Holothurian density, distribution and diversity comparing sites with different degrees of exploitation in the shallow lagoons of Mauritius

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Abstract

The current study aims to conduct a baseline investigation regarding the abundance, distribution and diversity of holothurians inhabiting shallow lagoons in southern and western Mauritius, comparing sites with different degrees of exploitation. During July and August 2011, 78 day time transects covering an area of 35,550 m² recorded a total of 3411 holothurians (152.56 ind. 100 m^{-2}) at 16 survey sites in shallow lagoons in the west (93.50 ind. 100 m^{-2}) and south (59.06 ind. 100 m^{-2}) of Mauritius. These were assigned to 17 species, including ten commercially important ones. The dominant species was *Synapta* spp. (41.6% of the total). The next most common species were *Holothuria atra* (29.14%), *H. leucospilota* (11.93%), and *Stichopus chloronotus* (6.39%). These three species had a commercial value. Overall similar densities of commercial (52.39%) and non-commercial (47.61%) species were assessed. Testing the correlation of habitat diversity, species density and diversity resulted in a patchy picture throughout the lagoons. However, the highest densities, but lowest diversity, were found in sites characterised by a cover that is predominantly sediment and vegetation.

Introduction

Sea cucumbers play an essential role as keystone species, bioturbators and recyclers of lagoons. Changes in their density may even have serious consequences for the survival of other species that are part of the same ecosystem (Birkeland 1988). As well as being ecologically significant, sea cucumbers are also associated with two major economic uses. First, processed sea cucumbers (beche-de-mer) are considered a gourmet food item in Asia, especially in Japan and Korea. Second, holothurians have pharmaceutical properties. Pharmaceutical companies invest in research related to the toxins produced by holothurians. Some compounds that are extracted from the sea cucumber feature antimicrobial activity or act as an anti-inflammatory. Other compounds exhibit antiviral, antitumor, anticancerous and antifertility properties (Bordbar et al. 2011).

Sea cucumber fishery in Mauritius has developed quickly in the past few years and Conand (2004) reported around 11 edible species there. *Bambara*, as sea cucumbers are often called in Mauritius, are easily handpicked by fishermen for local consumption and to be sold to hotels. However, they are mainly being sold to operators, who export the processed products to Asian countries (Luchmun et al. 2001). The current knowledge of sea cucumber diversity and the effect of exploitation in Mauritian waters that appear to be rich in holothurian resources, is virtually unknown (Luchmun et al. 2001). The present work aims to conduct a baseline investigation regarding density, distribution and diversity of holothurians inhabiting shallow lagoons in the south and west of Mauritius, comparing sites with different degrees of exploitation.

Materials and methods

With its total coastline of about 200 km, Mauritius is almost completely surrounded by lagoons that extend over 150 km², created by the formation of either barrier reefs or fringing reefs. On the eastern coast of the island, the width of the lagoons, which enclose the area from the shore to the reef crest, varies from 400 m to approximately 7 km. Tides are semi-diurnal, with a mean tidal range of 0.9 m during spring time and 0.1 m during neap time (McClanahan et al. 2005). Lagoons in Mauritius extend from the nearshore to the reef flat. A flat lagoon will generally have homogeneous species composition as opposed to a lagoon floor where there is great variation in bathymetry. The study was limited to two geographically separate areas – the south and the west of Mauritius – where surveys were carried out at a total of 16 sites (Fig. 1). The western lagoons of the island are comparatively calm and protected by the fringing coral reefs, while in the south, the coast is affected by the south-east trade winds and rough sea conditions prevail. However the west region is

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more susceptible to cyclone swells originating in the north and northwest (Padya 1984, 1989).

The survey sites have different degrees of exploitation, i.e. they are differently utilised and affected by, for example, their accessibility to fishermen or fishing activity, and the presence of hotels and tourism.

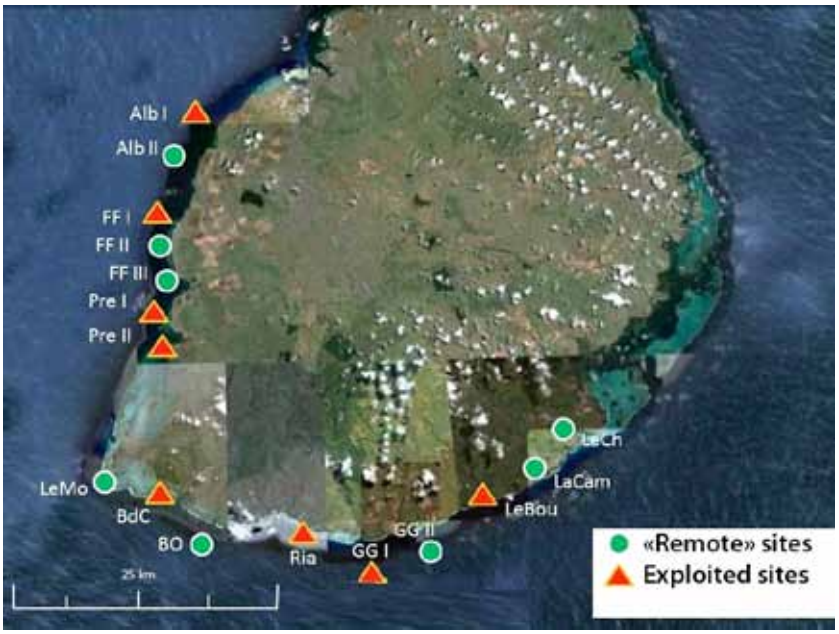

Figure 1. Satellite image displaying the 16 survey sites spread along the shallow lagoons of the west and the south coast of Mauritius. The red sites are exploited, while the green sites are considered "remote" (Snapshot Google Earth 2011).

Figure 2. Example of transects setting for survey of sea cucumber at the site called Flic en Flac II (Snapshot Google Earth 2011).

The surveys were conducted in five belt transects. Each belt transect consisted of a 50 m long main line with five 20 m side transects of 3 m width, thus covering an area of 450 m². According to that, the total covered area per survey site with its five transects was 2250 m² (or 450 m² x 5) (Fig. 2). The five transects were set in a staggered fashion, separated from one another by a minimum distance of 10 m. All surveys were conducted during daylight hours only.

A thorough search for holothurians was carried out snorkelling, starting with the first transect, along the mainline, then working up the side transects. Each individual holothurian found was counted and its species noted down. To understand the effect of habitat type on holothurian distribution and abundance in each of the survey sites, the percentage of different substrate types was also recorded. Substrates were classified into six different types (sand, live coral, coral rubble, seagrass, macroalgae and rocks).

The Shannon-Wiener Index (Nentwig et al. 2004) was calculated in order to measure the dominance and diversity of species and habitats at each of the 16 sites, as per the formula below.

$$H' = - \sum_{i=1}^{R} p_i \ln p_i$$

Where p_i is the proportion of one species (i) against the total number of species.

The non-parametric Spearman's rank correlation coefficient (R^2) was used to determine the strength of the dependence between the habitat diversity and species density. In this case, a Spearman correlation (R^2) would have a value +1 or -1, stating that the degree of habitat diversity explains the species density.

Table 1. Observed species with their absolute density and commercial value (ranging from 0 in white: no commercial value; to 1 in red: high-commercial value; to 2 in orange: medium-commercial value; to 3 in yellow: low-commercial value, as per Conand 2008) in a survey carried out in July–August 2011 in the lagoons of Mauritius.

Species	Commercial value	Absolute density	Total west (ind. 100 m^{-2})	Total south (ind. 100 m^{-2})
Holothuria nobilis	1	3	0.04	0.08
Actinopyga echinites	2	37	0.31	1.87
A. mauritiana	2	2	0.00	0.08
Stichopus chloronotus	2	218	8.98	0.71
S. herrmanni	2	1	0.04	0.00
Bohadschia atra	3	7	0.18	0.19
B. marmorata	3	110	3.35	1.24
Bohadschia sp.	3	8	0.27	0.07
Holothuria atra	3	994	38.73	5.39
H. leucospilota	3	407	14.13	4.67
Subtotal		**1787**	**66.04**	**14.31**
Holothuria hilla	0	120	0.76	4.58
Holothuria pervicax	0	68	1.29	1.73
Stichopus monotuberculatus	0	10	0.31	0.13
Stichopus sp.	0	6	0.27	0.00
Synapta spp.	0	1419	24.81	38.31
Unidentified species	0	1	0.03	0.00
Subtotal		**1624**	**27.46**	**44.76**
Total		**3411**	**93.50**	**59.06**

Results

During July and August 2011, 78 day time transects in 16 survey sites covering an area of 35,550 m² recorded a total of 3411 holothurians (152.56 ind. 100 m^{-2}) inhabiting the shallow lagoons in the west (93.50 ind. 100 m^{-2}) and the south (59.06 ind. 100 m^{-2}) of Mauritius (Table 1).

The relative proportion of the different habitat characteristics of the 16 survey sites was computed. The most common substrate types along each transect set were sandy patches (39.7%), followed by seagrass patches (20.9%). Coral rubble and live coral patches had similar proportions (15% and 12.2% respectively). The least represented habitat types were macroalgae and rocky patches, both with less than 8%. Nine out of 17 species had ten or more individuals found throughout all survey sites (Table 2) whereas species such as *Bohadschia* sp., *B. atra*, *Stichopus* sp., *Holothuria nobilis*, *Actinopyga mauritiana*, *Stichopus herrmanni* and one unidentified species occurred very rarely in all survey sites, with fewer than ten individuals surveyed.

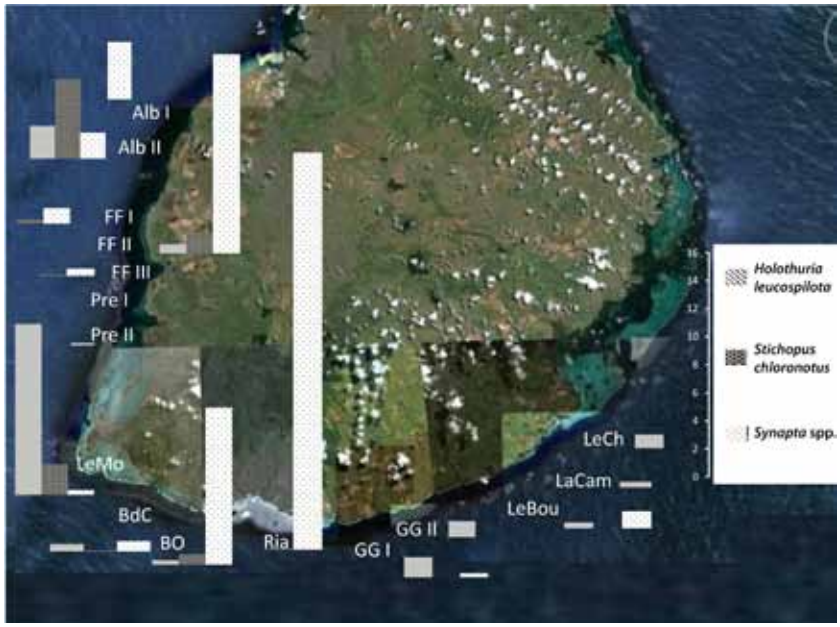

Figure 3. Map of the survey sites in the west and south shallow lagoons of Mauritius with the holothurians densities (ind. 100 m^{-2}) of *Holothuria leucospilota*, *Stichopus chloronotus* and *Synapta* spp. (Google Earth 2011).

Individuals from the genus *Synapta* were shown to be the most abundant, with a relative density of 42% and 1419 counted individuals (Table 2). As for their relative frequency (81%), they were observed in 13 out of 16 sites, most abundantly in Riambel, Flic en Flac II and Bel Ombre (Fig. 3). However, this percentage was less than the most frequently occurring species *Holothuria atra* with 94%, which was also the most abundant species with a total number of 994 individuals (Table 1; Fig. 4), featuring a relative abundance of 29% (Table 2), mostly in Le Morne, Bel Ombre, and Albion II (Fig. 4).

Table 2. The absolute density of each holothurian species and its relative density (%) and observation frequency (%), in the 16 different sites covering a total area of 35,550 m².

Species	Number of individuals	Relative density(%)	Observation frequency (%)
Actinopyga echinites	37	1.08	43.75
A. mauritiana	2	0.06	12.50
Bohadschia atra	7	0.21	18.75
B. marmorata	110	3.22	56.25
Bohadschia sp.	8	0.23	18.75
Holothuria atra	994	29.14	93.75
H. hilla	120	3.52	25.00
H. leucospilota	407	11.93	75.00
H. nobilis	3	0.09	18.75
H. pervicax	68	1.99	31.25
Stichopus chloronotus	218	6.39	50.00
S. herrmanni	1	0.03	6.25
S. monotuberculatus	10	0.29	18.75
Stichopus sp.	6	0.18	12.50
Synapta spp.	1419	41.60	81.25
Unidentified species	1	0.03	6.25
Total	**3411**		

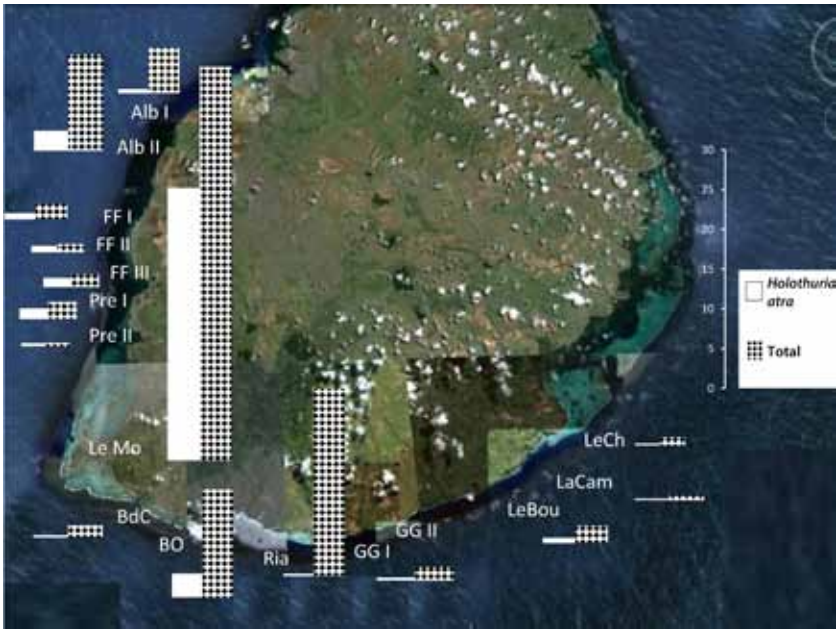

Figure 4. Map showing the survey sites in the shallow lagoons of Mauritius with the densities (ind. 100 m^{-2}) of *Holothuria atra* compared to the overall species density (Google Earth 2011).

Holothuria leucospilota and *Stichopus chloronotus* were the next most common species, constituting 12% and 6% of the total count, featuring 407 and 218 individuals respectively (Table 1; Fig. 3). But *H. atra* was observed at 12 sites (relative frequency of 95%), whereas *S. chloronotus* was less widespread, being found at eight sites only (50%) (Fig. 3 and 4).

In almost the same abundance, species such as *Bohadschia marmorata* and *Holothuria hilla* were found, featuring a total of 110 individuals (relative density of 3.22%) and 120 individuals (relative density of 3.52%) respectively, the former being more frequent than the latter (observation frequency 56.25% and 25% respectively) (Table 2). Some rare species, despite their low relative density as *Actinopyga echinites* (1.08%) and *Holothuria pervicax* (1.99%), were relatively widespread, with observation frequencies of 43.75% and 31.25% respectively, ranking just after the four most widespread species (Table 2). Rather rare species, featuring less than 1% of the relative density were *Actinopyga mauritiana*, *Bohadschia atra*, *Bohadschia* sp., *Holothuria nobilis*, *Stichopus herrmanni*, *S. monotuberculatus* and *Stichopus* sp. They were recorded at either three or two of the 16 sites and sometimes at just one site.

Abundance of commercial and non-commercial sea cucumber species

Ten species were identified as commercially important [key of Conand (2008)].

Holothuria nobilis ranked as being of a high-commercial value, while four other species were of medium-commercial value and five species of rather low-commercial value. The remaining six species (including one genus group) were designated as being of no commercial value. Whereas in the western sites there was a high absolute density of species of no commercial value of 93.5 ind. 100 m^{-2}, in the southern sites the density was 59.06 ind. 100 m^{-2}. The western sites also had the higher density of commercial species (66.04 ind. 100 m^{-2}) (Table 1).

There is one outstanding observation to be made when having a closer look at the western survey sites, and that is the comparatively high abundance of *Holothuria atra* and *H. leucospilota* at those sites. In the four survey sites classified as remote, an average of 79.87 ind. 100 m^{-2} was observed. *Holothuria atra*, which holds a low-commercial value (value of 3), was the species responsible for the high density, especially in Le Morne (Fig. 5). Moreover, the second most commercially important species, *Holothuria leucospilota*, was observed with a density of 11.38 ind. 100 m^{-2} exclusively in Le Morne.

Having compared the relation between the habitat differences to species density; the habitat differences to the respective Shannon-Wiener indices of the species; the Shannon-Wiener indices of the habitats to the species density as well as the Shannon-Wiener indices of the habitats to the Shannon-Wiener indices of the species, the highest correlation coefficient was revealed to be 0.6359, in the southern sites. The others featured a coefficient less than 0.5.

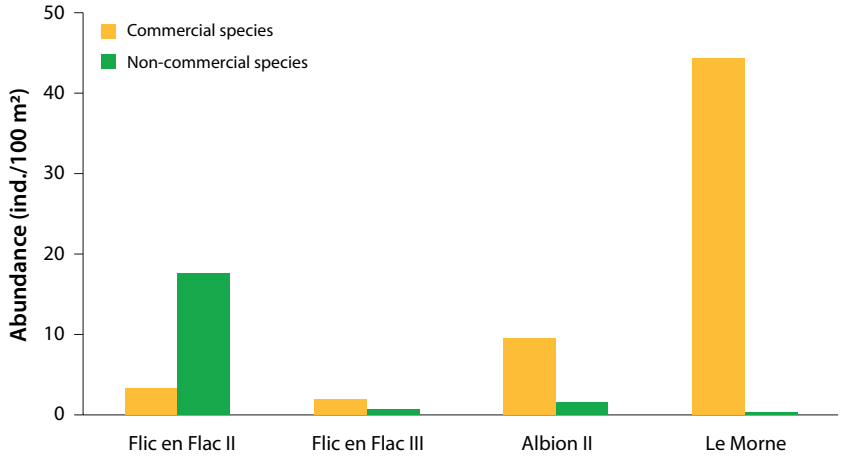

Figure 5. Holothurian densities at remote survey sites, distinguishing between commercial and non-commercial species in the shallow lagoons of western Mauritius, July–August 2011.

Discussion

Species richness and species composition

The results of the present study show a higher diversity of species than any previous studies done in Mauritius (Müller 1998; Luchmun et al. 2001; AFRC 2011). The shallow lagoons of Mauritius and Rodrigues are inhabited mainly by four species of holothurians in great abundance, although they are distributed in a heterogeneous manner in the lagoon. These four species are *Holothuria atra*, *H. leucospilota*, *Stichopus chloronotus* and *Bohadschia marmorata*, which are considered important commercial species. However, certain species of commercial value such as *Thelenota anax*, *T. ananas* and *Holothuria scabra*, which were previously surveyed in Mauritius (Luchmun et al. 2001; AFRC 2011), were missing in the current study. Species of non-commercial value, in particular the genus *Synapta*, contributed to the bulk of the individual densities.

Due to the high heterogeneity of species distribution, it is worth noting that there are areas in the lagoons of Mauritius that were not surveyed but which are likely to harbour the holothurians species missing in this study. The field surveys in this study were undertaken only in shallow lagoons, excluding other habitats such as the intertidal and shallow sublittoral zones, deep regions and channels within the lagoon, as well as habitats outside the shallow lagoon. *Thelenota anax* prefers habitats such as outer lagoons and near passes living on hard bottoms, and large rubble and sand patches. Conand (2006) stated that *H. anax* inhabits reef slopes that are not subject to the influence and passages of land runoffs, meaning that this species is therefore found in areas with strong water movement. Furthermore, this species has not been observed above a depth of eight metres but is found in depths of up to 28 m.

Commercial and non-commercial holothurian abundances in sites with different exploitation degrees

As expected, the highest density of sea cucumbers was measured in remote areas in the western sites (13.63 ind. 100 m^{-2} in the exploited sites and 79.87 ind. 100 m^{-2} in the remote sites of the west). Furthermore, the commercially valued species were more abundant in the remote sites.

For example, the density of *Holothuria atra* and *H. leucospilota* at the remote survey site in Le Morne was found to be striking when compared to exploited sites in the west, where these species' densities were exceedingly low. Also *Stichopus chloronotus*, a species of medium-commercial value, is mainly found in quite high densities in the western remote sites. The site of Le Morne, which is located on an extended piece of land in the southwest, is almost separate from the rest of the island. No local people live around this site, as it is exclusively allocated to hotel complexes. Its lagoon is mainly used by tourists for water sports such as kite surfing, discouraging fishermen from collecting holothurians there. This may be one cause of the abundance of holothurians. The high density of commercially important species may also be a result of the organic nutrients in the water, as this site also is the only one with high turbidity and accumulation of detritus.

The abundance of *Synapta* spp. accounts for the overall densities of the non-commercial species in both remote and exploited sites. However, they are more than twice as abundant in the remote sites as they are in the exploited sites. Such a great difference of abundance of non-commercial species between the two different types of site was not expected. Nevertheless this contrast may be explained by habitat composition at the sites where they were sighted, or other conditions such as salinity and nutrients that might affect the species density.

Habitat and shelter associations

In general, it is apparent that holothurian distribution is of a patchy nature, although there are some species where a preferred habitat type can be noted. For example, the highest density of *Synapta* spp. was found on sites characterised by sand and seagrass in very shallow water, ranging from 30–50 cm deep.

As for *Holothuria atra*, it seems that they live in a wide range of habitats. They occurred in high abundance in some habitats, like that at Le Morne (covered with sand and vegetation in deeper waters, a high extent of turbidity, and a muddy floor cover), where it was observed sometimes to be grouped with *Holothuria leucospilota* in one patch. On other sites, featuring more substrate variability, they tended to occur relatively often on coral rubble patches, on sediment and in mainly unsheltered places, slightly covered by sand. This association with sediment was to be expected, as this forms the primary feeding substratum for *H. atra* (Roberts and Bryce1982).

Physical parameters, such as salinity degrees, water temperature, turbidity of the water and depth at which species occur, as well as nutrient composition, may have a direct impact on holothurians distribution and occurrence.

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