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Chief Editor José Paula

Coral reefs of Mauritius in a changing global climate

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Aims and scope: The *Western Indian Ocean Journal of Marine Science* provides an avenue for the wide dissemination of high quality research generated in the Western Indian Ocean (WIO) region, in particular on the sustainable use of coastal and marine resources. This is central to the goal of supporting and promoting sustainable coastal development in the region, as well as contributing to the global base of marine science. The journal publishes original research articles dealing with all aspects of marine science and coastal management. Topics include, but are not limited to: theoretical studies, oceanography, marine biology and ecology, fisheries, recovery and restoration processes, legal and institutional frameworks, and interactions/relationships between humans and the coastal and marine environment. In addition, *Western Indian Ocean Journal of Marine Science* features state-of-the-art review articles and short communications. The journal will, from time to time, consist of special issues on major events or important thematic issues. Submitted articles are subjected to standard peer-review prior to publication.

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Word from the Editor

The last couple of years have been a time of change for the Western Indian Ocean Journal of Marine Science. The journal has a new and more modern layout, published online only, and the editorial Board was increased to include more disciplines pertaining to marine sciences. While important challenges still lie ahead, we are steadily advancing our standard to increase visibility and dissemination throughout the global scientific community. The central objective of the journal continues focused on the Western Indian Ocean region and serving its growing scientific community.

We are pleased to start the publication of special issues of the journal, launched here with the publication of manuscripts from the University of Mauritius Research Week 2016. The special issues aim to contribute for advancing marine science in the WIO by focusing on specific themes, geographical areas or assembling contributions from scientific meetings. The editorial processes are exactly the same as for regular issues, with double peer-review, and guest editors are considered.

José Paula
Chief Editor

Editorial Note · Coral reefs of Mauritius in a changing global climate

The University of Mauritius Research Week (UoM RW) has been held on an annual basis since 2007 and was organized for the 9th time from 19-23 September 2016. The Research Week is geared towards dissemination of knowledge generated through research activities at the University and by relevant stakeholders in accordance with the UoM's vision of "*Excellence in Research and Innovation*". In line with national priorities, the UoM organizes this event to provide insightful research outcomes not only for the advancement of academic knowledge, but for the benefit of the community at large, through robust policy recommendations.

Out of the multiple submissions made during the UoM RW 2016, a number of manuscripts in the field of ocean/marine sciences were selected to be published in the Western Indian Ocean Journal of Marine Science (WIOJMS), as a special issue entitled "Coral reefs of Mauritius in a changing global climate". This issue is presented in the context of Mauritius being surrounded by a beautiful but delicate coral reef ecosystem, which provides ample ecosystem services contributing to the national economy, but which is subjected to extreme climatic events. Hence, in this special issue several contributions advancing our scientific understanding for sustainable use and management of marine resources in a globally changing marine environment are articulated. The original article by Mattan-Moorgawa *et al.* investigates the photo-physiology of diseased and non-diseased corals. Coral diseases are becoming more common on reefs worldwide due to both local and global stressors. Ramah *et al.* then present a short communication related to substrate affinity by two giant clam species found on the Mauritian coral reefs. Giant clams are under threat worldwide and information on their substrate affinity and habitat aims at providing insightful information towards their sustainable management. In addition, Nandoo *et al.*, in an effort to optimize nucleic acid extraction protocols from marine gastropods, present an original article based on a comparative study using the gastropod genera *Planaxis*, *Cypraea* and *Drupella*. These marine gastropods are ecologically important for coral reefs, especially the coral-eating *Drupella*. Moreover, given the importance of intertidal molluscs, Kaullysing *et al.* document the density and diversity of the benthic molluscs while comparing sheltered and exposed coastal habitats. Appadoo & Beeltah report on the biology of *Platorchestia* sp. (Crustacea, Amphipoda) at Poste La Fayette, Mauritius. Studies on Amphipod diversity and distribution are important especially since studies on marine biodiversity are scarce around Mauritius. Another original article by Ragoonaden *et al*. analyses the recent acceleration of sea level rise in Mauritius and Rodrigues. Such studies are more important than ever in the light of a globally changing marine environment with small island states faced with issues related to rising sea level. Two field notes, based on field observations, are presented by Bhagooli *et al.*, documenting a variety of coral diseases, and *Stylophora pistillata*-like morphotypes occurring around Mauritius Island, respectively. Kaullysing *et al.* also present a field note on coral-eating gastropods observed around Mauritius.

Apart from the local contributors, international collaborators also contribute two original articles in this special issue. Casareto *et al.* characterize the chemical and biological aspects of a coral reef of Mauritius focusing on benthic carbon and nitrogen fixation. These studies related to benthic productivity are important for understanding sustainability of coral reefs and/or lagoonal fisheries. On the other hand, Tokumoto *et al.* document the first detection of membrane progestin receptor (mPR)-interacting compounds from Mauritian coral reef and lagoonal seawater. They used cutting-edge technology to detect key regulators of reproduction in seawater. These contributions in terms of original articles, short communications, and field notes generate new scientific knowledge that may better inform policy and decision making in the field of coral reef studies and management in Mauritius, while contributing to the understanding of coral reefs in the wider Western Indian Ocean region.

Prof. Sanjeev K. Sobhee
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A comparison of the density and diversity of intertidal benthic molluscs at a sheltered and an exposed tropical coast around Mauritius Island

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Abstract
This study compared spatial variations in the density and diversity of marine benthic molluscs along Belle Mare and Gris Gris, a sheltered and an exposed intertidal zone, respectively, in Mauritius. Species density was assessed using the random quadrat method (1 m x 1 m). Grain size distribution was measured by sieve analysis. Shannon-Wiener (*H'*), evenness (*E*) and Simpson's (*D*) indices were used to assess diversity. Coarser sediment was found at Gris Gris indicating the prevalence of relatively harsher wave conditions as compared to Belle Mare. Sixteen mollusc species were identified at Belle Mare (12 on rocky and 4 on sandy substrata) and seven species at Gris Gris (6 species on rocky and 1 on sandy substrata), with the families Planaxidae, Cerithiidae and Neritidae being common to both sites. Shannon-Wiener and evenness indices were higher at Gris Gris. Simpson's index indicated higher dominance at Belle Mare, evident from the high density of *Planaxis sulcatus* (514.42 ± 221.63 individuals m^{-2}) (mean ± SE). *Turbo setosus* was found in highest density (1.20 ± 0.20 individuals m^{-2}) at Gris Gris. Though Belle Mare has higher intertidal mollusc abundance, the diversity was lower due to high dominance of species. This observation possibly signifies suitable physical conditions for species growth and survival at Belle Mare.

Keywords: sheltered, exposed, molluscs, species density, species diversity, grain size

Introduction
Intertidal habitats are one of the most productive areas of the globe (MacKinnon *et al.*, 2012). They are hotspots of biodiversity and support several processes such as bioturbation and bioirrigation by lugworms (Volkenborn *et al.*, 2007), microbial hydrocarbon degradation (Cravo-Laureau & Duran, 2014), erosion and deposition (Shi *et al.*, 2012), and porewater exchange (Bouillon *et al.*, 2007) which determine the survival of intertidal communities. Flood and ebb tides, and river outflow allow continuous reworking of nutrients in the intertidal zone (Yin & Harrison, 2000), and subsequently control primary productivity (Davies & Ugwumba, 2013). Thus, primary consumers such as marine molluscs are also sustained by grazing on primary producers.

Marine molluscs (Phylum Mollusca) are one of the primary components of intertidal zones (Vaghela *et al.*, 2013) and are found at all latitudes, but are extremely diverse in tropical and temperate regions. Inherent physiological and behavioural adaptations of marine molluscs control their distribution and density in the intertidal region (Meyer & O'Gower, 1963). In addition to intrinsic adaptations, the distribution, density and diversity of intertidal molluscs are also a function of other factors such as predation (Navarrete *et al.*, 2000) and competition (Arribas *et al.*, 2016).

While temperature is a well-established factor in determining zonation in intertidal areas (Tomanek & Helmuth, 2002), it is noteworthy that wave action and sediment characteristics can also influence the abundance of intertidal molluscs (Harger, 1970; Denny, 1985; Etter, 1989; Boulding & Alstyne, 1993; Huz *et al.*, 2002; Vanagt *et al.*, 2008). It has been reported that strong wave regimes prevent gastropods from attaching to the substrate (Walsby, 1977) and their shell growth is adversely affected. Gastropods on sheltered coasts tend to grow a thicker shell compared to their conspecifics from exposed coasts (Avery & Etter, 2006). This has been reported as a defense or adaptation to the protected environment where the risk of predation by organisms such as crabs is higher (Boulding *et al.*, 1999). Brown & Quinn (1988) have reported greater mean shell length of intertidal molluscs such as limpets *Collisella digitalis* and *C. scabra*, and the thaidid whelk *Nucella* (*Thais*) *emarginata* at protected sites. Akester & Martel (2000) reported that the mussel *Mytilus trossulus* from wave-exposed habitats had a thicker shell and more robust dysodont teeth which helped in minimising the harsh effects of wave action.

Intertidal molluscs are undergoing an exceptional rate of anthropogenic removal, especially for consumption, via extractive means (Martins *et al.*, 2008) such as dredging or artisanal collection. This pressure has been further accentuated due to the higher accessibility to the intertidal zone (Hill *et al.*, 1998), especially during low tides. Intertidal molluscs have been overexploited from the shores of Mauritius mainly as a source of protein by coastal populations and as bait in artisanal and recreational fishing. More importantly, marine molluscs, especially gastropods, have been excessively removed from Mauritian waters for their attractive shells (Kay, 1995) which are used as jewellery and decorative items. With climate-change induced sea level rise, and other potential global and local stressors in action, such as ocean acidification (Parker *et al.*, 2013), heavy metal pollution and low hydrodynamics (Guerra-Garcia & Garcia Gomez, 2004), many coasts around the world are imminently faced with stronger wave action and greater wave heights (Wang *et al.*, 2014). Mauritius, as a small island in the Western Indian Ocean, will not be spared from such impacts.

There is a lack of reliable and validated baseline information on the distribution, abundance, density and diversity of marine molluscs as they have not been thoroughly investigated in varying hydrodynamic conditions in the coastal waters of Mauritius. The limited published scientific data on the spatial distribution and diversity of benthic mollusc diversity is restricted to only particular regions of Mauritius on selected rocky shores (Charles *et al.*, 2011) and mangrove sites (Appadoo & Roomaldawo, 2005). This work intends to provide additional data on the situation in Mauritius by comparing intertidal mollusc density and diversity on sandy and rocky substrata at a sheltered intertidal zone with relatively low wave action, and an exposed intertidal zone with relatively strong wave action.

Materials and Methods

Site description

The two study sites, Belle Mare and Gris Gris (Fig. 1a) were selected due to their differences in exposure to wave regimes. The differences were expressed qualitatively as being sheltered or exposed. Both intertidal zones are characterised by stretches of sandy and rocky substrata along the shoreline. Belle Mare (Fig. 1b) is situated along the eastern coast of Mauritius and it experiences relatively low wave activity throughout the year. The lagoon is bordered by a stretch of fringing reefs which dissipates the wave energy reaching the intertidal zone to a great extent. Belle Mare has a gently sloping topography and thus, the intertidal zone extends over an average width of 11 m. Conversely, Gris Gris (Fig. 1c), located on the southernmost coast of the island, experiences relatively strong wave action throughout the year, especially during high tides. Harsh conditions in terms of exposure to wave action in the intertidal area are prevalent at Gris Gris. The intertidal zone of Gris Gris stretches over a width of approximately 5 m with a relatively steep slope.

In situ survey of intertidal molluscs

The survey was carried out along the intertidal zone at low tide in April-May 2016 (summer) at Belle Mare and Gris Gris. At each site, 10 random transects perpendicular to the shoreline having an average length of 11 m and 5 m at Belle Mare and at Gris Gris, respectively, and stretching from the high to low water mark, were surveyed. Three random 1 m x 1 m quadrats (n=30 per site) were placed along each transect such that each of the following three tidal height locations distributed over the intertidal area was represented by one quadrat: supralittoral (Mean High Water, MHW); eulittoral (between MHW and Mean Low Water, MLW); and sublittoral zones (MLW). The quadrats were apportioned between sandy (Belle Mare, n = 18; Gris Gris, n = 25) and rocky (Belle Mare, n = 12; Gris Gris, n = 5) substrata within each site. The types and abundances of benthic mollusc species encountered were quantified within each quadrat and recorded for computing density and diversity.

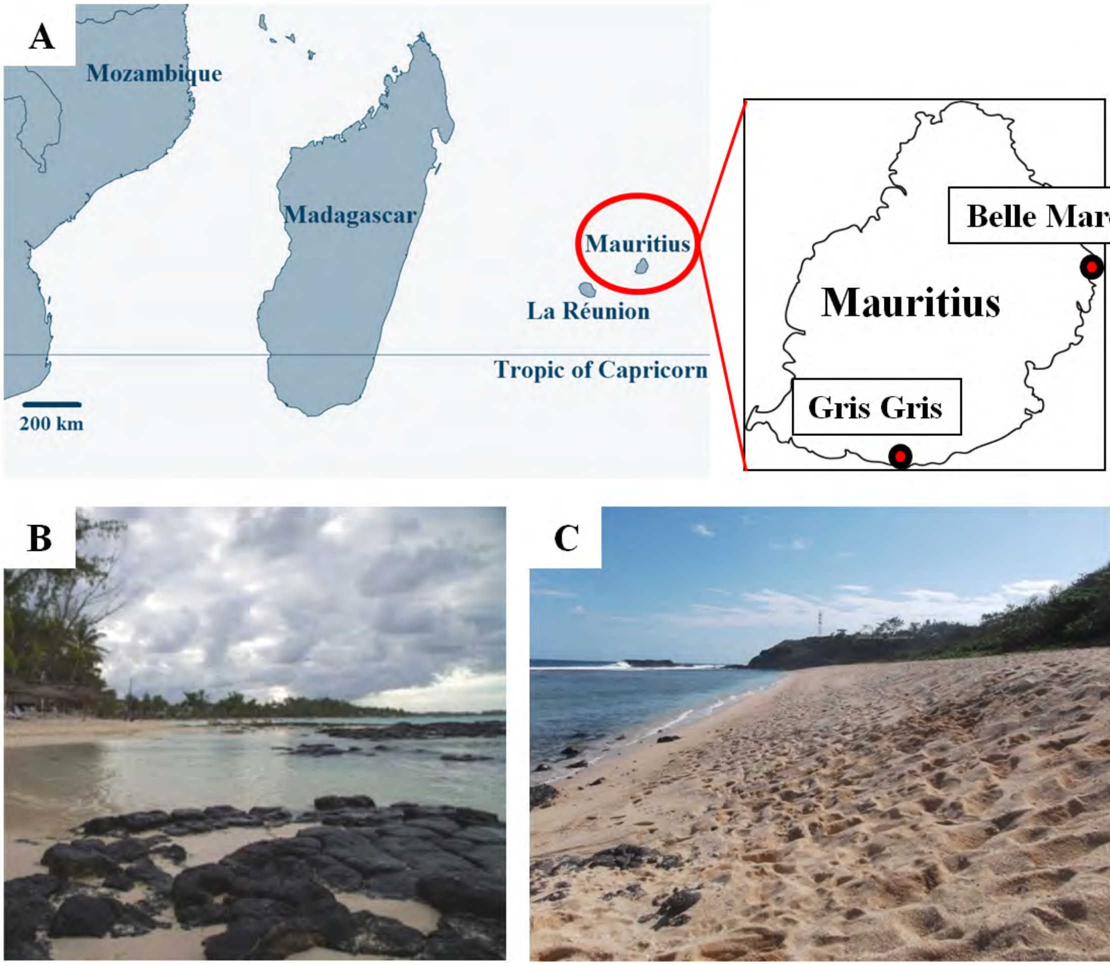

Figure 1. a) Map of the Western Indian Ocean and Mauritius (20.2000° S, 57.5000° E) showing location of Belle Mare and Gris Gris. b) The study site of Belle Mare. c) The study site of Gris Gris (Maps adapted from http://www.worldatlas.com/webimage/countrys/africa/outline/muout.htm and https://www.google.mu/maps/)

Identification of intertidal molluscs

Representative samples of intertidal molluscs were collected for morphological identification in the laboratory with a hand lens, or a light microscope (Novex B Series) for smaller specimens. Published guides of Michel (1985) and Abbott & Dance (2000) were used to identify marine molluscs at species level wherever possible.

Assessment of intertidal mollusc density and diversity

The density of intertidal benthic molluscs was expressed as the mean number of individuals m^{-2} ± standard error (mean ± SE). Shannon-Wiener (*H'*), evenness (*E*) and Simpson's (*D*) indices (Magurran, 1988) were used to assess intertidal mollusc species diversity.

Grain size distribution analysis

A sediment sample was collected from the eulittoral zone at each site. The sediment sample was further processed in the laboratory by oven-drying at 60°C for two consecutive days to remove the moisture content prior to further analysis. The method of Folk & Ward (1957) was followed to determine grain size distribution using a sieve shaker (Endecotts, EFL2 MK3). The mean grain size of the sample and the sorting (standard deviation) were logarithmically computed using the program GRADISTAT (version 8.0) (Blott & Pye, 2001). GRADISTAT uses a modified Udden–Wentworth grain size classification scale (Udden, 1914; Wentworth, 1922; Blott & Pye, 2001) to describe the mean grain size in terms of phi (ϕ) units.

Nutrient analyses

Seawater samples were collected from each site in triplicate for determination of nitrate and phosphate concentrations by the cadmium reduction and the ascorbic acid methods of Greenberg et al. (1992), respectively.

Statistical analyses

The normality of the data was determined by the

Shapiro-Wilk test. Upon lack of normality, density data was log (base-10) transformed and nutrient level readings were arcsine (square root) transformed before conducting further statistical analyses. A two-way ANOVA was carried out to analyse the differences in mean densities under the effect of the two site conditions (exposed at Gris Gris and sheltered at Belle Mare) and substrate type (sandy and rocky). A one-way ANOVA was performed to compare nutrient levels at both sites. A dendrogram was generated to depict the level of dissimilarity in terms of mollusc density for the substrata at both study sites. All statistical analyses were carried out using STATISTICA software (version 8.0).

Results

Density and diversity of intertidal molluscs

A total of 7,827 benthic mollusc specimens were recorded along the intertidal zones of Belle Mare and Gris Gris. These included 19 gastropod species belonging to 13 families and 2 bivalve species belonging to 2 families. At Belle Mare, 16 species were observed, out of which 12 species were found on rocky substratum and 4 on sandy substratum (Table 1). Gris Gris harboured 7 species, where 6 species occurred on rocky substratum and 1 on sandy substratum (Table 2).

The density and range for each species encountered are provided in Tables 1 and 2. At Belle Mare, the highest density was recorded for the family Planaxidae with a value of 514.42 ± 221.63 individuals m^{-2} from the rocky shore, followed by the family Isognomonidae (109.17 ± 86.42 individuals m^{-2}). Cypraeidae had the highest density (8.50 ± 5.36 individuals m^{-2}) along the sandy shore of Belle Mare. On the other hand, the family Turbinidae found on the rocky shore of Gris Gris had the highest density (1.20 ± 0.20 individuals m^{-2}), while only 1 species from the family Conidae (0.80 ± 0.80 individuals m^{-2}) was recorded from the sandy substratum. The families Planaxidae, Cerithiidae and Neritidae occurred both at Belle Mare and Gris Gris.

The total density of intertidal molluscs was higher along the rocky shore of Belle Mare as compared to

Table 1. Density of mollusc species (individuals m^{-2}) recorded in the intertidal zone of Belle Mare.

Sr. No.	Family	Species	Mean ± SE	Range
Rocky substratum				
1	Planaxidae	*Planaxis sulcatus*	514.42 ± 221.63	0 - 2120
2	Muricidae	*Morula* sp.	1.58 ± 1.01	0 - 12
3	Cerithiidae	*Cerithium* sp.	0.33 ± 0.26	0 - 3
4	Neritidae	*Nerita atramentosa*	4.00 ± 1.90	0 - 17
5	Neritidae	*Nerita plicata*	0.67 ± 0.67	0 - 8
6	Littorinidae	*Echinolittorina ziczac*	0.08 ± 0.08	0 - 1
7	Neritidae	*Nerita polita*	0.08 ± 0.08	0 - 1
8	Buccinidae	*Engina mendicaria*	0.08 ± 0.08	0 - 1
9	Littorinidae	*Littorina* sp.	7.83 ± 7.74	0 - 93
10	Isognomonidae	*Isognomon* sp.	109.17 ± 86.42	0 - 1023
11	Cypraeidae	*Cypraea moneta*	0.08 ± 0.08	0 - 1
12	Ranellidae	*Cymatium nicobarium*	0.17 ± 0.11	0 - 1
Sandy substratum				
13	Cypraeidae	*Cypraea annulus*	8.50 ± 5.36	0 - 90
14	Cypraeidae	*Cypraea caputserpentis*	0.06 ± 0.06	0 - 1
15	Strombidae	*Canarium mutabile*	1.28 ± 1.22	0 - 22
16	Pinnidae	*Pinna muricata*	0.33 ± 0.24	0 - 4

Table 2. Density of mollusc species (individuals m^{-2}) recorded in the intertidal zone of Gris Gris.

Sr. No.	Family	Species	Mean ± SE	Range
Rocky substratum				
1	Turbinidae	*Turbo setosus*	1.20 ± 0.20	1 - 2
2	Siphonariidae	*Siphonaria* sp.	0.08 ± 0.08	0 - 4
3	Patellidae	*Patella* sp.	0.40 ± 0.40	0 - 2
4	Neritidae	*Nerita plicata*	0.20 ± 0.20	0 - 3
5	Cerithiidae	*Cerithium* sp.	0.80 ± 0.80	0 - 1
6	Planaxidae	*Planaxis sulcatus*	0.80 ± 0.80	0 - 1
Sandy substratum				
7	Conidae	*Conus corronatus*	0.80 ± 0.80	0 - 2

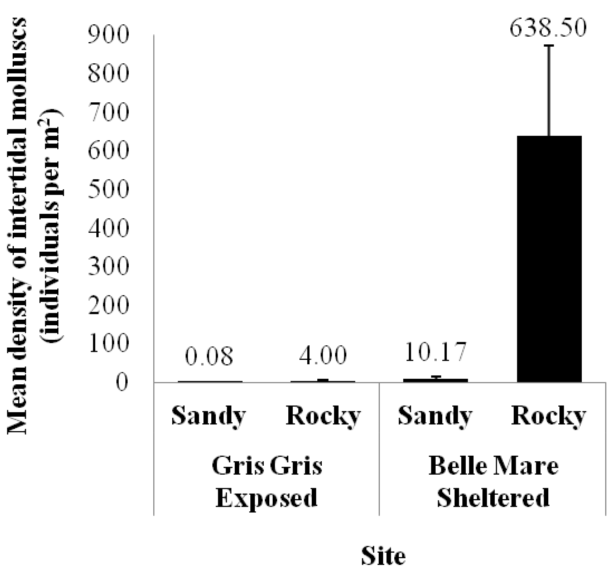

Figure 2. Total intertidal mollusc density on the sandy and rocky shores of Belle Mare and Gris Gris.

that of Gris Gris (Fig. 2). Significant differences were noted in the density of intertidal molluscs at the two sites and on the types of substrata (two-way ANOVA, $p<0.001$) (Table 3).

The dendrogram illustrated that the two substrate types at Gris Gris are very similar in terms of mollusc density. The rocky substratum at Belle Mare stands as an outlier having considerable dissimilarity to the sandy substratum at the same site and to both sandy and rocky substrata at Gris Gris. The sandy habitats of Belle Mare and Gris Gris, and the rocky habitat of Gris Gris are closely linked with regard to mollusc density (Fig. 3).

Both Shannon-Wiener and evenness indices were higher at Gris Gris (H' = 1.82, E = 0.94) as compared to Belle Mare (H' = 0.70, E = 0.25). Simpson's index revealed higher dominance at Belle Mare (D = 0.65) compared to Gris Gris (D = 0.18).

Grain size distribution

Sediment samples collected from the intertidal zones of Belle Mare and Gris Gris revealed differing sediment characteristics at both sites. The intertidal zone of Belle Mare consisted of moderately sorted medium sand (grain diameter 250 – 500 μm) while Gris Gris had well sorted coarse sand (grain diameter 500 – 1000 μm). The characteristics of the sediments at the two sites are summarised in Table 4.

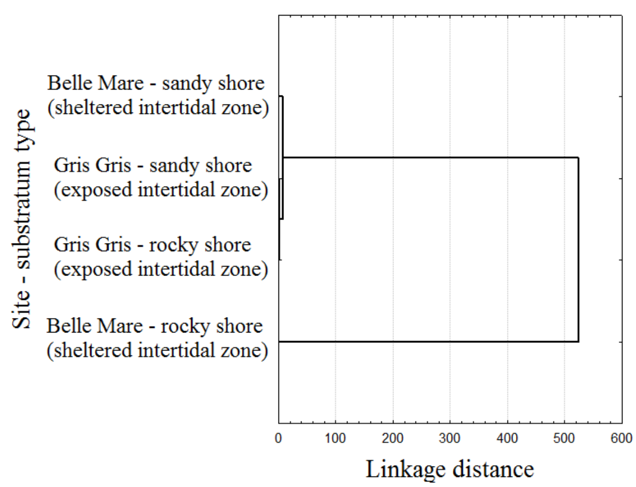

Figure 3. Dendrogram depicting the relationship in terms of mollusc density among the study sites, Belle Mare and Gris Gris, and the substrata, sandy and rocky.

Table 3. Two-way ANOVA to compare total intertidal mollusc density on sandy and rocky substrata at Belle Mare and Gris Gris. *** - $p<0.001$.

Dependent variable	Source of variation	df	MS	F	p-value
Intertidal mollusc density	Site	1	13.55196	62.5722	0.000000***
	Substratum	1	18.61021	85.9272	0.000000***
	Site*Substratum	1	6.44468	29.7564	0.000001***

The sediment at both intertidal zones had a unimodal distribution (Fig. 4 a, b).

Nutrient levels

Nitrate concentration recorded at Belle Mare and Gris Gris were 0.259 ± 0.001 $mgNO_3$-N/L (mean ± SE) and 0.017 ± 0.001 $mgNO_3$-N/L, respectively (Fig. 5a). Phosphate concentration did not vary much at the two sites; 0.231 ± 0.047 µmol/L (mean ± SE) at Belle Mare, and 0.278 ± 0.094 µmol/L at Gris Gris (Fig. 5b).

Nitrate concentration was significantly lower at Gris Gris as compared to Belle Mare (one-way ANOVA, $p<0.001$), whereas phosphate concentration at the two sites were comparable with no significant difference detected (one-way ANOVA, $p>0.05$).

Discussion

The intertidal region is home to a variety of marine molluscs. Though intertidal communities are among the most studied ecosystems worldwide due to their easy accessibility (Hill *et al.*, 1998), reliable scientific information on marine mollusc assemblages along the shores of Mauritius is scant. This study attempts to provide baseline data on the density and diversity of intertidal benthic molluscs under varying hydrodynamic and substrate conditions at two coastal sites in Mauritius.

In the present study, grain size distribution was used as a proxy in order to confirm the qualitative categorisation of the sites into sheltered and exposed in terms of relative wave action. Generally, high energy shorelines with strong wave activity are usually composed of coarse sediment (Gray, 2002; Light & Carlton, 2007; Karleskint *et al.*, 2013) having higher porosity (Karleskint *et al.*, 2013) and homogeneity due to constant mixing by wave action. However, a sediment sample is never completely of the homogeneous type. Sediments which are well-sorted and predisposed to homogeneity are representative of high wave action or high energy areas, whilst poorly sorted sediments are heterogeneous and typical of low wave activity or low energy areas (Gray, 1981). High energy beaches also consist of steep slopes (Gray, 2002; Adams, 2003). The present study confirms that Gris Gris is the exposed or high wave activity site and Belle Mare the sheltered or low wave activity site. The grain size distribution analysis of sediment collected at these sites confirmed the corresponding qualitative classification of the two sites into exposed and sheltered, and indicated a marked difference in the prevailing wave action. The analysis also revealed that Gris Gris, where a steep beach is present, had coarse sand ($\bar{x}$ = 0.35) in the intertidal area with well-sorted particles (σ = 0.36). On the other hand, Belle Mare, characterised by a gently sloping beach, had medium sand ($\bar{x}$ = 1.22) which was moderately sorted (σ = 0.75). Thus, Gris Gris exhibited reflective beach conditions (coarse sand, steep slope), whereas Belle Mare tended toward dissipative conditions (medium sand, flat slope).

Shannon-Wiener and evenness indices were higher at Gris Gris as compared to Belle Mare, whereas higher Simpson's index indicated the dominance of certain species at Belle Mare. Diversity and dominance are negatively correlated (Berger & Parker, 1970; Shaukat *et al.*, 1978). Thus, even though a higher number of

Table 4. Grain size distribution parameters based on Folk and Ward's logarithmic method (Folk & Ward, 1957), computed using GRADISTAT program (Blott & Pye, 2001).

	Belle Mare		Gris Gris	
Parameters	Logarithmic, ϕ	Description	Logarithmic, ϕ	Description
Mean ():	1.22	Medium sand	0.35	Coarse sand
Sorting (σ):	0.75	Moderately sorted	0.36	Well-sorted

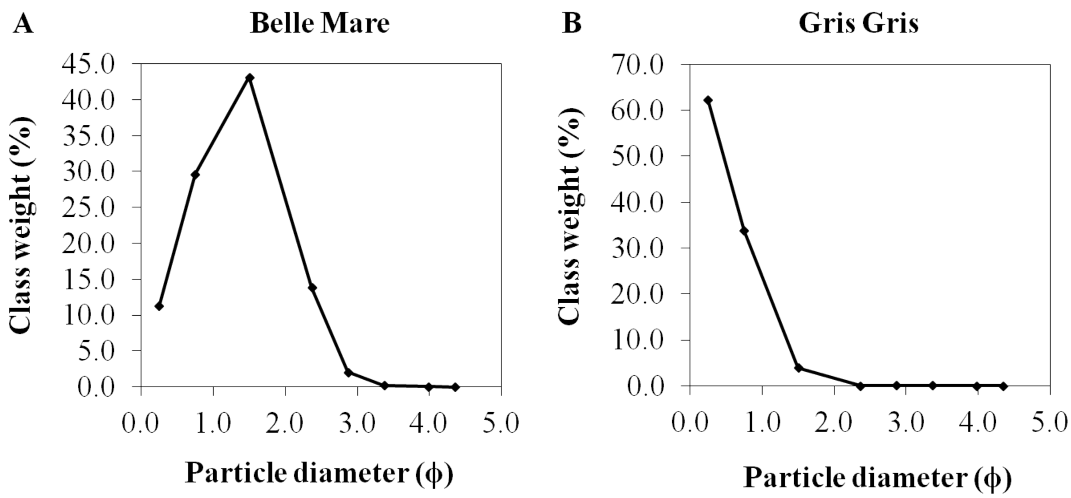

Figure 4. a) Distribution of intertidal sediment at Belle Mare. b) Distribution of intertidal sediment at Gris Gris. Grain size or particle diameter is expressed as ϕ units.

intertidal mollusc species was present at Belle Mare, high Simpson's index (dominance) at this particular site could be attributed to the high abundance of *P. sulcatus* in comparison to other species. In other words, the species were not evenly distributed along the intertidal zone. This also resulted in the low evenness value at Belle Mare. At Gris Gris, though a fewer number of species and individuals were recorded, they were more or less evenly distributed.

High concentration of dissolved nutrients in the intertidal region indicates anthropogenic input from adjacent coastal human settlements. On certain sections of the intertidal stretch of Belle Mare, fresh groundwater seepage from inland sources was observed. This could possibly explain the high level of nutrients recorded at this site. High nutrient (nitrate and phosphate) levels are known to promote the growth of phytoplankton (Sakka *et al.*, 1999) which in turn can boost filter feeding (Asmus & Asmus, 1991; Arapov *et al.*, 2010) and increase bivalve production. This observation probably explains the high density of Isognomonidae, deeply embedded within crevices, recorded in the present study at Belle Mare under high nutrient levels.

In general, the intertidal zones of both Belle Mare and Gris Gris were numerically dominated by gastropods. *P. sulcatus* vastly dominated the rocky shores of Belle

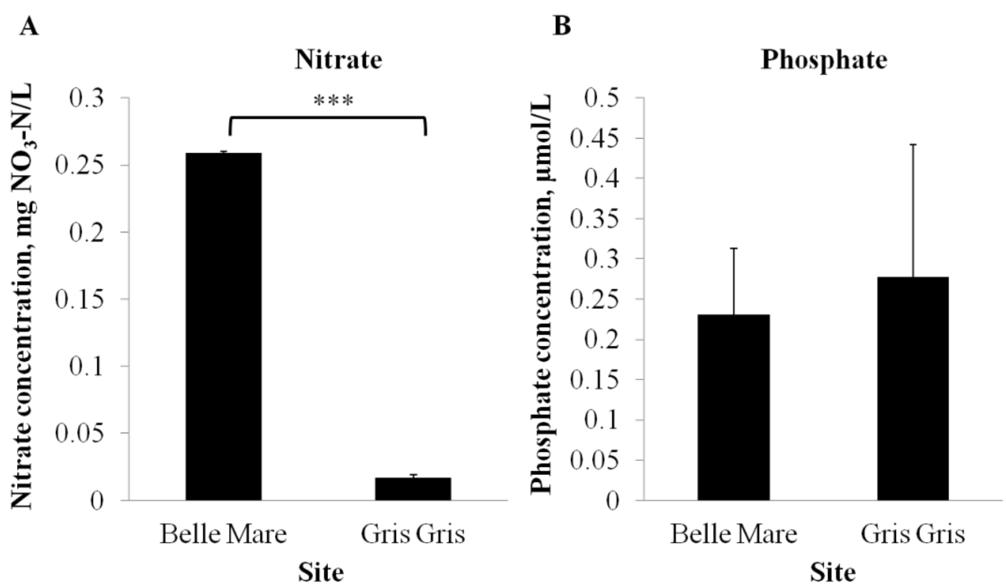

Figure 5. a) Nitrate concentration at Belle Mare and Gris Gris. b) Phosphate concentration at Belle Mare and Gris Gris. *** p<0.001 (one-way ANOVA) representing comparison between nutrient levels at Belle Mare and Gris Gris.

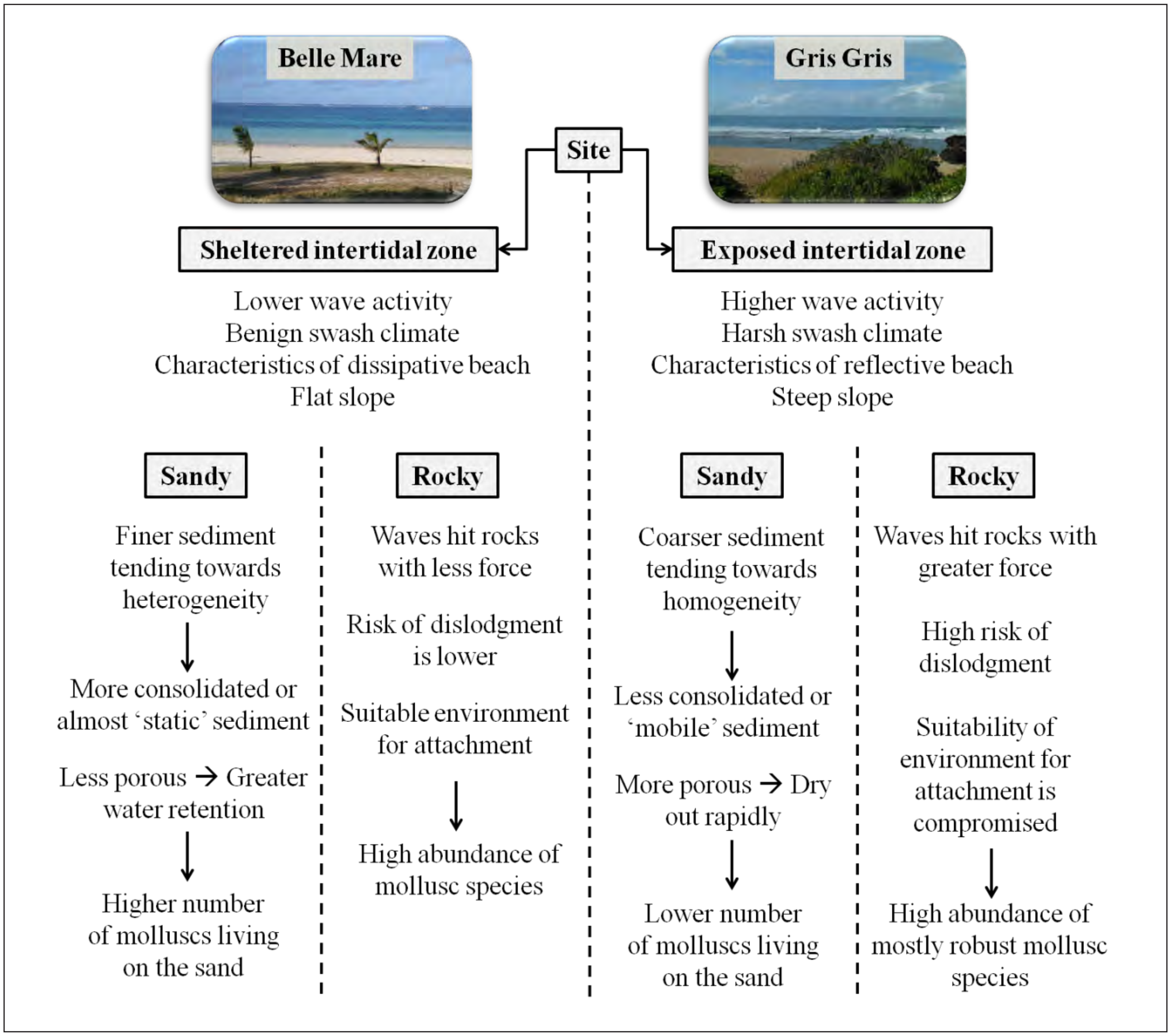

Figure 6. Scenario depicting conditions at sheltered and exposed regions and the effect on mollusc abundance (Adapted from: Gray, 1981; McLachlan, 1990; McLachlan, 1993; Adams, 2003; Light & Carlton, 2007; Karleskint *et al.*, 2013).

Mare, an observation in line with a study conducted by Charles *et al.* (2011), where the authors reported *P. sulcatus* as the dominant species at two stations along the rocky shores of Pointe aux Sables, with mean abundances of 196.86 ± 179.71 and 168.10 ± 113.44 per m^2. In this study, none of the mollusc species found on the rocky shore were recorded on the sandy shore. Gastropods from families such as Cypraeidae, Strombidae and Conidae were recorded on the sandy bottom. This is an indication of habitat preference by clinging gastropods for cracks and crevices in rocky shores, and burrows in sandy bottoms by bivalves and cypraeid gastropods. The bivalve *Pinna muricata* was recorded only at Belle Mare and no bivalves were seen on the sandy substratum at Gris Gris. Huz *et al.* (2002) reported the shortest burrowing time of the bivalve *Donax trunculus* in fine and medium sand compared to coarse sediment (gravel), an observation in accordance with the studies conducted by Trueman *et al.* (1966) for *D. vittatus*. Similar observations were made by Vanagt *et al.* (2008) in the case of the gastropod *Olivella semistriata* where an increase in burial time was noted with increasing sand size class. This is indicative of the suitability of fine to medium sediment (as in the case of Belle Mare) for burrowing activity, and consequently growth and survival.

In the intertidal zone, marine molluscs are vulnerable to predation (Underwood, 1979; Gosselin & Chia, 1995), competition (Underwood, 1979), desiccation/heat stress (Gosselin & Chia, 1995) and salinity stress (Pechenik, 1982). It is well documented and accepted that the distribution of many intertidal sessile animals is to some extent limited by wave exposure (Walsby, 1977). Wave exposure has the ability to affect the biology of intertidal organisms directly through dislodgement and indirectly by altering food availability, biotic interactions and foraging efficiency (Etter, 1989; Defeo *et al.*, 2001). McLachlan (1990) proposed the hypothesis that the distribution, abundance and diversity of species are controlled by the swash climate such that dissipative beaches that have a gentle slope and consisting of fine sediment have high species abundance and diversity. Further to this, McLachlan (1993) put forward the 'swash exclusion hypothesis' (SEH) where it was postulated that the swash climate becomes harsher from dissipative to reflective beaches and thus, increasingly vigorous swash excludes species from the intertidal zone. Moreover, the benign swash of dissipative conditions is suitable for all beach species, although only very mobile and robust ones can stand the harsh conditions of the reflective beaches (McLachlan, 1993; Brown & McLachlan, 2006). However, the SEH does not always hold true for all beach species (Gómez & Defeo, 1999; Defeo *et al.*, 2001). Though the SEH has mostly been tested on specific intertidal organisms rather than an amalgam of intertidal species, the observations during the present study conforms to the SEH in the sense that the total abundance of species recorded at Gris Gris was far less than that recorded at Belle Mare (Fig. 6).

The growth of intertidal organisms can also be a function of wave activity. Harger (1970) demonstrated the impact of waves on molluscs by the use of a simple device on two mussel species (*Mytilus edulis* and *M. californianus*) in an intertidal zone. The mussels were subjected to exposed and protected conditions. While no difference in the growth was observed for *M. californianus*, the growth of *M. edulis* in the exposed condition was only one-third of the growth in the sheltered condition. This difference in growth was attributed to increased exposure to high wave activity in the exposed condition.

The low abundance of intertidal molluscs at Gris Gris could possibly be explained by the fact that wave action displaces the organisms away from the intertidal zone toward areas of minimal wave effects. Organisms dislodged or washed off from wave-exposed sites may not be able to reattach to the substrate until they find a suitable condition for attachment, usually in calm water, and may eventually die as demonstrated by Walsby (1977) for the turbinid *Lunella smargda* in the waters of New Zealand. Harger (1970) showed that a greater force was required to dislodge *M. californianus* from a rock face compared to *M. edulis*. This suggests that an intertidal zone with high wave activity such as Gris Gris may not be a suitable environment for the growth and survival of bivalves with relatively weak attachment strength. Indeed, it is noteworthy that no bivalves were recorded from the intertidal shore of Gris Gris. Etter (1989) determined variations in the life history of the gastropod *N. lapillus* across a wave-exposure gradient and revealed that mortality rates increased with wave energy. The present study corroborated the study of Etter (1989) where very few benthic molluscs were observed along the exposed intertidal zone. The presence of high wave activity may potentially have a role in causing mortality of mollusc larvae, if not dispersing them away from the wave-swept intertidal zone.

In conclusion, it can be inferred that Belle Mare, with a sheltered intertidal zone, provides less stressful conditions for organisms to survive. Therefore, Belle Mare harboured a higher number of mollusc species owing to the suitability of the environment for growth as compared to Gris Gris, which is exposed to relatively stronger wave action. Future studies at various other sites around the island will provide further insight into the observations documented in this report.

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