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Aggregation behavior of suspension-feeding sea cucumbers in a tropical lagoon system of Rodrigues Island, Western Indian Ocean

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Abstract. *Gerzer F, Kaullysing D, Ramah S, Bhagooli R. 2025. Aggregation behavior of suspension-feeding sea cucumbers in a tropical lagoon system of Rodrigues Island, Western Indian Ocean. Indo Pac J Ocean Life 9: 124-132.* Suspension-feeding holothurians exhibit unique behavioral and ecological adaptations when compared to deposit-feeding sea cucumbers. Their population drivers, habitat preferences, and niche partitioning, however, remain poorly understood. In this study, we document a high-density aggregation of *Holothuria cinerascens* (Brandt, 1835) (16.9 ± 3.11 ind/m²), which was substantially higher than the coexisting deposit-feeders' density (*Holothuria atra* Jaeger, 1833: 0.8 ± 0.9 ind/m²; *Stichopus horrens* Selenka, 1867: 0.3 ± 0.5 ind/m²). The study site in Torrent, located on Rodrigues Island's east coast, is characterized by sandy flats and occasional limestone structures that clearly indicate habitat partitioning. The limestone structure along the transect showed 100% niche occupation by *H. cinerascens*, and the sandy flat had a composition of 72.7% *H. atra* and 27.3% *S. horrens*. The limestone's structural complexity provides a variety of crevices, access to water flow, predatory refuge, and attachment opportunities, ultimately creating a suitable habitat for suspension-feeding holothurians. Additionally, trade wind-generated hydrodynamics on Rodrigues Island likely enhance suspended nutrient flux on the east coast, favoring suspension-feeding plasticity of the sometimes trophically facultative *H. cinerascens*. These findings give insights into holothurian niche specialization, driven by microhabitat structure, hydrodynamic conditions, and trophic plasticity, delivering possible implications on conservation and mariculture strategies, as well as enhancing the overall understanding of holothurian ecology.

Keywords: Biogeograph aggregation behavior, high density occurrence, *Holothuria cinerascens*, niche differentiation, suspension-feeding sea cucumber

Abbreviations: H': Shannon diversity index, J': Pielou's evenness, S: Species richness

INTRODUCTION

Sea cucumbers are a diverse group of mostly benthic marine echinoderms with a variety of ecological functions. Their active behavior of digging and burrowing through benthic habitats makes them a significant contributor to marine bioturbation and sediment redistribution. Their feeding behavior of either deposit-feeding or suspension-feeding reduces the organic load, while the excretion of inorganic phosphorus and nitrogen enhances benthic biota productivity. Their ecological capability of symbiotic relationships enables them to host around 200 commensal and parasitic symbionts, significantly boosting marine biodiversity, as well as, being prey for trophically higher taxa displays their role in transferring detritus- and macroalgae-derived nutrients along the food web, which does not only highlight their ecological importance in maintaining ecosystem functioning and connecting benthic communities to the nekton but also their potential use for bioremediation (Purcell et al. 2016; Ribani et al. 2024).

In addition, sea cucumbers regenerate nutrients in coral reefs, alter carbonate content and pH of the surrounding water (Sun et al. 2018), enhance ammonium concentration through respiratory expulsion (Uthicke 2001), increase mineralization in organically-enriched sediments (Pierrat et al. 2021), control the growth of the microphytobenthos through grazing, decompose organic matter, and cause sediment-seawater exchange of dissolved oxygen (Mactavish et al. 2012) and reduce harmful algal blooms through feeding (Mohsen et al. 2020).

Furthermore, sea cucumber declines have been linked to increases in coral disease susceptibility, as they can reduce the pathogen load of the sediment and make the sediment microbiome less suitable for pathogens to thrive (Grayson et al. 2022; Clements et al. 2024). While deposit-feeding holothurians ingest sediment material that has been deposited on the benthos, suspension-feeding holothurians use their oral tentacles to filter particles suspended in the water column (Pierrat et al. 2021; Kabanova and Filgueira 2024). Most deposit-feeding holothurians are epibenthic deposit-feeders, meaning their feeding habitat is on the surface of sediments (Pierrat et al. 2021). The diet of deposit-feeders mainly consists of inorganic compounds, micro-organisms, organic matter, and fecal pellets (Dar and Ahmad 2006). While most sea cucumbers among the *Holothuria* (Linnaeus 1767) genus are deposit-feeders, *Holothuria cinerascens* (Brandt, 1835), which will be discussed in this study, stands out as a suspension-feeder (Purcell et al. 2016; Ahmed et al. 2023) with a diet consisting mainly of plankton, detritus, and other micro-organisms in the water column (Ahmed et al. 2021).

A variety of different factors influence the behavior of sea cucumbers. Changes in salinity, for instance, have shown effects on the feeding and burrowing cycles of sea cucumbers, causing some species to burrow themselves in the sediments during periods of decreased salinity (Mercier et al. 2000; Domínguez-Godino and González-Wangüemert 2020). Temperature and different thermal regimes also have an impact on the burrowing behavior of sea cucumbers (Zhang and Lai 2024). On Palawan Island in the Philippines, water flow and current variations have been shown to affect sea cucumber distribution and activity directly (Jontila 2017).

During reproductive periods, sea cucumbers have been observed to exhibit aggregation behavior (Mercier et al. 2000). Male individuals can release olfactory chemicals, attracting both females and males to initiate reproduction and spawning (Marquet et al. 2018). While some sea cucumbers have developed predatory-defense mechanisms, such as the excretion of Cuvierian tubules, evisceration, or possess toxins that make them undesirable prey (Conand 2008), others prefer to use their soft bodies to engulf themselves in small crevices.

There is an increasing interest in the potential commercial value of *H. cinerascens* due to its collagen moisturizing properties for cosmeceuticals (Badilli and Inal 2025). In the food industry, holothurians are recognized for their nutritional value, as they are low in fat, sugar, and cholesterol, and rich in minerals, vitamins, collagen, proteins, and polyunsaturated fatty acids (Ghallab et al. 2025). While approximately 90% of the market share of sea cucumbers in the food market is accounted for by dried sea cucumbers, some species like *Apostichopus japonicus* (Selenka, 1867) and *Cucumaria frondosa* (Gunnerus, 1767) are also consumed cooked, pickled, or raw (Harini et al. 2024). In areas like China, Japan, and Korea, sea cucumbers have a long history of traditional medicine or culinary uses; however, given the overexploitation of some species, scientists underscore the need for sustainable practices (Pérez-Lloréns and Mouritsen 2024). Within the Western Indian Ocean region, there is a growing market of wild sea cucumber harvesting in Madagascar (Rothamel et al. 2023).

Altogether, studying suspension-feeding sea cucumbers is of utmost importance for the understanding of their ecological importance in benthic-pelagic coupling, biofiltration, and water quality regulation, as well as their applications and possible commercial values. Despite extensive research on holothurian ecology, the behavior of suspension-feeding holothurians remains poorly understood. This study documents a localized high density of the sea cucumber *H. cinerascens* exhibiting localized aggregation behavior in the unique and dynamic lagoon system of Rodrigues Island.

MATERIALS AND METHODS

The study site is located on the east coast of Rodrigues Island, which belongs to the Republic of Mauritius and lies around 400 km north of the Tropic of Capricorn. It forms part of the Mascarene Islands, among which it stands out due to its different geological age and far-reaching lagoon system. The survey area is called Torrent (19°41'16"S 63°30'13"E) and is found off a small peninsula, within the lagoon, north of East Bay / Baie de l'Est (Figure 1). To the south of the peninsula, there is Fumier Beach, and to the north, Coton Beach.

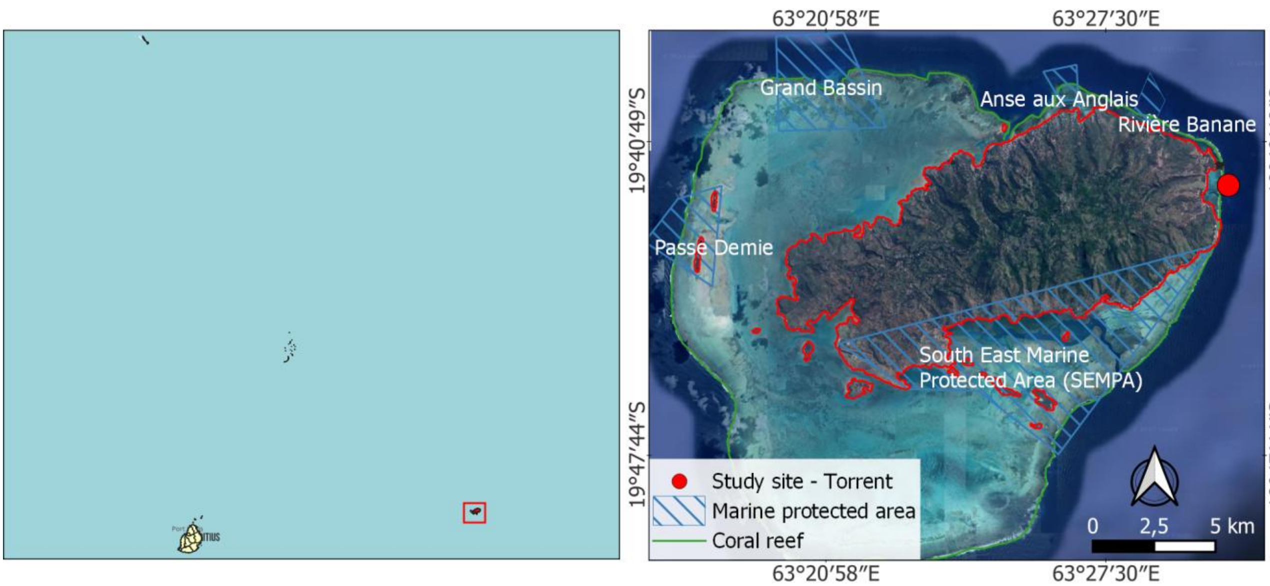

Figure 1. Map of Rodrigues Island showing the location of the survey site of Torrent in Rodrigues Island, Mauritius

A rocky shore with occasional sandy patches characterizes the coastal zone of Torrent. Further inland, behind a small coastal forest, lies a rural area with minimal human development. The lagoon system off Torrent is relatively narrow when compared to the large lagoons of the western part of the Island, and has an approximate depth of 2.6 m. The sea cucumber survey was conducted in April 2017 using ten 1 × 1 m quadrats placed randomly on a large limestone structure and the surrounding sandy benthos at Torrent. Within each quadrat, all sea cucumber species were identified, and their abundance was recorded. Environmental parameters such as habitat type and depth were documented and estimated. Photographs of the sea cucumber species were taken using an Olympus TG4 camera for species identification. Standard lenses and the automatic underwater mode were used for taking the snapshots. Species identification was carried out with the FAO "Commercially Important Sea Cucumbers of the World" guide and the PatriNat "Identification Guide: Commercial Sea Cucumbers" by Marie Di Simone, Arnaud Horellou, Frédéric Ducarme, and Chantal Conand. After the survey, data were compiled to calculate mean densities, which were expressed as individuals of sea cucumber per m^2. Species richness (S), Shannon diversity index (H'), and Pielou's evenness index (J') were calculated using R Studio. Sea cucumber length (in cm) was measured using a handheld wooden ruler. Additionally, visual observations and photographs of substrate type and characteristics were taken along the studied area.

Formula for species richness (S):

$$S = \text{Number of species present in the sample}$$

Formula for Shannon diversity index (H'):

$$H' = -\sum_{i=1}^{S} * pi * ln\ pi$$

Where: *H'*: Shannon diversity index, *S*: Total number of species in the transect, *pi*: Proportion of individuals of species *i* in the total sample, *ln pi*: Natural logarithm of *pi*.

$$p_i = \frac{\text{Number of individuals of species}}{\text{Total number of individuals in the sample}}$$

Formula for Pielou's evenness index (J'):

$$J' = \frac{H'}{\ln S}$$

Where: J': Pielou's evenness index, H': Shannon diversity index, S: Total number of species in the community (species richness), ln S: The natural logarithm of species richness.

RESULTS AND DISCUSSION

The study site was characterized by a sandy patch with rubble and benthic macroalgae with a depth of around 2.6 m. Within this sandy flat, there was a limestone structure with an approximate length, width, and height of 3.7, 2.3, and 2.2 m, respectively. Additionally, strong currents were observed at the site. Overall species richness is 3, with a value of 1 for the limestone structure and 2 for the sandy flat (Table 1). Shannon's diversity index was 0 on the limestone structure and 0.611 at the sandy flat. Pielou's evenness could not be defined for the limestone structure due to the fact that there was only 1 species present; however, the sandy flat showed an evenness value of 0.881. Sea cucumber density (Figure 2) was higher on the limestone structure than on the surrounding sandy flat, with an average of 16.9 ± 3.1 ind/m² on the limestone structure and 0.55 ± 0.7 ind/m² on the sandy flat. Community composition showed a clear dominance of 100% *H. cinerascens* on the limestone structure, while the sandy flat was composed of 72.7% *Holothuria atra* Jaeger, 1833 (0.8 ± 0.9 ind/m²) and 27.3% of *Stichopus horrens* Selenka, 1867 (0.3 ± 0.5 ind/m²). Sea cucumber species (Figure 3) showed an average length of 18 ± 3 cm for *H. cinerascens*, 7.5 ± 1.6 cm for *H. atra*, and 28 ± 3.6 cm for *S. horrens*.

The results clearly show an unexpected and unusually high-density mass occurrence of *H. cinerascens* (16.9 ± 3.11 ind/m²) on the limestone structure, while the surrounding sandy flat showed relatively low densities (0.55 ± 0.7 ind/m²). While all individuals of *H. cinerascens* recorded at the study site were concentrated on the structure, none were recorded around the sandy flat.

When interpreting these findings, several constraints should be taken into account. This study represents a snapshot documentation of an unusually high-density aggregation of holothurians, while an in-depth analysis of the underlying factors is limited. Hence, the omission of certain variables reduce the ability to draw firm conclusions on the causalities in this aggregation but do decribed and analyze this documented high-denstiy mass aggregation record from the east side of Rodrigues Island that considerably exceeds usual denisties, discusses differences in feeding and habitat derrived habitat requirements of holothurians, and provides an understanding of specific factors influencing aggregation behaviour in holothurians, in order to support a more comprehensive design for subsequent research efforts.

Table 1. Species richness (*S*), Shannon diversity index (*H'*), and Pielou's evenness (*J'*) per habitat type

Habitat type	Species richness (*S*)	Shannon diversity (*H'*)	Pielou's evenness (*J'*)
Limestone structure	1	0	Not defined
Sandy flat	2	0.611	0.881

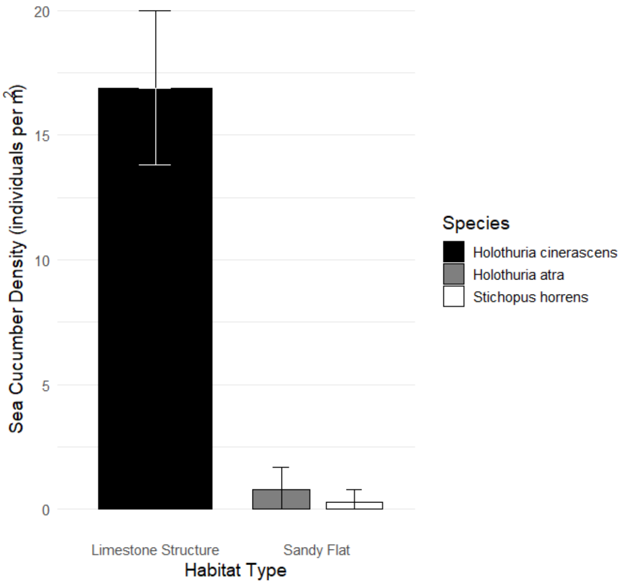

Figure 2. Density of different sea cucumber species by habitat (limestone structure, sandy flat)

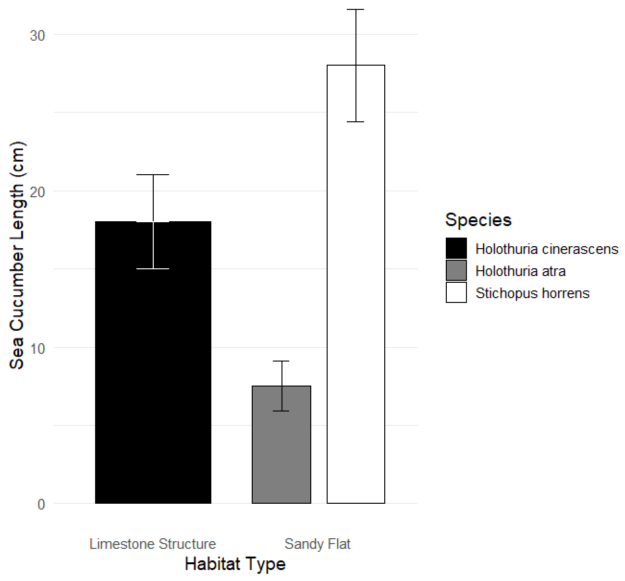

Figure 3. Length of different sea cucumber species (*Holothuria atra, Holothuria cinerascens, Stichopus horrens*)

A study within the Mascarene Island group found a total mean density of sea cucumbers, such as *H. atra* and *Stichopus chloronotus* Brandt, 1835, of 0.59 ± 0.38 ind/m² on sandy flat and coral reef /rubble habitats in La Reunion Island (Conand 2008), aligning with our results concerning deposit-feeding holothurians on the sandy flat substrate. In the Seychelles, a stock survey of two main fishing grounds has revealed an overall standing stock of approximately 0.002 ind/m² (Conand 2008). Throughout the Lakshadweep atolls, an average density of 8 ± 13 ind/m² was found, with numbers ranging from 0 to 177 ind/m². What this example clearly illustrates is that population densities can indeed tend to patchiness, highlighting the importance of understanding aggregation behavior.

The maximum was recorded at the intermediate lagoon area of Chetlat atoll. In the study, *H. atra* (0.37 ± 0.63 to 5.62 ± 24.86 ind/100m²), *S. chloronotus* (0.62 ± 1.11 to 4.76 ± 15.24 individuals/100 m²), and *Actinopyga mauritiana* (Quoy & Gaimard, 1834) (0 to 2.76 ± 3.67 individuals/100 m²) were most common, while *H. cinerascens* (0 to 1.05 ± 1.71 individuals/100 m²) was mainly found along the inner lagoon area, with none observed on the outer reef flat and the reef slope (Mohammednowshad et al. 2021). While Mohammednowshad et al. (2021) describe an east-west difference in species composition to be a major factor in density variations, they also highlight how different habitat zones cause species-specific distribution due to habitat preference. However, in this study, a high-density mass occurrence of non-deposit-feeders has been observed (Figure 4). *Holothuria cinerascens* is one of the few suspension-feeding holothuroids, with most others being deposit-feeders (Purcell et al. 2016). A study by Lampe-Ramdoo et al. (2014) showed an overall density of 0.05 ind/m² of *H. cinerascens* in Mauritius Island with a total of 47 individuals observed over 23 survey sites, posing the question of how such a high density, as observed at Torrent, is possible.

Figure 1 illustrates the crucial role of the lagoon of Torrent, which is notably smaller than the wider lagoons of Rodrigues Island, in influencing sea cucumber distribution. This size difference suggests increased pelagic influences, which are crucial for suspension-feeding sea cucumbers that rely on currents to bring them food. These factors, such as water flow, current strength, current direction, and organic load of food suspended, are the main drivers of density and distribution (Neil et al. 2014; Zhang and Lai 2024). Therefore, areas with strong water flow conditions and high food availability hold greater potential for supporting higher densities of suspension-feeding sea cucumbers. However, the study shows that the strong variation of sea cucumber density in our results is within the same area. This is particularly interesting given the sedentary behavior of suspension-feeding sea cucumbers, which hide in small crevices of reef structures, while holding their tentacles into the current to trap phytoplankton and micro-organisms passing by (Purcell et al. 2016). As explained by Ahmed et al. (2023), *H. cinerascens* relies on a hard substrate that provides a variety of crevices for suitable attachment points in order to extend its large oral tentacles into the current for feeding (Sloan 1979), while also offering protection from predators (Mercier et al. 2000).

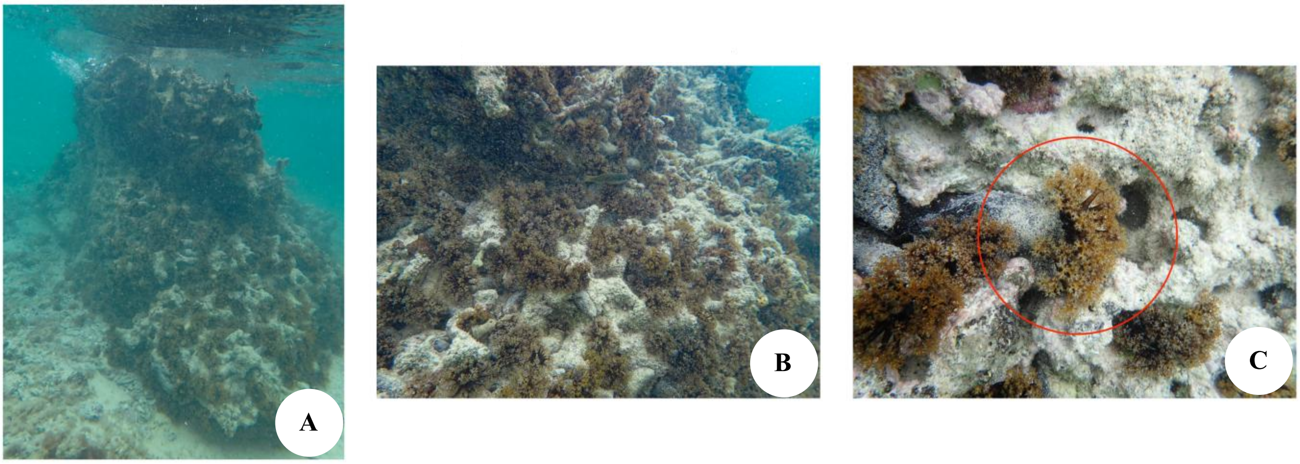

Figure 4. A. Picture of the limestone structure, B. High-density of *Holothuria cinerascens*, C. Oral tentacles protruding from crevices for suspension-feeding

As many holothurian species in Dendrochirotida, Persiculida, Synallactida, and Holothuriida can be opportunistic in their feeding mode, they can shift between suspension- and deposit feeding. Triggers for this shift can be variations in the concentration of suspended particulate organic matter in the water column and changes in water flow velocity, allowing many suspension-feeders to turn to deposited sediments in times of food scarcity or reduced food delivery (Pierrat et al. 2021). While *H. cinerascens* usually carries out suspension-feeding, gut content analysis and ex-situ feeding observations have indicated that *H. cinerascens* can handle deposited nutrients in an opportunistic way, when necessary (Roberts and Bryce 1982; Iwalaye et al. 2020; Ahmed et al. 2023). Hence, observations of behavioural responses to changes in water flow velocity or organic load could be indicative of a possible feeding-induced habitat shift of *H. cinerascens* from the limestone structure towards the sandy flat when nutrient availability in the water column is reduced. Field observations have shown that populations inhabiting the intertidal rocky zone exhibit primarily deposit-feeding behavior. In contrast, populations on outer reefs tend to feed on suspended particles within the water column (Ahmed et al. 2023).

The role of differences in complexity in habitat structure on food resource availability has been shown to ultimately lead to niche partitioning of populations relative to their feeding mechanisms (Pierrat et al. 2021). This is particularly evident in the case of the limestone structure, which was composed of 100% *H. cinerascens*, and the sandy flat, which did not contain a single individual. The direct impact of habitat structure can make higher flow velocity accessible to holothurians (Pan et al. 2015), in particular, can directly affect the distribution of suspension-feeding sea cucumbers (Sebens et al. 2016; Pierrat et al. 2024) is a key finding of this study.

As a result of the southeast trade winds, the Mascarene High, and tropical/extratropical storms from the central and southern Indian Ocean, relative to the geographic location of Mauritius, the east coast of the Island generally experiences higher wave action and increased water flow velocity, both persistent and episodic (Doorga et al. 2018). Due to the similar geographic exposure of Mauritius and Rodrigues Island to these oceanographic conditions, it can be assumed that the east/southeast coast of Rodrigues, as well, experiences increased flow velocity relative to other coasts. Additionally, the fact that the east coast of Rodrigues Island has the narrowest lagoon, compared to the far-stretching lagoons of the north, south, and west (Burney et al. 2015), it is reasonable to assume that the east coast is particularly exposed to high wave energy flux reaching the lagoons from the pelagic, creating strong hydrodynamic conditions (Escudero et al. 2021).

While the low species diversity of the results on the limestone structure precludes inter-specific competition, the possibility of intra-specific competition for food and space, however, could be a major factor in limiting population size, due to the limited niche space available on the habitat structure, ultimately making complexity in habitat structure a main driver for niche specific population biomass (Tanita and Yamada 2019). Variations in water flow, as well as suspended food availability, could be factors that influence the aggregation behavior, feeding cycles, and possible migration patterns of suspension-feeding sea cucumbers, which suggests possible seasonal variations in density and distribution (Hamel and Mercier 1998), hence increasing seasonal interspecific competition for space. As described by Zhang and Lai (2024), high-density aggregations can also be due to reproductive cycles, where male individuals release olfactory biochemicals into the water column to attract both males and females to aggregate at specific locations suitable for reproduction.

Although no reproduction-specific behavior has been observed on the study site, this possible reason that should not be excluded. A study conducted on another Mascarene Island, La Reunion, has taken a novel approach to investigate the reasons why some species of holothurians show patchy distribution patterns. The study, which emphasizes the role of substrate features, habitat type, conspecific attraction, and recruitment aggregations, also highlights the potential impacts of water flow regimes in creating such patchiness (Pierrat et al. 2024). This unique approach has led to significant findings that contribute to our understanding of holothurian distribution patterns. For instance, when comparing deposit-feeding and suspension-feeding holothurians, it becomes clear that suspension-feeding ones typically display a more sedentary behavior, as they do not always need to relocate to obtain food, while deposit-feeding ones must relocate once the sediments around them have been consumed.

An ex-situ experiment by Wang et al. 2023 investigated feeding rate, defecation rate, tentacle activity time, crawling frequency, adhesion time, and righting time of *A. japonicus*. One group was kept in a tank with crevices, and a control group was kept in a tank without crevices. Results have shown that the group with crevices had a significantly higher feeding rate (0.944 ± 0.023) than the control group (0.824 ± 0.026), as well as the defecation rate with 0.132 ± 0.01 and 0.089 ± 0.01, respectively. Potentially indicating a higher feeding efficiency provided by crevices. Tentacle activity time of the crevice group was also higher compared to the control group. Despite crevice-groups indicating more efficient values, crawling frequency did not differ significantly. The study also suggested that crevice availability might help holothurians in managing stressors and supporting overall fitness (Wang et al. 2023). The findings of this study also inspire ex-situ experiments of *H. cinerascens* investigating facultative feeding plasticity when faced with both nutritional resources for suspension- and deposit-feeding. Also, oxygen consumption rates and ammonium excretion rates could be considered to be evaluated when investigating the effects of crevice availability on *H. cinerascens* in ex-situ experiments (Yu et al. 2019). Another study that focused on modelling habitat and substrate preference of holothurians in in-situ surveys concluded that hard substrate typically suggests a higher ability to cope with environmental stressors and sea cucumber length was increasing with total organic matter suspended and decreasing when faced with elevated temperatures (Félix et al. 2024).

Apostichopus japonicus has been found to generally display reduced activity outside of crevices when temperatures rise (Vaschenko and Zhadan 2024), especially concerning early life stages, as rising temperatures have shown to affect larval growth and developmental processes negatively (Lang et al. 2023). An interesting study by Sun et al. (2018) has shown that the suspension-feeding sea cucumber *Cucumaria frondosa* (Gunnerus, 1767) has shown displacement behavior related to water flow and feeding efficiency in areas of weak dynamics by seeking stronger flow exposition for passive suspension-feeding in order to obtain phytoplankton and other suspended particles. Optimal water flow for this species has been shown to be between 21 and 40 cm/s (Sun et al. 2018). At the same time, increased flow velocity has been shown to pose a risk of dislodgement and an increased energy requirement for attachment (Pan et al. 2015).

Some holothurians have been shown to exhibit clumping behavior to enhance resistance to dynamic environments, in order to reduce drag and provide greater surface area for attachment (Brown et al. 2019). Individuals at the survey site (Figure 4) have shown to almost fully embody themselves into the abundant crevices, while protruding the oral tentacles into the current, which does lend strong support to the argument that their nature of aggregation is feeding related. So the limestone structure not only facilitates increased hydrodynamic exposure but also provides a space to engulf themselves in and, thus, reduces drag from increased water flow velocity and gives predation refuge.

The feeding requirements of *H. atra*, on the other hand, are closely related to the organic features of the substrate itself, rather than the positioning provided by the substrate. Enriched sediments with a high load of organic matter, chl-a, and ∂13C have been shown to provide a suitable habitat for holturians like *H. atra* to thrive (Brown et al. 2019). Regarding the habitat requirements for *S. horrens*, studies have shown that individuals do prefer coarser sediments, sand, and rubble habitats (Palomar-Abesamis et al. 2016). These habitat requirements explain the sharp boundary of habitats that causes both the diversity index as well as the evenness (Table 1) to drastically vary over the change of substrate-driven habitat characteristics between the limestone structure and the adjacent sandy flats.

Hence, a size-dependent (Figure 3) habitat selection is doubtful. However, what insight can be obtained from this data is that *H. atra* population seemed to consist mostly of juvenile individuals, as adults range from 12 to 16 cm, with some longer individuals up to 33cm (Pierrat et al. 2024). In a study from the Arabian Sea, adult individuals of *H. cinerascens* measured an average length of 17.8 ± 1.98 cm (Ahmed et al. 2023), which does indicate that individuals documented at the lagoon of Torrent were sexually mature adults. In a study from the Galapagos Islands, individuals of *S. horrens* were found to measure a length of 9-30 cm (Hu et al. 2013), while individuals over 15 cm are generally considered adults (Palomar-Abesamis et al. 2016). This implies that individuals of *S. horrens* documented at the study site are outgrown adults.

Limitations of this study include chemically driven behavior. In a study by Claereboudt et al. (2023), findings show that chemical communication through pheromones can cause holothurians to group. Chemoattraction has been shown to be specifically present when food availability and water quality were high (Pierrat et al. 2024). However, the documented aggregation behavior of this study was not limited to spawning periods.

Subsequent research on high-density mass aggregations of holothurians could benefit from employing a longitudinal design in order to establish causal relationships, such as in-depth habitat analysis of substrate, including dimensions, density, and rougthness of crevices, temporal variability of this aggregation on a both dial and seasonal scale, behavioral analysis of feeding-mechanisms, reproductive behavior, or locomotion documentation, as well as the potential presence of biochemical cues that might trigger aggregation, possible gut analysis and food availability, such as particulate organic matter load or possible small scale chl-a heterogenity to get a deeper insight into diets, and supporting data about environmental conditions as parameters for conclusive evidence on which factors drive such aggregations or could be possible triggers for facultative feeding switches that ultimately causes changes in habitat requirements. Hence, such a more structured design is recommended to investigate underlying mechanisms more thoroughly and provide a more comprehensive understanding of high-density mass aggregations in holothurians. In this specific case of Torrent, subsequent field observations alongside a comprehensive environmental factor influence analysis would shed more light on the temporal variability of this localized aggregation. Frequent monitoring of *H. cinerascens* population at Torrent could be of utmost importance in understanding general aggregation behaviour dynamics of suspension-feeding holothurians.

The deposit-feeding sea cucumber *Holothuria scabra* Jaeger, 1833, for instance, is known to exhibit aggregation behavior linked to specialized metabolites, called saponins, as well as through certain food odors present in the environment (Claereboudt et al. 2023). While generally seen as a sea cucumber with relatively low commercial value, some studies suggest its application for the extraction of collagen for moisturizing cosmetics (Li et al. 2020), as well as possible uses of *H. cinerascens* for aquaculture and bioremediation (Ahmed et al. 2023).

In addition, as described by Džeroski and Drumm (2003), management plans need to take into consideration the broader ecological role of holothurians in ecosystem services, such as food web dynamics, nutrient cycling, water chemistry, and sediment health, highlighting not only the interconnectedness of holothurian dynamics to overall ecosystem functioning but also possible implications of this study in adaptive coastal and ocean management. Studies found that climate change-induced threats, such as rising temperatures, could affect the feeding mechanism of suspension-feeding sea cucumbers by altering tentacle insertion movements (Kabanova and Filgueira 2024).

Thus, in cases of such high-density mass aggregations, coastal managers and marine spatial planners are expected to consider protective measures as ecological impact is not comparable to the usual ecological impact that marine ecosystem uses have on holothurian populations due to an abnormally high abundance of individuals in a specific area that ultimately increases ecological impact on holothurian populations, highlighting the need for context specific assessments. From a pollution-monitoring perspective, holothurians have been shown to be excellent indicators for contamination of microplastics and perfluoroalkyl substances due to their deposit uptake and strong accumulation (Cocci et al. 2025).

The facultative plasticity of *H. cinerascens* suggests a higher adaptive capacity of the species to environmental fluctuations in a changing marine ecosystem. It offers valuable insights into the habitat preferences and behavioral patterns of suspension-feeding sea cucumbers, such as *H. cinerascens*.

By examining the factors driving aggregation and mass occurrences, the findings suggest a non-uniform distribution of these populations influenced by habitat complexity. Such complexity is crucial in promoting niche differentiation in niche-specific communities, ultimately supporting overall reef biodiversity and ecosystem health within complex lagoon systems. Additionally, the results provide useful perspectives for potential aquaculture applications, particularly in multi-trophic systems, by shedding light on how environmental factors determine feeding and aggregation behavior, leading to the possible exploration of *H. cinerascens* implications in aquaculture systems, reducing both suspended particulate organic matter from the water column, as well as deposited organic matter in the sediments.

The results also contribute to improving monitoring strategies for holothurian biodiversity. Suspension-feeding sea cucumbers do not solely rely on strong currents with a high nutrient load but also on the availability of structured habitats for attachment, protection, and optimal feeding. Finally, it brings forward a new understanding of selective trophic plasticity in facultative feeders, enhancing our broader knowledge of their ecological roles and adaptive strategies. In conclusion, this documented high-density aggregation occurrence of *H. cinerascens* underscores how hydrodynamic conditions and habitat complexity interactions can generate localized ecological population hotspots for benthic suspension-feeding organisms.

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