

Ecological Approach of Marine Sponges: The Case of Martinique

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Abstract

This study is an ecological assessment of the Porifera on 22 stations in Martinique (Lesser Antilles). We used the quadrat method and counted each species present in a 32 m² area. Abiotic factors such as hydrodynamics, substrate type and inclination, and bathymetry were noted. These factors influence the distribution of sponges and their ability to recruit new spaces. The study shows that sites with a bedrock and a rather vertical slope have a specific diversity and therefore an interspecific competition higher than those with a sandy-rocky substratum. There are 7 species of sponges, including 4 families characteristic for the sandy-rocky bottoms against 20 species including 15 families for the bedrock. She also illustrated the impact of bathymetry. Stations ranging from 2 meters to 13 meters deep. The specific diversity increases when bathymetry also increases. The CHERRY 1, CHERRY 2, CHERRY 3 stations have 1 species (4 m), compared to 19 for the more diversified station LEZARDE 1 (10 m).

Keywords

Sea Sponges, Martinique, Caribbean, Diversity, Substrates, Benthic Habitats, Ecology

1. Introduction

The Caribbean region is a “hot spot” of marine species biodiversity [1] [2]. Marine sponges are sessile organisms that colonize reef environments. With ocean acidification, researchers have found a decrease in coral populations that are responsible for the construction of reefs in favor of algal and sponge populations [3]. The Caribbean coral populations have declined sharply by about 80% in most Caribbean reefs [4] [5]. Their development depends on abiotic factors (hydrodynamics, bottom slope, substrate nature, bathymetry) and biotic factors [6]. The objective

of this article is to highlight the influence of these factors on the distribution of Porifera in Martinique. There is an urgent need to determine the distribution patterns of these organisms and their abundance, so that biodiversity changes can be quantified due to increased human activities and their impacts on biodiversity [7] [8].

2. Material

2.1. Generalities about Marine Sponges

Spongiaria, from the Latin ‘spoggia’, meaning sponge, are metazoan animals belonging to the branch of the Porifera [9]. The oldest fossils date from 630 million years ago [10]. They inhale and exhale through pores connected to a chamber containing choanocytes, cells provided with flagella bringing nutrients. Spongiae have a very simple organization: it has an outer layer, the ectoderm, and an inner layer, the endoderm. They are diploblastic organisms. They have no tissue or differentiated organs and are therefore the most primitive metazoans. Choanocytes also ensure the digestion of nutrients and the entry of water through pores into an organism without circulation [9]. On the other hand, some sponges, carnivorous sponges in higher bathymetries, are not filtering organisms; they capture their prey using hook on their surface [10].

The morphology of Porifera is very variable within a group or even a species. For this reason, it cannot be used as a reference to their classification. Based on their skeleton [10].

Thus, four classes of Spongiaries are distinguished: Demospongiae, from the Greek “demos” people and “spoggia” sponge; Hexactinellida, siliceous, calcarea, limestone and homoscleromorpha [11]. There are 8730 species, including 680 genera in the four classes mentioned. The most important class is the Demosponges, which accounts for 83% of all species recorded [12].

2.2. Marine Habitats and Benthic Communities in Martinique

Martinique is an island with an area of 1100 km² which is bordered by the Caribbean Sea on the West side and by the Atlantic Ocean on the East side. Its shorelines include different types of habitat, namely coral reefs (fringing and barrier reefs), mangroves, seagrasses and sandy bottoms with variable granulometry and mineralization [13]. These habitats collect different benthic communities including coral communities biobuilt and on rock blocks. They also house the herbage of *Thalassium testudium* (turtle grass), *Syringodium filiforme* (mantis grass). These herbivores may be single species or mixed. There are also algal communities, spongians and gorgonians, soft-bottom communities with enfauna on mobile sediments [13].

2.3. Substrates of Marine Habitats

The substrate is the abiotic factor for attachment and development of spongiform larvae. Therefore, it is important to identify the type of substrate in characterizing

different environments and marine sponge species that grow there [14]. We find:

- Reefs, rocky platforms sometimes composed of blocks or coral structures made up of living or dead colonies [13].
- Sandy bottoms with grain sizes ranging from fine sand to coarse sand [13].
- Consolidated or disassembled rock blocks composed of coral fragments, shells, blocks or calcareous algae [13].
- Muddy seabed at the estuary level [13].
- Sand and rock reefs composed of boulders and interspersed with sandy spaces [13].

2.4. Choice of Study Sites

The sites chosen for the whole island of Martinique are the Anses d'Arlet (Cap Salomon, la Lézarde, Crique Abricot, la Pouponnière, la Petite Sirène, L'Arbre Mort), le Diamant (la Cerise), le Robert (îlets à l'Eau et Boisseau), Sainte-Anne (la Pointe Marin). Abiotic parameters such as temperature, salinity, pH, particle number and saturation percentage were taken 3 times per site and averaged and tabulated (Table 1 and Figure 1).

Table 1. Abiotic factors of studied sites.

Abiotic parameters	Sites of study					
	Anses d'Arlet	DiamantLa Cherry	Le Prêcheur	Sainte-AnnePointe Marin	Robert. îlet à l'Eau	Robert. îlet Boisseau
Temperature (°C)	30.4	30.4	29.8	30.0	29.4	29.5
pH	8.45	8.32	8.39	8.37	8.5	8.56
Particle rate (mg/L)	38182	19581	31023	31285	28976	31023
Oxygen saturation (% Sat)	107	97.73	107.8	96.875	99.5	105.7
Salinity (PSU)	24.5	19	32.2	31.4	28.77	31.77

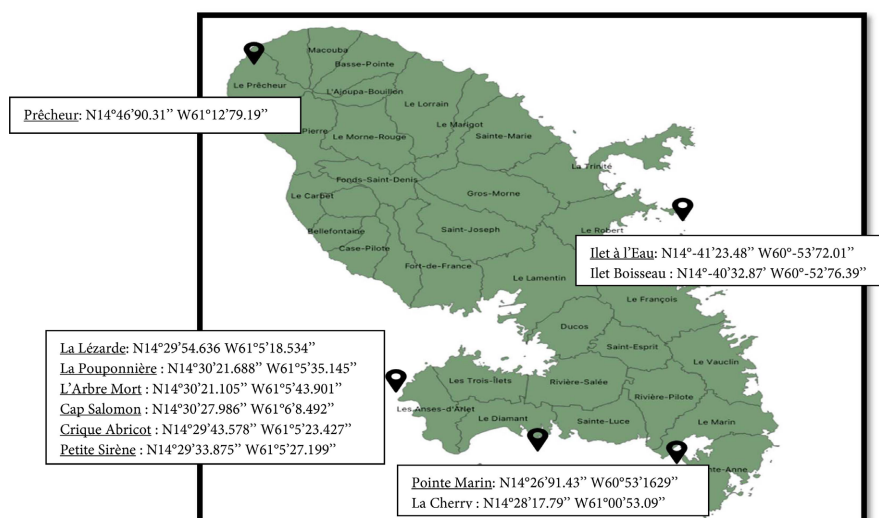


Figure 1. Map of study sites throughout Martinique and GPS coordinates.

3. Methods

Method for the Assessment of Sponges Populations

The stations are inventoried by the transect method and the quadrat method. Along an 8 m transect a square of 4 m² is moved for a total surface of 32 m² during 1 hour of diving. The number of individuals of each species present in each square was counted. The time limit is imposed by the autonomy of the bottle. Specific reconnaissance is done using atlas [15] [16] and underwater photographs with a GoPro 10. Bathymetry is measured, in meters, by a dive computer. The nature of the substrate (sand, rock, rock reef), the hydrodynamics (calm or agitated) and the inclination of the substrate (horizontal or vertical) were noted for each station (Table 2).

Temperature, salinity, pH, particle rate and saturation percentage measurements were taken 3 times per site by a multiparameter probe and averaged. The same probe was used to obtain GPS points from study sites.

Table 2. Descriptions of physics parameters of the 22 stations studied.

Stations	Description of physics parameters of the 22 stations				
	Inventoried surface (m ²)	Substrate	Hydrodynamics	Inclination	Bathymetry (m)
POUPONNIERE 1	32	Sand-rock Regular and stable	Calm	Horizontal	6
POUPONNIERE 2	32	Sand-rock Irregular and unstable	Calm	Horizontal	6
POUPONNIERE 3	32	Sand-rock Irregular and unstable	Calm	Horizontal	6
ARBRE MORT 1	32	Rock reef Irregular and unstable	Calm	Horizontal	8
ARBRE MORT 2	32	Sand-Rock with important presence of boulders Irregular and unstable	Calm	Horizontal	8
ARBRE MORT 3	32	Rock reef Stable and regular	Calm	Vertical	6
LEZARDE 1	32	Rock reef Stable and regular	Calm	Vertical	10
LEZARDE 2	32	Rock reef Stable and regular	Calm	Horizontal	10
LEZARDE 3	32	Rock reef Stable and regular	Calm	Vertical	10
PETITE SIRENE 1	32	Rock reef Stable and regular	Agitated	Vertical	13
PETITE SIRENE 2	32	Rock reef Stable and regular	Agitated	Vertical	13
CAP SALOMON 1	32	Rock reef Stable and regular	Agitated	Vertical	10
CAP SALOMON 2	32	Rock reef Stable and regular	Agitated	Vertical	13
CRIQUE ABRICOT 1	32	Rock reef Stable and regular	Agitated	Vertical	13
CHERRY 1	32	sand with low presence of small boulders Unstable and irregular	Agitated	Horizontal	4
CHERRY 2	32	sand with low presence of small boulders Unstable and irregular	Agitated	Horizontal	4
CHERRY 3	32	sand with low presence of small boulders Unstable and irregular	Agitated	Horizontal	4

Continued

PRECHEUR 1	32	Rock reef Stable and regular	Agitated	Vertical	7
POINTE MARIN 1	32	Sand-rock Stable and irregular	Calm	Horizontal	2
POINTE MARIN 2	32	Sand-rock Stable and irregular	Calm	Horizontal	2
ILET A L'EAU 1	32	Mixed of seagrass and sediment with low presence of small boulders Unstable and irregular	Calm	Horizontal	2
ILET BOISSEAU 1	32	Sand with low presence of small boulders Unstable and irregular	Agitated	Horizontal	2

4. Results

4.1. Specific Density per Quadrat

The density of each species is calculated by quadrat of 4 m² with a number of 8 per station, giving a total of 176 quadrats. The density of sponges was calculated from the following formula:

$$\text{Density} = \frac{\text{number of individuals of the population}}{\text{surface}}$$

We are going to recall that in our experiment a quadrat measures 4 m² (**Figure 2**).

4.2. Multifactorial Analysis of the Inventory Stations

The factorial analysis of the correspondences (FAC) and the hierarchical ascending classification (HAC) from the XLSTAT software made it possible to compare the stations with respect to the population structures of the different spongiform species. The AFC and the CAH are based on a contingency table composed of 34 lines (species) and 22 columns (inventoried stations) shows that there is a link between the rows and columns from a calculated p-value (0.0001) is below the significant level (0.05). The FAC axes F1 and F2 (inertia: 38.21%) in **Figure 1** distinguish stations according to taxonomic criteria.

4.3. Multifactorial Analyses of Quadrant Densities Inventoried

The correlation factor (FAC) analysis and from the XLSTAT software made it possible to compare the quadrats with respect to densities of different species of sponges. The AFC, applied to the contingency table (34 species × 155 squares), reveals a statistically significant association between the rows and columns. This conclusion is drawn from a p-value of 0.0001, which falls below the standard significance threshold of 0.05. The FAC axes F1 and F2 (inertia: 17.99%) in **Figure 5** distinguish stations according to taxonomic criteria.

4.4. Specific Density Results per Quadrat

Figure 2 is a graph of the evolution of the specific density for 34 species for 155 squares of 4 m² with values ranging from 0.25 to 5 individuals/m².

Based on the resulting graph (Figure 2), 6 species of spongiae are found in all types of media, namely *Xestospongia muta*, *Aplysina fistularis*, *Iotrochota birotulata*, *Amphimedon compressa*, *Niphates digitalis* and *Verongula sp.*

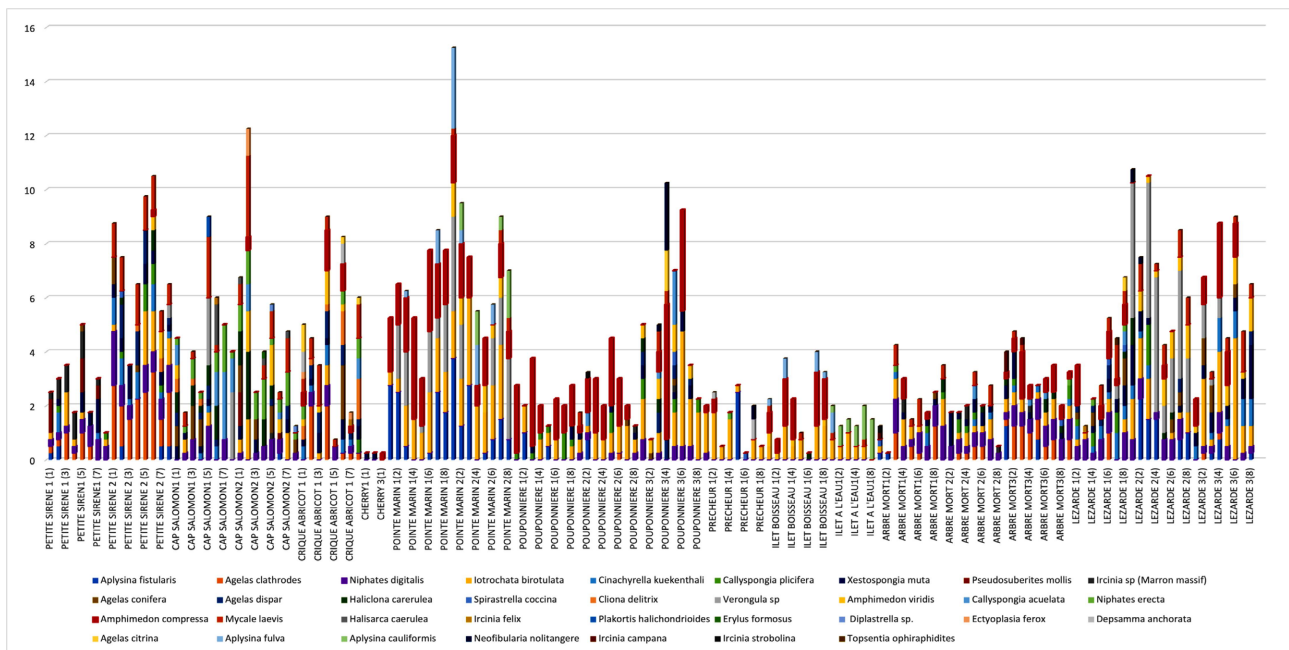


Figure 2. Graph of specific densities per quadrat of the 22 stations studied.

4.5. Number of Species per Station

Figure 3 shows the evolution of the number of sponges species per station for the 22 stations surveyed. Stations with minimum values are CHERRY 1, CHERRY 2 and CHERRY 3 with a single listed species. The stations with maximum values are LEZARDE 1 which has 19 species and CAP SALOMON 1, CRIQUE ABRICOT 1 with 18 species. Three other stations PETITE SIRENE 2, CAP SALOMON 2, and ARBRE MORT 1 include 14 species of marine sponges, a significant number of species. ILET A L'EAU 1 station records a small number of species with a total of 4 species, as well as the stations POINTE MARIN 1 and POUPONNIERE 1 which have a total of 5 species.

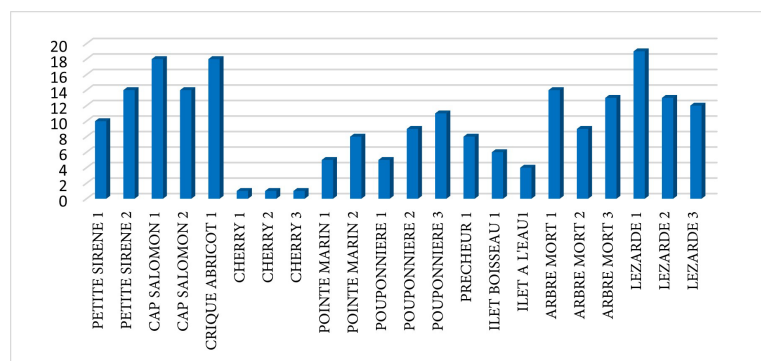


Figure 3. Graph of number of sponges species per station.

4.6. Sea Sponges Populations Description

Group 1

The stations POUPONNIERE 3, POUPONNIERE 2, LEZARDE 2, PRECHEUR 1 are colonized *Neofibularia nolitangere*, *Aplysina fistularis*, *Amphimedon compressa*, *Verongula sp*, *Amphimedon viridis* and *Iotrochota birotulata*. In the stations ILET BOISSEAU 1 and POINTE MARIN 2 there is only *Aplysina fulva* (Figure 4).

Group 2

The SALOMON 2 station is characterized by *Erylus formosus*. The SALOMON 1 station is characterized by *Plakortis halichondrioides* and *Niphates erecta*. The SIRENE 1 station is characterized by *Pseudosuberites mollis*. The stations DEAD TREE 1, LEZARDE 1, DEAD TREE 2, CHERRY 1 and CHERRY 2 are characterized by *Agelas clathrodes*, *Agelas conifera*, *Cliona delitrix*, *Ectyoplasia ferox*, *Topsentia ophiradites* and *Xestospongia muta*. The stations LEZARDE 3, SIRENE 2 and ARBRE MORT 3 are characterized by *Xestospongia muta*, *Ircinia campana*, *Niphates digitalis*, *Agelas dispar*, *Ircinia sp*, *Cinachyrella kuekenthali*, *Depsamma anchorata*, *Spirastrella coccina*, *Callyspongia plicifera* and *Mycale laevis* (Figure 4).

Group 3

The EAU 1 station is characterized by *Aplysina cauliformis* (Figure 4).

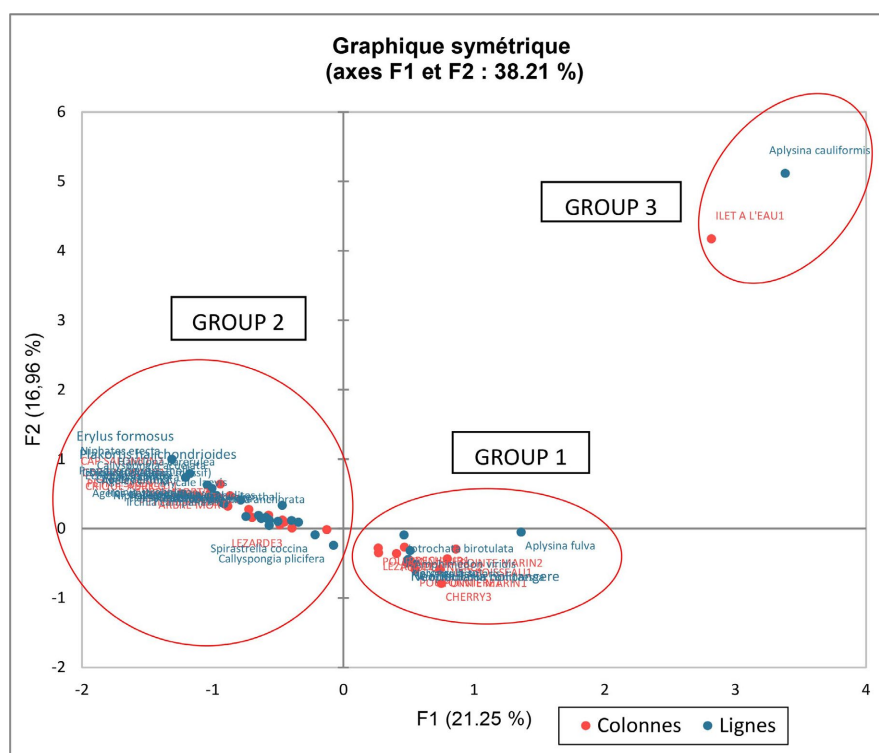


Figure 4. Factor Analysis of Correspondence of the 22 stations studied.

Stations are selected by the HAC through a dendrogram based on their percentage of similarity in sponges population (Figure 5).

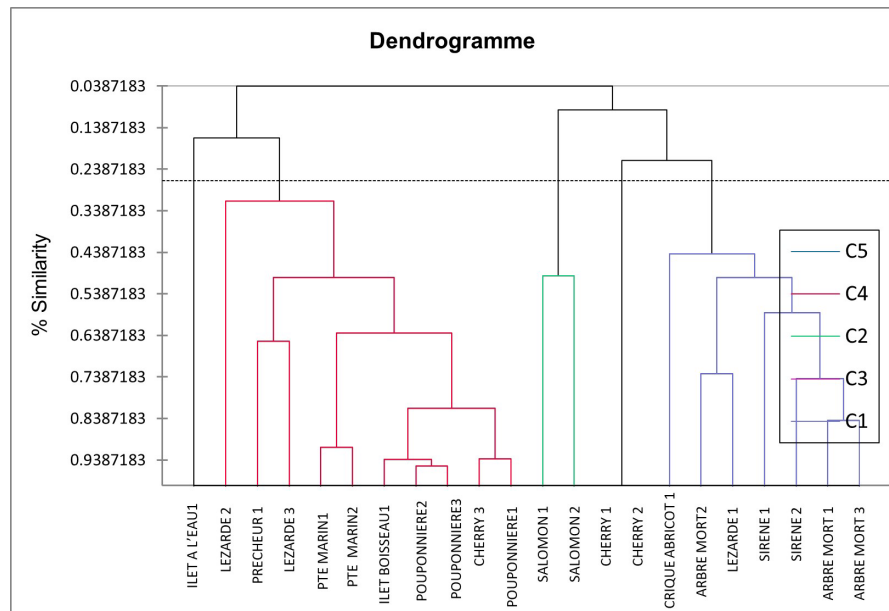


Figure 5. Hierarchical Ascending Classification of the 22 stations studied.

Stations of the same site with high similarity rate

CHERRY 1 and CHERRY 2 stations have 95% similarity. POUPONNIERE 2 and 3 stations have 95% similarity. POINTE MARIN 1 and POINTE MARIN 2 have 90% similarity. ARBRE MORT 1 and ARBRE MORT 3 have 84% similarity (Figure 5).

Stations from different sites with high similarity rates

The CHERRY 3 and POUPONNIERE 1 stations have 94% similarity. The ILET BOISSEAU 1 and POUPONNIERE 2 stations have 94% similarity. DEAD TREE 2 and LEZARDE 1 have 74% similarity. PRECHEUR 1 and LEZARDE 3 have 64% similarity (Figure 5).

The Ilet à l'Eau, particularity

Ilet à l'Eau is a unique station because it has a very small percentage of similarity with the other 21 stations. The most important similarity rate does not exceed 14% (Figure 5).

4.7. Sea Sponges Density Description

The CFA differentiated 5 groups according to the density of sponges per quadrats (Figure 6).

Group 1

Group 1 is composed of: quadrats 1, 2, 3, 5, 7 of station POUPONNIERE 3; quadrats 2, 4, 6 of station ARBRE MORT 3; quadrats 3, 5, 6, 7, 8 of station ARBRE MORT 1; quadrats 3, 7, 8 of station LEZARDE 3; quadrats 2, 3, 4, 5, 6, 7, 8 of the station DEAD TREE 2; of the squares 1, 3, 4, 5, 6, 7, 8 of the station LEZARDE 1; of the quadrat 6 of the station PRECHEUR 1; of the quadrat 1 of the station CHERRY 1; of the quadrat 1 of the CHERRY 2 station; of the quadrats 1, 2, 4, 5, 6, 7, 8 of the PETITE SIRENE 1 station; of the quadrats 1, 8 of the POU-

PONNIERE 2 station; of the eight quadrats of the stations PETITE SIRENE 2, CAP SALOMON 2, CRIQUE ABRICOT 1.

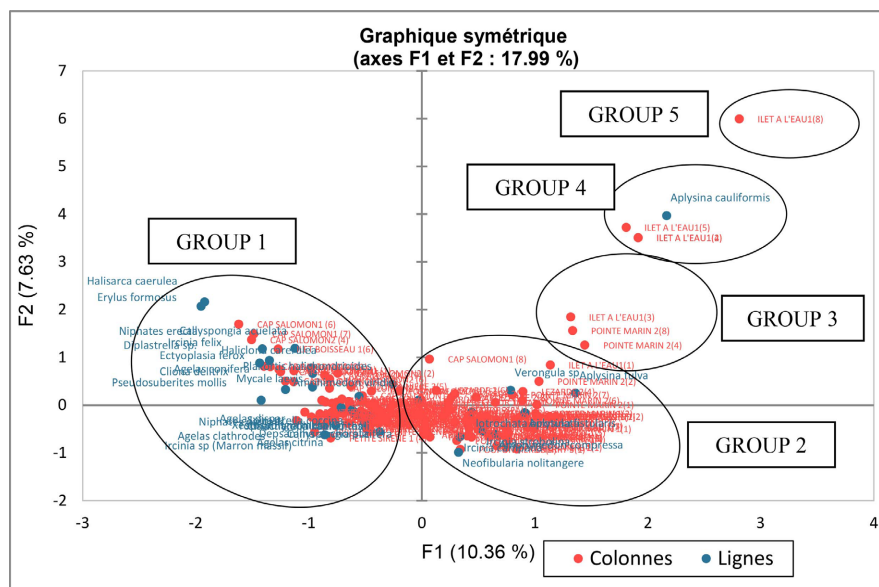


Figure 6. Factor Analysis of Correspondence of the quadrat of the 22 stations studied.

The characteristic species of this group are: *Halisarca caerulea*, *Erylus formosus*, *Niphates erecta*, *Callyspongia acuelata*, *Ircinia felix*, *Diplastrella sp*, *Haliclona carerulea*, *Cliona delitrix*, *Pseudomorites mollis*, *Agelas conifera*, *Ectyoplasia ferox*, *Spirastrella coccina*, *Mycale laevis*, *Ploakortis halichondroides*, *Amphimedon viridis*, *Agelas dispar*, *Niphates erecta*, *Cinachyrella kuekenhali*, *Callyspongia plicifera*, *Agelas citrina*, *Topsentia ophiraphidites*, *Ircinia sp*, *Agelas clathrodes*, *Niphates digitalis*.

Group 2

Group 2 is composed of: the quadrats 4, 6, 8 of station POUPONNIERE 3; the quadrats 1, 3, 5, 7, 8 of station ARBRE MORT 3; the quadrats 1, 2, 4 of station ARBRE MORT 1; the quadrats 1, 2, 4, 5, 6 of station LEZARDE 3; the quadrat 1 of station ARBRE MORT 2; of the quadrat 2 of station LEZARDE 1; of the quadrat 3 of station PETITE SIRENE 1; of the quadrats 1, 5, 6 of station PETITE SIRENE 2; of the quadrats 2, 3, 4, 5, 6, 7 of station POUPONNIERE 2; of the quadrat 1 of station CHERRY 3; of the eight quadrats of stations ILET BOISSEAU 1, LEZARDE 2, POUPONNIERE 1 and POINTE MARIN 1.

The characteristic species of this group are: *Iotrochota birotulata*, *Aplysina fistularis*, *Amphimedon compressa*, *Ircinia strobolina*, *Ircinia campana* et *Neofibularia nolitangere*.

Group 3

This group is composed of the quadrats 5 and 8 of EAU 1.

The characteristic species is *Aplysina fulva*.

Group 4

Group 4 is composed of the quadrats 4 and 8 of POINTE MARIN 2 and the

quadrat 3 of ILET A L'EAU 1.

The characteristic species is *Aplysina cauliformis*.

Group 5

Group 5 only includes the square 8 of ILET À L'EAU 1.

The species characteristic of this group is *Aplysina cauliformis*.

5. Discussion

5.1. Abiotic Factor Relations and Statistical Analysis

In general, there is heterogeneity in the distribution of species according to environmental factors across all quadrants (**Figure 6**).

In Group 1, 7 stations have a sand-rock substrate namely POINTE MARIN 1, POINTE MARINE 2, ILET BOISSEAU 1, POUPONNIERE 1, POUPONNIERE 2, POUPONNIÈRE 3, CHERRY 3 and 2 stations have a bedrock of PRECHEUR 1 and LEZARDE 2. The 2 rock stations are inclined horizontally (**Table 2**).

LEZARDE 1, LEZARDE 3, CAP SALOMON 1, CAP SALOMON 2, ARBRE MORT 1, ARBRE MORT 3, CRIQUE ABRICOT 1, PETITE SIRENE 1, PETITE SIRENE 2, and CHERRY 1, CHERRY 2, and ARBRE MORT 2 are the only stations in Group 2 that are covered by a bedrock. The 3 stations with sandy-rocky substrate have a horizontal slope while the other 8 stations with rock substrate have a vertical slope (**Table 2**).

The ILET BOISSEAU 1 station in Group 3 is unique because of its mixed substrate. It is sandy with a sparse presence of small boulders and seagrass (**Table 2**). The transition between a coral reef zone and a seagrass is characterized by this substrate [13].

The statistical analysis distinguishes three groups.

The first group is mainly composed of stations with a sandy-rocky bottom. While the second group is mainly composed of stations with a bedrock.

However, two Group 1 stations have a bedrock, namely LEZARDE 2 and PRECHEUR 1. Indeed, sandy and rocky substrates have lower specific recruitment compared to the bedrock. However, these stations, even if they have a bedrock, both have abiotic factors that can cause a regression of the specific recruitment, namely their degree of inclination. The LEZARDE 2 station is at a reef level but with a low degree of inclination. The relationship between inclination and specific abundance has been made [6]. A vertical slope allows for greater recruitment and therefore higher specific abundance [6]. PRECHEUR 1 is a bedrock with a vertical slope. However, the hydrodynamics of this station are strong. This is a factor that decreases specific abundance [6] [17].

In the second group, characterized by bedrock (reefs and boulders), 3 stations are distinguished, those with a sandy-rocky substrate. These are CHERRY 1, CHERRY 2 and ARBRE MORT 2.

The CHERRY 1 and CHERRY 2 stations are sandy with a small presence of small boulders. It should be noted that these two stations have a similarity rate of about 95% at population level (**Figure 5**). Indeed, CHERRY1 and CHERRY2 have

a low specific abundance and only count *Xestospongia muta* as the species listed on the entire inventory (**Figure 3**). Hence their presence in Group 2 where *Xestospongia muta* is a characteristic species. Aside from the low specific abundance of stations 1 and 2 in Cherry, it is important to note that *Xestospongia muta* is a species capable of colonizing any type of substrate, which explains its presence in these two sand-bottom stations rocky as well as rock-bottom [18].

The ARBRE MORT 2 and LEZARDE 1 stations have a population similarity rate of 74% despite differences in abiotic factors (**Table 2** and **Figure 5**). This high percentage of similarity between these two stations could be explained by the fact that the ARBRE MORT 2 station still has a significant presence of rocks allowing an important specific recruitment.

The nature of the substrate is a predominant abiotic factor in the distribution of marine sponges, particularly in their recruitment. The degree of inclination is also a discriminating factor. Indeed, it is noted that for stations with different types of substrate, the degree of inclination of the bottom becomes the factor allowing a high similarity in their population structure.

5.2. Influence of Bathymetry on Specific Diversity

There is also a small number of species for depths between 2 and 4 m (**Table 1**). The stations concerned are CHERRY 1, CHERRY 2, CHERRY 3, ILET BOISSEAU 1, ILET A L'EAU 1, POINTE MARIN 1 and POINTE MARIN 2. These stations have a maximum of 8 species compared to 19 for the more diverse station LEZARDE 1 (**Figure 3**). This is equivalent to seeing an increase in specific diversity with an increase in bathymetry [19]-[22].

5.3. Influence of Substrate Nature and Stability on Interspecific Competition

Substrate stability can affect specific diversity through its influence on the balance between supply of new spaces by disturbance and the taking over of these surfaces by dominant competitive species [23]-[25]. This balance is a compromise between competitive prowess and the recruitment efficiency of these spaces by species [23]. Our results are aligned with this reflection. The species *Neofibularia nolitangere* (family Desmacellidae), *Aplysina fistularis* (family Niphatidae), *Amphimedon compressa* (family Niphatidae), *Verongula sp* (family Aplysinidae), *Amphimedon viridis* (family Niphatidae) et *Iotrochota birotulata* (family Iotrochotidae) et *Aplysina fulva* (family Aplysinidae) characterize the sandy-rocky bottom stations (**Figure 4**).

The species *Erylus formosus* (family Geodiidae), *Plakortis halichondrioides* (family Plakinidae), *Niphates erecta* (family Niphatidae), *Pseudosuberites mollis* (family Suberitidae), *Agelas clathrodes* (family Agelasidae), *Agelas conifera* (family Agelasidae), *Cliona delitrix* (family Clionidae), *Ectyoplasia ferox* (family Raspalidae), *Topsentia ophiradites* (family Halicondriidae), *Xestospongia muta* (family Petrosiidae), *Ircinia campana* (family Irciniidae), *Niphates digitalis* (fam-

ily Niphatidae), *Agelas dispar* (family Agelasidae), *Ircinia sp* (family Irciniidae), *Cinachyrella kuekenthali* (family Tetillidae), *Depsamma anchorata* (family Desmacididae), *Spirastrella coccina* (family Spirastrellidae), *Callyspongia plicifera* (family Callyspongiidae) et *Mycale laevis* (family Mycalidae) characterize rocky substrates and reefs (Figure 4).

There are 7 sponge species, with 4 families belonging to sandy-rocky bottoms, whereas 20 species, with 15 families belonging to bedrock. This result shows a high specific diversity in the bedrock. Therefore, stations with an unstable substrate (Table 2) show less specific recruitment, while stations with a stable substrate (Table 2) are the site of interspecific competition for the occupation of these spaces. It should also be noted that these spaces are subject to interspecific competition from non-spongy benthic communities such as corals, gorgonians, algae and other colonial invertebrates [13] [26]-[29].

6. Conclusion

This study has allowed us to know the specific distribution of marine sponges in different habitats. It is a key to understanding the population structures of sponges in Martinique. It demonstrates the impact of substrate nature, hydrodynamics and degree of substrate inclination on the distribution of these communities. We found a higher specific richness for stations with a rock and stable substrate. This also reflects an important interspecific competition in the context of colonization of spaces. It would be interesting to study the biochemical responses, which are the lever of this competition. Marine sponges are also capable of allelopathy, which is the release into the environment of active biomolecules sought in the therapeutic field (anticancer, antibacterial, antifouling) [30] [31] [32].

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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