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Research Article

Diversity and Extent of Coastal Submerged Aquatic Vegetation in an Unexplored Coastal Upwelling Region of the Caribbean Sea

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Abstract

The Tropical North Western Atlantic (aka the wider Caribbean) is a large marine ecoregion with patterns of marine species' diversity that both need elucidation and protection. The wider Caribbean is facing rapid changes associated with anthropogenic activities of coastal alteration, pollution loading and weather patterns, with losses of biodiversity expected. Submerged Aquatic Vegetation (SAV) is a key component of marine communities adding both structural complexity and species diversity to the wider Caribbean. This study aimed to examine SAV species assemblages and their extent at a unique coastal ecosystem in the Southern Caribbean Sea. This ecosystem remains unexplored for its nearshore marine biodiversity due to its remoteness and harsh environmental conditions. The study took place at ten survey sites in shallow nearshore waters of northeastern La Guajira peninsula of Colombia. SAV specimens were manually collected at depths up to 4 meters along the coast and determined to the species level using taxonomic keys. Mixed seagrass-macroalgae SAV communities were observed along the study area, and the species richness was high (116 species) considering the sapling effort was low. Twenty-eight species of macroalgae found here were not known to occur in Colombia. SAV communities were dominated by macroalgae at several survey sites, particularly by rhodophytes, thus, these communities seem to differ from those on areas to the west of the peninsula where seagrasses are dominant. The new macroalgae species occurrences and the diverse SAV assemblages found in this study contribute new knowledge on the biodiversity of an unknown upwelling-associated coastal ecosystem in the Wider Caribbean. Further ecological studies of the area are recommended as it could be a reservoir or hotspot for marine plant biodiversity in the wider Caribbean with low anthropogenic disturbance.

Keywords: Benthic Macroalgae; Biological Diversity; Coastal Upwelling; Colombia; *Gracilaria* spp.; La Guajira

Introduction

Submerged Aquatic Vegetation (SAV) includes seagrasses and macroalgae (seaweeds) forming extensive and diverse benthic communities critical to marine ecosystem production and nutrient cycling [1,2]. SAV communities are dynamic, responding to changes in water quality as well as playing key ecological roles in the trophic structure and secondary production of nearshore ecosystems [3,4]. SAV species assemblages are used as predictors of ecosystem health and changes in hydrology or nutrient input [5-6]. SAV communities can be adversely impacted by eutrophication and lose diversity, as primary production moves to the water column via phytoplankton blooms [7-8]. Diverse assemblages of SAV provide forage and refuge resources to a diverse number of organisms in the food network (e.g. crustaceans, sea turtles, manatees) [9]. Diversity of forage resources and structural complexity are well known determinants of biodiversity in marine ecosystems [10,11]. The Caribbean ecoregion of the Tropical North Western Atlantic (TNWA) province is considered a hotspot of marine biological diversity [12,13]. The ecoregion extends over 13500 km of coastline surrounding the warm (22-29°C) waters of the Caribbean Sea. The region's physical environment has a profound influence on the organization and patterns of marine species [14,15]. The Caribbean Sea is generally oligotrophic (nutrient concentration < 10 μM), yet, areas with coastal upwelling are enriched with nutrients coming from deeper cool ocean waters (nitrogen and phosphorus > 50 μM). Upwelling areas of the Caribbean are highly dynamic with wind driven intensity and extent; and have been characterized as having the lowest seasonal temperature maximum, and relatively lower disturbance regimes from both chronic and acute physical disturbance regimes [15]. The Southern Caribbean Upwelling System (SCUS) off of the Northeastern Colombia [16] and the northeastern Venezuela [17] fuels a very productive marine ecosystem in the wider Caribbean, which biodiversity is not well known. In La Guajira peninsula of Colombia, upwelling events support a productive fishery [16-18]. However, towards the eastern side of the peninsula, studies of coastal marine ecosystems are scarce. The high winds and dessert-like weather conditions, as well as the remoteness of the area, have prevented ecological and biodiversity studies [18]. Basic species inventories of key coastal ecosystems such as the ones in La Guajira, Colombia, are important baseline data for change detection and coastal management prioritization in the wider Caribbean [13]. Species diversity assessments can identify areas of high endemism, taxonomic uniqueness, species richness, or even the threat of pathogens [19,20]. SAV assemblages can constitute unique habitat resource for a diversity of marine invertebrates, fishes and marine turtles [21-23]. Understanding naturally diverse SAV species assemblages is one aspect of understanding the Caribbean region biodiversity patterns and changes in species assemblages with anthropogenic threats. This study seeks to look at SAV species richness around the peninsula of La Guajira in an effort to understand patterns of coastal biodiversity at Caribbean upwelling ecosystems. The harsh environmental conditions in the eastern side of the peninsula have limited anthropogenic conversion and degradation of its coastal ecosystems, and thus, marine biodiversity may have been less impacted in eastern La Guajira compared to other coastal areas of the Caribbean. The survey was designed to characterize species diversity and geographic extent of SAV communities of eastern La Guajira; the western side of the peninsula has been more studied and described in terms of coastal ecosystems including SAV communities biodiversity [24,25]. In the eastern side fewer seagrass meadows, and larger areas of mixed macroalgae with no reference to the species composition have been reported [18]. This study intended to combine a classification of the coastal system with an inventory of conspicuous benthic macroalgae species, using taxonomic keys and the coastal marine and estuarine classification standard CMECS [26]. This hierarchical classification standard has universal applicability because of its flexible lexicon and the possibility of using multiple aspects of habitat, like substrate type or biotic components, as modifiers when classifying a complex or new habitat. The standard has been extensively used in the United States and the Greater Caribbean [27-29].

Materials and Methods

The study took place at the northeastern side of La Guajira peninsula, in the Uribia municipality of Colombia, a region called Upper Guajira. The region is characterized by a hot, semi-arid climate and warm seawater temperature (mean 25.1-26.3˚C). Water temperature is cooler than average for the Caribbean Sea (27˚C), due to the annual, moderate coastal upwelling experienced. Upper Guajira has a shallow, relatively wide, well-developed continental shelf of carbonated sediments, with soft (sandy and muddy) bottoms, which favor the establishment of submerged aquatic vegetation. The shallow shelf, fine bottoms and coastal upwelling cause the waters in the area to be highly turbid. Tides are mixed, semidiurnal microtides of 0.3m average amplitude.

Submerged Aquatic Vegetation (SAV) Surveys

Ten study sites were surveyed for SAV species and characterized in their coastal geomorphology, shore line type, and marine benthic substrate in year 2016 (Figure 1, Table 1). Sites were located at either of two distinct regions: a) Bahia Hondita region in the northern peninsula, which is a shallow hypersaline lagoon surrounded by mangrove forests with an ocean embayment at its mouth (Sites 1, 2 and 3) and b) Eastern Guajira region, which extended from Masichii Beach to Jiwotpolu Beach (Sites 4 through 10). In this region there is a variety of coastal types, including sandy beaches, cliffs and rocky shores. Each site was surveyed for coastal type by visual observation; basic water quality characteristics (Temperature, Salinity, Dissolved Oxygen) were measured via hand-held multi-probe (Model 85, YSI incorporated, OH, USA); and the species composition of SAV communities was determined. Surveys of SAV were carried out in the nearshore intertidal and subtidal zones of the ten study sites. SAV samples were collected over a period of forty-five minutes, by two surveyors. Each sampling site was surveyed only once. At each site, collectors sampled SAV manually and randomly, within an area not larger than 10m x10m, at shallow depths (from 0m -on the sand- to 4m deep, depending on the coastal geomorphology of the site). At low relieve rocky shores with some accessibility, SAV surveys were performed by sampling from intertidal rocks at very low depths (e.g. Puerto Chimare). Accessible sandy beaches such as sites Neimao and Jiwotpolu were sampled both in the subtidal and intertidal areas up to 2m deep. High relief, low accessibility rocky shores were accessed by motor boat and samples were collected by free diving at 2-4 m depth (e.g. in Patsualoru, Palei). After collection, SAV samples were held in seawater until laboratory sorting, and identified to the lowest taxonomic level possible using dichotomous classification guides [30]. Due to the exploratory nature of this research, new species records were expected, therefore, SAV species found here were searched in national and international plant and/or biodiversity databases that contain herbarium and museum collections information including the SIAM (Sistema de Información Ambiental Marina) (Invemar, available at: http://siam.invemar.org.co) and SIB (Sistema de Información Biológica de Colombia (Instituto Alexander von Humboldt, available at: https://sibcolombia.net/) databases in Colombia, and iOBIS system (Ocean Biogeographic Information System, available at: http://iobis.org/) for international records.

Records in published literature [31] were also revised. Species for which no occurrence records either in La Guajira or Colombia were found in these databases or the literature were considered new occurrences.

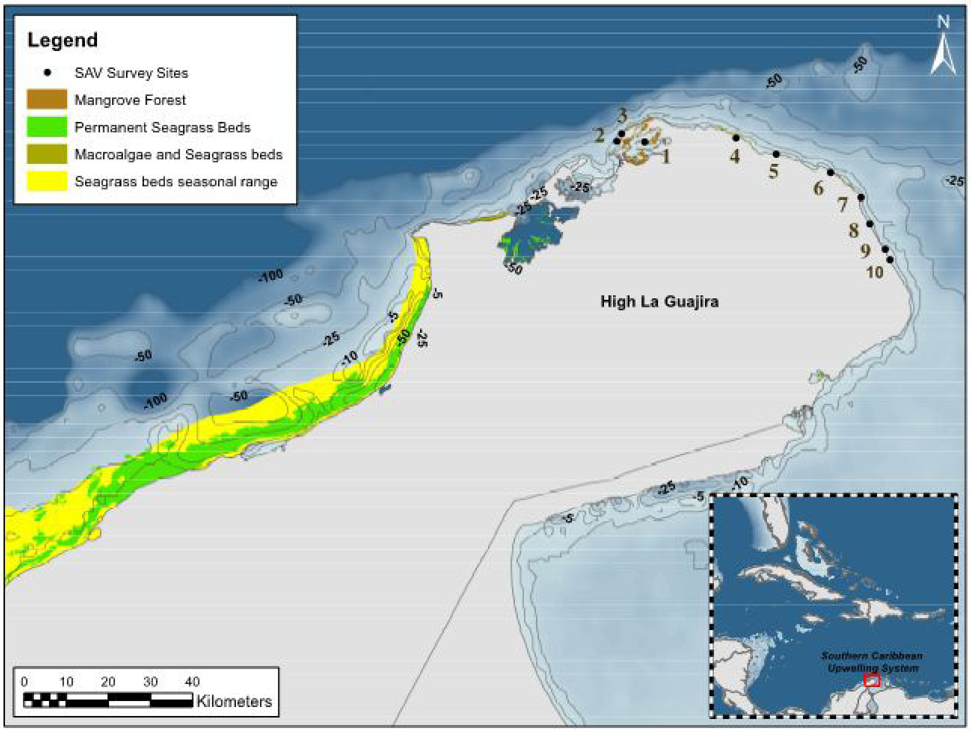

Figure 1: Location of the study area in northeastern La Guajira peninsula in the Caribbean Sea. The map displays the distribution of mangrove forests and types of submerged aquatic vegetation in yellow and green color codes and the location of SAV survey sites (See Table 1 for site descriptions).

SITE NAME	LAT N LON W	SHORE-LINE AZIMUTH (degrees)	WAVE EXPOSURE	COASTAL GEOMORPHOLOGY	SHORE TYPE	MARINE SUBSTRATE
1. Bahia Hondita	12.4096 71.685	240	Low	Narrow mouth, shallow (<5m depth) hypersaline lagoon with input from dry arroyos	Mangrove-dominated with intermixed pocket beaches	Vegetated and unvegetated sandy mud
2. Palei	12.4271 71.7348	60	Medium	Exposed rocky headland	Rocky shore with high relief Cliffs (> 5 meters)	Unvegetated and vegetated muddy sand with boulders
3. Patsualoru	12.4108 71.7451	30	Medium	Coastal embayment with protected rocky shore	Rocky shore with high relief Cliffs (> 5 meters)	Vegetated and unvegetated muddy sand
4. Masichii	12.4179 71.4899	100	Medium	Exposed sandy beach with back dunes	Sandy Beach - Unvegetated	Vegetated muddy sand with cobble and boulders,
5. Puerto Chimare	12.3835 71.4047	110	Medium	Exposed rocky shore with high relief cliffs	Rocky shore with high relief Cliffs (> 5 meters)	Vegetated muddy sand with small cobble islands and boulders

6. Neimao	12.3451 71.2882	140	High	Exposed beach with blocked river mouth, backdune with hypersaline wetlands associated with dried river beds	Sandy Beach - Unvegetated	Vegetated and unvegetated muddy sand with Cobble and Boulders
7. Punta Negra	12.2925 71.2239	170	High	Exposed, large, rocky headland with high relief cliffs	Rocky shore with high relief Cliffs (> 5 meters)	Large boulders in the intertidal zone; bottom was not explored
8. Wannal	12.2372 71.205	160	High	Exposed, Long, wide beach with blocked river mouth, backdune wetlands	Sandy beach - Unvegetated	Vegetated muddy sand with Cobbles and Boulders
9. Puerto Santa Cruz	12.1836 71.1716	170	High	Exposed elongated beach with blocked river mouth, backdune wetlands	Sandy Beach - Unvegetated	Vegetated sand with areas of Cobble and Boulders and unvegetated Sand Rubble
10. Jiwotpolu	12.1615 71.1615	170	High	Exposed beach with blocked river mouth, backdune wetlands	Sandy Beach - Unvegetated	Vegetated and unvegetated sand and rubbled sand with Cobbles and Boulders

Table 1: Description of Survey Sites in La Guajira following standard classification systems (CMECS). Sites are shown in Figure 1.

SAV Diversity and Extent Estimates

The presence-absence of SAV species per survey site data was used in non-parametric statistics to calculate species richness per survey site, and to make comparisons of species richness among surveyed sites. The total species count was calculated as the species richness (*S*). Common biodiversity estimators such as Shannon index could not be calculated due to the lack of data on species abundances (number of individuals per species recorded). Species abundances could not be recorded due to high water turbidity in the study area. Instead, in order to compare SAV *S* among survey sites, the Jaccard dissimilarity index was employed. This index was used in a non-metric multidimensional ordination to produce MDS plots using *Gracilaria* spp. presence-absence patterns because this group was the most common and diverse, facilitating comparison among all the surveyed areas [32], using software Primer 7.0 [33]. The Jaccard dissimilarities between sites were compared to a geographic Euclidean distance matrix using the Mantel test in the Vegan package of R to see if closer areas were more similar in species composition than areas farther apart [34].

Results

Diversity of Submerged Aquatic Vegetation of Northeastern La Guajira

A total of 116 SAV species were observed in northeastern La Guajira peninsula, Colombia, the majority of which (113 species) were macroalgae (polyphyletic group including Plantae: Chlorophyta and Rhodophyta, and Phaeophyceae) and only three species were seagrasses (Plantae: Tracheophyta) (Appendix 1). The species rarefaction curve suggests that the number of SAV species in the study area remains to increase with additional survey effort (Figure 2). Of the total macroalgae species found in the coasts of northeastern Guajira, the rhodophytes were the most common group with more than half of the species (57%), followed by the chlorophytes (27%) and the phaeophytes (16%) (Figure 3). The rhodophytes comprised eighteen families present, the most common of which were Rhodomelaceae (fifteen spp.), Gracilariaceae (eleven spp.) and Corallinaceae (ten spp.). The Chlorophytes were represented in the area by ten families, the most abundant in number of species were Ulvaceae (nine spp.)

followed by the Cladophoraceae and the Caulerpaceae with six species each (Figure 2). The phaeophytes were represented only by two families, the common Dictyotaceae (twelve spp.) and Sargassaceae (six spp.). Fifty of the 113 species of macroalgae recorded during this survey study had not been reported before for La Guajira region of Colombia (Table 2). Additionally, twenty-eight species of macroalgae from all three main groups had not been reported in Colombian waters previously according to the national and international databases search results. These species are typically found in coastal waters of the Caribbean Sea and included five species of chlorophytes, five species of phaeophytes and eighteen species of rhodophytes (Table 2).

Group	Class	Family	Genera	Species
Chlorophyta	Ulvophyceae	Anadyomenaceae	*Anadyomene*	*Anadyomene stellata*
Chlorophyta	Ulvophyceae	Bryopsidaceae	*Bryopsis*	*Bryopsis plumosa*
Chlorophyta	**Ulvophyceae**	**Cladophoraceae**	***Chaetomorpha***	***Chaetomorpha aerea***
Chlorophyta	Ulvophyceae	Cladophoraceae	*Cladophora*	*Cladophora catenata*
Chlorophyta	**Ulvophyceae**	**Cladophoraceae**	***Cladophora***	***Cladophora liniformis***
Chlorophyta	Ulvophyceae	Dichotomosiphonaceae	*Avrainvillea*	*Avrainvillea nigricans*
Chlorophyta	**Ulvophyceae**	**Halimedaceae**	***Halimeda***	***Halimeda scabra***
Chlorophyta	Ulvophyceae	Ulvaceae	*Enteromorpha*	*Enteromorpha flexuosa*
Chlorophyta	Ulvophyceae	Ulvaceae	*Enteromorpha*	*Enteromorpha flexuosa* subsp. *paradoxa*
Chlorophyta	Ulvophyceae	Ulvaceae	*Enteromorpha*	*Enteromorpha intestinalis*
Chlorophyta	**Ulvophyceae**	**Ulvaceae**	***Enteromorpha***	***Enteromorpha prolifera***
Chlorophyta	**Palmophyllophyceae**	**Palmophyllaceae**	***Verdigellas***	***Verdigellas fimbriata***
Phaeophyta	**Phaeophyceae**	**Dictyotaceae**	***Dictyopteris***	***Dictyopteris jolyana***
Phaeophyta	**Phaeophyceae**	**Dictyotaceae**	***Dictyopteris***	***Dictyopteris justii***
Phaeophyta	Phaeophyceae	Dictyotaceae	*Dictyota*	*Dictyota humifusa*
Phaeophyta	**Phaeophyceae**	**Dictyotaceae**	***Padina***	***Padina profunda***
Phaeophyta	Phaeophyceae	Dictyotaceae	*Stypopodium*	*Stypopodium zonale*
Phaeophyta	**Phaeophyceae**	**Sargassaceae**	***Sargassum***	***Sargassum platycarpum***
Phaeophyta	**Phaeophyceae**	**Sargassaceae**	***Sargassum***	***Sargassum pteropleuron***
Phaeophyta	Phaeophyceae	Sargassaceae	*Turbinaria*	*Turbinaria tricostata*
Rhodophyta	Florideophyceae	Ceramiaceae	*Centroceras*	*Centroceras clavulatum*
Rhodophyta	**Florideophyceae**	**Champiaceae**	***Champia***	***Champia salicornioides***
Rhodophyta	**Florideophyceae**	**Champiaceae**	***Champia***	***Champia vieillardii***
Rhodophyta	**Florideophyceae**	**Corallinaceae**	***Haliptilon***	***Haliptilon cubense***
Rhodophyta	Florideophyceae	Corallinaceae	*Haliptilon*	*Haliptilon subulatum*
Rhodophyta	**Florideophyceae**	**Corallinaceae**	***Jania***	***Jania pumila***
Rhodophyta	Florideophyceae	Corallinaceae	*Mesophyllum*	*Mesophyllum mesomorphum*
Rhodophyta	**Florideophyceae**	**Corallinaceae**	***Porolithon***	***Porolithon pachydermum***
Rhodophyta	**Florideophyceae**	**Corallinaceae**	***Titanoderma***	***Titanoderma pusttulatum***
Rhodophyta	Florideophyceae	Cystocloniaceae	*Hypnea*	*Hypnea valentiae*

Rhodophyta	**Florideophyceae**	**Dasyaceae**	***Dasya***	***Dasya ocellata***
Rhodophyta	**Florideophyceae**	**Dasyaceae**	***Dasya***	***Dasya spinuligera***
Rhodophyta	Florideophyceae	Galaxauraceae	*Wrangelia*	*Wrangelia bicuspidata*
Rhodophyta	**Florideophyceae**	**Gracilariaceae**	***Gracilaria***	***Gracilaria curtissae***
Rhodophyta	Florideophyceae	Gracilariaceae	*Gracilaria*	*Gracilaria damaecornis*
Rhodophyta	Florideophyceae	Gracilariaceae	*Gracilaria*	*Gracilaria tikvahiae*
Rhodophyta	**Florideophyceae**	**Hymenocladiaceae**	***Asteromenia***	***Asteromenia peltata***
Rhodophyta	**Florideophyceae**	**Kallymeniaceae**	***Kallymenia***	***Kallymenia cribogloea***
Rhodophyta	Florideophyceae	Lomentariaceae	*Gelidiopsis*	*Gelidiopsis planicaulis*
Rhodophyta	Florideophyceae	Rhodomelaceae	*Acanthophora*	*Acanthophora muscoides*
Rhodophyta	Florideophyceae	Rhodomelaceae	*Bostrychia*	*Bostrychia montagnei*
Rhodophyta	**Florideophyceae**	**Rhodomelaceae**	***Bostrychia***	***Bostrychia tenella***
Rhodophyta	**Florideophyceae**	**Rhodomelaceae**	***Chondria***	***Chondria capillaris***
Rhodophyta	**Florideophyceae**	**Rhodomelaceae**	***Chondria***	***Chondria cnicophylla***
Rhodophyta	**Florideophyceae**	**Rhodomelaceae**	***Chondria***	***Chondria floridana***
Rhodophyta	**Florideophyceae**	**Rhodomelaceae**	***Laurencia***	***Laurencia iridescens***
Rhodophyta	Florideophyceae	Rhodomelaceae	*Laurencia*	*Laurencia gemmifera*
Rhodophyta	Florideophyceae	Rhodomelaceae	*Wrightiella*	*Wrightiella blodgettii*
Rhodophyta	**Florideophyceae**	**Rhodymeniaceae**	***Rhodymenia***	***Rhodymenia divaricata***
Rhodophyta	**Florideophyceae**	**Solieriaceae**	***Agardhiella***	***Agardhiella ramosissima***
Rhodophyta	**Florideophyceae**	**Sporolithaceae**	***Sporolithon***	***Sporolithon episporum***

Table 2: Species list of macroalgae found in eastern La Guajira, Colombia in 2016 that had not been reported to occur in La Guajira's waters previously. Species highlighted in gray had not been reported in Colombian waters previously.

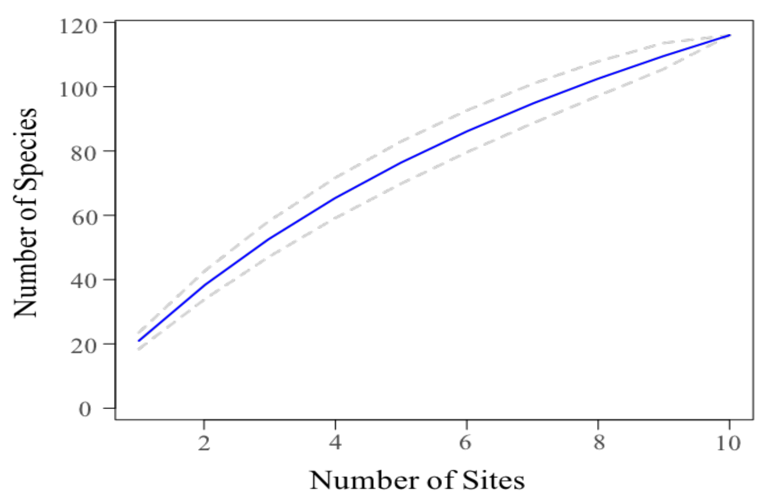

Figure 2: Species rarefaction curve of the expected number of SAV species with the number of survey sites.

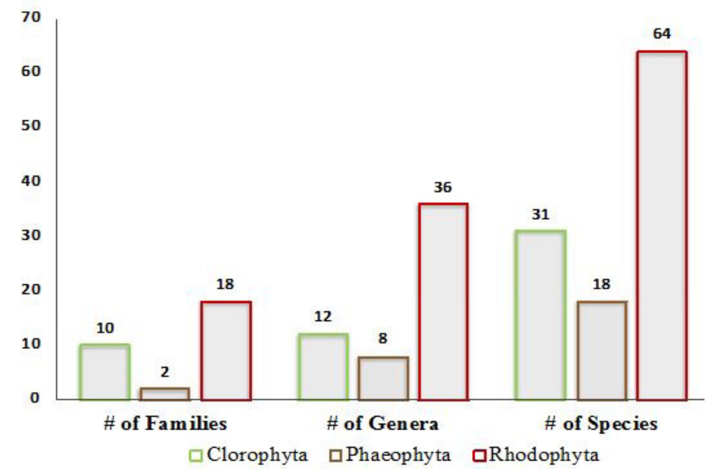

Figure 3: Number of species, genera and families of macroalgae species found in Northeastern La Guajira, Colombia.

Extent of Submerged Aquatic Vegetation in Eastern La Guajira

All surveyed sites in the study area had both macroalgae species and seagrasses except for Playa Jiwotpolu in which no seagrasses were observed (Appendix 1). Bahia Hondita region sites differed in the species composition from the eastern region. Bahia Hondita had SAV species that where not found on the eastern region, including *Codium* sp., *Ceramium* sp.*, Dasya ocellata, Heterosiphonia gibbeseii* and *Halodule wrightii*, whereas several species present on the eastern side were not found on Bahia Hondia region (*e.g. Bryopsis hypnoides, Chaetomorpha linum, Lobophora variegate, Spatoglossum schroederi, Gracilaria cervicornis, Gracilaria mammillaris, Osmundaria obtusiloba, Sporolithon episporum*) (Appendix 1). The sites with the highest species richness were the rocky shore of Puerto Chimare ($S = 49$), and three sandy beaches located to the south named Puerto Santa Cruz ($S = 37$), Neimao and Wannal beaches ($S = 29$, each) (Table 2). Bahia Hondita had a moderate species richness ($S = 26$). The species dissimilarity among survey sites did not correspond with the Euclidean distance separating them (Mantel test, *NS*). Over half of the species (fifty-five) occurred only at one survey site, and only ten species were shared or common among sites, meaning that these species were present at least at four of the ten survey sites. Common species include *Caulerpa* sp., *Chaetomorpa* sp., *Gracilaria* spp., *Hypnea* sp., *Sargassum* sp. and seagrass, *Thalassia testudinum.* The most common SAV were the seagrass *T. testudinum* and the macroalgae *G. dominguensis*; they were present at nine and eight sites of the ten surveyed sites respectively. In fact, *Gracilaria* genus was the most common in number of species (ten spp.) and number of sites present, thus this group significantly contributed to the observed similarities in species diversity among sites. The MDS plot using *Gracilaria* spp. illustrates the complexity of the diversity patterns of SAV in the study area (Figure 2). The SAV species assemblages are dissimilar among sites, with only three sites about 40% similar (the sandy beaches of Neimao-Site 6, Wannal-Site 8, and Puerto Santa Cruz-Site 9). The MDS plot shows the first three sites are largely outliers (Bahia Hondita region, Sites 1, 2 and 3). Indicating that the Bahia Hondita region differs from SAV species assemblages in comparison with the eastern region.

Site Number	Survey Site	*S*
1	Bahia Hondita	26
2	Patsualoru	4
3	Palei	11
4	Masichii	15
5	Puerto Chimare	49
6	Neimao	29
7	Punta Negra	6
8	Wannal	29
9	Puerto Santa Cruz	37
10	Playa Jiwotpolu	22

Table 3: Species richness and diversity indexes at ten sampling sites in La Guajira peninsula, Colombia, during 2016. *S* = Number of SAV species or Species richness.

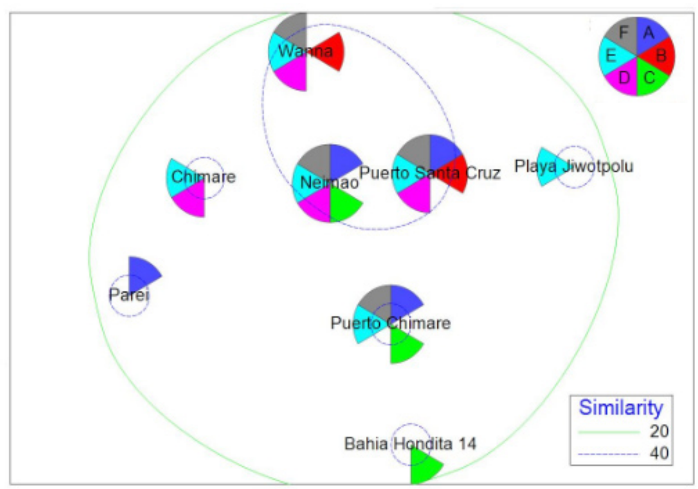

Figure 4: Multi-Dimensional scaling (MDS) for SAV surveyed sites in La Guajira using Bray-Curtis similarity, based on the presence-absence of rhodophytes of the genus *Gracilaria* sp. Species are letter-coded as follows: A. *Gracilaria caudata,* B. *Gracilaria curtissae,* C. *Gracilaria cylindrica,* D. *Gracilaria damaecornis,* E. *Gracilaria dominguensis,* F. *Gracilaria mammillaris*.

Discussion

The assessment of the nearshore SAV diversity at northeastern La Guajira peninsula suggests geographically extensive and species-rich, macroalgae-dominated, nearshore SAV communities, which differ from the monospecific and/or seagrass dominated SAV communities observed in other areas such as western La Guajira peninsula [18,25]. An inventory of intertidal and subtidal SAV species was compiled with almost thirty species not previously reported for Colombia. This lack of previous information on the species presence in Eastern Guajira's waters, reflects the difficulty of conducting field studies in this highly remote, arid area of Colombia, Southern Caribbean Sea. All the species recorded in this study have been previously reported in Caribbean waters in the literature [29]. However, several species recorded in the intertidal zone to 3 meters deep in this survey, are typically found at greater depths, from 10 to 30 meters in other areas of the wider Caribbean [29]. Coastal SAV communities are likely to be limited on their sea ward extent by bathymetry and lack of light. The high turbidity of upwelled waters and sandy-mud bottoms of eastern La Guajira may favor the growth of deeper macroalgae species in shallower areas. However, it is possible that the high energy and waves bring SAV specimens from deeper waters onto the intertidal zone, where some of the surveys took place, thus those species were included in this study. Species-rich SAV communities in eastern La Guajira are dominated by macroalgae and seem to extend widely along the coast, at least from Puerto Chimare to Neimao, and then from sandy beaches in Wannal to Puerto Santa Cruz. However, the oceanic extent of these communities was not assessed in this study due to the high water turbidity and energy. Further seawards studies of SAV communities are required in order to fully assess the species biodiversity of La Guajira's nearshore ecosystems. Regionally, western La Guajira, including Bahia Hondita (Sites 1, 2 and 3), is characterized by a broader continental platform and sandy substrates. Seagrass communities have previously been mapped and described for this environment [18]. Instead, eastern Guajira region (Sites 4 through 10) has a steeped continental platform, high energy shorelines, and finer substrates offshore (e.g. muddy sands and sandy muds) with embedded rocks and boulders (Table 1). SAV macroalgae were dominant in this region and were observed very close to shore forming species-rich communities often attached to rock's surfaces and often mixed with patches of seagrasses. The overall high richness of SAV species, and the differentiation among survey sites could partially be attributed to the diversity of nutrients made available through the coastal upwelling of the SCUS system [35]. This nutrient supply, which is unique in the Caribbean Sea, contributes to the growth of vegetation forms with differing nutritional requirements in the nearshore benthos [36]. Anecdotally, the biomass of macroalgae in several surveyed sites was large. For multiple species, leaves were longer than published records. Vertebrate fauna was observed in association with studied nearshore macroalgae communities including juvenile sharks and juvenile green sea turtles (*Chelonia mydas*). Macroalgae, especially of rhodophytes like *Gracilaria sp.*, are common diet items for the macro-herbivore *C. mydas* [23,37-39]. The structural complexity and diversity of marine plants in eastern La Guajira may be providing key nursing habitat for marine taxa in the wider Caribbean. Further characterizations of the unique SAV communities at higher depths and different seasons in the study area would provide insight into the dynamics and productivity of Guajira's ecosystem and even the SCUS system. Further studies can confirm whether the study area is an outstanding macroalgae diversity spot within the Tropical Northwestern Atlantic [40,41].

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Conflict of Interest

The authors of this manuscript confirm that there are no known competing interests associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed.

	Palei	Patsualoru	Bahia Hondita	Masichii	Neimao	Punta Negra	Wannal	Puerto Chimare	Puerto Santa Cruz	Playa Jiwotpolu
Anadyomene stellata	0	0	1	0	0	0	0	0	0	0
Avrainvillea nigricans	0	0	0	0	1	0	0	0	0	0
Bryopsis hypnoides	0	0	0	0	0	0	1	1	1	0
Bryopsis pennata	1	0	0	0	0	0	0	0	1	0
Bryopsis plumosa	0	0	0	0	0	0	0	0	1	0
Caulerpa mexicana	0	0	0	0	0	0	1	1	0	0
Caulerpa prolifera	0	0	0	0	1	0	1	1	1	0
Caulerpa racemosa	0	0	1	0	0	0	0	0	0	0
Caulerpa racemosa var. lamourouxii	0	0	0	0	0	0	1	0	0	0
Caulerpa sertularoides f. farlowii	0	0	0	0	0	0	1	0	1	0
Caulerpa taxifolia	0	0	1	0	0	0	0	0	0	0
Chaetomorpha aerea	0	0	1	0	0	0	0	0	0	1
Chaetomorpha antennina	0	0	0	0	0	0	0	1	0	0
Chaetomorpha linum	0	0	0	0	1	0	1	1	1	1
Cladophora catenata	0	0	0	0	0	0	0	1	1	0
Cladophora liniformis	0	0	0	0	0	0	0	0	1	0
Cladophora prolifera	0	0	0	0	1	0	0	1	0	0
Cladophoropsis membranaceae	0	0	0	0	0	0	0	1	0	0
Codium sp.	0	0	1	0	0	0	0	0	0	0
Codium repens	0	0	1	0	0	0	0	0	0	0
Enteromorpha flexuosa	0	0	0	0	0	0	0	0	0	1
Enteromorpha flexuosa subsp. *paradoxa*	0	0	0	0	1	0	0	0	0	0
Enteromorpha intestinalis	0	0	0	0	1	0	0	0	0	0
Enteromorpha lingulata	1	0	0	0	0	0	0	0	0	0
Enteromorpha prolifera	0	0	0	0	0	0	1	0	0	0
Halimeda scabra	1	1	0	0	0	0	0	0	0	0
Udotea unistrarea	0	0	0	0	1	0	0	0	0	0
Ulva fasciata	0	0	0	0	0	0	1	1	0	0
Ulva lactuca	0	0	1	0	1	0	0	1	1	0
Ulva oxysperma	0	0	1	0	0	0	0	0	0	0
Verdigellas fimbriata	0	0	0	0	0	0	0	1	0	0
Dictyopteris jamaicensis	0	0	0	0	0	0	0	0	1	0
Dictyopteris jolyana	0	0	0	0	0	0	1	0	1	1
Dictyopteris justii	0	0	1	0	0	0	0	0	0	0
Dictyopteris plagiogramma	0	0	0	0	0	0	0	1	0	0

Dictyota caribaea	0	0	0	0	0	0	0	1	0	0
Dictyota cervicornis	0	0	1	0	0	0	0	1	0	0
Dictyota crenulata	0	0	0	0	0	0	0	1	0	0
Dictyota humifusa	0	0	0	0	0	0	0	1	0	0
Lobophora variegata	0	0	0	0	1	0	1	0	1	0
Padina profunda	0	0	0	0	0	0	0	0	1	0
Sargassum filipendula	0	0	0	0	0	0	1	0	0	0
Sargassum platycarpum	0	0	1	0	0	1	0	1	1	1
Sargassum polyceratium	0	0	0	0	0	0	1	0	0	0
Sargassum pteropleuron	0	0	0	0	0	0	0	0	1	1
Sargassum vulgare	0	0	0	0	0	0	0	1	0	1
Spatoglossum schroederi	0	0	0	0	1	0	1	0	1	0
Stypopodium zonale	0	0	1	0	0	0	0	0	0	1
Turbinaria tricostata	0	0	0	0	0	1	0	0	0	0
Acanthophora muscoides	0	0	0	0	0	0	0	0	0	1
Acanthophora spicifera	0	0	0	1	0	0	0	0	0	0
Agardhiella ramosissima	0	0	0	0	0	0	0	1	0	0
Amphiroa rigida	0	1	0	0	0	0	0	0	0	0
Asteromenia peltata	0	0	0	0	0	0	0	1	0	0
Bostrychia montagnei	0	0	0	0	0	0	0	1	0	0
Bostrychia tenella	0	0	0	0	0	0	1	0	0	0
Bryothamnion triquetrum	1	0	0	1	0	0	1	0	0	1
Centroceras clavulatum	0	0	0	0	0	0	0	1	1	0
Ceramium cruciatum	0	0	0	0	1	0	0	1	0	0
Ceramium sp.	0	0	1	0	0	0	0	0	0	0
Champia parbula	0	0	0	0	0	0	0	1	0	0
Champia salicornioides	0	0	0	0	0	0	0	1	0	0
Champia vieillardii	0	0	0	0	0	0	0	1	0	0
Chondria capillaris	0	0	0	0	1	0	0	0	1	0
Chondria cnicophylla	0	0	0	0	1	0	0	0	0	0
Chondria floridana	0	0	0	0	0	0	0	1	0	0
Cryptonemia seminervis	1	0	0	1	0	0	1	0	0	0
Dasya baillouviana	0	0	0	0	1	0	0	0	0	0
Dasya ocellata	0	0	1	0	0	0	0	0	0	0
Dasya spinuligera	0	0	0	0	0	0	0	1	0	0
Galaxaura marginata	0	0	0	0	0	0	0	1	0	0
Gelidiella acerosa	0	0	0	0	0	0	0	1	1	1
Gelidiopsis planicaulis	0	0	0	0	0	0	0	0	1	0
Gracilaria blodgetti	0	0	0	1	0	0	0	0	0	0
Gracilaria caudata	1	0	0	0	1	0	0	1	1	0

Gracilaria cervicornis	0	0	0	0	1	0	1	0	1	0
Gracilaria cuneata	0	0	0	0	0	0	0	0	0	1
Gracilaria curtissae	0	0	0	0	0	0	1	0	1	0
Gracilaria cylindrica	0	0	1	0	1	0	0	1	0	0
Gracilaria damaecornis	0	0	0	1	1	0	1	0	1	0
Gracilaria domingensis	0	1	0	1	1	0	1	1	1	1
Gracilaria mammillaris	0	0	0	0	1	0	1	1	1	0
Gracilaria sp.	0	0	1	0	0	0	0	0	0	1
Gracilaria tikvahiae	0	0	1	1	1	0	0	1	1	0
Haliptilon cubense	1	0	0	0	0	0	1	0	1	0
Haliptilon subulatum	0	0	0	0	0	0	0	0	1	1
Heterosiphonia gibbeseii	0	0	1	0	0	0	0	0	0	0
Hydrolithon boergesenii	0	0	0	0	1	0	1	0	0	1
Hypnea musciformes	0	0	1	1	0	0	1	1	1	0
Hypnea spinella	1	0	1	1	1	0	0	1	1	1
Hypnea valentiae	0	0	0	0	0	0	0	1	0	0
Jania pumila	0	0	0	0	0	0	1	0	0	0
Jania rubens	0	0	0	0	0	0	0	1	0	0
Kallymenia sp.	0	0	0	0	0	0	0	0	0	1
Kallymenia criboglaca	1	0	0	0	0	0	0	1	0	0
Laurencia (Chondrophycus) iridescens	0	0	0	0	0	0	0	1	0	0
Laurencia gemmifera	0	0	0	1	0	0	0	1	0	0
Laurencia intricata	0	0	1	1	0	0	0	1	0	0
Laurencia obtusa	0	0	0	0	0	0	0	1	0	0
Laurencia poiteaui	0	0	1	0	0	0	0	0	1	1
Meristiella schrammii	0	0	0	0	0	0	0	1	0	0
Mesophyllum mesomorphum	0	0	0	0	0	1	1	0	0	0
Neogoniolithon spectabile	0	0	1	0	0	0	0	0	0	0
Osmundaria obtusiloba	0	0	0	0	0	0	1	1	0	1
Peysonellia sp.	0	0	0	0	0	0	0	0	0	1
Porolithon pachydermum	0	0	0	0	0	1	0	0	0	0
Rhodymenia divaricata	0	0	0	0	1	0	0	0	1	0
Solieria filiformis	0	0	0	1	1	0	0	0	0	0
Sporolithon episporum	0	0	0	0	0	1	1	0	1	0
Titanoderma pusttulatum	0	0	0	0	0	1	0	0	1	1
Tricleocarpa cylindrica	0	0	0	1	0	0	0	1	0	0
Wrangelia bicuspidata	0	0	0	0	1	0	0	0	0	0
Wrightiella blodgettii	0	0	0	1	0	0	0	0	0	0

Halodule beaudettei (wrightii)	0	0	1	0	1	0	0	0	0	0
Syringodium filiforme	1	0	1	0	1	0	0	1	1	0
Thalassia testudinum	1	1	1	1	1	0	1	1	1	0

Appendix 1: Matrix Presence (1)-absence (0) of all SAV species per survey site, found in northeastern coastal La Guajira, Colombia in 2016.

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