

# An assessment of holothurian diversity, abundance and distribution in the shallow lagoons of Mauritius

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## Abstract

The sea cucumber industry, which is known to be particularly vulnerable to overexploitation and collapse, has been under tremendous pressure in Mauritius since the mid-2000s. Consequently, in 2010, the Ministry of Fisheries imposed a two-year ban on the collection of sea cucumbers, which was later extended for another four years (2012–2016) to avoid the collapse of the fishery. This study collected data on the diversity and abundance of sea cucumbers in the shallow lagoons of Mauritius in order to assist with the sustainable management of the fishery. Previous surveys conducted in 2011 in the lagoons of the south and west coasts of the island revealed the presence of 17 holothurian species. The present study visited some of the earlier study sites as well as some new ones in the north and east coasts to assess sea cucumber abundance and diversity. From March to June 2013, 115 daytime transects at 23 sites (totally 92,000 m<sup>2</sup> in area) revealed a total of 7,488 holothurians, of which 76% were of commercial importance. The holothurians were distributed within a range of habitats with no significant correlation detected between abundance and habitat types. Holothurian distribution in the shallow lagoons of Mauritius seems to be influenced by physical, biological and anthropogenic factors. The present survey revealed that some species could be recovering from exploitation.

## Introduction

The lagoons of Mauritius are impacted by climatic changes and various anthropogenic factors, all of which cause a reduction in habitats for marine organisms and a potential loss of biodiversity (Moothien Pillay et al. 2012). Moreover, the overexploitation of commercially important species is threatening the persistence of the most demanded and high-priced species. The sea cucumber industry, which is vulnerable to overexploitation and collapse, has been under tremendous pressure in Mauritius since the mid-2000s. Surveys carried out in 2010 by the Ministry of Fisheries revealed a decrease in abundance, species diversity and size of sea cucumbers at the surveyed sites when compared with data collected in 2007–2008 (AFRC 2012). As a consequence, a two-year moratorium was imposed on the fishery, and later extended to 2016, to reverse the rapid decline of sea cucumber populations. Because little is known about the ecology of sea cucumbers and the extent of their exploitation in Mauritius, this study was undertaken at a larger scale to assist the Ministry of Fisheries with the sustainable management of this fishery. This study builds on the baseline study that was carried out in

2011 on the abundance, diversity and distribution of holothurian species inhabiting the western and southern shallow lagoons of Mauritius (Lampe 2013). For a more comprehensive understanding of the population dynamics of sea cucumbers around the island, besides the western and southern coasts, the northern and eastern regions were also studied. This was undertaken in light of the history and recent development of the sea cucumber fishery in Mauritius, including non-commercial species.

## Materials and methods

### Site description

Mauritius is a small island state of volcanic origin located in the western Indian Ocean, approximately 900 km east of Madagascar (Saddul 1995). The island forms part of the Mascarene Archipelago with La Reunion, Rodrigues, St. Brandon and a few other smaller islands. The coastline is surrounded by a fringing reef and includes a lagoon that extends from the near shore to the reef flat and is composed of different zones that are further subdivided, depending on the size of the lagoon, into shore reef, mid-lagoon, back-reef, reef flat and fore reef (Baird et al. 2003).

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## Methodology

From March to June 2013, 115 daytime transects were set within 23 survey sites in the north, west, south and eastern shallow lagoons of Mauritius (Fig. 1a) in a staggered fashion (Fig. 1b). Five belt transects were surveyed by a pair of divers swimming along a 100-m long main transect line with five 20-m long side transect lines (Fig. 1c), thus covering a total area of 4,000 m<sup>2</sup> per site. Species were identified and measured lengthwise in the relaxed state to the nearest 10 mm. The visibility, depth and temperature of the water were recorded along with currents and occurrences of other invertebrates within the same shallow water habitats. Survey sites were categorised as remote beaches with difficult access, public beaches, and beaches directly in front of hotels that are utilised mostly for tourism activities.

Generally, the collection of holothurians is possible at any of these shallow sites because all beaches in Mauritius are public and accessible<sup>4</sup>.

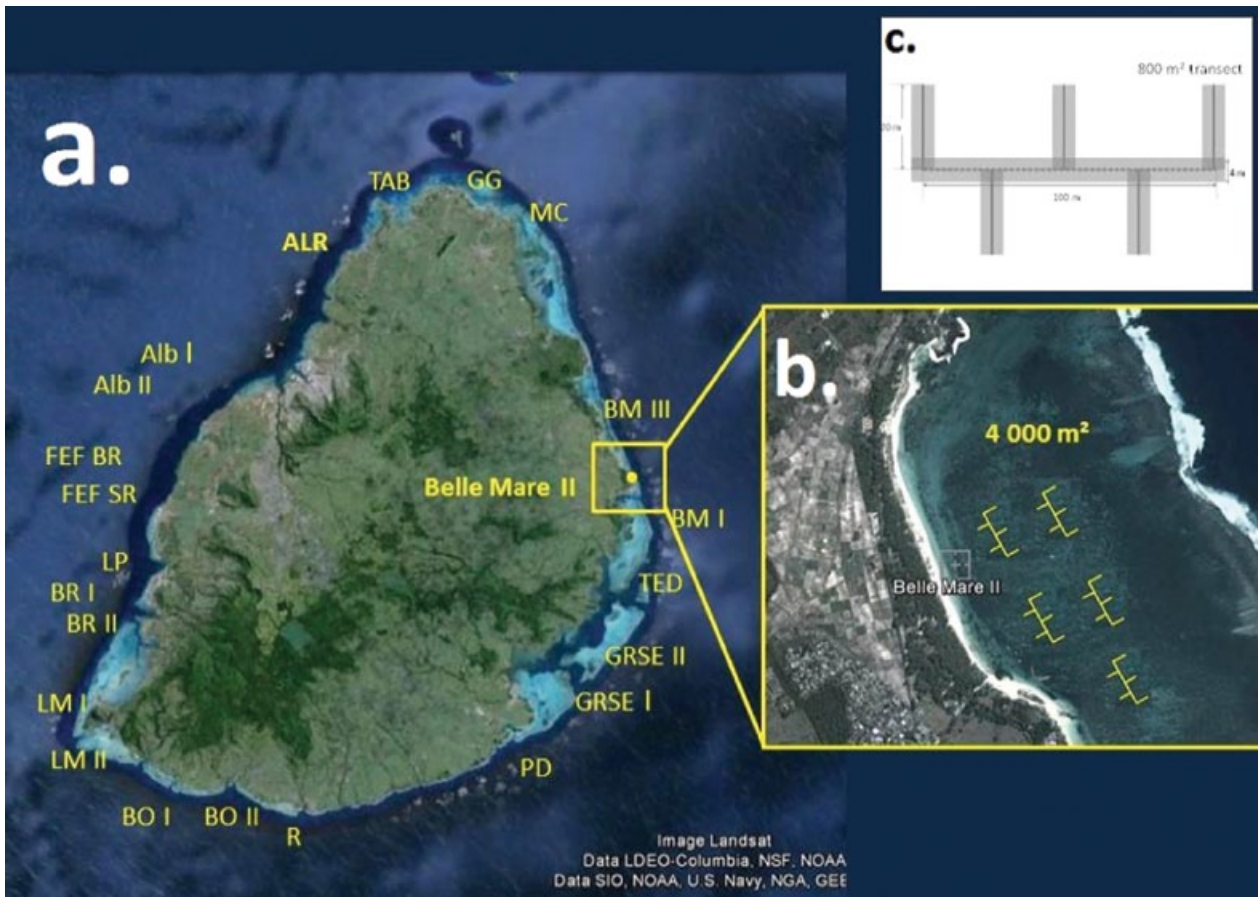
The percentage cover of the various substrate types (e.g. sand, coral rubble, live coral, dead coral, seagrass, algae and rocks) in each belt transect was recorded. For calculating the dominance and species diversity within the four regions and each of the 23 sites under study, the Shannon-Wiener index ( $H'$ ) (Nentwig et al. 2004) was used.

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

Body wall tissue samples were taken from each species to examine their microscopic skeletal ossicles for identification.

## Results

The total surveyed area of 92,000 m<sup>2</sup> contained 7,488 holothurians, comprising 19 species and one additional genus (*Synapta*) that was not identified to the species level (Table 1). Fourteen species (76% of all individuals) were of commercial value and five species (24% of all individuals) were of



**Figure 1.** a) The island of Mauritius and the location of the 23 survey sites in the four regions (Google Earth 2013);  
 b) five belt transects per site covering a total area of 4,000 m<sup>2</sup>;  
 c) one belt transect comprising five subtransects, covering an area of 800 m<sup>2</sup>.

<sup>4</sup> <http://beachauthority.intnet.mu/beach-authority-use-of-public-beach-regulations-2004.html>, last access:11.01.2014

**Table 1.** Total and relative abundance (%) of each holothurian species recorded, ordered from highest to lowest abundance and its occurrence (%) in the 23 survey sites around the island over an area of 92,000 m<sup>2</sup>.

Species	No. of individuals	Relative abundance (%)	Occurrence (%)
<i>Holothuria atra</i>	3,889	51.94	95.65
<i>Synapta</i> spp.	1,836	24.52	78.26
<i>Stichopus chloronotus</i>	881	11.77	56.52
<i>Bohadschia vitiensis</i>	354	4.73	82.61
<i>Holothuria leucospilota</i>	240	3.21	78.26
<i>Holothuria pervicax</i>	115	1.54	43.48
<i>Actinopyga echinites</i>	56	0.75	56.52
<i>Holothuria cinerascens</i>	47	0.63	4.35
<i>Holothuria hilla</i>	18	0.24	17.39
<i>Actinopyga mauritiana</i>	14	0.19	17.39
<i>Bohadschia subrubra</i>	11	0.15	30.43
<i>Holothuria arenicola</i>	10	0.13	8.70
<i>Stichopus monotuberculatus</i>	5	0.07	17.39
<i>Actinopyga capillata</i>	3	0.04	8.70
<i>Stichopus herrmanni</i>	3	0.04	8.70
<i>Bohadschia marmorata</i>	2	0.03	8.70
<i>Holothuria fuscocinerea</i>	2	0.03	8.70
<i>Holothuria nobilis</i>	1	0.01	4.35
<i>Holothuria scabra</i>	1	0.01	4.35
<b>Total</b>	<b>7,488</b>		

no commercial value, including *Synapta* (Table 1). The three most abundant species were *Holothuria atra* (3,889 individuals), individuals from the genus *Synapta* (1,836 individuals) and *Stichopus chloronotus* (881 individuals). The least abundant species were *Holothuria nobilis* and *H. scabra*, both represented by only one individual (Table 1).

*H. atra* was not only the most abundant species (52%), it was also present at 96% of the sites (Table 1). With 1,836 individuals (representing 25% of all holothurians recorded), holothurians from the genus *Synapta* were the second most abundant species, and were observed in 18 out of the 23 sites surveyed (78% occurrence) (Table 1). *B. vitiensis* was the most frequently encountered species, found in 19 of the 23 sites (83%).

### Substrate types

The most common substrate recorded at each site along each transect (4,000 m<sup>2</sup>) was sand (39%), followed by seagrass (15%) and coral rubble (15%). Areas of algal aggregations accounted for 12% and live coral patches 9%, while rocks and dead coral combined made up 5% of the substrate.

Although the substrate types were highly diverse and patchy within the 23 surveyed sites, sandy

areas were present everywhere, representing at least 15% of the substrate cover composition.

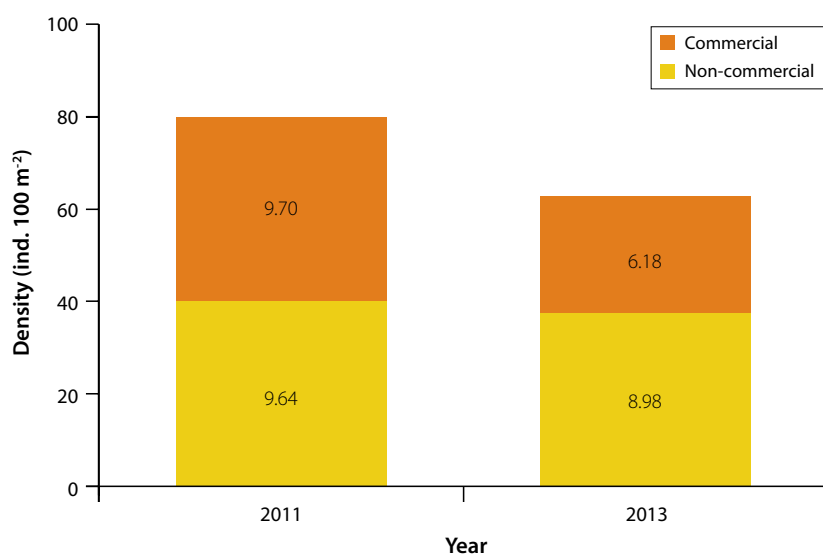
In general, the depth of the surveyed sites ranged from 0.5 m to 2 m, with a temperature ranging from 25°C to 27°C and visibility ranging from 1 m to 10 m. The sites were also characterised by the current strength, as well as the turbulence of the water surface.

### Commercial species

Following the commercial value key provided by Conand (2008), the identified holothurians in the current study were classified into four groups, indicating their commercial value: high, medium and low, as well as non-commercial. Among the commercially valuable species, two high-value species, *Holothuria nobilis* and *H. scabra*, were represented by one individual each, four species of medium value were represented by two individuals each, and eight species of low commercial value were represented by three individuals each. The remaining five species were without commercial value. Overall, species of commercial value were more abundant, with a total number of 5,511 individuals (70%), and those of no commercial value, consisted of only 1,977 individuals (30%) (Table 2).

**Table 2.** Total abundances and densities (ind. 100 m<sup>-2</sup>) of holothurians of high (red), medium (orange), low (yellow) commercial value, and no commercial (light grey) value observed between March and June 2013 in the shallow lagoons of Mauritius.

Species	Total abundance	Density (ind. 100 m <sup>-2</sup> )
<i>Holothuria nobilis</i>	1	0.00
<i>Holothuria scabra</i>	1	0.00
<i>Actinopyga echinites</i>	56	0.06
<i>Actinopyga mauritiana</i>	14	0.02
<i>Stichopus chloronotus</i>	881	0.96
<i>Stichopus herrmanni</i>	3	0.00
<i>Bohadschia marmorata</i>	2	0.00
<i>Bohadschia subrubra</i>	11	0.01
<i>Bohadschia vitiensis</i>	345	0.38
<i>Holothuria atra</i>	3,898	4.24
<i>Holothuria cinerascens</i>	47	0.05
<i>Holothuria fuscocinerea</i>	2	0.00
<i>Holothuria arenicola</i>	10	0.01
<i>Holothuria leucospilota</i>	240	0.26
<b>Subtotal</b>	<b>5,511</b>	<b>5.99</b>
<i>Actinopyga capillata</i>	3	0.00
<i>Holothuria hilla</i>	18	0.02
<i>Holothuria pervicax</i>	115	0.13
<i>Stichopus monotuberculatus</i>	5	0.01
<i>Synapta</i> spp.	1,836	2.00
<b>Subtotal</b>	<b>1,977</b>	<b>2.15</b>
<b>Total</b>	<b>7,488</b>	<b>8.14</b>



**Figure 2.** Commercial and non-commercial species' densities (ind. 100 m<sup>-2</sup>) in 2011 compared with 2013.

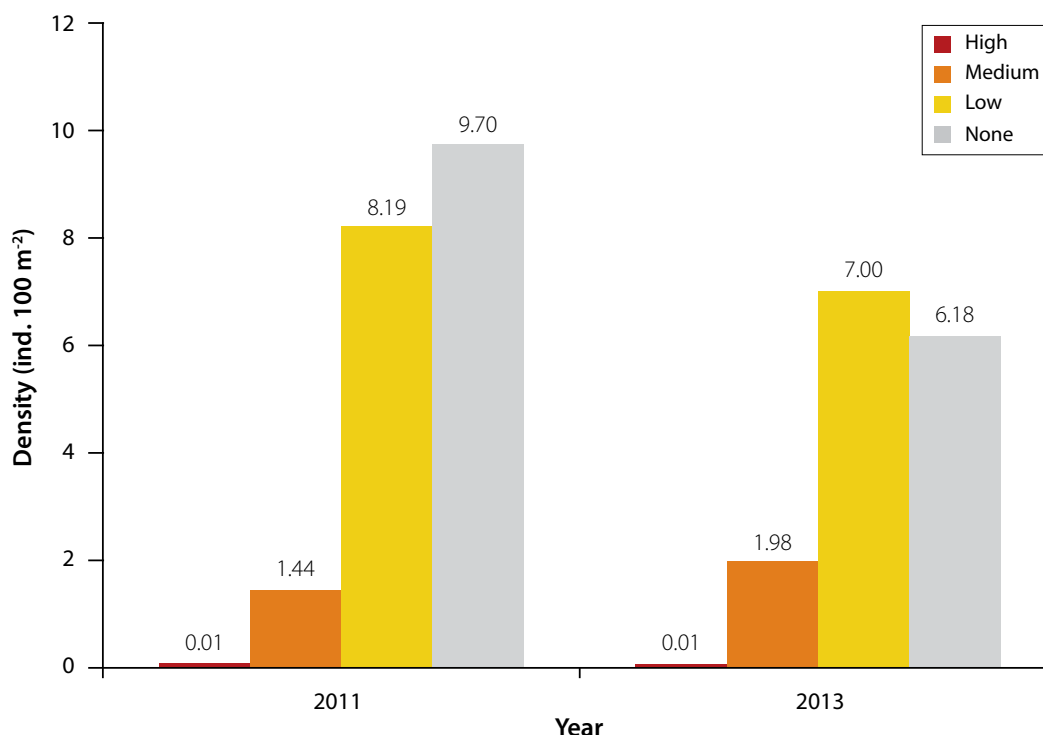
Species of low commercial value formed the largest group of holothurians assessed in the present study, and consisted mainly of *H. atra* (3,898 ind.) and *B. vitiensis* (345 ind.) (Table 2). Among the species of intermediate value, *Stichopus chloronotus* was the most abundant (881 ind.), followed by *Actinopyga echinites* (56 ind.) (Table 2). Among the species of no commercial value, the genus *Synapta* was most abundant (1,836 with 2 ind. 100 m<sup>-2</sup>), representing more than 80% of the non-commercial value species (Table 2). *H. pervicax* (115 ind.) and *H. hilla* (18 ind.) were among the non-commercial species.

A comparison of these results to those of Lampe (2013) in the western and southern shallow lagoons of Mauritius, shows a decreasing trend in density. Holothurian density (measured as individuals per 100 m<sup>2</sup>) was 19.33 ind. 100 m<sup>-2</sup> in 2011 and 15.16 ind. 100 m<sup>-2</sup> in 2013 (Fig. 2). The density of species of no commercial value decreased from 9.7 ind. 100 m<sup>-2</sup> in 2011 to 6.18 ind. 100 m<sup>-2</sup> in 2013, and the density of commercially important species from 9.64 ind. 100 m<sup>-2</sup> in 2011 to 8.98 ind. 100 m<sup>-2</sup> in the current study (Fig. 2).

The density of holothurians of medium value increased from 1.44 ind. 100 m<sup>-2</sup> in 2011 to 1.98 ind. 100 m<sup>-2</sup> in 2013, whereas the low value species decreased from 8.19 ind. 100 m<sup>-2</sup> (2011) to 7 ind. 100 m<sup>-2</sup> (2013) (Fig. 3). The density of species of high value did not change considerably (0.008 ind. 100 m<sup>-2</sup> in 2011 and 0.002 ind. 100 m<sup>-2</sup> in 2013) (Fig. 3).

### Species diversity

Overall, 19 different species of holothurians, including the genus *Synapta*, were inventoried in the present



**Figure 3.** Comparison of holothurian densities in Mauritius' shallow lagoons between 2011 and 2013. Species are grouped according to their respective commercial value: red = high; orange = medium; yellow = low; and grey = no commercial value (following the key of Conand 2008).

study. Following the previous study of Lampe (2013), four additional species were identified by spicules examination in the shallow lagoons of Mauritius for the first time: *Holothuria arenicola*, *H. scabra*, *H. fuscocinerea* and *Actinopyga capillata* (Fig. 4).

The highest species diversity was found among the eastern survey sites, whereas species abundance was lowest on this side of the island (Fig. 5). Similarly, the western side had a relatively high diversity of species ( $H' = 1.49$ ) whereas abundance was low (1,490 individuals). The highest holothurian abundance was found in the south (3,251 individuals) with a diversity of  $H' = 1.14$  (Fig. 5). On the other hand, the sites on the northern side showed the lowest diversity ( $H' = 0.21$ ) whereas abundance was the second highest (1,843 individuals).

## Discussion

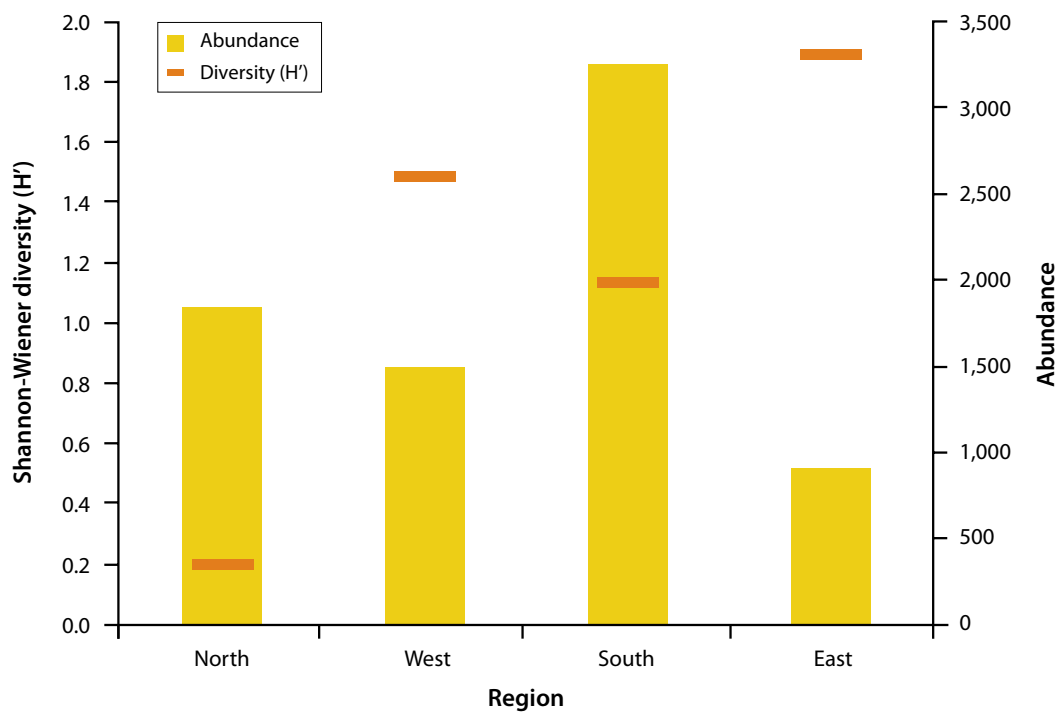
In this study, 18 species from the families Holothuriidae and Stichopodidae (Aspidochirotida) and 1 genus (*Synapta*) from Apodida were recorded. In general, similar patterns of species composition, especially of the six most abundant species recorded in this study, are typical of tropical shallow waters in the Mascarene Islands although they are distributed in a heterogeneous manner (Müller 1998; Conand and Mangion 2002; Conand 2004; Rowe and Richmond 2004; Conand et al. 2010).

## Habitat associations

Holothurian distribution in the current study did not show a clear correlation with habitats. Similar observations were made in the study conducted in 2011 in the western and southern shallow lagoons of Mauritius (Lampe 2013). It appears that the majority of species have a wide and diverse distribution, most probably due to a combination of physical, chemical and biological factors. However, there are two types of habitats that could favour species occurrences: the first type would consist of a high diversity of substrates, characterised by good visibility (6–8 m) as well as a depth range of 1–2 m. The second type would be more homogeneous and shallow (0.5–1.0 m), consisting mostly of two dominating substrates with high levels of turbidity (1 m visibility). This type of site is predominantly favoured by the species *H. atra*. In the former one, a variety of species may be encountered due to habitat heterogeneity. The loss of certain habitats could also influence species abundance and composition. In a study conducted by James (1982) in India, several species, such as *S. chloronotus*, which were abundant in 1927, had disappeared as a result of habitat destruction. Seagrass beds, for example, are essential during the early life history stages of sea cucumbers (Friedman et al. 2011). A loss of these settlement areas would have a severe impact on holothurian populations in shallow water areas (Eriksson et al. 2012).



**Figure 4.** Species that have been encountered for the first time in this study: a) *Holothuria arenicola*; b) *Actinopyga capillata*; c) *Holothuria scabra*; d) *Holothuria fuscocinerea*. (Photos: K. Lampe-Ramdoe)



**Figure 5.** The abundance of holothurians and the Shannon-Wiener diversity index ( $H'$ ) for the four regions of Mauritius: north (4 sites), west (7 sites), south (6 sites) and east (6 sites).

### Commercial value

Because species of commercial importance are the main targets of fishers, their densities were expected to be lower than species without commercial value. However, at all four regions (north, west, south, east) around Mauritius, holothurians of commercial importance were, by far, more abundant (5,271 individuals) than those without (2,217 individuals). It has been suggested that overexploitation of high-value commercial species leads to exploitation of low-value species, such as *H. atra* and *H. leucospilota* (Conand 2004; Moore 1998). This shift from high- to low-value species, and from easy access to deeper or more remote sites, are signs of an unsustainable fishery that needs urgent management attention (Purcell et al. 2013). Other signs of overexploitation are declining catches and decreases in sizes of individuals (Conand 2004).

Besides climatic impacts that degrade habitats of sea cucumbers, anthropogenic impacts could also account for holothurian occurrence and distribution in lagoons. For example, in sunbathing zones in front of resorts there is minimal collection of sea cucumbers by fishers, but the hotels themselves sometimes remove the holothurians, thus reducing their population densities.

### Species diversity

The eastern side of the island had the greatest species diversity due, most probably, to the large extent of the lagoon that would harbour a large variety of habitats. The lagoon in the east extends to 5 km in width and sites are, therefore, characterised by varying depths, current patterns, substrate types, visibility and other physical parameters. Various holothurian species could be using this diversity of habitats and environments in contrast to other lagoons. Furthermore, sea cucumbers within the eastern sites are naturally protected from exploitation because of the relative inaccessibility of these sites due to their depth (4–6 m) and remoteness. This study shows that lagoons that were characterised by shallow water and a homogenous substrate had low holothurian diversity. However, a few species such as *H. atra* were highly abundant, due most probably to their high adaptability to a variety of habitat types. It was observed that very few other species would occur in areas where *H. atra* was abundant. This dominance could be preventing other species to recruit successfully within the same habitat.

Generally, the relatively high abundances of *H. atra* and *S. chloronotus* might be due to their reproduction rate. In fact, they reproduce faster than other species that inhabit the same lagoon. Another point

to consider is the establishment of new ecological niches for other species once the population stock of a certain species under exploitation is depleted or drastically reduced. As a consequence, species with a wider range of possible habitats, such as *H. atra*, *H. leucospilota* and *Synapta* spp., may settle in new potential habitats or attain higher densities due to less interspecific competition.

### Conclusion

Little research was done on holothurian abundance and diversity prior to 2007 in Mauritius when this fishery was opened as a commercial fishery on a pilot basis (AFRC 2011). This study has provided baseline data for further investigations. It is of utmost importance to gather sound scientific data for the management and protection of sea cucumbers in Mauritius in order to address the decline in holothurian stocks. It is better to adopt the precautionary principle, and the moratorium in Mauritius should be maintained to prevent the collapse of the sea cucumber fishery.

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