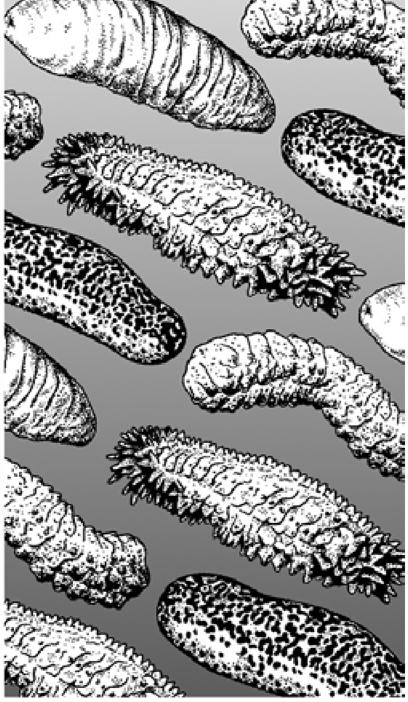

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Inside this issue

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Editorial

This 36th issue of the SPC *Beche-de-mer Information Bulletin* has 13 original articles relating to the biodiversity of sea cucumbers in various areas of the western Indo-Pacific, aspects of their biology, and methods to better study and rear them.

We open this issue with an article from Steven Purcell and coworkers on the opportunity of using rotational zoning systems to manage multispecies sea cucumber fisheries. These systems are used, with mixed results, in developed countries for single-species fisheries but have not been tested for small-scale fisheries in the Pacific Island countries and other developing areas.

The four articles that follow, deal with biodiversity. The first is from Frédéric Ducarme, who presents the results of a survey conducted by an International Union for Conservation of Nature mission on the coral reefs close to Ari Atoll in Maldives. This study increases the number of holothurian species recorded in Maldives to 28. Chantal Conand and colleagues detail the distribution of holothurians in the shallow lagoons of the two marine parks of Mauritius, and compare it to previous studies. Ahmed Quratulan and coworkers give some new insights into the knowledge of holothurians from Pakistan. And, finally, Vadim Stepanov and Elena Panina provide a checklist of holothurians from far eastern Russia.

The two following articles relate to juveniles and natural nurseries. Luca Palazzo and colleagues report their discovery and identification of *Stichopus herrmanni* nursery sites on Heron Reef (Great Barrier Reef, Australia); while Philippe Bourjon and Elisabeth Morcel describe 70 observations of juvenile holothurians made in 2014 and 2015 on Réunion reefs.

The ninth and tenth articles detail particular aspects of holothurian biology. Philippe Bourjon and Sébastien Vasquez provide an excellent description (and a link to a superb movie) of predation of the gastropod *Tonna perdix* on *Actinopyga echinites*. Kier Mitchel Pitogo and colleagues surveyed the size distribution of a *Holothuria scabra* population during full moon and new moon phases for four months to evaluate the intertidal population of this species in the Philippines. The results suggest that lunar phases have an effect on the size distribution of *H. scabra*, which explains the larger individuals collected by intertidal gleaners during a new moon.

The last four articles are about aquaculture methods, beche-de-mer processing, and a method for marking holothurians. Andrea Taylor reports on a modification to Purcell and coworkers' original marking method, to improve efficiency and reduce the likelihood of sample loss and cross-contamination. Steven Purcell and colleagues evaluate the postharvest processing of sea cucumbers, and compare methods used by fishers and commercial processors from Fiji, Kiribati and Tonga. Devarajen Vaintiligon and coworkers report on the production of *H. scabra* in a hatchery established in Malaysia, which is the result of a fruitful collaboration between the Malaysian government and an Australian-based private company. Finally, Fidèle Rakotonjanahary and colleagues describe the results of experiments to optimise juvenile growth in nursery ponds.

This issue also reports on new observations of juvenile black teatfish in Maldives (Michael Sweet et al.) and *Actinopyga* juveniles in Réunion (Bourjon and Morcel). Cathy Hair and her colleagues observed multispecies spawning in Papua New Guinea, and Wensy Vergana and others describe the poorly known *Carapus bermudensis* that infests *Isostichopus badionotus* on the Colombian Caribbean coast.

The last section of this issue includes communications about workshops and conferences that were held in 2015 and some that will take place in 2016. In addition, Choo Poh-Sze and colleagues give us the recipe for a salad (*kerabu*) dish that includes raw sea cucumber (*beronok*) and is popularly eaten on Langkawi Island in Malaysia; Igor Eeckhaut and Nathan Puozzo introduce a computer program designed for better understanding the body plans of metazoans, including holothurians; and Hal Koike reports incidents involving possible overharvesting of sea cucumbers in Hawaii and serious *Apostichopus japonicus* poaching in Japan. We close this 36th issue of the Bulletin with a request from Chantal Conand for information on illegal sea cucumber fisheries.

Congratulations are expressed to Mélanie Demeuldre who completed her PhD titled "Defence mechanisms in sea cucumbers: Morphology, biochemistry and mechanics of Cuvierian tubules in two species from the genus Holothuria". Last but not least, I want to thank our extraordinary and tireless Chantal Conand, without whom this issue would not have been produced.

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 bulletins will now only be produced in digital format and remain accessible from SPC's website at:

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

PIMRIS is a joint project of five international organisations concerned with fisheries and marine resource development in the Pacific Islands region. The project is executed by the Pacific Community (SPC), the Pacific Islands Forum Fisheries Agency (FFA), the University of the South Pacific (USP) and the Pacific Regional Environment Programme (SPREP). This bulletin is produced by SPC as part of its commitment to PIMRIS. The aim of PIMRIS is to improve the availability of information on marine resources to users in the region, so as to support their rational development and management. PIMRIS activities include: the active collection, cataloguing and archiving of technical documents, especially ephemera ('grey literature'); evaluation, repackaging and dissemination of information; provision of literature searches, question-and-answer services and bibliographic support; and assistance with the development of in-country reference collections and databases on marine resources.

PIMRIS
Pacific Islands Marine Resources Information System

Rotational zoning systems in multi-species sea cucumber fisheries

Steven W. Purcell[1,], Hampus Eriksson[2,3] and Maria Byrne[4]*

Abstract

Rotational zoning systems (RZSs) have been applied as a spatial management tool for fisheries in developed countries. Fishing grounds are divided into numerous plots and assigned a cyclical periodicity for harvest. This is a distinct spatial management measure that differs from more common measures in the tropics, like periodic closures or marine protected areas. We find that biological prerequisites for rotational closures are tenuous for many tropical reef species, and they are likely to put stocks of threatened species at further risk. RZSs can be successful if enough is known about the biology and ecology of target species, if the rotational cycles are long enough to allow population recovery, and if there is enough technical capacity to plan, implement and enforce management measures. However, RZSs are likely to fail in small-scale fisheries in the Pacific Islands and low-income countries owing to a combination of modest technical capacity for planning and monitoring, weak enforcement, complex access rights to fishing grounds, and high numbers of fishers.

Introduction

Rotational zoning systems (RZSs) are a relatively new management tool for sea cucumber fisheries. They have been called "rotational zoning systems" (Lowden 2005), "rotational harvest closures" (Purcell 2010) and "rotational zone strategies" (Plagányi et al. 2015).

The concept of RZSs is to subdivide fishing grounds into zones, and nominate zones to be fished in a certain year but not other years, in a cyclical fashion. For example, one-third of the zones are fished in the first year, the second third of the zones are fished in the second year, and the last third of zones are fished in the third year; then the cycle is repeated. This allows populations in each zone to be unfished for two years after each year of fishing. Such a scheme has been practised since 2004 on the Great Barrier Reef (GBR), where a portion of the fishing grounds is divided into 156 zones (Lowden 2005) (Fig. 1). These zones on the GBR have a broad range of shapes and sizes.

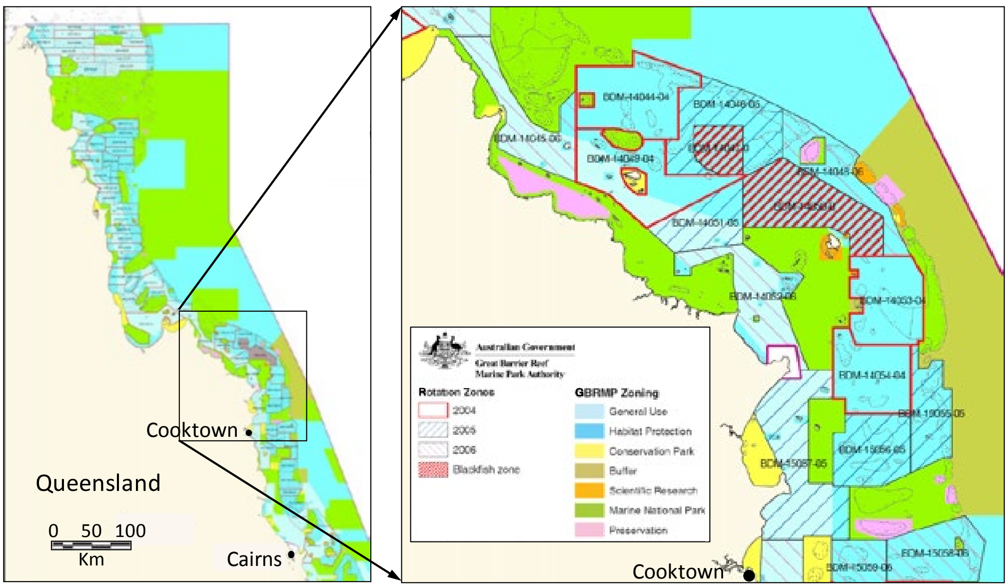

Figure 1. Northern section of the Great Barrier Reef (left), with enlarged section showing rotational zones of the east coast sea cucumber fishery in the Cooktown region (right). At least 15 species can be fished in plots every 3 years in the rotational cycle. Map courtesy of the Great Barrier Reef Marine Park Authority, with modification.

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Canada began a rotational-style fishery for its Pacific region sea cucumbers in 1993 but moved to an annual style fishery in 1997 (DFO 2014) (Fig. 2). Following a review, the Pacific region fishery returned to a three-year rotational style fishery in 2011. As on the GBR, some portions of the coast are closed to fishing. The fishery also relies on stock assessments, through research collaboration between fishers and the fishery agency, to determine a triennial harvest rate of approximately 10% for each zone, equivalent to a 3.3% annual harvest rate. The management plan explains that the RZS allows fishers to reduce costs of travel to fishing grounds and staffing of multiple offloading ports (DFO 2014). This is a feature of industrial-scale fisheries, and is different to artisanal fishers in the tropics where fishers are only accessing local grounds.

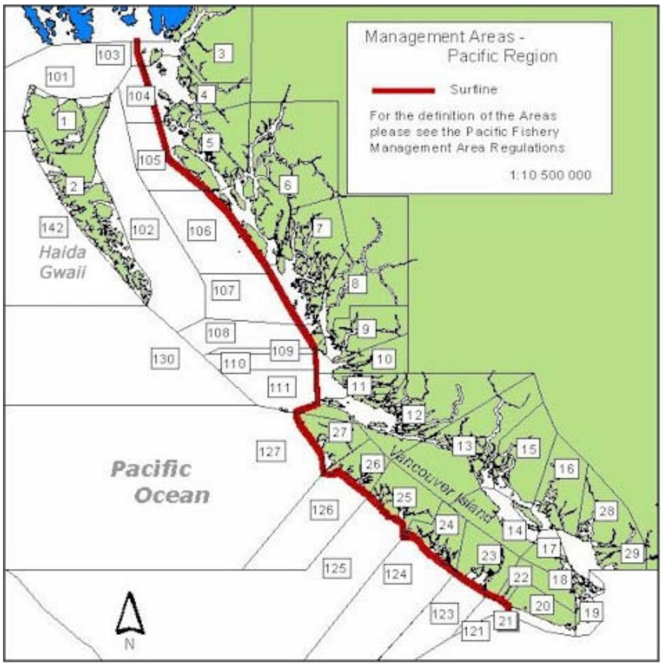

Figure 2. Rotational zones in the single-species specific sea cucumber fishery in British Columbia, Canada. *Parastichopus californicus* is fished in plots every three years in the rotational cycle. Map courtesy of the Department of Fisheries and Oceans Canada. Note that the map does not show areas closed to fishing and does not show new areas recently opened to fishing.

In Alaska, the entire fishery is managed under an RZS with one-third of the 46 areas of the sea cucumber fishing grounds open each year (Fig. 3). These grounds are subject to fishery-independent biomass surveys. The management authority states that "the 3 year rotation was put into place as a means of reducing management costs for surveys and management, and not as a method to allow stock rebuilding between harvests" (ADFG 2016). Fishers "expressed concerns that favorite harvest areas are not recovering between each three year rotational harvest", although this may not be the case across the fishery (ADFG 2016).

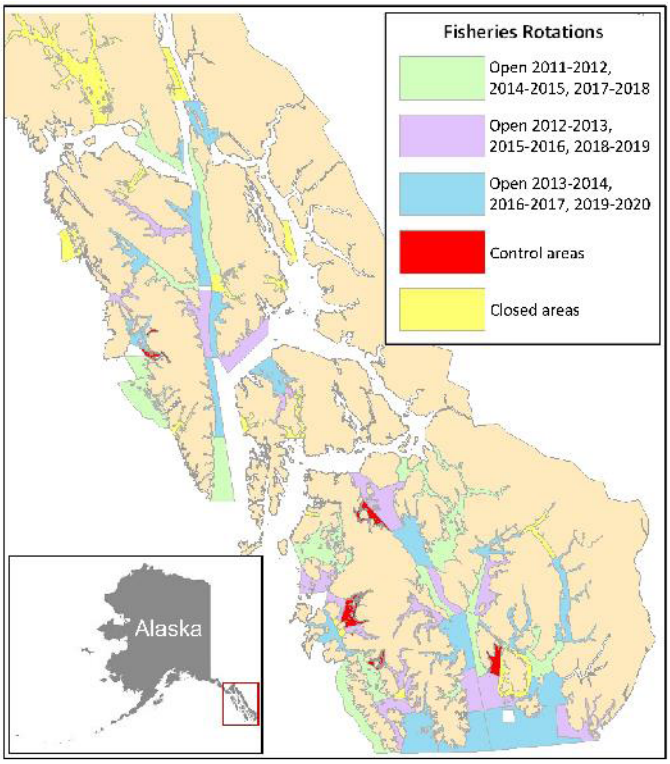

Figure 3. Rotational zones in the (monospecific) sea cucumber fishery in Alaska. *Parastichopus californicus* is fished in plots every three years in the rotational cycle. Map courtesy of the Alaska Department of Fish and Game, with modification.

Caution has been raised about the use of RZSs in multi-species fisheries such as those in the Indo-Pacific, because the approach assumes fast recovery of sea cucumber populations, which may not be true for many target species (Lincoln-Smith et al. 2006; Purcell 2010; Friedman et al. 2011). For instance, after the reduction of Chinese imports of beche-de-mer product following the Cultural Revolution, sea cucumber populations in previously fished areas slowly recovered over 50 years (Conand and Byrne 1993). A similar timeframe was estimated for full recovery of black teatfish populations fished on the GBR (Uthicke et al. 2004). Implementation of RZSs also requires significant investment in planning and surveillance, which is unlikely to be resourced in most low-income countries in the Indo-Pacific (Purcell 2010).

The merits of rotational zoning for the portion of the GBR sea cucumber fishery managed under this scheme were recently assessed through computer modelling of various biological data (Plagányi et al. 2015). For Pacific Island and low-income country fisheries, this management strategy is considered to be inappropriate (Purcell et al. 2015). Here we assess some of the assumptions and data on biological traits that underpin the design of RZSs, and discuss challenges in applying the strategy to multi-species sea cucumber fisheries in the Indo-Pacific.

Appraisal

Analogy with crop rotations?

Rotational harvesting is an agricultural concept that has been applied in multi-species sea cucumber fisheries in Australia (Lowden 2005), and single-species fisheries in Alaska (ADFG 2016), Washington state (Hamel and Mercier 2008) and western Canada (DFO 2014). In terrestrial farming, different crop species are rotated from one year to another in order to maintain soil quality. Plots of land can also be left fallow for a year or more to allow natural regeneration of soil properties.

"Crop rotation" principles are not directly relevant in natural marine ecosystems because marine animals are not seeded as crops are in agriculture, and they do not have the predictable production times of plant species to be confident in rotational cycle periodicity (Purcell et al. 2015). In addition, wild stocks in fisheries are not grown in controlled conditions. Instead, they are subject to natural reproductive limitations and variability in recruitment from year to year. In agriculture, habitat quality can be directly assessed and monitored for suitability for particular commercial species and soils can be fertilised for productivity – attributes not possible in the sea. Therefore, application of crop rotation principles in fisheries for relatively sedentary benthic species like sea cucumbers is tenuous. RZSs in the sea cannot be likened to crop rotation in agriculture.

Biological pillars for RZSs

The rationale underpinning RZSs is that wild populations are fished and then left for some years, during which time small individuals grow to harvest size and stocks are repopulated through natural recruitment. However, natural recruitment tends to be unpredictable and irregular for many marine species (Uthicke 2004; Friedman et al. 2011), due to annual variations in climatic and hydrological conditions that favour or disfavour reproduction, larval supply and settlement processes of planktotrophic larvae. To have confidence in rotational closures, it is important to assess whether commercial species in the fishery have fast growth rates and regular annual recruitment (Purcell 2010) and are not vulnerable to Allee effects. Sea cucumbers are highly vulnerable to Allee effects where spawner density is low (Bell et al. 2008).

Although early studies using size-based growth models (developed for finfish) indicated reasonably fast growth rates of some tropical sea cucumbers (Conand 1989), more recent studies using more sophisticated methods suggest that growth is much slower for some species (Uthicke and Benzie 2002; Uthicke et al. 2004). Models used to estimate the performance of RZSs on the GBR are quite liberal with data inputs on growth rates, and likely to result in the model predicting overly short rotational cycles. For example, for the black teatfish *H. whitmaei*, Plagányi et al. (2015) used an age at maximum length of 5–10 years and an age at first maturity of 4 years. This means that animals become mature at 4 years old, at which they are about 26 cm, then reach maximum length of 56 cm perhaps as little as one year later. Such fast growth in the wild is not possible, and is contrary to empirical studies that show much slower growth in this species (Uthicke and Benzie 2002; Uthicke et al. 2004). Clearly, more conservative inputs are needed with such models, especially for the teatfish species (*H. whitmaei*, *H. fuscogilva* and *H. nobilis*), which are threatened globally (Conand et al. 2014). On the other hand, some smaller species in the stichopodid group, such as *Stichopus chloronotus*, are likely to have comparatively fast growth rates (Conand 1988). In addition to species' biology, habitat variables and environmental productivity influence their abundance and growth (Conand 1989; Lee et al. 2008; Bellchambers et al. 2011). Together, these factors highlight the risk of a "one-size-fits-all" management approach to multi-species sea cucumber fisheries across heterogeneous environments, where different species have vastly different abundances, life history traits and growth trajectories.

A second biological pillar of RZSs is that species have regular recruitment so that population losses to fishing are replenished in zones in non-fishing years. Rotational cycles are commonly three years, so populations have two years in which to recover from fishing. Skewes et al. (2010) showed that black teatfish *H. whitmaei* populations recovered "to near natural (unfished) densities" after seven years of fishing closure in the Torres Strait fishery. However, recovery elsewhere may be very slow due to irregular recruitment, such as on the GBR (Uthicke 2004) and Tonga (Friedman et al. 2011). Similarly, recruitment and population recovery after 3–10 years of fishing closure may occur for some coral reef holothuroids but not others (Lincoln-Smith et al. 2006; Friedman et al. 2011). Thus, population recruitment appears spatially and taxonomically variable, likely species-specific, and the evidence for coral reef species does not give confidence that a three-year rotation is appropriate in a multi-species fishery unless fishing is highly conservative. This is a different case to fishing periods allowed with other management measures because the rotational closures generate more intense fishing in open zones each year when other zones are closed.

Management strategies should be particularly cautious for threatened species. Harvest cycles for species assessed by the International Union for the Conservation of Nature as being threatened globally with extinction (e.g. *Holothuria fuscogilva*, *Stichopus herrmanni* and *Thelenota ananas*) should be more conservative (e.g. 7–10 years) than for less vulnerable species. Computer modelling of the RZS region of the GBR fishery (Plagányi et al. 2015) suggests a 1 in 10 chance of depletion of black teatfish (*Holothuria whitmaei*) under the scheme. This is arguably unacceptable for an endangered species, which should be managed with much less perceived risk.

Success of RZSs in sea cucumber fisheries

RZSs have been running for a portion of the multispecies GBR fishing grounds for 11 years and for all the fishing grounds in the single-species Alaskan and British Columbian fisheries for 25 and 4 years, respectively. The success of this strategy as a sustainable management tool is indicated if catch rates are maintained for valuable species and if fishers do not need to switch to other species (Friedman et al. 2008).

On the GBR, catches for high-value white teatfish (*Holothuria fuscogilva*) and prickly redfish (*Thelenota ananas*) have both declined under the RZS. The last available fishery report shows roughly 50% lower catches of white teatfish in recent years than before 2003–2004, and reports declines "by approximately 3.5 t" in both of the last two years of reported fishing (DAFFQ 2012). That report also states that "Prickly redfish catch decreased again from approximately 42 t in 2008–09 and 21 t in 2009–10 to 17 t in 2010–11", reflecting a decrease by over 50% in catch. Decreases in catches were believed to be the result of greater focus by fishers on curryfish, and the report claims that "Prickly redfish is a less valuable species in comparison to other harvestable species" (DAFFQ 2012), although market data show otherwise (Purcell 2014). In addition, fishers have switched to other species and also operate in areas that are not managed under the RZS (Eriksson and Byrne 2015). These are symptoms of overexploitation of more accessible, shallow-water, high-value species (Friedman et al. 2008; Eriksson and Byrne 2015). Fishers should not need to look to development of new processing methods for lower value species if high-value species remain in abundance. More in-water science is required for assessment than is commonly perceived or presented when RZS outcomes are analysed.

In Canada, questionnaire surveys showed that the majority of fishers perceived abundance and catch rates to have declined and "harvesters most commonly cited overfishing as the most pressing problem facing the fishery" (O'Regan 2015). In that rotational harvest fishery, fishers attributed overfishing to "licence quotas being set too high, the annual harvest not having allowed sufficient recovery time, and overestimates of quota-management-area biomass" (O'Regan 2015). Fisher perceptions therefore indicate that, for various reasons, the rotational harvest strategy in western Canada has not been successful at maintaining stock abundance.

Applicability for Pacific Islands and low-income countries

RZSs have only been applied in developed countries, which have much higher governance capacity than, for example, Pacific Island countries (Fig. 4). Weak governance can of course be said to influence performance of all fishery management, but our point is that measures cannot simply be transferred across "the capacity gap". Strategies for fishery management need to be developed on a case-by-case basis considering contextual factors, including capacity.

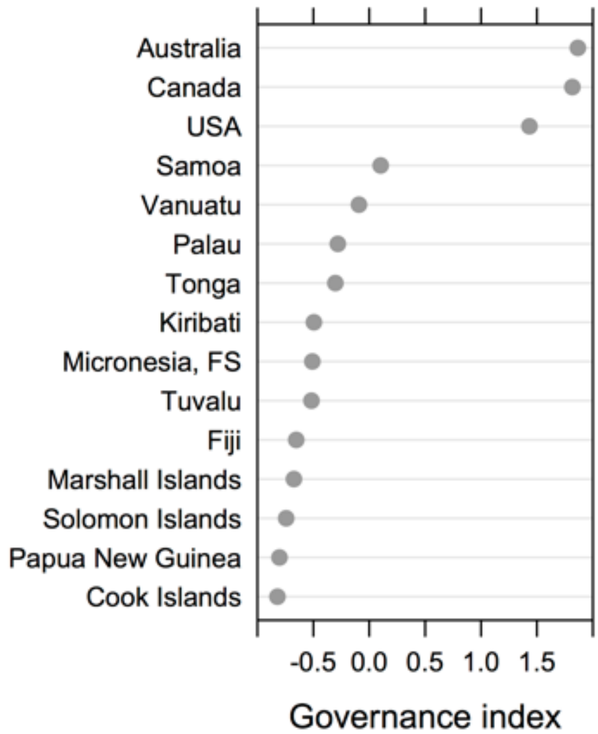

Figure 4. Composite governance index for year 2011, based on metrics for national "Government effectiveness", "Regulatory quality", "Rule of law" and "Control of corruption" in the Worldwide Governance Indicators by Kaufman et al. (2010).

We see three important factors in the three RZS fisheries that differ from most of the sea cucumber fisheries in the tropical Indo-Pacific and Caribbean. Firstly, they are managed by agencies with high technical capacity to plan and implement sophisticated management measures. Second, the agencies have high capacity for surveillance and enforcement, such as the satellite-monitored vessel monitoring systems used on the GBR. Third, there are very few fishers. In Australia just two fishing companies harvest sea cucumbers within the GBR. In British Columbia, Canada, there are 85 licences in the sea cucumber fishery and usually two divers per vessel (DFO 2014). In Alaska, there were 276 permits for the Southeast fishery and 30 permits for the Kodiak Island fishery for the 2015 season (M. Donnellan, pers. comm.). In contrast, fisheries that predominate in the Indo-Pacific mostly have weak capacity to plan management measures and conduct enforcement (FAO 2013; Purcell et al. 2014) and have hundreds, thousands or even hundreds of thousands of fishers (Purcell et al. 2013).

The planning of RZSs requires a lot of information and technical capacity to map out the zones. For successful implementation, fishery managers need extensive geographic and social information about where the rotational zones can be situated and how big they should be. We therefore doubt that RZSs can readily be applied in Pacific Island fisheries, or in most other artisanal-style fisheries throughout the Indo-Pacific. In addition to insufficient technical capacity for planning and surveillance of RZSs, it is unlikely that the scheme will be socially compatible, accepted and understood by the thousands of village fishers in coastal and island nations. For example, marine tenure in most Melanesian countries restricts fishers to certain fishing grounds, which would each need to be divided into zones and designated a cycle periodicity in order for fishers to have income year after year. Unless a co-management model can be found, a centralised zoning scheme may also disenfranchise customary resource owners, which seems to be a step away from current Pacific coastal fisheries policy in which communities are encouraged to have a stronger role in managing fisheries (SPC 2015). RZSs may prevent fishers from accessing nearby fishing grounds in the years when those plots are closed in the rotational cycle. Issues of access rights were legally challenged by American First Nation tribes when the fishery in Washington used a RZSs, and the rotational system was abandoned (Bradbury 1994).

Conclusions

We conclude that rotational zone closures are only applicable to fisheries in developed nations that have a high technical capacity to plan rotational plots and gazette them for the fishery, that have sophisticated surveillance, and that have few fishers. That said, even in developed nations RZSs are not without biological uncertainties and access issues. Rotational cycles must be long enough to allow species with slow growth and irregular recruitment to recover before being fished again, and this is very likely be more than five years for certain species depending on fishing effort. Particular caution needs to be implemented for species vulnerable to extinction.

Acknowledgements

For supplying maps and information, we wish to thank the Great Barrier Reef Marine Park Authority, Pauline Ridings from the Department of Fisheries and Oceans Canada, and Mike Donnellan from the Alaska Department of Fish and Game.

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Field observations of sea cucumbers in Ari Atoll, and comparison with two nearby atolls in Maldives

Frédéric Ducarme[1]

Abstract

This paper presents a sea cucumber survey conducted by an International Union for Conservation of Nature mission on the coral reefs of North Ari Atoll for three weeks in April–May 2015. The main result is the extremely low population of commercially important sea cucumbers in North Ari Atoll, consistent with other recent surveys in the country. The assemblage was largely dominated by two species in the family Holothuriidae, *Holothuria edulis* and *Pearsonothuria graeffei*, with strikingly different proportions than the neighbour atolls of Malé and Baa. This study increases the number of holothurian species recorded in Maldives to 28, with 10 records for Ari Atoll, including three new records for the country.

Introduction

The Republic of Maldives has been the scene of extreme beche-de-mer overfishing since 1985 (Joseph 1992), which led to a population collapse of most of the high-value species as early as 1990 (James and Manikfan 1994). This resulted in a tightening of exports but no serious regulation (FAO 2013). The current situation is still one of overexploitation (Purcell et al. 2013), and the local stock is judged to be "depleted" (Naeem 2013). Very little information has been available about the populations of sea cucumbers in Maldives, although some recent studies have shed more light on the region (Muthiga 2008; Ducarme 2015). The geography of Maldives, with wide atolls separated by deep channels, means there is a potential variability in assemblages between regions that is difficult to predict.

Ari Atoll is a wide atoll in the centre-west of Maldives, just southwest of the capital Malé. It has around 14,000 inhabitants on 36 main inhabited islands (along with 26 resort islands), and over 268 coral reefs, which is the highest number of reefs in all Maldivian atolls (Naseer 2006). Ari Atoll is divided into two administrative sectors, North Ari and South Ari.

This paper describes results from the International Union for Conservation of Nature "Regenerate" mission, funded by the US Agency for International Development. This mission was conducted on the coral reefs of North Ari atoll during April–May of 2015. Besides its geographical and economical significance, North Ari was chosen as the study atoll as it is ecologically and socio-economically representative of Maldives, containing a variety of reef habitats, 12 resort islands, 8 community islands and 7 main uninhabited islands. Ari Atoll echinoderm fauna had not been studied before, and the holothuroid assemblage was compared with the recently surveyed neighbouring atolls of Baa (Ducarme 2015) and Malé (Muthiga 2008).

Materials and methods

Study site

The 12 islands surveyed in North Ari Atoll (Alifu alifu) are exposed to different human impact and management regimes (four resort islands, four community islands and four uninhabited islands). The location of the 12 islands is shown in Fig. 1.

Survey methodology

At each island reef, three sites were surveyed on the cardinal directions closest to the island. At each site, three replicate 50-m transects were laid lengthwise along the reef slope, with a minimum of 3 m separating each transect. Holothuroids were surveyed and quantified in a 50 m by 2 m belt transect, by scuba diving at 10 m depth. At 7 out of 12 sites, this protocol was replicated at 7, 5 and 1 m depths along parallel transects. Large sea cucumbers sighted outside the transects (down to 25 m) were also recorded separately. Additional non-linear night surveys were carried out at most sites at shallow depths to spot potential nocturnal species. All surveys were carried out by examining the benthos, searching under crevices and rocks on the reef, and recording all sea cucumbers encountered. Pictures of each newly encountered species were taken for identification, as no specimen sampling was authorised for this mission. The benthos was surveyed separately, on 10-m depth transects using

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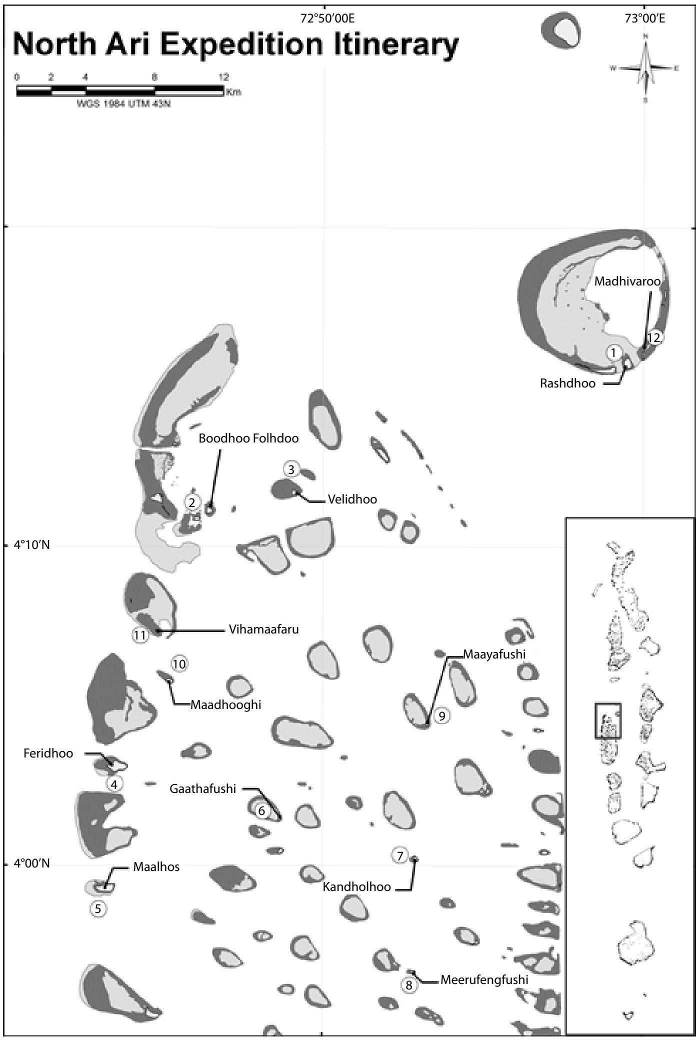

Figure 1. Location of sampling stations (North Ari Atoll), with inset showing North Ari Atoll position within Maldives. (Source: IUCN Maldives.)

a similar method, and the results will be published in a separate publication.

Results

Study site description

Most of the islands are small and surrounded by narrow reef flats. Outer reef slopes are often very steep, going more or less straight down to about 30 m depth. These slopes have a diverse coral cover, ranging from high coral cover to sand-dominated detritic substrate. The current can be quite strong, limiting the substrate complexity at some sites. The structural complexity was found to be quite evenly low at the study sites at 10 m depth. Coral cover was often very high at the reef crest (up to 90%, mostly dominated by big *Acropora* tables) and decreased with depth. Benthic cover at 10 m depth was in the region of 18–27% coral, around 1% macroalgae, 20–30% turf and 5–8% coralline crustose algae, the rest being sand and coral debris. No seagrass bed or mangrove was observed, and fleshy algae were also very rare. Rugosity, habitat richness and hydrodynamics were highly heterogeneous, resulting in quite a wide variety of ecological niches.

Holothuroidea abundance and diversity

A total of 14 species of sea cucumbers were encountered during the survey (Tables 1 and 2), including one probably unknown species and three new records for Maldives. Between one and six species were observed on each site. Of the 14 species, three were stichopodids, nine were holothurids and two were synaptids. None of the species recorded in this survey was of high commercial value, and only three were reported as commercially exploited in Maldives (*Stichopus chloronotus*, *Holothuria atra* and *Thelenota anax*) (Joseph 1992), despite the fact that nearly all the aspidochirotid species observed are considered edible and fished in some regions (Purcell et al. 2012). The species *Bohadschia marmorata* is also exported, and often confused with a species recorded during the survey: *Bohadschia koellikeri* (new record, but potentially mistaken in the past).

The total number of individual sea cucumbers encountered at all the sites was 692 in 83 standardised samplings. The overall density was 8.3 individuals transect^{-1}, equivalent to 0.16 individuals m^{-2}. The density of sea cucumbers was highest at Maayafushi with 390 specimens, whereas the second highest density was only 85 specimens at Maadhooghi.

The abundance of holothuroids was very variable, ranging from 1 to 390 individuals per island (0 to 225 per transect). While *Holothuria atra* was the most recorded species, 94% of *H. atra* observations were made on one site, and the species was observed only 13 times otherwise. *Pearsonothuria graeffei* was the second most abundant species, with 279 observations (35% of all observations, or 56% when the *H. atra* "hot spot" was removed), and was present on all islands and 80% of transects. It was followed by *Holothuria edulis* (22%). Shallow sites with a high live coral cover (and significant relief) had notable populations of *P. graeffei*, whereas *H. edulis* was mostly observed between 5 and 10 m, in more sloping and less complex coral landscape. *H. atra* was observed mostly on sand patches on reef tops (often in association with, *S. chloronotus*), or sometimes deeper on sandy banks with abundant detritic material (including under functioning sewage pipes). Both *Actinopyga lecanora* observations were made around 10 m depth in complex coral systems. *T. anax*, *Bohadschia atra* and *Actinopyga* cf. *miliaris* were rarely observed, mostly deep on sandy bottoms. In contrast, *Bohadschia vitiensis* was observed only once on a shallow sand bank, and *B. koellikeri* and *Stichopus* sp. were observed only once, in shallow reef flats at night. The latter species

Table 1. Abundance of holothuroid species at the seven multiple-survey sites on Ari Atoll. Species recorded only out of linear transects (side sightings, control night dives or non-standardised additional observations) are reported as "extra records".

Survey site	*Actinopyga lecanora*	*Actinopyga* cf. *miliaris*	*Bohadschia atra*	*Bohadschia koellikeri*	*Bohadschia vitiensis*	*Holothuria atra*	*Holothuria edulis*	*Holothuria insignis*	*Pearsonothuria graeffei*	*Stichopus chloronotus*	*Stichopus* sp.	*Thelenota anax*	*Opheodesoma* sp.	*Synaptula* sp.	**Total observations**	**Species diversity**
Gaathafushi						8	9		22				4		**43**	**4**
Kandholhoo							8		33			1	2		**44**	**4**
Meerufengfushi						1	19		39						**59**	**3**
Maayafushi			2			297	26		64	1					**390**	**5**
Maadhooghi			1			2	32	2	43	5					**85**	**6**
Vihaamafushi							6		9						**15**	**2**
Madhivaroo						2	35		19						**56**	**3**
Extra records	1	1		1	1						1			1		+6
Total	**1**	**1**	**3**	**1**	**1**	**310**	**135**	**2**	**229**	**6**	**1**	**1**	**6**	**1**	**692**	**13**

Table 2. Abundance of each holothurian species at 10 m depth at the 13 survey sites on Ari Atoll.[2]

Survey site	*A. lecanora*	*B. atra*	*H. atra*	*H. edulis*	*P. graeffei*	*Thelenota anax*	*Opheodesoma* sp.	**Total observations**	**Species diversity**
Rashdhoo	1		1	18	13		1	**34**	**5**
Boodhoo Folhdoo				8	13			**21**	**2**
Velidhoo			1	7	10	1		**19**	**4**
Vihamaafaru	1			7	8			**16**	**3**
Feridhoo					5			**5**	**1**
Maalhos					1			**1**	**1**
Gaathafushi				8	11		1	**20**	**3**
Kandholhoo				7	10	1	2	**20**	**4**
Meerufengfushi				14	10			**24**	**2**
Maayafushi		1	4	6	10			**21**	**4**
Maadhooghi		1		9	7			**17**	**3**
Vihaamafushi				4	1			**5**	**2**
Madhivaroo			2	11	4			**17**	**3**
Total	**2**	**2**	**8**	**99**	**103**	**2**	**4**	**220**	**7**

[2] Vihaamafushi and Vihaamafaru are two adjacent survey sites on the same island ("fushi" means submerged reef and "faru" means sand bar). Twelve islands were surveyed, representing a total of 13 survey sites.

shared resemblance with a previously signalled unknown *Stichopus* species, currently under phylogenetic analysis and determination (Ducarme 2015). *Opheodesoma* sp. was observed seven times, and constitutes a new record for Maldives. This species was extremely long (up to >1.30 m), with a uniformly solid greyish brown body and 15 bright white pinnate tentacles. All specimens were found hidden in bushy *Acropora muricata* colonies.

Discussion

Overall diversity of sea cucumbers

The assemblage found on Ari Atoll was quite diverse compared to Baa Atoll (Ducarme 2015), but similarly striking was the absence of high-value species. Even during non-standardised additional surveys, we were never able to record any *Actinopyga echinites*, *A. mauritiana*, *Holothuria fuscogilva*, *H. fuscopunctata*, *H. nobilis* or *Thelenota ananas*. This constitutes half of the 12 species listed as exploited locally by Joseph (1992), and none of the others was found abundantly (except *H. atra* in some particular sites). Marine biologists based in Baa Atoll found only one specimen of *T. ananas* in one and a half years of daily surveys over many sites (personal communication), and no "teatfish" (subgenus *Holothuria (Microthele)*). This may be due to overfishing, as suggested by Naeem (2013), although spatial variation may also be involved.

Comparison with results from neighbouring atolls

The assemblage of holothuroids was found to be very different from those found in previous studies in other atolls (Table 3) (methods and seasons were comparable), whereas reef type and fish assemblages are believed to be similar. Three new records were made for Maldives. One of them was quite common and obvious (*Opheodesoma* sp.), but it may have been confused with similar species in previous studies (especially *Synapta* or *Synaptula*). *B. koellikeri* is also a common confusion with *B. vitiensis* or *B. marmorata* (Kim et al. 2013), which were both recorded by previous studies; *B. vitiensis* was also observed separately in the present survey. *Bohadschia argus* is probably not present in the region (Conand 2008), and this name was given to *B. atra* in the Indian ocean before its description (Massin et al. 1999). *H. insignis* is a small and cryptic species, easily overlooked.

Relative abundance of the species found differed strikingly from previous quantitative studies on the neighbouring atolls of Malé and Baa (Fig. 2). The assemblage of Ari Atoll was found to be dominated by *P. graeffei*, *H. edulis* and *H. atra*, while Baa Atoll was found to be overwhelmingly dominated by *P. graeffei*, followed by *S. chloronotus* and *T. anax* (Ducarme 2015). Malé Atoll was dominated by *S. chloronotus* and *H. atra*, followed by *P. graeffei* (Muthiga 2008). Such variations were suggested by Joseph (1992), and may be even more striking on more remote atolls.

High-value species (*T. ananas*, *H. nobilis*, *A. echinites* and *H. fuscogilva*) were rare in all atolls: *A. echinites* has not been recorded by scientific surveys since 1999, and *H. nobilis* since 2008 (however there is a high risk of confusion with *H. fuscogilva*). As understanding of the ecological importance of sea cucumbers for tropical ecosystems is rising, there is an urgent need to set up proper fishing regulations in Maldives (Purcell et al. 2013), all the more since the whole country depends on the good ecological state of its reefs. Improving governance appears critical for maintaining both the fishery and the good ecological state of the ecosystem (Eriksson et al. 2015).

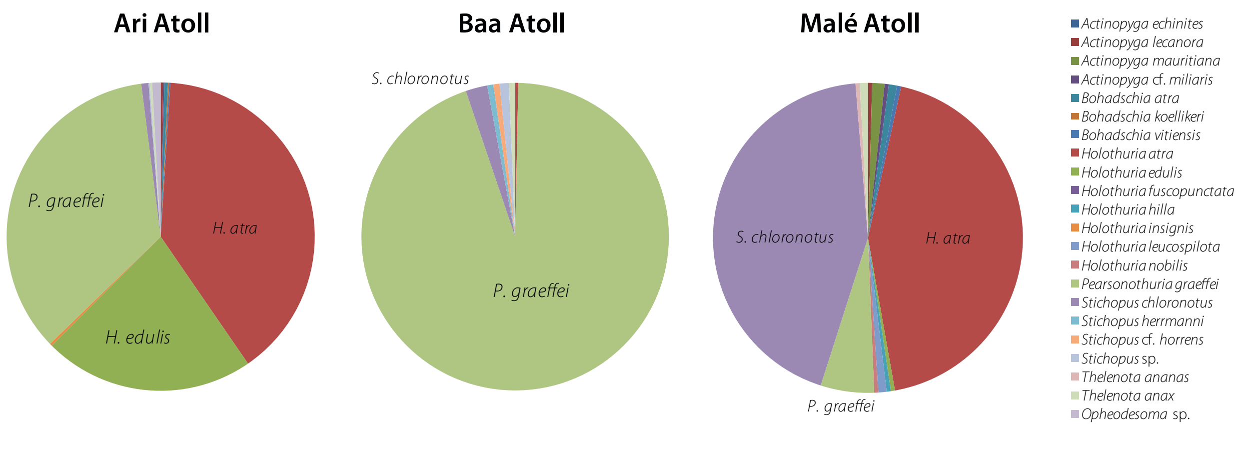

Figure 2. Assemblage comparison between the three atolls, using present results for Ari, Ducarme (2015) for Baa and Muthiga (2008) for Malé.

Table 3. Comparison of the present results with previous inventories. Stars indicate occurrence. Double stars mean first reports, and "?" indicates specimens that could not be identified with certainty. "Reported" means that the species is reported in the paper but was not directly observed by the scientists. Locally targeted species are indicated in bold.

	Present and previous inventories						
Species	Present study (Ari Atoll)	Ducarme (2015) (Baa Atoll)	Andréfouët (2012) (Baa Atoll)	Muthiga (2008) (Malé Atoll)	Reichenbach (1999) (Malé and Laamu Atolls)	James and Manikfan (1994) (Maldives)	Joseph (1992) (Maldives)
Actinopyga caerulea		Reported					
Actinopyga echinites					*	*	
Actinopyga lecanora	*	Reported	*	*		*	*
Actinopyga mauritiana			*	*	*	*	*
Actinopyga miliaris	?	Reported		*	*	*	
Actinopyga sp.							*
Bohadschia argus (dubious)			*				
Bohadschia atra	*			*			
Bohadschia koellikeri	**						
Bohadschia marmorata			*			*	*
Bohadschia vitiensis	*			*			
Holothuria atra	*	*	*	*		*	*
Holothuria edulis	*	Reported	*	*	*		
Holothuria fuscogilva			*		*		
Holothuria fusccopunctata		Reported			*	*	*
Holothuria hilla				*			
Holothuria insignis	**						
Holothuria leucospilota				*			*
Holothuria nobilis				*		Reported	*
Pearsonothuria graeffei	*	*	*	*			
Stichopus chloronotus	*	*		*		Reported	*
Stichopus herrmanni		*			*		
Stichopus cf. *horrens*		*					
Thelenota ananas		Reported	*	*	*	*	
Thelenota anax	*	*	*	*	*	*	
Unidentified stichopodid	?	*					
Opheodesoma sp.	**						
Synaptula sp.	?	Reported	*				
Synapta maculata						Reported	*

Besides the absence of commercially important species, this surprising diversity of assemblages may be the sign of overlooked ecological differences between atolls, which do not affect fish but have an effect on benthic invertebrates. Cross-studies with other organisms (such as corals or gastropods) may confirm this hypothesis, and increase the status of holothuroids as easy-to-survey indicator species.

This study increases the number of holothuroid species recorded in Maldives to 28 when *B. argus* is removed, but the final number depends on the determination of ambiguous observations.

Acknowledgements

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Distribution of holothurians in the shallow lagoons of two marine parks of Mauritius

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Abstract

Several studies have recently been carried out on the abundance and diversity of holothurians in the shallow lagoons of Mauritius. This paper presents data gathered on holothurians during two biodiversity inventories carried out in the two marine parks, namely Balaclava (surveyed in 2009) and Blue Bay (surveyed in 2012). Seventeen species were observed or photographed in Blue Bay Marine Park, with the most frequent and abundant species being *Holothuria atra*. Balaclava Marine Park has a lower diversity of habitats and only 10 species were recorded, mostly on the reef slopes and reef flat habitats. The data from the two marine parks were combined with those of a previous study, which found 20 species, to present an overview of the distribution of holothurians on the main island of Mauritius. We also present the first occurrence in Mauritius of the following four species: *Holothuria flavomaculata, H. impatiens, H. notabilis* and surprisingly *Thelenota ananas*.

Introduction

Holothurians, or sea cucumbers, are particularly vulnerable to overexploitation, and have been under pressure in Mauritius since the start of the sea cucumber fishery in the mid-2000s. Consequently, the Ministry of Fisheries imposed a two-year moratorium on the collection of sea cucumbers from 2009, which was later extended for another period of four years (2012–2016) to prevent the collapse of the fishery.

Previous studies on the holothurians of Mauritius include inventories and/or ecological surveys conducted at different sites by Müller (1998), Luchmun et al. (2001), Mrowicki (2006) and Rowe and Richmond (2004) for Rodrigues. The most recent studies on the abundance and diversity of holothurians in Mauritius were made by Lampe (2013) and Lampe-Ramdoo et al. (2014) at several sites in the shallow lagoons of the south and west coasts, and on the northern and eastern coasts. Short syntheses have also been presented in other documents by Conand (2008), Conand et al. (2013), FAO (2013), Mohit (2013) and Eriksson et al. (2015).

The Balaclava Marine Park is located in the northwest of Mauritius, and covers an area of 485 ha (Fig. 1). Marine biologists from ARVAM-Pareto (Réunion) were contracted in 2009 to carry out a biological inventory of the marine park under the project "Marine protected areas network of the Indian Ocean countries". This project aimed at promoting sustainable use and equitable sharing of benefits from marine protected areas throughout the Republic of Mauritius with the participation of all stakeholders (Nicet et al. 2009).

The Blue Bay Marine Park, designated in 1997, is located in the southeast of the island and covers an area of 353 ha (Fig. 1). The Fisheries and Marine Resources (Marine Protected Areas) Regulations

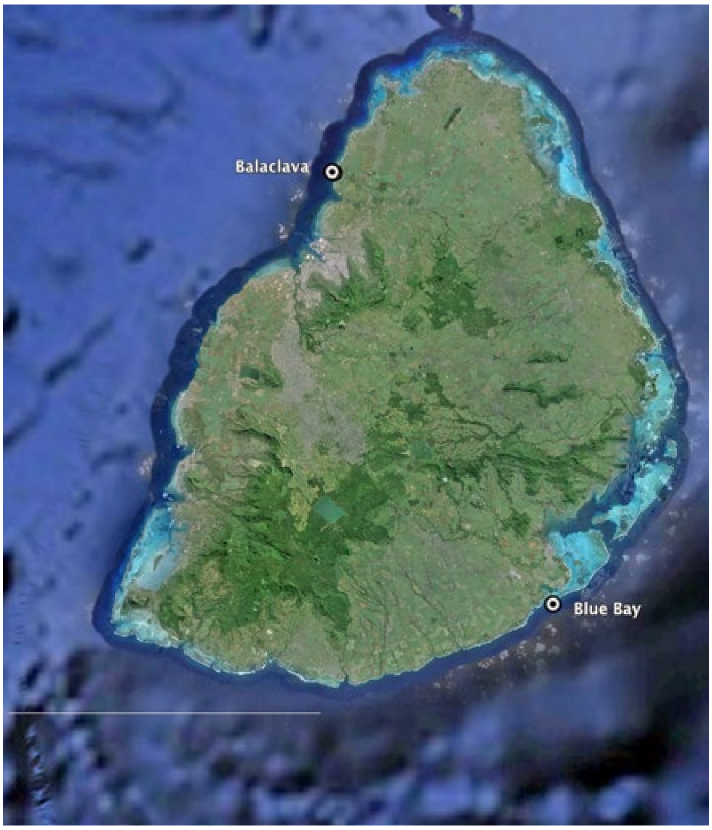

Figure 1. The main island of Mauritius, showing the location of Blue Bay and Balaclava marine parks. Source: Google Earth 7.1.5.1557 (accessed 20/05/2015), Mauritius (http://www.earth.google.com).

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were amended in 2007 to provide for a zoning system to control permissible activities in the marine park. In January 2008, the Blue Bay Marine Park was officially nominated as the second Ramsar site (Wetland of International Importance) for Mauritius. It was studied in 2012 by marine biologists from Réunion, in cooperation with Albion Fisheries Research Centre counterparts, under the United Nations Development Programme/Global Environment Facility/Government of Mauritius-funded project "Partnerships for marine protected areas in Mauritius and Rodrigues" (Simian et al. 2012).

The specific objective of the surveys in 2009 (Balaclava Marine Park) and 2012 (Blue Bay Marine Park) was to study the biodiversity of the sites in order to develop effective management measures in these protected areas. The holothurians (Echinodermata) are one of the taxonomic groups that was inventoried. This paper is based on the data obtained on holothurians during the studies.

Figure 2. Blue Bay Marine Park sampling sites. A: outer slope; B: lagoon; C: pass; D: bay; E: barrier reef flat; F: fringing reef flat. Source: Google Earth.

Materials and methods

The collection of in situ data on target species was done using a rapid assessment protocol (McKenna and Allen 2005). Each survey was carried out over seven days. Underwater sampling was carried out either by diving or snorkelling depending on the station depth. The sites were grouped into general habitat categories – six for Blue Bay Marine Park (Fig. 2) and four for Balaclava Marine Park (Fig. 3). Sampling was standardised for one hour at each site to obtain a uniform sampling effort.

Data on the holothurians include notes and photos and these have been used for preliminary identification of the families, genera and species, wherever possible.

Figure 3. Balaclava Marine Park sampling sites. A: outer slope; B: lagoon; C: pass; D: bay. Source: Google Earth.

Results

Blue Bay Marine Park

Blue Bay Marine Park has a high diversity of habitats (Fig. 2), which were grouped as follows (Simian et al. 2012): outer slopes (fringing and barrier reefs; A); lagoon (shallow and deep terraces; B); pass (C); bay (D); barrier reef flat (E); and fringing reef flat (F). The area is subject to local threats (e.g. the effects of land-based agriculture and tourism-related activities) and global threats (e.g. climate change). The species richness of the different taxa sampled was generally high, considering the small size of the site (Simian et al. 2012).

Holothurian diversity is presented by habitat in Table 1. Seventeen species were observed or photographed. The most frequent and abundant species in several habitats is *Holothuria atra.* The lagoon terraces host several species, including the commercial teatfish *H. nobilis*, several *Bohadschia* species and *Pearsonothuria graeffei.* The barrier reef flat has the highest diversity of holothurians, while the fringing reef flat has only the two common species *H. atra* and *Stichopus chloronotus.*

Balaclava Marine Park

Balaclava Marine Park has a lower diversity of habitats, as it is limited by fringing reefs (Fig. 3). Habitats are grouped as follows (Nicet et al. 2009): outer reef slope, which covers a large part of the park (A); reef flats and lagoon (B); pass (C); bay (D). The species richness was found to be high for scleractinarian corals, fish and molluscs during the survey.

Holothurian diversity is presented by habitat in Table 1. Only 10 species were recorded, mostly on the reef slopes and reef flat habitats. *Thelenota ananas* was recorded on the slope of the pass. Most of the species are relatively common in the west Indian Ocean region.

Table 1. Holothurians found in Blue Bay and Balaclava marine parks, by habitat.

			Blue Bay Marine Park[1]						Balaclava Marine Park[2]			
Family	Genus	Species	A	B	C	D	E	F	A	B	C	D
Holothuriidae	*Actinopyga*	*echinites*					x		x	x		
	Actinopyga	*capillata*										
	Actinopyga	*mauritiana*										
	Bohadschia	*atra*										
	Bohadschia	*marmorata*		x			x					
	Bohadschia	*subrubra*		x			x					x
	Bohadschia	*vitiensis*		x		x						x
	Holothuria	*arenicola*										
	Holothuria	*atra*		x		x		x		x		
	Holothuria	*cinarescens*										
	Holothuria	*flavomaculata*	x									
	Holothuria	*fuscocinerea*										
	Holothuria	*impatiens*					x					
	Holothuria	*hilla*					x			x		
	Holothuria	*leucospilota*		x								
	Holothuria	*nobilis*					x					
	Holothuria	*notabilis*					x					
	Holothuria	*pervicax*				x	x		x		x	
	Holothuria	*scabra*										
	Pearsonothuria	*graeffei*		x								
Stichopodidae	*Stichopus*	*chloronotus*		x		x		x	x	x	x	
	Stichopus	*herrmanni*		x			x		x			
	Stichopus	*monotuberculatus*				x						
	Thelenota	*ananas*									x	
Synaptidae	*Synapta*	*maculata*		x					x	x		

[1] A = outer slopes (fringing and barrier reefs); B = lagoon (shallow and deep terraces); C = pass; D = bay; E = barrier reef flat; and F = fringing reef flat.
[2] A = outer reef slope (which covers a large part of the park; B = reef flats and lagoon; C = pass; D = bay.

Discussion

The present inventories are mostly based on field observations and photographs taken during surveys of the marine parks in the north and south of the main island of Mauritius. No specimens were collected for ossicle examination or genetics, which are needed for precise identification (Purcell et al. 2012). Therefore no reference collection exists for verification.

The high diversity of habitats in Blue Bay Marine Park, despite the relatively small size, explains the diversity of holothurians. A few commercial species are found (*H. nobilis*, *T. ananas*, *Actinopyga* spp., *Bohadschia* spp.), which deserve protection since illegal captures are common in most of the world's protected areas (Conand et al. 2015).

In the Balaclava Marine Park survey and report, echinoderms have not been studied in detail. This could have introduced a bias in the results and explain why echinoderm diversity was found to be low.

Table 2 synthesises the distribution of holothurians on the main island of Mauritius, based on the current two surveys and Lampe-Ramdoo et al. (2014). The most extensive study was that by Lampe-Ramdoo et al. (2014), with 20 identified species. It is noteworthy that the present study, based on relatively short surveys in limited areas, has helped to increase the holothurian inventory for Mauritius, which now has a total of 25 species. This remains low compared with Réunion, a younger and less diversified island, where 37 species have been inventoried (Conand et al. 2010).

Table 2. Synthesis of holothurian species present on the main island of Mauritius.

			Blue Bay Marine Park	Balaclava Marine Park	Study by Lampe-Ramdoo et al. (2014)
			17 sp.	10 sp.	20 sp.
Family	Genus	Species			
Holothuriidae	*Actinopyga*	*echinites*	x	x	x
	Actinopyga	*capillata*			x
	Actinopyga	*mauritiana*			x
	Bohadschia	*atra*			x
	Bohadschia	*marmorata*	x		x
	Bohadschia	*subrubra*	x	x	x
	Bohadschia	*vitiensis*	x	x	x
	Holothuria	*arenicola*			x
	Holothuria	*atra*	x	x	x
	Holothuria	*cinarescens*			x
	Holothuria	*flavomaculata*	x		
	Holothuria	*fuscocinerea*			x
	Holothuria	*impatiens*	x		
	Holothuria	*hilla*	x	x	x
	Holothuria	*leucospilota*	x		x
	Holothuria	*nobilis*	x		x
	Holothuria	*notabilis*	x		
	Holothuria	*pervicax*	x	x	x
	Holothuria	*scabra*			x
	Pearsonothuria	*graeffei*	x		
Stichopodidae	*Stichopus*	*chloronotus*	x	x	x
	Stichopus	*herrmanni*	x	x	x
	Stichopus	*monotuberculatus*	x		x
	Thelenota	*ananas*		x	
Synaptidae	*Synapta*	*maculata*	x	x	x

In Mauritius some species of holothurians were observed long ago, such as *A. mauritiana* described by Quoy and Gaimard in 1833. Lampe-Ramdoo et al. (2014) noted the first occurrence of the following species: *H. arenicola*, *A. capillata*, *H. scabra* and *H. fuscocinerea*. In this paper, we present the first occurrence in Mauritius of the following four species: *H. flavomaculata*, *H. impatiens*, *H. notabilis* and, surprisingly, *Thelenota ananas*, a species commonly found in the Mascareignes and the tropical Indo-Pacific (Purcell et al. 2012).

Further studies are necessary to complete the inventory. A reference collection is also important, to confirm the evolution of this group, which includes commercially important species.

Acknowledgements

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New additions to the holothurian fauna of Pakistan: *Holothuria verrucosa, Holothuria cinerascens* and *Ohshimella ehrenbergii*

Quratulan Ahmed[1,], Qadeer Mohammad Ali[1] and Chantal Conand[2]*

Abstract

During coastal monitoring of Buleji and Sunehri beaches of Karachi coast, Pakistan from January to December 2014, 234 specimens of sea cucumber were collected from the intertidal zone. The specimens are deposited in the repository of the Marine Reference Collection and Resource Centre, University of Karachi. *Holothuria* (*Lessonothuria*) *verrucosa* (Selenka, 1867) and *Holothuria* (*Semperothuria*) *cinerascens* (Brandt, 1835) are new records from the coastal areas of Pakistan, while *Ohshimella ehrenbergii* (Selenka, 1868) is rediscovered after 43 years (earlier recorded by Clark and Rowe in 1971). The paper contains morphological descriptions of the specimens collected and information on habitat characteristics.

Introduction

From January to December 2014 sea cucumbers were collected off the beaches of Buleji and Sunehri, along Karachi coast, Pakistan (northern Arabian Sea) (Fig. 1). Among the 234 specimens of sea cucumbers collected, two species of Holothuriidae – *Holothuria* (*Lessonothuria*) *verrucosa* (Selenka 1867) and *H.* (*Semperothuria*) *cinerascens* (Brandt 1835) – were recorded for the first time from the coastal areas of Pakistan, while one species of Sclerodactylidae – *Ohshimella ehrenbergii* (Selenka 1868) – was "rediscovered" for the first time in 43 years, as the previous recording of this species had been by Clarke and Rowe in 1971. The family Holothuriidae includes 5 genera and 185 species (Kerr et al. 2005) of which the genus *Holothuria* is the most diverse. The family Sclerodactylidae is represented by 27 genera and 139 species. A detailed description of the collected specimens of *H. verrucosa*, *H. cinerascens* and *O. ehrenbergii*, and their habitat, is presented here.

Material and methods

Sea cucumber specimens were collected from the intertidal zones during low tide. The specimens, after relaxation, were preserved in 5% neutralised formaldehyde and later transferred to 70% ethyl alcohol. For taxonomic studies and identification, morphological features were examined and

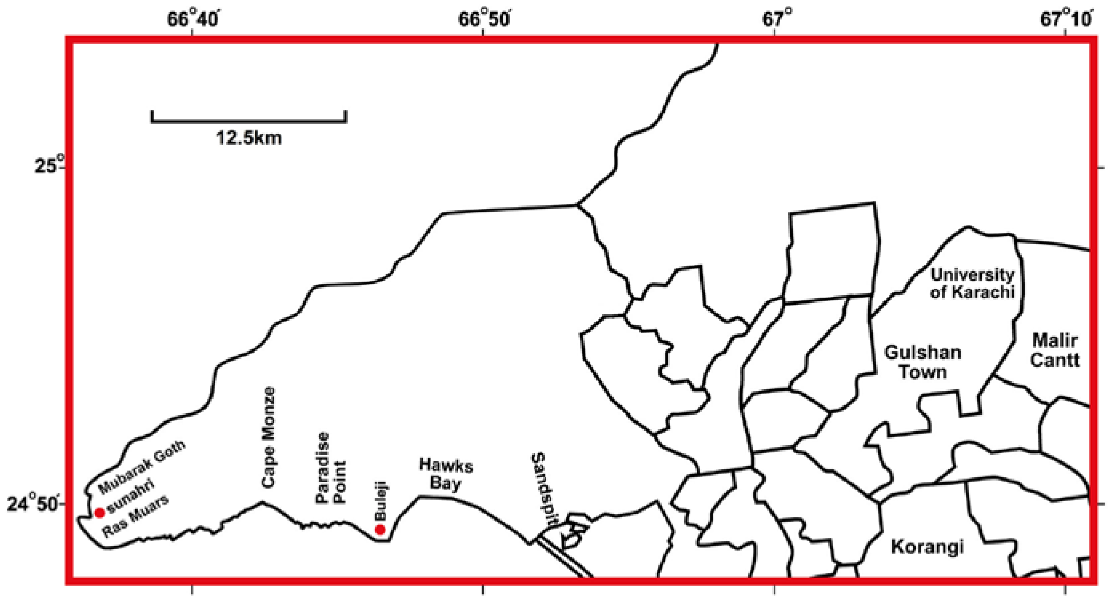

Figure 1. The two study areas (red dots).

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microscopic studies were conducted. Ossicles were taken from three positions (dorsal and ventral body walls, and tentacles); wet mounts were prepared by placing a small piece of skin tissue on a slide and adding a few drops of 3.5% bleach, and the slides were then rinsed with drops of distilled water. The slides were examined under a microscope at 10 × 10 magnification. Microphotography was also performed using a digital camera (Fujifilm 16 MP).

Results and discussion

Holothuria verrucosa

Order Aspidochirotida; family Holothuriidae; genus *Holothuria* (*Lessonothuria*); species *verrucosa.*

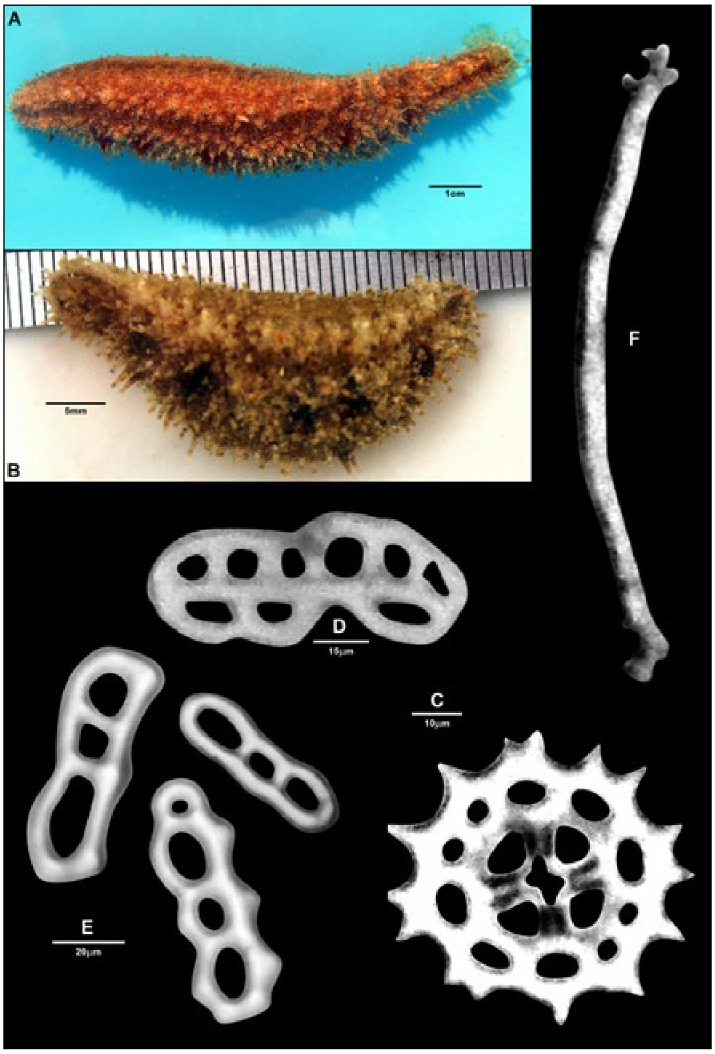

Figure 2. *Holothuria verrucosa*.
A: Dorsal view; B: ventral view;
C: Turret of dorso-ventral tegument;
D: buttons of dorsal body wall;
E: pseudo-buttons of podia;
F: tentacle rods.

This species is benthic, lives inshore, and is a deposit feeder. It is a cryptic species that is found buried in sand, sea grasses and rubble. It buries itself with its cloaca, and part of its upper surface exposed.

Material examined

Two specimens of *H. verrucosa* were collected from Buleji (24.8389°N, 66.8253°E) on 19 May 2014 and from Sunehri beach (24.8797°N, 66.6858°E) on 18 June 2014. They were collected from crevices within the intertidal area on rocky shores during low tides. The length of the specimens ranged from 80 to 130 mm and weight from 13 to 18 g. Colouration of fresh specimens was burnt sienna (Fig. 2A) and papillae were light brown (Fig. 2B). The body was roughly cylindrical, tapering towards the posterior end and enlarged at the anterior end. The thick tegument of the ventral mouth contained 28 shield-shaped tentacles. The tube feet were very clear in rows on the ventral side. The dorso-ventral spicules were table-, button- and rod-shaped with a spiny disc and irregular buttons (Figs. 2C, 2D and 2E). Spicules of the tentacles were rod-shaped (Fig. 2F).

Remarks

The specimens from the current collections as well as those described by Qaseem Tahera and Quddusi B. Kazmi (2005) were collected from intertidal areas. The specimens are almost identical to the specimen described by Samyn et al. (2006), which was cylindrical, measuring 45 cm, and with maroon colouration; the present specimens were burnt sienna, roughly cylindrical and tapering towards the posterior end. *H. verrucosa* is a new addition to the coastal fauna of Pakistan. The specimens are now deposited in the repository of the Marine Reference Collection and Resource Centre, University of Karachi, Cat. No. Holo. 13 and 14.

Holothuria cinerascens

Order Aspidochirotida; family Holothuriidae; genus *Holothuria* (*Semperothuria*); species *cinerascens*.

This species is benthic, lives inshore, and is a detritus feeder (Rowe and Gates 1995). It can be found on rocky bottoms in crevices with strong wave action where it suspension-feeds on organic particles from the water column (Purcell et al. 2012).

Material examined

One specimen of *H. cinerascens* was collected from Sunehri beach (24.8797°N, 66.6858°E) on 23 October 2014. It was collected from a rocky bottom in a crevice of the intertidal area during low tide.

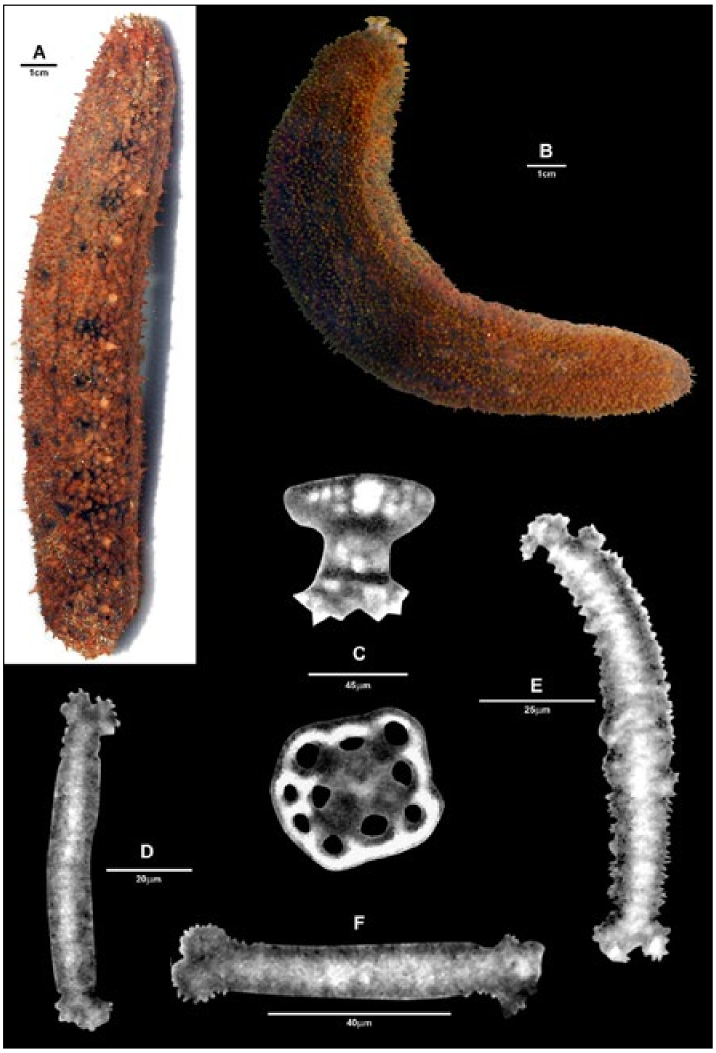

Figure 3. *Holothuria cinerascens*.
A: Dorsal view; B: ventral view; C: tables of dorsal body wall; D: rods of dorsal body wall; E: rods of tentacle; F: rods of podia.

The specimen measured 280 mm and weighed 248 g. Colouration of the fresh specimen was rusty brown and papillae were orangeish (Fig. 3A). The body was cylindrical with relatively long podia on the ventral side (Fig. 3B). The dorso-ventral skin was thin. The terminal mouth was surrounded by 20 dendro-peltate retractile tentacles. Large, clearly tube feet were present on the ventral side. The anus was terminal with three small papillae. Dorso-ventral spicules were similar to tables and rods (Figs. 3C, 3D and 3F). Tables were more numerous on the dorsal side than on the ventral body wall. Tentacle spicules were rod shaped (Fig. 3E).

Remarks

This species is commonly known as Ashy sea cucumber. The specimen observed resembles the specimens described by Samyn et al. (2006) and Purcell et al. (2012).

H. cinerascens is a new addition to the coastal fauna of Pakistan. The specimen is deposited in the repository of the Marine Reference Collection and Resource Centre, University of Karachi. Cat. No. Holo. 15.

Ohshimella ehrenbergii

Order: Dendrochirotida Grube, 1840; family: Sclerodactylidae Panning, 1949; subfamily: Cladolabinae Heding & Panning, 1954; genus: *Ohshimella* Heding & Panning, 1954; species: *ehrenbergii* Selenka, 1868.

Material examined

Four specimens of *O. ehrenbergii* were collected from Sunehri beach (24.8797°N, 66.6858°E); one on 24 April 2014, one on 22 May 2014 and two on 8 September 2014. All were collected from crevices in the rocky bottom in the intertidal area during low tide.

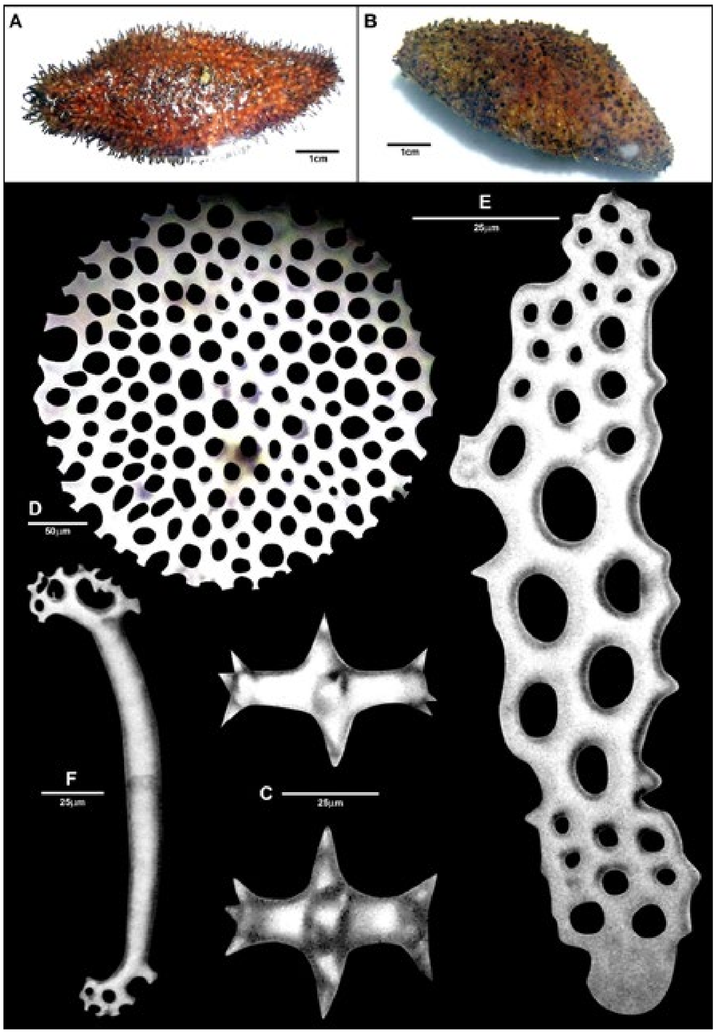

Figure 4. *Ohshimella ehrenbergii.*
A: Dorsal view; B: ventral view; C: sticks of teguments; D: plaques of ventral podia; E: plaque terminale of ventral podia; F: tentacle rods.

Length range of the specimens was 40–100 mm and weight was 6–19 g. Colouration of the fresh specimens was deep orange on the dorsal and ventral sides, and the papillae were brown (Figs. 4A and 4B). The body was cylindrical and slightly pointed or tapering from mouth to anus. The skin was thin. The ventral mouth contained 12 branched tentacles. Numerous tube feet were present on the ventral side. The anus was terminal. Ossicles from the dorsal body wall were rod-shaped and cruciform with well-developed spines (Fig. 4C); those from terminal and ventral podia were plaque-shaped (Figs. 4D and 4E); those from the ventral surface wall were stick- and plaque-shaped; while those from the tentacles were rod-shaped (Fig. 4F).

Remarks

The specimens found in 2014 are identical to those described by Massin (1999) and Samyn et al. (2006), with a deep orange colouration and a cylindrical body tapered at both ends. Rosettes were absent in all specimens found in 2014 and in specimens described by Samyn et al. (2006), but they were present in the specimens described by Massin (1999).

O. ehrenbergii has been rediscovered in Pakistan 43 years after it was first recorded by Clark and Rowe (1971). The specimens are deposited in the repository of the Marine Reference Collection and Resource Centre, University of Karachi. Cat. No. Holo. 16, 17 and 18.

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A checklist of the holothurians of the far eastern seas of Russia

Vadim G. Stepanov[1,2] and Elena G. Panina[1,3]

Introduction

A total of 638 literature sources were used to compile distribution records of holothurians of the far eastern seas of Russia. From these 638 sources, a checklist of 92 species was established. The following information was gathered for each species recorded: (1) the geographical distribution in the far eastern seas of Russia; and (2) the characteristic depth distribution across its entire known range of occurrence.

Checklist of the 92 species recorded in the far eastern seas of Russia

Subclass Synaptacea Cuénot 1891
[nom. transl. pro subclassis Al. Smirnov 2007 (ex Synaptida Cuénot 1891, pro classis)]
Order Synaptida Cuénot 1891
Suborder Myriotrochina Al. Smirnov 1998
Family Myriotrochidae Théel 1877
Genus *Myriotrochus* Steenstrup 1851
1. *Myriotrochus longissimus* Belyaev 1970
2. *Myriotrochus mitsukurii* Ohshima 1915
3. *Myriotrochus rinkii* Steenstrup 1851
Genus *Prototrochus* Belyaev and Mironov 1982
4. *Prototrochus kurilensis* (Belyaev 1970)
5. *Prototrochus minutus* (Östergren 1905)
6. *Prototrochus zenkevitchi* (Belyaev 1970)
Genus *Siniotrochus* Pawson 1971
7. *Siniotrochus spiculifer* Belyaev and Mironov 1981
Suborder Synaptina Al. Smirnov 1998
Family Chiridotidae Östergren 1898a
Subfamily Chiridotinae Östergren 1898a, sensu Al. Smirnov 1998
Genus *Chiridota* Eschscholtz 1829
8. *Chiridota albatrossii* Edwards 1907
9. *Chiridota discolor* Eschscholtz 1829
10. *Chiridota ochotensis* Saveljeva 1941
11. *Chiridota orientalis* Al. Smirnov 1981
12. *Chiridota pellucida* Vahl 1806
13. *Chiridota tauiensis* Saveljeva 1941
Subfamily Taeniogyrinae Al. Smirnov 1998
Genus *Scoliorhapis* H.L. Clark 1946
14. *Scoliorhapis lindbergi* (Djakonov in Djakonov, Baranova et Saveljeva 1958)
Genus *Taeniogyrus* Semper 1868
15. *Taeniogyrus inexpectatus* (Smirnov 1989b)
Family Synaptidae (Burmeister 1837), sensu Östergren 1898a
Subfamily Rynkatorpinae Al. Smirnov 1989a
Genus *Rynkatorpa* Rowe and Pawson 1967
16. *Rynkatorpa duodactyla* (H.L. Clark 1907)
Subfamily Leptosynaptinae Al. Smirnov 1989a
Genus *Anapta* Semper 1868
17. *Anapta amurensis* Britten 1906
18. *Anapta ludwigi* Britten 1906
Genus *Labidoplax* Östergren 1898a, sensu Heding 1931a
19. *Labidoplax variabilis* (Théel 1886)

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Subclass Elpidiacea Al. Smirnov 2012
Order Elasipodida Théel 1882
Family Laetmogonidae Ekman 1926
Genus *Pannychia* Théel 1882
20. *Pannychia moseleyi virgulifera* Théel 1882
Family Elpidiidae Théel 1882
Subfamily Peniagoninae Ekman 1926
Genus *Peniagone* Théel 1882
21. *Peniagone dubia* (Djakonov and Saveljeva in Djakonov, Baranova and Saveljeva 1958)
22. *Peniagone incerta* (Théel 1882)
23. *Peniagone purpurea* (Théel 1882)
Genus *Psychroplanes* Gebruk 1988
24. *Psychroplanes rigida* (Théel 1882)
Subfamily Elpidiinae Théel 1882, sensu Ekman 1926
Genus *Amperima* Pawson 1965
25. *Amperima naresi* (Théel 1882)
Genus *Ellipinion* Hérouard 1923
26. *Ellipinion papillosum* (Théel 1879)
Genus *Elpidia* Théel 1876
27. *Elpidia birsteini* Belyaev 1971
28. *Elpidia hanseni* Belyaev 1971
29. *Elpidia kurilensis* Baranova and Belyaev in Belyaev 1971
30. *Elpidia longicirrata* Belyaev 1971
31. *Elpidia minutissima* Belyaev 1971
Genus *Kolga* Danielssen and Koren 1879
32. *Kolga kamchatica* Rogacheva 2012
Genus *Scotoplanes* Théel 1882
33. *Scotoplanes hanseni* Gebruk 1983
34. *Scotoplanes kurilensis* Gebruk 1983
35. *Scotoplanes theeli* Ohshima 1915
Family Psychropotidae Théel 1882
Genus *Benthodytes* Théel 1882
36. *Benthodytes incerta* Ludwig 1894
Genus *Psychropotes* Théel 1882
37. *Psychropotes longicauda* Théel 1882
Subclass Holothuriacea Al. Smirnov 2012
Order Aspidochirotida Grube 1840
Family Mesothuriidae Al. Smirnov 2012
Genus *Zygothuria* Perrier 1898
38. *Zygothuria thomsoni* (Théel 1886)
Family Synallactidae Ludwig 1894
Genus *Bathyplotes* Östergren 1896
39. *Bathyplotes moseleyi* (Théel 1886)
Genus *Paelopatides* Théel 1886
40. *Paelopatides solea* Baranova 1955
Genus *Pseudostichopus* Théel 1886
41. *Pseudostichopus mollis* Théel 1886
42. *Pseudostichopus papillatus* (Djakonov 1952)
43. *Pseudostichopus profundi* Djakonov 1952
Genus *Synallactes* Ludwig 1894
44. *Synallactes chuni* Augustin 1908
45. *Synallactes nozawai* Mitsukuri 1912
Family Stichopodidae Haeckel 1896
Genus *Apostichopus* Liao 1980
46. *Apostichopus japonicus* Selenka 1867

Order Dendrochirotida Grube 1840 [nom. transl. Pawson and Fell 1965 (ex. Dendrochiroten Grube, 1840)]
Family Sclerodactylidae Panning 1949, sensu Smirnov 2012
Genus *Eupentacta* Deichmann 1938
47. *Eupentacta fraudatrix* (Djakonov and Baranova in Djakonov, Baranova and Saveljeva 1958)
48. *Eupentacta pseudoquinquesemita* Deichmann 1938
Genus *Havelockia* Pearson 1903
49. *Havelockia obunca* (Lampert 1885)
Family Thyonidae Panning 1949, sensu Smirnov 2012
Subfamily Thyoninae Panning 1949
Genus *Allothyone* Panning 1949
50. *Allothyone longicauda* (Öestergren 1898b)
Genus *Pentamera* Ayres 1852
51. *Pentamera calcigera* (Stimpson 1851)
Genus *Thyone* Jaeger 1833
52. *Thyone bicornis* Ohshima 1915
Subfamily Semperiellinae Heding and Panning 1954
Genus *Phyrella* Heding and Panning 1954
53. *Phyrella fragilis* (Mitsukuri and Ohshima in Ohshima 1912)
Family Cucumariidae Ludwig 1894
Subfamily Cucumariinae Ludwig 1894, sensu Panning 1949
Genus *Apseudocnus* Levin 2006
54. *Apseudocnus albus* Levin 2006
Genus *Cucumaria* de Blainville 1834 emended Panning 1949
55. *Cucumaria anivaensis* Levin 2004
56. *Cucumaria conicospermium* Levin and Stepanov 2002
57. *Cucumaria diligens* Djakonov and Baranova, in Djakonov, Baranova and Saveljeva 1958
58. *Cucumaria djakonovi* Baranova 1980
59. *Cucumaria fusiformis* Levin, 2006
60. *Cucumaria insperata* Djakonov and Baranova in Djakonov, Baranova and Saveljeva 1958
61. *Cucumaria japonica* Semper 1868
62. *Cucumaria levini* Stepanov and Pilganchuk 2002
63. *Cucumaria obscura* Levin 2006
64. *Cucumaria okhotensis* Levin and Stepanov in Levin 2003
65. *Cucumaria savelijevae* Baranova 1980
66. *Cucumaria vegae* Théel 1886
Genus *Pseudocnus* Panning 1949
67. *Pseudocnus fallax* (Ludwig 1874)
68. *Pseudocnus koraeensis* (Östergren 1898b)
69. *Pseudocnus lamperti* (Ohshima 1915)
70. *Pseudocnus pusillus* (Ludvig 1886)
Genus *Staurocucumis* Ekman 1927
71. *Staurocucumis abyssorum* (Théel 1886)
Genus *Stereoderma* Ayres 1851 emend. Panning 1949
72. *Stereoderma imbricata* (Ohshima 1915)
Subfamily Colochirinae Panning 1949
Genus *Leptopentacta* H.L. Clark 1938
73. *Leptopentacta sachalinica* (Djakonov 1958)
Genus *Ocnus* Forbes 1841
74. *Ocnus glacialis* (Ljungman 1880)
Family Psolidae Burmeister 1837
Genus *Psolidium* Ludwig 1887
75. *Psolidium djakonovi* Baranova 1977
Genus *Psolus* Oken 1815
76. *Psolus chitonoides* H.L. Clark 1901
77. *Psolus eximius* Saveljeva 1941
78. *Psolus fabricii* (Düben and Koren 1846)
79. *Psolus japonicus* Öestergren 1898b
80. *Psolus peronii* Bell 1882
81. *Psolus phantapus* (Strussenfelt 1765)
82. *Psolus squamatus* (O.F. Müller 1776)

Family Ypsilothuriidae Heding 1942
Genus *Ypsilothuria* Perrier 1886
83. *Ypsilothuria bitentaculata* (Ludwig 1894)
Family Thyonidiidae (Heding and Panning 1954), status Smirnov 2012
Genus *Ekmania* Hansen and McKenzie 1991
84. *Ekmania barthii* (Troschel 1846)
85. *Ekmania cylindricus* (Ohshima 1915)
86. *Ekmania diomedeae* (Ohshima 1915)
Genus *Thyonidium* Düben and Koren 1845
87. *Thyonidium kurilensis* (Levin 1984)
Order Molpadiida Haeckel 1896
Family Molpadiidae J. Müller 1850
Genus *Molpadia* Risso 1826
88. *Molpadia musculus* Risso 1826
89. *Molpadia orientalis* (Saveljeva 1933)
90. *Molpadia roretzi* (von Marenzeller 1877)
Family Caudinidae Heding 1931b
Genus *Paracaudina* Heding 1932
91. *Paracaudina chilensis* (J. Müller 1850)
Family Eupyrgidae Semper 1868
Genus *Eupyrgus* Lütken 1857
92. *Eupyrgus pacificus* Öestergren 1905

Geographical distribution of the 92 species recorded in the far eastern seas of Russia

The far eastern seas of Russia were divided into 14 geographical areas (Fig. 1), for which the following abbreviations were used: NWBS – northwest part of Bering Sea (from Cape Navarin to Bering Strait); MWBS – middle-west part of Bering Sea (from Cape Olytorsky to Cape Navarin); SWBS – southwest part of Bering Sea (Gulf Karaginsky, Gulf Korf, Gulf Olytorsky); CBS – central part of Bering Sea; KI – Commander Islands; SEK – off the southeast coast of Kamchatka (from Cape Lopatka to Cape Africa); KKT – Kurile-Kamchatka Trench; NKI – north Kuril Islands (Shumshu, Paramushir, Atlasova); MKI – middle Kuril Islands (Makanrushi, Onekotan, Harimkotan, Shiashkotan, Ekarma, Matua, Rasshua, Ushishir, Ketoy, Simushir, Urup); SKI – south Kuril Islands (Iturup, Kunashir, Shikotan etc.); EOS – east part of Okhotsk Sea (west coast of Kamchatka); WOS – west part of Okhotsk Sea; SI – coast of Sakhalin Island; and JS – continental shelf of Japan Sea.

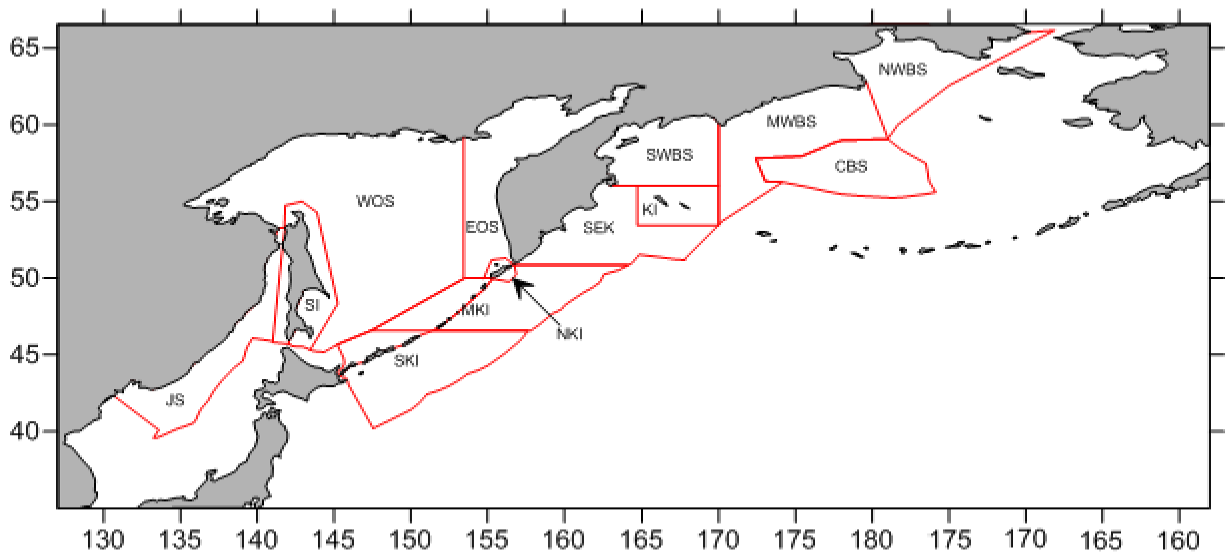

Figure 1. Division of the far eastern seas of Russia into 14 sectors. See text for abbreviations.

Detailed information on the sea cucumber species distribution in these 14 sectors is given in Table 1.

Table 1. Distribution of the 92 sea cucumber species in the checklist. Area abbreviations are defined in the text.

	Area													
Species	CBS	NWBS	MWBS	SWBS	KI	SEK	KKT	NKI	MKI	SKI	EOS	WOS	SI	JS
Myriotrochus longissimus							+							
Myriotrochus mitsukurii											+			+
Myriotrochus rinkii		+						+			+		+	
Prototrochus kurilensis							+							
Prototrochus minutus														+
Prototrochus zenkevitchi							+							
Siniotrochus spiculifer							+							
Chiridota albatrossii										+			+	+
Chirodota discolor		+			+	+					+	+		?
Chiridota ochotensis											+	+	+	
Chiridota orientalis				+		+		+					+	
Chiridota pellucida		+								+		+	+	
Chiridota tauiensis												+		
Scoliorhapis lindbergi										+			+	+
Taeniogyrus inexpectatus									+					
Rynkatorpa duodactyla	+		+							+				
Anapta amurensis													+	
Anapta ludwigi													+	
Labidoplax variabilis														+
Pannychia moseleyi virgulifera		+								+			+	
Pannychia moseleyi mollis											+			+
Peniagone dubia												+		
Peniagone incerta				+			+							
Peniagone purpurea							+							
Psychroplanes rigida							+							
Amperima naresi												+		
Ellipinion papillosum												+		
Elpidia birsteini							+							
Elpidia hanseni							+							
Elpidia kurilensis				+			+							
Elpidia longicirrata							+							
Elpidia minutissima				+										
Kolga kamchatica							+							
Scotoplanes hanseni							+							
Scotoplanes kurilensis				+			+							
Scotoplanes theeli										+				
Benthodytes incerta												+		
Psychropotes longicauda							+					+	+	
Zygothuria thomsoni							+				+			
Bathyplotes moseleyi												+	+	
Paelopatides solea			+		+									

Species	Area													
	CBS	NWBS	MWBS	SWBS	KI	SEK	KKT	NKI	MKI	SKI	EOS	WOS	SI	JS
Pseudostichopus mollis					+					+			+	+
Pseudostichopus papillatus				+										
Pseudostichopus profundi				+										
Synallactes chuni			+							+		+	+	+
Synallactes nozawai		+	+	+	+	+			+	+	+		+	+
Apostichopus japonicus										+	?	+	+	+
Eupentacta fraudatrix					+	+		+	+	+			+	+
Eupentacta pseudoquinquesemita									+					
Havelockia obunca													+	
Allothyone longicauda										+			+	+
Pentamera calcigera		+	+	+		+				+	+	+	+	
Thyone bicornis									+	+				+
Phyrella fragilis									+	+				+
Apseudocnus albus													+	+
Cucumaria anivaensis													+	
Cucumaria conicospermium									+	+				+
Cucumaria diligens													+	
Cucumaria djakonovi			+	+	+	+								
Cucumaria fusiformis												+		
Cucumaria insperata													+	
Cucumaria japonica										?			?	+
Cucumaria levini											+			
Cucumaria obscura													+	
Cucumaria okhotensis											+			
Cucumaria savelijevae						+		+			+			
Cucumaria vegae					+	+		+	+	+	+	+	+	?
Pseudocnus fallax					+	+				+			+	
Pseudocnus koraeensis										+			+	+
Pseudocnus lamperti					+									
Pseudocnus pusillus		+			+	+		+			+	+	+	+
Staurocucumis abyssorum			+	+	+	+								
Stereoderma imbricata													+	
Leptopentacta sachalinica									+	+			+	+
Ocnus glacialis		+	+	+						+	+	+	+	+
Psolidium djakonovi			+											
Psolus chitonoides		+	+		+				+	+	+	+	+	
Psolus eximius								+					+	
Psolus fabricii		+	+	+	+	+		+	+			+		+
Psolus japonicus										+			+	
Psolus peronii		+	+	+		+								
Psolus phantapus		+				+					+		+	+
Psolus squamatus										+	+		+	+
Ypsilothuria bitentaculata			+	+	+	+				+				
Ekmania barthii		+											+	

	Area													
Species	CBS	NWBS	MWBS	SWBS	KI	SEK	KKT	NKI	MKI	SKI	EOS	WOS	SI	JS
Ekmania cylindricus													+	
Ekmania diomedeae		+											+	
Thyonidium kurilensis									+					
Molpadia musculus													+	
Molpadia orientalis										+			+	+
Molpadia roretzi			+					+			+		+	+
Paracaudina chilensis													+	+
Eupyrgus pacificus														+

Depth distribution of the 92 species recorded in the far eastern seas of Russia

The depth distribution of the 92 species was classified according to the following categories:

- 0–350 / 400 m: sublittoral;
- 350 / 400–3,500 m: bathyal;
- 3,500–6,000 m: abyssal; and
- 6,000–11,000 m: ultra-abyssal.

Detailed information on the depth distribution pattern for the 92 species in the checklist is given in Table 2.

Table 2. Characteristic depth distribution of the 92 species across their entire known range of occurrence.

Species	Depth (m)	Characteristic depth distribution of the species
Myriotrochus longissimus	5,422–7,370	Abyssal–ultra-abyssal
Myriotrochus mitsukurii	67–1,760	Sublittoral–bathyal
Myriotrochus rinkii	2–790	Sublittoral–bathyal
Prototrochus kurilensis	7,795–8,430	Ultra-abyssal
Prototrochus minutus	60–3,357	Sublittoral–bathyal
Prototrochus zenkevitchi	7,400–8,135	Ultra-abyssal
Siniotrochus spiculifer	4,650-8,430	Abyssal–ultra-abyssal
Chiridota albatrossii	46–1,000	Sublittoral–bathyal
Chirodota discolor	0–1,037	Sublittoral–bathyal
Chiridota ochotensis	591–1,643	Sublittoral–bathyal
Chiridota orientalis	10–382	Sublittoral–bathyal
Chiridota pellucida	32–252	Sublittoral–bathyal
Chiridota tauiensis	0–1	Sublittoral
Scoliorhapis lindbergi	0–65	Sublittoral
Taeniogyrus inexpectatus	10	Sublittoral
Rynkatorpa duodactyla	1,006–2,980	Bathyal
Anapta amurensis	4.2	Sublittoral
Anapta ludwigi	0–53	Sublittoral
Labidoplax variabilis	0–250	Sublittoral
Pannychia moseleyi	212–2,499	Sublittoral–bathyal
Peniagone dubia	2,850	Bathyal

Species	Depth (m)	Characteristic depth distribution of the species
Peniagone incerta	2,293–7,230	Bathya–abyssal–ultra-abyssal
Peniagone purpurea	2,934–5,070	Bathya–abyssal
Psychroplanes rigida	3,194–5,230	Bathya–abyssal
Amperima naresi	1,889–7,160	Bathya–abyssal–ultra-abyssal
Ellipinion papillosum	700–5,400	Bathya–abyssal
Elpidia birsteini	8,060–9,345	Ultra-abyssal
Elpidia hanseni	8,610–9,735	Ultra-abyssal
Elpidia kurilensis	6,156–8,100	Abyssal–ultra-abyssal
Elpidia longicirrata	8,035–8,345	Ultra-abyssal
Elpidia minutissima	4,100–5,740	Abyssal
Kolga kamchatica	6,225–6,236	Ultra-abyssal
Scotoplanes hanseni	4,650–7,660	Abyssal–ultra-abyssal
Scotoplanes kurilensis	2,300–4,400	Bathyal–abyssal
Scotoplanes theeli	545–2,500	Bathyal
Benthodytes incerta	2,417–3,570 4,087?	Bathyal–abyssal
Psychropotes longicauda	2,210–6,420	Bathya–abyssal–ultra-abyssal
Zygothuria thomsoni	565–5,307	Bathya–abyssal
Bathyplotes moseleyi	50–1,730	Sublittoral–bathyal
Paelopatides solea	2,220–2,416	Bathyal
Pseudostichopus mollis	91–1,600	Sublittoral–bathyal
Pseudostichopus papillatus	182–4,200	Sublittoral–bathyal–abyssal
Pseudostichopus profundi	4,100–4,200	Abyssal
Synallactes chuni	75–653 1,000?	Sublittoral–bathyal
Synallactes nozawai	56–1,600	Sublittoral–bathyal
Apostichopus japonicus	0–150	Sublittoral
Eupentacta fraudatrix	0–40	Sublittoral
Eupentacta pseudoquinquesemita	0–200	Sublittoral
Havelockia obunca	0–20	Sublittoral
Allothyone longicauda	15–241	Sublittoral
Pentamera calcigera	0–500	Sublittoral–bathyal
Thyone bicornis	19–635	Sublittoral–bathyal
Phyrella fragilis	0–450	Sublittoral–bathyal
Apseudocnus albus	30.5–74	Sublittoral
Cucumaria anivaensis	29	Sublittoral
Cucumaria conicospermium	34–102	Sublittoral
Cucumaria diligens	47	Sublittoral
Cucumaria djakonovi	5–140	Sublittoral
Cucumaria fusiformis	36	Sublittoral
Cucumaria insperata	36	Sublittoral
Cucumaria japonica	0–300	Sublittoral
Cucumaria levini	60?	Sublittoral
Cucumaria obscura	88	Sublittoral
Cucumaria okhotensis	14–131	Sublittoral
Cucumaria savelijevae	36–183	Sublittoral
Cucumaria vegae	0–51	Sublittoral
Pseudocnus fallax	8–180	Sublittoral

→

Species	Depth (m)	Characteristic depth distribution of the species
Pseudocnus koraeensis	?–68	Sublittoral
Pseudocnus lamperti	79–247	Sublittoral
Pseudocnus pusillus	0–62	Sublittoral
Staurocucumis abyssorum	385–4,810	Sublittoral–bathyal
Stereoderma imbricata	127–136	Sublittoral
Leptopentacta sachalinica	0–28	Sublittoral
Ocnus glacialis	11–500	Sublittoral–bathyal
Psolidium djakonovi	1,440	Bathyal
Psolus chitonoides	0–624	Sublittoral–bathyal
Psolus eximius	60–128	Sublittoral
Psolus fabricii	0–180	Sublittoral
Psolus japonicus	40–300	Sublittoral
Psolus peronii	7–93	Sublittoral
Psolus phantapus	0–400	Sublittoral–bathyal
Psolus squamatus	7–1,206	Sublittoral–bathyal
Ypsilothuria bitentaculata	100–4,400	Sublittoral–bathyal–abyssal
Ekmania barthii	10–600	Sublittoral–bathyal
Ekmania cylindricus	133	Sublittoral
Ekmania diomedeae	10–300	Sublittoral
Thyonidium kurilensis	10–228	Sublittoral
Molpadia musculus	35–5,205	Sublittoral–bathyal–abyssal
Molpadia orientalis	17–450	Sublittoral–bathyal
Molpadia roretzi	44–620	Sublittoral–bathyal
Paracaudina chilensis	1–990	Sublittoral–bathyal
Eupyrgus pacificus	31–1,475	Sublittoral–bathyal

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Discovery and description of *Stichopus herrmanni* juvenile nursery sites on Heron Reef, Great Barrier Reef

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Abstract

The population biology of the curryfish, *Stichopus herrmanni*, was investigated at Heron Island in the Capricorn Bunker Group of the southern Great Barrier Reef (GBR), Australia. Heron Reef is of particular interest because it is a protected no-take area within the GBR Marine Park and is adjacent to areas where this species is fished. We report the discovery of a juvenile nursery site for *S. herrmanni*, which to date are still poorly understood. An area of ~3,200 m^2 across the leeward side of Heron Reef was found to support a density of 0.017 ind. m^{-2} of *S. herrmanni.* Sexually immature adults (<220 mm) constituted 49% of a population of 53 individuals, and 2 individuals were juveniles (≤100 mm). The mean length of *S. herrmanni* at site 1 was 190 mm (±7.5 mm) while individuals at site 2 had a mean length of 294 mm (±13.3 mm). The fact that individuals were larger at site 2 suggests ontogenetic migration of this species. This is an important documentation of juvenile *S. herrmanni* habitat, which should be considered in fisheries management strategies to better understand and protect this delicate life stage and avoid serious depletion of this important commercial species from the reef.

Introduction

The fishery operating within the Great Barrier Reef Marine Park (GBRMP), the East Coast Bêche-De-Mer Fishery (ECBDMF), exploits medium value beche-de-mer species, including the curryfish, *Stichopus herrmanni*, which sells on the Hong Kong market for around USD 197 ± 47 kg^{-1} (Purcell 2014). From 2007 to 2011 the total harvest of *S. herrmanni* increased at an average annual rate of 200% (Eriksson et al. 2013; Eriksson and Byrne 2015). The *S. herrmanni* fishery is now presenting an average annual catch of approximately 34,000 individuals, roughly equivalent to 17.2 t (landed weight) (Skewes et al. 2014). At this rapidly increasing level of harvest, it is vital to develop a better understanding of the biology and ecology of this species to provide useful guidelines for fisheries management.

Sea cucumbers play a fundamental role in the recycling of nutrients, helping to break down detritus and other organic matter after which bacteria continue the degradation process (Uthicke 1999; Mangion et al. 2004; Purcell et al. 2013). Furthermore, sea cucumbers have an important ecological role through their released nitrogenous waste compounds, which promote the growth of seagrass and microalgal communities (Uthicke 2001; Wolkenhauer et al. 2010). Their faecal casts also increase local seawater total alkalinity, and this is suggested to promote coral calcification processes and potentially provide a buffer against the negative effects of ocean acidification (Schneider et al. 2011, 2013; Friedman et al. 2011). In light of these discoveries it is clear that the depletion of sea cucumbers, such as *S. herrmanni*, from reef areas could seriously impact coral reef ecosystem resilience (Schneider et al. 2011).

Our study was conducted at Heron Reef, southern GBR, which is a no-take zone exposed to minimal anthropogenic and fishery disturbances. The collection of biota, including sea cucumbers, has been highly regulated since 1843. The reef is located close to reefs where the ECBDMF operates in the Capricorn Bunker Group. This island group supports a conspicuous population of *S. herrmanni* and is a major target region for this fishery (Eriksson et al. 2010, 2013; Skewes et al. 2014; DAFF 2014).

Heron Reef provides an opportunity to investigate the conservation and fishery biology of *S. herrmanni*. We encountered a population of juvenile *S. herrmanni* on the leeward margin of Heron Reef, allowing us to assess the characteristics of a potential recruitment site for this commercially important species. Other studies document similar juvenile habitat in the Capricornia Bunker Group at nearby One Tree Island (Eriksson et al. 2010, 2013; Eriksson and Byrne 2015). On One Tree Reef the smallest *S. herrmanni* encountered was 110 mm long, and this was located in shallow coral/crustose coralline algal habitat (Eriksson et al. 2010, 2013). We document the smallest individuals of *S. herrmanni* reported in situ in the southern GBR (Shiell 2004). Conand (1993) reports a juvenile *S. herrmanni* of 90 mm in length in New Caledonia.

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Aside from early planktonic larval life stages of marine invertebrates where mortality is around 99% (Gosselin and Qian 1997), little is known about the juvenile life stages, which are considered to be extremely vulnerable (Battaglene et al. 1999; Shiell 2004; Hu et al. 2010). Success at the juvenile stage is fundamental for establishing adult populations, which are necessary for fisheries. It is imperative that we develop a better understanding of the population structure of sea cucumbers to provide information for fisheries management strategies. Understanding the biology and ecology of recruitment and early juvenile stages is particularly important.

Methods

Observations were made across Heron Reef in a series of surveys over several days during April 2015. After identifying a specific habitat where small *S. herrmanni* were present, two sites were chosen along the leeward reef edge for further study (Fig. 1). This habitat is characterised by dense intertidal reef and thick crustose coralline algae shelves (Fig. 2). There are obvious spur-and-groove systems along the reef edge, with narrow gullies of sandy habitat between reef structures (Fig. 2).

The population structure of *S. herrmanni* was investigated using a targeted transect technique across the sand cay. Transects (40 × 2 m; n = 20 per site) were laid out randomly across sandy substrate, sometimes intercepting reef habitat, and employing the protocol of the Reef Fisheries Observatory (Secretariat of the Pacific Community) (Eriksson et

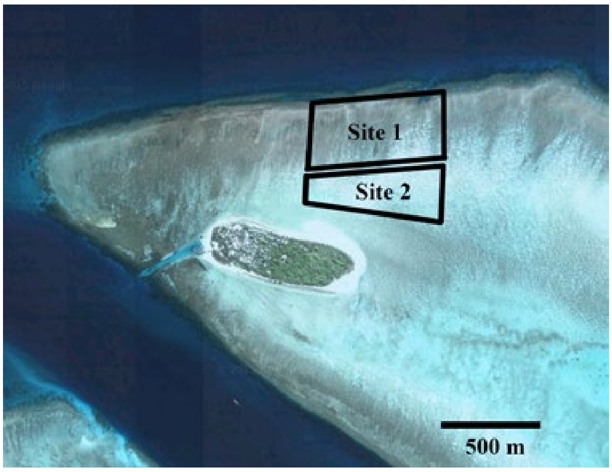

Figure 1. Satellite image showing Heron Island and sites 1 and 2, along the leeward reef edge, where the juvenile *Stichopus herrmanni* nursery was found. (Image: Kennedy Wolfe)

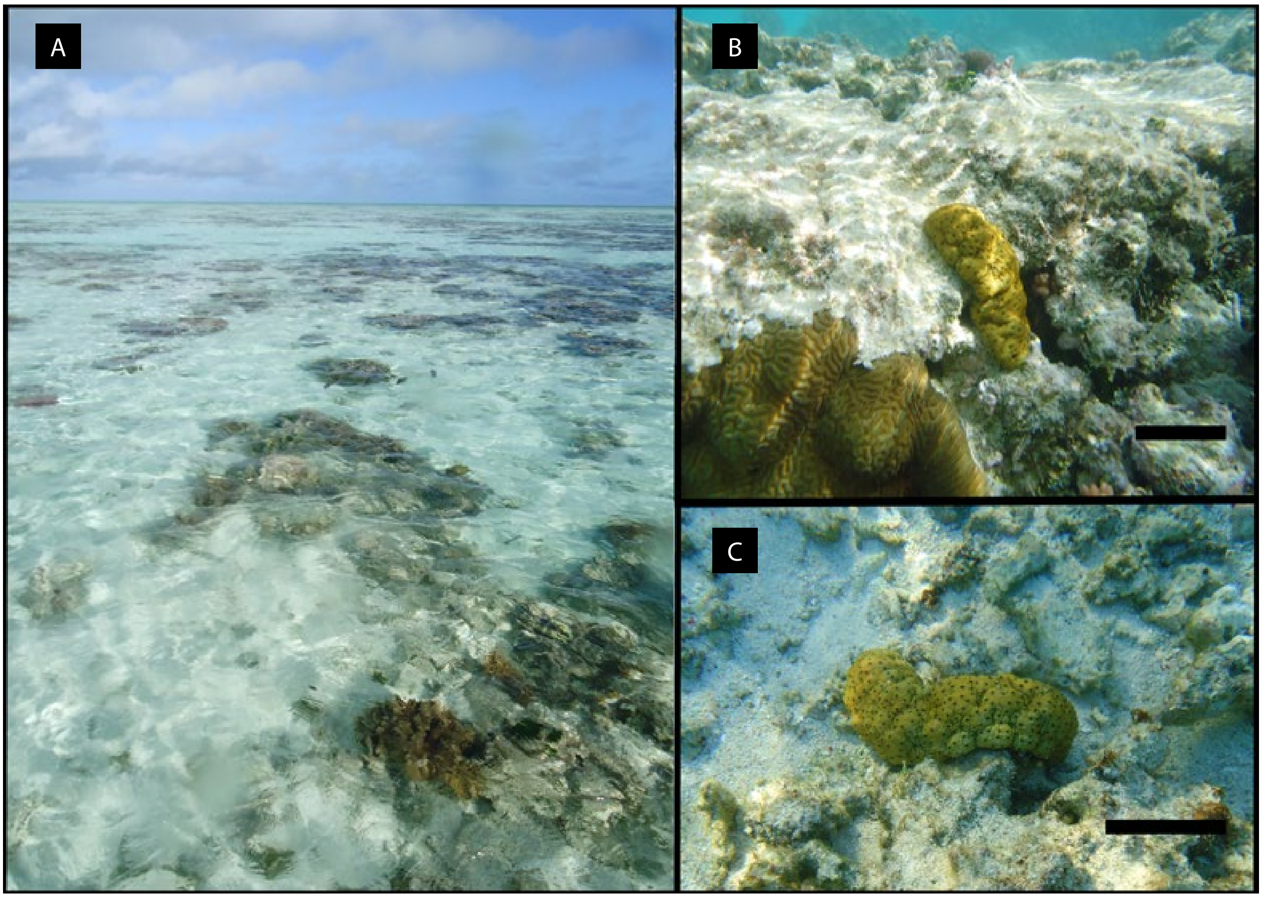

Figure 2. Habitat typical of site 1, where juvenile *Stichopus herrmanni* were found. A: Patches of reef around sandy channels; B and C: juvenile *S. herrmanni* in the reef network (scale bars = 4 cm). (Images: Kennedy Wolfe and Luca Palazzo)

al. 2010). All *S. herrmanni* inside each transect were counted, and the length and width of each individual were measured. Measurements were made using a flexible tape measure without touching or disturbing the individual, so as not to make it contract or change shape.

Results

A total of 53 *S. herrmanni* were found over an area of ~3,200 m^{2,} a density of 0.017 ind. m^{-2}. The density of *S. herrmanni* found at site 1 was 0.0175 ind. m^{-2} and at site 2 the density was 0.016 ind. m^{-2}. Over this area, considering sexually immature *S. herrmanni* are <220 mm in length (Eriksson et al. 2010), subadults represented 75% of the total population at site 1 and 20% at site 2. Individuals at site 1 had a mean length of 190 mm (SE 7.5 mm; n = 28; range 100–260 mm) while at site 2 they had a mean length of 294 mm (SE 13.3 mm; n = 25; range 190–400 mm) (Fig. 3). Two individuals were 100 mm in length at site 1 (Fig. 3).

Discussion

The lagoon system of Heron Reef supports a wide and stable population of *S. herrmanni*, similar to that recorded for nearby One Tree Island (~15 km to the east) (Eriksson et al. 2010, 2013). The discovery of juvenile nursery habitats has added more value to these lagoonal systems for the conservation of this vulnerable species in the Capricorn Bunker Islands. The data generated here indicate the need for more expansive research on *S. herrmanni* in the region to assist informed management for the beche-de-mer fishery that operates in the Capricorn Bunker Group. The density of *S. herrmanni* at Heron Island was lower than that found by Eriksson et al. (2010) on One Tree Island, but is still high compared to the literature (Kinch et al. 2008a, 2008b; Skewes et al. 2014). It is important to keep in mind that the density for this species seems to be significantly influenced by site (Eriksson et al. 2010, 2013). The population at Heron Reef presented a conspicuous number of juveniles (100 mm) and immature adults (<220 mm; Eriksson et al. 2013), in contrast to the smallest individuals observed on One Tree Reef (110 mm).

A population of juveniles is a rare observation for beche-de-mer species (Shiell 2004). Our surveys did not cover a very extensive area (3,200 m^2), and further surveys are needed for a better understanding of the extent of the recruitment/nursery habitat of *S. herrmanni* on Heron Reef, and for a deeper understanding of the juvenile life stage of *S. herrmanni*. More data are needed to determine the characteristics of juvenile nurseries for this beche-de-mer species, from physical and chemical perspectives. Since both juveniles and adults are present in the study area, Heron Reef provides an excellent opportunity for future research on the population structure and reproduction (e.g. spawning, Allee effects) of *S. herrmanni*.

Most *S. herrmanni* were found very close to reef structure and in sheltered sandy patches within the reef (Fig. 2). To date, habitats known to be suitable for larval settlement and metamorphosis to juvenile stage of holothurians are seagrass beds, intertidal reef, coralline algae and associated bacterial films (Shiell 2004; Hu et al. 2010; Skewes et al. 2014). We document juvenile/nursery habitat along the

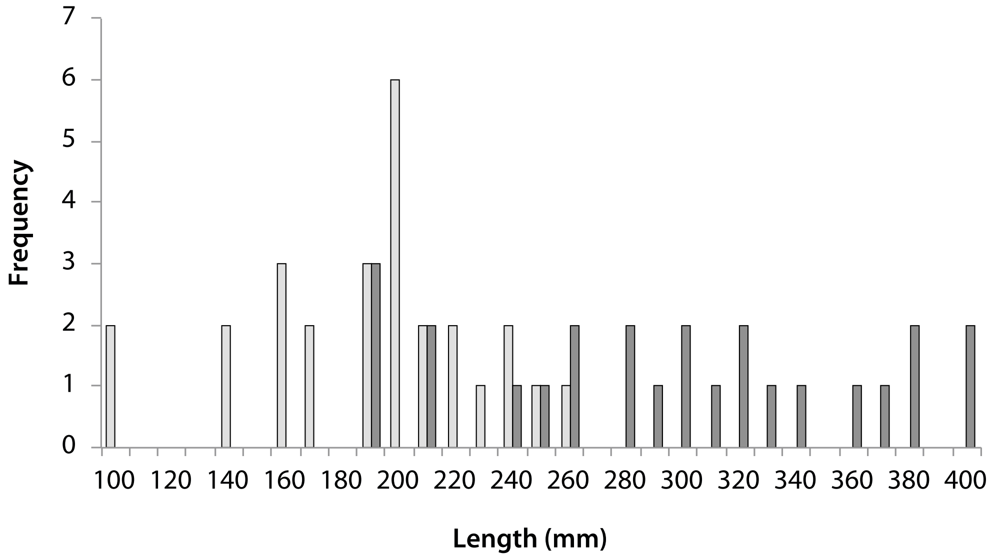

Figure 3. Length frequency diagram of *Stichopus herrmanni* specimens found at site 1 (light bars) and site 2 (dark bars) on Heron Reef (n = 53).

leeward side of Heron Reef, which is less exposed to the main wind and wave climate. We suggest that recruitment may occur once the larvae reach the outer leeward wall of Heron Reef, with juveniles developing along this margin and progressively moving inside Heron Lagoon to the deeper water as they grow; the deeper sediments are also more rich in nutrients (Larkum et al. 1988; Eriksson et al. 2010). All juveniles and a greater number of smaller individuals were found at site 1 compared to site 2, supporting the hypothesis of ontogenetic migration lagoonward (see also Eriksson et al. 2013).

Populations of beche-de-mer species often show very slow recovery following depletion by fishery removal. For example, the black teatfish, *Holothuria nobilis*, showed no recovery two years after fishery closure (Uthicke et al. 2004). This is suggested to be due to low recruitment and slow individual growth rates. Recovery of overfished sea cucumber populations on the GBR may take several decades (Uthicke et al. 2004). It is therefore important that fisheries identify recruitment habitats for protection and avoid collection from these locations.

There remains uncertainty around the population structure of commercially important beche-de-mer species. For example, there is still a lot of doubt on species longevity (Conand 1993; Friedman et al. 2011). For *S. herrmanni*, multiple cohorts across a broad size range were observed at One Tree Reef (Eriksson et al. 2013), leading to the suggestion that there is continuous replacement of individuals from recruitment and juvenile habitats to adult populations. Our findings support this. It is imperative that the fisheries operating within the Capricorn Bunker Group and elsewhere have a deeper understanding of the population structure and reproductive behaviour of commercially important species such as *S. herrmanni*. Surprisingly, there are no published data on the reproductive cycle for any of the populations of the major commercial species in the GBRMP. There is also a lack of published data on population recovery of reefs post-fishing. Regular population monitoring and fishery-independent data are essential to assess the sustainability of the fishery and the health of the reef itself.

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New observations of holothurian juveniles on Réunion reefs

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Introduction

The questionnaire published in issue #19 of the SPC *Beche-de-mer Bulletin* (Shiell 2004a) brought together numerous information that had been collected *in situ* on the recruitment of sea cucumber juveniles (Bourjon and Conand 2015; Shiell 2004b). This article concerns 63 observations made in 2014 and 2015 by the authors on the reefs of Réunion. The seven juveniles of *Actinopyga echinites* and *A. mauritiana*) that were observed in an area of recruitment during October and November 2015 are presented in another article in this bulletin (see p. 84).

Observations and results

Observations were made at the reefs of St Gilles-les-Bains and Etang Salé, and the platform-reef of Grand Fond. Forty-seven of the sixty-three observations were made in the area of the reef front. All study sites in this area are characterized by strong hydrodynamism, a depth of less than 1 m, and abundant coral rubble. Forty-five juveniles were hidden under slab-shaped debris. In other areas, the majority of juveniles were also concealed under the same type of coral rubble. All juveniles were photographed and most of them were measured or their length was estimated. The observation sites were not the same for each visit, thereby avoiding double reporting of individuals.

Because the size, or the age at first reproduction, is not known for all species (Kohler et al. 2009; Muthiga and Conand 2014), "juvenile" is not an accurate or reliable identifier. Size – an indirect indicator of age for individuals living in similar conditions – was therefore assessed in proportion to the size of the largest adults of the same species found on the same reef. The information concerning juveniles and young adults may also be useful because migration is observed at these stages in several species (Shiell 2004b).

The observations are grouped by families and species in Table 1 for Holothuriidae, and Tables 2 and 3 for Stichopodidae and Synaptidae. Furthermore, a 1.2-cm juvenile *Afrocucumis africana*, family Sclerodactylidae, was observed on 7 October 2015 near the front under a dead coral block.

Photos of each species (except *Actinopyga echinites* and *A. mauritiana*, see p. 84, this issue) are presented in Figures 1, 2 and 3.

Table 1. Juveniles of the family Holothuriidae.

Species	Length (contraction)*	Site	Habitat	Date	Time	Adults present
Actinopyga echinites	3 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	28/10/15	15:39	no
Actinopyga mauritiana	12 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	8/10/14	10:08	yes
	2.5 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	23/10/15	11:08	yes
	3.2 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	14/11/15	11:06	no
Holothuria arenicola	3 cm (C)	Saint Gilles	Sandy-detrital area, under dead coral	1/11/15	13:56	no
Holothuria cinerascens	5 cm (R)	Saint Gilles	Detrital area near a sea-grass bed, under dead coral	27/09/14	11:20	yes
	2 cm (C)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	21/10/15	11:47	no
	3 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	11/11/15	10:37	yes
Holothuria flavomaculata	7 cm (HC) 20 cm (HC) 22 cm (HC)	Saint Gilles	Three individuals grouped under dead coral, outer reef flat detrital zone, near surf	25/12/14	10:00	no
	7 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	26/08/15	10:47	no
	2 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	1/11/15	15:51	no
Holothuria hilla	12 cm (R)	Saint Gilles	Sandy-detrital area, under dead coral	14/01/15	15:52	no
	11 cm (HC)	Saint Gilles	Sandy-detrital area, under dead coral	8/04/15	11:00	no

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Species	Length (contraction)*	Site	Habitat	Date	Time	Adults present
Holothuria impatiens (complex)	5 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	22/11/14	11:40	no
	6 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	22/11/14	11:48	no
	12 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	5/12/14	14:56	no
	11 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	4/10/14	10:50	no
	6 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	23/09/15	11:01	no
	4 cm (C)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	26/09/15	10:57	no
	5.5 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	7/10/15	11:35	no
	4 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	1/11/15	15:40	no
Holothuria leucospilota	9 cm (HC)	Saint Gilles	Sandy-detrital area, under dead coral, with two adults	1/12/04	11:04	yes
	7 cm (HC)	Saint Gilles	Sandy-detrital area	23/05/15	10:32	yes
	5 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	23/05/15	10:40	no
Holothuria nobilis	15 (C)	Saint Gilles	Sandy-detrital area with sparse live coral	18/11/15	11:08	no
Holothuria pervicax	6 cm (C)	Etang Salé	Sandy-detrital area	7/05/14	09:56	yes
	6 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	6/08/14	10:26	no
	9 cm (R)	Saint Gilles	Sandy-detrital area, under dead coral	14/01/15	16:32	yes
	4 cm (C)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	1/07/15	10:54	no
	5 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	3/10/15	11:58	no
	7 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	23/09/15	10:22	no
	6 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	7/10/15	09:37	no
	5 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	7/10/15	10:06	no
	2.5 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	24/10/15	10:09	no
	8 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	1/11/15	14:00	no
	4 cm (C)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	11/11/15	10:12	no
Holothuria verrucosa	9 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral; two individuals side by side.	6/08/14	11:17	no
	5 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	26/08/15	10:31	no
Labidodemas sp.	3 cm (R)	Grand Fond	Coral reef platform, high hydrodynamics, under dead coral	22/02/15	15:34	no

* C = contracted, HC = half-contracted, R = relaxed

Table 2. Juveniles of the family Stichopodidae.

Species	Length (contraction)*	Site	Habitat	Date	Time	Adults present
Stichopodidae	3 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	21/09/14	10:20	no
Stichopodidae (post-larve)	2 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	3/10/15	11:46	no
	2.5 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	1/11/15	15:04	no
Stichopus chloronotus	4.5 cm (C)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	3/10/15	10:56	yes
	6 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	3/10/15	10:21	no
	5 cm (C)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	7/10/15	09:57	no
Stichopus herrmanni	11 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	1/11/15	14:40	no
Stichopus monotuberculatus	8 cm (C)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	5/12/14	14:54	no
	4.5 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	7/10/15	10:32	no
	5 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	7/10/15	10:32	no
	7.5 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	10/10/15	10:35	no
	6.5 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	1/11/15	15:32	no
	10 cm (R)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	25/11/15	10:29	no

* C = contracted, HC = half-contracted, R = relaxed

Table 3. Juveniles of the family Synaptidae.

Species	Length (contrac-tion)*	Site	Habitat	Date	Time	Adults present
Euapta godeffroyi	16 cm (C)	Saint Gilles	Sandy-detrital area, under dead coral	18/10/14	10:10	no
	18 cm (HC)	Saint Gilles	Sandy-detrital area, under dead coral	29/08/15	10:40	no
	7 cm (C)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	3/10/15	10:45	no
	18 cm (C)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	28/10/15	15:32	no
Synapta maculata	30 cm (HC)	Saint Gilles	Sandy area	17/05/14	09:47	yes
	20 cm (C)	Saint Gilles	Sandy-detrital area	30/08/14	11:00	yes
	13 cm (C)	Saint Gilles	Sandy area	1/11/14	09:37	yes
	12 cm (C)	Saint Gilles	Sandy-detrital area	27/12/14	09:17	yes
	20 cm (HC)	Saint Gilles	Sandy-detrital area, under dead coral	21/03/15	10:22	yes
	5 cm (C)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	2/09/15	10:47	no
	18 cm (HC)	Saint Gilles	Outer reef flat detrital zone, near surf, under dead coral	11/11/15	10:53	no

* C = contracted, HC = half-contracted, R = relaxed

Figure 1. Juveniles of the family Holothuriidae.
A: *Holothuria arenicola*; B: *H. cinerascens*; C: *H. flavomaculata*; D: *H. hilla*; E: *H. impatiens*; F: *H. leucospilota*; G: *H. nobilis*; H: *H. pervicax*; I: *H. verrucosa*; J: *Labidodemas* sp.).
(Images: © P. Bourjon)

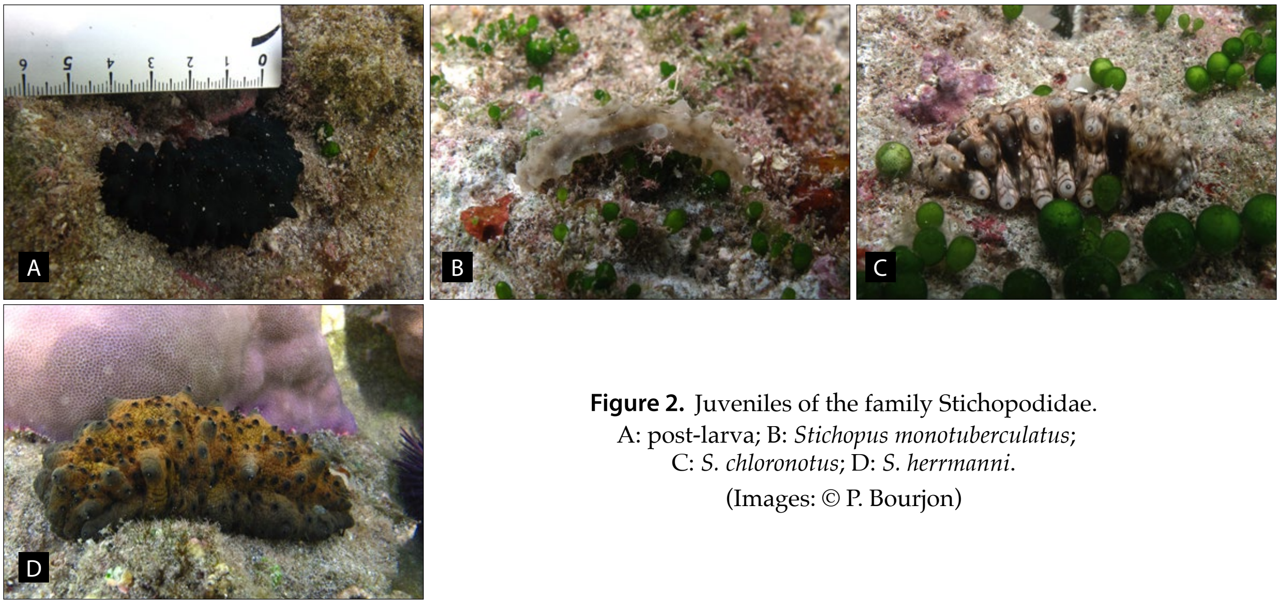

Figure 2. Juveniles of the family Stichopodidae. A: post-larva; B: *Stichopus monotuberculatus*; C: *S. chloronotus*; D: *S. herrmanni*. (Images: © P. Bourjon)

Figure 3. Juveniles of the family Synaptidae (A: *Euapta godeffroyi*; B: *Synapta maculata),* and Sclerodactylidae (C: *Afrocucumis africana*). (Images: © P. Bourjon)

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Predation by the gastropod *Tonna perdix* (Gastropoda: Tonnoidea) on the holothurian *Actinopyga echinites* (Echinodermata: Holothuroidea) on a reef of Réunion

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Introduction

Although holothurians are sometimes considered to have few predators, 76 specialist or opportunist predator species have been identified, with the most significant groups being sea stars, finfish and crustaceans (Francour 1997). A recent summary paper (Purcell et al. in press) adds yet more information based on recent observations of commercially important sea cucumber species. Holothurians have developed seven methods of defence against these predators, with each species of sea cucumber using one or more of the following tactics: 1) possessing a thick tegument and spicules; 2) possessing a toxic tegument and organs; 3) swelling and hardening the body; 4) eviscerating or autotomising (including the expulsion of the Cuvierian tubules); 5) swimming; 6) having nocturnal behaviour; and 7) having cryptic or burrowing behaviour (Francour 1997). *Actinopyga echinites* (Jaegger, 1833) uses the first four types of defence as well as the seventh. The fourth defence is, however, limited to a few observed cases of evisceration (Conand 1989), and this species possesses a rudimentary Cuvierian organ whose tubules, incapable of extension and becoming sticky, are never expelled (VandenSpiegel and Jangoux 1993). In addition, it does not swim and its activity is diurnal.

The prosobranch gastropod *Tonna perdix* (Linnaeus, 1758), which is a widespread species in the Indo-Pacific region, is a specialist predator on holothurians (Francour 1997; Morton 1991; Vos 2013). Its shell can reach 227 mm.[2] It has a highly extendable proboscis, into which lead two canals supplying a place close to the mouth with secretions containing sulphuric acid produced by two large salivary glands (Bolis et al. 1984). The percentage of sulphuric acid in the secretions is from 3 to 5 %, enough to paralyse the prey (Vos 2013). Like some sea star species, *T. perdix* seems to have immunity against the chemical defences – called saponins and known collectively as holothurin – used by sea cucumbers (Caulier et al. 2011). From experiments conducted, *T. perdix*, however, seems to be selective in its choice of prey (Morton 1991), preferring to attack species in which the content and nature of these chemical substances are less repellent than its own (Bondoc et al. 2013). Kropp (1982) observed that *Holothuria atra* is not a preferred prey of *T. perdix* in an experimental setting, and Van Dick et al. (2010) noted that *H. atra* only contains sulfated saponins, similar to *A. echinites* (Bondoc et al. 2013). It is, therefore, probable that the sulfated saponins have a stronger deterrent effect than non-sulfated saponins on this gastropod. In addition, Van Dick et al. (2010) observed a higher concentration of these substances in the Cuvierian tubes than in the tegument of *A. echinites*. Such a concentration within an apparently non-operational defence mechanism seems anomalous. The authors suggest that this means of defence has evolved in these species from an aggressive defence strategy based on the tubules sticking to the attacker in a defence strategy based on toxicity (Hamel and Mercier 1999). Some species of the genera *Actinopyga*, *Bohadschia* and *Holothuria* actually show their Cuvierian tubes without expelling them and then retract them. While most of the sulfated saponins found in the Cuvierian tubes are highly soluble in water and disperse rapidly in the environment, the mere exposing of the Cuvierian tubes can, therefore, be enough to obtain the desired repellent effect (Van Dick et al. 2010).

Predatory behaviour by Tonnidae on holothurians has infrequently been observed in the wild and has only been studied in experimental situations in aquaria (Kropp 1982; Morton 1991; Toscano et al. 1992; Heron Island Research Station 2009). Predation by *T. perdix* on *A. echinites* had never been observed in the wild until the observation recorded on 3 February 2015 on the fringing reef of Saint-Pierre, Réunion (21°07'S and 55°32'E). The observation[3] lasted from 20:45 to 21:15. When the observer came across the event, the gastropod was beginning to attack the holothurian (Fig. 1), which had already swollen itself up with water and pushed its podia out as far as they would go. Several fruitless attempts by the predator to suck the holothurian into its proboscis by grasping its sides were observed (Fig. 2). The

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[2] See http://www.gastropods.com/9/Shell_1499.shtml
[3] https://www.youtube.com/watch?v=mFftCx6BnUM
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holothurian was released three times. The gastropod seemed to be trying to move the prey using the end of its proboscis, particularly by trying to turn the prey onto its back, probably so as to be able to grasp it more easily by its anterior end. During the first attempt, four-fifths of the holothurian's body was enveloped by the proboscis; the proboscis was then retracted, with only one end of the prey still being held. It showed no sign of injury. A second attempt produced the same result, but after that, the posterior third of the holothurian was contracted, while the rest of the body remained swollen (Fig. 3). The separation zone between these two parts of the body was very clear, with the difference in diameter being 3 cm. The fact that the majority of the podia on the contracted part were retracted suggests that the prey was paralysed by the sulfuric acid in the gastropod's secretions. The fact that the predator had resumed its manoeuvre from this contracted part on the third attempt (Fig. 4) would tend to confirm this, and to suggest that the previous manoeuvres were intended to paralyse the prey. The last attempt led to the whole of the holothurian's body being absorbed. When the gastropod ceased moving, the observation was halted. No exposure of the Cuvierian tubes nor the dilation of the cloaca were noted in *A. echinites* over that half-hour. For this species to be a prey for *T. perdix*, despite its probable low palatability to this taxon because it only contains sulfated saponins (Bondoc et al. 2013), could be due either to a quantitative or qualitative failing in the development of saponin by the organism of the specimen concerned, or more probably to the fact that it was the first to be encountered by a specialised predator. The results of palatability tests carried out experimentally can be biased by the choice offered to the predator, which it may only infrequently encounter on a reef.

Morton (1991) recorded that, in an experimental situation, *Tonna zonatum* consumes approximately one holothurian per week. Also, juvenile holothurians suffer massive predation (Dance et al. 2003) as well as excessive fishing pressure (Uthicke and Conand 2005). Better knowledge of the impact of predation on adult holothurian population dynamics continues to be necessary in order to improve the effectiveness of management and conservation efforts for commercial holothurian species that suffer from overfishing, especially given the key ecological role these species play in nutrient recycling and bioturbation.

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Figure 1. The holothurian *Actinopyga echinites* after contact with the predator *Tonna perdix*. Note the holothurian has swollen itself up with water (defence mechanism #3).

Figure 2. *Tonna perdix* attempting to suck the holothurian *Actinopyga echinites* into its proboscis by grasping its sides.

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Figure 3. After almost being completely absorbed twice into the predator's proboscis, the holothurian is kept captive until the next attempt. Observe the contraction of the anterior part (paralysed during previous attempts?). The last attack began from the contracted area.

Figure 4. The gastropod's last attempt results in the absorption of the whole of the holothurian's body, in progress here. The predator remains motionless at the end of the operation.

Effect of lunar phases in the size distribution of *Holothuria scabra* on intertidal areas in Sarangani Bay, Philippines

Kier Mitchel E. Pitogo[1], Jennelyn P. Sumin[1], Ariel T. Ortiz[1]*

Abstract

There have been few studies conducted on sea cucumbers, specifically *Holothuria scabra*, in Sarangani Bay, Philippines; and thus, there is little information to guide conservation and management efforts of these organisms in this area. A survey on the size distribution of *H. scabra* was carried out in three shallow intertidal areas by using the belt transect method during two lunar phases – full moon and new moon – for four months to evaluate this species' intertidal population. The result shows a unimodal distribution of *H. scabra*, with specimens found during the new moon phase to be significantly larger than those found during the full moon phase. The sex ratio was estimated to be 1:1, consistent with most holothuroid studies, and not affected by the lunar phase. Population densities ranged from 0.17 individuals per square metre (ind. m^{-2}) during full moon periods, to 0.34 ind. m^{-2} during new moon periods at three stations. The calculated allometric coefficient of 1.84 indicates that *H. scabra* are leaner for a given length in these areas than in other areas. The results also suggest that lunar phases have an effect on the size distribution of *H. scabra,* which probably explains the larger individuals collected by intertidal gleaners during new moon periods.

Introduction

Overexploitation and habitat loss are the two main reasons for the population decline of sea cucumbers in the Philippines. These threats, coupled with the increasing demand by the sea cucumber trade, destabilize sea cucumber populations in the country. *Holothuria scabra,* a high-valued species, is actively harvested and exploited, leading to severe fishing pressure and serious depletion of natural populations (Akamine 2005). Although it is considered a commercially valuable species in the Philippines (Akamine 2001), management measures specific to sea cucumber conservation are still lacking in the country (Bruckner et al. 2003).

In Sarangani Bay, few studies have been conducted on sea cucumbers, which makes it difficult to establish conservation and management measures based on scientifically sound assessments. Previous work on sea cucumbers, specifically *H. scabra,* have failed to provide metrics about the size distribution of the local population or contribute to the very little information about this economically important species. Because it is a local delicacy, this species is also collected by intertidal gleaners during low tides, especially during a new moon when larger sized individuals can be collected. Unfortunately, anecdotal evidence suggests that there is a reduction in the size of *H. scabra* gleaned in the intertidal areas of the bay. A rapid survey was, therefore, conducted to evaluate the size distribution, sex ratio and density of *H. scabra* on selected intertidal areas in Sarangani Bay during two different lunar phases: full moon and new moon.

Materials and methods

Sarangani Bay is located in the southeast of Mindanao, Philippines between 5º33'25'',and 6º6'15''N and between 124º22'45'' and 125º19'45''E (Fig. 1). Three stations were selected in Sarangani Bay for the study. The stations were chosen based on reports of high abundance of sea cucumbers and the presence of intertidal gleaners. The first site is in Sitio Linao, Barangay Tinoto, Maasim, where the nearby Tausug community harvests sea cucumbers for subsistence; the second site is in Sitio S'nlang, Barangay Tinoto, Maasim, where harvesting is minimal; and the third site is in Sitio Macatimobol, Barangay Taluya, Glan, where sea cucumbers were harvested unsustainably.

In every station, six belt transects (50-m long and 4-m wide) were established perpendicular to the shore at 10-m intervals. Investigators surveyed these transects at the lowest ebb tide during the full moon and new moon phases. In total, sampling took place over 24 nights between October 2014 and January 2015. Three investigators collected all *H. scabra* found within the 200 m^2 transects. Sea cucumbers were put back into water to

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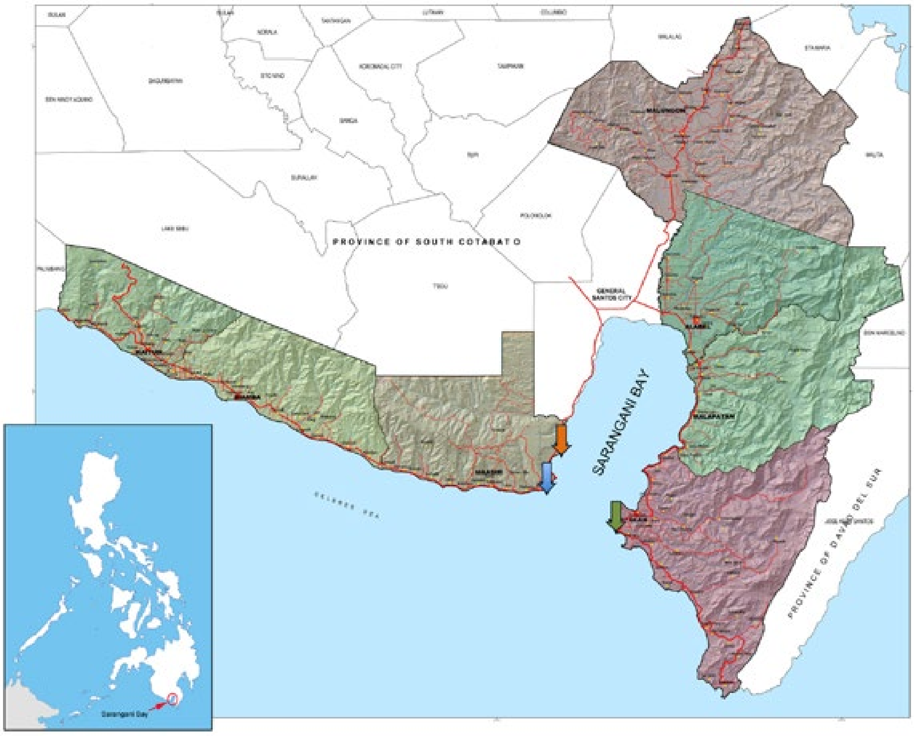

Figure 1. Location of Sarangani Bay and the three survey stations, indicated by downward arrows (orange = Sitio Linao; blue = Sitio S'nalang; and green = Sitio Macatimbol). Source: Provincial Planning and Development Office of Sarangani.

relax for five minutes. Then, total length – from mouth to anus – was measured to the nearest 0.5 cm with a tape measure. This operation was done quickly so that the sea cucumbers would not eviscerate. All of the measurements were recorded on pre-printed datasheets.

Sex identification

In total, 127 individuals measuring >16 cm in length, considered mature (Purcell et al. 2012), were taken from each transect for sex identification based on gonad color. This was done by squeezing the body to trigger the expulsion of the gonads (Al-Rashdi et al. 2007).

Results

The distribution of *Holothuria scabra* was found to be unimodal, with significantly larger sizes found during new moon phases (ANOVA, p = 0.01). About 67% of specimens collected during a new moon phase were >15 cm in size, 51% of which were found in Sitio Linao where the highest concentration of large specimens was recorded (see Figs. 2, 3, 4 and 5).

Of the 127 mature individuals, 18 were indeterminate in gender, 60 were males, and 49 were females. Female specimens were, on average, larger

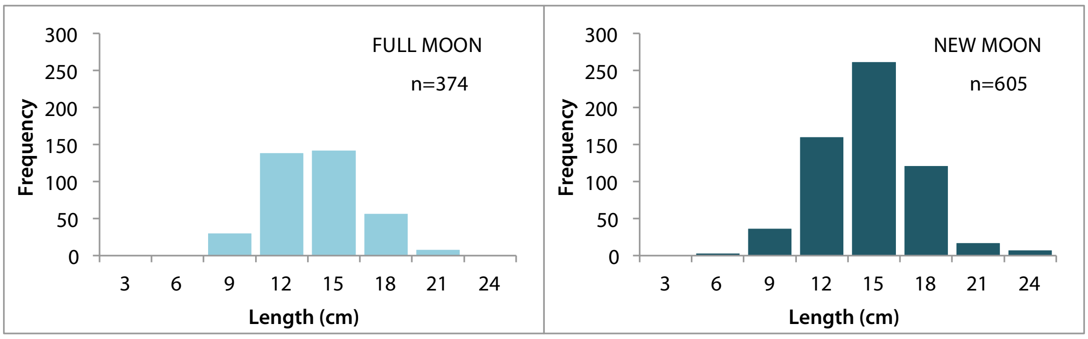

Figure 2. Combined length-frequency distribution of *Holothuria scabra* in Sarangani Province from October 2015 to January 2016 during full and new moon phases.

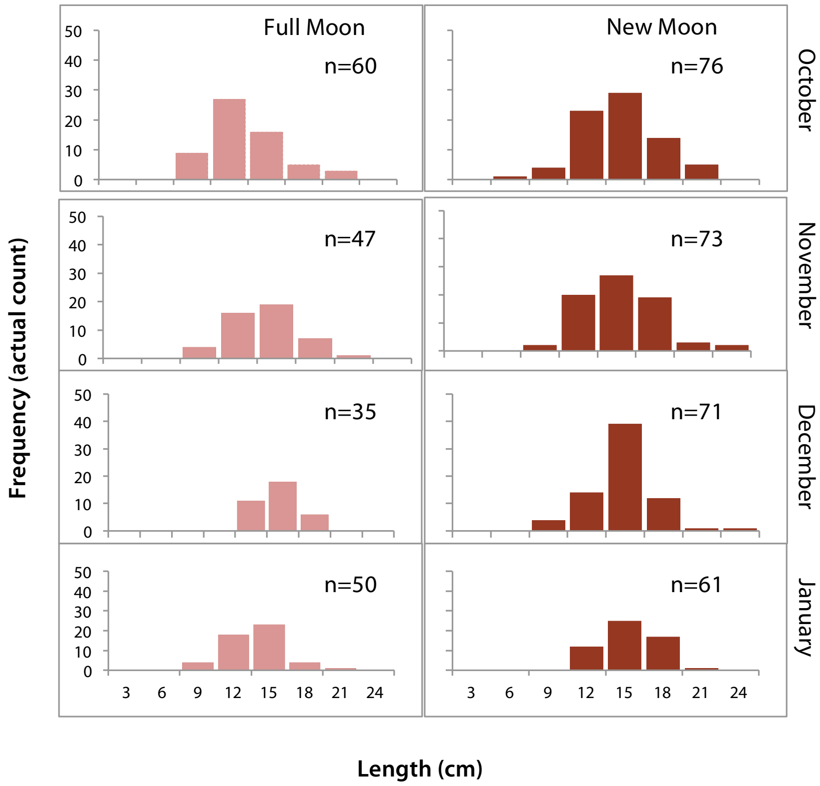

Figure 3. Length-frequency distribution of *Holothuria scabra* in Sitio Linao from October 2014 to January 2015 during full and new moon phases.

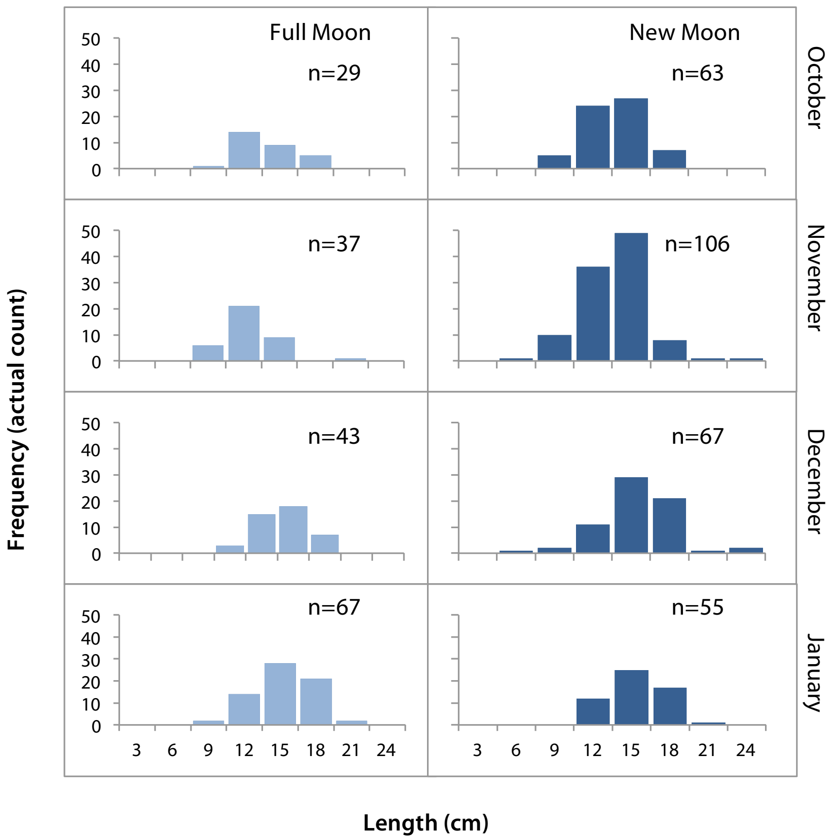

Figure 4. Length-frequency distribution of *Holothuria scabra* in Sitio S'nalang from October 2014 to January 2015 during full and new moon phases.

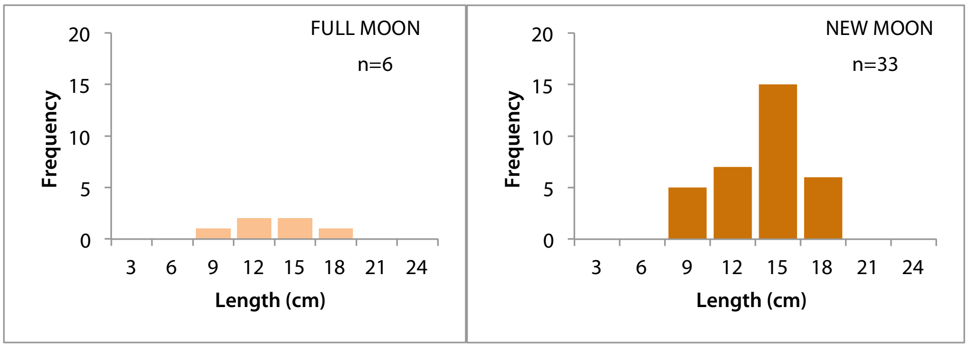

Figure 5. Length-frequency distribution of *Holothuria scabra* in Sitio Macatimbol from October 2014 to January 2015 during full and new moon phases.

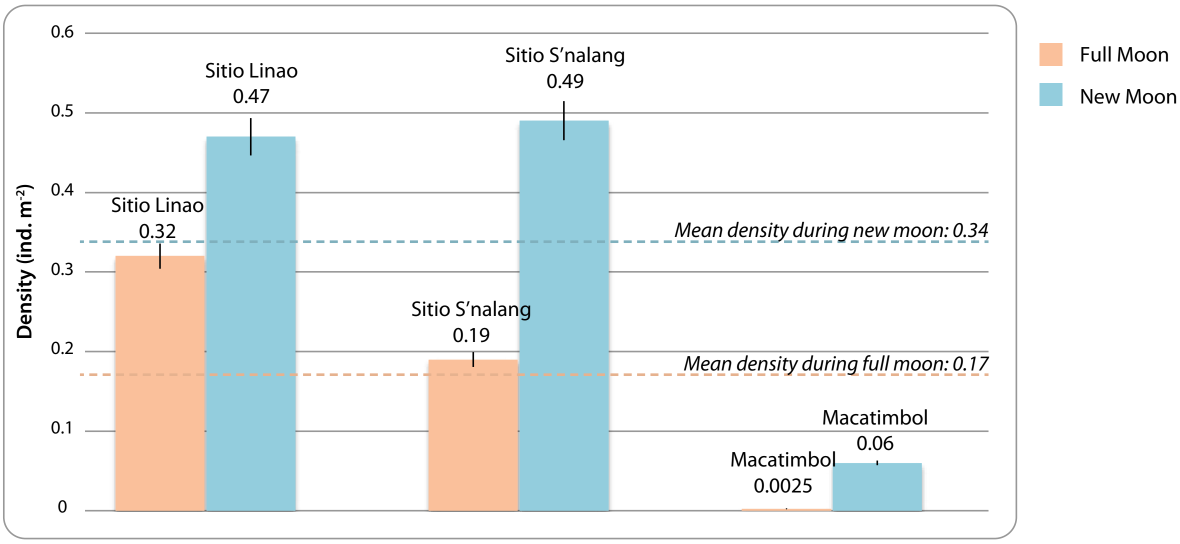

Figure 6. Density of *Holothuria scabra* in the three stations studied in Sarangani Bay from October 2014–January 2015 during full and new moon phases.

(18.10 cm ± 2.030) than males (17.25 cm ± 1.074). Among the specimens for which gender could be assessed, the female–male ratio was 50%–50% during a full moon phase, and 43.2–56.8% during a new moon phase. This is equivalent to an overall sex ratio of 1:1 for both full and new moon phases, as a Chi-square analysis with Yates' correction indicated the change in sex distribution between moon phases was not significant (Chi square = 0.162, p = 0.69).

The density of *H. scabra* was higher during new moon phases (mean: 0.34 ind. m^{-2}) than during full moon phases (mean = 0.17 ind. m^{-2}) all throughout the duration of the study (Fig. 6).

The calculated allometric coefficient (1.84) suggests that *H. scabra* individuals in these areas are leaner for a given length, when compared to other areas.

Discussion

We found that the size distribution of *Holothuria scabra* in all three stations was unimodal, which conforms to the results obtained from most other *H. scabra* population structure studies, such as those done in Dar es Salam (Kithakeni and Ndaro 2002), Gulf of Mannar, Palk Bay (Baskar 1994), Kitoni in Tanzania (Mmbaga 2013), and Al Eigah, Mahout Bay, Oman (Al-Rashdi et al. 2007). Significantly larger individuals were collected during a new moon than during a full moon, which supports the claim of intertidal gleaners in Sarangani Bay that collection is ideal during a new moon because of the abundance of larger sizes.

Lunar phases affected the distribution of individuals possibly due to the drastic changes in tides for both moon phases. In the study by Mercier et al. (2000), *H. scabra* was shown experimentally to aggregate in pairs, trios, or slightly larger groups before a full moon. The groups formed were larger before a new moon than before a full moon. The behaviour was observed prior to spawning in response to the lunar cycle. This study identified the sex of individuals through their gonads but did not measure the gonad index, which may fail to support the idea of reproductive-related behaviour during the aggregation of *H. scabra* observed during a new moon in this study. However, most specimens found during a new moon were in the 15–18 cm size class, which suggests that most were mature according to Kithakeni and Ndaro (2002), who give a size of 16.8 cm for first maturity. This is supported by this study because the most prevalent color of male gonads was creamy yellow, indicating stage IV of maturation; female gonads were dark orange to orange, also indicating stage IV, or even stage V (spawning) of maturation (Rasolofonirina et al. 2005). In the Philippines, the maturation of *H. scabra* gonads occurs from October to April, which excludes the main spawning events of May to June (Ong Che and Gomez 1985).

The *H. scabra* sex ratio of 1:1 for individuals collected during this study during full and new moon phases is in line with most species of holothuroids (Conand 1989; Hasan 2005; Uthicke 1997). This balanced ratio is important for ensuring the sustenance of local *H. scabra* stocks (Guzman and Guevarra 2002).

The Sitio Linao station had relatively high densities of *H. scabra* during both lunar phases. This is likely due to the area being a bay that is protected from strong waves. This habitat is favourable for *H. scabra* (Conand 1989) because it supports good settlement of detrital particles (Mercier et al. 1999), which are a food source for sea cucumbers. Furthermore, Sitio Linao has a high percentage of organic matter in its sediments at 1.42%, which could also explain the higher density of *H. scabra* because organic matter content is positively correlated with *H. scabra* density (Mmbaga 2013). The study by MacTavish et al. (2012) demonstrated the ability of sea cucumbers to ameliorate some of the adverse effects of organic matter enrichment in coastal ecosystems.

Community members of nearby Tausug collect *H. scabra* during ebb tides when they can forage the intertidal area on foot. This probably enables them to overharvest *H. scabra,* including those that are in pre-spawning stages.

The lowest *H. scabra* density was recorded in Macatimbol (see Fig. 3). According to gleaners, the area was once a rich place of *putian*, the local term for *H. scabra*. The reason for the reduction of stocks here is certainly due to overexploitation. In 2011, *H. scabra* were sold to visiting sea cucumber buyer boats from Davao for USD 6.50 per pail (a local type of bucket), which is a very high price by local standards. This was also observed in the fishing areas of Kunduchi and Magemani (Mmbaga 2013). Wild populations of sea cucumbers are very vulnerable to overfishing, and unregulated exploitation most often results in the demise of the fishery (Hasan 2005; Utchike and Conand 2005). Because reproduction among sea cucumbers requires a minimum number of individuals in a given area to be successful, overexploitation may quickly lead to unsuccessful reproduction (Levitan and Young 1995).

The allometric coefficient calculated for all three stations is 1.85, which is lower than the few published values for *Holothuria scabra* in Vietnam (2.84; Pitt and Duy 2004), New Caledonia (2.28; Conand 1990), and Oman (2.18; Al-Rashdi et al. 2007). The differences in values might be due to different procedural techniques in measuring or could be due to the shallowness of areas being assessed for this present study.

A possible factor that may explain the significantly larger sizes and aggregations of *H. scabra* during a new moon phase is the presence of biologically active chemicals secreted by other adult *H. scabra* in synchrony with the lunar phases. Chemicals can be a means of communication for invertebrates, mostly for purposes of reproduction. In the case of *H. scabra,* Hamel and Mercier (2004) showed that chemicals work synergistically with other factors to induce gonadal development in mature individuals.

Conclusion and recommendations

The present study shows that the size distribution of *Holothuria scabra* is influenced by lunar phases, with larger-sized individuals found during the new moon phase. The abundance of individuals collected was also greater during a new moon. The sex ratio, however, remained constant at 1:1 during new and full moon phases. Further study is recommended on the possible influence of other environmental factors related to lunar cycles on *H. scabra*, such as tides, wave action and light. Because *H. scabra* is a local delicacy, it is also recommended to further study its reproductive biology in order to establish conservation and management measures based on scientifically sound assessments. Precise knowledge of the timing of *H. scabra* spawning events in Sarangani Bay would enable the establishment of prohibitions on collection during the maturation season (or months before spawning) to ensure the healthiness of the stock, thereby positively affecting the recruitment rate in the bay.

Acknowledgement

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A modified method for processing fluorescently marked sea cucumber ossicles

Andrea Taylor[1]

Abstract

This communication presents a modification to the current method for processing fluorescently marked sea cucumber ossicles, used to identify hatchery-bred individuals from wild conspecifics in sea ranching, restocking and stock enhancement programs. Sea cucumbers are marked by immersing them in a fluorochrome solution, which is taken up by growing calcareous ossicles in the body wall. Mark detection is performed by digesting sea cucumber tissue samples from the outer body wall with bleach, allowing the remaining ossicles to be observed under an epifluorescence microscope. The bleach is removed by five freshwater exchanges using the current method, which is time consuming especially when large sample numbers are involved. Instead, one exchange of a solution of sodium thiosulfate was found to effectively neutralise bleach in samples, with no observed effect on processed samples. This modified method contributes time efficiencies to the development of sea cucumber marking, in addition to reducing the risk of sample loss and cross-contamination associated with multiple sample handling.

Introduction

The ability to tag or mark marine invertebrates is very useful for tag-recapture studies where parameters such as growth, movement and survival of individuals are being assessed. This is crucial in wild fishery interventions involving hatchery-bred animals because the ability to monitor and evaluate animal releases requires differentiation between wild and cultured individuals (Blankenship and Leber 1995).

The use of holothuroids in restocking, ranching and stock enhancement (Juinio-Meñez et al. 2013; Purcell 2012; Purcell and Blockmans 2009; Purcell and Simutoga 2008), has resulted in a need for suitable marking methods and techniques to identify marked individuals. An ideal marking method would be long lasting, visible in the field, inexpensive, and have no effect on growth and movement of the animal (Purcell et al. 2008). Most common tagging methods have been unsuccessful for sea cucumbers due to poor tag retention and animal stress (Conand 1990; Purcell et al. 2008; Purcell et al. 2006). Marking using passive integrated transponder (PIT) tags was recently found to successfully identify larger individuals but had lower efficacy in smaller animals (Gianasi et al. 2015), thus making it unsuitable for mass releases of small sea cucumbers, particularly where it is not necessary to identify individuals within the group. A novel technique for fluorochrome tagging of calcareous ossicles in the body wall was developed in 2006 (Purcell et al. 2006; Purcell and Blockmans 2009; Purcell and Simutoga 2008) and is currently the most suitable method for marking large numbers of small sea cucumbers. Fluorochrome marking has been used extensively in research involving cultured juvenile sandfish, *Holothuria scabra*, a commercial Indo-Pacific sea cucumber species (Conand 1990; Hamel et al. 2001). Animals are immersed in a fluorochrome solution, which is taken up by growing calcareous ossicles in the body wall. Marked sea cucumbers can then be released into marine areas and distinguished from wild conspecifics after recapture, although unfortunately not in the field. Marking sea cucumbers in this way also has applications for identifying individuals in experimental trials, particularly considering the availability of different fluorochromes that produce marked ossicles of different colours with the use of different optic filters in an epifluorescent microscope. Sea cucumbers can also be tagged with multiple fluorochromes (Purcell and Blockmans 2009), creating a double tag, further facilitating the use of multiple experimental treatments.

Marker detection is non-destructive, performed by processing very small samples taken from the ventral outer body wall. Samples are immersed in bleach ($NaClO_4$) to digest tissue, leaving the calcareous ossicles, and then rinsed five times with freshwater. Ossicles are then dried for examination under an epifluorescence microscope to determine the presence of fluorochrome exposure (Fig. 6 in Purcell 2012) (Table 1).

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After bleach digestion of sea cucumber tissue, performing five freshwater exchanges to remove bleach is time-consuming and fiddly, particularly when dealing with large numbers of samples, and provides opportunities for loss of ossicles at each exchange. Multiple samples handling also increases the risk of cross-contamination between samples. Because only a few marked ossicles in a sample are required to confirm the presence and colour of a fluorochrome tag, cross-contamination of ossicles between samples greatly reduces the reliability of results.

This communication reports on a modification to the original method (Purcell et al. 2006), detailed fully by Purcell (2012) and Purcell and Blockmans (2009), to improve efficiency and reduce the likelihood of sample loss and cross-contamination.

Material, method and results

The new method involves replacing the multiple freshwater rinses with one exchange of sodium thiosulfate ($Na_2S_2O_3$) solution. Sodium thiosulfate neutralises chlorine in water (DAFF 2008; McCauley and Scott 1960; OIE 2003) and is commonly used in hatcheries to remove bleach from water after use in sterilisation. The modified method is fully described and compared to the method detailed by Purcell (2012) and Purcell and Blockmans (2009) in Table 1. Explanatory technical points have been added.

As recommended by Purcell and Blockmans (2009), exposure to light was minimised using aluminium foil throughout the entire procedure to reduce photodegradation of fluorochrome. Pipettes should be thoroughly washed between each exchange, or a micropipette with a disposable tip should be used to avoid ossicle cross-contamination between samples.

Samples can be processed in microwell trays as described, or in Eppendorf vials. Microwell trays have the benefit of ease of viewing under a microscope if an appropriate microscope is available, and the ossicles do not need to be transferred to microscope slides for observing fluorochromes marks. If trays are not an option, 2-ml Eppendorf vials may be used. This may also be preferable when only a small number of samples are to be processed. To reduce the need to thoroughly wash pipettes between samples, or consume multiple disposable pipettes, liquid can be decanted from vials at each stage rather than be removed by pipette. This process can cause an increased loss of ossicles, and so an increased sample size – as recommended by Purcell and Blockmans (2009) – is recommended (5–8 mm^2) when using vials. Ossicles processed in vials are transferred to glass slides using a micropipette with individual disposable tips, and dried before viewing under an epifluorescence microscope. Larger samples will also provide enough ossicles to easily view on a glass slide because they will be less concentrated than in microwell cells. Samples up to 5 mm^2 in smaller and 10 mm^2 in larger animals are not found to cause any bacterial infection, and heal

Table 1. Modified method for processing fluorescently tagged sea cucumber ossicles compared with original Purcell (2012) method.

Original method	Modified method
Take a 2.5–5 mm^2 sample from outer body wall on ventral side of sea cucumber and place in a cell of a microwell tray. Preserve with buffered alcohol.	Take a 2.5–5 mm^2 sample from outer body wall on ventral side of sea cucumber and place in a cell of a microwell tray. Preserve with buffered alcohol unless sample is to be processed immediately.
Remove alcohol.	Remove alcohol.
Add bleach and leave for 30 minutes to digest body wall tissue.	Add 12% bleach and leave for 30 minutes to digest body wall tissue. Allow ossicles to settle to the bottom of the cell.
Remove bleach.	Remove bleach using a pipette, leaving a maximum of 0.5 ml in cell, including settled ossicles.
Add fresh water and remove.	Add sodium thiosulfate (50g L^{-1}) and ensure sample is thoroughly mixed. Leave ossicles to settle and remove liquid with a pipette.
Add freshwater and remove.	Add freshwater, leave ossicles to settle and remove liquid with a pipette.
Add freshwater and remove.	Once dry, view under epifluorescence microscope.
Add freshwater and remove.	
Add freshwater and remove.	
Once dry, view under epifluorescence microscope.	

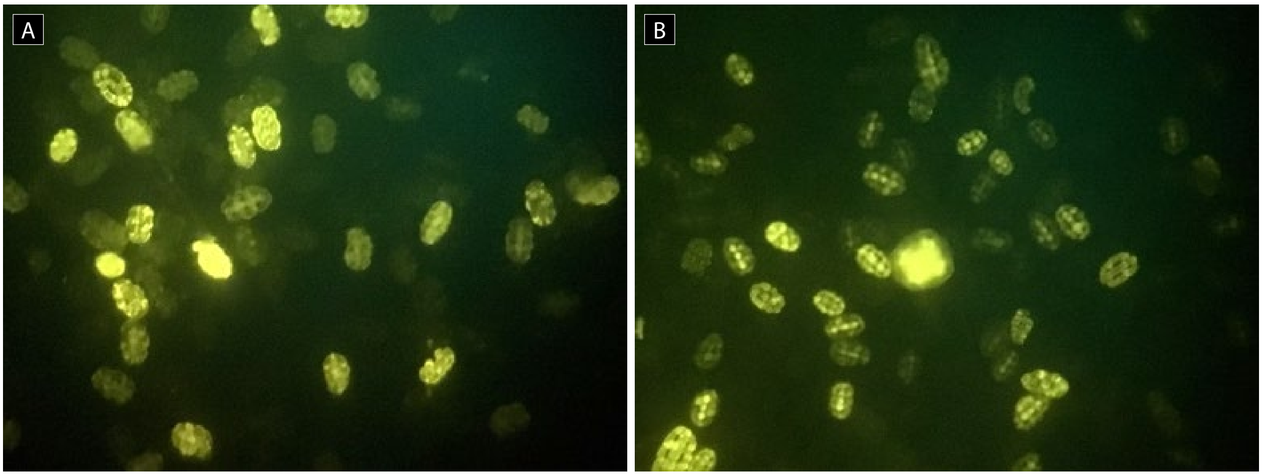

Figure 1. Sea cucumber *Holothuria scabra* ossicles marked with tetracycline and processed by original (A) and modified (B) methods, viewed through an epifluorescence microscope.

quickly in all cases (A. Birch unpublished data; C. Hair, pers. comm.)

The final freshwater exchange to remove the majority of the sodium thiosulfate solution is included in this modified method as a precaution. Further trials may show that this is not necessary, and should test the effect of removing this step on samples in the immediate and long term.

To assess any effects on the end result, the original method was used on samples collected from the same sea cucumbers alongside the modified method. There was no observable difference in the number or brightness of tagged ossicles produced from the two methods, when viewed under an epifluorescence microscope (see Fig. 1), and dried samples still fluoresced brightly after three years of storage (kept in the dark).

This revised method has been used to process ossicles from tagged *H. scabra* in experimental releases in the Northern Territory, Australia (A. Birch, unpublished data) using tetracycline and calcein. It has also been shown to be effective with calcein blue (C. Hair, pers. comm.). In addition to reducing the risk of sample loss and cross-contamination, the modified method contributes time efficiencies to the development of sea cucumber tagging. It is hoped that this will improve the ability to process large numbers of samples for sea cucumber tag-recapture projects.

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Variation in postharvest processing of sea cucumbers by fishers and commercial processors among three Pacific Island countries

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Abstract

The value of beche-de-mer exported from small-scale sea cucumber fisheries throughout the world depends partly on the postharvest processing methods used by fishers or commercial processors. Development programmes to help fishers in value adding need to understand current processing practices. We used questionnaire data to evaluate postharvest processing of sea cucumbers, and compared methods between fishers and commercial processors in Fiji, Kiribati and Tonga. Most fishers in Kiribati, and a minority of Fijian and Tongan fishers, process their sea cucumbers. Few fishers had received training or information on processing methods. The placement of the cut to gut sea cucumbers varied widely, especially among fishers. I-Kiribati fishers salted sea cucumbers for the least number of days. Coconut husks were mostly used in Kiribati as the fuel to heat water for cooking sea cucumbers, whereas wood was mostly used in Fiji and Tonga. Fishers practiced a second cooking less frequently than commercial processors. Smoke curing was not practiced in Tonga, owing to traditional practices, but was done frequently in Kiribati and Fiji. Fijian fishers invested the least amount of time in processing. We found few women fishers in Kiribati but they were often involved in processing. In both Fiji and Kiribati, other family members were frequently engaged in processing. We show that poor processing methods were often used by fishers. Our study reveals that postharvest processing cannot be generalised among countries, and a holistic view of the role of women and children in fisheries should examine more than just their involvement in fishing.

Introduction

Processing sea cucumbers in the Pacific Islands region

A market for beche-de-mer (dried sea cucumber) from Pacific Island countries has existed since the early 1800s (Conand 1990; Kinch et al. 2008). Nowadays, sea cucumbers from more than 20 species are caught by small-scale Pacific Island fishers (Purcell et al. 2012). Traditionally, the animals were gutted, boiled then dried in the sun or over a smouldering fire by artisanal fishers. Gutting and cooking methods used by fishers sometimes reflect those that they use for preparing sea cucumbers for subsistence consumption, such as in Tonga where several species are commonly eaten locally. After cooking and drying, beche-de-mer are then stockpiled until they can be sold to middlemen or export agents. Prices paid to fishers for beche-de-mer vary greatly, depending on the species, size and quality of postharvest processing (Kinch et al. 2008; Lavitra et al. 2008; Ram et al. 2014). Postharvest processing methods have been outlined in a few documents but few data have ever been published on methods used by fishers or commercial processors.

Conand (1990) briefly described previous methods used in New Caledonia to process sea cucumbers: one for sandfish and golden sandfish, and another for other species. She concluded that the main processing problems by fishers were an incorrect cut, outer damage to the body wall of the animals, and inadequate cleaning and cooking times. Two other reports provide information about processing methods employed in the Indian Ocean but contain no quantitative data comparing methods used by fishers (James 1994; Lavitra et al. 2008).

Ram (2008) was the first researcher to compare the general processing steps used by professional processors and fishers. His questionnaires and inspection of products in Fiji showed that fishers still used traditional methods to process sea cucumbers and incorrect methods were commonly used. In a later publication of that study (Ram et al. 2014), he concluded that poor processing resulted in spoilage of products, poor product quality for export, and diminished sale prices for fishers. Apart from that study from Fiji, little is known about the processing methods used by fishers and how those methods might vary geographically. This knowledge gap constitutes a weak foundation on which to identify

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needs for capacity-building programmes to improve product quality and livelihoods in fisheries.

Methods involved in processing sea cucumbers into beche-de-mer

The Secretariat of the Pacific Community (SPC) included small sections on postharvest processing of sea cucumbers in its field ID cards (4 pages; SPC 2004) and a, now outdated, identification guidebook of sea cucumbers in the tropical Pacific (7 pages; SPC 1994). However, neither information source explains processing methods in detail. More recently, research by the Australian Centre for International Agricultural Research determined the current best-practice methods used by successful commercial processors and outlined these methods in a training manual (Purcell 2014a). The methods also confer with "correct" product characteristics (e.g. cut, shape, colour) indicated by retail and wholesalers in China (Purcell 2014b). The following is a summary of the various processing steps given in that manual.

Different species groups require different processing methods due to differences in the thickness and softness of their body wall, and the extent of water retention after cooking. Slight variations in methods among commercial processors, according to their own beliefs and experiences, do not necessarily result in different product quality.

The cut made on sea cucumbers (to remove guts and aid drying) should be in different locations on the body for different species. Both black teatfish (*Holothuria whitmaei*) and white teatfish (*H. fuscogilva*) should be cut on the dorsal side, while other species that attain large sizes (i.e. *H. fuscopunctata*, *Thelenota ananas* and *T. anax*), should be cut on the ventral side. In both instances, the cut should stop short of the anus and mouth. For most other species, the general practice among processors is to make a small longitudinal cut (i.e. 2–3 cm) on the ventral surface at the anus. Certain species develop a better product shape if they are cut and gutted after the first cooking.

Generally, sea cucumbers are cooked first, starting in warm sea water that is brought to around 90°C, then salted for 1–5 days. Other species, especially those in the genus *Bohadschia*, are best salted first for 1–2 days and then cooked. Salt curing has several benefits to the products: 1) water is removed; 2) the flesh is cured, making it less prone to bacteria; and 3) salt adds weight to the product, which is later sold by weight.

After salting, sea cucumbers are cooked again in hot water, then smoked for 1–2 days and dried for 3–7 days. Smoke curing is also advantageous for processing sea cucumbers, although Chinese consumers do not want a strong smoky odour (Purcell 2014b). Drying by commercial processors is often done in drying rooms with dehumidifiers and heaters, whereas fishers simply dry the products in the sun.

Purpose and significance of this study

Poor processing practices result in beche-de-mer that have some or all of the following characteristics: physical damaged, bad odor, unattractive colour, poor shape, and/or insufficiently dried. These problems translate to lower prices in the marketplace (Purcell 2014b) and lower prices given by buyers to fishers. Poor processing also wastes the potential value of the resource and potential national revenue from export levies (Purcell 2010; Purcell et al. 2009).

Improving postharvest processing should be coupled closely with improved management and governance of sea cucumber fisheries. Training in processing could be presented as a "trade off" for reduced access to the resource (e.g. by shorter fishing seasons). In order to help fishers improve their processing methods, it is important to first determine which methods they use, and identify any unsuitable practices. Assessing who is doing the processing, and to what quality, is also advised when diagnosing a fishery before forming a management plan (Purcell 2010).

The trade in and market value of beche-de-mer from these Pacific Islands has already been reported (Purcell 2014b) and the value of the products to fishers will be the subject of other reports (Purcell et al. unpubl. data). Here, we examine variations in postharvest processing of sea cucumbers by fishers and commercial processors in Kiribati, Tonga and Fiji using questionnaire-based interviews. At the time of data collection, these three countries were among the few in the Pacific Islands region not having harvesting bans (moratoriums) in place. Our intention is to simply present the differences among countries, and provide comparative results for species groups. An understanding of such differences is crucial for identifying countries with the greatest need for training and processing steps that are most incorrectly done by fishers. Such information could also reveal deeper insights into the involvement of Pacific Islanders in seafood postharvest processing.

Materials and methods

Within Fiji, Kiribati and Tonga, we conducted the questionnaire-based interviews at multiple islands or island groups within each country to enable broad representation. The study island groups were as follows: Fiji – Ra, Kadavu, Bua, Cakaudrove, Taveuni, Yasawa, Lau (south), and Vanua Balavu; Kiribati – Tarawa, Butaritari, Abemama, Onotoa, Kiritimati; Tonga – Tongatapu, Ha'apai, Vava'u, Niuatoputapu. Within the islands and island groups, we generally collected data from five to eight fishers in each of several villages. We chose study locations and villages depending on advice from fishery management institutions about where sea cucumber fishing was active, and we sought to disperse our locations and villages within locations. At each village, we consulted the village elders and fishers to get the residences of sea cucumber fishers and then visited those residences.

Interviews were held in 2011 in Kiribati and Tonga, and in 2014 in Fiji. We interviewed fishers and processors and asked them questions from the questionnaires in a standardised fashion among respondents. The questionnaires primarily used closed questions, as described by Purcell et al. (2009) and Kronen et al. (2007). We also solicited additional (open-ended question) information. Human ethics approvals for interviews were given by an accredited ethic committee of Southern Cross University[5] and by the Fiji Ministry of Education[6]. Approvals for the research in Tonga and Kiribati were given by national fisheries ministries.

The project team conducted interviews with 84 sea cucumber fishers and 21 processors in Kiribati, 134 sea cucumber fishers and 13 processors in Tonga, and 235 fishers and 17 processors in Fiji. Our sampling was gender inclusive by interviewing women preferentially when possible. We used key informants to identify sea cucumber fishers to interview, and relied on the "snowball" effect to find other sea cucumber fishers in villages.

Local names for sea cucumber species were used in interviews along with species identification sheets to confirm each species with respondents. Responses from questions were entered as nominal data (e.g. "D" if sea cucumbers were cut on their dorsal side), continuous data (e.g. number of minutes to cook different sea cucumbers), or binomial data (e.g. "1" for yes and "0" for no in response to yes-or-no questions).

Cross-checks of data across respondents and exploratory graphs were made to ensure data accuracy. We use standard deviation as the error measure to indicate variation in responses within samples rather than the precision of the mean estimates. For this article, we pooled data across villages and locations for cross-tabulations of each country for fishers and commercial processors.

Results

Frequency of processing and training

In Kiribati, 76% of fishers process their sea cucumbers. Only 33% of fishers in Fiji and 18% of fishers in Tonga do their own processing of sea cucumbers. The majority of fishers sell their catch fresh to processors.

In Tonga, national fishery regulations prohibited fishers from doing their own processing due to concerns that fishers would damage the products. Since the distribution of training manuals and workshops on processing methods, however, that regulation has been removed from the country's Sea Cucumber Fishery Management Plan 2014 so that fishers can again process their catch.

The majority of fishers and processors in Kiribati were trained informally by a foreign export agent but they had never seen or received information on postharvest processing (Table 1). This contrasts with Fijian fishers, most of whom had not been trained by foreign export agents.

In Tonga, many fishers and processors had received or seen some published material on processing sea cucumbers, especially the the ID cards produced by SPC. Half of the processors interviewed in Fiji had seen processing methods in published media, particularly in the ID cards prepared by SPC (SPC 2004), but very few fishers had ever seen any published information on processing.

Cutting methods

There was considerable variation in the placement of the cut for different species, both among processors and fishers (Table 2). Cutting white teatfish and black teatfish on their dorsal sides is practiced by the vast majority of commercial processors although many fishers in each country incorrectly cut them.

Some processors in Tonga and Kiribati were not cutting *Thelenota* species (*T. ananas* and *T. anax*) in the correct place (ventral side), and many fishers in each of the three countries were also not cutting species of *Thelenota* correctly (Table 2).

As a general rule, species in the genera *Actinopyga*, *Bohadschia*, and *Holothuria* should receive a small, longitudinal cut at the anus on the ventral surface, but a small cut at the mouth is acceptable. Cuts on these species were usually made correctly by Tongan fishers, but appreciable proportions of Fijian and I-Kiribati fishers did not cut correctly.

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[6] Approval RA01/14

Table 1. Training and information on processing for fishers doing their own processing.

Location	% trained by foreign exporting agent	% never received printed information on processing methods
Kiribati		
Processors	89	68
Fishers	83	98
Tonga		
Processors	18	36
Fishers	55	55
Fiji		
Processors	18	82
Fishers	8	96

Table 2. Percentage of fishers and processors in each country who cut sea cucumbers in the preferred location. Values are percentages of respondents.

Location	% cutting teatfish dorsally	% cutting *Actinopyga* species at anus or mouth	% cutting *Bohadschia* species at anus or mouth	% cutting *Stichopus* species at anus or mouth	% cutting *Thelenota* species ventrally	% cutting *Holothuria* species at anus or mouth
Kiribati						
Processors	88	56	50	46	87	92
Fishers	66	50	82	78	86	96
Tonga						
Processors	100	82	73	82	64	91
Fishers	88	65	100	100	54	100
Fiji						
Processors	100	81	93	69	94	86
Fishers	66	87	93	77	47	95

Salt curing

While most processors practiced salt curing (Fig. 1), many fishers in Kiribati and Fiji did not (Table 3). In Fiji, processors salt the product after the first boil for most species. In contrast, 36% of processors in Tonga and 100% of processors in Kiribati salt the animals after gutting them, and before the first cooking for most species.

Processors and fishers in Tonga salt the animals for more days than those in Kiribati or Fiji (Table 3). In Kiribati, processors and fishers use salt curing far less frequently than in other countries. Only one-third of I-Kiribati fishers salt sea cucumbers, and they do so for the least amount of time of any group we studied.

Figure 1. White teatfish (*Holothuria fuscogilva*) being salted in a salting box by a commercial processor in Fiji.

Table 3. Salting methods. Values are averages with standard deviations in parentheses.

Location	% using salting	Days salting teatfish (± SD)	Days salting *Actinopyga* (± SD)	Days salting *Bohadschia* (± SD)	Days salting *Stichopus* (± SD)	Days salting *Thelenota* (± SD)
Kiribati						
Processors	71	2.5 (1.6)	2.6 (2.5)	2.6 (2.5)	1.0 (0)	2.1 (1.8)
Fishers	32	2.4 (3.4)	1.2 (1.1)	1.2 (0.9)	0.7 (0.6)	1.6 (1.7)
Tonga						
Processors	100	4.5 (2.0)	3.5 (2.1)	3.8 (2.3)	3.7 (1.5)	5.1 (1.6)
Fishers	78	3.6 (1.7)	3.7 (1.7)	3.8 (1.7)	4.5 (0.7)	3.6 (1.4)
Fiji						
Processors	100	3.1 (1.5)	3.0 (1.5)	2.7 (1.5)	2.4 (1.0)	3.3 (1.6)
Fishers	58	3.1 (1.4)	2.6 (1.3)	2.4 (1.1)	2.3 (1.2)	2.7 (1.3)

Table 4. Cooking methods (in hot or boiling water). Values are averages with standard deviations in parentheses.

Location	Temp. of water (1st boil) (°C)	Minutes 1st cook teatfish	% practicing 2nd cook for some species	Minutes 2nd cook teatfish	Minutes 1st cook *Actinopyga* species	Minutes 1st cook *Bohadschia* species
Kiribati						
Processors	94 (12)	53 (39)	63	41 (44)	47 (25)	43 (22)
Fishers		56 (36)	42	25 (23)	47 (37)	47 (39)
Tonga						
Processors	79 (17)	38 (19)	82	33 (18)	39 (19)	43 (24)
Fishers		25 (21)	42	43 (19)	29 (19)	29 (21)
Fiji						
Processors	53* (18)	12 (10)	100	23 (10)	18 (13)	19 (11)
Fishers		15 (12)	66	21 (21)	19 (13)	21 (21)

* Many processors put sea cucumbers in cool water or at 40°C, and then slowly bring the water to 90°C or boiling.

Cooking methods

Several Fijian processors seemed to be the best of all the processors we interviewed in the three countries; they were more experienced, displayed more knowledge about optimal methods for each species, took more care to process the animals to a higher standard, and attained the highest export prices. On average, Fijian processors cooked the animals for a shorter time (especially for the first cook) and practiced a second cooking for each species more commonly than processors in Kiribati or Tonga (Table 4). Many processors in Fiji put the animals in warm water (~40°C), then bring to the boil and cook for a relatively short period.

The majority of processors and fishers in Kiribati used coconut husks as the fuel to heat water for cooking sea cucumbers, and fishers who camped out at distant fishing sites tended to use wood (Fig. 2). In Tonga, the copra industry was inactive so the few fishers processing their catch mostly used wood. Likewise, 100% of Fijian fishers who processed sea cucumbers used wood as the fuel to heat water (Fig. 3).

While the majority of processors in both Kiribati and Tonga practice a second cooking of sea cucumbers, less than half of the fishers in those countries cook sea cucumbers more than once (Table 4). There were large variations (i.e. standard deviations) in the average cooking times for different species by processors and fishers, revealing inconsistent cooking methods.

Through unstructured questions, we found that many I-Kiribati fishers were using fresh water to cook sea cucumbers, which is not ideal because the skin can be damaged. This seems to be a problem and some processors told them that saltwater should be used.

Figure 2. An I-Kiribati fisher and his family cooking lollyfish (*Holothuria atra*) on Kiritimati Island, Line Islands Group, Kiribati.

Figure 3. Fijian female fishers cooking sea cucumbers in cut 44-gallon drums using bamboo and wood.

Figure 4. A smoke house on Tarawa, Kiribati, for smoking sea cucumbers. The sea cucumbers are placed on mesh trays that slide into the oven and sit well above a smouldering fire.

Figure 5. A basket of brown sandfish (*Bohadschia vitiensis*) that have been burned by a fisher in Kiribati by placing the rack too close to the fire.

Smoke curing and drying methods

Smoke curing, by treating sea cucumbers over a smouldering fire, is practiced by most fishers and processors in Fiji and Kiribati, and is sometimes done on a mesh table over a smouldering fire or in a purpose-built smoke house (Fig. 4). In Fiji and Kiribati, this is favourable for fishers because they do not have sophisticated drying ovens and often do not use salt curing, so the smoking stage helps to cure the sea cucumber flesh. Fishers sometimes smoked sea cucumbers too close to the fire, which was often too hot, resulting in burned products that would fetch much lower prices or be discarded (Fig. 5). In stark contrast, none of the processors in Tonga used smoke curing or dry sea cucumbers over a fire.

In the boom years in the early 1980s, Tongan fishers processed sea cucumbers using similar methods for processing locally eaten seafood, which does not involve smoke curing. This cultural difference from Pacific Island cultures that commonly practice smoke curing, such as in Kiribati, could explain why sea cucumbers were not smoke cured by Tongan fishers. The influence of cultural practices should be expected, especially where fishers have not been formally taught other processing methods specific to export commodities.

Figure 6.
A Fijian fisher with a mixture of sea cucumbers drying on a sheet of corrugated iron in the Lau Group, Fiji.

Sun drying was the most common method used to dry sea cucumbers (Fig. 6). Around one-third of processors in Tonga and most in Fiji used some form of drying oven to dry sea cucumbers (Table 5). The drying ovens used by commercial processors either use electric heaters and dehumidifiers in a closed room, or use the heat (not smoke) from a wood burner to create dry and hot conditions in a concrete drying house. Except for the few fishers processing sea cucumbers in Tonga, fishers generally do not use a drying oven, and those that do use a small and simple oven relying on heat and smoke from a smouldering fire. In Tonga, copra was dried in makeshift ovens when that industry was active, so oven drying was a familiar method.

Processing as a livelihood activity

Tongan fishers spent more time processing one day's catch of sea cucumbers than fishers in Fiji or Kiribati (Table 6), although processing times differed considerably among fishers (s.d. = 1.9 h). This investment in time is substantial, and compares closely to the time fishers spend in the water fishing for the sea cucumbers. Fijian fishers spend the least amount of time processing their catch, and the time investment corresponds to roughly half of the time, on average, that they spend in the water fishing for sea cucumbers (c.f. Purcell et al. in review).

Table 5. Drying methods.

Location and respondent group	% drying also over a fire	% drying also in an oven	% using smoking
Kiribati			
Processors	76	12	82
Fishers	95	0	85
Tonga			
Processors	0	36	0
Fishers	0	28	0
Fiji			
Processors	24	41	65
Fishers	3	7	91

Involvement of family members and other people in the processing of sea cucumbers was quite variable among fishers and among the three countries (Table 6). In many cases, the fishers themselves did the processing or were involved in it. In Kiribati, almost all of the fishers we interviewed were men and two-thirds of their spouses helped in postharvest processing. I-Kiribati tend to consider fishing by diving as a man's job. Women, however, joined

Table 6. Processing effort by fishers. Standard deviations of average processing time are superscripted.

Location	Average time to process one day's catch (h ± s.d.)	Who is involved in cooking and drying of sea cucumbers? (% of respondents)			
		themselves	spouse	children	other
Kiribati	2.5 $^{(1.2)}$	65	66	15	25
Tonga	3.9 $^{(1.9)}$	33	0	0	67
Fiji	1.9 $^{(1.1)}$	42	43	23	11

the sea cucumber harvesting when buyers began purchasing the low-value lollyfish (*Holothuria atra*), which they can collect on shallow sand flats where women usually glean for shellfish.

In Fiji, spouses also often help in processing, and children and other people often contribute to the processing work (i.e. family members often play a role in processing). This contrasts with the situation in Tonga, where only the fisher or another person processed the sea cucumbers.

Discussion

A main finding of our study was that fishers often do not process sea cucumbers in the same way as commercial processors. This resulted in the beche-de-mer by fishers often being improperly cut, physically damaged, poorly preserved and incompletely dried for export. These shortcomings can decrease prices in the marketplace, especially physical damage to the products (Purcell 2014b) that occurs through poor handling at sea prior to processing, over-cooking or drying too quickly. In the same way, Ram et al (2014) found that Fijian fishers often had problems in processing sea cucumbers to a good quality and rushed some steps to save time. Poor processing by fishers was also reported by processors in New Caledonia (Purcell et al. 2009). Poor processing no doubt has a significant bearing on the prices that traders can offer to fishers.

Cutting of most species appeared to be *ad hoc* and varied greatly among fishers. Essentially, there was often a lack of understanding of proper cutting methods to gut the animals. Salting time by I-Kiribati fishers was too short for most species compared with times used by successful processors. Most processors used a second cooking, and even a third, while a majority of fishers only cooked the sea cucumbers once. The lack of repeated cooking can prevent the product from drying thoroughly or taking a desired straight shape.

Some processors argued that a processing manual and training of fishers were not required because they visit fishers and train them. Our data refute this line of argument; a high proportion of fishers had not been formally trained in postharvest processing. In addition, although some basic information about processing had been previously distributed in the Pacific (SPC 1994, 2004), few fishers were aware of these. That the beche-de-mer produced by fishers was often damaged gives further rationale for a need for information sources and training of fishers. Training in postharvest processing has also been identified as a critical shortcoming in other fisheries (Eriksson et al. 2010, Ochiewo et al. 2010). The recent manual (Purcell 2014a), training videos (see below) and village-based workshops funded by the Australian Centre for International Agricultural Research seek to fill this gap in information. Our data showed that although women do not collect sea cucumbers, they should be given manuals and invited to workshops if they are involved in processing.

Improving postharvest processing will not be a "one-size-fits-all" solution because current processing methods (e.g. smoking) and resources (e.g. coconut husks for fuel) differ greatly among countries. In addition, species frequently caught by fishers differ among the three countries (Purcell et al. in review), so workshops should focus on locally common species. We also recognise other successful variations of the processing methods, which fishers or processors may prefer. For example, some processors in Fiji salted *T. anax* for several days, which seemed to avoid splitting of the body wall during the first cook. Further research could to be conducted to determine whether variations in processing methods affect the weight and the appearance of the animal, because these two factors will largely determine the price offered by buyers.

Postharvest processing can be viewed as a livelihood activity because it is sometimes a voluntary activity to earn more money from the resource through value adding. In Fiji, much of the family are involved in the processing. Although we interviewed few I-Kiribati women who harvest sea cucumbers, they are involved in processing the sea cucumbers of their spouses in a majority of cases. Therefore, diagnosis of gender in fisheries should also examine the roles of men and women (and children) in postharvest processing, in addition to their roles in fishing to fully understand their involvement in the industry.

This study has demonstrated a high degree of variation in seafood processing among island countries. Discussion about value adding in coastal fisheries must be underpinned by some understanding of this variation and the external factors underlying the methods and time investments of fishers.

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Resources: training videos

Downloadable postharvest processing training videos: http://scu.edu.au/environment-science-engineering/index.php/125

Online training videos: All language versions of the training video are available on Youtube with a root title of "Processing sea cucumbers into Beche-de-mer"

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Sea cucumber hatchery seed production in Malaysia: From research and development, to pilot-scale production of the sandfish *Holothuria scabra*

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Abstract

Sea cucumbers in Malaysia have been overexploited for decades, and their stock status in both Peninsular Malaysia and Sabah has dropped to an extreme low, resulting in direct impacts on both coastal communities and marine ecosystems. As a result, the Malaysian government is now looking for alternatives such as fisheries management, conservation and aquaculture to manage the depleting wild stocks. This project is a product of fruitful collaboration between the Malaysian government and an Australian-based private company. Since its inception in July 2014, a hatchery, nursery and broodstock rearing facility has been set up. The first spawning trials were done in February 2015 followed by nine other successful spawning events over a period of nine months. Overall, the spawning success rate was about 60% and the fertilisation rate was 85%. Broodstock are now being conditioned in tanks, with some male and female individuals kept separately. Spawning events produced around 4,300,000 larvae with a survival rate of over 30% during the larval stage. Settlement occurred at day 12 after fertilisation, and about 30,000 juveniles (3–5 mm long) have been produced so far.

Introduction

Sea cucumber (*gamat* in Malaysian) resources in Malaysia have been exploited for decades due to the animal's many health and nutritive benefits. It is traditionally used in local dishes or to derive products of local medicinal value. In addition, dried sea cucumber products are highly sought after by local Chinese communities for culinary purposes, and are also believed to bring good luck, money and fortune, particularly when eaten as part of the famous "treasure pot", during Chinese New Year celebrations. Over the last several decades, there has been an increasing demand from both local and regional markets and this demand has contributed to the dwindling of wild sea cucumber stocks. As a result, the status of sea cucumber stocks in Peninsular Malaysia and mainly in Sabah have dropped to an extreme low, resulting in direct impacts on both coastal communities and marine ecosystems (Choo 2012).

This situation is now worse due to the increased demand for derivative products such as *gamat* water and oil (medicinal values), personal care products (soap, toothpaste, acne cream), and products that were traditionally used in the *kampung* (villages), which are now gaining sales momentum at the commercial level. A survey undertaken in 2012 by a local marketing company revealed at least 13 registered Malaysian companies claiming to be involved in research and development activities to develop derivative products from sea cucumbers, mainly species in the genera *Stichopus* (BioSys Consulting Pty Ltd 2012; Purcell et al. 2014). The Malaysian government is now looking for alternatives such as fisheries management, conservation and aquaculture to manage the depleting wild stocks. This project is a product of fruitful collaboration between the Malaysian Department of Fisheries (DOF), AADCo Projects Malaysia Sdn Bhd[6] (spin-off from research conducted by an Australian-based company, Asia Aquaculture Development Co. Pty Ltd) and a local engineering company (Sesaga Engineering Snd Bhd). The project, led by the spin-off company, aimed at developing and commercialising a sea cucumber aquaculture system for producing premium quality trepang (beche-de-mer). This project is developed under the business incubator programme of the Fisheries Research Institute (FRI), Pulau Sayak, Kedah, Malaysia. Our aim within the next three years is to implement a commercially viable sea cucumber aquaculture facility that will:

- allow a continuous production of good quality trepang;

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- allow a better quality control on final products;
- achieve higher production rates; and
- supply the increasing worldwide demand with a labeled premium quality product.

Since its inception in July 2014, a hatchery, nursery and broodstock rearing facility has been set up. The first spawning trials were conducted in February 2015 and were followed by several other successful spawning events over a period of nine months. An overview of the project's achievements thus far is described in the following sections.

Rearing facilities

Our rearing facility is located within the complex of the Fisheries Research Institute (FRI), Kampung Pulau Sayak, Kedah. It extends over 600 m², and half of it is within an existing building while the other half is within an outdoor space. The facility is supplied with filtered seawater via FRI seawater intake and treatment systems, together with other utilities from the main complex. The salinity of the seawater varied between 29 ppt and 32 ppt, depending on the season, with temperatures ranging between 28ºC and 33ºC and pH averaging 8.1.

The building houses a fully biosecure and temperature controlled hatchery, where 85 m² is dedicated to larval culture and early juvenile rearing (nursery 1, or N1) and 15 m² is for phytoplankton production. The hatchery is equipped with 12 x 1000 L conical bottom tanks used for larval rearing (Fig. 1A), 1 x 4 m³ (Fig 1B) and 4 x 0.5 m³ tanks for N1. The room is supplied with 1-μm filtered and ultraviolet (UV) sterilised seawater produced from a filtration bank located outside the room (Fig. 1F) and distributed via an overhead ring. A centralised compressor supplies the hatchery with compressed air. The phytoplankton production room is equipped with a separate recirculating seawater system that continuously supplies filtered (to 1 μm) and UV sterilised seawater for the mass production of *Chaetoceros calcitrans* and *Pavlova* sp. (Fig. 1C). The phytoplankton production capacity is about 300 L of monoculture at any time. The other 200 m² is located within a non-biosecure and ambient temperature conditions. The tanks are kept under a roofed but opened space. This space is divided between, nursery 2 (N2, 120 m²) for juvenile grow-out and broodstock rearing and conditioning (80 m²). The tanks in N2 (Fig. 1D and E) are supplied with 15-μm sand-filtered seawater while the broodstock tanks are supplied with 30-μm filtered seawater, both running via a flow-through system.

The outdoor space is equipped with 8 x 13 m³ and 4 x 15 m³ tanks that are supplied by 30-μm filtered seawater via a flow-through system and compressed air. In the near future, this space will

Figure 1. Sea cucumber rearing facilities. A: Hatchery unit with larval culture tanks; B: Indoor nursery tank with settlement plates; C: Phytoplankton room with *Chaetoceros* sp. cultures; D and E: Outdoor nursery tanks holding juveniles > 10 mm in size; F: Seawater storage and filtration system.

be covered with a greenhouse structure and used to expand the N2 and broodstock conditioning facilities. In addition to the rearing facility is an office for our technical staff, a dry laboratory and storage facilities.

Broodstock management

Sandfish individuals > 25 cm in size (Fig. 2A) were collected on three occasions (October 2014, January and July 2015) along the coast of Pulau Balambangan off Kudat, Sabah, Malaysia. Between 30 and 40 individuals were collected on each occasion, transported by boat to Kudat, and then by road to Kota Kinabalu. They were allowed to settle overnight in tanks continuously supplied with fresh seawater before being packed for airfreight the next day. Eight to ten individuals were placed in a Styrofoam box fitted with two layers of plastic bag and prefilled with a 2–3 cm layer of filtered seawater (Fig. 2B). The bag was then filled with oxygen and sealed. Two ice packs of about 500 g each were placed in each box before being wrapped and prepared for airfreight. Once at Penang airport, the sea cucumbers were transported to our facilities in Kedah and recovered in dedicated broodstock tanks (Fig. 2C and D). The observed survival rates after recovery were 70% after the first shipment in October 2014, and 100% during the last two shipments. Few eviscerated individuals were noted during the first and second shipment, but none on the third shipment.

Broodstock individuals were fed on a regular basis with a mixture of dry algae: *Sargassum* sp., *Gracillaria* sp. and *Ulva* sp. The weight of broodstock individuals was monitored every two weeks and, after each spawning trial, the observed male and female individuals were placed in separate tanks and conditioned to favour gonadal growth and maturation.

Spawning trials

Thermal stimulation was used to induce spawning in sandfish and a rise in seawater temperature between 3°C and 5°C was observed to be enough to trigger spawning in mature individuals. Spawning was trialled at least twice a month and each time, between 20 and 45 individuals were induced. During each spawning event observed, males always spawned first, triggering females to spawn 30 minutes to 2 hours later (Fig. 3 A and B). Each female spawned, on average, about 1 million eggs. So far, two males and one female from the January 2015 batch have spawned twice over a five-month period.

Spawning success varied over the nine-month trial period (Fig. 4). Out of 14 spawning trials, 9 resulted in successful fertilisation (64%). From February to May 2015, the spawning success rate averaged around 25%, while no females spawned during June, July and August. Spawning in both males and females was observed again as in September. This observation could be due to the seasonality in reproductive cycle of the sandfish individuals.

Larval stage

Upon release of gametes following a spawning event, fertilisation was allowed to occur in the spawning tanks while care was taken to avoid polyspermy. Broodstock individuals were then removed and fertilised eggs were transferred to larval culture tanks at a density of 200–300 eggs per liter (L^{-1}). Larval culture tanks were prefilled with 1-μm filtered seawater the day before in order to allow the water temperature to reach the hatchery room temperature, which was set at 27ºC. Each larval culture tank was supplied with air via a diffuser or airstone.

Figure 2. *Holothuria scabra*. A: Adult sandfish (> 25 cm); B: Packaging and conditioning for airfreight; C: Sandfish individuals recovering in our broodstock tank (inset D).

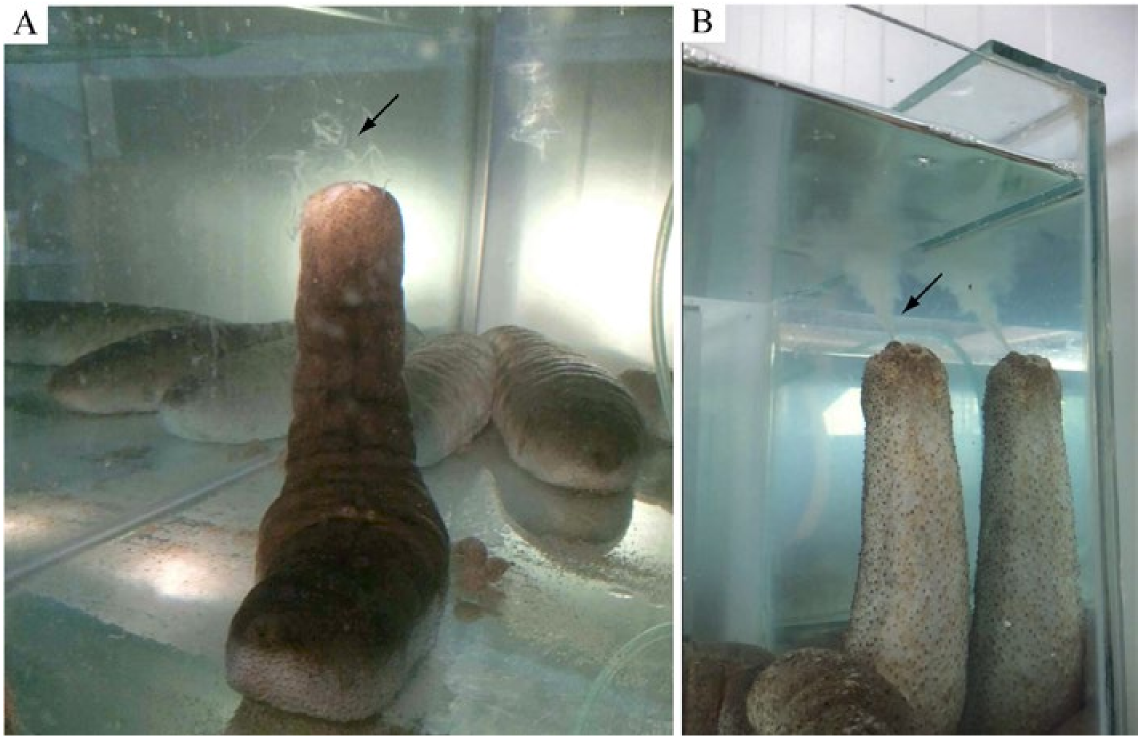

Figure 3. *Holothuria scabra* spawning events. A: Male; B: Female.

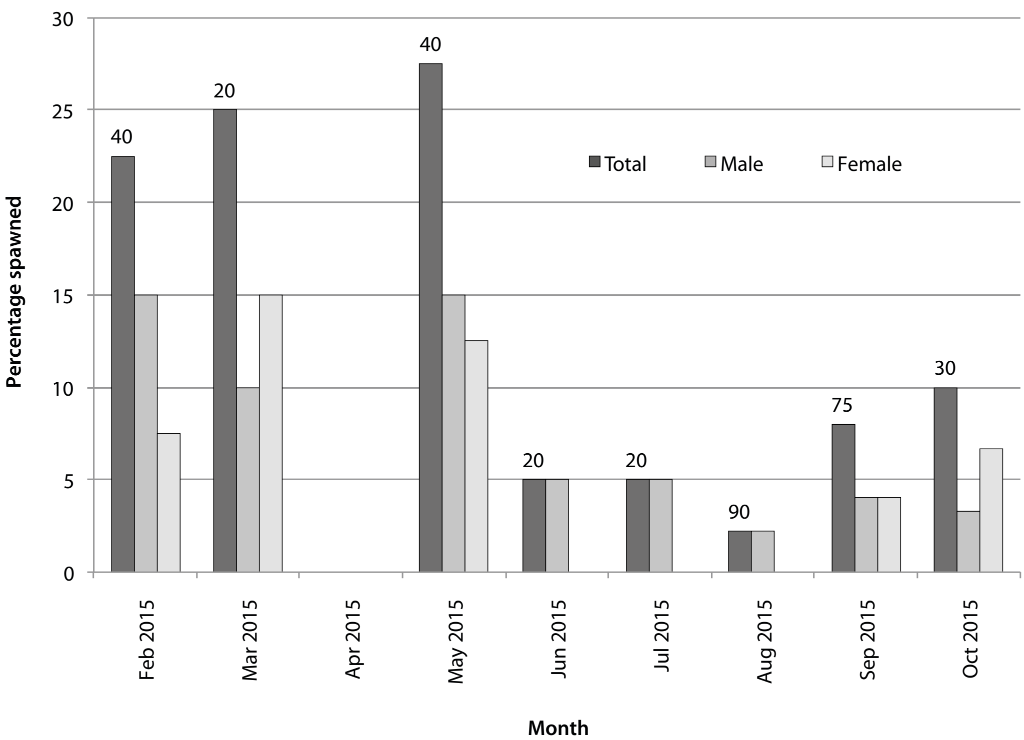

Figure 4. The success rate in spawning *Holothuria scabra* over a nine-month period. Total number of individuals induced to spawn is indicated above bars. Note: No trial was conducted in April.

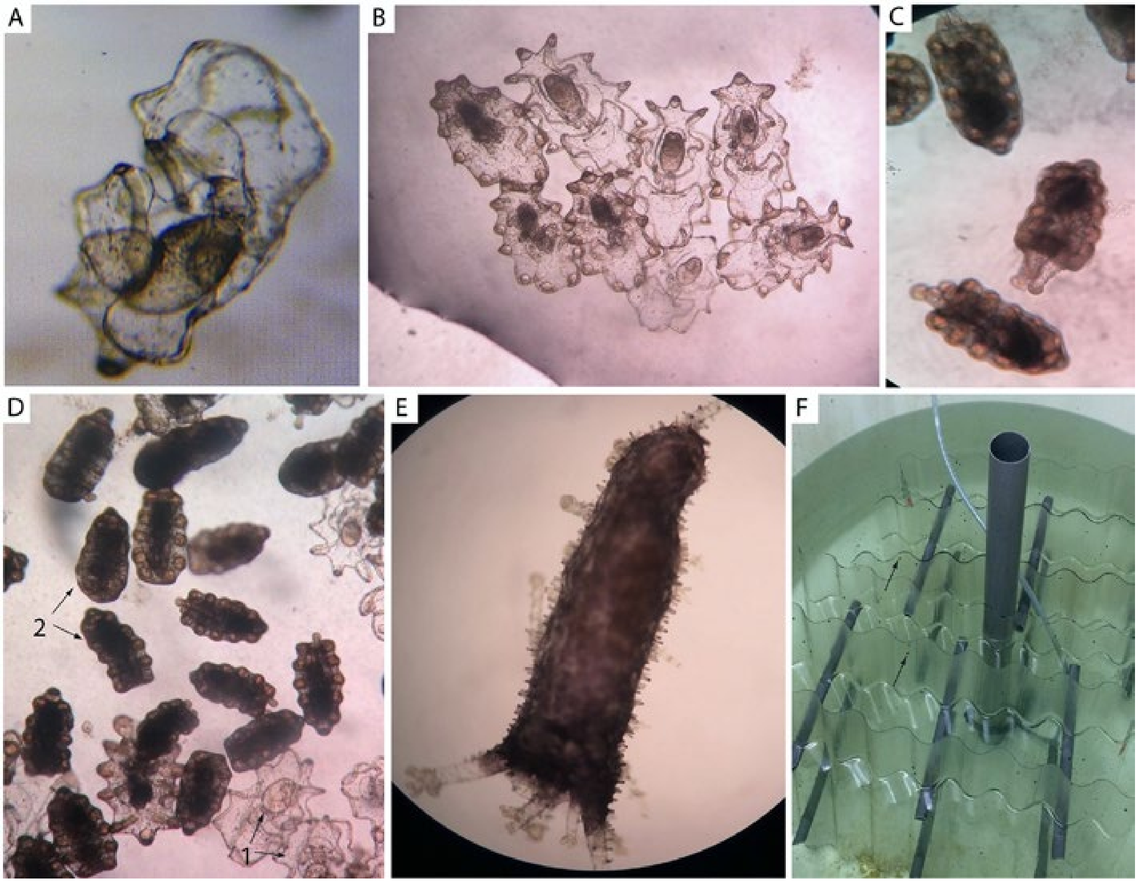

Figure 5. Larval developmental stages of *Holothuria scabra*.
A: Early auricularia; B: Late auricularia; C: Doliolaria;
D: Mixed doliolaria (2), and later auricularia (1);
E: Pentactula; F: Early juveniles (arrow) on settlement plates.

Depending on the number of females that spawned and the number of fertilised eggs collected, three to six larval culture tanks were filled with larvae at each trial.

The onset of feeding occurred two days after fertilisation and the resulting larvae were fed on a daily basis with 1 L of diatom *Chaetoceros calcitrans* per tank, cultivated at a density ranging between 4 x 10^6 and 6 x 10^6 cells per milliliter (ml^{-1}). The different larval stages are shown in Figure 5 (A–E) and larval development was completed within 12–15 days after fertilisation. Doliolaria larvae were allowed to settle on preconditioned settlement plates (Fig. 5F), and were introduced into the larval culture tanks eight days after fertilisation. The resulting pentactula postlarvae were reared in the same tank for another 20–30 days, and early juveniles were then transferred to the N1 tanks. About 50% of the water in the larval culture tanks was exchanged once a week, and after all larvae had settled the feeding ration was reduced to 500 ml, only until all early juveniles were transferred to nursery tanks. Throughout all the larval, postlarval and early juvenile rearing, water parameters such as salinity, temperature, pH and dissolved oxygen were monitored on a daily basis.

Juvenile stage

Figure 6 shows the early juvenile stages from N1 and N2 tanks. About 35–45 days after fertilisation, the resulting juveniles were transferred to the N1 tanks (Fig. 6A and B). The rearing density was about 500 individuals per m^2 (ind. m^{-2}). Their average size ranged between 1 mm and 5 mm, although some fast-growing individuals were observed to be around 10 mm long. Settlement plates that have been preconditioned to favour biofilm growth were added in N1 tanks to increase the surface area. The juveniles were fed every two days with both phytoplankton cultures (2 L for the 4-m^3 tank and 0.5 L for the 0.5-m^3 tanks) and a supplement of dry algal powder (mixture of *Sargassum* sp., *Ulva* sp. and *Gracillaria* sp.). About 50% of the water in N1 tanks was exchanged every two days before feeding. Once individuals reached 10–15 mm in length, they were transferred to N2 tanks. Some of the fast-growing juveniles from the larval culture tanks were transferred directly to N2 tanks.

N2 tanks had a 3–5 mm layer of sand at the bottom and water was supplied continuously to the tanks (Fig. 6C to F). The rearing density in those tanks varied from 450 ind. m^{-2} for 15 mm-long individuals to 200 ind. m^{-2} for 30 mm-long individuals, and 75 ind. m^{-2} for 60 mm-long individuals. The juveniles were fed every two to three days using the same mixture of dry algal powder as in N1. After nine months of the pilot production trial, our yield was about 30,000 juveniles of 3–5 mm in length, resulting in about 6,000 juveniles of 15–20 cm in length.

The growth rates of juveniles (n = 60) in both N1 and N2 are shown in Figure 7. Growth rates recorded among juveniles in N1 tanks showed an average increase in length of 8 mm $month^{-1}$ (or 0.3 mm day^{-1}), which is equivalent to 0.01 g day^{-1}. The arrow in Figure 7 indicates the time when the entire batch of juveniles from N1 was transferred to N2. Juveniles in N2 tanks grew, on average, 5 mm $month^{-1}$ (0.2 mm day^{-1}, 0.02 g day^{-1}).

The allometric relationship between wet weight (g) and length (mm) was investigated using a random sample of 220 juveniles from N1 and N2 tanks. The length of the juveniles was measured to the nearest 0.1 mm and weighed to the nearest 0.01 g. Juveniles were blotted with tissue paper before weight data were taken. Figure 8 shows the relationship between weight and length and the power curve fitted to the data. The relationship observed was highly correlated ($r^2 = 0.9$, $p < 0.01$) and the allometric coefficient obtained was 2.69, which was consistent with previous studies (Agudo 2012; Purcell and Agudo 2013).

Grow-out trial

A small trial for grow-out in sea pens has recently been set up off Pangkor Island, Perak (Fig. 9). The main sea pen is 100 m^2 and constructed with 1-m high high-density polyethylene mesh (6 mm mesh)

Figure 6. Juvenile stage of *Holothuria scabra*.
A: Early juvenile (arrow) in nursery tank; B: Juvenile from one batch showing differences in size;
C and D: 1.5–2.0 cm-long juveniles in outdoor nursery tanks;
E and F: 3–6 cm-long juveniles prior to transplant in sea pens for grow-out.

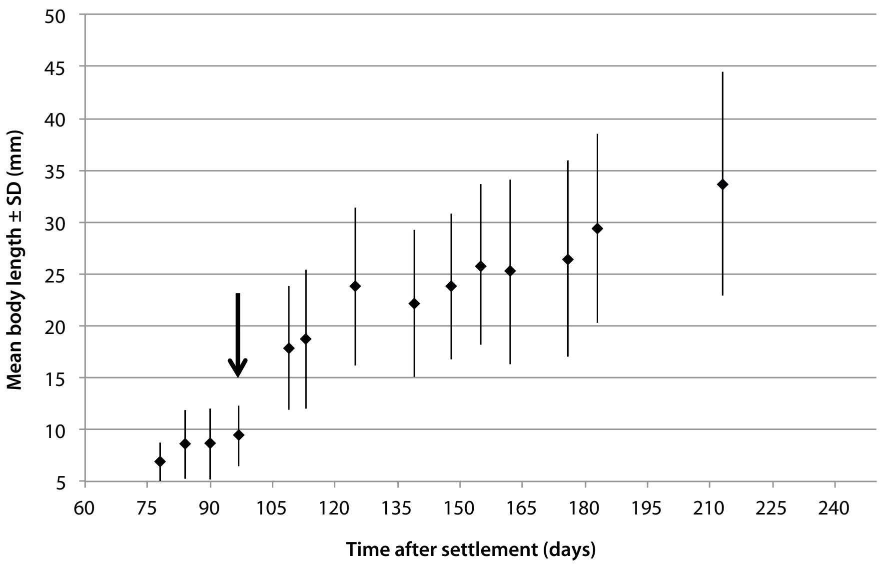

Figure 7. Growth data of early juveniles of *Holothuria scabra* from nursery tanks (n=60). Arrow shows time when juveniles were transferred from indoor N1 to outdoor N2 tanks.

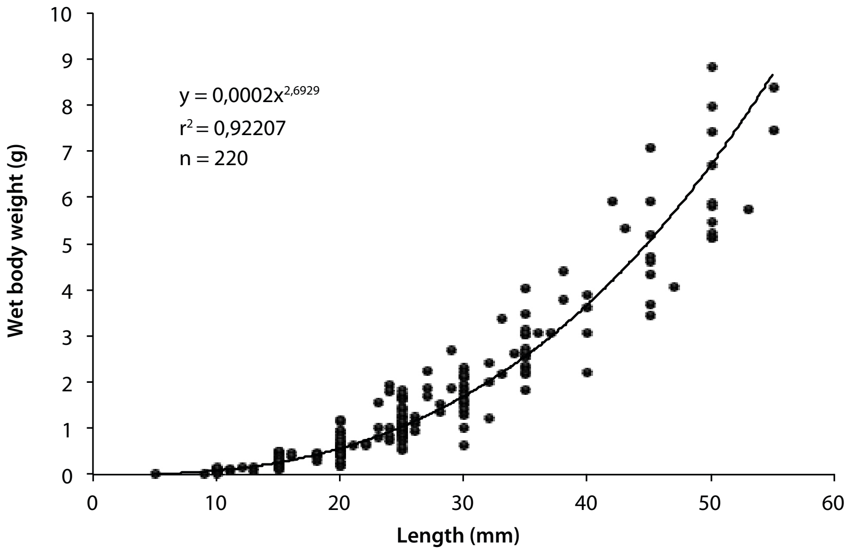

Figure 8. Allometric relationship between length and wet weight from 220 early juveniles of *Holothuria scabra*.

supported by wooden spikes. Within that surface area, sections were partitioned into smaller pens of about 3 m^2 with iron structures. These were for juvenile grow-out.

In October 2015, a small batch of 100 juveniles (length: 38 ± 10 mm; weight = 3.50 ± 2.19 g) was released in one of the small pens. After a month trial, the survival rate was 77%. Growth was very promising, with an average increase in length of 18% and a 48% gain in wet weight within one month of trial at sea (0.4 mm day^{-1}, 0.1 g day^{-1}).

Discussion

The results obtained after nine months of operation are very promising, but have also highlighted some bottlenecks in production. These are: 1) apparent seasonality in spawning success; 2) low fecundity of females; and 3) low survival rate of juveniles from 0.3 mm to 1.5 cm long as shown in Table 1 below.

The reproductive cycle of *Holothuria scabra* in the Sabah region is unknown, although it is generally accepted that spawning patterns in sandfish

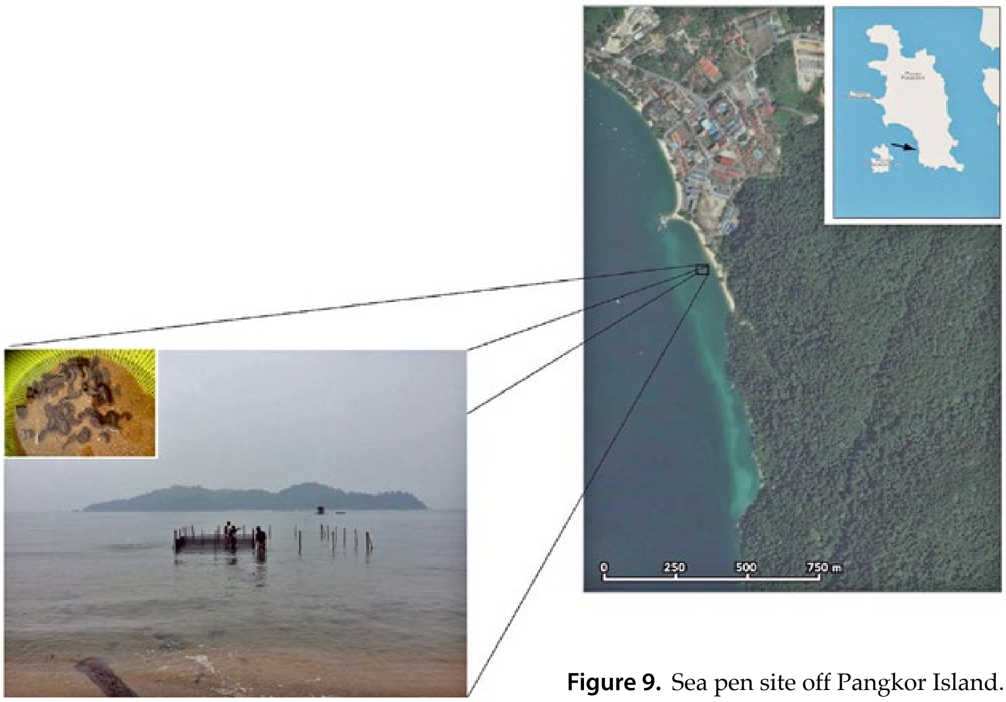

Figure 9. Sea pen site off Pangkor Island.

occurring at low latitudes are not seasonal but instead show continuous spawning throughout the year (Ramofiafia et al. 2003; Tuwo 1999). Although no analysis of the reproductive organs has been performed on our broodstock, indirect observations on spawning rates from the three samples obtained from Sabah (October 2014, January 2015 and July 2015) showed an apparent reproductive cycle, with low spawning rates among males and no spawning at all among females between June and August 2015. A proper study using histological analysis of the gonads will be required to confirm those observations. From our conditioned stock, only two males and one female spawned on two occasions within a five-month period. This indicates that our conditioning system will require further optimisation, in terms of water quality, stock density and feed types.

Although low production of eggs by females that have been artificially induced to spawn has been reported in other studies (Agudo 2006), however, sandfish from Madagascar that have been thermally induced to spawn did yield up to 4 million eggs (Devarajen Vaitilingon, pers. obs.). The fact that females are producing only about 1 million eggs per spawn is a limitation to our production. In order to operate the hatchery at full capacity (with a density of 200 eggs L^{-1}), we will need eggs from at least six females to be fertilised and this can be an issue if space for broodstock conditioning is limited. Spawning trials with other sandfish populations (namely from Thailand and Indonesia) are now underway to see if the low fecundity is inherent from the Sabah population.

Table 1 shows our output data from a typical production when the hatchery is running at full capacity. Survival rates of juveniles obtained during transition from larval culture tanks to N1 tanks are low and unpredictable (as seen by the high variability around the mean) and this is a major bottleneck in our production. In addition, the juveniles at this stage also show high variability in sizes (Fig. 6B), with larger individuals showing better survival rates than smaller ones. Future works will be focused on addressing this issue by putting more emphasis on transfer methods but also on broodstock conditioning in our rearing facilities and testing different feed types on broodstock individuals. Echinoderms are known to use egg triglyceride as a major energy lipid to fuel larval development and even early juvenile developmental stages (Byrne et al. 2008). The effect of such maternal provisioning on juvenile sandfish is unknown and will be investigated in the coming months. We hypothesised that by manipulating broodstock feed types and increasing triglyceride lipid in eggs, this might increase the performance of juvenile at this critical stage.

The growth rates obtained from juveniles in our nursery tanks are lower than those reported in pond-based or sea pen trials (Purcell and Agudo 2013). This is most probably due to the difference in water quality and rearing density between a tank-based vs a pond-based system. Our first trial at sea with 3.5 g (38 mm) individuals shows better growth rates of 0.1 g day^{-1}.

The next stage of the project will focus on the optimisation of production by eliminating these bottlenecks

Table 1. Summary of output data on *Holothuria scabra*, based on performances at every developmental stage from a representative production done when the hatchery was running at full capacity.

Rearing unit	Stage	Age (days)	Time (days)	Mean size (length)	Weight (g)	Rearing		Survival from previous stage (mean ± SD)	n	Mean global survival rate (%)	Output data (number of individuals)
						Density	System				
Hatchery	Embryo	2	2	100 µm	-	200 L^{-1}	LC - 12 x 1000-L tank	-	6	100.00	2,400,000
	Auricularia	8	10	800 µm	-	110 L^{-1}	LC- 12 x 1000-L tank	54.8 ± 5.6	6	54.80	1,315,200
	Doliolaria	2	12	450 µm	-	70 L^{-1}	LC- 12 x 1000-L tank	34.4 ± 11.1	6	34.40	825,600
	Pentactula	3	15	0.3 mm	-	-	LC- Settlement plates	68.8 ± 15.2	6	23.70	568,013
	Juveniles	45	60	5 mm	0.01	500 ind. m^{-2}	Nursery 1- Settlement plates	2.0 ± 1.5	22	0.47	11,360
Nursery	Juveniles	45	105	1.5 cm	0.3	450 ind. m^{-2}	Nursery 2 tanks	19.8 ± 6.3	3	0.09	2,249
	Juveniles	75	180	3 cm	2	200 ind. m^{-2}	Nursery 2 tanks	55*	2	0.05	1,237
	Subadults	70	250	6 cm	10	75 ind. m^{-2}	Nursery 2 tanks	80*	2	0.04	990

* Only average value was indicated when n < 2.

and expanding our facilities to the available outdoor area. This will increase space for broodstock rearing and conditioning. The access to the lagoon off Pangkor Island will also bring more opportunities for trialling grow-out at sea as opposed to tank systems.

Acknowledgements

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Assays for optimising the growth of *Holothuria scabra* juveniles during the nursery phase

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Abstract

The effect of sediment quality on the survival and growth of the sea cucumber *Holothuria scabra* reared in nursery ponds was previously studied by our team. Here, we tested the effects of three types of enrichment to optimise the growth of sea cucumbers in nursery ponds. The enrichments were: 1) marine sediment + provender based on fisheries byproducts; 2) marine sediment + green water, including tropical local diatoms; and 3) marine sediment + tilapia (*Oreochromis niloticus*) in co-culture. For this experimentation, eight outdoor ponds, each measuring 32 m^2, were used. The rearing density at the beginning of the experiment was 20 ind. m^{-2} (640 *H. scabra* juveniles in each pond). The results showed that at the end of the experiment, no significant differences could be detected between the survival rates, mean weights or biomasses obtained for each type of enrichment tested. However, marine sediment collected from a mangrove zone (control) and marine sediment + tilapia in co-culture produced good performance after seven weeks of rearing. The profitability of co-culture with tilapia should be further investigated.

Introduction

Juvenile *Holothuria scabra* pass from an epibenthic stage once they reach 1.0–1.5 cm in length, to an endobenthic stage, in which they bury in the substratum during the day (Eeckhaut et al. 2008). During aquaculture experiments run in southwest Madagascar, juveniles were transferred at the endobenthic stage from the hatchery to outdoor ponds filled with a layer of sediment. They remained in these ponds for 6–10 weeks until they reached an average size of 6 cm (approx. 15 g) (Lavitra 2008). At this point, they were able to cope with conditions in the natural environment (Battaglene and Bell 1999) and were then transferred to sea pens to allow them to grow to a marketable size (> 350 g).

The effect of sediment quality and stocking density on the survival and growth rate of *H. scabra* reared in nursery ponds and pens was previously studied by Lavitra et al. (2010). Three types of sediment (taken from a micro-atoll, and mangrove and seagrass beds) were tested for their food quality properties. Experiments were carried out in ponds at juvenile stocking densities of 10, 20, 30 and 40 ind. m^{-2}. The results showed that the nature of the sediment did not affect the survival or growth of *H. scabra*: high survival and good growth rates were observed during eight weeks of rearing in ponds (Lavitra et al. 2010). Yet, regardless of stocking density, juvenile growth ceased above a maximum biomass of 160 g m^{-2} in outdoor ponds (Lavitra et al. 2010).

The economic profitability of *H. scabra* aquaculture relies on the optimisation of each rearing phase and the two phases that are the most controllable are the hatchery and the nursery pond phases. Here, we show the effects of three assays for optimising the growth in nursery ponds: 1) the addition of green water including tropical local diatoms; 2) the addition of provender based on fisheries byproducts; and 3) co-rearing with tilapia *Oreochromis niloticus* together with the addition of provender. The three assays were compared with controls consisting of *H. scabra* reared on natural marine sediment collected from mangrove areas.

Materials and methodology

The experiments were run in the nursery ponds of a private company, Madagascar Holothurie S.A. Three types of sediment enrichments were tested:

- the addition of green water, including tropical local diatoms;
- the addition of provender based on fisheries by-products; and
- co-rearing with the tilapia *Oreochromis niloticus,* with the addition of provender.

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Preparation of green water

First, 200 g of chicken droppings were dried and mashed to produce a powder. Then, the powder was placed in sealed bags at the four corners of the pond, 10 cm under the water surface, and left to "infuse" in the water for three days in order to produce green water (Fig. 1). These bags are wiped three times a day – in the morning, at noon and in the late afternoon.

Provender

The provender is manufactured by the laboratory PRADA (Projet de Recherche Appliqué au Développement de la Région Analanjirofo). It consists of granules made of fish flour as a source of animal protein (30%), soya powder as source of vegetable protein (26%), peanut pieces as a source of lipids (17%), and rice or cassava as source of carbohydrates (12%) (Rahoasa 2014). A quantity of 20 g of provender per pond was distributed two times per week after water replacement.

Rearing H. scabra *with tilapia*

Thirty tilapia individuals with a mean size of 4 g were introduced into nursery ponds and fed with the same provender used in the second experiment. A quantity of 40 g of provender per pond was distributed two times per week after water replacement.

Preparation of the nursery ponds

Eight outdoor ponds measuring 32 m^2 (8 m x 4 m) were used (Fig. 2). Marine sediment collected from the mangroves was placed in each pond at a thickness of about 1 cm. Before putting the juveniles in the ponds, the sediment was treated with tap water

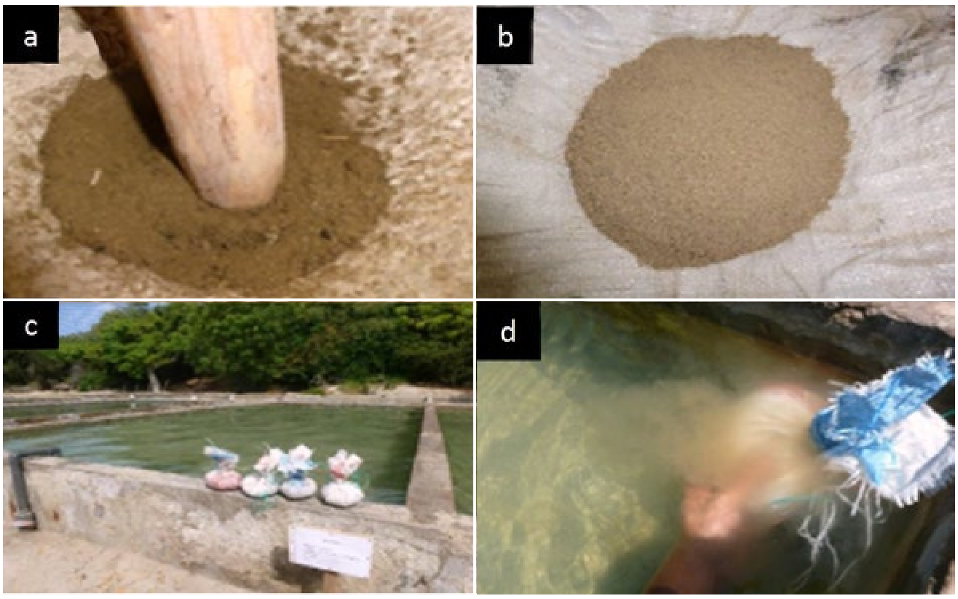

Figure 1. Preparation of green water.

a) dried and mashed chicken droppings;
b) powder;
c) powder packed in sealed bags;
d) bags placed in water at each corner of the pond.

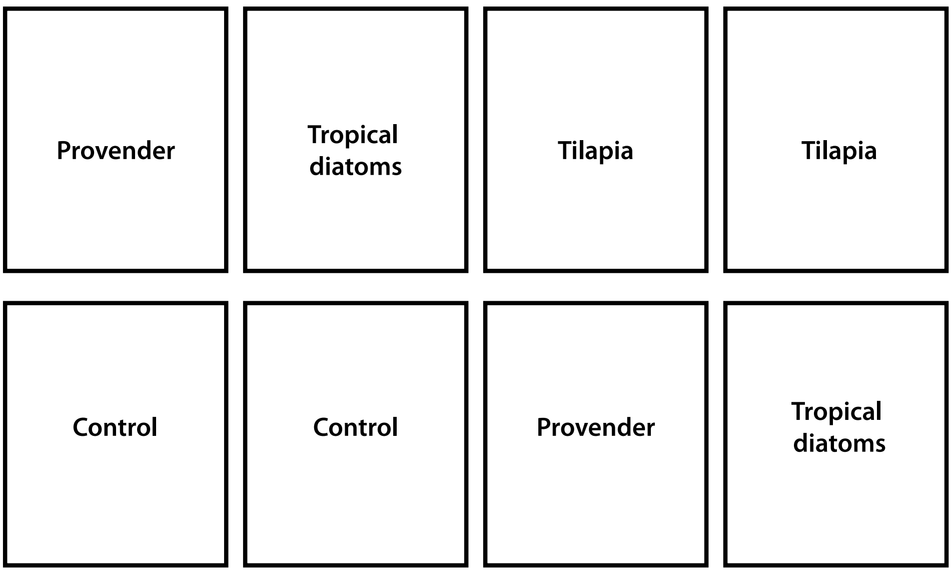

Figure 2. Design and disposition of the outdoor ponds.

- Control: Ponds where *H. scabra* juveniles were fed with only marine sediment.
- Provender: Ponds where *H. scabra* juveniles were fed with marine sediments + 20 g of provender per week per pond (20 g week^{-1} pond^{-1}).
- Tilapia: Ponds where *H. scabra* juveniles were reared with tilapia.
- Tropical diatoms: Ponds where *H. scabra* juveniles were fed with marine sediment + tropical diatoms (5 m^3 week^{-1} pond^{-1}).

for 24 hours to eliminate any possible predators and other organisms that would inhibit or infect the rearing of the individuals.

After the treatment of the sediment, tap water was replaced by seawater that was pumped directly from the bay of Toliara. The seawater flowed into the rearing ponds without any treatment or filtration.

Juvenile *H. scabra* were provided by the company Indian Ocean Trepang (IOT). At the beginning of the experiment, juveniles were 12 weeks old and had a mean weight of 0.03 g. After collection from the hatchery, juveniles were placed inside a bucket for counting. Counting was done manually, using no tools other than eyes and hands. After they were counted, the juveniles were put in a plastic bag full of filtered seawater for transportation. The transport took about 20 minutes; the distance between the IOT hatchery and Belaza, where the grow-out experiments took place, is about 10 km. Juveniles were then placed directly into the ponds. The rearing density was fixed at 20 individuals per m^2, equivalent to 640 juveniles per pond. In total, 5,120 juveniles were monitored during the experiment.

The temperature and salinity of the water were measured twice a day (in the morning at 07:00 and in the afternoon at 15:00). Because the experiment was conducted during the cool season (May–July 2014), each pond was covered with plastic sheeting to retain the heat, thereby producing a greenhouse effect.

For *H. scabra*, there is a tight correlation between length, width and weight (Lavitra 2008), with weight being the only parameter used to evaluate the growth of the studied specimens. The weight of all individuals in each pond was measured and recorded once a week. Weight was measured using an electronic balance.

The survival rate was only recorded at the end of the experiment by counting all of the remaining juveniles.

The biomass of the holothurians in each pond was calculated at the end of the experiment in order to evaluate the yield of each food type. The biomass is expressed in grams per square meter (g m^{-2}) and was calculated as:

(number of individuals x mean weight)/pond area

Statistical analysis of the data that were related to the survival and growth of the juveniles was done using the software SYSTAT V12.2. Analysis consisted of comparing the rate of survival and growth, and the mean biomass of the holothurians obtained for each type of enrichment at the end of the experiment. Therefore, a comparison test of proportions and an ANOVA test were done. It was noted that the data were homogenous and the distribution was normal after Ks and Leven tests.

Results

Physicochemical parameters of the water

The average temperature of the pond water during the experiment was 28°C, with an average minimum of 25.23°C and an average maximum of 30.74°C (Fig. 3). In general, no large variation in temperature was observed inside the rearing ponds during the experiment. The mean salinity value was about 34.5‰, and ranged from around 32‰ to 36‰ (Fig. 4).

Survival

At the beginning of the experiment, the number of juveniles in each pond was 640. After seven weeks, the survival rate varied from 42% to 66%, depending on the type of enrichment added (Fig. 5). However, a statistical analysis of the data did not show any significant difference between the values obtained ($p = 0.103$).

Growth

Juveniles had an average weight of 0.03 g at the beginning of the experiment. After seven weeks of rearing, the mean weight of juveniles was the highest (9.01 g ± 4.23) in the ponds where sea cucumber juveniles had been co-cultured with tilapia (Fig. 6). However, statistical analysis of the data revealed that the mean weights of *H. scabra* juveniles did not differ significantly ($p = 0.739$), no matter the enrichment type.

Biomass

The average biomass per pond at the beginning of the experiment was 0.6 g m^{-2}. After seven weeks of rearing, biomass varied, depending on the type of enrichment provided. It was higher (more than 110 g m^{-2}) in the control ponds and in the ponds in co-culture with tilapia than in the ponds using the two other types of enrichment (less than 72 g m^{-2} for juveniles fed with marine sediment enriched with tropical diatoms and for those fed with marine sediment enriched with provender). However, statistical analysis of data showed that there was no significant difference between the various enrichments ($p = 0.198$) (Fig. 7).

Discussion

The various enrichments did not produce significant differences in survival rates, mean weights or biomass of *H. scabra* juveniles at the end of the

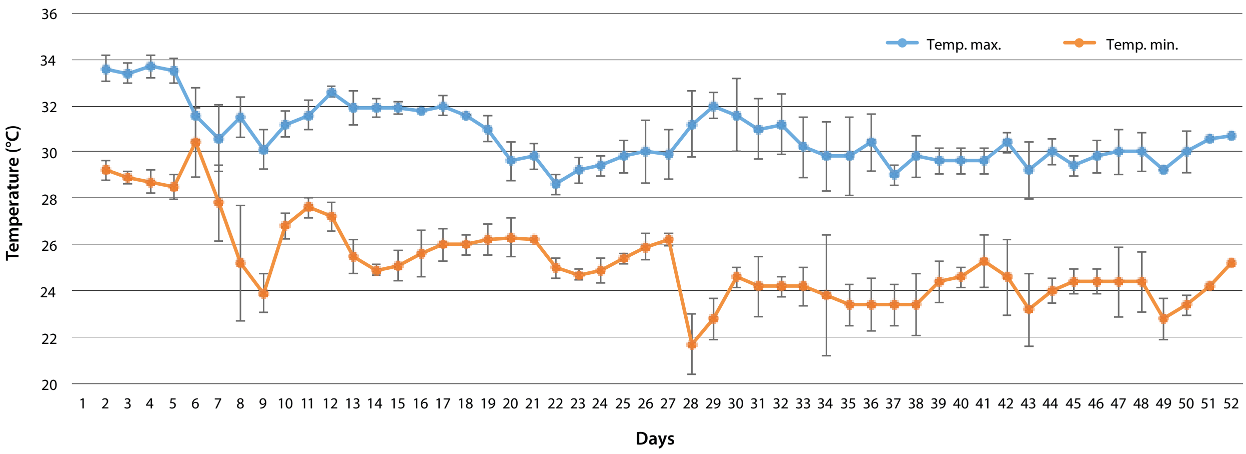

Figure 3. Maximum and minimum temperatures recorded each day in the rearing ponds (May–July 2014).

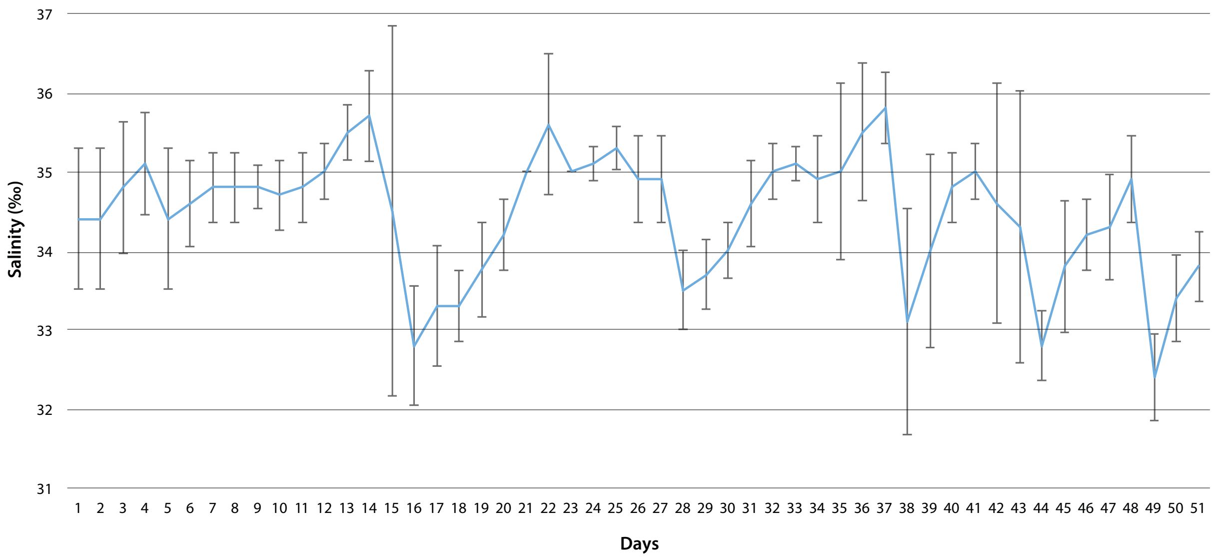

Figure 4. Salinity within the rearing ponds (May–July 2014).

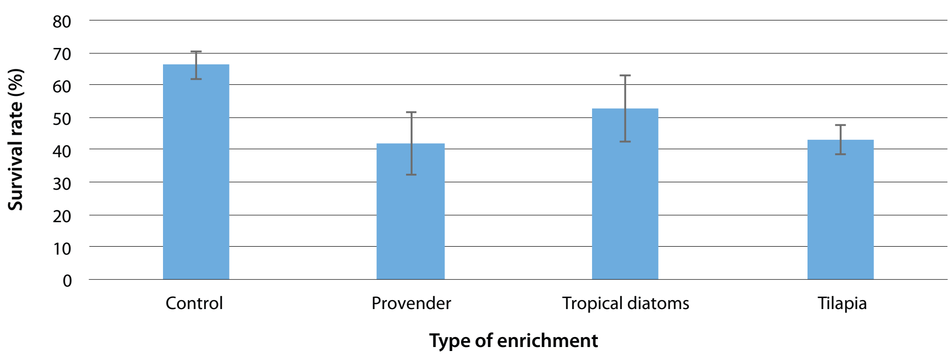

Figure 5. Survival rate of *H. scabra* juveniles after seven weeks of rearing.

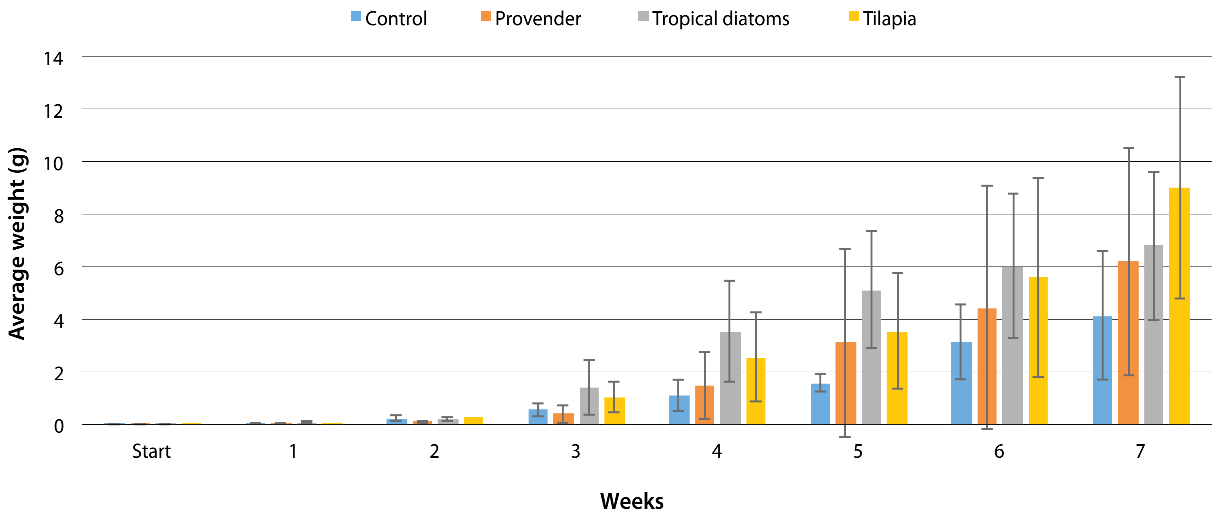

Figure 6. Average weight of *H. scabra* juveniles after seven weeks of rearing.

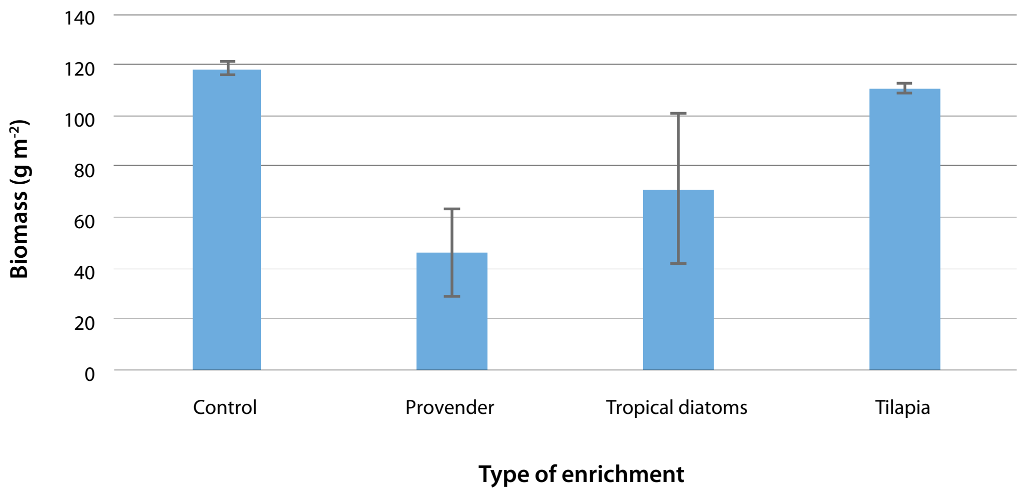

Figure 7. Biomass of *H. scabra* juveniles after seven weeks of rearing.

experiment. These results suggest that the organic matter present in the natural marine sediment collected from mangrove areas is sufficient for *H. scabra* growth during the nursery phases, and that the enrichments tested during the experiment were not necessary.

Much research has been conducted with marine sediment enrichments in order to improve *H. scabra* growth during the nursery phase; for example, marine sediment + *Thalassia hemprichii*; marine sediment + *T. hemprichii* + spirulina; marine sediment + *Sargassum latifolium*; marine sediment + *S. latifolium* + spirulina; marine sediment + *Thalassodendron ciliatum*; marine sediment + *Siryngodium isoetifolium*; and marine sediment + organic biofilm (Lavitra 2008). The results were the same as those obtained here: the enrichments had no significant impact on the biomass of reared *H. scabra*. All of these experiments suggest that the use of provender and tropical diatoms as sediment enrichment do not give good results in terms of growth, and they are not promising.

Before the end of the experiment, we found the co-culture with tilapia to be promising. The rearing of tilapia in seawater has been reported by multiple authors, some of whom reported the possibility of obtaining good growths (Persand and Bhikajee 1997; Watanabe et al. 1990). We originally thought that rearing sea cucumbers with tilapia would provide advantages for both the holothurians and the fish, with the first eating the waste material of the latter. However, our study showed that the average survival rate of juvenile *H. scabra* in the co-rearing experiment was very low (43.3%). This could be explained by the fact that either the juveniles were too small at the beginning of the experiment and could not consume all of the wastes of the tilapia, or they were prey for tilapia. Our experiment with the mixed rearing of holothurians and tilapia was the first of its kind. Nonetheless, many authors have tested the mixed rearing of holothurians with shrimp, and most authors affirmed that they obtained a good yield of holothurians and shrimp, while a few authors highlighted the uselessness of the mixed rearing (Bell et al. 2007; Pitt and Duy 2004). Further experiments are necessary to test the efficacy of sediment enrichments, especially those involving tilapia.

Acknowledgements

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Juvenile "black teatfish" in Maldives

Michael Sweet[1], Frédéric Ducarme[2] and Chantal Conand[3]*

Introduction

Juvenile holothurians remain poorly understood globally. This is likely the result of two main factors: they are rarely observed, and they are difficult to identify once found (given the changes in colouration of the body wall and ossicle morphology during growth).

We report on the discovery of four holothurian individuals that have been provisionally described as juvenile "black teatfish", *Holothuria* cf. *nobilis*. These juveniles were observed in August 2015 within the patch reef off Vavvaru on Lhaviyani Atoll in Maldives.

Observation

Although DNA analysis has yet to be undertaken, the observed individuals exhibited the classical morphology of "teatfish". These species, namely *Holothuria nobilis, H. fuscogilva, H. whitmaei* and the "pentard type" (Purcell et al. 2012) are among the most heavily fished and poached sea cucumbers in the world. The characteristics of these teatfish are, among the classical Holothuria body plan: an arched and stout shape, very firm sub-oval body, lateral rounded protrusions (called "teats"), and the presence of anal teeth. The individuals observed were black on their dorsal side and light brown or orange on the sides and the teats, with a white sole on the ventral face, which was covered with numerous grey podia. Individuals were also covered with fine sediment, and did not expel Cuvieran tubules when rubbed. Individuals ranged in length from 15–20 cm (Fig. 1A, B), suggesting that individuals were not adults, thus explaining the juvenile colour patterns observed (Conand 1981).

Identification

The above characteristics have led us to the identification of these individuals as belonging to either *H. nobilis* or *H. fuscogilva* (Purcell et al. 2012), although, given the general aspect, the former is more plausible. However, regardless of a definitive identification, as both species are equally targeted by fishermen and came under similar dramatic stock crumbling (James and Manikfan 1994), the information reported herein is equally important. Although the adults of *H. nobilis* are relatively easy to identify (black dorsal surface with white lateral protrusions ('teats'), the juveniles show similarities to three other species: *Holothuria* sp., *H. fuscogilva* and *H. whitmaei* (Conand 1981). Traditionally, destructive sampling is often preferred for identifying species; however, the careful documentation of the external anatomy can lead to quick identification without sacrificing an animal when populations are scarce (as in this instance). For visual identification, a series of images is needed, showing the whole animal (with a scale for reference), the anal cavity (exposing the anal teeth), and the buccal

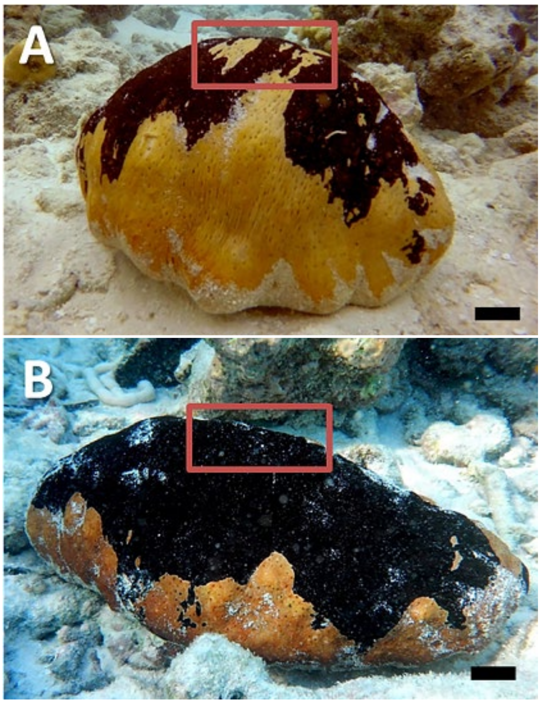

Figure 1. Variation in colour patterns (red square inserts) used to identify different individuals of *H.* cf. *nobilis* juveniles present at the site. Scale bars = 2 cm. (Images: M.J. Sweet)

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tentacles (if present and / or obviously feeding). Preparing ossicles is not always helpful (specifically in this instance) because these have been observed to change during the development of many species. Nevertheless, non-lethal DNA sampling and analysis must still be conducted for final determination of the species, and this is currently underway.

Significance

This is a rare record of any species of teatfish (*Holothuria [Microthele] nobilis* or *fuscogilva)* because severe overexploitation has left both of these species particularly scarce. In Maldives specifically, *H. fuscogilva* was previously described as being the most abundant in the country before overharvesting occurred (Reichenbach 1999). *H. nobilis*, in contrast, has been rare for many years with only one record published in scientific surveys since 1988 (Ducarme 2015; Muthiga 2008). Furthermore, both species are rare throughout their entire home range (East Africa eastward to French Polynesia) and are classified as "endangered" by the International Union for Conservation of Nature Red Data List. This trend is reflected in the majority of teatfish, largely due to overharvesting, with the exception of the "pentard" in the Seychelles (Conand and Muthiga 2008; Muthiga and Conand 2014).

The discovery of adults in any location is worthy of note, although the discovery of juveniles, albeit in low numbers, may suggest that recovery in certain sites is underway. To assess this recovery, work is currently being undertaken to assess the prevalence of *H.* cf. *nobilis* throughout Maldives using a network of resort-based marine biologists. However, as of yet, no additional confirmed observations have been reported. If this remains the case, with no further sightings being reported, this specific location deserves immediate protection to conserve the site as a nursery for this endangered species, with the hope that it may help recovery on surrounding islands and atolls.

Acknowledgements

We would like to thank J. Haskell and the staff at Korallion Lab, Vavvaru, Maldives where these observations took place.

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Observations of juvenile *Actinopyga echinites* and *Actinopyga mauritiana* (Echinodermata: Holothuroidea) near the reef crest in a lagoon of Réunion

Philippe Bourjon[1] and Elisabeth Morcel[1]*

Introduction

Continuous fishing pressure on holothurian populations (Purcell et al. 2014) has led to the collapse of stocks in many places around the world (Anderson et al. 2011; Conand 2004), and to a potential risk of extinction for commercial species in some areas (e.g. Hasan 2005). To ensure the success of replenishing efforts for overexploited commercial species from farm-raised individuals, it is necessary to understand the habitat preferences and ecological requirements of juveniles in their natural environment (Dance et al. 2002) and the role and importance of their predators (Francour 1997). *In situ* observations can improve our understanding of juvenile sea cucumber habits and help direct research efforts. This contribution is part of a series of field observations on size and habitat preferences of juveniles and recruitment that was initiated by Conand and Shiell in the SPC *Beche-de-mer Information Bulletin* (Shiell 2004a). It brings new data on two *Actinopyga* species that are abundant on Réunion reefs.

Observations

Several juveniles of *Actinopyga echinites* and *A. mauritiana* have been observed on the inner reef flat near the reef crest of the fringing reef of St Gilles, Réunion (21°07'S and 55°32'E), between 26 September 2015 and 10 October 2015 (i.e. at the end of the austral winter). The juveniles were in an area adjoining the reef front that was about 50 m in length and 10 m in width, outside of which no other juveniles of either species were observed. Small-sized individuals of other species were, however, spread out over this area of the reef flat (*Stichopus chloronotus, S. monotuberculatus, Holothuria pervicax, H. impatiens, Euapta godeffroyi*). These observations were made by the authors while snorkelling between 09:00 and 12:30 over three mornings spread over three to four days. For each day of observation, different sections of the reef, 10 m apart, were surveyed to avoid sampling the same individuals multiple times. Three transects of about 10 m x 10 m were explored. Additional observations targeting the northern and southern sections flanking this area of the reef flat (respectively 170 m and 130 m in length) were made to verify the absence of juveniles of the two *Actinopyga* species.

Four juveniles of *A. echinites* (Fig. 1A) and three juveniles of *A. mauritiana* (Fig. 1B) were observed. Their size ranged between 2.5 cm and 3.0 cm. The individuals were spread out, and the density was very low: the seven individuals were found in an area of approximately 300 m² (i.e. a density of 0.023 ind. m^{-2}). All individuals were found on the underside of dead coral blocks. None of the observed juveniles bore indications of lesions that could have been induced by predation, except for one juvenile of *A. mauritiana*, which had a small circular lesion on the bivium. A single adult of *A. mauritiana* and two adults of *A. echinites* were observed in this area. The occurrence of adults on a recruitment site has been documented for the same two species, but their abundances were not recorded (Shiell 2004b). Other juveniles of *A. echinites* of the same size were observed in other areas of the reef flat that are characterized by similar hydrodynamism.

Discussion

Except for *A. mauritiana,* none of the juveniles observed on the reef flat belonged to a species characteristic of a high hydrodynamics habitat (Purcell et al. 2013). It seems, therefore, that the recruitment of many sea cucumber species in reef environments begins with a period of time spent in the proximity of the reef front (see Bourjon and Morcel, p. 41 of this bulletin).

The hypothesis of a temporary recruitment site can be corroborated by previous observations: juveniles of *A. echinites* were abundant in the seagrass around the St Gilles reefs close of the shore (Kohler et al. 2009), and remain there until they reach a given size. The size of the smallest juvenile measured at this site is 4.2 cm (contracted individual, Fig. 1C). At this site we also found some juveniles of *A. mauritiana*

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(minimum size 7 cm, contracted individual, Fig. 1D). These juveniles presented the same morphology as the adults. These observations suggest that both species recruit in a microhabitat that is exposed to high hydrodynamics, before migrating towards a nursery area as juveniles, finally returning to the adult biotope.

The main factor determining the site of recruitment could be predation. Regarding the reef where these observations took place, the shallow water depth after the reef front (rarely more than 80 cm) and the strong water flow (or hydrodynamics) could be correlated with a low density of potential juvenile holothurian predators compared to the back reef. This part of the reef is, moreover, overwhelmingly occupied by coral rubble providing a multitude of shelters. Apart from *Stichopus chloronotus,* all juveniles were hidden under dead coral plates. The cryptic behaviour of juveniles was discussed by Cameron and Fankboner (1989), who consider that it probably lasts until individuals reach a size allowing them to escape many predators. These authors show that this strategy determines the recruitment of at least seven species of echinoderms. Wiedemeyer (1994) has shown that the cryptic behaviour of juvenile *A. echinites* could be attributed to the risk of predation, and that an increase in mortality due to predation accompanies the timing of the change in behaviour observed in juveniles.

More comprehensive observations of recruitment and juvenile migration patterns are necessary to better understand the factors determining the habitat choice for these species during their development stages.

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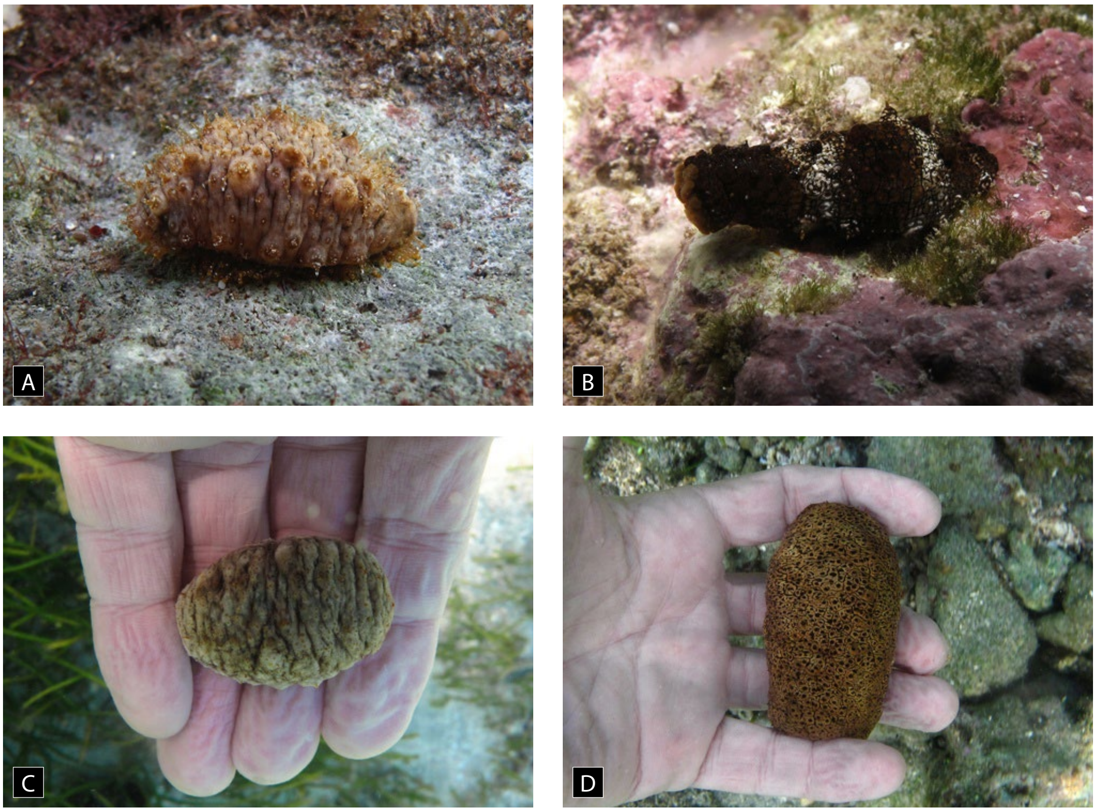

Figure 1. Juvenile sea cucumbers found on the reef crest – A: *A. echinites* (26 September 2015), and B: *A. mauritiana* (3 October 2015); and juveniles found in the seagrass bed – C: *A. echinites* (22 June 2013), and D: *A. mauritiana* (30 March 2013). (Identification by F. Michonneau). (Images: © P. Bourjon)

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Multi-species sea cucumber spawning at Limellon Island, New Ireland Province, Papua New Guinea

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On 11 and 12 November 2015, synchronised multi-species sea cucumber spawning events were observed at Limellon Island (2°40.557'S and 150° 46.231'E, Fig. 1), near Kavieng, New Ireland Province, Papua New Guinea (PNG). The observations were made during transect surveys conducted as part of an Australian Centre for International Agricultural Research (ACIAR) and PNG National Fisheries Authority (NFA) study investigating the potential for community-based sea cucumber mariculture in New Ireland. Limellon is the site of a proposed trial sea ranching site for the commercially valuable holothurian sandfish, *Holothuria scabra*. The 7 ha sea ranch is characterised by seagrass and bare sand habitats, with a maximum depth of around 2 m at high tide. The spawning events described here occurred in shallow seagrass meadows (predominantly *Enhalus acoroides*, *Thalassia hemiramppi*, *Cymodocea rotundata*) where depth varied from 0.01 m to 1.5 m when surveys were being undertaken. All surveys were carried out after 12:00 on a rising tide in order to maximise the number of sandfish counted because most sandfish remain buried during the early part of the day (Mercier et al. 2000) and are also more abundant on the surface at high tide (Wolkenhauer 2008.). Around 3,360 m^2 of the seagrass meadow was surveyed over the two days.

On 11 November, a few individuals of six sea cucumber species were observed spawning on the afternoon high tide: curryfish (*Stichopus herrmanni*), snakefish (*H. coluber, H. flavomaculata* and *H. leucospilota*), chalkfish (*Bohadschia marmorata*), hairy blackfish (*Actinopyga miliaris*), deepwater red fish (*A. echinites*) and an unidentified non-commercial species (possibly *H. percax*). However, a much larger event was observed on 12 November, the afternoon prior to the new moon, when nine species (out of 12 recorded in surveys) were observed spawning simultaneously. Small numbers of *H. percax*, curryfish, snakefish, hairy blackfish, brown sandfish (*B. vitiensis*), stonefish (*A. lecanora*) and deepwater red fish spawned alongside much greater numbers of chalkfish and sandfish (Figs. 2, 3, 4). Chalkfish and sandfish were the most common species recorded in transects, with counts of 846 and 230 individuals, respectively, on the two survey days. The spawning event was intense but relatively brief, commencing sometime before 13:00 (time of first observations), peaking at around 14:00 and ceasing at around 15:00. At its peak, hundreds of adult chalkfish and large numbers of small to medium size sandfish were observed in spawning

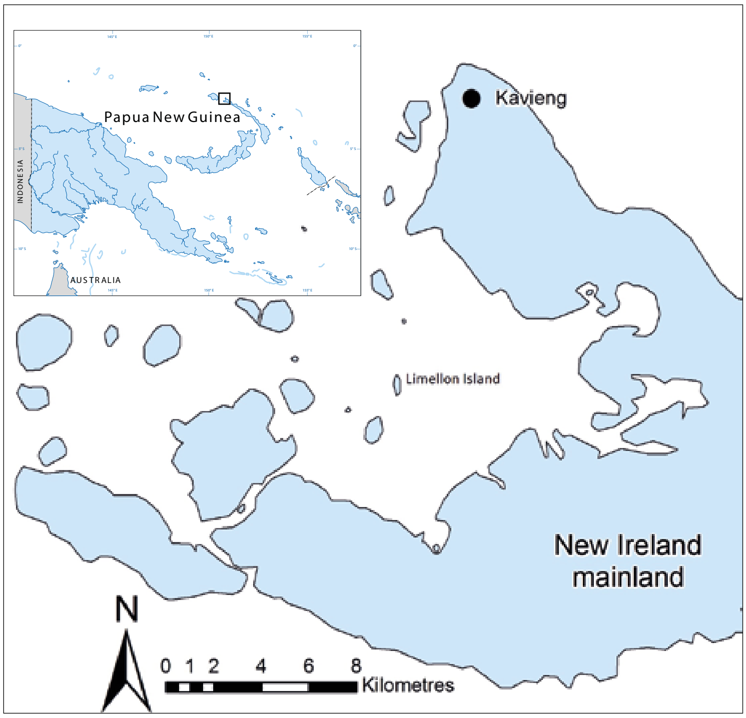

Figure 1.
The northern tip of New Ireland, PNG, showing the location of Limellon Island.

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attitudes with their anterior sections raised and waving around, or releasing gametes. According to available tide tables, there was a high tide of 1.38 m at 14:20, a barely discernable low tide of 1.36 m at 15:33 hours, followed by another high tide of 1.37 m at 16:22.

Of the 12 sea cucumbers recorded over the two-day period, only 3 species – golden sandfish (*H. lessoni*), leopardfish (*B. argus*) and lollyfish (*H. atra*) – were not observed spawning. However, these species were uncommon on transects (e.g. in the 3,360 m^2 surveyed, only 3 golden sandfish, 4 leopard fish and 11 lollyfish were counted). Moreover, the survey team was restricted to observations in proximity to the transect lines, and were not able to report on other parts of the site. No spawning of any holothurian species was observed during earlier survey days of 9–10 November.

Figure 2. Brown sandfish (*Bohadschia vitiensis*) exhibiting spawning behaviour. (Image: E. Leini)

Relatively small sandfish were spawning in short, sparse seagrass in shallow, nearshore areas where the water was very warm. Some spawning sandfish were less than 12 cm in length and estimated to be less than 130 g in weight (based on length and width measurements, see Purcell and Simutoga 2008). This is less than the published length at first maturity of 16 cm and weight of 184 g (Conand 1990). This could be due to fishing-induced selection for early maturing individuals (Law 2000) or possibly due to the different geographical location (cf. New Caledonia, Conand 1990). Small hatchery-bred sandfish have been observed spawning in sea ranches in the Philippines (Olavides et al. 2011) and experimental sea pens in Fiji (Hair 2012).

Due to reported low stocks of commercial sea cucumbers, NFA imposed a moratorium on sea cucumber harvesting in 2009 (Carleton et al. 2013) and the fishery remains closed at the current time. Although spawning events such as the one reported here do not guarantee successful recruitment of juveniles, it is nonetheless a positive sign for the

Figure 3. Female snakefish (*Holothuria flavomaculata*) releasing eggs. (Image: P. Bitalen)

Figure 4. Sandfish (*Holothuria scabra*) and chalkfish (*Bohadschia marmorata*) exhibiting spawning behaviour, side by side. (Image: E. Leini)

future of this valuable industry. Ongoing monitoring of sea cucumber stocks is required in order to determine whether recruitment is occurring and populations are increasing.

Acknowledgements

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Observations of *Carapus bermudensis* (Carapidae) in *Isostichopus badionotus* (Stichopodidae) from Taganga Bay, Colombia

Wensy Vergara[1], Vianys Agudelo[1] and Adriana Rodríguez[1]*

Introduction

This paper reports on the pearlfish, *Carapus bermudensis*, which inhabits the body cavity of the sea cucumber *Isostichopus badionotus* in Taganga Bay in Colombia (Colombian Caribbean Sea). The host *I. badionotus* is distributed in the western Atlantic Ocean and occurs in shallow waters of the northern coast of Colombia (Caycedo 1978). It is part of a group of sea cucumbers listed as commercially important in Latin America and the Caribbean (Toral-Granda 2008). The pearlfish, *Carapus bermudensis,* is an eel-like fish that spends its life within the body cavity of sea cucumbers using their hosts as shelter (Olney 2006; Parmentier and Vandewalle 2005; Parmentier et al. 2003; Smith et al. 1981).

Adult *Isostichopus badionotus* (222.29 g 81.02 SE, wet weight) were collected by snorkeling between depths of 2 feet and 5 feet in the beach town of Santa Marta (11°12′53,47″N to 11°12′32,01″N and 74°14′10,59″W to 74°14′23,02″W). Sea cucumbers were transferred to the Aquaculture Laboratory at Magdalena University in Colombia (20 min. drive), and randomly stocked in 500-L plastic tanks filled with seawater, which were aerated using airstones. During the next few days, we noted that some cucumbers had eviscerated, and the presence of two fish in the tanks was observed. Morphological characterization and taxonomic keys were used to identify the host species.

Observations

In assessing sea cucumber behavior, we observed an unusual movement in the tanks. Near the anus of a cucumber, a small fish (*Carapus bermudensis*) poked its head out (Fig. 1). We found one fish per sea cucumber for the 12 observations we made of *C. bermudensis* swimming in the rearing tanks. Most of the time, the fish swam around the sea cucumbers in the culture tanks. Carapid fish can be found in the sea cucumber body cavity, but are mainly found in the respiratory trees (Gustato 1976; Parmentier and Das 2004; Trott 1970; Van Meter and Ache 1974). Our findings show the presence of *Carapus bermudensis* inside the digestive tract of *I. badionotus*, which reaffirms statements made by native artisanal fishermen in the study area (Taganga Bay) and by other authors (Arnold 1956; Shen and Yeh 1987).

The *Carapus bermudensis* in this study (mean prevalence = 4%), had an average total length of 73 mm (± 2.55 SE), indicating that they were juveniles. Individuals were long and narrow, laterally compressed, and had soft fin rays. They were hyaline or slightly pigmented, with the exception of the visceral cavity due to food content. Blood flow was observed in their gills. The fishes' heads were greater in height than the rest of the body. They had no pelvic fins, 20 pectoral rays, 23 precaudal vertebrae, and did not have scales (Fig. 1).

Once the sea cucumbers evacuated their guts, the pearlfish made efforts to re-enter the visceral cavity of the sea cucumber, and we observed knocking and pecking motions at the cloacal opening. Pearlfish re-entry was done rapidly by bringing its tail towards the sea cucumber′s cloacal opening. Finally, the fish gained entry into the host, despite the fact that the sea cucumber host did not contain viscera.[2]

The *Carapus bermudensis* recorded in this study appear to have a commensal relationship with *Isostichopus badionotus* because the hosts appeared to be in good health and their internal organs did not show any damage. However, further observations should be done in the wild and under controlled conditions.

Acknowledgements

This work was supported by Colciencias Grant (No 1117-521-28356) and Vicerrectoría de Investigación (Universidad del Magdalena), Santa Marta, Colombia. The authors would like to thank sea cucumber fisherman Jorge Polo who helped collect holothurians, and the Group of Research and Technology Development in Aquaculture (GIDTA).

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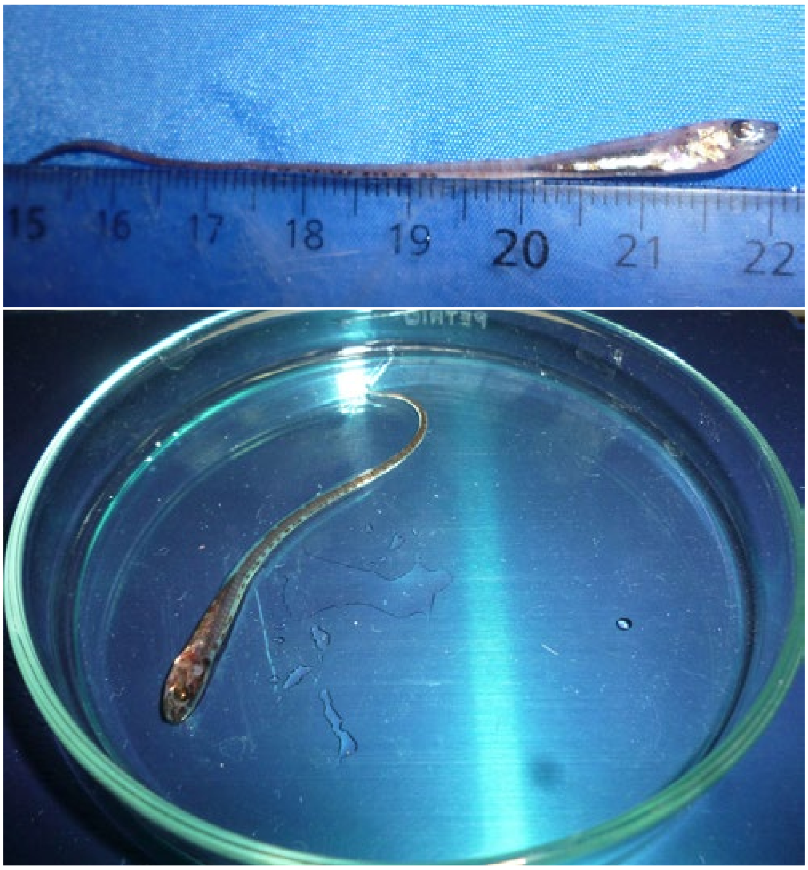

Figure 1. *Carapus bermudensis* expelled from *Isostichopus badionotus* from Taganga Bay in Colombia.

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COMMUNICATIONS

Computer programs, Master thesis and PhD dissertation

Computer programs

MetaMorphos 1.8: A unique tool for understanding the body plans of metazoans, including holothuroids

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MetaMorphos 1.8 (from Metazoan Morphology) is a program that illustrates the body plans of metazoans by high quality 3D reconstructions. It is intended for those wishing to understand the invertebrate body architecture. Intended for use by naturalists, zoologists, students or professors in animal biology. The 1.8 version is the first released. It includes the body plan of invertebrates from eight phyla: an anthozoan (Cnidaria), a tentaculate (Ctenophora) a turbellarian (Plathelminthes), a polychaete (Annelida), a gasteropod (Mollusca), a secernentea (Nematoda), a holothurian (Echinodermata) and an ascidian (Urochordata).

The invertebrates in MetaMorphos are presented through avatars. An avatar is a 3D reconstruction of a typical organization including the major features of a high-ranking taxon in the Linnaean hierarchy, usually a class. With MetaMorphos, the user can analyze the external morphology of the avatars and their systemic organization. The visualized organ systems are the digestive, excretory, nervous, reproductive, circulatory and the respiratory systems with some other unique systems observed in some taxa (e.g. the ambulacral system of echinoderms).

An organic system may be viewed alone or with other systems, inside a translucent representation of the animal body or without it. A mobile arrow-shaped cursor identifies the systemic organs. The avatar can be oriented in all dimensions of space thanks to two functions allowing rotation and displacement. A zoom function allows magnifying the analyzed body part. The two icons "snapshot" and "printscreen" take pictures of the avatars in jpg 300 dpi with a white or a colored background, respectively, allowing the user to insert any position of the avatar in, for example, a power point presentation. The Fig. 1 is a printscreen of the avatar "holothuroid" showing all the organs seen from the dorsal side (with the body translucent) and Fig. 2 is a snapshot of the digestive system, hemal system and the respiratory trees. The "histology" icon allows observing a layout of the histological tissues making the organ pointed by the cursor. Fig. 3 is the layout obtained when the cursor points a part of the hemal system. The two "larva" icons give views on a young and a late larvae from which an external or an internal view can be seen. In the case of the holothuroid, the auricularia (Fig. 4) and the pentactula (Fig. 5) are presented. Each taxon is described through a scientific text file that is illustrated by original drawings made by the excellent malgachian drawer Rakotomahefa Solofondraibe Jamieson Albert.

MetaMorphos 1.8 is available on PC, MacIntosh, Android devices and IOS devices. The program will be updated every two months by a new avatar, the ultimate goal being to illustrate the maximum number of phyla. A free demo-light version of the holothuroid is available on the stores.

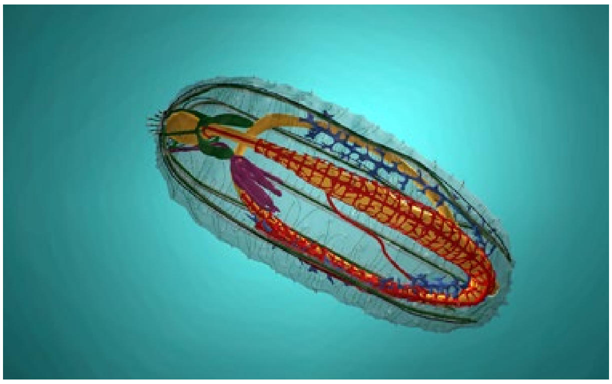

Figure 1. The avatar "holothuroid" showing all the organs seen from the dorsal side (body is translucent).

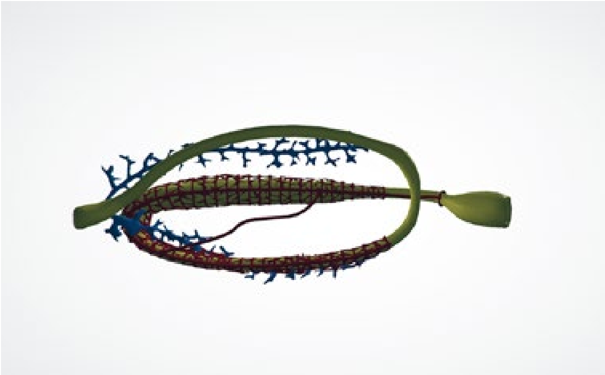

Figure 2. The digestive system, hemal system and respiratory trees of the avatar "holothuroid" (without the translucent body).

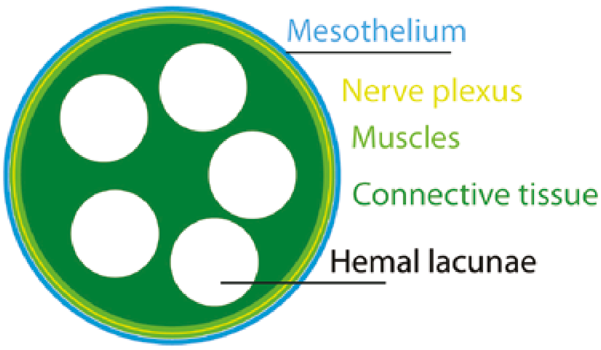

Figure 3. Layout obtained with the "histology" icon showing the histological tissues making the hemal system.

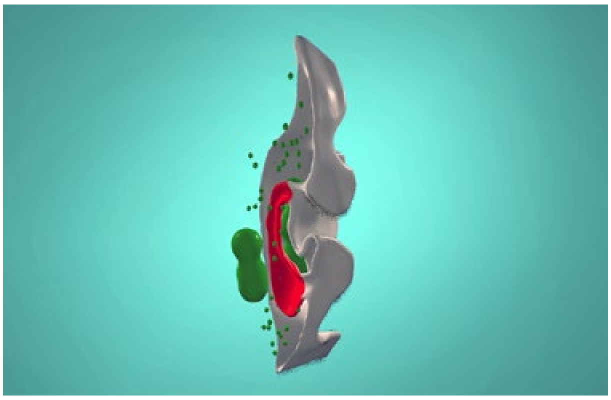

Figure 4. The auricularia larva with half part of the body showing the internal organs, especially the disposition of the coelomic cavities.

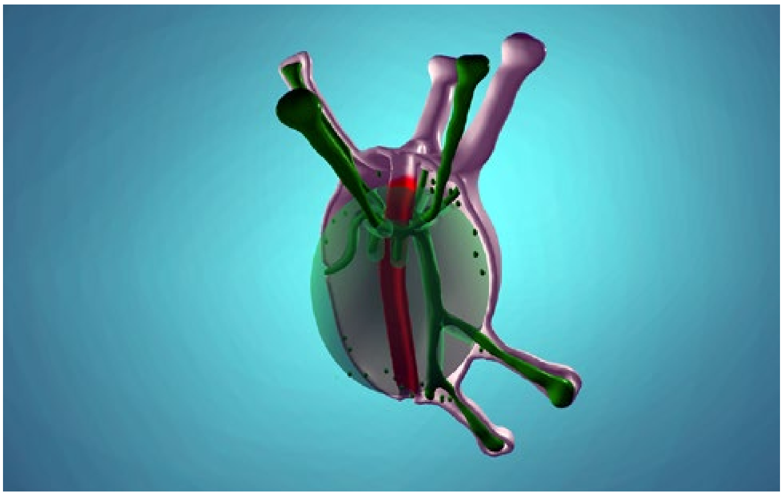

Figure 5. The pentactula larva with half of the body showing the internal organs, especially the disposition of the coelomic cavities.

Master's thesis

Master's thesis, University of Algarve, Centre of Marine Sciences (CCMAR)

Filipe Freitas Henriques: Genetic conectivity patterns in *Holothuria mammata* considering different spatial scales. 84 p. project CUMFISH.

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PhD dissertation

Demeuldre M. 2015. Defence mechanisms in sea cucumbers: Morphology, biochemistry and mechanics of Cuvierian tubules in two species from the genus Holothuria. Laboratory of Marine Organisms and Biomimetics. UMons (Belgium). Melanie.Demeuldre@umons.ac.be

2015 Meetings

15th International Echinoderm Conference, Mexico

25–29 May 2015

Francisco Alonso Solís Marín, Alfredo Laguarda Figueras
Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México, Mexico

Oral presentations

- How many species of psolids are there in Mexico?
  Arriaga-Ochoa JA, Solís-Marín FA, Laguarda-Figueras A (arriagaochoa@gmail.com)
- Discovery of novel peptide regulators of mutable collagenous tissue
  Blowes L.M., Gupta H.S. and Elphick M.R. (UK.l.m.blowes@qmul.ac.uk)
- DNA methylation and regulation of DNMTs in aestivation sea cucumber *Apostihopus japonicus*
  Chen M., Yang H., Zhao Y. and Storey K.B. (chenmuyan@ouc.edu.cn)
- Adhesion of Cuvierian tubules in *Holothuria forskali*: Identification of putative adhesive proteins
  Demeuldre M., Wattiez R., Ladurner P., Lengerer B., Hennebert E. and Flammang P. (melanie.demeuldre@umons.ac.be)
- Echinoderms' symbiotic gastropods
  Dgebuadze P (Russia.p.dgebuadze@gmail.com)
- Reproductive cycle of the sea cucumber *Holothuria leucospilota* in Hong Kong waters based on the application of the standardized gonadosomatic index
  Dumestre M., Sadovy de Mitcheson Y. and Dumas P. (marielle.dumestre@gmail.com)
- Annotated checklist of the echinoderms distributed in Mexican waters.
  Frontana-Uribe S.C., Solís-Marín F.A., Caballero-Ochoa A.A., Hernández-Robles D., Laguarda-Figueras A. and Durán-González A. (sfrontana@conabio.gob.mx)
- Night and day monitoring of reef echinoderms: Can we use the data for management purposes?
  Herrero-Pérezrul M.D. and Gardea-López A.M. (dherrero@ipn.mx)
- Echinoderm phylogeny reconstruction with broad sampling and a novel transcriptome based workflow. *Linchangco G.V., Reid R., Foltz D., Rouse G., Wray G., Kerr A. Hunter R. and Janies D. (glinchan@uncc.edu)*
- New insights on elasipodids and dendrochirotids from southwestern Atlantic Ocean (0–3,500 m). *Martínez M.I. and Penchaszadeh P. (mmartinez@macn.gov.ar)*
- Higher level systematics of the walking, swimming, and burrowing Holothuroidea (Echinodermata): A six-gene molecular phylogenetic approach.
  Miller A.K., Kerr A.M., Pawson D.L., Pawson D.J., Paulay G., Carvajal J.I. and Rouse G. (USA.a33miller@gmail.com)
- Feeding rate and sediment selection in the sea cucumber *Parastichopus regalis* (Aspidochirotida).
  Ramón Galimany E., Pérez-Ruzafa A. and Lleonart J. (Spain.mramon@icm.csic.es)

- Potential impact of ocean acidification on reproductive output of the subarctic holothuroid *Cucumaria frondosa. Verkaik K., Mercier A. and Hamel J.-F. (khv043@mun.ca)*
- The diversity and distribution of sea cucumbers in Singapore.
  Ong J.Y. and Tan K.S. (tmsojy@nus.edu.sg)
- Expanding inclusion of sea cucumbers in IMTA systems.
  Zamora L. and Slater M. (lzam004@aucklanduni.ac.nz)
- The movement and feeding behavior of the sea cucumber *Apostichopus japonicas.*
  Zhang L., Yang H., Zhang T., Pan Y. and Sun J. (China.libincas@163.com)
- Advances in the culture of Isostichopus badionotus in Yucatan, Mexico.
  Zhang-Huang B., Yinta L., Ramírez-González S., Pacheco-Vázquez P.J., Manrique-May C.B., Rosado-Romero W.J. and Santana-Cisneros A.D. (C.V.mvzsusana@hotmail.com)

Posters

- Sea cucumbers (Echinodermata: Holothuroidea) in Mexican waters of the Gulf of Mexico and the Mexican Caribbean .
  Cervantes Aguilar I.P., Solís-Marín FA. and Durán Gonzalez A.
- Thermal tolerance and immune response of the sea cucumber *Parastichopus regalis* exposed to a gradient of high temperatures.
  Galimany L., Baeta M. and Ramón M. (Spain.mramon@icm.csic.es)
- Novel use of PIT tags in sea cucumbers: Promising results with the commercial species *Cucumaria frondosa.*
  Gianasi B., Verkaik K., Hamel J.-F. and Mercier A. (brunolg@mun.ca)
- Illegal trade of echinoderms in Mexico: Threats and consequences.
  Herrero-Pérezrul M.D., Castro-Peláez M., Reuter A. and Mosig-Reidl P. (dherrero@ipn.mx)
- Taxonomic identification of holothurians (Echinodermata: Holothuroidea) from Cocinas Island, Jalisco, Mexico.
  Luna-Cruz A.K., Solís-Marín F.A., Laguarda-Figueras A. and Durán-González A. (analun93@gmail.com)
- Morphological phylogeny of the sclerodactylids and phyllophorids (Holothuroidea: Dendrochirotida) .
  Martins L., Souto C. and Tavares M. (martinsrluciana@gmail.com)
- First record of the sea cucumber *Holothuria grisea* Selenka, 1867 (Aspidochirotida: Holothuroidae) for the Golfo de Morrosquillo, Colombian Caribbean.
  Padilla J.M., Nisperuza C.A. and Quiros J.A. (junigon991@hotmail.com)
- Review of the family Cucumariidae (Holothuroidea, Dendrochirotida) at the Colección Nacional de Equinodermos "Dra. Ma. Elena Caso M" ICML, UNAM.
  Sánchez D., Arriaga-Ochoa J.A., Caballero-Ochoa A., Solís-Marín F.A. and Laguarda-Figueras A. (dmsalonzo@hotmail.com)

Participants of the 15th International Echinoderm Conference, Playa de Carmen, Mexico

MARE conference, June 2015, Amsterdam

Centre for Maritime Research – 8th People and the Sea Conference "Geopolitics of the Oceans"

- **Governability of global value chains originating from small-scale sea cucumber fisheries**
  Prescott J.
- **On the fisheries management merry-go-round: A blur of images passing by**
  Eriksson H.
- **Understanding social wellbeing and values of SSF among the Sama-Bajau of archipelagic South-east Asia**
  Stacey N., Steenbergen D., Clifton J. and Acciaioli G.

International seminar on the exploitation and sustainable management of sea cucumber resources: Lessons learned and recommendations for the State of Yucatan, Mexico

10–11 September 2015 in Mérida City, Yucatan, Mexico

Prepared by: Alejandro Flores, Alessandro Lovatelli, Matthew Slater and Veronica Toral

1. Introduction

This seminar was funded and organised by the State Government of Yucatan, Mexico, through the State's Rural Development and Fisheries Secretariat and the technical guidance of the Food and Agriculture Organization (FAO) led by Alejandro Flores (Senior Fisheries and Aquaculture Officer, FAO, Chile) and Alessandro Lovatelli (Aquaculture Officer, FAO, Rome). The workshop aimed at building a road map towards the sustainable use of sea cucumber resources in Yucatan within acceptable economic, social and environmental boundaries. The workshop benefitted from the presence of national scientists, entrepreneurs, market representatives and fisher as well as international researchers and managers.

The main objectives of the workshop were to: (a) present the main constraints affecting sea cucumber fisheries from the scientific, legal and livelihood points of view; and (b) propose concrete actions to improve the management and sustainable use of these valuable benthic organisms, based on local knowledge and lessons learnt from other regions within Mexico and further afar.

The event served as a platform to gather the views of local fishers and authorities regarding ways forward in better managing the fishery stimulated by a series of presentations from a broad range of national and international experts including: Alejandro Flores (FAO, Chile), Alessandro Lovatelli (FAO, Rome), Alvaro Hernández Flores (Marista University of Mérida, Mexico); Arlenie Rogers (Environmental Research Institute, University of Belize); Jesús C. Osuna (National Federation of Fisheries Cooperative Associations, Mexico); Javier Villanueva García Benítez (FAO, Chile); Armando Wakira Kusunoki and Alicia Poot Salazar (Regional Fisheries Research Center, Yucalpetén, National Fisheries Institute of Mexico); Jean-Francois Hamel (Society for the Exploration and Valuing of the Environment, Newfoundland, Canada); Miguel Olvera Novoa, Juan Carlos Murillo Posada and Oswaldo Huchim-Lara (Center for Research and Advanced Studies, National Fisheries Institute, Mérida, Mexico); Matthew Slater (Alfred-Wegener-Institute, Germany); and Manuel Mendoza (fisherman).

The two-day workshop was opened and attended by the Secretary of Rural Development and Fisheries of the State of Yucatan, Mr J. Carrillo Maldonado, clearly indicating that management of this marine resource is high in the State agenda.

Following completion of the workshop, international attendees were offered a field trip to the aquaculture research facility managed by Merida's Centre for Research and Advanced Studies (Unidad Mérida del Centro de Investigación y de Estudios Avanzados - CINVESTAV) in Telchac Puertoon located on the coast northeast of the State capital, Merida.

Sea cucumber fisheries in the Gulf of Mexico focusses on *Isostichopus badionotus* (also known as the four-sided sea cucumber). The fishery have exhibited the all-too-familiar "boom" phase similar to many other

Group photo of the participants attending the Mérida sea cucumber seminar. Visible in the front Mr A. Flores (second from the left) and Mr M.G. Aguilar Sánchez, the Federal Government Commissioner of Aquaculture and Fisheries (third from the left).

fisheries elsewhere; at present the resources have clearly entered the "bust" phase. Initial attempts to manage the fishery with limited licencing and closure periods met with increasing resistance from fishers and an expanding IUU fishery. Beyond the evident ecological concerns, the fishery is also associated with negative social impacts and conflict within fishing communities and also with increasing numbers of fatal decompression events among divers. Efforts to manage the fishery in a participatory manner continues, led by local and national fisheries authorities (the State Commission and the National Commission for Fisheries and Aquaculture, respectively) and the National Institute of Fisheries, responsible of stock assessments. Several research groups are also taking initial steps to establish aquaculture facilities with one commercial company currently establishing a hatchery and growout facilities off the coast of Campeche (the company is already farming *Isostichopus fuscus* on the west coast of Mexico).

2. Methodology

The workshop focused on three work areas: (a) research and management; (b) legal and governance; and (c) social and co-management. A number of working groups were established and worked separately. Each group identified key problems in each area of work and provided suggestions on how to deal with or minimise the threat identified. The results from each working group were then pooled together and frequency of the results expressed in percentage. A management roadmap was hence drafted through the identification of the main threats affecting the sustainable exploitation of sea cucumber and the recommendation of specific measures required to overcome these threats.

The first day of the seminar focussed on plans and strategies for managing sea cucumber fisheries. Presentations were made by state and national level actors from Mexico; these were significantly supplemented by presentations by international experts offering insights into lessons learned and best practices for management. The second day included a session focussed on aquaculture practices, lessons learned and advances in Yucatan (Mexico) in terms of culture applications. Additional presentations were delivered on social impacts of the fishery, as well as fishery monitoring and management in the wider region for example in Belize and the Galapagos Archipelago.

3. Results

3.1 Research and management

Regarding research, the lack of appropriate funding for long-term research programmes, scientific data collection, etc. was identified as a major constraint. Far too often insufficient data and information is provided through short-term investigation activities that make it difficult to take appropriate management decisions. Next, was the lack of synergies between different research bodies that may limit, delay or duplicate the information needed and, more importantly, sway away the confidence of fishermen in the managing institutions. The lack of adequate information on the natural population of sea cucumber juveniles was identified as a major handicap particularly when attempting to establish protection / no-take areas deemed essential for the sustainability of the fishery. Finally, the need for environmental education programmes was highlighted and deemed important to help build stewardship among the local coastal communities in better understanding the ecological and economical role of sea cucumbers.

3.2 Legal and governance

The main problem raised by all working groups at the seminar was the inadequate level with regards to inspection and surveillance, and the lack of sanctions to those fishing illegally. Corruption at all levels was also responsible for the smuggling of sea cucumber out of the country. Possible solutions included the strengthening of laws and regulations against corruption and to include a maximum time limit to export the product. This could be strengthened with educational programmes. The second problem identified was the lack of synergy between the institutions in-charge of law enforcement, including the lack of training to properly follow-up the custody chain throughout the marketing process and identification of false documentation and permits. An additional constraint raised by the seminar participants was the lack of an official degree to protect the zones where juvenile sea cucumbers are known to occur.

3.3 Social and co-management

The main problem was the lack of education on the importance of the species that could promote a sense of ownership of the resource. To solve this, the group proposed to strengthen a social-community policy which would help improve the conditions on the community and would promote ongoing education on the use of sea cucumbers by means of workshops and courses given in schools, permit granters, fishing cooperatives, etc. A second problem identified was related to health issues resulting from the fishing activity itself: decompression sickness, alcoholism, drug addiction and sexually transmitted diseases, which are in turn related to lack of training and education. On this subject, it was recommended to create a hookah diving training programs which could be accessed by all fishers and organization of awareness campaigns for diving security and possible health risks.

3.4 Roadmap

Based on the experiences from scientists, managers, entrepreneurs and fishers a roadmap dealing with each of the aspects highlighted above was conceived. It includes a chronological sequence of actions that will hopefully see the implementation of a sustainable plan for the management of sea cucumbers in Yucatan.

Several news links following the seminar:

- ✓ http://www.spc.int/coastfish/index.php?option=comcontent&Itemid=30&id=422
- ✓ http://estadodemexicoalamano.com/sociales/efectuan-seminario-internacional-sobre-manejo-y-aprovechamiento-sustentable-del-pepino-de-mar/
- ✓ http://conapesca.gob.mx/wb/cona/11deseptiembrede2015meridayuc
- ✓ http://sipse.com/milenio/yucatan-expertos-bases-manejo-produccion-pepino-mar-169472.html

A final report including summaries from speakers and working groups will be shortly published by FAO. Please contact Alejandro Flores (alejandro.flores@fao.org) or Alessandro Lovatelli for further information (alessandro.lovatelli@fao.org).

WIOMSA 9th International Symposium

Eastern Cape, South Africa 26–31 October 2015 (see www.wiomsa.org)

Oral presentations —Small-scale fisheries: Trends and impacts

- Management of sea cucumber fisheries: The problem of illegal captures
  Conand C., Eriksson H., Muthiga N., Leopold M., Prescott J., Purcell S.W. and Toral-Granda M.V.
- Seychelles' sea cucumber stock assessment: Management options for sustainable fishery
  Koike H., Gerry C. and Friedlander A.

Posters

- Diversity of the echinoderms of the Iles Eparses (Europa, Glorieuses, Juan de Nova), Mozambique Channel, France
  Conand C., Mulochau T., Stöhr S., Eléaume M. and Chabanet P.
- Feasibility of sea cucumber farming in the Bazaruto Archipelago, Mozambique
  Lavitra T.
- Test of liquid injection and elastomer implant for tagging edible sea cucumber *Holothuria scabra*
  Rakotonjanahary F., Tsiresy G., Rasolofonirina R., Eeckhaut I. and Lavitra T.

Other activities

During the symposium two actions were undertaken to prepare a message from the WIO to the COP 21: The film "Hokulea" was made in South Africa and the WIOMSA declaration was prepared (www.ird.fr/toute-l-actualite/actualites/declaration-des-scientifiques-du-wiomsa)

WIOMSA 9th International Symposium participants

Course: "Application of molecular tools on fishery management, aquaculture and restocking of sea cucumbers"

23–26 November 2015, Panamá

Mercedes Wangüemert (mwanguemert@ualg.pt)

Dr Mercedes Wangüemert and Jorge Domínguez, PhD student from the Marine Resource Management team from CCMAR (http://www.maresma.org/), were in the Universidad Marítima de Panama to teach the course "Application of molecular tools on fishery management, aquaculture and restocking of sea cucumbers". The course was organized with the collaboration of Panamanian and Portuguese institutions: INDICASAT AIP (Instituto de Investigaciones Científicas y Servicios de Alta Tecnología), ARAP (Autoridad de los Recursos Acuáticos de Panamá) and CCMAR (Centro de Ciências do Mar).

This course is one of the activities linked with the project "Genetic variability and physiology of sea cucumber (*Isostichopus fuscus*, Ludwig 1875) in the Pacific coast of Panama: an exploitable resource?" funded by SENACYT and leaded by Dr Vergara-Chen. Dr Wangüemert is part of the research team of this project, which started one year ago to study one of the main target species of sea cucumbers in Panamanian fisheries before the current moratorium.

During the course, Dr Wangüemert and Mr. Domínguez had the opportunity to discuss about the problematic of sea cucumber fisheries and potential solutions to their over-exploitation with the General Administrator of ARAP, Mr. Iván Flores, and the National Director of Research and Development Department, Mr. Marco Mendizabal. Both demonstrated a great interest on the new molecular tools to improve the fishery management and aquaculture development of sea cucumbers. Further collaborations between the research institutions were also assessed.

The attendance profile to the course included Msc and PhD students, fishery managers, aquaculture technicians, lecturers and owners of aquaculture companies (Fig. 1). A first introduction about the current status of sea cucumbers fisheries in the world was done and later showed a general view of the sea cucumber aquaculture. The course was then focused on the application of molecular tools to fishery management, aquaculture and restocking of sea cucumbers, including a reminder of genetic basic concepts, description of the main molecular markers and genetic diversity and differentiation parameters, uses of genetics in fisheries mainly stock identification, barcoding, traceability, genetic effects from over-exploitation, and applicability of molecular tools to aquaculture such as inbreeding assessment, paternity tests, barcoding of pathogens and genetic compatibility of restocking.

Figure 1. Course participants.

2016 Meetings announcements

Second International Mares Conference on Marine Ecosystems Health and Conservation
1–5 February 2016, Olhão, Portugal
http://www.maresconference.eu/

13th International Coral Reef Symposium (ICRS)
19–24 June 2016, Hawaii Convention Center, Honolulu, Hawaii USA
http://sgmeet.com/icrs2016/default.asp

4th International Symposium on the Ocean in a High-CO_2 World
3–6 May 2016, Hobart, Tasmania, Australia
www.highco2-iv.org

3rd Latin American Echinoderm Conference
18–22 July 2016, San José, Costa Rica, Central America
http://rediberoamericanaequinodermos.com/en/welcome-2/

9th European Conference on Echinoderms
17–19 September 2016, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland
http://www.iopan.gda.pl/ECoE2016/

GENERAL COMMUNICATIONS

Kerabu beronok (*Acaudina* salad) – Signature appetiser in Langkawi Island, Malaysia

Poh Sze Choo[1], Chantal Conand[2] and Devarajen Vaitilingon[3]*

1 Introduction

A salad (*kerabu*) dish prepared by mixing julienned vegetables and tropical fruits and tossed with pieces of raw sea cucumber (*beronok*), is popularly eaten in the Langkawi Island in Peninsular Malaysia.

The *beronok* sea cucumber belongs to molpadida, family Caudinidae). The main genera are presented in WORMS (Paulay 2015). *Acaudina molpadidoides* is a common species in the muddy shores in the west coast of Peninsular Malaysia. It is common in the region (O'Loughlin and Ong 2015; Ong and Wong 2015).

In the Langkawi Island, close to the Langkawi International Airport in the bay located between Pantai Kok and Pantai Cenaang (Fig. 1, Site a) is an area where *beronok* are frequently gleaned from the shallow waters (Figs 2 and 3). During low tide, members of households, including women and young children are often seen wading in the waters feeling the *beronok* with their feet. Only freshly caught *beronok* are used in the preparation of this delicious salad dish, which is often eaten as an appetiser.

Figure 1. Sampling site locations in Langkawi.
Site a, is opposite to Langkawi airport. Site b, is south of Pulau Tuba.

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2 UMR Entropie,Réunion University and MNHN, France
3 AADCo Projects Malaysia Sdn Bhd, 2980-02 Kompleks Chai Leng, Jalan Baru 13700, Prai, Pulau Pinang, Malaysia

Figure 2. A fresh specimen of *Acaudina molpadioides* collected in Langkawi. (Image: Chantal Conand)

Figure 3. Collecting *beronok* in Malaysia: A child after collection (left) and a catch from skin diving collection (right). (Images: Chantal Conand)

2. Preparation of the dish

The ingredients are: *Beronok*, fresh from the sea, are cleaned with the insides removed, and then cut into bite-size pieces; young leafy shoots of cashew nuts shredded; long beans shredded; green papaya shredded; young green mango shredded; one-half grated coconut fried in a frying pan without oil until fragrant; one-half cup of fried rice powder; one lemon; salt and sugar to taste; ingredients for making sambal (a spicy paste of one-half grated coconut, two red onions, five bird chili, five dried chili, thumb-size piece of *belacan*, which is a fermented shrimp paste)

Method: Pound or blend the ingredients for making *sambal* until a paste is formed, then fry the sambal with heated oil until dry and fragrant; mix all the ingredients (except *beronok*) together and stir well; add *beronok* and mix again; Squeeze lime over salad; add salt and sugar to taste and toss the salad.

During a trip to Pulau Tuba (Langkawi islands) in December 2014, *beronok* was observed in high densities in the south of the island (Fig. 1, Site b). At low tides, women and children were observed collecting *beronok* by searching the mud flats. Only pink, smooth and almost translucent sea cucumber individuals were collected, while those with a thick body wall were not (Fig. 5A), the latter being too tough to eat raw and the *kerabu* dish was only prepared with the young *beronok* individuals. The individuals were then brought to the jetty to be processed by the women. Each sea cucumber individual was cut at both ends to drain the coelomic fluid and the digestive tract, then cut lengthwise and the inside scrapped with a knife blade (Fig. 5B and 5C). They were then cut into slice, rinsed and placed aside for *kerabu* preparation (Fig. 5D). The local villagers were preparing the *kerabu* dish to be served at a wedding that afternoon.

Figure 4. Preparation of the dish, in a street... and tasting. (Images: Chantal Conand)

Figure 5. Processing *beronok* by local villagers on Pulau Tuba. A: Typical *beronok* used for *kerabu* dish; B and C: Gutting and cleaning of *beronok*; D: *Kerabu* dish. (Images: Devarajen Vaitilingon)

3. Live holding of *beronok* in tanks

Another trip to Pulau Tuba was organised (August 2015) to collect around 50 *beronok* individuals and brought to the facilities at Fisheries Research Institute (FRI) in Pulau Sayak, Kedah (Fig. 6). The aim was to keep the animals live in the holding tanks and try to induce spawning. The 50 individuals were collected at Site b (Fig. 1), packed in plastic bags with minimal water and filled with oxygen. The bags were then placed in a Styrofoam box with two ice packs. The animals were then transported for about 3 hours before being recovered in tank with flow through seawater at the marine station. Although all the animals recovered well in the tanks during the next 12 hours (Fig. 6B), one day later most of the individuals were eviscerated and

Figure 6. *Acaudina molpadioides*. Live holding of *beronok* in tanks. A: *Beronok* collected at Pulau Tuba; B: Recovery in tanks at FRI after transport; C and D: 24 to 36 hours after recovery, almost all individuals were eviscerated and dead. (Images: Devarajen Vaitilingon)

died within the following 12 hours (Fig. 6C and 6D). The lack of mud in the tank could be the reason for total loss of the batch. The same observation was later reported from another independent trial at FRI (Ilias, personal communication).

4. Discussion

Malaysians value sea cucumbers for their medicinal benefits and also as culinary delicacies. Processed sea cucumber species such as *Stichopus* sp. (locally known as "*gamat*") are traditionally used in wound healing, treatment of stomach ulcers and as a painkiller. Other species such as sandfish (*Holothuria scabra*) are highly sought after and used in traditional Chinese cuisine. Likewise, *beronok* is also consumed by local villagers around Langkawi islands for their general health benefits. The health benefits from sea cucumber is known to be due to the presence in their body wall of bioactive compounds such as triterpene glycosides, chondroitin sulphates, sterols and many others (Boardbar et al. 2011). Past studies on *Acaudina* sp. has shown that they are rich in vitamins and minerals (Chen 2003), and a more recent study highlighted the bioactivity of polysaccaride fucoidan from *beronok* and its role in preventing chemotherapeuthic mucositis in mice (Zuo et al. 2015).

The uniqueness of *beronok* is that it is one of the rare species of sea cucumber that can be eaten raw when young. This characteristic is of great interest to Japanese and Korean chefs since many seafoods in those two countries are eaten raw. A first survey among Japanese and Koreans chefs from restaurants in Penang has revealed great interests from those culinary experts.

The habitat where *beronok* occurs is quite peculiar in the fact that the mud flats can be anoxic or level of dissolve oxygen very low. Although no proper DO level was measured in situ, however, the black colour of the mud and hydrogen sulfite smell indicate an anoxic condition. The same black mud is found in the intestinal tract of the animal. Further studies should focus on the preferred habitat of *beronok*. If a low DO level is revealed to be their preferred habitat, then this could explain why all of the animals die in our holding tanks.

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Beche-de-mer sold in San Francisco shops

San Francisco has a large Chinese community that is able to find a variety of beche-de-mer species and quality shops in Chinatown. The photos below were taken by Jacques Conand in August 2015.

Beche-de-mer on offer in a shop of Chinatown, San Francisco. (Images: Jacques Conand)

Bibliography on holothurians: Access to modern tools to follow new publications

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It is now easy to make a "Google Alert" with the word "holothurian" and then to receive the references weekly, or at any another frequency. From my experience, it gives access to numerous papers, covering many different fields; a PDF can be uploaded in many cases, and/or the author's email can facilitate obtaining the paper, which is generally still in press.

The Table below shows the results I obtained for 2015, from March to November. More than 400 had the word holothurian in the title or in references.

They have been dispatched between five categories. Despite some possible overlap, it appears that publications in category 3, biochemistry and microbiology, fields not covered traditionally by the SPC *Beche-de-mer Information Bulletin*, display the highest number of references.

Table 1. Number of new publications found with a Google Alert search using the key word 'holothurian' (March–November 2015).

	Category				
Month	general, ecology, biology	biochemistry, microbiology	genetics	aquaculture	fishery, socioeconomics
March (partial)	6	9	3	3	0
April	6	9	4	4	0
May	16	26	8	6	4
June	12	17	3	8	5
July	13	30	3	5	10
August	20	13	4	4	9
September	13	15	5	7	12
October	15	30	4	3	2
November	9	20	4	7	7
total	**110**	**169**	**38**	**47**	**49**
%	27%	41%	9%	11%	12%

I believe that the difficulty is now to identify what is really relevant for us, people from different disciplines involved in commercial sea cucumbers.

For the SPC *Beche-de-mer Information Bulletin*, it is not necessary to present a list of new of articles published in journals, but it should keep publishing a list of theses and dissertations, and reports that may not necessarily be recorded by Google, as was done in this present issue.

It is also very important to make our publications available to our community.

Hawaii's proactive action with the sea cucumber fishery

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Tropical sea cucumber fisheries are known for unsustainable harvest leading to eventual collapse due to limited management capacity and vulnerable nature of the animal (Toral-Granda et al. 2008; Purcell et al. 2013). However, Hawaii recently became a rare case where managers halted the operation to prevent stock depletion after intense fishing activities were reported.

Sea cucumbers (locally known as "loli") have long been used for traditional practices in Hawaii, but with the exception of the harvest of two aquarium species (*Holothuria hilla* and *H. edulis*), large-scale commercial exploitation had never been reported. In 2014, however, sea cucumber fishermen from Tonga collaborating with Hawaii based fishermen contacted the Hawaii State, Department of Land and Natural Resources

(DLNR), Division of Aquatic Resources (DAR) to inquire about current regulation and to obtain a license for starting a sea cucumber fishery aimed at exporting *H. atra* and *Actinopyga varians* to China for medicinal and consumption use. Although these species are categorized as low- and medium-value species for the beche-de-mer trade (Purcell et al. 2012), people increased its value by processing it on island and marketing it as medicine ingredients.

The fishery started in March 2015, and rapidly developed during the following first three months of operation. Seeing the intense fishing pressure and disappearance of sea cucumbers, local communities began to express concerns for their resource and environment. The public concern peaked when a picture of zodiac filled with sea cucumbers was posted on a popular social media and later aired on TV. In response to this public outcry, DLNR acted swiftly and put into effect an emergency four-month ban on the fishery. The DLNR then sought out scientific advice to help develop a permanent sustainable management plan for the fishery. Currently, permanent rules have been developed and are under review. If approved, these rules would include a state-wide ban on the commercial consumption fishery until proper management capacity is installed; species limits, seasonal limits, and daily catch limits for the aquarium fishery; and daily bag limits for personal non-commercial harvest.

It gives us hope to see such precautionary action initiated by local communities and management agency responding with swift action.

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Short report on the recent *Apostichopus japonicus* poaching incidents in Aomori, Japan

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Note: This article is a translated compilation of three newspaper articles and one blog post regarding recent poaching incidents that occurred in Aomori, Japan.

Aomori, Japan is one of the top fishing grounds for *A. japonicus* in Japan (Motokawa et al. 2003). Their landing has been sold both within country and for export to China. The species is known to be one of the most expensive species of beche-de-mer and high-quality specimens have been sold for more than USD 2,000 per kg in Japan.

Driven by high prices, repeated poaching has been observed in Mutsu Bay, Aomori. After the arrests of poachers in October 2015, the fishery guild has requested: 1) increased punishment for poaching by the central government; and 2) the creation of a vigil network and stronger enforcements to prefectural government to prevent future violations.

So far, there have been three arrest cases of poachers for Aomori. The first case was reported in 2007, where 12 people were arrested for poaching. The second case was in 2014 where 11 poachers were arrested by Aomori coast guards. It took the coast guards more than two years of undercover operations to obtain evidence for poaching a total of 700 kg *A. japonicus*. The third case was in 2015 when eight poachers were arrested by the prefectural police for poaching 960 kg of *A. japonicus* (worth USD 28,800). The poaching group was based in the neighbouring prefecture. Further investigations suggest that the group have been poaching since last year, and the total poached revenue is estimated to be more than USD 2 million. The poached sea cucumbers were then transported to Hokkaido and exported to China. The poachers usually divided their respective roles – boat drivers, divers, watchmen and truck drivers – to hide their operations.

Furthermore, all poachers arrested were members of Japanese mafias. It is speculated that these poaching revenues are becoming a funding source for other mafia activities.

The Kamata village fishing guild was impacted the most by these poaching incidents because it had the right to fish *A. japonicus* in Mutsu Bay where the poaching took place. The guild had just started harvesting sustainably after their juvenile restocking programme that took 10 years and cost USD 660,000. Sea cucumber annual sales could increase to USD 30 million dollars and is a very important income substitute when the scallop fishery does not fare well in Aomori. Members of the guild have been guarding their resources in collaboration with fishery managers, but they feel limited in results. Some worry that the current punishment for poaching is not enough to stop poachers. These concerns have led to the recent request for stricter and stronger enforcement to both prefecture and central government.

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Request for information on illegal sea cucumber fisheries

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The concern with IUU (illegal, unreported and unregulated) fisheries has been raised with guidelines produced by FAO (1992) for decision-makers and policy-makers associated with fisheries managers to fight irresponsible fishing, which undermines the efforts to establish sustainable fisheries. Meetings, committees and regulations have followed.

Sea cucumber fisheries management has been progressing during the last decade, with efforts from international, regional and national agencies, as reported in many previous contributions of the SPC *Beche-de-mer Information Bulletin*. Despite the development of management tools, such as marine protected areas, rotational harvesting, IUCN Red listing, CITES, and national legal decisions on fisheries and export, illegal captures or exports remain an important issue. High prices, declining resources and stricter management (with fishing bans set up in an increasing number of countries) are incentives for increased illegal fishing or export activities, and these have become an urgent issue to address. A synthesis has recently been presented at the WIOMSA Symposium (see 2015 Meetings, p. 94, this issue) and a publication is being prepared.

It will probably be very useful, as was done previously in the *Beche-de-mer Bulletin* for several aspects of the biology of holothurians (e.g. spawning or juvenile observations) to set up a section in the Bulletin related to 'Information on illegal captures', with newspapers reports, links to websites, and published or anecdotal reports. Reports from those who have experience in fighting illegal activities related to sea cucumber fishing or trade would be very useful.

Original text: English

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