# Holothurian communities of Reunion Island's reef complex within the Natural Marine Reserve

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## Abstract

One of the long-term objectives of the management plan for Reunion Island's Natural Marine Reserve is to monitor holothurians, a taxon that plays a major role on the reefs. This study gave the first large-scale mapping (km scale) of the distribution of holothurian communities on the reef flats of La Saline/L'Hermitage. Surveys used the fixed-point method in seven habitats. Of the 14 species of sea cucumbers surveyed, three were the most abundant: *Holothuria leucospilota*, *Holothuria atra* and *Stichopus chloronotus*. *Synapta maculata* almost disappeared. In terms of habitat, 87% of holothurian individuals were found in the back reef zone in areas of high eutrophication, with a maximum recorded at the Planch'Alizés site (1015 ind./100 m²). Rare specimens were concentrated on the outer reef flat, inner reef flat, and inner reef flat, detritic zones.

## Introduction

Reunion Island is a volcanic island in the western Indian Ocean, located around 700 km east of Madagascar and 170 km west-southwest of Mauritius at S 21° 07' and E 55° 32'. Together with Mauritius and Rodrigues, Reunion lies within the Mascarenes Archipelago. It has a coastline of around 210 km, with only 25 km of discontinuous coral ecosystems on the west coast (Montaggioni and Martin-Garin 2020). The total surface area of the coral reefs is 12 km² (Montaggioni and Faure 1980).

The main reef complexes of Reunion Island are the fringing reefs of L'Hermitage/La Saline (the largest), Saint-Leu, L'Étang-Salé and Saint-Pierre. They are exposed to strong hydrodynamic conditions, such as the swell generated by the southeasterly trade winds during the dry season or by tropical cyclones during the wet season. The tides are semi-diurnal, with a maximum tidal range of 0.9 m (Chabanet et al. 2000). In addition, the reef is an interface between the watershed and the oceanic environment due to its narrowness. It is, therefore, directly or indirectly impacted by human activities, such as increased run-off and eutrophication (Tessier et al. 2008).

Since the early 1970s, signs of degradation of benthic populations have been observed (Faure 1982; Cuet et al. 1988). Now, the coral reefs of Reunion Island are monitored by a number of scientific organisations and associations including Tropical Marine Ecology of the Pacific and Indian Oceans, associations such BestRun and l'Agence de Recherche pour la Biodiversité de La Réunion, the Natural Marine Reserve of Reunion and Vie océane. They are also studied by participatory science associations such as Reef Check (Corbel and Neff 2022).

Worldwide, 1774 species of sea cucumbers have been recorded (WoRMS 2023). At Reunion Island, four of the seven known orders are represented (Miller et al. 2017; Purcell et al. 2023). Sea cucumbers have been extensively studied there, especially for their reproductive (Uthicke 1994; Gaudron et al. 2008; Conand et al. 2016) and their feeding behaviour (Kolasinski et al. 2010; Cuvillier 2016). The recent PhD thesis of Pierrat (2023) analysed the genetic, feeding and environmental factors driving the heterogeneous distribution, over space, of *Holothuria atra*, *H. leucospilota* and *Stichopus chloronotus* as these species were found in patches and reach very high densities (> 1 individual/m²) at some locations. However, most of the studies to date, have given scattered information about diversity and abundance (Conand 2003; Conand et al. 2010; see also Pierrat 2023) and no large-scale (kilometric) data is available on sea cucumber distribution. *Holothuria atra* and *H. leucospilota* are known to be the two dominant species on Reunion Island (Conand and Mangion 2002; Pierrat 2023). New information is needed to optimise benthic communities' monitoring and protection, and the present study aims at giving a first overview of the distribution of sea cucumber populations over the L'Hermitage/La Saline coral reef complex.

## Methodology

The study site is the largest reef formation on Reunion Island (150 ha of reef flats, 81 ha of back reef areas) and extends over 8 km from the mouth of Saint-Gilles ravine to Trois Bassins ravine. Its area represents 48% of the coral reefs on the island (Naim et al. 2000). At its centre, L'Hermitage pass divides the complex into two sectors: L'Hermitage (north) and La Saline (south). The reef habitats (146 types) defined by Nicet et al. (2017) were simplified in order to give an easy-reading mapping. This simplification led to the definition of seven main habitats (Fig. 1).

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Data were acquired with several field surveys. The BestRun Association agreed to share their field data acquired in October and November during the UTOPIAN project,[8] for habitats "Inner reef flat" (137 stations), "Inner reef flat detritic" (87 stations), "Outer reef flat" (51 stations), "Inner reef flat with dense coral colonies" (43 stations), and "Back reef with coral colonies" (23 stations). The MAREX firm agreed to share their field data acquired for "Back reef with seagrass on detritic substrate" (49 stations) in February. The field survey for this study was targeted on the back reef (241 stations) in March. All of these surveys used the fixed-point method, named CORRAM (COral Reef Monitoring Network) funded by l'Initiative Française pour les Récifs Coralliens (IFRECOR) (Pinault et al. 2017; Pinault and Broudic 2023; Kolasinski et al. 2024).

The fixed-point method used here is a rapid assessment method because the number of metrics surveyed was low (species and numbers of holothurians and sea urchins, depth, habitat and current assessment). The data collected and pooled were then interpolated, using a large number of stations, to produce an accurate map. The first step was to determine the position of the survey sites in each habitat, using QGIS (QGIS Association 2022). A 50-m grid was positioned over the entire study area, creating a surface area of 2500 $m^2$. The GPS coordinates of the centres of each grid square will be recorded and will define the station to be studied. In total, 631 sites were studied (Fig. 2), and each represents an area of 100 $m^2$. Habitat type was confirmed *in situ* by visual check. In the event of any change, the habitat type was moved to the nearest corresponding substrate. All visible holothurians were identified and counted (Fig. 3A). In the event of very high abundance (i.e. >100 individuals over ¼ of the circle), count was stopped at the first quarter (Fig. 3B). If any doubt arose about the identification of a specimen, a photo was taken for later analysis. Inverse distance weighted spatial interpolation was used in this study to produce distribution maps of holothurian populations.

# Results

## *Species richness*

Across the entire reef complex, 45,162 individuals were counted. A list of 14 species recorded and their abundance are presented in Table 1. *Holothuria leucospilota*, *H. atra* and *S. chloronotus* were the three most abundant species, accounting for 97% of all individuals on the reef complex. *Stichopus maculata*, formerly abundant on fringing reefs (Conand and Mangion 2002; Conand 2003), accounted for only 19 individuals. The back reef, with a surface of 63 ha, had the highest species richness with 10 species (Fig. 4). It was the most common habitat, with 241 sites recorded. The back reef with coral colonies, covering 13 ha, had the lowest richness, with four species recorded, but was also the least common habitat, with only 23 sites. The back reef with seagrass on detritic substrate, had the smallest surface area (5 a) but has a richness of 6 species.

## *Spatial distribution of holothurian populations*

Distribution is variable both inter- and intra-habitat. Figure 4 shows the results for all species and highlights "patches" of individual density. The majority of species were found in the La Saline sector, in the back reef habitat of the post-reef zone. This density is variable, both between and within habitats, but also between sectors. It also shows the "rare" species, from which the dominant species *Holothuria leucospilota, H. atra and Stichopus choloronotus* have been removed to highlight them. Their spatial distribution is different. These species are close to the reef crest on the outer reef flat. Several aggregation zones have been observed, with densities ranging from 0 to 1015 individuals/100 $m^2$, divided into four groups (Fig. 5):

1. ≥ 1000 individuals/100 $m^2$ at Planch'Alizés
2. Between 500 and 1000 individuals/100 $m^2$ between MNS La Saline, Bodega and Lux sites
3. Between 200 and 500 individuals/100 $m^2$ at MNS La Saline and MNS L'Hermitage sites
4. ≤ 200 individuals/100 $m^2$ at Passe de L'Hermitage site.

# Discussion

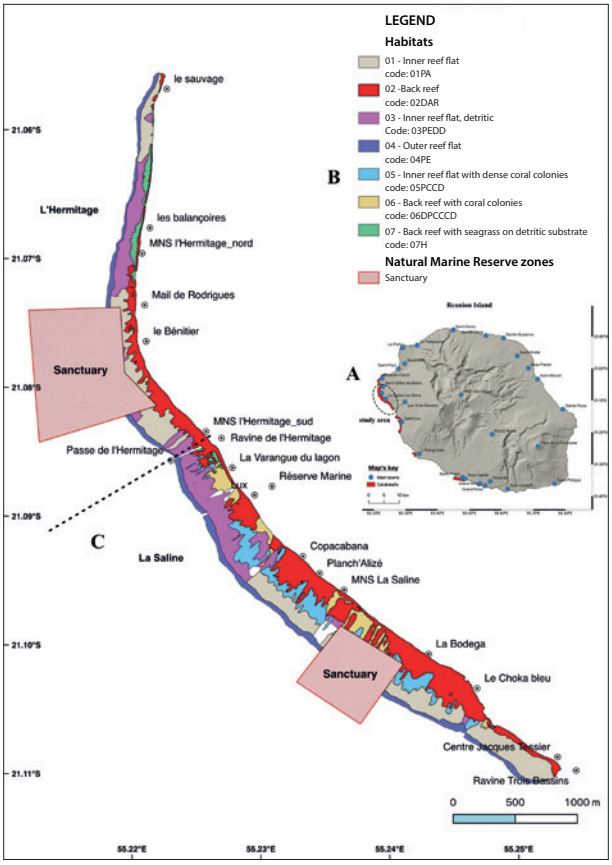
## *Species richness*

In 2002, 17 species of Holothuroidea were reported on the reefs of Reunion Island (Conand and Mangion 2002; Conand 2003; Conand et al. 2010). In 2018, it reached 38 species (Conand et al. 2018). This difference corresponds to an increased sampling effort between these dates, and the inclusion of reef slopes.

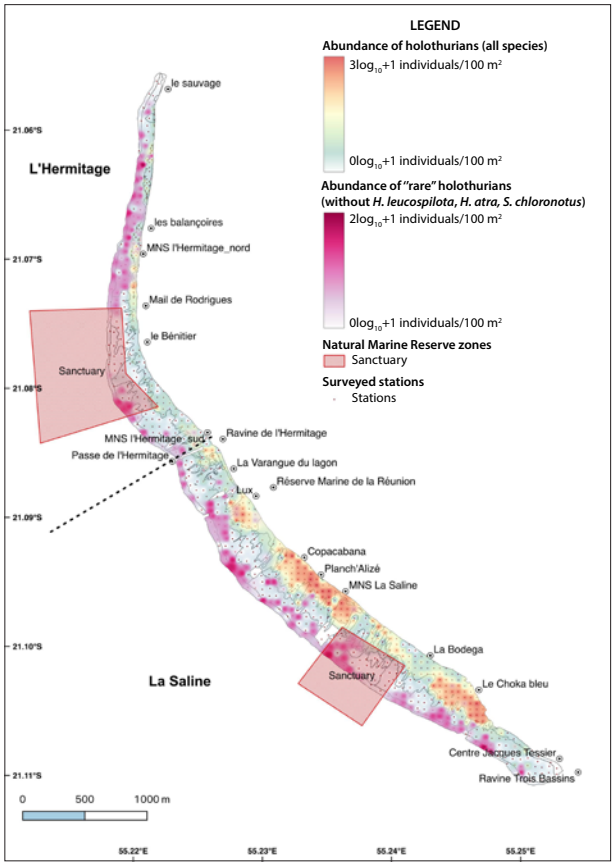
## *Community spatial pattern*

Three species of holothurian massively dominate the La Saline/L'Hermitage reef complex: *Holothuria leucospilota, H. atra and Stichopus chloronotus*. The collapse of *S. maculata* populations could be linked to the upsurge in sea turtle populations since 2007, particularly *Chelonia mydas* and *Eretmochelys imbricata*, which have increased significantly (Soria et al. 2015). A green turtle has been observed feeding on two specimens of *S. maculata* (Mulochau et al. 2021). The density of *S. chloronotus* on Reunion is among the highest worldwide (Pierrat 2023; Pierrat et al. 2023). It has a dominant asexual mode for reproduction (Pirog et al. 2019; Pierrat 2023). Pierrat et al. (2023) analysed a multiseasonal monitoring that revealed the three species have their own dynamics, with *H. leucospilota* increasing in density, *H. atra* remaining stable, and *S. chloronotus* decreasing since the 1990s. *Stichopus chloronotus* seems to be a specialist while the two other are generalists. The drastic diminution of *S. chloronotus* populations could be linked to over 30 unstudied factors such as illegal harvesting, disease, predation and climate change (Pierrat 2023).

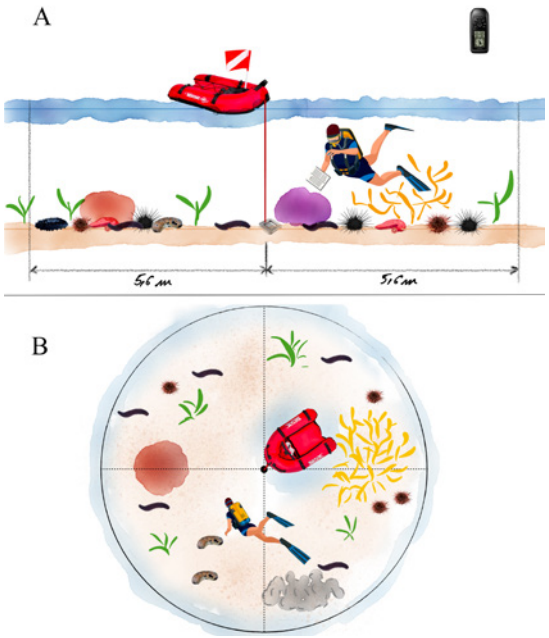
[8] The UTOPIAN project aims to map the state of health of Réunion's coral reefs. It is a scientific project for the conservation of natural environments led by the BestRun Association (ecology students) and the University of La Réunion.




**Figures 1.** A: Reunion Island; B: coding system; C: simplified habitat map (Nicet 2016) of the La Saline/ L'Hermitage reef complex.



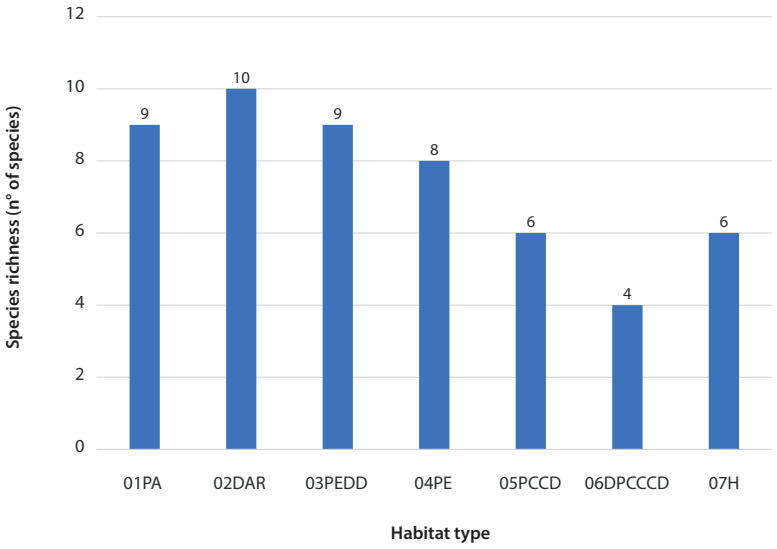

**Figures 2.** The spatial distribution of all holothurian communities, as well as that of "rare" specimens, where *Holothuria leucospilta, H. atra* and *Stichopus chloronotus* have been removed from the calculation to highlight them. The stations surveyed are indicated by black dots.



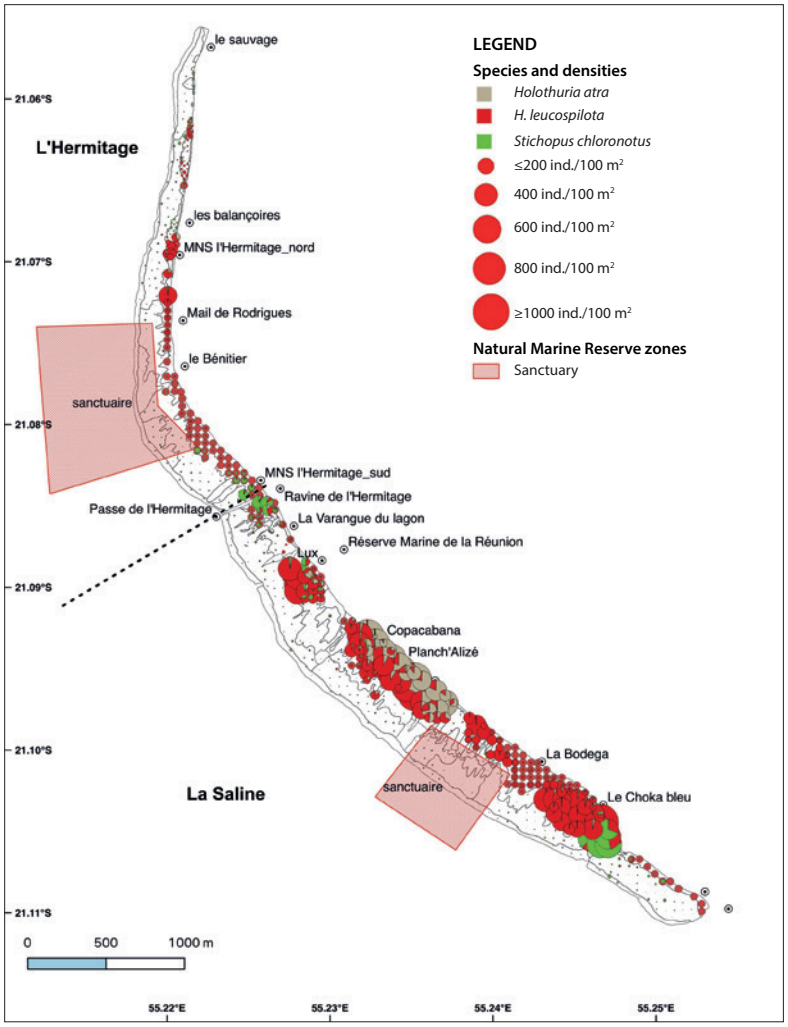

**Figures 3.** Survey method for "fixed point" stations. A: profile view of the station and the radius of 5.6 m. B: top view of the station with subsampling by one-fourth of the circle.

**Table 1:** Species abundance at all sites.

| Species | Abundance |
|---|---|
| ***Holothuria leucospilota*** | **23,984** |
| ***Holothuria atra*** | **13,818** |
| ***Stichopus chloronotus*** | **5850** |
| *Actinopyga mauritiana* | 981 |
| *Actinopyga echinites* | 213 |
| *Holothuria cinerascens* | 111 |
| *Holothuria nobilis* | 107 |
| *Holothuria verrucosa* | 53 |
| *Synapta maculata* | 19 |
| *Holothuria* cf. *pervicax* | 12 |
| *Holothuria flavomaculata* | 11 |
| *Bohadschia vitiensis* | 2 |
| *Actinopyga* spp. | 1 |
| *Actinopyga capillata* | 1 |




**Figures 4.** Holothurian species richness by habitat.
01PA: Inner Reef flat; 02DAR: back reef; 03PEDD Inner Reef flat, detritic;
04PE: Outer reef flat; 05PCCD: Inner reef flat with dense coral colonies;
06DPCCCD: Back reef with coral colonies; 07H: Back reef with seagrass on detritic substrate.




**Figures 5.** Spatial distribution of communities of the three dominant holothurian species on the La Saline/L'Hermitage reef complex.

The Holothuroidea community on the reef is spatially heterogeneous and an aggregative phenomenon has been documented elsewhere (e.g. Shepherd et al. 2003; Taddei 2006; Shiell and Knott 2010; Obura 2014)such as diver efficiency and diver error; and 2. This was confirmed during this study, with the presence of areas with very high densities such as Trou d'eau, Planch'Alizés, Lux, Passe de L'Hermitage sites and, to a lesser extent, between the Mail de Rodrigues and MNS L'Hermitage sites. The highest density was found at Planch'Alizés, where up to 1015 individuals/100 $m^2$ (*H. leucospilota* and *H. atra* combined) were noted. Although it is difficult to compare these data with previous studies, the value obtained in this area is equivalent to that recorded 30 years ago, which was 1100 individuals/100 m2 (Naim and Cuet 1989). The mapping carried out in this study enables the identification of those high-density spots.

Most individuals (83%), mainly from the three dominant species, were found in the reef flat zone. In contrast, the "rare" species (Table 1 and Fig. 4) were found on the back reef, which has a more complex structure and is subject to strong hydrodynamics.

One hypothesis that has been put forward, is the possible correlation between the level of enrichment of the site and the densities of *Holothuria leucospilota*, *H. atra* and *S. chloronotus*, with higher abundances in eutrophic zones (Mangion et al. 2004). In our study, patches of high abundance are actually located in areas known for their eutrophication feature, which include the sites of Planch'Alizés, Trou d'eau and Passe de L'Hermitage (Cuet et al. 1988; Naim 1993; Guigue et al. 2015; Tedetti et al. 2020)Indian Ocean. The distribution pattern described in this study is probably a multifactor effect, including nutrient enrichment, water flow, reproduction mode, and others that have yet to be identified.

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