Sea cucumber species from Mediterranean lagoon environments (Tunisia western and eastern Mediterranean)

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Summary

Few studies have examined the diversity of sea cucumbers in Mediterranean lagoons. This work presents the first data collected from two Tunisian lagoon ecosystems: Bizerte Lagoon and Boughrara Lagoon. The surveys reveal the existence of six species of Holothuroidea, with five species belonging to the order of Aspidochirotida and one species belonging to the order of Dendrochirotida. In Bizerte Lagoon, *Holothuria poli* was the most abundant sea cucumber (70% of specimens recorded), followed by four other species belonging to the *Holothuria* genus: *H. tubulosa* (18.5%) and *H. forskali, H. sanctori* and *H. mammata* (6.5% each). In Boughrara lagoon, *H. poli* is also the most common species (65% of records), followed by *Cucumaria syracusana* (26.5%), *H. sanctori, H. impatiens* and *H. tubulosa* with percentages of 4.1–0.8%.

Key words: Mediterranean lagoons, Tunisia, Holothuroidea

Introduction

Along the Tunisian coast, sea cucumbers are prevalent echinoderms (Sellem et al. 2017). During the last wo to three years, they have been collected without permission, predominately and preferentially in the intertidal zones and in lagoons. In fact, lagoonal ecosystems are numerous along the Tunisian seashore and constitute the region where fishery activities are significant.

Few studies pertaining to the identification and diversity of sea cucumbers have been conducted in Tunisia. Basic references include outdated inventories (Le Danois 1925; Cherbonnier 1956); systematic studies of these organisms have never been performed. In response to this lack of information, this study was done to determine which species of sea cucumbers live in the two lagoon ecosystems on the Tunisian coast: Bizerte Lagoon and Boughrara Lagoon. Management recommendations and proposals are suggested for the sea cucumber fishery.

Material and methods

Region of study

The Tunisian coast extends from the northwest of the country to the east-southeast. Tunisia is surrounded by numerous lagoonal ecosystems that extend mainly to areas close to the seashore but also close to major cities. Our study was carried out in two geographically different lagoons: Bizerte Lagoon and the Boughrara Lagoon (Fig. 1).

Bizerte Lagoon is located in the northern part of the country near the city of Bizerte, and is characterised by an average depth of 8 m and an area of ±128 km$^{2.}$

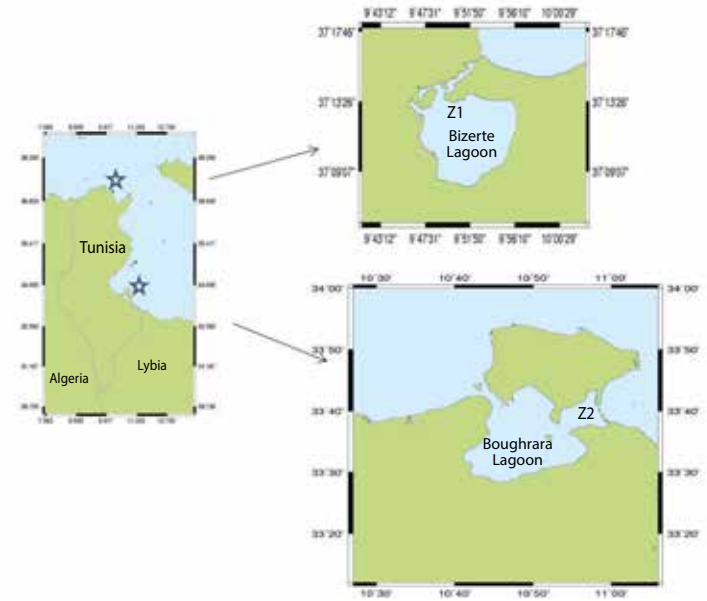

Figure 1. Location of Bizerte and Boughrara lagoons. Z1 and Z2 are sea cucumber fishing areas.

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This ecosystem is connected to the Mediterranean Sea through a 6-km-long channel (Bejaoui et al. 2008). The lagoon is located in a region where the climate is typically subhumid, and where environmental conditions fluctuate throughout the year, with an average temperature ranging between 15°C and 27°C and waters with a salinity of 20‰ to 40‰ (Hammami et al. 2016). This lagoon is a natural ecosystem where oyster and clam aquaculture takes place. These kinds of activities affect the environmental quality of the lagoon because they provide a supplement of minerals and organic matter (Alves Martins et al. 2015). Wastewater discharges are particularly high in the northern part of the lagoon, where most of the population and industrial activities are concentrated (Ben Garali et al. 2009).

Situated along the southeastern coast of Tunisia and to the south of Djerba Island, Boughrara Lagoon has a semi-desert-like climate. This ecosystem has two connections with the Mediterranean Sea: one in the northeast (El Kantara channel, length 12.5 m and depth of 4 m) and one in the northwest (Ajim channel, length 2200 m and depth of 15 m). The lagoon has an average depth of about 4 m and a maximum depth of 16 m in the centre. The water surface temperature in Boughrara Lagoon varies from an average of about 25°C in summer to 19°C in winter. Similarly, the salinity can vary from 38‰ to 43‰. An attractive harbour is located in the lagoon's southern zone. Consequently, a considerable amount of organic matter is released into the lagoon through harbour-related activities (Guetat et al. 2012). Sewage is the main source of pollution in the lagoon, produced by the traffic of the surrounding ports and the entry of phosphorus-laden seawater from the Gulf of Gabes.

Sampling methods

Sea cucumber sampling was carried out in the northwestern part of Bizerte Lagoon by scuba diving in depths of 5–7 m on a silt and sand substrate. Three georeferenced transects covered with the seagrass *Cymodocea nodosa* and tufts of algae, *Caulerpa prolifera* and *Enteromorpha* spp., were explored during random dives by two scuba divers. Sixty specimens of sea cucumbers were harvested and transported to the laboratory for identification.

In the northeastern part of Boughrara Lagoon, sea cucumbers were collected from 17 georeferenced points along the El Kantara area. The marine vegetation in the lagoon consists primarily of *Cymodocea nodosa*, *Gracilaria verrucosa* and *Ectocarpus* spp. Some 121 sea cucumber specimens were collected from the lagoon for this study.

In the laboratory, all specimens were first photographed and then examined morphologically. Taxonomic identification was based on the animal's internal morphology and the shapes of the ossicles, which were examined under a binocular microscope (Khoeler 1921; Tortonese 1965).

Results

Diversity and proportion of Holothuroidea

Seven sea cucumber species were identified in the two ecosystems. Six species belong to the family Holothuriidae (order Aspidochirotida) – *Holothuria poli* Delle Chiaje, 1823; *H. tubulosa* Gmelin, 1791; *H. forskali* Delle Chiaje, 1823; *H. sanctori* Delle Chiaje, 1823; *H. impatiens* Forskal, 1775; and *H. mammata* Grube, 1840, and only one species belongs to the family Cucumariidae (order Dendrochirotida) – *Cucumaria syracusana* Grube, 1840 (Fig. 2).

Figure 2. Ventral side of the different species of sea cucumbers harvested in the lagoons of Bizerte and Boughrara. A: *Holothuria poli*; B: *Holothuria tubulosa* ; C: *Holothuria forskali* D: *Holothuria sanctori* ; E: *Holothuria impatiens* ; F: *Holothuria mammata* ; G: *Cucumaria syracusana*. (images: F. Sellem and F. Guetat)

Holothuria poli Delle Chiaje, 1823

Holothuria poli rarely reached 20 cm in length and the minimum size encountered was 5 cm. It has fairly thick skin with the presence of fine conical tubers irregularly arranged on the dorsal side. Its mouth is located in the terminal position on the ventral side, and is surrounded by a crown of short tentacles in the shape of an umbrella. *Holothuria poli* readily expels its viscera. This species has one gonad, which consists of a tuft or tubules of light pink or white. Cuvierian tubules are absent. The pedicels or papillae are blackish-brown from the base, and gradually fade to a white tip that contrasts sharply with the colour of the rest of the body. On the ventral surface, they consist mainly of numerous and very tight tubules. Microscopic observation of the ossicles shows three kinds of plates. We note abundant plates with a surface always perfectly smooth with oval contour or loops frequently with three pairs of holes. Some of these loops are a bit longer and offer four to six pairs of holes. We also observed elongated or rod-shaped plates with irregular contours and with numerous and unequal perforations but always smooth surfaces. The shape of these last plates can be straight, elongated or arched with a smooth surface, or bristling with spikes. Finally, we noticed the corpuscle plate, which has a base with spiny edges, pierced by four orifices with a crown.

Holothuria tubulosa Gmelin, 1791

The body of *Holothuria tubulosa* is cylindrical and usually larger in size than *H. poli* (up to 24 cm). This species is characterised by a thick and rather tough tegument of brown colour (more or less dark), sometimes with reddish or purple hues. The mouth is surrounded by a crown of tentacles with a form of shield. The dorsal surface presents conical and scattered prominences ending in a small elongated papilla, not white and without a suction cup. The colour of the ventral surface is much lighter, usually with more or less flat brown spots. It is also distinguished by many pedicels that are tight and irregularly distributed. Cuvierian tubules are absent and its only gonad is located on the left of the dorsal mesentery with pinky colour but darker than that in *H. poli. Holothuria tubulosa* readily expels its viscera through the anus. The ossicles reveal widespread rounds and oval plates or loops with small sharp and conical asperities. These loops have three to four and even six pairs of successive orifices. Second plates are elongated or rod-shaped, and are observed with straight or slightly arched forms and generally perforated. Their irregular edge and the surface are covered with very tight asperities. Perforations or small orifices are absent in the medial region but sometimes these small orifices were observed in the extremities. We also found very small corpuscles with an almost circular spiny edge with four perforations.

Holothuria sanctori Delle Chiaje, 1823

The body of *Holothuria sanctori* is almost cylindrical and fairly flattened on the ventral side. The specimens measured between 10 cm and 12 cm. The dorsal surface is covered with large papillae that are strongly contracted while the ventral side is dense with podia whose arrangement is not distinct. The colour is usually brownish on the dorsal side, and a little lighter on the ventral side. Cuvierian tubules are present and formed by thin and elongated tubes. The morphology of the ossicles shows the presence of regular oval-shaped loops with perforations, and arranged in two and even three to six rows. We also observed other loops but these were generally wider and their perforations more numerous and especially widened transversely. The elongated plates are of the widened and perforated form. They are curved with, on the sides, small denticulations whose dimensions are variable. The corpuscles are slightly scalloped and smooth. Around the central perforation, there is a circle of 8 to 12 peripheral orifices of approximately equal sizes, and outside of this first circle there may be a second circle of much smaller orifices. This type of ossicle is characterised by completely smooth periphery of its disk.

Holothuria forskali Delle Chiaje, 1823

Holothuria forskali is recognisable by its deep black colour, and the body is more or less studded with fine white dots. It has a vermiform aspect, elongated along a bucco-anal axis and measures an average of 15 cm. The mouth is surrounded by 20 small tentacles. This species emits Cuvierian tubules when it feels threatened. The body is covered with little prominent conical papillae, the end of which is white. The ventral side is clearer. The microscopic observation of the ossicles is marked by the presence of very small loops compared to other sea cucumber species. These are composed of very small calcareous plates with two to four holes or pores. These plates vary little in form. The rods or elongated plates are elongated and slightly arched and have rough ends with denticules. None of the different ossicle structures of *Holothuria forskali* are abundant.

Holothuria impatiens Forskal, 1775

Holothuria impatiens does not exceed 15 cm in length. The integument is quite thin and soft, but the surface is rough. The papillae are irregularly arranged and not very tight. The colour of the specimens we encountered is yellowish-brown or purplish, with darker brown spots; but the papillae are clearer. *Holothuria impatiens* has Cuvierian tubules that are not easily expulsed. Microscopic observation of the spicules reveals very numerous, oval and elongated plates or loops with very uniform dimensions but

with 6 to 10 pairs of pores. Their surface is perfectly smooth. The elongated plates are variable in shape and are mainly marked with two to six perforations at the ends and in the middle of the plate. The corpuscles or turriform towers have circular disks and smooth edges with eight large peripheral orifices.

Holothuria mammata Grube, 1840

Holothuria mammata is characterised by large nipples on its dorsal surface. The integument is quite thick and black-brown in colour. *Holothuria mammata* looks like *H. tubulosa*, but its surface is rough and the taste buds are arranged regularly and are larger. The Cuvierian tubules are not easily expulsed. Observation of the ossicles shows oval and elongated loops with uniform size, and composed of five to six pairs of pores. The surface of these loops is not smooth, but rather has small tubercles. There are also larger loops with reduced or absent perforations, but the surface is wrinkled. The elongated plates are straight and thin and slightly arched, and their surface is covered with asperities. The turriform towers or corpuscles have circular disks and sharp edges.

Cucumaria syracusana Grube, 1840

This species is remarkable for its small size; it has a small and cylindrical body, which does not exceed 4 cm. The integument is quite leathery but smooth, and the colour is a rather dark-brownish violet. The mouth is in the terminal position on the dorsal surface, and surrounded by a crown of tree-shaped tentacles. This species has a pharynx with special retractor muscles and no anal teeth. Microscopic observation of ossicles shows thick, rounded or oval loops with large tuberosities. These plates are provided with several perforations ranging from four to six. Plates are often symmetrical but are numerous and dominant compared to other forms of plates. The elongated plates are straight or arched with some perforations.

Distribution and proportion of sea cucumber species in lagoon environments

Our results indicate that proportions of the sea cucumber species identified are different. *Holothuria poli* Delle Chiaje, 1823 is the most abundant sea cucumber species in both lagoons, constituting 70% of all specimens recorded in Bizerte Lagoon and 65% of those recorded in Boughrara Lagoon. Other species encountered in Bizerte Lagoon included *Holothuria tubulosa* Gmelin, 1791, which represented 18% of all specimens, followed by *Holothuria forskali* Delle Chiaje, 1823, at nearly 7%, *Holothuria sanctori* Delle Chiaje, 1823, at over 3%, and *Holothuria mammata* Grube, 1840, at nearly 2%.

Holothuria poli was also the most abundant sea cucumber species in Boughrara Lagoon, constituting 65% of all specimens recorded. It was followed by *Cucumaria syracusana* Grube, 1840 at 26%, *Holothuria sanctori* Delle Chiaje, 1823, at 4%, *H. impatiens* Forskal, 1775 at 3%, and *H. tubulosa* Gmelin, 1791 at less than 1%.

Discussion

The first study of Tunisia's Echinodermata phylum was conducted by Le Danois (1925). This first inventory provided a list of species living along the coast, belonging to the five classes of this phylum. As regards to sea cucumbers (Holothuroidea), Le Danois only recorded animals of the genus *Stichopus* from the Gulf of Hammamet, and Chambost (1928) reported the genus *Holothuria* in the Gulf of Tunis. In 1940, Bruun identified for the first time *Holothuria tubulosa, H. poli, H. impatiens* and *Cucumaria syracusana* in the Gulf of Tunis.

In 1956, Cherbonnier survey the whole country and established the most extensive collection of the group, considered today as the reference. He identified the four species of sea cucumbers determined by Bruun (1940) but also identified *Holothuria helleri, Cucumaria planci, Stichopus regalis, Phyllophorus urna* and *P. granulatus*, thus making a total of nine sea cucumber species along Tunisia's coast.

An overview of bibliographic references from 1925 to 1999 allowed us to adjust the list of sea cucumber species for along the coast in the three main regions of: the Gulf of Tunis, Gulf of Hammamet and Gulf of Gabes (Table 1). Overall, we listed 17 species of sea cucumbers in these regions, but none had been found in a lagoon. Of these 17 species, 8 species belong to the Aspidochirota order, 7 to the *Holothuria* genus and 1 species to the *Stichopus* genus. Seven species belong to the Dendrochirota order: four species of *Cucumaria*, two of *Phyllophorus* and one of *Neocucumis*. Finally, two species belong to the Apoda order and the Synaptidae family, comprising one *Leptosynapta* and one *Lapidoplax* (Le Danois 1925; Chambost 1928; Bruun 1940; Cherbonnier 1956; Gautier-Michaz 1958; Lubet and Azzouz 1969; De Gaillande 1970; Ktari Chakroun and Azzouz 1971; Azzouz 1973; Boudouresque et al. 1986; Zaouali 1993; Ben Mustapha et al. 1999).

During our study, 181 sea cucumber specimens were examined and identified, with 6 species belonging to the *Holothuria* genus and 1 species to the *Cucumaria* genus. All of these species were studied for the first time in the Bizerte and Boughrara lagoons. Six species had already been identified and reported from Tunisian waters (Table 1), but one species, *Holothuria mammata,* was identified in Tunisia for the first time in Bizerte Lagoon. In both lagoons, there was

Table 1. Species of Holothuroidea present along the Tunisian coast. Species in bold are those identified in this work. Cited means how many times the species has been referenced in the literature.

Species of Holothuroidea	Cited (1925–1999)	Areas	Lagoon
Cucumaria kirschbergi Heller, 1868	1	SST	
Cucumaria montagui Flemming, 1828	2	SST and GG	
***Cucumaria syracusana* Grube, 1840**	3	GT, T, GG	LBG
Cucumaria (Ocnus) planci Brandt, 1835	5	T GG NE	
Holothuria helleri Marenzeller von, 1878	1	T	
***Holothuria impatiens* Forsskal 1775**	5	GT, T, SST, GG	LBG
***Holothuria mammata* Grube, 1840**	-		LB
***Holothuria poli* Delle Chiaje, 1823**	4	GT, T, IZ, GG	LB, LBG
***Holothuria sanctori* Delle Chiaje, 1823**	2	SSC, IZ	LB, LBG
Holothuria stellati Delle Chiaje, 1823	1	GG	
***Holothuria tubulosa* Gmelin, 1791**	7	GT, T, SST, GG, NE, IZ	LB, LBG
Labidoplax digitata Montagu, 1815	2	SST NE	
Leptosynapta sp.	1	NE	
Neocucmis marionii Marenzeller von, 1878	1	SST	
Phyllophorus urna Grube, 1840	1	T	
Phyllophorus granulatus Grube 1840	1	T	
Stichopus regalis Cuvier, 1817	5	GH, T, GT, GG, NE	

T = Tunisia, GT = Gulf of Tunis, NE = northeast, GH = Gulf of Hammamet, GG = Gulf of Gabès, SST = Tunisian Siculo threshold, IZ = Zembra Island, LB = Bizerte Lagoon, LBG = Boughrara Lagoon.

a high abundance of *Holothuria poli*. Four other species of *Holothuria* (*H. sanctori, H. forskali, H. impatiens* and *H. mammata*) had much lower abundances. The sixth *Holothuria* species, *H. tubulosa*, was almost absent in Boughrara Lagoon (0.8% of all specimens recorded), but represented a significant portion of the records from Bizerte Lagoon (18.4%). Finally, *Cucumaria syracusana*, a Mediterranean endemic species was found exclusively in Boughrara Lagoon where it represented a fair portion of the specimens recorded (26.5%). This study showed differences in species composition and proportions between the two lagoons. These differences can probably be attributed to environmental factors, including the slightly different climatic conditions affecting the two lagoons.

Nowadays, sea cucumbers have become more appealing to fishers along the Tunisian coast, including in lagoons where fishers are present in large numbers. These lagoons are well known as areas of biological and ecological interest, as they shelter many Mediterranean plants and animals. Currently, these fragile ecosystems are subject to intense fishing pressure, and the sea cucumber population is exposed to risks of overexploitation if management measures are not taken.

In 2013, a survey conducted in the southern area of the port at Sidi Daoud (Cap Bon, northwestern part of Tunisia) unveiled a certain degree of illegal fishing of sea cucumbers in the area. This is also the case in Bizerte Lagoon where illegal fishing has been observed. Therefore, it is urgent to put in place some management measures, such as fishing periods and catch limits, to reduce the impact of uncontrolled and unregulated fishing activities, which place sea cucumber stocks at risk, as well as ecosystem biodiversity. A recent study of *Holothuria poli* from Kerkenah Island (Sellem et al. 2017) provides biological parameters that could be used to implement precautionary measures for this new fishery.

In conclusion, this study has provided information on the diversity of sea cucumbers species living in two lagoons on the Tunisian coast. Each lagoon has a specific composition of sea cucumbers, with *Holothuria poli* being the most common and represented species in both ecosystems. The population of *H. poli* may become overexploited if immediate management actions are not initiated to stop illegal fishing. Sea cucumber stocks are vulnerable and require protection, particularly in lagoon ecosystems. Surveys of sea cucumber population dynamics will be fundamental for drafting proper regulations for the fishery.

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