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Initial states of fish of food interest in the south-west region of Mauritius

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Abstract

The marine environment of Mauritius has suffered from rapid colonization and exploitation of the land since the 16th century. The reefs of Mauritius are today considered at high risk. The decline of coral reef health and fish catch affects fishing yield and could seriously threaten Mauritius' economy. To improve the quality of the marine environment, a project of marine protected area (MPA) implementation has taken place on the south west coast. We used under-water visual census (UVC) as a before-control-impact to investigate the sub population of food interest fishes and the coral coverage of the lagoon and fringing reef of "l'île aux Bénitiers". A relatively low diversity of fishes were observed. A total of 95 species were encountered during the study. We found on average a fishable biomass of 188.4g/100m² in the lagoon, 725.6g/100m² in the back reef, 2042.7g/100m² on the reef and 4950.4g/100m² in the pass. The area presents the characteristics of an over exploited zone with low coral cover; dominance of herbivorous fishes on the reef and the absence of apex predators such as sharks and large groupers or snappers. This paper confirms the necessity of conservation measures within the area. It also provides data that will allow temporal control impact to be performed in the case of MPA implementation.

Key words: Mauritius, Western Indian Ocean, Ichtyofauna, Coral reefs, UVC, Before Control Impact.

Introduction

Coral reef is a hot spot of diversity. It offers unique habitat for numerous species in tropical and inter-tropical water. Reef all over the world undergo major damage, mainly due to the increase of human pressure. At the same time marine resources are being overexploited worldwide since the industrialized fisheries has started (Reynolds et al. 2001) and have dramatically affected marine fish stocks (Cooke and Cowx, 2004). It is estimate that the population of large predatory fishes has declined over 90% (Myers and Worm, 2003) in worlds' oceans. Near shore zones are also facing severe pressure from recreational fishing activities (Cooke and Cowx, 2004).

The reef of Mauritius was relatively preserved thanks to its isolation. It was pristine prior to man's arrival, and the Dutch colonization in the 16^{th} century. Coral reef supply numerous people with goods and services such food resources, recreational possibilities, coastal protection as well as aesthetic and cultural benefits. The population of Mauritius have increased rapidly and today is one of the most densely populated countries in the world. Reef located adjacent to highly populated coastal areas are more sensitive to degradation. Nowadays the reef of Mauritius is considered at high risk (Bryant et al., 1998). Coral reef is a great natural asset for tourism in Mauritius. Fisheries plays a major role for tourism economy (Sobhee, 2006) and have an important roles in employment and food resources for coastal communities in Mauritius (Boistol et al., 2011). Fisheries management measures include a closed season for seine nets and prohibited fishing methods such as poisoning, spears or explosives and artificial light. However, in Mauritius a low compliance with fisheries restrictions can be observed. The decrease of fish catch associated with marine environment degradation is a major concern for fishermen and tourist operators (Anderson et al., 2010). Fishing pressure nowadays seems to exceed maximal sustainable yield (Graham et al., 2006; Turner and Klaus, 2005).

A project of implementation of marine protected area (MPA) has taken place on the west coast. An MPA is an area of sea dedicated to the protection and maintenance of biodiversity and of natural resources, which is managed through legal or other effective means. MPAs include marine parks, nature reserves and locally managed marine areas. Their benefits on fish recovery in term of species richness, size class density and total density have been demonstrate worldwide (Barrett et al., 2007; Kulbicki et al., 2007; McClanahan et al., 2009, 2007).

Between January 2014 and March 2014 a study focusing on fishes of food interest was carried out. This study aimed to 1) set an initial state of the commercial fish fauna prior to the implementation of an MPA, as a before control impact in the BACI (before-after-control-impact) design (Claudet and Guidetti, 2010) 2) describe briefly the spatial distribution of commercial fishes in the area.

Materials & Methods

Study area

Mauritius with Rodrigues and Reunion form the Mascarene Islands, located west of Madagascar in the Indian Ocean. It is an island of volcanic origins, the reef is well described by *Turner & Klaus* (2005), and it is composed of a fringing reef surrounding almost the whole island. The west coast of Mauritius is sheltered from the dominant wind coming from the south-east. Mauritius has a semi-diurnal tide with a low tidal range of less than 1 meter. The area of interest (Fig.1) is located on the south west region of Mauritius (20°57'S to 20°44'S, 57°31'E to 57°37'). Human pressure is high in this part of the island; the density of population in Mauritius is about 673 inhabitants/km² and 306 inhabitants/km² for the Black River region. The lagoon and reef are visited daily by hundreds of tourists coming with speedboat or catamaran for picnic on "L'île aux Bénitiers", by hotel guests performing water skiing and by fishermen. The fishing methods used are line fishing, basket trap and the seine net on the fore reef zone. This area includes the largest lagoon of the west coast, representing approximately 40km² out of the 300km² of the Mauritian lagoon (Boistol et al., 2011). The lagoon is shallow with a maximum depth recorded of 5m. All sampling was carried out during suitable meteorological condition. We assume that the area is large enough to include future inside MPA and outside MPA replicate for the BACI design.

Sampling Design

In order to study the distribution of fishes with substrate type, 27 sampling stations were randomly place in the lagoon. Sampling effort was proportional to habitat cover: 7 habitat types including the most present were selected from the map of Turner & Klaus(2005); lagoonal sand (10 Stations), branching and tubular coral (5), lagoonal sand and silt (4), seagrass on sand (5), dead standing coral(1), sparse filamental algae (1), sparse filamental algae & coral on sand (1). Sampling sites were randomly place on the map.

On the fringing reef 8 sites were investigated, all separated by approximately 1km. Each site is composed of 3 sampling stations with three different depths: 12m, 5m and the reef flat. The passes were composed of 2 sampling sites one on each side, both sites were composed of 3 stations as for the reef slope. For each station 2 transects (2 replicates) were investigated.

Sampling Techniques

Fish

The list of fish of interest containing 24 families (Acanthuridae, Caesionidae, Carangidae, Chaetodontidae, Ephippidae, Fistulariidae, Gerreidae, Haemulidae, Hemiramphidae, Holocentridae, Kuhliidae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Mugilidae, Mullidae, Priancanthidae, Scaridae, Serranidae, Siganidae, Sparidae, Sphyraenidae and Zanclidae) and the subclass of Elasmobranchii (Rays and Sharks) were established prior to the study. This list included most of the fish of food interest and the species used as bio indicator. Over 275 species were targeted without counting the Elasmibranchii.

The underwater visual census (UVC) methods are well accepted. UVC is non-destructive (Bell et al., 1985; Cheal and Thompson, 1997; Gust et al., 2001; Kulbicki et al., 2010), but subject to various bias. One of the most commonly used methods is the fixed width transect. This method suffers from: environmental bias (Mapstone and Ayling, 1998), bias related to observers (Bell et al., 1985; Bernard et al., 2013; Hill and Wilkinson, 2004; Mapstone and Ayling, 1998; Samoilys and Carlos, 2000; Thompson and Mapstone, 1997), and fish detectability variation (Edgar et al., 2004; Kulbicki, 1998; La Mesa et al., 2011; Mapstone and Ayling, 1998; Watson and Quinn II, 1997). UVC is intrusive for fish population, in fact divers play a major role in fish detectability, influencing greatly the estimate densities (Dickens et al., 2011). On one hand transect width greatly influences the fish density estimation (Chabanet et al., 2002; Cheal and Thompson, 1997), as larger transect provide lower density . On the other hand narrow transects do not allow to include all possible species, since commercial fishes in disturbed environments tend to avoid divers (Kulbicki and Sarramégna, 1999; Kulbicki, 1998). To meet the aims of this study we used Distance-sampling Underwater Visual Census (D-UVC) (Labrosse et al., 2002) (Fig.2). This method allowed to include all species of interest without limiting the transect width. We were then able to cut the transect width at the most appropriate distance to include at least 95% of the sighting and species observed.

All surveys were conducted within a 3 hours interval either side of high tide and between 9am and 4pm to avoid change in activity of diurnal and nocturnal fishes, and prevent fish mobility between low and high tide (Darwall and Dulvy, 1996). After a training period 2 divers were selected to carry out the sampling, there was no significant difference in their size and distance estimation (t-test, α=0.05).

Observations were carried out along a 50m long transect by scuba diving or snorkelling in shallow water. The transect on the reef was laid perpendicularly to the reef slope to avoid depth change during the census. Divers swam side by side along the transect, each diver counting the fishes of interest (>5cm) on his own side. For each fish sighting observers recorded: the species, its size and the perpendicular distance to the transect.

Substrate

Habitat of the lagoon was extracted from the study of Turner & klauss (2005). On the reef the Line Intercept Transect (LIT) method (English et al., 1997) was used to estimate the different substrate coverage. This methods has been widely used for coral community survey. It provides an accurate quantitative description of habitat and does not require excessive training to be conducted by divers. However the LIT method does not provides any description of complexity of the habitat which has been shown to be an important component in fish biodiversity (Beukers, 1997; Clua et al., 2006; Meager and Schlacher, 2013). For this purpose an index of habitat complexity was estimate for each transect. This index ranges from 1 to 5, 1 being a habitat with low 3D structure such as sandy bottom and 5 being a habitat of high complexity, such as coral reef with canyon and complex coral structure. After every fish census divers swam along the same transect laid over the reef and estimated the coverage of different substrate as a fraction of the total length of the line that is crossed by each substrate or type of organism.

Data analysis:

To test the size and distance estimation between observers; mean of divers estimation was compare with a known normal distribution using student test.

Biomass estimates were made for each fish by converting UVC length into equivalent weight. The length-weight conversion equation are species specific and is obtained with the formula $W = a^L * b$ where W is the biomass, L is the Length, a and b are species specific values.

Transect width was cut at 5m on each side. Over 95% of the sightings occurred within the 5m distance to the transect. This 5m distance included 99% of the species encountered. We assumed that few data will be lost by cutting the transect at 5m on each side.

The densities obtained for each species by replicate (50m) were averaged for each sampling site. Furthermore, for reef and pass station in order to minimize the effect of fish migrating between different depths and double counting twice, transects at 12m, 5m deep and reef flat were averaged to provide one single assemblage per sampling site.

S index and total biomass were calculated using PRIMER 6 software (Plymouth Marine Laboratory, 2006). Using R software version 3.0.0 (R Core Team, 2013) PCoA and PERMANOVA were performed on Bray-Curtis dissimilarity matrices of square-roots transformed fish biomass and 999 permutations were performed. PERMANOVA was used to establish factors explaining fish distribution. Differences in fish size among habitats were tested by non-parametric ANOVA (Kruskal-Wallis one analysis of variance). Fish diet were simplified and 4 diet types were considered: Herbivorous (H), Zooplankton feeder (Z), Carnivorous (C), Piscivorous (P).

Results

A total of 114 transects were investigated. For the 6 sampling sites L13, L14, L16, L18, L24 and L27 visibility was less than 5m. It was then decided to remove these sampling sites, as under water visual census method was not appropriate for fish census in these condition. Sampling effort can be observed through the species accumulation curved (Fig.3). Using PCoA fish assemblages show close likeness between sampling sites of similar habitat for the tubular and branching coral, reef slope and pass. However other habitat types in the lagoon did not show distinct fish assemblages. Though two distinct groups could be observed for the lagoon sampling sites. It was decided to regroup sites into one habitat to simplify. In total 4 habitats types (Fig.4) were extracted from the PCoA; The reef, the pass, the back reef represented by the habitat of branching and tubular coral, and the lagoon. Results from PERMANOVA indicated that among the factors investigated (Table 1), distance to reef and live coral were the most significant ($P<0.001$), explaining respectively 11.6% and 10.6% of the assemblages. The next significant factor was habitat complexity ($P<0.005$) explaining 6.1% of variances.

Before averaging 2390 sighting representing a total of 7784 fishes were made during the study. A total of 95 species representing 16 families and 37 genera were recorded. (Table 2) The dominant families were Acanthuridae and Chaetodontidae representing with both 15.8% of the species (15 species). The Scaridae was the third most abundant family with 14.7% (14 species) then the Serranidae with 12.6% of the species (12 species). These 4 families represent 58.9% of the species recorded. The others families present a species diversity of less than 10 species observed.

Coral coverage and habitat complexity

On the back reef we found an average coral coverage of 15.7%. Massive coral were the abundant type of coral, with the exception of site L12 were branching Acropora were the dominant coral.

Live coral on the reef and pass was relatively low, the maximum coral coverage was found in site R8 (14%) and the minimum was in the site P3 (3%). Encrusting and sub massive coral were the most common types of coral found on the reef. The coral structures were scattered and of small size. The majority of the substrate was composed of dead coral; at sites R4 and P3 consisting of up to 94% of the bottom (Fig.5). Their death were not recent. All the dead coral was covered with a thin layer of sand and largely colonized by turf or algae assemblages.

The reef within this area shows a rapid drop off from the reef flat to 5m deep. Then the reef slope is nearly flat. This particular slope shape didn't allowed us to perform two fish census in a single dive. In fact 12m deep stations and 5m deep stations were separated by several hundred meters at some sampling sites. Only P2 showed abrupt slope from the reef flat to 12m deep. Low habitat complexity (value lower than 3 out of 5) was observed at 5 reef sampling sites (R1, R4, R5, R6, R7 and R8) and on the sampling site P3. The sampling sites R2 and R3 had a relatively high complex habitat and the sampling site P2 show very high habitat complexity (Fig.5).

Species richness and fish biomass

The highest species richness was found in the Pass with 61 and 41 species respectively for P2 and P3. The lowest species richness was found in the lagoon with no species recorded for sampling sites L4 and L20. We found on average 4.4 species per sampling site in the lagoon, 15.7 at the back reef, 51 in the pass and 33.4 on the reef. The total biomass varied from 0 at sampling sites L4 and L20 to a maximum of 5763 g/100m² at the sampling site P2. The average biomass of fish found in the lagoon was 188.4g/100m², 725.6g/100m² in the back reef, 4950.4g/100m² in the pass and 2042.7g/100m² for the reef.

Fish diversity and biomass were both higher in the pass than in other habitat types. The reef was the second habitat with the highest species richness and total biomass. The back reef had higher species richness and fish biomass than the lagoon.

None of the species were found in all the sampling sites. Moreover 32 species (34%) were found in only one sampling site. The most abundant species in both abundance and range distribution was *Acanthurus nigrofuscus*, it was found in 18 sampling site including every back reef site, every reef and pass site and in 3 of the lagoon site. *Acanthurus nigrofuscus* was present with a maximum average of 614g/100m² in the pass, 522g/100m² for the reef, 201g/100m² in the back reef and 2g/100m² in the lagoon. The parrotfish species *Scarus psittacus* was found at densities of 0.4g/100m² in the lagoon, 34g/100m² in the back reef, 273g/100m² on the reef and 326g/100m² in the pass. The third most abundant species was *Chlorurus sordidus* with 6.2g/100m² in the lagoon, 32.7g/100m² in the back reef, 101.6g/100m² on the reef and 528g/100m² in the pass. Also *Cheilinus trilobatus* was a common species found at 16 sampling sites but in low density. This species was found at 0.4g/100m² in the lagoon, 20g/100m² for the back reef, 29.4g/100m² on the reef and 18g/100m² in the pass.

Both biomass and species richness of bio-indicator fishes (Chaetodontidae and Zanclidae) were positively correlated with live coral but the proportion of variation explain by the linear regression was low ($r^2=0.5$). A total of 16 species (15 species of Chaetodontidae and 1 species of Zanclidae) were found. The lowest species richness of bio-indicator fish were found in the lagoon, a total of 7 species were observed within the 16 sampling sites located in the lagoon. The average abundance were 0.19ind/500m² for the lagoon. A total of 4 different species were spotted among the 4 sampling sites in the back reef. The average abundance was 3.9ind/500m². It may be noted that the sampling site L19 did not have any bio-indicator fish present despite having one of the highest measurements of coral cover (28%). On the reef a total of 14 species were observed. The highest species richness was found on the sampling site R2 with a total of 10 species. The lowest species richness was found at R5 with a total of 4 different species. On the pass 14 different species were found in total between the two sampling sites P2 and P3. The highest species richness was recorded at sampling site P2 with a total of 11 species of bio-indicator fish. Abundance was higher on the pass than on the reef with on average 7.7ind/500m² for the pass and 5ind/500m² on the reef. The community of bio-indicator fishes were dominated both in abundance and distribution range by two species: *Chaetodon auriga* and *Zanclus cornutus*.

Trophic structure

There were significant size differences between individual fish weight using non-parametric anova (Kruskal-Wallis one analysis of variance) ($P<0.001$). On average single fish biomass in the lagoon was found to be 60g, 80g in the back reef, 113.5g on the reef and 152g in the pass. Comparisons of size for the 4 most common species resulted in significant size differences between habitat types for *Acanthurus nigrofuscus, Chlorurus sordidus, Scarus psittacus* ($P<0.001$) and *Cheilinus trilobatus* ($P<0.05$). The amplitude of size variation for the lagoon was very little in the lagoon for the four species (Fig.6). The pass showed the largest sizes for *Acanthurus nigrofuscus, Scarus psittacus* and *Chlorurus trilobatus.*

Analysis of the trophic structure showed a dominance of biomass from carnivorous species in the lagoon and back reef with these species representing 59% and 51% of the total biomass respectively (Fig.7). Herbivorous fish were well represented in term of biomass with 77% of the fish biomass on the reef, 47% in the pass, 40% in the back reef and 30% in the lagoon. The herbivorous fish were represented mainly by parrotfish (*Chlorurus spp* and *Scarus spp*) and surgeon fishes (*Acanthurus spp*).

Zooplankton feeders and piscivorous fish represented a small portion of total biomass. Zooplankton feeders portion is maximum at the pass with 18% of total biomass. Piscivorous fish's biomass remain lower than 10% of total biomass in all four habitat types.

A total of 18 species of piscivorous fish were observed. *Epinephelus merra* represented 80% of the sightings in the lagoon and 94% in the back reef. On the reef the most abundant was *Epinephelus fasciatus* with 33% of the sightings, while *Epinephelus merra* was the second most common with 15%. The passes were dominated by *Epinephelus fasciatus* (39%) and *Cephalopholis nigripinnis* (21%). Analysis of piscivorous fish size showed significant difference between the four habitats ($P>0.001$). A gradient of size from the lagoon to the pass could be observed. Average size of piscivorous fish was 11.9cm in the lagoon, 14.4cm in the back reef, 18.5cm on the reef and 19.9cm in the pass. The largest fish observed was *Torpedo sinuspersici*. Its size was estimated to be 50cm long. This species was observed only once at the back reef sampling site L12. Large species likely to be seen in the area such as large predatory fishes belonging to Serranidae, Sphyraenidae families or the carcharhiniformes order were not encountered during the study.

Discussion

This study was designed to determine the initial states of fishable biomass within the specific area in the south-west coast of Mauritius (Indian Ocean). We focused on the sub-population of commercial fish. The data collected will be a baseline from which to compare and monitor data as a before control impact in the perspective of MPA implementation in the region. The total duration of the sampling period was two months, we assume that the temporal variation in fish distribution was negligible.

Coral coverage, habitat complexity and distance to the reef were significant factor explaining the fish distribution. The portion of unexplained was about 56%, we believe that inter species competition, fishing effort factors and nutrients availability might also explain fish distribution and should be investigated.

Coral coverage and habitat complexity

Coral reefs are one of the most productive and diverse ecosystems. They support numerous ecosystem goods and services (Moberg and Folke, 1999). Among the ecological goods, coral reefs provide local population with renewable resources. The reefs of the Mascarenes, especially Mauritius are particularly vulnerable (Turner and Klaus, 2005). Though reef of Mauritius was relatively preserved from the 1998 coral bleaching event (Quod, 1998) with only

1 to 15% coral cover affected (Graham et al., 2006). Past surveys on coral reef on the Mascarene islands have shown constant decrease in total coral cover within the past ten years in Mauritius (Anderson et al., 2010). The present study confirm this trend. We found very low coral cover in every habitat where coral were present. The coral patches on the reef were scattered and mainly composed of sub massive and encrusting coral form. This type of coral (porites) offer a low habitat value for fish. In comparison branching, plate and digitate Acropora forms offer good habitat value for fishes, yet Acropora were not common on the reef. Acropora species are more vulnerable, they can break into pieces during cyclones. The particular reef shape with a relatively flat reef slope produce a low habitat complexity. The role of habitat complexity on fish population has been demonstrated to influence fish density and diversity (Beukers, 1997; Chabanet et al., 1997; Komyakova et al., 2013; Williamson et al., 2014).
The abundance of turf and algae assemblages could be correlated with high nutrients input. Eutrophication and degradation induce coral-macroalgal shift. This phase shift can be difficult to reverse. We found the coast line in poor condition. Larges amount of rubbish such as plastic bottles and plastic bags were laying on the shores and in the mangroves, as well as water sewage running directly into the lagoon. The turbidity found on the sampling site behind "l'île aux Bénitiers" is due to terrigenous inputs from rivers. Mauritius streams and rivers carry numerous pollutant from manufacturing industries into the lagoons (Daby, 2006). Concentration of nitrates, phosphates and silicates have been measured nearly three time higher than in Reunion Island (Turner and Klaus, 2005). Improvement in water quality should be made to help with coral reef restoration.

Species richness and fish biomass

The fishable biomass found on the reef (204kg/ha) is far below the window of fishable biomass expected to produce a maximum multispecies sustainable yield hypothesised by McClanahan et al., (2011). This window of fishable biomass ranges from 300kg/ha to 600kg/ha. The habitat type pass with 495kg/ha reaches the window of fishable biomass expected to produce a maximum multispecies sustainable yield. Passes are usually places of high fish biomass and species richness. Mauritius is one of densest country in the world in terms of population density. The number of species observed: 95, is low compared to the number of potential species targeted in this study. The density of population and the over exploitation of marine resources put high pressure on the fish population. Reef fish biomass and species richness are limited by the density of the local population (Cinner et al., 2013; D'agata et al., 2014). Moreover low coral cover combined with low habitat complexity on the reef do not offer favourable habitat for reef fishes. Complex habitat can be shared by more species. The species richness is positively correlated with coral cover and habitat complexity (Chabanet et al., 1997). It was found that small changes in live coral cover can significantly alter species richness and fish abundance (Bell and Galzin, 2000; Graham et al., 2006). However in Seychelles (Western Indian Ocean) low live coral cover was found to have very large fish biomass with numerous apex predators but required the maintenance of high habitat complexity and reduction of fishing pressure (Friedlander et al., 2014).

Chaetodontidae and Zanclidae species are not fishes of food interest but they present several advantages; they are conspicuous species that make them easy to identify among the other coral reef fishes, they live in close association with coral reefs. In fact some species feed mainly on coral polyps. For these reasons butterfly fishes are commonly used as bio-indicators (Brokovich and Baranes, 2005; Pereira and Videira, 2005) and furthermore are promising indicators for coral reef health and fish diversity estimation (Kulbicki and Bozec, 2005). The number of species of Chaetodontidae encountered during the study is relatively high, 15 out of the 18 listed on the Mauritian island of Rodrigues (Heemstra et al., 2004). The abundance found on the reef and pass was very low. We found 1ind/100m² on the reef and 1.5ind/100m² on the pass. In comparison, in Southern Mozambique 7.8ind/100m² were found on the reef (Pereira and Videira, 2005). The two dominant species of the community of bio-indicator fishes (*Chaetodon auriga* and *Zanclus cornutus*) have a wide distribution throughout the Indo-Pacific region and are not strictly coral feeders. In fact only 3 species of the 15 encountered during the study are exclusively coral feeder (*Chaetodon melannotus*, *Chaetodon trifascialis* and *Chaetodon trifasciatus*). The low coral cover probably explains the low abundance of butterflyfishes and the dominance of generalist feeders. At sampling site L12 in spite of the relatively high coral coverage no bio-indicator fish were observed. The coral forms at this site were dominated by branching Acropora. The coral habitat was occupied by large numbers of Pomacentridae fish. These fish are known to be territorial. They defend their territory by chasing away any fish passing by.

Trophic structure

In one hand habitat utilization appears to be specific with particular fish assemblages for each habitat. On the other hand the different habitat types are linked. The species size class distribution investigated shows different habitat use. In fact fish use different habitats during their life cycle. The lagoon, mainly composed of sea grass beds and sandy bottom contains higher numbers of small size fishes than other habitats. The size classes observed in the lagoon were smaller for the two species of parrot fish (*Chlorurus sordidus* and *Scarus psittacus*) and with a lower size distribution range for the 4 most common species investigated. Sea grass beds are a nursery area for numerous coral reef fish that occupy the reef during their adult life stage (Nagelkerken et al., 2000; Nakamura et al., 2012; Sedberry and Carolina, 1993). Sea grass beds provide food resources and the structural complexity provides protection from predators for juvenile fish. Furthermore, sea grass beds are often remote from coral reef therefore less visited by large predators. It is known to be a habitat with high species diversity(Nagelkerken et al., 2000). However, we did not find high species diversity in the sampling sites located on the sea grass beds. It was assumed that a negligible numbers of individuals were excluded by sampling the fish of minimum size 5cm.

To compare the trophic structure fish diet were simplified into 4 groups. It was assumed that this simplification was enough for the purpose of the present study. The dominance of carnivorous fish in the lagoon was explained by the well represented family of Mullidae that feed on macro benthic invertebrates found in the sand. Analysis of the Figure 7 shows that the biomass of herbivorous fish are dominant on the reef and in the pass. Planktivorous fish have been commonly observed as the dominant species on the reef slope (Chabanet et al., 2002). In our study the planktivorous fishes in addition with macro-invertebrate feeders were only the second most represented fish on the reef. The abundance of herbivorous fish is characteristic of a fished area and may be also influenced by the large algal coverage. Piscivores were the least common group of fish found in all habitat types. Piscivorous fish are the first species targeted by fishermen. While herbivorous fishes are the last group targeted in heavily exploited areas (Jennings et al., 1996; McClanahan et al., 2011). The high proportion of herbivorous fishes could actually facilitate the coral reef recovery. Herbivorous and grazer fishes can enhance coral recruitment by reducing the algae propagation and removing sediment (Green and Bellwood, 2009; Heenan and Williams, 2013).

In addition, not a single shark was observed during this study. Neither large grouper nor snapper were found in the study. Although we did not census deeper than 12m, numerous species of grouper were likely to be seen in water shallower than 12m deep. Apex predators seem to have vanished from the area. In pristine reef, fish assemblages are dominated by apex predators (Friedlander et al., 2010). Yet these species are the most vulnerable to exploitation (J. D. Reynolds et al., 2001). Overfishing induces a decline in the mean size of fish populations. A decline in mean size of the fish population was noted for Mauritius at the beginning of the 20th century (Boistol et al., 2011).

Conclusion

The results of this study highlight the exploited state of the area. Low live coral cover colonized by turf and algae assemblages, the absent of apex predators and large fishes, the persistence of herbivorous and small size fishes are all characteristic of a heavily exploited area. Nevertheless, pass habitat especially P2 present a relatively high fish biomass and diversity. However, the habitat type "pass" represents a small portion of the area. Mauritius tourism and local population both depend on the coral reef ecosystem. The state of the reefs are affecting fishing yield and could threaten the tourism economy. Conservation measures such as no take zones seem to be necessary within the region to initiate and enhance reef fish biomass and diversity recovery. The area investigated represents different assets; the reef is far away from the shore so less accessible by people, various habitats such as mangrove forests and sea grass beds are present and are important for the different life stages of reef fishes. With the high pressure from fishing and tourism activities, future MPA allocation should take into consideration the few mangrove forests remaining and the low habitat complexity of the reef slope.

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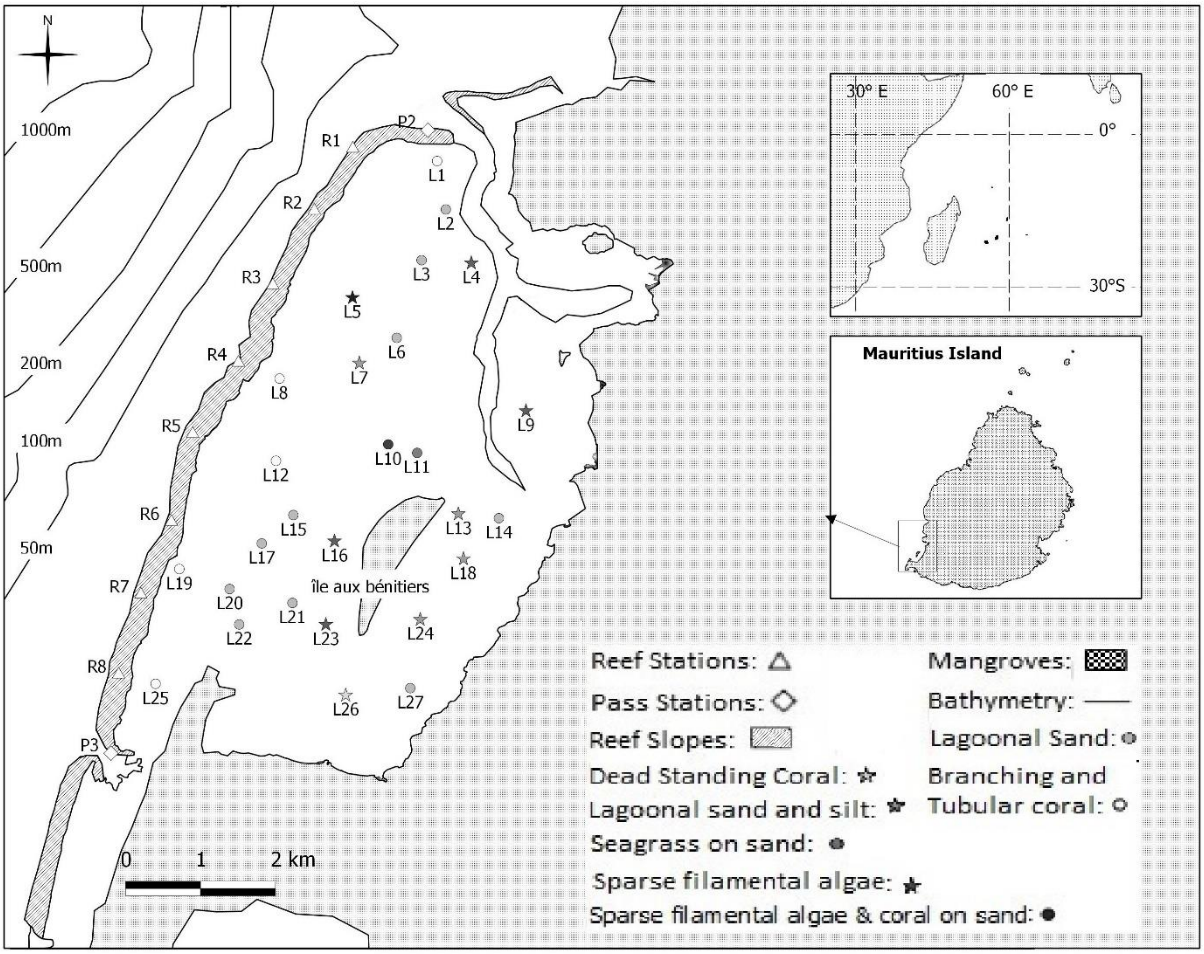
Figure1:


N
1000m
500m
200m
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R1
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P2
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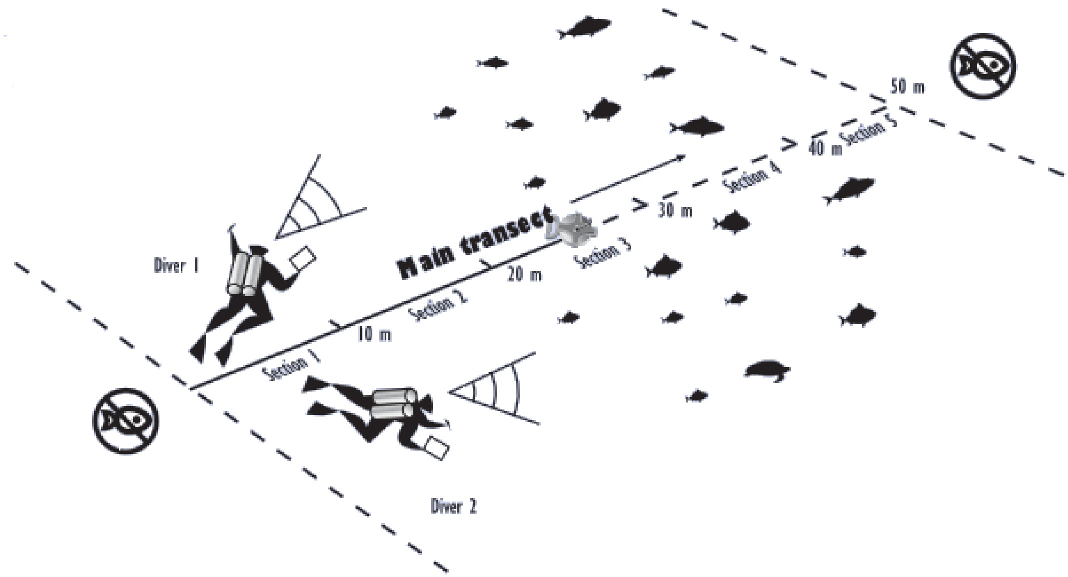
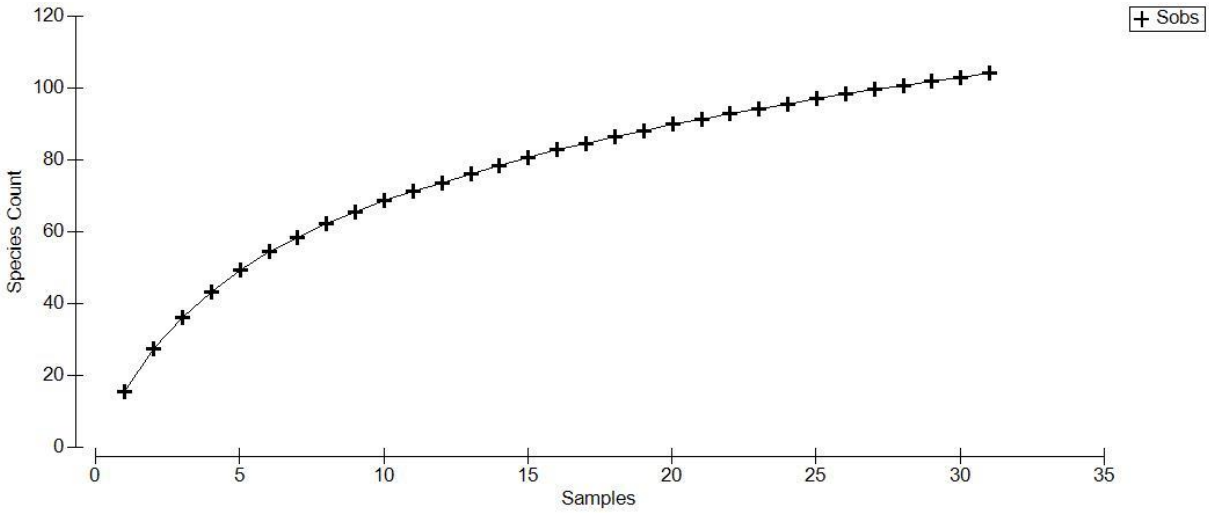
L27
île aux bénitiers
0
1
2 km
30° E
60° E
0°
30°S
Mauritius Island
Reef Stations:
Pass Stations:
Reef Slopes:
Dead Standing Coral:
Lagoonal sand and silt:
Seagrass on sand:
Sparse filamental algae:
Sparse filamental algae & coral on sand:
Mangroves:
Bathymetry:
Lagoonal Sand:
Branching and
Tubular coral:

Figure2:



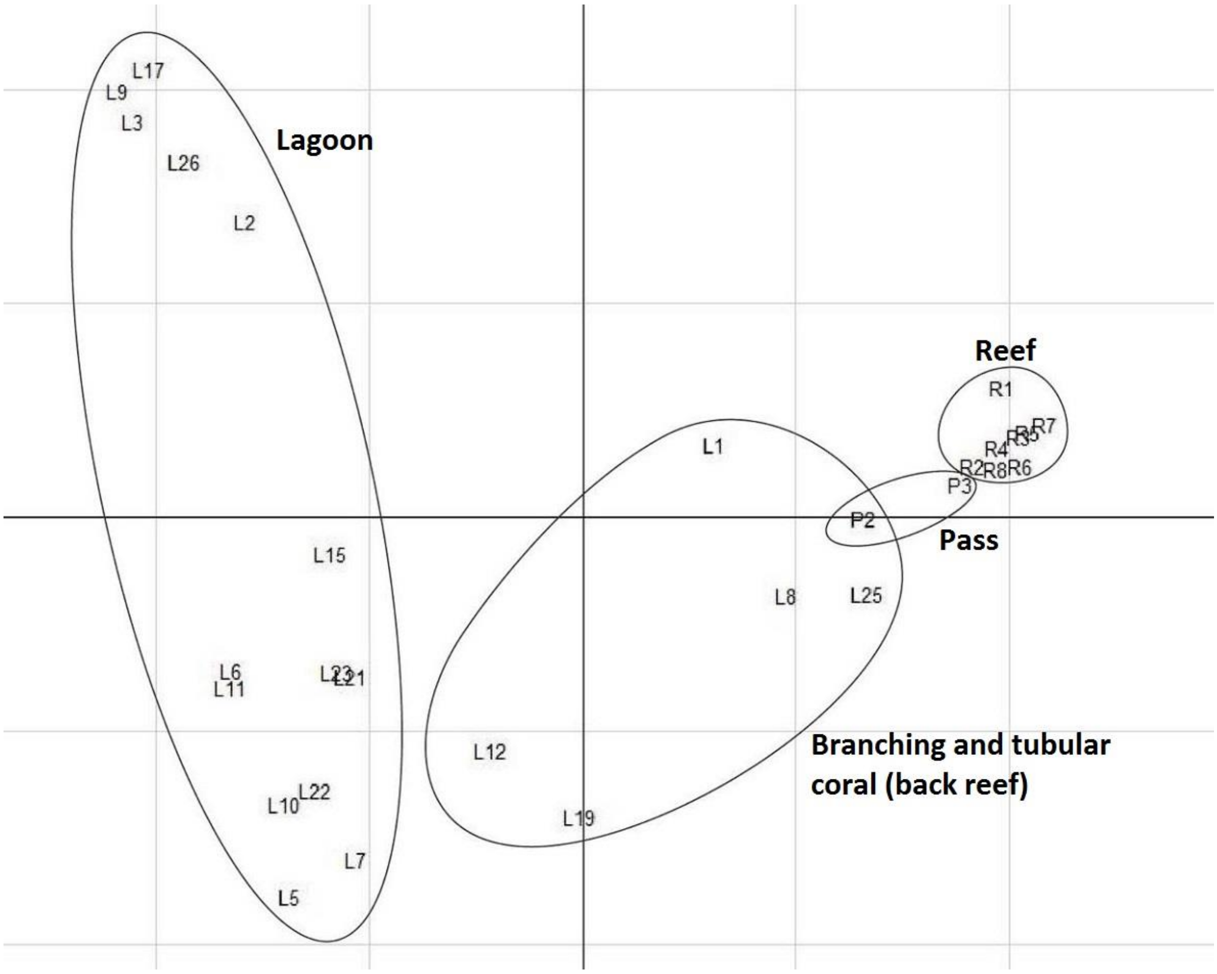
50 m
Section 5
40 m
Section 4
30 m
Main transect
Section 3
20 m
Section 2
10 m
Section 1
Diver 1
Diver 2

Figure 3:



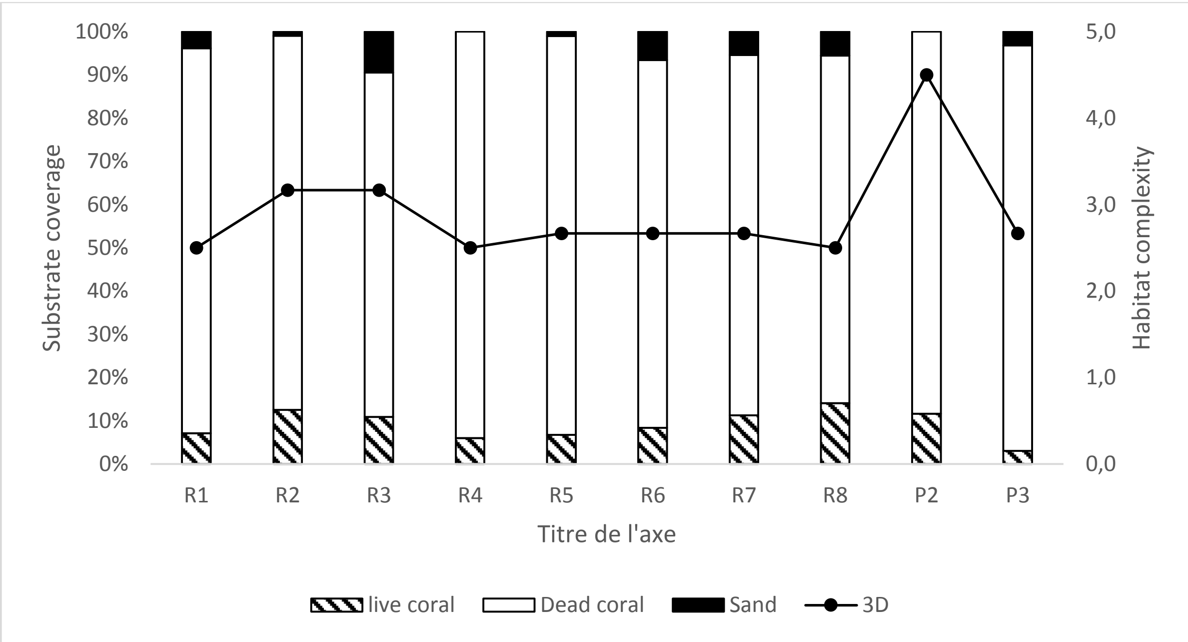
Sobs
Species Count
Samples
120
100
80
60
40
20
0
0
5
10
15
20
25
30
35

Figure 4:



Lagoon
L17
L9
L3
L26
L2
L15
L6
L11
L23
L21
L22
L10
L7
L5
Reef
R1
R7
R4
R2
R8
R6
P3
L1
P2
Pass
L8
L25
L12
L19
Branching and tubular coral (back reef)

Figure 5:



100%
90%
80%
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50%
40%
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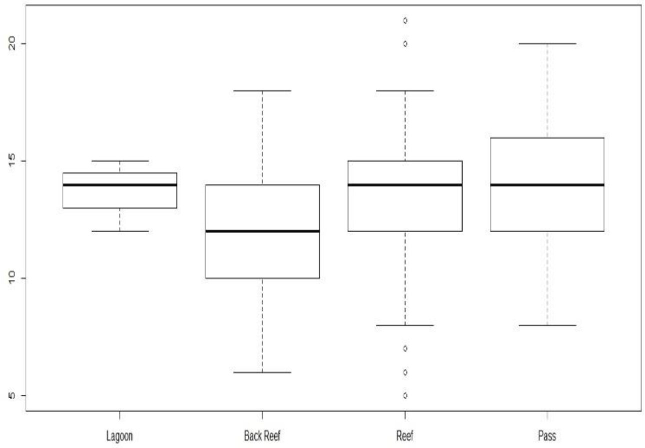
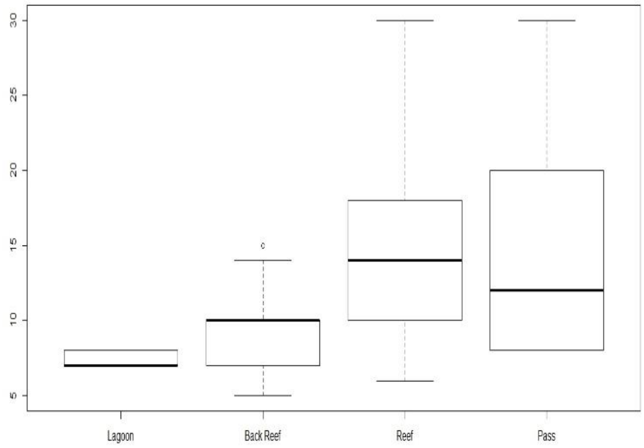
0%
Substrate coverage
5,0
4,0
3,0
2,0
1,0
0,0
Habitat complexity
R1
R2
R3
R4
R5
R6
R7
R8
P2
P3
Titre de l'axe
live coral
Dead coral
Sand
3D

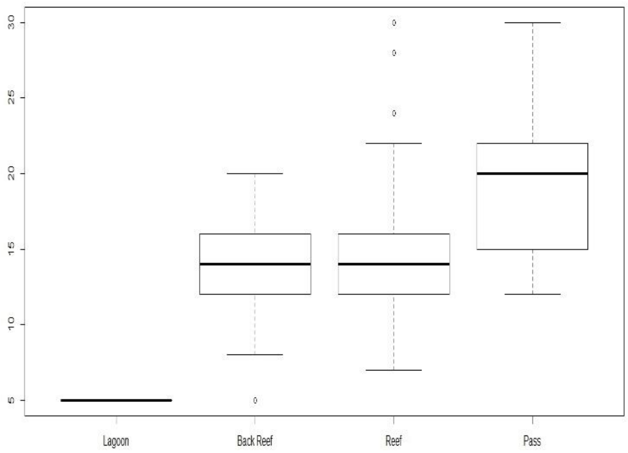
Figure 6:



Acanthurus nigrofuscus



Scarus psittacus



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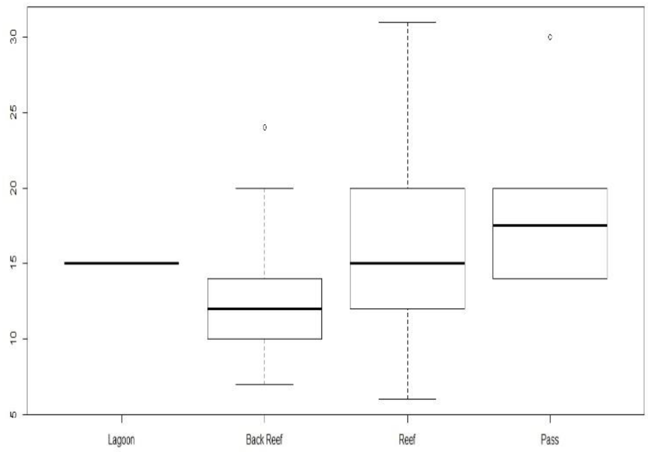

Cheilinus trilobatus

Figure 7:

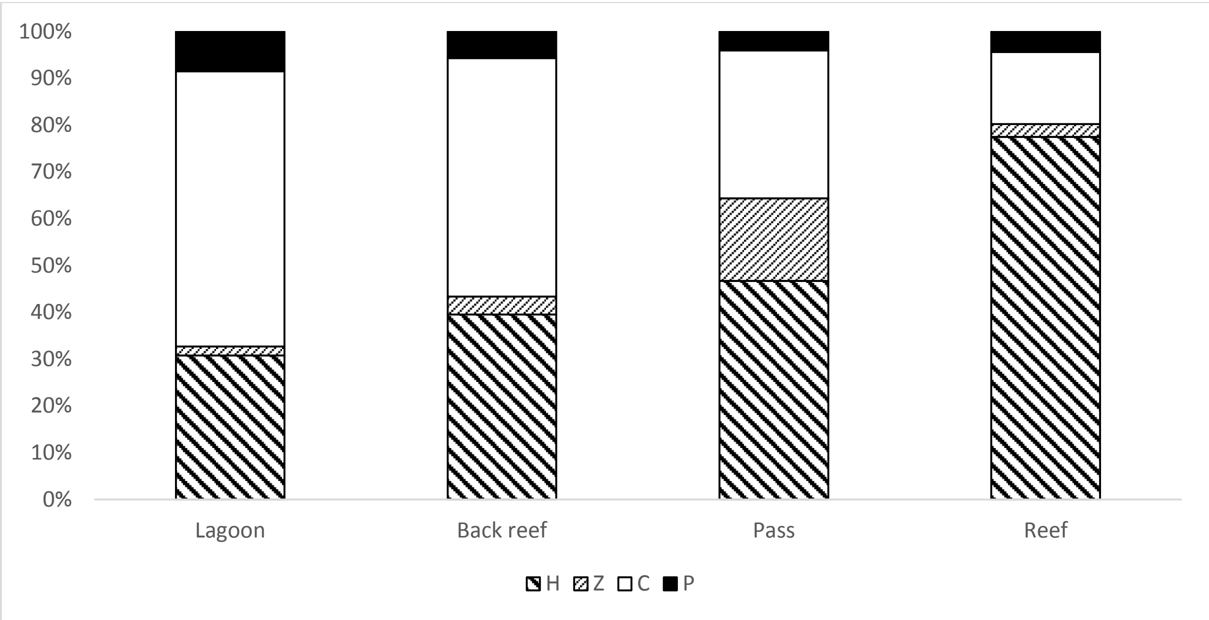

Table caption

Table1: Species composition and biomass in g/500m² (mean value per transect) of fish estimated during this study.

Table 2: Results of permutational multivariate analysis of variance (PERMANOVA) on the basis of Bray–Curtis dissimilarities square roots- transformed biomass. P values were obtained using 999 random permutations of appropriate units. Estimates of multivariate pseudo-variance components.

Table 1

station	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L15	L17	L19	L20	L21	L22	L23	L25	L26	P2	P3	R1	R2	R3	R4	R5	R6	R7	R8
Acanthuridae																															
Acanthurus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66.24	0	0	22.61
Acanthurus blochii	0	220.6	0	0	0	0	0	74.8	0	0	0	0	588.9	191.7	0	0	0	0	0	0	0	153.8	0	840.3	934.3	530.3	278.1	2356	110.3	36.76	72.31
Acanthurus guttatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37.24
Acanthurus nigricauda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	267.2	295.9	0	0	0
Acanthurus nigrofuscus	1024	96.11	0	0	0	0	0	1219	0	0	0	272.8	38.99	0	720.6	0	0	0	0	1787	24.45	2988	3158	2281	2696	3594	2467	4068	2159	4927	3938
Acanthurus tennentii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3467	30.37	1995	0	0	0	0	133.7	1353
Acanthurus thompsoni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	169.6	0	0	0	0	0	89.82	0	0	0
Acanthurus triostegus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.6	184.8	0	0	77.07	90.39	0	2640	76.3	14.36	60.18	16.42	3893
Ctenochaetus striatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	284.4	0	7.8	319.3	0	12.51	0	4.46	0	504.7
Ctenochaetus strigosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.84	0	0	0	0	0	0	0
Ctenochaetus truncatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	161.2	0	0	0	0	0	0
Naso elegans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39.84	0	11.01	0	0	0
Naso unicornis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.73	0	0	483	0	20.1	7.68	93.86	31.9	0	0	179.5
Zebrasoma desjardinii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	82.96	0	0	0	0	113.7	7.33	136.3	104.9	0	0	0	16.02	0	82.96	32.05	16.02
Zebrasoma scopas	0	0	0	0	0	0	0	21.98	0	0	1.79	31.98	0	0	0	0	0	0	0	0	0	314.5	144	0	133.4	71.33	55.31	37.9	330	0	0
Caesionidae																															
Caesio caerulaurea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	778.2	34.5	0	0	0	0	0	0	0	0
Pterocaesio marri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77.91	0	0	0	0	0	0	0	0	0
Carangidae																															
Carangoides sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	194.5	0	0	0	0	0	0	0	0	0
Caranx melampygus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	318.7	0	0	0	0
Elagatis bipinnulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	121.9	0	0	0	0	0	0	0	0	0
Chaetodonoidae																															
Chaetodon auriga	71.95	0	0	0	0	0	0	229.1	15.56	0	3.84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetodon guttatissimus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17.78	0	0	140.9	31.66	0	0.64	9.44	22.73	0
Chaetodon interruptus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.55	0	0	3.49	23.56	0	15.23	0	4.55
Chaetodon kleinii	0	15.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.71	0	0.71	0	0.71	0	1.89	0	0
Chaetodon lunula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.92	0	0	0	0	14.32	106.9	15.23	7.61	7.61	0	0	17.19	32.31	0
Chaetodon madagaskariensis	0	0	0	0	0	0	0	0	0	0	1.92	0	0	0	0	0	0	0	0	0	0	16.71	0	0	100.8	38.67	2.42	12.85	36.91	63.28	0
Chaetodon melannotus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41.17	41.7	0	0	17.35	0	0	0	4.98	13.88
Chaetodon meyeri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23.56	0	0	0	0	0	0

station	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L15	L17	L19	L20	L21	L22	L23	L25	L26	P2	P3	R1	R2	R3	R4	R5	R6	R7	R8
Chaetodon trifascialis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32.3	0	0	46.05	0	0	0	0	21.73	0
Chaetodon trifasciatus	75.88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.22	212	0	16.86	26.66	0	0	0	0	9.8	8.43
Chaetodon vagabundus	0	0	0	0	0	0	0	26.11	13.06	0	0	0	0	0	0	0	0	0	0	0	0	23.67	14.97	82.55	60.92	19.32	29.06	7.48	34.18	14.97	42.06
Chaetodon xanthocephalus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51.56	0	44.09	121.5	64.63	0	0	0	0	0	0	32.31
Forcipiger sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.28	0	0	10.09	2.08	0	0	0	22.78	0
Heniochus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.25	0	0	0	0	0	0	0	0	0
Heniochus monoceros	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76.47	0	0	0	0	0	42.59	0	0
Haemuidae																															
Plectorhinchus picus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.65	0	0	0	0	0	0	0	0	0
Plectorhinchus playfairi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13.23	0	0	0	0	0
Holocentridae																															
Myripristis sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1118	0	0	0	0	0	0	0	0	0
Myripristis adusta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	510.5	0	0	0	0	0	0	0	0	0
Myripristis berndti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	783.3	0	3410	1725	37.3	1965	0	0	0	0	23.76	64.48
Myripristis kuntee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1312	0	0	0	0	0	0	0	0	0
Neoniphon aurolineatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46.66	0	0	0	0	0	0	0	0	0
Neoniphon sammara	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36.16	0	0	0	0	0	0	710.6	0	0	0	0	0	0	0	0	0
Sargocentron diadema	0	0	0	0	0	0	0	56.8	0	0	0	11.3	0	0	19.36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sargocentron spiniferum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127	0	0	0	0	0	0	0	0	0
Kyphosidae																															
Kyphosus bigibbus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.92	0	0	0	0	0
Kyphosus vaigiensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141.3	0	0	0	0	0	0	0	0	0
Labridae																															
Cheilinus chlorourus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16.48	37.59	0	18.8	18.8	0	14.77	0	3.32	52.85
Cheilinus trilobatus	231.1	0	0	0	0	32.18	0	47.02	0	0	0	26.06	0	0	121.8	0	0	0	0	74.83	0	31.28	150	109.5	85.36	225.8	85.22	147.1	337.7	97.25	95.11
Coris aygula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.07	0	0.75	93.83	71.52	67.63	159.8	21.37	5.16
Coris gaimard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.21	0.39	1.72	0	0	0.39	0	0
Epibulus insidiator	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	280.2	0	0	95.66	0	0	0	0	0	0
Hemigymnus fasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	228.5	145.7	0	11.64	0	62.69	16.66	100.4	16.66	48.05
Novaculichthys taeniourus	0	129.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62	0	0	0	0	0	0	0	9.74	7.68
Lethrinidae																															
Gnathodentex aureolineatus	0	0	0	0	0	0	0	108.2	0	0	0	611.3	0	0	80.71	0	0	0	0	197.5	0	1358	3991	0	98.11	0	0	0	0	0	14.65
Lethrinus sp	0	0	0	0	0	0	0	0	0	0	18.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lethrinus harak	541.5	134.4	0	0	0	134.4	0	265.1	0	0	0	0	151.4	0	265.1	0	0	0	0	152.2	0	607.5	562.8	0	0	1687	432.7	396.9	107.5	176.7	622.6

station	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L15	L17	L19	L20	L21	L22	L23	L25	L26	P2	P3	R1	R2	R3	R4	R5	R6	R7	R8
Lethrinus nebulosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100.9
Lethrinus olivaceus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25.03	0	0	0	0	0	0	0	0
Monotaxis grandoculis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33.4	0	162.4	11.13	0	0	0	0	0	0	0	0
Lutjanidae																															
Aprion virescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70.2	0	0
Lutjanus fulviflamma	0	0	0	0	0	0	0	0	0	0	74.68	0	0	0	0	0	0	0	0	0	0	0	249.2	0	0	0	0	0	0	0	0
Lutjanus fulvus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	356.3	0	0	945.6	16.04	0	0	86.85	230.2	44.72
Lutjanus kasmira	0	0	0	0	0	0	0	0	0	0	0	0	0	7.44	0	0	0	0	0	0	0	474.4	0	0	0	0	0	0	0	0	0
Lutjanus monostigma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.85	0	519.8	0	0	0	0	0	0
Lutjanus notatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72.96	0	0	0	82.29	0	0	0	37.28
Mullidae																															
Mulloidichthys flavolineatus	0	0	0	0	2414	292.6	53.2	391.6	0.88	0	0	55	306.1	0	6847	0	0	26.6	0	322.9	0	64.84	0	0	0	17.73	8.87	0	0	0	2.52
Mulloidichthys vanicolensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1309	986.6	0	0	0	0	0	0	0	0
Parupeneus barberinus	0	45.92	0	0	93.01	0	0	24.77	3.84	1.99	24.14	0	0	0	0	0	0	0	1.76	0	0.99	675.9	0	0	0	127.4	27.05	214.1	220	89.19	0
Parupeneus ciliatus	0	0	0	0	0	17.36	0	431.7	0	0	0	0	0	0	323.5	0	0	0	0	179.9	3.73	94.03	929.8	0	390.1	5.79	0	0	0	0	0
Parupeneus cyclostomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110.1	0	0	0	7.01	0	0	0	88.93	0
Parupeneus macronemus	0	0	0	0	11.58	0	0	9.19	0	0	0	1.87	0	0	0	0	0	0	0	0	0	144.9	4.29	41.32	56.84	66.98	83.99	50.23	67.11	42.17	11.14
Parupeneus pleurostigma	0	0	0	0	5.95	0	0	16.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.98	0	4.06	0	0	0	0
Parupeneus trifasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	266.4	448.5	25.28	430.2	96.74	162.9	178.7	112.6	133.7	115.5
Scaridae																															
Calotomus carolinus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	118.9	0	0	0
Chlorurus atrilunula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.83	0
Chlorurus enneacanthus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	191
Chlorurus sordidus	91.6	0	0	0	0	0	0	11.68	0	0	0	77.85	0	0	460.5	0	0	0	0	177.4	7.23	4311	970.8	0	631.6	860.4	140.5	817	158.4	981.9	475.2
Hipposcarus harid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	93.43	0	0	0	0	0	0	0	0	0
Scarus sp	74.02	0	0	0	0	18.16	0	106.1	0	0	0	0	0	0	0	0	0	0	0	0	65.78	9.64	133.5	385.4	37.24	221.9	38.83	442.6	37.24	67.23	28.73
Scarus frenatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	246.8
Scarus ghobban	0	0	0	0	0	74.68	294.4	0	0	0	0	147.2	0	0	0	0	0	0	0	689.5	0	336.6	86.68	0	88.55	358.6	555.4	808.7	443.5	0	511.4
Scarus globiceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35.71	0	0	0	0	0	0	0	0	0
Scarus oviceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17.5
Scarus psittacus	66.22	0	0	0	0	0	0	456.1	0	0	0	0	0	0	0	0	0	0	0	167.2	28.9	1520	1729	1434	369.6	866.3	601.2	2885	1810	2477	495.5
Scarus russelii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	785.3	74.21	0	0	0	0	0	0	0	0
Scarus scaber	0	0	0	0	0	0	0	0	0	0	0	0	0	0	414.1	0	0	0	0	338.6	0	1583	0	0	0	0	0	0	0	0	264.3
Scarus viridifucatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91.46	0

station	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L15	L17	L19	L20	L21	L22	L23	L25	L26	P2	P3	R1	R2	R3	R4	R5	R6	R7	R8
Scarus viridifucatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91.46	0
Serranidae																															
Cephalopholis sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28.23	8.53	0	0	0
Cephalopholis argus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15.23	0	0	0	0
Cephalopholis leopardus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.48	0	0	0	0	0	0	0	0	0
Cephalopholis nigripinnis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.19	10.47	0	100.3	12.2	0	21.29	49.89	75.46	64.45
Cephalopholis spiloparaea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.53	0	19.42	0
Epinephelus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44.69	0	0	0	0
Epinephelus fasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	204.9	27.82	174.2	0	203.5	57.46	113.2	38.19	81.28
Epinephelus hexagonatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.56	0	0	0	0	0	0	0	0	0
Epinephelus macrospilos	0	0	0	0	0	0	0	0	3.27	0	0	0	0	5.14	0	0	0	0	0	24.2	31.93	16.14	0	0	0	6.55	0	0	0	0	0
Epinephelus merra	266.8	81.66	41.9	0	39.76	38.48	0	7.33	100.4	0	14.66	0	0	57.27	7.33	0	0	0	0	108.9	59.67	9.07	35.35	0	0	6.63	27.48	0	0	0	0
Epinephelus spilotoceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.65	0	11.77	0
Variola louti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20.6	0	0	46.2	0	0	0	0	71.78
Siganidae																															
Siganus argenteus	0	0	0	0	0	7.78	0	118.3	0	0	16.27	0	0	0	7.77	0	0	0	0	0	12.7	407	39.62	0	0	0	53.63	19.02	0	0	33.1
Siganus sutor	0	0	0	0	128.4	0	0	42.79	0	96.62	186.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	62.94	70.43	0	0
Torpedinidae																															
Torpedo sp	0	0	0	0	0	0	0	0	0	0	0	840.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zanclidae																															
Zanclus cornutus	0	0	0	0	0	0	0	137.5	0	0	0	0	0	0	0	0	0	0	0	800.9	0	433.6	183.9	141.9	186	99.84	115.5	89.63	80.24	104.3	429.4

Table 2:

Source	df	MS	F	R^2	Pr(>F)	
Live coral	1	1.18827	3.945	0.10592	0.001	***
Distance to reef	1	1.30479	4.3318	0.11631	0.001	***
Habitat complexity	1	0.68521	2.2749	0.06108	0.005	**
Live coral:distance to reef	1	0.40423	1.3420	0.03603	0.135	
Live coral:Habitat complexity	1	0.44392	1.4738	0.03957	0.084	.
Distance to reef:Habitat	1	0.33699	1.1188	0.03004	0.315	
Live coral:Distance to reef:Habitat complexity	1	0.52972	1.7586	0.04722	0.027	*
Residuals	21	0.30121		0.56383		
Total	28			1		