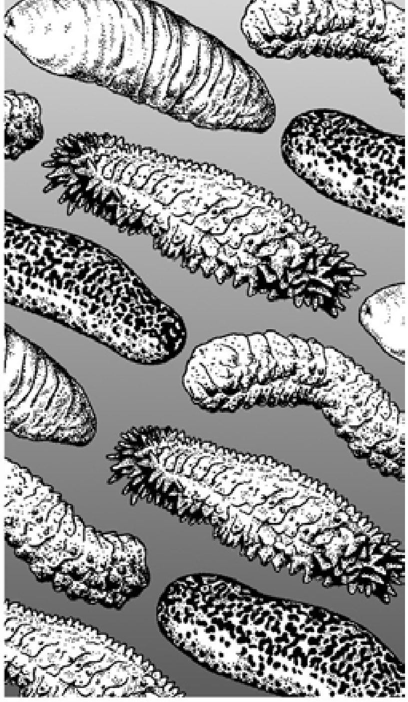

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Inside this issue

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
Fisheries Information Section
SPC, BP D5, 98848 Noumea Cedex
New Caledonia
Fax: +687 263818
Email: cfpinfo@spc.int
www.spc.int/coastfish

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Editorial

This 38th issue of the *SPC Beche-de-mer Information Bulletin* includes eighteen original articles. The first two relate to the Pacific Islands region. Hair et al. highlight a case study of the sea cucumber fishery of the Tigak Islands (New Ireland Province, Papua New Guinea), which was carried out after the lifting of a seven-and-a-half year nationwide moratorium on sea cucumber fishing and the beche-de-mer trade (p. 3). Lee makes observations about the length-weight relationship, movement rates and spawning of *Holothuria scabra* in Fiji (p. 11).

Information is also reported from the Indo-Pacific region with Mulochau presenting first his study on the trading of sea cucumbers from Geyser Bank (Scattered Islands, Gloriosos, Indian Ocean) (p. 15). In the following article, the same author describes the monitoring of commercially important sea cucumber populations in the reefs of Mayotte (Indian Ocean) (p. 21). The two next articles show different *in situ* observations: Setyastuti et al. have discovered a *Holothuria leucospilota* natural nursery on Pai Island, Biak-Papua (Indonesia) (p. 29) and Bourjon and Desvignes describe asexual reproduction in a population of *Holothuria difficilis* (Echinodermata; Holothuroidea) at Reunion Island p. 37).

Four articles relate to experiments made *in situ*, in laboratories or in hatcheries. Ahmed et al. made a pilot study on grow-out culture of *H. scabra* in bottom-set sea cages in lagoons of Maniyafushi Island (Kaafu Atoll, Maldives) (p. 45). González-Wangüemert and Domínguez-Godino assessed rehydration protocols on the dried sea cucumber *Holothuria arguinensis* (Portugal) (p. 51). Belbachir and Mezali studied the food preferences of four aspidochirotid holothurians species (Holothuroidea: Echinodermata) that inhabit the *Posidonia oceanica* meadow of the Mostaganem area (Algeria) (p. 55). Todinanahary et al. investigated the influence of phytoplankton densities on the time of appearance of doliolaria and pentactula in sandfish hatcheries (Madagascar) (p. 60).

There are then two articles that are about bibliographic and statistical analyses, which deal with the sea cucumber market and the illegal fisheries. To et al. update news about the Hong Kong market (p. 64) and Conand gives new information on worldwide illegal fisheries for sea cucumbers (p. 68).

Diseases and parasites are the subjects of the two next articles. Burel shows strange blisters found on *Holothuria scabra* integument that occurred under fresh water influence (Madagascar) (p. 72) and Rogers et al. report on the pearlfish *Carapus bermudensis* from the sea cucumber *Holothuria mexicana* in Belize (Central America) (p. 73).

Various short reports and communications end this issue such as the new data on the distribution of the sea cucumber *Molpadia musculus* in Russian seas, given by Stepanov and Panina (p. 77). Quratulan et al. determine the effects of seasonal variation on the sea cucumber *Ohshimella ehrenbergii* weight–length relationships in Pakistan (p. 79). Bermudes talks about the initiative led by the Pacific Community's Fisheries, Aquaculture and Marine Ecosystems Division: participants from five Pacific Island countries took part in activities in Papua New Guinea, Fiji and New Caledonia to improve their knowledge of sandfish (*Holothuria scabra*) aquaculture during October and November 2017 (p. 81). Léopold and Govinden detail the project SEACUSEY that focuses on the management of the sea cucumber fishery in the Seychelles (p. 85). A couple of pages are dedicated to observations of sea cucumbers spawning into the wild, made by Byrne and Wolfe in Australia, and Champagnat and Moisson in the Mediterranean Sea (p. 88 and 89).

We then propose information and communications, listing the workshops and conferences that were held in 2017 (p. 90) and those that will take place in 2018 (p. 94), a call for collaboration is relayed by Friedman (p. 95) and a list of publications related to holothurians that were published in 2017 is compiled by Conand (p. 99).

Finally, congratulations are expressed to Nathalie Marquet who completed her PhD that is titled 'Study of the reproductive biology and chemical communication of sea cucumbers (*Holothuria arguinensis* and *H. mammata*)' (p. 100).

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 *SPC Beche-de-Mer Information Bulletin* has only been produced in digital format since issue #36. All issues remain accessible from SPC's website at:

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

Re-opening of the sea cucumber fishery in Papua New Guinea: A case study from the Tigak Islands in the New Ireland Province

Cathy Hair[1], Jeff Kinch[2], Terencehill Galiurea, Posolok Kanawi[3], Mathew Mwapweya, Joshua Noiney

Abstract

On 1 April 2017, the Papua New Guinea (PNG) nationwide moratorium on sea cucumber fishing and the beche-de-mer trade was lifted seven-and-a-half years after it was introduced. The National Fisheries Authority (NFA) had revised the National Bêche-de-mer Fishery Management Plan (the Plan) prior to the fishery opening and allocated provincial total allowable catch (TAC) quotas based on estimated fishable stocks of sea cucumber in each maritime province. This article presents the results of a study on the sea cucumber fishery (harvest of live animals, processing and selling of beche-de-mer) from three island communities in the Tigak Islands of the New Ireland Province (NIP). Almost 35,000 sea cucumbers that belong to 21 species were recorded from 10 days of catch monitoring. Catch composition and fishing patterns varied between villages and survey times. However, medium- and low-value species replaced high-value species and catch-per-unit-effort (by number and weight) decreased as the fishery progressed. The NIP fishery was closed eight weeks after opening, and the TAC of 43 tonnes (t) was exceeded by at least 36 t. Results from the study highlight the need to increase awareness of fisheries regulations (particularly species size limits to reduce the amount of undersized beche-de-mer that is brought in for sale), to strengthen the reporting requirements for companies and also to implement extension services to improve processing so as to lower the high rejection rates of poorly processed beche-de-mer. In the first year of opening, the NFA revised Plan was not administered properly, causing multiple problems in how the fishery operated in the study area and recommendations are made for improvements in future sea cucumber fishing seasons.

Introduction

On 1 April 2017, the Papua New Guinea (PNG) National Fisheries Authority (NFA) ended the nationwide moratorium on sea cucumber fishing and the beche-de-mer trade, which had been in place since 31 September 2009. During this time, the NFA revised the National Beche-de-mer Fishery Management Plan (hereafter referred to as the Plan), which was formally gazetted on 15 September 2016. NFA had carried out sea cucumber stock assessment surveys between 2010 and 2016, concluding that recovery had occurred for some species, recruitment was limited for others, and most sea cucumber were below the minimum legal size in 2016 (R. Lis, pers. comm.). The surveys were used to estimate fishable (i.e. legal size) stocks of sea cucumbers and allocate total allowable catch (TAC) of beche-de-mer for each of PNG Maritime Provinces and the National Capital District.

Prior to the moratorium, the PNG sea cucumber fishery was extensive, operating in all maritime provinces of the country, supporting up to 200,000 PNG villagers and providing as much as 30% of annual villager income (Polon 2004; Kinch et al. 2008; Barclay et al. 2017). Here, we report on the sea cucumber fishery in the Tigak Islands near Kavieng, New Ireland Province (NIP), where a joint NFA/ Australian Centre for International Agricultural Research (ACIAR) project is investigating the potential for mariculture of sandfish (*Holothuria scabra*), which is a high-value sea cucumber. The lifting of the moratorium provided a window of opportunity to monitor the fishery at a time when sea cucumber stocks would presumably be at their most abundant since the beche-de-mer industry began in earnest in the 1980s.

Under the revised Plan, the fishery would run from 1 April to 31 September 2017 or until NIP's TAC of 43 t was reached. This TAC of 43 t was actually reached seven weeks after opening and the fishery was officially closed on 17 May 2017. After a delay in registering that the TAC had been reached and granting of a one-week grace period to allow news

[1] Australian Centre for Pacific Islands Research and Faculty of Science, Health, Education and Engineering, University of the Sunshine Coast, Maroochydore, Queensland, Australia
[2] National Fisheries College, National Fisheries Authority, Kavieng, Papua New Guinea
[3] Nago Island Mariculture and Research Facility, National Fisheries Authority, Kavieng, Papua New Guinea

of the closure to reach remote areas and for sea cucumbers already harvested to be sold, the fishery eventually closed on 26 May 2017. This article presents preliminary data from catch monitoring, describes events associated with the 2017 season and concludes with suggestions on how to avoid some of the problems that were identified during the 2017 season.

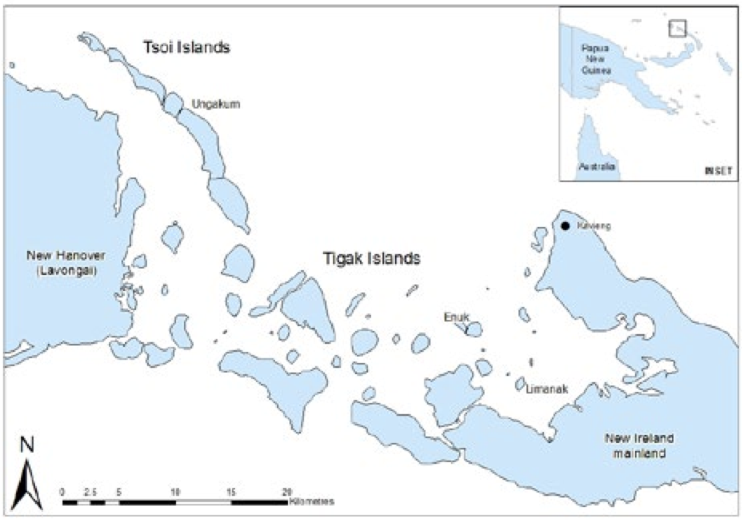

Figure 1. Location map showing the three communities involved in the study.

Study design

Data collection was carried out in three villages that are the collaborators in the NFA/ACIAR mariculture research. These are Limanak, Ungakum and Enuk (Figure 1). Limanak and Enuk are located within Balgai Bay in close proximity to the provincial capital of Kavieng (less than 15 minutes boat ride), while Ungakum is one of the eastern islands, bordering the Tsoi group and is at least one hour from town.

Sea cucumber catch and effort were monitored for six days in the opening week of the fishery, then for 48-hour periods in Week 3 and then again in Week 6. Enumerators were accompanied by local assistants from each village. Information on effort for each sea cucumber fishing trip was collected in personal interviews as near as possible to the landing time, ideally as the fisher returned to shore with a fresh catch, although in some cases, beche-de-mer processing had already commenced. Number and weight of each species was recorded and the catch photographed on a plastic sheet marked with a 10 cm grid to facilitate length estimation (Figure 2). Very large catches were sub-sampled.

All sea cucumbers were included in abundance estimates, but only fresh whole and freshly eviscerated individuals were measured for length. The weight of individual species within each catch was recorded but should be regarded as an approximation only due to inaccuracy of the field scales, errors introduced through subsampling, and varying condition of sea cucumber. Some catches were not measured, weighed or photographed because sea cucumbers were either in bad condition or were already undergoing processing.

Figure 2. A sea cucumber catch laid out on the 10 x 10 cm grid plastic sheets (left) and an enumerator photographing a catch (right).

Interviews about various aspects of the fishery and beche-de-mer industry with fishers were carried out during the fishing season and three months after closure. Additional information and observations on the fishing, processing and selling process have also been used to inform this study.

Fisheries effort

When the fishery opened on 1 April 2017, collecting and processing sea cucumber into beche-de-mer became the main activity of most people in the study villages (Figure 3). In the course of the monitoring programme, 152 landings were recorded at Enuk, 231 at Limanak and 245 at Ungakum, with much fewer trips recorded in the final surveys in Week 6. Very few fishing trips were missed during the survey periods.

Figure 3. Processing a sandfish catch at Limanak Island.

Figure 4. A canoe being used as a sea cucumber catch container. (Photo: P. Kanawi)

Gender break up of effort showed that males accounted for 421 landings, 126 landings were by females and four by mixed gender groups. Diving was the most common harvest method (over 86% of all records), predominantly, but not exclusively, conducted by males with different trends being exhibited at the individual village level. For example, at Enuk, which had an extensive area of shallow marine habitats accessible from shore, more than one-third of the landings were made by females and gleaning was very common (47% of all landings). Females made a much smaller contribution to landings at the other villages where gleaning was uncommon due to habitat differences. The average age of fishers (for both genders) was between 30–37 years of age across all villages and survey times, with a range of 9–67 years of age for males and 10–66 for females. Paddling canoe were the most popular means of transport in the fishery, accounting for over 94% of all fishing trips. Canoes doubled as a holding container for fresh sea cucumber (Figure 4). Walking was most common at Enuk and absent at Limanak.

In Enuk and Limanak, most fishing trips were recorded in zones closest to the village. At Ungakum, almost 99% of landings were recorded from zones where sandfish occurred, despite being further from the village centre. However, changes in fishing zone use through time were observed in Enuk, whereby fishing effort switched to a more distant zone in Week 6, and in Ungakum, where effort shifted to a more distant and deeper zone.

Sea cucumber landings

A total of 34,611 sea cucumbers belonging to at least 21 species were recorded in the surveys. Enuk fishers collected 10,070 sea cucumbers from 20 species; Limanak 19,874 sea cucumbers from 16 species; and Ungakum 4667 sea cucumbers from 14 species (Table 1).

Table 1. Abundance and percentage contribution to total for common sea cucumber species.

Common name	Species name	Number	% of total
Sandfish	*Holothuria scabra*	12,677	36.6
Pink curryfish (yellowfish)	*Stichopus naso*	5309	15.3
Blackfish spp.	*Actinopyga miliaris, A. palauensis*	3995	11.5
Curryfish spp.	*Stichopus hermanni, S. vastus, S. ocellatus*	3351	9.7
Chalkfish	*Bohadschia marmorata*	2941	8.5
Brown sandfish	*B. vitiensis*	2604	7.5
Golden sandfish	*H. lessoni*	1141	3.3
15 species		2658	7.7

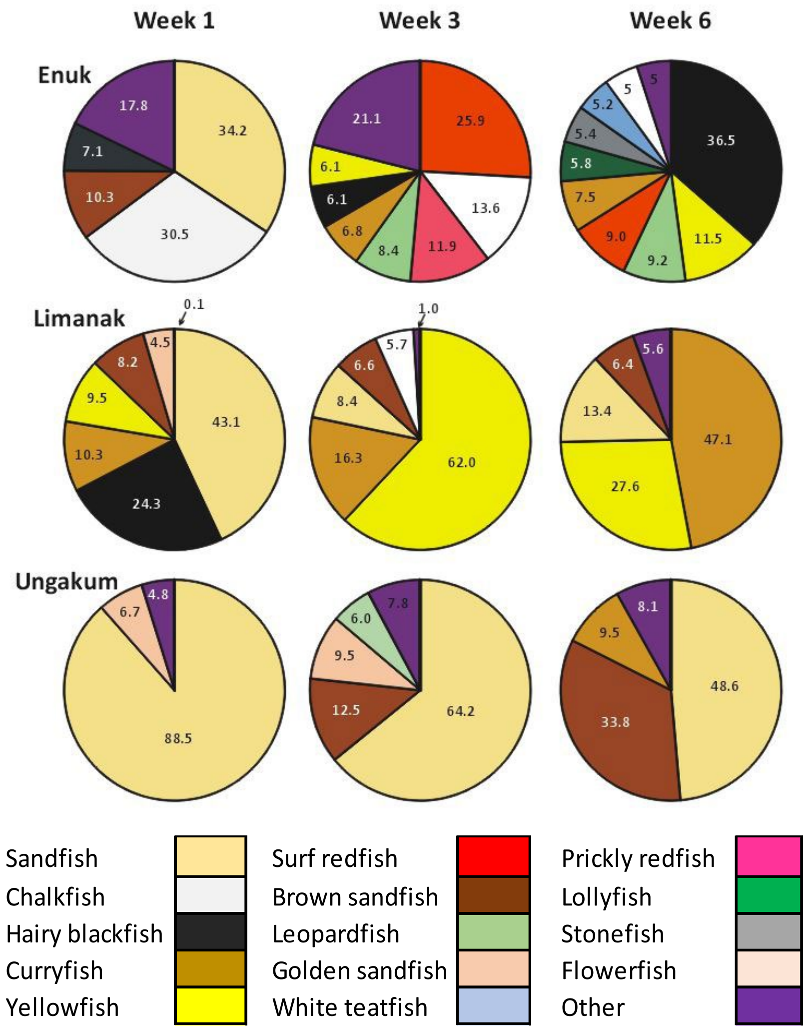

Figure 5. Changes in sea cucumber species composition in surveyed villages over the three surveys (Enuk top row, Limanak middle row, Ungakum bottom row). Species contributing more than 5% in abundance to the landing are shown as a slice of the pie chart.

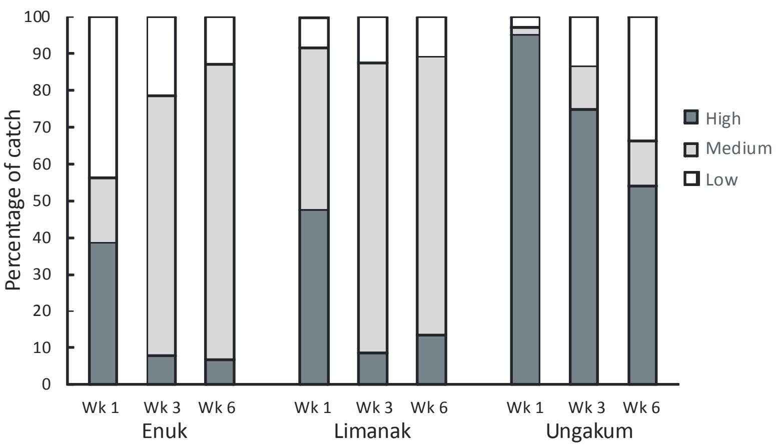

Figure 6. Percentage of catch by number of high-, medium- and low-value species for each village in each survey week (Wk).

Enuk consistently had a higher number of species in landings and Ungakum fewer species. Sandfish was the most common species collected in every village (n = 2722, 6142, and 3813 or 27%, 31% and 82% of the total catch for Enuk, Limanak and Ungakum, respectively). The composition and diversity of the catch varied with survey week (Figure 5).

Overall, 41% of total sea cucumber catch was of high-value species, 42% was of low-value species, and 17% was of low-value species (Purcell et al. 2008, 2014). By village: Enuk returned 31%, 31% and 38% (high-, medium- and low-value species, respectively); Limanak 34%, 56% and 10%; and Ungakum 89%, 5% and 6%. However, these proportions shifted as the fishery progressed (Figure 6), generally medium- and low-value species replaced high-value ones.

The weight of the sea cucumber landings are underestimated due to reasons explained above but nonetheless provide valuable information on species' contributions to the fishery. Some 28.6 t of sea cucumber (corrected weight) were recorded from all surveys. Six species each had combined landing weight greater than 1 t (Table 2).

Table 2. Landed weight and percentage contribution to total weight for common sea cucumber species.

Common name	Weight (tonne)	% of total
Sandfish	11.6	40.7
Curryfish spp.	6.3	21.9
Pink curryfish	2.8	9.7
Brown sandfish	2.1	7.4
Golden sandfish	1.7	6.3
Blackfish spp.	1.8	6.0
Chalkfish	0.5	1.9
15 species	1.7	6.1

There were no obvious trends of decreasing individual size for most species although estimated mean length and weight did decrease for some species in some villages. For example, sandfish declined in length at Limanak, although remained above legal minimum length in all surveys. The largest single species landing by number was a catch of 600 pink curryfish (known locally as yellowfish), and by weight was 300 kg of sandfish. Each village had different catch-per-unit-effort (CPUE) values but the general trend was for both the number and weight of sea cucumber collected per hour to decrease as the fishery progressed (Figure 7).

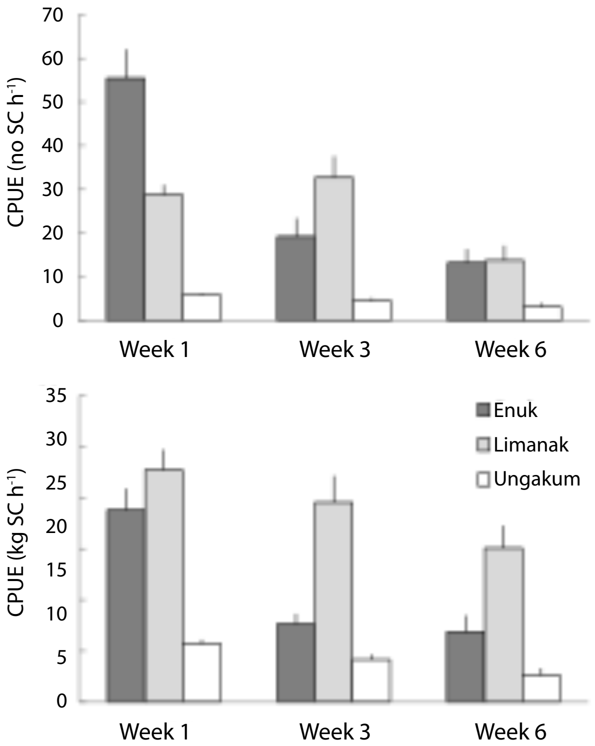

Figure 7. CPUE by number (± SE) (top) and weight (± SE) of sea cucumber collected per fisher hour in each survey week in each village (bottom).

Beche-de-mer buying and selling

Many fishers had their beche-de-mer rejected by buyers – Enuk had the worst quality issues with 87% of respondents having some or all of their beche-de-mer rejected by buyers at their first selling attempt, compared to 40% and 61% for Limanak and Ungakum, respectively. Commonly cited reasons for rejection was that beche-de-mer that was offered for sale was not fully dried (i.e. still had high moisture content), was undersized or was damaged (i.e. broken, misshapen, twisted, etc.). Rejected wet beche-de-mer was mostly re-dried and re-sold, but undersized or broken beche-de-mer were usually discarded. Some of the rejected beche-de-mer was retained by buyers (as stipulated in the Plan) but the majority was dumped in the Kavieng streets or at the Kavieng town rubbish depot (until this was stopped by local government authorities), or back in the village (dumped, buried or thrown in the sea).

Most fishers were unhappy with the buyers and the buying process. Long queues at buyers' premises (Figure 8) were a problem for both buyers and fishers where a full day wait was normal for at least the first week of buying. This was exacerbated by delayed issuance of licences three weeks after the fishery opened. Fishers who were not satisfied with prices usually did not shop around because they had already invested considerable time in waiting. Some buyers worked long hours to help people make their sale and get back home, some even providing food and a place to sleep. Fishers' major complaints concerned undersized product

Figure 8. Beche-de-mer sellers lined up outside a buyer's premises the day after buying commenced.

(saying that 'it's already dead, why waste it?') and no sales of wet product as had been the case in the past. Fishers also reported that graders at buying premises lacked expertise; that grading (and therefore pricing) was inconsistent and unfair; and that beche-de-mer parcels were not weighed accurately. Nonetheless, when asked what they might do differently if the fishery reopens again in 2018, 15% of all interviewed fishers said they would process higher-quality beche-de-mer and 20% said they would harvest larger sea cucumbers.

Additional challenges for exporters included a lack of clear policy over who would be awarded a licence and a delay of three weeks after the fishery had opened before these licences were issued. In total, seven licences were eventually issued in the NIP instead of the two as recommended by the National Management and Advisory Committee (NMAC).

Discussion

Harvest of sea cucumbers in PNG had been banned for seven-and-a-half years prior to the opening of the 2017 fishing season. It's not possible to ascertain if the TAC allocated to the NIP had been set at an appropriate level but monitoring the TAC was certainly complicated by the three-week delay in issuing licences after the fishery opening and NFA's inability to track of purchases in real-time, even though the new Plan stated that companies were to provide purchasing records on a weekly basis.

Potential indicators of overfishing

As observed across the Pacific Islands Region, sea cucumber moratoria often precede another cycle of rapid depletion instead of the envisaged revitalised fishery on re-opening (Friedman et al. 2011; Carleton et al. 2013; Pakoa et al. 2013) with recovery being either slow or absent (Anderson et al. 2011). Signals of overfishing in tropical, multispecies sea cucumber fisheries include the replacement of high-value species with medium- and then low-value species; declining size of sea cucumber individuals within a species; declining catch-per-unit-effort; and fishers accessing more distant and deeper fishing grounds, to name a few (Friedman et al. 2008; Carleton et al. 2013).

In our survey, species composition changes showed that high-value species, notably sandfish, were preferentially targeted in the early stages of the fishery and over-exploited very quickly. The early, high catches of this species were reminiscent of the late-1980s boom when sandfish supported a monospecific fishery in the Tigak Islands for almost two years before declining (Lokani 1996; Hair et al. 2016). Medium- and low-value species replaced high-value species in all villages during the season. For the most part, CPUEs declined as the fishery progressed, although absolute CPUE values and rate of decline varied between villages.

Other possible indicators of overfishing were less conclusive. Heavy fishing occurred close to the major village centres in the early weeks of the fishery, and fishers later accessed more distant and/or deeper fishing grounds. However, the brevity of the fishing season and limited data collection does not allow for firm conclusions, also the choice of fishing site was influenced by other factors such as weather. Overall, we did not detect decreasing length or weight for most species. Given that this study was a one-off and the limitations of individual measurements, these aspects are best left for comparison with future surveys.

Future sea cucumber fishing seasons

Data collected and observations made during the 2017 season suggest that various actions are required to improve management outcomes and benefits for all stakeholders in the future. First and foremost, awareness of the rules and regulations should be provided to everyone well in advance of the opening of the season, and regularly updated throughout the season. NFA and Provincial Fisheries Officers, non-governmental organisations that are focused on natural resource management, beche-de-mer dealers and other interested stakeholders can provide awareness and training at the grassroots level. Ward Councillors and Ward Development Committees should also take a proactive role in ensuring their village constituents are informed and empowered with the appropriate distribution of information at village level.

NFA's revised Plan was a good step in bringing better management to the sea cucumber fishery and the beche-de-mer trade (Hair et al. 2016; Barclay 2017), but as was witnessed in the 2017 season, many of its own regulations were not implemented properly or were contravened. With respect to exporters, the impact of licensing delays reverberated through all aspects of the fishery with negative consequences. It is of paramount importance that exporters and their buyers be licensed well ahead of the next season, so they can have their premises in readiness and their graders prepared. The licensing of seven exporters over the two originally recommended by the NMAC may have increased competition, which may have also benefited fishers but it did not contribute to the proper reporting as required in the Plan. Real-time recording and reporting of beche-de-mer purchases was necessary to facilitate proper monitoring of the TAC. The late closure of the sea cucumber fishery and the beche-de-mer trade in the NIP was compounded by the granting of a one-week 'grace' buying period, which essentially became a fishery extension. In future, it is also recommended that all exporters and their buyers must retain and record all rejected beche-de-mer in the same way as normal sales are recorded and reported for several important reasons: (1) when added to the purchased product, it provides an estimate of the total harvest from the source area; (2) to prevent indiscriminate dumping and the associated environmental and health hazards; and (3) to assist in identifying priority communities for awareness and extension services. The presence of buyers in remote areas benefited many fishers; however, these buyers must remain in communication with the exporter so that their purchases can be included in the records submitted to NFA, which is then added to the running TAC calculations.

More local management at the community level should be encouraged. Before the next season, communities should be supported in forming community management bodies and provided with information on natural resource management and training on beche-de-mer processing. Understanding the relationship between sound management practices and optimum profit from beche-de-mer would also be beneficial. There are a range of resources available that could be distributed quickly and easily (e.g. Friedman et al. 2004; Purcell 2014).

Fishers had many complaints about the buying process. Conversely, exporters and their buyers complained about the quantity of undersized and badly processed beche-de-mer that was offered for sale. Many new fishers entered the fishery in 2017 due to abundant stocks in nearby shallow waters, requiring minimal skill to harvest. High beche-de-mer prices were an added incentive for inexperienced fishers to try their hand, despite knowing little about the fishery regulations or how to process sea cucumber into good beche-de-mer. There is probably truth in both the exporters and their buyers' and sellers' versions of events. Exporters and their buyers quite rightly rejected undersized beche-de-mer. However, this practice was common in the past (NFA 2000) as was the practice of buying wet beche-de-mer at a lower price. Not surprisingly, fishers assumed it would be business as usual (i.e. pre-moratorium). The problem was exacerbated by the delay in licensing because any opportunity to learn by trial and error (i.e. rejection of a small catch) was lost. Increased awareness of what constitutes high quality beche-de-mer and training in how to produce it are therefore needed. All fishers (new and experienced) should be made aware of the fishery rules, in particular, the size limits. A combination of improved knowledge and processing skills for fishers, training of graders, sufficient time for buyers to prepare for the buying season and a code of conduct (e.g. calibration of weighing scales and a transparent buying process) might address some of these problems.

Future catch data should be collected using similar methods to monitor changes in sea cucumber species composition, size and CPUE in further seasons for Enuk, Limanak and Ungakum (and possibly expanded to include other villages elsewhere). The survey methods are now established and training materials are prepared. Feedback was given to community members who appeared to be supportive of future monitoring as it also assists them in understanding and managing their marine resources. The value of this critical baseline data will increase once subsequent seasons' data are available for comparison. Lessons learnt during the 2017 surveys can be used to better train enumerators for monitoring of the future seasons.

Conclusions

Continued monitoring will provide feedback on the health of the Tigak Islands sea cucumber fishery. In 2017, the fishery was not closed when the TAC was reached as the most recent progressive NFA export figures show that the TAC in NIP was overshot by at least 36 t (and this does not take into account the additional tonnage of rejected beche-de-mer). Barclay et al. (2017) noted that the success of the revised Plan would rest in part on the ability to close the fishery on time, or render this management measure ineffective. Production in subsequent seasons will be affected to an unknown extent by the harvest of undersized sea cucumber in the 2017 season.

The current study collected baseline data on the sea cucumber fishery in three Tigak island communities after an extended moratorium. Through surveys and observations, we were able to describe the progress of the fishery for various stakeholders, and suggest some ways that stakeholders can benefit more from the fishery while not compromising future productivity of this very valuable resource. A unified approach and initiation of the joint management bodies (government, community and industry) is advocated.

Acknowledgements

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Length-weight relationship, movement rates, and in situ spawning observations of *Holothuria scabra* (sandfish) in Fiji

Steven Lee[1,2,3], Amanda Ford[2,3], Sangeeta Mangubhai[4], Christian Wild[3], Sebastian Ferse[2]

Abstract

This study investigated the length-weight relationship and movement rates of the sea cucumber *Holothuria scabra*, and reports on two *in situ H. scabra* spawning events at a site with relatively healthy stocks in Vanua Levu, Fiji. A length-weight equation was established − weight = 0.1878 × length$^{2.5807}$ − which explained 90% of the variance for *H. scabra* of length 5–24 cm. *H. scabra* moved at a rate of 40 cm h^{-1} ± 3.40 SE and appeared active for 10 h day^{-1}, displayed a home-ranging behaviour, and therefore are considered mobile within a limited range. Spawning occurred during October and December, coincided with spring tides, and was only observed around enclosures that were stocked with high densities (ca. 350 g m^{-2}) of *H. scabra*. The animals aggregated around high-density enclosures prior to spawning, suggesting that spawning is density dependent. Observations during spawning indicate the length at first maturity is ca. 15 cm.

Introduction

Holothuria scabra is a deposit-feeding species of sea cucumber found in low-energy environments behind fringing reefs or within protected bays and shores of the tropics (Hamel et al. 2001). Despite being an important species in the domestic Fijian and international beche-de-mer market (Hair 2011; Purcell 2014), there are key information gaps that are relevant to the management of Fiji's *H. scabra* fishery. Beche-de-mer is sold by weight, and the relationship between dollar value and mass of *H. scabra* is exponential (Purcell 2014). As such, estimates of mass from length, and therefore the potential value of an animal prior to harvest, are important to understand. Fijian communities have strong cultural and historical rights over customary fishing grounds (*qoliqoli*) and have used a range of traditional management methods such as *tabu* (i.e. periodically harvested closures) areas (Jupiter et al. 2014). Given the area, the level of resource management and management practices can differ considerably from one *qoliqoli* to the next, and the movement of valuable resources such as *H. scabra* can be a cause for conflict between communities. Hence, there is a strong need to understand movement rates and patterns of *H. scabra*, particularly for communities using *tabu* areas or restocking as a way of replenishing stocks (Bell et al. 2008). Fishery closures during spawning seasons are commonplace (Overzee and Rijnsdorp 2014; Jupiter et al. 2017); however, the basic information required for this management approach – timing of the spawning season – for *H. scabra* in Fiji remains unknown. The research presented aimed to: (a) determine the length-weight relationship based on a simple 'field-friendly' methodology in order to allow estimates of biomass; and (b) calculate movement rates of *H. scabra*. Two *in situ* spawning events are described, with their associated environmental conditions. These provide an estimate of the spawning season of *H. scabra* in Fiji.

Materials and methods

This study was part of a larger one investigating the impact of *H. scabra* removal on reef sediment function on Vanua Levu, Fiji (Lee et al. 2017). At the study site, 12 enclosures of 9 m^2 each were constructed and stocked with different densities of *H. scabra* depending on treatment (n = 4 enclosures per treatment). High-density treatment enclosures were stocked with approximately 15 *H. scabra* (ca. 350 g m^{-2}), 'natural' density enclosures contained approximately 3 *H. scabra* (ca. 60 g m^{-2}), and exclusion enclosures contained no *H. scabra*. Enclosures used in the Lee et al. (2017) study were positioned in the centre of the Natuvu reef flat, while the current study surveyed *H. scabra* from the entire reef flat.

Length-weight relationship

A total of 689 *H. scabra*, ranging in lengths from 5–24 cm, were collected on the extensive reef flat in front of Natuvu village, Wailevu East District, Vanua Levu, Fiji (16°44.940'S, 179°9.280'E) between August 2015 and February 2016, and again in December

1 Email: steven.d.a.lee@gmail.com
2 Leibniz Centre for Tropical Marine Research (ZMT), Bremen, Germany
3 Faculty of Biology and Chemistry (FB2), University of Bremen, Bremen, Germany
4 Wildlife Conservation Society, Fiji Country Program, 11 Ma'afu Street, Suva, Fiji

2016. The animals were collected during belt transects and surveys of two deeper pools – covering a total area of ca. 5400 m^2 and ca. 22,170 m^2, respectively – were carried out by foot or snorkel where appropriate.

The lengths and weights of *H. scabra* were recorded following similar methods used by Seeto (1994) and Al-Rashdi et al. (2007). *H. scabra* individuals were removed from the water and allowed to initially contract and expel water, which happened almost immediately following handling (<3 s). The animal's length was recorded from anus to mouth by placing a ruler along its ventral surface. All measurements were recorded to the nearest centimetre. Sea cucumbers were then placed into containers filled with water from the site. Water in the containers was continuously exchanged to reduce stress on the animals. All *H. scabra* of the same length were kept together in containers (Figure 1). Following each collection, the animals were taken ashore and weighed on a digital scale (± 0.02 g) to the nearest gram. Time from initial capture to weighing took no longer than 1 hour. Individuals were allowed to contract and expel water before being weighed, as described above. Following weighing, all sea cucumbers were released back into the site.

Movement rate

The movement rates of 28 *H. scabra* (lengths 8–16 cm, mean length = 13 cm ± 0.22 SE; mean mass = 145 g ± 6.27 SE) were studied over two weeks in January 2016. The study was conducted during day and night, flood and ebb tides, and within three habitats: sand, *Halodule* seagrass beds, and *Syringodium* seagrass beds. Markers (made using 4.0 mm diameter wire) were driven vertically into the sediment at a standardised distance (ca. 1 cm) behind the caudal end of the animal. If the animal appeared disturbed (e.g. contracted its body, stopped feeding or moving) then another one was chosen. Approximately every hour the animal was spotted again by following its trail of sediment pellets, and another marker was placed; after three hours the third and final marker was placed. Time was recorded each time a marker was placed. The animal's length and weight were recorded. Distance travelled by *H. scabra* was measured as straight distance between each marker, rounded to the nearest centimetre.

Results and discussion

Length-weight relationship

The length and weight of *H. scabra* (n = 689, 13 cm ± 0.15 SE, 168 g ± 4.91 SE) were recorded; a power regression () in Microsoft Excel 2010 explained 90% of variance (r^2 = 0.90) (Figure 2).

Figure 1. *H. scabra* of the same length (measured to the nearest cm) were placed in the same containers prior to weighing (Photo: Steven Lee).

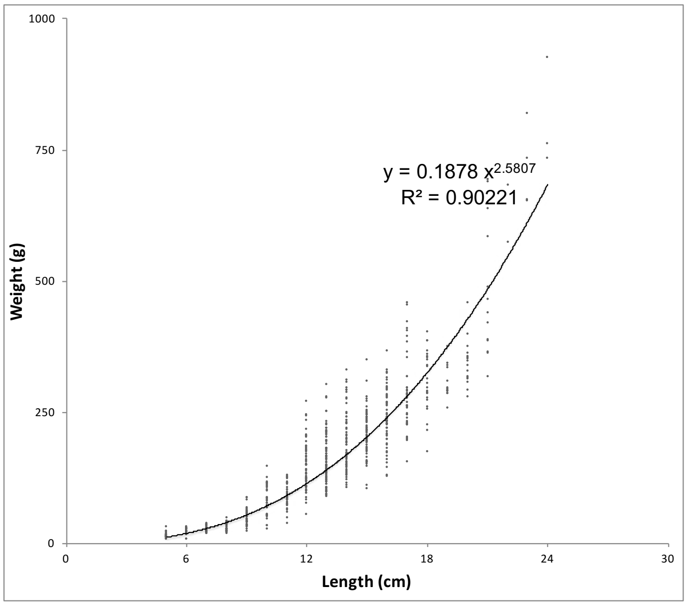

Figure 2. Length-weight relationship of *H. scabra* (n = 689). Power regression (Microsoft Excel 2010), *weight* = 0.1878 *length*$^{2.5807}$, r^2 = 0.90.

The calculated length-weight equation was limited to *H. scabra* between lengths of 5–24 cm, as there was a lack of data outside this size range. Two studies of *H. scabra*, the first in Toliara (Madagascar) and the second in Mahout Bay (Oman), using a similar method, produced a length-weight equation that explained 97% and 80% of variation, respectively (Lavitra 2008; Al-Rashdi et al. 2007). The dataset produced by Al-Rashdi et al. (2007) had considerably more data for lengths ≥24 cm, but lacked data for lengths ≤10 cm. The length-weight equation produced by Al-Rashdi et al. (2007) was $weight = 0.0033\ length^{2.178}$. The dataset produced by Lavitra (2008) comprised animals between a length of 6 and 24 cm, and the equation produced was $weight = 0.111\ length^{2.685}$. Lavitra (2008) provided a separate equation for juveniles (1–6 cm length), which explained 93% of variance; $weight = 0.070\ length^{2.992}$.

Movement rate

As the animals were active for ca. 10 h day^{-1}, movement rate for *H. scabra* was in the range of 2–8 m day^{-1} (mean = 4 m day^{-1} ± 0.34 SE), thus an individual could potentially travel up to 120 m $month^{-1}$. Although movement was measured as straight distance, observed movement patterns appeared to be more random – similar to findings by Mercier et al. (2000). Observations of *H. scabra* with distinct natural markings (e.g. scarring) over the course of six months revealed a 'home ranging' behaviour (moving about a restricted area – roughly 100 m radius in this study) similar to that of *Bohadschia argus* and *Thelenota ananas* (Purcell et al. 2016). Therefore, *H. scabra* are relatively mobile, but appear to have a limited range. Movement patterns of sea cucumbers may be linked to the distribution of food, as some species of sea cucumbers exhibit patch selectivity (Uthicke and Karez 1999).

In the case of *H. scabra*, movement may also be driven by the availability of soft-bottom sediment in which to shelter through burying (Mercier et al. 1999). Given the 'home ranging' behaviour of *H. scabra*, the animal was assumed buried when not seen above the substratum. Given their limited range, the main method by which *H. scabra* would spread into other areas may be during their planktonic larval stage (Hamel et al. 2001). The migration of these mobile invertebrates into neighbouring *qoliqolis* is of concern for communities that rely on these high-value organisms for their livelihood (Natuvu village headman, pers. comm.), particularly in small *qoliqolis*. Results of the current study suggest *qoliqoli* and *tabu* areas may be able to contain stocks of *H. scabra* with little loss to neighbouring *qoliqolis*. Spatial planning of networks of *tabu* areas for sea cucumbers and fishery management plans should therefore pay special attention to the dispersal of larvae and the safeguarding of brood stock.

In situ spawning observation

H. scabra (≥20 individuals) were observed spawning around 14:00 and 17:00 on 28 October 2015 and 15 December 2015, respectively. These events coincided with spring tides and the full and new moon, respectively. Spawning appeared to be synchronised and only occurred within and around enclosures stocked with high densities of *H. scabra* (n = ca. 16 *H. scabra* $enclosure^{-1}$) and where the water depth was ca. 1 m. Only individuals ≥15 cm in length were observed spawning.

These findings are consistent with previous observations at the same study site in November 2009 (Hai 2011). The peak spawning period in the Solomon Islands occurs during similar conditions; i.e. the dry season (August–November) coinciding with the full moon, and during the afternoon or early evening (Battaglene et al. 2002). The findings of the current study suggest that *H. scabra* in Fiji spawns from October–December, with multiple spawning events occurring around the full and new moon. Aggregate behaviour prior to and during spawning only took place in and around enclosures stocked with high densities of *H. scabra,* and no spawning occurred in and around enclosures stocked with natural densities (60 g m^{-2}) of *H. scabra,* suggesting density-dependent spawning that is possibly linked to chemical cues (Lovatelli et al. 2004). Accordingly, reduced densities of *H. scabra* may inhibit the ability of this species to spawn or significantly reduce the chances of successful spawning (fertilised gametes), further inhibiting chances of population recovery and increasing the risk of an Allee effect (Bell et al. 2008). As only *H. scabra* ≥15 cm were observed spawning in these aggregations, length at maturity for *H. scabra* in Fiji is assumed to be at least 15 cm.

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Commercially important sea cucumbers on Geyser Bank (Scattered Islands – Gloriosos – Indian Ocean)

Thierry Mulochau[1]

Abstract

A survey and abundance estimate of commercially important sea cucumbers were carried out on Geyser Bank in the waters of the Marine Park of the Gloriosos. A total of 32 stations were surveyed on its reef flats and inner and outer slopes. Some seven commercially important sea cucumber species were recorded, including three with high market values, i.e. *Holothuria nobilis*, *H. fuscogilva* and *Thelenota ananas*. A total of 11 specimens were recorded for all the stations, i.e. 32,000 m$^{2.}$ *T. ananas* was the most frequently observed species and represented 27% of the relative abundances. Commercially important sea cucumber population densities had been estimated at 6 (± 3.2) specimens per hectare in 2006, while the estimate was 3.4 (± 1.8) spec. ha^{-1} in 2016. A great many observations have confirmed regular illegal fishing on this bank since the 2000s. The increasing scarcity of commercially important sea cucumbers along the coasts of Madagascar encourages fishers to widen their fishing grounds towards more distant sites that have been comparatively protected from fishing, including marine protected areas.

Introduction

A survey and abundance estimate of commercially important sea cucumbers on Geyser Bank were carried out as part of the Epicure programme[2] under the supervision of IFREMER, the Mayotte university training and research centre (CUFR) and the French Southern and Antarctic Lands (TAAF). The first survey of sea cucumbers on this reef bank was carried out by Mulochau et al. (2007).

Geyser Bank is located in the western Indian Ocean, north of Mozambique Canal, between Mayotte and the Glorioso Islands, some 300 km west of the northern tip of Madagascar and 110 km north-east of Mayotte. This coral atoll, which is ab out 17.5 km in diameter, is built on shoals in the open ocean and only certain parts of Geyser Bank can be seen at the surface during low tide. Geyser Bank has a reef and lagoon surface area of some 257 km^2, with three geomorphologic units: outlying sub-surface reefs, outlying submerged reefs and lagoon terraces (Mulochau et al. 2007; Andréfouët et al. 2009). It is part of the Glorioso Islands' marine nature park[3] and has been a marine protected area since 2012, covering an exclusive economic zone of some 43,000 km^2. The Marine Nature Park of the Glorieuses was especially designed to create a strong marine biodiversity protection zone and become an area of excellence in terms of sustainable fishing. Fishing is prohibited in territorial waters (Order no. 2010-151 dated 9 December 2010) and regulated in the exclusive economic zone (Order no. 2014-137 dated 21 October 2014), more specifically on Geyser Bank. In contrast to Grande Glorieuse, which is continually monitored by military contingents[4], it remains difficult to monitor Geyser Bank due its isolation and lack of dry land.

The problems with managing commercially important sea cucumber populations in the southwestern part of the Indian Ocean have already been emphasised (Conand and Muthiga 2007; Conand 2008; FAO 2013; Muthiga and Conand 2014; Conand 2017). Comparative studies on sea cucumber conservation and fisheries in the western Indian Ocean have demonstrated the value of implementing precautionary management approaches to protect stocks (Cariglia et al. 2013; Eriksson et al. 2015). Data on illegal fishing in Geyser Bank are sparse; it mainly involves fleets from Madagascar, beginning in the 2000s when commercially important sea cucumber resources had been overexploited in that country (Conand et al. 2015; Le Manach and Pauly 2015). These illegal harvests are difficult to estimate and such data are based on interventions by the French Government in the exclusive economic zone involved.[5]

1 BIORECIF, 3 ter rue de l'Albatros 97434 La Réunion, France – biorecif@gmail.com
2 http://wwz.ifremer.fr/institut_es/Actualites-et-Agenda/Toutes-les-actualites/Xe-FED-regional-ocean-Indien
3 http://www.aires-marines.fr/L-Agence/Organisation/Parcs-naturels-marins/Parc-naturel-marin-des-Glorieuses
4 http://www.taaf.fr/Les-Glorieuses
5 http://www.ecpad.fr/fazsoi-le-malin-intercepte-des-pecheurs-illegaux/

Materials and methods

Sampling of commercial sea cucumber species on Geyser Bank took place from 16 October to 9 November 2016. The survey covered 32 stations spread out over the entire island group, including 13 reef flat stations (emerged, intertidal and subtidal), 9 outer slope stations, 7 lagoon stations (shallow, intermediate and deep), 2 inner slope stations, and 1 pass station (Table 1 and Figure 1). Each station was uniform in terms of habitat and the various hydrodynamics parameters.

Table 1. Commercially important sea cucumber-population monitoring stations on Geyser Bank in October-November 2016: stations, longitudes (Long. pts.) and latitudes (Lat. pts.) in WGS84 (in decimal degrees), date, depth in metres (Depth), and geomorphology.

Stations	Long. pts.	Lat. pts.	Date	Depth	Geomorphology
UVC1	46.4461	-12.3300	16/10/2016	15	Outer slope/spread out rubble
UVC1bis	46.4389	-12.3426	16/10/2016	3	Above water reef flat
UVC2	46.4272	-12.3550	21/10/2016	19	Outer slope/spread out rubble
UVC3	46.4677	-12.3716	27/10/2016	12	Outer slope/spurs and grooves
UVC4	46.4596	-12.3582	21/10/2016	6	Shallow 5-15m lagoon/coral formations
UVC5	46.4749	-12.3024	18/10/2016	17	Outer slope/spurs and grooves
UVC6	46.4806	-12.3079	17/10/2016	7	Inner slope/coral colonies
UVC8	46.5401	-12.4107	26/10/2016	22	Submerged subtidal reef flat/coral heads
UVC9	46.5652	-12.4200	25/10/2016	24	Pass/Coral formations/extensive coral cover
UVC11	46.5750	-12.2658	20/10/2016	13	Subtidal reef flat/seagrass bed
UVC13	46.4972	-12.2724	11/09/2016	17	Subtidal reef flat/seagrass bed
UVC14	46.5231	-12.2447	20/10/2016	21	Outer slope/spread out rubble
UVC16	46.5194	-12.3462	11/08/2016	25	Deep lagoon/seaweed
UVC17	46.5629	-12.2946	28/10/2016	20	Deep lagoon/coral formations
UVC18	46.5172	-12.2970	11/05/2016	22	Deep lagoon/coral formations
UVC20	46.4771	-12.3359	19/10/2016	16	Intermediate 15–30 m lagoon/coral formations
UVC21	46.5852	-12.2742	22/10/2016	15	Subtidal reef flat
UVC22	46.4882	-12.3831	11/07/2016	5	Subtidal reef flat/small transverse strips and spread out rubble
UVC23	46.5025	-12.3933	11/07/2016	9	Subtidal reef flat/small transverse strips and spread out rubble
UVC24	46.6153	-12.3586	11/03/2016	25	Submerged subtidal reef flat/spread out rubble
UVC25	46.5355	-12.4075	29/10/2016	25	Submerged subtidal reef flat/spread out rubble
UVC30	46.4381	-12.3396	17/10/2016	14	Outer slope/spread out rubble
UVC33	46.5985	-12.2788	24/10/2016	25	Outer slope/coral formations
UVC34	46.6036	-12.3153	11/03/2016	12	Outer slope/spurs and grooves
UVC35	46.5519	-12.2567	22/10/2016	18	Outer slope/spurs and grooves
UVC38	46.5345	-12.4134	26/10/2016	20	Subtidal reef flat/small transverse strips/coral colonies
UVC40	46.5744	-12.4132	25/10/2016	14	Subtidal reef flat/dense coral colonies
UVC42	46.5110	-12.2589	20/10/2016	17	Subtidal reef flat/coral colonies
UVC43ter	46.4874	-12.3759	11/08/2016	7	Inner slopes/grooves and spurs
UVC46	46.5125	-12.2711	19/10/2016	18	Intermediate 15–30 m lagoon/coral formations
UVC46bis	46.5657	-12.2685	24/10/2016	26	Intermediate 15–30 m lagoon/coral heads

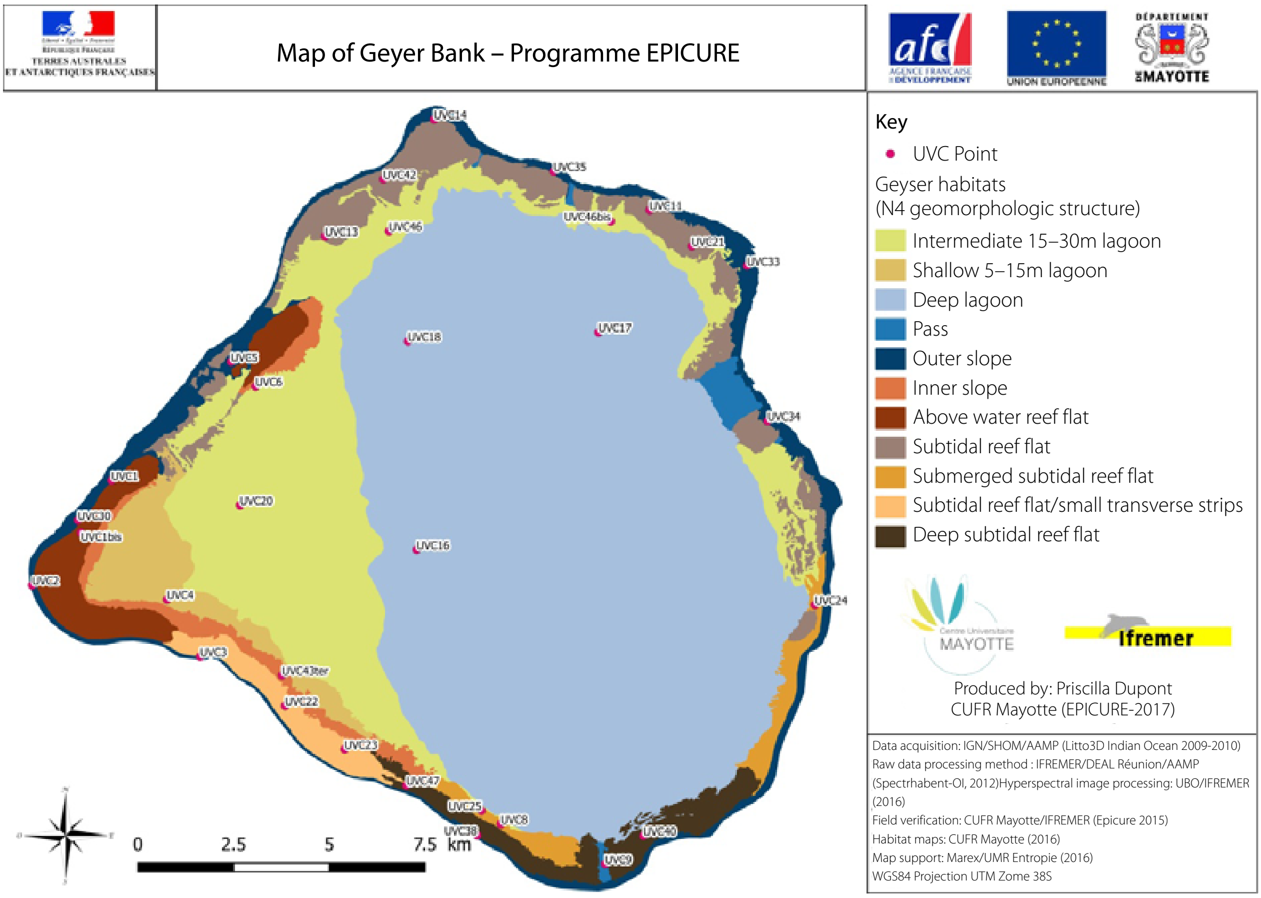

Figure 1. Locations of the 32 stations sampled on Geyser Bank in October and November 2016 in order to monitor commercially important sea cucumbers (Dupont et al. 2016).

Sampling was carried using underwater diving on beds at depths of between 3 to 25 m. Two 50 m measuring tapes were set up and two 5-m-wide zones located on either side of them were sampled, i.e. a total surface area of 1000 m^2 per station. Observers recorded all the commercially important sea cucumber species they encountered. These counts were done visually at the surface of the substrate and did not include cryptic species hidden under the rocks or inside the reef. Less sampling was done on the outer and inner reefs located in the south and southeast due to difficult weather conditions.

Results

Species richness and abundance

Seven commercially important sea cucumber species were recorded (Table 2): 3 high-market-value species, i.e. *Holothuria nobilis*, *H. fuscogilva* and *Thelenota ananas*, and 4 low-to-medium market value species, i.e. *H. edulis*, *Actinopyga miliaris*, *Bohadschia subrubra*, *Pearsonothuria graeffei*. All of the species observed were sampled over 11 stations, while no commercially important sea cucumber species were observed in two-thirds of the stations (21 stations).

T. ananas (9.4%) was the most frequently observed species over the 32 stations in this study (Table 3). In terms of abundances (Table 3), 11 species were recorded over the 32 stations, i.e. 32,000 m^2 The most abundant species was *T. ananas* at 27% of the relative abundances and three specimens observed over all the stations.

As a whole the species recorded during this study had an average of 0.34 ± 0.09 specimens observed by station, which means an average of 3.4 sea cucumbers per hectare for the stations sampled with the method use. No station had an abundance of more than one specimen.

Discussion

Commercially important sea cucumber-species diversity was low on Geyser Bank: seven species were observed over the 32 stations surveyed during this study, which supplements preceding surveys (Table 2) (Mulochau et al. 2007; Pareto and Arvam 2015) bringing the total to 11 species recorded on Geyser Bank since 2006. Three species had never been recorded on this reef bank before, i.e. *H. fuscogilva*, species listed as 'Endangered'

Table 2. Commercially important species (Purcell et al. 2012 and 2013) observed on Geyser Bank in 2007 (Mulochau et al.), 2015 (Pareto and Arvam) and 2016 ('This study'), market value and status on the International Union for Conservation of Nature's red list (Conand et al. 2014 ; IUCN 2016). x = observed.

	2007	2015	This study	Market value	IUCN status
Actinopyga mauritiana	x			Medium	Vulnerable
Actinopyga miliaris		x	x	Medium	Vulnerable
Actinopyga obesa	x			Medium	Data Deficient
Bohadschia subrubra	x		x	Medium	Data Deficient
Holothuria atra		x		Low	Least concern
Holothuria edulis		x	x	Low	Least Concern
Holothuria fuscogilva			x	High	Vulnerable
Holothuria fuscopunctata			x	Medium	Least concern
Holothuria nobilis	x			High	Endangered
Pearsonothuria graeffei			x	Low	Least Concern
Thelenota ananas	x	x	x	High	Endangered
Total	5	4	7		

Table 3. Observation frequencies for commercially important sea cucumber species (% of the number of stations where the species was observed in comparison to the total number of stations [32]) and relative abundances of the various commercially important sea cucumber species (in % of the number for a single species out of the total number of sea cucumbers [11]) in Geyser Bank for the 32 stations monitored.

	Observation frequency (%)	Relative abundances (%)
Thelenota ananas	9.4	27
Actinopyga miliaris	6.3	18
Pearsonothuria graeffei	6.3	18
Bohadschia subrubra	3.1	9
Holothuria fuscogilva	3.1	9
Holothuria fuscopunctata	3.1	9
Holothuria edulis	3.1	9

by the IUCN (2016), *H. fuscopunctata* and *P. graeffei*. These three species are found in the zone, particularly in Mayotte (Eriksson et al. 2012) and in the Glorioso Islands (Mulochau and Guigou 2017). Some of the species observed in 2006 were not found during this study, i.e. *H. nobilis,* species listed as 'Endangered' by the IUCN (2016), *A. mauritiana*, listed as 'Vulnerable' and *A. obesa*. *Holothuria atra*, observed for the first time in 2015, was not found in 2016, either. *Bohadschia atra*, a recently described species (Massin et al. 1999), was not observed on this bank although this species is found in the zone and is frequently observed in Mayotte (Eriksson 2012; Mulochau 2018) and in the Gloriosos where it is abundant, especially on inner slopes (Conand et al. 2013; Mulochau and Guigou 2017). These data do not cover species considered to have no market value.

The abundances of commercially important sea cucumbers during this survey on Geyser Bank were low compared to other nearby sites such as Mayotte (Eriksson 2012; Mulochau 2018) or the Gloriosos (Conand et al. 2013; Mulochau and Guigou 2017). These low abundances had already been highlighted by Mulochau et al. (2007). The large number of stations covered provided a robust estimate of the abundances of commercially important sea cucumbers on Geyser Bank and to compare that estimate to the 2006 survey. During that study (Mulochau et al. 2007), densities were estimated at 6 (± 3.2) specimens/hectare, which seems to indicate that sea cucumber population abundances have decreased, since in 2016 the estimate was 3.4 (± 1.8) spec. ha-1. Table 3 gives the observation frequencies and abundances for the two most frequently observed and most abundant species in 2006, recorded again in 2016. *T. ananas* and *B. subrubra* are the only species sampled during both studies and while they were found on half of the stations in 2006, they were found on less than 10% of the stations in 2016. Relative abundances for those two species were also down; while *T. ananas* remained the most abundant species as had been the case during the 2006 study. *B. subrubra* is a species that covers itself with coral debris or sand and can be difficult to sample as opposed to *T. ananas*, a species that is easily seen and recorded.

Table 4. Comparison of observation frequencies in % of the total (ratio of the number of stations where the species was observed to the total number of stations), relative abundances in % (ratio of the number of specimens of a species to the total number of sea cucumbers) and the average number of specimens between 2006 and 2016 for *T. ananas* and *B. subrubra.*

	Observation frequency (%)		Relative abundances (%)		Number of specimens per hectare	
	2006	2016	2006	2016	2006	2016
Thelenota ananas	54.5	9.4	39	27	2.3 (± 1.6)	0.9 (± 1.0)
Bohadschia subrubra	46.0	3.1	33	9	1.7 (± 1.6)	0.3 (± 0.6)

The Manta Tow technique (Friedmann et al. 2008) appears to be more appropriate for estimating sea cucumber populations particularly in shallow zones, over large surface areas with diversified habitats and with relatively low sea cucumber abundances as is the case with Geyser Bank. Study stations have to be set up for commercially important sea cucumber populations in order to understand changes in such populations and the impacts they are subjected to. The abundances observed during this study are tendencies; monitoring the stations over time and repeating this approach would provide a more reliable analysis of the situation so as to understand changes in commercially important sea cucumber populations on Geyser Bank.

Fishing is regulated on Geyser Bank and only authorised for fishing vessels registered in Mayotte that are under 15 m in length[6]. No commercial French fish vessels currently meet the requirements for developing such activities on Geyser Bank. So fishing impact is mainly linked to the presence of fishing vessels from neighbouring countries. As their coastal sea cucumber-fisheries resources have become scarce, these fishers prospect ever wider zones in order to support themselves. The many observations and a few interventions by the French military (local press;[7] Conand et al. 2015; pers. obs.) confirm regular fishing on the bank, particularly by ships from Madagascar equipped with diving equipment. Impact on sea cucumber populations may be continually since the 2000s when commercially important sea cucumber resources were overexploited in northern Madagascar (Conand et al. 2015; Le Manach and Pauly, 2015). As this bank is remote and isolated, control efforts are rare. The increasing scarcity of commercially important sea cucumbers on Geyser Bank has probably encourage fishers to move to fishing grounds further north towards the Glorioso Islands, particularly to Lys Island where the lack of surveillance allows mooring and fishing (local press;[8] Mulochau and Guigou 2017) as well as to other protected areas such as Mayotte or Juan de Nova, which are remarkable for reef biodiversity studies (Chabanet et al. 2016; Conand et al. 2016; Quetel et al. 2016). Nevertheless, sea cucumber harvests seem to continue on Geyser Bank as it is a passage zone than can be prospected before moving on to other sites in Mozambique Canal.

Given sea cucumbers' critical role in reef ecosystems (Purcell et al. 2016) and the threats that weigh on several species due to overfishing, it seems that urgent action must be taken by all the necessary means to put a halt to the illegal harvest of sea cucumbers on Geyser Bank in order to allow populations to recover.

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Monitoring commercially important sea cucumber populations in the reefs of Mayotte (Indian Ocean)

Thierry Mulochau[1]

Abstract

One of the Mayotte Marine Nature Park's major challenges is protecting marine resources, including commercially important sea cucumber species. In December 2016, eight stations were set up to study commercially important sea cucumber species in the reefs of Mayotte. Park agents were given training in sampling methods and in how to identify the main species so that they could carry out regular monitoring. A total of 15 commercially important sea cucumber species were observed during this study, with *Holothuria atra* and *Bohadschia atra* observed most frequently. A total of 258 specimens were recorded, with the most abundant species being *Stichopus chloronotus* and *B. atra*. The observations made seemed to show that certain high-market-value species, such as *Holothuria nobilis* and *Thelenota ananas*, were observed less frequently than in previous studies, particularly on the outer slopes of the barrier reefs. In 2016, illegal harvests seem to have developed in certain areas of the reef. Since the sea cucumber's various environmental roles are vital to the reef ecosystem, urgent measures should be taken to prevent illegal fisheries.

Introduction

Mayotte is located north of the Mozambique Canal between the East African Coast and the coasts of Madagascar (Figure 1). This eight-million-year-old volcanic island (Marty 1993) is part of the Comoros Archipelago, which has four big islands (Grande Comore, Moheli, Anjouan and Mayotte). Mayotte has two main islands, i.e. Petite Terre (Pamanzi) and Grande Terre (Maore), with a 984.91 km^2 lagoon and a 342.4 km^2 reef (Andréfouët 2009).

Commercially important sea cucumber populations have already been studied in Mayotte (Pouget 2004, 2005; Pouget and Wickel 2003; Conand et al. 2005; Eriksson et al. 2012) and an inventory of the various species was recently carried during the ZNIEFF (natural marine areas of ecological interest due to their flora and fauna) survey (Pareto and Arvam 2015). It seems that Mayotte's reefs were protected from harvesting up till the early 2000s. Due to the overexploitation already underway in nearby countries such as Madagascar and the Comoros, harvesting developed in certain zones in Mayotte (Pouget and Wickel 2003). About 6000 kg of sea cucumbers were harvested in Mayotte in this way and exported to countries in the region (e.g. Tanzania, Madagascar, Mauritius Island) between 2002 and 2003, without taking into account clandestine exports. This fishery appears to have disappeared after 2004 following the ban on harvesting, transporting, sales or purchase of sea cucumbers throughout Mayotte (Prefectural Order no. 32/SG/DAF/2004). However illegal harvests seem to have developed in 2016 in certain reef areas (pers. obs.).

In order to try to better quantify this illegal fishery and its impact on sea cucumber populations, a study and a training session for Mayotte Marine Nature Park agents[2] were carried out in December 2016 with a view to setting up monitoring stations on Mayotte's reefs. The Mayotte Marine Nature Park is specifically designed to protect, restore and study coral reefs and related fauna, including various sea cucumber species. Due the overharvesting underway regionally, it is vital that such protection and study objectives continue over the long-term.

Materials and method

Stations

The study took place from 28 November to 2 December 2016 on all the reefs in Mayotte, both barrier and fringing reefs, and involved their outer slopes, inner slopes, reef flats and grass beds. A large number of sites and habitats were prospected and eight monitoring stations for commercially important sea cucumber populations were set up around Mayotte (Figure 1 and Table 1). Each station was uniform in terms of habitat and the various hydrodynamics-related parameters. Different data concerning the biotopes and biocenoses were recorded during the study in order to characterise each station: GPS points, geomorphologic unit, substrate in %, coral cover, seaweed, etc., through to depth in metres (Table1).

[1] BIORECIF, 3 ter rue de l'Albatros 97434 La Réunion, France – biorecif@gmail.com

[2] http://www.aires-marines.fr/L-Agence/Organisation/Parcs-naturels-marins/mayotte

Figure 1. Mayotte's location in Mozambique Channel and the location of the eight sampling stations set up in December 2016 to monitor commercially important sea cucumbers. Geomorphology (green thumbtacks: seagrass bed; red thumbtacks: reef flats; yellow thumbtacks: outer slopes; black thumbtacks: inner slopes) (H MTZA: Mtzamboro Island seagrass bed; P CHOI: Choizil Island reef flat; P RANI: Rani inner reef flat; PE BAND: Bandrélé outer slope; PERF Kolo: MtsangaKolo fringing reef outer slope; PI GRNE: Great north-eastern reef inner slope; PIRF PAM: Pamandzi fringing reef inner slope) (DigitalGlobe 2012;[3] Google Earth[4]).

Table 1. Monitoring stations for commercially important sea cucumber populations set up in Mayotte in December 2016, Sites, GPS Points (GPS Pts) in WGS84 with longitude/latitude (in decimal degrees), depth in meters (Depth (m)), Geomorphology.

Stations	Sites	GPS Pts	Depth (m)	Geomorphology
H MTZA	Mtzamboro Island North-west	-12.649260 N 45.024623 E	2	Sparse multispecies seagrass bed whose dominant species was Halodule universis – sandy zones
P CHOI	Choizil Island West	-12.677271 N 45.050248 E	1.5–2	Below-surface flat at the island's fringing reef with sparse coral cover, sandy and rubble zones
P RANI	Rani Inner reef South-east	-12.941800 N 45.056871 E	4–8	External flat of inner reef with sparse coral cover – algal communities - sandy and rubble zones
PI GRNE	Great Reef North-east	-12.748483 N 45.279667 E	3	Inner slope of barrier reef with coral formations spread out over a sandy zone
PI SADS	Sada Pass South	-12.909540 N 44.969501 E	5–10	Inner slope of barrier reef open to the sea with coral heads and spans and sparse coral cover - sandy and rubble zones
PE BAND	Bandrélé	-12.906945 N 45.251620 E	4	Outer slope of barrier reef with average coral cover - sandy and rubble zones
PERF KOLO	Mtsanga Kolo Sazilé	-12.984490 N 45.197810 E	6	Outer slope of fringing reef with extensive coral cover – soft coral – sandy zones
PIRF PAM	Pamandzi	-12.812663 N 45.276269 E	3	Inner slope of fringing reef with coral formations spread out over a sandy zone

[3] https://www.digitalglobe.com/
[4] http://www.earth.google.com

Method

The stations were surveyed using the Manta Tow method (Friedmann et al. 2008) in order to count the number of commercially important sea cucumbers on beds at between 1.5 and 6 to 8 m depending on visibility. The observer was towed by a boat and the stations divided into six 300 m x 2 m transects, i.e. 600 m^2 each. The speed was very slow and the position and distance were monitored by an above-water observer on the boat using a portable GPS. The surface area sampled at each station was 3600 m^2 and observers noted the number of specimens for each species. All six transects of the station were recorded with GPS points at the beginning and at the end of each transect, which makes it possible to know the exact zone sampled for future monitoring.

Results

Species richness

A total of 15 species of commercially important sea cucumber species were observed during this study (Table 2).

Holothuria atra (75%) and *Bohadschia atra* (62.5%) were the species most frequently observed at the eight stations (Figure 2). Several species were only observed at a single station: *Actinopyga* cf. *obesa*, *Bohadschia subrubra*, *B. vitiensis*, *Holothuria fuscogilva*, *H. fuscopunctata*, *Pearsonothuria graeffei* and *Thelenota anax*.

The average number of species observed by station for the eight stations in this study was 4.25 species (± 1.5). The H MTZA station, located north of Mayotte (Figure 1 and Table 1), was the station that had the greatest diversity in this study with seven sea cucumber species recorded there (Figure 4). The PIRF PAM station (Figure 1 and Table 1) was the station with the lowest diversity with only two species recorded there (Figure 4).

Abundances

Some 258 specimens of commercially important sea cucumbers were recorded at the eight stations (Figure 3).

Stichopus chloronotus (31%) and *B. atra* (30.6%) were the most abundant species at the eight stations with

Table 2. Commercially important sea cucumbers (Purcell 2014; Purcell et al. 2012 and 2013) observed in Mayotte in 2005a (Pouget), 2005b (Conand et al.), 2012 (Eriksson et al.), 2015 (Pareto et al.) and 2016 ('this study'), market value and International Union for Conservation of Nature (IUCN 2016) status. x = observed.

	2005a	2005b	2012	2015	'This study'	Market value	IUCN status
Actinopyga echinites		x	x			Average	Vulnerable
Actinopyga caerulea			x	x		Low	Data Deficient
Actinopyga mauritiana	x	x	x	x	x	Average	Vulnerable
Actinopyga miliaris		x	x	x	x	Average	Vulnerable
Actinopyga obesa		x	x	x	x	Average	Data Deficient
Bohadschia atra	x	x	x	x	x	Average	Data Deficient
Bohadschia marmorata		x				Low	Data Deficient
Bohadschia vitiensis	x	x	x	x	x	Low	Data Deficient
Bohadschia subrubra	x	x	x	x	x	Average	Data Deficient
Holothuria atra	x	x	x	x	x	Low	Least concern
Holothuria fuscogilva		x	x	x	x	High	Vulnerable
Holothuria fuscopunctata		x	x		x	Average	Least concern
Holothuria nobilis	x	x	x	x	x	High	Endangered
Holothuria scabra	x	x	x			High	Endangered
Holothuria lessoni		x				High	Endangered
Pearsonothuria graeffei		x	x	x	x	Low	Least Concern
Stichopus chloronotus	x	x	x	x	x	Low	Least Concern
Stichopus herrmanni		x	x	x	x	Average	Vulnerable
Thelenota ananas	x	x	x	x	x	High	Endangered
Thelenota anax		x	x	x	x	Average	Data Deficient
Total	9	19	18	15	15		

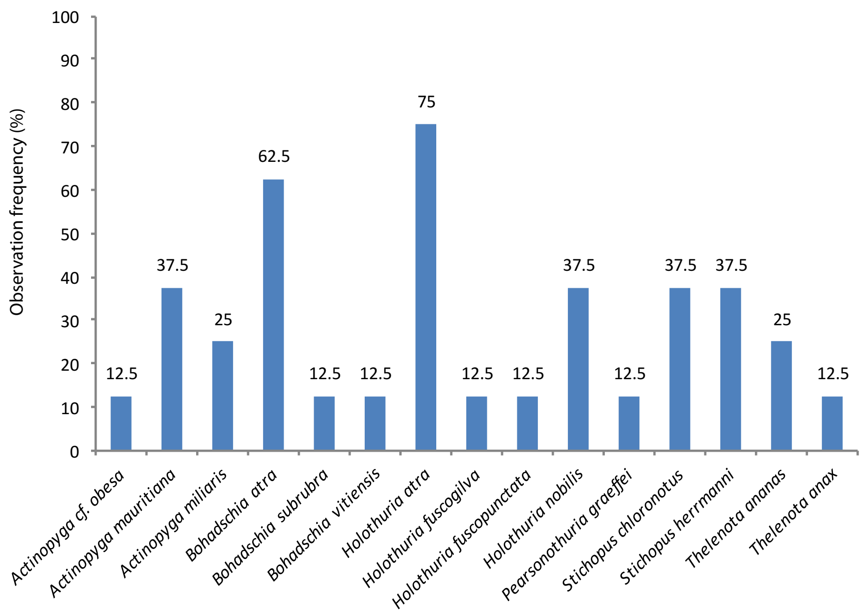

Figure 2. Observation frequency in % of total (ratio of the number of stations where the species was observed to the total number of stations) for commercially important sea cucumbers at the eight stations monitored.

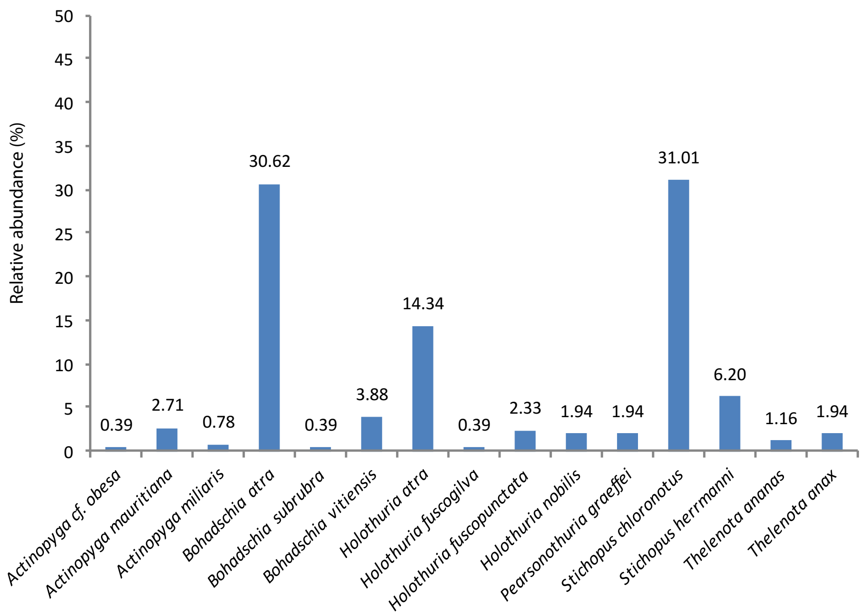

Figure 3. Relative abundances in % (ratio of the number of specimens per species to the total number of sea cucumbers) of the various species of commercially important sea cucumbers sampled in Mayotte at the eight stations monitored.

totals of 80 and 79 specimens recorded, respectively, for those two species. *S. chloronotus* was more abundant at the two reef flat stations (Table 1 and Figure 4), where it accounted for 72% of the relative abundances with a total of 68 specimens observed at those two stations. This species was also found at the seagrass bed station (H MTZA) (Table 1), where it accounted for 22.6% of the relative abundances with 12 specimens recorded, but it was absent from the other stations. *Bohadschia atra* was more abundant at the PERF KOLO station (Table 1 and Figure 4), where it accounted for 83% of the relative abundances with 44 specimens recorded. This species was also dominant at the two inner slope stations, PI SADS and PIRF PAM, with an abundance of 60%. *Holothuria atra* was the most abundant species at the seagrass

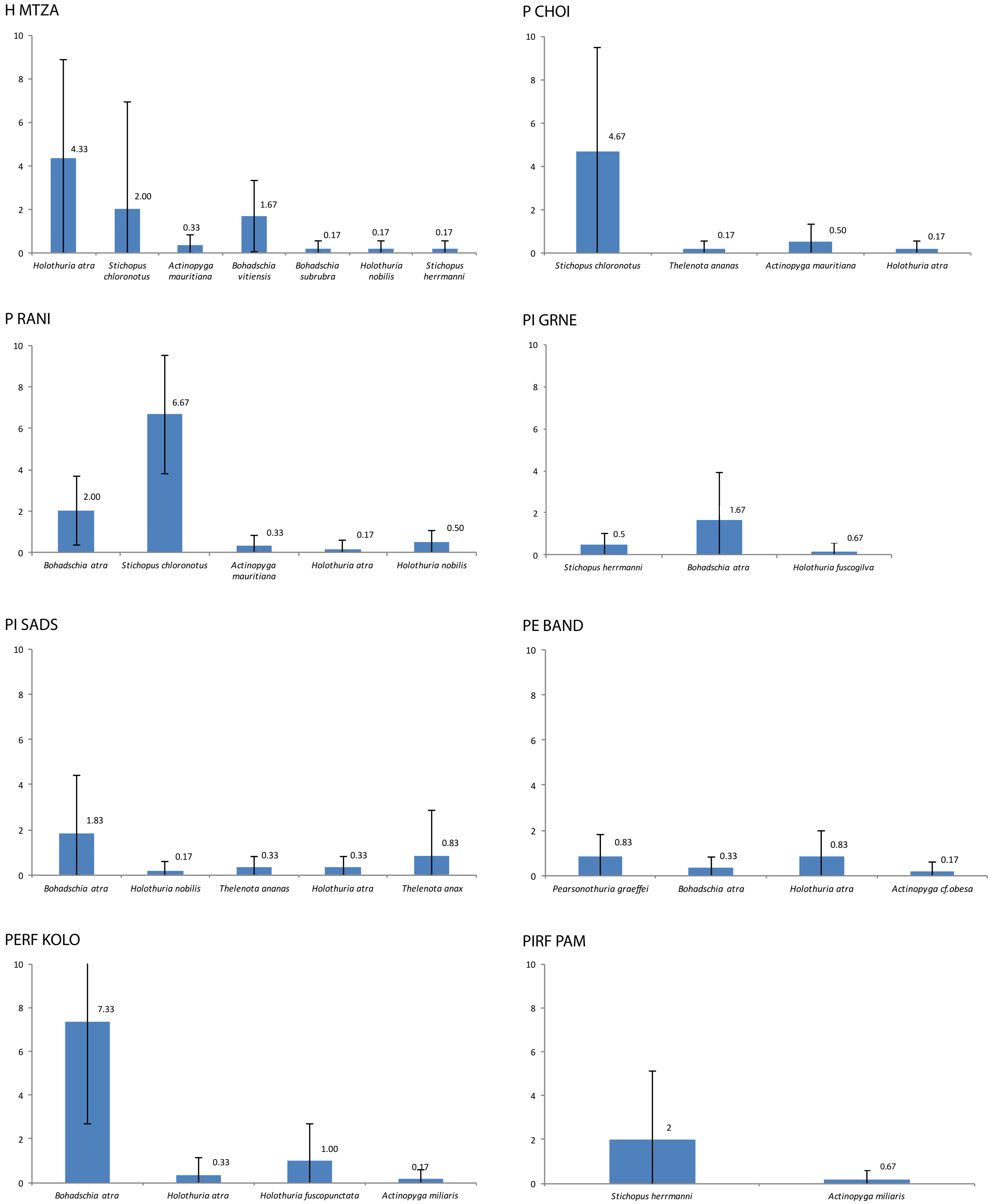

Figure 4. Average abundances (± standard deviation) of the various species of commercially important sea cucumbers in number of specimens per transect (600 m^2) for the eight sampling stations (Table 1).

bed station H MTZA with 49.1% and 26 specimens recorded, and found in lower abundance at the five other stations where it was recorded. *Actinopyga* cf. *obesa*, *B. subrubra* and *H. fuscogilva* were found in very low abundances; each with a single specimen recorded for all eight stations.

Discussion

A total of 15 sea cucumber species were observed at the eight stations set up during this study. These species had already been recorded during previous studies (Pouget 2005; Conand et al. 2005; Eriksson et al. 2012; Pareto et al. 2015) and are Mayotte's main commercially important sea cucumber species (Table 2). Eriksson et al. (2012) recorded 18 commercially important species in Mayotte, including *Holothuria scabra*, a species that is especially found in seagrass beds and is listed as 'Endangered' by the IUCN (2016), and *Actinopyga echinites*, a species that is found on reef flats in Mayotte and is listed as 'Vulnerable', but neither species was observed during this study. During the ZNIEFF (natural marine areas of ecological interest due to their flora and fauna) survey in 2014 (Pareto et al. 2015), 15 commercially important sea cucumber species were sampled, including *Actinopyga caerulea*, which was not observed during this study. In the region, Samyn et al. (2006) recorded 20 commercially important species in the Comoros and Mulochau et al. (2007 and pers. obs.) observed 11 species on Geyser Bank located 110 km north-east of Mayotte. Those data do not take into account non-market-value species.

Bohadschia atra, a recently described species (Massin et al. 1999), was one of the most abundant (with *S. chloronotus*) and most frequently encountered (with *H. atra*) species in this study, which was also the case in the Glorioso Islands (Mulochau and Guigou 2017). *Holothuria nobilis* and *T. ananas*, classified as 'Endangered' on the IUCN red list (Conand et al. 2014) and facing a very high risk of extinction, especially due to overharvesting in this part of the Indian Ocean, were observed at a few stations (Figure 4) but in very low abundances. *Actinopyga mauritiana*, *A. miliaris* and *H. fuscogilva*, also recorded during this study and classified as 'Vulnerable' by IUCN, also had very low abundances. During the Mayotte sea cucumber-population distribution and habitat study carried out in 2012 by Eriksson et al., the most frequently encountered and most abundant species were *B. atra, H. nobilis, T. ananas, H. atra, S. chloronotus* and *H. fuscopunctata*. Sampling was carried out at a larger scale in 2012, so it appears difficult to compare to monitoring done as part of this study due to the lower number of stations used. A more in-depth study would be needed to be able to compare changes in commercially important sea cucumber-population trends in Mayotte since 2012 and better measure the impacts they are subjected to. Nevertheless, the observations made this year seem to show that certain high-market-value species, such as *H. nobilis* and *T. ananas*, were less frequently observed and appear to be less abundant than during the 2012 study. Some sites, tentatively chosen for future monitoring and then sampled during this study, were not selected for regular monitoring due to their very low sea cucumber abundance and richness. The very low values at the two seagrass bed stations, which were not selected, each covering a surface area of 3600 m^2, were remarkable since seagrass beds are, in fact, known to be the preferred habitat for certain sea cucumber species and their juveniles (Muthiga and Conand 2014). The eight stations set up will make it possible to monitor abundance and stock status over time beginning with the 2016 estimate, thereby provided a solid foundation on which the Mayotte Marine Nature Park can base its management measures. Regular monitoring of all these stations is vital to understanding changes in commercially important sea cucumber populations on Mayotte's coral reefs and this study should be extended by setting up other stations, particularly on the outer slopes.

Illegal sea cucumber harvests appeared to exist in Mayotte in 2016 (pers. obs.) in spite of the prefectural order prohibiting collection of these animals. Such harvests may, in particular, take place during traditional fishing on foot in fringing-reef flats (Aboutoihi et al. 2010), but also by boat on most distant barrier reefs, as in the early 2000s. Since such harvests are illegal, park agents have difficulties determining the quantities and species involved. Such harvests do not seem to be destined for local consumption – while one part may be processed and packaged on land before export (pers. obs.), another may be shipped directly after harvest to nearby countries (Madagascar, Comoros).

The Mayotte Marine Nature Park's main goal is to protect all its ecosystems from the shore to the open ocean, e.g. seagrass bed, mangroves, coral reefs. Given the vital environmental role that sea cucumbers play in the reef ecosystem (Purcell et al. 2016), it seems that urgent action must be taken by all the necessary means to put a halt to the illegal harvest, transport, packaging and sales of sea cucumbers from Mayotte's reefs.[5] In addition, in many regions affected by such harvests, the depletion of high-market-value sea cucumber species leads to increased harvests of species of lower market value and of those with no market value at all (Conand 2004; Purcell et al. 2012; Eriksson and Byrne 2013).

5 http://www.dm.sud-ocean-indien.developpement-durable.gouv.fr/IMG/pdf/AP_32-Holoturies_cle146c36.pdf

The Mayotte Marine Nature Park has a vital role to play in the south-western Indian Ocean in terms of restoring commercially important sea cucumber populations. Stocks have collapsed in all the countries in this zone and Mayotte's reefs form a coral biodiversity hotspot, with a remarkable diversity of habitats y and a high – most likely underestimated – number of sea cucumber species. Mayotte's sea cucumber populations must be preserved so that, through connections between populations and larvae dispersal, stocks can be reformed as part of both protection programmes and the creation of marine protected areas within the countries in this region. The Mayotte Marine Nature Park needs to protect these sea cucumber populations and inform the public and fishers of the major environmental role they play in the reef ecosystem.

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Discovery of *Holothuria leucospilota* juveniles on Pai Island, Biak-Papua, and an overview of sea cucumber nursery grounds in Indonesia

Ana Setyastuti[1,*], I Wayan Eka Dharmawan[2], Muhammad Hafiz[1], Indra Bayu Vimono[1] and Ludi Parwadani Aji[2]

Abstract

To date, little research has been conducted on the ecology of sea cucumber juveniles. This project investigated a nursery ground of *Holothuria leucospilota* on Pai Island, Biak-Papua. Sea cucumber abundance, sea grass cover and density, and juvenile abundance within algal clumps were measured to characterise the nursery. The abundance of juveniles, seagrass cover, density and height, and algal biomass all decline seaward. This suggests that vegetation is an important factor for nursery sites, as well as land contour, substrate type, and organic material. An overview of sea cucumber nursery grounds throughout Indonesian waters, based on a literature survey and direct interviews with divers, showed that only limited data are available, and mostly in central and eastern parts of Indonesia. Documentation of juvenile nursery sites of *H. leucospilota* in particular is just a small snapshot of Indonesian discovery, with broad opportunities and challenges for further research remaining.

Introduction

The number of sea cucumber species fished around the world is increasing. In Indonesia, 54 species are commercially fished (Setyastuti and Purwati 2015). The number of species fished is increasing compared with the previous data by Choo (2008), who noted 35 species of sea cucumber were fished for trade, and Purwati (2005) who stated that as many as 26 species were fished. However, the condition of sea cucumber stocks in Indonesian waters is still uncertain. The only information about natural stocks is from community communications in particular areas in Indonesia that reported either stable conditions or overexploitation and declining populations. These limited published data about natural stocks are in contrast with the vast sea cucumber habitat that Indonesia possesses.

Successful management cannot be achieved without key ecological and socioeconomic information (Conand et al. 2006). From an ecological viewpoint, comprehensive information on life history of the small juvenile stages is still inadequate (Wiedemayer 1994). However, a clearer understanding of habitat and ecological requirements of juvenile sea cucumbers will enhance the success of conservation management programmes (Shiell 2004; Purcell 2004; Wiedenmayer 1994). In Indonesia, studies on juvenile life history and ecology of sea cucumbers are limited. Most studies are about restocking techniques using seed from nature (Hana 2011; Tangko and Mustafa 2008; Marizal et al. 2013), and these techniques were highly dependent on the availability of a natural seed stock that is invariably irregular (Pangkey et al. 2012). To address this shortcoming, a programme on sea cucumber cultivation is maintained to produce hatchery-product juveniles in several research institutions in Indonesia, but follow-up studies of released seed products in the wild are lacking (UPT LPBIL Mataram 2015). Recently, at Candi Manik Village (Lombok Island), more than 500 individuals of hatchery-reared juveniles from BBIL-LIPI Mataram failed because of the decline in salinity (Setyastuti, pers. obs.). It was not ascertained whether the population failed because of heavy rainfall or freshwater intrusion from the river. This finding indicates that our understanding of the microhabitat area for nursery ground and successful restocking are still in their infancy.

Most of the existing literature on juvenile ecology or nursery habitat is from fortuitous field observations (Wiedemayer 1994; Shiell 2004; Taquet et al. 2011; Palazzo et al. 2016). Most sea cucumber juveniles are enigmatic until they are large enough to avoid predation (Wiedemayer 1994; Purcell 2004; Shiell 2004).

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[1] Research Center for Oceanography-Indonesian Institute of Sciences (LIPI)
[2] Conservation Unit for Biak Marine Life-Indonesian Institute of Sciences (LIPI)
* Author for correspondence: ana.setyastuti@gmail.com

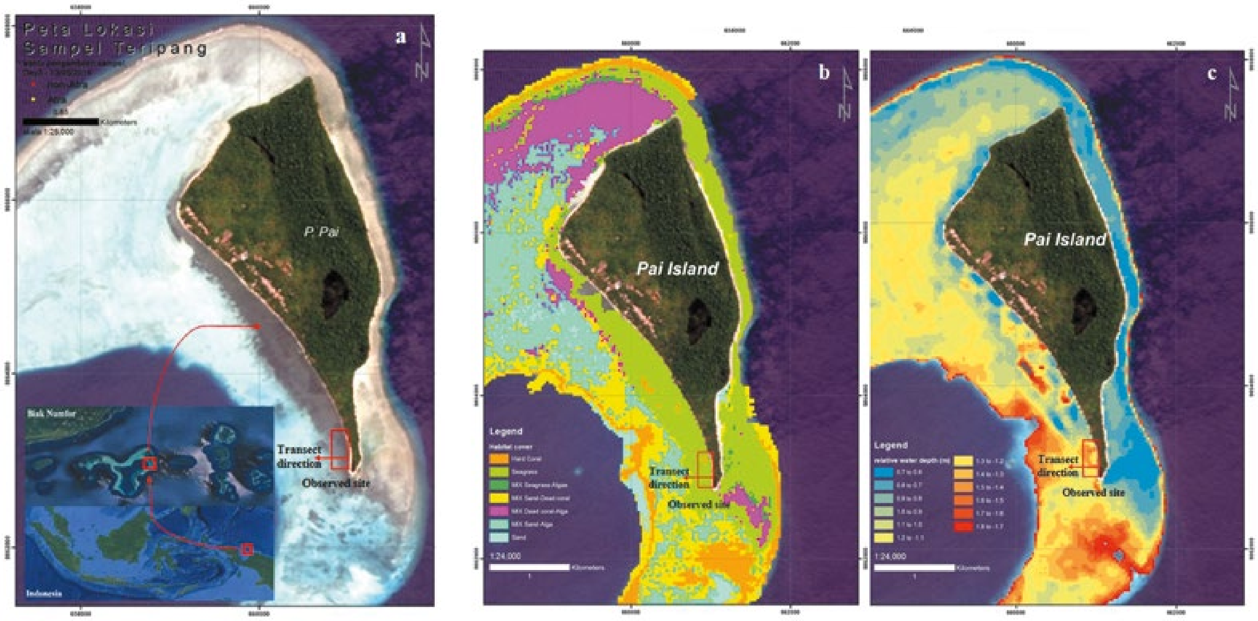

Figure 1. a: Survey location at Pai Island, Biak-Papua, Indonesia;
b: Habitat cover on observed site using satellite;
c: Relative depth of water based on satellite altimetry.

P2O-LIPI, a high number of *H. leucospilota* juveniles were fortuitously observed in Pai Island, Biak-Papua, Indonesia. These small individuals were only in a specific area on Pai Island. To take advantage of this observation, we set out to assess the density of juveniles in relation to the density of seagrass, algae and depth, to better understand these relationships. We also assembled available data on the occurrence of other nursery areas in Indonesian waters to provide context.

Methods

Pai Island is part of Padaido archipelago located in Biak Numfor Regency, Papua Province, Indonesia (Figure 1). Padaido archipelago has been established as a TWP (*Taman Wisata Perairan*/Marine Park for tourism) area by the decision of the Indonesia Ministry of Marine Affairs and Fisheries (No. 68/MEN/2009). Pai Island is surrounded by a vast (about 467.7 hectares) intertidal to shallow sub tidal characteristic reef and sand flat habitats (KKP 2014).

Surveys were conducted along the south side of Pai Island on 13 May 2016 at around 2–4 pm East Indonesia Time (WIT). Before deciding the specific location for sampling, rapid assessment of habitat using satellite imagery was conducted to determine the best location with high variability in vegetation cover and depth (Figures 1a and 1b).

Sampling methods were as follows:

1. Sampling was along a 1 x 100 m long transects. This single transect was purposefully conducted in order to get the precision density of juveniles *only*; not for an ecological approach.

2. Population density of sea cucumber juveniles, and cover and density of sea grass were measured in five 0.5 x 0.5 m quadrats along the transect that was orthogonal to the coast.

3. Algal clumps hold particularly high density of sea cucumbers. Five algal clumps were sampled in addition to the above by collecting entire clumps, counting all sea cucumber juveniles in the clump, then measuring the dried biomass of the algae.

4. Five sediment samples were taken at each sea grass quadrat transect and the total organic matter was determined by burning the sediment at 550°C in a furnace, as recommended by Fourqurean et al. (2012).

Statistical data were analysed using R Studio 1.0.136. The mean variances of juvenile abundance, seagrass density, seagrass coverage, and total organic matter were analysed using ANOVA and Tukey tests, respectively. The relationship among parameters was examined by Spearman rank analysis.

Results

Large numbers of juvenile black sea cucumbers were observed on the south side of Pai Island, Biak-Papua, Indonesia. Field identification of juvenile sea cucumbers as *Holothuria leucospilota* was based on morphological appearance (long black body, uniformly brown body colour when preserved in alcohol, smooth tegument), behaviour of expelling the cuvierian tubules when disturbed (hand contact), and confirmed by laboratory observations on ossicles in sampled specimens (Figure 2).

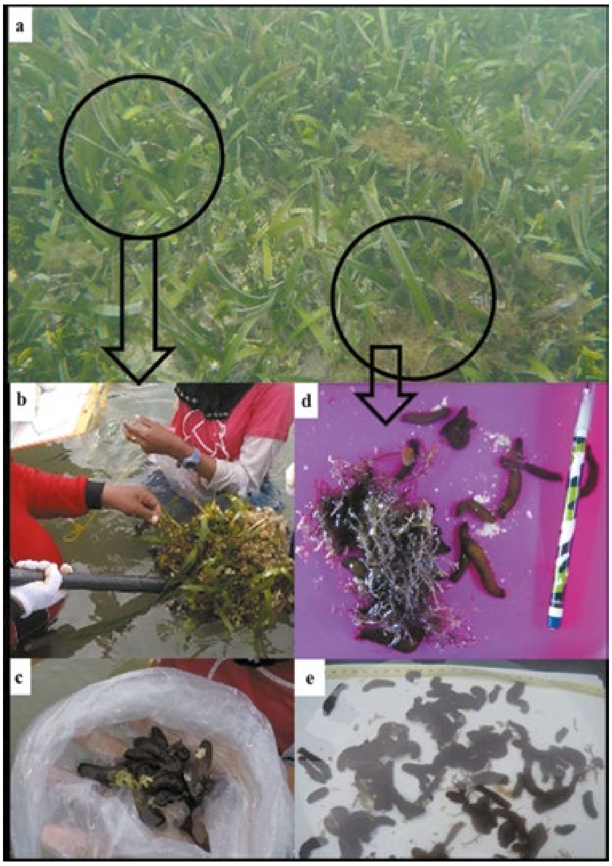

Figure 2. a: Vegetation at observed area; b-c: digging the bottom of the seagrass stand, where juveniles were collected, counted and measured; d-e: algae clump of *Hypnea* sp. and juveniles from the clump.

The juvenile microhabitats preference was observed on two areas, firstly on the sandy, mixed coral rubble or shell fragments bottom within the seagrass bed (Figure 2a). The seagrass stands on the spot were only *Thalasia hemprichii* and *Enhalus acoroides*. Secondly, the juveniles' habitat preference was adhered to clumps of the specific alga *Hypnea* sp. (Figure 2d). During the observation it was noted that species composition and cover of seagrass decreased seaward (Figure 3). Thus algal clumps were only collected along the first 40 m from the shoreline (Figure 4).

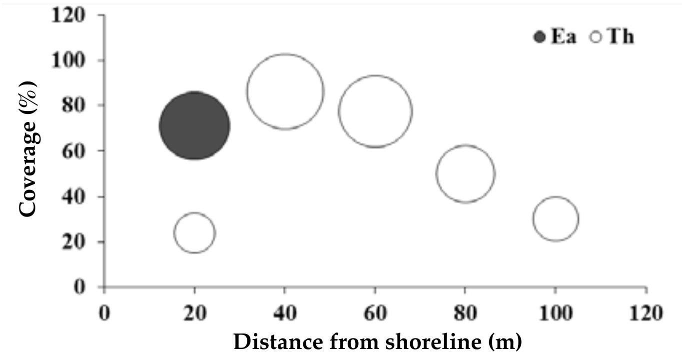

Figure 3. Seagrass cover along transect at Pai Island, Biak-Papua (Ea = *Enhalus acoroides*; Th = *Thallasia hemprichii*).

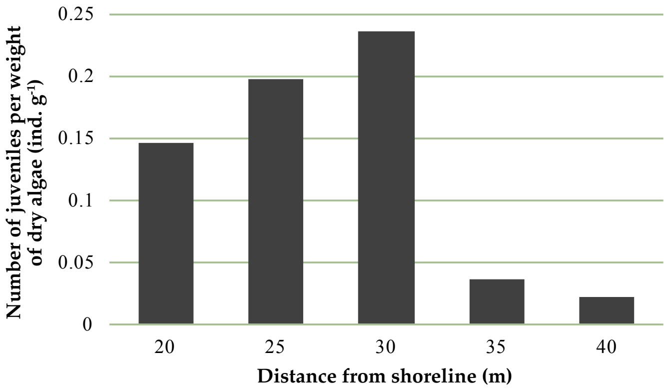

Figure 4. Abundance of juveniles per dry algal biomass.

Seagrass cover and density decreased constantly from landward to seaward (91.25 ± 5.00% to 30.00 ± 7.56%; Figure 5). The 20 m plot was dominated by *E. acoroides* with a leaf height of 0.5–1 m, which was the highest among all plots. The 40–100 m sites were dominated by *Thallasia hemprichii* with a leaf height that gradually dropping seaward. The abundance of *H. leucospilota* juveniles decreased constantly seaward, and they were reaching zero at 100 m (Figure 5).

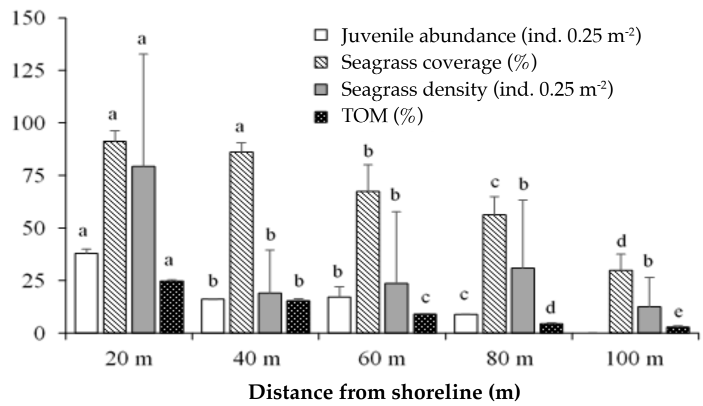

Figure 5. Juvenile abundance; seagrass cover and density; and total organic matters along the transect. (abcde : Tukey test result among five sites. Same letter on each parameter represented no significant difference among sites).

Seagrass cover and juvenile abundance were positively correlated (Spearman correlation coefficient of (0.831, P<0.01) (Table 1). Total organic matters (TOM) was also positively correlated with both seagrass cover and density (0.884, P<0.01) and *H. leucospilota* juvenile abundance (0.931, P<0.01) (Table 1). Dense algal clumps also had a high density of sea cucumbers (Figure 4), and in these the holothurians were up in the algae, while in seagrass they remained on the sediment surface.

In the review of literature and the internet, most records on juvenile sea cucumbers in Indonesia related to observations of only single specimens (Table 2). Only three other observations pertained to large abundance of juveniles, two of *H. leucospilota* and one of *H. edulis* (Table 2). All four observations of the abundance of *H. leucospilota* encountered animals in a similar microhabitat.

Table 1. Spearman correlation coefficient among juvenile abundance, seagrass profile and substrate total organic matter (TOM).

Parameters	Juvenile abundance	Seagrass		
		Density	Coverage	Structure
Juvenile abundance				
Seagrass density	0.385			
Seagrass coverage	0.831**	0.175		
Seagrass structure	0.240	0.539*	-0.047	
Total organic matter	0.931**	0.362	0.884**	0.173

* significance level at alpha = 0.05
** significance level at alpha = 0.01

Discussion

Recruitment of larvae is more likely to occur in certain habitats (Purcell 2004). Juveniles and adults frequently occupy different habitats in terms of substrate type, food availability and type, and depth (Slater and Jeffs 2010). Several microhabitat characteristics of the south side of Pai Island make it a nursery ground for *H. leucospilota* juveniles. Firstly, suitable sandy mixed coral rubble/shell fragment substrate was available there. Based on Slater et al. (2010) this kind of substrate may not only be suited for larval settlement but also for predator avoidance. Secondly, the contour of the site acts like a basin. At low tide the area is still underwater. When currents come from the eastern side, they are hindered by the south edge of the island. When currents come from the western side, they are constrained by the coral reef (see map on Figure 1). These conditions shelter the observed site from high currents. Thirdly, the observed site has dense vegetation stands of seagrass or algae clumps. In littoral areas, vegetation has an ecological role as a nutrient trapper as well as a shelter for juveniles, not only from predators but also from waves and currents (Fonseca and Fisher 1986; Mercier et al. 2000b; Komatsu et al. 2004; Duffy 2006; Dissanayake and Steffansson 2011). Finally, Table 1 and Figure 5 indicate that there is a close relationship between the number of juveniles and the levels of organic matter, as well as with the density of seagrass cover. The high aggregation of juveniles in this study area suggests a preference towards high levels of organic material, as expected for deposit feeders. The importance of organic material to habitat choice by sea cucumbers has also been observed by several researchers (Conand 1990; Conand and Mangion 2002; Purcell 2004; Purcell et al. 2009; Slater and Jeffs 2010; Dissanayake and Steffansson 2011).

The hypotheses above fit with the observations of high densities of *H. leucospilota* juveniles found on the south side of Pai Island. Meanwhile, no adults were observed at the site. The best habitats for larvae settlement and juvenile growth may not be the best habitats for adults (Purcell 2004). Ontogenetic habitat shifts in some echinoderms, including sea cucumber, have been reported (Bos et al. 2011; Eriksson et al. 2013). Migration to deeper water or more exposed sandy areas were reported in several publications (Conand 1981; Conand 1993; Hamel and Mercier 1996; Mercier et al. 2000a; Hamel et al. 2001; Purcell 2004; Bos et al. 2011; Eriksson et al. 2013). Our working hypothesis about adult origins is that currents bring planktonic larvae to the observation site and the larvae are then trapped and settle in the restricted nursery ground. Most juvenile sea cucumbers are believed to have enigmatic behaviour during the earliest stage of their life cycle (following settlement) that may be related to avoiding predation (Shiell 2004; Slater et al. 2010). We found no predators of juveniles of this size (big sea stars, molluscs, crustaceans or fish) on the observed site during the survey.

Juvenile abundance at bottom of seagrass or adhering on *Hypnea* sp. algae generally decreases seaward (Figures 3–5). This pattern may be due to the cover and density of seagrass and biomass of algae declining seaward, although there is probably a more complex relationship between algal biomass and sea cucumber density (Figure 4). Decreasing vegetation is also correlated with a decline in nutrient concentration in the substrate (Table 1 and Figure 5) and the absence of settlement surface and sheltering area. Thus, the concentration of both seagrass and algal vegetation is likely to have a considerable effect on distribution of juvenile sea cucumbers. Slater and Jeffs' (2010) experimental

Table 2. *In situ* observations of juvenile sea cucumbers in Indonesia waters.

Species observed	Approx. size and numbers	Location	Habitat	Time	Date	Adults present	Observers' name(s) and affiliation / Source of further information
H. leucospilota	3–5 cm, 151 specimens observed on the transect	South side of Pai Island, Biak-Papua, East Indonesia	Bottom of seagrass bed and adhere on the *Hypnea* seaweed colony, 1–2 m water depth	2–4 pm WIT*	May 13, 2016	No	This study
H. leucospilota	3–5 cm, specimen not counted (a lot)	Coastal water of Bindusi to Orwer Village, East Biak-Papua, East Indonesia	Bottom of seagrass bed (*T. hempricii, C. rotundata, H. pinnifolia* and *E. acoroides*), 1–2 m depth	Day time	2009	Yes	Ludi Parwadani Aji; Conservation Unit for Biak Marine Life - LIPI
H. leucospilota	1.5–3.5 cm, 35 specimens	Pantai Kalinaun, Eastern side of Manado Peninsula, Nort of Bitung, Sulawesi, Center Indonesia	Seagrass bed, 50 cm water depth	3–7 pm WITA**	May 15, 2010	No	Taquet et al., 2011
H. edulis	2–3 cm, specimen not counted (a lot)	Bilangan Gili, Sekotong Lombok Barat	Sand, coral	Day time	June, 2006	Yes	Taufan; gala-aksi.blogspot.co.id
B. argus	1 specimen	Selat Lembeh, Madidir, North Sulawesi	Corall	Day time	2010	-	Rakus Groeneveld and Sanne Reijs; www.diverosa.com
P. graeffei	1 specimen	Kubu, Batu Kembar, Bali	Corall	Day time	2011	-	Rakus Groeneveld and Sanne Reijs; www.diverosa.com
S. horrens	1 specimen	Seraya Slope, Bali	Corall	Day time	2016	-	Rakus Groeneveld and Sanne Reijs; www.diverosa.com
Actinopyga sp.	5 cm, 1 specimen	Hative Besar, ambon Bay, Maluku, East Indonesia	Adhered under the dead coral, 4 m water depth	3 pm WIT*	October 15, 2009	No	Ana Setyastuti; RC Oceanography LIPI. Data published in field report of SBL Dikti 2009-UPT BKBL LIPI-Ambon
Actinopyga sp.	5 cm, 1 specimen	Tanjung Tiram, Ambon Bay, Maluku, East Indonesia	Seagrass bed of *Enhalus acoroides*, 0.5 m water depth	3 pm WIT*	April 30, 2014	No	Ana Setyastuti, RC Oceanography LIPI.
S. horrens	10 cm, 1 specimen	Wainuru, Ambon, Maluku, East Indonesia	Adhered on the stone, 1 m water depth	Day time	March 19, 2014	Yes	Ana Setyastuti, RC Oceanography LIPI.

* WIT: East Indonesia local time

** WITA: Centre Indonesia local time

work specifically demonstrated the importance of shell fragments as initial settlement surfaces. They noted that shell fragments were one of the important factors of *Australostichopus mollis* juvenile survival. Another possible explanation of juvenile distribution in this study could be that there were sufficient seagrass beds and algae clumps landward, which provide suitable shelter even under the influence of tidal change, while the reef slope is constantly impacted by waves and current, making it an unsuitable habitat. Setyastuti (2014) also noted the importance of seagrass (*Enhalus acoroides*) for small individuals of *Holothuria atra* in Baluran National Park, Indonesia.

The abundance of the alga *Hypnea* sp. was conspicuous during the survey. *Hypnea* sp. clumps always had abundant *H. leucospilota* juveniles. The algae may facilitate the initial settlement of larvae, serve as a source of detritus and a place for predation avoidance (review of Slater and Jeffs 2010; Mercier et al. 2000b). Juvenile abundance fluctuates with algal biomass, rising steadily to a peak of 30 m from shore, then dropping sharply seaward (Figure 4). This suggests that algal biomass is not the primary driver of juvenile abundance. Instead, juvenile abundance may be tracking the general abundance of algal clumps, which decrease after 30 m and disappear after 40 m from shoreline.

To date, studies of sea cucumber nursery grounds in Indonesia are few. Based on the *in situ* observation list data presented in Table 2, similar observations to this study were made by Taquet et al. (2011) and Ludi Purwadani Aji (pers. obs.). They both observed high abundance of juveniles *H. leucospilota*, at Pantai Kalinaun, Manado Peninsula and coastal water of Bindusi to Orwer Village, East Biak-Papua, respectively. Juveniles were found on the bottom among seagrass beds with sandy mixed coral rubble substrate in both studies. These three studies suggest that *H. leucospilota* utilises nearshore, sand / coral rubble with seagrass habitats as nursery grounds.-

Findings herein support the studies of Shiell (2004), Purcell (2004), Slater and Jeffs (2010) and Palazzo et al. (2016) that among sea cucumbers, juveniles have a wide range of habitat preferences. At present, our understanding of the habitats occupied by juvenile sea cucumbers is based mostly on anecdotal observations of a few species in a limited area (Table 2). Given the diversity of species found in the commercial market of Indonesia and the few studies available on early life history and ecology of only a handful of species, more studies are needed to inform sustainable practices of this important fishery. Research challenges and opportunities for both taxonomically and regionally are vast.

Conclusions

Comprehensive studies on factors that support an area as a nursery ground for sea cucumbers are needed to inform recommendations for designation of marine protected areas (MPA). Conservation programmes will find these studies useful as they will not only indicate likely regions for natural recruitment, but also identify regions that are likely to be successful for restocking hatchery-product juveniles. Herein, we found that vegetation coverage, local geomorphology, substrate type and organic material levels may be important factors for making an area successful as a nursery ground for juvenile sea cucumbers. The denser the vegetation and the taller the seagrass stands, the more juveniles there were. The more complex the substrate, the more successful larvae settlement will be. In the future, studies on nursery grounds throughout Indonesian waters should be encouraged, in order to get a bigger picture of potential areas for both re-stocking, conservation, and management of waters that are used for fishing.

Acknowledgements

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Asexual reproduction in a population of *Holothuria difficilis* (Echinodermata; Holothuroidea) on Reunion Island

Philippe Bourjon[1*] and Thomas Desvignes[2]

Abstract

Asexual reproduction in *Holothuria difficilis* was monitored from May 2016 to May 2017 on Reunion Island's Saint Gilles Reef. The study population had a very low density level (0.12 ind. m^{-2} for the study as a whole, with a maximum of 0.19 ind. m^{-2}), in comparison with levels recorded elsewhere. Sparse distribution was another unique feature of that population, as the species is characterised by high-density aggregations. Asexual reproduction occurred within the population all year round, but a peak was observed during the transition between Southern Hemisphere summer and winter. The mean percentage of regenerating specimens in the population was 19.32%, with maximum levels barely exceeding 40%. These values are low in comparison to those recorded elsewhere in the same species.

Introduction

Many echinoderm species, including the sea cucumber *Holothuria* (*Platyperona*) *difficilis* (Semper, 1868), can reproduce both sexually and asexually via fission or fragmentation (Mladenov 1996). After an initial observation of transverse fission in preserved specimens by Benham (1912), a detailed description of the regeneration process in this species was proposed by Deichmann (1922) using the same type of material.

Holothuria difficilis is a small sea cucumber. The maximum length in a contracted specimen is 4 to 5 cm (Lawrence 1980; Lee et al. 2009) and 12 cm in an uncontracted individual (Rowe 1969; Samyn et al. 2006). The species is wide-spread in the Indo-Pacific Basin with an irregular distribution made up of large local concentrations. It is generally found in shallow water on coral-reef flats (Rowe and Doty 1977; Kerr 1994; Conand and Mangion 2003) or near the shore in intertidal zones (Lee et al. 2009).

Not a lot is known about the biology of this species' reproduction. The only study on asexual reproduction in *H. difficilis*, carried out on One Tree Island (OTI) in Australia's Great Barrier Reef, showed that this reproduction mode occurred year-round, with a peak at the beginning of the Southern Hemisphere winter (Lee et al. 2009). The purpose of this article is to document the seasonal nature of asexual reproduction in an *H. difficilis* population on a Reunion Island reef.

Materials and methods

These observations were made on the west coast of Reunion Island (21°07'S, 55°32'E), located in the south-western Indian Ocean about 680 km east of Madagascar, on the Saint Gilles-La Saline fringing reef (Figure 1A). This reef, which is 7.6 km long with a maximum width of about 500 m and an average depth of less than 1.5 m, is divided into two parts by L'Ermitage Pass. The site selected for this study, located in the southern part of the reef, is situated about 80 m from the reef front and 425 m from the shore (21°5'45.47''S and 55°13'48.72''E; 21°5'44.68''S and 55°13'47.64''E) (Figure 1B). Its depth varies from 0.3 to 0.8 m depending on the tide. It is characterised by a sandy-rubble substrate covered by a few damaged coral mounds and a great deal of coral rubble in the form of a slab (Figure 1C). It is subject to trade-wind swells throughout the year, which are stronger during the Southern Hemisphere winter (from May to October), and sometimes violent Southern Hemisphere swells (Tourand et al. 2013). This reef is included at the edges of the Reunion Island Natural Marine Reserve's marine protected area (GIP-RNMR) and the study site is in a Level 2a enhanced protection zone.

Length measurements were used rather than weight in spite of sea cucumbers' contractibility since hydrodynamics at the site made weighing impracticable and it was not possible to collect observed specimens to weigh on the shore and then return to the site.

[1] Les Sentinelles du Récif (Sentinels of the Reef, Volunteer Observers Network of Reunion Marine Park), France.
[2] Institute of Neuroscience, University of Oregon, 97401-1254 OR, Eugene, USA. Email: desvignes@uoneuro.uoregon.edu
* Author for correspondence: seizhavel@wanadoo.fr

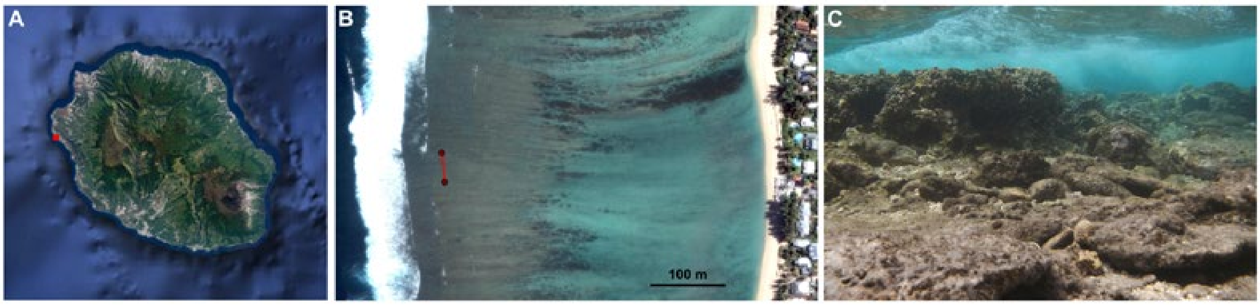

Figure 1. A) Reunion Island (red dot = location of the Saint Gilles-La Saline reef). B) Study site and transect position (red line) close to the reef crest. C) Typical habitat of Holothuria difficilis on the reef of Saint-Gilles-La Saline (Reunion Island). This habitat is characterised by the presence of slab-shaped rubbles scattered on a sandy-detrital substrate, and strong hydrodynamics.

A 40 m x 5 m (200 sq. m) transect parallel to the reef front was marked out on a site where *H. difficilis* aggregations had previously been observed. It was monitored once a month in the late morning from 15 May 2016 to 15 May 2017. Observations were done via snorkelling. All the specimens observed in the transect were measured and photographed *in situ*. The following morphological features were then recorded: 1) specimen status: whole specimen (W), or regenerating individual (R), and 2) state of contraction determined by the body's appearance: uncontracted (nc) or contracted (c). In regenerating specimens, the following features were also recorded: 1) nature of the regenerating part when that could be determined: anterior end regenerating the posterior end [anterior part] (AP), posterior end regenerating the anterior end [posterior part] (PP), or specimens for which the anterior-posterior axis could not be determined (P ?) and, 2) the length of the regenerating part.

All the individuals resulting from fission observed had begun to regenerate their missing parts. All the observed specimens were hidden in coral rubble, which was carefully removed and then put back into place after observation. None of the animals were removed from their locations.

It is easy to differentiate between Ws (Figure 2A) and Rs (Figure 2B) due to the yellowish-orange colour of the regenerating part, which stands out against the even, dark-brown colour of Ws. They are also easy to distinguish from juveniles, which have an even, fairly light orange to greenish-yellow colour (Figure 2C).

In addition, random two-hour explorations from the shore to the breakers were carried out once a month by two observers at six different sites (three north of L'Ermitage Pass and three south of it), to allow species density and distribution estimates, along with possible sightings of regenerating specimens.

Results

H. difficilis' very low density on Saint-Gilles-La Saline Reef, which is atypical for the species, limited quantitative analysis of the measurements taken on the transect since out of 13 samplings, only 5 provided observations of 30 or more specimens (May 2016 and February–May 2017). In addition, it was impossible to estimate the number of specimens counted repeatedly during successive samplings, but the wide variations in W densities, and, to a lesser degree, R densities, suggest that such bias was minor. It was also impossible to estimate recruitment, emigration and immigration rates in the transect or mortality rates since population numbers did not remain constant.

Figure 2. A) Whole individual, ≈3.5 cm. B) Fission product regenerating its anterior part (PP), ≈2 cm. C) Juvenile, ≈1.75 cm. Scale bars = 1cm.

Population structure

Sizes

Some 326 specimens were measured during this study, including 263 Ws and 63 Rs. Some 86.8% were contracted (n = 283), and 13.2% were uncontracted (n = 43). The prevalence of contracted specimens in the sample was probably due to stress linked to removing the rocks the animals were hiding under, thereby exposing them to both light and the currents. There were relatively few small or large specimens: 4.91 % were under 2.0 cm in length (n = 16) and 9.20 % were over 5.0 cm (n = 30) (Figure 3A).

The Ws' median size was 3.3 cm, while the Rs' was 3.0 cm (Figures 3A–B). Whatever the regenerating part (i.e. AP, PP and P?), Rs were significantly smaller than Ws but were of similar sizes within that category (Figure 3B). For the Ws, and for the Rs, contracted specimens were significantly smaller that uncontracted ones (Figure 3C), so contraction does affect specimen size. For that reason, including contracted-specimen measurements does lead to a bias in estimates of the population's average specimen size. The average specimen size of uncontracted animals in the total population was 4.61 ± 1.42 cm (n = 43), for W-nc 5.13 ± 1.43 cm (n = 29) and for R-nc 3.59 ± 0.75 cm (n=14) (Figure 3C).

The average size of all the specimens observed during the study was 3.51 ± 1.07 cm, with a median of 3.2 cm, a maximum in July 2016 (4.27 ± 1.66 cm, n = 11) and a minimum in May 2017 (2.98 ± 1.07 cm, n = 32) (Figure 3D).

Only five juveniles, all under 2 cm in length, were observed during the random explorations while none were spotted in the transect.

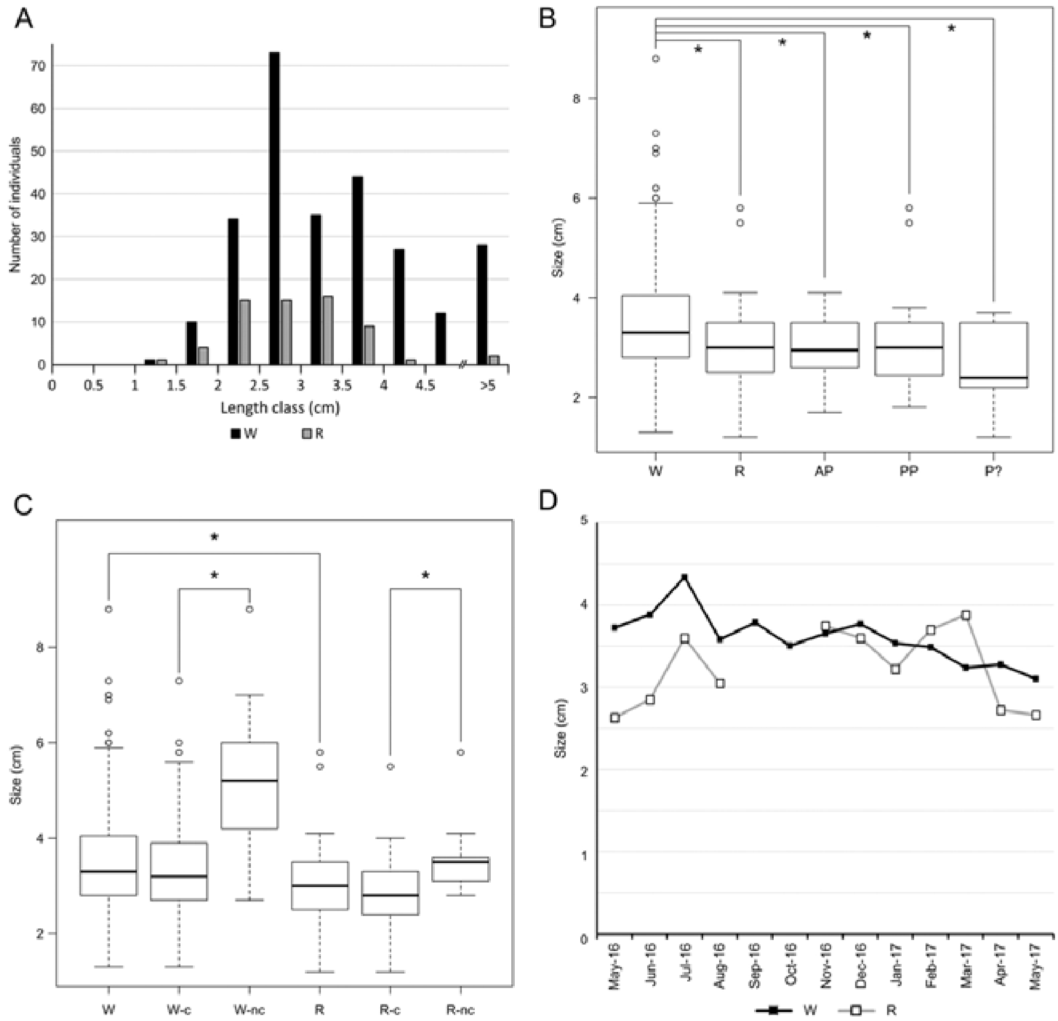

Figure 3. A) Size frequency distribution of whole (W, black bars) and fissioned individuals (R, grey bars) on the transect over the 13-month study. B) Fissioned individuals, (R, AP, PP, and P?) were significantly smaller than whole individuals (W). C) Contraction status (c = contracted, nc = uncontracted). D) Average size variations over the study period. No data are available for Rs in September and October 2016 (no specimens observed). * indicates a significant difference at $p < 0.05$.

Densities

The study population's average density fluctuated greatly over the course of the study (Fig. 4A). It averaged about 0.12 ind. m^{-2} (n = 326) over the 13 months, with a maximum observed in May 2016 (0.19 ind. m^{-2}, n = 39) and a minimum in July 2016 (0.06 ind. m^{-2}, n = 11). A second peak occurred in September 2016 (0.13 ind. m^{-2}, n = 26), following a sharp drop in numbers from May to July and preceding another decrease through to November. A constant increase in density was observed from December 2016 to April 2017 and in April the density was 0.18 ind. m^{-2} (n=36). The average density for Ws over the course of the study was 0.1 ind. m^{-2} (n = 263) and for Rs, it was 0.02 ind. m^{-2} (n = 63) (Figure 4A).

The qualitative estimates made during the random explorations suggested that *H. difficilis* could be found in very low densities in most reef flat zones near the reef front. Aside from some rare one-to-two metre zones where densities were higher (about 5 ind. m^{-2}), all the observed specimens were isolated, often located more than 20 m from each other.

Asexual reproduction

No specimens undergoing fission, wound healing or internal organ regeneration (i.e. without any visible regeneration) were observed either in the transect or during random explorations. The average percentage of Rs was 19.32% of the study population, with rates of more than 20% in May, June and November 2016 (41.02%, 42.85% and 26.66, respectively) (Figure 4B), and in April and May 2017 (22.22% and 28.12%, respectively). In September and October 2017, no Rs were observed in transect (Fig. 4A–B), although three Rs were observed during the random explorations. For the Rs, there were 32 PP, 26 AP and five specimens whose anterior-posterior axis could not be determined. On average, the original part accounted for 77.65 ± 12.23% of the body length in Rs (77.54% ± 14.72% in R-nc, n = 14) (Figure 4C). On average, the original part of the PPs was 76.82% ± 14.53% of the body length (78.14 ± 20.08% in PP-nc, n = 6), for APs it was 79.60 ± 9.22% (78.63 ± 12.28% in AP-nc, n = 8) (Figure 4C). The average length of the original part was 2.57 ± 0.41 cm in AP-nc (n = 8) and 3.03 ± 1.28 cm in PP-nc (n = 6).

Discussion

Population structure

Size

The sample population's average specimen size (3.51 ± 0.7cm) changed little over the study period. It was 4.61 cm ± 1.42 cm (n = 43) in uncontracted specimens, which is similar to Bakus' (1968) estimated average size at Enewetak Atoll, i.e. 4 cm, and the maximum size recorded by Lawrence (1980) in other populations of the same atoll (4 cm contracted). In contrast, size distribution between Reunion Island and OTI differed greatly. On OTI, Lee et al. (2009) observed a population dominated by specimens under 2 cm in length and mainly composed of regenerating specimens, whereas on Reunion Island, more than 95% of the animals measured were over 2 cm in length in a population composed of one-fifth regenerating specimens. In addition, Lee et al. (2009) estimated that the

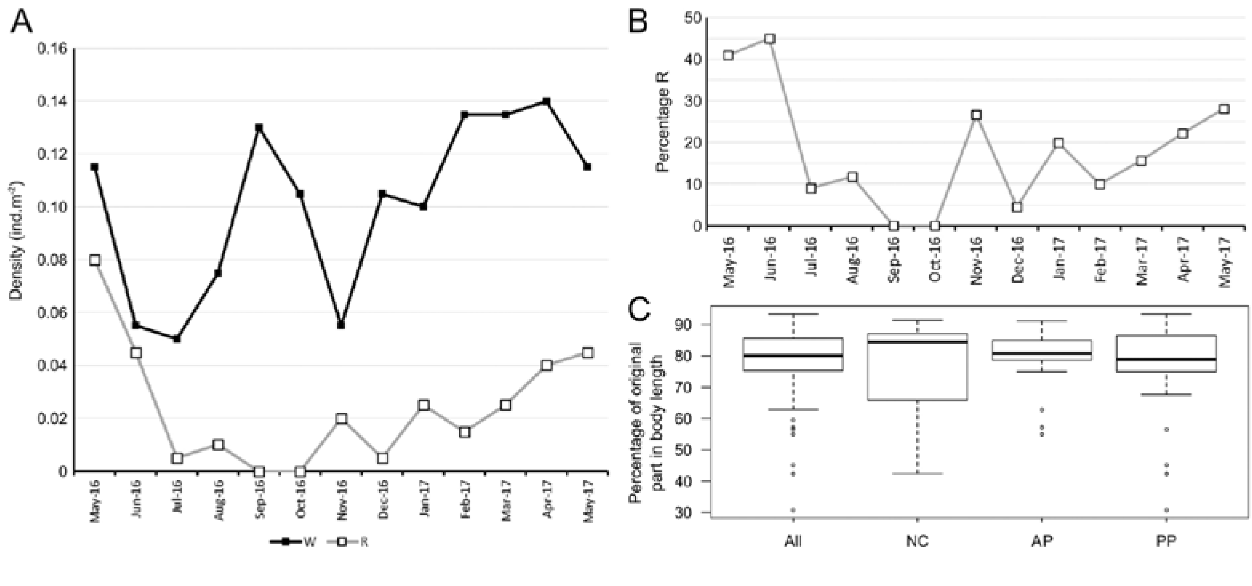

Figure 4. A) Distribution of the average density (individual per sq. m) of whole (W, black line) and fissioned individuals (R, grey line) on the transect. B) Distribution of the percentage of Rs in the population. C) Percentage of original part in body length.

maximum specimen length on OTI was 5 cm. In the study population on Reunion Island, specimens measuring more than 5 cm in length accounted for 9.20% of the population (n = 30) and the maximum sizes measured were 8.8 cm (nc) in the transect and 10.9 cm (nc) during the random explorations. These differences in size distribution may be linked to the low percentage of regenerating specimens observed on Reunion Island in comparison to those recorded on OTI or to a probably limited sexual recruitment. We did, in fact, only observe 11 out of 263 Ws (4.18%) of a size equal to or less than 2 cm, which suggests that recruitment from sexual reproduction is low or that the mortality rate for larvae and/or juveniles is high. Both assumptions are supported by the fact that only five juveniles were observed, during the random explorations, over the 13 months of the study.

In contracted Rs, the regenerating part was not contracted or only slightly so, and that specific characteristic was probably due to the short diameter of the regenerating longitudinal muscles as compared to those in the original section (Conand et al. 1997).

Habitat and density

H. difficilis' preferred habitat on Reunion Island was the same as the main one recorded elsewhere, i.e. on semi-exposed or exposed reef flats (Conand and Mangion 2003; Lee et al. 2009; Kerr 2014; Lawrence 1980) and near the reef front (Rowe and Doty 1977; Kerr 1994), as such habitats are quite shallow but experience strong hydrodynamics. The species' sparse spatial distribution on Saint Gilles-La Saline Reef did differ from the high-density-zone distribution recorded elsewhere.

The study population's density on Saint Gilles-La Saline Reef (0.12 ind./$m^{-2)}$ was the lowest recorded one (Table 1). It is believed that the high densities recorded elsewhere in certain tropical sea cucumbers are linked to asexual reproduction, which may be able to maintain – and sometimes increase – population density (Emson and Mladenov 1987; Chao et al. 1993, 1994; Conand 1996; Uthicke 1997, 2001; Conand et al. 1998, 2002; Uthicke and Conand 2005; Lee et al. 2009; Pirog et al. 2017). Our observations suggest that on Reunion Island the population can maintain itself, even though at a very low density, through asexual reproduction since 1) its peak in May, 2016 was linked to the high density in Rs throughout the study (0.08 ind. m^{-2}, n = 16), 2) its peak in September 2016 could be linked to the growth in Rs observed in May 2016 (it happened at the same time as a peak in Ws and an absence of Rs), and 3) its peak in April 2017 was linked to the increased density of both species from January onwards. Moreover the similarity of the densities in May 2016 (0.19 ind. m^{-2}, n = 39) and April 2017 (0.18 ind. m^{-2}, n = 36), i.e. during periods of high density for Rs, suggest that the overall density is maintained over a one-year cycle through asexual reproduction, whose contribution may therefore compensate for mortality and emigration in this population.

Asexual reproduction

Regenerating specimens accounted for 19.32% of the study population over the 13 months, with two peaks of more than 40%. Deichmann (1922) calculated 68.29% for 123 sample specimens under the synonym *Actinopyga parvula*, and Lee et al. (2009, Figure 3A) calculated more than 30% in 9 of 10 samples spread

Table 1. Documented densities in *Holothuria difficilis*, with localities, sampling duration and references.

Locality	Duration	Estimated density	Reference
Enewetak Atoll, Marshall Islands	1 month	1.4 to 32 ind. 900 cm^{-2}. Maximum 130 ind. m^{-2} (day) and estimated 200 ind. m^{-2} at night	Bakus 1968
Enewetak Atoll, Marshall Islands	nd	324 ind. m^{-2}	Lawrence 1980
Kosrae, Caroline Islands	3 months	572 ind. 100 m^{-2} (abundance)	Kerr 1994
One Tree Island, GBR, Australia	October 2006 (duration nd)	102 ind. m^{-2}	Lee et al. 2009
Fantome Island, GBR, Australia	nd	247 ind. m^{-2}	Uthicke pers. obs., cited in Lee et al. 2009
Reunion Island	13 months (once a month)	0.12 ind. m^{-2}	This study

over a period of 20 months, with peaks of more than 60%. So, the percentages of regenerating specimens recorded in the study population on Reunion Island appear to be low for this species.

Seasonal nature

The on-going presence of regenerating individuals observed in the transect and during the random explorations throughout the study period suggests that asexual reproduction of *H. difficilis* occurs year-round on Saint Gilles-La Saline Reef. However, monthly percentages of individuals produced by fission exceeding 20% of the population revealed two periods of higher intensity for that reproduction mode. The first, in May and June, formed a peak; the second was in November but the small sample size that month (11 Ws and 4 Rs) limits interpretation of those data. Asexual reproduction in *H. difficilis* on OTI also takes place year-round with a peak in the number of regenerating specimens in May, but unlike the study population on Reunion Island, the percentage of regenerating individuals was more than 50% from May to September, i.e. throughout Southern Hemisphere winter. However, peaks in the numbers of specimens that have begun regenerating their missing sections only indirectly indicates peak fission periods (Dolmatov 2014), as regeneration of internal organs takes place before the regenerating segment appears. The time needed for *H. difficilis* to regenerate its internal organs is not known but it is generally one to two months after induced fission in many species (Kille 1942; Uthicke 1997; Purwati et al. 2009; Dolmatov et al. 2012), though it can be more in others (Reichenbach and Holloway 1995). So fission peaks were probably before the month of May on both Reunion Island and OTI (where the observed specimens were in various stages of regeneration), i.e.; at the end of the Southern Hemisphere summer. As these two islands are located in similar latitudes in the Southern Hemisphere, it may be that abiotic factors that can promote asexual reproduction, such as seasonal variations of the photoperiod (Mladenov 1996; Conand et al. 2002) or ocean surface temperatures, which reach their maximums during that period (Donguy and Meyers 1996; Conand et al. 2007), are decisive for both populations.

AP/PP survival rates

The small difference in the numbers of AP and PP specimens observed (44.8% and 55.2%, respectively) suggests a relatively balanced survival rate for both parts, which agrees with Deichmann's sample composition (1922) that had 48.8% of APs and 51.2% of PPs. Similar survival rates are generally found in species whose fission site is near the middle of the body, e.g. *Stichopus chloronotus* (Conand et al., 1998, 2002), *Holothuria atra* (Conand 1996; Thorne and Byrne 2013) in spite of regional differences (Uthicke 2001), or *H. parvula* (Emson and Mladenov 1987), whereas in other species the posterior section shows a much higher survival rate (see for review Thorne and Byrne 2013).

Fission site

The place on the body where fission occurs seems to be specific to each species (Purwati 2004; Dolmatov 2014) but this had not been documented for *H. difficilis*. Although no specimens in the fission or wound healing stages were observed during the study, our results allow us to suppose that fission may occur in this species near the middle of the body. Based on the average size of the original part in AP-nc and PP-nc specimens, whose lengths were not modified by contraction (2.57 ± 0.41 cm and 3.03 ± 1.28 cm, respectively), the average size of uncontracted animals before fission would be about 5.60 ± 1.69 cm [which would be in agreement with Lee at al.'s assumption (2009), suggesting that fission may only take place in this species once they have reached 4 to 5 cm in length]. This size would place the fission site at 46% of the body from the mouth. Such a fission site near the middle of the body is found in most species for which this issue has been documented (see for review Dolmatov 2014, Table 1).

Conclusion

This study is the second to document asexual reproduction in *H. difficilis*, a species whose biology is largely unknown. It showed some similarities with the first study, which took place in the Pacific (Lee et al. 2009), particularly in regard to the species' preferred habitat and the peak asexual reproduction period. Our study also uncovered certain differences, notably so in terms of the specimen size frequency distribution. The Reunion Island study population displayed two striking differences from all previous studies, i.e. a scattered distribution without any aggregations and very low densities, not at all in line with those that had been recorded for this species.

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Pilot study on grow-out culture of sandfish (*Holothuria scabra*) in bottom-set sea cages in lagoon

Hussain Ahmed[1,*], Hassan Shakeel[1], Shafiya Naeem[1] and Kosuke Sano

Abstract

Although mariculture is relatively new to the Maldives, sandfish culture has been practiced in the country for a little over a decade. Currently, sandfish grow-out in pens is being carried out by island communities on a limited scale.

This study was carried out in the lagoon of Maniyafushi Island, Kaafu Atoll, to determine the growth and survival of hatchery-produced juvenile sandfish cultured in bottom-set cages in lagoon in order to assess the potential use of such cages in small-scale sandfish grow-out operations. It was conducted to assess the growth and survival of sandfish in bottom-set cages in the lagoon without varying stocking density and feeding frequency. Feed was introduced in each experimental cage at the rate of 3% of the total sea cucumber biomass in the cage.

Results of this study showed that the survival was high; mean survival was 97.14%. At the end of the 124-day culture period the animals reached a mean body weight of 147.05g and yielded an average biomass of 1424.64 g m^{-2}. The specific growth rate for the culture period was 1.58% day^{-1}.

Based on the growth and survival of sandfish in bottom-set cages that were used in this study and the performances of sandfish in other culture systems, it can be concluded that the bottom-set cage is a suitable culture system for small-scale grow-out of sandfish with feed inputs – particularly for the early stages of grow-out. This type of cage can also be used for nursing smaller juveniles in the sea before putting them in sea pens for further growing. Further studies are needed to determine the most suitable cage size and materials, stocking density, culture period and scale of grow-out operation. Pens, bottom-set cages and off-bottom cages can be used in different environmental conditions of the lagoons. These culture systems have the potential for widening sea cucumber grow-out in the country.

Introduction

Island communities of the Maldives rely heavily on natural marine resources for both their economic base as well as their subsistence. The fisheries sector has played a significant role in employment as well as in foreign exchange earnings in the Maldives for many years. The development of a tourism sector and improvements in transportation have led to the diversification of the Maldivian fisheries sector from the traditional pole-and-line skipjack tuna fishery to hand-lining for yellowfin tuna and harvesting of high-valued reef animals that target tourist resorts as well as export markets. Sea cucumber and grouper fisheries are the most significant reef fisheries today. They provide additional or alternative income to fishers.

Sea cucumber fishery activities in the Maldives began in 1985, with a single shipment of 30 kg of prickly redfish (*Thelenota ananas*) to Singapore. Since then, the fishery quickly expanded, targeting high-valued species like the white teatfish (*Holothuria fuscogilva*) and *T. ananas*. Within a few years, over 16 sea cucumber species, including those that fetched lower market prices, were being harvested. High-valued sea cucumbers in shallower waters are now depleted to the extent that the bulk of these species is now caught at depths ranging from 5–30 m.

A review of the sea cucumber fishery in the Maldives by Joseph (1992) revealed that the stocks of high-valued species were extensively harvested and highlighted the urgent need for managing the fishery. It is believed that in addition to conventional fishery management measures, marine aquaculture (mariculture) is a potential solution to reducing fishing pressure on threatened sea cucumber stocks, while simultaneously meeting market demands. The development of sea cucumber

[1] Marine Research Centre, Ministry of Fisheries and Agriculture Malé, Maldives
[2] MASPLAN, Japan International Corporation Agency (JICA)
* Author for correspondence: hahmed@mrc.gov.mv. hussahmed77@gmail.com

mariculture could also provide an alternative livelihood for communities.

Culture techniques for some species of sea cucumbers have been developed and are being used commercially in the Asia-Pacific region. Australia, Philippines, Vietnam and Madagascar have been practicing commercial aquaculture of sandfish (*Holothuria scabra*) at different scales (Bowman 2012; Duy 2012; Lavitra et al. 2009, 2010; Eeckhaut et al. 2008; Olavides et al. 2011; Juinio-Menez et al. 2012) and some Pacific Island countries are trialling small-scale production for community-managed sea ranching (Hair et al. 2011).

Maldives is believed to have an ideal setting for mariculture development, based on the widespread nature of the islands and the availability of sheltered lagoon areas. Although mariculture is relatively new to the Maldives, sandfish culture has been practiced by a single private group in the Maldives for a little over a decade. Currently, the Mariculture Enterprise Development Project (MEDeP), which is implemented by the Ministry of Fisheries and Agriculture (MoFA) and International Fund for Agricultural Development (IFAD), is assisting island communities to grow sandfish in shallow, sandy sea pens (low tide minimum depth: 15 cm). MoFA is also trying to develop other sea cucumber grow-out systems such as submerged bottom-set cage (submerged cage sitting on the seabed) or off-bottom cage (submerged cage sitting on legs) to expand sea cucumber grow-out for island communities. These studies were carried out by Marine Research Centre (MRC) of MoFA and the MASPLAN project (a Japanese Government funded project to formulate a framework for the sustainable development of the Maldivian fisheries sector) to assess the potential use of bottom-set cages in small-scale grow-out of sea cucumber that is carried out by island communities.

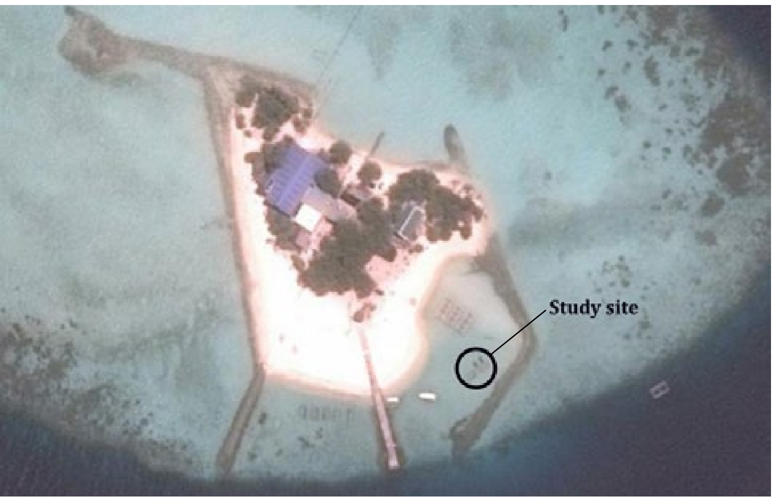

Figure 1. Study sites in the lagoon of Maniyafushi Island, Kaafu Atoll.

The objective of the studies was to determine the growth and survival of hatchery-produced juvenile sandfishes that are cultured in bottom-set cages in lagoons in order to assess the potential use of such cages in small-scale sandfish grow-out operations. Submerged bottom-set or off-bottom cages can be used in different environmental conditions of the lagoons. These cages, together with the traditional pen, can be used to widen sea cucumber grow-out in the country.

Materials and methods

Study sites

The study was carried out in the lagoon of Maniyafushi Island, Kaafu Atoll, Maldives, at the location of the Mariculture Training and Demonstration Facility (MTDF) of MRC (Figure 1). The lagoon was relatively protected from strong currents and waves. It had good water quality and visibility. Tidal fluctuation in the lagoon was approximately 1 m, with a mean depth of 0.5 m and 1.5 m at low and high tides, respectively. The study sites are shown in Figure 1.

On land juvenile nursing

To conduct this study, juvenile sandfishes with a mean body weight of 2.12 g were obtained from a private hatchery. As the juveniles were too small for stocking in sea cages, they were first reared in land-based tanks at a stocking density of 100 individual's m^{-2} for 2 months. During this period the juveniles attained a mean weight of 11.43 g, a size adequate for stocking in sea cages. The rearing tanks had 4–5 mm layer of fine sand at the bottom and continuous water flow at the rate of 6 L min^{-1}. They were siphoned daily to remove accumulated wastes and the tank water quality was monitored daily.

Sea cage culture

The study was carried out from August to December 2016 for 124 days. Two rectangular bottom-set cages, each measuring 2.7 m x 1.3 m x 0.5 m (height) and having a bottom area of 3.5 m^2 were constructed in this study. The cage walls and bottoms were covered with two layers of nets to make them strong. Nylon nets with a mesh size of 12 mm and 7 mm were used as the outer and inner layers respectively.

A piece of PVC canvas was set on the net at the bottom of the cage. It was raised to a height of 20 cm at the sides of the cage. Fine sand was placed in the cage bottom to a thickness of 10 cm. The top of the cage was covered with a nylon net of 12 mm mesh size. The seawater got in and out of the cage through the top part of the sides (the part without canvas) and through the entire top of the cage. Three sides of top net could be unfastened to get access to the inside of the cage when introducing feed and making daily observations. The cages were labelled as A1 and A2 for identification purposes. They were deployed in a calm site in the lagoon (Figure 1).

From a stock of sea cucumber juveniles, 35 individuals were randomly selected for each of the two cages and placed in them to obtain a stocking density of 10 m^{-2} (Figure 2). Each juvenile was individually weighed. The average weight of the stocked juveniles was 20.6 g.

Feed for the land-based nursing and sea cage culture was prepared at MTDF using locally produced fish meal and imported soybean meal, rice bran, rice, vitamin premix and mineral premix. Microalgae paste was made from microalgae cultured at MTDF and sea grass powder was made from dead sea grass collected from the beach. The composition of the feed is given in Table 1 and Table 2.

Table 1. Composition of feed used for land-based juvenile nursing.

Ingredient	Quantity (g)
Fishmeal	40
Sea grass powder	20
Rice bran	15
Soybean meal	10
Microalgae paste	14
Vitamin premix	0.5
Mineral premix	0.5
Total	100

Table 2. Composition of feed used for sea cage culture.

Ingredient	Quantity (g)
Fishmeal	40
Sea grass powder	11
Rice bran	3
Soybean meal	5
Rice flour	14
Fine sand	26
Vitamin premix	0.5
Mineral premix	0.5
Total	100

Feed was put in the cages every other day at the rate of 3% of total sea cucumber biomass present in the cage. The cage walls and top net were cleaned of biofouling every two weeks. All the animals in the cage were weighed every month, and the feed amount was adjusted every month based on the biomass in the cage. Weather conditions, water quality, and sea cucumber health were also monitored and recorded.

Results and discussion

Growth and survival data for sea cucumbers cultured are presented in Table 3, and Figures 3 and 4. The survival was high; mean survival for the two cages was 97.14%. At the end of the culture period the animals reached a mean body weight of 147.05 g and yielded an average total biomass of 1424.64 g m^{-2} (Table 3, and Figures 5 and 6). The specific growth rate (% weight gain day^{-1}) for the culture period was 1.58% day^{-1}.

Figure 2. Juvenile sea cucumbers being stocked in bottom-set cages deployed in the lagoon.

Table 3. Growth and survival of sandfish in bottom-set sea cages.

Indicator	Cage A1	Cage A2	Mean
Survival (%)	100	94.29	97.14
Mean initial body weight (g)	20.17	21.02	20.6
Mean final body weight (g)	147.86	146.24	147.05
Specific growth rate (% day^{-1})	1.61	1.56	1.58
Biomass yield (g m^{-2})	1474.36	1374.93	1424.64

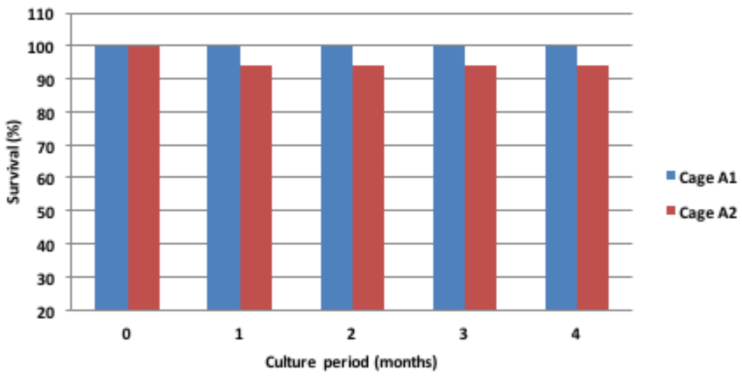

Figure 3. Monthly survival of sandfish in bottom-set sea cage culture over 124 days.

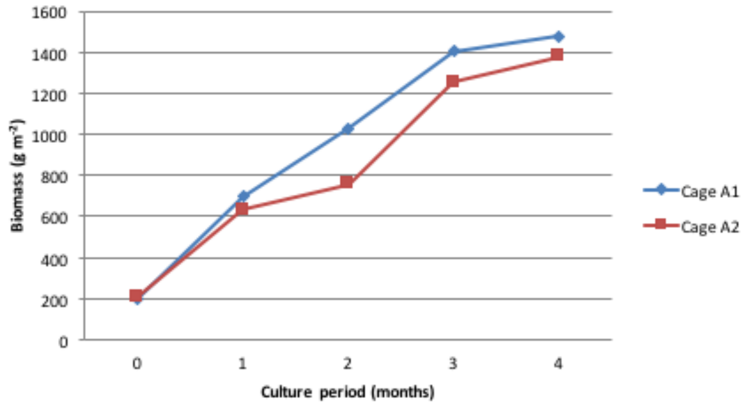

Figure 6. Biomass yield per unit area for sandfish cultured in bottom-set cages in shallow lagoon.

Figure 4. Harvested sandfish after 124 days of culture in bottom-set sea cages in shallow lagoon.

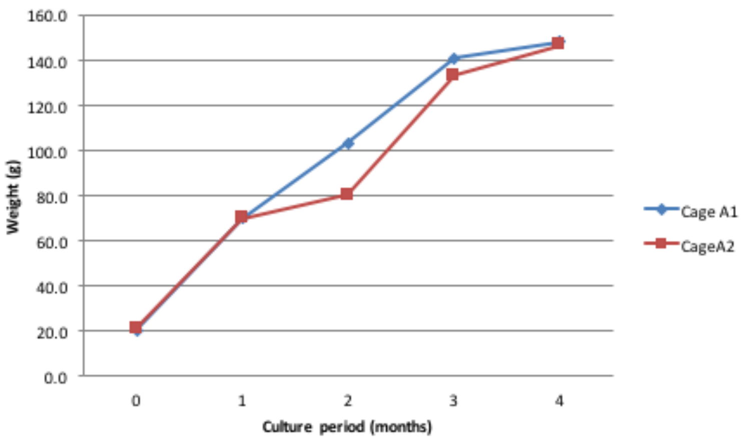

Figure 5. Mean monthly growth of sandfish in bottom-set sea cage culture in shallow lagoon.

Studies on sandfish growth and survival have been done in various culture systems including ponds, sea pens and bottom-set cages (Table 4). However, most of these studies were on culturing sandfish from larvae to juveniles. A limited number of studies has been done on grow-out culture of sandfish (Lavitra et al. 2009 and 2010; Duy 2012; Robinson and Pascal 2011; Bell et al. 2007; Agudo 2012; Purcell and Simutoga 2008; Purcell and Agudo 2013; and Junio-Menez et al. 2016). These grow-out studies were based on extensive methods of culture with no feed inputs. The studies listed in Table 4 differ from the present study in initial weight of the stocked juveniles and length of the study; these studies used smaller juveniles and cultured them for a longer period of time. Due to these differences, comparisons between the listed studies and present study may not be meaningful. However, growth and survival of sandfish in bottom-set cages used in the present study show that this type of cage is a suitable culture system for small-scale grow-out of sandfish with feed inputs.

Pens, submerged bottom-set cages and off-bottom cages require different levels of habitat modification. Pens, when constructed in seagrass areas, require the removal of seagrass to make a favourable sandy bottom for the sea cucumbers. Bottom-set cages make the seabed area immediately under the cage inaccessible to living organisms. The

Table 4. Sandfish culture studies carried out in different culture systems.

Culture system	No. of days	Initial weight (g)	Final weight (g)	Stocking density (ind. m^{-2})	SGR (%BW gain day^{-1}) / Absolute growth* (g day^{-1})	Biomass yield (g m^{-2})	Survival (%)	Source
Bottom-set cage	124	20.6		10	1.58/1.0	1424.6	97.15	Present study
Pond	56	0.24–15		10, 20, 30 and 40	0.64/0.22	160	>95	Lavitra T., Rasolofonirina R. and Eeckhaut I. 2010
Pond	420	2	350	1	1.22/0.83	434	80	Duy 2012
Pond	305	10	310	1	1.12/0.97	147	85	Duy 2012
Pond	365	11.7	400	0.8	0.96/-	N/A	70	Bell et al. 2007
Pond	360–390	0.9–11.7	325–395	1.6	0.9–1.6/0.9–1.0	N/A	69–73	Agudo 2012
Sea pen	270	15		3, 6, 9 and 12	-	692	>95	Lavitra T., Rasolofonirina R. and Eeckhaut I. 2010
Sea pen	250	15	350	1	1.25/1.4	220	80	Robinson and Pascal 2011
Sea pen	365	8–20	180	3	0.6–0.85/1–1.8	250	7–20	Purcell and Simutoga 2008
Sea pen	162	21.9	106.20	0.6	0.97/1.09	430	86.95	Junio-Menez et al. 2016

* Absolute growth was calculated using the data provided in the study reports.

off-bottom cages do not have the inaccessibility disadvantage. Living organism and water current can pass between the seabed and bottom of the cage. Unlike pens and bottom-set cages, an off-bottom cage can be deployed with minimum impacts in areas of coral rubble and patchy seagrass. Various viable sea cucumber grow-out systems allow island communities to conduct sea cucumber grow-out in different bottom conditions of lagoons and minimise habitat modification impacts of the grow-out operation.

Conclusions and recommendations

Based on the growth and survival of sandfish in bottom-set cages that were used in the study and the performances of sandfish in other culture systems, it can be concluded that bottom-set cage is a suitable culture system for small-scale grow-out of sandfish with feed inputs, particularly for the early stages of grow-out. This type of cage can also be used for nursing smaller juveniles in the sea before putting them in sea pens for further growing. Further studies are needed to determine the most suitable cage size and materials, stocking density, culture period and scale of grow-out operation.

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Assessing rehydration protocols on dried sea cucumber *Holothuria arguinensis*

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

Abstract

Sea cucumbers have been traditionally consumed as a tonic food in Asia for thousands of years; between 80% and 90% of sea cucumbers are dried to prevent their autolysis and to facilitate their storage, exportation and sale. Although in recent years, an increase of fresh and frozen sea cucumber products has been observed in the Asiatic markets.

Scarce information about rehydration protocols has been published on sea cucumbers until now. *Holothuria arguinensis* is one of the new target species caught from NE Atlantic. In this paper, its rehydration ratio (Rr) is assessed using two different protocols and compared with ratios obtained with other commercial species such as *Holothuria scabra* and *Apostichopus japonicus.* The highest value of rehydration rate on *H. arguinensis* (Rr = 3.78) was relatively close to the value registered for *Apostichopus japonicus* (Rr = 4.07) by other authors, and higher than the value obtained for *H. scabra* (Rr = 3.05). The obtained results are very valuable to improve the rehydration protocols used on *H. arguinensis,* allowing the maximum recovery rates of weight and length from the dried product.

Introduction

Holothuria (Roweothuria) arguinensis Koehler and Vaney, 1906, is being considered as a target species in the expanding sea cucumber fishery (González-Wangüemert et al. 2016, 2018). This species had been considered to be a north-eastern Atlantic species that is distributed from Portugal to Morocco and Mauritania, including the Canary Islands (González-Wangüemert and Borrero-Pérez 2012). It has not been found in other Macaronesian Islands such as Açores, Selvagens or Madeira, or in the Cape Verde Archipelago (Pereira 1997; Borerro-Pérez et al. 2010; Micael et al. 2012). However, its geographical distribution is changing, and includes the colonisation of the Mediterranean Sea (González-Wangüemert and Borrero-Pérez 2012; Mezali and Thadar 2014).

Sea cucumbers have been traditionally consumed as a tonic food in Asia and the Middle East for thousands of years (Zhang et al. 2016); they contain certain nutrients, which are beneficial to health. In the case of *H. arguinensis* high levels of protein were found and its lipid profile was rich in polyunsaturated fatty acids (PUFA) (Rogattz et al. 2016).

In recent years, sea cucumber consumption has been increasing in the Asian region with fisheries focusing on exportation of products in at least 70 countries (Purcell et al. 2012). More than 66 species are being fished, their dried product (the beche-de-mer) reaching prices up to USD 500 kg^{-1} (Purcell et al. 2013). Sea cucumber-derived food products, including instant sea cucumber, sea cucumber capsules and sea cucumber caplets, can be found on the market (Zhang et al. 2016).

Usually, fresh sea cucumbers autolysis occurs rapidly after being harvested, due to the presence of autolytic enzymes in their body. Therefore, between 80% and 90% of sea cucumbers are dried to prevent autolysis and to facilitate their storage, exportation and sale (Aydin 2008; Zhang et al. 2016; González-Wangüemert et al. 2018). Although in recent years, an increase of fresh and frozen sea cucumber products has been observed in Asian markets (Purcell et al. 2014; Sze and Conand 2015).

Rehydration of dehydrated food is a complex phenomenon that is affected by numerous factors including medium characteristics, pre-soaking time, number of rehydration times, size of the food sample, and drying method (Geng et al. 2015). Most of the rehydration protocols of dried sea cucumbers are done in cold, clean water for 2–3 days before further processing or cooking (Duan et al. 2008).

The published information about sea cucumber rehydration process is scarce (Fukunaga et al. 2004; Liu and Ko 2002; Xiang et al. 2007). Hong et al. (2014)

[1] CCMAR- Centro do Ciencias do Mar, Universidade do Algarve, Gambelas, 8005-139 Faro, Portugal
* Author for correspondence: mwanguemert@ualg.pt

who worked with different rehydration methods on hot air-dried sea cucumber, found a rehydration ratio ranging from 5 to 6 for *Apostichopus japonicus*. Zhang et al. (2016) used ultrasound-assisted rehydration and obtained rates ranging from 2.71 to 4.35 for the same species. No information on the rehydration of *H. arguinensis*, a newly targeted species from the Mediterranean and NE Atlantic, has been published. Therefore, our objective has been to assess the rehydration ratio (Rr) of *H. arguinensis* using two different protocols and to compare it with ratios obtained with other commercial species, either by us (*Holothuria scabra*) or by other authors (*A. japonicus*).

Material and methods

Two methodologies for rehydration of four *H. arguinensis* specimens from Ria Formosa (Southern Portugal) were used (Figure 1): A) the dried sea cucumbers were soaked in filtered water (filter of active carbon) during 96 hours at 4°C; the water was changed every 24 h; B) the dried sea cucumbers were submerged in filtered water during 3 hours, then boiled for 30 minutes, and finally, when the water temperature had decreased, they were conserved at 4°C overnight; this procedure was repeated at 40 h and 96 h. The recycling of water was carried out every 24 h, during the 96 h. One individual of *H. scabra* from Australia was also rehydrated using protocol-A.

The eviscerated weight (EW ± 0.01 g) and eviscerated length (EL ± 0.1 mm) for each individual were registered along the different phases of process. Water absorption by sea cucumbers was determined after rehydration. The rehydrated sea cucumbers were blotted with absorbent paper to remove excess water from their surface. Rehydrated ratio (Rr) was calculated by the following equation: $Rr = W_f / W_0$, where W_f and W_0 are the weights of the sea cucumber before and after rehydration, respectively. Also, the patterns of change in weight (ΔW) and length (ΔL) of the individuals along the time period of rehydration (96 h) were evaluated.

Results and discussion

The second methodology of rehydration (B) was more effective than the first one (A) taking into account the Rr, and length-weight recovering rates on *H. arguinensis* (Table 1): an average Rr of 3.775, was registered; this value being higher than the one obtained for *H. scabra* (Rr = 3.05) and *H. arguinensis* under rehydration protocol-A (Rr = 2.9). The highest value (Rr = 3.78) was relatively close to the Rr registered for *A. japonicus* (Rr = 4.07), which was obtained from a traditional rehydrated protocol in high-quality individuals (Zhang et al., 2016). It is important to highlight that the methodology used to produce beche-de-mer has an influence on its porous structure and therefore on its water holding capacity, which is linked to the rehydration ratio (Chong et al. 2015).

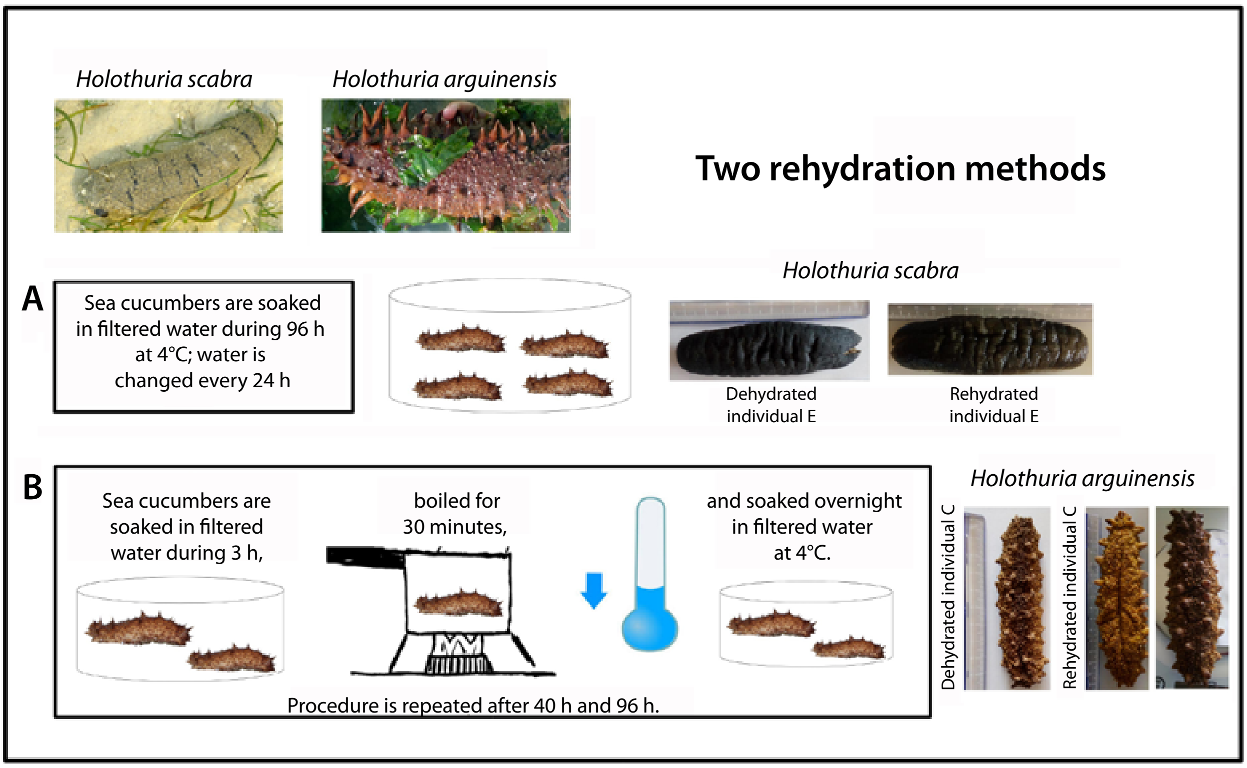

Figure 1. Rehydration protocols used on dried sea cucumbers (*Holothuria arguinensis* and *Holothuria scabra*).

Table 1. Values of length and weight increases (ΔL and ΔW) and rehydration rate (Rr) for *Holothuria arguinensis* and *Holothuria scabra* specimens. Methods 'A' and 'B' are described in Material and methods section.

Individual	Species	Method	ΔL (%)	ΔW (%)	Rr
Individual A	*H. arguinensis*	A	28.00	65.57	2.90
Individual D	*H. arguinensis*	A	32.79	66.67	3.00
Individual B	*H. arguinensis*	B	37.04	73.49	3.77
Individual C	*H. arguinensis*	B	35.53	73.47	3.78
Individual E	*H. scabra*	A	34.92	67.21	3.05

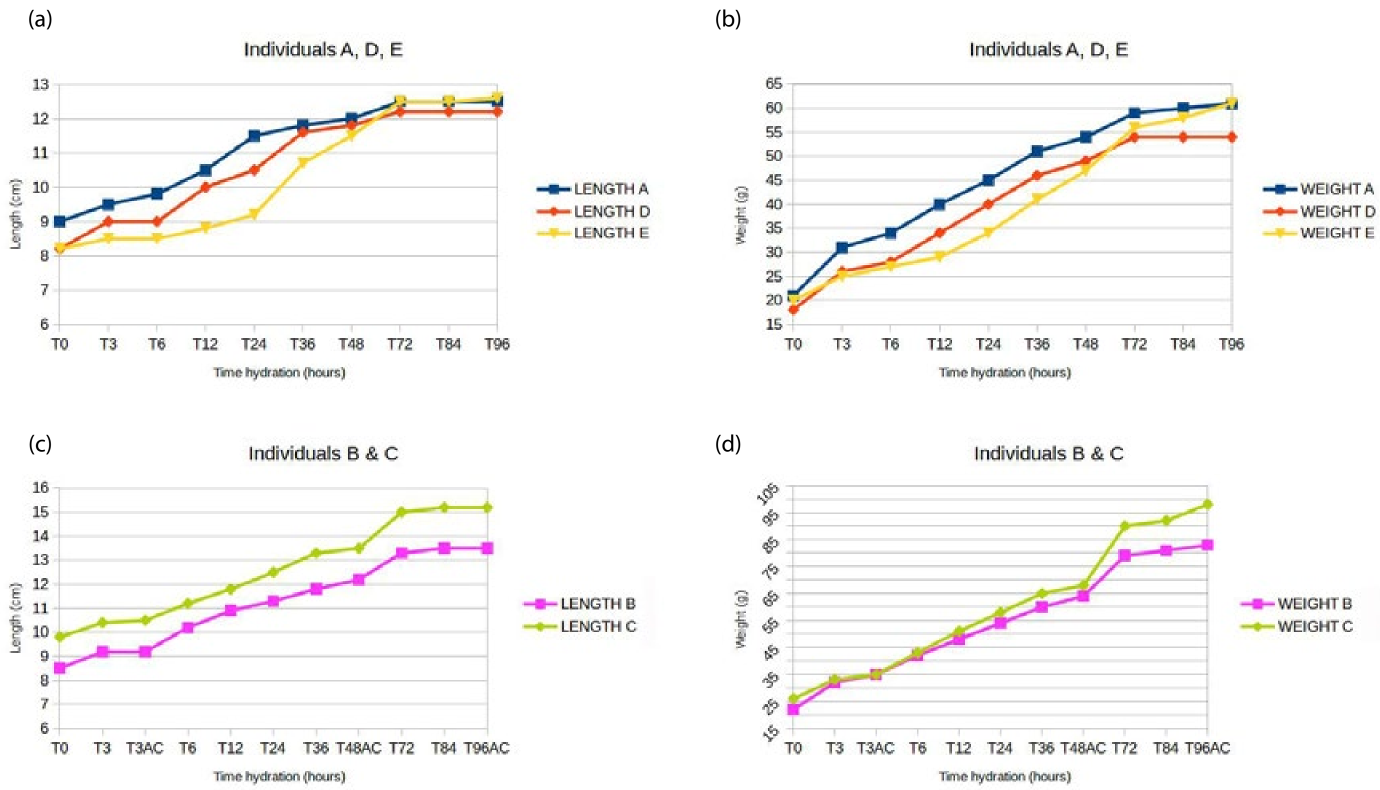

Figure 2. Length (a) and weight (b) changes along rehydration protocol-A on individuals A, D, E (*Holothuria arguinensis* and *Holothuria scabra*); Length (c) and weight (d) changes along rehydration protocol-B on individuals B and C (*Holothuria arguinensis*).

H. arguinensis, which was rehydrated according the second methodology (B) showed average recovery rates of weight and length close to 73.4% and 36.3% respectively (Table 1; Figure 2). These values were also higher than rates registered with *H. scabra* (67.2% and 34.9%) or *H. arguinensis* rehydrated using methodology A without boiling (average values: 66.1% and 30.4%) (Table 1; Figure 2).

These results are very valuable to improve the rehydration protocols used on *Holothuria arguinensis*, as they allow for the maximum recovery rates of weight and length from the dried product.

Acknowledgements

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Food preferences of four aspidochirotid holothurians species (Holothuroidea: Echinodermata) inhabiting the *Posidonia oceanica* meadow of Mostaganem area (Algeria)

Nor-Eddine Belbachir[1,2] and Karim Mezali[2]

Abstract

Analysis of the digestive contents of four aspidochirotid holothurians species (*Holothuria poli, H. tubulosa, H. forskali* and *H. sanctori*) sampled in two localities in the Mostaganem area (Stidia, Salamandre) were carried out in order to overview the different food sources appreciated by these animals.

Our results show that holothurians feeds on diatoms, cyanophytes, macrophytes algae, *Posidonia oceanica* leaves (alive and dead), foraminifera, crustaceans, molluscs bivalve shells, sponge ossicles and nematodes. Diatoms were mostly consumed by holothurians at both sites. The greatest rates of ingested diatoms are recorded for *H. poli* (38.66% and 34.44% respectively at Stidia and Salamandre). The *Posidonia oceanica* leaves (alive and dead) are also consumed, but with low rates. *Holothuria forskali* feeds in a preferential way on the *Posidonia oceanica* leaves (3.33% dead leaves, 14% live leaves at Stidia and 9% live leaves at Salamandre). Foraminifera are consumed mostly by *H. forskali* (13.33% and 15% respectively at Stidia and Salamandre), even if that food source is not appreciated very much (Ivlev index: -0.3 and -0.06 respectively at Stidia and Salamandre). At both sites, most holothurian species consume large amounts of sponge ossicles and this is their preference. Crustaceans and nematodes are less consumed, regardless of their significant electivity index (Ivlev index = 1 for nematodes, in most holothurians species of Stidia area).

Introduction

The 'deposit feeders' aspidochirotid holothurians species represent the major component of the *Posidonia oceanica* ecosystem in the Mediterranean Sea. They play an important role in the detritus food web by recycling of organic matter (Zupo and Fressi 1984). The sediments ingested by holothurians are mainly composed of 1) inorganic material (coral scraps, coralline, skeletons and inorganic remnants of the benthos); 2) organic detritus matter (fragments of algae and marine phanerogams, decaying dead animals); and 3) microorganisms (bacteria, diatoms, protozoa and cyanophytes) (Massin 1982; Moriarity 1982).

In Algeria, several research works have been carried out on systematics, biology, ecology, population dynamics and valorisation of holothurians (Mezali 2004, 2008; Mezali et al. 2003, 2006, 2014, 2016). The sediment particle size selectivity and the assimilation of organic matter by these animals were also discussed (Mezali and Soualili 2013; Belbachir et al. 2014). Nevertheless, their diet strategy is still not well known.

Materials and methods

Sampling was carried out during winter 2015 by scuba diving at 3 m depth, at two sites (Stidia and Salamandre) on the Mostaganem coastline (Algeria) (Figure 1). Ten individuals of each of the following species (*Holothuria poli, H. tubulosa, H. forskali* and *H. sanctori*) were collected. The first millimetres of the sediment (biotope) on which these animals feed were also sampled.

Figure 1. Geographical sites of the sampling areas (red circles).

[1] Departement of Biology, Faculty of Natural Sciences and Life, Abedelhamid Ibn Badis University, Mostaganem, P.O. Box 300, 27000 Algeria

Each sample (containing an individual of each holothurians species and the sediment originating from its biota) was isolated separately in a plastic bag containing seawater for its laboratory investigation. The 'contact method' described by Jones (1968) and Nédélec (1982), was used for the analysis of digestive contents. For that, a sub-sample of 1 g of the digestive content was added to 10 mL of formalin-fixed seawater. Then 1 mL of the preparation was observed under a light microscope objective (using a lens with magnification of 40x). The preparation on the slide was moved randomly. At each position, the food item, which is located exactly in the centre of the visual field, was identified; this constitutes a contact. Ten contacts were made for ten microscope slides (100 contacts were analysed for all the digestive content). The sum of the contacts for a given food item established the percentage of its presence in the digestive content. This method was also used for the sediment of the biota. The selectivity in the choice of food item was studied by calculating the Ivlev electivity index (*E′*): *E′* = (ri – pi) / (ri + pi) [ri: % of food item in the digestive content, pi: % of food item biota sediment. E′= 0 indicates no selectivity; -1 < E′ < 0, indicates avoidance; 0 < E < 1, indicates preference] (Ivlev 1961; Whitlatch 1974 in Stamhuis et al. 1998).

Results

The main types of food items found in the digestive content are divided into two large fractions: 1) a plant fraction composed of diatom (Dt), cyanophytes (Cy), macrophytes algae (Al), and live (Pv) and dead (Pm) *Posidonia* leaves; 2) an animal fraction, represented by foraminifera (Fo), crustaceans (Cr), sponge ossicles (Sp), nematodes (Nm) and shells of bivalve molluscs (Cq) (Figures 2 and 3). Organic particles that couldn't be identified due to their advanced degradation are referred to as organic debris (Do) (Figures 2 and 3). The contribution of each food source is different for each species.

At both study sites, diatoms (Dt) were the most consumed food of almost all holothurians species. The highest rates were recorded for *H. poli* (38.66% and 34.44% respectively at Stidia and Salamandre) (Figure 2). The preference for this food was observed only for holothurians collected at Stidia site (*E′*: 0.11, 0.07 and 0.07 respectively for *H. poli*; *H. forskali* and *H. sanctori*) (Figure 4). Sponge ossicles (Sp) were the second most widely consumed food item in all holothurians of both studied sites. In fact, the highest rates were obtained in the Salamandre site for *H. forskali* and *H. sanctori* [with 25% and 23.33% respectively (Figures 2 and 3)]. *Holothuria forskali* selected the most sponge ossicles (Sp), as shown by the important electivity index for this food [*E′*: 0.22 and *E′*: 0.23 respectively at Stidia and Salamandre] (Figures 4 and 5)]. The contribution of cyanophytes (Cy) in the food bowl of holothurians at both sites was relatively large. The highest rates were obtained for *H. forskali* [12.33% and 12% respectively at the sites of Stidia and Salamandre (Figures 2 and 3)] and *H. sanctori* [17.66% and 11.66% respectively at Stidia and Salamandre] (Figures 2 and 3)]. In addition,

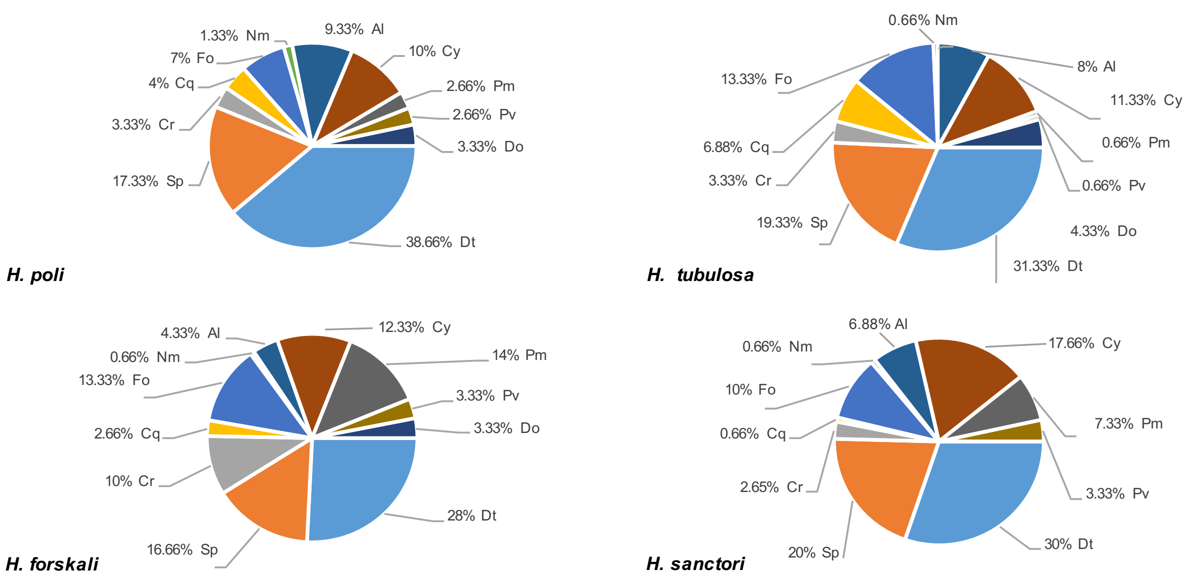

Figure 2. Contribution (in percentage) of the different types of food items in the diet of holothurians originating from the site of Stidia. Sp = sponge ossicles; Cr = crustaceans; Cq = shells of bivalve molluscs; Fo = foraminifera; Nm = nematodes; Al = macrophytes algae; Cy = cyanophytes; Pm = dead *Posidonia* leaves; Pv = live *Posidonia* leaves; Do = organic debris; Dt = diatom.

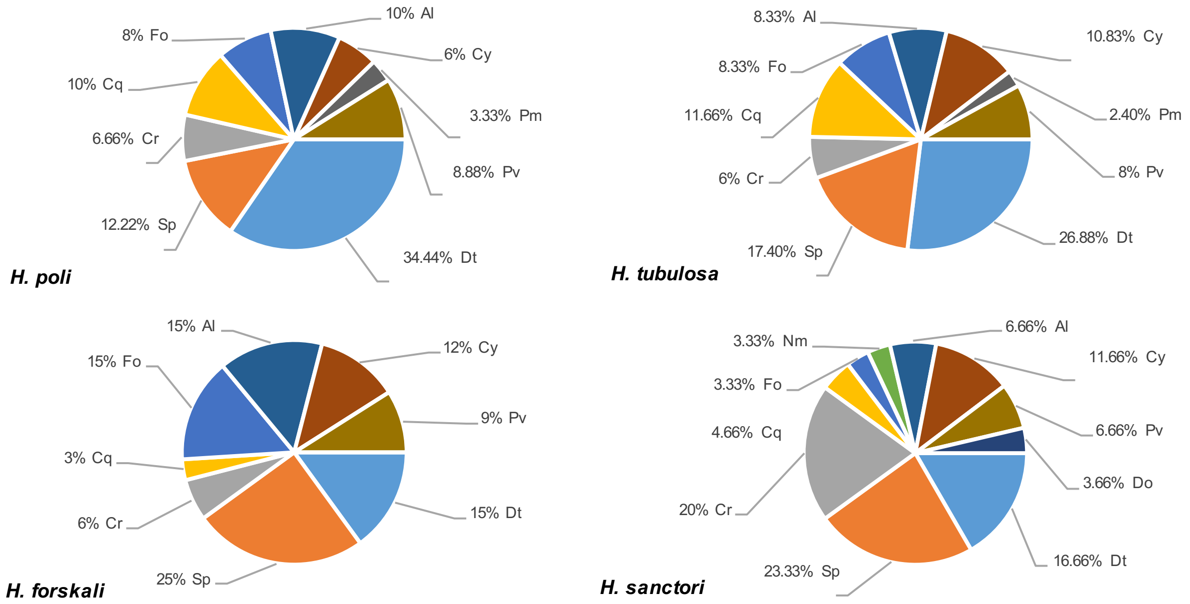

Figure 3. Contribution (in percentage) of the different types of food items in the diet of holothurians originating from the site of Salamandre. Sp = sponge ossicles; Cr = crustaceans; Cq = shells of bivalve molluscs; Fo = foraminifera; Nm = nematodes; Al = macrophytes algae; Cy = cyanophytes; Pm = dead *Posidonia* leaves; Pv = live *Posidonia* leaves; Do = organic debris; Dt = diatom.

cyanophytes (Cy) were preferred by holothurians that originated from Salamandre site (Figure 5). At both sites, all the studied holothurians consumed relatively small amounts of dead (Pm) and live (Pv) *Posidonia* leaves. Among the considered species, it was *H. forskali* that mostly consumed them [3.33% for live leaves (Pv); 14% for dead leaves (Pm) at Stidia and 9% for live leaves (Pv) at Salamandre (Figures 2 and 3)] and in a preferential manner [*E*′: 0.69, 1 respectively for dead leaves (Pm) and live leaves (Pv) at Stidia; *E*′: 0.2, 1 for dead leaves (Pm) and live leaves (Pv) respectively for Salamandre (Figures 4 and 5)]. The macrophytes (Al) algae were hardly consumed (Figures 4 and 5).

Overall, foraminifera (Fo) were less consumed by holothurians of the Salamandre site compared with the Stidia site (Figures 2 and 3); This food was preferred only by *H. poli* and *H. tubulosa* (Figures 4 and 5). Crustaceans (Cr) took an important place (20%) in the diet of *H. sanctori* from the Salamandre site, unlike other species (Figures 2 and 3). However, this food item had a very important electivity index in the majority of species (Figures 4 and 5). Nematodes (Nm) were the preferred food for holothurians of the Stidia site [*E*′: 1 for *H. poli*; *H. tubulosa* and *H. sanctori* (Figure 4)], even if their contribution to the digestive contents was very low (Figure 2).

Discussion

The food sources of holothurian species are very diverse at both sites. The plant fraction prevails over the animal fraction for all studied holothurian species. This indicates that the plant fraction plays a very important role in the feeding process of these benthic animals. This allows us to conclude that holothurians have a significant impact on the transfer of primary production from the areas where they live. The high rates of diatoms (Dt) and macrophytes algae (Al) found in the digestive tracts of all the studied holothurians, was also reported by Sonnenholzner (2003) for the aspidochirotid holothurians *Holothuria theeli* of the central coast of Ecuador. Consumption of dead *Posidonia* leaves (Pm) by holothurians has already been reported in literature; this could have a positive impact on the transfer of organic matter produced by the *Posidonia oceanica* meadow. In fact, the 'litière' biota (composed mainly of dead *Posidonia* leaves) (Mezali 2004) appears to be an important source of organic matter for the 'deposit feeder' communities living in the *Posidonia oceanica* meadow (Walker et al. 2001). It has even been suggested that this is the main pathway for the transfer of organic matter from the *Posidonia oceanica* meadows (Cebrián et al. 1997). The fact that live *Posidonia* leaves (Pv) are a preferential food

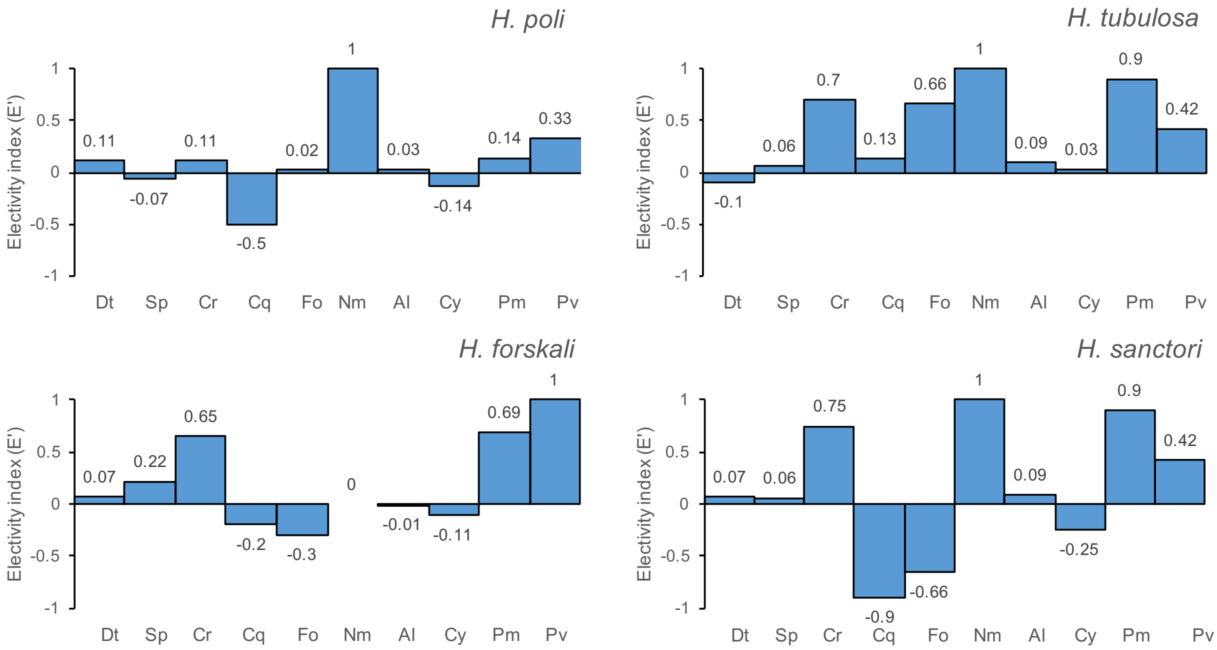

Figure 4. Ivlev electivity index indicating the preference or rejection of food item in the diet of holothurians originating from Stidia site. Dt = diatom; Sp = sponge ossicles; Cr = crustaceans; Cq = shells of bivalve molluscs; Fo = foraminifera; Nm = nematodes; Al = macrophytes algae; Cy = cyanophytes; Pm = dead *Posidonia* leaves; Pv = live *Posidonia* leaves.

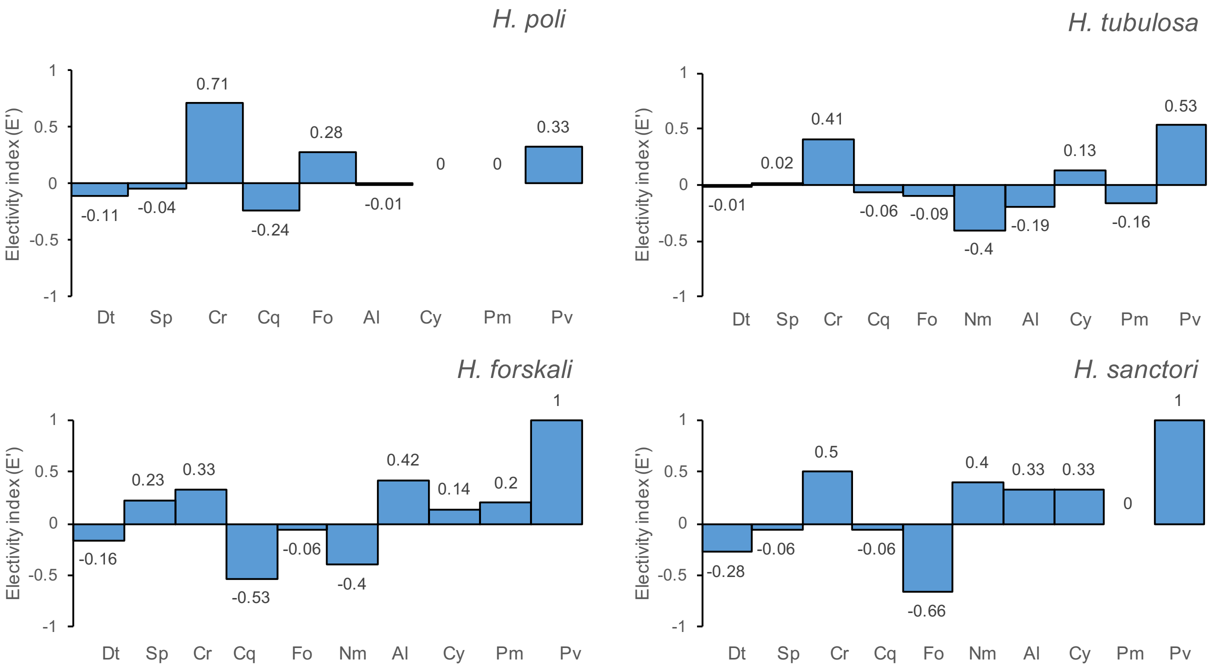

Figure 5. Ivlev electivity index indicating the preference or rejection of a food item in the diet of holothurians originating from Salamandre site. Dt = diatom; Sp = sponge ossicles; Cr = crustaceans; Cq = shells of bivalve molluscs; Fo = foraminifera; Nm = nematodes; Al = macrophytes algae; Cy = cyanophytes; Pm = dead *Posidonia* leaves; Pv = live *Posidonia* leaves.

source, especially for *H. forskali*, is very interesting as few marine animals consume them. The majority of food items of animal origin can be consumed and holothurians sometimes prefer these items more than other food sources – if we refer to the obtained Ivlev electivity index (*E′*). This selectivity that is exercised on certain food items can only be beneficial in terms of energy intake.

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Potential influence of phytoplankton density on doliolaria and pentactula appearances in sandfish hatcheries

Gildas G.B. Todinanahary[1,2*], Nicolas Fohy[1], Cristophe Andriatsialonana[1] and Igor Eeckhaut[1,3]

Abstract

The present study reports on the influence of phytoplankton food density on the time of appearance of doliolaria and pentactula. 72 h-old auricularia of *Holothuria scabra* were used at the beginning of the experiment. Two different food concentrations were used during the larval rearing: ~1500 cells mL^{-1} day^{-1} (F1) and ~120 cells mL^{-1} day^{-1} (F2). Results show that doliolaria appears significantly – *ca* 7 days – earlier with F1. Pentactula appears from 22 ± 6.6 days with F1, while with F2 they appear after 29.8 ± 9.3 days, but the difference is not significant. The results suggest that when the sea water is saturated with food (as in F1), the density of auricularia does not affect the larval life span (time of appearance of doliolaria). With low food concentration (as in F2), when the larval density is high, the quantity of food in the medium remains low, suggesting that food competition occurs between the larvae and slows down their development into doliolaria and pentactula.

Introduction

In sea cucumber aquaculture and farming, larval development is one of the most sensitive steps: to be able to supply farmers with sea cucumber juveniles, the larval production must be adequate because it regulates the number of juveniles transferred into sea pens. The metamorphosis of auricularia larvae into doliolaria and pentactula represents a major challenge in sandfish hatchery and requires careful control of rearing parameters, including physicochemical parameters and biological parameters such as the quality and quantity of food given to the larvae (James et al. 1994; Battaglene 1999; Asha 2004; Qiu et al. 2015). It is known that the variation of temperature, salinity and pH influences the growth and development of auricularia larvae (Asha and Muthiah 2005). The same is true concerning the amount of phytoplankton and the phytoplankton species given to the larvae (Asha 2004).

Several studies report on the optimal values of all these parameters for the best development of sea cucumber larvae and for different species (e.g. Giraspy and Walsalam 2010). Most of these studies demonstrate the effect of different amounts of food on larval growth, but most show minimal differences in metamorphosis patterns from auricularia larvae to doliolaria and pentactula.

Moreover, although many studies report that the transition from auricularia to doliolaria varies between 7 and 15 days (Qiu et al. 2015), Madagascar Holothurie SA, the Research and Development Unit of Indian Ocean Trepang (Eeckhaut 2008), observed that this can last much longer depending on various parameters like the season and the level of maturity of the parents.

Very few studies report on the influence of parameters (physicochemical and biological) on the time auricularia enter into metamorphosis to give doliolaria and pentactula. The aim of the present research is to demonstrate the influence of phytoplankton density on the time when auricularia enter into metamorphosis.

Materials and methods

The practical experiments were performed in Madagascar Holothurie SA. Auricularia larvae were obtained using *in vitro* fertilisation of eggs from mature broodstock (Leonet et al. 2009; Eeckhaut et al. 2012). From the same batch of broodstock, we selected the biggest auricularia that were >125 μm (filtered on a 125 μm mesh size plankton net) of 3 days of age to start the experiment.

[1] Madagascar Holothurie SA, Research and Development Unit of Indian Ocean Trepang, Avenue de France, Mahavatse II, Toliara, Madagascar
[2] Institut Halieutique et des Sciences Marines, University of Toliara, PO Box 141, 601-Toliara, Madagascar
[3] Biology of Marine Organisms and Biomimetics, University of Mons, 6 Avenue du Champs de Mars, 7000 Mons, Belgium
* Author for correspondence: gildas.todinahary@ihsm.mg

Rearing density and feeding rate

A total of 5,080,000 auricularia were reared in 18 tanks with a mean density of 0.10 ± 0.04 larvae mL^{-1}. The rearing density varied from one tank to another tank (0.04 larvae mL^{-1} to 0.18 larvae mL^{-1}). We used the phytoplankton species *Thalassiosira pseudonana* for daily feeding of the larvae. Two feeding rates were compared: F1 ~1500 cells mL^{-1} day^{-1} each for 9 tanks with auricularia mean density of 0.09 ± 0.02 larvae mL^{-1} and F2 ~120 cells mL^{-1} day^{-1} each for 9 tanks with auricularia mean density of 0.10 ± 0.06 larvae mL^{-1}. We used a haemocytometer (also known as cell of Malassez) for phytoplankton counting. The mean rearing density and its variation from each tank were the same for F1 and F2 ($p = 0.613$). During the experiment, the temperature was maintained between 25°C and 27°C, salinity ranged between 35psu and 36psu, and pH averaged 8.2.

Statistical analysis

Statistical analyses were performed using the R software (R Core Team 2017). Statistical difference was determined using t-test, with a level of 5%. Pearson's correlation coefficient was also calculated to determine correlation between larval density and time of appearance of doliolaria and pentactula.

Results

Influence of rearing density and feeding rate on appearance of doliolaria

Doliolaria appeared significantly earlier with F1 ($p = 0.029$). With the feeding rate F1, they were observed from 17.5 ± 4.5 days, while with F2 they were observed after 24.9 ± 7.8. Within F1, the Pearson's correlation coefficient is $r = -0.50$, showing no significant correlation between the appearance speed of doliolaria and the rearing density ($p = 0.172$). Within F2, the higher the density, the longer the appearance of doliolaria, with a significant Pearson's correlation coefficient of $r = 0.87$ ($p = 0.002$).

Influence of rearing density and feeding rate on appearance of pentactula

With F1, pentactula appeared from 22 ± 6.6 days, while with F2 they appeared after 29.8 ± 9.3 days. Despite a slight difference, no significant difference was observed between F1 and F2 ($p = 0.059$). However, the Pearson's correlation coefficient shows negative value with F1, $r = -0.76$, and a positive value with F2, $r = 0.89$. With F1, the higher the density, the faster the appearance of pentactula ($p = 0.017$), while with F2, the higher the density, the longer the appearance of pentactula ($p = 0.001$).

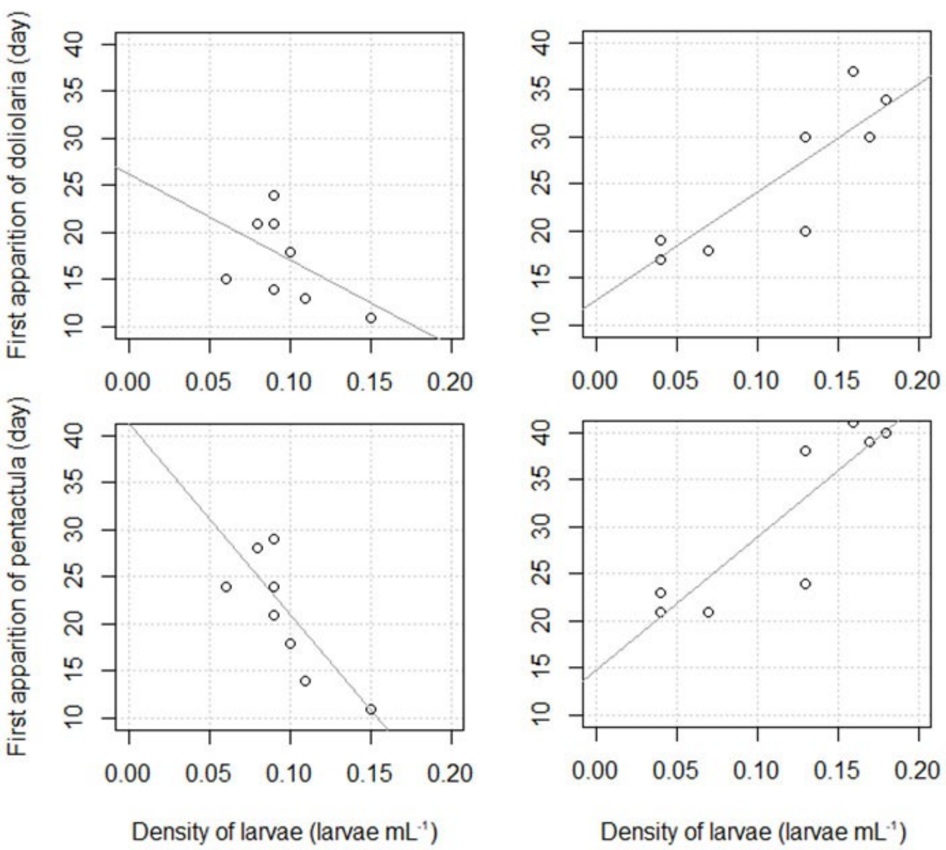

Figure 1. Relationship between the time of appearance of doliolaria (upper graphs) and pentactula (lower graphs), and the larval rearing density. In the left graphs, the phytoplankton concentration was of ~1500 cells mL^{-1} day^{-1}, in the right graphs, it was of ~120 cells mL^{-1} day^{-1}.

Discussion

The present study highlights the potential influence of phytoplankton density on the larval development of *Holothuria scabra*, especially on the doliolaria and pentactula appearance time in hatcheries. With similar rearing parameters (temperature, salinity and pH), larvae of holothurians, in this case *Holothuria scabra,* should grow in a similar way (Asha and Muthiah 2005; Giraspy et al. 2010). Results of the current experiment prove that, despite similar physical rearing parameters, auricularia metamorphose into doliolaria faster when fed with a higher concentration of phytoplankton. Asha and Muthiah (2006) already reported that food concentration has an effect on larval growth, survival and development of the species *Holothuria spinifera*. The optimal feed concentration for this species is 2 x 10^4 cells mL^{-1} of the flagellate *Isochrysis galbana*. Moreover, optimal phytoplankton concentrations differ from one holothurian species to another: 2 to 3 x 10^4 cells mL^{-1} was suggested *for Holothuria scabra* (James et al. 1994), 10^4 to 10^5 cells mL^{-1} for *Actinopyga echinites* (Chen and Chian 1990) and 0.5 to 3 x 10^4 cells mL^{-1} for *Stichopus japonicus* (Ito 1995). The food concentrations that were used in the present study are considerably lower than these references. However, the counting methods, which are usually not provided in detail, may differ from one result to another, and depending on the culture method and culture medium, the size of the phytoplankton can vary. The phytoplankton species used in the present study (*Thalassiosira pseudonana*) is of a bigger size than *Isochrysis galbana*. *Thalassiosira pseudonana* can range in diameter from 2.5–15 µm (Belcher and Swale 1977, 1986; Harris et al. 1995; Hasle 1976; Lange et al. 1983; Lowe and Busch 1975; Muylaert and Sabbe 1996; Price et al. 1987), while *Isochrysis galbana* average size range is less than 7 µm (Cordoba-Matson et al. 2013).

The results show that when phytoplankton concentration is of ~120 cells mL^{-1} day^{-1} the higher the density, the longer the appearance of both doliolaria and pentactula. We suggest that this concentration is not enough to feed all larvae and it induces a competition for food between the larvae. It is probable that metamorphosis is delayed when larvae do not possess enough nutrient reserve in their body. This would explain that the metamorphosis is delayed at higher larval densities. When the phytoplankton concentration is of ~1500 cells mL^{-1} day^{-1}, the sea water is probably saturated with food and the density of auricularia does not affect the time of appearance of doliolaria. We even see a negative correlation between the time of appearance of pentactula and the density of larvae. As doliolaria is a non-feeding pelagic stage, doliolaria could potentially be influenced by a high late auricularia (i.e., those ready to enter into metamorphosis) density: their 'interest' would be to settle fast and to transform into benthic pentactula.

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Trade patterns of beche-de-mer at the global hub for trade and consumption – an update for Hong Kong

To A.W.L.[1], Shea S.K.H.[2] and Chantal Conand[3]

Hong Kong is considered to be the main hub for the trade and consumption of beche-de-mer (To and Shea 2012). Locally observed patterns in supply countries/territories, volumes and re-export trades reflect the global trade pattern of this seafood commodity, which is highly valued among Asian communities (Eriksson and Clarke 2015; Fabinyi 2012; Conand 2017). It is the intention of this review to focus on beche-de-mer recorded under two specific commodity codes, 'dried, salted or in brine' (code: 03081990) (hereafter, 'dried') and 'frozen' (code: 03081910), as explained in a later section.

The local whole sale markets are illustrated Figures 1 and 2. The retail markets offer diverse packaging of dried or frozen product (Figures 3, 4 and 5).

Trade patterns from 1996–2011

An earlier review of the trade patterns of dried beche-de-mer in Hong Kong, based on 16 years of statistics from 1996 to 2011, revealed that five supply countries – including Indonesia, the Philippines, Papua New Guinea, Fiji and Japan – accounted for more than 50% of all dried beche-de-mer imported into Hong Kong, and that since 2004 Vietnam has taken over the role of mainland China to become the largest re-export destination of dried beche-de-mer from Hong Kong (To and Shea 2012).

The review did not look at the trade patterns of frozen beche-de-mer, as trade statistics for the product were merged with that of other frozen molluscs and aquatic invertebrates in the records at the time, nor did the review provide figures on transportation modes for the import and re-export of beche-de-mer into and from Hong Kong (To and Shea 2012).

Change in commodity codes in 2012

Notably, in 2012 the statistics for beche-de-mer trade in Hong Kong, which are extracted from the database of the Census and Statistics Department of the Government of Hong Kong SAR, have undergone major modifications. These include modifications to the commodity code for dried beche-de-mer, and the addition of a specific commodity code for frozen beche-de-mer (Conand et al. 2014). Specific commodity codes for sea cucumbers include three other codes: 'live, for cultivation', 'live, not for cultivation' and in 'prepared or preserved' forms (Conand et al. 2014).

Trade partners – dried and frozen beche-de-mer from 2012–2016

From 2012 to 2016, 119 and 48 countries/territories reportedly supplied dried and frozen beche-de-mer to Hong Kong respectively. Compared with To and Shea's (2012) study, the top five dried beche-de-mer origins have remained largely the same. The only exception is Papua New Guinea, which now falls outside the top ten (Table 1). This decline in imports from Papua New Guinea may be the result of the country's national closure of sea cucumber fisheries since 2009 (Carleton et al. 2013). Furthermore, while the above-listed top five origins used to make up about 51.5% of the total trade volume (To and Shea 2012), their contribution has dropped to about 40.7% in the 2012–2016 period.

Since the emergence of the commodity code for frozen beche-de-mer in 2012 and up until 2016, the top five origins have contributed 72.7% of total recorded frozen beche-de-mer imports to Hong Kong.

Notably, only one country, Japan, is reportedly in the top five lists for both dried and frozen beche-de-mer. The USA and Mexico, which are both in the top five for frozen beche-de-mer imports into Hong Kong, are also the 6th and 7th largest supply countries of dried beche-de-mer to Hong Kong, contributing to about 4.9% and 4.6% of total recorded import quantity, respectively. Other than these three countries, overlapping between dried and frozen beche-de-mer supply countries/territories appears limited.

[1] WWF-Hong Kong, 15/F, Manhattan Centre, 8 Kwai Cheong Road, Hong Kong
[2] BLOOM Association, Suite 2405, 9 Queen's Road, Hong Kong
[3] Laboratoire d'Écologie Marine (Ecomar), La Réunion University. and MNHN, Paris, France

Figures:

1. In wholesale markets, sea cucumbers are typically displayed openly and in bulk (Photo: Stan Shea / BLOOM).
2. Large quantities of sea cucumber may be found drying in the sun on the streets (Photo: Kathleen Ho / BLOOM).
3. Frozen sea cucumbers from South America sold in local supermarkets (Photo: Kathleen Ho / BLOOM)
4. Spiky sea cucumbers from Japan, one of the most expensive dried beche-de-mer in the retail market in Hong Kong (Photo: Allen To).
5. Dried sea cucumbers packaged and for sale in retail markets (Photo: Kathleen Ho / BLOOM).

For re-export destinations, Vietnam was found to dominate in both dried and frozen beche-de-mer trades in To and Shea's (2012) study, and this has remained unchanged in the current study period from 2012 to 2016. It is worth mentioning that one reason for such an exceptionally high percentage of beche-de-mer products destined for Vietnam is reportedly the accessibility of smuggling routes at the border of Vietnam and mainland China, in order to circumvent tax and food safety inspections (WenWeiPo 2016; The Paper 2014).

Table 1. Top five import and re-export countries of dried and frozen beche-de-mer into and from Hong Kong respectively and the percentage contribution within each of these product types, 2012–2016.

Dried				Frozen			
Import	%	Re-export	%	Import	%	Re-export	%
Japan	11.5	Vietnam	95.7	Canada	17.7	Vietnam	77.8
Indonesia	10.4	Taiwan	1.5	China	17.5	China	12.3
Fiji	7.2	S Korea	0.7	Japan	13.2	Taiwan	7.6
Madagascar	5.6	Singapore	0.4	USA.	13.0	Macau	0.8
Philippines	6.0	Canada	0.3	Mexico	11.2	U.S.A.	0.5

Trade quantities and transportation modes – dried and frozen beche-de-mer from 2012–2016

The annual import quantity of dried beche-de-mer has been declining since 2012, and the trend became obvious starting from 2013 (Figure 6). Such decline is also recorded for frozen beche-de-mer, starting from 2013. Nonetheless it is worth noting that from 2012 to 2016, beche-de-mer imported into Hong Kong under frozen and dried forms contributed 97.8% of the total weight reported under all five commodity codes for sea cucumbers / beche-de-mer listed above. For dried and frozen beche-de-mer, the reported value in 2016 was about HKD 2.3 billion (≈ USD 294 million).

Interestingly, for dried beche-de-mer, the import quantity was documented to be larger than the re-export quantity from 1996 to 2011 (To and Shea 2012); however, starting from 2014, the reverse became true. Although stockpiling has been documented for some dried seafood products (Clarke 2002), it is unreasonable to assume stockpiling of such large amounts in local markets where cost of storage space rental can be high. This observed abnormality thereby warrants further in-depth examination.

Ocean transport was found to be relatively more important than other transportation modes for the import of both dried and frozen beche-de-mer into Hong Kong (Table 2). Although transportation by air made up only about 40% of the imports, such level of use on air transport has already exceeded the level used by other high value dried seafood products, such as shark-fin related products. The great majority of shark-fin related products arrive in Hong Kong via ocean (Shea and To 2017). In the re-export trade, ocean transport was also found to be more important than air transport for the re-export of beche-de-mer.

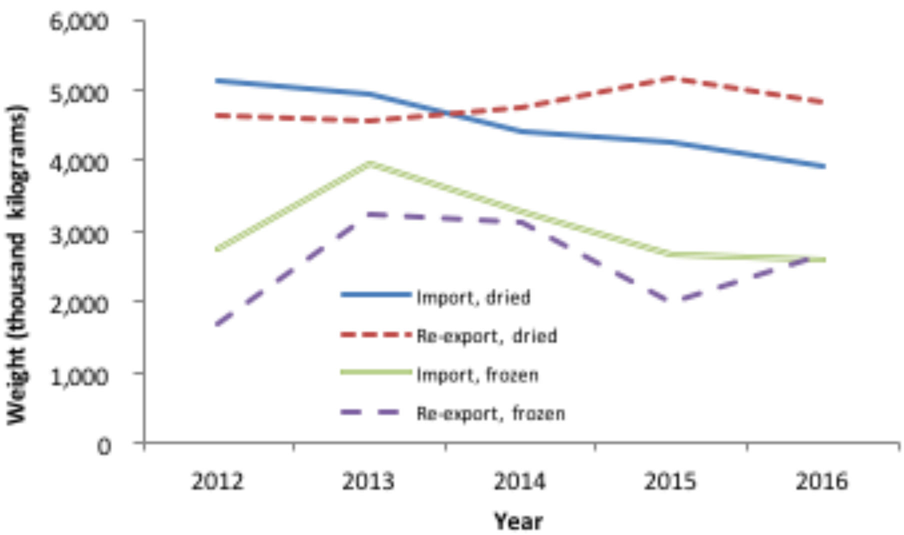

Figure 6. Import and re-export quantity (weight, in tonnes) of dried and frozen beche-de-mer.

Table 2. Transportation modes of dried and frozen beche-de-mer imports and re-exports by quantity in Hong Kong in 2016.

	Dried		Frozen	
Transportation mode	% import	% re-export	% import	% re-export
Air	42.1	1.1	38.1	<0.1
Land	0.1	<0.1	0.4	0
Others	<0.1	0.2	0	0.5
Sea	57.8	98.7	61.5	99.5

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Recent information on worldwide illegal fisheries for sea cucumbers

Chantal Conand[1]

Introduction

Sea cucumber fisheries mostly target Chinese consumers who consider the dried body wall of holothurian species a delicacy. For a long time, they were limited to the Pacific (temperate and tropical) and the tropical Indian Oceans (Conand 1989; Lovatelli et al. 2004). During the last decade they have expanded worldwide (Purcell et al. 2013; Conand 2017a) and recently have developed in the temperate seas and oceans (Gonzalez-Wanglemert et al. 2017). To address problems linked to the management of these resources, FAO and other international and regional agencies have evaluated and proposed better practices for these small scale fisheries (SSF) (Lovatelli et al. 2004; Toral-Granda et al. 2008; Purcell et al. 2012). Nevertheless, during the same period, illegal fisheries have bloomed. Firstly, they must be reported and categorised. This paper presents recently documented cases of illegal fisheries of sea cucumbers from many countries worldwide and discusses the best ways to fight them (Conand et al. 2015). To collect this information, we have monitored scientific literature on sea cucumbers by using a Google alert on 'holothurian' (see the contribution in this issue), checked ResearchGate publications, contacted scientists belonging to web lists such as 'Aspidolist' and used information from newspapers or provided by colleagues. Several cases from 2015–2017 are reported here, listed by regions. They allow us to describe the characteristics of the poaching.

Results

Illegal fisheries for sea cucumbers are now found worldwide, where they are abundant and exploited. Examples for the last three years are reported here.

1. Western Pacific Ocean

Northern Australia

The illegal fisheries by Indonesian and Vietnamese fishers in Australian waters (northern and Great Barrier Reef) have a very long history (Conand 1989; Conand et al. 2015; Purcell and Eriksson 2016). High-value species, *H fuscogilva* and *T ananas* are mostly collected by Indonesian fishers who avoid apprehension by keeping their bags on the seabed. Elsewhere, the situation is improving with logbooks and fishery data being collected.

Vietnamese 'blue-boats' were apprehended several times north of Darwin, carrying stocks of several holothurian species and of other marine resources, such as turtles, fish and clams. Many cases are reported in Newspapers; for example in 2016 on Torres Strait: (http://www.cairnspost.com.au/news/cairns/ten-foreign-fishermen-detained-with-sea-cucumber-haul-in-torres-strait/news-story/80904c7c4b37f2f72cf40e5951128a85) and on the Great Barrier Reef: (http://www.theguardian.com/environment/2016/mar/30/vietnamese-fishing-boats-caught-with-sea-cucumbers-in-great-barrier-reef).

Hawaii

The fishing of holothurians was previously allowed if fishers had a licence, but exploitation was at modest levels and a management plan was not developed for commercial harvests. But then large quantities were taken at Maui and Oahu, apparently unreported, prompting public concern. These indiscriminate harvests prompted a temporary ban on collection. Authorities are working to develop a management plan for sustainable harvests (Ilima Loomis, 'The Sea Cucumber's Vanishing Act,' *Hakai Magazine*, 30 March 2016, accessed 30 March 2016 at: http://bit.ly/1PAS1PZ).

Palau

The harvesting was once restricted to subsistence consumption, but in June 2015, Vietnamese fishers in 'blue-boats' were caught fishing sea cucumbers. The authorities burned four Vietnamese boats which 'sent a very strong message' to illegal fishers.

Several other examples of arrests of Vietnamese blue-boats with illegal catches of sea cucumber are reported from Malaysia: (http://www.thestar.com.my/News/Nation/2015/04/23/Vietnamese-held-for-poaching-sea-cucumber/).

New Caledonia

In January 2017 (after previous observations in 2016), several 'blue boats' were apprehended by the

[1] Emeritus Pr. La Reunion University and Honorary Attached at MNHN Paris. Email: chantal.conand@mnhn.fr

French Navy (FANC). Many details are provided in an article by Francisco Blaha (http://www.franciscoblaha.info/blog/) in SPC Fisheries Newsletter 151:20–23 (http://purl.org/spc/digilib/doc/mgpz3). The author discusses the problems for authorities when boats are boarded and their crew arrested; and those for local fishers when they are not. There are no easy solutions, but in international rules it is the flag state's responsibility to control illegal fishing fleets. The local newspapers have largely reported on this actuality.

2. Western Indian Ocean

Madagascar

The ancient fishery for sea cucumbers recently attracted attention with several projects and legislation to manage the resource (COI programme, Wiomsa/Masma: Conand and Muthiga 2007; Muthiga and Conand 2014). Nevertheless, some local fishers migrated to new settlements to capture holothurians illegally; some also went to neighbouring countries. They use prohibited equipment such as scuba diving to collect sea cucumbers. Poaching has even been noticed in mariculture enclosures, by night, at low tides and therefore surveillance towers have been built. Many poachers have been arrested in the sea pens of the Indian Ocean Trepang Company, south-west of Madagascar. Thefts in Madagascar are one the biggest challenges for solving because they could lead to the cessation of sea cucumber aquaculture: the cost of day and night guardians protecting sea pens is one of the highest parts of the functioning cost of the company (Eeckhaut pers. comm.). Poachers are local coastal villagers or inland villagers. They sell their stolen products to known local buyers.

Îles Éparses (Mozambique Channel)

These islands are isolated, scattered and without a permanent population, which is a situation that provides good conditions to study biodiversity, but also makes them vulnerable to poaching. Several cases of illegal fishing have been reported by French Authorities (TAAF 2014), local newspapers from La Reunion (LINFO.RE) and scientists (Conand et al. 2015). A collaboration between French and Australian authorities was organised and information was obtained on poaching near Juan de Nova in 2014, at Glorieuses Islands in 2015 and Juan de Nova again 2016. A new boat 'Ile de La Réunion' will survey and control the marine environment in the zone (TAAF 2017).

Several earlier observations of illegal fishing activities have come from other countries and are useful for the present study.

Tanzania, Chumbe Island Marine Park and Mafia Marine Park in 2014: boats (dows) arrested; *Kenya*, Mombasa MPA in 2013: fishers were arrested, got a fine, but explained that they had got an order from a Chinese dealer whose name was not recorded! (N. Muthiga pers. comm.). For these two countries and *Mozambique*, Eriksson et al. (2012) have presented detailed maps of the spatial scale of scuba diving fishing operations and trade in East Africa, documenting the processes and emphasising the need for regional management. In the *Chagos* archipelago (Price et al. 2010) the holothurian resources were under increasing pressure through heavy and illegal harvesting.

3. Eastern Indian Ocean

India

Important recent publications and a report on the conservation and sustainable use of the resources in India (Asha et al. 2017) detail the history and the present situation of the clandestine exploitation since the ban imposed by the Government in 2001, which put an end to the sea cucumber fishery and trade from the country. Its social and economic impacts are discussed and the authors note that 'a controlled mechanism of collection and trade might be a preferred policy solution and put an end to the thriving illegal trade'. Guidelines are also detailed for a sustainable use.

4. Eastern Pacific Ocean

Galapagos

Fishing activities for sea cucumbers started in 1994, after the collapse of the fishery in mainland Ecuador (1991). Despite the ecosystem-based spatial management plan put in place in the Galapagos Marine Reserve, conflicts have been serious and illegal fishing has not stopped (Toral-Granda 2008). *Isostichopus fuscus* is still the only holothuroid species put on CITES Appendix III (2003). The shortcomings were evaluated and governance issues analysed, but despite a participatory management structure, illegal captures were still going on in June 2015.

5. Atlantic Ocean

The sea cucumber fisheries are more recent in this ocean, but illegal fisheries have been noticed both in tropical and temperate countries.

Mexico

The species *Isostichopus badionotus* is currently fished and there are plans to start fishing *Holothuria floridana*. A management plan is in place with detailed information on biology, ecology and distribution of both species. Yet, corruption, illegal fisheries and smuggling of sea cucumbers happens in Mexico. ('Smuggling, diving and death: the Mexican rush for sea cucumbers' by John Holman https://www.youtube.com/watch?v=43P1Zxo-mTQ).

Colombia

In Colombia (Eeckhaut pers. comm.), both fishing and exportation of sea cucumbers are prohibited by law; however, important illegal fishing has been reported in the region of Santa Marta (Caribbean Coast). The dried sea cucumbers would pass through Venezuela before being exported to China. The main collected species seems to be Isostichopus badionotus.

Portugal

Several species, including Holothuria arguinensis, are new targets of fisheries and scientific projects in ecology and mariculture (Gonzalez-Wanglemert et al. 2016; Gonzalez-Wanglemert et al. 2017). Poaching has been noticed several times.

Madeira and Canarias

Recent mentions of illegal captures have been published for these islands (Gonzalez-Wanglemert pers. comm.). (https://funchalnoticias.files.wordpress.com/2017/03/pepinos-mar.png and https://www.canarias7.es/sucesos/incautados-83-kilos-de-pescado-y-900-pepinos-de-mar-de-pesca-ilegal-FD647153).

Discussion

Characteristics of illegal fisheries

From the recent examples presented here, it appears first that they share some common characteristics, depending on the situations and regulations. They have been apprehended as:

- local people, within countries composed of isolated islands, with some examples being within Marine Protected Areas … or when different regulations exist between regions of a country, as in, for example, Tanzania ; and
- mostly foreign divers, poachers coming in remote sites, who are very mobile in order to escape the controls – 'roving bandits' (Osterbloom 2014; Eriksson et al. 2015a).

Different categories of illegal fisheries

From recent examples, illegal sea cucumber fishing mostly takes place in:

- countries where there is a permanent ban on exports;
- countries where management plans and regulations for export are weak;
- less developed countries where poverty drives poachers to smuggle illegal catches to nearby ports where they can be sold legally; and
- countries with remote fishing areas where enforcement is difficult.

How to fight illegal fisheries

Several general principles and methods of management and conservation are necessary, such as:

- raising awareness at international, regional and national levels, through programmes of organisations such as ACIAR, FAO, SPC, WIOMSA, WorldFish, as well as at regional (Eriksson et al. 2015b, Conand 2017b) and national meetings;
- increasing scientific input to monitor the changes in species that are exploited and countries involved in the fisheries;
- providing fishery statistics at different levels, to enable comparisons with market statistics, therefore facilitating the evaluation of illegal products entering the market; and
- encouraging collaboration between the different stakeholders, administrations and scientists.

Many other actions can be useful at international, regional or national levels, such as:

- supporting the actions of international organisations and conservation bodies, such as IUCN that have already assessed nearly 400 species (Conand et al. 2014) and CITES that discusses the possible addition of holothurians to follow up on previous listings for sea cucumbers (Bruckner et al 2006);
- establishing random inspections at sea and on land;
- informing police and land-based enforcement bodies of regulations;
- setting stern pre-determined penalties in management plans;
- enforcing penalties as a visible deterrent to illegal fishers;
- publicising seizures of sea cucumbers in media; and
- encouraging fisheries agencies to work with coast guards and border security to intercept foreign vessels and identify poaching.

The list could easily be extended, and should take the role of poverty into account. It is also hoped that with the use of new technologies, some of these problems will be solved.

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Gonzalez-Wanglemert. Thanks are also due to the French Southern and Antarctic Lands (TAAF) and the Western Indian Ocean Marine Science Association (WIOMSA) for the presentation made at the 9th WIOMSA Scientific Symposium.

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Holothuria scabra tegument blister under fresh water influence, south-west of Madagascar

Benoit Burel[1]

In July 2015 – after more than one year of sandfish growth in Indian Ocean Trepang S.A. sea pens in the south of Toliara, Madagascar – *Holothuria scabra* with podia blisters were found on the sediment. These animals, which weigh about 100 g, have been seen in sea pens that are crossed by a fresh water stream every day during outgoing tides. This disease seems to be provoked by the stress of fresh water excess (less than 30 ppm salinity), mixed with relatively low temperatures during the cold season in Madagascar, from May to September (the pictures below were shot in July 2015). The normal crawl movement, feeding and burying of the animals look to be disturbed given that we have not seen these animals buried.

The blisters are mostly bulging on the dorsal part of the animals. Blisters have the same firmness as a normal tegument. Even under pressure, blisters do not leak or explode. When animals with blisters are put in quarantine in an area with 35 ppm salinity, they fully recover. Figure 1 shows four different views of *H. scabra* with blisters from July 2015.

Figure 1. Four sandfish specimens with blisters. A) profile view; B) top view; C) top view on sediment; D) top view.

1 Indian Ocean Trepang, Mahavatsy II, Toliara, Madagascar

Pearlfish *Carapus bermudensis* from the sea cucumber *Holothuria mexicana* in Belize (Central America)

Arlenie Rogers[1,*], Jean-François Hamel[2] and Annie Mercier[3]

Pearlfish (Carapidae) are specialised fishes that mainly live in the respiratory tree of sea cucumber hosts (Arnold 1956; Shen and Yeh 1987; Smith and Tyler 1969; Smith 1964) in a relationship that has generally been defined as commensalism (Parmentier et al. 2003; Van Den Spiegel and Jangoux 1989; Parmentier et al. 2016). However, some species such as *Encheliophis* spp. are known to feed off their host's gonad (Murdy and Cowan 1980; Parmentier et al. 2003; Pamentier and Vandewalle 2005; Parmentier et al. 2016).

The present article highlights the occurrence of the pearlfish *Carapus bermudensis* (Figure 1) inside the sea cucumber *Holothuria mexicana* in Belize. Adults of *H. mexicana* were collected from Buggle Caye (16°28.377′ N: 88°21.77′W) on 14 July 2015 at a depth 1.2 m; at Frenchman Caye (16°06.347′N: 88°33.702′W) on 9 June 2014 at a depth of 10.7 m; and from the Range (16°05.616′N: 88°42.827′W) on 12 February 2012 at a depth of 7.6 m. The latter two sites consisted of seagrass (*Thalassia testudinum*), sand and coral rubble and were within the Port Honduras Marine Reserve, while the former site consisted of patch coral, sand and *T. testudinum* (Figure 1).

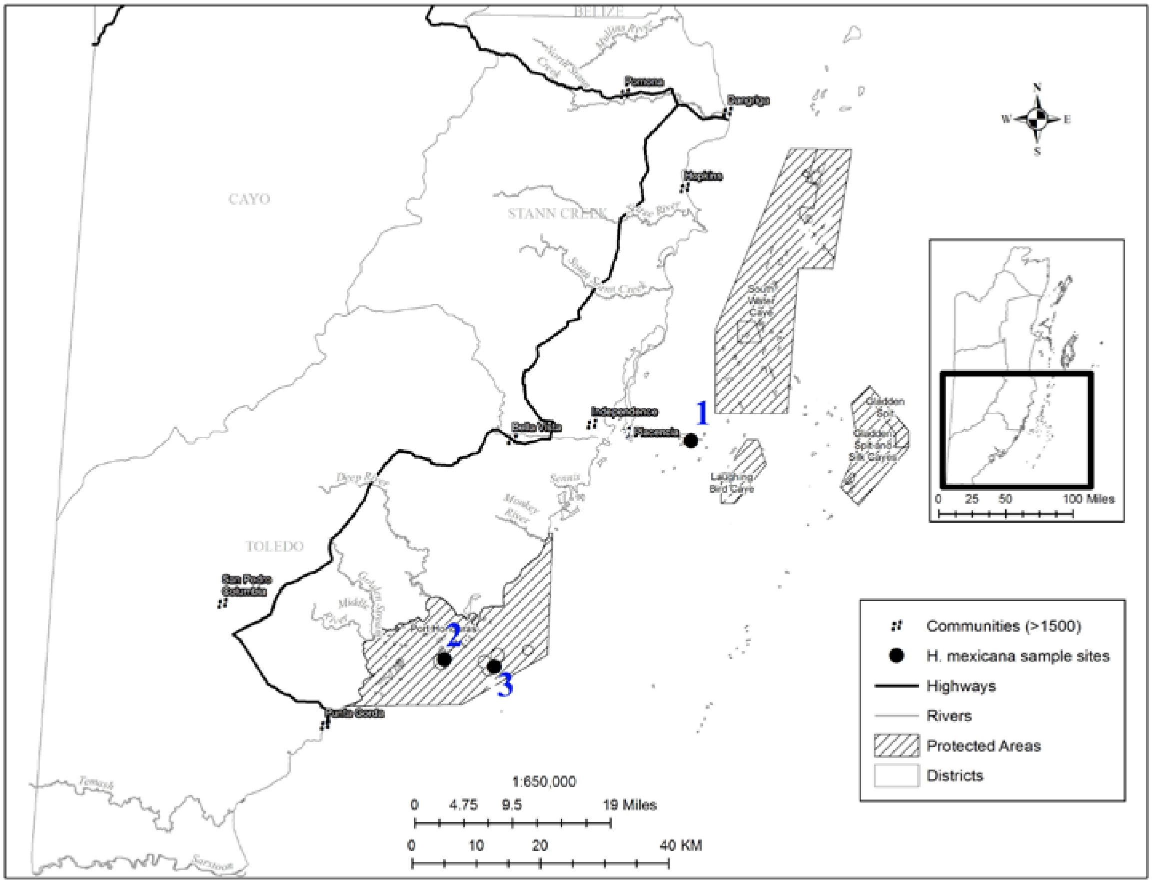

Figure 1. Locations where sea cucumbers (*H. mexicana*) hosting the pearlfish *C. bermudensis* were found. The map shows 1: Buggles Caye, 2: Frenchman Caye and 3: the Range (Port Honduras Marine Reserve). See Table 1 for details about samples.

1 University of Belize Environmental Research Institute, UBERI, Price Center Road, Belmopan City, Belize
2 Society for the Exploration and Valuing of the Environment (SEVE), St. Philips (Newfoundland), Canada
3 Department of Ocean Sciences, Memorial University, St. John's (Newfoundland), Canada
* Author for correspondence arogers@ub.edu.bz

The distribution range of the sea cucumber *H. mexicana* primarily includes the Western Central Atlantic and the Caribbean Sea (Bruckner 2006); it is reported to occur in Florida (Engstrom 1980), the Yucatan Peninsula of Mexico (Fuente-Betancourt et al. 2001), Belize (Perez and Garcia 2012), Panama (Guzman and Guervarra 2002), Venezuela (Conde et al. 1991; Laboy-Nieves et al. 2001; Rodriguez-Milliet and Pauls 1998; Tagliafico et al. 2011), as well as in the Azores (Hansson 2001; Toral-Granda et al. 2013). The distribution of the pearlfish *C. bermudensis* centres in the Western Atlantic, including North Carolina, Bermuda, the Bahamas, the Gulf of Mexico from the Florida Keys (USA) to Cuba, throughout the Caribbean Sea, and along the South American coast to southern Brazil (Smith-Vaniz et al. 2015). Known sea cucumber hosts of *C. bermudensis* include *H. mexicana* (Smith and Tyler 1969; Trott 1970; Tyler et al. 1992; Hasbun and Lawrence 2002) *Actinopyga agassizi* (Arnold 1956; Van Meter and Ache 1974; Hasbun and Lawrence 2002), *Isostichopus badionotus* (Smith and Tyler 1969; Vergara et al. 2016); *Eostichopus arnesoni, Holothuria lentiginosa* (Miller and Pawson 1979; Valentine and Goeke, 1983), *Selenkothuria glaberrima, Theelothuria princeps* and *Thyone* sp. (Phyllophoridae, Dendrochirotida) (Smith et al. 1981; Trott 1970; Markle and Olney 1990; Tyler et al. 1992), *Astichopus multifidus* (Trott 1970); *Holothuria glaberrima* (Trott 1970) and *Holothuria princeps* (Dawson 1971).

In this study, a total of 12 individuals of *C. bermudensis* were found in seven out of 172 adult sea cucumbers that were examined (Table 1). All sea cucumbers containing pearlfish were strictly collected in seagrass (*T. testudinum*) between patch coral reefs or coral rubble and sand habitats. In two cases, more than one pearlfish (Figure 2A) were found living in the same host (Figure 2B). One sea cucumber contained five pearlfishes, one contained two pearlfishes and the other five contained only one pearlfish each. Multiple pearlfish infestation has previously been described by Pamentier and Vandewalle (2005) where a total of six individuals of *C. homei* were found in one sea cucumber of the species *Bohadschia argus* and Meyer-Rochow (1977) found 15 individuals of *C. mourlani* in the sea cucumber *Bohadschia argus* (Jaeger) at Banda Island (Indonesia). Aronson and Mosher (1951) reported four individuals of *C. bermudensis* in a single host in the Bimini Lagoon (Bahamas) whereas other studies have reported only single individuals of this species occurring in the *H. mexicana* hosts in Belize (Tyler et al. 1992) and Honduras (Hasbun and Lawrence 2002).

No obvious side effect was noted in the hosts during the present study. The sea cucumbers hosting pearlfish ranged from 15–27 cm total length (relaxed) and the pearlfish ranged from 10–12.5 cm total length (Table 1). Pearlfishes were either found in the respiratory tree or in the coelomic cavity of *H. mexicana* (see table 1). Previous reports of *C. bermudensis* found in *H. mexicana* do not mention the location where they were found inside the host (Smith and Tyler 1969; Trott 1970; Tyler et al. 1992; Hasbun and Lawrence 2002). Five of the specimens were deposited at the ECOSUR museum in Chetumal, Mexico with sample number SCBZ001 and Field ID PHMR001. They were identified using genetic barcoding; the species had previously been identified by the Smithsonian Institute in Belize with sequences deposited in Gene Bank (accession: GU224746).

Table 1. Collection sites of the sea cucumber *H. mexicana* and the pearlfish *C. bermudensis* (see also Figure 1 for the map). The sea cucumbers' total length (relaxed) and the number of pearlfish per sea cucumber, with their sizes and location in the host.

H. mexicana	Collection sites (on fig. 1)	Sea cucumber total length (cm)	Number of pearlfish per sea cucumber	Pearlfish total length (cm)	Location of the pearlfish in host
1	1	15	1	10	Coelomic cavity
2	1	17	1	10.5	Coelomic cavity
3	1	21	1	10	Respiratory tree
4	1	23	1	12.5	Coelomic cavity
5	1	27	1	11.5	Respiratory tree
6	2	27	5	10; 10; 11.5; 12; 12.5	Coelomic cavity
7	3	23	2	11; 11	Coelomic cavity

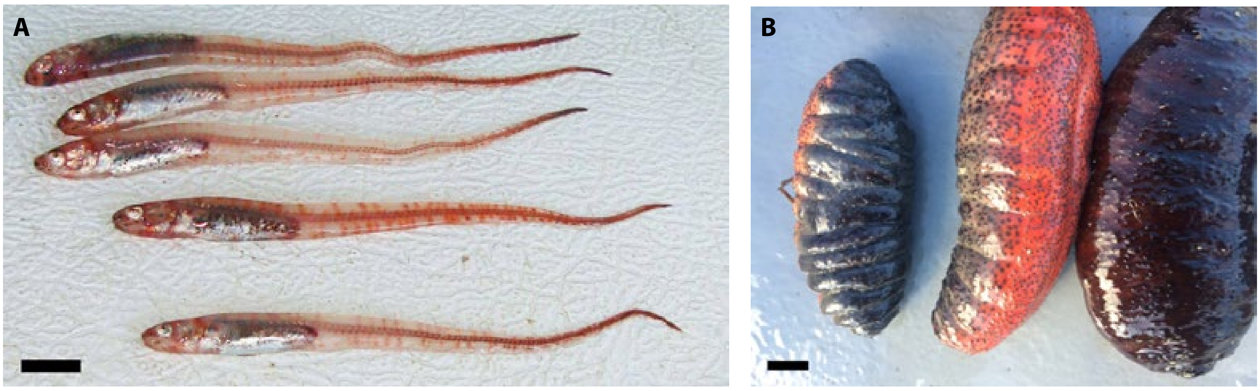

Figure 2. (A) Individuals of *Carapus bermudensis* found in (B) sea cucumbers *Holothuria mexicana* in Belize. Scale bar represents 2 cm in A and 3 cm in B.

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New data about distribution of the sea cucumber *Molpadia musculus* Risso, 1826 (Holothuroidea: Molpadiida: Molpadiidae) in Russian seas

Vadim G. Stepanov[1,*] and Elena G. Panina[1,**]

Introduction

Molpadia roretzi (von Marenzeller, 1877) and *M. orientalis* (Saveljeva, 1933) are known to be present in the far eastern seas of Russia (Stepanov and Morozov 2014). *M. musculus* (Risso, 1826), was first recorded by Ohshima (1915) from the east coast of southern Sakhalin in Japan. The following information about *M. musculus* was recorded in 2015 during the Russian-German deep-sea expedition SokhoBio, 71st Cruise, aboard the R/V *Akademik M.A. Lavrentyev* and includes data about geographical and depth distributions, a short description of a specimen, and photos of the external appearance and of the body wall and tail ossicles.

Date and location of collection of *Molpadia musculus* samples

11 July 2015, Russian-German deep-sea expedition SokhoBio, 71st Cruise, R/V *Akademik M.A. Lavrentyev*, 46°09.044′ N – 46°08.738′ N and 146°00.789′ E – 145°59.512′ E, depth 3305 m;

14 July 2015, Russian-German deep-sea expedition SokhoBio, 71st Cruise, R/V *Akademik M.A. Lavrentyev*, 46°37.982′ N – 46°37.740′ N and 148°59.934′ E – 149°00.920′ E, depth 3363 m;

16 July 2015, Russian-German deep-sea expedition SokhoBio, 71st Cruise, R/V *Akademik M.A. Lavrentyev*, 47°12.139′ N – 47°11.803′ N and 149°36.745′ E – 149°37.518′ E, depth 3366 m;

23 July 2015, Russian-German deep-sea expedition SokhoBio, 71st Cruise, R/V *Akademik M.A. Lavrentyev*, 46°56.854′ N – 46°57.485′ N and 151°04.923′ E – 151°05.210′ E, depth 3301–3300 m;

1 Aug. 2015, Russian-German deep-sea expedition SokhoBio, 71st Cruise, R/V *Akademik M.A. Lavrentyev*, 45°36.929′ N – 45°37.861′ N and 146°22.879′ E – 146°21.898′ E, depth 3211–3217 m.

Description

The body of *Molpadia musculus* is barrel-shaped with a well-defined tail (see Figure 1). The specimens collected varied considerably in colour and size. Their body length was 43–70 mm, with a maximum diameter of 19–24 mm. The colour when placed in alcohol is light-grey to dark-brown. The skin is thick or thin, smooth or wrinkled. There are 10 simple tentacles.

Figure 1. External view of *Molpadia musculus*.

The ossicles of the body wall include tables with three or more perforations in the disk and a solid spire (see Figures 2 A and 2 B), fusiform rods (see Figure 2 C) and racquet-shaped plates (see Figure 2 D). Anchors were not found. Phosphatic deposits were present.

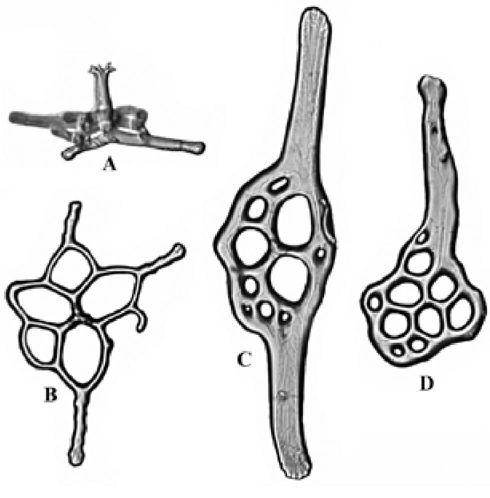

Figure 2. Ossicles of the body wall of *Molpadia musculus*. A: table, side view; B: table, top view; C: fusiform rod; D: racquet-shaped plates.

[1] Kamchatka Branch of Pacific Geographical Institute of Far-Eastern Branch of Russian Academy of Sciences, Petropavlovsk-Kamchatsky, Russia, 683000.
[*] Email: vgstepanov@inbox.ru
[**] Email: panina1968@mail.ru

The ossicles of the tail are fusiform rods with three or four perforations in the centre (see Figure 3).

Figure 3. Ossicles of the tail of *Molpadia musculus*.

Distribution

Molpadia musculus distribution is widespread but has not been recorded in the Arctic. It has been recorded at depths of 35–5205 m. In the far eastern seas of Russia, *M. musculus* had only been found by Oshima in the east coast of southern Sakhalin in Japan (46°29.30′ N and 145°46′ E) at a depth of 1800 fathom (i.e., 3291.84 m; Ohshima 1915). In 2015, *Molpadia musculus* specimens were collected near the station indicated by Ohshima and near Urup and Simushir Islands (Kurile Islands) at depths of 3300–3366 m (see Figure 4).

Acknowledgements

The authors are grateful to V.I. Kharlamenko (Institute of Marine Biology of the Far Eastern Branch of the Russian Academy of Sciences, Russia, Vladivostok) for collecting the *Molpadia musculus* specimens that were used for this article.

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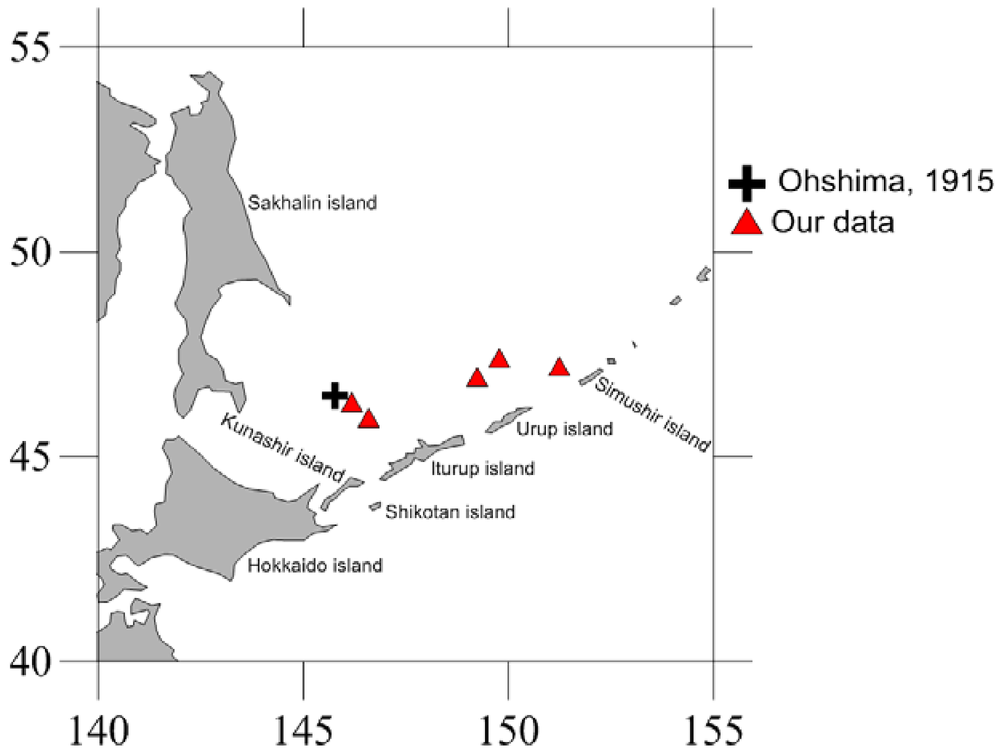

Figure 4. Distribution of *Molpadia musculus* in the Far Eastern seas of Russia.

Weight–length relationship of Sclerodactylidae sea cucumber, *Ohshimella ehrenbergii* (Selenka, 1868) (Echinodermata: Holothuroidea), from Karachi coast, Pakistan

Ahmed Quratulan[1,*], Mohammad Ali Qadeer[1] and Bilgin Sabri[2]

Abstract

This study was conducted to determine weight–length relationships (WLRs) of sea cucumber *Ohshimella ehrenbergii* that was sampled during three seasons, pre-monsoon, monsoon and post-monsoon, in January to December 2014 from Sunehri coast in the Arabian Sea, Pakistan coast. The results showed that *Ohshimella ehrenbergii* has negative allometric growth characteristics in all seasons. Namely, the value of *b* was calculated as 0.924 in pre-monsoon, as 1.044 in post-monsoon, as 0.982 in monsoon and as 0.992 in combined data with significant differences from isometric growth.

Introduction

According to the World Register of Marine Species (WoRMS) (2014) the Sclerodactylidae sea cucumber, *Ohshimella ehrenbergii* (Selenka, 1868) (Echinodermata: Holothuroidea), lives in rock crevices or under stones and is distributed in south-eastern Arabia, western India, Pakistan, Maldives and Sri Lanka. Knowledge on biological features such as weight–length relationships (WLRs) of sea cucumbers is an important tool for marine biologist. The WLRs can be used as a tool in stock assessment studies, fish biology, fish population dynamics and also fisheries research studies. In Pakistan, monsoon winds carry moisture from the Indian Ocean and bring heavy rains between May and September. More than fifty per cent of annual rainfall occurs in the monsoon season, mostly from July to August (Hussaina et al. 2010). Mobilised sea life during pre- and post-monsoon seasons directly or indirectly affect the life of marine flora and also fauna species such as the sea cucumber *Ohshimella ehrenbergii*. In Pakistan, there is no knowledge on WLRs of *Ohshimella ehrenbergi*. The present study deals with first time seasonal variation of the WLRs in *Ohshimella ehrenbergii* from the Sunehri coast, Karachi, Pakistan.

Materials and methods

Sample collection

Sea cucumbers were collected by hand especially in the intertial area from the Sunehri coast (around 24°52′33.49′′N and 66°40′40.20′′E) (see Figure 1). A total of 34 sea cucumbers *Ohshimella ehrenbergii* were collected in 2014 at three different periods: n = 10 in pre-monsoon (January to April), n = 12 in monsoon (May to September) and n = 12 in post-monsoon (October to December).

Weight–length relationships (WLRs):

The total length (*TL*) (cm) and weight (g) data were measured for each sea cucumber. Total length from mouth to anus was measured using a flexible ruler after allowing the sea cucumber to relax in sea water for 5 min. Wet weight and total length were measured to the nearest 0.1 g and 0.1 cm, respectively.

Least squares regression analysis was applied using MS Excel software to calculate the WLRs parameters for sea cucumber specimens. The WLRs was estimated as follows: $W = aTL^b$, (where *W* is the wet body weight (g), *TL* is the total length (cm), *a* is the intercept, and *b* is the slope of the regression line).

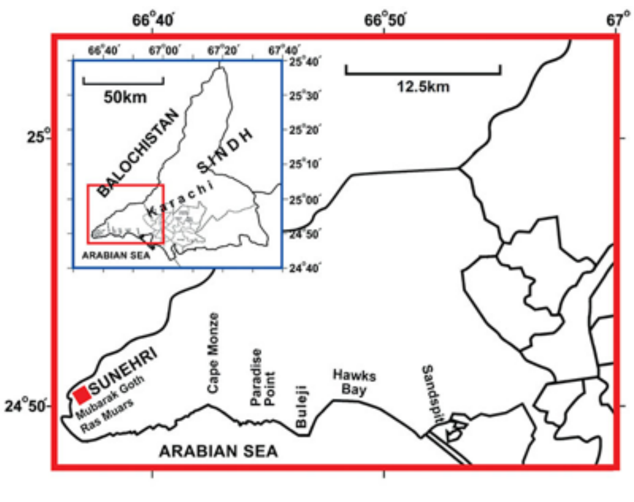

Figure 1. Study area.

[1] The Marine Reference Collection and Resource Centre, University of Karachi, Karachi, Pakistan
[2] Sinop University Faculty of Fisheries and Aquaculture, TR57000, Sinop, Turkey
[*] Author for correspondence: qurutulanahmed_ku@yahoo.com

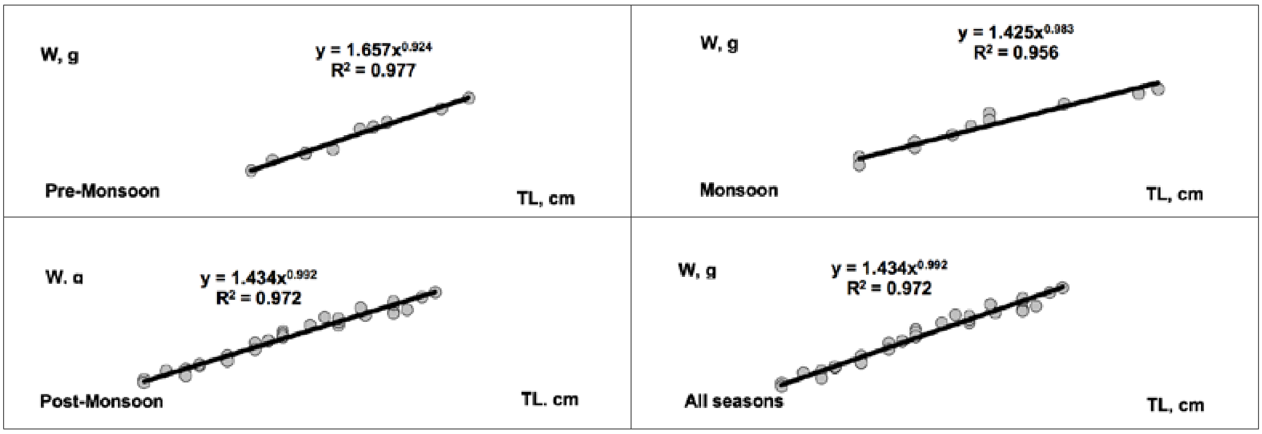

Figure 2. Total weight–length relationships (WLRs) of *Ohshimella ehrenbergii* in pre-monsoon, monsoon, post-monsoon and combined seasons during January to December 2014.

Table 1. Seasonal length and weight results of *Ohshimella ehrenbergii* samples collected during pre-monsoon, monsoon and post-monsoon seasons in 2014 from Sunehri coast. L_{mean} = mean length, L_{min} = lowest length, L_{max} = maximum length, L_{SE} = Standard error of length; W_{mean} = mean weight, W_{min} = minimumt weight, W_{max} = maximum weight, W_{SE} = Standard error of weight.

Seasons	N	Length (cm)				Weight (g)			
		L_{mean}	L_{SE}	L_{min}	L_{max}	W_{mean}	W_{SE}	W_{min}	W_{max}
Pre-monsoon	10	7.63	0.81	4.0	12.0	10.81	1.09	6.0	16.5
Monsoon	12	9.17	0.82	5.5	13.5	12.56	1.06	6.7	17.5
Post-monsoon	12	10.57	0.87	4.0	14.5	15.23	1.27	5.5	20.3
Combined	34	9.21	0.51	4.0	14.5	12.99	0.72	5.5	20.3

Comparison of the difference of slope (b) value from isometric growth (b = 3) for seasons (pre-monsoon, monsoon and post-monsoon) and combined data, Pauly's *t*-test was performed (Pauly 1984). Comparison of the difference of correlation coefficient (r) from zero *t*-test was calculated (Snedecor and Cochran 1989).

Results and discussion

The WLRs results of *Ohshimella ehrenbergii* in pre-monsoon, monsoon and post-monsoon seasons are showed in Table 1. Mean total length of *Ohshimella ehrenbergii* was 4.0–12.0 cm (mean: 7.63 ± 0.81 cm, n = 10) in pre-monsoon, 5.5–13.5 cm (mean: 9.17 ± 0.82 cm, n = 12) in monsoon, and 4.0–14.5 cm (mean: 10.57 ± 0.87 cm, n = 12) in post-monsoon. Overall mean total length was 4.0–14.5 cm (mean: 9.21 ± 0.51 cm, n = 34).

Weight–length relationships (WLRs)

The WLRs of the *Ohshimella ehrenbergii* samples that were collected during pre-monsoon, monsoon and post-monsoon seasons showed that *Ohshimella ehrenbergii* have negative allometric growth (Pauly's t test, $P > 0.05$).

The values for the exponent (b) of all seasons remain mostly out of the expected range of $b = 2.5$ and $b = 3.5$. These results may be due to different body shape of the sea cucumber than other marine animals such as fish and crustaceans. However, comparison of the difference of correlation coefficient (r) from zero *t*-test (Snedecor and Cochran 1989) was applied and the values of 'r' for pre-monsoon ($r = 0.976$), monsoon ($r = 0.955$), post-monsoon ($r = 0.984$) and combined data ($r = 0.971$) are different from zero ($P < 0.05$), indicating that sea cucumber *Ohshimella ehrenbergii* has higher correlation in WLRs equations.

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Did you say pislama, dairo, bislama, kereboki or bêche-de-mer?

Michel Bermudes[1,*]

Sea cucumbers are named pislama in Papua New Guinea (PNG), dairo in Fiji, bislama in Vanuatu, kereboki in Kiribati and bêches or bêche-de-mer in New Caledonia. During October and November 2017 participants from these five Pacific Island countries took part in activities in Papua New Guinea, Fiji and New Caledonia to further their knowledge of sandfish (*Holothuria scabra*) aquaculture for restocking by visiting their neighbouring counterparts. For this initiative, which was led by the Pacific Community's Fisheries, Aquaculture and Marine Ecosystems Division, we set ourselves a few criteria and targets. It had to be regional, technical and most importantly, it had to be about the people who work in this field. It was as much about 'how far we have come', as it was about 'how far we still have to go'. It was introspective and intended that way so that regional experts could meet and share their experiences in a setting that would foster networking among Pacific islanders.

The region has many national sandfish restocking programmes – some of which are carrying out ground breaking research and development in hatchery/nursery production, restocking/sea ranching and processing. All programmes have great stories to tell. They may be stories of success and sometimes failure but all have some precious lessons to share in creativity and in the way they have been able to adapt processes and technology to make things happen under challenging local conditions and contexts.

The group of participants that gathered represented sandfish programmes ranging from highly advanced where sandfish aquaculture and ranching are being tested at a large scale, down to countries that have fledgling programmes and are in the process of developing seed production capacity.

The regional participants included the following: Esther Leini (Hatchery Manager, National Fisheries Authority [NFA], Papua-New-Guinea [PNG]), Nicholas Daniels (Mariculture Research Technician, NFA, PNG), Shalendra Singh (Principal Fisheries Officer, Ministry of Fisheries [MOF], Fiji), Sheik Saheb (Fisheries Officer, MOF, Fiji), Ajay Arudere (Senior Fisheries Management and Fisheries Officer, Vanuatu Fisheries Department [VFD]), Rocky Kaku (Research Officer, VFD, Vanuatu), Derek French (Hatchery Operator, Aquaculture Solutions Vanuatu), Andrew Williams (Aquaculture Development Officer, VFD, Vanuatu), Joana Rabaua (Hatchery Manager, Ministry of Fisheries and Marine Resources Development [MFMRD], Kiribati), Kamarawa Tamton (Aquaculture Technician, MFMRD, Kiribati), Bernard Fao (Fisheries Division Manager, Southern Province, New Caledonia), and Laurent Burgy (Hatchery and Farm Manager, Société d'élevage aquacole de la Ouenghi, New Caledonia).

The exchange programme was structured in three chapters for three different locations: PNG, Fiji and New Caledonia. In each chapter, participants were taken for one week to see and experience the way that sandfish research and development is being carried out in neighbouring countries. The Fiji chapter also included 2–4 week placements at the Galoa Fiji government hatchery for delegates from PNG, Kiribati and Vanuatu.

Pislama sea ranching in Kavieng, PNG

The exchange programme started in Kavieng at the Nago Island Mariculture Research Facility (NIMRF) where Esther Leini and Nicholas Daniels are based, and where we were welcomed by Facility Manager Peter Minimulu and ACIAR scientist Thane Militz. PNG's National Fisheries Authority has made a significant investment in developing NIMRF into a state of the art research facility that is currently housing several mariculture initiatives that are supported by the Australian Centre for International Agricultural Research (ACIAR). One of those initiatives is the sandfish sea ranching project, which started in 2010. During the week we were chaperoned by Esther and Nicholas who took us through their work from hatchery production and nursery to sea ranching and the research being conducted in those areas. It was an action-packed week during which activities were organised for participants to experience production phases such as spawning, larvae culture, nursery, the release of juveniles and bio-physical survey of sea ranching sites. We learned about the challenges

[1] Mariculture and Aquatic Biosecurity Specialist, Pacific Community, Noumea, New Caledonia
[*] michelbe@spc.int

that Esther and Nicholas faced; for instance, with feeding live micro algae to larvae and with mortality during nursery stages. Importantly, we were able to see first-hand the solutions that had been developed through repeated research trials for the development of larvae culture protocol using 100% algal paste instead of live micro algae (Figure 1) and to increase juvenile survival in floating hapa net systems.

Figure 1. Shalendra Singh (left, Fiji Ministry of Fisheries) and Ajay Arudere (right, Vanuatu Fisheries Department) feeding sandfish larvae under the watchful eye of Esther Leini (centre, PNG's National Fisheries Authority) (Image: Michel Bermudes, SPC).

Hatchery placements and restocking of dairo in Fiji

During the PNG chapter, activities also started in Fiji with the placement of Derek French (Aquaculture Solutions Vanuatu) at the Ministry of Fisheries marine hatchery in Galoa. Derek was later joined by Esther Leini and Joana Rabaua (MFMRD, Kiribati). Placements were overseen by Anand Prasad (Facility Manager) and Teari Tekebo (Sandfish Hatchery Manager). Sandfish production at the Galoa hatchery is, like at NIMRF, a story of adaptation to local conditions and the systems available to work with. In Galoa, Teari Tekebo was able to develop her unique blend of hatchery techniques to overcome early difficulties during larval stages caused by copepod infestations. With the presence of Teari and other sandfish hatchery managers, the Fiji chapter was a unique opportunity to hold a small workshop on hatchery techniques. We heard presentations from the perspective of PNG, Fiji, Kiribati and New Caledonia and from this workshop we were able to see some changes and evolution from the manual by Natacha Agudo (Agudo 2006), which is still considered as a benchmark in all four hatcheries:

- Spawning techniques: All hatcheries use dry and heat shock with spirulina bath as recommended in Agudo's manual;
- Feeding: There is an evolution toward using paste with all hatcheries, partly using paste and some like NIMRF using only paste. New Caledonia feeds mostly live algae with a little paste and Algamac Protein Plus supplement. Fiji feeds only 10% live algae, the rest being paste.
- First feeding and feeding rates: Some hatcheries feed at day 1 (Fiji and New Caledonia) and New Caledonia feeds a little more than what is prescribed by Agudo. Other hatcheries (PNG and Kiribati) follow Agudo's manual for both start of feeding and feeding rates.
- Water exchange: There are two methods being used, the first being for minimal water exchange with larvae staying in the same tank throughout the cycle and until 3–5 mm size and the second being for full regular water exchange every 2 to 4 days until settlement, complemented or not with partial exchange. The full water exchange method is favoured in hatcheries (Fiji and Kiribati) with limited capacity for UV water filtration to keep copepod infestations under control.
- Settlement: Spirulina and/or Algamac coated plates are used in all hatcheries except in New Caledonia where they have stopped using plates. New Caledonia has also developed an effective technique to induce settlement.

Additional details for each hatchery is provided in Table 1. The productivity to 5 mm relative to the volume of each hatchery is comparable across facilities in PNG, Fiji and New Caledonia. A range of systems is being used across all hatcheries with production statistics available – hapa nets in ponds being the most effective techniques used in New Caledonia and Fiji.

The Fiji chapter concluded with the release of sandfish juveniles at Vitawa village (Figure 2), which was followed by a customary ceremony during which the village chief, the village head and elders, and our group of regional experts engaged in a question and answer session on sandfish restocking and the management of community-based marine protected areas.

Beche-de-mer farming in New Caledonia, a broader regional perspective

With a large-scale hatchery capable of producing in excess of 1 million sandfish juveniles per year, tens of hectares of ponds that are potentially available for stocking and sea ranching are still being investigated, and New Caledonia has the most advanced sandfish programme in the region. Participants were able to see all this during a series of visits to the hatchery, farms and beche-de-mer processing plant. This level of development is still a long way off for other countries in the region. The gap is not necessarily due to the production technology being applied – sandfish hatchery and grow-out technology is still fairly low tech and apart for some local variations, similar techniques are being used across all countries represented. What sets New Caledonia apart is the investment in a public–private partnership venture, the scale of the operations and the opportunities that exist for large-scale production using shrimp ponds and applying state-of-the-art processing techniques to craft a premium product that is able to demand higher prices. It helped for the participants to see this state of advancement and completed the picture of what is being done and what is possible in the region.

Figure 2. Releasing sandfish at the Vitawa village marine protected area, Fiji (Image: Michel Bermudes, SPC).

Figure 3. Workshopping a regional approach to common constraints to sandfish aquaculture (Image: Melinda Morris, SPC).

These last field visits set the backdrop for the first Regional Workshop on Sandfish Aquaculture for Restocking held in Noumea (22–23 November 2017) to conclude the exchange. The goal of the meeting was to identify gaps and potential solutions going forward.

Two main constraints were highlighted during the workshop:

1. Insufficient seed supply; and
2. Lack of effective model for sea ranching and restocking.

To address insufficient seed supply, participants suggested the creation of a working group to facilitate exchange, increase transfer of technology between countries and raise the pace of hatchery development in the region. Regarding the lack of an effective model for sea ranching and restocking, it is important to note that participants did not perceive this to be a technical issue but rather a challenge to address (at a governance level) the involvement of private operators, governments, NGOs and communities for developing integrated and harmonious models. Again, participants voiced the need for greater regional exchange on

Table 1. Information on the mode of operation and productivity of sandfish hatcheries in four countries of the Pacific region.

	Fiji	PNG	Kiribati	New Caledonia
No. of successful production cycles using current techniques	2/2	17/17	2/5	17/18
Broodstock	Wild from destination	Wild from destination	Wild from Fiji	4th generation
Production per cycle	30,000 @ 5 mm and 5000–10000 @ 5–10 g juveniles	50000 @ 5 mm juveniles	1000–5000 2 g juveniles	100,000 to 400,000 @ 5 mm (with ~70% survival to 2 g)
Hatchery size (volume of larval tanks)	8000 L	10,000 L	6000 L for larvae + 22,000 L of settlement raceways	Up to 90,000 L
Settlement	Plates in larvae tanks	Plates in larvae tanks	Plates in settlement raceways	No plates
Nursery to 5 mm	In larvae tanks	In larvae tanks	In settlement raceways	In larval tanks
Nursery to 1 g	Hapa nets in ponds	Raceways, nursery tanks, floating bag-nets	In settlement raceways	Hapa nets in ponds
Nursery to release	Hapa nets in ponds	Sand bag nets in pond and ocean	In settlement raceways	Hapa nets in ponds to 2 g and pond to 20 g
Release size	5–10 g	3 g	2 g	1.5 g for ponds, 15–20 g for sea ranching

this topic so that countries can learn from each other's experience.

Overall the regional exchange was full of lessons for the participants and for SPC as the organiser and facilitator of this event. For a start, this is a great model for technical and leadership capacity building, and for professional networking in the region. All participants came in with a positive attitude and were able to show case their country's experience in an environment that was conducive of sharing and learning from each other. Aquaculture is challenging and sea cucumber aquaculture probably even more so given the place and impact of sea cucumbers in the culture and politics of Pacific Island countries. In such an environment, for regional experts to continue working together will provide the necessary perspective for the development of sound and sustainable mariculture and sandfish sea ranching and restocking models.

Acknowledgments

First of all, we would like to acknowledge the funding assistance from the New Zealand Ministry of Foreign Affairs and Trade, which made this exchange possible. We also wish to acknowledge the special contributions by in-country colleagues who, unfortunately, could not be part of the whole journey. In particular, thank you to Thane Militz and Thomas Requillart for your openness and your assistance during in-country activities. A very special *vinaka vaka levu* to Teari Tekebo who shared so much of her knowledge and experience with participants during Fiji activities.

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SEACUSEY: Co-management of the sea cucumber fishery in the Seychelles (2017–2018)

Marc Léopold[1] and Rodney Govinden[2]

Project background

The sea cucumber fishery has been of major national importance to the Seychelles over the past 10 years, second only to the tuna industry. This fishery's sustainability has been an exception in the southwestern region of the Indian Ocean (Aumeeruddy and Payet 2004; Aumeeruddy et al. 2005), but a downward trend in catches has been observed in recent years (Figure 1). A formal co-management agreement between the Seychelles Fishing Authority (SFA) and the Association of Members of Seychelles' Sea Cucumber Industry (AMSSI) was in place from December 2013 through to 2017. The challenge now is to strengthen the governance process between the SFA, AMSSI, and the new Skipper and Fishermen Association through collaborative adaptive management.

In this context, the SEACUSEY project's specific objective is to define and implement operational sea cucumber fishery management measures that are appropriate for the resource's diversity, genetic structure, abundance, distribution and trends in the four main commercial species ('pentard' – *Holothuria* 'pentard'; white teatfish – *H. fuscogilva*; black teatfish – *H. nobilis*; and prickly redfish – *Thelenota ananas*).

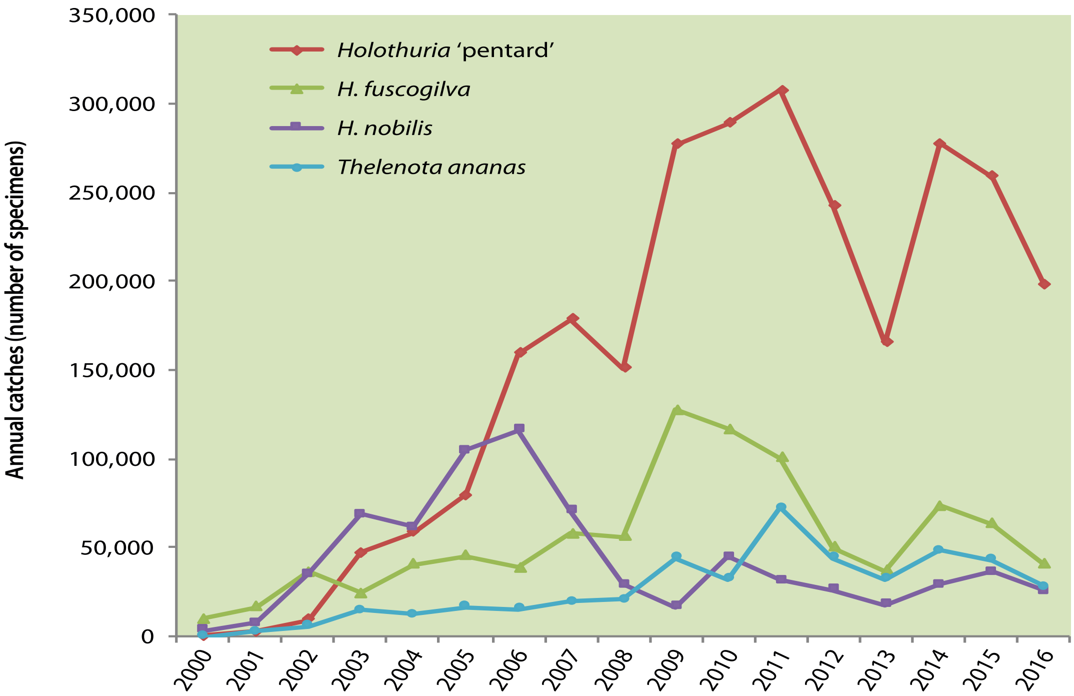


Figure 1. Catch trends (in number of specimens) for the four main commercial sea cucumber species from 2000 to 2016 (Source: SFA).

[1] The SEACUSEY project has received EUR 100 k in funding from the 10th European Development Fund's "Coastal marine biodiversity management of Indian Ocean Island States" programme, which is being managed by the Indian Ocean Commission. SEACUSEY is coordinated by the French Institute of Research for Development (IRD), in partnership with the Seychelles Fishing Authority (SFA), the Association of Members of Seychelles' Sea Cucumber Industry in (AMSSI) and the University of Reunion Island.

[2] French Institute of research for Development (IRD) - marc.leopold@ird.fr
[3] Seychelles Fishing Authority - rgovinden@sfa.sc

Project content

Part 1. Characterising sea cucumber diversity and genetic structure throughout the Seychelles

Although sea cucumber species in the Seychelles have been subject to intense commercial fishing since the late 1990s, curiously little is known about them (Aumeeruddy 2007; Aumeeruddy and Conand 2008). SEACUSEY proposes to analyse the genetic and biological characteristics of these resources in order to support the co-management process. More specifically, samples will be collected in 2018 from on-board commercial fishing boats in order to determine: 1) the size at sexual maturity of the four main commercial species; and 2) the spatial structures of their populations by analysing their microsatellite DNA markers. This information will be used to both implement appropriate minimum catch sizes and determine possible management units for these species, given that in the Seychelles the fishing grounds are spread over several thousand square kilometres.

Part 2. Proposing co-management measures as part of an adaptive approach

An experiment has made it possible to measure fishers' catches under real conditions using a sea cucumber density gradient. A statistical model was developed and will be applied to fishing logsheet data in order to statistically estimate the main commercial stocks' abundance and distribution. With this in mind, the project will get fishers more involved in both the fishery monitoring system and in producing resource status indicators, via the development of an electronic logbook. A smartphone application (via the Open Data Kit: http://docs.opendatakit.org/collect-intro/) will allow skippers to accurately record relevant dive-fishing data faster and with a lower risk of error. An information system (BDMer, see Léopold 2014 for

Figure 2. The SEACUSEY project mobilises stakeholders and vessels from the sea cucumber fishery and the SFA to carry out experimental fishing (B, C, D) and study the main commercial species' genetic structure and size at maturity (A).

a previous version) hosted on the SFA server will carry out semi-automatic downloading and storage of these data, which will then undergo routine analysis by a dedicated web application so as to estimate sea cucumber abundance.

By strengthening the fishery's technical capacities and optimising management costs, the project will support the SFA's management role in collaboration with the sector's stakeholders. Over the longer term this will inform discussions about the relevance of a future national sea cucumber fishery co-management plan. A national workshop will be held in the Seychelles in August 2018 to evaluate the outcomes of these actions, possible extensions and interactions that could be considered with other countries in the region.

For further information on project progress, see http://seacusey.ird.nc/.

References

Aumeeruddy R. 2007. Sea cucumbers in Seychelles. pp. 41–52. In: Conand C. and Muthiga N.A. (eds). Commercial sea cucumbers: a review for the Western Indian Ocean. WIOMSA Book Series No. 5.

Aumeeruddy R. and Conand C. 2008. Seychelles: a hotspot of sea cucumber fisheries in Africa and the Indian Ocean region. pp. 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 516.

Aumeeruddy R. and Payet R. 2004. Management of the Seychelles sea cucumber fishery: status and prospects. pp. 239–46. 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.

Aumeeruddy, R., Skewes, T., Dorizo, J., Carocci, F., Coeur de Lion, F., Harris, A., Henriette, C. and Cedras, M. 2005. Resource assessment and management of the Seychelles sea cucumber fishery. FAO Project Number: TCP/Seychelles/2902(A). 37 p.

Léopold M. 2014. BDMer Version 2.0 User Guide. 74 p. [http://bdmer.ird.nc/index1.php?lang=en&pays=vnt] Accessed 14 March 2018.

Spawning observations

Australia

Species: ***Stichopus herrmanni***

Location: One Tree Island, Great Barrier Reef, Queensland, Australia.

Date and time: Late spring (November) through to summer (December to February), typically in January near sunset (17:30–18:30 local time – AEST).

Moon phase: Spawning was most common the day following the new moon.

Observers/Photographers: Maria Byrne and Kennedy Wolfe

Notes: Individuals climbed up coral bommies to elevated spawning locations. Males spawned before females. Small fishes ambushed the anterior end of spawning individuals, consuming the gametes that were released.

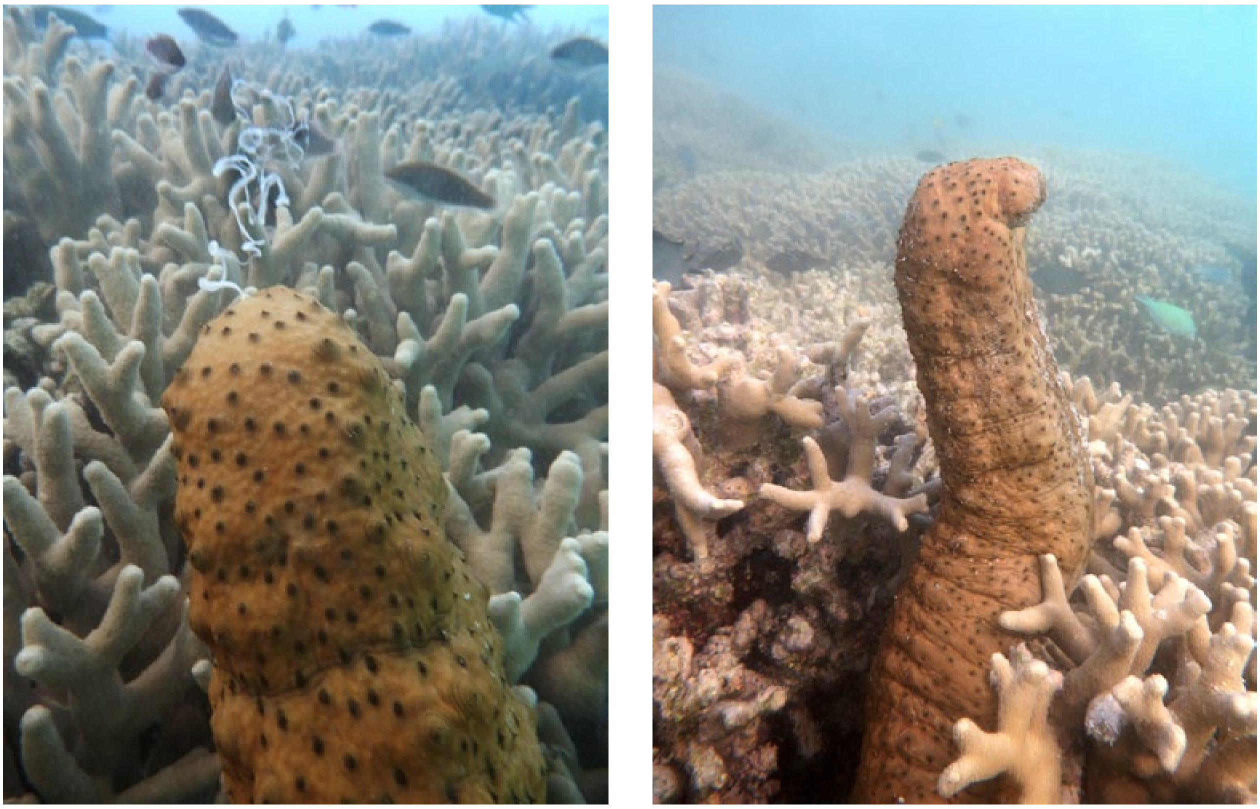


Figure 1. Broadcast spawning behaviour of *Stichopus herrmanni* showing (left) the erect posture typical of spawning holothuroids, and (right) a male releasing sperm which attracts small fishes. (Photos: Maria Byrne and Kennedy Wolfe).

Mediterranean Sea

Species: ***Holothuria tubulosa***

Location: Colera, Punta Negra, Mallorca, Balearic Islands, Spain.

Date and time: 2 July 2017, 17:00 local time – (CEST).

Observers/Photographers: Frederic Champagnat and J. Moisson

Notes: The site is a rockslide followed by a slope, up to a *Posidonia* seagrass bed at 20 m depth on a sandy bottom.

Many individuals were spawning, showing the same behaviour, some at 20 m depth and several others between 12 and 15 m.

Figure 2. Male *Holothuria tululosa* spawning. (Photo: J. Moisson).

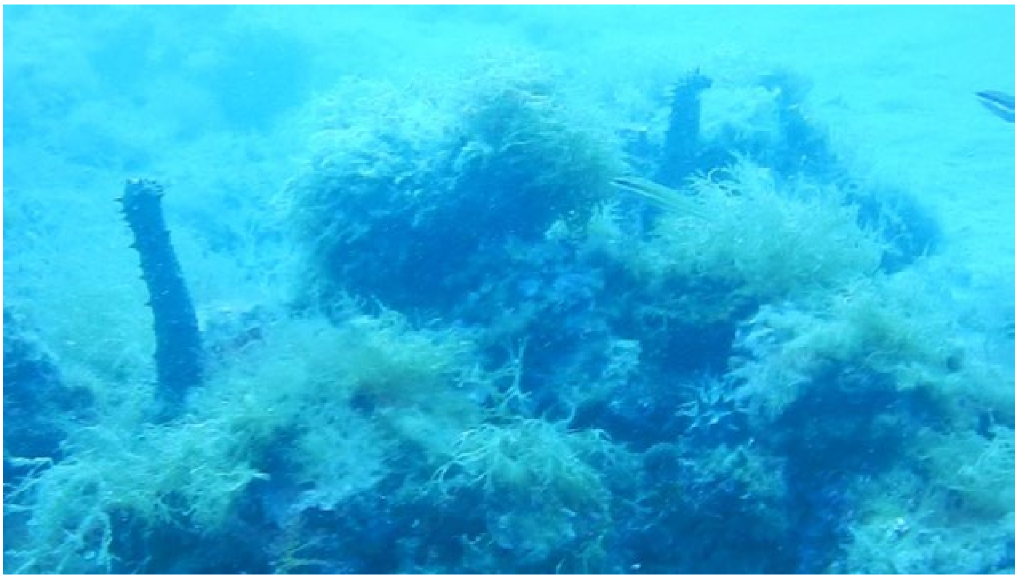


Figure 3. Several *H. tubulosa* showing typical erected spawning behaviour. (Photo: J. Moisson).

COMMUNICATIONS

2017 conferences

Costa Rica (see *SPC Beche-de-Mer Bulletin 37*)

Communication from Juan José Alvarado

Access to the new supplement from Revista de Biologia Tropical, Proceedings of the 3 Latin-American Echinoderm Conference, San Jose, Costa Rica, 2016, is available at: http://rediberoamericanaequinodermos..com/2017/10/29/estudios-latinoamericanos-en-equinodermos-iv/

8th North American Echinoderm Conference Worcester, Massachusetts, USA. 9–13 July 2017

Presentations on holothurians

- Population density and spatial arrangement of two holothurian species in a coral reef system: is clumping behavior an anti-predatory strategy?
  Sanvicente Añorve L., Solís-Marín F.A., Solis-Weiss V. and Lemus Santana E.
- Echinoderm diversity in Chamela Bay, Jalisco, Mexico (North East Pacific).
  Solís-Marín F.A., González Moguel P., Savarino Drago A., Pardo Granillo, I, Laguarda-Figueras A. and Durán González A.
- The potential for isolation and characterization of collagen from the body wall of sea cucumbers in Mexico.
  Salgado-Ortiz N., Arreguín Espinosa de los Monteros R., Conejeros-Vargas C.A., Simental Crespo D., Solís-Marín F.A. and Caballero-Ochoa A.A.
- Baja California Peninsula echinoderm biodiversity and distribution.
  Caballero-Ochoa A.A., Conejeros-Vargas C.A., Solís-Marín F.A., Laguarda-Figueras A. and Rivas Lechuga G.
- Understanding the color variability and confusion of the valuable sea cucumber *Isostichopus badionotus* (Echinodermata: Holothuroidea) based on mitochondrial DNA, morphology and habitat preferences
  Borrero-Pérez G.H., Solís-Marín F.A. and Lessios H.
- Cloning starfish larvae and the discovery of the adult in the life cycle by virtue of collaboration in the echinoderm community.
  Janies D., Solís-Marín F.A., Hernández Y.Q. and Codd J.
- Effect of burrowing sea cucumbers, *Holothuria arencicola*, on seagrass beds in Abaco, Bahamas
  Boyd L., Stoner E., Murata P., Archer S., Comer Santos K., Heithaus M. and Whitman E.

Highlights from the World Aquaculture 2017 Conference

Communication from B. Gianasi, C. Hair and G. Robinson

On 28 June 2017, sea cucumber experts from around the world met up in Cape Town, South Africa at the World Aquaculture 2017 conference to discuss the latest developments in hatchery technology, grow-out systems, stock enhancement, processing and markets. The sea cucumber session, chaired by Dr Georgina Robinson and Cathy Hair, was one of the largest sessions at the conference with a total of 14 oral presentations and four poster presentations (listed below). The session was well attended and attracted a great audience throughout the day. The talks covered a variety of topics, which included the optimisation of diets for larvae, juveniles and adults of *Holothuria arguinensis* and *H. scabra*, determination of growth and survival in floating hapa nets and different sea ranching sites, as well as the effect of stocking density and the stress physiology of *H. scabra*. A presentation about morphometrics and behaviour changes of early juveniles of the cold-water sea cucumber *Cucumaria frondosa* was also given. Geographic information system (GIS) was proposed as an effective low-cost technique to assess potential areas suitable for culturing *H. scabra* in Papua New Guinea. Two presentations highlighted the challenges of polyculture between *H. scabra* and Pacific white shrimp, and *Apostichopus japonicus* and tunicates. Finally, there was a presentation on the potential to harness the interaction of *H. scabra* and sediment bacterial communities in sediment-based aquaculture bioremediations systems to treat effluent from land-based aquaculture.

At the end of the session, a discussion forum was held with participation from the session presenters and the audience in order to identify potential bottlenecks for the sea cucumber production and to brainstorm future research directions. The availability of broodstock for spawning, survival of juveniles in grow-out systems and diet composition were the main areas of the discussion. Following the discussion forum, the sea cucumber meeting was successfully closed with a poster session highlighting information about: 1) the environmental control of gametogenesis and egg quality in the cold-water sea cucumber *Cucumaria frondosa*; 2) the nutritional value of *Holothuria scabra* in Fiji Islands; 3) the role of microbiome in regulating growth of *H. scabra*; and 4) the performance of floating hapa bag nets for rearing juvenile sandfish, *H. scabra*, in central Philippines.

Oral presentations

- Establishing the baseline of sea cucumber aquaculture in Europe
  Domínguez-Godino, J.A. and González-Wangüemert, M.
- Detecting thermal shock and acclimation in the sea cucumber *Holothuria scabra*, using a multiple biomarker approach
  Kuehnhold H., Slater M.J., Kamyab E., Novais, S.C., Lemos M.F., Indriana L. and Kunzmann A.
- A new approach to feeding larvae and early juveniles of sandfish *Holothuria scabra* supporting simplified hatchery culture methods
  Duy Nguyen Dinh Quang and Southgate P.C.
- Morphometric and behavioural changes in the early life stages of the sea cucumber *Cucumaria frondosa*
  Gianasi B.L., Hamel J-F. and Mercier A.
- The microbiome is the nexus between sediment bioremediation and deposit feeder growth
  Robinson G., Reid W.D.K., Nelson A., Jones C.L.W., Rushton S.P.R., Stead S.M. and Caldwell G.S.
- Understanding bio-physical variability in sea cucumber ranching sites in the Philippines
  Altamirano J., Juinio-Meñez M.A., Uy W., dela Cruz M., Rodriguez B.D.R., Hair C. and Mills D.
- Using GIS classification methods to predict suitable habitat for sea ranching of cultured sandfish *Holothuria scabra* in Papua New Guinea
  Hair C., Wood P. and Southgate P.C.
- Farming model changes and their rationale after experimental trials and 7 years project history farming *Holothuria scabra* in sea pens in south-west Madagascar
  Klückow T.M. Gough C. and Humber F.
- Effect of biomass density, handling stress, and non-fallowing of sediment on the growth and survival of *Holothuria scabra*
  Klückow T.M.
- Growth of sandfish *Holothuria scabr*a juveniles during an ENSO
  Gamboa R. Bulseco R. Concepcion L. Aurelio R. and Abreo N.A.
- Polyculture of sandfish *Holothuria scabra* and Pacific white shrimp *Litopenaeus vannamei* – A viable approach for a sustainable future?
  Spreitzenbarth S. and Slater M.
- A study of the polyculture of the sea squirt *Halocynthia roretzi* and sea cucumber *Apostichopus japonicus* under a hanging culture system
  Young Dae Kim, Mi Seon Park, Yun Kyung Shin, Myoung Ae Park and Yong Hyun Do
- Microbial–Deposit feeder aquaculture bioremediation systems
  Robinson G.
- Short term approach to epidemiology of skin disease in the new target species for aquaculture in Europe *Holothuria arguinensis*
  Cánovas F.G., Domínguez-Godino J. and Mercedes González-Wangüemert M.

Poster presentations

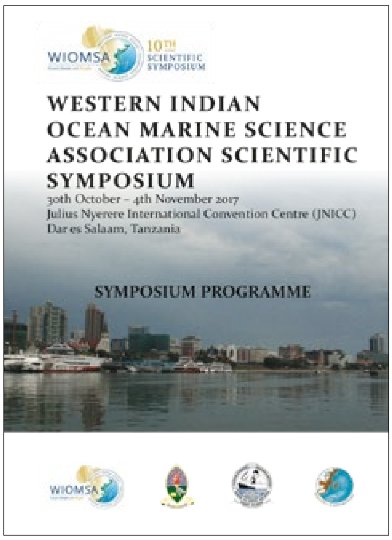
- Environmental control of gamete production, spawning, and egg quality in the sea cucumber *Cucumaria frondosa*
  Gianasi B.L., Hamel J-F. and Mercier A.
- Nutritional value of the sea cucumber Holothuria scabra from the Fiji Islands
  Ram R., Chand R.V. and Southgate P.C.
- Rearing performance of floating hapa bag nets for juvenile sandfish Holothuria scabra in central Philippines
  Noran R.D., Altamirano J.P. and Recente C.P.
- The microbiome is the nexus between sediment bioremediation and deposit feeder growth
  Robinson G., Reid W.D.K., Nelson A., Jones C.L.W., Rushton S.P., Stead S.M. and Caldwell G.S.

Participants to the World Aquaculture 2017 Conference.

Indo-Pacific Fish Conference

Information available at: https://ipfc10.sciencesconf.org

WIOMSA 10th International Scientific Symposium



Dar es Salaam, Tanzania (30 October–4 November 2017)

Oral presentations on holothurians (Session XXII: Sea cucumber: Ecology and management options)

- Estimating sea cucumber resource abundance in the Seychelles using spatially-explicit fishery-dependant data
  Leopold M., Govinden R. Caquelard J. and Bach P.
- Effect of biomass density, handling stress, and non-fallowing of sediment on the growth and survival of *Holothuria scabra*
  Klückow T.M. and Donah A.
- Clonal structure through space and time in Reunion Island: high stability in the holothurian *Stichopus chloronotus* (Echinodermata)
  Pirog G., Bédier, B., Georget F. and Magalon H.

- The effect of exploitation on reproductive potential of *Holothuria scabra* in Tanzanian coastal waters
  Mmbaga T.K., Mgaya Y.D. and Ndaro S.G.M.

Posters

- Marine biodiversity of Reunion Island: Echinoderms
  Conand C., Ribes-Beaudemoulin S., Trentin F., Mulochau T. and Boissin E.

XIth International Larval Biology Symposium

Honolulu, Hawaii (10–13 August 2017)

With, among others, Dustin Marshall, Peter Marko, Mary Sewell, Maria Byrne, Brian Nedved, Megan Hintz, Donald Kobayashi and Jeff Shima.

Participants to the XIth International Larval Biology Symposium.

Up-coming conferences

16th International Echinoderm Conference, Nagoya, Japan

Information available at: http://www.num.nagoya-u.ac.jp/iec16/

It is our great pleasure to announce that the 16th International Echinoderm Conference will be held in Nagoya, Japan from 28 May to 1 June 2018. This is the second IEC in Japan since the 7th conference was held in Atami in 1990. We have already received many inquiries and comments about this conference, for which we are very thankful.

Nagoya is a big city located between two large cities, Tokyo and Osaka, and is located in the central part of Japan. The Chubu Centrair International Airport (code NGO) is a convenient distance from Nagoya, and takes less than one hour by train to the city centre. There are direct flights from many Asian cities, Europe and USA. Nagoya is also connected to Tokyo, Osaka and other cities by Shinkansen (bullet trains, JR system). Therefore, if you plan to extend your stay in Japan and would like to visit other cities such as Tokyo or Kyoto etc., you can use other airports in Japan.

3rd Aquaculture Conference: Recent Advances in Aquaculture Research

Date and location: 25–28 September 2018 at the Hyatt Regency Qingdao, China

The conference will bring together top senior scientists in all of aquaculture's disciplinary, interdisciplinary and transdisciplinary research areas.

Download the preliminary programme available at: https://www.elsevier.com/events/conferences/aquaculture/programme

International Conference Co-Chairs

Barry Costa-Pierce, *University of New England, US*

Wenbing Zhang, *Ocean University of China, China*

4th World Conference on Marine Biodiversity

13–16 May 2018, Montréal, Québec, Canada

4th WCMB Congress Secretariat – JPdL International

1555 Peel Street, Suite 500 Montréal, QC H3A 3L8 Canada

Tel: +1 514 287-9898 (ext. 334); Fax: +1 514 287-1248; wcmb2018secretariat@jpdl.com

Abstract submission is now open for the 4th world conference on marine biodiversity in Montreal in May 2018. Available at: http://wcmb2018.org/call-for-abstracts.html

You can register for the WCMB newsletter at: https://visitor.eliteemail.net/WCMB/signup

Registration is also open at: http://wcmb2018.org/registration.html

ICRS14

The Society is pleased to announce that the next Global International Coral Reef Symposium will be held in Bremen, Germany, in the first or second week of July, 2020.

After the great success of ICRS13 in Honolulu, Hawaii, it is anticipated that very large numbers of members and others will be eager to attend.

But if you cannot wait until then, note that a number of ISRS regional meetings are expected to take place in 2018. For details see the ISRS website at: www.coralreefs.org.

Call for collaboration from Kim Friedman (FAO Senior Fishery Resources Officer)

Development of new digital technologies for fish identification and request for species imagery (sharks and rays, tuna, billfish, **sea cucumbers**, ornamental fish of the aquarium trade)

Dear sea cucumber colleagues,

FAO's Fisheries and Aquaculture Department services the needs of fisheries as a global information provider of species identification materials. This service gives knowledge to fishers and assists countries in documenting catches and landings of commercially exploited aquatic resources, as well as information on other species of interest to fisheries.

In order to assess the potential for moving FAO's (and willing collaborators) species identification and dissemination processes from traditional methods to one that exploits modern machine learning digital techniques, FAO is seeking to establish a collaborative workgroup ('FishFinder 2.0 Development Platform'), where interested individuals and groups (fisheries, taxonomy and IT experts) can work together on the development of more automated species identification systems.

FAO has taken some first steps in this approach, and has been running a study to identify opportunities that such digitised systems could bring by collecting ideas and requirements from staff members at FOA (including a questionnaire sent to Regional Fisheries Bodies), IT services and the systematics/taxonomic ichthyological community at large. FAO is also detailing knowledge on the current status of machine learning and other related IT technologies that could help us progress the above objectives – the capabilities of which would form part of any future digitised system.

The aim is for FAO is to help coordinate this work – with the suggestion of an inaugural meeting in 2018 to bring interested parties together – to assess the current opportunities and define a path forward. In preparing for such an approach, FAO has also set aside some funds for developing a test mobile application that is provisionally named 'FishID' (a prototype app for development over the short term), which should help inform collaborators of the opportunities, challenges and knowledge gaps in using digital technologies for species identification.

This memo is a chance to inform everyone of the direction that FAO is taking, but also to reach out and see if anyone can assist with the short-term development of the app. For help with this latter task we are looking for fish images. We need images so that we can to run tests and are reaching out to ask if you or someone you know has access to 200+ images of a fish species, so that we can use those images to train machine learning algorithms in terms of recognising fish species from images. The results of this test will then be jointly reviewed in 2018.

At present, the specifications for the images that we are asking for are as follows:

- Fish species most targeted are: sharks and rays, tuna, billfish, **sea cucumbers**, ornamental fish of the aquarium trade.
- Each image must have a reliable species ID.
- Repeats of the same fish are possible if images are taken from different angles, although images of different fish of the same species that are taken from across its range are naturally preferable if we are to test the system.
- Image format: preferably jpg images (since the compression is much higher, so the size is much smaller) that are in excess of 50 KB (normally the size ranges from 300 KB to 1.5 MB). We will crop and resize the pictures, so they are suitable for training.
- The fish in the image is in focus and not obstructed by other articles or within/on top of other fishes.
- The image of the fish should preferably be in a natural type position (not crumpled or bent, or cut and frozen, underwater, in poor visibility conditions, etc.).

- Please alert FAO to any picture 'sets' that you have and are willing to share for such training purposes. FAO has set aside funds to cover the extra costs that might be associated with collating such image sets, which can be discussed on a case-by-case basis. To be able to proceed with short-term development of a test app, FAO will need to be given permission from you, the owner of the images for their use. FAO is not asking to hold copyright over individual images; however, FAO would need to hold copyright over the 'repository collection' for the purpose of testing machine learning systems. The image 'repository collection' may be shared freely under a Creative Commons license in the future, which permits sharing, provided FAO is acknowledged as the source and copyright holder of the collection, and that the owner of the individual image is also properly acknowledged.

So to summarise, the short term plans that FAO has are as follows:

- To collect images of fish from experts (we aim at some 200+ or up to 500 images per species) for the running of a number of tests as part of a test app.
- Images would be stored in a temporarily 'closed' repository (only accessible to selected data-manager and computing algorithms – individual images will not be published).
- The test app would go into production as soon as the images are collated, using image 'sets' that are provided to run many tests.
- FAO would then like to bring like-minded experts together for a meeting in 2018 (if we can acquire sufficient funds), to exchange what we know and have learnt, and try to articulate a development pathway for any future work.

Looking further into the future, FAO would continue to work jointly with the collaborators of the Fish-Finder 2.0 Development Platform, to:

- develop easy to use but more sophisticated digital systems to facilitate species recognition from digital imagery, and well resolved Artificial Intelligence tools that could either: i) suggest a species name; ii) request a further more defined image; and iii) deliver a truncated dichotomous tree to facilitate species identification, once an image is uploaded into such a system.
- start to link these types of apps and tools into practical work flows (e.g. 'smart' forms, recreational and non-commercial/artisanal reporting), but importantly, always focusing on assisting countries to document catches and landings of exploited aquatic resources, as well as other species of interest to fisheries.
- develop related tools, such as ones that recognise and identify fish diseases.

Thanks in advance for getting in touch to highlight your interest in offering image 'sets' or for suggesting other potential source(s) of imagery or assistance (email Kim.Friedman@fao.org or Anton.Ellenbroek@fao.org). If you are able but do not have sufficient images of a particular species then even sharing what you do have through Dropbox would be much appreciated, and I will try and build the sets of 200 for two to five common species for the test.

Kim Friedman

F602, Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations (FAO), Vialle delle Terme di Caracalla, 00153 Rome, Italy

Tel: +39 06 570 56510 / Skype: kim.j.friedman / Kim.Friedman@fao.org

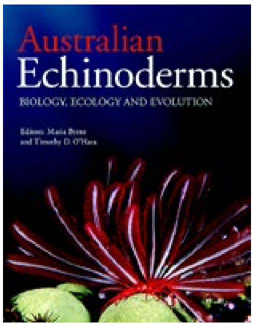
Food and Agriculture Organization of the United Nations

Books and other information

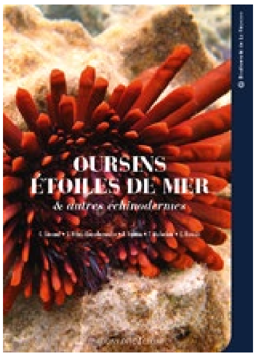
(communicated by Chantal Conand)

New books

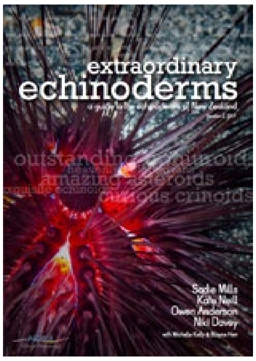
Information on new books with a chapter on holothurians



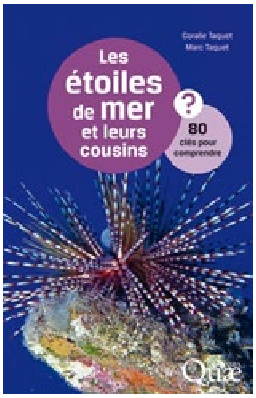
Australian echinoderms
Maria Byrne and Timothy D. O'Hara (eds)
More information at: http://www.publish.csiro.au/book/6484/



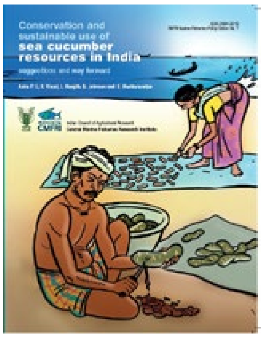
Oursins, étoiles de mer et autres échinodermes [in French only]
C. Conand, S. Ribes-Beaudemoulin, F. Trentin, T. Mulochau and E. Boissin
More information at: http://www.editions-ducyclone.fr/product/oursins-etoiles-de-mer-autres-echinodermes/



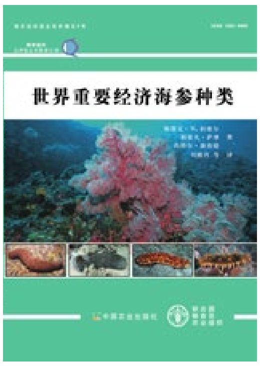
Extraordinary echinoderms: A guide to the echinoderms of New Zealand
S. Mills, K. Neill, O. Anderson and N. Davey
Available from: https://www.niwa.co.nz/static/web/MarineIdentificationGuidesandFactSheets/Extraordinary_Echinoderms_Vers2.0_2017.pdf



Les étoiles de mer et leurs cousins: 80 clés pour comprendre [in French only]
M. Taquet and C. Taquet
More info at: http://www.quae.com/fr/r4868-les-etoiles-de-mer-et-leurs-cousins.html



Conservation and sustainable use of sea cucumber resources in India
P.S. Asha, K. Vinod, L. ranjith, B. Johnson and E. Vivekanandan
Available from: http://eprints.cmfri.org.in/11957/1/Sea%20cucumber.pdf



Publication of a Chinese version of the FAO book **Commercially important sea cucumbers of the world**
S.W. Purcell, Y. Samyn and C. Conand
English version available from: http://www.fao.org/docrep/017/i1918e/i1918e.pdf/

Information from Madagascar posted by Ben Parker

Mama Bevata: Tampolove's new security watchtower: Sea cucumber farmers in Tampolove are now protected by a state of the art watchtower designed to deter potential thieves from making off with valuable stock.

Available from: https://blog.blueventures.org/mama-bevata-tampoloves-new-security-watchtower/

Sea cucumber pictures

Sulawesi, Indonesia

Sea cucumbers (Stichopodids) drying at Bunaken in Indonesia
(Photo: Narp, 2017).

Melbourne, Australia

Frozen sea cucumbers at the Victoria market (Photo: G. Conand).

Publications related to holothurians published in 2017

Chantal Conand

A 'Google Alert' using the word 'holothurian' has been set up for the period from January to 15 December 2017. 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* #36. Table 1 presents a summary of the findings and uses the same five categories (themes) that were used in 2015.

Table 1. Number of documents related to 'holothurians' published in the period 1 January to 15 December 2017.

Month	General, ecology, biology	Biochemistry, microbiology	Genetics	Aquaculture	Fishery, socio-economics	Total per month
January	12	11	4	7	9	43
February	14	17	4	4	3	42
March	12	14	3	6	7	42
April	10	21	1	6	10	48
May	11	17	2	5	13	48
June	10	14	7	2	8	41
July	8	18	4	2	10	42
August	14	11	3	5	4	37
September	15	21	5	5	6	52
October	13	15	4	7	6	45
November	5	15	8	5	8	41
December (partial)	4	6	1	1	3	15
Total	**128**	**180**	**46**	**55**	**87**	**496**
Ratio (%)	**26%**	**36%**	**9%**	**11%**	**18%**	**100%**

The total number of references – nearly 500 – shows the interest for the subject among scientists. It is not significantly different from the 2015 count (413 references listed for the period March to December 2015).

The ratios of documents for the five categories remain quite similar to that of 2015, and once again the highest ratio was found for the biochemistry and microbiology category, followed by the general, biology and ecology category.

[1] http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/BDM/36/BDM36.pdf

PhD thesis

Study of the reproductive biology and chemical communication of sea cucumbers (*Holothuria arguinensis* and *H. mammata*)

Nathalie Marquet *(defended on the 24 November 2017 at the University of Algarve, Portugal)*

Supervisors: Prof Adelino V.M. Canário, Dr Peter C. Hubbard and Dr Mercedes González-Wangüemert

Abstract

New sea cucumber fisheries are emerging in the Mediterranean Sea and Atlantic Ocean in response to a strong demand from the Chinese market. However, little is known about the biology of the new target species, which is hindering decisions on their management. The main objective of the present thesis was to study the reproductive biology and the role played by chemical communication and chemosensory systems in *Holothuria arguinensis* and *Holothuria mammata*. The different populations that were sampled in a narrow range along the Iberian Peninsula varied in size/weight, gonadal production, and maturity profile within each species, which suggests the influence of singular features of each location. However, they all had the same general reproductive pattern – summer–autumn spawning. These results, which are essential for managing populations, are also useful for determining when to develop bioassays to test whether and how these species communicate during reproduction. Male sea cucumbers, but not females, release chemicals that attract and induce spawning in both sexes. A preliminary analysis of the male spawning water suggests a pheromone with multiple components, among them possibly phosphatidylcholine derivatives. Histology, histochemistry and immunohistochemistry of the potential chemosensory structures involved in the detection of these cues – tentacles, papillae and tube feet – show no obvious differences between them. However, the disc was the most specialized area, with a specific nerve arrangement that was rich in nitric oxide synthase and contained numerous cells, some of which are likely to be sensory neurons. The analysis of tissue transcriptomes revealed the presence of at least 591 G-protein coupled receptors, and, among them, at least seven putative odorant receptors that were distributed mainly in the tentacles, oral cavity, calcareous ring and, papillae and tegument. Overall, this thesis gives valuable insights into managing sea cucumbers from the region and to better understand how sea cucumbers communicate during reproduction.

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