Field observations of sea cucumbers in the north of Baa atoll, Maldives

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Abstract

This report describes the results of a sea cucumber survey that was conducted on the coral reefs of the islands north of Baa atoll for two months in 2014. The main result of this survey is the scarcity of sea cucumbers — and echinoderms in general — in Baa atoll, along with poor diversity, largely dominated by the Holothuriidae *Pearsonothuria graeffei*, followed by several Stichopodidae. This study increases the number of holothurian species recorded in the Maldives to around 25, depending on determination of ambiguous observations, and 18 for Baa atoll alone.

Introduction

The Republic of Maldives is known by sea cucumbers specialists for its recent yet spectacular beche-de-mer fishery, which began only around 1985 but led to dramatic over-exploitation as early as 1990 (Joseph 1992), with the population collapse of most of the high value species (James and Manikfan 1994), leading to a tightening of exports, along with feeble regulations (FAO 2013). For years, very little information has been available about the diversity and abundance of sea cucumbers in Maldives, although recent studies have shed some light on the region (Muthiga 2008).

This part of the UNESCO Biosphere Reserve of Baa atoll is quite an isolated region and has been poorly covered by biological studies (Jimenez et al. 2012). It was not covered by the main scientific survey for marine invertebrates of this atoll (Andréfouët 2012). Nevertheless, this region has some characteristics that make it stand out from general studies of the Maldives and Baa atoll, including its echinoderm populations.

The present study describes the result of a sea cucumber survey that was conducted on the coral reefs of the islands in the north of Baa atoll for two months in 2014. Only one of the island reefs surveyed was an inhabited island, Landaa Giraavaru, which is a resort island (built in 2006). Three similar surveys were conducted in three different sites in Malé atoll as a control, which led to observations consistent with results from Muthiga (2008), indicating that the difference of results with former studies is not due to a methodological bias.

Materials and methods

The survey of distribution and abundance of holothurians was carried out in 13 sites off nine islands, all located in the north-east part of Baa atoll in July–September 2014 (Fig. 1). Habitats were described using a hierarchy of coral cover (from 0 for no coral cover to 5 for >90% of cover, as in Jimenez et al. 2012), as well as for damaged coral and sand. Rugosity was also reported in a similar scale (from 1 for a flat surface to 5 for highly rugose 3D architecture, as in Jimenez et al. 2012), habitat richness (1 for homogenous habitat to 5 for highly heterogenous) and hydrodynamics (from 1 for quiet water motion to 5 for medium current, which constitutes the maximum in this rather calm region).

At each location, 45-minute searches were made along a visual transect parallel to the reef crest, using scuba or snorkel, depending on depth. Some sites were surveyed several times, at different hours of the day and night, in order to avoid sampling bias. A total of 45 surveys were done, including nine night surveys and 11 dives deeper than 10 m. All surveys were carried out by examining the benthos, searching under crevices and rocks on the reef, and identifying and recording all sea cucumbers encountered. Pictures of each newly encountered species were taken for identification confirmation (Fig. 2). Occurrence was calculated as a percentage of the number of sites where each species was recorded (one site corresponding to 7.5%).

Most of the islands of this region are very small, surrounded by narrow reef flats without a lagoon, followed by very steep reef edges, going straight

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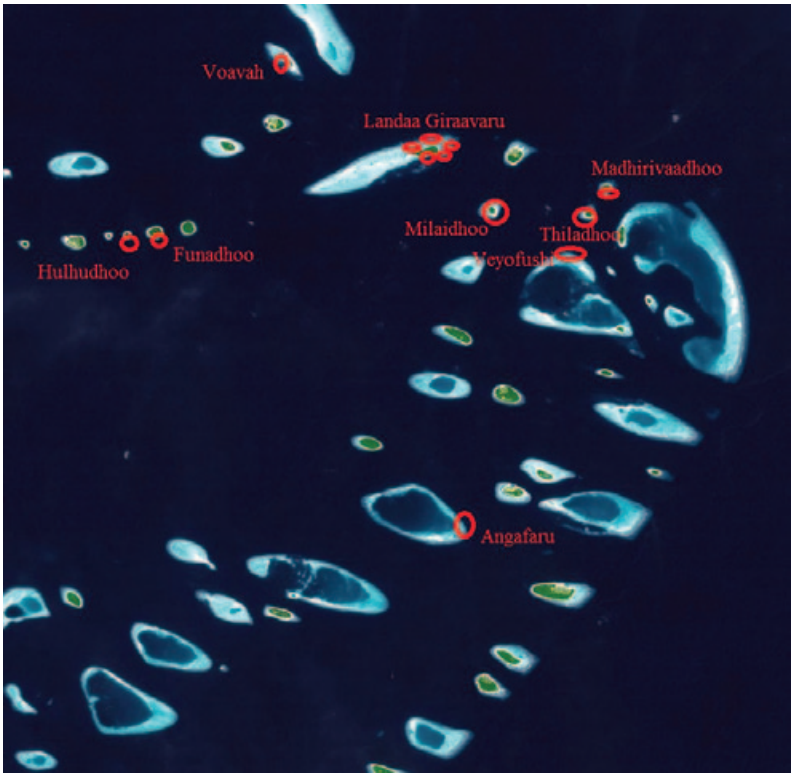

Figure 1. Location of sampling stations (north-east part of Baa atoll), with an indication of Baa atoll position relative to the Maldives.

down to a depth of about 30 metres (Kench 2012). The current can be steady, allowing important populations of sessile filter-feeding animals such as crinoids to develop; though wave action is moderate in this part of the atoll (Kench 2012).

Results

Study site description

The characteristics of the sites, including the benthic cover of the main ecological components of the substrate, are reported in Table 1. The benthic cover is largely dominated by live coral (more than 50%, often up to 80%), followed by dead coral more or less covered by turf algae and sand in some sites. No seagrass bed or mangrove was observed, and fleshy algae were also very rare. Rugosity, habitat richness and hydrodynamics were highly heterogenous, allowing quite a wide variety of ecological niches.

Aspidochirotid holothurians abundance and diversity

Seven species of aspidochirotid sea cucumbers were encountered during the survey (Table 2), including one species probably unidentified and one species not recorded in former studies (*Stichopus* cf. *horrens*). Seven more species were reported by colleagues and locals (from pictures or specimens) in the area but were not observed in the surveys. They are therefore listed as "reported" in Table 3. Among the species recorded in this survey, none was of high commercial value, and only three were reported as commercially exploited in the Maldives: *S. chloronotus*, *H. atra* and *T. anax* (Joseph 1992), despite the fact that all of them are considered edible and are fished in some regions (Purcell et al. 2012). Among the seven species recorded, five were stichopodids and two holothurids. The total number of individual sea cucumbers encountered at all the sites was 308 within a total search period of 33 hours. The overall density was 6.8 individuals per 45-minute search. The density of sea cucumbers was highest at Thiladhoo where the mean was 14.25 individuals per search.

The density of observations was very variable, ranging from 0 to 20 individuals per 45-minute search. *Pearsonothuria graeffei* was by far the most abundant species, accounting for 291 observations out of 308 (= 94.5%), and present in all sites but one (a site without live corals). It was followed by *Stichopus chloronotus* (2.3% of observations, recorded in three sites, corresponding to 23%). More individuals were found on live coral substrate (especially the most abundant species), but softer bottoms provided more diverse species. Sites with a high live coral cover (and important relief) provided important populations of *P. graeffei*, whereas *S. chloronotus* was observed in more simple sites with a less complex coral landscape and more algal turf. *H. atra* was observed only once, on a sandy reef flat with abundant detritic material (coming from coral but also partly human activities). Big stichopodids, such as *T. anax*, *S. herrmanni* and *S.* cf. *horrens*, were observed on large sandy patches in open reefs, but never on sandy detritic reef flats. Nearly all of the observations were made at snorkelling depths (1–7 m), and deeper dives showed a fast decrease of observations, and no additional species. Night surveys tended to find less abundance but a higher level of diversity, some species being observed mostly at night, especially the big stichopodids.

An unknown species (Fig. 2G) was observed three times at the same site, Landaa Giraavaru south, involving at least two different specimens. One specimen was collected and is currently under study at the National Museum of Natural History: it is a large (20–30 cm), robust species of stichopodid

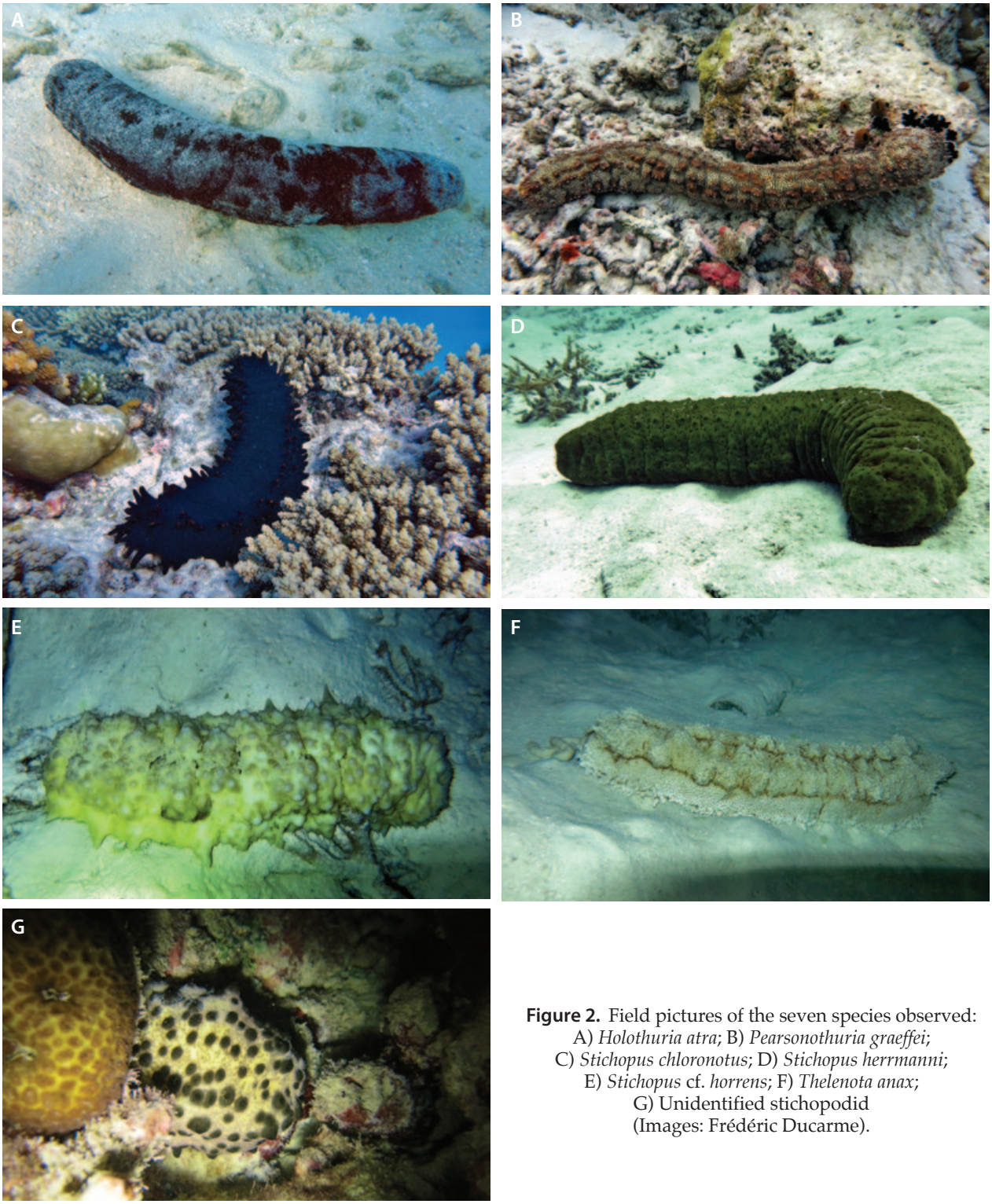

Figure 2. Field pictures of the seven species observed: A) *Holothuria atra*; B) *Pearsonothuria graeffei*; C) *Stichopus chloronotus*; D) *Stichopus herrmanni*; E) *Stichopus* cf. *horrens*; F) *Thelenota anax*; G) Unidentified stichopodid (Images: Frédéric Ducarme).

sea cucumber, with light greenish skin spotted with large dark spots.

Overall echinoderm diversity in the study sites

The study sites showed a strikingly scarce population of echinoderms compared to data from other atolls of the Maldives (field observations and Muthiga [2008]). The most abundant class was Asteroidea, with a large population of *Linckia multifora* and *Culcita schmideliana* (consistent with Andréfouët 2012), followed by, in order of abundance, *Fromia indica*, *Linckia guildingi*, *Choriaster granulatus*, *Fromia nodosa*, *Gomophia egyptiaca* and *Fromia nodosa*; big specimens of *Mithrodia clavigera* and *Leiaster* cf. *speciosus* were also observed at night (both new records for this area). *Acanthaster planci*, though reported earlier (Andréfouët 2012), was not observed in Baa (but individuals were observed during control surveys in Kuda Huraa, east of Malé atoll). The second

Table 1. Characteristics of the survey sites and diversity of holothurians. Observed live coral cover, rugosity (3D complexity), habitat richness and hydrodynamics of sampling stations, in relation to the number of species observed.

Survey site	Live coral	Turf and damaged coral	Sand	Rugosity	Habitat richness	Hydrodynamics	Number of surveys	Diversity of sea cucumbers
Angafaru	2	2	1	1	3	1	1	1
Funadhoo	5	1	0	4	4	3	1	1
Hulhudhoo	5	1	0	4	4	3	3	1
Landaa south	4	2	1	5	4	2	15	5
Landaa east	2	2	1	2	2	4	3	4
Landaa north	0	3	3	1	1	2	1	0
Landaa NE	3	2	2	3	3	3	1	1
Landaa SE	2	2	2	2	4	2	1	2
Madhirivaadhoo	4	2	1	4	3	2	4	1
Milhadhoo	3	3	1	3	4	2	6	2
Thiladhoo	4	2	1	4	4	3	4	1
Veyofushi	2	1	3	3	3	3	1	1
Voavah	5	1	2	5	5	1	3	1

Table 2. Abundance of each holothurian species in the survey sites and occurrence (number of sites with presence / total number of sites).

	Angafaru	Funadhoo	Hulhudhoo	Landaa south	Landaa east	Landaa north	Landaa NE	Landaa SE	Madhirivaadhoo	Milhadhoo	Thiladhoo	Veyofushi	Voavah	Total abundance	Occurrence (%)
Pearsonothuria graeffei	7	3	10	90	21		5	6	30	50	57	5	7	291	92.0
Stichopus chloronotus				1	1					5				7	23.0
Holothuria atra					1									1	7.5
Thelenota anax				1				1						2	15.0
Stichopus herrmanni					2									2	7.5
Stichopus cf. *horrens*				2										2	7.5
Unidentified sp.				3										3	7.5

most abundant class was *Crinoidea*, represented by at least six different morphotypes including probable *Lamprometra*, *Himerometra*, *Comanthus*, *Oxycomanthus*, *Stephanometra* and *Commissia* sp. *Echinoidea* were surprisingly cryptic, with hardly any observation during the day, except burrowing species like *Echinostrephus molaris* (the most abundant species) and scarce, small specimens of *Echinometra mathaei*. Nevertheless, large populations of *Heterocentrotus mamillatus* (both white-red and purple morphs) and *Phyllacanthus imperialis* were observed at night. Other observations included very scarce and small *Diadema savignyi* and *Echinothrix diadema*, along with stranded tests of *Fibularia* sp. (quite common on beaches), *Metalia sternalis* and *Clypeaster humilis*. *Ophiuroidea* were extremely rare and cryptic, represented only by scarce observations of Ophiothrichidae.

Discussion

The main result of this survey is the scarcity of sea cucumbers — and echinoderms in general — in Baa atoll, along with poor diversity, largely dominated by the holothuroid *Pearsonothuria graeffei*, followed by several stichopodids. The number of species by survey as well as the overall abundance were both strikingly weaker than what was observed in Malé atoll, and recorded by Muthiga (2008) (Table 3). Such a result is consistent with the overall rarity of

benthic organisms noted by Andréfouët (2012) for this atoll, where most of the species were seen only once. In this survey, stichopodid sea cucumbers were better represented than expected, given previous work, whereas holothuroids showed less diversity, though they dominate the Maldivian assemblage in most of the other surveys. This result, therefore, differs from previous studies for Baa atoll (Andréfouët 2012), as well as Malé atoll (Muthiga 2008), Laamu atoll (Reichenbach 1999) and Maldives (Joseph 1992; James and Manikfan 1994), which were clearly dominated by *Holothuria*, *Actinopyga* and *Bohadschia* (Table 3). The dominance of *P. graeffei* is consistent with Andréfouët 2012, but more pronounced in our study with occurrence accounting for 92%, compared to 53.5% in the previous study. The fact that we recorded *Stichopus chloronotus* as the second most abundant species (seven observations in three sites) was surprising, given the fact that this species was not even recorded by Andréfouët 2012 (Table 3). This leads to a total of 18 recorded species for Baa atoll for both studies, including eleven holothurids, six stichopodids and one synaptid.

Two individuals of *Stichopus* cf. *horrens* were observed, rather big, uniformly clear and highly warty individuals (Fig. 2E). These constitute the first record of this species in Baa atoll, and it was absent from the most recent studies (Muthiga 2008; Andréfouët 2012). As the taxonomy of this group and its relation with morphology is still debated (Byrne et al. 2010), exact determination of the species could not be made. The external features of these animals possibly suggest a new morph, subspecies or even species, and further work could concentrate on this animal. *Actinopyga caerulea* is also a new record for the region.

This scarcity of sea cucumbers could be partly explained by the ecosystem characteristics — small islands with little vegetation and no mangrove, no true lagoon, and no seagrass bed — all ecosystems that are used to shelter an important part of the holothurian

Table 3. Comparison of the present results with previous inventories. Four species were reported by locals (picture or specimen) in the area but were not observed during the surveys.

	Present study (Baa atoll)	Andréfouët (2012) (Baa atoll)	Muthiga (2008) (Malé atoll)	Reichenbach (1999) (Malé & Laamu atolls)	James (1994) (Maldives)	Joseph (1992) (Maldives)
Holothuria atra	*	*	*		*	*
Pearsonothuria graeffei	*	*	*			
Stichopus chloronotus	*		*		*	*
Stichopus herrmanni	*			*		
Stichopus cf. *horrens*	*					
Thelenota anax	*	*	*	*	*	
Unidentified sp.	*					
Actinopyga lecanora	Reported	*	*		*	*
Actinopyga mauritiana		*	*	*	*	*
Bohadschia argus		*				
Bohadschia marmorata		*			*	*
Holothuria edulis	Reported	*	*	*		
Holothuria fuscogilva		*		*		
Thelenota ananas	Reported	*	*	*	*	
Synaptula sp.	Reported	*				
Actinopyga caerulea	Reported					
Actinopyga echinites				*	*	
Actinopyga miliaris	Reported		*	*	*	
Bohadschia atra			*			
Bohadschia vitiensis			*			
Holothuria fuscopunctata	Reported			*	*	*
Holothuria hilla			*			
Holothuria leucospilota			*			*
Holothuria nobilis			*		*	*
Synapta maculata						*

biodiversity. Even fleshy algae were very rare as well, which is consistent with the almost complete absence of green turtle, compared to a high population of hawksbill turtle. The sites at Hulhudhoo, Voavah and Thiladhoo had the highest hard coral cover (Table 1), and Landaa Giraavaru east had the lowest (sand and rubble bed). This is significantly higher than is reported for most Maldivian reefs (Muthiga 2008).

This trend can also be related to the relative scarcity of diurnal benthic invertebrates, which might be linked to a high level of predation, as suggested by the rarity and cryptic behaviour of most benthic animals, and the evidence of predation on big and strong benthic invertebrates (especially *H. mamillatus*).

However, human exploitation could also be a cause of this low diversity, and explain in part the absence of high value species, such as *Thelenota ananas* (the main target of fishermen in Maldives, according to James and Manikfan [1994] and FAO [2013]), which is known in the region but could not be found in this survey. This could suggest a high level of fishing, even on uninhabited island reefs in a weakly populated UNESCO Biosphere Reserve. According to field-gathered information, sea cucumber processing documented by FAO (Joseph 1992) in Hithaadhoo and Thulhaadhoo is no longer in activity, but little information could be gathered on site about current fishing. Nevertheless, illegal fishing is known to occur throughout all the Maldivian area (Ahmed et al. 1996; FAO 2013).

This study increases the number of holothurian species recorded in Maldives to around 25, depending on determination of ambiguous observations, and 18 for Baa atoll alone.

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