echinoderms (ECE11), 16–20 October 2023, Lyon, France

Website: https://ece11.univ-lyon1.fr

Contact: ece11@univ-lyon1.fr

Provisional schedule

- Pre-conference excursion to Villefranche-sur-Mer marine station: October 11$^{th–15th}$, 2023
- Registration, icebreaker: 16 October 2023
- Indoor scientific sessions: 16–17 and 19–20 October 2023
- Mid-conference excursion in Ardèche (la Voulte Lagerstätte): 18 October 2023
- Gala Dinner: 19 October 2023

Important dates

31 January 2023:

- First Circular

28 February 2023:

- Deadline for suggestions for workshops and scientific sessions
- Second Circular
- Opening of abstract submission
- Opening of pre-registrations

31 March 2023:

- Opening of registrations for conference and excursions

15 May 2023:

- Deadline for abstract submission

15 June 2023:

- Decisions on abstracts
- Deadline for registration to pre- and mid-conference excursions

30 June 2023:

- Deadline for early-bird registrations
- Third Circular, with full-program of conference and excursions

31 March 2024:

- Deadline for submission of manuscripts to the proceedings volume in Cahiers de Biologie Marine

Sea Cucumber Aquaculture: New Challenges, 3–4 October 2022 Concarneau Marine Station, France

The conference was supported by the French Agence Nationale de la Recherche, and the Belgian Fond National pour la Recherche Scientifique. The conference was part of the global project: South Est Asia -Europe Founding Scheme for Research and Innovation.

Programme included presentations by:

- Chantal CONAND (MNHN/Univ. La Réunion, France)
  Global sea cucumbers fisheries: an update of the past decade
- Jean-François HAMEL (SEVE, Canada)
  Community-based emerging fisheries in Nunavut (Canadian Arctic)
- Mercedes GONZALEZ-WANGUEMERT (WANGUMAR SLU, Spain)
  Sea cucumber aquaculture, why not?
- Matthew James SLATER (Alfred Wegener Institute, Germany)
  The uses of European sea cucumbers in integrated multitrophic aquaculture
- Frank DAVID (MNHN, France)
  A screening of methods to differentiate wild vs. farmed European sea cucumbers
- Arnold RAKAJ (University of Rome Tor Vergata, Italy)
  Aquaculture and IMTA applications with Mediterranean sea cucumbers: progress and problems
- Marc-André LAFILLE (French Polynesia Marine Ressources Department)
  Strategic approach and sustainable development of sea cucumber farming adapted to French Polynesia context
- Igor EECKHAUT (Mons University, Belgium)
  Ovarian and oocyte maturations of *Holothuria scabra* in the context of aquaculture production
- Philippe DUBOIS (ULB, Belgium)
  Sea cucumber aquaculture in a changing world
- Patrick FROUIN (University of La Réunion, France)
  Wild sea cucumber stress: what do enzymatic activities and oxidation protein products tell us about three tropical species (*Holothuria atra, Holothuria leucospilota* and *Stichopus chloronotus*)
- Alessandra WHAITE (Mons University, Belgium)
  Tube feet and cuvierian tubules: two different adhesive systems from sea cucumbers
- Mohammad MAGDY (University of Rome Tor Vergata, Italy)
  Towards sea cucumbers as a new model in embryo-larval bioassays in ecotoxicological studies
- Laurent BURGY (Tahiti Marine Products, French Polynesia)
  Development of sustainable sea cucumber farming (*Holothuria fuscogilva*) in French Polynesia
- Bastien SADOUL in videoconference (Institut Agro Rennes-Angers, France)
  Latest advances in the breeding and rearing of *Holothuria forskali*
  Gyda CHRISTOPHERSEN (Møreforsking AS, Norway)
  Initiating reproduction in captivity – emerging species *Parastichopus tremulus*
- Annie MERCIER (Memorial University, Canada)
  Latest advances on *Cucumaria frondosa*: biology, fisheries and aquaculture
- Gaëtan TSIRESY (ISTRCE, Madagascar)
  Technical feasibility of sea cucumber farming (*Holothuria scabra*) at the pioneer site in North-Eastern of Madagascar
- Jérôme DELROISSE (Mons University, Belgium)
  Story of a sea cucumber disease: a multidisciplinary approach of the skin ulceration syndrome in *Holothuria scabra*
- Anchana PRATHEP (Prince of Songkla University, Thailand)
  The first observation of Skin Ulceration Disease (SKUD) in *Holothuria (Metriatyla) scabra* Jaeger, 1833 from seagrass meadows in Thailand and some metagenomic studies.
- Guillaume CAULIER (Mons University, Belgium)
  From diseases to coelomocytes : the mysterious immune system of sea cucumbers

- Noé WAMBREUSE (Mons University, Belgium)
  How do sea cucumbers cope with bacterial infection? Let's bring cœlomocytes into the world of omics
- Patrick LE CHEVALIER (University of Bretagne Occidentale, France)
  Plasticity and specificity of the bacterial microbiota in the Sea Cucumber *Holothuria forskali*
- Wilson IANONA (IANONA Wilson, Madagascar)
  Looking for investors for sea cucumber (*Holothuria scabra*) farming project in the Northeastern of Madagascar in the SAVA region
- Agnès JOLY (Aquaprimeur, IOT, France)
  Indian Ocean Trepang, the pioneer and leading private company of the West Indian Ocean producing *Holothuria scabra* in aquaculture

Participants to the Conference: Sea Cucumber Aquaculture: New Challenges

17th International Echnioderm Conference, 2024

NEW COURSES

Sea cucumber aquaculture, why not?

Where: Instituto de Formacion Profesional Maritimo-Pesquero de Canarias – Arecife (Lanzarote, Canary Islands, Spain)

When: 10–14 July 2023 or 17–21 July 2023

The aim of this course is to present the basic concepts and methodologies applied to sea cucumber aquaculture but adapted and developed for commercial species native to Europe and Africa. The course will include theoretical and practical lessons that will enable participants to learn basic concepts and methods of sea cucumber aquaculture that they can apply to their local species.

This course is aimed at professionals related to the aquaculture sector, but also at students interested in this subject, officials from fisheries and aquaculture departments, investors, researchers, managers, etc. The professors teaching this course have extensive experience and training in the field of sea cucumber aquaculture (https://www.wangumar.com/about-us/). In fact, they are a successful example of research, development and innovation transfer from a research centre/university to private companies.

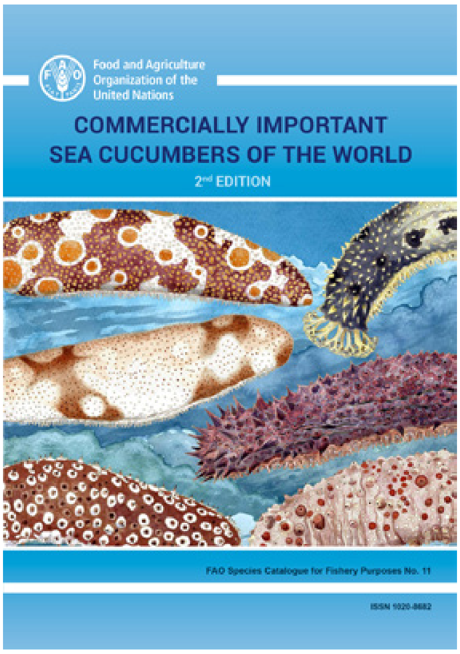
More information and pre-registration form available from: https://www.wangumaqua.com/landing/

Certificate in the Science of Artisanal Mariculture and Village Farming

See article by Igor Eeckhaut and co-authors on page 63 of this bulletin.

NEW BOOKS AND PUBLICATIONS

Commercially important sea cucumbers of the world



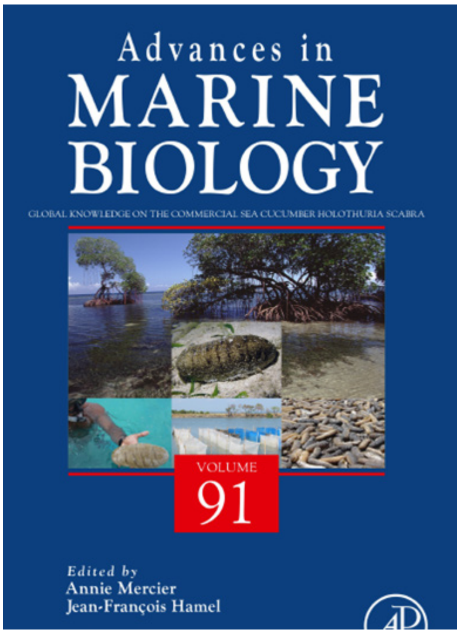
In 2012, the Food and Agriculture Organization of the United Nations (FAO) published the 1st edition of the guide on "Commercially important sea cucumbers of the world". Since then, the number of commercially exploited sea cucumber species has increased and more species are traded from regions that were not traditionally engaged in this sector.

The preparation of the 2nd edition of the FAO guide started in 2022 and will be finalised in early-2023.This new edition contains information of 84 different species, and includes identification keys covering live and processed animals. There are updates to some taxonomic designations, identifying information, trade prices and distribution maps.

The guidebook will be first published online and the PDF version will be freely accessible on the FAO website. A limited number of printed copies will then be available shortly afterwards and distributed at no cost. Hard copies will be mailed by courier. Interested parties should provide their name, surname, full mailing address and a contact phone number (with country code and area code), as the latter is required by the courier service. Due to the limited number of printed copies and mailing expenses, FAO aims at distributing the guide to all those interested parties that would make good use of it, particularly trade and custom officers, fishery workers and scientists involved with sea cucumbers.

When sending your contact details please briefly indicated the reason you require a copy (please justify if you need more than one). Please send your requests directly to Mr Alessandro Lovatelli, FAO Fisheries and Aquaculture Officer, at the following address: alessandro.lovatelli@fao.org

The following information was provided by Prof. Chantal Conand:

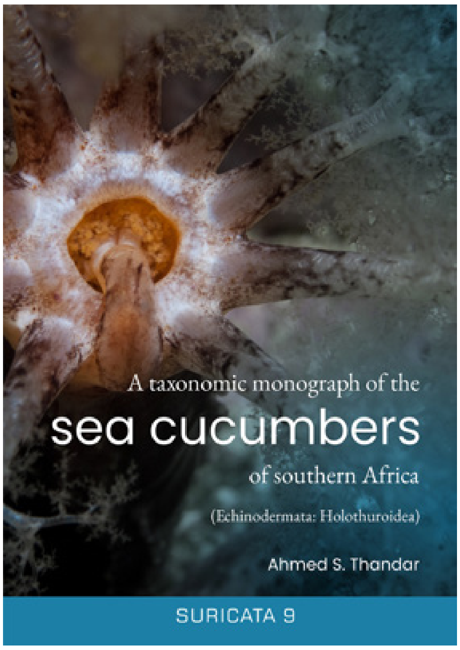


Global knowledge on the commercial sea cucumber Holothuria scabra

by Jean-François Hamel, Igor Eeckhaut, Chantal Conand, Jiamin Sun, Guillaume Caulier and Annie Mercier

In: Advances in Marine Biology, volume 91. https://doi.org/10.1016/bs.amb.2022.04.001

Holothuria scabra is one of the most intensively studied holothuroids, or sea cucumbers (Echinodermata: Holothuroidea), having been discussed in the literature since the early 19th century. The species is important for several reasons: 1) it is widely distributed and historically abundant in several shallow, soft-bottom habitats throughout the Indo-Pacific; 2) it has a high commercial value on the Asian, where it is mainly sold as a dried product (beche-de-mer); and 3) it is the only tropical holothuroid species that can currently be mass-produced in hatcheries. Over 20 years have elapsed since the last comprehensive review of *H. scabra* published in 2001. Research on *H. scabra* has continued to accumulate, fuelled by intense commercial exploitation, and further declines in wild stocks over the entire distribution range. This review compiles data from over 950 publications pertaining to the biology, ecology, physiology, biochemical composition, aquaculture, fishery, processing and trade of *H. scabra*, presenting the most complete synthesis to date, including scientific papers and material published by local institutions and/or in foreign languages. The main goal of this project was to summarise and critically discuss the abundant literature on this species, making it more readily accessible to all stakeholders aiming to conduct fundamental and applied research on *H. scabra*, or wishing to develop aquaculture, stock enhancement and management programs across its geographic range.



A taxonomic monograph of the sea cucumbers of southern Africa (Echinodermata: Holothuroidea)

by A.S. Thandar, University of KwaZulu-Natal, Westville Campus, P/Bag x54001, Durban 4000, South Africa. thandara@ukzn.ac.za

The southern African marine region, which lies in the transition zone between the Atlantic and Indo-Pacific biomes, has a very rich biodiversity, with elements from the two major oceanic regions. This taxonomic monograph, long awaited by local enthusiasts, marine biologists and holothuroid specialists worldwide, focuses on the southern African Holothuroidea. It is based on the author's approximately 55 years of research on the taxonomy of sea cucumbers, with specific emphasis on the southern African fauna.

The monograph includes a brief account of the materials used; fixation, preservation and other techniques; an illustrated account of gross morphological features of mostly the shallow-water holothuroids; an illustrated glossary of the microscopic ossicles; some zoogeographical considerations; an updated checklist that summarises the composition, biodiversity and faunistic components of all southern African holothuroids; a dichotomous key to orders, families, genera and species; and the systematic account of all recorded species. All seven currently recognised orders are represented, distributed over 26 families, 76 genera and 171 nominal and 10 indeterminate species. These include a couple of new records for the southern African region. South Africa has 152 nominal species.

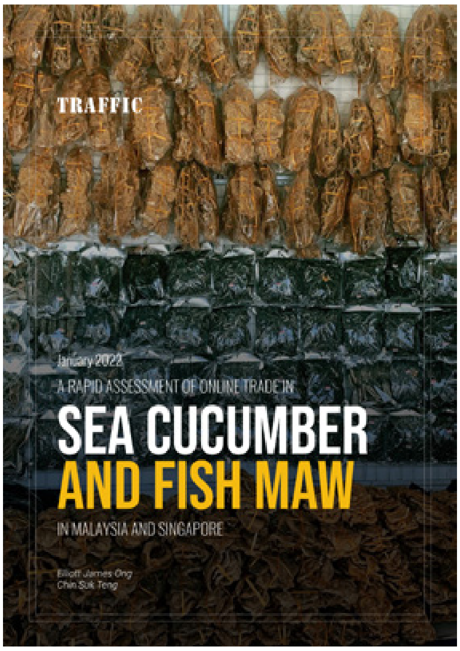
Each species account has a selected synonymy indicating the most pertinent synonyms, a brief diagnosis, the type locality, habitat notes, distribution data, concise remarks, a figure of the most important diagnostic characters and a distribution map. A comprehensive index and a full list of references that are cited or used in the text are also provided.

A rapid assessment of online trade in sea cucumbers and fish maw in Malaysia and Singapore

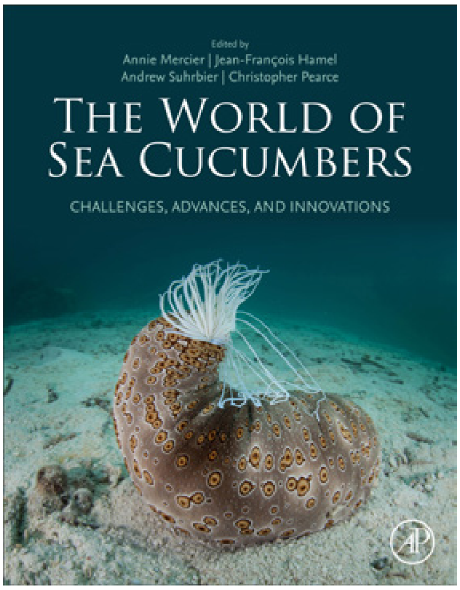
by Ong E.J. and Chin S.T. 2022. TRAFFIC, Southeast Asia Regional Office, Petaling Jaya, Selangor, Malaysia

An initial scoping exercise conducted for Malaysia and Singapore found sea cucumber and fish maw to be two of the most prevalent seafood commodities advertised for sale online. As legal trade volumes remains high along with concerning trafficking incidents, several countries have reported sea cucumber fishery closures due to population declines from overfishing. Equally, the illegal trade in these products is rife.

PDF available from: https://www.traffic.org/publications/reports/a-rapid-assessment-of-online-trade-in-sea-cucumber-and-fish-maw-in-malaysia-and-singapore/



Books to be published in 2023



The World of sea cucumbers – Challenges, advances and innovations

by Annie Mercier et al.

The World of Sea Cucumbers: Challenges, Advances, and Innovations provides broad coverage of sea cucumber biology, ecology, fisheries, aquaculture, and trade while also bringing forward novel cultural, socioeconomic and scientific topics related to commercial and non-commercial species worldwide. Written by international experts in their respective fields, the book offers a unique outlook into the fascinating world of sea cucumbers while also providing valuable information to various stakeholders and researchers. Commercial fisheries and aquaculture programs are addressed, especially as they relate to emerging species, but the book also covers novel, understudied or lesser-known biological, ecological, and commercial aspects. The involvement of Indigenous peoples and minorities in various community-level initiatives and on the cultural significance/impact of sea cucumbers in many regions are also examined. Finally, breakthroughs and emerging biotechnologies centered on sea cucumbers are presented.

https://www.elsevier.com/books/the-world-of-sea-cucumbers/mercier/978-0-323-95377-1

Information from the web or journals

Sea cucumber smuggling to Hong Kong sinks East African coastal livelihoods

by Willis Okumu, Senior Researcher – East and Horn of Africa, ENACT Project, ISS

https://enactafrica.org/enact-observer/sea-cucumber-smuggling-to-hong-kong-sinks-east-african-coastal-livelihoods

Préservation des holothuries blanches à mamelles à Tahiti: quand le savoir traditionnel devient le pivot d'un projet scientifique

https://lnkd.in/eigjyMEb

Sandfish: Expensive, endangered and ecologically essential

https://www.seafdec.org.ph/2020/sandfish-expensive-endangered-and-ecologically-essential/

Youtube – Sea cucumbers: Educational edition

https://www.youtube.com/watch?v=Ttu9AfRR8C8

Seychelles – Sea cucumber season opens with a ban on white teatfish

https://www.nation.sc/articles/15344/sea-cucumber-season-opens-with-a-ban-on-white-teat-fish-

Dr Myriam Sibuet

It is with great sadness that we announce the death of Dr Myriam Sibuet, former scientist at Ifremer (French Research Institute for Exploitation of the Sea). She had intensively contributed to the advancement of knowledge on deep sea echinoderms, and in particular on holothurians. Many of her scientific publications are listed in ResearchGate, including the following recent ones:

Levin L. and Sibuet M. 2012. Understanding continental margin biodiversity: a new imperative. Annual Review of Marine Science 4(1):79–112

Campos S. de L., Bassoi M., Nakayama C., Valentin Y.Y., Passeri Lavrado H., Menot L., Sibuet M. 2011. Antarctic-South American interactions in the Marine environment: A COMARGE and CAML effort through the South American Consortium on Antarctic Marine biodiversity. Oecologia Australis 15(1):5–22

Danovaro R., Company JB.., Corinaldesi C., D'Onghia G., Galil B. Cristina Gambi, Gooday A.J., Lampadariou N., Luna G.M., Morigi C., Olu K., Polymenakou P., Ramirez-Llodra E., Sabbatini S., Sardà F., Sibuet M. and Tselepides A. 2010. Deep-sea biodiversity in the Mediterranean Sea: the known, the unknown, and the unknowable. PLoS ONE 5(8): e11832. doi:10.1371/journal.pone.0011832

Olu K., Caprais J. C., Galéron J., Causse R., Cosel R. Von, Budzinski H., Le Ménach K., Le Roux C., Levaché D., Khripounoff A. and Sibuet M. 2009. Influence of seep emission on the non-symbiont-bearing fauna and vagrant species at an active giant pockmark in the Gulf of Guinea (Congo-Angola margin). Deep-Sea Research II. Topical studies in Oceanography. 56. 23:2259–2269.

We offer our sincere condolences to her family and loved ones.