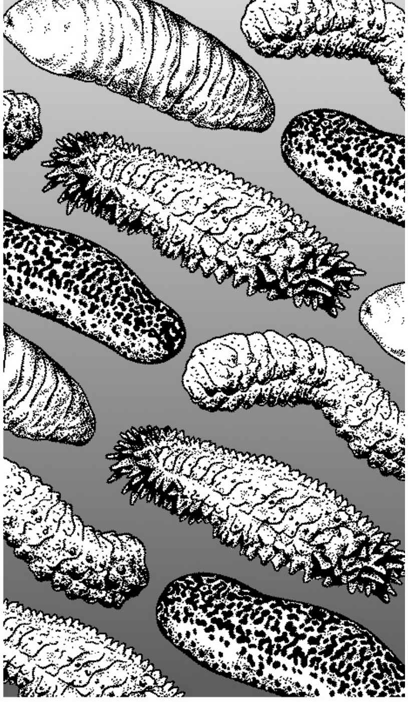
Pacific Community
Communauté du Pacifique

ISSN 1025-4943

Issue 39 – March 2019

BECHE-DE-MER information bulletin



Inside this issue

→

Editor
Igor Eeckhaut
Marine Biology and bioimitation
6, Av. Champ de Mars
University of Mons
7000 Mons Belgium
Email: Igor.Eeckhaut@umons.ac.be

Production
Pacific Community
BP D5, 98848 Noumea Cedex
New Caledonia
Fax: +687 263818
Email: cfpinfo@spc.int
www.spc.int

Produced with financial assistance from the government of Australia, the European Union, France and the New Zealand Aid Programme.

Editorial

This issue of the *Beche-de-mer Information Bulletin* is well supplied with 15 articles that address various aspects of the biology, fisheries and aquaculture of sea cucumbers from three major oceans.

Lee and colleagues propose a procedure for writing guidelines for the standard identification of beche-de-mer in Solomon Islands. Andréfouët and colleagues assess commercial sea cucumber populations in French Polynesia and discuss several recommendations specific to the different archipelagos and islands, in the view of new management decisions. Cahuzac and others studied the reproductive biology of *Holothuria* species on the Mahé and Amirantes plateaux in the Seychelles during the 2018 northwest monsoon season. Bourjon and Quod provide a new contribution to the knowledge of holothurian biodiversity on La Réunion, with observations on two species that are previously undescribed. Eeckhaut and colleagues show that skin ulcerations of sea cucumbers in Madagascar are one symptom of different diseases induced by various abiotic or biotic agents. This particular article describes how sediments ingested by *Holothuria scabra* can induce skin ulcerations when they are enriched with different types of organic matter.

Hamel and others document the extension of the distribution range of the pea crab *Holotheres semperi* associated with the sea cucumber *Holothuria scabra* off the island of Rempang in Indonesia. Ruffez describes a mission in Viet Nam to investigate the safety of fishers who dive for sea cucumbers. Calderon-Aguilera shows that the mean density of sea cucumbers has decreased more than five times in the Gulf of California, Mexico, from 2007 to 2016, and suggests that this reduction is largely due to illegal fishing.

Four articles relate to research conducted on Mediterranean sea cucumbers. Slimane-Tamacha and colleagues studied the reproductive biology of the aspidochirotid sea cucumber *Holothuria poli* at Kristel Bay in Algeria. Sellem and others determined which species of sea cucumbers were living in two lagoon ecosystems on Tunisia's coastline. Recommendations and management proposals are suggested towards this eventual fishery. Domínguez-Godino summarises the main results of his PhD on the aquaculture of *H. arguinensis*. His PhD was supervised by Mercedes González-Wangüemert. Mecheta and Mezali analysed the biometry, and the amount of water and the effects of pepsin digestion on the dry body in three economically important sea cucumber species that are common in the waters of Algeria in order to highlight their economic and nutritional values. Neghli and Mezali provide an overview of the sea cucumber fishery in Algeria and propose recommendations before opening that fishery.

Finally, the article by Simone and colleagues explains a proposal to list some teatfishes on Appendix II of the Convention of the International Trade in Endangered Species (CITES).

Also included are several communications: two about spawning observations in Australia, and others on workshops and conferences that were held in 2018 and those that will take place in 2019. Congratulations are expressed to Jorge Antonio Dominguez-Godino, Nor-Eddine Belbachir and Woo Sau Pinn who presented their PhD work on sea cucumbers.

Igor Eeckhaut

P.S: In line with a worldwide trend to limit the impact of producing printed publications on the environment, SPC has decided to stop the production and distribution of printed copies of this and other information bulletins. The BDM bulletin is now only produced in digital format but remains accessible from SPC's website at:

http://www.spc.int/coastfish/en/publications/bulletins/beche-de-mer.html

Original text: English

Pacific Community, Fisheries Information Section, BP D5, 98848 Noumea Cedex, New Caledonia
Telephone: +687 262000; Fax: +687 263818; cfpinfo@spc.int; http://www.spc.int/coastfish

Towards producing a standard grade identification guide for beche-de-mer in Solomon Islands

Steven Lee,[1] Frederic Iro,[2] Hugh Govan[3] and Ian Bertram[4]

In early 2018, beche-de-mer (BDM) from six exporting companies based in Honiara, Solomon Islands were photographed by staff of the Ministry of Fisheries and Marine Resources (MFMR) in order to compile a photographic identification guide. The guide aims to help fisheries officers and customs inspectors identify various BDM grades set by the market. Once BDM species and grade can be readily identified, then standard minimum buying prices can be set per species and grade for buyers and/or exporters.

Establishing a standard grade guide is required in order to set and enforce standard minimum prices. There are indications that the market can sustain moderate increases in buying prices but that this will not result in benefits to fishers unless emphasis is placed on ensuring that fishers are provided with the information on minimum prices and empowered or supported in ensuring that buyers adhere to the prices.

In countries where levies and taxes are imposed on exporters, a standard grade guide will be vital to ensure that the value of products are not underdeclared, thereby reducing revenue to government. However, these efforts require each country to carry out their own assessment of fishing and trader expenses to appropriately set minimum prices (James, in prep.).

For this research, MFMR staff relied on traders and companies to provide specimens and identify the species and grade of the specimens being photographed. Photography followed a guide and standard template previously provided by the Pacific Community (SPC).

The photographs were shared with SPC, which organised them by species and grade. Specimens were re-identified and graded, and then compared with the identification and grading provided by MFMR staff. Details are provided in Table 1. The general findings were:

- 201 specimens of BDM were photographed, representing 22 of the 32 species of sea cucumber present in Solomon Islands (Pakoa et al. 2014); 14 of the 22 species that were photographed had fewer than 3 specimens of grades A and B (highlighted in yellow, Table 1).
- Of the 201 specimens photographed, 8 could not be identified to species level, and 11 were misidentified.
- 11 specimens were misidentified as: *Bohadschia vitiensis, Holothuria atra*, *H. scabra* or *H. edulis*. These were re-identified as follows:
    - o 3 specimens of *B. vitiensis* (medium value species) were in fact *H. fuscogilva* (high value), *Actinopyga lecanora* (high value) and *Pearsonothuria graeffei* (low value);
    - o 5 specimens of *H. atra* (low value) were in fact *P. graeffei* (low value), *H. fuscogilva* (high value), *H. fuscopunctata* (2) (medium value), and 1 specimen could not be re-identified;
    - o 2 specimens of *H. scabra* (high value) were in fact *A. miliaris* (high value), and 1 specimen could not be re-identified;
    - o 1 specimen of *H. edulis* (low value) was in fact *H. fuscopunctata* (high value).
- 6 out of 11 misidentified specimens were originally identified as lower value species, 2 were identified as species of similar value, 1 was identified as a higher value species, and the remaining 2 could not be re-identified.

These findings highlight the need for fisheries and customs staff – in all countries with sea cucumber fisheries – to be adept at identifying dried sea cucumbers (BDM) in order to reduce the risk that traders mislabel or misidentify species, thereby reducing the amount they pay fishers or tax authorities.

[1] Consultant. Email: steven.d.a.lee@gmail.com
[2] Ministry of Fisheries and Marine Resources, Solomon Islands. Email: FIro@fisheries.gov.sb
[3] Consultant, SPC-World Bank PROP/Adjunct Senior Fellow, University of the South Pacific (USP), School of Government, Development and International Affairs (SGDIA). Email: hgovan@gmail.com
[4] SPC Coastal Fisheries Science and Management Adviser. Email: ianb@spc.int

The main issues encountered in the preparation of this photographic guide were: i) the correct identification of processed sea cucumbers; ii) irregularities and variations in grading criteria; and iii) labelling and sorting of photographs. In order to avoid some of these difficulties in future studies, guidelines for photographing BDM are proposed in Annex 1.

To create a comprehensive guide, it is estimated that three different specimens should be photographed for each grade and for each species (hence, 384 photographs would be needed for all 32 species present in Solomon Islands). At this stage, only *H. fuscogilva* meets the required minimum for all grades (see Fig. 1), while *B. vitiensis, H. atra, H. fuscogilva, H. whitmaei, Stichopus herrmanni, S. horrens, Thelenota ananas,* and *A. lecanora* meet the required minimum for grades A and B. Further studies are required to photograph the remaining under-represented species (see yellow cells, Table 1).

Figure 1. *Holothuria fuscogilva* (white teatfish) grades according to the photoset provided by the Ministry of Fisheries and Marine Resources - Solomon Islands. (A) Grade A - cut is straight and well placed, there is no flaring (separation of body wall) along the cut, animal shape is straight and texture is relatively smooth. (D) Grade D - cut extends too far to both ends of the animal, there is some flaring along the cut and the top end is damaged, body shape appears twisted and curves slightly. Admittedly the Grade D specimen is in relatively good shape. Figure 5 of Ram et al., 2014 shows more obvious/drastic differences between grades.

Table 1. Beche-de-mer photographed by staff of the Solomon Island Ministry of Fisheries and Marine Resources. Letters correspond to re-assigned grades, numbers under the grade column correspond to the number of specimens of that particular species and grade that were photographed. Yellow highlight indicates species that have fewer than three images of specimens for each grade, red highlight indicates species that were not photographed. ** Species included in Solomon Islands Fisheries (Beche-de-mer) regulations 2014 – Schedule 5: Minimum harvest sizes and minimum purchase and export size. Y = included, N = not included

FAO code	Common name	**	Genus	species	A	B	C	D	Total
KUE	Deepwater redfish	Y	*Actinopyga*	*echinites*	0	1	1	0	**2**
YVV	Stonefish	Y	*Actinopyga*	*lecanora*	5	11	2	0	**18**
KUY	Surf redfish	Y	*Actinopyga*	*mauritiana*	1	4	0	0	**5**
KUQ	Hairy blackfish	Y	*Actinopyga*	*miliaris*	1	1	0	0	**2**
YGP	Deepwater blackfish	N	*Actinopyga*	*palauensis*	0	0	0	0	**0**
KUW	Tigerfish	Y	*Bohadschia*	*argus*	0	3	1	0	**4**
BDX	Chalkfish	N	*Bohadschia*	*marmorata*	2	4	3	0	**9**
BDV	Brown sandfish	Y	*Bohadschia*	*vitiensis*	5	4	2	1	**12**
HFA	Lollyfish	Y	*Holothuria*	*atra*	3	4	0	2	**9**
HHW	Snakefish	Y	*Holothuria*	*coluber*	2	1	3	2	**8**
HFE	Pinkfish	Y	*Holothuria*	*edulis*	1	0	1	0	**2**
JCI	Red snakefish	Y	*Holothuria*	*flavomaculata*	0	1	0	0	**1**
HFF	White teatfish	Y	*Holothuria*	*fuscogilva*	11	11	9	6	**37**
HOZ	Elephant trunkfish	Y	*Holothuria*	*fuscopunctata*	0	6	1	0	**7**
JCK	Tigertail fish	N	*Holothuria*	*hilla*	0	0	0	0	**0**
JCO	Golden sandfish	Y	*Holothuria*	*lessoni*	0	0	0	0	**0**
HFQ	White snakefish	Y	*Holothuria*	*leucospilota*	0	0	0	0	**0**
HFC	Sandfish	Y	*Holothuria*	*scabra*	1	7	1	0	**9**
JDG	Black teatfish	Y	*Holothuria*	*whitmaei*	6	3	1	0	**10**
EHV	Flowerfish/Ripplefish	Y	*Pearsonothuria*	*graeffei*	1	1	1	0	**3**
JCC	Greenfish	Y	*Stichopus*	*chloronotus*	2	1	1	0	**4**
JNG	Curryfish	Y	*Stichopus*	*herrmanni*	5	5	1	0	**11**
KUN	Peanutfish	Y	*Stichopus*	*horrens*	5	5	2	0	**12**
JPW	Brown curryfish	N	*Stichopus*	*vastus*	0	3	0	0	**3**
TFQ	Prickly redfish	Y	*Thelenota*	*ananas*	10	4	0	0	**14**
HLX	Amberfish	Y	*Thelenota*	*anax*	0	1	1	0	**2**
JDZ	Lemonfish/Candyfish	Y	*Thelenota*	*rubralineata*	0	0	0	0	**0**
	Blue sea cucumber	N	*Actinopyga*	*caerulea*	0	0	0	0	**0**
	Hongpai fish	N	*Holothuria*	sp.	0	0	0	0	**0**
	Peanutfish	N	*Stichopus*	*monotuberculatus*	0	0	0	0	**0**
	Dragonfish/Peanutfish	N	*Stichopus*	*pseudohorrens*	0	0	0	0	**0**
	Kingfish	N	*Synapta*	*maculata*	0	0	0	0	**0**
				TOTAL	**61**	**81**	**31**	**11**	**184**

Acknowledgements

The authors of this report thank Ivory Akao, Rosalie Masu, Stenneth Atu, Dr Steven Purcell, Watisoni Lalavanua and all other persons we may have failed to mention for their contributions to this report.

References

James P. In preparation. Government intervention in the sea cucumber value chain: The case for minimum prices. Noumea, New Caledonia: the Pacific Community.

Pakoa K., Masu R., Teri J., Leqata J., Tua P., Fisk D. and Bertram I. 2014. Solomon Islands sea cucumber resource status and recommendations for management. Noumea, New Caledonia: Secretariat of the Pacific Community. 60 p.

Ram R., Chand R.V. and Southgate P.C. 2014. Effects of processing methods on the value of beche-demer from the Fiji Islands. Journal of Marine Science Research and Development 4:3.

Annex 1: Guidelines for photographing beche-de-mer

- Place beche-de-mer specimen on white graph paper (A3 or A4 size) to be photographed. Grid squares should be 1 cm x 1 cm, with markings made at the baseline (0 cm) and every subsequent 5 cm.
- Place animal at the 'baseline' = 0 cm mark. See example below (Fig. A)
- Photograph the side of the BDM with the cut. If possible, also take a photograph of the opposite side (i.e. top and bottom of the animal).
- If possible, use natural lighting, and a lot of it.
- Place a card with the species ID (identification) (FAO species code) and grade next to the BDM specimen being photographed (see Figure A). Ideally, each fisheries officer or inspector should have a set of these for all species and all grades (cut out cards provided in Figures B and C).
  If uncertain of the grade, place both grade cards next to the specimen in question.
  If uncertain of the species, place all ID cards that you suspect the specimen to be next to the animal, with the top ID card being what you suspect it is most likely to be.
- **Aim to get good photographs of at least three specimens of each species and each grade.**
- Question traders and/or companies on why a particular specimen is given a certain grade. Keep note of their response, and correlate this response to the BDM specimen that it was based on. **Aim to do this for at least three specimens of each grade, for each species.**
- Record the stated buying price for each species and each grade. If possible, record the stated buying price for each specimen (see Figure D for record table template).

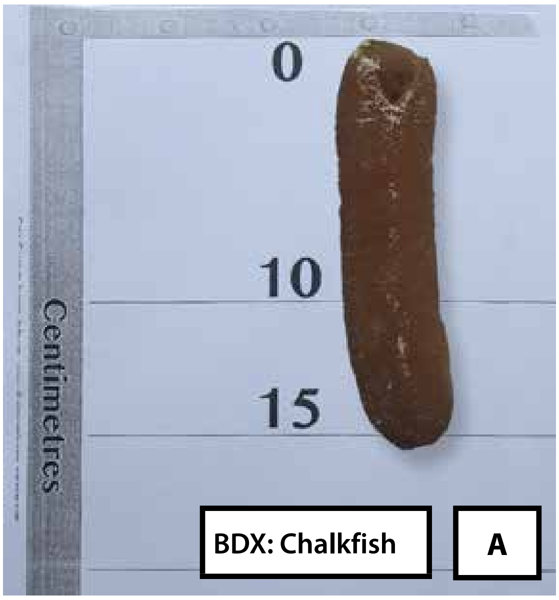


Figure A. Example of how BDM should be photographed with ID and grade cards. Note that the cut is visible and one end is placed on the baseline (0).

BDV : Brown sandfish	**JDG: Black teatfish**
BDX: Chalkfish	**JDZ: Lemonfish / Candyfish**

Figure B. Cut-out cards of sea cucumber/beche-de-mer FAO species codes with common names. These should be placed next to the BDM specimen being photographed.

A	**B**
C	**D**

Figure C. Cut-out cards of sea cucumber/beche-de-mer grades. These should be placed next to the BDM specimen being photographed. If unsure of which grade to assign (i.e. either A or B), both A and B cards should be placed next to the specimen being photographed.

Company/trader name	
Company/trader business licence	
Company/trader location	
Inspector name and signature	
Inspection date	

FAO code	Species/common name	Grade	Price (per kg)	Grading criteria

Figure D. Log sheet for recording grade, buying price, and grading criteria.

An assessment of commercial sea cucumber populations in French Polynesia just after the 2012 moratorium

Serge Andréfouët,[1,*] Amélie Tagliaferro,[1] Laureline Chabran-Poete,[1] Joseph Campanozzi-Tarahu,[2] Fabien Tertre,[2] Gabriel Haumani[2] and Arsène Stein[2]

Abstract

Sea cucumbers were virtually unfished in French Polynesia until 2008, when their exports sky rocketed several years later, leading to the immediate closure of the fisheries in November 2012. A survey of commercial sea cucumber abundance took place around that period in 23 islands and atolls in three archipelagos (Society, Tuamotu and Gambier), which allowed the inference of the status of sea cucumbers on a wide scale. The Society Islands were severely impacted, with many sites depleted of the resource, especially high inhabited islands with lagoons. Conversely, the Gambier Archipelago and, in particular, Mangareva Island had a healthy population, characterised by a lack of dominant species and the highest species richness, with records from Mangareva only. The situation was mixed in the Tuamotu Islands. Abundances in lagoons and fore reefs were dominated by *Bohadschia* sp. and *Thelenota ananas*, respectively. The 2012–2013 moratorium was followed by a transition period where sea cucumber fishing could be performed at selected locations on certain Tuamotu atolls, but included a number of new management measures that included the monitoring of exports from the different islands. Considering the 2012–2013 survey results and the 2014–2017 fishery statistics, we discuss here several recommendations specific to the different archipelagos and islands, in the view of new management decisions.

Keywords: Gambier, Tuamotu, Society, moratorium, fishery management, sea cucumbers

Introduction and objectives

In French Polynesia, research efforts on sea cucumbers (locally called *rori*) are few. Historically, species have been recorded in several places in the course of various ecological or taxonomic surveys (e.g. Adjeroud et al. 2000). More recently, the Moorea Biocode Project[3] provided the most complete inventory for one single French Polynesian island. From a commercial sea cucumber population perspective, Moorea's populations were studied in 2011 (Preuvost 2011) and the Secretariat of the Pacific Community's PROCFish project[4] described the commercial populations of four fishing grounds in three high islands (Moorea and Tahiti in the Society Islands, and Raivavae in Austral Islands), and two atolls in the Tuamotu Islands (Fakarava, Tikehau). The PROCFish surveys occurred in 2003–2006 (Kronen et al. 2009).

It was found that the high-value species, *Holothuria fuscogilva*, would need additional specific surveys in all sites to make a conclusion regarding its population status. The high-value species, *H. whitmaei*, was generally rare or absent from most sites, and at all depths. *Thelonota ananas* could be found at all sites and in varying densities, from low to medium at Moorea and Tahiti, and to high at Fakarava. The mid-value species, *Stichopus chloronotus*, was never found in any of these surveys, suggesting it is absent from French Polynesia. The low-value leopardfish, *Bohadschia* sp., was very common at Fakarava, Tahiti and Moorea, but less so in Tikehau and Raivavae. The PROCFish surveys generally diagnosed a low potential for a commercial sea cucumber fishery in French Polynesia. When exploitation could be recommended, it was for *Actinopyga mauritiana*, which was abundant in some places, especially at Raivavae.

1 UMR9220 ENTROPIE, IRD, Université de la Réunion, CNRS, B.P.A5, 98848 Nouméa, New Caledonia
2 Direction des Ressources Marines et Minières de Polynésie française, BP 20, 98713, Papeete, Tahiti
* Corresponding author: Serge Andréfouët, serge.andrefouet@ird.fr
3 The Moorea Biocode Project aims to create the first comprehensive inventory of all non-microbial life in a complex tropical ecosystem. See: https://mooreabiocode.org/ https://mooreabiocode.org/
4 The Pacific Regional Oceanic and Coastal Fisheries (PROCFish) project was initiated in March 2002. The coastal component of PROCFish was designed to enhance management of reef fisheries in the Pacific Islands by providing Pacific Island governments and communities with accurate, unbiased scientific information about the status and prospects of reef fisheries. See: https://coastfish.spc.int/en/projects/procfish

French Polynesia has never been a significant source of beche-de-mer for the Asian market until 2008, when fishing, processing and exports of sea cucumbers became quickly organised due to the initiatives of some private investors. Because of French Polynesia's lack of regulations, and the easy access to an abundant, unfished resource, exports (frozen and dried) sky-rocketed from zero in 2007 to 126 tonnes (t) in 2011 and 2012 (Fig. 1). Considering the serious risks of a quick population collapse in many islands, and the lack of control on fisher numbers and activities, the Direction des Ressources Marines et Minières (DRMM) and the French Polynesian government established a complete moratorium on sea cucumber fishing throughout French Polynesia in November 2012, which immediately stopped new harvests, although sea cucumbers already collected could still be sold in 2013 (representing 6.8 t, Fig. 1).

In September 2012, the Living Ocean Foundation (LOF)[5] planned three cruises in the Society (September–October), Tuamotu (November–December) and Gambier (January 2013) archipelagos on board the R/V *Golden Shadow*, a large vessel that could accommodate up to 24 divers and investigators. These cruises offered the possibility of surveying sea cucumber populations just before and after the moratorium for a vast number of islands and locations, some of would have been difficult to access otherwise. The French Institute of Research for Development (IRD), DRMM and LOF agreed to have an onboard team dedicated to sea cucumber surveys. This team also surveyed giant clams and green snails on the same cruises, and these results are described elsewhere (Andréfouët et al. 2014a, b).

The sea cucumber census results presented hereafter were discussed with DRMM immediately after the cruises in March 2013. The trend was clear, showing a poor situation in the Society Islands, and a less dramatic one elsewhere in the Tuamotus and Gambiers. The government decided to reopen the fishery in 2014 at several Tuamotuan atolls but instated catch limits (in numbers of individuals, quotas, and periods) for all targeted species. Catches also had to be hand collected only, and in accordance with size limits per species. However, the 2012 findings were not used to guide further actions to improve knowledge about stocks and establish precise quotas for selected places, and no biological data were collected after 2012. Between 2014 and 2017, the same management measures continued, leading to exports that ranged from 3.9 t in 2014 (dried only) up to 7.6 t in 2016. However, the numbers of lagoons open to fishing increased, as new lagoons can be opened if a local management committee is organised (9 atolls in 2014 and 2015, 13 in 2016 plus Tahaa Island in the Society Islands, and 17 in 2017). Unlike the pre-2012 period, DRMM collected detailed information on the number of fishers per island and on the number of exports per species (weight and individual counts) from each island in 2014–2017. These data helped put into perspectives the pre-2012 period of fishing; for example, showing that some atolls were heavily fished for *H. fuscogilva* (Fakarava, Toau, Apataki) while other islands were targeted for *Bohadschia* spp. (Raroia, Kaukura), or *A. mauritiana* (Faaite, Makemo). At this stage it is impossible to know if this reflects the pre-2012 period, or if fishing has evolved to target lower-value species after *H. fuscogilva* or *H. whitmaei* became depleted. It is already possible, however, to see that between 2014 and 2017, there has been a decrease in the total catch of *H. fuscogilva* from Kaukura or Apataki. In 2017, the decreasing catch rate per registered fisher in several atolls may suggest that sea cucumber populations have now been impacted by the previous fishing years (Fig. 1).

In anticipation of DRMM's future surveys in places where sea cucumber fishing has become a significant source of income, and where the sustainability is at risk, we revisit here the data collected in 2012–2013 for all archipelagos and sites in order to establish a baseline and offer some recommendations.

Methods

Between September 2012 and January 2013, the three Global Reef Expedition French Polynesia cruises of LOF on board the R/V *Golden Shadow* visited 23 islands in three archipelagos: Society, Tuamotu and Gambier, including a number of rarely visited locations such as the small, mainly uninhabited remote atolls of the Acteon group or Temoe in the Gambiers. Surveys for sea cucumbers took place in 22 of these islands (Fig. 2).

Most of the stations were selected by the LOF scientific cruise director, who prioritised coral and fish surveys; hence, many stations were located on oceanic fore reefs. However, we completed lagoonal and reef flat surveys as a separate team when possible, especially for Raiatea, Fakarava, Hao and Mangareva, which were identified prior to the cruises as high priority islands for data collection by various French Polynesian institutions. Visits to these sites lasted between six and nine days, while most other islands were visited for only one (or three dive sites) to four days at most.

[5] The Khaled bin Sultan Living Oceans Foundation is a non-profit environmental science organisation and ocean research foundation established to help preserve, protect and restore the world's oceans and aquatic resources through research, education, and outreach. See: https://www.livingoceansfoundation.org/about/

We focused on commercial species that are present in French Polynesia: *Holothuria fuscogilva, H. whitmaei, Thelenota ananas, T. anax, Actinopyga mauritiana, Stichopus chloronotus* and *Bohadschia* spp. The *Bohadschia* group included *B. argus* and green to brown specimens identified thus far as *B. vitiensis* (in Kronen et al. 2009, and G. Paulay, Curator, Florida Museum of Natural History pers. comm.), although this identification has not been confirmed genetically. Also included in this group was a *Bohadschia* specimen from Mangareva that could not be identified to species level. *Holothuria atra*, which was not fished in French Polynesia, was recorded on fore reefs or as isolated specimens on lagoons and reef flats, but these counts are not reported here. We also did not census *H. atra* when they aggregated as small individuals in the shallowest part of lagoons, sometimes reaching tens of individuals per square meter. The low number of commercial species in French Polynesia is explained by the country's position in the central Pacific, far from the center of biodiversity in Asia and the western Pacific. Several other species were also recorded, but proved to be extremely rare: *Thelenota rubrolineata* and *Holothuria edulis*.

When diving, the census was done between 30 m and the shallowest part of the visited location (i.e. generally from the deep sand plain or deep coral slopes up to the shallow spur-and-groove zone of the reef). All observed sea cucumber

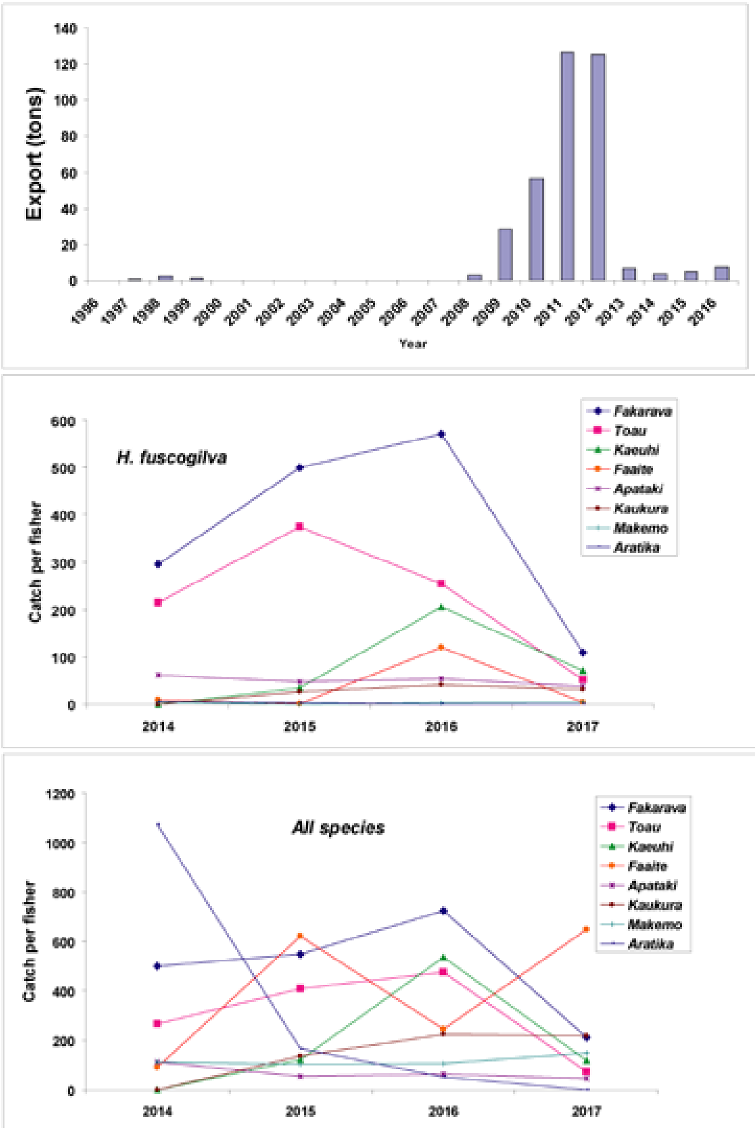


Figure 1. Statistics from Direction des Ressources Marines et Minières de Polynésie française (DRMM 2014, 2015, 2016, 2017). Top: total exports (dried specimens). Middle and bottom: for atolls with at least three years of data between 2014 and 2017, the number of catches per fisher, for *Holothuria fuscogilva* (middle) and all species (bottom).

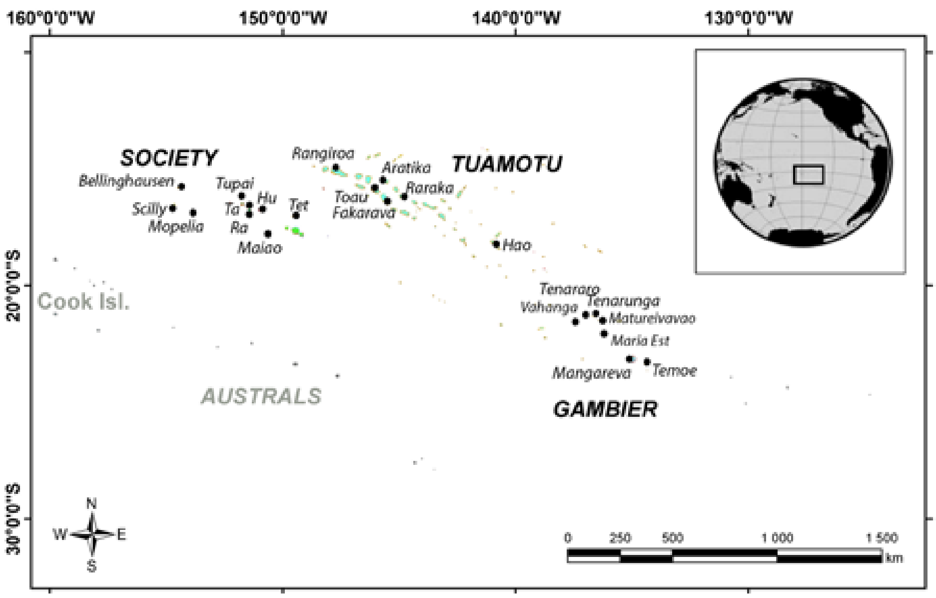


Figure 2. Study site. Ta = Tahaa, Ra = Raiatea; Tet = Tetiaroa; Hu = Huahine.

individuals were counted and photographed during a one-hour dive that was staged by depth (5 min. at 30 m, 20 m, 10 m, 5 m, 2–0 m). In the shallows (5–0 m), the exact depth was dependent on wave conditions, but if possible, we conducted surveys into the shallowest spurs and grooves to the crest to look, in particular, for specimens of *A. mauritiana*. Several 5-min. search times could be performed per depth range, especially in the shallows. The swimming speed was constant and slow, and we intentionally avoided strong currents that would significantly bias the surveys. Considering the generally very good visibility and position above the reef of the swimming surveyor (~3 m above the bottom), we estimated that each search time covered about 250 m^2 per minute (Andréfouët et al. 2014b), except in spur and groove areas where the surfaces covered were much smaller and less consistent.

Hereafter, densities per species are thus provided per minute of search time considering the entire dive (60 min), but a correspondence with densities per surface area is reasonably possible due to this constant speed. All searches were conducted during daytime. The data collected (i.e. richness and species density) could be reported per depth range, per habitat (fore reef *vs* lagoon), per island, and per archipelago. Lagoonal habitats were not separated according to substrate type as search time was spent in both patches of soft and hard bottom areas. However, some species could be preferentially found on patches of soft substrate, rubble or hard bottom.

The exact fishing pressure in the islands between 2008 and 2012 is unknown (Table 1). During that time, DRMM had information only at the export level from Tahiti (i.e. global weight, and the difference between dry and frozen weights), and no information from individual islands or atolls. However, it was known that the area from the southeastern Tuamotus (from Hao) down to the southeastern Gambiers (Mangareva and Temoe) was unfished, or fished very little, as well as Aratika Atoll in the central Tuamotus, due to the mayor's decision to prohibit this exploitation. Lagoons closed to fishing at uninhabited islands or atolls, or without easy access from the outside (e.g. Tupai or Tetiaroa) were considered to be unfished, although

Table 1. Summary of information by island.

Island/group	Abbreviation	Fished in 2014–2017	Fished in 2012	Lagoon sites	Ocean sites
Gambier					
Mangareva	MG	n	n	20	11
Maria Est	M-E	n	n	1	3
Matureivavao	MV	n	n	0	3
Temoe	TE	n	n	1	4
Tenararo	TR	n	n	0	3
Tenarunga	GT	n	n	0	3
Vahanga	VA	n	n	0	3
Society					
Huahine	HU	n	y	12	0
Maiao	MA	n	?	0	2
Raiatea	RA	n	y	23	13
Tahaa	TA	2016–2017	y	0	4
Tetiaroa	TEt	n	y	0	3
Tupai	TU	n	y	3	1
Scilly	SC	n	n	0	1
Mopelia	MO	n	n	0	3
Bellinghausen	BE	n	n	0	3
Tuamotu					
Aratika	AR	2014–2017	n	2	5
Fakarava	FA	2014–2017	y	13	8
Hao	Hao	n	n	9	8
Rangiroa	RG	n	y	10	4
Raraka	RK	2016–2017	y	4	5
Toau	TO	2014–2017	y	8	0

their fore reefs could be fished. For all other locations, it can be assumed that fishing could occur, with heavier pressure in the Society Islands than in the Tuamotus due to a larger human population equipped with numerous fishing vessels and closer proximity to processing sites. There are several no-take areas in the Tuamotus, but none in the surveyed Society Islands. This is the case of the atolls of the UNESCO Man and the Biosphere (MAB) Fakareva reserve. The atolls of Fakarava, Raraka, Aratika and Toau are MAB atolls. However, possible occurrences of poaching cannot be discarded in these protected areas.

Results and discussion

Results per archipelago

In total, 68 sites were surveyed in the Society Islands (Mopelia, Scilly, Bellinghausen, Tupai, Huahine, Raiatea, Tahaa, Maiao and Tetiaroa), in which 286 commercial sea cucumbers were inventoried. Twenty-two stations (32% of the sites) had no records of commercial species. The dominant species was *B. argus*, but in low densities, and seen at 48% of the sites. *Holothuria fuscogilva* (the most valuable species) and *T. anax* were found mostly on exposed eastward facing fore reefs and in the deeper sand plains in depths of at least 30 m. *Holothuria whitmaei* was seen only once. *Thelenota ananas* was also present on fore reefs, at all depth ranges, and at most atolls and islands, but in low numbers. Tetiaroa had the highest count per dive for this species (average = 9.3). *Actinopyga mauritiana* juveniles were very abundant on algal crests, which characterise high island barrier reefs such as those of Raiatea, but they were rarely seen as adults.

In the Tuamotus, 77 sites were surveyed at Rangiroa, Aratika, Raraka, Fakarava, Toau and Hao, and 923 commercial sea cucumbers were inventoried. Twenty-two stations had no records of commercial species, but 13 of these stations were among the 17 Hao stations, and in particular among the lagoon stations. The absence of records for the lagoon was a peculiar feature for all Tuamotu atolls. Only two species were recorded in Hao (*T. ananas* and *B. argus*). The atoll's lagoon was completely depleted of sea cucumber communities as all records were from the fore reefs or the pass. Without Hao, the Tuamotu atolls had only 15% of sites without records, thus less than half that of the Society Islands. The dominant taxon overall was the genus *Bohadschia.* It was dominant in most lagoons, and generally – but not always – found in high densities around pinnacles. This genus was seen in 65% of the stations. *Holothuria fuscogilva, H. whitmaei* and *T. anax* were found mostly in lagoons, but never in high densities. The only exception was high numbers of *T. anax* in some locations, particularly in the central part of Raraka lagoon, which was never fished according to our guides (themselves ex-fishers).

In total, 52 sites were surveyed in the Gambiers (Tenararo, Tenarunga, Vahanga, Matureivavao, Maria Est, Temoe and Mangareva), and 286 commercial sea cucumbers were inventoried. This is the exact same number recorded from the Society Islands, but from a fewer number of sites. The Gambiers were a relative 'hot-spot' of diversity, including several species only seen in the Acteon atolls (*T. rubrolineata, H. edulis*) and Mangareva (*S. chloronotus*). *Stichopus chloronotus* was abundant in Mangareva's lagoon, while it was never seen elsewhere in the other 21 surveyed islands or in any of the PROCFish surveys (Kronen et al. 2009). *Holothuria whitmaei* was also much more abundant in Mangareva than anywhere else in French Polynesia, and in shallow water (39 sightings, present in 30% of the sites). On the other hand, *H. fuscogilva* was only seen once at Temoe Atoll. Unlike the other archipelagos, there is no dominance of species or genus in the Gambiers, particularly for *Bohadschia*. In the Gambiers, 34% of the sites (18 sites, including 13 on the fore reefs) are without records, but this is because *H. atra* was not included and this was the only species (as large individuals) seen on several Gambier island fore reefs.

Overall, in all archipelagos, the majority of sites without any records were oceanic fore reefs. In both the Society and Gambier islands, 27% of the sites without records were lagoonal, while in Society Islands alone, the proportion rose to 52%.

Results per island

The average densities by species are reported for each surveyed island and per habitat Figures 3 and 4.

We also compared the average of counts (all species) per surveyed site, for both oceanic and lagoonal stations (Fig. 5). For oceanic sites and in the Gambiers, this average varies significantly between the small Acteon atolls, and the larger islands of Mangareva and Temoe. The low number of sea cucumbers found on the Acteon fore reef is attributed to very high coral cover, compared with the other sites where deep sand plains and more suitable habitats are present. The average count found for lagoonal sites in the Tuamotus are as much as three times greater than for fore reef sites (except for Hao). However, this dominance is not the case for the Society and Gambier islands where the situation is more balanced. Tuamotu lagoon ratios are especially high for Fakarava and Toau, which have been the most heavily fished atolls since 2014 (Fig. 1).

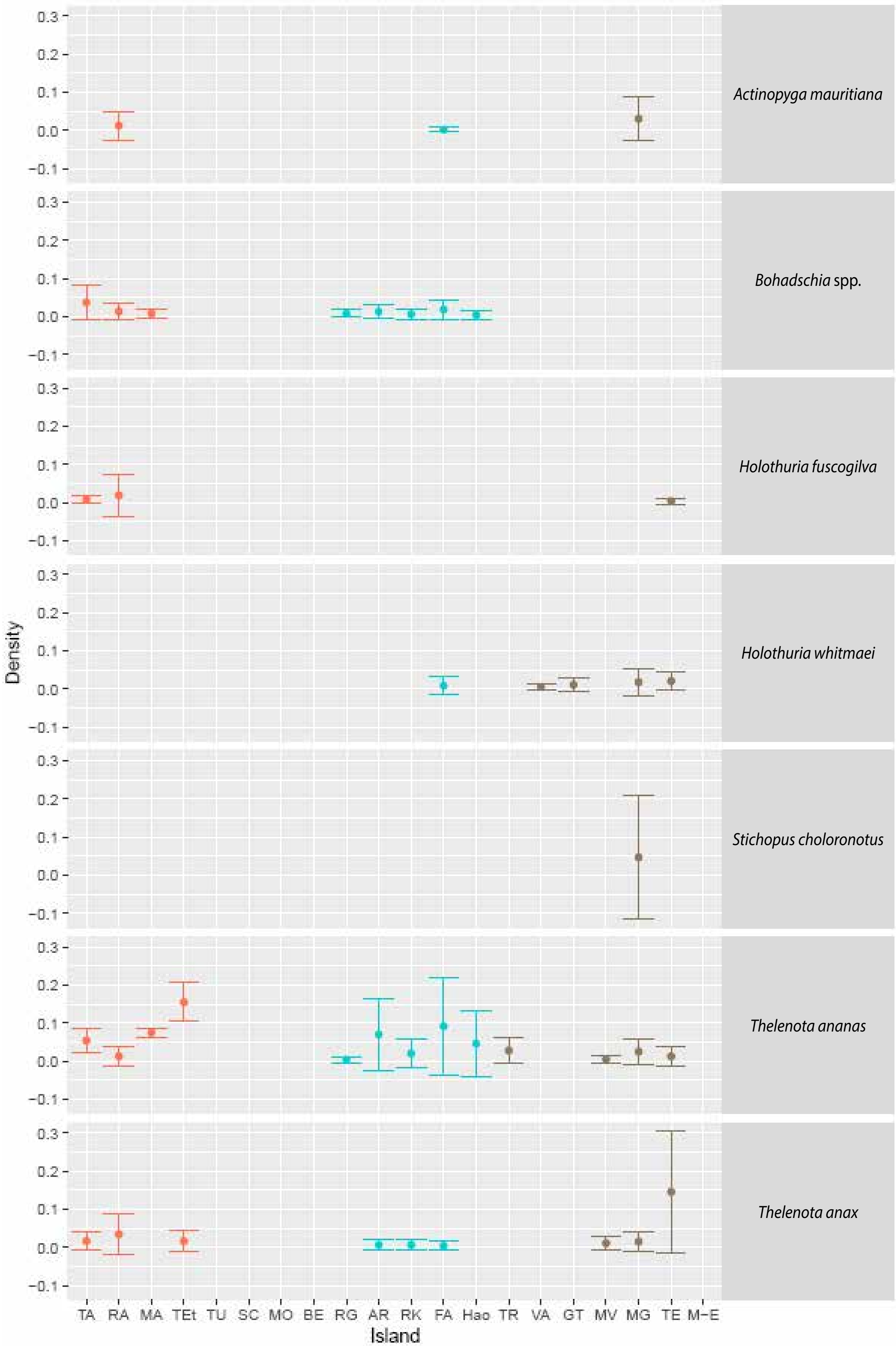


Figure 3. Density (in number of individuals per minute) per island, per species, and for ocean fore reef stations. Island name abbreviations are in Table 1.

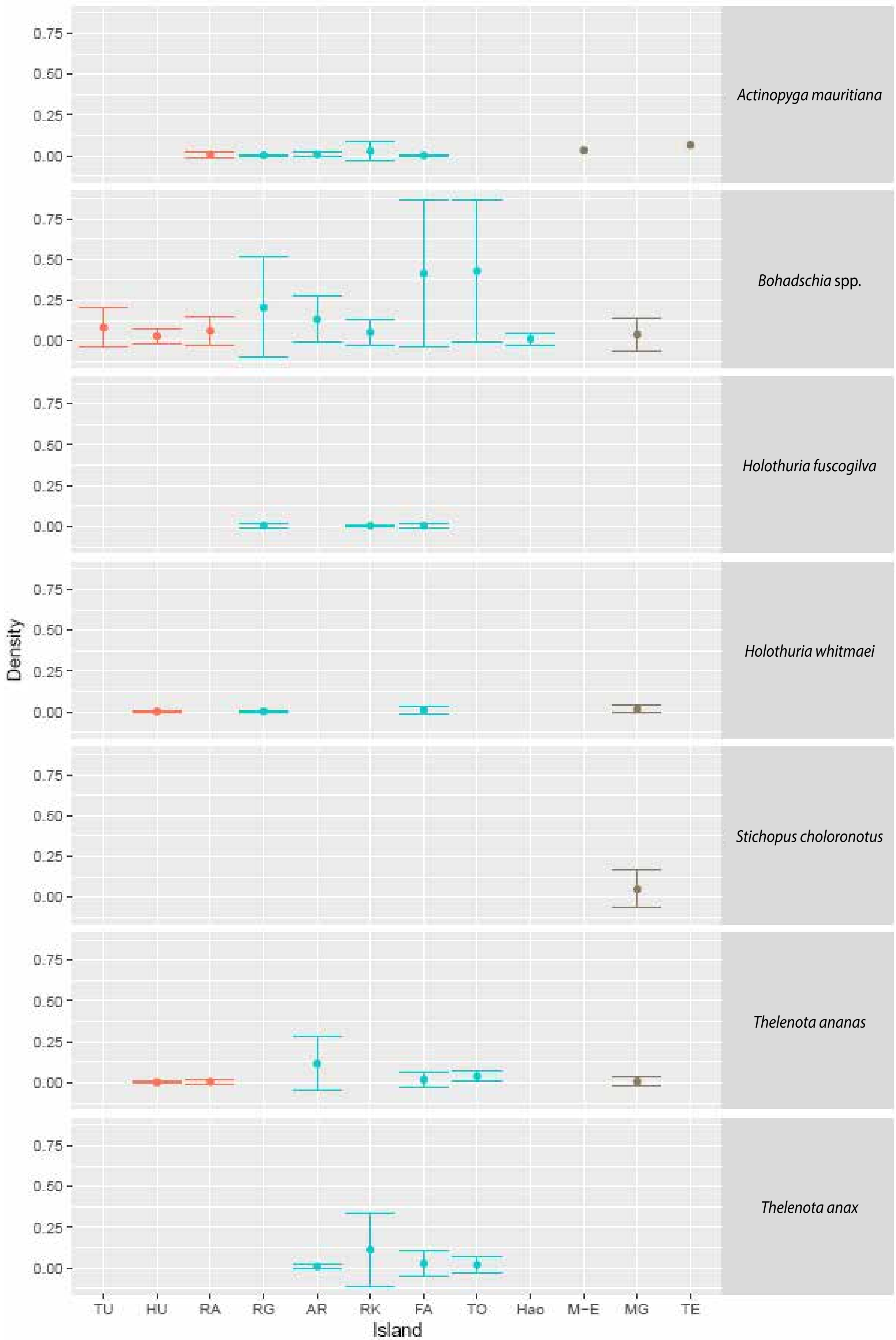


Figure 4. Density (in number of individuals per minute) per island, per species, and for lagoonal stations. Island name abbreviations are in Table 1.

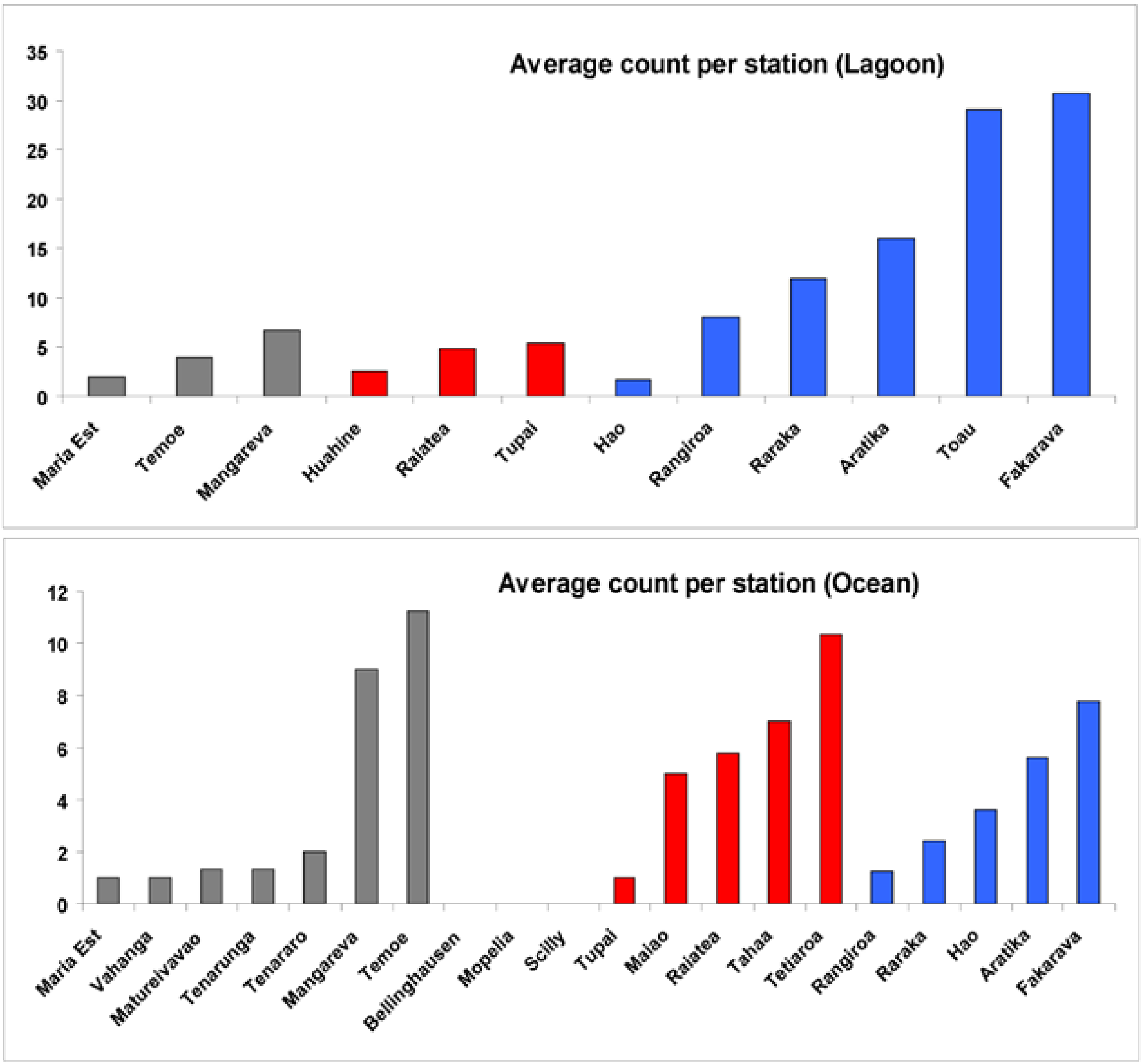


Figure 5. Histograms representing the average count (or ratio between the total counts and the number of stations) per station for each island, for lagoonal and oceanic stations. If no census took place at lagoonal or oceanic sites, the island is not shown. Zero values report a lack of sightings. Grey = Gambiers, red = Societies, blue = Tuamotus.

An archipelago-scale gradient of fishing impact

The total number of records per dive and the density of sea cucumbers per search time were lowest in the Society Islands. Also, 32% of the sites were completely depleted, and the highest proportion of sites without records was lagoonal sites. There was also an almost complete absence of valuable species in shallow areas. *Bohadschia* spp. densities were low, especially compared with the Tuamotus. These observations confirm that the islands have been impacted by the 2008–2012 period of open fishing. Within the most studied islands in the Societies, Raiatea exhibited patterns that confirmed the assumption that fishing activities had reduced sea cucumber densities in the Society island. Valuable specimens could be found, but only at depth (~ 30 m), which is unreachable by most free divers who opportunistically began fishing for sea cucumbers in 2008. Densities were also higher on the exposed fore reefs, which are more difficult to exploit due to their exposure to swells generated by the easterly trade winds (Fig. 6).

It is worth noting the case of Scilly, Mopelia and Bellinghausen, the three westernmost Society atolls. The seven stations on these atolls, all oceanic, show no records at all, although other teams have seen a couple of *T. ananas* when doing their own survey (e.g. , IRD's Research Fellow Sylvain Petek sponge survey), and we saw a few *B. argus* and *H. atra* in the lagoons when collecting other samples. The paucity of echinoderms at these atolls may be general and unrelated to fishing in this western part of the archipelago, as previous expeditions in Scilly have also reported a lack of echinoderms (Salvat 1983).

In the Tuamotus, the pattern varied among atolls. Hao lagoon densities were surprisingly very low

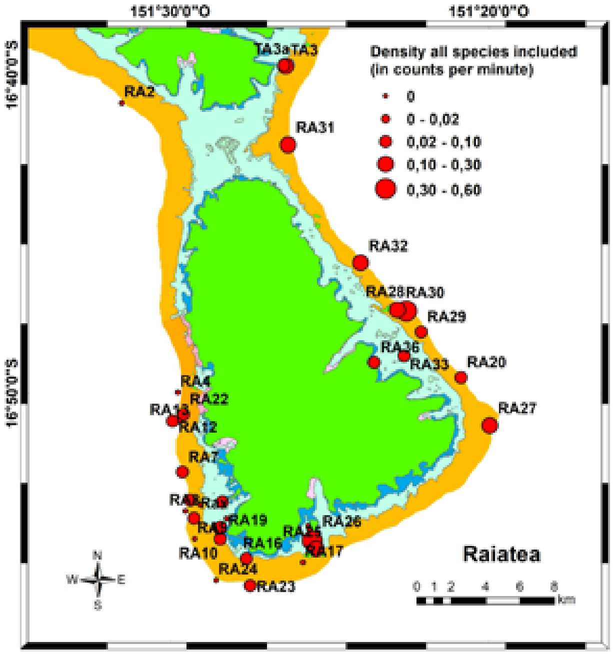


Figure 6. Survey stations at Raiatea, with densities of commercial species.

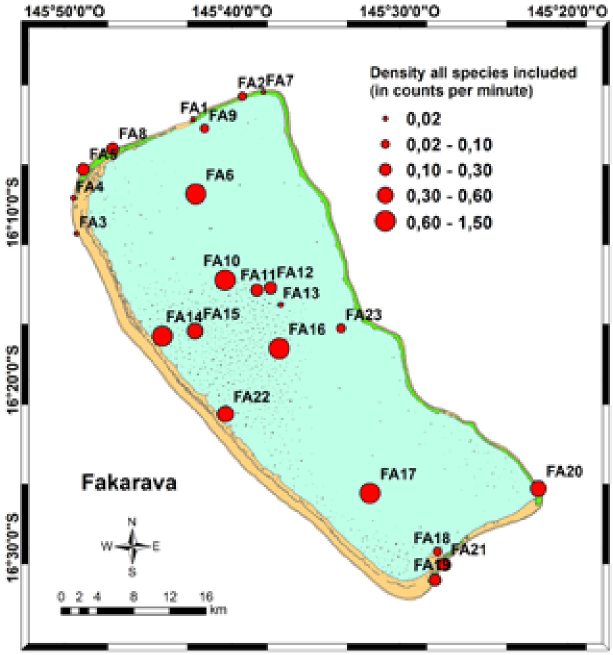


Figure 7. Fakarava survey stations, with densities of commercial species. Villages are near FA27 and FA19.

(Figs. 3, 4 and 5). Local inhabitants confirmed that sea cucumbers vanished almost entirely from the lagoon but this occurred two decades ago, and the reason why is unclear. A large specimen of *B. argus* could still be found near the Hao pass in very shallow water (0–5 m), confirming that significant fishing had not taken place there recently. *Thelenota ananas* was the most dominant species on the fore reefs of all atolls. Aratika, which was never fished, had high densities of *T. ananas* even at sites close to the pass and village, and in shallow water (5 m). Although this would need further investigation, a distance-to-village effect seems to be confirmed when looking at the densities of all species at Fakarava (Fig. 7).

The case of *T. fuscogilva* in Tuamotu is interesting, as DRMM data show contrasting catch levels between atolls, even between large ones. For instance, very few were harvested from Makemo (10 individuals in 2017, DRMM 2018), while several thousands of individuals came from Fakarava and Toau per year since 2014, and probably much more before 2012 (Fig. 1). The differences between Makemo and Fakarava atolls, both of similar sized atolls, can likely be explained not by environmental features or habitat quality, but rather by fishers' habits. In Makemo, the primary catch is *A. mauritiana*, suggesting that gleaning in shallow outer reef flats is the dominant mode of fishing there, whereas in Fakarava, fishers free-dive deep in the pass area and lagoon in search of the most valuable species, *H. fuscogilva*. Both our data and the PROCFish data do not suggest a particularly high potential for *H. fuscogilva* at Fakarava (or elsewhere), but aggregations have likely been missed in the surveys.

We found a healthy population of sea cucumbers in the Gambiers, especially in Mangareva's lagoon where the species richness was high, including the presence of the only *S. chloronotus* population we observed during the three cruises. Despite an overall low density and number of records, these observations confirmed the lack of significant fishing because the high-value *H. whitmaei* was fairly abundant in shallow reefs even those close to the main village. All other commercially important species (*T. ananas, T. anax, A. varians*) were present. Based on the data collected, the Gambier and Society islands have several common characteristics, but the abundance of *H. whitmaei*, and the absence of fishing, suggests that the sea cucumber population at Mangareva is not impacted. Temoe is also likely to be non-impacted considering the records.

Consequences for management

Even if the sampling could not be perfectly replicated the same way within the various islands during the LOF expeditions, the global image drawn by the results and by DRMM fishing statistics led us to recommend, in 2013, that both the Society and the Gambier islands should be declared as no take-areas and remain closed to fishing, although for different reasons. In the Society Islands, this is to allow the population to recover from four years of unregulated and intense exploitation, and in the Gambiers it is to leave intact an untouched population that possibly may include several cryptic species. Hence, a programme focused on the biodiversity of sea cucumbers could be a priority at Mangareva (or the Gambiers as a whole). In contrast, Tuamotu's atolls showed similar species richness between islands, but with evidence of different levels of harvest; none of the atolls were depleted. So, we confirmed that the Tuamotu's could have controlled exploitation. These recommendations from 2013 still remain valid. Four years was likely not enough to rebuild the Society Islands' populations, but revisiting some sites in the near future could determine whether there was recovery, or not.

Mangareva appeared as the hot-spot for sea cucumbers French Polynesia, and a dedicated survey coupled with a population genetics study will certainly bring interesting results. Beyond Mangareva, this statement can be extended to the Gambier region, with the only observations of *T. rubrolineata* in this region. This species is also absent from the Moorea Island Biocode records. Although one specimen was genetically identified as *T. rubrolineata* using bar-coding markers (G. Paulay, pers. comm.), some apparent morphological and coulor variations could warrant further investigations on the isolation of these populations. Furthermore, it has been recently confirmed with genetic tools that a *Bohadschia* individual sampled during the LOF expedition is a new endemic species (G. Paulay pers. comm., and unpublished data).

The next critical step from a fishery perspective is to ensure that exploitation n the Tuamotus remains sustainable. In addition to the continued monitoring of catches, exports and fisher licenses, periodic surveys of populations seem necessary to establish more soundly what could be the total allowable catch per species and per island open to fishing. This would need to be linked with a socioeconomic survey to understand fisher habits. A co-management framework with the participation of fishers was successfully established in New Caledonia for the exploitation of *H. scabra* in the shallow seagrass beds of the Plateau des Massacres near the Boyen tribe in the North Province (Léopold et al. 2013). Every year, a survey provides information on the state of the population and a quota is dynamically established for a given temporary period of fishing by local authorities. The quota is also distributed among the fishers, who endorsed and respected the process, which has demonstrated its efficiency both ecologically for *H. scabra* populations and economically for the fishers. A similar procedure would make sense in the Tuamotus, especially because each island that is open to fishing has a local committee monitoring quotas and the way they are distributed among fishers. However, the challenges of conducting multi-species surveys every year for (thus far) 17 atolls and islands would likely be quite significant. Instead, a rotational procedure may be more feasible, with a subset of four atolls investigated every year, and a definition of quotas valid for four years for instance, with a particular focus on the large atolls that are more heavily fished such as Fakarava, Toau or Apataki. The present state of knowledge and data, as summarised here, is clearly insufficient to establish precisely quotas for a sustainable fishery at each island and new initiatives for data collection are therefore recommended.

Acknowledgements

We are grateful for the generous support of the Khaled bin Sultan Living Ocean Foundation that made this study possible. We also acknowledge the crew of the R/V *Golden Shadow* and its scientific team, the mayors and people of the visited islands, as well as the authorities in French Polynesia that authorised the expedition. We are also grateful to the island and atoll inhabitants that guided us in several areas and discussed their *rori* fishing practices. *Mauruuru*.

References

Adjeroud M., Andréfouët S., Payri C. and Orrempuller J. 2000. Physical factors of differentiation in macrobenthic communities between atoll lagoons in the Central Tuamotu Archipelago (French Polynesia). Marine Ecology Progress Series 196:39–48.

Andréfouët S., Bruckner A., Chabran L., Campanozzi-Tarahu J. and Dempsey A. 2014a. Spread of the green snail *Turbo marmoratus* in French Polynesia 45 years after its introduction and implications for fishery management. Ocean and Coastal Management 96:42–50.

Andréfouët S., Van Wynsberge S., Fauvelot C., Bruckner A.W. and Remoissenet G. 2014b. Significance of new records of *Tridacna squamosa* Lamarck, 1819, in the Tuamotu and Gambier Archipelagos (French Polynesia). Molluscan Research 34:277–284.

DRMM 2014. Bulletin statistique: synthèse des données de la pêche professionnelle de l'aquaculture et de la perliculture Edition 2014, Papeete. http://www.ressources-marines.gov.pf/cdi/bulletin-statistique/ (accessed July 2018). 52 p.

DRMM 2015. Bulletin statistique: synthèse des données de la pêche professionnelle de l'aquaculture et de la perliculture Edition 2015, Papeete. http://www.ressources-marines.gov.pf/cdi/bulletin-statistique/ (accessed July 2018). 56 p.

DRMM 2016. Bulletin statistique: synthèse des données de la pêche professionnelle de l'aquaculture et de la perliculture, Papeete, http://www.ressources-marines.gov.pf/cdi/bulletin-statistique/ (accessed July 2018). 56 p.

DRMM 2017. Bulletin statistique: synthèse des données de la pêche professionnelle de l'aquaculture et de la perliculture, Papeete. 59 p.

Kronen M., Friedman K.J., Pinca S., Chapman L.B., Awira R., Pakoa K., Vigliola L., Boblin P. and Magron F. 2009. Polynésie française - Rapport de Pays: profils et résultats des enquêtes réalisées à Fakarava, Maatea, Mataiea, Raivavae, et Tikehau (septembre–octobre 2003, janvier–mars 2004, avril–juin 2006). Noumea, New Caledonia: Secretariat of the Pacific Community.

Léopold N., Cornuet N., Andréfouët S., Moenteapo Z., Duvauchelle C., Raubani J., Ham J. and Dumas P. 2013. Co-managing small-scale sea cucumber fisheries in New Caledonia and Vanuatu using stock biomass estimates to set spatial catch quotas. Environmental Conservation 40:367–379.

Preuvost M. 2011. Estimation des stocks d'holothuries commerciales dans le lagon de Moorea et recommandations de gestion associées. Master 2 Université de Perpignan, PGEM Moorea-CRIOBE. 31 p.

Salvat B. 1983. La faune benthique du lagon de l'atoll de Scilly, archipel de la Société. Journal de la Société des Océanistes 39:5–15.

Size at sexual maturity of the flower teatfish *Holothuria* (*Microthele*) sp. in the Seychelles

Salomé Cahuzac,[1*] Chantal Conand,[2] Rodney Govinden,[1] Ameer Ebrahim,[3] Stephanie Marie[1] and Marc Léopold[4]

Abstract

The intensive harvesting of sea cucumbers in the Seychelles over the last decade has raised concerns about the sustainability of this resource. The flower teatfish *Holothuria (Microthele)* sp. (locally called pentard) is one of the main target species, representing about two-thirds of annual sea cucumber catches. The biology of this species is largely unknown. To inform fishery management, the reproductive biology of the species was studied on the Mahé Plateau and the Amirantes Plateau during the 2018 northwest monsoon season. A macroscopic analysis of the gonads, and a description of the tubules were performed on 63 sea cucumbers. We observed that the population at the Amirantes Plateau was smaller in size than those from the Mahé plateau, although that difference was not statistically significant. Female tubules were wider and shorter than male tubules, showing there is sexual dimorphism in this species. The size at sexual maturity of flower teatfish was estimated at 30.3 cm (95% confidence interval: 28.5–32.3 cm) through logistical regression. Based on this result, a minimal harvest size of 31 cm may be recommended for this species as a conservative measure in the Seychelles.

Introduction

Holothurians have been fished in the Seychelle Islands of the southwest Indian Ocean for hundreds of years (Aumeeruddy and Conand 2008). They are mostly collected by divers using scuba gear at depths of around 15 to 45 m. They are further processed and dried and exported to Asian markets as beche-de-mer. Globally, holothurian resources have increasingly been overexploited since the 1990s, due to the rising demand by the Chinese market. Up until the end of the 20th century, sea cucumber harvesting in the Seychelles was an open access fishery, without any management control due to the low economic value of the fishery. However, the Seychelles Fishing Authority (SFA), the governing body responsible for fisheries management, introduced a national management plan in 2005 to guide the management of the fishery as a response to the increase in fishing pressure and annual catches (Conand and Muthiga 2007). The teatfish group within the genus *Holothuria* (white teatfish *H. fuscogilva,* black teatfish *H. nobilis,* and flower teatfish *H.* (*Microthele*) sp. (locally known as pentard, Fig. 1) has been heavily targeted in the Seychelles in the 2000s because they are among the most valuable species on the world market (Purcell et al. 2012, 2017, 2018; Diassanayake and Gunnar 2010). With approximately 150,000–300,000 individuals harvested per year, the flower teatfish has been the main commercial species targeted in the Seychelles since 2006, followed by prickly redfish

Figure 1. Flower teatfish – *Holothuria* (*Microthele*) sp. (locally called pentard) – from the Seychelles.

[1] Seychelles Fishing Authority (SFA), PO Box 449, Victoria, Mahé, Seychelles
[2] UMR ENTROPIE IRD-Université La Réunion-CNRS, Paris, France
[3] Consultant for the SEACUSEY project
[4] UMR ENTROPIE c/o IH.SM, University of Toliara, BP 141 Toliara, Madagascar
[*] Corresponding author: cahuzac.salome@gmail.com

Thelenota ananas (15,000–72,000 individuals per year) and white teatfish (37,000–127,000 individuals per year) (Aumeerudy and Conand 2008; Léopold and Govinden 2018). The increasing demand for these species, driven by their increasing commercial value, has progressively led to their potential overexploitation as observed by the declining trend in catches over the last five years.

The flower teatfish has been observed in the Seychelles, Comoros, Tanzania, Madagascar, Sri Lanka and the Maldives (Purcell et al. 2012). However, to date, that species has not yet been formally described, although this work is ongoing (G. Paulay, Curator, Florida Museum of Natural History, pers. comm.). Information on the ecology of flower teatfish is poor, which makes stock assessment difficult and the design of suitable management or conservation measures uncertain.

To address this gap, this study aimed to improve our knowledge of the reproductive behavior of flower teatfish. Specifically, we conducted a biological survey to determine its size at first sexual maturity. The present work was performed as part of a larger research programme whose overall purpose was to strengthen the sustainability of the sea cucumber fishery in the Seychelles through adaptive co-management (Léopold and Govinden 2018).

Materials and methods

Survey area and sampling

The survey was carried out on board SFA's research vessel at two sites: one close to Fregate Island on the Mahé Plateau and the other close to Marie-Louise Island on the Amirantes Plateau, in February and March 2018, respectively. According to fishers, flower teatfish spawns during the monsoon period (October–March), which is also the spawning period of the related species white teatfish. Eight fishers, working on two commercial fishing vessels, volunteered to participate in the survey and facilitate the collection of sea cucumbers. This served to also improve awareness of the research program among fishers. The fishers manually and opportunistically collected flower teatfish specimens while scuba diving at depths ranging between 25 m and 30 m depth at different locations in both survey sites.

The following observations were made by the scientific team on the fishing boat and on all specimens immediately after capture. Total body length (TL) was measured from mouth to anus to the nearest 5 mm with a metric tape and weighed to the nearest 1 g using an electronic balance without an anti-rolling system, and this likely affected the accuracy of weight measurements. Fishers then made a cut on the dorsal side of each specimen (Fig. 2). The entire gonad was removed, weighed to the nearest 1 g, and stored in individual 50-mL tubes filled with 10% formalin. After removing the internal organs and excess coelomic fluid, the gutted body was weighed to the nearest 1 g.

Figure 2. A fisher making a dorsal cut on a freshly harvested flower teatfish in order to remove the viscera.

The sexual stage was determined using the procedure defined by Conand (1981). Firstly, the gonad index (GI) was calculated as follows:

$$GI = Wgonad \times 100 / Wtot$$

where Wgonad = gonad weight (g) and Wtot = total weight (g). GI was expected to be high when gonads were mature.

Secondly, a macroscopic description of the gonads was conducted at SFA's laboratory. Although the sexes are separated in this species, there is no morphological sexual dimorphism (Ghobadyan et al. 2012). Each gonad sample was first placed in a Petri dish. The approximate longest tubule was measured with a measuring tape to the nearest 0.1 mm. The average width of the tubules was measured to the nearest 0.1 mm on digital pictures using a trinocular microscope (x 1.8 zoom) using the Motic Image Plus 2.0 software. Then the tubules were cut using a scalpel. Their content was placed within a concave blade to determine the sex and maturity stage based on the description of maturity stages by Conand (1981), whereby five maturity stages were established according to morphological parameters of the gonad tubules: immature (I), resting (II), growing (III), mature (IV) and post-spawning (V). Holothurians were defined as mature between stages III and V. For females, digital pictures were used to measure the diameter of approximately 10 oocytes to the nearest 0.1 mm using the same procedure as described above.

Data analysis

The total body weight and gonadal morphological parameters were compared across maturity stages using the Kruskal Wallis non-parametric test. The same test was used to compare the weight and size of specimens between the two survey sites.

Finally, the size at first sexual maturity (L50) of flower teatfish was defined as the length at which the gonads of 50% of individuals were mature (Conand 1981; Navarro et al. 2012; Muthiga and Conand 2014). To estimate the L50 and its 95% confidence interval, the proportion of mature individuals at different size intervals was modelled using a logistic regression as defined by the following equation:

$$P = \frac{1}{1 + e^{-r\,(L_t - L_{50})}}$$

where P = proportion of mature individuals, L_t = total length (cm), L_{50} = length at first maturity (cm), and r = model's parameter.

Statistical data analysis was performed using R v 1.1.442.

Results

In this study, 92 flower teatfish were sampled (31 from Mahé Plateau and 61 from Amirantes Plateau), and 54 gonads (88.5% of the sea cucumbers collected) were collected from the Mahé Plateau and 9 gonads (29%) from the Amirantes Plateau.

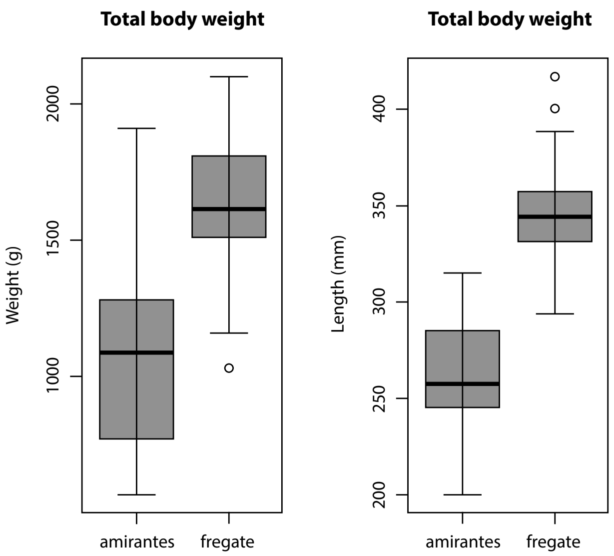


Figure 3. Differences in total weight (g) and length (mm) between the two sampling sites (Amirantes Plateau and Fregate Island on the Mahé Plateau). Lower and upper levels of the boxplot: lower and higher quartiles; black line: median. Dotted lines: lower and upper whiskers.

On the Amirantes plateau, the length of the individuals ranged from 200 mm to 315 mm (mean 263 mm, SD 26 mm) and the total body weight ranged from 563 g to 2153 g (mean 1,068 g, SD 38 g). The length and total weight at Mahé Plateau and Amirantes Plateau are shown in Figure 3. The difference in weight and length between sites was not significant: Kruskal Wallis test, p(weight)=0.36, p(length)=0.06.

Gonad morphology

The characteristics of the five maturity stages were described (Figs. 4 and 5):

- Stage I and II: Because we did not know the size at first sexual maturity, it was not possible to distinguish stage I (immature) from stage II (resting). At both stages, the sex could not be determined.
- Stage III: Maturation started, with growing gonads and exposed and branching tubules evident. Small oocytes were visible, while only unclear liquid was observed within the gonads of the males.
- Stage IV: Gonads were fully grown and mature. Female tubules were filled with oocytes and male tubules showed several bulges filled with sperm.
- Stage V: Although gonads were broadly similar to those at stage III, they displayed a smaller gonad size and dropped tubules typical of the post-spawning stage. Some atretic oocytes were also present.

The gonad weight, tubule length, tubule width and gonad index measured showed significant differences between males and females and between mature and immature individuals (Table 1).

The sex ratio was 1:1 (24 males, 24 females, and 19 undetermined).

Gonad index

As expected, GI increased from an average of 0.60 (immature specimens) up to 1.45 (mature specimens). Gonad weight, tubule length and tubule width increased with GI (Fig. 6). GI increased with the total body length up to about 330 mm total length (Fig. 6D).

Size at first sexual maturity

Several sexual stages were observed at the same period in both sampling sites. The most important part of the sample from Mahé Plateau consisted of individuals at post-spawning (stage V) and maturation (stage III) stages. The distribution of sexual stages in the whole sample indicated that the

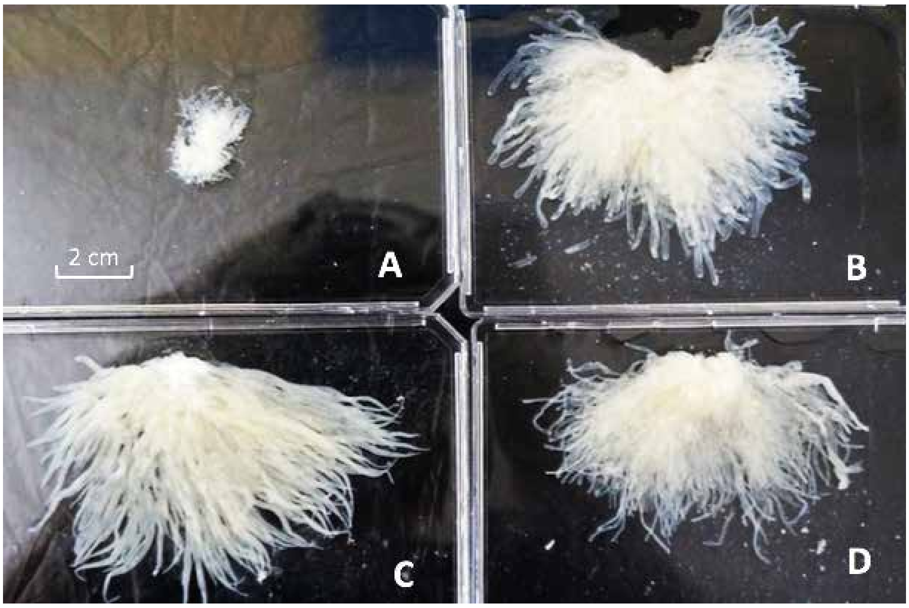


Figure 4. Female gonads of flower teatfish. A: Immature (stage I–II), B: maturation (stage III), C: mature (stage IV), D: post-spawning (stage V).

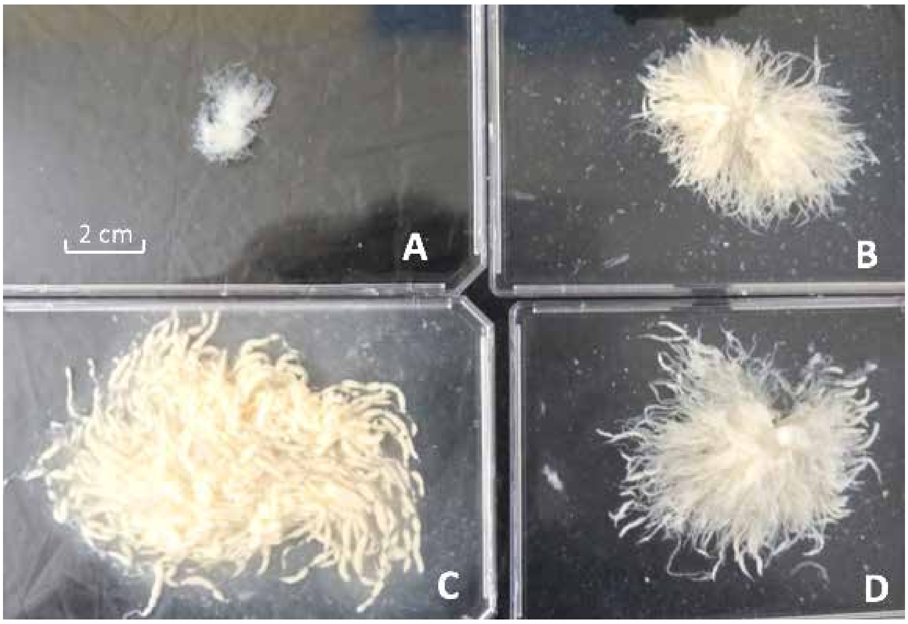


Figure 5. Male gonads of flower teatfish. A: Immature (stage I–II), B: maturation (stage III), C: mature (stage IV), D: post-spawning (stage V).

Table 1. Description of the gonads of immature and mature flower teatfish specimens: gonad weight, tubule length, tubule width and gonad index, with the p-value, mean (SD). The p-value of the Kruskal-Wallis test is indicated (see Methods section for more details).

	Gonad weight (g)	Tubule length (mm)	Tubule width (mm)	Gonad index
Immature	1.56 (0.53)	18.62 (9.38)	0.24 (0.05)	0.58 (1.46)
Mature	23.53 (27.87)	50.27 (16.69)	0.99 (0.52)	1.45 (1.55)
p-value	<0.001	<0.001	<0.001	<0.001

Table 2. Number of flower teatfish specimens at each sexual maturation stage sampled at both survey sites in the Seychelles.

	Immature (I)	Maturation (III)	Mature (IV)	Post-spawning (V)	Non detected gonad
Amirantes	5	0	1	3	23
Mahé	5	19	10	20	8
Total	10	19	11	23	31

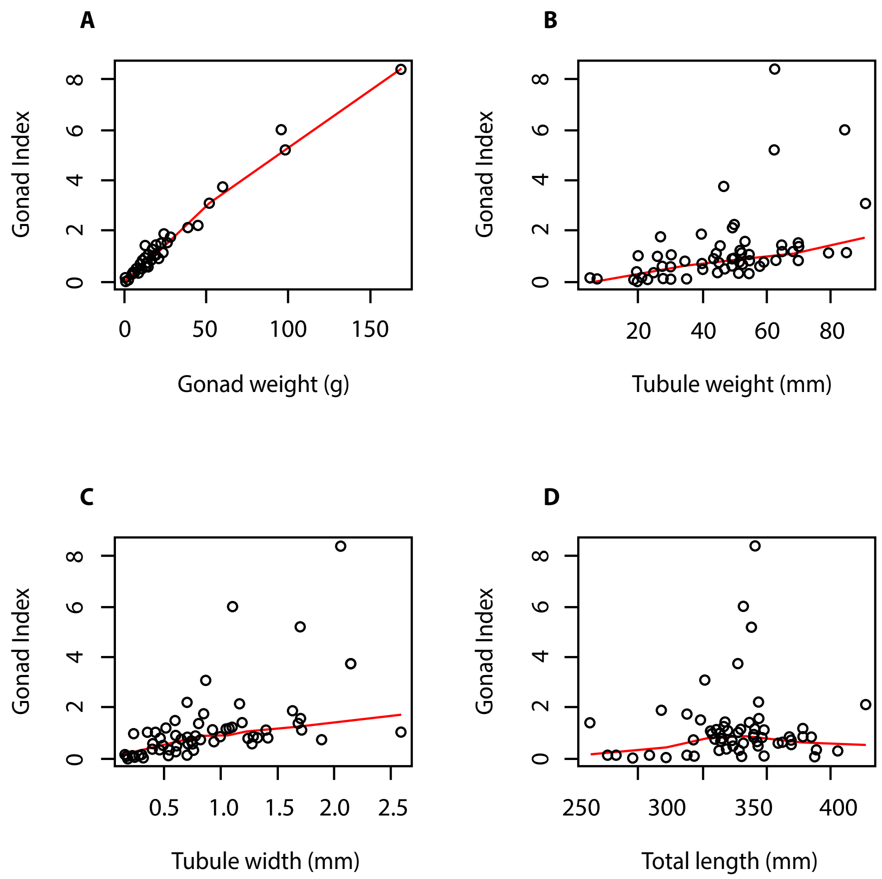


Figure 6. Gonad index as a function of gonad weight (A), tubule length (B), tubule width (C) and total individual length (D). Red lines show trends.

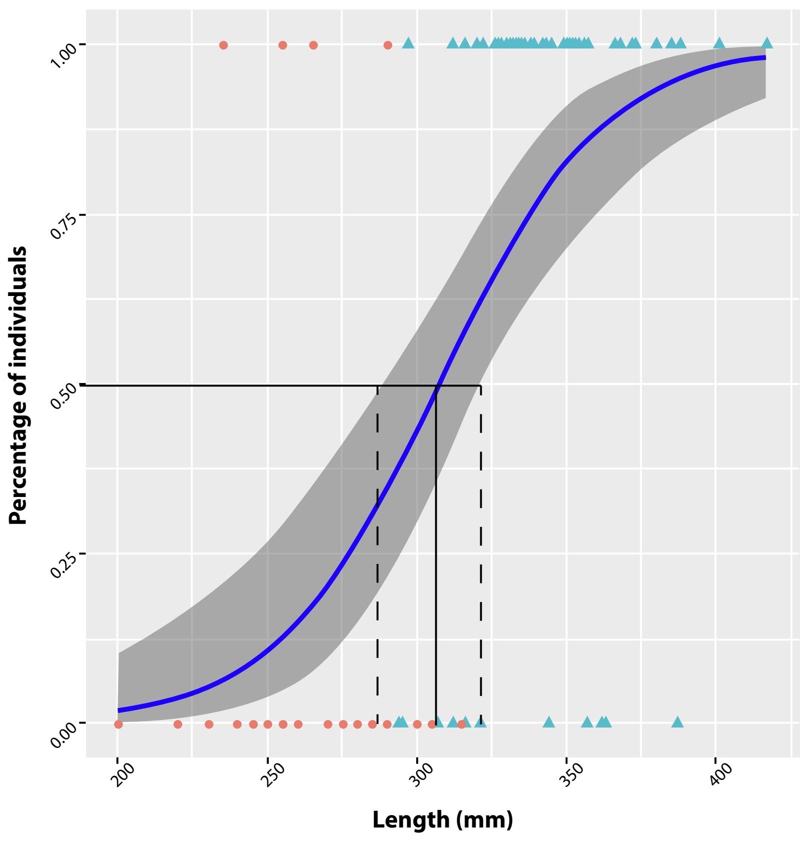


Figure 7. Proportion of mature flower teatfish as a function of individual length (n = 92). The logistic regression and the L_{50} (i.e. size at first sexual maturity) are shown. Red dots represent sea cucumbers from Amirantes Plateau, blue dots represent sea cucumber from Fregate Island on Mahé Plateau.

sampling occurred during the breeding season of this species. The predominant sexual stage of specimens was different between the two sites. Although all stages were found at Mahé Plateau, stages I and II were the ones most commonly observed at Amirantes Plateau, including those specimens for which no gonads were detected during onboard observations. Indeed, because most of those specimens were smaller than the ones from Mahé Plateau, and because our observations provided evidence that the survey was conducted during the breeding season of flower teatfish, we hypothesised that the individuals without gonads were immature. Based on the logistic regression, the length at sexual maturity was estimated at 303 mm (95% confidence interval: 285–323 mm) (Fig. 7).

Discussion

Reproductive biology of flower teatfish

This is the first study examining the reproductive biology of flower teatfish. It provides the first estimate of size at first sexual maturity for this species. The size at first sexual maturity had been determined for other teatfish holothurians in New Caledonia, such as white teatfish (324 mm) and black teatfish (227 mm), using cumulative curves (Conand 1981).

The description of maturity stages of flower teatfish was similar to other teatfish species in the family Holothuridae, especially the teatfish described in Conand (1981, 1989). We found that the distribution of gonad stages among samples was not uniform between the sampling sites. The five stages were observed simultaneously (although at varying rates) at Mahé Plateau, whereas no stage III was reported at Amirantes Plateau. Such a pattern was observed in other sea cucumber species. For instance Ramofafia and Byrne (2002) described that the gonad development of *H. scabra* was different across individuals within a single site in Salomon Islands. A one-year study with monthly observations would help to determine the reproductive cycle of flower teatfish more accurately as the species may spawn at different periods, which could explain the occurrence of the various sexual stages during our survey. Previous studies in New Caledonia have proven that white teatfish and prickly redfish spawn from December to February while black teatfish preferentially spawns from July to November (Conand 1981, 1993).

The presence or absence of gonads at the same period could also be linked with gonad resorption. This process was observed for white teatfish after the spawning season (Ramofafia and Byrne 2002; Muthiga and Conand 2014). In this study, the breeding season was hypothesised based on fishers' knowledge and the reproduction cycle of white teatfish, a genetically close species (G. Paulay, pers. comm.). The absence of gonads at the Amirantes site was interpreted as immaturity rather than gonad resorption because the specimens were smaller at Amirantes. Indeed, we observed that the size of flower teatfish was different between the sample sites, although this result was not statistically validated, likely due to the low number of specimens sampled at Amirantes Plateau. It has already been reported that sea cucumber morphology may vary according to environmental conditions and fishing pressure (Conand and Muthiga 2007). Our results should, therefore, be confirmed by using larger sample sizes collected in different habitats, and evaluating fishing pressure across those sites. Gonad sizes of holothurians can also spatially vary, as observed for *Cucumaria frondosa* along the Canadian coast (Hamel and Mercier 1996). It would be useful to explore this hypothesis in the Seychelles.

Mean GI appeared greater for male flower teatfish than for females, despite both sexes having similar average body weights. This is in contrast to observations of black teatfish and white teatfish in Kenya and New Caledonia which showed the opposite (Conand 1981; Muthiga and Kawaka 2009). This difference was very likely due to higher gonad weights for males than for females because no difference in total body weight was noticed. It should be further investigated using larger sample sizes and longer sampling periods.

Gonad tubule length was correlated to sexual maturity as observed by other authors (e.g. Muthiga and Conand 2014). The mean tubule length of flower teatfish during spawning (49.9 mm) was smaller than that of other species such as white teatfish, which ranges between 79 mm and 88 mm in New Caledonia (Conand 1993), and 119 mm in Kenya (Muthiga and Conand 2014). Gonad tubule growth can, therefore, be used to monitor the reproductive activity of sea cucumbers. Throughout the study, female tubules were wider than male tubules, which is a common pattern for many holothurians (Conand 1981; Navarro et al. 2012; Ghobadyan et al. 2012). However, male tubules were slightly longer than those of females, as observed for other aspidochirotida species such as white teatfish, black teatfish and sandfish (*H. scabra*) (Conand 1993).

Despite a lack of statistical robustness in this study, due to the small sample size and the variability of observations, gonads displayed a clear sexual dimorphism. Such a dimorphism has been reported for teatfish species in other studies (Conand 1981, 1993; Navarro et al. 2012).

Management implications

Inadequate regulatory measures have contributed to the poor resource status of most sea cucumber fisheries in the Indian Ocean (Eriksson et al 2015). In the Seychelles, for instance, the lack of knowledge on the biology of flower teatfish prevented the introduction of an appropriate minimum catch size limit for that species, which may be a relevant management recommendation for preserving resource biomass. Based on our estimate of the size at maturity of flower teatfish, a minimum catch size of 31 cm may be suitable for that species in the Seychelles, although the results should be confirmed by additional data from other fishing sites and/or larger samples.

The potential impact of such a rule is currently unknown given that there are no statistics on the size structure of sea cucumber catches in Seychelles. Nevertheless, some indications may be derived from Purcell et al. (2017) who reported that the mean dried size of flower teatfish recorded on the Chinese market ranged between 14 cm and 25 cm, although there was no information about the fishing sites from where these products came from. Using the available conversion ratio (Aumeeruddy and Conand 2007; Purcell et al. 2009, 2017), the estimated live size of these sea cucumber would range between 23 cm and 42 cm, which includes non-mature specimens. This highlights the need for introducing a minimum catch size in the Seychelles.

To date, fishers in the Seychelles have usually been paid per unit of sea cucumber landed rather than per kilogram (pers. obs.), which provides little incentive to search for large specimens of commercial species. The establishment of a minimum catch size could, therefore, modify catch rates and, consequently, the landed value of the fishery. According to Purcell et al. (2017), the introduction of a minimum catch size for flower teatfish could lead to a significant increase in income from the fishery given that large sea cucumbers are given a higher price on the Chinese market. Using the above conversion rates for instance, specimens of 23–26 cm and 36–39 cm in length would be priced USD 5–17 and USD 54–66 per piece, respectively.

In conclusion, this study provides the first data on the reproductive biology of flower teatfish in the world. The results provide guidance for further research investigation and fishery management.

Acknowledgments

This study was conducted through a grant of the SEACUSEY project (http:\\seacusey.ird.nc) as part of the 'Coastal, Marine and Island Specific Biodiversity Management in ESA-IO Coastal States program' funded by the European Union and implemented by the Indian Ocean Commission. We thank Andrew Souffre, Joshua Maria, Nathalie Bodin, the skippers and divers of *L'Escapade* and *Great White* fishing vessels, and the crew of SFA'ss research vessel, R/V *L'Amitié* for their assistance in data collection.

References

Aumeeruddy R. and Conand C. 2007. Seychelles' sea cucumber fishery: Data on processed products and other parameters. SPC Beche-de-mer Information Bulletin 26:19–25.

Aumeeruddy R. and Conand C. 2008. Seychelles: a hotspot of sea cucumber fisheries in Africa and the Indian Ocean region. p. 195–209. In: Toral-Granda V., Lovatelli A.and Vasconcellos M. (eds). Sea cucumbers. A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper. No. 516. Rome: FAO.

Conand C. 1981. Sexual cycle of three commercially important holothurian species (Echinodermata) from the lagoon of New Caledonia. Bulletin of Marine Science 31(3):523–543.

Conand C. 1989. Les Holothuries aspidochirotes du lagon de Nouvelle-Calédonie: biologie, écologie et exploitation. Editions de l'ORSTOM, Bondy.

Conand C. 1993. Reproductive biology of the holothurians from the major communities of the New Caledonian Lagoon. Marine Biology 116(3):439–450. https://doi.org/10.1007/BF00350061

Conand C. and Muthiga N.A. 2007. Commercial sea cucumbers: A review for the Western Indian Ocean. Western Indian Ocean Marine Science Association (WIOMSA) book series no. 5. 66 p.

Dissanayake D.C.T. and Gunnar S. 2010. Abundance and distribution of commercial sea cucumber species in the coastal waters of Sri Lanka. Aquatic Living Resources 23:303–313. doi: 10.1051/alr/2010031

Eriksson H., Conand C., Lovatelli A., Muthiga N. and Purcell S.W. 2015. Governance structures and sustainability in Indian Ocean sea cucumber fisheries. Marine Policy 56:16–22.

Ghobadyan F., Morovati H., Ghazvineh I. and Tavassolpour E. 2012. Étude des caractéristiques macroscopiques et microscopiques des tubules gonadiques *d'Holothuria leucospilota* (golfe persique, Iran). SPC Beche-de-mer Information Bulletin 32:6–14.

Hamel J-F. and Mercier A. 1996. Gonad morphology and gametogenesis of the sea cucumber *Cucumaria frondosa*. SPC Beche-de-mer Information Bulletin 8:22–33.

Léopold M. and Govinden R. 2018. SEACUSEY: Co-management of the sea cucumber fishery in the Seychelles (2017–2018). SPC Beche-de-mer Information Bulletin 38:85–87.

Muthiga N.A. and Kawaka J.A. 2009. The breeding pattern and variations in timing and reproductive output of the commercial sea cucumber *Holothuria fuscogilva* in Kenya. Western Indian Ocean Journal of Marine Science 8(2):183–192. https://doi.org/10.4314/wiojms.v8i2.56978

Muthiga N.A. and Conand C. 2014. Sea cucumbers in the western Indian Ocean: Improving management of an important but poorly understood resource. Western Indian Ocean Marine Science Association (WIOMSA) book series 13. 74 p.

Navarro P., García-Sanz S. and Tuya F. 2012. Reproductive biology of the sea cucumber *Holothuria sanctori* (Echinodermata: Holothuroidea). Scientia Marina 76(4):741–752. https://doi.org/10.3989/scimar.03543.15B

Purcell S.W., Gossuin H. and Agudo N. 2009. Changes in weight and length of sea cucumbers during conversion to processed beche-de-mer: Filling gaps for some exploited tropical species. SPC Beche-de-mer Information Bulletin 29:3–6.

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 p.

Purcell W.S., Poasi N., Wang G. and Lalavanua W. 2017. Market value of flower teatfish (”pentard”): A highly exploited Indian Ocean holothuroid. SPC Beche-de-mer Information Bulletin 37:18–21.

Purcell S.W., Williamson D.H. and Poasi N. 2018. Chinese market prices of bêche-de-mer: Implications for fisheries and aquaculture. Marine Policy 91:58–65.

Ramofafia C. and Byrne M. 2002. Assessment of the «tubule recruitment model» in three tropical Aspidochirote holothurians. SPC Beche-de-mer Information Bulletin 15:13–16.

Contribution to the knowledge of holothurian biodiversity at Reunion Island: Two previously unrecorded dendrochirotid sea cucumbers species (Echinodermata: Holothuroidea)

Philippe Bourjon[1*] and Jean-Pascal Quod[2]

Introduction

A comprehensive knowledge of biodiversity at the local scale is needed to design management and conservation strategies, and to adapt regional management plans to population connectivity as well as to formulate biogeographic hypotheses. This information is all the more important when the biology and distribution of species are poorly known, as is the case with many sea cucumbers. Consequently, reliable field observations accompanied by photographic evidences and information on location and habitat can allow experts to better understand spatial patterns, and infer distributions using ecological niche modelling (Michonneau and Paulay 2015). Moreover, these data, even if not enabling precise identification of previously unrecorded species, allow the inclusion of these species in the research programme of future inventory missions. This article is written with that in mind.

The most recent inventory of holothurians at Reunion Island includes 39 species (Conand et al. 2018) belonging to four orders (Holothuriida, Synallactida, Apodida, Dendrochirotida) and five families (Holothuriidae, Stichopodidae, Chiridotidae, Synaptidae, Sclerodactylidae). The order Dendrochirotida is represented by two species belonging to the family Sclerodactylidae (*Afrocucumis africana*, *Ohshimella ehrenbergii*).

Two clearly different species of dendrochirotid holothurian were observed in the island's waters between 2014 and 2018. Several individuals of one species, probably belonging to the Cucumariidae family, were observed at various locations on Saint Gilles-La Saline reef between 2014 and 2017. An individual of the second species, probably belonging to the Phyllophoridae family, was observed on the same reef in 2016, and another was found in 2018 in a pond on the supralittoral zone of the rocky southeastern coast of the island, near the town of Sainte Rose. These observations add two species, and probably two families, to the biodiversity of holothurians on Reunion Island. This article provides information on the main external morphological characteristics of these two species, and some aspects of their ecology.

Methodology

Observations were carried out on Saint Gilles-La Saline reef, located on the western coast of Reunion Island (21°07'S, 55°32'E), and in ponds scattered along the supralittoral zone of the rocky western, southern and southeastern coasts of the island. Saint Gilles-La Saline reef is less than 8 km long; its maximum width is about 500 m, and the mean depth is 1.2 m. Ponds are located on basaltic platforms and connect to the ocean only under swell effect. Their surface ranges from a few tens of square centimetres to over 100 square metres; their depth ranges from a few centimetres to 5 meters.

Observations by the authors were made by snorkelling. For exploration, each observer held an underwater camera and a ruler.

Results

Individuals probably belonging to the family Cucumariidae

Physical description

The description is based on the first observed individual. Length slightly contracted 2.9 cm, mid-body width 0.9 cm; non-contracted body elongated,

[1] Agence de Recherche pour la Biodiversité de La Réunion (ARBRE). 18, rue des Seychelles, 97436 Saint Leu, La Réunion, France.
[2] Agence pour la Recherche et la Valorisation Marines (ARVAM). c/o Technopole de la Réunion, BP 80041, 97491 Sainte Clotilde Cédex
[*] Author for correspondence: Philippe Bourjon. Email: seizhavel@wanadoo.fr

tapering slightly at the posterior end, with prominent dorsolateral edges; sub-quadrangular in cross-section with interradii of the bivium slightly concave when body not contracted; contracted body barrel-shaped with five deep longitudinal grooves (Fig. 1A); body wall rough to the touch, probably thick; bivium bright red-orange with greenish yellow anterior end and yellowish posterior end (Fig. 1B), trivium yellowish (Fig. 1C); interradii and anterior part with thin longitudinal black lines, also present on the stem of tentacles; no apparent interradial papillae; mouth terminal, tentacles apparently branched, yellowish (Fig. 1D); number of tentacles not determined; anus terminal, rounded, dorsal during excretion; presence or absence of anal teeth not determined; tube feet extending from mouth to anus, relatively short and thick, restricted to the ambulacra and arranged in two irregular rows, far fewer on the dorsal ambulacra; same colour as the body with distal white ring and dark red brown endplate; tube feet apparently not fully retractile.

The other individuals had the same overall characteristics. The non-contracted size range was 2.6 cm to 3.8 cm (Fig. 1E); a pear-shaped individual (Fig. 1F) was also observed.

Ecology

All individuals were found on a reef flat at a depth of less than 1 m, approximately 50–70 m from the reef front, in strong hydrodynamic areas characterised by a sandy-detrital substrate. All individuals adhered to the underside of slab-shaped coral debris. Two were observed within a few metres of each other at two different sites. Other individuals were isolated, with no individuals found within 50 m on either side of their position. None of the individuals eviscerated while being handled.

Individuals probably belonging to the family Phyllophoridae

Physical description

The description is based on the first observed individual. Length slightly contracted 3.2 cm, mid-body width 1.2 cm; body wall wrinkled, soft to the touch, probably thin; colour light brown with yellowish, white and greyish areas and small blackish smears scattered all over the body (Fig. 2A); both ends blackish, posterior end with a distal white ring (Fig. 2B); body arched, slightly U-shaped when contracted, with blunt anterior end and tapering posterior end; mouth terminal; colour and number of tentacles not determined; anus terminal surrounded by small thin yellowish tube feet, presence or absence of anal teeth not determined; tube feet relatively long, tubular, abundant, more or less uniformly scattered over the whole body without any arrangement; same colour as the body parts where they are located, with clearer irregular transverse lines on the stem and white endplate; tube feet apparently not fully retractile.

The second individual (Fig. 2C) had the same overall characteristics, except for the following features: semi-contracted length 2.9 cm; half-body width 1 cm; dominant colour dark brown with whitish areas limited to the trivium and lateral sides of the bivium; posterior end with a whitish protrusion disappearing when the body was fully contracted.

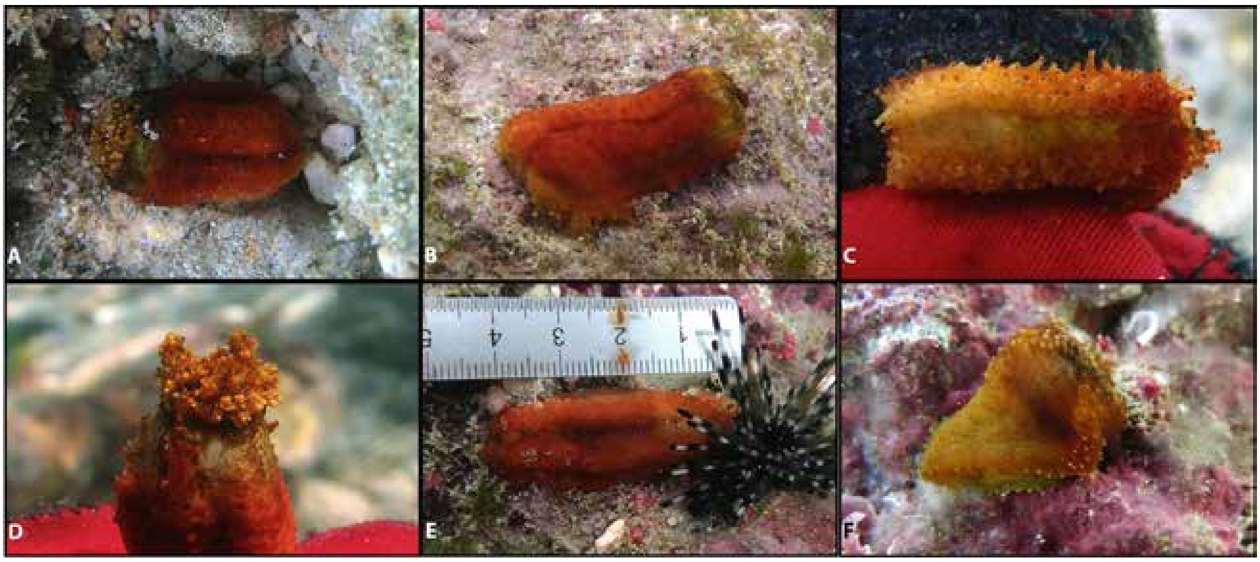


Figure 1. Individuals probably belonging to the family Cucumariidae. A) The contracted body is barrel-shaped, with five longitudinal grooves. B) The bivium is bright orange-red with yellowish ends. C) The trivium is yellowish, tube feet are present only on radii. D) Tentacles appear branched. E) This individual measuring 3.8 cm is the largest of those observed. F) Pear-shaped individual. (photos by P. Bourjon)

Ecology

The first individual was found at a depth of 1 m on the reef flat, 200 m from the reef front, in a moderately hydrodynamic area occupied by a layer of coral debris colonised by algal turf. The individual was hidden under some debris on the surface of the layer. The second individual was in a pond about 150 m^2 and 40 cm deep on a basaltic platform a few metres from the surf zone, in a site where the swell is regularly strong. These two extremely different habitats show that this species is able to adapt to various biotopes. Neither of the two individuals eviscerated while being handled.

Discussion

The taxonomy of dendrochirotids is currently based mainly on differences between calcareous ring morphologies and ossicle assemblages (Panning 1949; Heding and Panning 1954), and on the shape of the tentacles rather than on their number (Pawson and Fell 1965). However, many species remain in an uncertain position, and some families or subfamilies are not clearly distinguishable (Byrne and O'Hara 2017). This makes photo-based determinations most often impossible with this order, unlike what remains possible in others (e.g. Kim et al. 2013; Kerr 2013). However, more or less precise assumptions based on external morphology or geographical distribution can be made in the dendrochirotid group.

The body shape, conspicuous colour and tube feet restricted to the ambulacra, and observable in individuals of the first group that was observed on Reunion Island suggests that they could belong to the family Cucumariidae. Nevertheless, it is impossible to be more precise in determining these individuals in the context of photo-based identification, due to the difficulties associated with the taxonomy of dendrochirotid holothurians.

Some aspects of the external morphology of the second group individuals make them close to the genus *Phyrella* (Heding and Panning 1954) (Phyllophoridae). This genus, revised by Michonneau and Paulay in 2014, and based on morphological and molecular analyses, includes eight species (*P. trapeza* (Clark 1932), *P. drozdovi* (Levin and Stepanov 1999), *P. fragilis* (Mitsukuri and Ohshima in Ohshima 1912), *P. mookiei* (Michonneau and Paulay 2014), *P. thyonoides* (Clark 1938), *Phyrella? ambigua* (Cherbonnier 1988), *Phyrella? bedoti* (Koehler 1895); *Phyrella? tenera* (Ludwig 1875). The last three species were putatively assigned to this genus due to a lack of sufficiently numerous and accurate data. Among these species, only *Phyrella? ambigua* can be found in the southwest Indian Ocean (Madagascar, Mauritius and Rodrigues). Our individuals have external characteristics (small size, body shape and colour, blackening of both extremities, tube feet shape and distribution) similar to those of *Thyonidiella cherbonnieri* (Rowe and Richmond, 2004), as re-described by the authors of the revision of the genus, and considered by them a synonym of *Phyrella? ambigua*. The individuals observed on Reunion Island could, therefore, belong to *Phyrella? ambigua*. Samyn and Tallon (2005) consider that dendrochirotid holothurians have a low dispersal capacity due to their larval development pattern (lecithotrophic doliolaria and direct development, without auricularia stage). However, the record of *Phyrella? ambigua* in Mauritius, located 170 km east-northeast of Reunion Island, as well as a local current pattern favourable to larval transport from Mauritius to Reunion Island (Pous et al. 2014), may reinforce this hypothesis. Nevertheless, only the examination of preserved specimens and molecular analyses can confirm that *Phyrella? ambigua* is indeed present on Reunion Island.

The present observations confirm the assumption of Conand and colleagues (2010) that the group of dendrochirotida could be more diversified on Reunion Island than what the inventory of holothurians has shown so far. Other species in this group are likely to remain undiscovered in the island's waters, particularly those with cryptic behaviour.

Figure 2. Individuals probably belonging to the family Phyllophoridae. (A and B: individual found on the Saint Gilles-La Saline reef, C: individual found on the southeast coast of the island). A) The colour pattern is a mix of light brown, yellowish, white and grey zones, and has irregularly scattered blackish traces on the body. B) Both ends are blackish, the anterior end is rounded and the posterior end is tapered (photos by P. Bourjon). C) The dominant colour is dark brown in this individual. The anus is surrounded by thin yellowish tube feet and is located at the tip of a whitish protrusion. (photo by J.-P. Quod)

Acknowledgements

We thank François Michonneau for the discussions about the families and genera to which the two observed species might belong, and Chantal Conand for her comments on the first draft of this communication.

References

Byrne M. and O'Hara T.D. (eds). 2017. Australian echinoderms: Biology, ecology and evolution. Melbourne Australia: CSIRO Publishing and Australian Biological Resources Study. 630 p.

Conand C., Michonneau F., Paulay G. and Bruggemann H. 2010. Diversity of the holothuroid fauna (Echinodermata) in La Réunion (Western Indian Ocean). Western Indian Ocean Journal of Marine Science (9) 2:145–151.

Conand C., Ribes-Beaudemoulin S., Trentin F., Mulochau T. and Boissin E. 2018. Marine biodiversity of La Reunion Island: Echinoderms. Western Indian Ocean Journal of Marine Science 17(1):111–124.

Heding S.G. and Panning A. 1954. Phyllophoridae. Eine Bearbeitung der polytentaculaten dendrochirotiden Holothurien des Zoologischen Museums in Kopenhagen. Spolia Zoologica Musei Hauniensis 13:1–209.

Kerr A.M. 2013. *Holothuria* (*Semperothuria*) *roseomaculata* n. sp. (Aspidochirotida: Holothuriidae), a coral-reef inhabiting sea cucumber from the western Pacific Ocean. Zootaxa 3641(4):384–394.

Kim S.W., Kerr A.M. and Paulay G. 2013. Colour, confusion and crossing: Resolution of species problems in *Bohadschia* (Echinodermata: Holothuroidea). Zoological Journal of the Linnean Society 168(1):81–97.

Michonneau F. and Paulay G. 2014. Revision of the genus *Phyrella* (Holothuroidea: Dendrochirotida) with the description of a new species from Guam. Zootaxa 3760 (2):101–140.

Michonneau F. and Paulay G. 2015. Using iNaturalist to learn more about echinoderms. Reef Encounter 30(1):29–31.

Panning A. 1949. Versuch einer Neuordnung des Familie Cucumariidae (Holothurioidea, Dendrochirota). Zoologische Jahrbücher Abteilung für Systematik, Okologie und Geographie der Tiere 78 (4):404–470.

Pawson D.L. and Fell H.B. 1965. A revised classification of the dendrochirote holothurians. Breviora 214:1–7.

Pous S., Lazure P., André G., Dumas F., Halo I. and Penven P. 2014. Circulation around La Reunion and Mauritius islands in the southwestern Indian Ocean: A modelling perspective. Journal of Geophysical Research – Oceans 119(3):1957–1976.

Samyn Y. and Tallon I. 2005. Zoogeography of the shallow-water holothuroids of the western Indian Ocean. Journal Biogeography 32:1523–1538.

Skin ulcerations in *Holothuria scabra* can be induced by various types of food

Igor Eeckhaut,[1,2,3] Kévin Van Wayenberghe,[1] Fohy Nicolas[3] and Jérôme Delroisse[1]

Abstract

Skin ulceration disease and skin ulceration syndrome (SKUD-SUS) affecting sea cucumbers have been described from various regions in the world. Both are attributed to bacteria and/or viruses. *Holothuria scabra* is, as many sea cucumbers are, a deposit feeder that feeds on organic matter from the sediment. Here, we demonstrate that sediments enriched with different types of organic matter can induce skin ulcerations in *H. scabra*. The various tested organic matter added to the sediment included: i) crushed integument ulcerations from ulcerated *H. scabra* adults; ii) crushed integument from healthy *H. scabra* juveniles; iii) crushed skin from healthy fishes; and iv) crushed healthy red seaweed. The three first types of organic matter induce skin ulcerations in less than three days of exposure, sometimes leading to the death of an individual. The last, non-animal, organic matter did not induce skin ulcerations. Our results indicate that: i) skin ulceration is not a single disease but a symptom of bad health, and it occurs in various diseases induced by either biotic agents or abiotic factors (e.g. the ingestion of non-adequate food); and ii) fish meal comprising animal organic matter, which when added to food, can be deleterious for sea cucumbers.

Introduction

Skin ulceration disease and syndrome (SKUD-SUS) affect the integument of sea cucumbers. The first sign of these diseases is the appearance of whitish spots on the skin. These spots are actually the result of the breakdown of the cuticle, and the epidermis putting the partially degraded underlying dermis in contact with the water. Microscopic observation reveals disorganised collagen fibers and scattered ossicles (Eeckhaut et al. 2004). The first spots are often on the periphery of the cloaca of the affected individual (Becker et al. 2004), but then colonise more and more areas until they become widespread after 24 hours in a large posterior lesion. New spots appear all over the body until the entire surface is covered with them. After three days, affected individuals die. During the evolution of the disease, the individual is characterised by a state of general weakness and an inability to retract its tentacles and to adhere to the substrate. It can also present anorexia, swollen mouth and uncontrolled tremors (Eeckhaut et al. 2004; Wang et al. 2004).

Two main causes of the disease mentioned in the literature are a viral agent (Deng et al. 2008; Hongzhan et al. 2010) or bacteria, with some research on *Apostichopus japonicus* showing that both agents can induce ulcerations in this species. Previously, members of our team showed that bacteria in skin ulcerations of *H. scabra* juveniles could not be transmitted through contact, and that most bacteria present in the lesions are probably opportunistic bacteria (Becker et al. 2004). With regard to bacteria, *Vibrio* (Proteobacteria, Gammaproteobacteria) are the most commonly observed species in lesions, and some can induce ulceration in *A. japonicus* (Becker et al. 2004; Eeckhaut et al. 2004; Deng et al. 2008; Hua et al. 2010; Liu et al. 2012; Ma et al. 2006; Morgan 2001; Yancui et al. 2011; Yancui et al. 2012). Other Gammaproteobacteria, represented by the genera *Pseudoalteromonas* and *Pseudomonas*, which are common and abundant in muddy sands, are also observed in lesions (Hongzhan et al. 2010; Hua et al. 2010). *Bacteroidetes* bacteria are usually present in the intestinal flora and can, in certain cases, be pathogenic (Becker et al. 2004, Eeckhaut et al. 2004). Alphaproteobacteria are also commonly found in marine sediments and have some representatives that are abundant in the digestive system of *H. scabra* (Eeckhaut et al. 2004; Plotieau et al. 2013).

The hypothesis in this work was that skin ulcerations could be induced by factors other than bacteria and viruses. For that purpose, we tested whether sediments that are ingested by *H. scabra* can induce skin ulcerations when they are enriched with different types of organic matter.

[1] Laboratoire de Biologie des Organismes Marins et Biomimétisme, Université de Mons, B-7000 Mons, Belgique
[2] Unité de recherche en polyaquaculture, IHSM, Université de Toliara, 601 Toliara, Madagascar
[3] Madagascar Holothurie, Research Department of Indian Ocean Trepang, Mahavatsy, 601 Toliara, Madagascar

Materials and methods

The experiments were performed in the R & D Department (Madagascar Holothurie) of the Indian Ocean Trepang company in Madagascar in 2016. Four types of organisms were crushed using a manual food grinder: 1) diseased *H. scabra* adults taken from the Indian Ocean Trepang sea pens; 2) healthy *H. scabra* juveniles taken from the Indian Ocean Trepang land ponds; 3) healthy, small perciform fishes (caught in the harbour); and 4) healthy *Kappaphycus alvarezii* (red seaweed) taken from the farms of the company Ocean Farmer. The fluid obtained was mixed with healthy sediment from marine enclosures where the disease has never been reported. Daily monitoring of the sea cucumbers (i.e. healthy sea cucumbers with no ulcerations) placed on the various sediments was carried out in order to observe the potential emergence of ulcerations and other symptoms.

Ten kilos of wet sediment were deposited in experimental basins measuring 2 m^2. In the enriched sediments, 50 g kg^{-1}or 25 g kg^{-1} of crushed, diseased *H. scabra* adults was added against 50 g kg^{-1} for healthy *H. scabra* juveniles, healthy fishes and healthy *K. alvarezii*. Thirteen sea cucumbers were placed on normal sediment (i.e. i.e. free of crushed organisms) and were monitored for three days as a negative control. Sediment enriched with diseased *H. scabra* adults was tested on 26 sea cucumbers: 21 for the first condition (50 g kg^{-1}) and 5 for the second (25 g kg^{-1}). Sea cucumbers were monitored for two days. The experiment involving the highest concentration of 50 g kg^{-1} was carried out twice, the first time with 16 individuals and the second time with 5 individuals. Sediment enriched with healthy *H. scabra* juveniles was tested on four sea cucumbers and monitored for two days. Sediment enriched with crushed fish was tested on five sea cucumbers and monitored for two days. *K. alvarezii*-enriched sediment was tested on five sea cucumbers and monitored for two days.

Pictures of individuals were taken every day. Ulceration coverage within the bivium and trivium was estimated by measuring the total ulceration surface based on dorsal and ventral pictures using ImageJ (Schneider et al. 2012). The integument ulceration coverage was expressed as a percentage of the total integument surface.

Results

In the control and in the sediment enriched with *K. alvarezii*, none of the individuals showed any degradation of their integument. No signs of disease onset or evisceration could, therefore, be detected after six days of observation.

All healthy sea cucumbers placed on sediment enriched with diseased *H. scabra* adults, at a concentration of 50 g kg^{-1}, died during the night following contact with the sediment. All individuals were found eviscerated and with a strongly disintegrated integument in the majority of cases (Fig. 1). Thirteen out of sixteen individuals present in the first batch showed a particular behaviour a few minutes after

Figure 1. Eviscératied and dead sea cucumbers placed on sediment enriched with diseased *H. scabra* adults at a concentration of 50 g kg^{-1} after one day of experiment. Scale: 3 cm

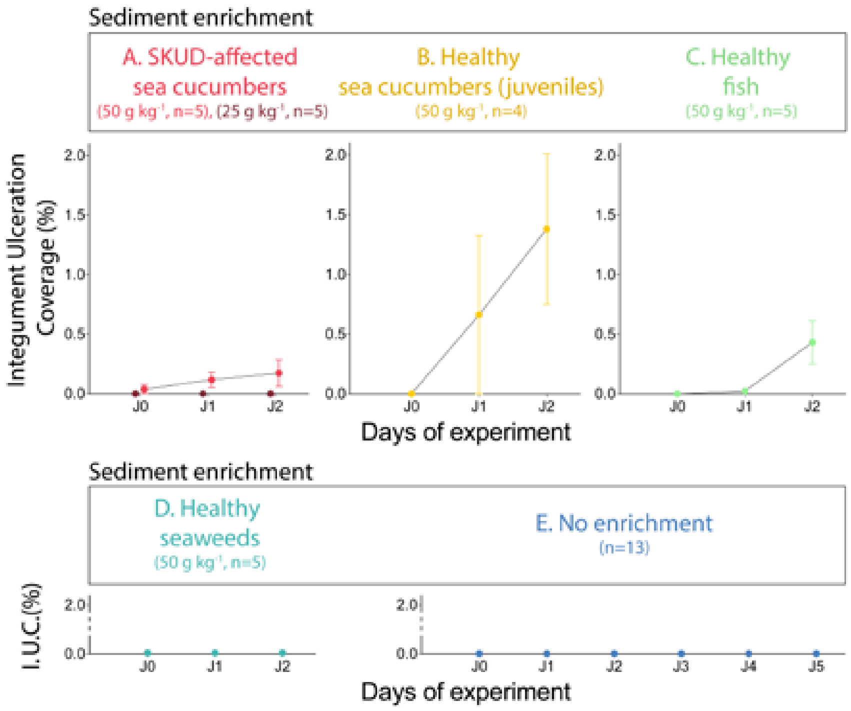


Figure 2. Integument ulceration coverage observed in *Holothuria scabra* sea cucumbers placed on an enriched sediment. The different enrichment treatments were: A) sediment enriched with crushed diseased adults of *H. Scabra*; B) sediment enriched with crushed healthy juveniles of *H. scabra*; C) sediment enriched with healthy fishes; D) sediment enriched with healthy red seaweed (*Kappaphycus alvarezii*); E) no enrichment.

Figure 3. Integument ulceration coverage observed in three *Holothuria scabra* individuals placed on sediment enriched with crushed diseased adults of *H. scabra* (A–C); crushed healthy juveniles of *H. scabra* (D–F); and healthy fishes (G–I). Two days of exposure are presented (J0 and J2). Scales A, B, D, E, G, H: 2 cm; Scales C, F, I: 1 cm.

their interaction with the enriched sediment: they were very agitated, stirred quickly and exposed their trivium upwards. They also tried to avoid the black patches that line the sediment where the density of crushed organisms was greater. The repetition of this experiment has yielded somewhat different results. At the end of the two days of observation, only 60% of individuals had moderate integumentary damage (Figs. 2A and 3), which resulted in the evisceration and death of two individuals.

None of the individuals placed on sediment enriched with diseased *H. scabra* adults at a concentration of 25 g kg^{-1} showed any sign of ulceration or evisceration (Fig. 2A).

The health of the five individuals placed on sediment enriched with crushed healthy *H. scabra* juveniles (Fig. 2B) and four individuals placed on sediment enriched with crushed healthy fishes (Fig. C) were significantly altered, even leading to the evisceration and death of one individual. All of the individuals placed on sediment enriched with crushed fishes also had ulcerated integuments, with two individuals that finally died. The other three died more slowly but still had whitish lesions on different parts of their body.

Discussion

Several studies conducted, mainly on *A. japonicus*, have suggested that certain bacteria and viruses are the agents of SKUD (Morgan 2001; Ma et al. 2006, Deng et al. 2008; Deng et al. 2009, Hongzhan et al. 2010, Hua et al. 2010; Li et al. 2010; Yancui et al. 2011; Liu et al. 2012; Yancui et al. 2012). SKUD symptoms are found in several species of sea cucumbers that have varying geographic distributions (Morgan 2001; Deng et al. 2008; Deng et al. 2009; Hongzhan et al. 2010; Yancui et al. 2011; Liu et al. 2012). Here, we have demonstrated that enriched sediments with various types of organic matter can induce skin ulcerations in *H. scabra*. The concept of SKUD does not refer to one single disease but to a group of diseases characterised by similar macrosymptoms, including skin ulcerations. In this context, this work refers to a specific SKUD that is present in the sea pens in Toliara, Madagascar.

Another point suggested by these results is that a high proportion of animal organic matter in ingested sediments does not seem to be good for the survival of *H. scabra*. Indeed, not only does sediment enriched with crushed sea cucumbers with skin ulcerations induce ulcerations in healthy individuals following ingestion, but also sediment enriched with healthy integument from sea cucumbers or with crushed fishes. On the other hand, seaweed-enriched sediment does not induce skin ulcerations. This result goes in the same direction as the results of Plotieau and colleagues (2014) who compared sea cucumber growth in two villages on the coast of Madagascar: Tampolove and Fiherenaramasay. Sea cucumber growth was better in Tampolove, where sediments contain a high proportion of primary producers, than in Fiherenaramasay, where organic matter contains fragments of organisms from a higher level of the food chain. They explained this situation by the presence of a very important population of ophiurids (*Ophiocoma scolopendrina*) at a density of > 3 ind. m^{-2} at Fiherenamasay, but not in the other three villages. Once they die, ophiuroids may greatly contribute to the formation of organic matter, a hypothesis supported by the high proportion of magnesian calcite found in the sediment, since the skeleton of echinoderms consists mainly of magnesian calcite.

Animal organic matter does not appear to be good for the survival and growth of *H. scabra*. In previous research (Rakotonjanahary et al. 2016), different foods were tested in ponds on juveniles that grew under the same conditions (i.e. temperature, salinity and density). The worst results were obtained with sediments with added provender. The provender was made with fish flour as a source of animal protein (30%), soya powder as a source of vegetable protein (26%), peanut pieces as a source of lipids (17%), and rice or cassava as a source of carbohydrates, and was added two times per week. After seven weeks, the survival rate was of 42% and the biomass was less than 50 g m^{-2}, both values being the worst results of the tested food.

These researches indicate that the presence of vegetal organic matter seems preferable than animal organic matter in the food of *H. scabra*. With regard to farming, we suggest checking the trophic level of the sediment through δN isotopic analysis, when possible, or at least checking the presence of well-developed seagrass beds in the vicinity of the farming sites that would bring vegetal organic matter during the natural recycling.

Bibliography

Becker P., Gillan D., Lanterbecq D., Jangoux M., Rasolofonirina R., Rakotovao J. and Eeckhaut I. 2004. The skin ulceration disease in cultivated juveniles of *Holothuria scabra*. Aquaculture 242:13–30.

Deng H., Zhou Z., Wang N. and Liu C. 2008. The syndrome of sea cucumber (*Apostichopus japonicus*) infected by virus and bacteria. Virologica Sinica 23:63–67.

Deng H., He C., Zhou Z., Liu C., Tan K., Nianbin Wang N., Jiang B., Gao X. and Liu W. 2009. Isolation and pathogenicity of pathogens from skin ulceration disease and viscera ejection syndrome of the sea cucumber *Apostichopus japonicas*. Aquaculture 287:18–27.

Eeckhaut I., Parmentier E., Becker P., Gomez da Silva S. and Jangoux M. 2004. Parasites and biotic diseases in field and cultivated sea cucumbers. p. 311–325. In: Lovatelli A., Conand C. Pucell S., Uthicke and Hamel J.-F. (eds). Advances in Sea Cucumber Aquaculture and Management. FAO Fisheries Technical Paper. 463. Rome: FAO.

Hongzhan L., Fengrong Z., Xiuqin S., Xuguang H., Shuanglin D., Bo W., Xuexi T. and Yongqiang W. 2010. Identification of the pathogens associated with skin ulceration and peristome tumescence in cultured sea cucumbers *A. japonicas*. Journal of Invertebrate Pathology 105:236–242.

Hua L., Guo Q., Jie-Quan G., Wei Z., Qiang L., Sung-Ho W., De-Hai X. and Soo-Il P. 2010. Phenotypic and genetic characterization of bacteria isolated from diseased cultured sea cucumber *Apostichopus japonicus* in northeastern China. Diseases of Aquatic Organisms 91:223–35.

Li H., Qiao G., Li Q., Zhou W., Won K. M., Xu D.-H. and Park S.-I. 2010. Biological characteristics and pathogenicity of a highly pathogenic *Shewanella marisflavi* infecting sea cucumber, *Apostichopus japonicus*. Journal of Fish Diseases 33:865–877.

Liu Z. M., Ma Y.X., Yang Z.P., Li M., Liu J. and Bao P.Y. 2012. Immune responses and disease resistance of the juvenile sea cucumber *Apostichopus japonicus* induced by Metschnikowia sp. C14. Aquaculture 368:10–18.

Ma Y., Xu G., Cang Y., Zhang S., Zhou W. and Song L.S. 2006. Bacterial pathogens of skinulceration disease in cultured sea cucumber *Apostichopus japonicus* (Selenka) juveniles. Journal of Dalian Ocean University 21:13–18.

Morgan A.D. 2001. Aspects of sea cucumber broodstock management (Echinodermes: Holothurides). SPC Beche-de-mer Information Bulletin13:2–8.

Plotieau T., Lavitra T., Gilan D.C. and Eeckhaut I. 2013. Bacterial diversity of the sediments transiting through the gut of *Holothuria scabra* (Holothuroidea: Echinodermata). Marine Biology 160:3087–3101.

Plotieau T., Lepoint G., Baele J.M., Tsiresy G., Rasolofonirina R., Lavitra T. and Eeckhaut I. 2014. Mineral and organic features of the sediment in the farming sea pens of *Holothuria scabra* (Holothuroidea : Echinodermata). SPC Beche-de-mer Information Bulletin 34:29–33.

Rakotonjanahary F., Lavitra T., Fohy N. and Eeckhaut 2016. Assays for optimising the growth of *Holothuria scabra* juveniles during the nursery phase. SPC Beche-de-mer Information Bulletin 36:76–81.

Schneider C.A., Rasband W.S. and Eliceiri K.W. 2012. NIH Image to ImageJ: 25 years of image analysis. Nature methods 9(7):671–675.

Wang Y.G., Zhang C.Y., Rong X.J., Chen J.J. and Shi C.Y. 2004. Diseases of cultured sea cucumber, *Apostichopus japonicus*, in China. p. 297–310. In: Lovatelli A., Conand C. Pucell S., Uthicke and Hamel J.-F. (eds). Advances in Sea Cucumber Aquaculture and Management. FAO Fisheries Technical Paper. 463. Rome: FAO.

Yancui Z., Hongming M., Wenbing Z., Qinghui A., Kangsen M., Wei X., Xiaojie W. and Zhiguo L. 2011. Effects of dietary β-glucan on the growth, immune responses and resistance of sea cucumber, *Apostichopus japonicus* against *Vibrio splendidus* infection. Aquaculture 345:269–274.

Yancui Z., Wenbing Z., Wei X., Kangsen M., Yanjiao Z. and Zhiguo L. 2012. Effects of potential probiotic *Bacillus subtilis* T13 on growth, immunity and disease resistance against Vibrio splendidus infection in juvenile sea cucumber *Apostichopus japonicas*. Fish Shellfish Immunology 32:750–5.

Note on the pea crab *Holotheres semperi* (Bürger, 1895) parasitising the sea cucumber *Holothuria scabra* in Rempang, Indonesia

Jean-François Hamel,[1] Peter K.L. Ng,[2] Seth McCurry[3] and Annie Mercier[4]

Abstract

The present study documents the extension of the distribution range of the pea crab *Holotheres semperi*, which was recently found associated with the sea cucumber *Holothuria scabra* off the island of Rempang in the Riau Islands of Indonesia. The pea crabs were found in the right respiratory tree of the host, mainly as heterosexual pairs. The presence of *H. semperi* elicited detrimental effects on the development of the host's gonads, and can thus be considered parasitic. Aspects of its biology are discussed.

Introduction

Pea crabs (family Pinnotheridae) are decapod crustaceans that are often associated with holothuroid echinoderms or sea cucumbers, with a number of genera found only in these hosts (Schmitt et al. 1973; Jangoux 1987; Ng and Manning 2003; Ng 2018). They were historically grouped in *Pinnotheres* but are currently placed in *Holotheres*, a genus in which all members live in sea cucumbers (Ng and Manning 2003). Some species were described as colonising the respiratory tree exclusively (Hamel et al. 1999), while others to occur throughout the gut and cloaca of the host (Schmitt et al. 1973; Jangoux 1987). Pea crabs associated with holothuroids have been classified as commensal, inquilistic, parasitic or undetermined symbionts (Jones and Mahadevan 1965; Vanden Spiegel and Jangoux 1989; VandenSpiegel et al. 1992; Hamel et al. 1999). Several authors mentioned that the crabs did not feed on host tissues, nor cause detrimental effects, except to slightly wound the wall of the respiratory tree or the cloaca, forming a membranaceous cyst (Tao 1930; Jones and Mahadevan 1965; Jangoux 1987; VandenSpiegel et al. 1992). Hamel et al. (1999), however, indicated that *Holotheres halingi* in Solomon Islands induced atrophy of the right respiratory tree in its host *Holothuria scabra*. A number of other pea crabs have been previously found in *Holothuria scabra*. One, *Buegeres deccanensis*, was observed in the respiratory tree of sea cucumbers collected in Indian coastal waters (Chopra 1931; Jones and Mahadevan 1965).

Study of parasites of *Holothuria scabra* in Rempang Island, Indonesia

Between September and December 2015, specimens of the sea cucumber *Holothuria scabra* were collected at 1–3 m depth around the village of Tanjung Kertang on Pulau Rempang in the Riau Islands of Indonesia (0.934925N and 104.08063E). Upon dissection, a number of pea crabs were found. The precise location of the pea crabs in the respiratory tree was described, their sex was determined, and any visually noticeable side effects on the host (on the respiratory tree itself and other organs, including the gonads) were recorded. Voucher specimens were deposited in the Zoological Reference Collection of the Lee Kong Chian Natural History Museum at the National University of Singapore (catalogue number ZRC 2017.0823).

The crab was identified as *Holotheres semperi* (Bürger, 1895) on the basis of its carapace, third maxilliped, male pleonal and gonopod structures, as discussed in Ng and Manning (2003) (Fig. 1). Although this species has been described as a parasite of *H. scabra* around Singapore by Lanchester (1900) and Chuang (1961), the biology of this species is not well known, and its ecology and biology remain virtually unstudied. The present work extends its distribution range by 50 km to the south.

Holotheres semperi have always been found in the right respiratory tree of *H. scabra*, as described in Lanchester (1900) and Chuang (1961), have always

[1] Society for the Exploration and Valuing of the Environment (SEVE), St. Philips (NL) Canada
[2] Department of Biological Science, National University of Singapore, Singapore
[3] Innovare Development and Consulting, Batam, Indonesia
[4] Department of Ocean Sciences, Memorial University, St. John's (NL) Canada

been found to be firmly attached to the inner body wall. The infestation frequency was ~86.2% of all sea cucumbers examined (n = 29), including 13 males and 12 female hosts (4 sea cucumbers were found without crab). Occurrences of the pea crabs in the different hosts included single individuals (n = 3), pairs (n = 21) and one trio.

Holotheres semperi is light brown or beige when alive. The carapace width is 750 ± 45 µm in males and 1,100 ± 85 µm in females (Fig. 1). The single individuals found were all males, the pairs were composed of one individual of each sex, and one trio was composed of a male, a female, and one small juvenile (435 µm). In pairs, individuals were positioned side by side, touching each other; the male was always deeper inside the respiratory tree than the female. Both were attached firmly to the inner surface of the respiratory tree with elastic threads. In the case of the trio, the smaller individual was the one closest to the cloaca.

The proximity of both sexes may facilitate fertilisation during the reproductive season. Moreover, the fact that the female is closer to the cloacal opening likely favours the release of larvae outside the host, as previously suggested for *H. halingi* (cf. Hamel et al. 1999). The pelagic first zoeae of *H. halingi* were observed during exhalation of a host sea cucumber *H. scabra* (expulsion of seawater through the anus) (Hamel et al. 1999). When a third pea crab was found in the same host, but was not attached to the inner wall of the respiratory tree, suggests that it was an established pair that was visited by another pea crab, presumably an immature individual seeking a new host. As colonisation of the host is believed to primarily occur at the final larval stage (Hamel et al. 1999), it is possible that the third individual metamorphosed in an area where the number of infected sea cucumbers was already very high and there were few or no 'uncolonised' hosts available.

The respiratory tree of *H. scabra* individuals hosting *H. semperi* showed signs of atrophy and thickening of its general structure, similar to what was seen with *H. scabra* infested by *H. halingi* in Solomon Islands (Hamel et al. 1999). When compared with other individuals of *H. scabra* collected during the same period, in which normally developed gonads were found (n = 4 individuals), the sea cucumbers infected by pea crabs always possessed small degenerated gonads or no gonads at all, suggesting that the association is a parasitic one. This, to our knowledge, represents the first documentation of a major detrimental effect associated with the presence of a pea crab in a sea cucumber host. Because pea crabs are commonly found deep inside sea cucumbers, and thus are difficult to detect and monitor, our understanding of their behaviour and social interactions remains fragmentary. The present observations are significant as the pea crabs can affect how well and how fast cultured sea cucumbers grow, and whether they can be used as broodstock, especially if the degree of parasitism is high.

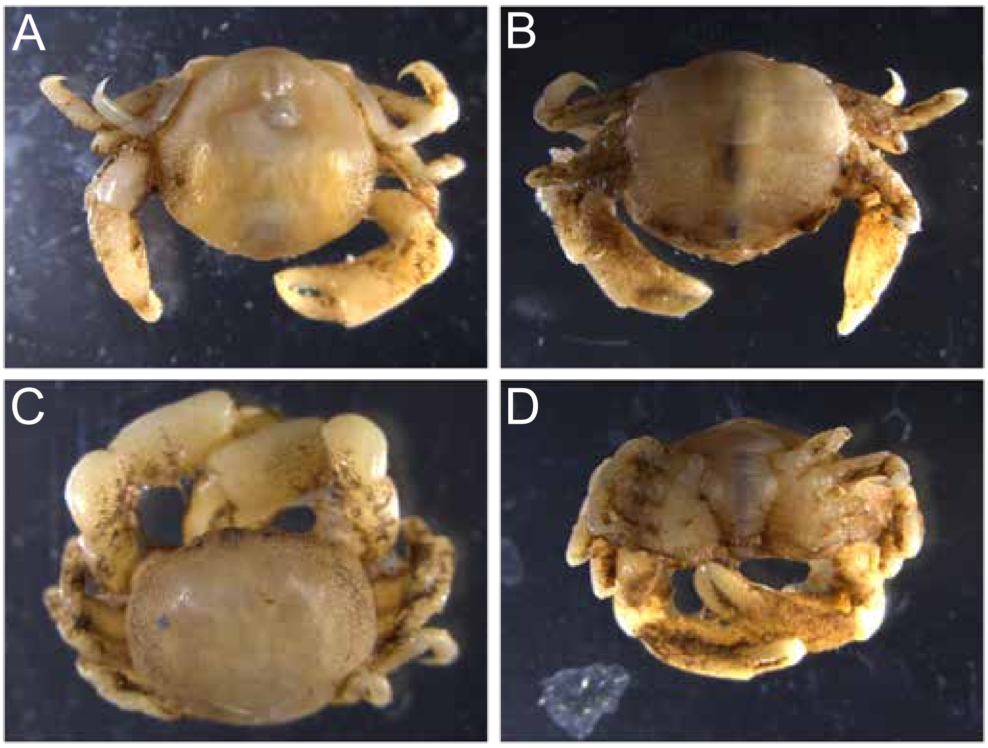


Figure 1. *Holotheres semperi*. (A) Dorsal view and (B) ventral view of female (~980 µm carapace width). (C) Dorsal view and (D) ventral view of male (~750 µm carapace width).

Acknowledgements

We would like to thank the team of technicians and the president of Innovare, John McCurry, as well as Jo Calcutt, for their help with the collection of sea cucumbers and the study of this pea crab in Indonesia.

References

Chopra B. 1931. Further notes on Crustacea Decapoda in the Indian Museum. II. On some decapod crustacea found in the cloaca of holothurians. Records of the Indian Museum 33:303–325.

Chuang S.H. 1961. On Malayan shores. A log cabin book. Singapore: Muwu Shosa Publishers, 225 p. + 112 pls.

Hamel J.-F., Ng P.K.L. and Mercier A. 1999. Life cycle of the pea crab *Pinnotheres halingi* sp. nov., an obligate symbiont of the sea cucumber *Holothuria scabra* Jaeger. Ophelia 50:149–175.

Jangoux M. 1987. Diseases of Echinodermata. III. Agents metazoans (Annelida to Pisces). Diseases of Aquatic Organisms 3:59–83.

Jones S. and Mahadevan S. 1965. Notes on animal associations. 5. The pea crab *Pinnotheres deccanensis* Chopra inside the respiratory tree of the sea cucumber, *Holothuria atra* Jaeger. Journal of the Marine Biological Association of India 7:377–380.

Lanchester W.F. 1900. On the collection of crustaceans made at Singapore and Malaca. Part I. Crustacea Brachyura. Proceedings of the Zoological Society of London 1900:719–770, pls. 44–47.

Ng P.K.L. 2018. On the identities of *Pinnotheres villosissimus* Doflein, 1904, *P. dofleini* Lenz, in Lenz & Strunck, 1914, and *P. pilumnoides* Nobili, 1906 (Decapoda, Brachyura, Pinnotheridae) from the western Indian Ocean. Crustaceana 91(5):611–633.

Ng P.K.L. and Manning R.B. 2003. On two new genera of pea crabs parasitic in holothurians (Crustacea: Decapoda: Brachyura: Pinnotheridae) from the IndoWest Pacific, with notes on allied genera. Proceedings of the Biological Society of Washington 116(4):901–919.

Schmitt W.L., McCain J.C. and Davidson E.S. 1973. Fam. Pinnotheridae. Brachyura I: Decapoda I. In H.-E. Gruner and L.B. Holthuis (eds): Crustaceorum Catalogus 3. P. 1–160. In: Tao L. 1930. Notes on the ecology and physiology of *Caudina chilensis* (Miiller), in Matsu Bay. Pacific Science Congress 3:7–11.

Tao L. 1930. Notes on the ecology and physiology of *Caudina chilensis* (Miiller), in Matsu Bay. Pacific Science Congress 3:7–11.

VandenSpiegel D. and Jangoux M. 1989. Sur la symbiose entre le Pinnotheride *Pinnotheres villosissimus* (Crustacea, Decapoda) et l'holothurie *Actinopyga mauritiana* (Echinodermata). Vie Marine, Hors Série 10:205–213.

VandenSpiegel D., Ovaere A. and Massin C. 1992. On the association between the crab *Hapalonotus reticulatus* (Crustacea, Brachyura, Eumedonidae) and the sea cucumber *Holothuria* (*Metryatila*) *scabra* (Echinodermata, Holothuridae). Bulletin de l'Institut Royal des Sciences Naturelles de Belgique 62:167–177.

Are Vietnamese fisher-divers aware of the need to preserve their health and maritime environment?

Jean Ruffez[1*] and AFEPS[1]

Introduction

In the mid-1990s, the Institut Pasteur of Nha Trang, which monitors the health of fishers in central Vietnam, alerted the Association francophone d'entraide et de promotion des sciences de la vie (AFEPS) to the high mortality and morbidity of fishermen who dive using compressed air to carry out their fishing activities. These 'fisher-divers' collect everything that has a market value and, essentially, any holothurian that they find at depths of up to 65 m. Responding to the alert, the AFEPS Aid to Fishermen Divers programme was established in Vietnam in 1998. The programme operates in two provinces: Kanh Hoa and Binh Thuan, where more than 200 people have been trained in safe diving techniques.

Training in Khanh Hoa Province

In Khanh Hoa Province, we, at AFEPS, sensed there was a willingness on the part of both fisher-divers and local authorities to move towards the use of protected marine areas and more sustainable fishing practices.

In the village of Ninh Phuoc (Ninh Hoa District), fisher-divers have joined forces with the maritime police (voluntarily or not) to conduct night patrols in protected areas and prevent 'electric fishing' and the use of chemicals to capture fish and other marine organisms.

A large number of fisher-divers, sometimes too many, expressed interest in receiving training in accident prevention, accident management and first aid adapted to seafarers.

We were surprised by the number of active fisher-divers who have already had neurological accidents and are still suffering from their after-effects. All fisher-divers complained of osteoarthritis and muscular pain.

The local People's Committee[2] has organised the handling of accidents and have distributed TIR (therapeutic immersion recompression) kits in clinics along the coast. In this way, injured divers can quickly benefit from the equipment necessary to manage their accident (e.g. oxygen and re-immersion kit). We do not know, however, how boats leaving for a long-distance fishing trip are able to access the rescue equipment or if they are allowed to carry TIR kits.

Indeed, several crews continue to head to the distant coasts of countries bordering the South China Sea (East Sea for the Vietnamese). They have difficulties fishing in the Paracel or Spratly Islands and prefer to go to Malaysia, Indonesia and the Philippines. Some crews go even farther out to sea.

During the training, we noted that fishermen who dove frequently understood that their enemy is the nitrogen (nito in Vietnamese) they breathe under pressure. Even if they did not entirely give up some of their beliefs – such as blaming a diving accident on either 'an evil wind' or 'an offence allegedly done to an ancestor' or 'the omission of a tribute paid to the sea before diving' – they took into account our advice on the rate of ascent (tu tu, go slowly in Vietnamese). They especially agreed to make stops and never to recompress themselves to a depth of more than 9 m.

Trained people told us that our 40-L oxygen cylinders were too heavy and difficult for one person to handle. We have, therefore, decided that in the future we will purchase 20-L oxygen cylinders. This volume allows only one oxygen TIR and two

[1] Association francophone d'entraide et de promotion des sciences de la vie. 8, rue du Général-Renault, BP 167 - 75011 Paris. AFEPS is a French non-governmental organisation involved in collaborations with fisher-divers (see: http://purl.org/spc/digilib/doc/v4nj5).

[2] In Vietnam, the People's Committee (Uỷ Ban Nhân Dân) is the executive arm at provincial level, and is responsible for formulating and implementing policy (source: https://en.wikipedia.org/wiki/Provinces_of_Vietnam#Governance).

* Email: afepsparisiledefrance@gmail.com

A. Theoretical training; B. In the corridor for exercises; C. Therapeutic immersion recompression (TIR) practice at sea; D. Group photo.

hours of normobar oxygenation. Ideally, two 20-L cylinders should be available. This is what we recommend for recreational diving clubs working in isolation.

Training three lecturers from Nha Trang Sea University

During the course of the programme, three lecturers from the Nha Trang Sea University were introduced to diving and followed the training of fisher-divers. We hope they will be able to add the prevention and management of diving accidents to the training curriculum for seafarers and future seafarers, a programme under their responsibility at the university.

Training in Binh Thuan Province

In Binh Thuan Province, where AFEPS began operations, we appreciated the cooperation of three governmental departments: Health, Maritime Affairs and Maritime Police.

We first trained about 50 medical staff, and discussed with them the different accidents that can happen to divers. Our delegate in Vietnam, Dr Nguyen Van Mui, was able to explain the projected images and texts directly in the Vietnamese language. We discussed diving accident management techniques and the equipment needed to deal with them.

Practical training of three lecturers from Nha Trang Sea University.

We then trained a dozen crew members of diving fishing boats. We conducted the theoretical training at the Maritime Affairs Department. The practical training at sea was organised in the port of Phan Thiet. AFEPS gave 10 TIR kits (one 40-L oxygen cylinder, a pressure reducer, 12.5-m hose and a nitrox octopus) to these crews. The kits will be kept onboard the boats. These boats are used for distant fishing and we are confident that the kits, if needed, will be used by trained people.

Throughout the crew training, we were very satisfied with the involvement of the three government departments. Their representatives actively participated in the training sessions and showed great enthusiasm.

It now seems to us that training could be done in fisher-diver villages along the coast of the province and especially on the islands that shelter most of the divers.

Training of medical personnel by Dr Nguyen Van Mui.

Training at sea.

In 2019, we will respond to new requests from three additional provinces (Khanh Hoa, Binh Thuan and Quang Ngai), and will continue to train teacher-researchers at Nha Trang Sea University if they so wish and if the university authorities encourage them to do so. We plan to relaunch our assistance to disabled diving fishers (self-rehabilitation training). We have also requested the Hanoi authorities to renew our work permit, which ends in October 2019. We hope to have it extended for several more years.

Illegal fishing of the sea cucumber *Isostichopus fuscus* is rampant in the Gulf of California, Mexico

Luis E. Calderon-Aguilera[1]

Abstract

The brown sea cucumber, *Isostichopus fuscus*, has been harvested in the Mexican Pacific since 1988 but the fishery was closed in 1994 due to overfishing, and the species was listed as at-risk in the Official Mexican Standard (NOM-059). In 2000, its status changed to under special protection and some permits to fish for this species were granted. However, illegal, unreported and unregulated fishing has always taken place in the Gulf of California where *I. fuscus* is more abundant. This work shows that the mean density of this sea cucumber has decreased from 15 ind. 100 m^{-2} in 2007 to 2.8 in 2016, a reduction of more than five fold, and that the reductions are largely due to illegal fishing. Official sources report that between 2013 and 2018, 1,024,813 individual sea cucumbers were confiscated in the region, so the illegal catch is certainly much larger. It is essential to increase surveillance in the field and law enforcement at borders, otherwise this species will soon become commercially extinct.

Keywords: poaching, unreported, illegal fishing, *Isostichopus fuscus*, protected area, Mexico, Gulf of California

Introduction

One of Mexico's most valuable marine resources is the brown sea cucumber *Isostichopus fuscus* Ludwig, 1875. This precious commodity is exported to Asia where there is a huge demand for sea cucumbers,[2] and species such as *I. fuscus* can fetch up to USD 1,030 kg^{-1} (Purcell et al. 2014).

The sea cucumber fishery in the Gulf of California is a textbook example of a boom-and-bust cycle: from non-existent until 1988 when the fishery began (Singh-Cabanillas and Vélez-Barajas 1996), to a peak in 1991, followed by a sharp decrease in 1993 (Fig. 1). In 1994, *I. fuscus* was listed in the Official Mexican Standard (NOM) 059 as being a species at-risk (SEMARNAP 1994) and the fishery was totally banned until 2000 when its status changed to a species under special protection, and some permits to harvest it were granted. The use of *I. fuscus* is regulated by the General Wildlife Law (Ley General de Vida Silvestre) and its regulations, and can only be harvested if ad hoc technical studies show that the population will not be affected (SEMARNAT 2010). Moreover, it is listed as an endangered species by the International Union for Conservation of Nature[3] and is included in the Convention on the International Trade in Endangered Species Appendix III[4] as per the Government of Ecuador's request.[5]

Methods

Fieldwork

In 2005, at the request of Mexico's Secretariat of Environment and Natural Resources (Secretaría del Medio Ambiente y Recursos Naturales, SEMARNAT), we began conducting surveys along the east coast of Baja California to estimate the density of *Isostichopus fuscus*. Night surveys were conducted (during the day the sea cucumber hides among crevices, holes and rocks) using semi-autonomous diving gear, known as 'hooka', which consists of a compressor that supplies air through a hose to the diver. Despite the fact that at the time no permits were being issued, we frequently observed poachers boiling sea cucumbers in the islands.

Sampling consisted of band transects 2 m wide by 25 m long, so that a surface area of 50 m^2 was covered by each transect and two transects were made at each depth. If the site was more than 20 m deep,

[1] Professor Department of Ecology, Ensenada Center for Scientific Research and Higher Education, Mexico. (Centro de Investigación Científica y de Educación Superior de Ensenada, or CICESE). Email: leca@cicese.mx
[2] http://www.eluniversal.com.mx/articulo/periodismo-de-investigacion/2016/03/6/mafia-china-arrasa-con-pepino-de-mar
[3] http://www.iucnredlist.org/details/180373/0
[4] https://www.cites.org/eng/app/appendices.php
[5] *Isostichopus fuscus* has been found in: Colombia (mainland and Malpelo Is.); Costa Rica (mainland and Cocos Is.); Ecuador (mainland and Galápagos); El Salvador; Guatemala; Honduras; Mexico (Pacific coast and Revillagigedo Is.); Nicaragua; Panama; and Peru (Source: https://www.iucnredlist.org/species/180373/1621878#geographic-range)

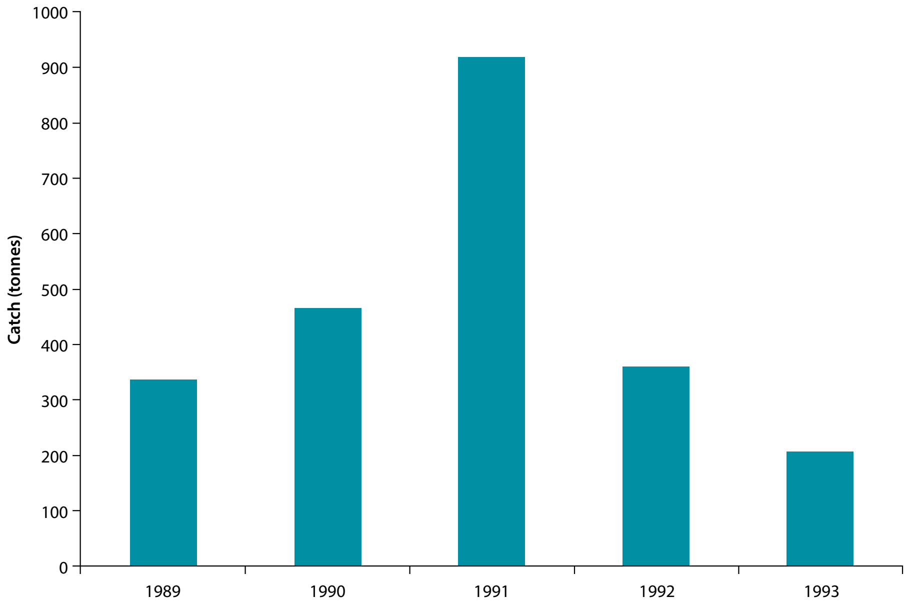


Figure 1. Historical catches of the sea cucumber *Isotihopus fuscus* from the Gulf of California.

two transects were made at maximum depth, two at medium depth, and two in shallow water (3–5 m). If that depth was not reached, then three dives were made at the greatest depth and three at a shallower depth, in order to complete six transects per dive. In all cases, two divers (previously trained professional fishermen) collected all specimens found, brought them on board for weighing and sizing, and threw them back in the sea afterward.

Estimation of illegal fishing

In order to gain a rough idea of how many sea cucumbers were illegally being caught, local press and official reports, mainly those of the Federal Attorney for Environmental Protection (Procuraduría Federal de Protección al Ambiente, PROFEPA), were reviewed for the period 2013 to April 2018.

Data analysis

The mean density and standard deviation for each polygon were fitted to a lognormal model of nonzero survey values (a delta-distribution), as suggested by Pennington (1996).

Results

During the surveys conducted between November 2005 and August 2007, the overall mean density was 15 ind.·100 m^{-2}, with values ranging from as low as 0.0065 to 0.6600 (Fig. 2).

By 2013 the mean density (± SD) had decreased to 7 (± 1) and the most recent data (October 2016) shows that it is around 2.8 (Table 1), a substantial decrease in just three years.

A summary of press-reported confiscations of sea cucumbers is presented in Table 2. As can be seen, in just 11 reports found between May 2013 and April 2018, over a million pieces of sea cucumber from the Gulf of California have been confiscated. Taking an average of 38.5 g per dried piece[6] means that over 26,618 tonnes of sea cucumber have been illegally caught in the region, according to official sources.

Discussion

Based on the evaluations carried out between 2005 and 2007, in 2008 SEMARNAT – through the General Directorate of Wildlife – (General de Vida Silvestre, DGVS), granted exploitation quotas to 10 permit holders. Those quotas were 4, 8, 17, 36, 46, 65, 80, 96, 114 and 225 tonnes (wet weight) to each permit holder, supposedly according to the granted area. It is difficult to obtain data after 2009 from DGVS, in part due to the frequent change of director, and because there are no reliable statistics of catches. While catches of any resource that is under the management of the National Commission for Fisheries (Comisión Nacional de Acuacultura y Pesca, CONAPESCA) must be reported, the sea cucumber is under the management of SEMARNAT, which does not publish harvesting data.

In a previous study conducted in the same region, Glockner-Fagetti et al (2016) pointed out that, according to interviewees, poaching is the major

[6] Assuming, according to Glockner-Fagetti et al. (2016) that the mean wet weight is 303 g and the dried weigh is 12% (after Ngaluafe and Lee 2013).

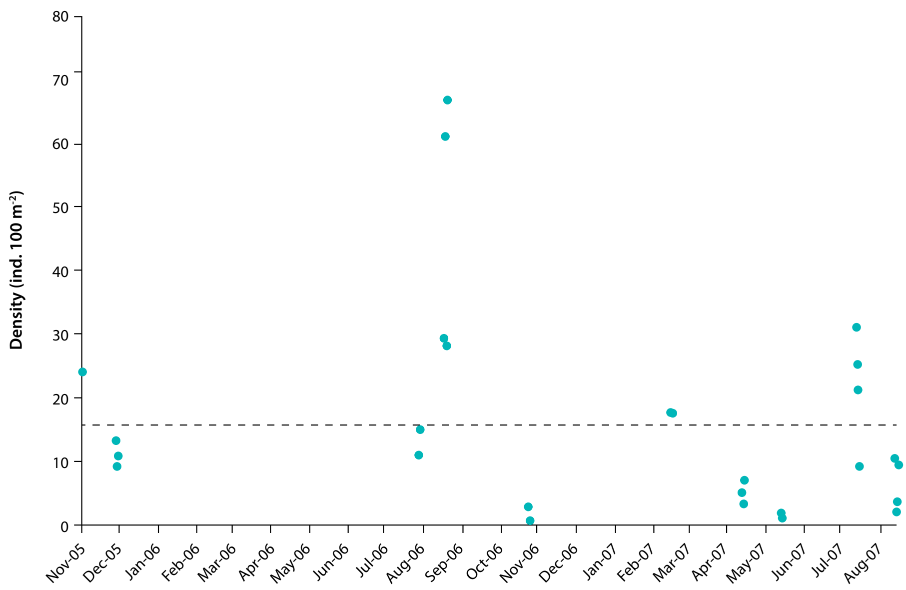


Figure 2. Mean density of the sea cucumber *Isotichopus fuscus* found in surveys conducted along the east coast of Baja California between November 2005 and August 2007. The dotted line is the overall mean density.

threat to the sea cucumber *Isotichopus fuscus*. Illegal, unreported and unregulated fishing is a significant issue all over the world (Agnew et al. 2009) and due to their high value, illegal sea cucumber fishing happens everywhere (Conand 2018). Mexico is not exempt from this problem and in a global analysis of all fisheries, Cisneros-Montemayor et al. (2013) estimate that illegal sea cucumber fishing in Mexico accounts for twice the number of reported catches. Considering that in less than 10 years the relative abundance of *I. fuscus* has decreased in number from 15 ind.·100·m^{-2} in 2007 to 2.8 in 2016, the only possible explanation is excessive poaching in the region.

Finally, from the results of this work, the following management recommendations are proposed:

1. Restrict fishing to daylight hours only. It is well known that the sea cucumber *Isotichopus fuscus* is nocturnal and hides in hollows during the day. Banning nightly harvesting has two advantages: i) everyone who fishes at night will clearly be illegally fishing, and ii) it will work as a precautionary measure. Recent work (Reyes-Bonilla et al. 2016) shows that, on average, 15% of the organisms in a place go unnoticed during the day.

2. Limit catches to the 30-m isobath. This measure also has a double purpose: 1) to safeguard the lives of divers, and ii) to protect the proportion of the sea cucumber population that is found at greater depths.

Table 1. Central coordinates of the sampling area, total number of transects conducted (n), transects with the presence of organisms (P) and density (ind. 100 m^{-2}, delta mean) of the sea cucumber *Isotichopus fuscus* in the Gulf of California.

N	W	n	P	Mean	SD
29.50964	-113.57037	24	17	2.41	39.31
29.09823	-113.15294	16	8	1.86	22.9
29.11297	-113.27457	40	30	3.69	36.94
29.19238	-113.63514	32	25	2.69	45.29
28.95545	-113.48222	98	76	3.57	34.54
28.94544	-113.42378	48	13	1.56	25.61
28.81920	-113.21543	56	38	2.62	35.24
28.56816	-113.11781	12	10	2.46	40.37
28.36875	-112.85321	46	37	2.91	41.51
29.37953	-113.74209	14	11	2.71	43.19
29.28451	-113.28955	60	38	2.74	28.13
29.05177	-113.51384	34	24	3.15	31.7
28.61218	-112.80464	18	15	3.56	33.82

3. Establish a minimum size of 20 cm and a minimum weight of 500 g. The only way to avoid overfishing is to ensure that sea cucumbers have had a chance to reproduce at least once (Pañola-Madrigal et al. 2017).
4. Set a quota on the number of individual sea cucumbers. This measure would discourage the capture of young and subadult organisms, which, in addition to having very low market prices, would lead to overfishing and no or little recruitment.
5. Close the fishing season from the beginning of May to the end of October. A recent study (Pañola-Madrigal et al. 2017) shows that in September there are still reproductively active organisms, so fishing for them could negatively affect recruitment.
6. Establish a standardised pre-season monitoring programme. For the allocation of harvest quotas, it is necessary to know the current state of the stock. It is also necessary that the evaluation of all sites is done in the same way systematically.
7. Establish non-fishing zones to ensure reproduction and recruitment. Although it is a difficult measure to implement due to the possible reluctance of the person assigned to the federal land, it is necessary for ensuring the sustainable use of this resource.
8. Strengthen surveillance. Illegal fishing of sea cucumbers (and many other species) is a well-known and poorly addressed problem. Surveillance needs to be strengthened and carried out at all steps of the trade, from harvesting to marketing.

Conclusion

It is very difficult to prove an incidence of illegal fishing. However, everyone in the fisheries sector recognises that this is a very serious problem. Moreover, many acknowledge that they themselves sometimes fish illegally, arguing that the process of getting a permit is cumbersome, expensive and dependent on the good-will of a bureaucrat. Because sea cucumbers are an export commodity, more attention should be focused at customs and borders. Nonetheless, this species is listed in Convention on the International Trade in Endangered Species Appendix III and, therefore, the international trade of this species is allowed only on presentation of the appropriate permits and/or certificates. It is a race against time: either illegal fishing stops immediately, or the sea cucumber *Isotichopus fuscus* will soon be commercially extinct.

Table 2. Date of operation, number of sea cucumber pieces confiscated in the Baja California peninsula by source of information.

Date	Number of pieces confiscated	Source
25/05/2013	898,660	http://www.profepa.gob.mx/innovaportal/v/5078/1/mx.wap/asegura_profepa_millonario_cargamento_ilegal_de_pepino_duro_de_mar__hipocampos_y_buche_de_totoaba.html
10/11/2014	58,115	https://www.gob.mx/profepa/prensa/dicta-juez-federal-auto-de-formal-prision-a-1-persona-por-posesion-ilegal-de-58-115-ejemplares-de-pepino-de-mar-en-baja-california
20/02/2016	8,263	https://www.gob.mx/profepa/prensa/semar-profepa-y-sea-shepherd-conservation-society-liberan-ballena-jorobada-atrapada-en-una-red-en-el-alto-golfo-de-california-84803
27/03/2016	229	https://www.gob.mx/profepa/es/prensa/la-profepa-y-semar-aseguran-cargamento-de-229-pepinos-de-mar-y-presentan-ante-el-mpf-a-tres-personas-en-baja-california-85669?idiom=es
22/06/2016	40,396	https://www.gob.mx/profepa/prensa/asegura-profepa-cargamento-de-40-396-ejemplares-de-pepino-de-mar-en-baja-california
29/09/2016	871	https://www.gob.mx/profepa/prensa/asegura-profepa-y-policia-municipal-de-ensenada-baja-california-cargamento-de-871-ejemplares-de-pepino-de-mar-presentan-a-una-persona-ante-el-mpf
21/02/2017	200	https://www.gob.mx/profepa/prensa/asegura-profepa-200-ejemplares-de-pepino-de-mar-en-b-c-s
23/04/2017	15,764	https://www.gob.mx/profepa/prensa/aseguran-profepa-15-764-ejemplares-de-pepino-de-mar-en-tijuana-que-pretendian-enviar-ilegalmente-a-e-u-a
26/04/2017	1,540	https://www.gob.mx/profepa/prensa/asegura-profepa-1-540-ejemplares-de-pepino-de-mar-en-sonora
15/06/2017	256	https://www.gob.mx/profepa/videos/asegura-profepa-sedena-y-semar-cargamento-de-256-piezas-de-pepino-de-mar-en-baja-california-114443
09/04/2018	519	http://www.elvigia.net/911/2018/4/9/decomisan-metanfetaminas-pepino-300672.html

Acknowledgements

Data from 2005–2007 were gathered with the support of Fundacion PRODUCE (grant number 02-2006-5578) in 2013 by the Government of Baja California and in 2016 by the CONANP (PROCER O1SC). Thanks are due to A. Scanlan for proofreading.

References

Agnew D.J., Pearce J., Pramod G., Peatman T., Watson R., Beddington J.R. and Pitcher.T.J. 2009. Estimating the worldwide extent of illegal fishing. PLoS ONE 4 (2). https://doi.org/10.1371/journal.pone.0004570.

Cisneros-Montemayor A.M., Cisneros-Mata M.A., Harper S. and Pauly D. 2013. Extent and implications of IUU catch in Mexico's marine fisheries. Marine Policy 39(1):283–88. https://doi.org/10.1016/j.marpol.2012.12.003.

Conand C. 2018. Recent information on worldwide illegal fisheries for sea cucumbers. SPC Beche-de-Mer Information Bulletin 38:68–71.

Glockner-Fagetti, A., Calderon-Aguilera L.E. and Herrero-Pérezrul M.D. 2016. Density decrease in an exploited population of brown sea cucumber *Isostichopus fuscus in a biosphere reserve from the Baja California peninsula, Mexico. Ocean and Coastal Management 121:49–59*. https://doi.org/10.1016/j.ocecoaman.2015.12.009.

Ngaluafe P. and Lee J. 2013. Change in weight of sea cucumbers during processing: Ten common commercial species in Tonga. SPC Beche-de-mer Information Bulletin 33:3–8.

Pañola-Madrigal A., Calderon-Aguilera L.E., Aguilar-Cruz C.A., Reyes-Bonilla H. and Herrero-Pérezrul M.D. 2017. Reproductive cycle of the sea cucumber (*Isostichopus fuscus)* and its relationship with oceanographic variables at its northernmost distribution site. Revista de Biologia Tropical 65(1):S180–96. https://doi.org/10.15517/rbt.v65i1-1.31687.

Pennington M. 1996. Estimating the mean and variance from highly skewed marine data. Fishery Bulletin 94(3):498–505.

Purcell S.W, Polidoro B.A., Hamel J.F., Gamboa R.U. and Mercier A. 2014. The cost of being valuable: Predictors of extinction risk in marine invertebrates exploited as luxury seafood. Proceedings of the Royal Society B 281 (1781): 20133296. https://doi.org/10.1098/rspb.2013.3296.

Reyes-Bonilla H., Ramírez-Ortiz G., Herrero-Pérezrul M.D. and Calderon-Aguilera L.E. 2016. Underestimation of the abundance of brown sea cucumber *Isostichopus fuscus* (Holothuroidea: Echinodermata) in daylight compared to nighttime surveys in the Gulf of California. [Subestimación de La Abundancia Del Pepino Café Isostichopus fuscus (Holothuroidea: Echinodermata) en muestreos diurnos con respecto a nocturnos en el golfo de California]. Revista Mexicana de Biodiversidad 87(2):519–522. https://doi.org/10.1016/j.rmb.2016.05.004.

SEMARNAP. 1994. Norma Oficial Mexicana NOM-059-ECOL-1994, que determina las especies y subespecies de flora y fauna silvestres terrestres y acuáticas en peligro de extinción, amenazadas, raras y las sujetas a protección especial, y que establece especificaciones para su aprovechamiento. Mexico: Diario Oficial de la Federación.

SEMARNAT. 2010. Norma Oficial Mexicana NOM-059-ECOL-2010, que determina las especies y sub- especies de flora y fauna silvestres terrestres y acuáticas en peligro de extinción, amenazadas, raras y las sujetas a protección especial, y que establece especificaciones para su aprovechamiento. México: Diario Oficial de la Federación.

Singh-Cabanillas J. and Vélez-Barajas J.A. 1996. La Pesquería de Pepino de Mar *Isostichopus fuscus* en la Costa Oriental de Baja California Sur y Propuesta de Regulación. Cienc Pesq 12:13–18.

Reproductive biology of *Holothuria* (*Roweothuria*) *poli* (Holothuroidea: Echinodermata) from Oran Bay, Algeria

Farah Slimane-Tamacha,[1*] Dina Lila Soualili[1] and Karim Mezali[1]

Abstract

Our study is a first contribution of the reproductive biology of the aspidochirotid sea cucumber *Holothuria (Roweothuria) poli* at Kristel Bay at Ain Franine in Oran Province, Algeria. Sampling was conducted on 305 individuals (129 males, 131 females and 45 of indeterminate sex) from October 2016 to September 2017. Five macroscopic and microscopic sexual maturity stages have been identified in the gonadal tubules: recovery (I), growing (II), early mature (III), mature (IV) and spent (V). Also, the size at first sexual maturity within the entire population is 135 mm. Our results show that the maturation of the gonads (stages III and IV) occurs from March until May. From May to July, the entire sampled population is at full sexual maturity, and it is only in July that spawning begins, which extends up to September. The period of non-reproductive activity is between October and November.

Key words: *Holothuria poli*, reproduction, sexual maturity, southwest Mediterranean Sea

Introduction

Holothuria poli Delle Chiaje, 1824 is a frequent and abundant sea cucumber along the Algerian coast (Mezali 2008). It plays an important role in the recycling of organic matter in marine bottom sediment and it is now considered a target species for the Mediterranean fisheries (Purcell et al. 2013). The main countries that exploit *H. poli* are Turkey, Spain, Greece, Italy and Portugal. The Turkish sea cucumber fishery started in 1996 and reached about 600 tonnes (t) in 2011; *Holothuria poli* represented 80% of the catches (González-Wangüemert et al. 2014). Sea cucumbers are mainly exported to Asian countries in the form of frozen, dried and salted products (Aydin 2008; Aydin et al. 2011).

In Algeria, detailed studies have been carried out on the population dynamics of *H. poli* (densities and biomasses) (Mezali et al. 2006). Biological aspects such as biometrics, growth and feeding behaviour have also been detailed (Mezali and Semroud 1998; Mezali et al. 2003, 2006; Mezali and Soualili 2013). Although some aspects of reproduction have been studied for the two main sea cucumber species *Holothuria sanctori* and *H. tubulosa* (Mezali et al. 2014; Mezali and Soualili 2015), no studies exist on the reproductive cycle and the maturation of the gonads of *H. poli*.

Material and methods

Study area

The Ain Franine station is located on the western end of Algeria's coast, and is in the Bay of Oran, 8 km from Kristel (35° 46′52.40″N and 0° 30′50.12″ W) (Fig. 1). This area is considered as being little impacted by anthropogenic activity (Hebbar 2013).

Identification and characteristic of the studied species

Identification of *H. poli* is based on morphological, anatomical, and endo-skeletal criteria (Koehler 1921; Tortonese 1965). This species does not present a defence organ (Cuvierian tubules), but does present white podias that are scattered throughout the ventral part of the body (Mezali 2008). Microscopic observation of the ossicles showed the presence of different forms of regular and smooth loops and pseudo-buttons and small tables (Mezali 2008). The gonad of *H. poli* is located in the left of the dorsal mesentery and has a single genital duct at its base to the outer part of gonopore, and consists of a single clump of tubules.

[1] Protection, Valuation of Marine and Coastal Resources and Molecular Systematics Laboratory, Department of Marine Sciences and Aquaculture, Faculty of Natural Sciences and Life, Abdelhamid Ibn Badis University-Mostaganem, 27000, PO Box 227, Algeria
[*] Author for correspondence: aqua.tamacha@yahoo.fr

Figure 1. Sampling site location: A) Oran Bay, B) Ain Franine station. Source: adapted from Google Earth, 2018

Sampling

In total, 305 individuals of *H. poli* were harvested over 12 months (from October 2016 to September 2017). The sampling was carried out randomly by hand using snorkelling and scuba equipment at an average depth of 8 m. During sampling, to avoid the loss of internal organs (gonads) due to the process of autotomy practiced by these marine invertebrates, each individual was isolated in a plastic bag. In the laboratory each individual was dissected, and the gonads carefully removed, drained and weighed (Wg ± 0.01 g). Each gonad was stored in a pill box and fixed in formalin (10%).

hematoxylin-eosin, and observed under an optical microscope at x100 and x400 magnification. Sex was determined primarily on the basis of gonad colour. The tubules of the female gonads are usually yellow or orange, and in the male, they are whitish. We noted that determining sex in some cases was not easy macroscopically, and necessitated microscopic observations. The identification of the various stages of sexual maturity was based on the gonad maturity scale established by Conand (1981) and modified by Ramofafia and colleagues (2000): I) recovery, II) growth, III) early mature, IV) mature and V) spent.

Gonad maturity stages

The macroscopic characteristics of each gonad were observed (colour, number, length, diameter and branching of the tubules). Histological analysis was performed on a monthly subsample of 10 gonads (males and females) selected from an average sample of 25 individuals collected each month (120 individuals of the 305 individuals collected in total). One piece (0.5 mm) of each part of the tubules was removed, dehydrated, embedded in paraffin, sectioned at 7 µm, stained with

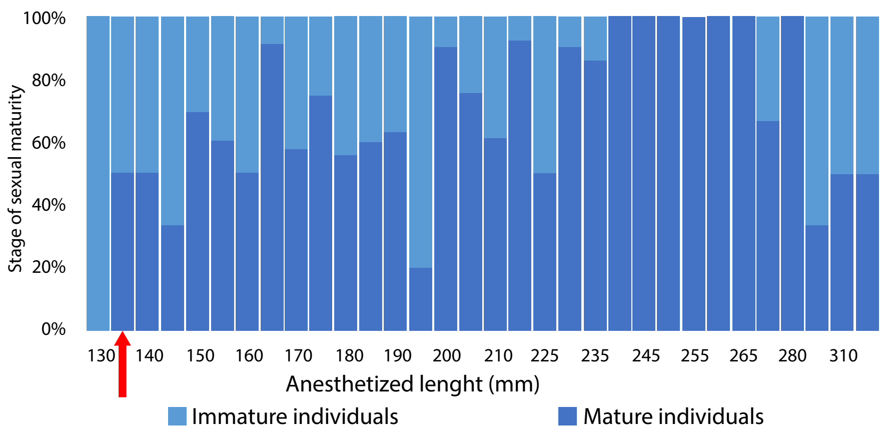


Figure 2. Distribution of immature individuals (% of individuals at stages I and II) and mature (% of individuals at stages III, IV and V), depending on the size of *Holothuria poli* at the Ain Franine station. The red arrow indicates the size at first sexual maturity.

Results

Size at first sexual maturity

The analysis of the variation of sexual maturity stages (depending on the size of the holothuroid) showed that 50% of individuals are mature when they reach 135 mm (Fig. 2).

Macroscopic and microscopic observations of female and male gonads

During stage I (recovery), determining the sex of the gonads is impossible. The ovarian tubules are thin, white and transparent, and very slightly branched and short (Figs. 3A and 3a). In females, the lumens of the tubules are almost empty. The pre-vitellogenic oocytes are attached to the germinal epithelium of the tubule with the presence of some more rounded early vitellogenic oocytes (Fig. 3B). In males, the wall of the gonad is at its maximum thickness. The presence of early stages of sperm maturation is noted on the borders of the tubules with the presence of empty zones (Fig. 3b).

In stage II (growth) in both sexes, the number of gonad tubules increases and they can become divided. They have a whitish colour (Figs. 3C and 3c). In females, the tubules are very pale white to orange colour. The number of oocytes increases and the lumen of the tubules is not completely occupied by oocytes of different sizes (Figs. 3D and 3E). In males, the germinal epithelium extends towards the lumen of the tubule, giving rise to the development of spermatocytes colonies (Fig. 3d).

At stage III (near maturation) in both sexes, the gonad tubules are longer, more numerous, dilated and branched (Figs. 3F and 3e). In females, their colour is light pink to orange. The presence of different stages of development is observed (e.g. mature oocytes in the centre of the tubules and small oocytes near the tubular wall, see Fig. 3G). In males, the tubules are cream colour, long, numerous, dilated and branched (Fig. 3f).

At stage IV (maturity) in females, the number of tubules and their ramifications reach their maximum. During this stage, ovary weight is generally higher than that of the testicle; the largest ovary is 17.94 g; female gonads are orange in colour and are completely dilated (Fig. 3H). There is a predominance of mature oocytes with a single nucleolus (Fig. 3J) and few immature oocytes are also observed (Fig. 3I). In males at this stage, the gonad weight reaches 12.64 g, and the tubules are milky in colour, dilated to a maximum diameter (Fig. 3g). The walls of the tubules are thin, and the spermatozoa are numerous and mature (Figs. 3h, 3i).

At stage V (spent), in females, the tubules regress and become flaccid, wrinkled and more or less empty. At this stage, tubules or the tubular region are seen and they always occupy un-expelled gametes in atresia (Fig. 3k). In males, after the release of gametes, the tubules regress and become transparent. They are flaccid and more or less empty, with the presence of residual gametes (Fig. 3j).

Monthly variability of sexual maturity stages

The monthly variability in sexual maturity stages of mature individuals (all confused sexes) is followed in order to specify the spawning period. Figure 4 shows that 70% of individuals are at full sexual maturity (stage IV) in July 2017, while the percentage of individuals observed at stage V is greater than 90% in October and November. Stage I was observed from November 2016 to January2017 and is marked by the presence of a maximum number of individuals at this stage (in November 2017). The growth of the tubules was noted during stages II and III from February to June 2017, with a presence of less than 10% of the gonads in stage III during July and August.

Discussion

Holothuria poli is a common species in the Mediterranean Sea, but data on its reproduction are lacking. Sampled individuals of *H. poli* are gonochoric and show no sexual dimorphism, which is observed in many aspidochirotid holothurians (Despalatovic et al. 2004; Asha and Muthiah 2007; Navarro et al. 2012; Mezali et al. 2014). Sea cucumbers often show an annual reproductive cycle (Tuwo and Conand 1992; Conand 1993a, b; Chao et al. 1995). Although half yearly or even a continuous reproductive cycle throughout the year is also common, especially in tropical regions (Harriott 1985; Conand 1993b). In total, 305 individuals of *H. poli* (129 males, 131 females and 45 of indeterminate sex) were considered in the present study. During our survey, the absence of hermaphroditic individuals was noted. This result is similar to that obtained by Bardanis and Batjakas (2018) for the same species at Lesvos Island in Greece.

Holothuria poli is a typical temperate sea cucumber, which presents a single annual reproductive cycle (Tuwo and Conand 1992; Hamel and Mecier 1996). Maximum reproductive activity was observed during the warm months of the year (July and August 2017) while minimum activity (rest) was observed during the coldest months of the year (November and December 2016). The macroscopic and microscopic observations suggest that the development of male and female gonads of *H. poli* adapts an asynchronous 'tubular recruitment model', showing the tubules in different stages of development

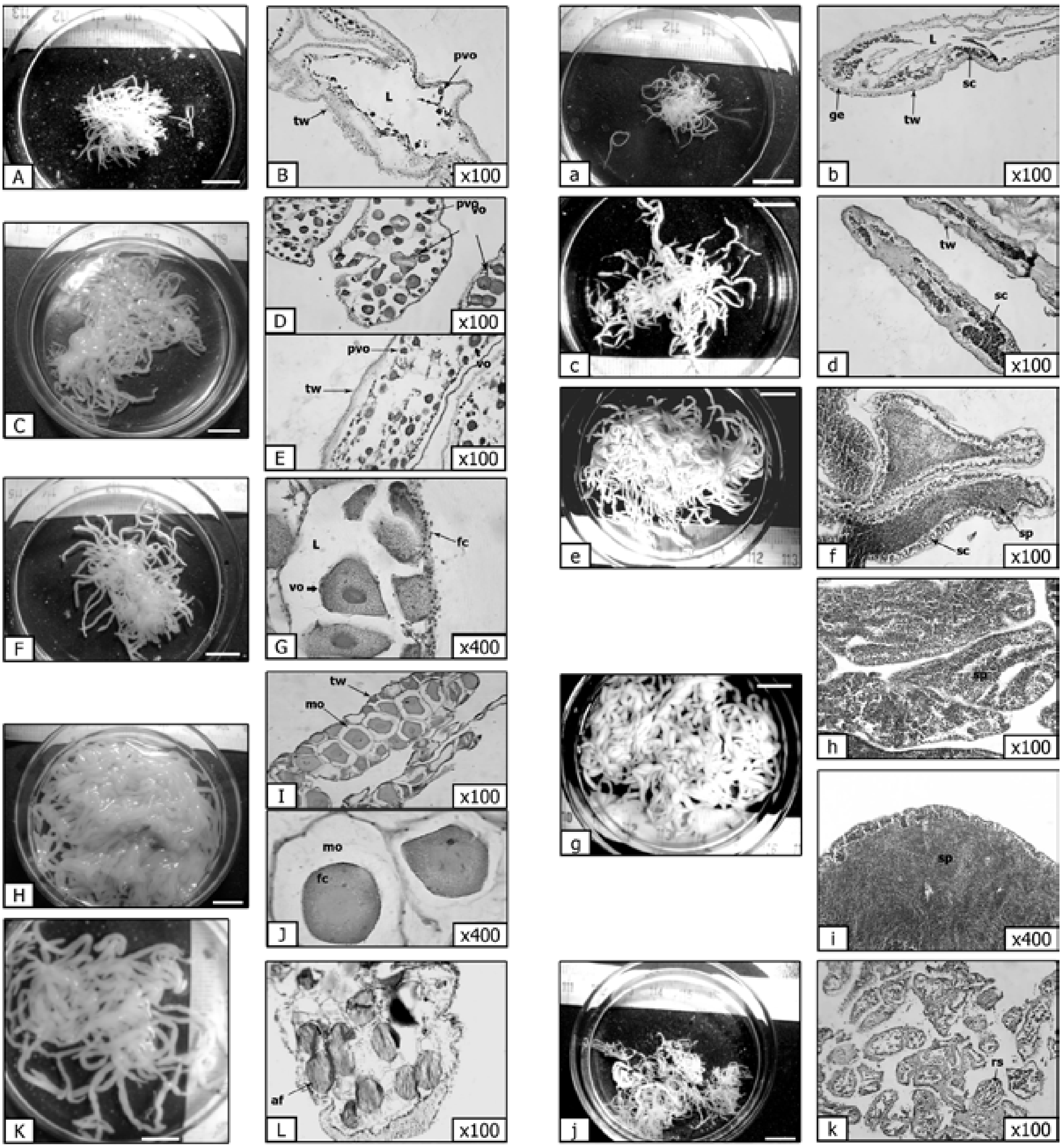


Figure 3. Macroscopic and microscopic description of female (left) and male (right) gonads characteristics of *Holothuria poli* at different maturity stages, scale bar = 10mm. **A, a.** Gonad at recovery stage. **B, b.** Empty tubule [Light (L), thin tubule walls (tw); with pre-vitellogenic oocytes (pvo), spermatocytes (sc) along the germinal epithelium (ge)]. **C, c**. Gonad at growth stage. **D, E.** details of tubules with various development stages [Early vitellogenic oocytes (vo) detached from the thin tubule wall (tw); pre-vitellogenic oocytes (pvo)]. **d.** Thin tubule wall (tw) with spermatocytes (sc); **e, F.** Gonad at early mature stage**. f.** Male tubule lumens are occupied by several stages of spermatogenesis, spermatocytes (sc) and spermatozoa (sp); **G.** Early mature tubules [with vitellogenic oocytes (vo) and follicular cells (fc)]. **H, g.** Gonad at mature stage. **I.** Tubule [with densely packed fully mature oocytes (mo) and thin tubule walls (tw)]. **J.** Mature oocyte (om) separated from its follicle (fc). **K.** Gonad at partially spawned stage. **L.** Residual oocytes with atretic follicle (af). **H, i.** Tubules engorged with mature spermatozoa. **j.** Gonad at spent stage (tubules turn thin and translucent). **k.** Extremely wrinkled wall almost empty tubules, only relict spermatozoa (rs) patches.

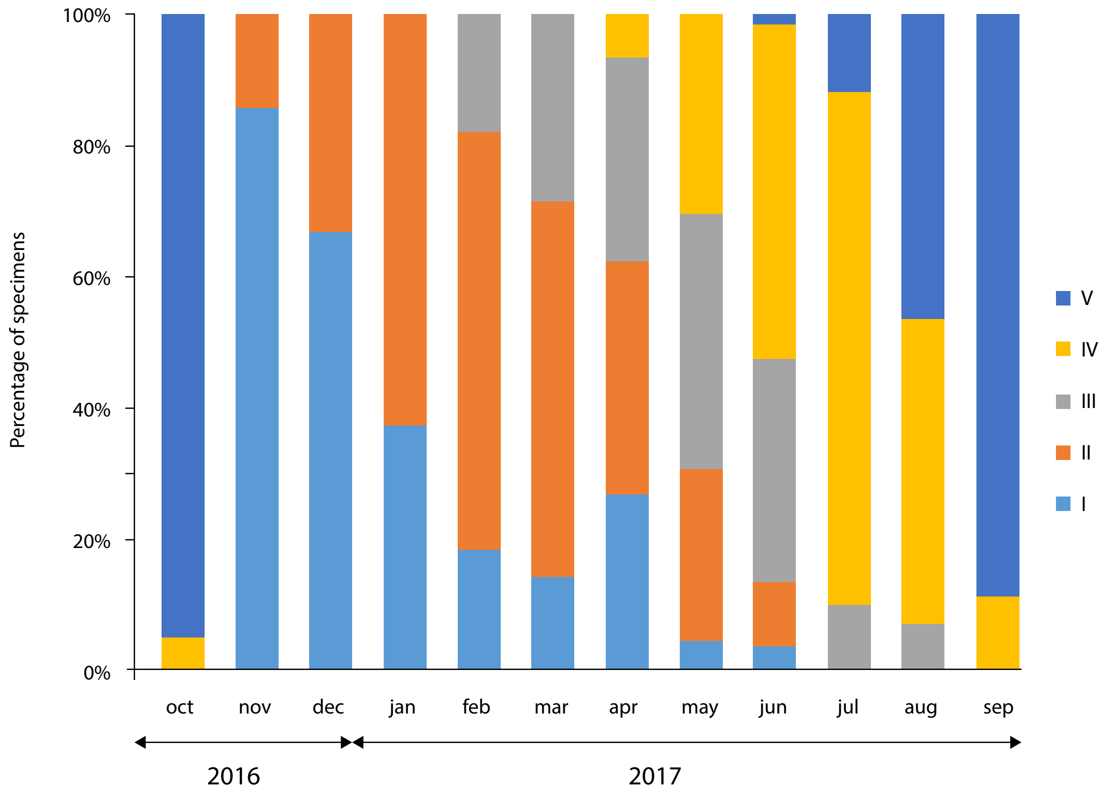


Figure 4. Monthly evolution of sexual maturity stages in mature individuals of *Holothuria poli* at Ain Franine station.

together. This case is not unusual, because there are many other species of sea cucumbers that do not follow the model of recruitment of the tubules, such as *H. leucospilota* (Ong Che 1990), *H. atra* (Chao et al. 1994), *H. fuscogilva* and *H. mauritiana* (Ramofafia and Byrne 2001).

In *H. poli*, the percentage of sexual maturity stages of the sampled individuals varies from March to June 2017, where stage III is predominant in both males and females. From the end of June 2017 and into early July 2017, individuals reach full sexual maturity, which is marked by the presence of a high percentage of individuals in stage IV. At the last stage of maturation (stage V), a regression of tubule size in length and diameter in males and females is observed, and this is most probably due to post-emission gonad regression, In their studies on *H. leucospilota*, Purwati and Luong-Van (2003) explain that this species has the ability to 'reintegrate' its gonad once its gametes are expelled. This regression of male and female tubules was also observed by Ong Che (1990). In work conducted in New Caledonia, Conand (1981) explains the presence of individuals without gonads during the resting phase, showing that the gonad grows throughout its maturation, until fertility, then retracts after spawning. This was observed for *H. poli*, which presents a large number of non-gonadal individuals in November.

Conclusion

Our study shows that size at first sexual maturity is around 135 mm (both sexes combined). As for maturation, *H. poli* sampled from Ain Franine station present a general reproduction pattern marked by an increase in the percentage of mature individuals (stages III and IV) from March to June, with spawning beginning in July and extending until September, while the period of rest is observed from October to November. The reproduction parameters obtained in the present work will provide a database for the establishment of regulatory measures for the exploitation of *H. poli* on the western end of Algeria's coast, such as defining a harvest season, and establishing a ban on catching this species during the breeding period in order to manage sea cucumber stocks on Algeria's coast.

Acknowledgements

The first author thanks the team of the laboratory AquaBior at the University of Oran, especially Professor Sidi Mohammed El-Amine Abi Ayad, Mr Larbi Sofiane Neghli and Mr Karim Chekkai.

References

Aydin M. 2008. The commercial sea cucumber fishery in Turkey. SPC Beche-de-Mer Information Bulletin 28:40–43.

Asha P.S. and Muthiah P. 2007. Reproductive biology of the commercial sea cucumber *Holothuria spinifera* (Echinodermata: Holothuroidea) from Tuticorin, Tamil Nadu, India. Aquaculture International 16:231–242.

Aydin M., Sevgili H., Tufan B., Emre Y. and Kose S. 2011. Proximate composition and fatty acid profile of three different fresh and dried commercial sea cucumbers from Turkey. International Journal of Food Science and Technology 46:500–508.

Bardanis E. and Batjakas I. 2018. Reproductive cycle of *Holothuria poli* in Gera Gulf, Lesvos Island, Greece. 3rd International Congress on Applied Ichthyology and Aquatic Environment, 8–11 November 2018, Volos, Greece. (www.hydromedit.gr)

Chao S.M., Chen C.P. and Alexander P.S. 1994. Reproduction and growth of *Holothuria atra* (Echinodermata: Holothuroidae) at two contrasting sites in southern Taiwan. Marine Biology 119:565–570.

Chao S.M., Chen C.P. and Alexander P.S. 1995. Reproductive cycles of tropical sea cucumbers (Echinodermata: Holothuroidea) in southern Taiwan. Marine Biology122:289–295.

Conand C. 1981. Sexual cycle of three commercially important holothurian species (Echinodermata) from the lagoon of New Caledonia. Bulletin of Marine Science 31:523–543.

Conand C. 1993a. Ecology and reproductive biology of S*tichopus variegatus,* an Indo Pacific coral reef sea cucumber (Echinodermata: Holothuroidea). Bulletin of Marine Science 52(3):970–981.

Conand C. 1993b. Reproductive biology of the holothurians from the major communities of the New Caledonian Lagoon. Marine Biology116:439–450.

Despalatovic M., Grubelic I., Simunovic A., Antolic B. and Zuljevic A. 2004.Reproductive biology of the holothurian *Holothuria tubulosa* (Echinodermata) in the Adrian Sea. Journal of Marine Biological Association of the United Kingdom 84: 409–414.

González-Wangüemert M., Aydin M. and Conand C. 2014. Assessment of sea cucumber populations from the Aegean Sea (Turkey): First insights to sustainable management of new fisheries. Ocean Coastal Management 92:87–94.

Hamel J.F. and Mercier A. 1996. Studies on the reproductive biology of the Atlantic sea cucumber *Cucumaria frondosa*. SPC Beche-de-Mer Information Bulletin 8:22–33.

Harriott V.J. 1985. Reproductive biology of three congeneric sea cucumber species, *Holothuria atra, H. impatiens* and *H. edulis*, at Heron Reef, Great Barrier Reef. Australian Journal of Marine and Fresh Water Research 36:51–57.

Hebbar C. 2013. Contribution à l'étude de la biologie et de l'exploitation de *Mullus barbatus* pêché dans le littoral oranais. These de doctorat. Université d'Oran. 1, 208 p.

Koehler R. 1921. Faune de France – 1. Echinodermes. Paris, France: Librairie de la faculté des sciences. 210 p.

Mezali K. 2008. Phylogénie, Systématique, dynamique des populations et nutrition de quelques espèces d'holothuries aspidochirotes (Holothuroidea: Echinodermata) inféodées aux herbiers de Posidonies de la côte algéroise. Thèse de Doctorat d'état. Institut des Sciences Biologiques, Université des Sciences et de la Technologie Houari Boumediene, Alger, Algérie. 208 p.

Mezali K. and Semroud R. 1998. Analyse modales et essai d'estimation des paramètres de croissance, de l'âge et du mois de recrutement de trois espèces d'holothuries aspidochirotes (Holothuroidea: Echinodermata) de la région de Sidi-Fredj (Algérie). Rapports P.V. Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée : Dubrovnik 35(2):466–467.

Mezali K. and Soualili D.L. 2013. The ability of holothurians to select sediment particles and organic matter. SPC Beche-de-Mer Information Bulletin 33:38–43.

Mezali K. and Soualili D.L. 2015. Reproductive cycle of the sea cucumber *Holothuria tubulosa* (*Holothuroidea: Echinodermata*) in the Southwestern Mediterranean Sea. p. 88–94. In: Ergün M., Cirik Ş. and Kingueleoua K.C.K. (eds). Proceedings of the International Congress on Estuaries and Coastal Protected Areas, ECPA, 4–6 November 2014, *İzmir*, Turkey. Mezali K., Zupo V. and Francour P. 2006. Population dynamics of *Holothuria (Holothuria) tubulosa* and *Holothuria (Roweothuria) poli* of an Algerian *Posidonia oceanica* meadow. Biologia Marina Mediterranea 13:158–161.

Mezali K., Chekaba B., Zupo V. and Asslah B. 2003. Feeding behavior of five aspidochirotid holothurians species (Holothuroidea: Echinodermata) of the Sidi-Fredj peninsula – Algeria. Bulletin de la Société Zoologique de France 128:49–62.

Mezali K., Soualili D.L., Neghli L. and Conand C. 2014. Reproductive cycle of the seacucumber *Holothuria (Platyperona) sanctori* (Holothuroidea: Echinodermata) in the southwestern Mediterranean Sea: Interpopulation variability. Invertebrate Reproduction and Development 58:179–189.Navarro P.G., García-Sanz S. and Tuya F. 2012. Reproductive biology of the sea cucumber *Holothuria sanctori* (Echinodermata: Holothuroidea). Marine Biology 76:741–752.

Ong Che R.S. 1990. Reproductive cycle of *Holothuria leucospilota* Brandt (Echinodermata: Holothuroidea) in Hong Kong and the role of body tissues in reproduction. Asian Marine Biology 7:115–132.

Purcell S.W., Mercier A., Conand C., Hamel J.F., Toral-Granda V., Lovatelli A. and Uthicke S. 2013. Sea cucumber fisheries: Global analysis of stocks, management measures and drivers of overfishing. Fish and Fisheries 14:34–59.

Purwati P. and Luong-Van J.T. 2003. Sexual reproduction in a fissiparous holothurian species, *Holothuria leucospilota* Clark 1920 (Echinodermata: Holothuridea). SPC Beche-de-mer Information Bulletin18:33–38.

Ramofafia C. and Byrne M. 2001. Assessment of the "tubule recruitment model" in three tropical aspidochirote holothurians. SPC Beche-de-Mer Information Bulletin 15:13–16.

Ramofafia C., Battaglene S.C., Bell J.D. and Byrne M. 2000. Reproductive biology of the commercial sea cucumber *Holothuria fuscogilva* in the Solomon Islands. Marine Biology 136:1045–1056.Tortonese E. 1965. Echinodermata. Fauna d'Italia. Calderini Bologna. 422 p.

Tuwo A. and Conand C. 1992. Reproductive biology of the holothurians: *Holothuria forskali* (Echinodermata). Journal of the Marine Biological Association of the United Kingdom 72:745–758.

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

Feriel Sellem,[1*] Fatma Guetat,[2] Wejdi Enaceur,[1] Amira Ghorbel-Ouannes,[1] Afif Othman,[1] Montassar Harki,[1] Abdesslem Lakuireb[1] and Sarra Rafrafi[3]

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}.

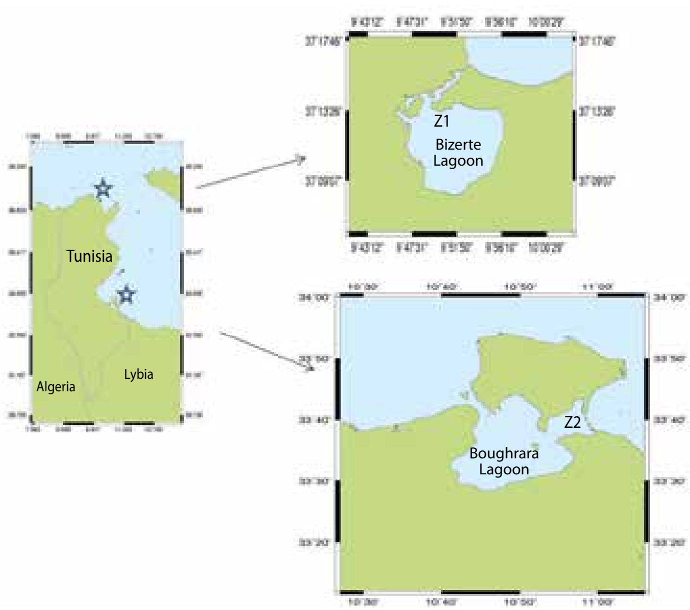


Figure 1. Location of Bizerte and Boughrara lagoons. Z1 and Z2 are sea cucumber fishing areas.

[1] Institut National des Sciences et Technologies de la Mer, Laboratoire des sciences halieutiques, 28 rue du 2 mars 1934, 2025 Salammbô, Tunisie
[2] Institut National Agronomique de Tunisie, Avenue Charles Nicole, Tunis, Tunisia
[3] Biology Department, Faculty of Science and Arts Al Ula, Taibah University, Al Madinah Al Munawarh, Kingdom of Saudi Arabia
[*] corresponding author: feriel.sellem@instm.rnrt.tn

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.

Acknowledgements

Special thanks are extended to the two diving teams who participated in collecting the data used for this study. Part of this survey was funded by the modapex-biz national project of the Institut National des Sciences et Technologies de la Mer. We thank also the fishermen and shipping agents of Bizerte and Boughrara who helped us to achieve the fieldwork.

References

Alves Martins M.V., Zaaboub N., Aleya L., Frontalini F., Pereira E., Miranda P., Mane M., Rocha F., Laut L. and El Bour M. 2015. Environmental quality assessment of Bizerte lagoon (Tunisia) using living foraminifera assemblages and a multiproxy approach. PLoS ONE 10(9): e0137250.doi:10.1371/journal.pone.0137250.

Azzouz A. 1973. Les fonds chalutables de la région nord de la Tunisie. 1 cadre physique et biocénoses benthiques. Bulletin Institut Océanographique Pêche Salammbô 2(4):473–565.

Bejaoui B., Harzallah A., Moussa M., Chapelle A. and Solidoro C. 2008. Analysis of hydrobiological pattern in the Bizerte lagoon (Tunisia). Estuarine Coastal and Shelf Science 80:121–129.

Ben Garali A., Ouakad M. and Gueddari M. 2009. Contamination of superficial sediments by heavy metals and iron in the Bizerte lagoon, northern Tunisia. Arabian Journal of Geosciences 3(3):295–306

Ben Mustapha K., Hattour A., Mhetli M., El Abed A. and Tritar B. 1999. Etat de la bionomie benthique des étages infra et circalittoral du golfe de Gabès. Bulletin de l'Institut National des Sciences Technologies Mer Salammbô 26:5–48.

Boudouresque C.F., Harmelin J. G. and Jeudy de Grissac A. 1986. Le benthos marin de l'ile de Zembra (parc national Tunisie). Marseilles, France: GIS Posidonie Publisher. 199 p.

Bruun A.1940. Etudes quantitatives sur la faune du lac de Tunis et du golfe de Tunis dansla région de Salammbô. Bulletin Station Océanographique Salammbô 40:1–20.

Chambost L.1928. Essai sur la région littorale dans les environs de Salammbô. Bulletin Station Océanographique Salammbô 8:1–27.

Cherbonnier G. 1956. Les échinodermes de Tunisie. Bulletin Station Océanographique Salammbô 53: 1–23.

De Gaillande D. 1970. Peuplements benthiques de l'herbier de *Posidonia oceanica* (Delile) de la pelouse à *Caulerpa prolifera* Lamouroux et du large du golfe de Gabès. Téthys 2(2):373–384.

Gautier-Michaz M. 1958. Echinodermes. Annales Institut Océanographique 34:145–155.

González-Wangüemert M., Braga T., Silva M., Valente S., Rodrigues F. and Ester Serrao E. 2013. Estimation des populations d'*Holothuria arguinensis* de la Ria Formosa (sud du Portugal). SPC Beche-de-mer Information Bulletin 33:44–48.

Guetat F., Sellem F., Akrout F., Brahim M., Atoui A., Ben Romdhane M.S. and Daly Yahia M.N. 2012. Etat environnemental de la lagune de Boughrara et ses environs deux ans après les travaux d'aménagement et d'élargissement du pont d'EL Kantara. Bulletin de l'Institut National des Sciences et Technologies de la Mer 39:149–160.

Hammami J., Brahim M. and Guedari M 2016. Assessment of the water quality of Bizerte lagoon of Tunisia by use of statistical analyses. Hydrology: Current Research 7(2):1–8.

Koehler R. 1921. Faune de France – 1. Echinodermes. Paris, France: Librairie de la faculté des sciences. 210 p.

Ktari Chakroun F. and Azzouz A. 1971. Les fonds chalutables de la région Sud-Est de la Tunisie (golfe de Gabès). Bulletin Institut Océanographique Pêche Salammbô 2(1): 5–47.

Le Danois 1925. Recherches sur les fonds chalutables des côtes de Tunisie et d'Algérie (croisière du chalutier «Tanche» en 1924). Annales de la Station Océanographique de Salammbô n°1. 56 p.

Lubet P. and Azzouz A. 1969. Etude des fonds chalutables du golfe de Tunis. Bulletin de l'Institut Océanographique de Salammbô 1(3):87–111.

Purcell S.W., Samyn Y. and Conand C. 2012. Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes 6. Rome: FAO. 190 p.

Ramónd M., Lleonart J. and Massutí E. 2010. Royal cucumber (*Stichopus regalis*) in the northwestern Mediterranean: Distribution pattern and fishery. Fisheries Research 105:21–27.

Sellem F., Graja S. and Brahmi Z. 2017. Données biologiques et valeur nutritive de la paroi *d'Holothuria poli* (Delle Chiaje, 1823) Holothuoidea, Aspidochirotida des îles Kerkennah (golfe de Gabès, Tunisie). Bulletin de l'Institut National des Sciences et Technologies de la Mer de Salammbô 44:1–18.

Sicuro B. and Levine J. 2011. Sea cucumber in the Mediterranean: A potential species for aquaculture in the Mediterranean. Reviews in Fisheries Science 19(3):299–304.

Tortonese E. 1965. Fauna d'Italia. Echinodermata. Bologna, Italy : Edizioni Calderini Bologna, Officine Grafiche Calderini. 422 p.

Zaouali J. 1993. Les peuplements benthiques de la petite Syrte, golfe de Gabès, Tunisie. Résultats de la campagne de prospection du mois de juillet 1990. Etude préliminaire biocénoses et thanatocénoses récentes. Marine Life 3(1–2):47–60.

Holothuria arguinensis: A new sea cucumber species for aquaculture

Jorge A. Domínguez-Godino[1*] and Mercedes González-Wangüemert[1]

Abstract

Sea cucumber fisheries have developed along the northeast Atlantic Ocean and Mediterranean Sea since the early 1990s, with an important incidence of illegal harvesting across these waters. Subsequently, in recent years, research has focused on aquaculture development. *Holothuria arguinensis* is a commercial sea cucumber species from the northeast Atlantic Ocean and Mediterranean Sea that has largely been studied for aquaculture. This work summarises the main findings on and advances in aquaculture involving *H. arguinensis*.

Introduction

Sea cucumbers are economically valuable and are in high demand from Asian markets because they are considered a delicacy and functional food,[2] and are also used in traditional Chinese medicine (Chen 2004; Conand 2000, 2004; Bordbar et al. 2011; Fabinyi 2012; To and Shea 2012). High market demand, uncontrolled exploitation and inadequate fisheries management, have all led to many sea cucumber stocks becoming heavily overfished, and have driven fishers to target lower-value species around world (Conand 2004). Nowadays, fishing pressure is also focused on species from the northeast Atlantic Ocean and Mediterranean Sea (Aydin 2008, 2017; González-Wangüemert et al. 2014, 2015, 2018; Maggi and González-Wangüemert 2015). Sea cucumber aquaculture began in China in the 1980s to: 1) supply beche-de-mer (dried sea cucumber) to the Asian market, 2) compensate for reduced wild stocks, and 3) allow restocking for enhancement of depleted populations (Chen 2004; Hu et al. 2010). Traditionally, sea cucumbers have been farmed in earthen ponds and in sea ranching systems, and have been grown in polyculture systems with other species (Hu et al. 2010). Sea cucumber aquaculture in Europe has great potential for development, which could include integrated, multi-trophic systems.

Holothuria arguinensis (Fig. 1) is restricted in distribution to the northeastern Atlantic, from Peniche, Portugal, to Mauritania, and the Canary Islands (Costello et al. 2001; Rodrigues 2012; Rodrigues et al. 2015; Thandar 1988). It has recently been found colonising the waters of the Alborán Sea in the western portion of the Mediterranean Sea (González-Wangüemert and Borrero-Pérez 2012; Mezali and Thandar 2014). This species has been illegally harvested in Portugal and Spain, mainly due to the high prices it fetches: EUR 70–350 per kilo of dried product (beche-de-mer), depending on the quality (Domínguez-Godino and González-Wangüemert 2018a; González-Wangüemert et al. 2018). *Holothuria arguinensis* has a nutritional value similar to that of other commercial sea cucumber species and is suitable for human consumption (Roggatz et al. 2015). Therefore, *H. arguinensis* is a good candidate for aquaculture development. Since 2014, techniques needed for *H. arguinensis* aquaculture have been developed.

Holothuria arguinensis broodstock maintenance and larvae rearing

Holothuria arguinensis broodstock can be maintained in tank-based conditions with sediment, and their weight increased (SGR[3] = 0.2 % day^{-1}) by feeding them the supplied sediment (mean feeding rate: 27.88 g ind.$^{-1}$ day^{-1}), which shows high values of absorption efficiency (80%) in terms of organic matter (Domínguez-Godino and González-Wangüemert 2018a). *Holothuria arguinensis* is highly influenced by seawater temperature and salinity,

1 CCMAR, Universidade do Algarve, MARESMA team, Campus de Gambelas, 8005-139 Faro, Portugal
2 See: https://academic.oup.com/jn/article/132/12/3772/4712139
3 SGR = special growth rate
4 AGR = absolute growth rate
* Corresponding author : jorge.adg86@gmail.com

Figure 1. a) Juvenile specimen of *Holothuria arguinensis* (image: Pepe Brix). Specimens of *H. arguinensis* b) dorsal side, and c) ventral side with different colouration. (images: Jorge Antonio Domínguez Godino)

both of which can induce a hibernation period (Domínguez-Godino and González-Wangüemert 2018a). When the seawater temperature drops below 19°C, *H. arguinensis* reduces its feeding, movements, absorption efficiency and growth (Domínguez-Godino and González-Wangüemert 2018a). During broodstock maintenance, artificial feed from the debris of the seagrass *Zostera noltii* can be used to ensure growth (Fig. 2, SGR = 0.09 ± 0.06 % day^{-1}, AGR[4] = 0.11 ± 0.07 g day^{-1}) (Domínguez-Godino 2018). However, biodebris from the seagrass *Cymodocea nodosa* seems to be an unsuitable food source for *H. arguinensis*, causing negative growth (Domínguez-Godino 2018). Independently of the seagrass species and the proportion used in the diets, any important change to the nutritional values of *H. arguinensis* was registered (Domínguez-Godino 2018).

Domínguez-Godino and colleagues were able to induce *Holothuria arguinensis* to spawn by thermal stimulation during the summer months, which correspond to its reproductive period of June–October. The authors followed and described the embryonic and larval development thereafter (Domínguez-Godino et al., 2015). *Holothuria arguinensis*, as with most aspidochirote holothurians, exhibits the classic five larval stages (early, mid and late auricularia, doliolaria and pentactula), reaching the juvenile stage after 18 days (Domínguez-Godino et al. 2015). Low mortality was registered by Domínguez-Godino and colleagues (2015) during the pelagic larval stages, but high mortality (85–95%) was registered at the doliolaria and juvenile stages during the first year. Survival has since been improved, and juvenile production has increased (Domínguez-Godino et al. 2015). Feeding diets based on single-life microalgae (*Chaetoceros calcitrans*, *Isochrisys galbana* and *Tetraselmi chuii*) were compared with two combined microalgal diets: 1) *C. calcitrans* and *T. chuii* (C:T) (pre-established feeding diet), and 2) *C. calcitrans*, *T. chuii* and *I. galbana* (C:T:I)) to improve the growth and survival of *H. arguinensis* (Domínguez-Godino 2018). Larvae fed with the combined microalgal diet of T:C:I showed higher survival rates and larger larval and stomach sizes than larvae fed with the single microalgal diet and the pre-established microalgal diet (C:I) (Domínguez-Godino 2018).

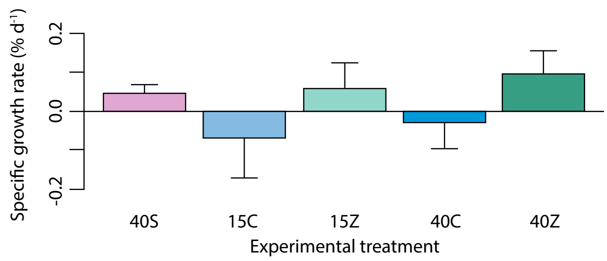


Figure 2. Specific growth rate (%/d) of *Holothuria arguinensis* individuals over eight weeks for each feeding treatment: sediment (40S), 15% of *Cymodocea nodosa* (15C), 15% of *Zostera noltii* (15Z), 40% of *C. nodosa* (40C), 40% of *Z. noltii* (40Z). Values are given as mean ± SE (n = 3).

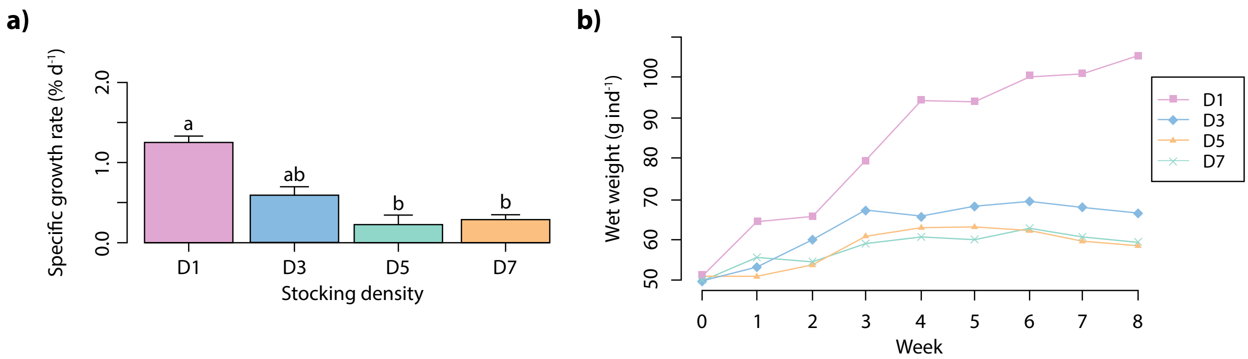


Figure 3. (a) Specific growth rate (%/d) of *Holothuria arguinensis* individuals over eight-weeks for each stocking density: 1 ind. 0.2 m^{-2} (D1), 3 ind. 0.2 m^{-2} (D3), 5 ind. 0.2m^{-2} (D5), 7 ind. 0.2 m^{-2} (D7). (b) The mean wet weight of *H. arguinensis* (g) in the different stocking densities during the eight-weeks period. Values are given as a mean ± SE (n = 3). Different letters indicate significant differences (Nemenyi post hoc, P<0.05).

Holothuria arguinensis stocking density and grow-out habitat selection

Stocking density is one of the main parameters affecting the growth, feeding and survival of the sea cucumber. Juvenile *H. arguinensis* showed the best growth (SGR = 1.25 ± 0.08 % day^{-1}, AGR = 0.94 ± 0.05 g d^{-1} and %WC = 104.66 ± 9.98 %) at a stocking density of 5 ind. m^{-2}, decreasing significantly as the stocking density increased (Fig. 3a) (Domínguez-Godino and González-Wangüemert 2018b). Critical biomass (471.65 g m^{-2}) was reached in four weeks (Fig. 3b) (Domínguez-Godino and González-Wangüemert 2018b).

Additionally, habitat preferences of *H. arguinensis* were assessed in the coastal lagoon at Ria Formosa Natural Park (south Portugal). There, *H. arguinensis* was preferentially distributed along the lower intertidal zone and linked to *Zostera noltii* meadows on muddy and sandy bottoms, where the densest population and largest individuals were found (Domínguez-Godino 2018). This habitat selection by *H. arguinensis* could be linked to the greater amount of emersion time and exposure to high temperatures and ultra-violet rays of the upper intertidal zone (Domínguez-Godino 2018). Therefore, areas located in the lower intertidal zone with *Z. noltii* meadows on sand-muddy bottoms should be selected for sea pen grow-out of *H. arguinensis*.

Holothuria arguinensis in integrated multitrophic aquaculture

The monoculture growth, productivity and economic benefits of *H. arguinensis* were compared with three polyculture systems where the green macroalgae *Ulva lactuca* and purple sea urchin *Paracentrotus lividus* were included (Domínguez-Godino 2018). The highest growth, productivity and economic benefits for both cultured species occurred where *H. arguinensis* was co-cultured with *U. lactuca* and where artificial feed (dry powder of *U. lactuca*) had been added (Fig. 4) (Domínguez-Godino 2018). The three polyculture systems produced greater economic benefits than the monoculture systems; therefore, these systems could be implemented to improve productivity in terms of biomass and profits (Domínguez-Godino 2018). Additionally, the feasibility of using biodeposits of the sea bream, *Sparus aurata*, as a food source for *H. arguinensis* was assessed (Domínguez-Godino and González-Wangüemert 2018a). *Holothuria arguinensis* showed a low feeding rate, negative absorption efficiency, and growth, but this could have been a consequence of the low seawater temperature during the experiment, which was performed in winter (Domínguez-Godino and González-Wangüemert 2018a). Previous similar experiments had shown high feeding rate and absorption efficiency (Domínguez-Godino and González-Wangüemert 2018a), so further research should be done during spring and summer months.

Conclusion

Different and important techniques to develop sea cucumber aquaculture have been studied in recent years. This study is the first one to focus on the northeastern Atlantic Ocean and Mediterranean Sea holothurian, *H. arguinensis*. This work has established the baseline for its aquaculture, and shows that *H. arguinensis* is a highly suitable sea cucumber species for one-species and integrated multi-trophic aquaculture. Further research is needed to confirm the results obtained and address issues that will arise when entering production stages.

References

Aydın M. 2008. The commercial sea cucumbers fishery in Turkey. SPC Beche-de-mer Information Bulletin 28:40–43.

Aydın M. 2017. Present status of the sea cucumber fishery in Turkey. SPC Beche-de-mer Information Bulletin 37:30–34.

Bordbar S., Anwar F. and Saari N. 2011. High-value components and bioactives from sea cucumbers for functional foods-a review. Marine Drugs 9:1761–1805. http://dx.doi.org/10.3390/md9101761

Chen JX. 2004. Present status and prospects of sea cucumber industry in China. p. 25–38. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. (eds). Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463. Rome: Food and Agriculture Organization.

Conand C. 2000. Sea cucumber retail market in Singapore. SPC Beche-de-mer Information Bulletins 14:12–13.

Conand C. 2004. Present status of world sea cucumber resources and utilization: an international overview. p. 13–24. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. (eds). Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463. Rome: Food and Agriculture Organization.

Costello M.J., Emblow C. and White R.J. (eds). 2001. European register of marine species: A check-list of the marine species in Europe and a bibliography of guides to their identification. Paris: Muséum national d'histoire naturelle. 463 p.

Domínguez-Godino J.A. 2018. The sea cucumber *Holothuria arguinensis*,as a new species for aquaculture. Doctoral thesis, Universidad de Cádiz.

Domínguez-Godino J.A. and González-Wangüemert M. 2018a. Assessment of *Holothuria arguinensis* feeding rate, growth and absorption efficiency under aquaculture conditions. New Zealand Journal of Marine and Freshwater Research 53(1): 60–76. https://doi.org/10.1080/00288330.2018.180499

Domínguez-Godino J.A. and González-Wangüemert M. 2018b. Does space matter? Optimizing stocking density of *Holothuria arguinensis* and *Holothuria mammata*. Aquaculture Research 49(9):3107–3115. https://doi.org/10.1111/are.13773

Domínguez-Godino J.A., Slater M.J., Hannon C. and González-Wangüemert M. 2015. A new species for sea cucumber ranching and aquaculture: Breeding and rearing of *Holothuria arguinensis*. Aquaculture 438:122–128. ttps://doi.org/10.1016/j.aquaculture.2015.01.004

Fabinyi M. 2012. Historical cultural and social perspectives on luxury seafood consumption in China. Environmental Conservation 39:83–92. http://dx.doi.org/10.1017/S0376892911000609

González-Wangüemert M and Borrero-Pérez G. 2012. A new record of *Holothuria arguinensis* colonizing the Mediterranean Sea. Mar Biodivers Rec 5. https://doi.org/10.1017/S1755267212000887

González-Wangüemert M., Aydin M. and Conand C. 2014. Assessment of sea cucumber populations from the Aegean Sea (Turkey): First insights to sustainable management of new fisheries. Ocean and Coast Management 92:87–94. http://dx.doi.org/10.1007/s10750-014-2006-2

González-Wangüemert M., Valente S. and Aydin M. 2015. Effects of fishery protection on biometry and genetic structure of two target sea cucumber species from the Mediterranean Sea. Hydrobiologia 743:65–74. http://dx.doi.org/10.1007/s10750-014-2006-2

González-Wangüemert M., Domínguez-Godino J.A. and Cánovas F. 2018. The fast development of sea cucumber fisheries in the Mediterranean and NE Atlantic waters: From a new marine resource to its over-exploitation. Ocean and Coast Management 151: 165–177. https://doi.org/10.1016/j.ocecoaman.2017.10.002

Hu C.Q., Xu Y.H., Wen J., Zhang L.P., Fan S.G. and Su T. 2010. Larval development and juvenile growth of the sea cucumber *Stichopus* sp. (curry fish). Aquaculture 300(1–4):73–79. https://doi.org/10.1016/j.aquaculture.2009.09.033

Maggi C. and González-Wangüemert M. 2015. Genetic differentiation among *Parastichopus regalis* populations in the Western Mediterranean Sea: Potential effects from its fishery and current connectivity. Mediterranean Marine Science 16(3):489–501. http://dx.doi.org/10.12681/mms.1020Mezali K and Thandar A. 2014. First record of *Holothuria (Roweothuria) arguinensis* (Echinodermata: Holothuroidea: Aspidochirotida: Holothuriidae) from the Algerian coastal waters. Mar Biodivers Rec 7:e40. https://doi.org/10.1017/S1755267214000438

Rodrigues N.V. 2012. New geographic distribution records for Northeastern Atlantic species from Peniche and Berlengas Archipelago. ARQUIPÉLAGO. Life and Marine Sciences. 4 p.

Rodrigues F., Valente S. and González-Wanguemert M. 2015. Genetic diversity across geographical scales in marine coastal ecosystems: *Holothuria arguinensis* a model species. Journal of Experimental Marine Biology and Ecology 158–167. https://doi.org/10.1016/j.jembe.2014.12.006

Roggatz, C.C., González-Wangüemert, M., Pereira, H., Rodrigues, M.J., da Silva, M.M., Barreira, L., Varela, J., Custódio, L., 2015. First report of the nutritional profile and antioxidant potential of *Holothuria arguinensis*, a new resource for aquaculture in Europe. Nat. Prod. Res., 30(18), 2034-2040. https://doi.org/10.1080/14786419.2015.1107555

Thandar A.S. 1988. A new subgenus of *Holothuria* with a description of a new species from the south-east Atlantic Ocean. Journal of Zoology 215(1):47–54. https://doi.org/10.1111/j.1469-7998.1988.tb04884.x

To A.W. and Shea S.K. 2012. Patterns and dynamics of bêche-de-mer trade in Hong Kong and mainland China: Implications for monitoring and management. Traffic Bulletin 24:65–76.

A biometric study to determine the economic and nutritional value of sea cucumbers (Holothuroidea: Echinodermata) collected from Algeria's shallow water areas

Asmaa Mecheta[1] and Karim Mezali[1]

Abstract

Traditionally in Algeria, sea cucumbers were exploited at a very small scale. Nowadays, however, sea cucumber fisheries are emerging in the Mediterranean Sea due to the high commercial value of these organisms. Three economically important species – *Holothuria (Roweothuria) poli*, *H. (Holothuria) tubulosa* and *H. (Roweothuria) arguinensis* – are common in shallow water areas along Algeria's coast. In order to enhance and highlight the economic and nutritional value of these unexploited holothurian species, a biometric study estimating the amount of water and pepsin digestion of the dry body wall, was undertaken. The three holothurians species were collected at two stations: Stidia and Hadjadj near the port city of Mostaganem. After their transformation into dried products, called beche-de-mer, we noticed a considerable decrease in their length (50–73%) and weight (88–93%). The dried body wall analysis showed a high moisture rate (over 80%) and pepsin digestibility (varying between 25% and 52%). We compared our results with those obtained for other holothurian species commonly exploited in the Indo-Pacific region.

Keywords: holothurians, biometrics, dried product, digestibility, Algerian west coast

Introduction

The demand for beche-de-mer by consumer countries is constantly rising, resulting in increasingly intensive fisheries and a considerable decrease, and in some areas disappearance, of natural populations (Samyn et al. 2006). For that reason, Asian markets are in search of new target species, mainly from the Mediterranean Sea and the northeast Atlantic Ocean (Gonzalez-Wangüemert et al. 2015, 2016). In these regions, the most important species are *Holothuria (Roweothuria) poli* Delle Chiaje 1823, *Holothuria (Holothuria) tubulosa* Gmelin 1791, *Holothuria (Platyperona) sanctori* Delle Chiaje 1823, *Holothuria (Panningothuria) forskali* Delle Chiaje 1823 and *Parastichopus regalis* Cuvier, 1817.

Recently, *Holothuria (Roweothuria) arguinensis* Koehler and Vaney 1906, an invasive species originating from the Atlantic Ocean, has been reported in the Mediterranean (González-Wangüemert and Borrero-Pérez 2012; Mezali and Thandar 2014). In Algeria, holothurians are exploited on a very small scale (mainly as fishing bait) and no attempt has been made to process these species into dried product. In order to enhance and highlight the economic and the nutritional value of these unexploited holothurian species, a biometric study estimating the amount of water and pepsin digestion of the dried body wall was conducted.

Methodology

Sampling was carried out during the summer of 2018. Three batches of 30 individuals of each species – *H. poli*, *H. tubulosa* and *H. arguinensis* – were harvested from two sampling sites on the Algerian west coast: Stidia (35° 50′N, 0° 00′E) and Hadjadj (36° 06′N, 0° 20′E) (Fig. 1). Each individual from each species was isolated in a plastic bag for later analysis.

Biometry

In the laboratory, each sea cucumber individual was cleaned and then measured. The contracted length was obtained according to the standardised method described by Mezali (1998) using a semi-cylindrical scale (± 0.5 mm). Each measured individual was kept straight, and then compressed by hand until the coelomic fluid was expelled. After that, the individuals were dissected by making an incision

[1] Protection, Valuation of Marine and Coastal Resources and Molecular Systematics Laboratory, Department of Marine Sciences and aquaculture, Faculty of Natural Sciences and Life, Abdelhamid Ibn Badis University-Mostaganem, 27000, PO Box 227, Algeria
* Author for correspondence: asmaamecheta@gmail.com

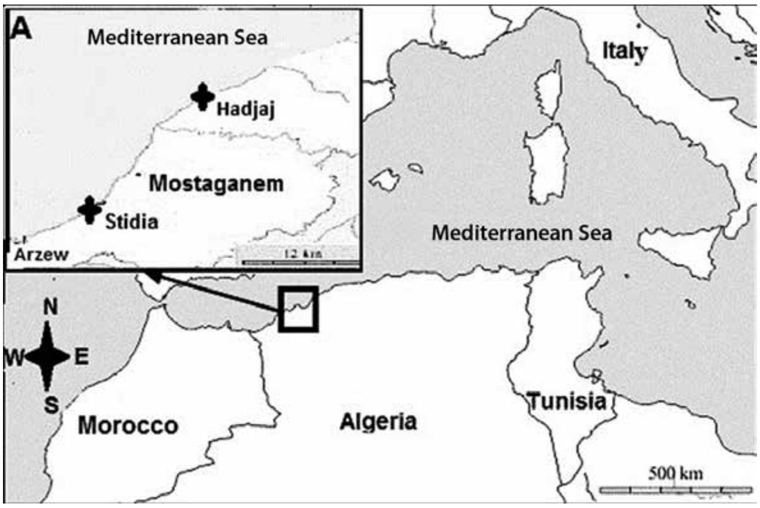


Figure 1. Detailed map of the two sampling sites (A) (black crosses).

of the trivium using a scalpel blade (Purcell 2014). Each individual was eviscerated, its gut and viscera removed, rinsed with tap water, drained and finally weighed: wet weight of the body wall (WW) (± 0.001g). The wet weight included the body wall, longitudinal muscle and the buccal bulb (Kazanidis et al. 2010; Mezali et al. 2014), and gave more accurate information than total body weight, which varies considerably, depending on the amount of water in the respiratory trees and the gut contents (mainly composed by exogenous materials) (Mezali 1998). The trivium thickness was measured using a caliper (± 0.1 mm). The moisture content of the body wall was measured according to the Official Methods of Analysis (AOAC 950.01 1990). The results have been expressed in percentages (%) (the mean of three replicates). The dried body wall of each individual was placed into a labelled plastic bag and stored in a freezer (-4 °C) for latter biochemical analysis. Fresh sea cucumbers were processed into dried products based on the simple, traditional methods described by Purcell (2014), and organised in three basic steps: cooking, salting and sun drying. Freshly collected holothurians were placed in a large container and boiled in sea water (60–80°C), and afterwards were placed in cold water (15°C for 1–2 h). An incision (with a scalpel blade) was made along the trivium, starting at 3 cm from each end, and the samples then gutted and rinsed in tap water. The specimens were kept in bins and entirely covered with salt for 2–5 days. Sea cucumbers were boiled again in sea water for ½ h, until a hard and chewy consistency was obtained. Finally, they were sun dried for 4–14 days.

In vitro *digestion of the dried body wall with pepsin*

Dried body wall of *H. poli*, *H. tubulosa* and *H. arguinensis* were digested *in vitro* according to the method of Escudero et al. (2010) and amended by Wen et al. (2015). For this, 0.5 g of dried body wall of each species was weighed (± 0.001 g) (Jinghua JA3003, Shanghai, China) and then homogenised twice in 2 mL of distilled water for 30 s at 9,500 rpm min^{-1} and then twice again for 30 s at 13,500 rpm min^{-1} with a 30 s cooling time between the two centrifugations. The homogenates were adjusted to a pH of 2 with an acid (HCl 1M). Pepsin was added in a 1:31.25 ratio based on the body wall mass. The mixture was maintained at 37°C for 2 h, and then was made inactivate by adjusting the pH to 7.5 using a base (NaOH 1M). The undigested body wall was dried in an oven at 60°C for 72 h and then weighed. The *in vitro* digestibility was evaluated according to the following formula:

$$DT = (1 - Wi / Wt) \times 100\%$$

Where DT = digestibility (%);

Wi = dried weight of body wall after digestion;

Wt = total weight of the body wall of the dried product before digestion.

Results and discussion

Biometry

Our specimens demonstrated larger class sizes than those recorded by Mezali (1998) and Purcell et al. (2009) (Table 1). This difference could be due to several factors, such as a rapid growth due to a decrease in predation (Olaya-Restrepo et al. 2018). Although few predators feed on holothurians, several anti-predation mechanisms have been described in the literature for sea cucumbers (Francour 1997), and some of these mechanisms appear to be related to the animal's size. Moreover, this could also be linked to the high productivity of

Posidonia oceanica meadows, the preferred habitat for *H. poli* and *H. tubulosa* (Mezali 2004). In addition, the smaller the sediment particles, the higher the quantity of organic matter that can be ingested by holothurians, due to a higher volume-to-surface ratio that has previously been demonstrated to promote the adhesion of organic matter (Mezali and Soualili 2013). Moreover, Plotieau et al. (2013) suggested that the nutritional value of fine sediment would be higher than that for coarse sediments due to the greater number of nutritious microorganisms.

It is still, however, important to point out that estimating total body length is not a reliable measure. In fact, the error is likely to be higher than the actual weight because it is very difficult to obtain complete relaxation of holothurians' bodies; the length indeed changes significantly by contraction and elongation of their body (Battaglene et al. 1999). Therefore, weight measurements are more reliable (Mezali 1998). Based on this assertion, the average eviscerated weight was measured for the three species, and the maximum values were recorded as: *H. tubulosa* (112.64 ± 45.57 g), *H. arguinensis* (244.8 ± 61.26 g) and *H. poli* (90.22 ± 16.07 g) (Table.1). The relationship between length and weight differ between species, depending on the shape and strength of the body (Cone 1989). This is also due to food availability, species biology, growth rates and fishing pressure (González-Wangüemert et al. 2018).

A difference in body wall thickness could be observed between the three studied species: (5.99 ± 0.8 mm) in *H. tubulosa*, (3.44 ± 0.56 mm) in *H. poli* and (4.53 ± 1.03 mm) in *H. arguinensis* (Table1). According to González-Wangüemert et al. (2018), food is used differently by the two species – *H. poli* and *H. tubulosa* – with *H. poli* increasing in length while *H. tubulosa* increasing its body wall robustness (thickness of the body wall) and weight. Our results are not in agreement with this hypothesis because *H. tubulosa* presents the largest size classes, and a weight and body wall thickness greater than those recorded for *H. poli*, despite its more rigid body wall. Regarding *H. arguinensis*, although its specific growth model has already been determined by Olaya-Restrepo et al. (2018), there is no information on the relationship

Table 1. Biometric measurements obtained for the three studied holothurians species compared with other species of the Mediterranean and Indo-Pacific regions (n = sample size = 30). CL = contracted length (mm); T = thickness of the body wall (mm); WW = wet weight of the body wall (g); DW = dry weight of the body wall (g); and DL = dry length of the body wall (mm).

Species	CL (mm)	T (mm)	WW (g)	DW (g)	DL (mm)	WW/DW	References
Actinopyga echinites	190.00 ± 3.00	-	231.00 ± 14.00	35.00 ± 2.00	80.00 ± 2.00	-	Purcell et al. (2009)b
A. palauensis	270.00 ± 7.00	-	985.00 ± 44.00	165.00 ± 11.00	150.00 ± 5.00	-	Purcell et al. (2009)b
A. spinea	270.00 ± 10.00	-	735.00 ± 39.00	99.00 ± 11.00	130.00 ± 10.00	-	Purcell et al. (2009)b
Holothuria arguinensis	261.00 ± 55.16	4.53 ± 1.03	244.80 ± 61.26	15.51 ± 3.60	67.30 ± 5.22	15.78	this study
H. forskali	108.04 ± 28.90	-	-	-		8.89	Mezali (1998)
H. lessoni	310.00 ± 10.00	-	1456.00 ± 50.00	221.00 ± 7.00	280.00 ± 10.00	-	Purcell et al. (2009)b
H. poli	144.03 ± 23.07	3.44 ± 0.56	90.22 ± 16.07	4 12.85 ± .59	71.60 ± 8.68	7.02	this study
H. poli	91.03± 43.10	-	-	-	-	6.44	Mezali (1998)
H. sanctori	115.60 ± 27.90	-	-	-	-		Mezali (1998)
H. sanctori	225 ± 38.90	02.69 ± 1.95	76.90 ± 18.37	-	-	-	Mezali et al. (2014)a
H. tubulosa	187.30 ± 39.79	5.96 ± 1.26	112.64 ± 45.57	12.95 ± 1.32	74.20 ± 9.80	8.69	this study
H. tubulosa	120.15 ± 38.52	-	-	-	-	6.53	Mezali (1998)
H. whitmaei	250.00 ± 8.00	-	1174.00 ± 45.00	213.00 ± 14.00	150.00 ± 4.00	-	Purcell et al. (2009)b

[a] anesthetised total length
[b] length measurement criteria not indicated

between food availability and the strength of the body wall of this species. After being processed into beche-de-mer, the dried sea cucumbers were weighed and measured to estimate the weight and length loss. The results demonstrate a significant decrease in weight and size in all studied species (Table 1, Fig. 2). Lengths varied between 40.10% and 74.21%, and weights ranged from 85.72% to 93.65%. According to Conand (1990), after the drying process, the weight decreases between 90% and 97%, depending on the species. The salting phase allows dehydration of the sea cucumbers and removes part of the water contained in the body wall prior to sun drying. Similar studies conducted by Purcell et al. (2009) and Lavitra et al. (2009) on sea cucumber species exploited in New Caledonia and southwestern Madagascar, confirm our results as these authors have also found considerable decreases in the length and weight of fresh and dried sea cucumbers.

The ratio between wet weight and dry weight was calculated for all species. Considerable variations were observed between the three studied species (Table 1). The wet weight to dry weight ratio for both *H. poli* and *H. tubulosa* approximates the standard value 10:1 established for sea cucumbers by Newell and Courtney (*in* Astall and Johns 1991). But the ratio obtained for *H. arguinensis* is greater than the standard value 10:1. Our results also differ from those obtained by Mezali (1998) for similar species: *H. poli* (6.44:1) and *H. tubulosa* (6.53:1).

Water content and in vitro digestion of the dry *integument*

Our results show very high moisture content for the three studied holothurian species (Table 2). Sea cucumbers generally have a higher moisture content than that of fish and seafood (Chang-Lee et al. 1989).

Table 3 shows the digestibility rate of the body wall of the three studied sea cucumbers by the digestive enzyme pepsin. The digestibility

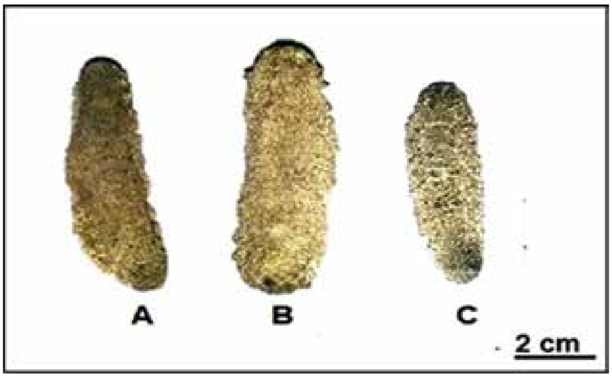


Figure 2. Dried sea cucumbers A. *H. poli*; B. *H. tubulosa*; C. *H. arguinensis* after processing into beche-de-mer, according to the traditional method. (image: Asmaa Mecheta)

Table 2. Water content (%) in the body wall of the three studied holothurians compared with Indo-Pacific species (no. replicates = 3).

Species	Body wall water content (%)	References
Actinopyga mauritiana	76.54 ± 0.09	Haider et al. (2015)
Holothuria arenicola	72.12 ± 0.25	Haider et al. (2015)
H. arguinensis	88.13 ± 4.16	this study
H. fuscogilva	84.34 ± 0.72	Fawzya et al. (2015)
H. leucospilota	81.41 ± 0.60	Omran (2013)
H. poli	93.53 ± 1.95	this study
H. poli	81.24 ± 0.40	Aydin (2009)
H. scabra	85.76 ± 0.30	Omran (2013)
H. tubulosa	81.99 ± 1.97	this study
H. tubulosa	84.30 ± 0.20	Aydin (2009)
Parastichopus californicus	04.03 ± 0.19	Bechtel et al. (2013)
Stichopus herrmanni	10.20 ± 0.32	Wen et al. (2010)
Thelenota ananas	90.81 ± 2.08	Fawzya et al. (2015)
T. anax	01.20 ± 0.06	Wen et al. (2010)

Table 3. Digestibility (%) of the holothurian body wall when digested using pepsin.

	Digestibility (%)	References
Holothuria arguinensis	53.56 ± 3.41	this study
H. poli	34.68 ± 8.66	this study
H. tubulosa	25.96 ± 2.04	this study
Pork	47.22	Wen and al. (2015)
Fish	46.98	Wen and al. (2015)
Chicken	44.67	Wen and al. (2015)
Beef	42.75	Wen and al. (2015)

of *H. arguinensis* (53.56 ± 3.41%) was significantly higher than that of *H. poli* (34.68 ± 8.66%) and *H. tubulosa* (25.96 ± 2.04%) (Table 3). The digestibility level of *H. arguinensis* was more or less similar to that obtained by Wen et al. (2015) for commonly consumed meats (pork, fish, chicken and beef). This digestibility variation was attributed to the changes in protein bioavailability (depending on the protein decomposition rate when degraded by digestive enzymes), peptide size (Hur et al. 2011; Pennings et al. 2013), and protein and collagen contents that constitute the major components of the holothurians body wall (about 70% of the total body wall protein) (Saito et al. 2002; Wen et al. 2015). This latter factor may be significant due to the presence of glycosaminoglycans, which are widely distributed among the bundles of collagen fibers (Kariya et al. 1990).

Conclusion

This biometric study of three aspidochirotid holothurian species – *H. poli*, *H. tubulosa* and *H. arguinensis* – before and after processing into beches-de-mer showed that our specimens are smaller in size and weight than those exploited in the Indo-Pacific region. A lower trophic factor combined with less organic matter content mostly explains these outcomes. Despite these two factors, the studied holothurians species showed significant nutritional value as their body wall is degraded by the digestive enzyme pepsin. Thus, they could become common sources of protein and other nutrients.

Acknowledgments

The first author thanks the microbiology and animal biology laboratory teams of the Natural Sciences and Life Faculty, Abdelhamid Ibn Badis University at Mostaganem, for their help in carrying out the experiments. Also, thanks to scuba diver Mr Abdelkader who helped during the field work.

References

Astall C.M. and Johns M.B. 1991. Respiration and biometry in the sea cucumber *Holothuria forskali.* Journal of the Marine Biological Association of the United Kingdom 71:73–81.

Aydin M., Huseyin S., Bekir T., Yilmaz E., Sevim K. 2010. Proximate composition and fatty acid profile of three different fresh and dried sea cucumber commercial from Turkey. International Journal of Food Science and Technology 46: 500–508.

Battaglene S.C., Seymour J.E. and Ramofafia C. 1999. Survival and growth of cultured juvenile sea cucumbers, *Holothuria scabra*. Aquaculture 178:293–322.

Bechtel P.J., Oliveira A.C.M., Demir N., Smiley S.2013. Chemical composition of the giant red sea cucumber *Parastichopus californicus*, commercially harvested in Alaska. Food Science & Nutrition 1:63–73.

Chang-Lee M.V., Price R.J. and Lampila L.E. 1989. Effect of processing on proximate composition and mineral content of sea cucumbers (*Parastichopus* spp.). Journal of Food Science 54:567–572.

Conand C. 1990. The fishery resources of Pacific Island countries. Part 2: Holothurians. FAO Fisheries Technical Paper, No. 272.2. Rome: Food and Agriculture Organization. 143 p.

Cone R. S. 1989.The need to reconsider the use of condition indices in fishery science. Transactions Journal of the American Fisheries Society 118:510–514.

Cuvier G. 1817. Les Annélides. p. 515–532. In : Le règne animal distribué d›après son organisation, pour servir de base à l'histoire naturelle des animaux et d'introduction à l'anatomie comparée. Volume 2. Contenant les Reptiles, les Poissons, les Mollusques et les Annélides. Paris, France : Deterville.

Della Chiaje S. 1823. Descrizione zoologica ed anatomica di alcune specie di Oloturie. p. 77–116. In: Memorie su la storia e notomia degli animali senza vertebre del Regno di Napoli. Volume 1 Fratelli Fernandes, Napoli. pls. 6–8.

Escudero E., Sentandreu M.A. and Toldra' **F. 2010**. Characterization of peptides released by in vitro digestion of pork meat. Journal of Agricultural and Food Chemistry 58:5160–5165.

Fawzya Y.N., Januar H.I., Susilowati, R., Chasanah E. 2015. Chemical composition and fatty acid profile of some Indonesian sea cucumbers. Squalen Bulletin of Marine and Fisheries Postharvest Biotechnology 10:27–34.

Francour P. 1997. Predation on holothurians: A literature review. Invertebrate Biology 116:52–60.

Gmelin J.F. 1791. Vermes. p. 3021–3910. In: Gmelin J.F. (ed). Caroli a Linnaei Systema Naturae per Regna Tria Naturae, ed. 13. Tome 1(6). Lipsiae: G.E. Beer.

González-Wangüemert M. and Borrero-Pérez G. 2012. A new record of *Holothuria arguinensis* colonizing the Mediterranean Sea. Marine Biodiversity Records 5:1–4.

González-Wangüemert M., Valente S. and Aydin M. 2015. Effects of fishery protection on biometry and genetic structure of two target sea cucumber species from the Mediterranean Sea. Hydrobiologia 743:65–74

Gonzalez-Wangüemert M., Domínguez-Godino J.A. and Canovas F. 2018. The fast development of sea cucumber fisheries in the Mediterranean and NE Atlantic waters: From a new marine resource to its over-exploitation. Ocean and Coastal Management 151:165–177.

González-Wangüemert M., Valente S., Henriques F., Domínguez-Godino J.A. and Serrão E.A. 2016. Setting preliminary biometric baselines for new target sea cucumbers species of the NE Atlantic and Mediterranean fisheries. Fisheries Research 179:57–66.

Haider M.S, Sultana R., Jamil Lakht-e-Zehra K., Tarar O.M., Shirin K., Afzal W. 2015. A Study on proximate Composition Amino Acid Profile, Fatty Acid Profile and Some Mineral Contents in Two Species of Sea Cucumber. Journal of Animal and Plant Sciences 25:168–175.

Hur S.J., Lim B.O., Decker E.A. and Mc Clements D.J. 2011. In vitro human digestion models for food applications. Food Chemistry 125:1–12.

Kariya Y., Watabe S., Ochiai Y., Murata K. and Hashimoto K. 1990. Glycosaminoglycan involved in the cation-induced change of body wall structure of sea cucumber *Stichopus japonicus*. Connective Tissue Research 25:149–159.

Kazanidis G., Antoniadou C., Lolas A.P., Neofitou N., Vafidis D., Chintiroglou C. and Neofitou C. 2010. Population dynamics and reproduction of *Holothuria tubulosa* (Holothuroidea: Echinodermata) in the Aegean Sea. Journal of the Marine Biological Association of the United Kingdom 90:895–901.

Lavitra T., Rachelle D., Rasolofonirina R., Jangoux M. and Eeckhaut I. 2009. Processing and marketing of holothurians in the Toliara region, southwestern Madagascar. SPC Beche-de-mer Information Bulletin 28:24–33.

Mezali K. 1998. Contribution à la systématique, la biologie, l'écologie et à la dynamique des populations de cinq espèces d'holothuries aspidochirotes (*Holoturia tubulosa*, *Holothuria poli*, *Holothuria stellati*, *Holothuria forskali* et *Holothuria sanctori*) de l'herbier à *Posidonia oceanica* (L.) Delile de la presqu'ile de Sidi-Fredj- Algérie (Thèse de Doctorat d'état. Alger, Algérie : USTHB) 208. 8 p.

Mezali K. 2004. Micro-répartition des holothuries aspidochirotes au sein de l'herbier de *Posidonies* de la presqu'île de Sidi-Fredj (Algérie). p. 534. CIESM (ed.). Rapport du 37e Congrès de la Commission internationale pour l'exploration scientifique de la Mer Méditerranée. Monaco : Commission internationale pour l'exploration scientifique de la Mer Méditerranée. 574 p.

Mezali K. and Soualili D.L. 2013. The ability of holothurians to select sediment particles and organic matter. SPC Beche-de-mer Information Bulletin 33:38–43.

Mezali K. and Thandar A. 2014. First record of *Holothuria (Roweothuria) arguinensis* (Echinodermata: Holothuroidea: Aspidochirotida: Holothuriidae) from the Algerian coastal waters. Marine Biodiversity Records 4:7–40.

Mezali K., Soualili D.L., Neghli L. and Conand C. 2014. Reproductive cycle of the sea cucumber *Holothuria (Platyperona) sanctori* (Holothuroidea: Echinodermata) in the southwestern Mediterranean Sea: interpopulation variability. Invertebrate Reproduction and Development 58(3):179–189.

Olaya-Restrepo J., Erzini K. and González-Wangüemert M. 2018. Estimation of growth parameters for the exploited sea cucumber *H. arguinensis* from South Portugal. Fishery Bulletin 116:1–8.

Omran N. 2013.Nutritional value of Some Egyptian sea cucumbers. African Journal of Biotechnology 12:35.

Pennings B., Groen B.B., van Dijk J.W. and de Lange A. 2013. Minced beef is more rapidly digested and absorbed than beef steak, resulting in greater postprandial protein retention in older men. The American Journal of Clinical Nutrition 98:121–128.

Plotieau T., Baele J.M., Vaucher R., Hasler C.A., Koudad D. and Eeckhaut I. 2013. Analysis of the impact of *Holothuria scabra* intensive farming on sediment. Cahiers de Biologie Marine 54:703–711.

Purcell S.W. 2014. Processing sea cucumbers into beche-de-mer: A manual for Pacific Island fishers. Noumea, New Caledonia:Southern Cross University, Lismore, and the Secretariat of the Pacific Community. 44 p.

Purcell S.W., Gossuin H. and Agudo N.S. 2009. Changes in weight and length of sea cucumbers during conversion to processed bêche-de-mer: Filling gaps for some exploited tropical species. SPC Beche-de-mer Information Bulletin 29:3–6.

Saito M., Kunisaki N., Urano N. and Kimura S. 2002. Collagen as the major edible component of sea cucumber (*Stichopus japonicus*). Journal of Food Science 67:1319–1322.

Samyn Y., Van den Spiegel D. and Massin C.2006. Taxonomie des holothuries des Comores. AbcTaxa vol 1 : i-iii. 130 p.

Wen S., Zhou G., Song S., Xu X., Voglmeir J., Liu L, Zhao F., Li M., Li L., Yu X., Bai Y. and Li C. 2015. Discrimination of in vitro and in vivo digestion products of meat proteins from pork, beef, chicken, and fish. Proteomics 15:3688–3698.

Algeria's sea cucumber fishery: Challenges for a new fishery

Larbi Neghli[1,2,*] and Karim Mezali[1]

Abstract

Traditionally in Algeria, sea cucumbers were only exploited on a very small scale, mainly as bait for fishing. There are no official data on the exploitation status of sea cucumber stocks along the Algerian coast. However, for some years, there has been clandestine networks that fish for and sell sea cucumbers, specifically for the benefit of the Chinese communities established in Algeria, and perhaps for export. Information collected from fishers and snorkelers indicate that exploitation started in 2013 on the western and central coast, before extending to the entire Algerian coast. The harvesting of sea cucumbers is still an artisanal activity but is growing rapidly and is capable of extracting significant amounts of these benthic animals, estimated at a few tens of kilograms wet weight per day and per person. Hence, the urgency of setting up a national management strategy for the nascent fishery, which, if we rely to the exploitation scheme already observed in other regions of the world, will soon face important challenges in terms of resource preservation and environmental impact.

Keywords: Sea cucumbers, exploitation status, stock management, Algeria

Sea cucumber exploitation in Mediterranean countries

In the Mediterranean, there are 37 known sea cucumber species, belonging to 9 families and 5 orders (Fisher et al. 1987). The most coveted Mediterranean species are *Holothuria (Roweothuria) poli, H. (Holothuria) tubulosa* and *H. (Roweothuria) arguinensis,* which all belong to the order Aspidochirote (Jorge Antonio et al. 2016). European exporting countries include Greece at 353 tonnes (t) a year, Spain at 167 t and France 29 t. Importers (who probably re-export to Asian markets) are Spain at 2,152 t, France at 363 t and Belgium at 236 t (González-Wangüemert et al. 2018).

Turkey was the first Mediterranean country to engage in sea cucumber harvesting (in 1996), exporting primarily to Singapore, Hong Kong and Japan (Sicuro and Levine 2011). Its production (mainly frozen) increased from 20 t in 1996 to almost 80 t in 2007 (Aydin 2008), before reaching 600 t in 2011 (González-Wangüemert et al. 2014). Since then, production has dropped to less than 270 t in 2015 (Aydin 2017).

In Spain, 10 companies exploit *H. arguinensis,* generating profits estimated at USD 1–2 million for some of them (Jorge Antonio et al. 2016). All production is exported to China. For southern Mediterranean countries, the interest in exploiting sea cucumbers came later. In 2001, Morocco managed to export 2.1 t to Hong Kong and waited until 2014 to complete a study on the status of stocks in the area of Essaouira on the Atlantic coast (Malouli Idrissi 2014). In 2014, the Government of Tunisia authorised the exploitation and marketing of natural stocks in Bizerte Bay (Ben Mustapha and Hattour 2016). The authors proposed as a precautionary approach to limit extractions to 50 individuals per day, for only three months a year, with the possibility of revising the rule when data on the ecological impact became available. Much sooner, in 1998, Egypt began exploiting its Red Sea stocks but was forced to impose a harvest ban in 2003 following observations of overexploitation (Ahmed and Lawrence 2007).

Illegal exploitation of sea cucumbers in Algeria

Because sea cucumbers were not traditionally harvested in Algeria, except for some artisanal fishermen who used the animals as bait, no regulations were in place to manage their exploitation. The illegal exploitation of wild stocks began in 2013 by people who glean and use destructive harvesting

1 Laboratoire de Protection, Valorisation des Ressources Marines et Littorales et Systématique Moléculaire. Département des Sciences de la Mer et de l'Aquaculture, Faculté des Sciences de la Nature et de la Vie, Université Abedelhamid Ibn Badis, Mostaganem, 27000, Boite postale 227, Algeria
2 Centre National de Recherche et de Développement de la Pêche et d'Aquaculture, 11 boulevard Colonel Amirouche Bou-Ismail, Tipasa, Algeria
* Author for correspondence: nelasof@gmail.com

Figure 1. *Holothuria tubulosa* specimens processed into beche-de-mer before being sold to local Chinese buyers. A) Dried product; B) quality product selection; C) bagging for sale. (images: Slimane-Tamacha 2018)

practices. The phenomenon reached such proportions that the administration in charge of the fisheries sector began looking to determine a minimum individual size in the hopes of regulating exploitation and preventing overfishing.

In Algeria, it is permissible to collect sea cucumbers by gleaning and by diving (Order of 16 July 2008), but not to exploit them commercially because they are not listed in the marine living resources regulation text that defines minimum authorised sizes for resources commercial exploited. This did not, however, prevent their clandestine commercial exploitation at the artisanal scale. A recent survey conducted by the fishery administration, indicates that sea cucumbers are not available for sale at fish stalls or at traditional outlets and are not appreciated by Algerian consumers. However, an investigation on the network and chain of the fishery product in the Oran region (western Algeria) (Slimane-Tamacha unpublished data) showed that harvested animals (mixed species) are eviscerated by fishers before being sold to an intermediary (Fig. 1). The later processes the product to a dried form before selling it to the local Chinese community. Fishers manage to get a price between DZD 300 and 800[3] a kilogram (wet weight).

Another investigation (Neghli, personal inquiry), conducted in the central region, revealed the existence of an incipient network of intermediaries collecting holothurians without knowing for sure the final destination of the beche-de-mer. This unregulated exploitation poses a serious threat to natural stocks, as fishing takes place mainly during the summer season, which for the majority of targeted species coincides with their spawning season (Mezali et al. 2014) (Table 1).

Indeed, it was shown that the highest biomass or density ratios were recorded in the summer (Mezali et al. 2006). The fact that adults migrate to the shallower waters to feed and reproduce (Mezali et al. 2014) at a period of the year when fishing activities are at their peak, exposes them to overfishing. The other threat to the fishery comes from overseas markets. Even if initially sea cucumbers in Algeria were mainly sold to the Chinese community in the country, the economic stakes have since increased dramatically, and investors are becoming more and more insistent about opening up the exploitation of national stocks for export.

Recommendations before opening the sea cucumber fishery in Algeria

The administration in charge of the fisheries sector recently attempted to regulate the exploitation of sea cucumbers through the introduction of a minimum size for specimens to be traded. Considering the experiences from other countries, and given the current scattered and fragmentary data available in Algeria, the approach chosen can only be of short term. It can be justified as a precautionary approach, or as a measure to ensure the sustainability of the resource and to the fishery. Vulnerability to human predation is an important concept to understand in the case of sea cucumber stocks. These animals are totally helpless because they have no real escape mechanism.

[3] DZD 100 = USD 0.85 as of 28 February 2019

Table 1. Length and weight of the smallest observed mature individuals and the spawning period of the most common Mediterranean holothurian species.

	Length and weight of the smallest observed mature individuals	Spawning period
HOLOTHURIIDAE		
Holothuria (H.) tubulosa Gmelin 1790	Length not mentioned; 220 g whole weight. Pagasitikos, Greece (Kazanidis et al. 2014)*	Summer (August–September) Algeria (Neghli 2013; Mezali and Soualili 2015), Turkey (Aydin and Erkan 2015) and Greece (Kazanidis et al. 2010)
Holothuria (H.) stellati Delle Chiaje 1823	No data	No data
Holothuria (P.) sanctori Delle Chiaje 1823	150 mm relaxed length for 40–45 g gutted weight. Central region of Algeria (Neghli 2013; Mezali et al. 2014) 201–210 mm relaxed length for 101–110 g weight. Canary Islands, Spain (Navaro et al. 2012)*	Summer (July-August), Algeria, (Neghli 2013; Mezali et al. 2014)
Holothuria (R.) poli Delle Chiaje 1823	135 mm relaxed length. Oran region (Slimane-Tamacha et al. unpublished data)	Summer (July–September), Algeria (Neghli 2013) (Slimane-Tamacha et al. unpublished data) Turkey (Aydin and Erkan 2015)
Holothuria (P.) forskali Rowe 1969	~ 180 mm relaxed length or ~ 85 g gutted weight Glénans Archipelago, Atlantic, France (Tuwo and Conand 1992).	Winter (February–March), Algeria (Neghli 2013); France (Tuwo and Conand 1992)
Holothuria (R.) arguinensis Koehler and Vaney 1906	210–230 mm relaxed length or 110–130 g eviscerated weight. Iberian Peninsula (Marquet et al. 2017)*	Summer (June–October) Portugal (Marquet et al. 2017)
CUCUMARIIDAE		
Ocnus planci Brandt 1835	No data	March–April (André and Le Granché 2014) in the Mediterranean Sea
STICHOPODIDAE		
Parastichopus regalis Cuvier 1817	No data	No data

* Sizes reported are length and weight at first maturity.

Therefore, the adopted approach must imperatively be followed by a more elaborate management plan based on well-thought-out and well-structured scientific surveys, centred around a research programme that includes all stocks open to exploitation.

Since the first works undertaken in the early 1990s (Mezali 1998; Mezali and Semroud 1998), several attempts have been made to set up a research programme to study wild stocks of Algerian aspidochirote sea cucumbers. Unfortunately, the projects submitted to the National Research Program failed to convince decision-makers because sea cucumbers were not identified as a priority resource by the sectorial development plan, especially as sea cucumbers are not part of the typical Algerian diet. Since then, the world economic situation has forced Algerian decision-makers to make urgent decisions that do not necessarily accommodate the time needed for adequate scientific studies of sea cucumbers.

Research results concerning aspidochirote species do, however, exist and can be very useful. Some of these studies have investigated the population dynamics of Mediterranean species (Mezali et al. 2006), and the biological and ecological role of those invertebrates in the ecosystems to which they belong (i.e. *Posidonia oceanica* ecosystem) (Mezali and Francour 2012; Belbachir et al. 2014; Belbachir 2018).

It is also worth mentioning the results of studies on the reproduction and exploitation of Algerian aspidochirote sea cucumbers (Neghli 2013; Mezali et al. 2014; Slimane-Tamacha and Mezali 2018), as well as all studies from the Department of Marine Sciences and Aquaculture research team at the University Abedelhamid Ibn Badis of Mostaganem (Algeria). The information provided by these studies should allow to set some minimum rules, or at least a kind of code of conduct before a proper management plan can be put in place.

In addition, the previously cited works all concluded that the distribution and specific composition of sea cucumbers varies from one site to another, in connection with prevailing environmental conditions (mainly trophic ones) and the substrate. An assessment of each site of exploitation, even an approximate one, is therefore necessary before the beginning of the fishing season in order to carry out an inventory of species and determine the state of the stocks before fishing starts. Harvesting must absolutely be prohibited during breeding season of the target species (see Table 1) for two obvious reasons: 1) to ensure spawning success, and 2) because of the reproductive behaviour of these animals, which exposes them to overfishing during large breeding assemblages. It is also recommended to ban night fishing, which is another period of vulnerability during which animals come out of hiding to feed. It's also necessary to define minimum capture sizes for each species based on local data and on other Mediterranean studies when local data are lacking (see Table 1).

Finally, the limited knowledge of the systematics of some species, and the possible confusion between species – the two unidentified groups of species of *H. tubulosa* and the two *H. sanctori* morphotypes (Mezali and Francour 2012; Mezali 2013) – can be a problem. Efforts must be carried out, particularly in the direction of operators (fishers, intermediaries and traders), to facilitate species identification for strict monitoring of the fishery.

Establishing permanent study sites and protected areas (taboo areas) will be essential as they will constitute reference points for a continuous readjustment of the fisheries management plan. Detailed documentation on harvesting must be required, and product sales outside of controlled outlets should be prohibited. Also, making exploitation data available to the scientific community would ensure greater transparency and enable more informed management decisions.

The development of an aquaculture sector could help relieve pressure on wild stocks by supplementing fishing activity. For that purpose, the Department of Marine Sciences and Aquaculture could provide a good scientific basis.

Concerning the definition of commercial legal size for sea cucumbers, because of their body plasticity, measuring individual length is far from being a reliable method as size depends on the amount of water stored in the internal cavity (Conand 1983). Drained weight is a more stable measure of sea cucumber age (Mezali 1998; Neghli 2013).

Finally, following an efficient and an ecosystem-based approach to exploitation is essential in order to monitor the recruitment of wild stocks, the health of the ecosystem and the socioeconomic systems exploiting the sea cucumbers (FAO 2010).

References

Ahmed M.I. and Lawrence A.J. 2007. The status of commercial sea cucumbers from Egypt's northern Red Sea Coast. SPC Beche-de-mer Information Bulletin 26:14–18.

André F. and Le Granché P. in : DORIS, 01/05/2014 : *Ocnus planci* (Brandt, 1835), http://doris.ffessm.fr/ref/specie/206.

Aydin M. 2008. The commercial sea cucumber fishery in Turkey. SPC Beche-de-mer Information Bulletin 28:40–41.

Aydin M. 2017. Present status of the sea cucumber fishery in Turkey. SPC Beche-de-mer Information Bulletin 37:30–34.

Aydın M and Erkan S. 2015. Identification and some biological characteristics of commercial sea cucumber in the turkey coast waters. International Journal of Fisheries and Aquatic Studies. 3(1):260-265.

Belbachir N. 2018. Rôle de la macrofaune benthique dans le fonctionnement du réseau trophique de l'écosystème à *Posidonia oceanica* (L.) Delile 1813 de la frange côtière de Mostaganem. Thèse de doctorat. Mostaganem (Algeria) : Université Abdelhamid Ibn Badis de. 169 p.

Belbachir N., Mezali K. and Soualili D.L. 2014. Selective feeding behaviour in some aspidochirotid holothurians (Echinodermata: Holothuroidea) at Stidia, Mostaganem Province, Algeria. SPC Beche-de-Mer Information Bulletin 34:34–37.

Ben Mustapha K. and Hattour A. 2016. Densité et diversité des holothuries de la zone lagunaire du sud du port de Sidi Daoud (Tunisie). Bulletin de l'Institut National des Sciences et Technologies de la Mer de Salammbô 43:85–93.

Conand C. 1983. Methods of studying growth in holothurians (beche-de-mer), and preliminary results from a beche-de-mer tagging experiment in New Caledonia. SPC Fisheries Newsletter 26:33–40.

FAO (Food and Agriculture Organization). 2010. Putting into practice an ecosystem approach to managing sea cucumber fisheries. Rome: FAO. 81 p.

Fisher W., Schneider M. and Bauchot M.L. 1987. Guide FAO d'Identification des Espèces pour les Besoins de la Pêche Méditerranée et Mer Noire - Zone de Pêche 37, Volume 1: Végétaux et Invertébrés. Organisation des Nations Unies pour l'Alimentation et l'Agriculture. 1529 p. (also available at: http://www.fao.org/docrep/009/x0170f/x0170f00.htm)

González-Wangüemert M., Aydin M. and Conand C. 2014. Assessment of sea cucumber populations from the Aegean Sea (Turkey): First insights to sustainable management of new fisheries. Ocean and Coastal Management 92:87–94.

González-Wangüemert M., Domínguez-Godino J.A. and Canovas F. 2018. The fast development of sea cucumber fisheries in the Mediterranean and NE Atlantic waters: From a new marine ressource to its over-exploitation. Ocean and Coastal Management 151:165–177.

Jorge Antonio D.G., Mehmet A. and Mercedes W. 2016. Profitability of the new target sea cucumber species from Mediterranean and NE Atlantic: *Holothuria polii*, *H. mammata*, *H. tubulosa* and *H. arguinensis*. Frontiers in Marine Science. Conference Abstract: IMMR | International Meeting on Marine Research. Sunny Peniche: Portugal, 14–15 July 2016. (also available at: http://www.frontiersin.org/marine_science/10.3389/conf.FMARS.2016.04.00024/full)

Kazanidis G., Antoniadou C., Lolas A.P., Neofitou N., Vafidis D., Chintiroglou C., Neofitou C. 2010. Population dynamics and reproduction of *Holothuria tubulosa* (Holothuroidea: Echinodermata) in the Aegean Sea. Journal of the Marine Biological Association of the United Kingdom 90(05):895-901.

Kazanidis G., Lolas A. and Vafidis D. 2014. Reproductive cycle of the traditionally exploited sea cucumber *Holothuria tubulosa* (Holothuroidea: Aspidochirotida) in Pagasitikos Gulf, western Aegean Sea, Greece. Turkish Journal of Zoology. 38(3):306-315.

Malouli Idrissi M. (ed). 2014. Institut National de Recherche Halieutique (INRH) – DRH. Rapport annuel de l'état des stocks et des pêcheries marocaines. Casablanca, Morroco: INRH. 320 p.

Marquet N., Conand C., Power D.M., Canário A.V.M. and González-Wangüemert M. 2017. Sea cucumbers, *Holothuria arguinensis* and *H. mammata*, from the southern Iberian Peninsula: Variation in reproductive activity between populations from different habitats. Fisheries Research 191:120–30.

Mezali K. 1998. Contribution à la systématique, la biologie, l'écologie et la dynamique de cinq espèces d'holothuries aspidochirotes (*Holothuria tubulosa*, *Holothuria polii*, *Holothuria stellati*, *Holothuria forskali* et *Holothuria sanctori*) de l'herbier à *Posidonia* oceanica (L) Delille de la presqu'île de Sidi Fredj. Thèse de magister. Sidi Fredj, Algériea, Institut des Sciences de la Mer et de l'Aménagement du Littoral. 238 p.

Mezali K. 2013. Polymorphism in *Holothuria (Platyperona) sanctori* from the Algerian coastal area. p. 647. In: Rapport du 40ème congrès de la CIESM. De Lange G.J., Gačić M., Romaña A., Da Costa M., Boero F., Turan C. and Sala E. (eds). Proceeding du 40eme Congrès de la Commission International pour l'Exploration Scientifique de la Mer Méditerranée (40th CIESM Congress Proceedings), October 2013. Marseille (France) : CIESM.

Mezali K. and Francour P. 2012. Systématique phylogénétique des holothuries Aspidochirotes de quelques sites des côtes algériennes : révision systématique et relations phylogénétiques. Bulletin de la Société Zoologique française 137:181–196.

Mezali K. and Semroud R. 1998. Analyses modales et essai d'estimation des paramètres de croissance, de l'âge et du mois de recrutement de trois espèces d'holothuries aspidochirotes (Holothuroidea: Echinodermata) de la région de Sidi-Fredj (Algérie). Rapport de la Commission Internationale de la Mer Méditerranée 35:466–467.

Mezali K. and Soualili D. L. 2015. Reproductive cycle of the sea cucumber *Holothuria tubulosa* (Holothuroidea: Echinodermata) in the southwestern mediterranean sea. p. 88-94. In: International Congress on « Estuaries and Coastal Marine Protected Areas » ECPA. İzmir -Turkey. 04-06 November 2014.

Mezali K., Zupo V. and Francour P. 2006. Population dynamics of *Holothuria (Holothuria) tubulosa* and *Holothuria (Lessonothuria) polii* of an Algerian *Posidonia oceanica* meadow. Biologia Marina Mediterranea 13:158–161.

Mezali K., Soualili D.L., Neghli L. and Conand C. 2014. Reproductive cycle of the sea cucumber *Holothuria (Platyperona) sanctori* (Holothuroidea: Echinodermata) in the southwestern Mediterranean Sea: interpopulation variability. Invertebrate Reproduction and Development 58(3):179–189.

Navarro P.G., García-Sanz S. and Tuya F. 2012. Reproductive biology of the sea cucumber *Holothuria sanctori* (Echinodermata: Holothuroidea). Scientia Marina 76(4):741-52.

Neghli L. 2013. Cycles de reproduction et exploitation des holothuries Aspidochirotes (Holothuroidea: Echinodermata) inféodées aux herbiers à *Posidonia Oceanica* de la côte algéroise [Mémoire de Magistère]. Mostaganem (Algeria). Université Abdelhamid Ibn Badis. 153 p.

Sicuro B. and Levine J. 2011. Sea cucumber in the Mediterranean: a potential species for aquaculture in the Mediterranean. Reviews in Fisheries Science 19:299–304.

Slimane-Tamacha F. and Mezali K. 2018. Etude du développement macroscopique des gonades du 'concombre de mer' *Holothuria (Platyperona) sanctori* (Holothuroidea: Echinodermata) dans la baie d'Oran. In : 8e Journées Nationales de la Faculté des Sciences de la Nature et de la Vie, 9–10 Mai 2018. Mostaganem, Algeria : Université Abdelhamid ibn Badis (UMAB).

Tuwo A. and Conand C. 1992. Reproductive biology of the holothurian *Holothuria forskali* (Echinodermata). Journal of the Marine Biological Association of the United Kingdom 72(04):745.

Towards a CITES listing of teatfish

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

Introduction

At the end of the 17th meeting of the Conference of the Parties (CoP17) of CITES (the **C**onvention on International Trade in Endangered Species of Wild Fauna and Flora) in October 2016, the French CITES Scientific Authority (SA), under the initiative of Chantal Conand, decided to work on a proposal for listing sea cucumbers at the next CoP. The CITES CoP is the 'supreme decision-making body' of this Convention (CITES Secretariat 2018a), and brings together 183 Parties to CITES every two to three years to review the implementation of CITES, and determine ways to improve its effectiveness (European Commission 2007).

The role of the Scientific Authority

The Scientific Authority (SA) is in charge of 1) gathering and analysing information on the biological status of species; 2) prioritising indigenous species affected by trade so as to make appropriate recommendations for import and export applications; and 3) assisting with the preparation of proposals necessary for amending the CITES appendices (MEEM/DEB 2016). In France, the mission of the CITES SA is entrusted to the Muséum national d'Histoire naturelle (MNHN).

Draft proposal to include teatfish in CITES Appendix II

The French SA worked with experts of the MNHN, under the coordination of Chantal Conand, to prepare a proposal for including sea cucumbers in CITES Appendix II. The proposal concerns the subgenus *Holothuria (Microthele)*, named teatfish, which includes four species: *Holothuria fuscogilva*, *H. fuscopunctata*, *H. nobilis* and *H. whitmaei*. These species are illustrated in the Food and Agriculture Organization (FAO) of the United Nations publication by Purcell et al. (2012). Note that a another morphotype of teatfish, *H. (Microthele)* sp., currently named 'pentard' by fishers and scientists, is likely to be described as a new species. The data shared by FAO and other partners led to the removal of *H. fuscopunctata* from the proposal because its commercial value is low and the absence of any distinguishing morphological characteristics (see below) makes it visually similar to other sea cucumbers. The remaining three species, however, are commercially important and are threatened by a sharp decline in their stocks.

These species meet the CITES criteria for inclusion in Appendix II, in accordance with Resolution Conf. 9.24 (Annex 2a and b), which states that a "regulation of trade in the species is required to ensure that the harvest of specimens from the wild is not reducing the wild population to a level at which its survival might be threatened by continued harvesting or other influences" (CITES 2016:5).

The French SA, thus, considered that CITES was the right tool to implement the required regulation to ensure the sustainability of the exploitation of these species.

Why include only these three sea cucumber species?

The three teatfish species concerned – *Holothuria fuscogilva*, *H. nobilis* and *H. whitmaei* – as well as *Holothuria (Microthele)* sp. (the 'pentard'), have a common morphological characteristic that makes them easy to identify (i.e. it is visible in their live, fresh and dried forms): lateral protuberances (teat-like) that are clearly visible on the tegument (Fig. 1). Unlike these three species (+ the 'pentard', if accepted as a new species), other commercially important sea cucumbers are very difficult to differentiate from one another, especially for untrained border control agents. However, the effective application of control measures is key to any regulation or prohibition.

[1] French CITES Scientific Authority, Muséum national d'Histoire naturelle. Email: marie.di-simone@mnhn.fr and/or arnaud.horellou@mnhn.fr
[2] Muséum national d'Histoire naturelle. Email: chantal.conand@mnhn.fr

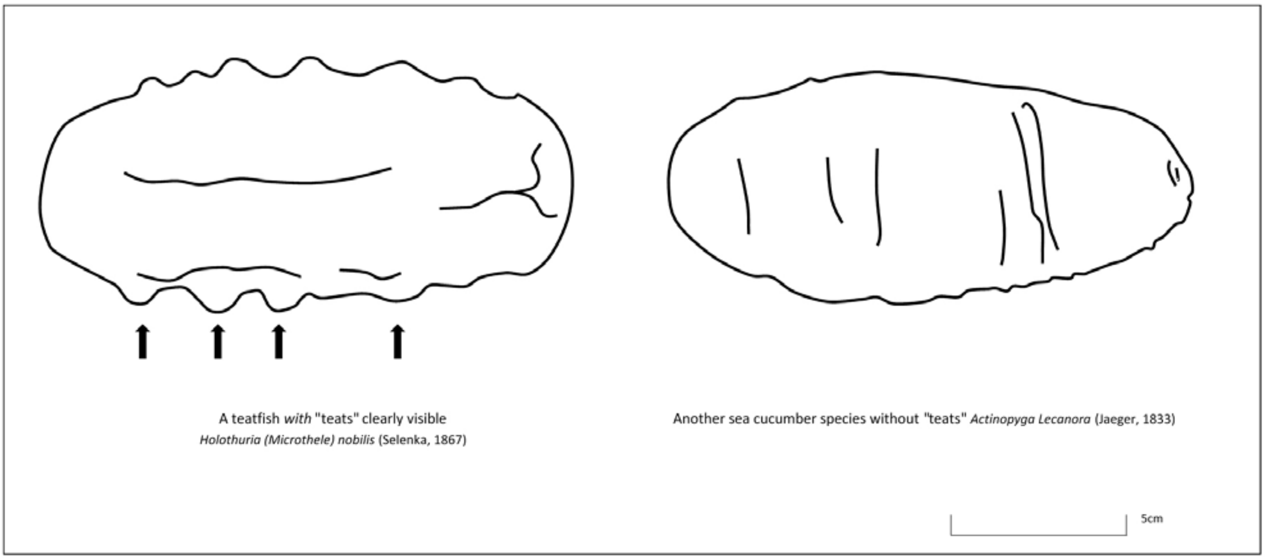


Figure 1. Comparison of a teatfish (left) and another sea cucumber species without teats (right) in their dried form.

The possibility of including all sea cucumber species in CITES Appendix II has also been considered, and is based on Annex 2b of Resolution Conf. 9.24 (Rev. CoP15), which allows the listing of non-endangered species that may be confused with species already listed in CITES, in order to make controls possible and to avoid trafficking under false scientific names. However, according to the French SA, such a proposal is currently unrealistic, given the socioeconomic and commercial importance of sea cucumbers, especially for Asian countries (Conand 2018).

Presenting the listing proposal to the European Union and then to the international level

As a member state of the European Union (EU), France must respect the European regulation of CITES. In particular, this regulation requires that when a member state wishes to submit a proposal for amending CITES Appendices I and II, it must first be accepted by other member states in order to be presented to the next CoP, under the EU delegation. This process of EU delegation to CoP is quite new. It comes from the "Gaborone Amendment", which was adopted at CoP4 (in 1983) in Botswana, which allows a regional organisation to become a full member of CITES (CITES Secretariat 2018b). The EU applied for, and was granted, membership to CITES as a regional organisation in 2013, which became effective in 2015 (it is the only regional organization to do so). As a result, the EU has the votes of all 28 member states.

Therefore, the French SA presented its draft proposal in June 2017 at the 79th meeting of the Scientific Review Group, bringing together the SA of each member state (including France) to discuss scientific issues related to European regulations pertaining to CITES (European Commission 2007; MEEM/DEB 2016).

This draft proposal has been favourably received by other EU member states, and was presented at the Animals Committee, the technical committee of scientific experts of the Parties to CITES, in Geneva in July 2018 under the EU delegation. The proposal's acceptance during this committee was not without controversy. Some Asian members were opposed to it, arguing that the proposal was insufficiently documented. On the other hand, European members, Mexico and the non-governmental organisations Wildlife Conservation Society and the Humane Society International have expressed their support, supporting the need to control the currently unsustainable trade of sea cucumbers.

The Animals Committee noted the document and encouraged those Parties and organisations that had any comments or useful information to send them directly to the proponents (CITES Secretariat 2018c).

The proposal is currently online on the CITES website (https://cites.org/fra/cop/18/prop/index.php), and will officially be presented by the EU at the next CoP in Colombo, Sri Lanka at the end of May 2019.

References

CITES. 2016. Resolution Conf 9.24 (Rev CoP17). https://www.cites.org/eng/res/09/09-24R16.php

CITES Secretariat. 2018a. Convention sur le commerce international des espèces de faune et de flore sauvages menacées d'extinction. URL https://www.cites.org/fra (Accessed 22 November 2018).

CITES Secretariat. 2018b. Gaborone amendment to the text of the Convention. URL https://www.cites.org/fra/disc/gaborone.php (Accessed 22 November 2018).

CITES Secretariat. 2018c. Executive summaries – 30th meeting of the Animals Committee. URL https://cites.org/sites/default/files/fra/com/ac/30/sum/F-AC30-ExSum-03-R1.pdf (Accessed 22 November 2018).

Conand C. 2018. Tropical sea cucumber fisheries: Changes during the last decade. Marine Pollution Bulletin 133:590–594.

European Commission. 2007. La réglementation du commerce des espèces sauvages dans l'Union européenne : présentation de la CITES et de sa mise en oeuvre dans l'Union européenne. Luxembourg: Office des publications officielles des Communautés européennes. 24 p.

MEEM (Ministère de l'Écologie, du Développement Durable et de l'Énergie)/ DEB (Direction de l'Eau et de la Biodiversité). 2016. Mise en oeuvre de la CITES, convention de Washington. Ministère de l'écologie, du développement durable et de l'énergie.

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. 150 p.

COMMUNICATIONS

Observation of mass spawning of the sea cucumber *Holothuria coluber* at Lizard Island, Great Barrier Reef, Australia

Víctor Huertas[1*] and Maria Byrne[2]

Location

Northwest reef of the Blue Lagoon at Lizard Island, northern Great Barrier Reef

Date and time of observation

18 December 2018 between 15:30 and 16:00

We report an *in situ* observation of a mass spawning event of sea cucumbers at Lizard Island in the northern Great Barrier Reef. On 18 December 2018, a minimum of 20 sea cucumbers spawning within an estimated area of 200 m^2 were observed on the shallow fringing reef in the northwest margin of the Blue Lagoon at Lizard Island. The sea cucumbers were identified as *Holothuria coluber* by their slender bodies, dark colouration, yellow tentacles, and the presence of numerous white papillae throughout their bodies (Fig. 1A). All individuals were observed on the reef flat at a depth of 2 m (Fig. 1B). This observation coincided with a waxing gibbous moon and a rising tide (high tide of 2.34 m occurred at 18:04).

All individuals elevated the anterior end of their body above the reef substrate, high in the water column. However, in doing so, they became exposed to the current, and appeared to actively adjust their orientation to remain erect. This behaviour is consistent with previous observations of spawning holothurians (Mortensen 1937; Hendler and Meyer 1982; Balogh et al. 2018). Our record adds to previous opportunistic observations of *H. coluber* spawning in the area (Babcock et al. 1992).

The reproductive cycles of many reef invertebrates that have predictable synchronised spawning events are well-known (Harrison et al. 1984; Babcock et al. 1992; Wolstenholme et al. 2018). The factors that trigger spawning events of *H. coluber*, however, are unknown, but are likely to be cued by daylength and lunar cycle as in other sea cucumbers (Balogh et al. 2018). Further research is needed to identify the environmental cues that underpin sexual reproduction of *H. coluber*. Until this information becomes available, anecdotal observations, like this one, provide a glimpse into the reproductive biology of these animals.

References

Babcock R., Mundy C., Keesing J. and Oliver J. 1992. Predictable and unpredictable spawning events: *In situ* behavioural data from free-spawning coral reef invertebrates. Invertebrate Reproduction and Development 22:213–228. doi: 10.1080/07924259.1992.9672274

Balogh R., Wolfe K. and Byrne M. 2018. Gonad development and spawning of the vulnerable commercial sea cucumber, *Stichopus herrmanni*, in the southern Great Barrier Reef. Journal of the Marine Biolgical Association of the United Kingdom 1–9. doi:10.1017/S0025315418000061

Harrison P.L., Babcock R.C., Bull G.D., Oliver J.K., Wallace C.C. and Willis B.L. 1984. Mass spawning in tropical reef corals. Science 223:1186–1189.

Hendler G. and Meyer D.L. 1982. Ophiuroids *Flagrante delicto* and notes on the spawning behavior of other echinoderms in their natural habitat. Bulletin of Marine Science 32:600–607.

Mortensen T. 1937. Contributions to the study of the development and larval forms of echinoderms. IV Kongel. Danske Vidensk. Selsk. Skrifter 7:1–65

Wolstenholme J., Nozawa Y., Byrne M. and Burke W. 2018. Timing of mass spawning in corals: potential influence of the coincidence of lunar factors and associated changes in atmospheric pressure from northern and southern hemisphere case studies. Invertebrate Reproduction and Development 62:98–108. doi: 10.1080/07924259.2018.1434245

[1] College of Science and Engineering, James Cook University, Townsville, QLD 4811, Australia
[2] School of Life and Environmental Sciences, University of Sydney, Sydney, NSW 2006, Australia
[*] Author for correspondence: victor.huertas@my.jcu.edu.au

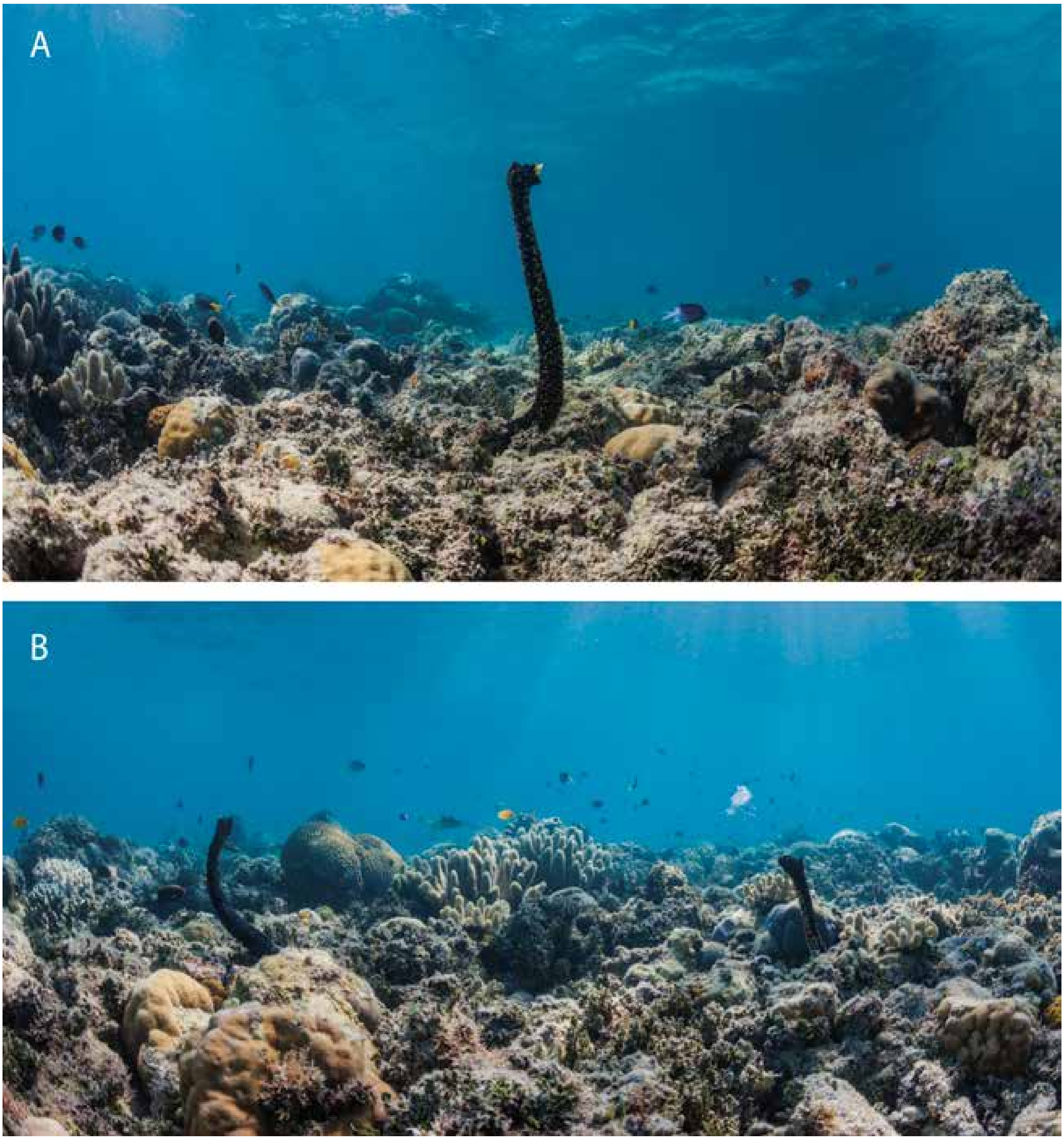


Figure 1. *Holothuria coluber* spawning on the reef flat at Lizard Island. A: A reproductively active *H. coluber* rises its anterior end above the reef substrate during the spawning event; B: Two erect *H. coluber* in close proximity. Note the cloud of gametes released by the sea cucumber to the right. (images: Victor Huertas, James Cook University)

Other spawning observations

Communicated by Prof. Maria Byrne

Stichopus chloronotus, Guttter inlet site, One Tree Island, Great Barrier Reef, Australia, 17:00, 24 October 2018.
(image: Maria Byrne, University of Sydney)

Actinopyga lecanora and *A. miliaris*, Big Vickis Reef, Lizard Island, GBR, Australia, 17:00, 11 December 2018. Two *A. lecanora* spawning, both males; one *A. miliaris* spawning, a male.
(image: Jonathan Allen, College of William & Mary)

Stichopus herrmanni, One Tree Island Lagoon, GBR, Australia
6 Feb. 2019: 16:30–17:00 nothing; 7 Feb.: 16:30–17:00 spawning; 8 Feb.: 16:30–17:00 spawning; 9 Feb.: 16:30–17:00 nothing.
All at low tide and 2–3 days after the new moon.
(image: Mike Kingsford, James Cook University)

Other images of *Holothuria coluber*, Lizard Island Lagoon NW, 18 December 2018, 15:30–16:00. About 20 individuals spawning over a 30 m distance, 2-m depth. (images: Victor Huertas, James Cook University)

CONFERENCES

The 16th International Echinoderm Conference – Nagoya, Japan 2018

Oral presentations on holothurians

Echinoderm diversity and distribution along the Pacific coast of Costa Rica

Alavarado J.J., Mena-González S., and Guzmán-Mora A.G. (* juan.alvarado@ucr.ac.cr)*

Characterization of tensilin-like proteins from the body wall and Cuvierian tubules of the sea cucumber *Holothuria forskali*

Bonneel M., Hennebert E., Wattiez, R. and Flammang P. (* marie.bonneel@umons.ac.be)*

How different sterols contribute to saponin tolerant plasma membranes in sea cucumbers

Claereboudt E., Eeckhaut I., Lins L. and Deleu M. (* emily.claereboudt@doct.uliege)*

An attempt to conserve the highly depleted *Holothuria fuscogilva* in the northwest coast of Sri Lanka

Dissanayake D.C.T. (* chamid4@gmail.com; chamari@sjp.ac.lk)*

A high risk small-scale marine fishery in the coastal livelihoods of northern Sri Lanka

Dodangodage P.K. (*dodangodage5@gmail.com)*

***Holothuria mammata*: a new emergent species for sea cucumber aquaculture in north-eastern Atlantic and Mediterranean Sea**

Domínguez-godino J.A., Cruz J.M.G., and González-Wangüemert M. (* jorge.adg86@gmail.com)*

Problems with estimating survival in echinoderm populations

Ebert T., Hernández J. and Clemente S. (* ebertt@science.oregonstate.edu)*

A field guide to coastal echinoderms of the Kerguelen Islands

Feral J.-P., Poulin E., De Ridder C. and Saucede T. (* jean-pierre.feral@imbe.fr)*

Frizzled genes expression patterns during regeneration of internal organs in *Eupentacta fraudatrix*

*Girich A.S.*and Dolmatov I.Y. (* astromoon@mail.ru)*

Molecular tools to assess the stocks of *Holothuria arguinensis* and implications for its management

González-Wangüemert M., Diaz-suárez A., Domínguez-Godino J.A. and Cánovas F. (* mwanguemert@ualg.pt)*

Influence of vibration caused by sound on migration of sea cucumber *Apostichopus japonicus*

Lin C., Yang H., Zhang L., Sun L. and Zhang T. (* linchenggang@qdio.ac.cn)*

Indications of conspecific passive interference in *Stichopus horrens*

Juinio-Meñez M.A., Gorospe J.C., Soy R.C., Rioja R. and Lambio K.A.F. (* ajmenez@msi.upd.edu.ph)*

Cryptic genetic diversity in *Stichopus* cf. *horrens*: Reproductive isolation revealed by microsatellite and SNP markers

Kim K.M., Lizano A.M.D. and Ravago-Gotanco R. (* kimkennethm@gmail.com)*

Limited genetic connectivity of *Stichopus* cf. *horrens* across the western Philippines revealed by microsatellite markers

Lizano A.M.D., Juinio-Meñez, M.A. and Ravago-Gotanco R. (* marcopolo132004@gmail.com)*

Taxonomic status of some Algerian shallow-water sea cucumber species (Holothuroidea: Echinodermata) deduced from morphology and mitochondrial DNA sequences

Mezali K. and Mansouri T. (* karimmezali14@gmail.com)*

Reproductive biology and early development of the Dendrochriotid ball sea cucumber, *Phyllophorus proteus*, in western Visayas, central Philippines

Nievales MFJ., Genisan A., Dejuan F., Madarcos N.R. and Madas C. (* mjnievales1@up.edu.ph)*

The high road and the low road: multiple processes lead to latitudinal diversity gradients across the seafloor

O'Hara T.D. and Hugall A.F. (* tohara@museum.vic.gov.au)*

Taxonomic revision of genus *Pannychia* (Holothuroidea, Elasipodida, Laetmogonidae) from Japanese waters

Ogawa A. and Fujita T. (* a-ogawa@kahaku.go.jp)*

Transcriptomic resources for *Holothuria scabra*: identification of growth-related genes H and ancestry-informative SNP marker development

Ordoñez J.F.F., Galindez G.S.T. and Ravago-Gotanco R. (* junefordonez@gmail.com)*

Recent advances in understanding higher-level sea cucumber relationships and classification

Reich M. and Paulay G. (* mike.reich@lmu.de)*

Evaluating the direct and indirect effects of light on *Stichopus* cf. *horrens*' behavior, growth and survival

Rioja R.A., Palomar-Abesamis N. and Juino-Meñez M.A. (* riojangeli@gmail.com)*

Stock enhancement of the sea cucumber A*postichopus japonicus* by release of the post-settled juveniles in Hokkaido, Japan

Sakai Y., Honke K., Mori N., Michibayashi N., Sato N. and Kanno M. (sakai-yuichi@hro.or.jp)*

Effects of food abundance on the diel burying behavior, growth, and survival of juvenile *Holothuria scabra*

Sinsona M.J. and Juinio-Meñez A.J.M. (* msinsona@msi.upd.edu.ph)*

The sea cucumber genome provides insights into morphological evolution and visceral regeneration

Sun L., Yang H., Zhang L., Lin C. and Zhang T. (* sunlina@qdio.ac.cn)*

Re-establishment of the anteroposterior axis in regenerating intestines of a sea cucumber *Apostichopus japonicus*

Takatani K., Nakano H. and Kondo M. (* konmari@mmbs.s.u-tokyo.ac.jp)*

Softenin, novel protein which softens the dermis isolated from a sea cucumber *Stichopus chloronotus*

Tamori M., Takehana Y., Yamada A. and Motokawa T. (* mtamori@bio.titech.ac.jp)*

The southern African Holothuroid fauna: a synopsis

Thandar A.S. (* thandara@ukzn.ac.za)*

A systematic revision on sea cucumbers of the family Stichopodidae using two molecular markers

*Woo S.P. *, Kajihara H., Byrne M., Tan S.H., Zulfigar Y., Yeemin T., Suttacheep M. and Fujita, T.
(* abe_woo@hotmail.com)*

Biological characteristics and aquaculture of sea cucumber *Apostichopus japonicus*

Yang H., Zhang T., Zhang L., Sun L. and Lin C. (hshyang@qdio.ac.cn)*

Locomotion and feeding behavior of sea cucumber *Apostichopus japonicus*

Zhang L., Pan Y., Sun J., Ru X., Zhang T. and Yang H. (* zhanglibin@qdio.ac.cn)*

Application of non-invasive imaging techniques in echinoderm research: past, present, and future
Ziegler A. (* aziegler@evolution.uni-bonn.de)*

Poster presentations on holothurians

New reports of echinoderms on the Caribbean coast of Central America Deep Basin: perspectives and projections
Benavides R., Cambronero S., Alvarado J. J. and Solís-Marín F.A. (* sergiocambroscs@gmail.com)*

Adhesion of sea cucumber Cuvierian tubules: identification and characterization of adhesive proteins
Bonneel M., Hennebert E., Demeuldre M., Wattiez R. and Flammang P. (* marie.bonneel@umons.ac.be)*

Dynamic changes of gene expression during larval development of holothurian *Apostichopus japonicus*
Boyko A., Girich A., Eliseikina M., Maslennikov S. and Dolmatov I. (* alteroldis@gmail.com)*

The marine biotechnology of the sea cucumber and its exploitation in Mexico
Caballero-Ochoa A.A., Simental-Crespo D., Solís-Marín F.A. and Conejeros-Vargas C.A. (* a.caballero.ochoa@ciencias.unam.mx)*

Sniffing out disease: Ulcerated holothuroids induce different chemotaxis behaviors in symbiotic and predatory crabs
Caulier G., Claereboudt E., Flammang P., Gerbaux P. and Eeckhaut I. (* Guillaume.Caulier@umons.ac.be)*

Transcriptomic and proteomic identification of neuropeptide precursors and neuropeptides in the sea cucumber
Chen M., Hou Y., Storey K., Talarovicova A. and Elphick M. (* chenmuyan@ouc.edu.cn)*

Potential species for the isolation and characterization of cytotoxic compounds of sea cucumbers in Mexico
Conejeros-vargas C.A., Simental-Crespo D., Solís-Marín F.A. and Caballero-Ochoa A.A. (*conejeros@ciencias.unam.mx)*

Assessing the validity of ossicles as a taxonomic criteria for Mediterranean and north-western Atlantic sea cucumbers
Diaz-Suárez A., Cánovas, F. and González-Wangüemert M. (* mwanguemert@ualg.pt)*

Mass mortality of echinoderms across the Algarve coast (south Portugal) after the storm Emma
Domínguez-Godino J.A., Domínguez-Godino S., Ricart A. and González-Wangüemert, M. (* jorge.adg86@gmail.com)*

Is magnesium concentration in the skeleton a predictor of echinoderm sensitivity to ocean acidification?
Dubois P. (* phdubois@ulb.ac.be)*

Genetic population structure of the black sea cucumber *Holothuria (Halodeima) atra* around Okinawa-Jima island
Hamamoto, K., Soliman, T. and Reimer, J.D. (*hamachanman1@gmail.com)*

Purification and kinetic characterization of novel proteases from the sea cucumber *Holothuria inornata* from Chamela Bay, Jalisco, Mexican Pacific
Hernández Melgar A.G., Osorio Kuan J.A., Espinosa de los Monteros R.A., Solís-Marín F.A., Salgado Ortiz N. and Simental D. (froz9@comunidad.unam.mx)*

Inducing in vitro oocyte maturation of H*olothuria arguinensis* and *Holothuria leucospilota*, using radial nerve extract
Kalvani B., Sodagar M., Mazandarani M., Noori A. and González-Wangüemert M. (* mwanguemert@ualg.pt)*

Regeneration after fission and transverse cutting in the holothurian *Cladolabes shcmeltzii*

Kamenev Ya.O. and Dolmatov I. Yu. (jarolkam@mail.ru)*

New discovery of wheel fossils of Ophiocistioidea and Holothuroidea from Japan

Ogawa A., Takahashi Y. and Fujita T. (* a-ogawa@kahaku.go.jp)*

Observation of intestinal regeneration after induced evisceration in a sea cucumber, *Eupentacta quinquesemita*

Okada A. and Kondo M. (* akari@mmbs.s.u-tokyo.ac.jp)*

Sea cucumbers as a potential marine collagen source: a high performance method

Osorio Kuan J.A., Espinosa de los Monteros R.A., Solís-Marín F.A., Salgado Ortiz N. and Simental, D. (* jorgeosoriokuan@gmail.com)*

Sea cucumber type material of Carl Gottfried Semper (1832–1893) at the Danish natural History Museum in Copenhagen

Reich M., Ilsemann B. and Schiøtte T. (* mike.reich@lmu.de)*

Sea cucumber as a potential source of photoprotective compounds: collagen and mycosporine-like aminoacids

Salgado-Ortiz N., Arreguín Espinosa de los Monteros R., Solís-Marín F.A. and Simental Crespo D. (* noesalgadortiz@gmail.com)*

Echinoderm collection of the Zoological Institute of RAS as information base of fundamental biological investigation

Smirnov I., Ananjeva N., Pugachev O., Khalikov R., Lobanov A. and Voyta L. (* smiris@zin.ru)*

Unusual ossicle morphology in sea cucumbers (Apodida) from the late Triassic Cassian formation, Italy

Stegemann T.R. and Reich M. (* tstegem@gwdg.de)*

Development of adult organs and the pentaradial body plan in a sea cucumber, *Apostichopus japonicus*

Udagawa S., Nagai A., Saito M. and Kondo M. (* udagawa@mmbs.s.u-tokyo.ac.jp)*

Vasa and piwi-like proteins in the tissues of the holothurian *Eupentacta fraudatrix* (Dendrichirota, Holothuroidea)

Zavalnaia E.G., Petrova I. Yu., Eliseikina M.G., Girich A.S. and Dolmatov I.Yu. (eugenia_94@inbox.ru)

The effect of melatonin on locomotor behavior and muscle physiology in sea cucumber

Zhang T., Ding K., Zhang L. and Yang H. (* dingkui0929@163.com)*

Distribution and abundance of the sea cucumbers *Holothuria* spp. on coral communities in the Gulf of Thailand

Yeemin T., Sutthacheep M., Ruangthong C., Pengsakun S., Klinthong W. and Putthayakool J. (* thamasakyeemin@hotmail.com)*

A few photos from Nagoya International Echinoderm Conference

CIEC - Sea cucumbers sold in Nishiki food market de Kyoto, Japan.
(photo J-P Féral)

Up-coming conferences

1) 10th European conference on Echinoderms Moscow, 16–19 September 2019

Organizers of the conference:

- Borissiak Paleontological Institute of the Russsian Academy of Sciences (RAS)
- Shirshov Institute of Oceanology (RAS)
- A.N. Severtsov Institute of Ecology and Evolution (RAS)
- Zoological Institute (RAS)
- A.P. Karpinsky Russian Geological Research Institute (VSEGEI)
- White Sea Biological Station of Lomonosov Moscow State University (WSBS)
- Department of Invertebrate Zoology, Biological Faculty of Lomonosov Moscow State University
- Lomonosov Moscow State University Marine Research Centre
- The Center of Oceanografic and Marine Biology (Moskvarium)

For more information: https://10ece2019.com/

2) WIOMSA 11th Scientific Symposium, 1–6 July 2019

The Western Indian Ocean Marine Science Association (WIOMSA), the University of Mauritius, and the Nairobi Convention are pleased to announce the 11th WIOMSA Scientific Symposium to be held in Mauritius in July 2019

Contributions from all relevant scientific disciplines are welcome at this multidisciplinary symposium.

For more information: www.wiomsa.org

3) 4th European conference of Tropical Ecology, 9–12 April 2019

The conference will take place in the UK city of Edinburgh, jointly hosted by the University of Stirling, the University of Edinburgh and the Royal Botanic Garden Edinburgh.

For more information: www.britishecologicalsociety.org/events/ute2019/

4) Islands Biology – La Reunion, 8–13 July 2019

For more information: https://ib2019.sciencesconf.org

5) World Congress on Recent Advances in Aquaculture Research & Fisheries

Aquaculture Research 2019 is scheduled from 9 to 11 June 2019 in Dublin, Ireland, on the theme "Sustainable Aquaculture and Fisheries".

For more information: https://aquaculture-fisheries.pulsusconference.com/

Publications related to holothurians, published in 2018

By Chantal Conand

As usual, a 'Google Alert' using the word 'holothurian' has been set up for the period from January to 15 December 2018. The same method had been used to produce the article 'Bibliography on holothurians: Access to modern tools to follow new publications'[1] , which was published in the SPC Beche-de-mer Information Bulletin #38.

Table 1 presents a summary of the findings and uses the same five categories (themes) that were used n the two previous issues of the bulletin.

Table 1. Number of documents related to 'holothurians' published in the period 1 January to 15 December 2018.

Month	General, ecology, biology	Biochemistry, microbiology	Genetics	Aquaculture	Fishery, socio-economics	Total per month
January	16	19	5	3	7	50
February	9	19	4	5	8	45
March	8	16	4	2	3	33
April	14	21	5	7	7	54
May	10	11	1	5	1	28
June	10	7	1	1	3	22
July	17	4	1	2	1	25
August	10	7	2	3	2	24
September	13	4	0	5	8	30
October	9	4	2	3	3	21
November	12	7	1	2	1	23
December	6	4	1		4	15
total	134	123	27	38	48	370
Ratio (%)	36.2%	33.2%	7.3%	10.3%	13%	100%

New book on echinoderms

We are happy to announce the upcoming publication of the Guide of the echinoderms of Mayotte and its region, by F. Ducarme, edited by Les Naturalistes de Mayotte, already known for their impressive work on molluscs (Deuss/Richard/Verneau 2013).

This illustrated book will contain 168 species (of which 77 are new records for Mayotte), including 47 species of sea cucumbers. Next to classical species such as *Thelenota ananas* or *Holothuria atra*, there are locally abundant species (quite rare elsewhere) as *Bohadschia atra* (described from Mayotte specimens) or *Bohadschia subrubra* (illustrated below), but also rarer species, deep-sea species (down to 120 m) and illustrations of some probably not-yet described species.

The aim of this work is to shed light on echinoderms in some classical works like Richmond 2011 (Guide to the al. 2016 (Oursins, étoiles de mer et autres échinodermes : ecological, behavioural, taxonomic and cultural informa-followed by a research paper in English.

Bohadschia subrubra from Mayotte. (image: F. Ducarme)

PhD theses

The sea cucumber *Holothuria arguinensis*, as new species for aquaculture

Jorge Antonio Dominguez Godino

Presented the 5 December 2018, Cadiz University, Spain.

Role of the benthic macrofauna in the functionning of the food web of the *Posidonia oceanica* (L. Delile 1813) ecosystem, in the coastal zone of Mostaganem

Nor-Eddine Belbachir

Presented the 13 December 2018, Department of Biology, University Abdelhamid Ibn Badis, Mostaganem, Algeria.

Abstract

Among the fauna inhabiting the *Posidonia oceanica* seagrass meadow, holothurians are particularly abundant and provide essential ecological roles, including the organic matter recycling within seagrass sediments. This work aims to (1) have an idea about the *Posidonia* meadow of the Mostaganem coast (Stidia), through the characterization of the most important aspects of the biology of this marine plant, which is the flowering and fruiting; (2) have an insight about the feeding behavior of the four most abundant holothurians species on the Mostaganem coast [*Holothuria (Roweothuria) poli, Holothuria (Holothuria) tubulosa, Holothuria (Panningothuria) forskali* and *Holothuria (Platyperona) sanctori*)]; (3) investigate the trophic niche of these organisms, through the measurement of nitrogen and carbon stable isotope ratios. Inflorescences of November 6, 2017 bear only flowers. Each inflorescence carries between 1 and 4 spikelets, with an axis length ranging between 24 mm and 27 mm. The majority of the examined spikelets carry 2 to 3 flowers. The latter are 56.2% to 78.6% hermaphrodite and 21.4% to 43.8% are male. The inflorescences of January 8, 2018 bear aborted fruits and ovaries. Each inflorescence carries between 2 and 4 spikelets, with an axis length ranging between 20 mm and 33 mm. The spikelets of the second prospecting carry a single fruit, sometimes two and some does not carry any. The fruit length is between 7 mm and 15 mm. Most holothurians have a selective behavior for organic matter and eject feces with high levels of organic matter, which is attractive to other consumers. Stable isotope mixing models demonstrated the importance of epiphytic material in holothurians diets. Interestingly, the contribution of *P. oceanic*a to the holothurians diet was limited. The stable isotope approach did not reveal dietary differences between species and the four species exhibited significant isotopic niche overlap. However, niche sizes differ between species showing more variable individual trophic diversity in some species. High values of δ^{15N} in holothurians and their food sources were observed at both sites. This highlights that the site of Stidia is also impacted by human activity (agriculture) despite the presence of a relatively healthy seagrass meadow.

Systematic studies on sea cucumbers of the family Stichopodidae (Echinodermata: Holothuroidea)

Woo Sau Pinn

Presented in December 2017, Graduate School of Science, Hokkaido University Department of Natural History Sciences, Japan.

https://eprints.lib.hokudai.ac.jp/dspace/bitstream/2115/69423/1/Woo_Sau_Pinn.pdf

Holothurians sold in retail markets in France and Australia

By Chantal Conand

In a supermarket in Paris, France

Frozen sea cucumbers from Viet Nam can now be found in Paris (Fig. 1A) at a price of EUR 48 kg^{-1}. The identification is incorrect, as the sandfish *Holothuria scabra* does not look like the ones presented here (Fig. 1B) and *H. vagabunda* is not a valid scientific name (Fig. 1C).

Figure 1. Frozen sea cucumbers from Viet Nam found in a Paris market.

In a shop in Melbourne, Australia

Many different species of different origins are presented in a shop (Fig. 2) where photos were not allowed to be taken, but the prices were advertised as AUD 300 for a species sold as teatfish (certainly *Holothuria fuscogilva* or *H. whitmaei)* and AUD 200 for *Thelenota ananas*. There were also many *Apostichopus japonicus*, *Holothuria scabra* and other species. Most products were dried, but some were frozen.

Figure 2. A shop in Melbourne, Australia selling boxes of dried sea cucumbers.

Sea cucumbers in the news

List compiled by Chantal Conand

Reported by Tim Gentle

Washington man gets prison for overharvesting sea cucumbers
https://www.theguardian.com/environment/2018/sep/27/sea-cucumber-poacher-washington

Sea cucumber framing in Borneo
http://www.theedgemarkets.com/article/reuters-special-report-ocean-shock-big-aquaculture-bulldozes-borneo

Reported by Mercedez Gonzalez-Wangüemert (mwanguemert@ualg.pt)

Maritime police seizes 550 kilos of sea cucumbers illegally fished (June 2018)
https://www.acores24horas.pt/arquivo/86372

Fifteen days opening for sea cucumber fishing in Yucatan (March 2018)
http://progresohoy.com/noticias/autoriza-sagarpa-15-dias-para-la-pesca-de-pepino-de-mar-en-yucatan-10099005/?utm_source=dlvr.it&utm_medium=facebook

Reported By Alice Chen

Chinese sea cucumber farmers count cost of deadly heatwave – but for some it's a boon (August 2018)
https://www.scmp.com/news/china/society/article/2158698/
chinese-sea-cucumber-farmers-count-cost-deadly-heatwave-some-its

Reported by Steven Purcell

Here's a YouTube video that was apparently uploaded recently – very popular. Good facts for the general public (although I have to say I've never considered them dangerous).
https://youtu.be/CUA7MAlOok4

Reported by Chantal Conand

Opening of the sea cucumber fishing season in French Polynesia (August 2018)
https://www.tahiti-infos.com/Ouverture-de-la-campagne-de-peche-reglementee-aux-rori-a-Raroia-et-Faaite_a173868.html

Original text: English

Pacific Community, Fisheries Information Section, BP D5, 98848 Noumea Cedex, New Caledonia
Telephone: +687 262000; Fax: +687 263818; cfpinfo@spc.int; http://www.spc.int/coastfish