Fish species community composition of Curacao bays and reef

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Abstract

Tropical coastal bays often border coral reefs and host connected ecosystems such as seagrass beds and mangrove forests. Similarly, the bays of the Caribbean island of Curaçao support unique coastal systems that include submerged multi-species seagrass beds and fringing red mangroves. These marine plants are form productive systems that are an important habitat for a variety of species. This includes nursery habitats for juvenile coral reef fish species, which utilizes food resources and refuge for predators prior to migrating to the coral reef. Many Caribbean marine habitats are under pressure due to growing tourism, overfishing and climate change, resulting in fish species disappearing form the reef. Concurrent, nursery habitats are threatened by coastal construction and eutrophication of waters. For effective protection of fish species, it is essential to include all lifecycles and their habitats. This study focused on 1) determining the fish species community composition of 6 Curaçao bays and reefs, focusing on five nursery species (French grunt, Schoolmaster, Mangrove snapper, Yellowtail snapper and Mutton snapper). 2) Determine how environmental factors influence the fish species community composition, and 3) get insight in the historical changes in reef fish species community composition in the last 25 years. For this, conducted a field survey across 6 Curaçao bays (Bartolbaai, Fuikbaai, Piscadera, Santa Martha, Sint Joris, and Spanish Water) and adjacent reefs. On 9 mangrove and 9 seagrass sites in each bay we sampled abiotic and biotic environmental parameters and fish species using a ~0.5mm mesh size seine net. Reef fish data was collected through diving transect surveys. Surprisingly, species diversity did not differ among sampled bays when taking all fish species taken into account. In contrast, species abundance did differ among bays. Santa Martha had a significantly lower species abundance than Fuikbaai. Focusing on five nursery species, we observed a surprising difference in both species diversity and abundance between bays and the connected reef habitats. Fuikbaai and Santa Martha show a lower abundance for nursery species on the reef than in the bay. In the bays there are significant difference for species diversity and abundance between Bartolbaai/Piscadera and Santa Martha. Furthermore, our environmental analysis furthermore showed that both bay size and mangrove root density are determinants for fish species composition. Additionally, to mangrove root density, seagrass shoot density and bay depths are important determinants for the species composition of the selected nursery fish species. Multivariate tests showed that a shift in the reef species community composition has occurred. The results of this study help determine which environmental factors are critical in supporting fish species communities in Curaçao. In addition, it gives insight into alternative conservation measures to protect coral reef fish species.

Introduction

Marine ecosystems all over the planet are being threatened by global warming, growing tourism, pollution, eutrophication, (coastal) construction and overfishing (Halpern *et al.*, 2007; Boström *et al.*, 2011). In response to these threats marine species from corals to whales are disappearing and/or migrating away from effected areas (Blowes *et al.*, 2019) . Especially, marine ecosystems that are in close proximity to densely populated coastal regions, are the area's most heavily impacted by these threats (Weslawski & Snelgrove, 2004; Lotze *et al.*, 2006). At a global scale, there are a numerous conservation efforts being pushed in protecting coral reefs and their inhabitants. These conservation efforts include Marine protected areas (MPAs) and coral restauration (Côté & Reynolds, 2006). In 2006, already 980 MPAs contained coral reefs, covering 98.650 km^2 (18.7%) of the world's coral reef habitats (Mora *et al.*, 2006). Coral reefs are generally colorful and attractive habitats that are popular ecotourism destinations, making these habitats attractive for environmental organizations to put on their conservation agenda. These conservation measures have sometimes led to local increases in coral cover and an increase in fish recruitment (Almany *et al.*, 2006; Riegl *et al.*, 2009), but in general, reef fish species are still disappearing from their habitat.

Some reef fish species undergo an ontogenetic shift during their lives. They grow up in connected nursery systems as juveniles before migrating to the coral reef. Nursery systems are defined as "a habitat is a nursery for juveniles or a particular species if its contribution per unit area to the production of individuals that recruit to adult populations is greater, on average, than production from other habitats in which juveniles occur (Beck *et al.*, 2001). Nursery habitats are generally located closely to coral reefs. A study conducted by Nagelkerken et al. (2001) shows that nursery species only transition successfully through their life stages, when their nursery habitat is in close proximity to a coral reef. The suitability of nursery habitats requires sufficient stage-specific food sources and refuge for predators. Migration toward of nursery species the coral reef may be driven by growth inducing ontogenetic changes in diet and shelter requirements, and by the onset of reproductive behavior (Kramer & Chapman, 1999; Cocheret de la Morinière *et al.*, 2003; Grol *et al.*, 2014).

Nursery habitats in the tropics consist of a mosaic landscape of mangrove forests and seagrass meadows. These productive habitats provide ample resources and protection against predators due to the complex structure of seagrass leaves and mangrove roots (Beck *et al.*, 2001; Verweij, 2007). In these nursery systems, available food sources consists of plant detritus, plankton, epiphytes and small invertebrates (Cocheret de la Morinière *et al.*, 2003). High survival of juveniles in nursery systems is due to low predation pressure. Low predation pressure has two causes. First, there is a low abundance of piscivore fish species, compared to deeper offshore waters (Sweatman & Robertson, 1994). Secondly, present piscivores have a low predation efficiency due to the high structural complexity and, sometimes, high turbidity of these waters, like low light intensity between the mangrove roots (Primavera, 1997). The importance of mangroves and seagrass beds goes beyond their functioning as a nursery habitat. They contribute to sediment stability, water quality and protection against coastal erosion (Barbier *et al.*, 2011; Mtwana Nordlund *et al.*, 2016). The combination of mangroves forest and seagrass beds are only found in the tropics and are mostly dependent on the tide (Igulu *et al.*, 2014). Habitat accessibility is decreased and can only be accessed at high tide.

Nursery systems face the same threats as coral reefs, however as mentioned above, conservation efforts are still mainly focused on coral reefs and their inhabitants. In addition, different connected habitats are generally studied separately, with again a greater focus on coral reefs. The bays of Curaçao, located in the Caribbean Sea, consist of mangrove forest and seagrass meadows that are permanently submerged. The bays contribute to a healthy coral reef and supports the reefs ecosystem services it facilitates, including coastal protection, improving water quality and ecotourism (Boström *et al.*, 2011). However, like most marine ecosystems, both seagrass beds and mangrove forests are under pressure of anthropogenic threats, i.e. mangroves have to make way for coastal construction and seagrass is overgrown by algae as a result of eutrophication of coastal waters (Govers *et al.*, 2014).

For effective protection of coral reefs, it is essential that all life stage habitats of coral reef fish are included in conservations plans (Boström *et al.*, 2011). This will have a beneficial effect on the biodiversity and the overall health of coral reefs. In addition, this approach will also increase the economic value, as a lot of nursery fish species are of economic importance to fisheries. Nursery habitats do not provide equal recruitment of sub-adults to the coral reef, this is dependent on environmental conditions and habitat quality (Aburto-Oropeza *et al.*, 2007; Wilson *et al.*, 2017). Over time, changes in recruitment has cascading changes on the coral reef, since nursery species composition is dependent on the recruitment of nursery habitats. By identifying nurseries that have a high recruitment strength, protection of high value nursery habitats is critical to supporting conservations of reef fish populations, both regionally as local. In addition, changes in nursery species community composition on the reef can indicate a shift at earlier life-stages.

This study conducts a field study in order to gain insight on the nursery habitats in six bays of Curaçao and the adjacent reefs. We focused on 1) determining the fish species community composition of 6 Curaçao bays and reefs, focusing on five nursery species (French grunt, Schoolmaster, Mangrove snapper, Yellowtail snapper and Mutton snapper). 2) Determine how environmental factors influence the fish species community composition, and 3) get insight in the historical changes in reef fish species community composition in the last 25 years. We hypothesized that not all bays are equal in their relevance as a nursery habitat (Nagelkerken, 2000), as species diversity is expected to differ among bays with different habitat properties such as presence and density of habitat-building species (e.g. mangroves and seagrasses) and water quality parameter (Beck *et al.*, 2001; Wilson *et al.*, 2017). Last, fish species are disappearing from the reef and are being replaced (Wilson *et al.*, 2008; Blowes *et al.*, 2019). We expect this to have happened on Curaçao as well. These result may contribute to the development of cross-habitat conservation and management plans in which the improvement of bay habitat quality can be included. in determining which aspects of the bays should be taken into policy plans.

Material and methods

Study area and environmental factors

From January to March 2020 fieldwork was conducted on the Caribbean island of Curaçao. In total six bays were sampled: Bartolbaai, Fuikbaai, Piscadera, Santa Martha, Sint Joris, and Spanish Water (Fig. 1). Each bay was divided into two habitat types: mangrove and seagrass. For each habitat type nine locations per bay were randomly selected with Qgis. (GPA type: Garmin GPSMap 66 St; GPS locations, see appendix I). At each individual location, multiple environmental parameters were measured; Water temperature, pH and salinity/conductivity were measured using a YSI multiprobe meter (type: 556 MPS). Horizontal visibility was measured using a secchi disk and depth (m) was measured, using measuring tape. Afterwards the size of the bay was calculated by manually drawing polygons in Google Earth© and calculating the surface area of all bays.

Figure 1. Map of Curacao and the sampled bays. West of the island Bartolbaai and Santa Martha, central of the island Piscadera and East of the island Sint Joris, Spanish water and Fuikbaai.

Biological parameters

At each location where environmental parameters were measured, we additionally studied biological properties of mangrove forests and seagrass beds. Atlocations categorized as 'mangrove', only one species of mangrove was present: Red mangrove (*Rhizophora mangle*). Of mangrove roots, the root density was calculated by determining the number of roots m^2 area by counting the number of roots in a 1m*1m square. In addition, the circumference was measured of five random mangrove roots per sampling size.

In the seagrass beds, a total of four different species of seagrass were encountered: Turtlegrass (*Thalassia testudinum),* Manatee grass (*Syringodium filiforme*), Shoal grass (*Halodule wrightii*) and the invasive species Halophila seagrass *Halophila stipulacea*. All species were included in this study as nursery habitat with the exception of *Halophila stipulacea*, since studies show lower juvenile fish abundance and diversity in *H. stipulacea* beds compared to native seagrass beds (Willette & Ambrose, 2012; Hylkema *et al.*, 2015; Viana *et al.*, 2019). For seagrass beds, seagrass shoot density per m^2 was determined by counting the number of shoots in one part of a quadrant (0.5·0.5m, divided into 4 quadrants) and dividing it by 0.0625 m2 to standardizing it to the number of seagrass shoots per $1m^2$. Besides the seagrass shoot density, the height of five random seagrass shoots was measured with a ruler around 80% of the longest shoot in the quadrant. Of those five lengths the mean lengths for that location was calculated and used in the environmental driver analysis.

Fish community composition

In all six bays, fish species community compositions was determined. In every bay, 5 locations on the shore line were selected that were accessible by car or boat (see appendix II), close to an environmental parameter sampling site. A knotless seine net (type: Delta, 30m long, 1,80m width, 0.47cm mesh size) was used to sample the fish. In total the seine net enclosed a surface area of 73.93 m^2. All fish species present were taken into the analysis. After the net was pulled ashore, all live fish were placed in a temporary holding bin (black opaque, dimensions: 1x0.5 m, oxygenated with a battery operated fish tank air pump SB-980) in order to measure the fork length of every individual. After all fish were measured, individuals that were still alive were released. Unfortunately, high mortality occurred among baitfish species. At few locations, a cast net (diameter 1.8 m) was used to catch fish that were hiding between the mangrove roots that were not accessible with the seine net. Catches from the cast net were added to the seine net catches. For both the seine net and the cast net the catch was standardized per meter squared surface are. In total, 29 locations divided among six bays were sampled with a seine net and occasionally a cast net.

Environmental sampling locations were not equivalent to the seine net locations. In order to study the environmental factors that determine the fish species composition in the bays the closest possible environmental sampling location was chosen. When multiple environmental locations were available, habitats were compared. The habitat resembling the seine net locations the most closely. Distances between the seine net locations and the environmental sampling locations ranged from 2 to 380 meters, see appendix IV.

On the reef, a non-destructive fish survey (diving) was possible due to higher visibility than in the bays. Surveys were only conducted on the south side of the island, since ocean currents did not allow diving activities on the north A visual census of the reef community composition was conducted on coral reefs on both sides of the sampled the bay on three different depths; 5, 10 and 15 meters and were 30m long. While visual techniques are prone to observer biased, with regular training it can be used quickly and provide a reliable and effective means of determining abundance and diversity. In addition, surveys were conducted by two researches swimming side by side and comparing the results after the survey was conducted. The combinations of depth and side of the reef were surveyed, resulting in twelve surveys per reef connected to a respective bay. In order to get more robust results for every transect, five target species were chosen and counted at 2.5 meters of either side of the physical transect line. visual census was focused on only 5 target species: French grunt (*Haemulon flavoluneatum*), Schoolmaster snapper (*Lutjanus apodus*), Mangrove snapper (*Lutjanus griseus*), Yellowtail snapper (*Lutjanus chrysurus*) and the Mutton snapper (*Lutjanus analis*). These species are nursery species that use the bays of Curaçao as nursery habitat. In addition to this important feature, they have a high economical value for the local fisheries. Per bay inlet, we had 12 replicas since all transects were taken together and used as a replication. While fish species diversity and abundance decreases with an increase in depth (Pinheiro *et al.*, 2016), they do move between depths and different seascapes in which they would have to cross at different depths (Verweij *et al.*, 2007; Hitt *et al.*, 2011).

Observations on the reef were only made for Fuikbaai, Piscadera and Santa Martha. This is due to unfavorable diving conditions on the north coast, which include Sint Joris and Bartolbaai. Due to COVID-19, we were unable to sample the left side of the Fuikbaai inlet and Spanish waters.

Historical data

In order to investigate the species composition of reef inhabitants and possible changes in the past 25 years, I utilized a citizen science-based dataset which is managed by the Reef Environmental Education Foundation (REEF). This program uses the roving-diver method, where trained divers volunteer to survey reefs all over the globe. During these roving surveys, divers swim freely throughout a location and record every observed fish species that can be positively identified (Schmitt *et al.*, 2002). Each recorded species is assigned into one of four abundance categories based on the number of individuals seen throughout the dive: single=1, few=2-10, many=11-100 and abundant >100. No information on fish size is collected. For this study only data that was gathered by divers categorized as expert was used. From this dataset, I used data from 1995 - 2019 to analyze changes in reef fish community. The reef database displayed the density index and sighting frequency for every present species in that respective year calculated as followed:

$$\text{Density index} = \frac{(\#\text{Single}\cdot 1)+(\#\text{Few}\cdot 2)+(\#\text{Many}\cdot 3)+(\#\text{Abundant}\cdot 4)}{\text{Total number of surveys in which species was reported}} \quad \textbf{Eq. 1}$$

$$\text{Sighting frequency} = \frac{\text{Number of surveys that the species was reported}}{\text{Total number of surveys conducted}} \quad \textbf{Eq. 2}$$

By simultaneously examining the sighting frequency and density index, data summaries can be interpreted for different species. The density index and sighting frequency scores can also be multiplied to provide a measure of species abundance which includes zero value observations:

$$\text{Weighted abundance} = \text{sighting frequency} \cdot \text{density index} \quad \textbf{Eq. 3}$$

Data and Statistical analysis

Data processing and statistical analysis were done in R (version 4.0.0 (Kindt & Coe, 2005; Dag *et al.*, 2018; Fox & Weisberg, 2019; Oksanen *et al.*, 2019; R Core Team, 2019; Ogle *et al.*, 2020)) within R-studio (version 1.3.959, (RStudio Team, 2020)).

Species abundance and diversity

To understand the current conditions of fish species community composition in all locations where seine netting took place multiple indices for species diversity and abundance were calculated. In addition, the following diversity indices were calculated manually: Simpson’s index (D), Simpson’s index of diversity, Simpson’s reciprocal index, Simpson’s evenness (ED), Shannon index (H), max species diversity in Shannon’s index (Hmax) and Shannon evenness (EH). They were calculated as followed:

$$\text{Simpson's index (D)} = \sum P_i^2 \quad \textbf{Eq. 4}$$

$$\text{Simpson's index of diversity} = 1 - D \quad \textbf{Eq. 5}$$

$$\text{Simpson's reciprocal index} = 1/D \quad \textbf{Eq. 6}$$

$$\text{Simpson's evenness } (E_D) = \frac{1/D}{S} \quad \textbf{Eq. 7}$$

$$\text{Shannon index } (H) = -\sum P_i \cdot \ln(P_i) \quad \textbf{Eq. 8}$$

$$\text{Shannon index } (H_{max}) = \ln(S) \quad \textbf{Eq. 9}$$

$$\text{Shannon evenness } (E_H) = H/H_{max} \quad \textbf{Eq. 10}$$

Where *Pi* is the proportion of the total number of individuals in the location represented by species *i*, also known as the relative abundance and *S* is the species richness, the total number of species for a location.

Diversity indices are mathematical measures of species diversity in a given community. Both the Shannon and the Simpson index give different information about the community. The Shannon index assumes all species are represented in a sample and that they are randomly sampled. The Simpson's index gives the probability that two individuals randomly selected from a sample will belong to the same species, and gives more weight to common or dominant species. Thus, rare species with only a few representatives will not affect the diversity. This value ranges from 0 to 1, where 1 gives the absence of diversity and 0 indicates that both species richness and evenness among abundance increases. It can also be used as a measure for dominants in a community. Simpson’s index of diversity represents the probability that two individuals randomly selected from a sample will belong to a different species, and thus is the reverse of the Simpson's index. Simpson's reciprocal index quantifies biodiversity by taking into account species richness and evenness. The lowest possible value for this index is 1, representing a community containing only 1 species. The higher the value, the greater the species diversity. The maximum value of the reciprocal index is the number of species in the community, the species richness (S). Simpson's evenness ranges from 0 to 1 and represents how even species are divided in a community. For this index, a value of 1 represents complete evenness in the community (Mittelbach & McGill, 2019).

The Shannon index ranges from 0 to a maximum value, which occurs when all species are present in equal numbers (H_{max}). If Shannon index has a value of 0, it indicates that there is an absence of diversity within the community. For the Shannon evenness also gives an index of evenness of the species community, same as the Simpson's evenness index.

In addition, individual bays and reefs were compared to each other by using a one-way analysis of variance test (ANOVA) test (Dag *et al.*, 2018; R Core Team, 2019; Ogle *et al.*, 2020), Normal distribution of the models residuals was tested by performing a Shapiro-Wilk Normality test and homogeneity of variance was checked by Levene's test for homogeneity of variance across groups. In the bays for both all the species present as for the focus species all these diversity indices are calculated and compared. For the focus species the bays and their respective connected reefs are also compared to each other.

Environmental drivers of species community composition

Species communities are driven by their environment. In order to determine which environmental factors measured are driving the fish species community for both all species present and the focus species in the bays, a canonical correspondence analysis (CCA) was used (Oksanen *et al.*, 2019). The CCA visualizes and describes the relationships between the fish species and measured environmental variables (Lara & González, 1998). While, simple principle components analysis (PCA) or principle coordinates analysis (PCoA) show the ecological distances between species within the community composition, it does not utilize environmental variables to guide the ordination. The CCA is a multivariate technique that aids in unraveling how multiple species respond simultaneously to environmental data. It is designed to extract environmental gradients from matching ecological data. The gradients are used as a basis for describing the species differential habitat preference via ordinations diagrams (ter Braak & Verdonschot, 1995). The proportion of species data variation attributable to environmental factors is expressed in the eigenvalues (Lara & González, 1998). The full model of the CCA contained all environmental variables measured. Via model selection using permutation tests, a final model was chosen with the environmental factors that turned out to be significant determinants for fish species abundance.

Historical changes in species community reef

Before determining whether changes in species community on the reefs of Curaçao occurred in the last 25 years, the dataset was filtered for rare species and years with limited number of fish observations. To decrease the impact of rare species of misidentifications, all species that occurred only once in the 25 years of available data were removed from the dataset prior to analysis. a species was categorized as rare, when it was only registered once in all 25 years. In addition, the years with less than 10% of fish species observations (a total of 36 fish species) were not removed prior to the analysis as well. After filtering for rare species and years with too few observations, there remaining number of species is 305 different species recorded in total 21 years. In that time a total of 2183 surveys were conducted, see appendix V for the number of surveys per year. After implementation of these adjustments, the dataset was transformed so the ecological distances between years could be calculated (Kindt & Coe, 2005), using the Hellinger method. With the ecological distances and principle component analysis (PCA) (Kindt & Coe, 2005; Oksanen *et al.*, 2019) can be performed to show graphically the ecological distances. The eigenvalues show how much variance is found in each of the principle components.

To test whether the species community composition has changed the individual years were grouped into 5 year periods: 1995-1999, 2000-2004, 2005-2009, 2010-2014, and 2015-2019. A Permutational Multivariate Analysis of Variance (PERMANOVA) test was then used to test whether the centroids and dispersion of the groups as defined by the measured space are equivalent for all the groups (Oksanen *et al.*, 2019). If this is true, any observed differences among the centroids in a given set of data will be similar in size to what would be obtained under random allocation of individual sample units to the groups. In this case there were no differences in the composition and/ or relative abundance of organisms of different species (variables) in samples from different groups or treatments. A rejection of this hypothesis indicates that either the centroid and/or the spread of the object is different between the groups. A dispersion tests the differences in location, whether composition among groups is similar or dissimilar (Oksanen *et al.*, 2019). The centroid of two groups at a very similar position in the ordination space, can have a different dispersion. Thus, no difference between two test groups is detected, there are differences in species composition within the groups present.

Besides performing the analysis on all the species that are present at least twice in the last 25 years, the top 25 percent of the most abundant species, 76 species, is also tested on differences between (PERMANOVA) and within (dispersion) years. The most abundant species were chosen by summing the weighted abundance from all the 25 years and the first 76 species that had the highest abundance throughout the years were chosen.

Results

Species abundance and diversity

In total 54, different fish species were found in the bays of Curaçao. . Twelve of these species were considered nursery species as defined by Nagelkerken *et al.*, (2000). However, not all species could be identified at a species level. Not all diversity indices will be presented here, a complete overview for every category is given in appendix III.

Species abundance of all species present in the bays indicate there is a difference between Fuikbaai and Santa Martha (ANOVA, p-value 0.034) (Fig. 2c), where Santa Martha has a lower species abundance than Fuikbaai. The other bays show no difference in species abundance. For the focus species in the bays, there is a difference between the Bartolbaai and Santa Martha (Welch's test, p-value = 0.012) (Fig. 2a). While both bays do not have a lot of variation in the measured abundance, Bartolbaai has a species abundance that is almost equal to 0. Santa Martha has a higher measured abundance. Considering the focus species on the reef, no differences in species abundance are present (Fig. 2b). However, comparing the bays with their respective connected reef, there is a significant difference present for Fuikbaai (Tuckey test, p-value= 0.010) and Santa Martha (Tuckey test, p-value= 0.042) (Fig. 2a and b).

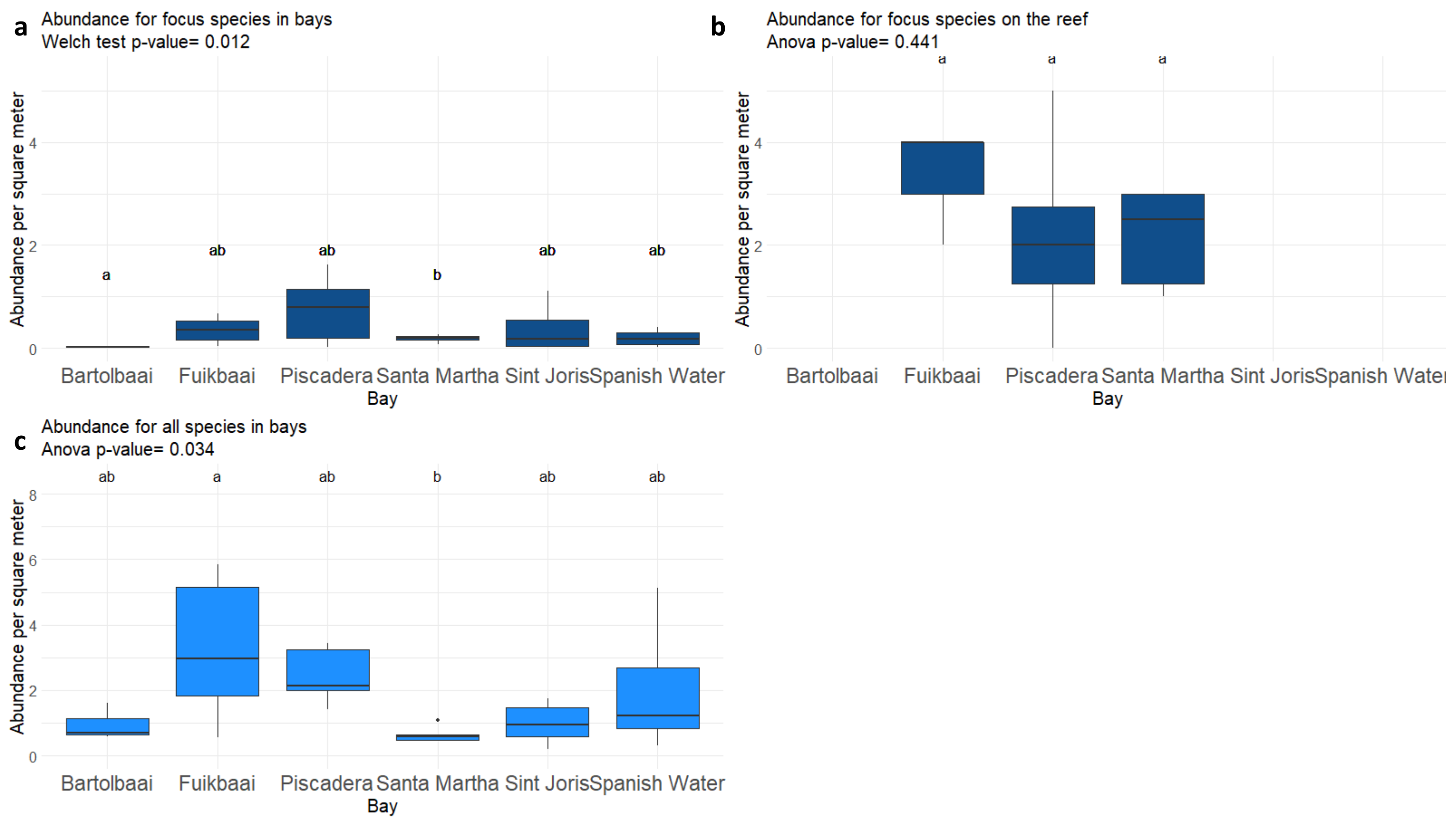

Figure 2. Total abundance per square meter for the in the bays and on the reef. a) All species present in the bays, b) focus species in the bays and c) focus species on the reef. Significance is indicated with letters.

Considering all species present in the bays, there are no differences between the bays for all diversity indices, with the exception of Simpson's evenness. For this diversity measure, Piscadera and Santa Martha are significantly different (ANOVA, p-value = 0.035). Where Piscadera has almost no evenness in their species abundances and Santa Martha has more evenness in their proportional abundances. This indicates that there are more dominant species present is Piscadera than in Santa Martha.

For the focus species in the bays, all diversity indices show a significant difference between bays, Table 1, with the exception of Simpson's evenness. Species richness, Simpson's index, Simpson's diversity, Simpson's reciprocal, Shannon index and Shannon max show a differences between Bartolbaai and Santa Martha. Bartolbaai has a lower species richness, which is also represented in the Shannon max. Both the Simpson's index and the Shannon index indicate that the there is an absence of diversity in Bartolbaai, but in Santa Martha there is a level of community diversity present. For Simpson's index, Simpson's diversity, Simpson's reciprocal, Shannon index and Shannon max there is also a difference between Piscadera and Santa Martha. The indices for Simpson and Shannon present that there is less diversity in species than in Santa Martha.

All differences in diversity indices present for the focus species in the bays disappear on the reef. None of the diversity indices tested indicate a differences between the different parts of the reefs.

Table 1. Species rank of all species present. Proportional abundance per bay is shown with standard error. Species marked in black cells are the focus species.

Rank	English name	*Species name*	Bartolbaai	Fuikbaai	Piscadera	Sint Joris	Santa Martha	Spanish Water
1	Reef Silverside	*Hypoatherina harringtonensis*	0.203 ±0.203	0.005 ±0.005	0.922 ±0.566	0	0.014 ±0.014	1.042 ±0.485
2	Mojarra	*Gerres cineus*	0.487 ±0.338	0.618 ±0.276	0.076 ±0.027	0.314 ±0.121	0.084 ±0.005	0.195 ±0.088
3	French grunt	*Haemulon flavolineatum*	0	0.198 ±0.094	0.714 ±0.295	0.28 ±0.183	0.049 ±0.03	0.138 ±0.075
4	Pilchard	*Sardina pilchardus*	0.036 ±0.036	0.839 ±0.532	0.043 ±0.032	0.023 ±0.023	0	0.252 ±0.252
5	Dwarf herring	*Jenkinsia lamprotaenia*	0	0.614 ±0.378	0	0.011 ±0.011	0.024 ±0.016	0.003 ±0.003
6	Bluestriped grunt	*Haemulon sciurus*	0	0.192 ±0.113	0.254 ±0.103	0.014 ±0.014	0	0.124 ±0.061
7	Parrotfish	*Scaridae sp.*	0.108 ±0.055	0.311 ±0.147	0	0.032 ±0.019	0.022 ±0.009	0.084 ±0.084
8	Bermuda Anchovy	*Anchoa choerostoma*	0	0.216 ±0.184	0.005 ±0.005	0.074 ±0.030	0.197 ±0.174	0.014 ±0.014
9	Sea bream	*Archosargus rhomboidalis*	0	0	0.214 ±0.140	0	0	0.041 ±0.015
10	Schoolmaster snapper	*Lutjanus apodus*	0.018 ±0.012	0.073 ±0.070	0.027 ±0.014	0.025 ±0.022	0.057 ±0.012	0.011 ±0.008
11	Crested goby	*Lophogobius cyprinoides*	0	0.008 ±0.005	0.027 ±0.011	0.025 ±0.017	0.051 ±0.032	0.051 ±0.027
12	Four-eye butterflyfish	*Chaetodon capistratus*	0	0.032 ±0.032	0.027 ±0.011	0.045 ±0.030	0.019 ±0.012	0.003 ±0.003
13	Yellowtail snapper	*Ocyurus chrysurus*	0	0.003 ±0.003	0.008 ±0.008	0.036 ±0.016	0.057 ±0.013	0.008 ±0.008
14	Barracuda	*Sphyraena barracuda*	0	0.043 ±0.017	0.016 ±0.008	0.018 ±0.008	0.005 ±0.005	0.011 ±0.005
15	Striped grunt	*Haemulon striatum*	0	0.014 ±0.01	0.051 ±0.027	0.002 ±0.002	0	0
16	Beaugregory	*Stegastes leucostictus*	0	0.061 ±0.037	0	0	0	0
17	Sergeant major	*Abudefduf saxatilis*	0.050 ±0.050	0	0	0	0	0
18	Mahogany snapper	*Lutjanus mahogoni*	0	0.008 ±0.008	0.022 ±0.018	0	0.014 ±0.007	0

19	Mutton snapper	*Lutjanus analis*	0.005 ±0.005	0.003 ±0.003	0.003 ±0.003	0.009 ±0.005	0.019 ±0.010	0
20	Bonefish	*Albula vulpes*	0	0	0	0.025 ±0.016	0	0.008 ±0.008
21	Ballyhoo	*Hemiramphus brasiliensis*	0	0	0.005 ±0.005	0 ±0	0	0.019 ±0.019
22	Doctorfish	*Acanthurus chirurgus*	0.018 ±0.018	0	0	0 ±0	0	0.005 ±0.005
23	Sailor's choice	*Haemulon parra*	0	0	0.022 ±0.013	0 ±0	0	0
24	Needlefish	*Belonidae sp.*	0	0	0	0.020 ±0.020	0	0
25	Bandtail puffer	*Sphoeroides spengleri*	0.005 ±0.005	0.008 ±0.008	0	0.005 ±0.005	0	0
26	Seagrass filefish	*Acreichthys tomentosus*	0	0.011 ±0.011	0	0.005 ±0.003	0	0
27	Scad	*Decapterus punctatus*	0	0.003 ±0.003	0	0.009 ±0.009	0	0
28	Hairy blenny complex	*Labrisomus nuchipinnis*	0.009 ±0.005	0	0	0.002 ±0.002	0	0
29	Longsnout seahorse	*Hippocampus reidi*	0	0	0	0	0	0.011 ±0.005
30	Pipefish	*Cosmocampus albirostris*	0	0	0.005 ±0.005	0	0	0.005 ±0.005
31	Slippery dick	*Halichoeres bivittatus*	0.005 ±0.005	0.003 ±0.003	0	0	0	0
32	Smooth trunkfish	*Lactophrys triqueter*	0	0.003 ±0.003	0	0.002 ±0.002	0	0.003 ±0.003
33	Mangrove snapper	*Lutjanus griseus*	0	0	0	0.005 ±0.005	0.003 ±0.003	0
34	Flounder species	*?*	0	0	0	0	0.008 ±0.005	0
35	Grouper	*Epinephelus striatus*	0	0	0	0.008 ±0.008	0	0
36	Horse-eye jack	*Caranx latus*	0	0.003 ±0.003	0.003 ±0.003	0	0	0
37	Lizardfish	*Synodus intermedius*	0	0	0	0	0.003 ±0.003	0.003 ±0.003
38	Blue runner	*Caranx crysos*	0.005 ±0.005	0	0	0	0	0

39	Peacock flounder/Eyed flounder	*Bothus mancus*	0.005 ±0.005	0	0	0	0	0
40	Flying gurnard	*Dactylopterus volitans*	0.005 ±0.005	0	0	0	0	0
41	Striped butterfly fish	*Chaetodon sp.*	0.005 ±0.005	0	0	0	0	0
42	Goatfish	*Mulloidichthys martinicus*	0	0.005 ±0.005	0	0	0	0
43	Unknown eel species	*?*	0	0	0	0	0.005 ±0.005	0
44	Jawfish	*Opistognathus schrieri*	0	0	0	0	0.005 ±0.005	0
45	Hogfish	*Lachnolaimus maximus*	0	0	0	0	0	0.005 ±0.005
46	Flounder species	*?*	0	0	0.003 ±0.003	0	0	0
47	Sharpnose puffer	*Canthigaster valentini*	0	0	0	0	0.003 ±0.003	0
48	Spotted goatfish	*Pseudupeneus maculatus*	0	0	0	0	0.003 ±0.003	0
49	Flounder species	*?*	0	0	0	0	0.003 ±0.003	0
50	Lookdown	*Selene vomer*	0	0	0	0	0	0.003 ±0.003
51	Bridled goby	*Coryphopterus glaucofraenum*	0	0	0	0	0	0.003 ±0.003
52	Dragon	*Gobioides broussonnetii*	0	0	0	0	0	0.003 ±0.003
53	Buffalo trunkfish	*Lactophrys trigonus*	0	0	0	0.002 ±0.002	0	0
54	Banded butterflyfish	*Chaetodon striatus*	0	0	0	0.002 ±0.002	0	0

Environmental drivers of fish species community composition

In determining which environmental factors drive the species community composition in the sampled bays for all the species present, we found that both bay size (permutation test, p-value= 0.014) and mangrove shoot density (permutation test, p-value= 0.004) were significant determinants of bay community composition (Fig 3.). However, the variation in the data is for only 16% (cumulative eigenvalues) explained with the first two Canonical correspondence axes. A surprising feature of the ordination plot is that all the grunt species, French grunt, Bluestriped grunt, Striped grunt and the Sailors' choice, are all grouped on the left side of the origin of the first CCA. Whereas, snapper species: Schoolmaster snapper, Mahogany snapper, Mutton snapper and the Yellowtail snapper are grouped on the left side. These results show that the sampled snapper species seem to have a preference for smaller bays, while the grunt species are more spread over variety of bay sizes (Fig. 4). Indicating they overlap in their preference for bay size with the snappers, but are also partial to larger bays sizes, Sailor's choice and Bluestriped grunt.

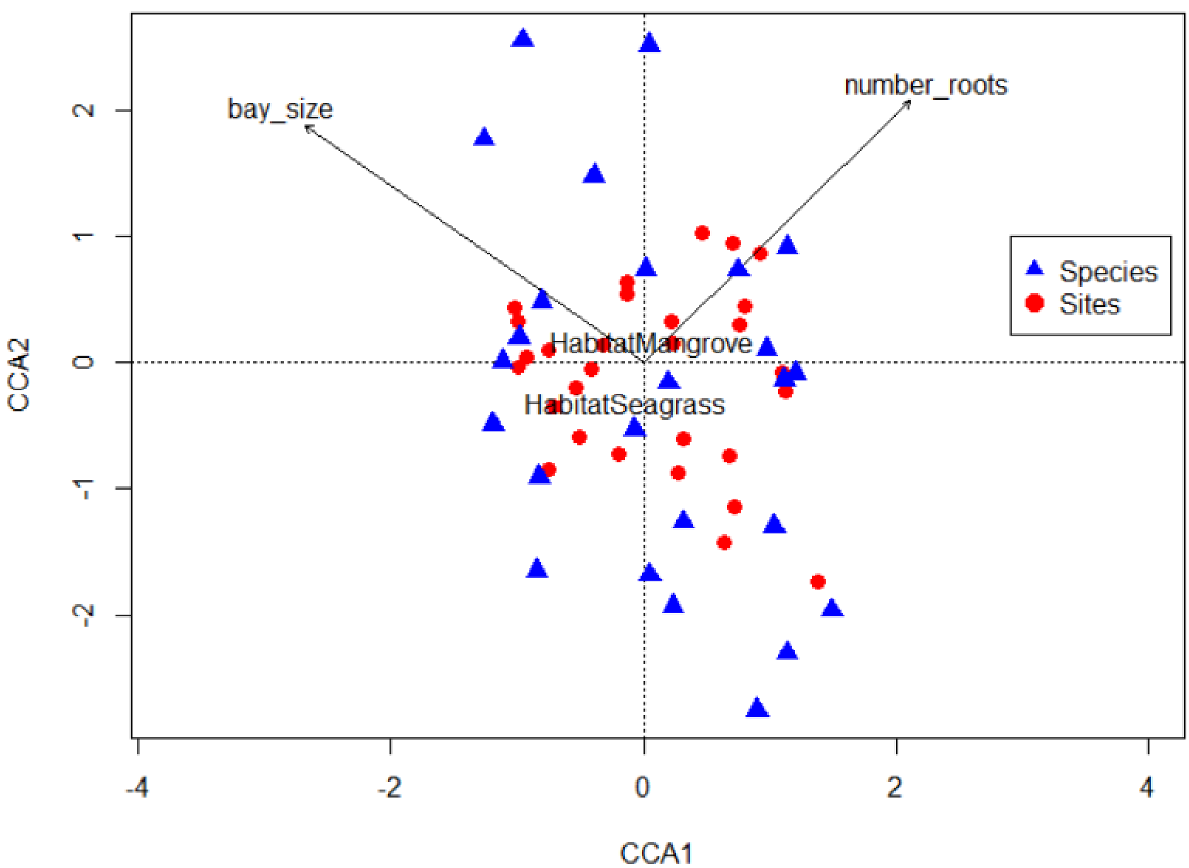

Figure 3. Ordination plot with the significant environmental determinants for the fish species community composition. Fish species (red triangle) and sites (blue solid circles) are plotted based on their ecological distance. Seagrass and mangrove habitat are shown in the ordination plot. However, since these are categorical variables, they are not determined significant for driving species community composition. Bay size and the mangrove root density are determinants and show a mirrored pattern.

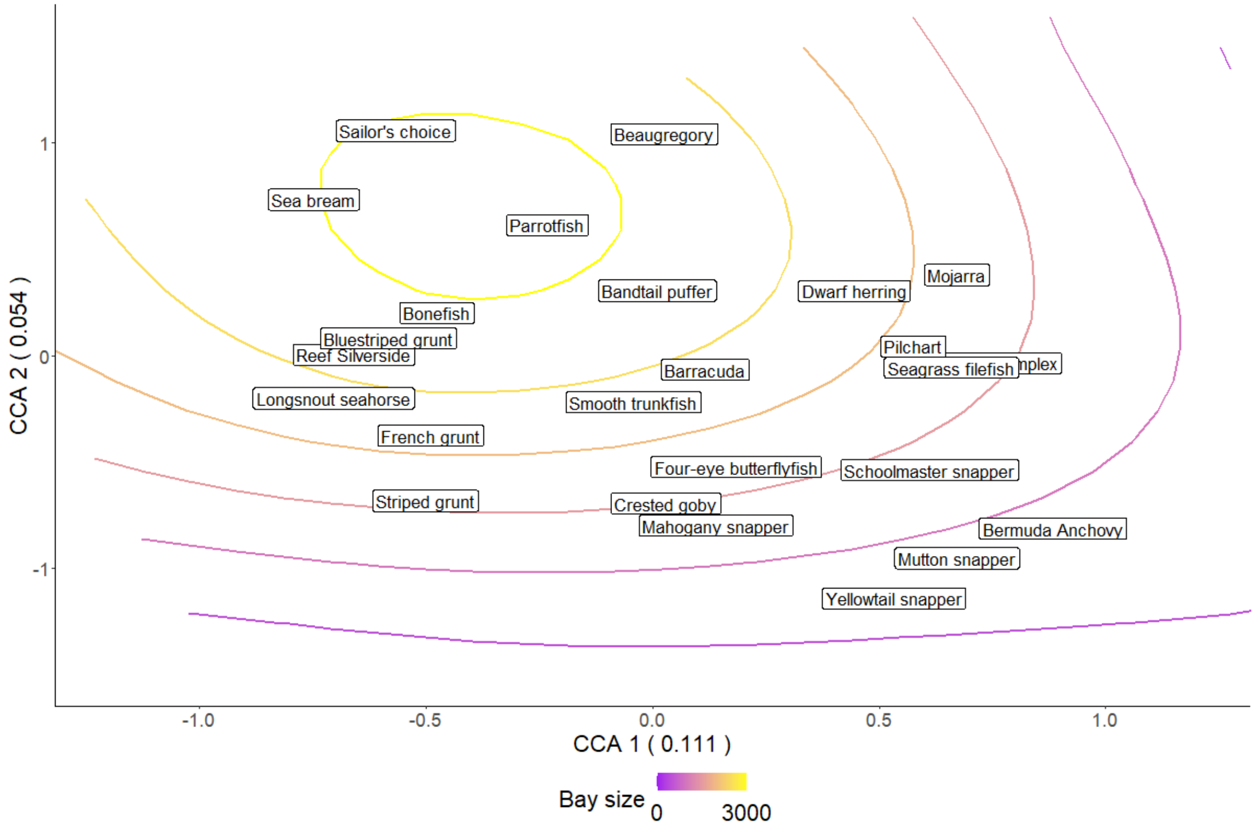

Figure 4. Ordination plot of the effect of bay size on all fish species composition. Size ranges from 0 to 3000m, with small bay size in purple to larger bays in yellow. CCA1 and CCA2 are shown, which contribute to 16 percent of the variation explained.

Mangrove root density shows a different contour pattern to bay size. In this situation it seems that both snapper and grunt species prefer similar mangrove root density, between 4 and 8 roots per m^2 (Fig. 5) The Yellow tail snapper, seems to have a preference for the least dense mangrove root aggregations, around $4m^{-2}$. In contrast, the Mojarra prefers the highest mangrove root density, of 14 roots m^{-2}.

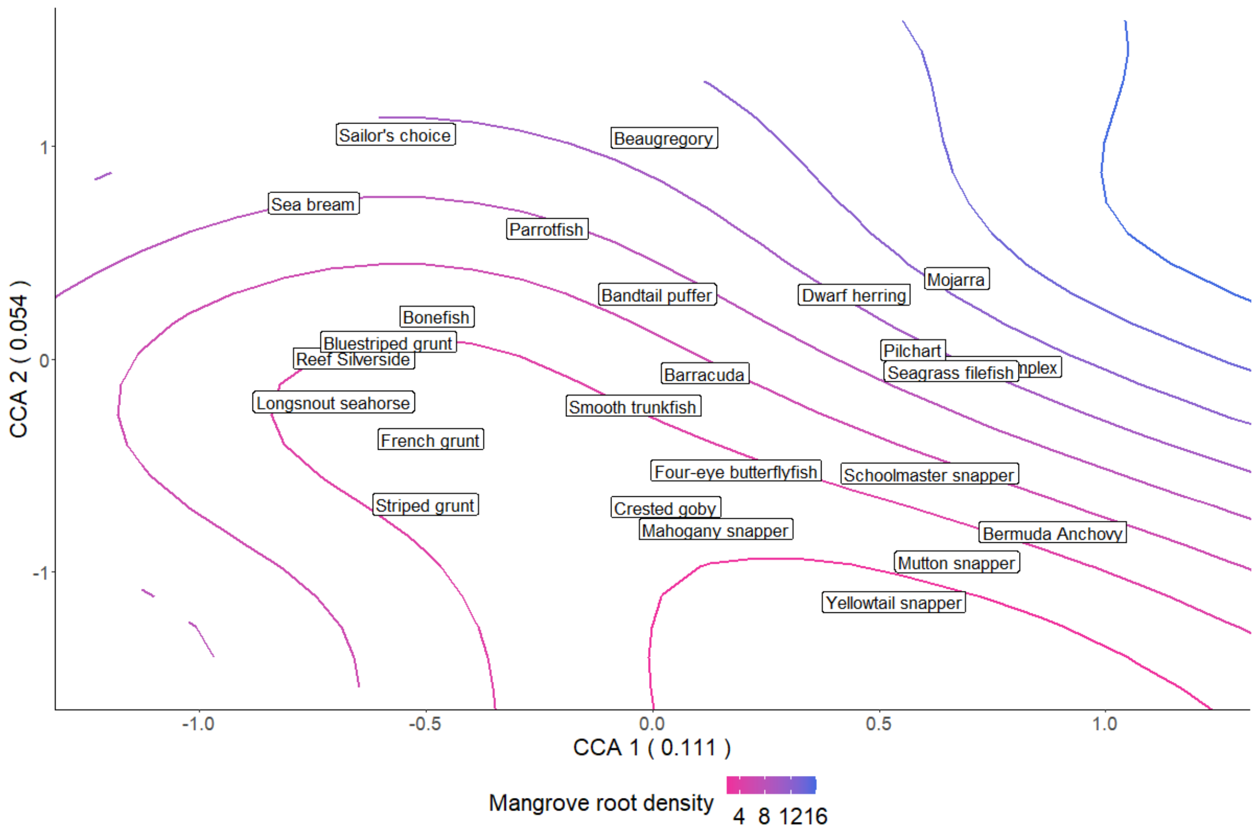

Figure 5. Ordination plot of the effect of mangrove root density on the all fish species composition. Density ranges 4 to 16 roots per meter squared. Less mangrove roots per area is shown in pink and a higher mangrove root density is shown in blue. CCA1 and CCA2 are shown, which contribute to 16 percent of the variation explained.

For the five focus species there are additional environmental drivers that determine the species composition in the bays. For these nursery species, there are three environmental factors that seem to determine the species composition. This include mangrove root density (permutation test, p-value= 0.022), seagrass shoot density (permutation test, p-value= 0.021) and water depth (permutation test, p-value= 0.011) (Fig. 6). All species, both French grunt and all the snapper species, are grouped on together on the ordination plot (Fig. 6-9). In this case, the first two CCA axes explain around 26 percent of the variation. As with the ordination plot for all the species present in the bays, the focus species do not seem to have a clear preference for mangrove root density (Fig. 7). They are all plotted on the same contours, which are around 9 roots m-2. For seagrass shoot density, the range plotted, for which the focus species seem to have a preference for, is very small (172.66-172.69) (Fig. 8). While indicating that it is a significant factor for determining the species composition, there does not seem to be a hard preference in seagrass shoot density in the first two CCA axes. The last environmental factor that drives the fish species composition is water depth. It seems that the French grunt has a preference for deeper waters than the Mutton snapper, the rest of the species fall between these ranges of 0.56 and 0.60 meters deep (Fig. 9).

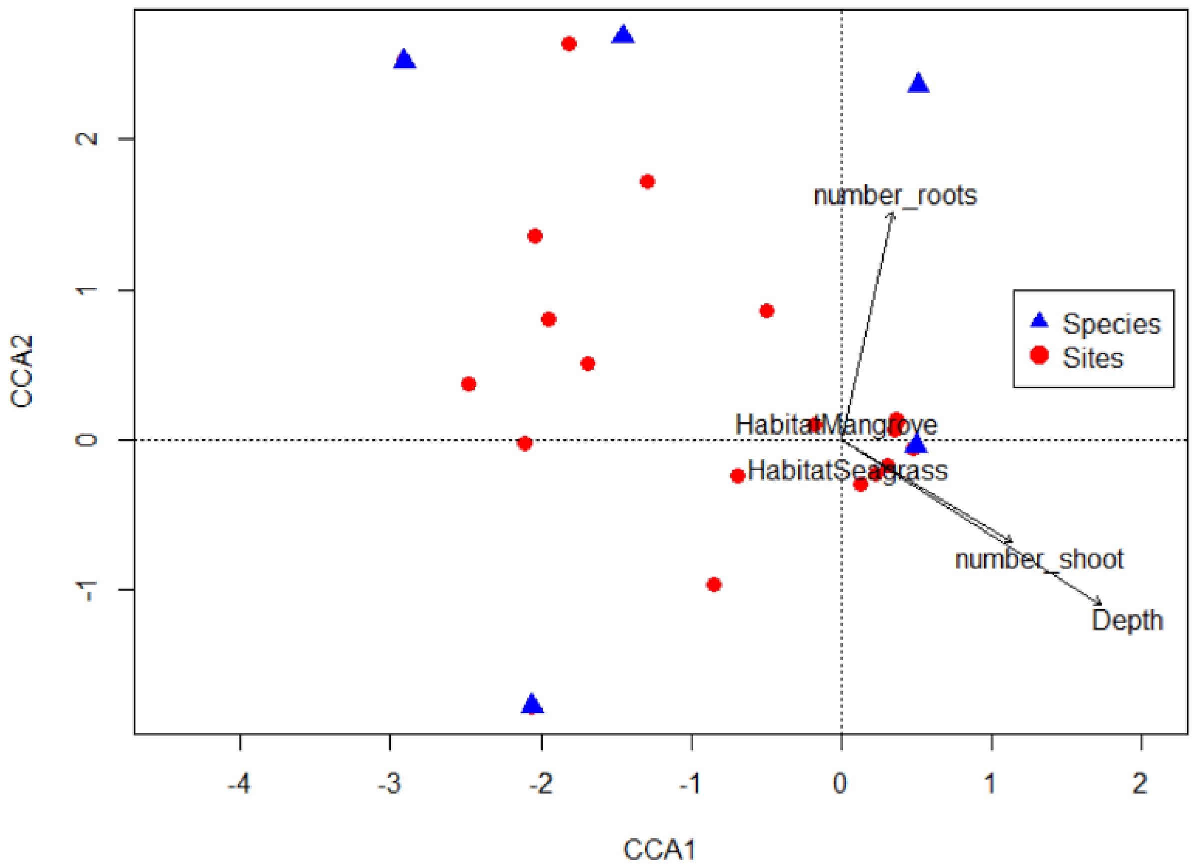

Figure 6. Ordination plot with the significant environmental determinants for the focus fish species community composition. Fish species (red triangle) and sites (blue solid circles) are plotted based on their ecological distance. Seagrass and mangrove habitat are shown in the ordination plot. However, since these are categorical variables, they are not determined significant for driving species community composition. Seagrass shoot and mangrove root density and water depth are determinants for the focus fish species community composition

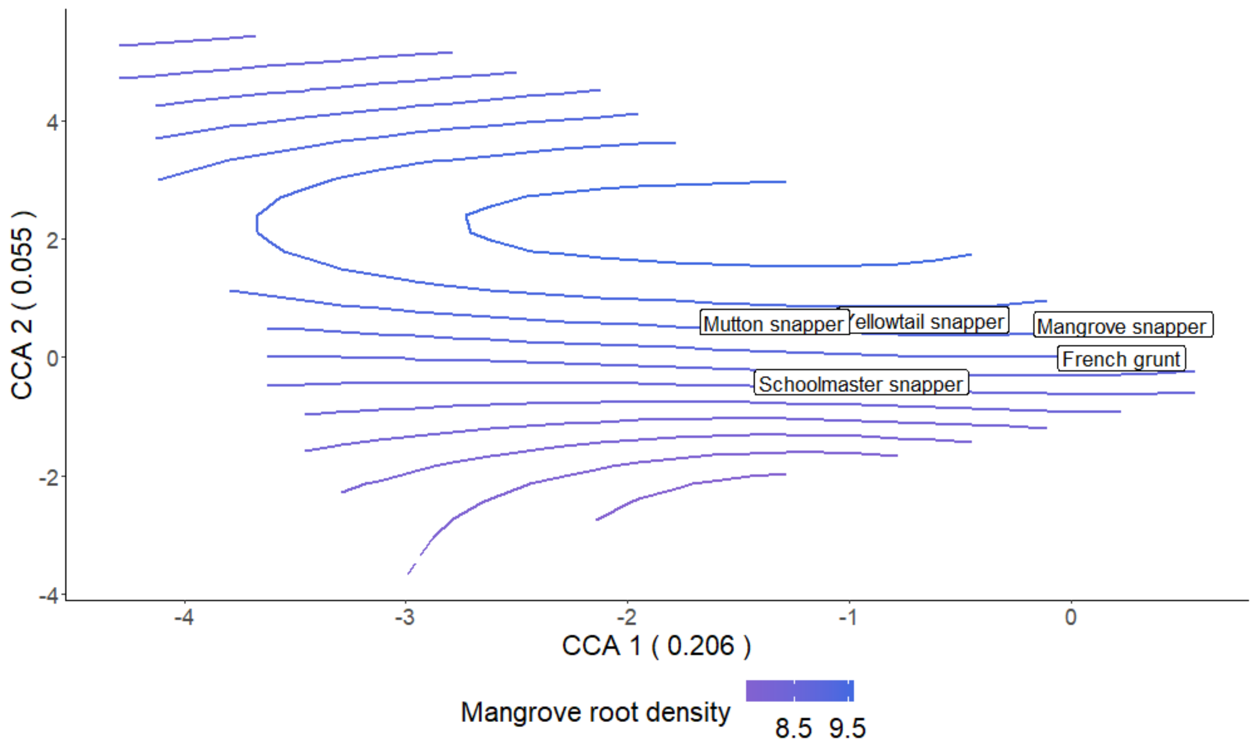

Figure 7. Ordination plot of the effect of mangrove root density on the focus fish species composition. Density ranges 7.5 to 9.5 roots per meter squared. Less mangrove roots per area is shown in purple and a higher mangrove root density is shown in blue. CCA1 and CCA2 are shown, which contribute to 26 percent of the variation explained.

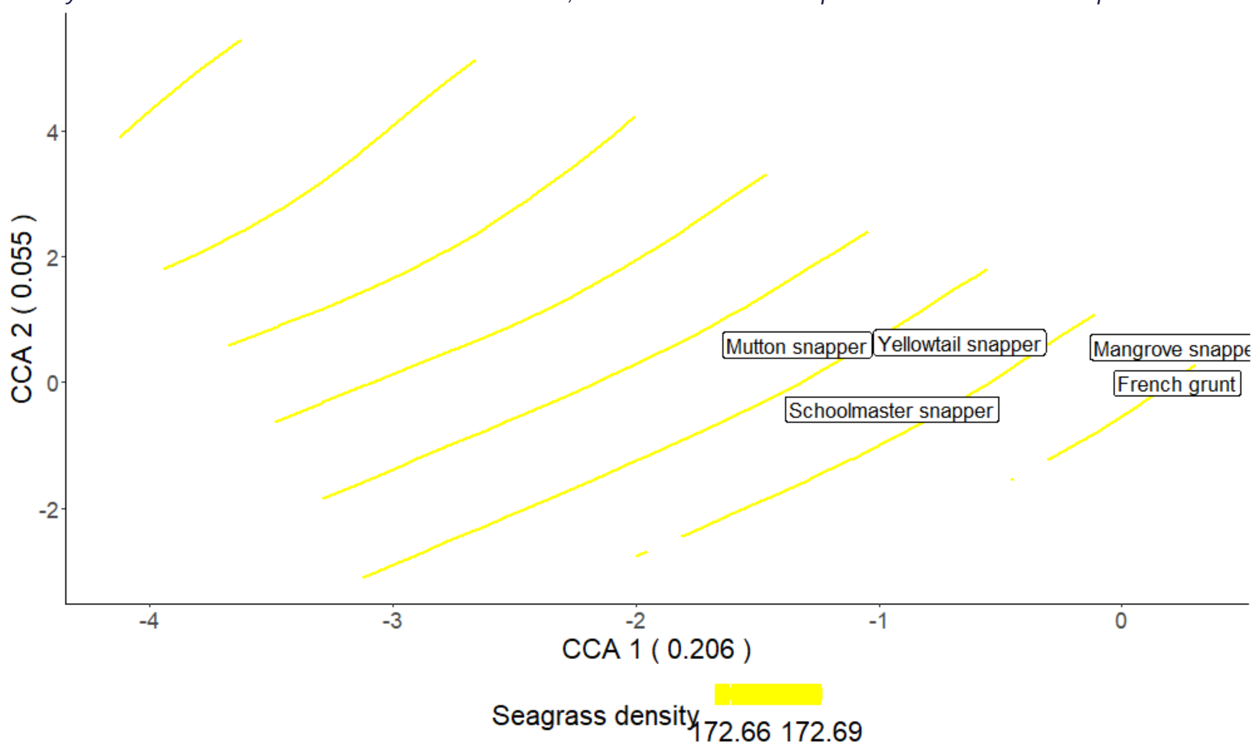

Figure 8. Ordination plot of the effect of seagrass shoot density on the focus fish species composition. Density ranges 172.66 to 172.69 shoots per meter squared. Contours are shown in yellow, since the difference between the ultimate are very low. CCA1 and CCA2 are shown, which contribute to 26 percent of the variation explained.

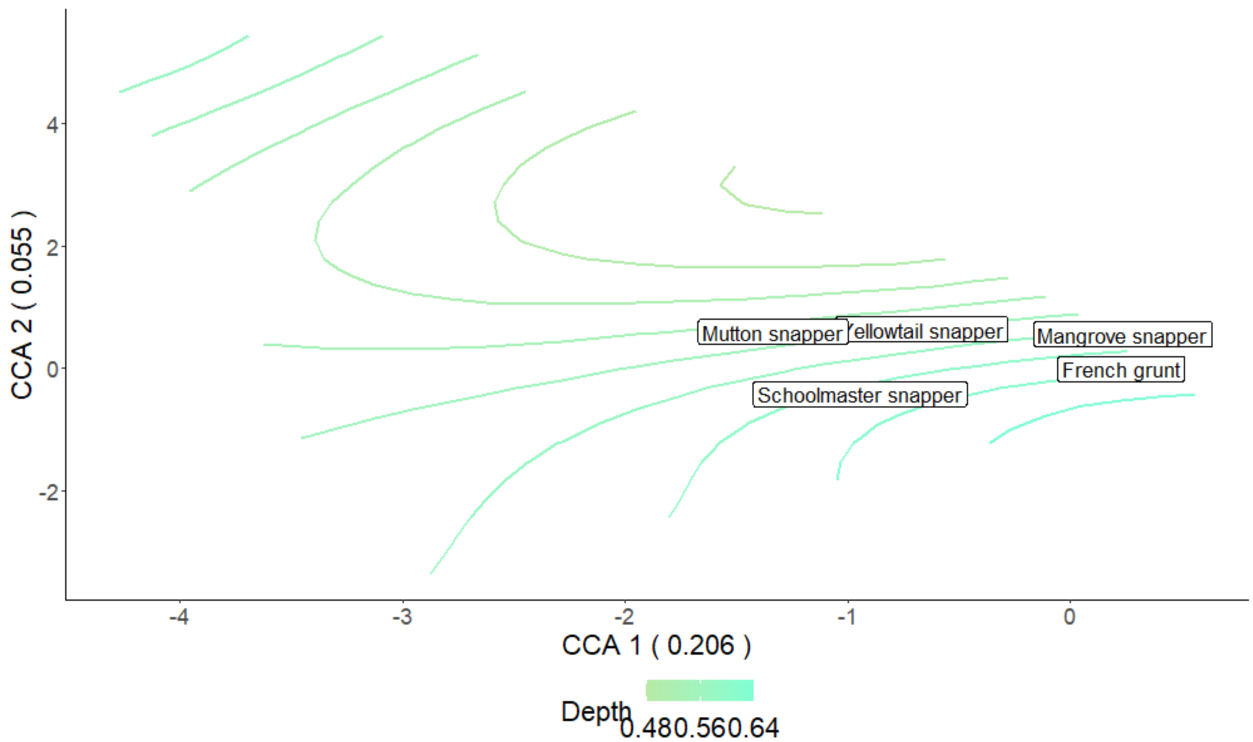

Figure 9. Ordination plot of the effect of depth on the focus fish species composition. Depth ranges 0.48 to 0.65 meters. Color bar ranges from green to turquoise blue. CCA1 and CCA2 are shown, which contribute to 26 percent of the variation explained.

Historical changes in reef fish community composition

Our redundancy analysis explained 36% of the variation within the. The reef community composition seemed similar from 1999-2015, whereas 2016-2018 have a dissimilar species composition than the aforementioned years (Fig. 10). After dividing the 25 years into 5 year periods, the community compositon indeed differed significantly among the 5-year block periods (PERMANOVA, p-value <0.001). Years 2005-2009 and 2010-2014 are grouped together, indicating a low ecological distance between these groups (Fig. 11). Years 1997 and 1999 are plotted away from the other years and the years 2015-2019 is covering the largest area on the dispersion plot. In addition, species community composition within all 5 year blocks are similar to each other.

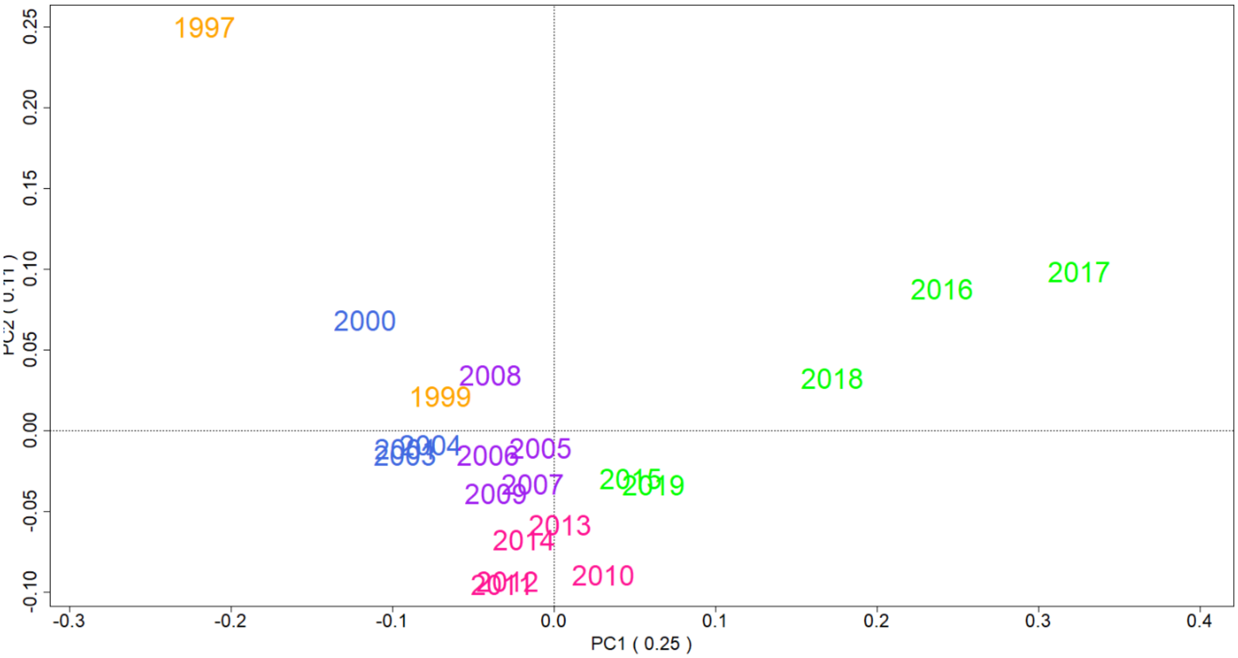

Figure 10. Ordination plot showing the ecological distance between the years. 25 years of data is split up into five groups, 1995-1999 (yellow), 2000-2004 (blue), 2005-2009 (purple), 2010-2014 (pink), and 2015-2019 (green).

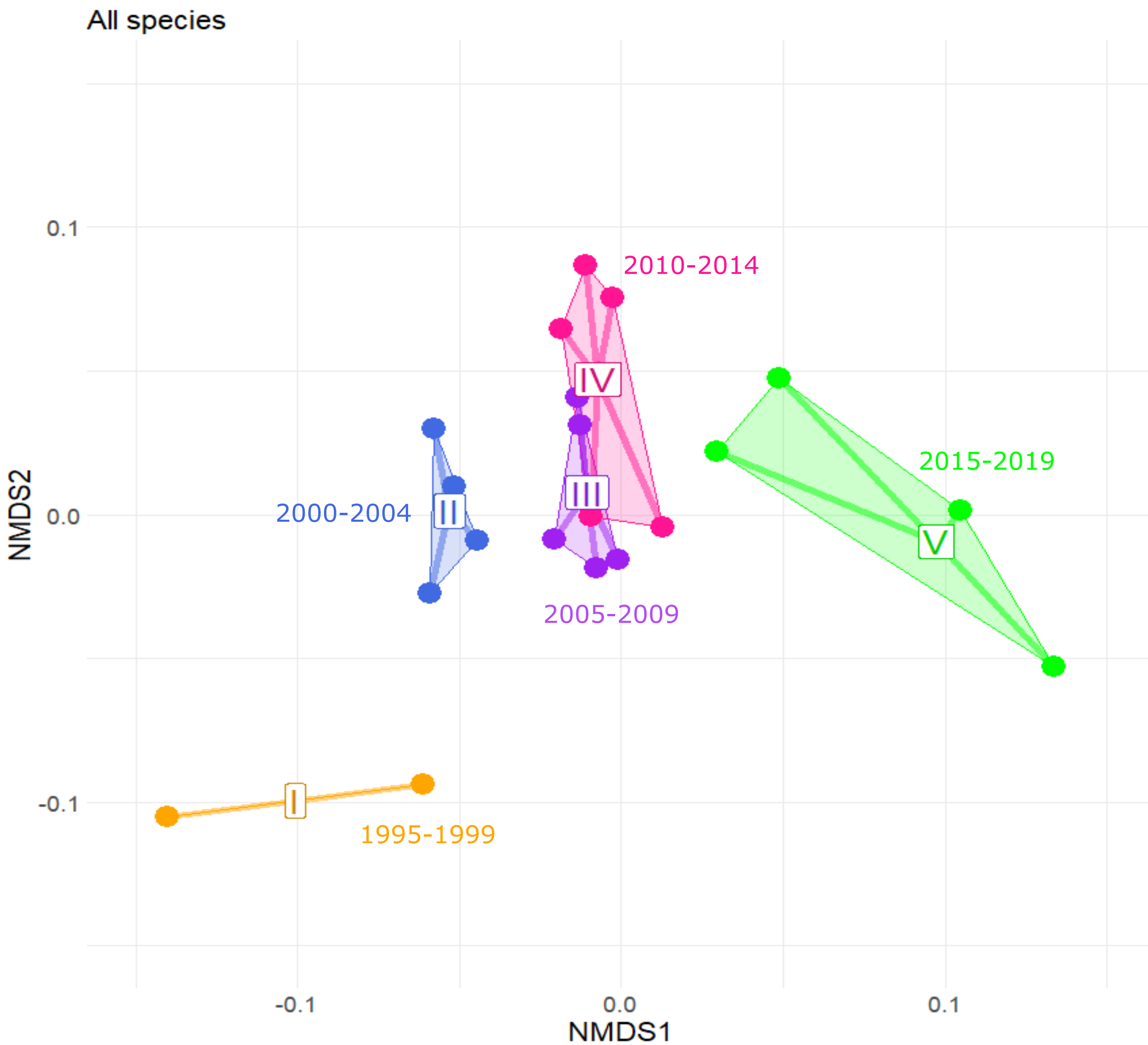

Figure 11. Dispersion plot showing the ecological distance between the 5 year groups. Group 1: 1995-1999 (yellow), group 2:2000-2004 (blue), group3: 2005-2009 (purple), group 4: 2010-2014 (pink), and group 5: 2015-2019 (green).

After selecting only the top 25% of species (appendix VI for species list and abundances), the ecological distance between the years are slightly different compared to the complete community composition. The abundant fish species community seemed still to have a similar composition in the years 199-2015 and 2019 (Fig. 12). The principle component analysis now explains 47% of the variation within the first two components. PERMANOVA results show that the 5-year groups are still significantly different from one other (PERMANOVA, p-value<0.0001). After calculating the dispersion, years 1997 and 1999 are still grouped separate from the other years (Fig. 13). However, the dispersion test shows that the species community composition within the 5 year groups are dissimilar (dispersion test, p-value=0.027).

As the dispersion plot shows, group I is still plotted away from the other groups (Fig. 11). However, in contrast to all the species observed in the history, the variation within the individual groups.

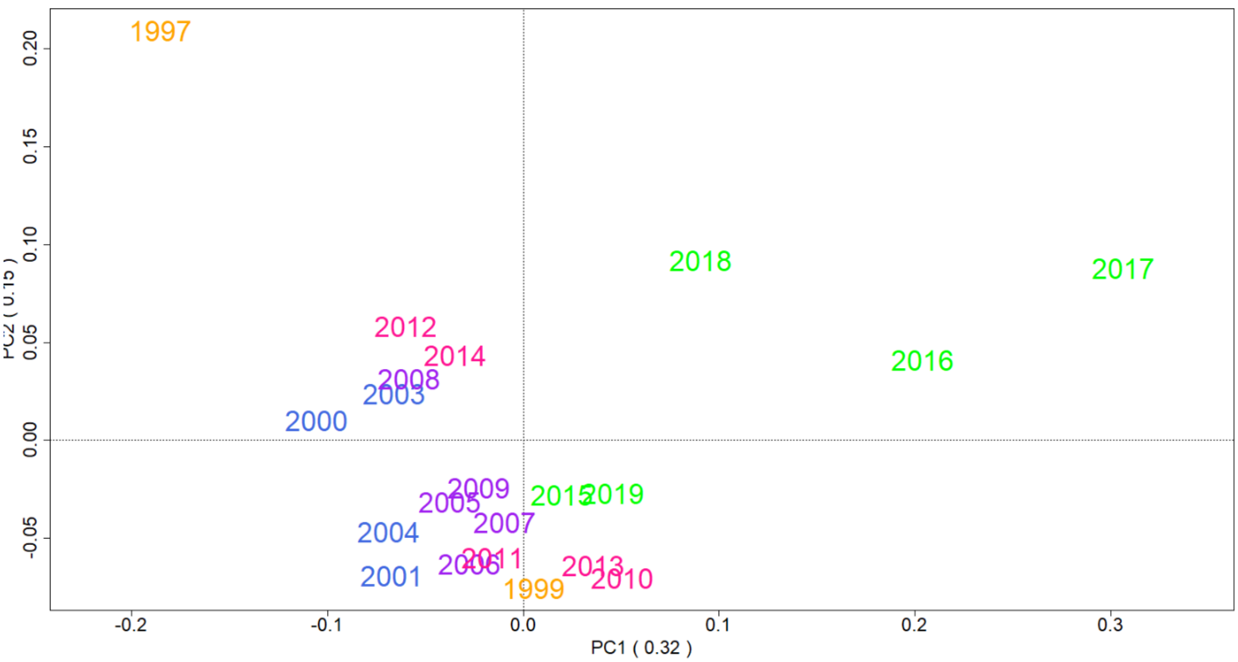

Figure 12. Ordination plot showing the ecological distance for the top 25 percent of most abundant species between the years. 25 years of data is split up into five groups, 1995-1999 (yellow), 2000-2004 (blue), 2005-2009 (purple), 2010-2014 (pink), and 2015-2019 (green)

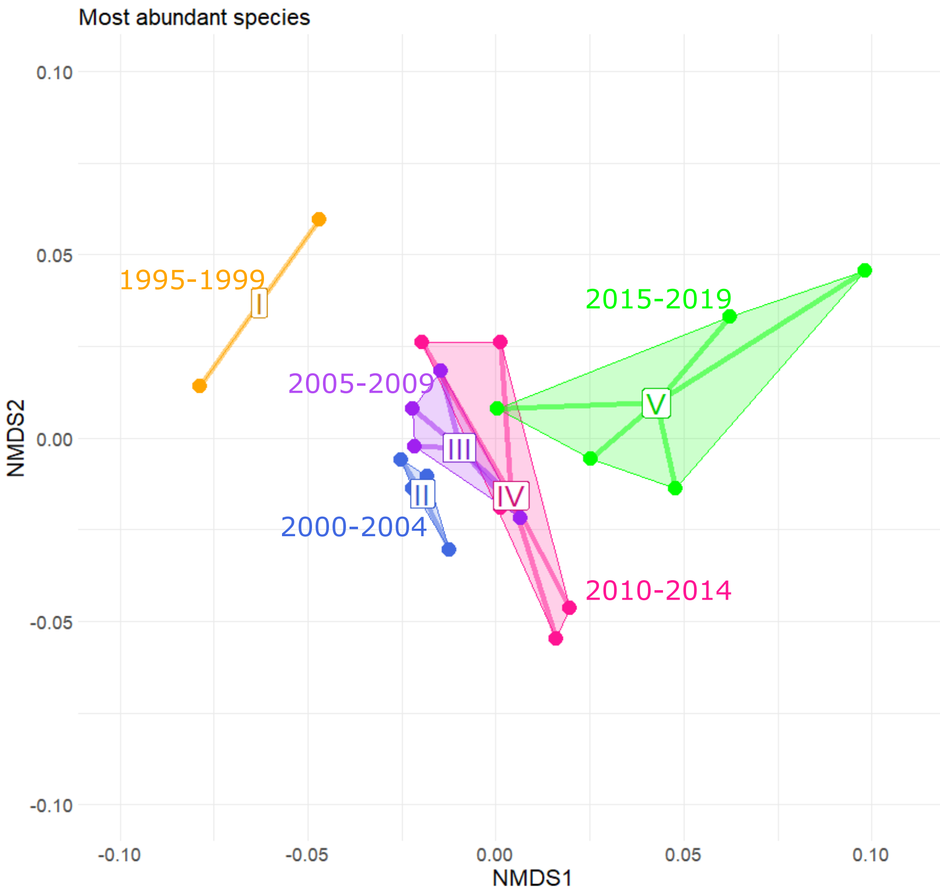

Figure 13. Dispersion plot showing the ecological distance for the top 25 percent of most abundant species between the 5 year groups. Group 1: 1995-1999 (yellow), group 2:2000-2004 (blue), group3: 2005-2009 (purple), group 4: 2010-2014 (pink), and group 5: 2015-2019 (green).

Discussion

Coral reefs are currently protected on a large scale, in order to maintain a healthy ecosystem and a high biodiversity. Unfortunately, reef inhabitants are still disappearing despite conservation efforts. For productive conservation of coral reef inhabitants, all life stage habitats of coral reef fish should be taken up into conservation policy plans (Boström *et al.*, 2011). In order to make these policy plans, Fundamental knowledge about fundamental ecological processes that play a role in nurseries and their effectiveness is needed. Ecological processes and thus quality between nursery systems can differ. This study aims to gain insight in the nursery habitats of six bays of Curaçao and their adjacent reefs. By focusing on determining the current fish species composition and abundance, with a focus of five nursery species. Second, extrapolate which environmental factors are significant determinants of the fish species community composition. Last, determine whether there has already been a shift of reef fish species in the last 25 years.

Current conditions species diversity

The current conditions for species diversity and abundance in the bays and on the reef of Curaçao show different results. Both for the focus species as for all the species present in the bays show a strong difference between bays. This could give an indication that the recruitment varies between the bays. Considering all species present, Santa Martha has relatively lower abundance than Bartolbaai. Surprisingly the abundance for the nursery species was higher in Santa Martha bay, since it is considered to have a low nursery function, due to the lack of seagrass beds and decreased mangrove forests (Nagelkerken 2000, and personal observations). Especially these features are important aspect of a nursery system. At the same time, the range of nursery species is still relatively low compared to other bays, e.g. Piscadera, Fuikbaai, Sint Joris and Spanish waters, which were considered bays with a high nursery function (Nagelkerken, 2000; Nagelkerken *et al.*, 2001b, 2002; Whitfield & Whitfield, 2017). These bays have a high surface are of mangrove forests and seagrass beds, which cause increase the nursery fish species abundance.

On the reef, the abundances of the focus species was significantly lower compared to their respective connected bay. This occurrence can have several causes. First, there has been a methodological mismatch between the results from bays and reef. In the bays, information about the focus species was gathered using seine nets and on the reef by conducting diving surveys. Connell,' *et al.*, (1998) show that underwater visual census and Catch per unit effort have a dissimilar abundance estimations.

The disadvantage of a seine net is that not all fish are caught in the targeted sampling area. Due to obstacles, e.g. rocks, fish may escape, and the net cannot go between mangrove roots. The results of the environmental drivers show that the focus species have a preference for a mangrove root density of 8-9 roots per m^2. The seine net is unable to venture between the roots, possibly creating a bias in the data, missing out on mangrove-specific fish species. On the reef all the fish that are encountered in an area are counted, removing a proportion catch bias in the data. Second, while some species have a high site fidelity, they do migrate between locations on the reef sometimes to even 200m (Verweij *et al.*, 2007). Only a small surface area of the reef outside the bay inlet is sampled, so a large part of the focus species can be evenly dispersed on the reef.

Environmental drivers driving fish species community

Our results have shown that environmental parameters such as bay size, mangrove root and seagrass shoot density determine bay fish community composition. This confirms the importance of seagrass and mangrove presence as nursery habitat for fish as they function as a refuge for predators and facilitate high food abundance (Nagelkerken *et al.*, 2000, 2002; Koenig *et al.*, 2007; Igulu *et al.*, 2014; Whitfield & Whitfield, 2017). This results in enhanced growth and survival of juvenile fishes (Verweij, 2007).

The Canonical Correspondence analysis show that seagrass shoot density is a significant determinant for nursery fish species community composition. However, the ordination plot shows a very small range of seagrass shoot density for which the nursery species seem to show a preference. The ordination plot only shows the first two CCA axes, while the seagrass shoot density could have a greater influence on the third and fourth CCA axes.

In selecting the environmental drivers of fish species community composition, there is a mismatch between the environmental factors and the fish species community. The locations that were sampled for environmental factors are not the same as the locations were fish species were sampled. In order to make a determination of which environmental factors are determining the fish species community composition, the closest locations were chosen (appendix IV). This could have resulted in that only a few environmental drivers were determined significant. Besides mangrove root and seagrass shoot density, expected was that visibility is also a determining factor (Primavera, 1997).

Additional environmental parameters were gathered at the environmental sampling sites. Nutrient levels in surface and porewater, as in seagrass and mangrove leaves will measured, but due to COVID-19 these samples are not yet analyzed. Expected is that these variables will be a significant determinant in addition to the aforementioned. Nutrient levels influence seagrass, mangrove and algae growth. Eutrophication lead to algae blooms, which overgrow seagrass shoots (Govers *et al.*, 2014).

Historical changes in reef inhabitants

Our analysis showed that the reef fish community composition has changed in the last 25 years. How the community composition has changed over the last 25 years has not been answered by this study. Studying the top 25% of the most abundant species does not reveal a possible shift that occurs within the species community between years. Probably the less abundant species are causing a change in the species community composition on the reef, but that has not been explored in this study. Taken into account all the species, there is no variation within the different year groups. However, in the top 25 percent, the species communities within the year groups are dissimilar, indicating that a shift is taking place between the years in a 5-year block. This shift is probably caused by the lower part of the list. In addition, it cannot be determined that the shift is solely caused by nursery species, i.e. parrotfish species are not changing in their abundance, but is considered to be a nursery species.

Possible causes for the change in species community composition are unknown. However, coral bleaching is one of the major factors affecting coral reef fish species communities (Munday *et al.*, 2008). The loss of corals is causing a rapid population decline in coral-dependent fish species. However, many other fish species will exhibit long-term declines due to the loss of settlement habitat and erosion of habitat structural complexity. Surprisingly, Nagelkerken *et al.*, (2005) show that while the reefs of Curaçao have degraded considerably from 1973-2003, it does not seem to have a major effect on the population size of on the graysby (*Cephalopholis cruentata*), a commercially important grouper species. However, *C. cruentata* is a coral-associated fish species, signifying that coral bleaching can have a negative effect on the changes seen in the community composition. Besides coral bleaching, degradation of nursery habitats can also cause a shift in reef fish communities. Adjacent nursery habitats have a significant effect on community structure of species that use mangrove or seagrass beds as nurseries (Nagelkerken *et al.*, 2012). E.g. proximity to nursery habitat results in 249% higher biomass than in areas with no nursery access. Even though information about habitat quality might not be available, determining the cause of changes in species community composition can be done by selecting e.g. coral-dependent or nursery fish species.

Environmental conservation

These analyses do raise some valuable answers and future questions that need to be answered in order to be constructive in conservation efforts. Mangrove root and seagrass shoot density being one of the main environmental drivers for nursery species show that conservation efforts should focus mainly on the prevention of eradication of mangrove roots for coastal construction and to keep the waters free from eutrophication and pollution to preserve seagrass beds. Since most nursery species are of economic value, conservation efforts in these habitats will have a beneficial economic effect on the local population of Curaçao.

The shift in species composition of reef inhabitants in the last 25 years shows again the importance of not only r studying only the reef as ecosystem. This study has not been able to determine what the cause of this shift is. So it raises interesting questions on the causes of this shift. The change in reef inhabitants could have happened from two directions. The first being overfishing, a top-down approach. Fisheries is an important economic sector on Curaçao and a large protein source. Or from a bottom-up direction, habitat quality of both the reef and bays is decreasing, due to e.g. climate change or pollution in bays and/or reef, resulting in a diminished recruitment of juveniles of nursery species out of the bays towards the reef, and survival of adult individuals on the reef is also declined. As it is unclear which is the potential cause of the shift, further research should be done. Historical fishery data can give information about fish landing and the potential for overfishing, and historical environmental data of the reef and bays could give further insight in habitat quality. So in order to make conservation efforts as powerful as possible, multiple habitats and their connection should be studied. Especially nursery species that prefer structural complexity can have a negative effect of habitat loss.

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Appendix I. Coordinates locations of environmental parameters

Table I-1. Coordinates of the locations were environmental parameters and biological parameters were sampled and measured. Latitude and longitude is shown in decimal degrees.

Location	Latitude	Longitude
PS001	12.1361197°	-68.9726012°
PS003	12.1316096°	-68.9708983°
PS002	12.1350199°	-68.9664245°
PS004	12.1358274°	-68.9660077°
PS005	12.1352057°	-68.9725798°
PS006	12.133884°	-68.9712802°
PS007	12.1321293°	-68.9709931°
PS008	12.1382363°	-68.972315°
PS009	12.134697°	-68.9717184°
PM001	12.136043°	-68.965831°
PM002	12.1313005°	-68.9665879°
PM003	12.1379552°	-68.9712204°
PM004	12.140967°	-68.970295°
PM005	12.134813°	-68.971702°
PM006	12.1351171°	-68.9668814°
PM007	12.1370348°	-68.9674872°
PM008	12.1357826°	-68.9647211°
PM009	12.1307103°	-68.9706082°
SJM001	12.1272527°	-68.8202981°
SJM005	12.1219898°	-68.8104424°
SJM006	12.1244047°	-68.8258412°
SJS006	12.1250299°	-68.8125177°
SJS007	12.1254087°	-68.8173784°
SJS008	12.1264499°	-68.8259177°
SJS009	12.126081°	-68.826085°
SJM008	12.1181008°	-68.8289333°
SJM009	12.12058°	-68.8222767°
SJS001	12.1204674°	-68.8232453°
SJM002	12.1154784°	-68.8229168°
SJM003	12.1150705°	-68.8199939°
SJM004	12.1148567°	-68.8082033°
SJM007	12.1126494°	-68.8084782°
SJS002	12.113602°	-68.8128199°
SJS003	12.1162575°	-68.817405°
SJS004	12.1164505°	-68.8229807°
SJS005	12.1164353°	-68.8151109°
SPWM003	12.075943°	-68.852183°
SPWM004	12.0734532°	-68.8480649°
SPWM005	12.0765316°	-68.8411681°
SPWM006	12.0766777°	-68.8602472°
SPWM007	12.0865431°	-68.8416101°
SPWM009	12.0714379°	-68.8437471°
SPWM002	12.0842144°	-68.8555884°
SPWS004	12.0847022°	-68.852752°
SPWS007	12.0768423°	-68.8603009°
SPWS008	12.0730709°	-68.8527115°

SPWS009	12.0842847°	-68.8546959°
SPWM001	12.0856159°	-68.8609915°
SPWM008	12.0829426°	-68.8678544°
SPWS001	12.0876323°	-68.8489915°
SPWS002	12.0871428°	-68.8436142°
SPWS003	12.0836482°	-68.8463502°
SPWS005	12.0802997°	-68.8576892°
SPWS006	12.0848017°	-68.8619798°
BBM001	12.3108718°	-69.0585659°
BBM002	12.3112941°	-69.0580863°
BBM003	12.3123612°	-69.0601411°
BBM004	12.3104615°	-69.0581081°
BBM005	12.3124978°	-69.0579751°
BBM006	12.3123171°	-69.0597021°
BBS001	12.3128452°	-69.0576848°
BBS002	12.3126381°	-69.0578583°
BBS003	12.3132855°	-69.0596295°
BBS004	12.3131686°	-69.0596974°
BBS005	12.3134329°	-69.0595182°
BBS006	12.3130197°	-69.0597192°
FBM001	12.0485892°	-68.8221571°
FBM002	12.0587304°	-68.8361457°
FBM003	12.047599°	-68.822315°
FBM004	12.0471198°	-68.8249474°
FBM005	12.0441671°	-68.8209149°
FBM006	12.0448317°	-68.8202401°
FBM007	12.052514°	-68.836643°
FBM008	12.056907°	-68.840553°
FBM009	12.0444544°	-68.8224464°
FBS001	12.057411°	-68.8407344°
FBS002	12.059553°	-68.8422644°
FBS003	12.0587268°	-68.8368687°
FBS004	12.0587221°	-68.841898°
FBS005	12.0586469°	-68.8357808°
FBS006	12.0582494°	-68.835043°
FBS007	12.0524028°	-68.8364126°
FBS008	12.054309°	-68.8343507°
FBS009	12.0580129°	-68.8413056°
SMM001	12.2788618°	-69.1209377°
SMM002	12.2760139°	-69.1175678°
SMM003	12.2746137°	-69.1272354°
SMM004	12.274422°	-69.122139°
SMM005	12.2762386°	-69.1208365°
SMM006	12.278171°	-69.125695°
SMM007	12.2706774°	-69.1247167°
SMM008	12.2770847°	-69.1285096°
SMM009	12.2746698°	-69.1241646°

Appendix II. Coordinates seine net locations

Table II-1. Coordinates of the locations were fish were caught with a seine net and occasionally a cast net. Latitude and longitude is shown in decimal degrees.

Location	latitude	longitude
BBNET2	12.313035°	-69.059783°
BBNET3	12.313305°	-69.059635°
BBNET4	12.315095°	-69.0574862°
FBNET1	12.0545812°	-68.8342762°
FBNET2	12.056151°	-68.8344°
FBNET3	12.055455°	-68.83992°
FBNET4	12.057157°	-68.84081°
FBNET5	12.058891°	-68.842061°
PBNET1	12.138008°	-68.970517°
PBNET2	12.137858°	-68.970829°
PBNET3	12.134785°	-68.971659°
PBNET4	12.130011°	-68.967661°
PBNET5	12.127552°	-68.971649°
SJNET1	12.127092°	-68.823842°
SJNET2	12.12785°	-68.820258°
SJNET3	12.121627°	-68.821243°
SJNET4	12.11668°	-68.826038°
SJNET5	12.114846°	-68.823903°
SJNET6	12.115792°	-68.82264°
SMNET1	12.275563°	-69.121737°
SMNET2	12.274518°	-69.124224°
SMNET3	12.273095°	-69.124834°
SMNET4	12.273032°	-69.124789°
SMNET5	12.271873°	-69.124289°
SPWNET1	12.076863°	-68.86273°
SPWNET2	12.076612°	-68.860051°
SPWNET3	12.070703°	-68.860492°
SPWNET4	12.083397°	-68.855935°
SPWNET5	12.087315°	-68.847487°

Appendix III. Species diversity results

Species richness

The range of the number of species in the bays of Curaçao is between 5 and 16 species, with an average of 9.4 species (Fig. III-1c). While there is some variation between the bays, there was no statistical difference measured in species richness. Species richness for the focus species range between 0 and 4. The average number of species is 2.11 (Fig. III-1a). In contrast to all species, there is a difference in species richness for the focus species in the bays (Kruskal-Wallis, p-value 0.047). The number of focus species present in Bartolbaai is significantly lower than for in Santa Martha. On the reef there is no difference in species richness between the respective connected reefs. The species richness ranges from 0 to 5. On average there are 2.4 number of focus species present on the reef (Fig. III-1b). There are no observed differences between the different reefs. While there is greater variation on the reef than in the bays for the focus species, we do not see a significant difference between the bays and their respective reef.

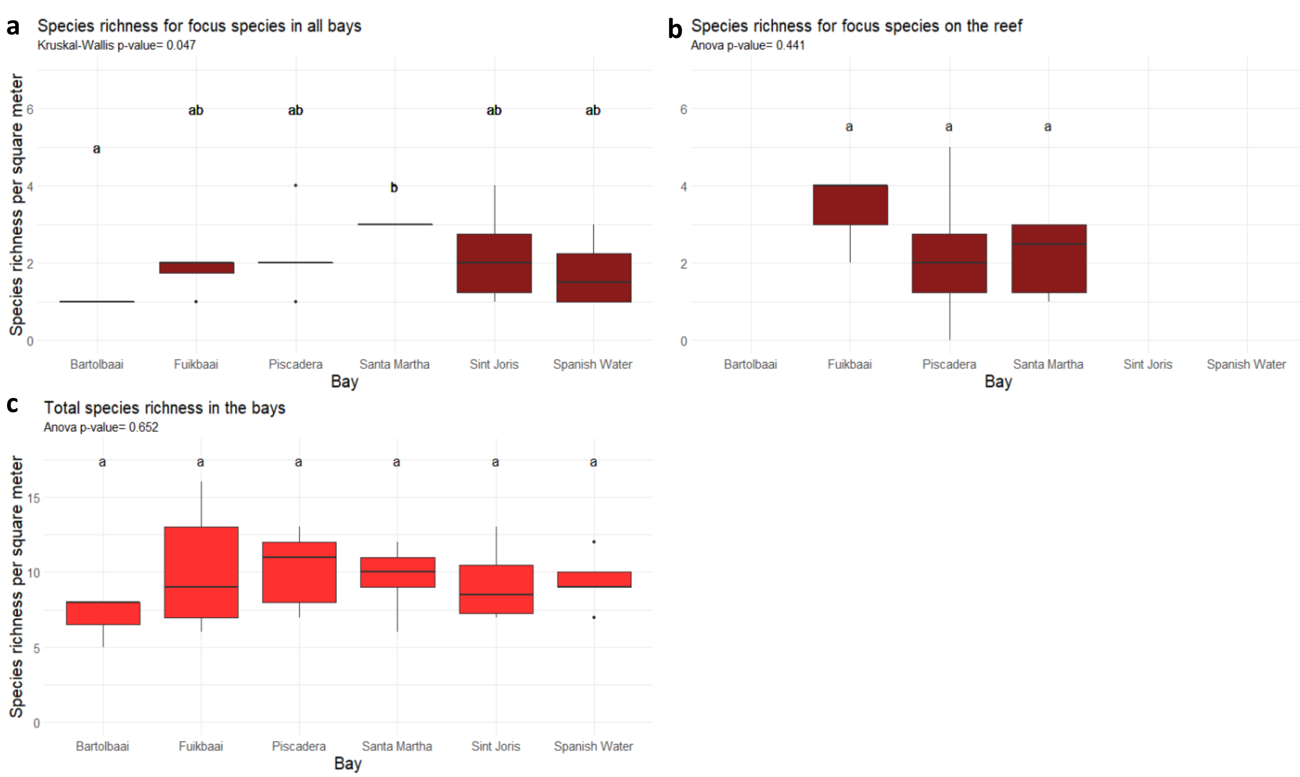


Figure III-1. Species richness per square meter for the bays and reefs. a) All species present in the bays, b) focus species in the bays and c) focus species on the reef. Significance is indicated with letters.

Simpson's index

Simpson's index values for all species in the bays ranges from 0.1065 to 0.783, average value is 0.345 (Fig. III-2c). There is variation between the bays, Santa Martha seems to have the lowest vales for Simpson's index and Bartolbaai ranges higher. However, there is no significant difference between the bays. Simpson's index for the focus species in the bays ranges from 0.333 to 1, with a mean of 0.7348 (Fig. III-2a). All bays, with the exception of Santa Martha, have in at least one location within the bay an absence of diversity for the focus species. This leads to a significant difference between Bartolbaai and Piscadera compared to Santa Martha (Welch's test, p-value= 0.003). On the reef Simpson's index is between 0.3019 and 1, with an average of 0.6097 (Fig. III-2b). There are no differences in the values between the reefs. Comparing the bays with their respective connected reef, there are also no significant differences.

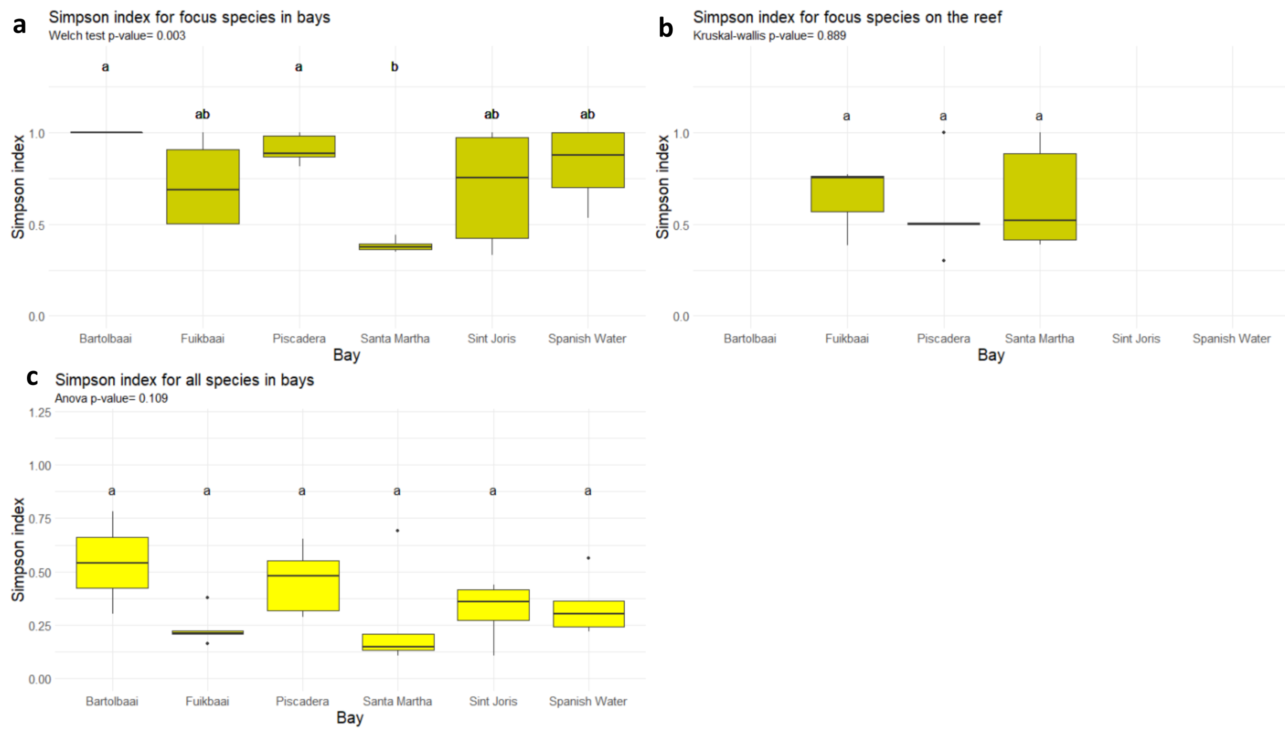


Figure III-2. Simpson's index per meter squared. a) All species present in the bays, b) focus species in the bays and c) focus species on the reef. Significance is indicated with letters.

Simpson's diversity index

Simpson diversity index for all species present in the bays ranges from 0.2168 to 0.893, on average Simpson diversity is 0.6541 (Fig. III-3c). Since it is the inverse of the Simpson's index, it is not surprising that there are no differences in Simpson's diversity between the bays. For the focus species in the bays Simpson diversity is between 0 and 0.667 (Fig. III-3a). The average value for Simpson diversity for the focus species in the bays is 0.26. There is a significant difference between Bartolbaai/Piscadera and Santa Martha (Welch's test, p-value = 0.003), Where Santa Martha has a higher value for the Simpson diversity index. On the reef the values ranges between 0 and 0.6981, with a mean of 0.39 (Fig. III-3b). Equivalent to the

Simpson's index there is no significant differences between the reefs for the focus species. Comparing the bays with their connecting reefs shows no significant differences.

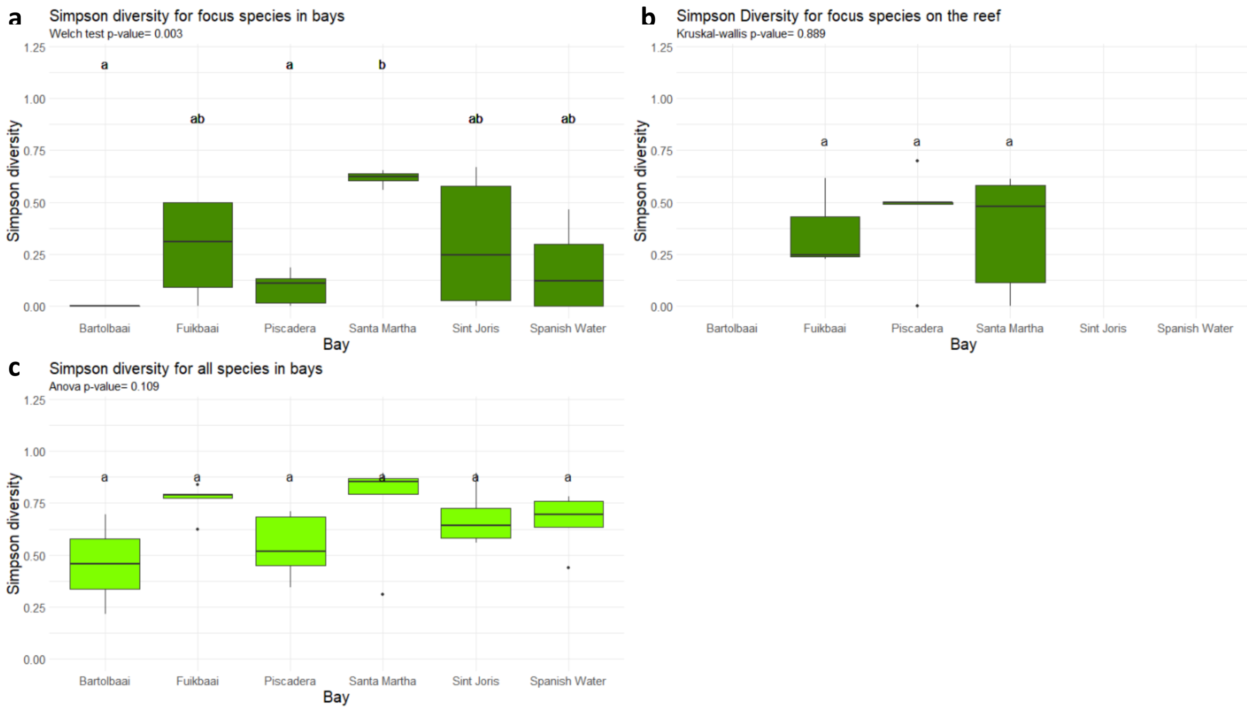
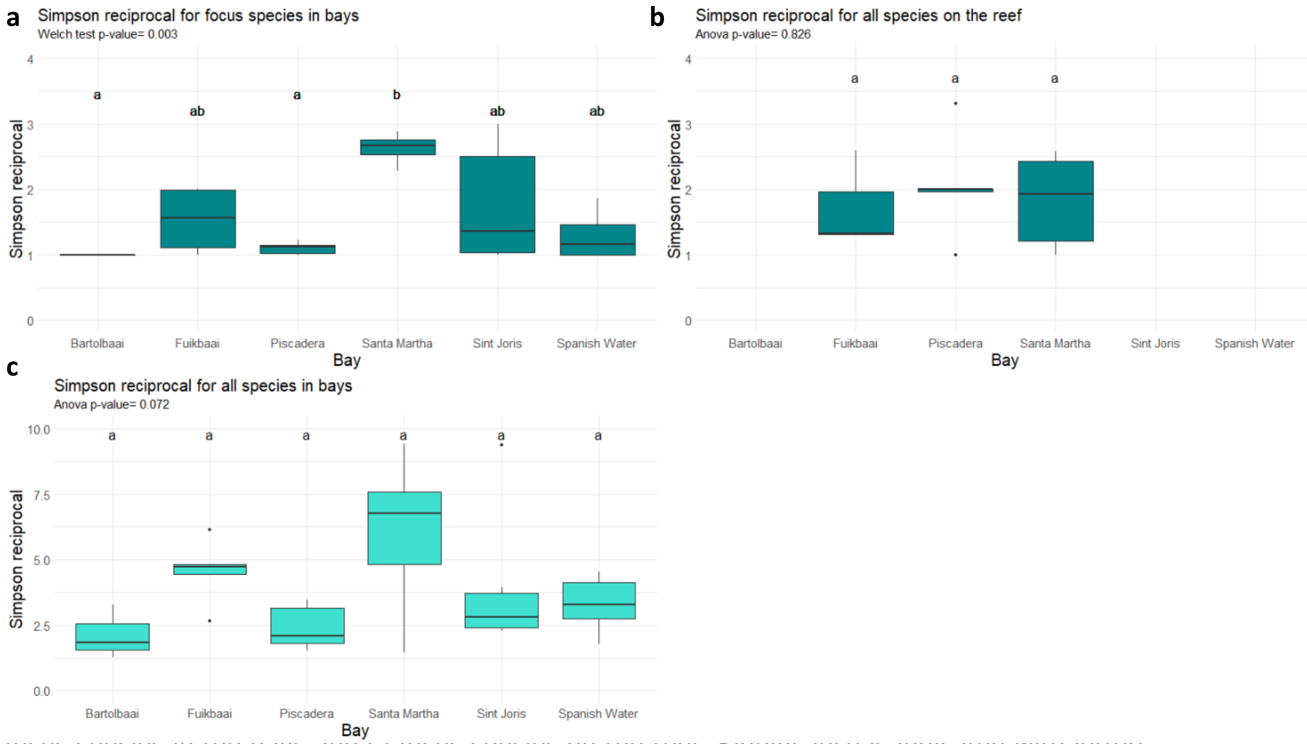


Figure III-314. Simpson's diversity per meter squared. a) All species present in the bays, b) focus species in the bays and c) focus species on the reef. Significance is indicated with letters.

Simpson's reciprocal index

Simpson's reciprocal index for all the fish species present in the bays range from 1.27 to 9.388, with an average value of 3.835 (Fig. III-4c). While there are no significant differences between the bays, there is some variation between the bays. However, the p-value for this group is almost significant, indicating that there is a significant trend. For the focus species in the bays, the Simpson's reciprocal index is between 1.0 and 3.0, a mean of 1.611 (Fig. III-4a). The variation between the bays for the focus species is similar to those of all the species. In this group there is a significant difference between Bartolbaai/Piscadera and Santa Martha (Welch's test, p-value 0.003). On the reef the values range from 1.0 to 3.3, with an average of 1.893 (Fig. III-4b). Between the bays there is less variation than in the bays, resulting in that there are no statistical differences between the reefs.



focus species in the bays and c) focus species on the reef. Significance is indicated with letters.

Simpson's evenness index

The range of Simpson's evenness index values in the bays of Curaçao for all species present is between 0.1731 and 0.789, with an average of 0.3356 (Fig. III-5c). There is variation present between the bays, the anova indicates a statistical difference (ANOVA, p-value 0.035). The differences between Piscadera and Santa Martha, where Piscadera does has unevenness in the proportional abundance of the species present. Values for the focus species for Simpson's evenness range between 0.2817 and 1. The average value is 0.8889 (Fig. III-5a). In contrast to all species, there is a no difference present for the focus species in the bays. On the reef there is no difference in evenness as well. The values ranges from 0.324 to 1. On average the Simpson's evenness is 0.8064 on the (Fig. III-5b). There are no observed differences between the different reefs. While there is greater variation on the reef than in the bays for the focus species, we do not see a significant difference between the bays and their respective reef.

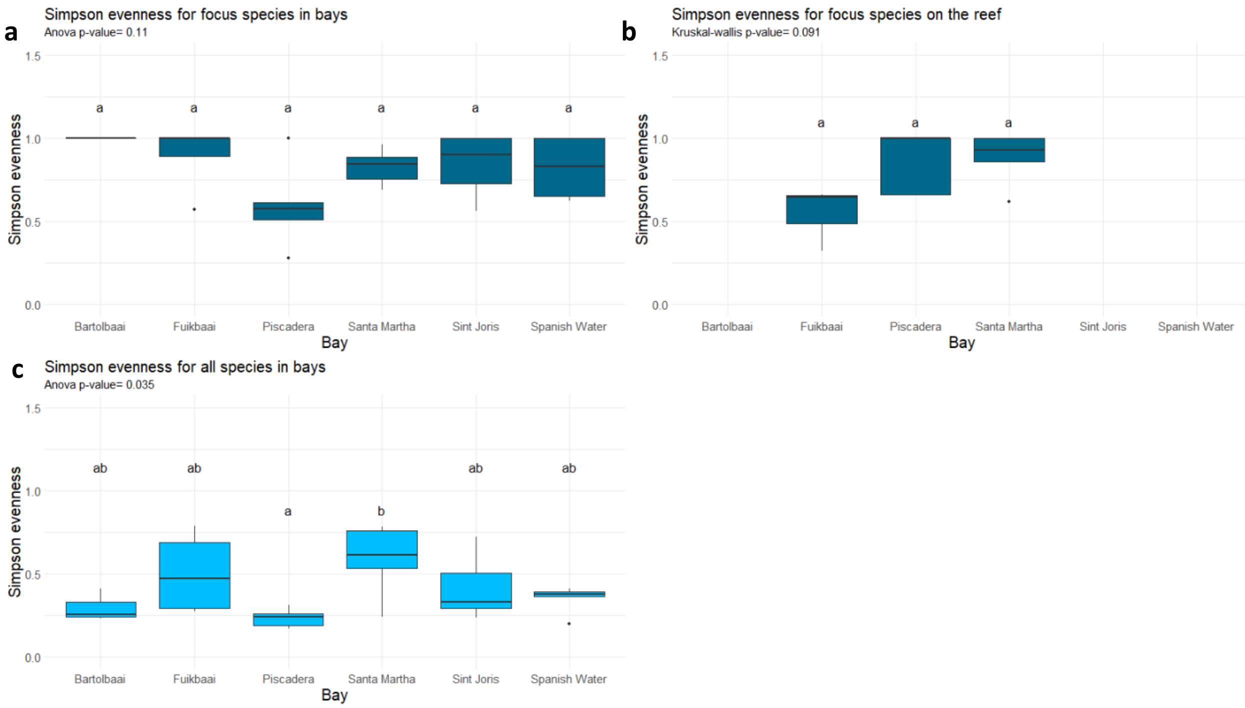


Figure III-5. Simpson's evennessl index per meter squared. a) All species present in the bays, b) focus species in the bays and c) focus species on the reef. Significance is indicated with letters.

Shannon index

Shannon index values for all species in the bays ranges from 0.5084 to 2.3549, average value is 1.4923 (Fig. III-6c). There is variation between the bays, where Santa Martha has somewhat higher values. However, there is no significant difference between the bays. Shannon index for the focus species in the bays ranges from 0 to 1.1674, with a mean of 0.4456 (Fig. III-6a). All bays, with the exception of Santa Martha, have in at least one location within the bay an absence of diversity for the focus species. This leads to a significant difference between Bartolbaai and Piscadera compared to Santa Martha (Welch's test, p-value= 0.005). On the reef Simpson's index is between 0 and 1.3571, with an average of 0.606 (Fig. III-6b). There are no differences in the values between the reefs. Comparing the bays with their respective connected reef, there are also no significant differences.

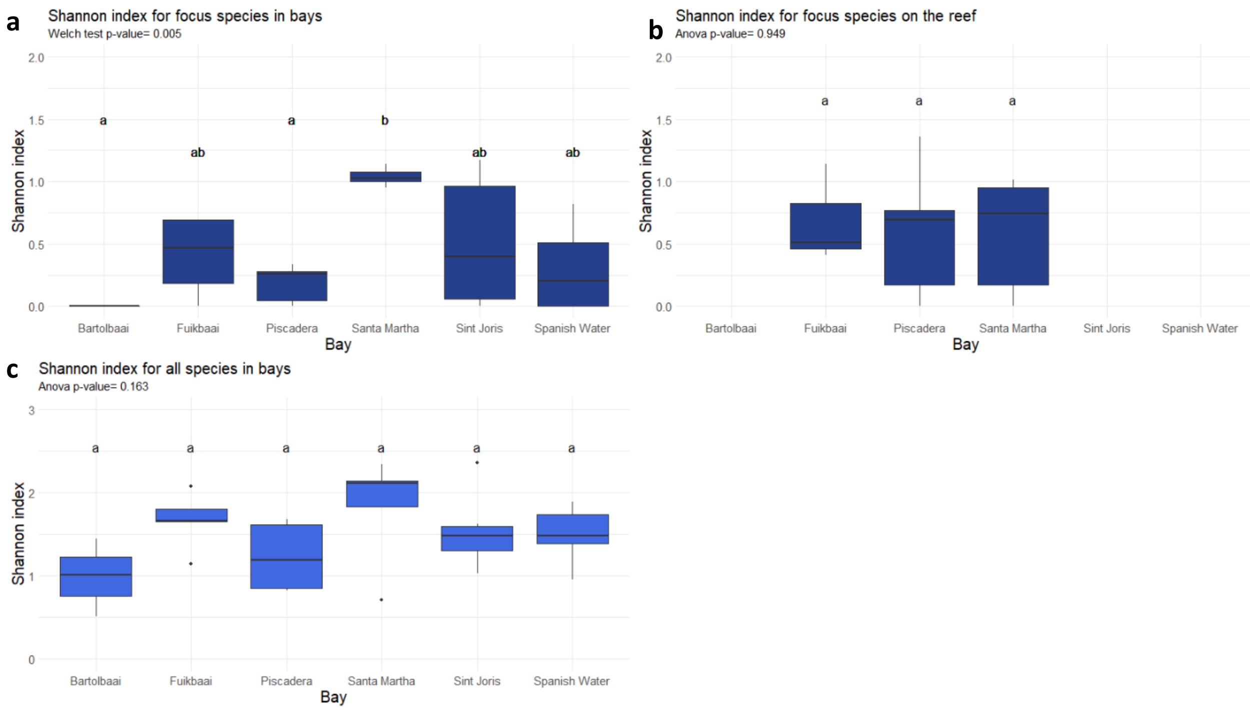


Figure III-6. Shannon index per meter squared. a) All species present in the bays, b) focus species in the bays and c) focus species on the reef. Significance is indicated with letters.

Shannon max

Shannon max for all species present in the bays ranges from 1.609 to 2.773, on average Shannon max is 2.205 (Fig. III-7c). there are no differences in Shannon max values between the bays. For the focus species in the bays, Shannon max between 0 and 1.3863 (Fig. III-7a). The average value for the focus species in the bays is 0.6292. There is a significant difference between Bartolbaai and Santa Martha (ANOVA, p-value = 0.033), Where Santa Martha has a higher value for the Shannon max. On the reef the values ranges between 0 and 1.6094 (Fig. III-7b). Equivalent to the other diversity indices there is no significant differences between the reefs for the focus species. Comparing the bays with their connecting reefs shows no significant differences.

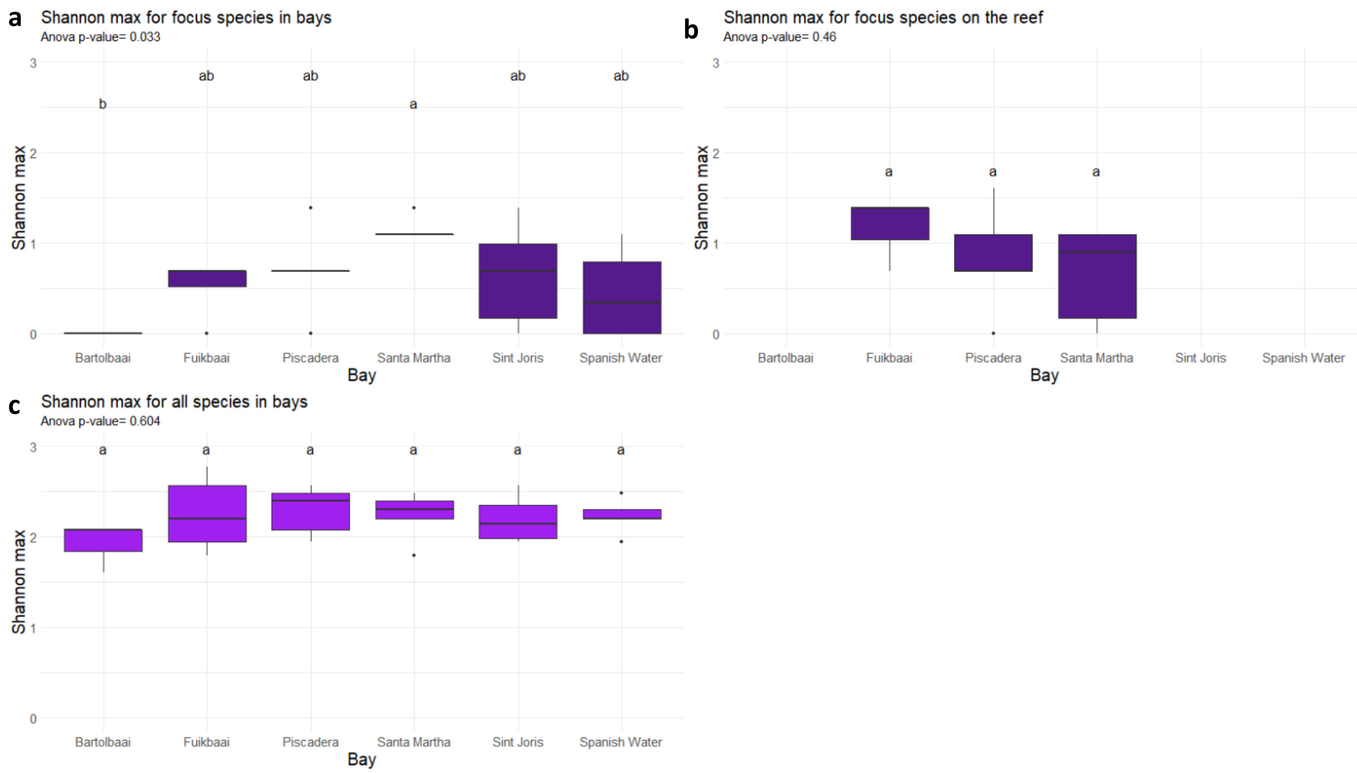


Figure III-7. Shannon max per meter squared. a) All species present in the bays, b) focus species in the bays and c) focus species on the reef. Significance is indicated with letters.

Shannon evenness

Shannon evenness index for all the fish species present in the bays range from 0.3159 to 0.9416, with an average value of 0.6687 (Fig. III-8c). While there are no significant differences between the bays, there is some variation between the bays. However, the p-value for this group is almost significant, indicating that there is a significant trend. For the focus species in the bays, the Shannon evenness index is between 0.06953 and 1, a mean of 0.683 (Fig. III-8a). The variation between the bays for the focus species is similar to those of all the species. In this group there is a significant difference between Piscadera and Santa Martha (ANOVA, p-value 0.015). On the reef the values range from 0 to 1.0, with an average of 0.7417 (Fig. III-8b). Between the bays there is less variation than in the bays, resulting in that there are no statistical differences between the reefs.

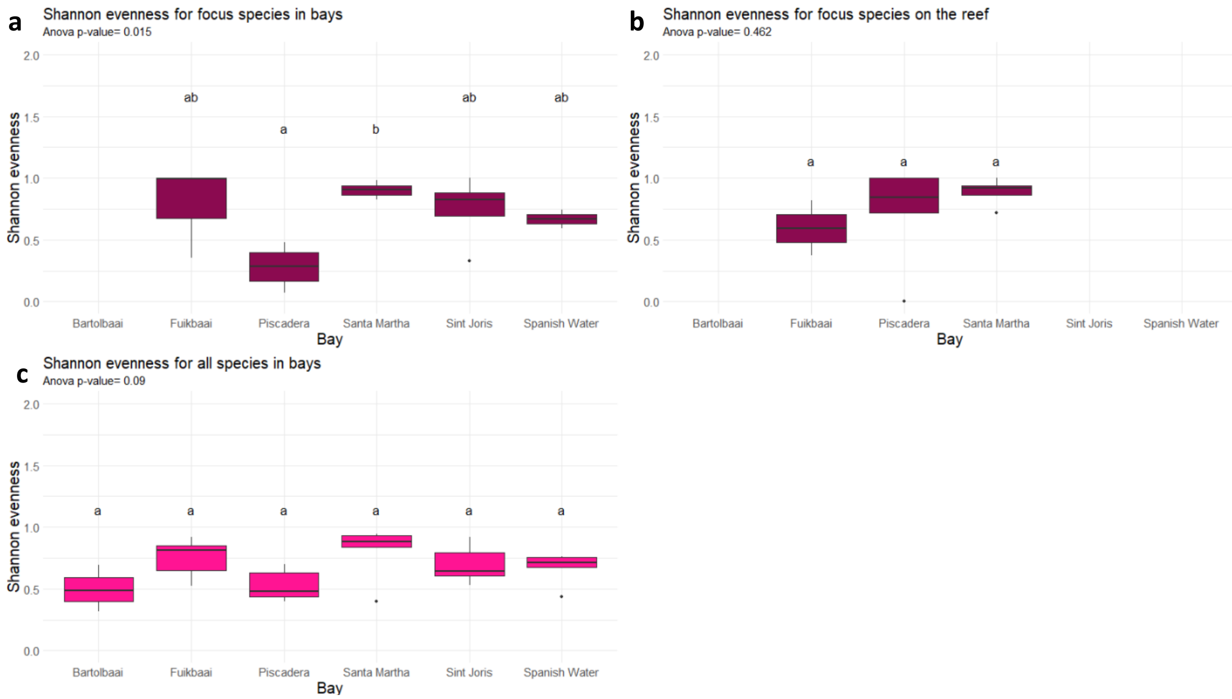


Figure III-8. Shannon evenness per meter squared. a) All species present in the bays, b) focus species in the bays and c) focus species on the reef. Significance is indicated with letters.

Appendix IV. Environmental sampling locations coupled to seine net locations

Seine net location	Environmental sampling location	Distance between two locations (m)
BBNET2	BBS006	8
BBNET3	BBS003	2
BBNET4	BBS005	278
FBNET1	FBS008	28
FBNET2	FBS006	246
FBNET3	FBM008	182
FBNET4	FBS001	28
FBNET5	FBS004	25
PBNET1	PM004	216
PBNET2	PM003	44
PBNET3	PM005	7
PBNET4	PM002	192
PBNET5	PM009	378
SJNET1	SJS008	234
SJNET2	SJM001	63
SJNET3	SJM009	158
SJNET4	SJM008	352
SJNET5	SJM002	117
SJNET6	SJS004	80
SMNET1	SMM005	128
SMNET2	SMM009	19
SMNET3	SMM009	194
SMNET4	SMM009	196
SMNET5	SMM007	132
SPWNET1	SPWS007	263
SPWNET2	SPWM006	22
SPWNET3	SPWS008	903
SPWNET4	SPWM002	100
SPWNET5	SPWS001	162

Appendix V. Number of surveys per year

Table V-1. Number of surveys conducted each year and stored in the REEF database. In 25 years a total of 2354 surveys were conducted. Orange marked years are filtered out in this analysis, due to a limited species observation. Resulting in a total of 2138 surveys used to determine historical changes in reef inhabitant community composition.

Year	Number of surveys
1995	2
1996	8
1997	4
1998	2
1999	13
2000	58
2001	389
2002	159
2003	139
2004	147
2005	103
2006	89
2007	76
2008	48
2009	259
2010	69
2011	53
2012	36
2013	108
2014	100
2015	157
2016	56
2017	83
2018	32
2019	164
Total	2354
Total surveys used	2183

Appendix VI. Top 25 percent of the most abundant species over the last 25 years

Table V-1. Most abundant species over the last 25 years. Abundance is averaged over the 25 years. Marked species are nursery species as presented in Nagelkerken et al. 2000.

Rank	Species	Average abundance 25 years	1997	1999	2000	2001	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	Brown Chromis (*Chromis multilineata*)	315	400	400	367	365	388	389	391	346	395	387	376	338	377	363	400	367	400	343	342	400	331
2	Bicolor Damselfish (*Stegastes partitus*)	304	400	389	400	364	390	378	374	305	389	374	367	316	348	319	387	358	391	336	306	400	311
3	Bluehead (*Thalassoma bifasciatum*)	277	400	356	300	346	379	311	320	295	337	365	330	330	345	256	370	270	381	321	305	294	302
4	Creole Wrasse (*Clepticus parrae*)	264	400	378	250	326	355	367	348	287	358	317	307	330	304	310	354	288	354	264	179	294	218
5	Masked Goby/Glass Goby (*Coryphopterus personatus/hyalinus*)	249	367	389	292	354	316	389	361	228	358	326	331	262	311	338	336	304	326	100	47	239	243
6	Yellow Goatfish (*Mulloidichthys martinicus*)	236	300	400	292	245	305	266	308	259	274	330	246	284	244	256	280	284	297	207	268	267	296
7	Blue Chromis (*Chromis cyanea*)	236	400	322	267	298	364	266	301	203	311	274	275	254	304	288	340	300	306	179	153	250	243
8	Stoplight Parrotfish (*Sparisoma viride*)	226	300	333	242	248	276	256	269	269	295	287	272	238	281	240	327	263	279	243	258	244	238
9	Blue Tang (*Acanthurus coeruleus*)	221	267	322	234	260	224	217	266	231	284	282	258	254	244	228	327	250	277	293	263	283	272
10	Yellowhead Wrasse (*Halichoeres garnoti*)	217	200	323	250	293	314	289	266	264	290	282	294	231	237	237	300	283	308	178	137	228	218
11	Sergeant Major (*Abudefduf saxatilis*)	216	200	300	225	252	254	222	263	267	284	270	247	277	233	222	310	246	260	272	294	267	247
12	Ocean Surgeonfish (*Acanthurus bahianus*)	215	333	389	200	234	279	144	241	254	268	213	250	261	222	225	273	254	257	286	274	256	262

13	Blackbar Soldierfish (*Myripristis jacobus*)	214	300	333	267	289	345	267	293	277	242	230	269	261	263	228	297	242	249	171	131	172	212
14	Redband Parrotfish (*Sparisoma aurofrenatum*)	211	300	344	250	227	269	256	265	205	248	265	243	238	248	203	304	200	273	214	221	239	260
15	Threespot Damselfish (*Stegastes planifrons*)	211	300	389	275	249	307	239	274	239	284	274	251	261	244	241	320	229	262	86	163	167	218
16	Princess Parrotfish (*Scarus taeniopterus*)	201	300	300	250	239	269	233	238	238	258	244	251	223	241	119	340	225	289	186	158	189	243
17	French Grunt (*Haemulon flavolineatum*)	199	200	311	250	200	205	217	234	256	205	217	200	231	204	244	293	204	243	271	290	250	256
18	Striped Parrotfish (*Scarus iseri*)	199	200	300	125	221	265	206	223	213	258	209	214	270	267	234	297	225	244	236	263	239	263
19	Smallmouth Grunt (*Haemulon chrysargyreum*)	194	233	300	275	213	271	245	265	218	158	253	191	270	141	240	224	175	214	272	274	239	184
20	Foureye Butterflyfish (*Chaetodon capistratus*)	188	233	256	208	244	238	222	229	221	242	209	221	192	204	206	270	220	222	200	216	212	231
21	Queen Parrotfish (*Scarus vetula*)	174	300	300	242	207	233	172	211	159	211	192	177	200	133	200	237	171	205	200	221	189	184
22	Bridled Goby Complex (Bridled/Sand-Canyon/Patch-Reef) (*C. glaucofraenum/C. bol/C. tortugae*)	174	200	389	275	241	107	245	152	259	237	239	186	223	196	169	276	108	266	193	121	45	211
23	Trumpetfish (*Aulostomus maculatus*)	173	300	289	192	218	241	189	215	225	184	205	201	154	178	169	226	195	211	178	168	211	172
24	Longfin Damselfish (*Stegastes diencaeus*)	172	267	244	275	273	193	106	194	207	221	257	226	177	170	191	300	142	242	86	174	144	221
25	Graysby (*Cephalopholis cruentata*)	170	200	256	242	207	245	239	217	190	237	231	202	154	204	203	247	179	223	136	79	183	168
26	Mahogany Snapper (*Lutjanus mahogoni*)	169	233	278	167	159	176	200	217	215	231	226	201	169	181	172	233	187	219	200	231	145	182
27	Yellowtail Damselfish	167	167	289	234	242	195	106	202	200	258	209	186	177	163	175	263	162	185	193	221	184	167

	(*Microspathodon chrysurus*)																						
28	Schoolmaster snapper (*Lutjanus apodus*)	167	200	189	192	164	157	206	228	174	210	257	178	185	167	206	237	192	213	222	205	211	184
29	Clown Wrasse (*Halichoeres maculipinna*)	164	267	267	208	215	124	139	162	169	242	217	194	231	148	131	237	113	214	236	247	150	184
30	Sharpnose Puffer (*Canthigaster rostrate*)	162	200	256	216	208	186	194	200	151	221	209	190	169	163	197	317	220	205	122	116	122	194
31	Slippery Dick (*Halichoeres bivittatus*)	160	200	322	200	149	143	200	186	187	231	204	196	261	133	109	220	112	172	214	221	167	175
32	Smooth Trunkfish (*Lactophrys triqueter*)	159	233	267	225	165	184	211	208	172	184	204	157	162	163	138	210	179	182	200	174	183	169
33	Fairy Basslet (*Gramma loreto*)	157	233	289	209	252	231	212	237	187	284	196	230	154	189	162	203	116	89	93	63	128	162
34	Banded Butterflyfish (*Chaetodon striatus*)	148	100	189	142	182	172	167	195	187	179	191	175	200	159	181	197	183	180	193	173	178	179
35	Harlequin Bass (*Serranus tigrinus*)	145	233	256	217	171	184	200	211	172	231	183	184	154	185	175	173	166	150	71	53	128	130
36	Spanish Hogfish (*Bodianus rufus*)	145	200	233	192	166	176	183	198	126	190	191	150	162	130	175	180	171	157	157	163	183	142
37	Bar Jack (*Caranx ruber*)	133	200	200	134	115	122	183	184	90	179	191	133	177	122	100	154	154	189	200	179	183	148
38	Peppermint Goby (*Coryphopterus lipernes*)	127	300	244	250	241	152	200	206	118	137	148	130	169	107	119	127	113	167	43	21	67	121
39	Yellowtail Snapper (*Ocyurus chrysurus*)	126	67	200	134	216	167	144	185	185	142	200	174	208	133	122	190	104	140	157	42	161	69
40	Goldspot Goby (*Gnatholepis thompsoni*)	122	233	311	158	100	48	139	183	95	232	200	106	169	137	69	187	79	180	136	121	45	134
41	Puddingwife (*Halichoeres radiatus*)	117	133	222	150	151	115	122	129	108	142	122	130	169	122	75	160	71	163	214	184	117	118
42	Coney (*Cephalopholis fulva*)	115	267	156	117	33	131	134	145	118	158	126	116	138	85	153	130	121	154	200	189	139	64
43	Doctorfish (*Acanthurus chirurgus*)	114	200	89	117	116	62	133	117	41	116	48	151	192	141	72	287	96	180	250	189	72	172

44	Yellowtail Hamlet (*Hypoplectrus chlorurus*)	113	200	156	134	138	172	183	175	152	121	166	151	116	137	134	137	129	104	64	26	122	108
45	Spinyhead Blenny (*Acanthemblemaria spinosa*)	107	0	148	197	176	102	135	152	115	147	146	100	128	130	56	223	79	183	172	90	100	87
46	Yellowline Goby (*Elacatinus horsti*)	104	133	189	183	142	72	150	109	125	179	52	109	177	170	56	197	117	163	86	42	39	119
47	Sharknose Goby (*Elacatinus evelynae*)	103	0	267	50	165	107	167	196	198	173	26	97	184	141	69	167	92	201	79	47	17	125
48	Rainbow Wrasse (*Halichoeres pictus*)	98	200	145	58	141	71	189	151	87	258	161	66	123	159	44	146	58	183	57	58	28	67
49	Redtail Parrotfish (*Sparisoma chrysopterum*)	98	167	111	108	90	69	134	112	110	111	118	123	184	181	44	170	67	121	100	111	111	99
50	Longjaw Squirrelfish (*Neoniphon marianus*)	97	133	178	125	120	109	117	128	105	111	96	115	154	152	116	170	79	93	86	53	78	101
51	Orangespotted Filefish (*Cantherhines pullus*)	96	167	145	108	132	114	72	123	100	95	130	82	162	96	91	130	109	135	78	89	111	134
52	Yellowtail (Redfin) Parrotfish (*Sparisoma rubripinne*)	94	67	156	134	127	48	106	100	77	179	131	109	146	111	47	150	58	85	129	205	117	83
53	Caesar Grunt (*Haemulon carbonarium*)	94	100	44	75	115	112	100	122	123	152	169	88	177	108	109	160	75	103	122	79	128	95
54	Bluestriped Grunt (*Haemulon sciurus*)	90	167	122	117	88	55	133	127	105	105	165	99	162	104	81	153	75	113	78	26	67	102
55	Creolefish (Atlantic) (*Paranthias furcifer*)	89	100	89	33	104	67	78	123	49	163	65	58	46	85	75	124	109	196	236	179	161	92
56	Redlip Blenny (*Ophioblennius macclurei*)	89	67	200	109	188	64	33	133	74	210	148	114	131	89	63	97	29	46	57	163	106	109
57	Dusky Damselfish (*Stegastes adustus*)	87	0	244	92	77	109	145	160	72	63	61	88	146	96	25	163	21	50	164	195	95	103
58	Rock Beauty (*Holacanthus tricolor*)	85	233	222	142	37	126	67	95	41	63	135	42	62	74	138	53	137	56	143	105	89	77
59	French Angelfish (*Pomacanthus paru*)	75	0	111	25	58	57	72	118	79	100	57	90	123	85	112	130	104	96	150	95	128	89

60	Spotted Drum (*Equetus punctatus*)	75	67	156	109	65	112	83	118	72	84	109	82	108	63	103	133	96	76	43	63	67	70
61	Longspine Squirrelfish (*Holocentrus rufus*)	74	100	44	67	37	148	100	162	82	126	117	59	92	78	122	133	71	59	57	79	56	47
62	Unidentified Silvery Fish (Silversides / Anchovies / Herrings) (*Atheriniformes sp./ Clupeiformes sp.*)	73	0	167	0	5	19	44	49	62	79	48	57	269	74	13	143	17	52	193	316	89	132
63	Yellowfin Mojarra (*Gerres cinereus*)	72	133	166	100	24	69	56	95	69	90	69	62	146	41	38	53	50	72	129	147	95	90
64	Barred Hamlet (Caribbean) (*Hypoplectrus puella*)	71	167	145	134	72	100	111	137	87	74	135	91	69	56	75	56	63	49	14	0	72	72
65	Spotted Goatfish (*Pseudupeneus maculatus*)	68	100	200	84	81	74	83	80	64	58	118	89	146	56	6	80	63	86	72	37	44	76
66	Butter Hamlet (*Hypoplectrus unicolor*)	67	167	100	100	88	124	139	123	82	100	109	89	61	22	56	50	29	52	7	32	72	68
67	Glassy Sweeper (*Pempheris schomburgkii*)	67	0	89	159	27	57	56	100	67	42	126	57	31	70	128	103	129	75	71	105	72	100
68	Honeycomb Cowfish (*Acanthostracion polygonius*)	63	100	78	75	65	64	105	115	64	58	74	57	123	71	72	73	62	52	93	42	72	52
69	Boga (*Haemulon vittatum*)	61	133	22	150	7	57	56	128	38	53	126	48	92	126	100	107	79	55	93	0	22	41
70	Pallid Goby (*Coryphopterus eidolon*)	60	200	178	133	88	31	78	94	87	100	96	49	108	67	28	43	21	14	36	0	0	44
71	Longsnout Butterflyfish (*Chaetodon aculeatus*)	59	133	33	100	60	69	117	83	59	37	100	52	69	74	106	94	113	33	43	26	39	39
72	Redspotted Hawkfish (*Amblycirrhitus pinos*)	56	133	111	58	82	36	17	100	28	111	35	52	62	59	41	70	38	63	157	63	33	45
73	Glasseye Snapper (*Heteropriacanthus cruentatus*)	50	0	89	83	53	67	39	79	46	42	30	44	46	82	78	110	117	59	64	26	50	46

74	Spotted Trunkfish (*Lactophrys bicaudalis*)	50	133	22	109	66	48	72	57	38	58	65	53	23	26	44	56	59	42	65	84	89	39
75	Sand Diver (*Synodus intermedius*)	47	67	156	58	11	76	72	97	62	53	26	41	62	48	35	83	33	30	14	37	72	47
76	Whitespotted Filefish (*Cantherhines macrocerus*)	47	100	56	25	47	60	50	86	46	26	74	54	85	44	53	57	50	63	78	53	44	18