

Sea cucumbers on La Reunion Island fringing reefs: Diversity, distribution, abundance and structure of the populations

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Introduction

A broken line of coral formations, about 25 kilometres long, are found off the western coast of La Reunion Island in the Indian Ocean. As the island's only reefs, these structures are a few hundred meters wide at most, and have a modest surface area (about 12 km²). La Reunion's main coral structures are the Saint Leu, Etang-Salé, and Saint Pierre reefs and the Saint Gilles/La Saline reef system; the latter is the most extensive, measuring 9 km. These reefs are very important in terms of natural heritage and tourism and with regards to international, national and regional research. Inventories of the biodiversity of the diverse zoological groups in these coral ecosystems have begun. This needs to be done so that the many types of reef degradation can be monitored, particularly those caused by humans.

Some relatively dated information exists for a few sea cucumber species (Cuet et al. 1989; Naim and Cuet 1989; Semple 1993). In addition, studies have been made on the biology of various sea cucumber populations (e.g. *Holothuria atra*, *H. leucospilota*, *Stichopus chloronotus*), particularly the influence of scission on these populations (Conand et al. 1997; Conand et al. 1998; Jaquemet et al. 1999; Uthicke et al. 2001; Conand et al. 2002). However, no inventory of species in various biotopes has been made nor has a list of the dominant species and population structures been compiled until this recent survey (Mangion 2002). A synopsis of these data is presented in this paper.

Material and methods

The species inventory was made using a wide range of information and photos taken over the past 10 years, which the authors collected from various people involved in "reef research" on La Reunion.

To get data on dominant sea cucumber species abundance and population structures, we limited ourselves to the Saint Gilles/La Saline reef where sampling was conducted at three sites that our laboratory monitors on a regular basis (i.e. Toboggan

(Tb) and Trou d'Eau (Tr)). These sites are considered to be relatively healthy, and Planch'Alizes (Pl) is a site with a high level of eutrophication. At each site, transects were made in two biotopes: the back reef hollow (Station 3) and the inner reef flat (Station 2). The external reef flat (Station 1) will be studied later.

The quadrat method was used for this study. As during previous studies by Cuet et al. (1989) and Semple (1993), a 20 m² surface area (2 m x 10 m) was sampled at each station. Counting and weighing specimens was done by going along a 10 m x 1 m corridor in one direction and then sampling another 10 m x 1 m corridor in the opposite direction. These elongated 10 m x 1 m quadrats, located side by side parallel to the beach, were marked using two 50-meter tape measures laid out on the bottom, one meter apart and attached at either end. All the sea cucumbers in the quadrat were counted and weighed. The stations surveyed corresponded to the median zone of each biotope (inner reef flat or back reef hollow) for the study sites.

The quadrats were surveyed during the summer season, from 20 March to 9 May 2002.

Population structures were obtained from live weights, measured on-site during sampling or during additional experiments. Each specimen was weighed using a spring scale and tray. Weight frequency distributions then made it possible to compare population characteristics.

Results

Distribution and abundance

Table 1 lists 17 sea cucumber species collected from or photographed on La Reunion reefs, as well as certain aspects of their distribution and abundance.

Several categories of species became apparent, depending on classification criteria based on: 1) observation frequency (i.e. the number of stations where the sea cucumber was observed in comparison to the total number of stations) and 2) abundance (i.e. species density).

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Table 1. List of La Reunion Island sea cucumber species with reefs and observation sites. Site where species is: + very rare, ++ quite rare, +++ abundant, +++++ very abundant

	St. Gilles-La Saline				St. Leu	Étang Salé	St. Pierre	Dominant populations and main biotopes
	Toboggan	Planch'Alizés	Trou d'eau	Other				
<i>Actinopyga echinites</i>	++	+	+	Hermitage sea grass bed	+	+	+	outer reef flats at various stations
<i>Actinopyga mauritiana</i>	+	+	+			+	+	outer reef flats and reef front
<i>Bohadschia vitiensis</i>		+	++			+		back reef hollow
<i>Holothuria atra</i>	+	++++	++		+		+	back reef hollow
<i>Holothuria leucospilota</i>	+++	++++	+++		+++		+	mainly inner reef flat; outer reef flat and back-reef
<i>Holothuria pervicax</i>	+			Hermitage sea grass bed				inner reef flat
<i>Holothuria hilla</i>					+	+		inner reef flat
<i>Holothuria nobilis</i>	+	++	+	Outer slope of Cap Homard at 15 m	+			reef flats and outer slope
<i>Holothuria difficilis</i>	+							outer reef flat
<i>Holothuria cinerascens</i>	+			Boucan Canot – Cap Homard – Hermitage sea grass bed				area with heavy wave action
<i>Holothuria</i> sp.1			+					back-reef
<i>Holothuria</i> sp.2	+	+						reef flat
<i>Stichopus chloronotus</i>	+	++	++++	small 15 m deep canyons. 3 basins	++	++	+	back reef hollow, reef flats, outer slope
<i>Stichopus hermanni</i>								
<i>Stichopus horrens</i>		+	+					
<i>Thelenota ananas</i>				Grand Fond, at a depth of 15 m				outer reef flat
<i>Synapta maculata</i>	++	+++	+		++	+	+	back reef and reef flats

Table 2. Abundance (specimens per 20 m²) for main species, by station and by site, and overall percentages. Stations: 2 inner reef flat, 3 outer reef flat. Sites: Tb Toboggan, Pl Planch'Alizés, Tr Trou d'Eau.

Station	<i>Holothuria leucospilota</i>	<i>Holothuria atra</i>	<i>Synapta maculata</i>	Total
Tb 2	7	0	0	7
Tb 3	0	0	1	1
Pl 2	20	5	0	25
Pl 3	8	132	1	141
Tr 2	5	1	0	6
Tr 3	3	1	1	6
Total	43	139	3	185
Each species' percentage in comparison to Holothuridea total	23.24	75.13	1.62	100

The first category corresponded to species that were both frequent and abundant. The dominant species were *Holothuria atra*, *H. leucospilota*, *Actinopyga echinites*, *Stichopus chloronotus* and *Synapta maculata*. Detailed information on their characteristics at the Saint Gilles/La Saline reef are given below.

The second category corresponded to those species that were fairly frequent and whose abundance could vary. Sparse populations of *Actinopyga mauritiana* were observed on the outer reef flats on a regular basis.

Holothuria nobilis, which always had white ends on its teats — a problem for its taxonomy as they are black in specimens in the Pacific (Conand 1989) — was also generally a solitary species.

The third category corresponded to species that were fairly rare.

Because *Holothuria pervicax* is beige, and is nocturnal and solitary in its habits, it is difficult to see in the daytime. It is easy to recognise due to its large Cuvierian tubules. On La Reunion, it was most often found in seagrass beds or coral rubble areas on the inner reef flat.

Holothuria difficilis is a small cryptic species whose population was fairly dense under boulders. Its Cuvierian tubules are very thin.

Holothuria cinerascens is a medium-size species whose outstanding feature are its dendritic tentacles. It was the only filter feeding aspidochirote found, and was occasionally abundant under boulders where there is strong wave action.

Bohaschia vitiensis was only abundant on a limited part of the back reef at the Trou d'Eau station where it dug down into the sediment.

Individual *Holothuria hilla* specimens were observed near seagrass beds or in the coral rubble.

Stichopus hermanni was rare. The photos come from the outer reef flats at Planch'Alizes.

Stichopus horrens is nocturnal and solitary.

The fourth and final category covered two rare species. *Holothuria* sp.1 was collected on 6 March 2002 in the sediment at the Trou d'Eau back reef and *Holothuria* sp.2 was photographed twice at the Toboggan and Planch'Alizes stations.

Thelenota ananas is rare on La Reunion's outer reef flats. One specimen was recorded at Grand Fond at 15 m.

Table 2 and Figure 1 show total specimen abundance for the main three species — *Holothuria atra*, *H. leucospilota* and *Synapta maculata* — at Saint Gilles/La Saline reef along with the relative size of each species group. Certain characteristics did appear.

Table 2 and Figure 1 also show that sea cucumbers are not evenly distributed throughout La Reunion's reefs. In fact, the dominant species that were found during this field survey were widely distributed, depending on the reef zone and sampling site. In general, sea cucumber populations appeared to be particularly abundant at the so-called degraded Planch'Alizes site. In fact, about 90 per cent of the sea cucumbers were recorded from there. A closer look at the data on each species shows that this particular abundance could be explained by the *Holothuria atra* population in the Planch'Alizes back reef. In fact, these specimens accounted for nearly 80 per cent of the sea cucumbers found at the site, all stations combined. Moreover, this population reached a density of 6.6 specimens/m². This high density signals a very unique population at the station. In fact, at the inner reef flat station of the same site, the *Holothuria atra* density was only 0.25 specimens/m². In addition, no *Holothuria atra* specimens were recorded at either Toboggan or Trou d'Eau during this survey. Calculated densities were on the order of 0.05 specimens/m² for both the inner reef flat and the back

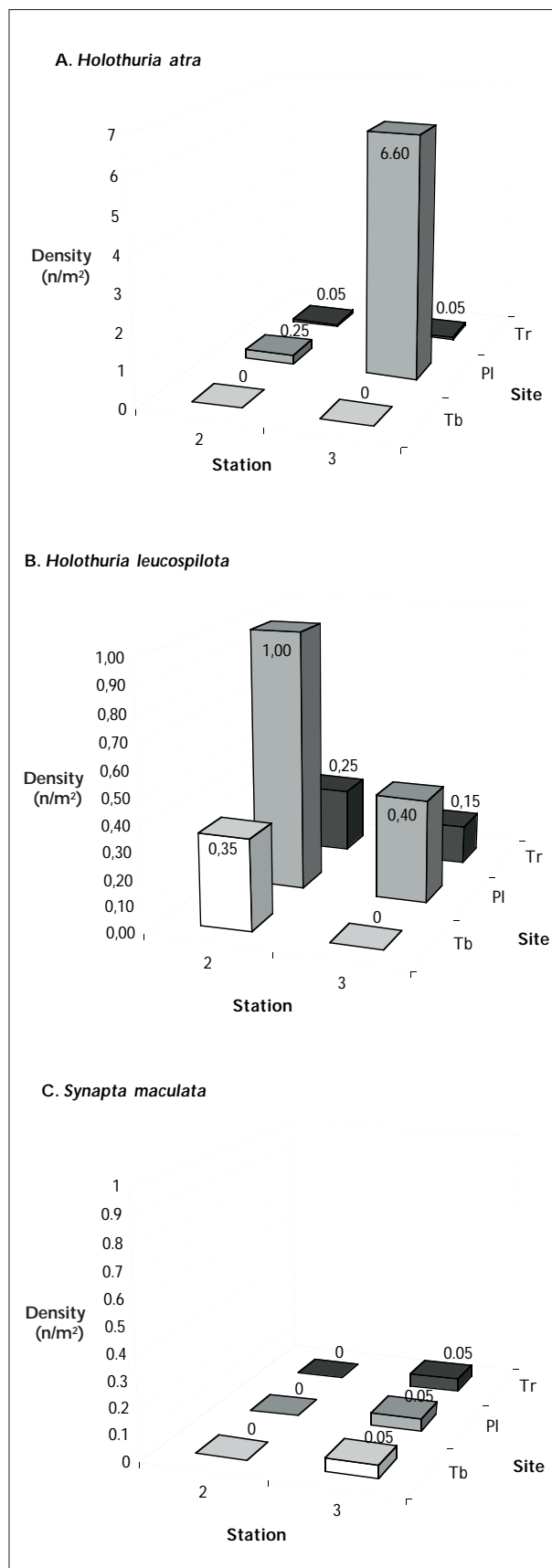


Figure 1. Density of the three dominant sea cucumber species at Saint Gilles/La Saline reef. Stations: 2 inner reef flat, 3 back reef. Sites: Tr Trou d'Eau, Pl Planch'Alizes, Tb Toboggan.

reef hollow (i.e. much lower than those at the Planch'Alizes back reef hollow).

Holothuria leucospilota was another sea cucumber species that was fairly numerous at Planch'Alizes. It was also more abundant on the inner reef flat at this site, where it reached densities of 1 specimen/m². This was also the highest density recorded at St. Gilles/La Saline reef for this species. This population appeared to be fairly unusual in that the densities recorded elsewhere were much lower (i.e. from 0 to 0.4 specimens/m²).

The fact that *H. atra* had a higher density than *H. leucospilota* can be explained by the smaller size of *H. atra* specimens. Overall, densities for both species were much higher at Planch'Alizes than at other sites. This site seems to be favourable for sea cucumbers, probably because of the high level of eutrophication, which results in a greater availability of organic material resources.

Finally, the species seemed to be distributed differently depending on the reef zone. *H. atra* and *Synapta maculata* were found in the back reef hollow, while *H. leucospilota* was located on the inner reef flat.

Population structures of the dominant species

Table 3 gives the weight characteristics by site and by station for the principal species sampled. Live weight frequency distributions are only shown for *Holothuria atra* (Fig. 2) and *H. leucospilota* (Fig. 3), as the number of specimens from other species was too low.

The structures of the two *Holothuria atra* populations (i.e. the inner and outer reef flat populations), differed greatly in terms of weight frequencies. Specimens from the back reef hollow population were, in fact, much smaller. Their mean weight was half that of the inner reef flat population — going from a modal weight of 51 g for Station Pl 3 to a modal weight of 110 g for Pl 2. The low number of specimens at the other stations where *Holothuria atra* was observed made it impossible to make any comparison with the Planch'Alizes populations.

Table 3. Live weight characteristics of main sea cucumber species at Saint Gilles/La Saline reef. Stations: 2 inner reef flat, 3 back reef; sites: Tr Trou d'Eau, Pl Planch'Alizes, Tb Toboggan.

Species	Variables	TR 2	TR 3	PL2	PL3	TB2	TB3
<i>Holothuria leucospilota</i>	Mean weight (g)	770	320,5	422,6	341,5	382,1	
	Min. weight (g)	610	142	140	72	250	
	Max. weight (g)	980	500	690	660	500	
	n	4	4	19	8	7	0
<i>Holothuria atra</i>	Mean weight (g)	162	54	110	51		
	Min. weight (g)	162	54	80	6		
	Max. weight (g)	162	54	140	130		
	n	1	1	5	132	0	0
<i>Synapta maculata</i>	Mean weight (g)		500		610		480
	Min. weight (g)		450		610		480
	Max. weight (g)		550		610		480
	n	0	2	0	1	0	1

Table 4. Live weight characteristics for the species *Actinopyga echinites* and *A. mauritiana* at Planch'Alizes outer reef flat station (Pl 1)

Species	Variables	Pl 1
<i>Actinopyga echinites</i>	Mean weight (g)	138.3
	Min. weight (g)	84
	Max. weight (g)	227
	n	13
<i>Actinopyga mauritiana</i>	Mean weight (g)	374
	Min. weight (g)	270
	Max. weight (g)	440
	n	5

In contrast to *H. atra*, both *Holothuria leucospilota* populations at Planch'Alizes followed the same weight distribution trend. Modal weights only differed slightly with 422 g at Pl 2 and 341 g at Pl 3, and both curves followed the same trend, with a maximum number of specimens between 300 and 400 g. In the same way, weight frequencies at the Toboggan inner reef flat station had the same shape as previous ones and the modal weight value was also similar. For those reasons, the two different *Holothuria leucospilota* populations seemed to have similar structures.

In addition, the abundance of *Actinopyga echinites* and *A. mauritiana* on the Planch'Alizes outer reef flat justified sampling, the results of which are presented in Table 4. *Actinopyga echinites* was found in the transition zone between the inner and outer



Figure 2. Live weight frequency distributions for *Holothuria atra* at Planch'Alizes site

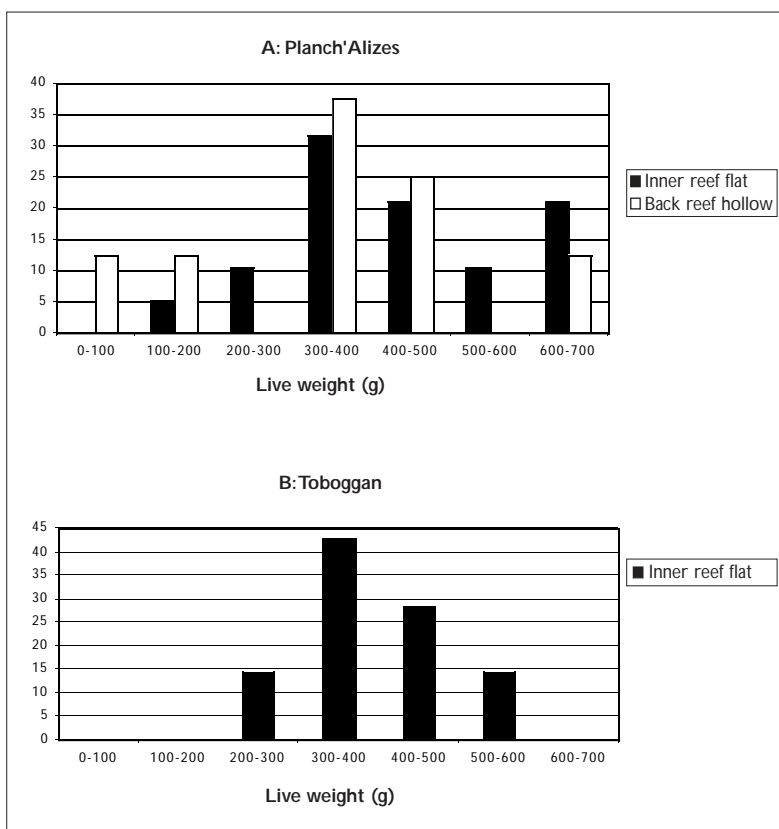


Figure 3. Live weight frequency distributions for *Holothuria leucospilota*:
 A: Planch'Alizes inner reef flat and back reef
 B: Toboggan inner reef flat

reef flats, while *A. mauritiana* was found in the surf zone (reef front), where the small starfish *Asterina burtoni* can be found under the boulders (Emeras and Falquet 2002). *A. echinites* was more abundant and smaller (mean weight about 140 g) than *A. mauritiana* (mean weight about 375 g).

Discussion

This initial inventory of 17 species on La Reunion is probably not comprehensive. In particular, no dendrochirote sea cucumbers have been collected yet and small sized species were probably underestimated. In addition, most observations came from the Saint Gilles/La Saline reef, generally on the reef flats and back reef.

For these reasons, the most common species are *Holothuria atra*, *H. leucospilota*, *Actinopyga echinites*, *Stichopus chloronotus* and *Synapta maculata*. They were also the most abundant species. However, frequency and abundance classification can differ. For example, when *H. cinerascens* was observed in the slab or rocks with heavy wave action biotopes, it was abundant. In the same way, *H. difficilis*, a small cryptic species, could be very abundant under boulders on the outer reef flat. It would also be wise to identify the two *Holothuria* species observed recently.

Species ecology generally corresponded to the biotopes occupied elsewhere, as these are all species found throughout the tropical Indo-Pacific region (Conand 1989, 1998).

Species diversity was relatively low, and five of the 17 species were dominant.

The results on abundance obtained here can be compared to existing data for La Reunion (Cuet et al 1989; Semple 1993), which are rare outside of some studies on sexual reproduction and scission in certain populations of *H. atra*, *H. leucospilota* and *S. chloronotus* (Conand 1996;

Conand et al 1997; Conand et al 1998; Conand et al 2002; Hoareau and Conand 2001; Jaquemet et al 1999; Uthicke et al 2001). Semple (1993) presented detailed information on abundance for the same three species — *H. atra*, *H. leucospilota* and *S. maculata* — using quadrats every 20 metres in radials

going from the shore to the reef front. He gave the results for two sites, Planch'Alizes and Trois Chameaux (TC), a site which is very close to Toboggan and which has the same characteristics. According to his results, there were no *H. atra* specimens at TC, as had already been mentioned by Cuet et al (1989); it was very abundant at Pl and a maximum number were found at 80 m from the shore, corresponding to Pl 3 (i.e. some 110 specimens/m²). It considerably decreased in numbers toward Pl 2, which is comparable to our data. *H. leucospilota* was found at the various stations studied by Cuet et al (1989) and Semple (1993), as also shown here. The highest density was at Planch'Alizes at about 140 m with 25 specimens/20 m², with numbers decreasing towards the reef front. At TC, the maximum density was at about 120 m with 10 specimens. These densities are very close to those measured in 1997 (Conand et al. 1997) which found a higher density (0.96 specimens/m²) at Trou d'Eau. The density values for these two species are consistent with those from our study. This relative stability had also been demonstrated on an annual basis for *H. atra* at Pl 3 (Jaquetmet et al 1999). *S. maculata* was abundant 60 m from the shore (Pl 3) with 10 specimens/20 m², but the density dropped to two specimens, which is also the TC value (Semple 1993). These values are much higher than those observed here and must be confirmed by a large sampling.

With regards to the population structure of the dominant species at the Saint Gilles/La Saline reef (*H. atra* and *H. leucospilota*), the difference in live weight distributions for *H. atra* between the back reef (modal weight of about 50 g) and reef flat (modal weight of about 110 g) stations confirms Conand's 1996 results and can be correlated to the frequency of scission, a phenomenon that brings about reduced specimen weights and high densities in the back reefs, where rates are high. *Holothuria leucospilota* populations from various stations were, in contrast, very similar. Conand et al. 1997 demonstrated that scission also took place in this species, but this did not seem to affect the various populations at the Saint Gilles/La Saline reef. Unlike *H. atra*, there did not seem to be any major differences between the *H. leucospilota* populations.

Comparisons with other Indian Ocean sites can be made with Madagascar, where diversity is much higher. In fact, Cherbonnier (1988) described 122 species, 47 of which were new to science, and Conand (1998) listed 28 exploited species (i.e. only those which are both large in size and whose populations are dense and readily accessible). Richmond (1997) presented 26 species in his guide to east African coasts and islands. In New

Caledonia, Conand (1989) recorded some 49 aspidochirote sea cucumber species and Guille et al. (1986) described 54 species of various orders.

In conclusion, the low level of diversity observed on La Reunion can be linked to the fringing reefs' relatively recent appearance, their reduced size and low level of structure. In fact, habitat size appears to be a primary factor for biodiversity, as has been demonstrated with fish and coral in the tropical Indo-Pacific region (Bellwood and Hughes 2001). However, the high densities of certain populations indicate an important ecological role, which will be assessed in later studies.

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Economic reasons, ecological actions and social consequences in the Mexican sea cucumber fishery

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Introduction

Increasing attention is being given to the effects of international trade on the environment, especially in situations where biodiversity conservation is opposed to export-led industries such as fisheries. Even many small-scale fisheries are not an exception. When a natural resource represents high revenues to artisanal fishermen, fishing effort rapidly increases and fish stocks become overexploited. This is what Grainger and Garcia (1996) call the 'boom and bust' cycle of fisheries. When an open-access fishery develops, it passes through four phases:

- Undeveloped: the fishery commences and stocks remain under-exploited.
- Developing: the catch keeps on growing and the industry flourishes.
- Mature: the level of captures becomes constant but more and more fishing effort is needed to maintain these levels.
- Senescent: captures decrease in spite of increasing fishing effort. The stocks become overharvested and a number of jobs are put at risk.

Once this cycle finishes, a new fishing ground, a new stock, or a new fishery is developed, and the cycle starts all over again. Sea cucumber fisheries around the globe have gone through this cycle (Conand 1998, 2001). In order to find a solution to this problem, the United Nations organised the 1992 Conference on Responsible Fishing, which

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