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Conservation under warming ocean conditions for endemic corals and reef fishes of Rodrigues Island, Republic of Mauritius

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Abstract. *Munbodhe V, Bhagooli R. 2025. Conservation under warming ocean conditions for endemic corals and reef fishes of Rodrigues Island, Republic of Mauritius. Indo Pac J Ocean Life 9: 140-155.* Ocean warming has accelerated coral-algal phase shifts, threatening reef biodiversity and ecosystem functions. This study assessed coral reef conditions across 14 sites around Rodrigues Island, Mauritius, including four Marine Protected Areas (MPAs) and ten Non-Protected Areas (NPAs), surveyed from November 2019 to December 2020. Coral cover, macroalgae, and substrate covers were quantified using underwater visual censuses and 15 quadrats per site (~4 m² each). Live coral cover in MPAs was 2.5 times higher than in NPAs, with significant differences in benthic composition (GLM–Poisson, p<0.001). Significant differences in live corals, macro-algae, and soft coral covers were observed between MPAs and NPAs, GLM-Poisson Distribution, p<0.001. The MPA harbored 2.5-fold more live corals than NPAs. Relatively low coral genera richness was noted in the no-take marine reserves (Pielou's Evenness Index, J=0.31 and Simpson Dominance, D=0.65) as compared to multiple use MPAs (0.65<J<0.96) and NPAs (0.94<J<0.83). Of the 150 coral species recorded, 47 were from the genus *Acropora,* which mostly occurred in the MPAs. The MPAs demonstrated significantly higher reef structural complexities than the high macroalgal and rubble covers in the NPAs, ANOVA Post-hoc, p<0.007. No endemic coral, *Acropora rodriguensis*, was observed at the surveyed sites, while *Pomacentrus rodriguensis*, the endemic reef fish, was dominant in algal-dominated NPAs. The presence of regionally and nationally endemic species highlights Rodrigues as a biodiversity hotspot requiring strengthened reef management. This study provides critical baseline data for coral reef resilience and underscores the need for genetic and long-term ecological monitoring to support ecosystem-based conservation in a warming ocean.

Keywords: *Acropora*, coral species, endemic and rare, reef fishes, marine protected area

Abbreviations: HC: Hard Cover, GLM: General Linear Model, MA: Macroalgal cover, MPAs: Marine Protected Areas, Npas: Non-Protected Marine Areas, RUB: Rubble, SC: Soft coral cover, SIDS: Small Island Developing States

INTRODUCTION

Coral reefs are vital for being one of the world's most productive ecosystems (Graham et al. 2006). Besides providing ecosystem functions, coral reefs play a fundamental role in supporting fisheries and the tourist industries (Bellwood et al. 2004; Obura et al. 2019). Despite being recognized for its diverse socio-economic benefits, coral reefs have been continuously undergoing structural and functional modifications due to human disturbances (Hughes et al. 2017) which are further exacerbated by prolonged marine heating (Reimer et al. 2024). Overall, the three-dimensional complex structure corresponds to the wide range of habitats extending from food, shelter, to nursery ground to associated biomes (Martinez and Altvater 2024). As such, one hectare of coral reefs is valued at about $352,000 for one year of economic and ecological goods and services (Fezzi et al. 2023).

Yet, the reef functions are severely compromised (Hughes et al. 2018) for instance, phase shifts from coral to algal dominated habitat and reduction in reef structural complexity give rise to (i) the loss of reef fish biodiversity (Darling et al. 2017) and (ii) reduced coastal protection (Spalding et al. 2014) and reduction in fisheries, wave attenuation and carbon sequestration (Powell et al. 2020). Persistent overfishing has been amongst the leading stressor resulting in the collapse of many of the world's fisheries (Gaylord et al. 2005). The failure of traditional fisheries management including maximum sustainable yield, fisheries quotas, amongst others led to the emergence of ecosystem-based management in the form of marine reserves (Long et al. 2015). With growing knowledge in reef community structural changes, the establishment of marine reserves became instrumental to protect, maintain, and restore most of the targeted species and other reef associated organisms with the hope of mitigating some of the anthropogenic threats (Lester et al. 2009; Eli et al. 2025).

Likewise, the reefs of the Indian Ocean are also exposed to both human-induced disturbances and the warming environment. Studies of 822 reefs of the Western Indian Ocean have shown that post-1998 bleaching has claimed the loss of over 25% of the coral functionalities in the region due to significant loss of live coral covers (Obura et al. 2019), while recent findings suggest that there has been a considerable increase in rubble and macro-algal dominance (Elliott et al. 2018; Ricot et al. 2025) with severe loss in coral diversity (McClanahan and Muthiga 2020). Furthermore, the latest photo-physiological experiment on common corals from the Mascarene Plateau from Saya de Malha, St Brandon, and Mauritius described the degree of vulnerability of reefs under anthropogenic influences to prolonged climate variabilities (Munbodhe et al. 2025). Situated in the easternmost tip of the Mascarene Plateau, Rodrigues Island, considered a marine biodiversity hotspot, harbors endemic coral, *Acropora rodriguensis*, and endemic reef fish, *Pomacentrus rodriguensis*. However, limited ecological information is available on their distribution and abundance.

Along with increasing population and intensifying tourism industry, the Rodrigues Island, a Small Island Developing State (SIDS), is continuously threatened by the climatic challenges (IPCC 2023). Subsequently, the reefs are exposed to unprecedented impacts of the warming ocean and the sea level rise (Doorga et al. 2025). The mounting pressures on coastal fisheries, compounded by significant impact from thermal-driven coral bleaching and coral diseases (Jogee et al. 2025), further fragilize the benthic and fish community structures (Ricot et al. 2025; Moreno-Borges et al. 2025). Moreover, ongoing reef structural alteration profoundly reduces reef functionality, coral reef resilience (Wu et al. 2024), and biodiversity functions, leading to a critical reduction in certain specialist reef fish abundance (Zhang et al. 2025). In view of the escalating ecological threats and biodiversity loss globally, this study attempts to generate vital scientific data on the occurrence and abundance of the endemic coral, *A. rodriguensis,* and endemic reef fish, *P. rodriguensis,* along with targeted rare coral and reef fishes, while evaluating the reef status of understudied shallow backreefs and mid-lagoons at 14 selected sites within the Marine Protected Areas (MPAs) and Non-Protected Areas (NPAs) of the Rodrigues Island. It is therefore hypothesized that by virtue of its enhanced reef management strategies, Marine Protected Areas (MPAs) sustain higher live coral coverage and coral diversity than Non-Protected Areas (NPAs), and that endemic and rare species occur more frequently in structurally complex, low-impacted reef habitats.

MATERIALS AND METHODS

Study area

Rodrigues Island, a sovereign part of the Republic of Mauritius, is surrounded by a fringing reef, which forms a continuous band approximately 90 km long. The reef encloses a shallow lagoon of 240 km^2, Table 1, (twice the area of the island). It is situated on a submarine spur lying eastward of the main Mascarene Plateau and is the smallest of the Mascarene Islands (108 km^2 which lies on a submarine rise between the Mascarene and St Paul-Chagos ridges (Duncan and Hargraves 1990). The island lies 570 km to the East of Mauritius, sits on an east-west axis, along which runs a spine-like mountain range approximately 600 meters above sea level. It is volcanic in origin and is dominated by a central ridge which crosses the island almost throughout from the East to the South-west, over a distance of about 10 km, tapering off in the West into a calcareous coral plain (Thébault et al. 2009). It is surrounded by a large fringing reef that encloses 240 km^2 of lagoon area with 18 small islets. Rodrigues is the only Mascarene Island with extensive limestone deposits (Middleton and Burney 2013). The main coastal features include basaltic rock shores, coral reefs, lagoons, sand beaches, estuaries, wetlands, and mangroves. It has a population density of about 40,000 is largely dependent on agriculture and fishing (about 90% of the workforce) (Pasnin et al. 2016)

The South East Marine Protected Area (SEMPA) zoning has been subdivided into a no-take marine reserve and several multiple-use Marine Protected Areas (MPAs), and key planning documents have been drafted for successful management, including several studies and the development of SEMPA's Management Plan (Pasnin et al. 2016). SEMPA was designed to be a showcase of participatory MPA management. SEMPA includes both Trou Blanc, the no-take and the multiple-use MPAs, which are separated by the natural reef opening giving rise to a channel. Important global benefits were generated through the creation of SEMPA and its strengthened management through participatory approaches. A main challenge in SEMPA was noted, which was recognized as the lack of local capacity in MPA management (Pasnin et al. 2018). In addition, 4 other Marine Reserves were gazetted in 2007 in the northern and north-western sectors of the lagoon and occupy ~20 km^2.

The four Marine Reserves (MR) are Riviere Banane, Anse aux Anglais, Grand Bassin, and Passe Demi Marine Reserves. Riviere Banane MR is situated in the northeast of the island, which covers an area of 1.5 km^2 of shallow lagoon extending to the fore reef, which has been reported as degraded (Pasnin et al. 2018). Anse aux Anglais MR is located in the north most of the island with an area of 1.5 km^2 with relatively high coral cover in the reef slope (Pasnin et al. 2018) while Grand Bassin MR is located in the northwest with an area of 14.1 km^2 with low coral cover in the backreef as compared to about 46% coral cover in the reef slope and Demi Passe MR covers an area of 7.2 km^2 with relatively low coral cover (Pasnin et al. 2018). Fenner et al. (2004) reported the occurrence of the endemic coral *A. rodriguensis* and the endemic reef fish *P. rodriguensis* and *Amphiprion chrysogaster* at Riviere Banane and Anse aux Anglais Marine Reserves, Mauritius.

Survey sites

All surveys conducted in the lagoons of Rodrigues Island were covered under the authorization obtained from the Commission for Agriculture, Environment, Forestry, Fisheries, and Marine Parks, Rodrigues Regional Assembly, Republic of Mauritius. Due to the limited number of field days and boat availability, only 14 sites were assessed, whereas on 17 November 2019, contact with boat operators, diving sites, and the fishermen community was established, and the site selection was done based on accessibility, along with a stock-taking exercise. However, all the 14 sites were surveyed from 17 to 20 December 2020 which included one no-take MPA at Trou Blanc bordering the reef opening (channel) in the south-east along with three multiple-use MPAs, namely, Vas Brulee (south-east), Riviere Banane (East) and Anse aux Anglais (north), Figure 1. In addition, 10 non-protected lagoons and backreef areas were also surveyed viz. Trou Mullet I (south-east mid-lagoon), Gros Pot, Bar Chirurgien, Trou Mullet II (south mid-lagoon), La Butte (west backreef), La Ferme (North-west backreef), Baie aux Huitre, Terre Rouge, Cavern Provert, and Grand Baie, the northern backreef sites (Figure 1).

Research strategy and sampling design

Extensive island-wide field surveys were carried out at 14 sites. Irrespective of the coral diversity and reef structural complexity, sites were selected based on site accessibility, and random surveys for benthic assessment were done randomly (McClanahan et al. 2005), conversely to coral and targeted reef fish search. The survey area varied from backreefs (<1m deep) to mid-lagoons (>2 m deep), ranging from 0.1 to 0.2 km^{2,} which included shallow reefs and larger lagoons/mid-lagoons in both Marine Protected Areas (MPAs) and non-managed sites, Non-Protected Marine Areas (NPAs). Three sets of data were compiled from each ecologically surveyed site. Firstly, a stock-taking exercise of each site was done by collecting substrate cover data for about 30 minutes of snorkeling randomly so as to cover a wider area (McClanahan et al. 2005), as opposed to LIT and Photo-quadrants, which are more time-consuming and limited to a pre-defined area; these methods are suited best for long-term reef monitoring (Urbina-Barreto et al. 2021; Carneiro et. al 2024). The Visual Census technique was used for approximately 90 minutes for the search for endemic and rare coral and reef fishes, as well as to photograph all coral colonies encountered during that period, providing insight into the different coral diversity.

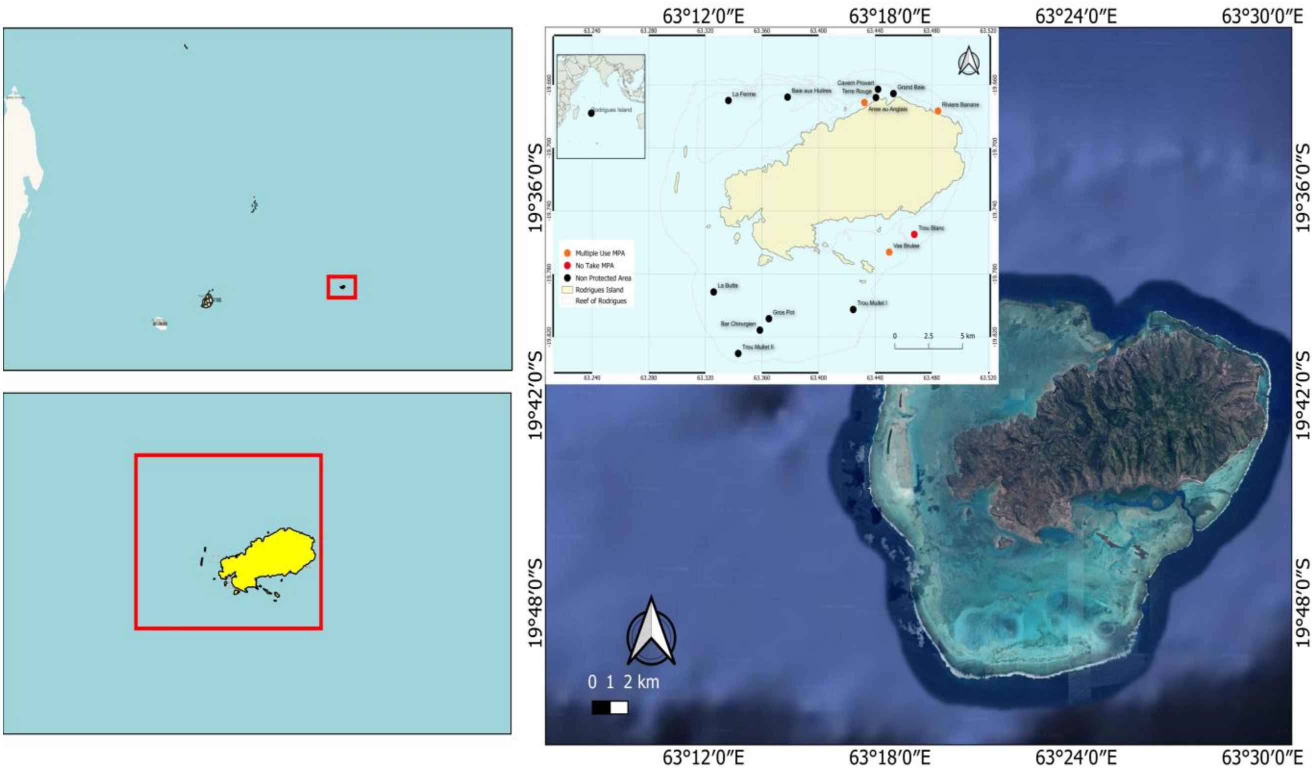

Figure 1. The geo-referenced map of Rodrigues Island, a sovereign part of the Republic of Mauritius, shows the geo-location of the no-take and the multiple-use MPA, and the NPA of the 14 surveyed. Note: Geo-referenced map indicates the location of each site as per the respective GPS coordinates recorded during the surveys

Table 1. Characteristics of Rodrigues Island (Mauritius) and reef management framework

		Rodrigues Island
Geomorphology	Longitude	19°40’S
	Latitude	63°20’E
	Landmass	108 km²
	Coastline	322 km
	Lagoon area	240 km²
	Reef type	Fringing
Climate		Mild tropical
	Temperature	20.4°C-24.7°C
	Wind	Prevalent Southeast Trade Wind
	Mean Annual Rainfall	about 1140 mm
Demography	Population size	41,000
Economic contribution	Main activities	Fisheries activities: octopus fisheries as a major fisheries activity, along with large net and handline fisheries Tourist industry
Reef Management	Marine Protected Areas	5 Fisheries Reserved Areas, 4 Marine Reserves, and a multiple-use Marine Protected Area in the south-east of Rodrigues (SEMPA) with a strict no-take zone
Legal Framework	Legislation and Regulation	Fisheries Act 2023 Closed Season for Net fishing starting from the 1st day of October of one year to the last day of February the following year Fisheries and Marine Resources (fishing of octopus) (Amendment) Regulations GN No. 138 of 2020 Fisheries and Marine Resources (Fishing of Sea Cucumbers) (Amendment) Regulations 2020, the Toxic Fishes Regulations 2004. Prohibition of Removal of Coral and Seashell Regulations 2006. The Undersized Fish Regulations 2006. Fishing of Sea Cucumbers Regulations 2008, 2009 & 2012. Prohibition of the Use of Hooks of Small Size Regulations 2011 The Marine Protected Areas Regulations 2001.

Note: Source: Statistics Mauritius, Government of Mauritius, https://statsmauritius.govmu.org/SitePages/Index.aspx

Reef benthic communities survey

This study focused on random data collection of benthic coverage with respect to hard coral cover, soft coral cover, and macroalgal assemblages. The underwater visual census method was used to evaluate the benthic communities. The benthic cover data collection was conducted by estimating the percentage of the live hard coral cover (HC), soft coral cover (SC), the macroalgal cover (MA), and rubble (RUB) at each selected site. Prior to data collection, each site was geo-referenced. At each selected site, a diver, after getting into the water, swims for about 30 seconds with closed eyes randomly, and then the diver after opening the eyes, selects an imaginary quadrat of approximately 4 m^2. After demarcating the quadrat, the observer then scans the benthic cover and records the estimated % cover of the attributes (HC, SC, MA, and RUB) within the imaginary quadrat. Due to time constraints and to avoid limitations in the area covered, unlike the Line Intercept transect, this underwater visual census exercise was randomly repeated 15 times for each site over a wider range so as to maximize area coverage of the relatively larger and heterogenous reefs. However, after every quadrat, the observer closes their eyes and makes five kicks to start another quadrat, making the sampling as unbiased as possible. As such, 15 random quadrats per survey site were used to estimate the % live coral cover of that particular site (McClanahan et al. 2005), covering a wide area, conversely to Line Intercept Transect or photoquadrants (Jokiel et al. 2015). The imaginary quadrat was more time-efficient both in terms of data collection and data inputs, whereby within 30-45 minutes, in-situ data were collected.

Coral inventory

A list of coral species occurring at each site was compiled based on surveys conducted between 2018 and 2021 by snorkeling the entire lagoon. Over 15,000 photos of the multitude of coral colonies were taken, including close-up shots using the Canon D30 (109×68×28 mm; 4.29×2.68×1.1″) for coral identification at the species level using Allen and Steene (1994), Veron (2000), Moothien-Pillay et al. (2002) and WORMS (2024). The survey was conducted in the near-shallow, mid-lagoon, and MPAs where the coral colonies were most abundant; nevertheless, the near-shore area was also inventoried, which harbored mainly massive *Porites* and occasional branching *Acropora* with macroalgal assemblages and rubbles on the sandy bottom.

Coral diversity, data generation, and coral identification

A high-resolution photographic underwater camera (Canon PowerShot D30 Full HD 21.1 Mega Pixel) was used to capture individual coral colonies as well as to take close-up photos, which were later used for morphological identification and quantification of the coral genera at each selected site. Over 400 to 500 photos per site were captured for image analysis. The number of colonies of the listed corals (genus–level) was recorded during the survey. Image analysis, i.e., coral identification to species level, was performed using Allen and Steene (1994), Veron (2000), and Moothien-Pillay et al. (2002). Differences and similarities in the coral morphologies, i.e., massive, tabular, branching, corymbose, encrusting, and foliose, were observed, and close-up characteristics of the corals were compared with those of Veron (2000) and others. Closed-up characteristics of corals were mainly differences in corallites, axial and radial, branches thickness, tips, regularity for branching corals, while walls, budding stages, and paliform lobes were used to differentiate among *Favia*, *Favites*, *Montastrea*, and *Goniastrea* spp, whereas the depth, length, regularity, and continuity of valleys in *Lobophyllia*, *Euphyllia*, *Symphyllia*, *Platygyra*, *Leptoria* spp., and others. Coral diversity was quantified at the taxa level among 66 taxa to assess genus-level coral diversity and evaluate the coral structural dominance at each site (McClanahan et al. 2005). Over 6,000 photos were analyzed for the 14 sites.

Targeted species – Endemic and rare corals and reef fishes

Due to a lack of prior assessments on the endemic and rare corals and reef fishes, we evaluated the literature to identify rare and endemic species. Upon consultation with fishermen, coastal communities, and conservation organizations concerned with coral reefs, and after consideration of the literature and communication from diving communities, one endemic coral, *A. rodriguensis*, and one endemic reef fish, *P. rodriguensis*, from Rodrigues Island were selected as endemic species for the study. The list of regionally endemic and rare coral and reef fish species was compiled from the literature. The regionally endemic coral species were *Acropora branchi, Horastrea indica,* and *Pocillopora indiania,* while *Seriatopora hystrix*, *S. calendrium,* and *Stylophora pistillata* were identified as rare coral species. The regionally endemic reef fishes that were identified as rare were *Abudefduf margariteus, Zebrasoma gemmatum, Ostracion trachys, Pomacentrus pikei*, and *Amphiprion latifasciatus* (anemone fish) (Table 2).

Statistical analyses

General Linear Model (GLM)-Poisson Distribution was used to compare the substrate covers of the MPAs and NPAs for Rodrigues, Jamovi (Version 5) Model Fit, R^2=0.37, p<0.001; Omnibus Tests, Management, Substrate and Management v/s Substrate p<0/001. One-way ANOVA- Welch's Test, p<0.005, Shapiro-Wilk Test for normality, p>0.05, were used to assess the variation in the distribution of coral genera, while ANCOVA, Post-hoc Bonferroni corrected, p<0.05, determined the coral species diversity and the dominance of *Acropora* species between the MPAs and NPAs. Shannon-Wiener (H), Simpson Diversity (D), and Pielou's Evenness (J) were used to determine the diversity of coral species harbored by the MPAs, mid-lagoon, and shallow-reef NPAs. The Q-GIS software was used to generate geo-referenced maps to demonstrate the site-wise benthic coverage and to show the occurrence and distribution of the coral genera, indicating the dominance of certain different corals in specific regions around Mauritius and Rodrigues, along with targeted species regionally and endemic rare coral and reef fishes.

Table 2. Summary on targeted coral and reef fishes for the study

List of endemic and rare coral species under study			
Scientific name	**Occurrence**	**Status**	**IUCN Red List**
Acropora rodriguensis (Pichon, 1980)	Shallow reef environment (Hardman et al. 2004)	Endemic to Rodrigues Island (Pasnin 2011)	**Status:** Not clearly documented; Data deficient, **Population:** Unknown
Acropora branchi (Riegl, 1995)	Indian Ocean, coastal region in the upper reef slope (Veron 2000)	Regionally Endemic Western Indian Ocean (Obura 2012)	**Status:** Data deficient, **Population trend:** Decreasing
Acropora clathrata (Brook, 1891)	Indo-Pacific, upper reef slopes, backreefs and fringing reefs (Veron 2000)	Occurs in the tropical and subtropical reef regions	**Status:** Data deficient, **Population trend:** Decreasing
Horastrea indica (Pichon, 1971)	Very rare coral, occurrence limited to sandy reef areas (Veron 2000)	Regionally endemic Western Indian Ocean (Obura 2012)	**Status:** Vulnerable, **Population trend:** Unknown
Pocillopora indiania (Veron, 2000)	Indian Ocean, coastal region in the upper shallow reef (Veron 2000)	Regionally Endemic Western Indian Ocean (Obura 2012)	**Status:** Vulnerable, **Population trend:** Unknown
Seriatopora hystrix (Dana, 1846)	Shallow reef environment (Veron 2000)	Occurs in the tropical and subtropical reef regions	**Status:** Vulnerable, **Population trend:** Decreasing
Seriatopora caliendrum (Ehrenberg, 1834)	Upper reef slope (Veron 2000)	Occurs in the tropical and subtropical reef regions	**Status:** Near Threatened, **Population trend:** Unknown
Stylophora pistillata (Esper, 1797)	Exposed reef fronts to shallow reef flats (Veron 2000)	Occurs in the tropical and subtropical reef regions	**Status:** Near Threatened, **Population trend:** Unknown

List of endemic and rare reef fish species under study			
Scientific and common name	**Occurrence**	**Status**	**Ecological niche**
Stegastes rodriguensis (Allen and Wright, 2003)	Inhabits reef areas, commonly found in *Acropora* dominated reefs (Fishbase.de)	Endemic to Rodrigues Island	Reef-associated and territorial
Stegastes pelicieri (Allen and Emery, 1985)	Inhabits rocky reefs, rubble substratum area in shallow and calm lagoon near crevices and holes (Fishbase.de; Terashima et al. 2001)	Endemic to Mauritius and Reunion Islands (Fishbase.de)	Reef-associated and non-migratory, Shallow lagoon/Reef flat
Amphiprion chrysogaster (Cuvier, 1830)	Inhabits reef areas, more specifically in sea anemone, *Hectaractis magnifica*, *Stichodactyla mertensii* (Fishbase.de)	Endemic to Mauritius (Fishbase.de)	Specialist – habitat specific, Shallow lagoon/Reef slope
Pomacentrus pikei (Bliss, 1883)	Inhabits rocky reefs, rubble substratum area in shallow and calm lagoon near crevices and holes (Fishbase.de; Terashima et al. 2001)	Distributed in the Western Indian Ocean, regionally endemic (Fishbase.de)	Reef-associated and non-migratory, Shallow lagoon/Reef slope
Stegastes limbatus (Cuvier, 1830)	Inhabits branching coral in the lagoon areas and exhibits territorial behaviour (Fishbase.de; Terashima et al. 2001)	Distributed in the Western Indian Ocean, regionally endemic (Fishbase.de)	Territorial reef-associated and non-migratory, Shallow lagoon/Reef slope
Ostracion trachys (Randall, 1975)	Occurs mainly in the outer reef between 15 to 30 m, found chiefly in holes and crevices (Fishbase.de)	Endemic to Mauritius and Reunion Islands (Fishbase.de)	Reef-associated and non-migratory, Outer reef
Abudefduf margariteus (Cuvier, 1830)	Inhabits coral and rocky reefs around lagoons and reef slopes (Fishbase.de; Terashima et al. 2001)	Distributed in the Western Indian Ocean (Fishbase.de)	Supposedly common in Mauritius
Zebrasoma gemmatum (Valenciennes, 1835)	Occurs mainly in the outer reef between 15 to 60 m, found chiefly in holes and crevices (Fishbase.de)	Distributed in the Western Indian Ocean, regionally endemic (Fishbase.de)	Reef-associated
Amphiprion latifasciatus (Allen, 1972)	Associated with the anemone *Stichodactyla mertensii.* Resides both lagoons and outer reef (Fishbase.de)	Distributed in the Western Indian Ocean, regionally endemic (Fishbase.de)	Specialist – habitat specific, Shallow lagoon/Reef slope
Pomacentrus agassizii (Bliss, 1883)	Inhabits lagoon and inshore coral reef areas (Fishbase.de)	Distributed in the Western Indian Ocean (Fishbase.de)	Reef-associated and non-migratory
Plectroglyphidodon randalli (Allen, 1991)	Inhabits lagoon and inshore coral reef areas (Fishbase.de)	Distributed in the Western Indian Ocean (Fishbase.de)	Reef-associated and non-migratory

Mapping

A free and open-source Geographic Information System (GIS) software, QGIS Software version 3.34.8-Prizren, was downloaded, available at QGIS.org, and used to create all the maps in this project. Data was acquired by downloading the required base map layers from MarineRegions.org, including various marine and coastal datasets consisting of the Indian Ocean, Mauritius, Rodrigues, and the reef of Mauritius/Rodrigues basemaps. All the downloaded files were downloaded in a compatible shapefile format as vector layers. The World Map was also used in this project to verify all the maps from MarineRegions.org.

The world map and the Coordinate Reference System (CRS) were imported into the project with the project's CRS correctly set. For all maps used in this project, the commonly used projection is WGS 84. Layers were arranged in the Layers Panel so that the base maps appear below any thematic layers. Symbology was applied by double-clicking on each layer in the Layers Panel to open the Layer Properties dialog, and appropriate symbology was chosen for each layer. For example, use different colors to differentiate between MPA and NPA as orange/red and black, respectively. Labels were customized using the callout option to allow labeling for sites without overlapping each other. In the Labels tab of the Layer Properties, options such as placement and rendering were constantly used to attribute all labels, sites, and graphs.

RESULTS AND DISCUSSION

Coral cover in the MPAs and NPAs

Overall, 14 sites within the lagoons of Rodrigues Island were surveyed for their substrate covers, which included hard coral (live), soft coral, macroalgae, and rubble. Of the surveyed sites, four were Marine Protected Areas (MPAs), of which Trou Blanc was a no-take MPA, and the three others were multiple-use MPAs, whereas the 10 remaining sites were areas open to fishing activities, Non-Protected Marine Areas (NPAs). Trou Blanc harbored the most live coral cover (mean: 60.33±6.04%, S.E) with hardly any macroalgae, 6.33±5.65% and 23.76±3.03% of soft corals and rubbles, respectively (Figure 2). Vas Brulee, Riviere Banane and Anse aux Anglais, the three multi-use MPAs had 34.74±4.85%, 33.33±4.01%, and 39.67±4.71%, respectively. The results further showed that Baie aux Huitres was the only NPA which had over 28.0% of live coral cover (28.67±4.74%) whereas the rest of the surveyed NPAs registered between 11.67 to 18.67% live coral cover with the highest macroalgal at Bar Chirurgien (71.33±2.99 %) followed by La Butte (70.67±2.84%) and Gros Pots (69.67±2.95%). Rubbles were dominant at Trou Mullet II (63.67±4.32%), followed by Terre Rouge and La Ferme (53.67±3.51% and 48.67±3.57%). It is noteworthy that Riviere Banane (multiple-use MPA) had almost two-fold rubbles (52.33±4.73%) than Vas Brulee (29.67±5.97%), followed by Anse aux Anglais, whereas denser macroalgal cover was recorded at Riviere Banane. The dominance of soft corals was more pronounced at Vas Brulee (33.33±6.07%) as compared to Trou Blanc with 16.33±5.66%), while the soft coral cover was negligible at Riviere Banane and Anse aux Anglais. Whereas Trou Mullet I had the most soft-coral coverage with 50.33±6.87%.

Significant differences in live coral, macro-algae, and soft coral covers were observed between MPAs and NPAs, whereas no significant difference in rubble dominance between the MPAs and NPAs was observed, Bonferroni Post-hoc Test, $p<0.001$, GLM -Poisson Distribution, Model Fit, $R^2=0.37$, $p<0.001$ (Table 3). Overall, the mean live coral cover within the MPAs was 41.92±2.8% whereas the NPAs registered 16.23 ± 0.93%. There was a visible dominance of macroalgae in the NPAs, with 48.57±1.88% compared to 12.75±2.45% in the MPAs. On the contrary, mean rubble was 32.50±2.60% and 30.13±4.73% in MPAs and NPAs, respectively (Figure 2).

Table 3. General Linear Model (GLM)-Poisson Distribution was used to compare the substrate covers of the MPAs and NPAs, Model Fit, $R^2=0.37$, $p<0.001$; Omnibus Tests, Management, Substrate and Management v/s Substrate $p<0.001$

		Comparison						
Management	**Substrate**	**vs**	**Management**	**Substrate**	**Ratio**	**SE**	**z**	**$P_{bonferroni}$**
MPA	HC	-	NPA	HC	2.58	0.07	33.37	<.001
MPA	MA	-	NPA	MA	0.26	0.01	-35.19	<.001
MPA	RUB	-	NPA	RUB	1.08	0.03	2.79	0.147
MPA	SC	-	NPA	SC	2.53	0.13	18.18	<.001

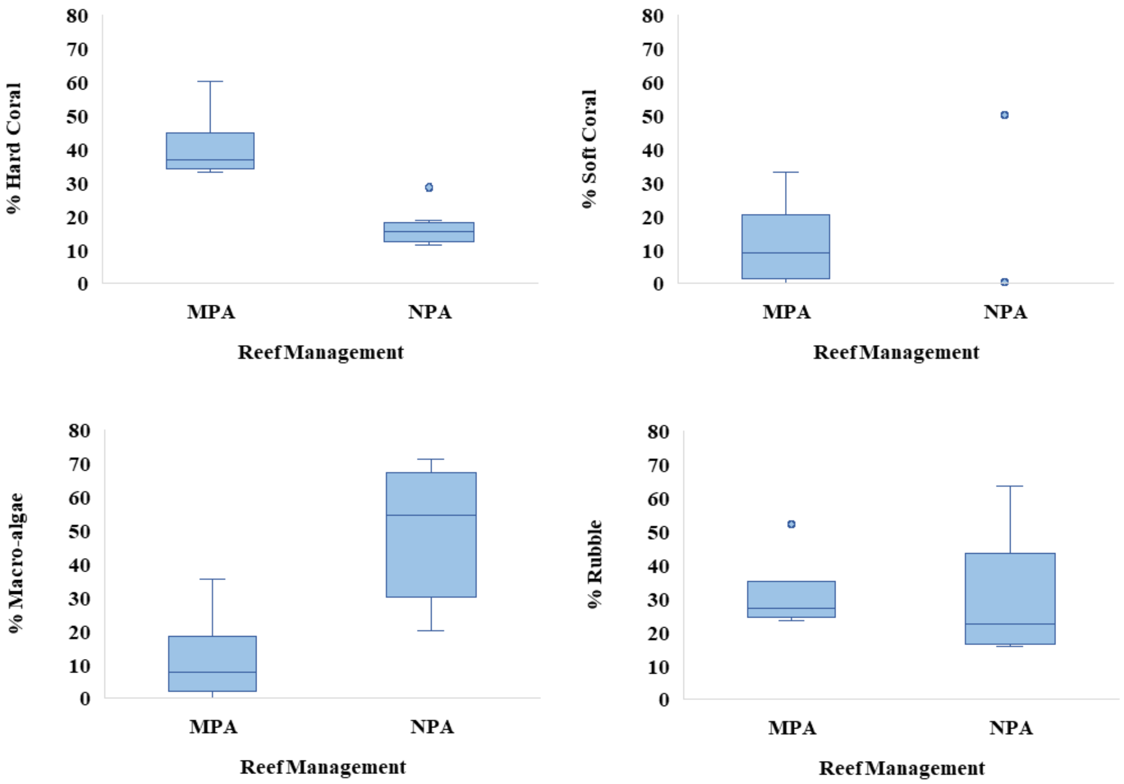

Figure 2. The difference in % substrate cover between MPAs and NPA sites surveyed around Rodrigues Island, Republic of Mauritius

Occurrence and distribution of corals in Rodrigues

Overall, 150 coral species were inventoried from the 14 sites surveyed, which included the targeted 9 rare and regionally endemic coral species from 38 genera and an addition of 2 coral species, one from the genus Acropora and one from Stylophora, which could not be identified. Furthermore, the results showed that 32 coral species occurred in relatively low numbers of colonies (n<3) within one or two surveyed sites, while 27 different coral species, which are geographically limited to the Pacific Ocean, were also found to occur at some studied sites in Rodrigues (Table 4). The MPAs had harbored the most coral genera ranging between 12 and 17 with mean occurrence of 14.25±1.11 (± S.E.) coral genera per site, which significantly differed from that of the NPAs which had a mean occurrence of 9.20±1.30 coral genera per site, one-way ANOVA, Welch's Test, p=0.014 (Figure 3 and Table 4, respectively). The no-take MPA, Trou Blanc, harbored 15 coral genera, while the multiple-use MPA, Vas Brulee, had 17 coral genera, whereas only one known coral genus, *Acropora*, was registered at Baie aux Huitres, contrary to La Ferme (NPA), where 15 coral genera were recorded, which included *Acropora*, *Montipora, Porites,* and *Anacropora* amongst others.

Of the 47 coral species, 20 *Acropora* species were recorded at Trou Blanc, which also included one Astreopora, one Cyphastrea, one Favia, one Favites, six Fungia, one Lithophyllon, eight Montipora, two Pavona, three Platygyra, five Pocillopora, and three *Porites* species. *Seriatopora*, *Stylophora, Symphyllia,* and *Turbinaria* occurred mainly at Anse aux Anglais, Terre Rouge, Gros Pot, and La Butte were found in low numbers of colonies (<3) sparsely distributed at the surveyed sites. Foliose and encrusting *Montipora* occurred in almost all surveyed sites, dominant at Anse aux Anglais, with all eight different species recorded, with the exception of Baie aux Huitre, Bar Chirurgien, and Grand Baie. Moreover, *Gardineroseris planulata*, *Hydnophora exesa*, *Oxypora lacera*, and *Plesiastrea versipora* were uniquely found at Gros Pot (NPA), whereas *Heliopora coerulea* was observed at Trou Blanc and Vas Brulee (MPAs). The common coral *Galaxea* and the endemic *A. rodriguensis* were hardly observed at the surveyed sites.

Coral species dominance in MPAs v/s NPAs (fishing zones)

Trou Blanc, the no-take MPA was the most dominant in coral species of all surveyed sites with 47 coral species of which 20 were from *Acropora* genus followed by Anse aux Anglais (MPA- Multiple use zones) with 16 *Acropora* species from 39 total coral species registered while Riviere Banane (MPA- Multiple use zone) had only two *Acropora* species from a total of 18 coral species recorded. La Ferme, Bar Chirurgien, and Gros Pot had the most coral genera and species of all the NPAs surveyed, while Baie aux Huitres had the lowest coral genera with only eight coral species from two genera, of which seven were *Acropora* spp. Moreover, 13 coral genera were recorded at Trou Mullet II (NPA) with 18 coral species, which included two Acropora species. Likewise, La Pass La Butte had seven coral genera with three Acropora spp. of a total of nine coral species recorded. It was further observed that the fishing activities had a significant impact on both coral genera and Acropora diversity within the NPAs, while hardly any such differences were found between no-take and multi-use zones MPAs (Table 5).

Table 4. Comparison of coral genera diversity between MPAs and NPAs, One-way ANOVA-Welch's Test, p<0.005, Shapiro-Wilk Test for normality, p>0.05

	F	df1	df2	p
Coral Genera MPA v/s NPA	8.75	1	10.37	0.014

Table 5. Comparison of coral species diversity in no-take and multi-use MPAs and areas subject to fishing activities, i.e., the NPAs, ANOVA, Post-hoc Tukey Test, p<0.05

ANOVA - Coral spp.				
Sum of squares	**df**	**Mean square**	**F**	**p**
Activities	1206.76	2	603.38	8.13
Residuals	816.67	11	74.24	

Post Hoc Tukey comparisons - activities					
Activities	**Mean difference**	**SE**	**df**	**t**	**P Tukey**
Fishing - Multi-Use	-16.33	5.67	11.00	-2.88	0.037
Fishing - No-Take	-29.00	9.04	11.00	-3.21	0.021
Multi-Use - No-Take	-12.67	9.95	11.00	-1.27	0.438

Note: Comparisons are based on estimated marginal means

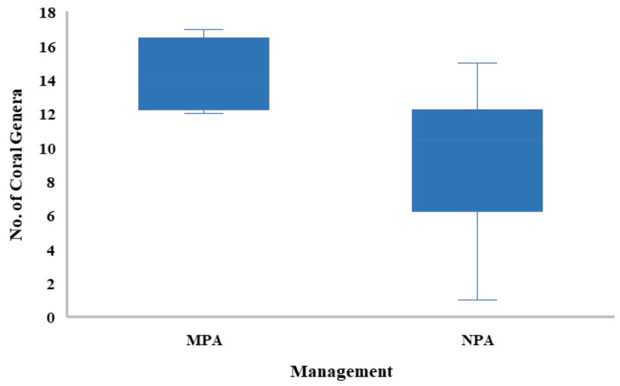

Figure 3. The difference in coral genera between MPAs and NPAs, and between MPA and NPA sites

Coral diversity indices in Rodrigues

The *Acropora* genus was the most dominant in the MPAs, followed by *Montipora*, *Favia*, *Porites*, *Pocillopora*, *Platygyra*, and *Pavona*, while *Anacropora*, *Astreopora*, *Cyphastrea*, *Echinopora*, *Favites*, *Goniopora*, *Leptatsria*, *Leptoria*, *Lobophyllia*, *Seriatopora*, and *Stylophora* were mainly observed in the NPAs, with limited *Acropora* and *Montipora* species. The reef of the no-take MPA, Trou Blanc, had a moderate genus richness (Shannon Index, H=1.67) with 15 coral genera and 47 coral species, of which 20 were *Acropora* and 7 *Montipora* species, including non-*Acropora* species evenly distributed (Pielou's Evenness, J=0.65) as compared to any other study sites (Table 6). The dominance of certain corals were considerable in the multiple-use MPAs and NPAs whereby some coral genera mainly the foliose, encrusting and massive ones were comparatively higher in densities, for instance, the highest level of coral genera richness occurred at Riviere Banane, La Ferme, Trou Mullet II and Terre Rouge (H'=2.41, 2.15, 2.14, and 2.13, respectively) with the Pielou's Evenness Index, J<0.16, indicating uneven genera distribution with potential high rarity rate against Trou Blanc (H'=1.67; J=0.65). For the rest of the sites, the H-value varied between 1.71 and 1.82, with the exception of Trou Mullet I, where the genera were relatively the lowest, H' = 0.92, with four coral genera and 12 coral species, of which eight corals were from the genus *Acropora*.

The highest level of coral genera occurred at Riviere Banane, La Ferme, Trou Mullet II, and Terre Rouge (H'=2.41, 2.15, 2.14, and 2.13, respectively) as compared to Vas Brulee (H'=1.99) and Trou Blanc (H'=1.67). For the rest of the sites, the H-value varied between 1.71 and 1.82, with the exception of Trou Mullet I, where only four genera were recorded, H'=0.92, which included 12 coral species, of which eight corals were from the genus *Acropora*. Thus, the multiple-use MPAs Riviere Banane harbored the most diverse coral genera, followed by Vas Brulee, and Anse aux Anglais, with more varying coral forms such as encrusting and foliose *Montipora*, submassive *Pocillopora*, branching *Seriatopora*, encrusting and massive *Favia*, *Favites*, amongst others, J=0.96; 0.70; 0.65, respectively. Similar results were displayed in the NPAs, whereby the various coral genera were evenly distributed at La Butte, Trou Mullet II, Terre Rouge, Grand Baie, Cavern Provert, and Bar Chirurgien (0.94<J<0.83), with over 10 coral genera per site, with the exception of Trou Mullet I. Overall, Trou Blanc displayed remarkable dominance of *Acropora* species over non-*Acropora* species as compared to NPAs, which favored relatively homogeneous low abundance non-*Acropora* species with low density of tabular *Acropora* and encrusting *Montipora*.

Occurrences and distribution of targeted endemic and rare coral species

No *A. rodriguensis*, and *Hoastrea indica*, the endemic and targeted rare coral species, respectively, were observed at the 14 surveyed sites (Figure 4). *Acropora branchi* and *P. indiania*, the two regionally endemic corals, occurred at all the surveyed MPAs when compared to NPAs. *Pocillopora indiania* was limited to Terre Rouge, while *A. branchi* further extended to Trou Mullet I and II, Gros Pot, Baie aux Huitre, and Cavern Provert in colony numbers (n<7, per site). *Acropora clathrata*, another targeted branching coral, was found to be limited to three MPA and one NPA sites, with colony numbers per site varying between n=3 to 9. *Seriatopora hystrix*, the targeted rare coral species, was only found at bar Chirurgien (n=14) and La Ferme (n=6) in limited abundance (n<3 per site); likewise, *Seriatopora caliendrium* was observed at Riviere Banane and Terre Rouge in low density (n<5). On the contrary, the targeted rare species *S. pistillata* was recorded at Anse aux Anglais, Terre Rouge, Gros Pot, La Butte, and Trou Mullet II with relatively higher colony numbers than the *Seriatopora* spp. (Figure 4).

Occurrences and distribution of targeted endemic and rare reef fishes

The endemic reef fish, *P. rodriguensis*, was observed at only one MPA surveyed site, Anse aux Anglais, while it occurred mostly in the NPAs at Trou Mullets, La Butte, La Ferme Baire aux Huitre, Terre Rouge, Cavern Provert, and Grand Baie. The other targeted regionally endemic and rare reef fishes, *Stegastes pelicieri*, *Stegastes limbatus, P. pikei*, *A. latifasciatus*, and *A. chrysogaster* were sporadically recorded in the NPA sites, contrary to *Abudeduf margariteus* and *Zebrosoma gemmatum,* which were not observed at any of the 14 surveyed sites. The Mauritian endemic fish, *S. pelicieri*, Mauritian Gregory, and *S. limbatus*, rare reef fish, were recorded in three of the surveyed MPAs, with the exception of Riviere Banane, as well as five and six MPAs respectively with numbers of individuals less than 10 (n<10), while only *S. pelicieri* was relatively numerous (n=12) in Trou Blanc (MPA): the Mauritian anemone-fish, *A. chrysogaster,* a specialized fish, limited to residing mainly in the anemone, *Heteractis magnifica,* was only observed in Trou Blanc, Vas Brulee, and Riviere Banane in areas where the anemone was present, whereas the Madagascar anemonefish, *A. latifasciatus,* mainly harboring both anemones, *Stichodactyla mertensii* and *H. magnifica,* was hardly observed in the surveyed areas (Figure 5).

Table 6. Interpretation of diversity indices to illustrate the site-wise coral species richness, the degree of variation in species using Shannon-Wiener (H) and Pielou's Evenness Index (J), indicating the diversity of coral species along with Simpson Dominance Index, D, within the surveyed MPAs and NPAs

Sites	Shannon Index (H)	Simpson Diversity (D)	Pielou's Evenness (J)	Site-wise coral diversity
Trou Blanc (No-Take MPA)	1.67	0.31	0.65	Moderate diversity with relatively fair distribution of different coral genera within the community. 47 coral spp. from 15 genera, of which 20 were *Acropora* and 7 *Montipora* spp. while others were non-*Acropora* species, which included *Favia, Porites, Pocillopora, Platygyra, and Pavona,* were observed within the no-take MPA while the reef community was dominated by *Acropora* spp.
Vas Brulee (Multiple-Use MPA)	1.99	0.71	0.21	Relatively high diversity comprising 17 coral genera with disproportionate dominance of *Acropora* and *Montipora* species, along with the new records of rare coral species, for instance, *Favia helianthoides, Pocillopora meandrina,* and *P. compressa,* were also present in low abundance.
Riviere Bananes (Multiple-Use MPA)	2.41	0.94	0.10	High coral diversity with high dominance of some non-*Acropora* genera unevenly distributed, composing mainly of *Echinopora, Favia, Fungi, Lobophyllia, Montipora, Pocillopora,* and *Seriatopora,* whereas only 2 *Acropora* species were observed
Anse aux Anglais (Multiple-Use MPA)	1.55	0.65	0.32	Moderate diversity richness with 11 coral genera dominated mainly by 16 *Acropora* spp., with uneven distributions of *Favites, Fungia, Leptoria, Pavona, Platygyra,* and certain newly recorded, rare corals such as *Acanthastrea ishigakiensis, Acropora rufus, Acropora seriata,* and *Montipora hodgsoni*
Trou Mullet I (NPA)	0.92	0.66	0.53	Low coral genus diversity with only four coral genera, whereby 8 *Acropora* spp., one *Alveopora* sp., two *Fungia* spp., and three *Porites* spp. were moderately distributed within the reef community, which also included rare *Acropora cuneata* and *A. pinguis*
Trou Mullet II (NPA)	2.14	0.89	0.14	High diversity but uneven distribution of corals with high dominance of certain corals, such as *Pavona* and *Porites.* Overall, 18 coral species from 13 coral genera were recorded, of which only three *Acropora* spp. were observed, whereas uncommon corals such as *Hydnophora excesa, Madracis kirbyi, Oxypora lacera, Pachyseris* sp., and *Stylophora pistillata* were also observed.
Bar Chirurgien (NPA)	1.99	0.22	0.83	Relatively high coral diversity and genera fairly distributed within the reef, with 25 coral species from 12 genera, consisting of 7 *Acropora* spp., including the non-*Acropora* species and an uncommon *Acropora polystoma*.
Gros Pot (NPA)	1.82	0.79	0.22	Relatively high coral diversity with the dominance of 13 *Acropora* spp. from 11 coral genera, including *Anacropora, Cyphastrea, Favia, Fungia, Gardineroseris, Leptastrea, Oullophyllia, Platygyra, Porites,* and *Stylophora*
La Pass La Butte (NPA)	1.86	0.96	0.17	Relatively high diversity with high dominance of non-*Acropora* spp. unevenly distributed amongst the seven coral genera, namely, *Acropora, Cyphastrea, Echinopora, Favites, Goniastrea, Seriatopora,* and *Stylophora*
La Ferme (NPA)	2.15	0.81	0.15	High coral genus diversity with 14 coral genera, namely, *Acropora*, *Cyphastrea*, *Echinopora*, *Gardineroseris*, *Goniastrea*, *Montipora*, *Pavona*, *Platygyra*, *Plesiastrea*, *Pocillopora*, *Porites*, *Seriatopora*, *Stylophoran*, and *Turbnarea*, including 11 *Acropora* spp. unevenly distributed
Terre Rouge (NPA)	2.13	0.89	0.12	High diversity of coral genera dominated by non-*Acropora* spp. disproportionately distributed, consisting mainly of *Cysphastrea, Favia, Montastrea, Montipora, Platygyra, Pocillopora, Seriatopora, Stylophora,* and *Turbinaria*
Cavern Provert (NPA)	1.90	0.86	0.18	Relatively high coral diversity is disproportionately distributed, consisting of *Acropora*, *Acanthastrea*, *Cyphastrea*, *Leptastrea*, *Montipora*, *Platygyra*, *Pocillopora*, *Porites*, and *Symphyllia* genera
Grand Baie (NPA)	1.70	0.87	0.22	Moderate coral diversity with seven coral genera, including *Acropora*, *Acanthastrea*, *Cyphastrea*, *Favites*, *Montipora*, *Platygyra*, and *Porites*, unevenly distributed within the reefs
Baie aux Huitres (NPA)	0	0	1.0	Only one genus, *Acropora,* consisting of eight *Acropora* spp. evenly distributed

Note: Uncommon coral indicates coral species newly recorded in the Indian Ocean as per Veron (2000) and World Register for Marine Species (WoRMS 2024)

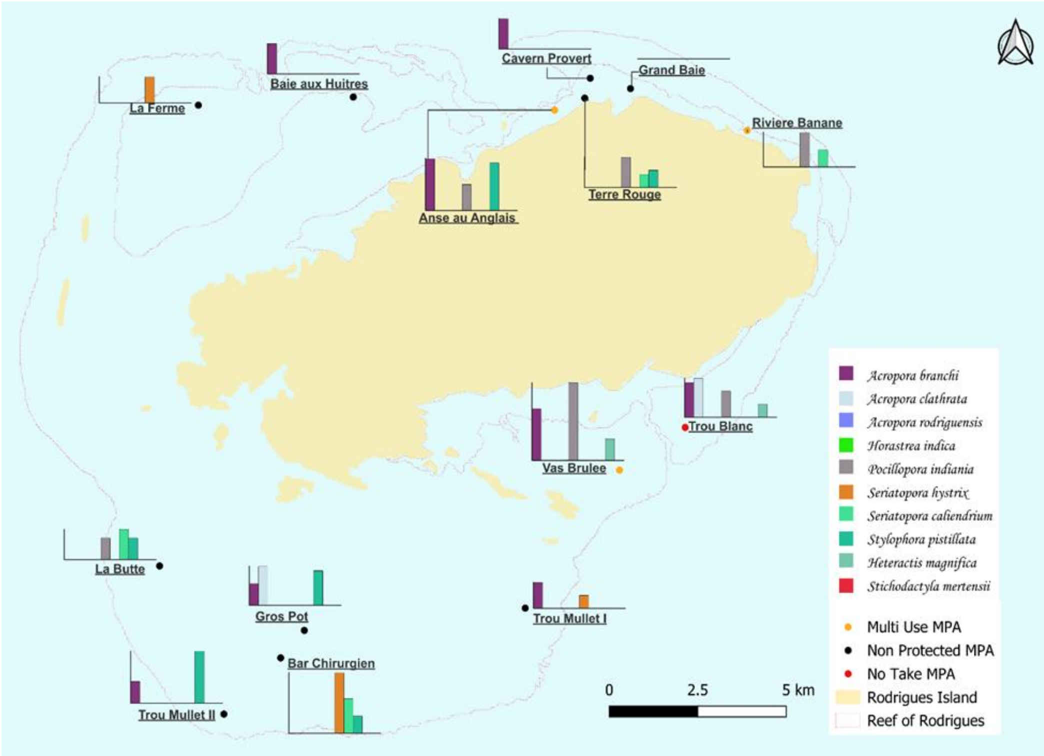

Figure 4. The geo-referenced color-coded map illustrates the occurrence of targeted rare and endemic corals recorded at the 14 surveyed sites around Rodrigues Island, Mauritius. The histograms show the occurrence of the targeted corals under the study and their relative no. of colonies with respect to other target corals, for example, only *Seriatopora hystrix* was observed at La Ferme, whereas at Grand Baie, no targeted species were observed. Likewise, no *Acropora rodriguensis* and *Hoastrea indica* were observed at the 14 surveyed sites. Note: Geo-referenced map indicates the location of each site as per the respective GPS coordinates recorded during the surveys

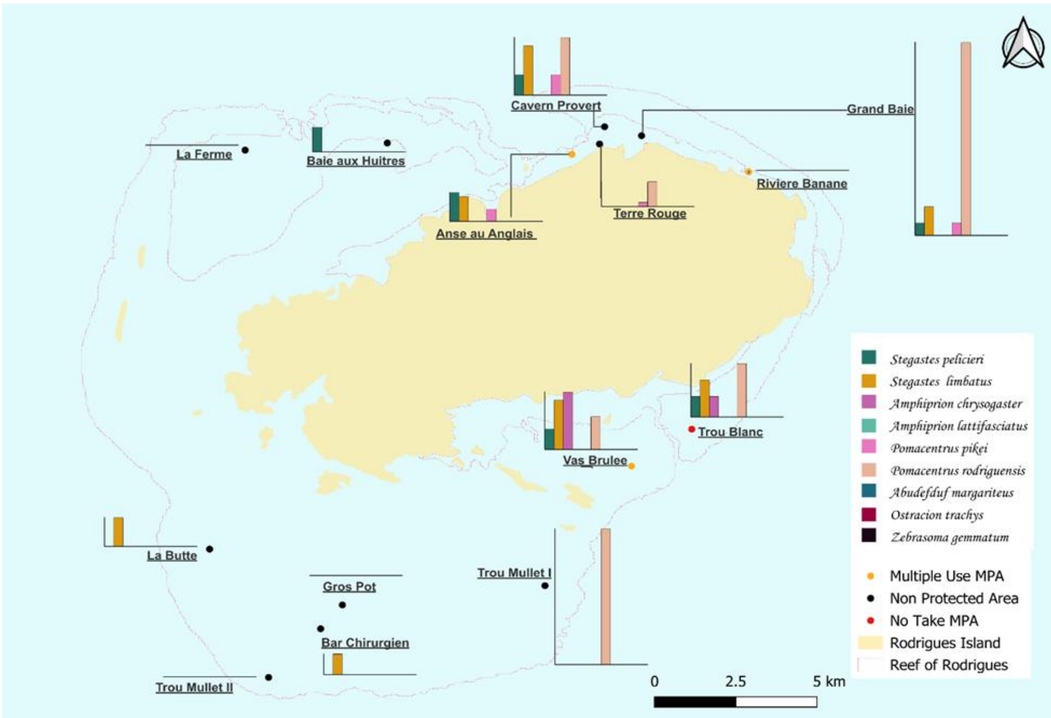

Figure 5. The geo-referenced color-coded map illustrates the occurrence of targeted rare and endemic reef fishes recorded at the 14 surveyed sites around Rodrigues Island, Mauritius. The histograms show the occurrence of the targeted reef fish species under the study and their relative density with respect to other target reef fishes within their respective site. For example, only *Pomacentrus rodriguensis* was observed at Trou Mullet I, whereas at La Ferme, Gros Pot, Trou Mullet II, and Riviere Banane, no targeted reef fish species were observed

Discussion

Coral reefs of the MPAs and NPAs in Rodrigues

This island-wide, extensive, and extended study around Rodrigues provides an in-depth insight into the status of the coral reefs within the data-limited protected and understudied non-protected areas, emphasizing targeted endemic and rare corals and reef fishes with a major focus on the implications of coral diversity and coverage both in MPAs and NPAs. This study further underpins the 3-dimensional structural functionality of the reefs with respect to the no-take marine reserve in comparison to the multiple-use MPAs and NPAs. Of the 14 sites, the no-take MPA, Trou Blanc, had the highest coral cover, dominated by the *Acropora* genus with 20 *Acropora* species along with 27 other coral species from 15 coral genera. Although 150 coral species were identified during the study, the endemic coral, *A. rodriguensis*, and the common coral *Galaxea* were hardly observed at the 14 surveyed sites, while the endemic reef fish *P. rodriguensis* was mainly found in the algal-dominated NPAs. Moreover, corals were more diverse and widely distributed in MPAs, with the dominance of the branching *Acropora* and *Montipora*, contrary to the dominance of massive, sub-massive, foliose, and encrusting corals despite low coverage in the NPAs, such as *Porites, Pocillopora, Pavona,* and *Montipora* species. Overall, the MPAs harbored the highest live coral, while the NPAs had lower live coral cover with lesser coral species diversity in algal-dominated reefs in algal and rubble-dominated reefs. It is noteworthy, the reefs of Rodrigues have been subject to continuous coastal development due to increasing population and tourists, causing mounting pressures from fisheries exploitation (Hardman et al. 2009).

MPAs v/s NPAs

Though there has been inadequate monitoring of thermal-driven coral bleaching, the fact remained that the no-take MPA, multi-use MPAs, and NPAs of Rodrigues are all exposed to the same SST warming trend with the SST anomaly fast-reaching +1.5°C (Werner et al. 2025), whereas the reefs exposed to fishing activities were the most degraded, while the multiple-use MPAs provided a limited buffer against intense fishing activities, especially during the closed season for seine netting and octopus fishery (Pasnin et al. 2018). Pasnin et al. (2018) further highlighted that the fishing activities in the Marine Reserves, for instance, octopus fishing with a harpoon, which involves trampling on the reefs, the use of a basket along with a seine net, caused serious damage to the reefs, resulting in higher rubble density both in the multiple-use MPAs and NPAs. Evidently, the reefs in the open access, NPAs exhibited extensive macroalgal coverage, especially in larger lagoons in the western region, such as Bar Chirurgien, Gros Pot, and La Butte, including the lagoons in the north at Grand Baie and Baie aux Huitres, whereas Trou Mullet I, Terre Rouge, and La Ferme had comparatively higher densities of rubbles.

The dominance of macroalgae in those mid-lagoons might be explained by the fact that larger lagoons sustained longer nutrient-rich seawater residence time due to inadequate water exchange from the ocean on account of the lack of natural passes (openings) to allow oceanic mixing (Safaie et al. 2018). The impact of the reef degradation was evident, which was depicted by high rubble coverages within the reef of Riviere Banane and Anse aux Anglais, combined with macroalgae, yet the coral cover was relatively higher at Anse aux Anglais. On the contrary, the multiple-use MPA, Vas Brulee, had the third highest coral cover with the second lowest macroalgal coverage, and half of the coral cover as compared to Trou Blanc, the strict conservation no-take MPA. These findings therefore demonstrate that strictly conserved zones, no-take MPAs effectively conserved and protected both coral cover and coral diversity (Strain et al. 2019), conversely to reefs exposed to ongoing impacts of human activities interfering with the coastal ecosystems in the multiple-use MPAs and NPAs, mainly dominated by macroalgae and rubbles (Hein et al. 2015; Cartwright et al. 2023).

On the contrary, higher coral cover with high coral diversity was observed in the backreef of the relatively smaller lagoons closer to natural reef openings. Furthermore, with a mean annual precipitation of 1,348 mm (150Mm^3/year) over an area of about 110 km^2, mountainous landmass of Rodrigues, (Ministry of Public Utilities 2008) and a predominantly north-westerly wind-driven surface current ranging between <0.1 to <0.5 m/s in the lagoon, the reefs are continuously exposed to runoffs and mass sedimentation leading to eutrophication and macroalgal proliferation (Rees et al. 2005). Conversely, the two MPAs, Trou Blanc and Vas Brulee, had the lowest macroalgal proliferation. In addition to high coral cover, the two MPAs also harbored rarely occurring soft corals at relatively higher coverage. In contrast, Trou Mullet I (NPA) had the highest soft corals of the studied sites. Unlike hard corals, soft corals were previously considered a poor habitat due to their biochemical defence mechanisms and lack of structural complexity (Dinesen 1983; Norström et al. 2009). However, recent studies have revealed that soft corals are capable of supporting diverse reef fishes in higher density (Pratchett 2005; Ferrari 2017; Epstein and Kingsford 2019), which was noticeable in Trou Blanc and Vas Brulee.

Endemic and rare species

No *A. rodriguensis*, the endemic coral of Rodrigues, was observed at the 14 surveyed sites, whereas Pasnin et al. (2018) noted the occurrence in low density at Anse aux Anglais, a common study site. During the field surveys and communication with the fishermen community and dive centers in Rodrigues, most participants associated Riviere Banane (multi-use MPA) with *A. rodriguensis*, yet despite intensive and extended coral search activities, no *A. rodriguensis* was observed; instead, only one *Acropora* species, namely, *A. irregularis,* was recorded over two one-hour coral searches. *In situ*, the dive instructor showed plate-like corals most likely to be an *Echinopora* species as the *A. rodriguensis*, which was common at the study site. No morphologically comparative study could be carried out as the literature search was limited to Fenner et al. (2004) and Pasnin et al. (2018), which only mentioned the occurrence of *A. rodriguensis* without any coral morphological description, color, or habitat or abundance status. Further online search on the endemic coral species from the World Register of Marine Species (WORMS 2024), and Corals of the World (Veron et al. 2016) resulted in no data. Under such circumstances, it is ecologically critical that genetic studies be carried out to eliminate any scientific misidentification of such corals.

The findings of this study support the observation of Obura (2016), who has indicated that the regionally endemic *A. branchi* and *P. indiania* occurred widely in the Indian Ocean, while no observation of these two corals in Rodrigues was made by either Fenner et al. (2004) or Pasnin et al. (2018). However, the current findings have demonstrated that the occurrence of both corals extended eastward of the Indian Ocean within the reefs of Rodrigues. Moreover, despite ongoing repetitive thermal stresses (Zinke et al. 2018) and vulnerability to fishing activities (Pasnin et al. 2018), both the MPAs and the NPAs harbored the regionally *A. branchi* while *P. indiana* was recorded in all MPAs, but was limited to Terre Rouge (NPA) only. Similar observation was made for another targeted rare tabular coral, *A. clathrata*, which was limited to MPAs, with the exception of only one NPA.

Moreover, the rare *S. hystrix* was relatively dominant at Bar Chirurgien (NPA), a reef dominated by macroalgae with only 12% live coral, which might potentially be explained by the fact that *S. histrix* finds its resilience under the shade (low-light) of the macroalgal mat against thermal stresses (Lewis and Altieri 2025), which also aligns with the observation made on the occurrence of *S. histrix* in an algal-dominant reef at Bamboux Virieux in Mauritius (Munbodhe et al. 2023). Furthermore, the thermal stress experiment (Munbodhe et al. 2023) showed that *S. histrix* had a comparatively higher thermal threshold than A. *branchi* and *P. indiania*, although the low colony numbers might be explained by the fact that algal-overgrowth outcompetes the expansion of these corals. Of the 14 surveyed sites, *S. caliendrium* was limited to low density at only two sites, Riviere Banane (MPA) and Terre Rouge (NPA). Under the current situation, should *S. caliendrium* be unable to acclimate to the ongoing thermal stresses, in the long run, there exists a potential threat that the latter might undergo extirpation (McClanahan et al. 2021).

Conversely, *S. pistillata* had an extended occurrence both at Riviere Banane (MPA) and three NPAs in greater densities as compared to *S. histrix*, thus showing better adaptation to algal-dominated reefs, conversely to *H. indica*, which was not observed at all at the 14 surveyed sites. Overall, the MPAs harbored both the regionally endemic corals along with other coral species, providing protection and efficiently conserving higher coral diversity, in particular, the no-take MPA, which remained an instrumental tool for conservation.

The Rodriguan endemic reef fish, *P. rodriguensis,* was abundantly found in the NPAs and at only one MPA, Riviere Banane. *Pomacentrus rodriguensis* was evidently dominant in high densities (n>100) in algal-dominated reefs of the NPAs and the one MPA, indicating that the preferred habitat for *P. rodriguensis* was the algal mats. The Mauritian endemic reef fish *S. pelicieri* and the Mauritian clownfish *A. chrysogaster* were also found for the first time in the waters of Rodrigues, more precisely in the non-protected reefs of Rodrigues, with the exception that *S. pelicieri* was also observed at Riviere Banane (MPA). The occurrence of both fish species endemic to Mauritius in the reefs of Rodrigues suggests that the range of these endemics expands further to the East of the Mascarene Plateau, thereby signifying wider dispersal capabilities, which warrant dispersal and connectivity studies for potential extension within the different islands of the Indian Ocean. Similarly, the targeted rare reef fishes, *S. limbatus* and *P. pikei,* were mostly observed at some NPA sites in low densities, whereas the Madagascar anemonefish *A. latifasciatus*, *A. margariteus,* and *Z. gemmatum* were hardly encountered at any of the 14 surveyed sites, which need further in-depth investigation for better clarity on the occurrence and distribution of these species within the Mascarene Plateau.

Coral diversity richness

Of the 14 sites surveyed, 150 coral species were recorded from 38 genera, while 47 species belonged to the genus Acropora, which mainly occurred in the MPAs, with the exception of Riviere Bananes, where only two *Acropora* species were observed. These detailed observations supplement the last coral inventory for Rodrigues, which dates back to 2004, whereby 130 coral species from 40 coral genera were recorded from 26 inside and off-lagoon sites, inclusive (Fenner et al. 2004). As such, the dominance of branching and submassive *Acropora* indicated the reef structural complexities in the MPAs, while the low *Acropora* diversity along with high macroalgal and rubble cover was significantly reflected in the NPAs (Hardman et al. 2009). Similar observations were also made by Pasnin et al. (2018), who summarized 14 *Acropora* species from Riviere Bananes, Anse aux Anglais, Grand Bassin, and Passe Demie multiple-use MPAs (the last two were not included in this study). It was further observed that the fishing activities had a significant impact on both coral genera and *Acropora* diversity within the NPAs, while hardly any such differences were found between no-take and multi-use zones MPAs.

Moreover, both the no-take zone and the multiple-use MPAs had most of the branching *Acropora* and encrusting *Montipora* at the studied sites. Although the coral species diversity was higher in MPAs, the NPAs harbored various branching non-*Acropora* at low coverage, such as *Pocillopora*, *Porites*, *Seriatopora*, and *Stylophora* species, along with encrusting and plate-like *Montipora,* encrusting *Astreopora*, *Cyphastrea*, *Echinopora*, *Leptoria*, *Pavona***,** and *Turbinaria*, as well as sub-massive and massive *Porites*, *Heliopora*, *Gardineroseris*, *Goniastrea*, *Goniopora*, *Oulophyllia*, *Platygyra*, and *Symphyllia*. Non-Acropora. Despite low densities, the NPAs also included uncommon and rare species, for instance, *Acanthastrea regularis*, *Montipora kellyi*, and *Porites cumulatus* were found in Grand Baie; likewise, *Anacropora forbesi* and *Cyphastrea calcidium* were recorded for the first time in

Rodrigues at Gros Pot. As such, despite being low in coral density, the NPAs supported the existence of rare non-*Acropora* branching, plate-like, and encrusting corals, which also contributed to the species diversity, mandating an ecosystem approach to fisheries for better biodiversity protection and conservation.

Future reef management strategies

This comparison between the NPAs and MPAs, therefore, essentially provides research-driven evidence that the MPAs harbored the most structurally complexed corals, high in diversity and extended to a wider area despite a challengingly warming environment at the expense of fishing areas driven by dense macroalgae and rubbles (Hardman et al. 2009; Elliott et al. 2018; McClanahan and Muthiga 2021; De et al. 2022; Doorga et al. 2025). Although this study is limited to a one-time coral reef survey around Rodrigues, it has demonstrated the crucial roles of MPAs as the main buffer against major human disturbances by maintaining the ecologically essential 3-dimensional functional reef structures while enhancing ecosystem resilience against ongoing accelerating trends in marine heating. Besides biodiversity protection and through spillover, the no-take MPA effectively provides both social and economic sustainability to the immediate coastal communities of the Small Island Developing States (SIDS). It is therefore advocated that, in addition to no-take MPAs, replications of multiple-use MPAs shall be promoted to establish effective MPA networks (Eli et al. 2025). Such initiatives shall be accompanied by the implementation of an ecosystem approach to fisheries, supported by appropriate policies including reinforced enforcement and collaborative management strategies, which in turn, may potentially mitigate the predicted decline in marine species (Hughes et al. 2017) and, in the future, reinforce the existing marine biodiversity and ensure food security within the region.

In conclusion, this multifaceted study, first of its kind in the reefs of Rodrigues, has demonstrated that intense human activities leading to irreversible degradation of reefs are causing major shifts from functionally active coral ecosystems to macroalgal and rubble-dominated reefs. In an era of prolonged marine heating, frequent and severe coral bleaching events, the study clearly demonstrated that the areas under permanent fishing pressure have been significantly impacted, provoking widespread algal growth with a major shift from live coral to rubble-dominated reef, while the strictly conserved reef remarkably sustained a high coral cover and coral diversity with negligible algal coverage. As such, the no-take MPA in Rodrigues remained instrumental in reef management by protecting the marine biodiversity. Furthermore, the study also established that all the studied MPAs effectively act as a buffer for sustaining complex coral structures, both in terms of coral coverage and diversity, and, by virtue, provide enhanced reef resilience, more specifically in the no-take marine reserve, as compared to the macroalgal and rubble-dominated MPAs.

However, the study was limited to a single survey period, lacked temporal replication, and relied on visual census methods that may overlook cryptic species. Absence of genetic and physicochemical data restricted confirmation of species identity and environmental drivers of reef change. Future work should employ long-term monitoring, molecular identification, and remote sensing to validate coral diversity and detect recovery trends. Integrating water quality, sedimentation, and socio-ecological assessments will strengthen MPA management and coral reef conservation strategies in Rodrigues. Overall, these findings align with one of the United Nations goals, SDG 14: life below water, to "conserve and sustainably use the oceans, seas and marine resources" whereby the results provide vital information on the health status of the coral reefs of Rodrigues and suggest that collaborative reef management is crucial for ecological and socio-economic sustainability. Furthermore, while complementing the critical scientific information gap on regionally endemic and rare corals and reef fishes, the study also provides critical insights into reef vulnerability due to intense fishing activities. These findings therefore suggest that reefs under protection are more resilient and that promoting an ecosystem approach to fisheries may further enhance overall reef resilience and strengthen the conservation strategies for the critical marine ecosystem and its associated biodiversity in a challengingly warming environment.

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