National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Virgin Islands National Park and Virgin Islands Coral Reef National Monument

Natural Resource Report NPS/VIIS/NRR—2022/2408

ON THE COVER
View of Trunk Bay and Trunk Cay, taken from the North Shore Road lookout, St. John, USVI.
Photo credit: Danielle Ogurcak

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Executive Summary

Natural Resource Condition Assessments (NRCAs) provide managers with concise assessments for select focal resources within National Park Service (NPS) units. These assessments evaluate indicators of condition for a resource and determine status and trends over time for best management of the resources within a unit. Virgin Islands National Park (VIIS) encompasses 7259 acres of terrestrial and shoreline habitat (~ 60% of the island of St. John in the US Virgin Islands) and 5,650 acres of adjacent submerged lands. Virgin Islands Coral Reef National Monument (VICR) extended the area of protected submerged lands by an additional 12,708 acres. Combined, the units include marine and terrestrial components, consisting of habitats ranging from rhodolith beds and patch reefs located 40–50 m below mean sea level to the highest elevations of the island of St. John (390 m) in moist tropical forest. Marine communities include soft bottom habitats of both mud and sand, colonized by seagrass and algae, and hardbottom habitats (pavement and rhodoliths) dominated by coral reefs and algae. Terrestrial habitats are dominated by dry tropical forests and woodlands, but also include areas of moist tropical forests, shrublands, mangroves, salt ponds, and beaches.

The VIIS-VICR NRCA considers five focal resources within the park and monument categorized as either pertaining to the supporting environment or biological integrity. These include shoreline water quality in the framework category of supporting environment, and macroalgae, seagrass, corals, and reef fish, in the framework category of biological integrity. Full assessments were conducted for all above-listed resources. In each focal resource section, a discussion of threats, stressors, and data gaps relevant to the resource accompanies the assessment of condition. Resource issues relevant to all components within the park and monument are discussed separately and include impacts of hurricanes/tropical storms, land cover/land use changes, and human interactions related to boat traffic, marine debris, and poaching.

Assessment of focal resources in VIIS-VICR resulted in the majority, four of five (80%), warranting significant concern. Only the supporting environment resource, water quality, warranted moderate concern. None of the focal resources was found to be in good condition. The focal resources assessed in this report are all marine resources, so we make no judgement on the condition of the many terrestrial resources found within the park boundaries. The overall condition of the marine resources of VIIS/VICR suggests a system under a wide range of threats. Deteriorating trends were recorded for four of the five focal resources. Only reef fish were in an unchanging condition. No resources or indicators were found to be in an improving condition. Taken as whole, the assessment suggests that the marine resources of VIIS/VICR are experiencing degraded conditions compared to the reference conditions for these resources. Deteriorating conditions for seagrass and corals combined with a lack of recovery of the reef fish communities are especially concerning. The current conditions for these resources appear to have resulted from the interaction of disturbance events and anthropogenic impacts, including extent of hurricane damage, increasing sea surface temperatures, contaminants, introduction of invasive species and continued fishing pressure.

Water quality as a supporting environmental resource is an important driver of change in the condition of biological integrity. The decision to assess the resource as warranting moderate concern

with a declining trend was related to the condition and status of three water quality indicators with potential links to coral degradation, namely fecal indicator bacteria, terrestrial sediments, and contaminants. Additionally, increasing development outside the park in St. John is likely to result in increases in fecal indicator bacteria from leaky septic systems and boat dumping, as well as from terrestrial run-off. On a positive note, recent territorial bans on potential endocrine disruptors in sunscreens may alleviate those contaminants.

A moderate level of confidence was assigned to the assessments for most focal resources, with individual indicators of the resources varying between low, medium and high. The assessment of the seagrass focal resource has assigned low confidence. The only assessment having high confidence was the coral focal resource. Given that a minority of focal resources had high confidence in their assessments, we infer that most resource condition assessments were constrained by either a lack of recent data, insufficient temporal or spatial coverage of datasets, or differences between survey methods for datasets compared. Important information gaps, as well as protocols for future data acquisition and monitoring are suggested.

Recommendations for future monitoring include the following: 1) design of an integrated approach to monitoring and data collection of marine focal resources of VIIS-VICR, incorporating metrics of water quality, coral health and abundance, seagrass cover, and the presence of non-native invasive species, 2) expansion of research on the use of the marine and terrestrial resources by visitors to estimate benefits from ecosystem services provided and amount of anthropogenic pressure on the resource, including the extent of illegal fishing and poaching, and 3) creation of updated benthic cover maps to understand changes in seagrass extent combined with compositional sampling for the identification of species. Expansion of current monitoring programs will add to the large body of research already conducted within the park and monument and will be invaluable for understanding changes to these resources resulting from future hurricane disturbance, rising seas, and increasing temperatures and changing rainfall patterns expected in a warming climate.

Acknowledgments

The authors would like to acknowledge personnel at Virgin Island National Park and Virgin Islands Coral Reef National Monument, especially Thomas Kelley and Dave Worthington, for useful discussions during the scoping portion of this project. Thank you to Caroline Rogers from the US. Geological Survey for sharing expertise related to the status of park and monument resources. We also would like to thank staff from the NPS South Florida Caribbean Inventory and Monitoring Network, including M. Feeley, J. Miller, J. Patterson, B. Shamblin, and K. Whelan, for providing datasets and documents used in the analysis of resources. Thank you to B. Lockwood and S. Bruscia from the Florida and Caribbean Invasive Plant Management Team for providing datasets and reports. Special thanks to Peter J. Edmunds and Ranjan Muthukrishnan for kindly providing figures for the macroalgae and seagrass condition assessments, respectively. Many thanks to R. D. McPherson, Southeast Region Natural Resource Condition Assessment Coordinator, for facilitating reviews and providing reporting guidance.

1. NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs Strive to Provide…

- *Credible condition reporting for a subset of important park natural resources and indicators*
- *Useful condition summaries by broader resource categories or topics, and by park areas*

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue-and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and GIS (map) products; [4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

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[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ➪ indicators ➪ broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park’s desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations* ***(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values* ***(longer-term strategic planning)***
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public* ***("resource condition status" reporting)***

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

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[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation

Virgin Islands National Park (VIIS) was established by Congress in 1956 in order to preserve the national park "in its natural condition for the public benefit and inspiration" (Public Law 925). In 1962, Congress amended the Virgin Islands National Park enabling legislation to add several thousand acres of submerged lands "in order to preserve for the benefit of the public significant coral gardens, marine life, and seascapes" (Public Law 87-750). Congress again amended the legislation in 1978 to add Hassel Island to the park (Public Law 95-348).

Virgin Islands Coral Reef National Monument (VICR) was established by Presidential Proclamation 7399 in 2001. The Proclamation recognized that the national monument contains "all the elements of a Caribbean tropical marine ecosystem" (Presidential Proclamation 7399). The Proclamation withdraws territorial and submerged lands in the national monument from extractive uses and unauthorized anchoring, and calls for the National Park Service to establish proactive management plans for the monument.

2.1.2. Geographic Setting

The Virgin Islands are part of the northerly Leeward Islands in the Caribbean, situated between the Greater Antilles and the Lesser Antilles (Figure 2.1.2.1). Politically, the islands fall into several jurisdictions: the British Virgin Islands, which are a British overseas territory, the Puerto Rican Virgin Islands, which is a territory of the United States, and the United States Virgin Islands (USVI), which is also a territory of the United States. The USVI consists of four larger islands: St. Croix, St. Thomas, St. John and Water Island, and some 50 smaller islets and cays. The total area of the USVI is 133 square miles.

Virgin Islands National Park (VIIS) occupies almost 60% of the island of St. John located approximately 6.5 miles East of St. Thomas (Figure 2.1.2.1). VIIS occupies the majority of the north shore and a considerable part of the central and southeast parts of the island. The park includes 7,259 acres of terrestrial and shoreline habitat and 5,650 acres of adjacent submerged lands (offshore underwater habitat, added to the park in 1962). In addition, 128 acres on Hassel Island in Charlotte Amalie Harbor on St. Thomas were added to the park in 1978. The Virgin Islands Coral Reef National Monument (VICR) occupies 12,708 acres of submerged lands and associated marine resources within the 3-mile belt off St. John. Consequently, the VIIS-VICR complex consists of more than 18,000 acres of offshore underwater habitat (NPS 2016).

The island of St. John is accessible only by boat. VIIS has white beaches, miles of trails, abundant marine life and abundant flora and fauna (Friends of Virgin Island National Park Foundation 2019). The park also contains important cultural and historical resources, including ruins of sugar plantations and petroglyphs carved by Taino Indians. Archeological sites dating from as early as 840 BC can be found in the park. The area within VIIS is considered to be one of the most comprehensive and undisturbed Caribbean landscapes (NPS 2018a). In turn, submerged ecosystems of VICR are rich and varied, consisting mostly of coral reefs, seagrass beds and shoreline mangrove forests (NPS 2018b).

In 1976, the United Nations Educational, Scientific and Cultural Organization (UNESCO) designated Virgin Islands National Park as an International Biosphere Reserve making VIIS among the first protected areas in the world to receive this designation (NPS 2018b). However, in 2017 the US requested that UNESCO withdraw VIIS from the list of International Biosphere Reserves (Austin 2017, UNESCO 2020).

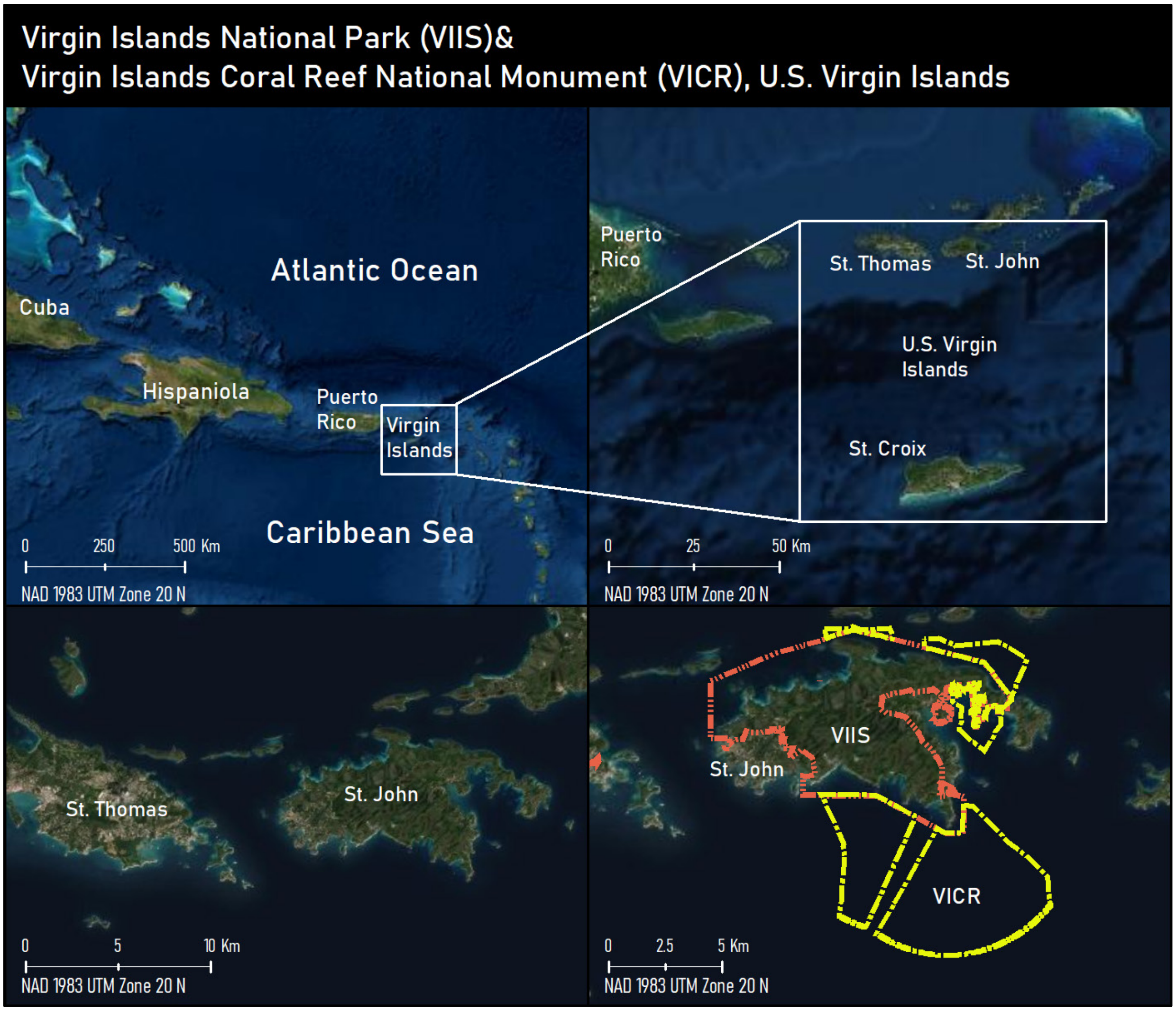

Figure 2.1.2.1. Geographic location of the US Virgin Islands in the Caribbean (upper panels). Location of the island of St. John in reference to the island of St. Thomas in the Virgin Islands (lower left panel) Demarcation of VIIS and VICR boundaries in orange and yellow respectively. Boundaries provided by NPS.

2.1.3. Visitation Statistics

From 1957 to 2019, VIIS has had 23,992,640 visitors to the park (NPS 2020); most visits occurred between the months of December and April (NPS 2020). No specific statistics exist for VICR (NPS 2019a). The assumption is made that most visitors to VIIS also visit VICR. The average number of recreational visitors to the park since its opening in 1957 through the end of 2019 has been 412,115 per year (NPS 2019a). Visitation in the park has declined over the past 10 years, from average annual visitations of around 670,500 between the 1980s to 2005, to around 355,000 visitors annually for the period 2010 to 2019 (Figure 2.1.3.1). After the passage of Hurricanes Irma and Maria in September 2017, the park closed for over 3 months. The storms caused severe damage to the coral reefs, marine life and mangroves in VIIS and VICR. This has likely impacted the number of park visitors for the past three years. A full recovery from the extensive damage wrought by Hurricanes Irma and Maria has yet to happen. Notwithstanding, there are numerous activities that visitors may enjoy while visiting VIIS and VICR. The VIIS beaches, coral reefs, historic ruins, and hiking trails provide numerous opportunities of exploration and enjoyment of the island's natural environment. Visitors can enjoy a variety of activities on the land and in the water, including swimming, snorkeling and scuba diving; sailing, kayaking and windsurfing; and camping, hiking, bird watching and archaeology (NPS 2019a). NPS offers ranger-guided tours to visitors. Within the boundaries of VICR exists pristine mangrove habitat, located in a portion of Hurricane Hole and offshore coral reefs and algal plains, which visitors can explore. Hurricane Hole also provides a peaceful soundscape and serves as a refuge for registered boaters during hurricane season (NPS 2019b).

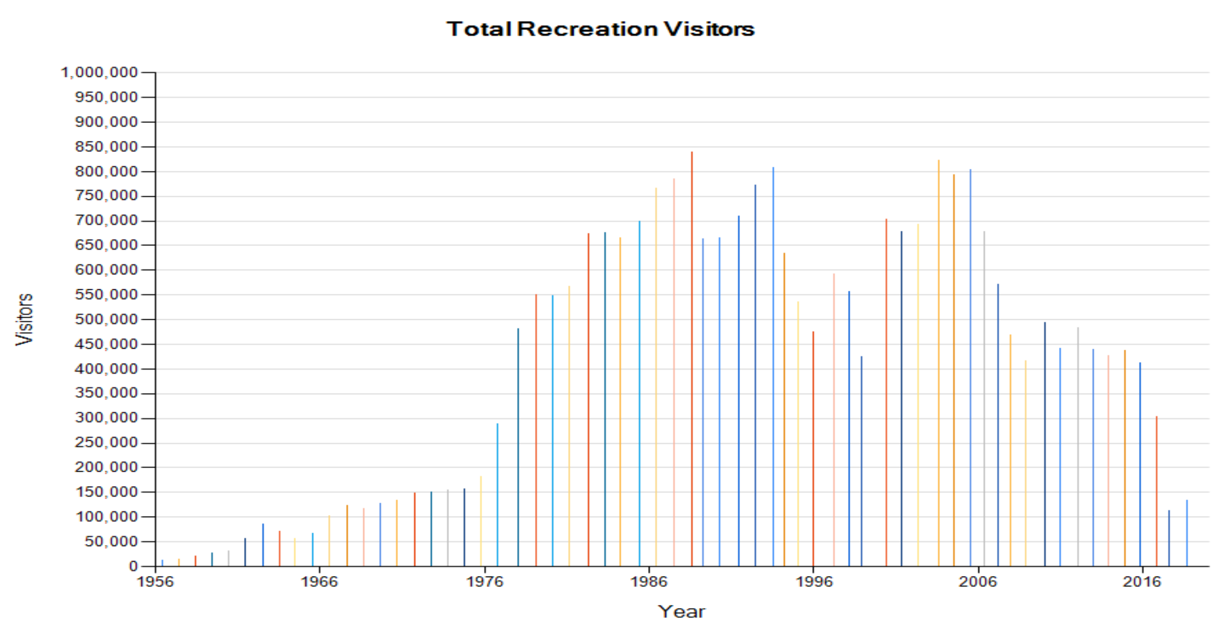

Figure 2.1.3.1. Annual visits to VIIS-VICR during the period 1957 to 2019. (Data from NPS 2020).

2.2. Natural Resources

2.2.1. Ecological Units and Watersheds

St. John is an island of complex geology with more than 80% of the island exposed to slopes exceeding 30% (CH2M Hill 1979). It has an area of ~49 km² (Rankin 2002), and the highest elevation is 390 m (1,280 ft) above sea level. Many of the steep slopes (guts) present little or no vegetation as result of erosion and flash floods. Abandoned sugarcane plantation terraces are common in the landscape and are now predominantly covered by dry forest (Rankin 2002). The protected areas around St. John include Virgin Islands National Park (VIIS) and Virgin Islands Coral Reef National Monument (VICR). The former covers a significant part of the island and the protected area encompasses terrestrial, coastal, and shallow to moderate depth marine habitats. The latter protects only marine habitats north and south of the island from shallow to deep areas. Terrestrial surface area is predominantly dry forest, shrubland and woodland, whereas the aquatic benthic habitats surrounding the island are dominated by coral reefs and seagrass beds.

Ecological Units

The benthic habitats are comprised of a mosaic of unconsolidated sediments, coral reefs, sand, and pavement with algae presenting the most common benthic cover (Table 2.2.1.1; Figure 2.2.1.1). Within VIIS and VICR, coral reef and hardbottom (66.21%) are the dominant major benthic habitats, followed by unconsolidated sediment (22.8%). About 11.5% of the benthic area with the parks presents Unknown cover. Within the coral reef and hardbottom, rhodoliths and pavement are the most significant detail benthic structure with 45.81% and 9.05% cover, respectively (Table 2.2.1.1; Figure 2.2.1.1). Algae is the main cover for rhodoliths (45.8%) and pavement (8.37%). Within the unconsolidated sediment, sand is the most prevalent with 19.80% representation. Algae (8.39%) and seagrass (4.97%) are the most important benthic covers in the sand (Table 2.2.1.1; Figure 2.2.1.1). In general, algae (75.2%) is the main benthic cover in the mapped area. Although live coral and seagrass are important features of the benthic ecosystems, their presence throughout seascape was low (0.69% and 2.07% respectively). Detailed description of the different benthic units can be found in Zitello et al. (2009).

Table 2.2.1.1. Major benthic ecological units for Virgin Island National Park (VIIS) and Virgin Islands Coral Reef National Monument (VICR). Data source: For Moderate Depth Habitats Data collected in 2003–2005, processed 2005 & 2009 (Costa et al. 2009). For Shallow Depth Habitats data were collected in 2003–2005, processed 2008–2009 (Zitello et al. 2009).

Location	Ecological Unit	Area (ha)	% Cover
Benthic	Aggregate Reef	202.18	2.53
	Aggregated Patch Reefs	289.88	3.63
	Boulder	35.87	0.45
	Individual Patch Reef	30.08	0.38
	Mud	118.10	1.48
	Pavement	722.58	9.05
	Pavement with Sand Channels	95.68	1.20
	Reef Rubble	26.55	0.33
	Rhodoliths	3658.28	45.81
	Rhodoliths with Scattered Coral and Rock	136.86	1.71
	Rock Outcrop	70.81	0.89
	Sand	1581.59	19.80
	Sand with Scattered Coral and Rock	79.46	0.99
	Spur and Groove	19.01	0.24
	Unknown	919.62	11.51
	Total Area (ha)	7986.54	–

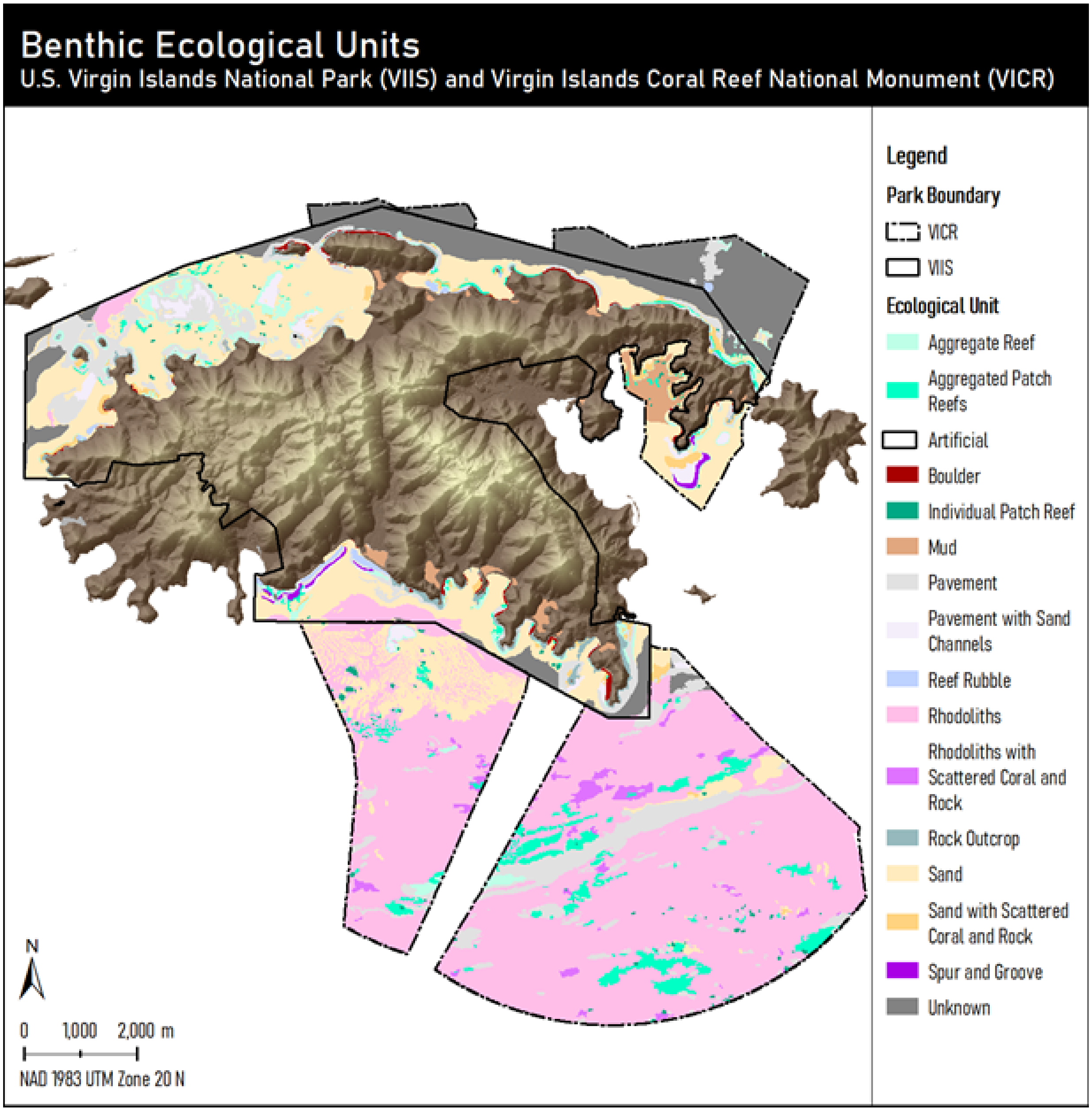

Figure 2.2.1.1. Benthic Ecological Units for Virgin Islands Coral Reef National Monument (VICR, black hatched line) and Virgin Island National Park (VIIS, black solid line, Costa et al. 2009).

Terrestrial habitats within VIIS host a variety of drought-adapted plants. Based on the study by Thanawastien et al. (2015, unpublished), forests are the most dominant cover type (56.91%) (Table 2.2.1.2; Figure 2.2.1.2). Dry forests, which include semi-evergreen, semi-deciduous, gallery semi-deciduous and drought deciduous forests occupy about 47.55% of the mapped area (Table 2.2.1.2; Figure 2.2.1.2). Moist forest, which includes upland, gallery and basin moist forests, cover about 9.36% of the park surface area (Table 2.2.1.2; Figure 2.2.1.2). Woodland covers about 18.13% of the area and consist of evergreen, semi-deciduous, gallery semi-deciduous and drought deciduous woodlands (Table 2.2.1.2; Figure 2.2.1.2). With a similar percent cover, shrublands (17.56%) occupy areas with low moisture availability and include coastal hedge, gallery shrubland, thicket scrub, sclerophyllous evergreen shrubland, and mixed dry shrubland (Table 2.2.1.2; Figure 2.2.1.2). The herbaceous vegetation has a very low cover with just 0.37% of the mapped area and includes coastal and mixed grasslands. An important element of the shoreline dynamics, mangroves cover a small area (0.67%) of the park (Thanawastien et al. 2015, unpublished).

Table 2.2.1.2. Major terrestrial ecological units for VIIS and VICR. (Data source Thanawastien et al. 2015, unpublished).

Location	Class	Ecological Unit	Area (ha)	% Cover
Terrestrial	Moist Forest	Gallery moist forest	77.3	2.16
	Moist Forest	Basin moist forest	119.3	3.33
	Moist Forest	Upland moist forest	138.9	3.87
	Dry Forest	Gallery semi-deciduous woodland	23.6	0.66
	Dry Forest	Gallery semi-deciduous forest	88.4	2.47
	Dry Forest	Drought deciduous forest	100.1	2.79
	Dry Forest	Semi-evergreen forest	584.4	16.30
	Dry Forest	Semi-deciduous forest	931.9	25.99
	Woodland	Evergreen woodland	102.0	2.85
	Woodland	Drought deciduous woodland	110.0	3.07
	Woodland	Semi-deciduous woodland	414.4	11.56
	Shrubland	Gallery shrubland	0.8	0.02
	Shrubland	Coastal hedge	4.3	0.12
	Shrubland	Sclerophyllous evergreen shrubland	6.7	0.19
	Shrubland	Mixed dry shrubland	126.0	3.52
	Shrubland	Thicket scrub	491.6	13.71
	Mangrove	Mangrove woodland	3.2	0.09
	Mangrove	Mangrove shrubland	4.2	0.12
	Mangrove	Mangrove forest	6.8	0.19
	Mangrove	Fringing mangrove	10.0	0.28
	Herbaceous	Coastal grassland	0.6	0.02
	Herbaceous	Mixed grassland	12.7	0.36
	Other	Fresh pond	0.2	0.01
	Other	Pasture	0.6	0.02
	Other	Salt flat	3.5	0.10
	Other	Beach	18.4	0.51
	Other	Salt pond	28.6	0.80
	Other	Rock pavement	33.4	0.93
	Other	Developed	143.3	4.00
Total Area (ha)	–	–	3585.2	–

Mangrove cover includes fringing mangroves, mangrove shrubland, mangrove woodland, and mangrove forest. Mangrove forests have the largest cover percentage with 0.28% (Table 2.2.1.2; Figure 2.2.1.2). The park also has salt ponds and salt flats, which are important features for coastal dynamics (Table 2.2.1.2; Figure 2.2.1.2). With just 0.01% of the park area, freshwater ponds and wetlands present the rarest cover types (Table 2.2.1.2; Figure 2.2.1.2). These freshwater habitats are likely to be important for some species. Other non-vegetated areas such as rock pavement and beaches occupy less than 2% of the mapped area, and developed areas within the park cover about 4% (Table 2.2.1.2; Thanawastien et al. 2015, unpublished).

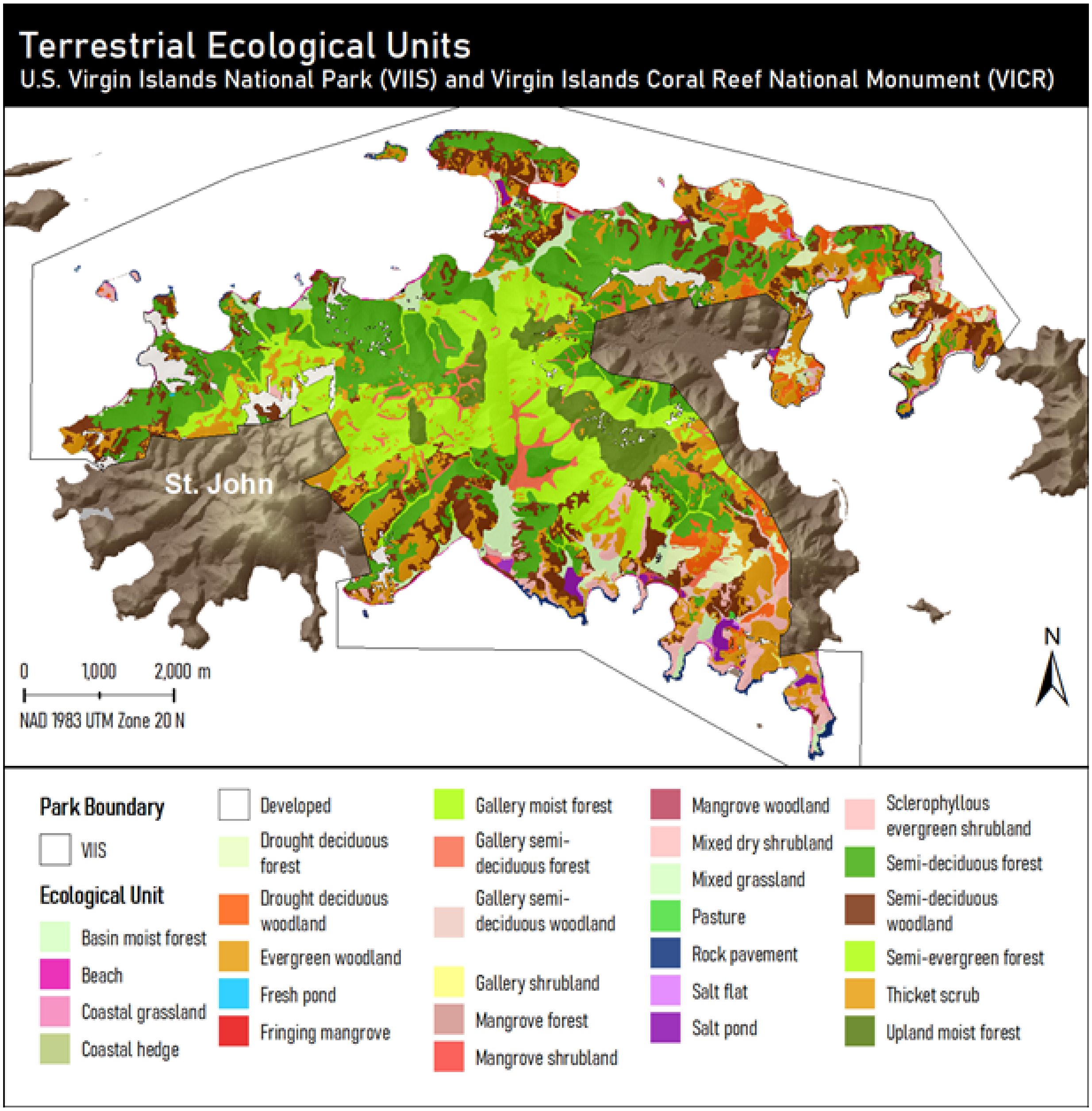

Figure 2.2.1.2. Terrestrial Ecological Units for Virgin Island National Park (Thanawastien et al. 2015, unpublished).

Watersheds

There are no permanent rivers or streams on the island. However, there are several streams that flow during certain times of the year. These streams drain watersheds that, for the most part, are covered by some natural vegetation that can reduce sediment transport into bays, such as moist forest (Figure 2.2.1.3). West and Northwest areas of the island have anthropogenic development that can result in an increased sedimentation load into the bays of the island. Some of these areas, such as Cruz Bay are adjacent to the park, while other areas like Caneel Bay are within VIIS. Cruz Bay has the highest population density of St. John and as a result, water draining from these developed areas is likely to have a strong impact on the bay. In the case of Caneel Bay, Caneel Bay Resort has a strong influence on the drainage area, which includes managed areas including manicured lawns that can be a potential source of contamination for the bay when surface runoff delivers them to the bay (Downs et al. 2011). A summary of the hydrology of St. John is provided in the section on surface hydrology.

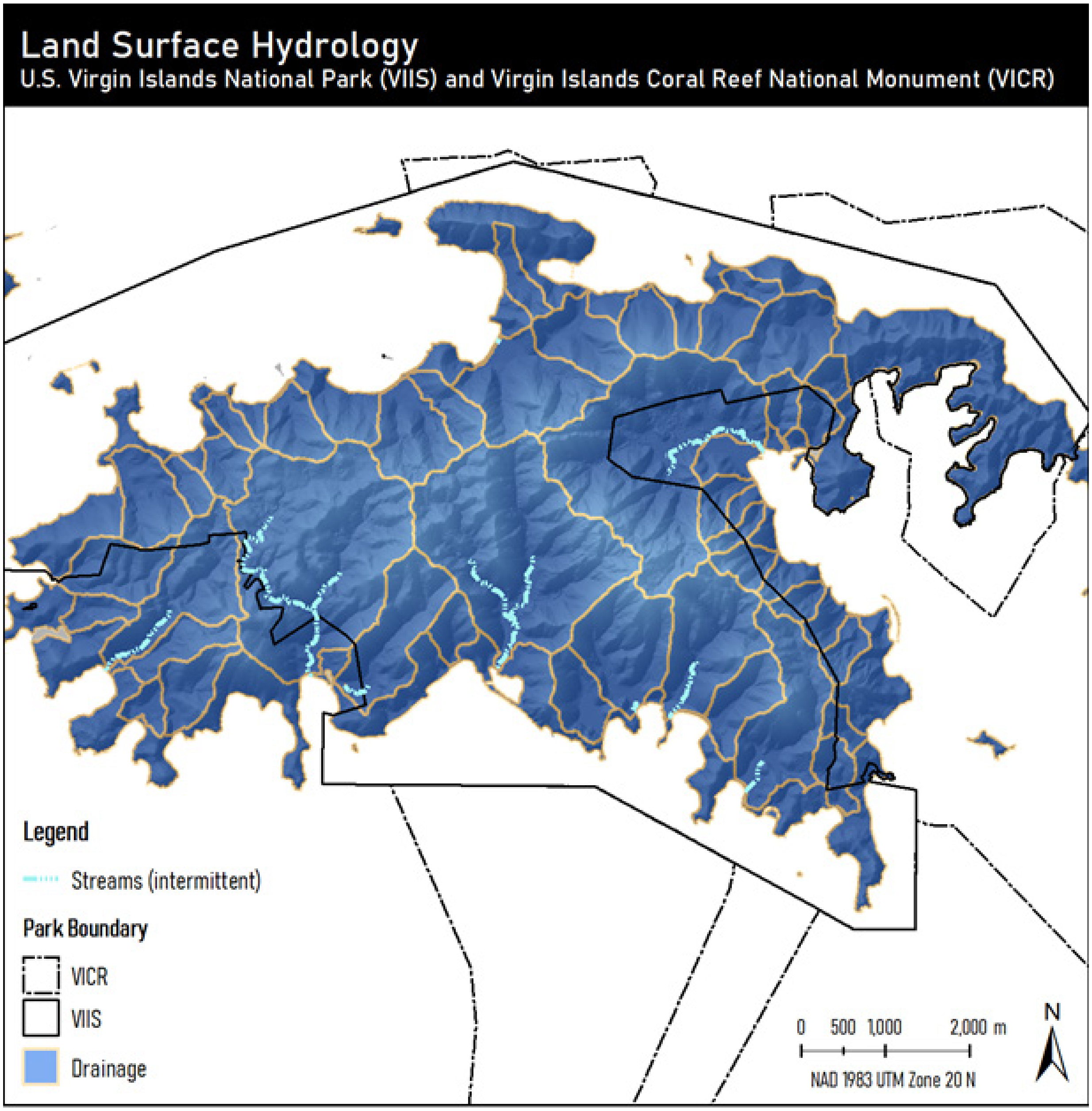

Figure 2.2.1.3. Watersheds (drainage area in blue and boundary in orange) and intermittent streams for the island of Saint John and for Virgin Island National Park (VIIS, black solid line). Black hatched line: Virgin Islands Coral Reef National Monument (VICR). Watersheds and rivers were delineated in ArcGIS using the St. Thomas and St. John DEM-CKAN (data.gov).

2.2.2. Resource Descriptions

Coastal Dynamics

Shoreline Dynamics

The shoreline includes volcanic and sedimentary rocks, and limestone, which have contrasting resistance to weathering (Rankin 2002). As a result, both terrestrial and marine sediment composition likely reflect the weathering patters of these rocks. Sediment transport is strongly influenced by the sediment type and size. For example, sandy particles transport more easily than cobble. Thus, the sediment dynamics of sandy beaches such as Trunk Bay are very different from those of cobble and pebble beaches found at Saltpond Bay, and as a result, their rates of erosion differ (Hall and KellerLynn 2010).

The main mechanism of sediment transport and coastal change is longshore transport, which is generated by waves that reach the coast at a non-perpendicular angle (Hall and KellerLynn 2010). Some of the wave action is mitigated by the presence of coral reefs, which function as barriers and reduce coastal erosion. However, recent decline in reef cover is likely to increase coastal wave action and change the shoreline dynamics (Lundgren 2008). An increase in wave energy coupled with sea level rise is likely to have a strong impact on highly and very highly vulnerable areas such as gravel and sandy beaches respectively (Pendleton et al. 2005).

Salt ponds are common features along the shoreline and function as shelter for terrestrial and marine animals but also for sediment control. Terrestrial runoff gets trapped into these ponds reducing the input of silt and other suspended sediments into the marine system (Stengel 1998). Salt ponds form as a result of the upward growth of fringing reefs on which mangroves will establish closing the pond from the sea (Jarecki 1999, Gangemi 2003). The presence of mangroves plus the terrestrial nutrient input create very productive habitats that form an effective barrier against wave action, reducing coastal erosion (Stengel 1998). However, a reduction in coral reef cover can increase wave action which could have a negative impact on the mangrove cover and the salt ponds. In turn, the reduction of mangrove and salt pond cover could result in higher load of terrestrial sediment into the reef which results in a negative feedback to the coral reef.

Coastal Geomorphology

The rocks on the island of St John are comprised of basalts, andesite and keratophyre and a lesser amount calcareous rocks and cherts. These rocks were produced during Cretaceous volcanism. As a result, the geology of the island is very complex (Rankin 2002) and strongly influences the geomorphology of the coast. The island shoreline is composed of a mix of sandy beaches, steep rock slopes, and areas with cobbles and beachrock. Igneous and volcanic rocks contribute to the formation of steep coastal profiles. The southern and eastern shores of the island are characterized by hard bedrock and cobble beaches, whereas more easily eroded rock results in the formation of sandy beaches, which are usually located between areas of rocky headlands (Hall and KellerLynn 2010).

Depending on the geomorphological characteristics, the vulnerability of the coast varies. For instance, areas such as rock cliffs present low vulnerability. Alluvium and cliffs with fringing reefs present moderate vulnerability. Areas with gravel beaches or cliff backed beaches present high vulnerability and areas with sandy beach shoreline present very high vulnerability (Pendleton et al. 2005). Pendleton et al. (2005) found that after geomorphology, coastal slope and wave energy are the most important variables that affect coastal vulnerability.

An important factor that affects wave energy, and thus shoreline dynamics, is water depth. For instance, areas with shallow water are likely to experience lower wave energy than areas with deeper water conditions. Data related to water depth (bathymetry) were gathered from two resources: 2005 and 2011 NOAA data surveys (NOAA NCCOS 2017). The data sets were merged using a common coordinate systems and spatial resolution (4x4 m). Data from 2005 covered most of the area in the southern section of the VICR monument, while the 2011 data covered most the area around the island.

Bathymetry data for both Virgin Island National Park (VIIS) and Virgin Island Coral Reef National Monument (VICR) show that most of the island is surrounded by shallow water ranging from 0–10 m depth below mean lower low water (MLLW), while deeper waters are found to the south (Figure 2.2.2.1).

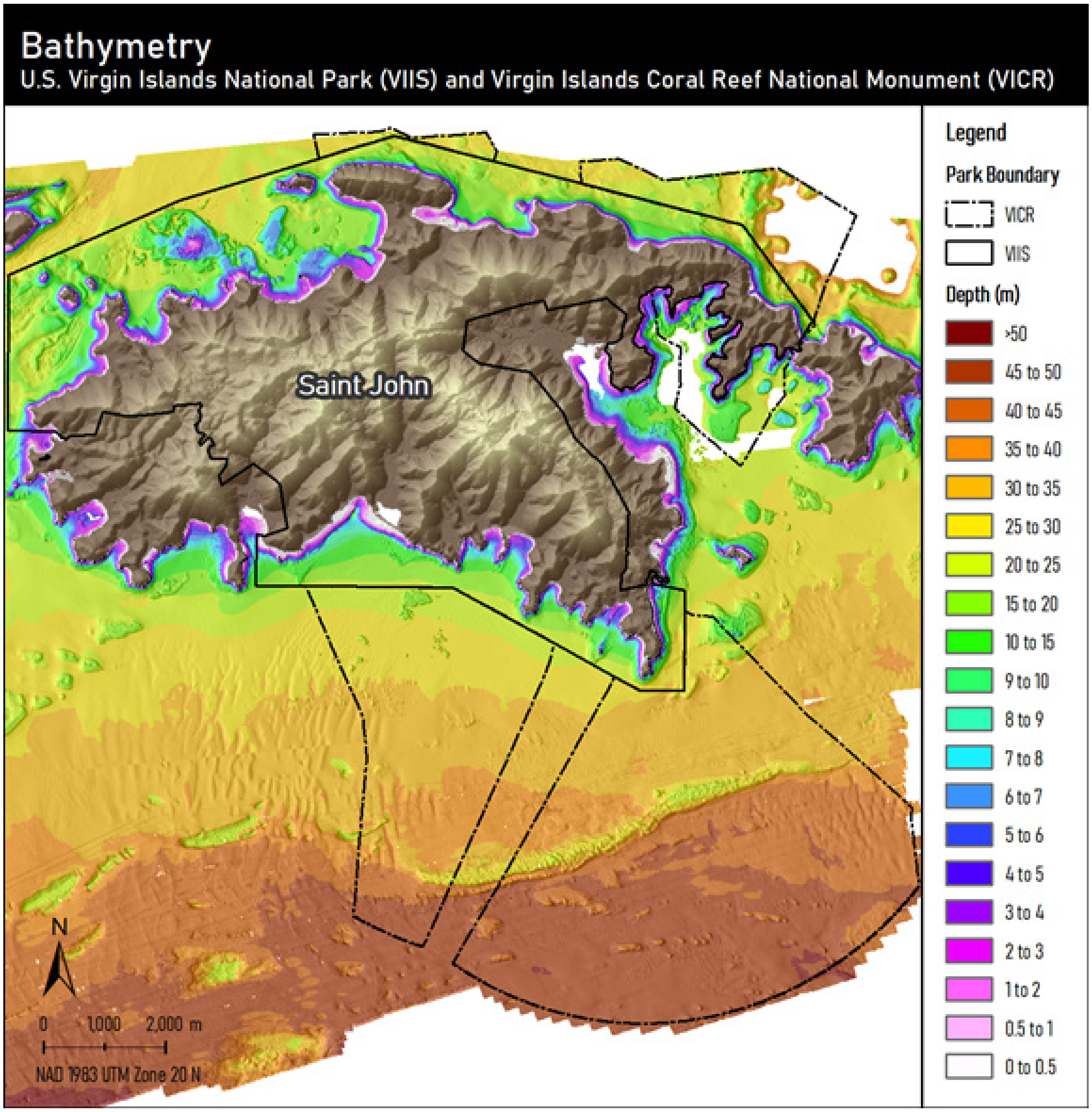

Figure 2.2.2.1. Bathymetry for Virgin Islands Coral Reef National Monument (VICR, black hatched line) and Virgin Island National Park (VIIS, black solid line, NOAA NCCOS 2017).

The bathymetry data were plotted using a density distribution (similar to a histogram) to quantify the most prevalent depths within the protected areas. The plots were constructed using density function in ggplot2 (RStudio, version 1.2.1335). Water depths between VICR and VIIS vary considerably. In general, VICR presents mostly deeper water, with depths around −49 and −34 m below MLLW being the most common, whereas for VIIS, the most common water depth was approximately −20 m. However, most of the park contains shallower waters (Figure 2.2.2.1 and 2.2.2.2).

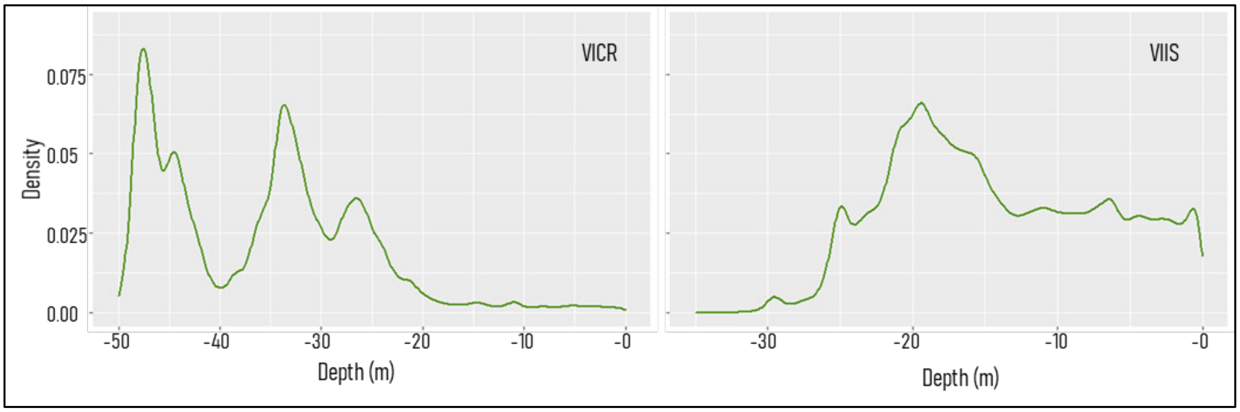

Figure 2.2.2.2. Density distribution for bathymetry estimates for Virgin Islands Coral Reef National Monument (VICR) and Virgin Island National Park (VIIS). Higher density values represent higher occurrence.

Chemical / Physical Conditions

Water Quality

The clear blue waters surrounding St. John make it extremely picturesque and are one of the main attractions for the park and monument. However, not all areas have good water quality. Water quality in VIIS-VICR is quite variable across space and time. Offshore areas generally reflect more open ocean conditions and are very clear and amenable to marine life and recreation. This is also typical of all areas inside VIIS-VICR on the northern side of St. John. However, water quality in some embayments is impacted by run-off from land, which appreciably alters ocean water conditions. This occurs in Fish Bay and Coral Bay, located on the south and southeast of St. John, respectively, where residential development and unpaved roads on steep hillsides deliver sediments and waste nutrients to nearshore waters. A detailed analysis of the state of the quality of the waters surrounding St. John is provided in Section 4.2.1.

Weather and Climate

The climate in the Virgin Islands is tropical. In St. John, the average high temperature ranges between 84°F and 90°F (29°C to 32°C), with lows between 72°F and 79°F (22°C to 26°C). The temperatures of 98°F (37°C) and 51°F(11°C) are respectively the maximum and minimum temperatures registered for the period January 1953 to December 2019 at the Charlotte Amalie Cyril E. King Airport located on the neighboring Island of St. Thomas (less than 6.5 miles from St. John). The coolest months of the year occur from December to April. Average temperatures in the winter are 73°F (23°C). May through November is the hottest time of the year, with average high temperatures in the upper 80s and low 90s (29°C to 32°C) (NOAA 2020).

The rainy season extends from May to December, with a short dry spell in June and July, while the dry season goes from January through April. However, in certain years, there has been substantial precipitation in December, with rainfall reaching 200 mm to 400 mm (8 in to 16 in). The months with least precipitation are February and March, while the wettest period is from September to November. The total annual precipitation is of the order of 1,000 mm to 1,200 mm (40 to 47 in) per year and is generally slightly more abundant on the northern slopes of the island. The maximum 24-hour rainfall registered for the period January 1953 to December 2019 at the Cyril E. King Airport in Charlotte Amalie was 301.2 mm (11.86 in). This precipitation was recorded during the passage of Hurricane Dolly in early September 1953. Major rain episodes are commonly linked to hurricanes events. Hurricane season in the region starts officially on June 1 and extends until November 30, with peak months for storms between months of August to October. Hurricanes will be discussed in more detail later in this chapter.

To assess the validity of using the rainfall data from Charlotte Amalie airport to derive patterns and statistics of the rainfall over the VIIS+VICR complex, the registered observation were compared to a data set (Boulon 2016) based on daily rainfall readings collected at Windswept, near Trunk Bay in St. John. Unfortunately, the data set covers only the period from January 1984 to December 2014. Although there are differences in the rainfall daily values registered by both sets, as expected, the overall general patterns and values coincide during major events (particularly those linked to the passage of hurricanes and tropical storms). Therefore, we chose to use the longer time series from Charlotte Amalie to infer precipitation patterns for climate analysis on St. John. Figure 2.2.2.3 shows the distribution of rainfall at the Cyril E. King Airport in Charlotte Amalie and at the Windswept site in St. John.

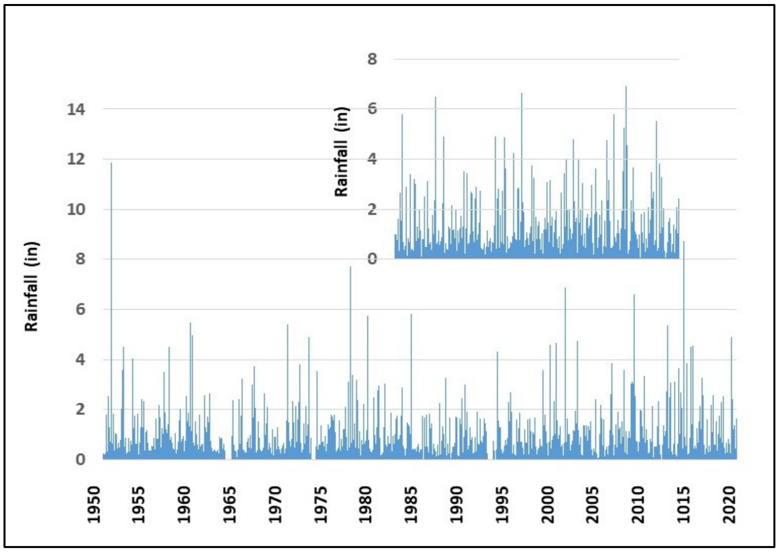

Figure 2.2.2.3. Daily rainfall at the Cyril E. King Airport in Charlotte Amalie precipitation station for the period January 1953 to December 2019 (lower histogram) and the Windswept, site in St. John, for the period 1984–2014 (upper histogram). Data obtained from the NOAA GHCN (NOAA 2020).

The weather in the Caribbean is also modulated by the trade winds (easterlies) blowing east to west. The strong easterlies can sometimes bring clouds of African dust from the Sahara; millions of tons of dust can be transported each year, affecting air quality, and potentially affecting marine life, including coral reefs. The intensity of the winds in the Virgin Islands vary, but the strongest wind episodes, not linked to hurricanes, occur from December to February and correspond to systems with winds from the north, aka Christmas Winds. The maximum average daily wind speed and the fastest 2-minute wind speed registered at the Charlotte Amalie Cyril E. King Airport in the neighboring Island of St. Thomas for the period August 1998 to December 2019 were 34.9 miles per hour (mi/h) and 76.1 mi/h, respectively (NOAA 2020).

Data for weather parameters presented in this chapter were obtained from the NOAA GHCN (Global Historical Climatology Network)-Daily database. GHCN-Daily is a composite of climate records from numerous sources that are merged and then subjected to a suite of quality assurance reviews (Menne et al. 2012). The archive includes over 40 meteorological parameters, including temperature daily maximum/minimum, temperature at observation time, precipitation, snowfall, snow depth, evaporation, wind movement, wind maximums, soil temperature, cloudiness, and more (NOAA 2020). The Caribbean region has undergone relatively consistent seasonal rainfall periods, small annual temperature fluctuations, and a variety of extreme weather events, such as hurricanes, tropical storms, and droughts. Notwithstanding, these patterns are changing and are projected to be increasingly altered due to climate change.

Climate change is anticipated to add to the stresses of coastal environments by modifying temperature and precipitation patterns, increasing the likelihood of extreme precipitation events, and accelerating rates of sea level rise. Changing climate and weather patterns interacting with human activities are affecting land use, air quality, and resource management and are posing growing risks to food security, the economy, culture, and ecosystems services. Some coral reefs in the Caribbean are already experiencing transformational changes (USGCRP 2018).

Climate variations due to these large-scale patterns directly impact water resources in the U.S. Caribbean because the islands largely rely on surface waters and consistent annual rainfall to meet freshwater demands. According to recent studies (Henareh et al. 2016, Campbell et al. 2011), the Caribbean is envisaged to have longer dry seasons and wetter rainy seasons. Extended dry seasons are expected to increase the stress on already scarce and vulnerable water resources. Dependable and safe water supplies for U.S. Caribbean communities are threatened by drought, flooding, and saltwater contamination due to sea level rise (Cashman et al. 2010). Air and seawater temperatures are predicted to rise. Rising air and water temperatures along with changes in precipitation are intensifying droughts.

The island of St. John, like so many other islands in the Caribbean, is among the Earth's most vulnerable places to the impacts of climate change, particularly sea level rise. Sea level rise, combined with stronger wave action and higher storm surges, will worsen coastal flooding and increase coastal erosion, likely leading to diminished beach area, loss of storm surge barriers, decreased tourism, and negative effects on livelihoods and well-being (USGCRP 2018).

The NOAA-developed Sea Level Rise (SLR) and Coastal Flooding Impacts Viewer can be used to visualize the impact of high tide flooding and sea level rise. This viewer presents coastal managers and scientists with a preliminary look at SLR and coastal flooding impacts and helps gauge trends and prioritize actions for different scenarios. The viewer is a screening-level tool that uses nationally consistent datasets and analyses presented in a Web mapping application format using ESRI's ArcServer and Adobe's FLEX technology (http://www.csc.noaa.gov/digitalcoast/tools/slrviewer/). Figure 2.2.2.4 shows a simulation of the extent of flooding in St. John during high tide.

Figure 2.2.2.4. High Tide Flooding in St. John. Red marking depicts the coastline during Mean High Water (MHW). Image derived using the NOAA SLR and Coastal Flooding Impacts Viewer (https://coast.noaa.gov/slr/#/layer/slr/0/)

Figure 2.2 2.5 shows the impact of a 4 feet (1.2 meters) sea level rise above mean higher high water (MHHW) in St. John, US Virgin Islands. In the graphic display provided by the viewer, areas that are hydrologically connected (according to the digital elevation model used) are shown in shades of blue that represent depth of inundation. Low-lying areas, displayed in green, are hydrologically "unconnected" areas that may flood. These are determined solely by how well the elevation data capture the area's hydraulics (NOAA 2011). Water levels are shown as they would appear during MHHW and do not take into consideration future erosion, subsidence, or man-made alterations of the shoreline.

In addressing climate change, it is important to be aware that the islands have unique issues related to data availability and the capacity to develop datasets comparable to those available for the continental United States. For example, the small size of the islands, particularly the USVI, affects the availability and accuracy of downscaled climate data and projection.

Air Quality

The National Park Service participates in several national, multiagency air quality monitoring networks. These networks focus on ozone, visibility, particulate matter, and atmospheric deposition of nitrogen, sulfur, and mercury. The trade winds blowing across the tropical Atlantic Ocean bring millions of tons of dust from the Sahara and Sahel regions of Africa to the Caribbean every year. The dust that reaches the Caribbean limits visibility and research indicates that this dust also contains viable bacteria, viruses, and fungi, as well as nutrients, metals, and persistent organic pollutants (e.g., pesticides, PAHs, PCBs) (Kellogg and Griffin 2003, Garrison et al. 2006). During the periods of high wind-blown dust concentration, known as dust pulses, the number of microbes present in the air can be as much as ten times higher than during normal times. This condition represents a hazard to the health of humans and ecosystems. For example, the soil fungus, *Aspergillus sydowii*, causes sea fan disease and results in widespread coral mortality (Kellogg and Griffin 2003).

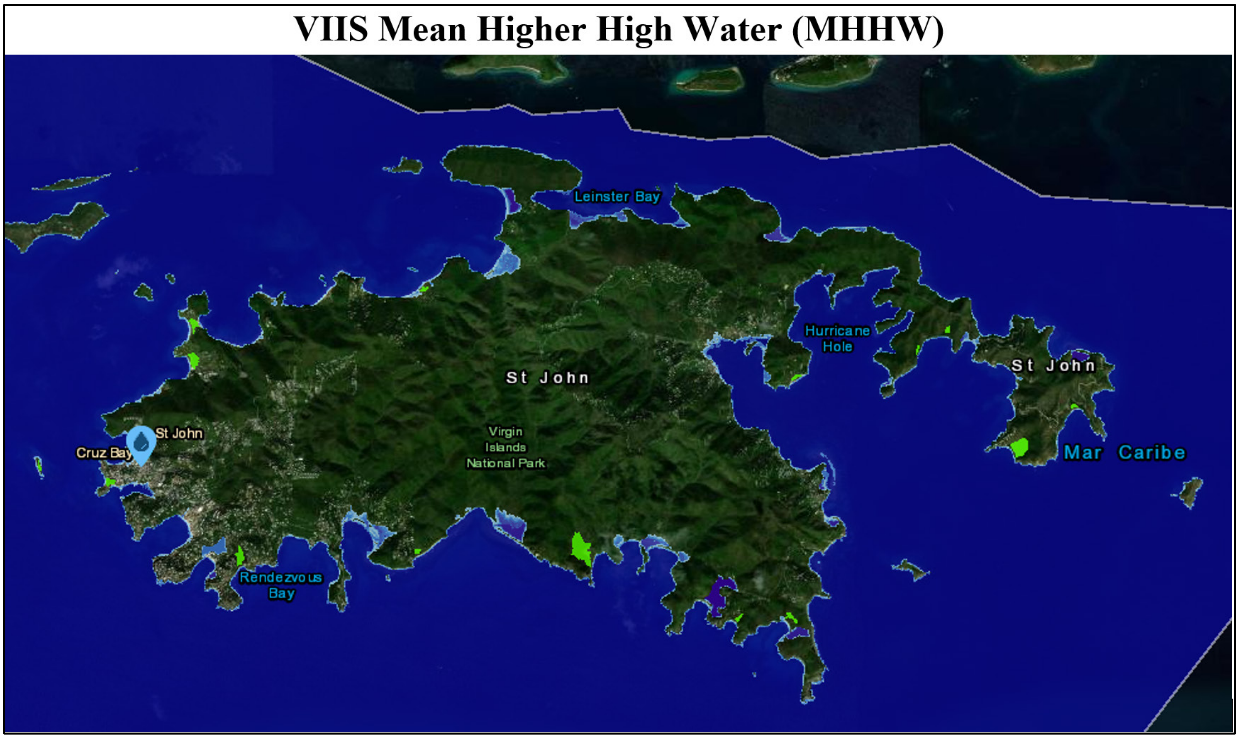

Figure 2.2.2.5. St. John coastline for a 4 ft rise corresponding to the estimated sea level in 2080. Low-lying areas, displayed in green, are hydrologically "unconnected" areas that may flood. Graphic display under this scenario derived using the NOAA SLR and Coastal Flooding Impacts Viewer (https://coast.noaa.gov/slr/#/layer/slr/0/)

Certain chemicals transported by the wind may also have harmful effects on surface waters, marine environments, and vegetation similar to those found in VIIS-VICR. Nitrogen and sulfur can contribute to ocean acidification. Ocean acidification, caused by greenhouse gas emissions, may contribute to the degradation of coral communities (Sullivan et al. 2011). Figure 2.2.2.6 shows an increasing trend in nitrogen deposition (kg ha-1 yr-1) in VIIS for the years 1999 through 2018 (NPS 2019c).

African dust or human-caused haze from fine particles of air pollution may also affect visibility. Observations of air quality are made at the air quality permanent monitoring site in St. John (Figure 2.2.2.7). Pollution in the VIIS+VICR complex and neighboring areas may be reduced from the average natural visual range of 120 miles (without pollution) to about 65 miles on days with pollution. During high pollution days, the visual range can be reduced to below 40 miles (NPS 2019c).

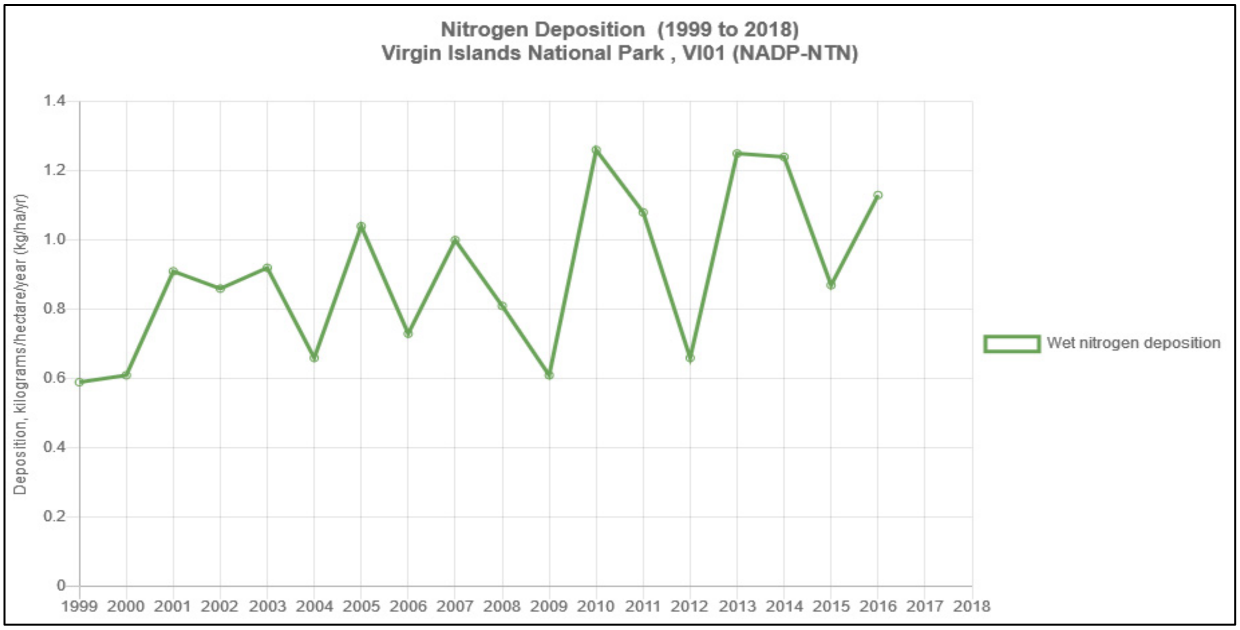

Figure 2.2.2.6. Nitrogen Deposition in the Virgin Islands National Park during the period 1999–2016 (NPS 2019c).

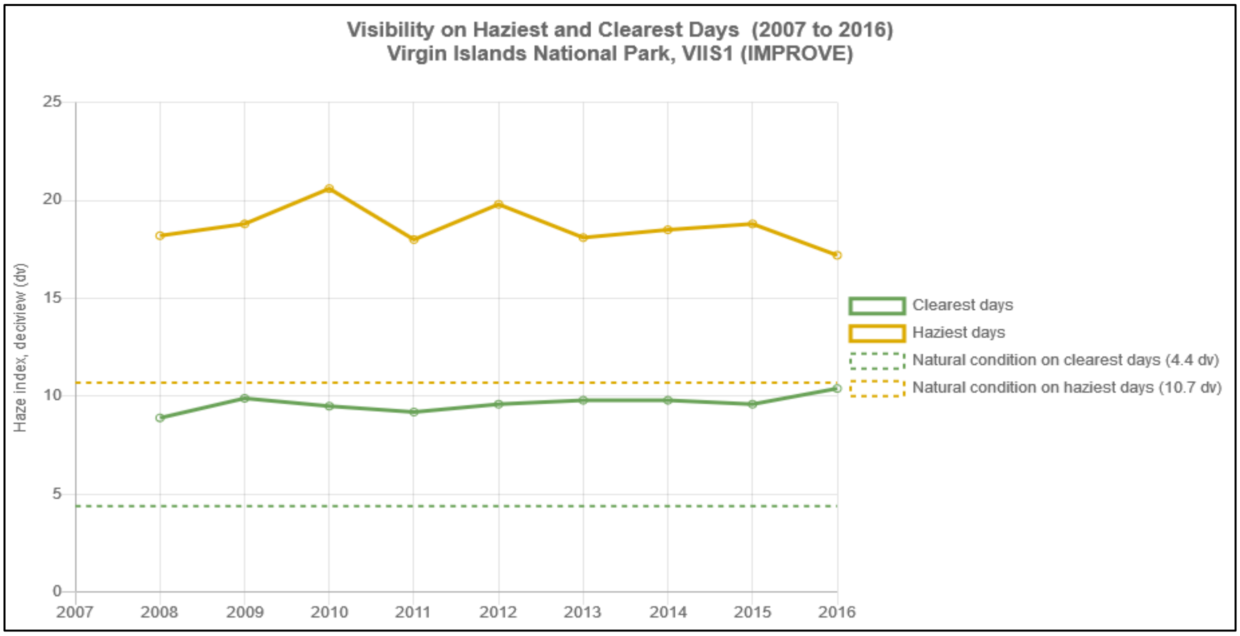

Figure 2.2.2.7. Visibility on haziest and clearest days at the Virgin Islands National Park during the period 1999–2016 (NPS 2019c)

Land Surface Hydrology

There are no rivers or permanent streams in VIIS (Rogers et al. 2008). However, precipitation associated with hurricanes can be significant and last for several days. From August to December, very intense rains can fall within very short periods. During such episodes, water runoff can collect in guts[1] and turn into strong intermittent rivers (Rogers et al. 2008). Overall, runoff is controlled by topography, soil moisture, local evaporation rates, and vegetation cover. Figure 2.2.1.3 shows a map of St. John and delineates the various watersheds in the island. On an annual basis, surface runoff, which is a major factor in the formation of streamside and coastal wetlands, is low. Stormwater runoff can cause considerable erosion which in turn can have profound effects on local marine sedimentation (KellerLynn 2011).

Streams in St. John are not being monitored on a regular basis, in part because of them not being perennial. Guinea Gut, which has base flow from spring discharge, is the only intermittent streams on St. John (J. Miller 2017, personal communication). The only runoff data available is for the period from 1979–1989 for the 1.7 km^2 Guinea Gut catchment. Over the 10 years of record, peak discharge exceeded 1.0 cm/h only five times, with the April 1983 storm generating a uniquely high peak flow of 5.5 cm/h (MacDonald et al. 1997).

Ocean Currents

A characteristic feature of the oceanography of the Caribbean Sea is the exchange of water with the Atlantic Ocean, which takes place through a number of passages between the islands and the shallow plateaus. The major surface and near-surface exchange with the Caribbean occurs through the eastern passages. Surface flow is fed into the Caribbean by the Guinea[2] and the Atlantic North Equatorial Current (Watlington and Donoso 1996). The Caribbean Current flows at an average rate in the range of 35 to 45 cm (13 to 18 inches) per second in a westward direction and is modulated by the annual migration of the Intertropical Convergence Zone (ITCZ; Donoso 1990). Upon flowing into the Gulf of Mexico, the current enters a clockwise loop, and ultimately moves out of the Gulf south of Florida (Keller Lynn 2011). Part of the Atlantic North Equatorial Current that has flowed on the eastern side of the Antilles as the Antilles Current merges with the with the Florida Current which issues from the Gulf through the Florida Straits to form the initial portion of the Gulf Stream system. In the vicinity

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[1] Local term used for watercourses. “In the U.S. Virgin Islands (USVI), a watercourse is commonly referred to as a “gut”, and the Virgin Islands Code uses both terms. It is possible that in the USVI the word was derived as a shortened form of the word “gutter”, which could mean (i) a shallow trough below the eaves of a house, (ii) a shallow channel along the side of a road to carry off rainwater, or (iii) a track made by the flow of water.”

Oldendorp (1987) wrote that the streams that “…*come up after a rainfall*...” are called

“…*guts or waterguts*”. (Gardner et al. 2008)

[2] The Atlantic South Equatorial Current (SEC) flows westward toward the Brazilian shelf, and or splits at Cabo de Sao Roque, near 16°S with one branch, the stronger of the two, heading northwards as the North Brazil Current (NBC) and the other, weaker southwards branch, as the Brazil Current. The NBC flows north along the northeastern coast of South America, it reaches French Guiana, where part of it separates from the coast and turns to join the North Equatorial Counter Current moving eastward. The rest of the NBC continues flowing northwestward to form the Guiana Current. The Guiana (Guyana) Current has been previously referred to as the South Equatorial Current, the North Brazil Coastal Current, and the North Brazilian Current. The confusion surrounding its name is due partly to the seasonal change in flow of nearby currents (https://oceancurrents.rsmas.miami.edu/atlantic/atlantic.html)

of St. John, the speed of the ocean current is of the order of 10 cm (4 in) per second. These currents are not as intense as those in the central portions of the Caribbean (Figure 2.2.2.8).

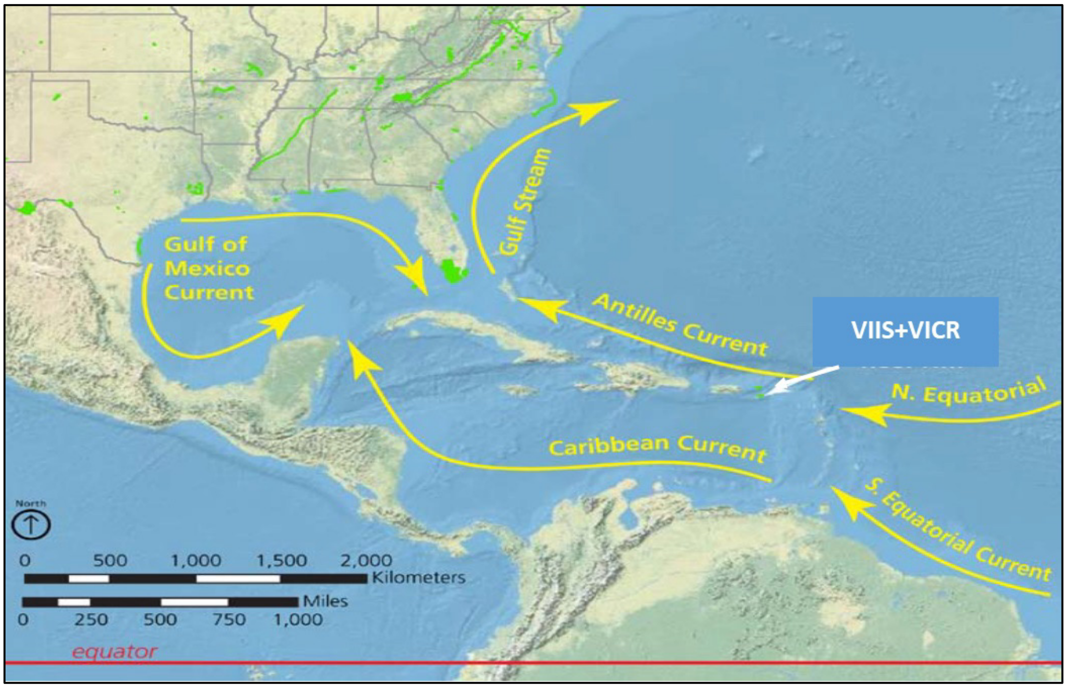

Figure 2.2.2.8. Major oceanographic currents. Global circulation around the equator drives oceanographic currents in the Caribbean. Ocean currents around Virgin Islands flow predominantly from east to west. Current directions after Hubbard (1989). Aerial imagery from ESRI Arc Image Service, USA Prime Imagery, compiled by Jason Kenworthy (NPS Geologic Resources Division). (Modified mage and caption from KellerLynn 2011)

In terms of the strength of the currents within the various bays around St. John, testimony from swimmers and snorkelers indicate that the current is strong at Waterlemon Cay. Salt Pond was reported as to have a bit of a current as well, whereas Francis Bay, Honeymoon, Maho Bay and Caneel Bay are very calm. Trunk Bay has an underwater snorkel trail and has been reported to be calm; however, the current may be strong by the tip of that island (TripAdvisor 2019).

Marine Communities

Marine Plants

Seagrass

Native seagrasses to VIIS and VICR include *Thalassia testudinum* (turtle grass), *Syringodium filiforme* (manatee grass), and *Halodule wrightii* (shoal grass) (Rogers and Beets 2001). The invasive seagrass, *Halophila stipulacea*, was first reported off St. John in 2012 along Mennebeck Reef in a mixed bed of native seagrasses and subsequently observed at multiple sites within both VIIS and VICR (Willette et al. 2014; Figure 2.2.2.9).

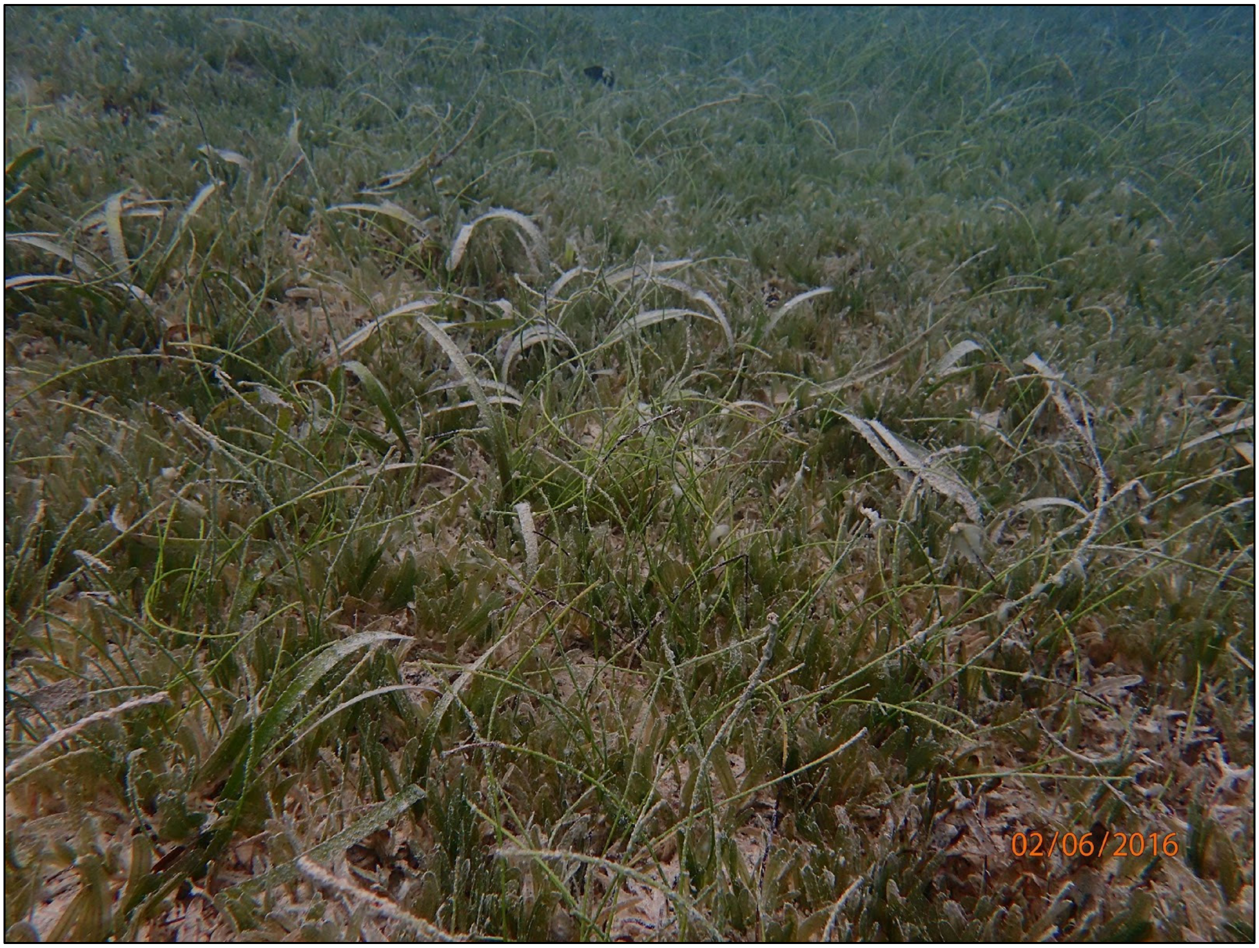

Figure 2.2.2.9. The invasive seagrass *H. stipulacea* (short elliptic/oblong blades 3–8 cm long, with distinct mid-veins) growing intermixed with *T. testudinum* and *S. filiforme* near St. John, USVI. Photo credit John Cassell.

Estimates of historical trends in seagrass cover around St. John from photographs and density surveys suggest that benthic cover and shoot density decreased towards the end of the 20th century (Rogers and Beets 2001). The declines were attributed to high anchorage and severe weather events. The restriction of anchoring and placement of mooring balls may have mitigated the decline. The spread of the non-native *H. stipulacea* now has the potential to increase the total seagrass habitat area but the increase might be at the expense of native seagrasses.

Algae

Macroalgae is often found in mixed seagrass meadows and, along with filamentous algae, on coral rubble inside fringing coral reefs (Zitello et al. 2009; Figure 2.2.2.10). Rhodolith beds, fields of unattached fragments of layered coralline red algae, are found in moderate-depths relative to surrounding habitats. Algae provide habitat structure and are the base of food webs for diverse ecosystems. Protected and commercially important fish species such as Nassau grouper (*Epinephelus striatus*) use macroalgae as near-shore nursery habitat and chalk bass (*Serranus tortugarum*) that primarily live on the algal plain throughout their lives (Garrison et al. 1998).

Figure 2.2.2.10. Macroalgae (dark green) growing within a *S. filiforme* meadow. Photo credit: NPS (https://npgallery.nps.gov/AssetDetail/36DE1204-08F7-CAFD-665720F46CD2529F)

Marine Invertebrates

Corals

Stony corals (Order Scleractinia) are the most important habitat forming species in VIIS-VICR and coral reefs support the highest diversity of marine plants, animals, and microorganisms. Coral reefs and coral communities cover approximately a quarter of the benthic habitat. Shallow water (< 30 m depth) coral reefs are particularly conspicuous as fringing reefs around the main island of St. John and its lesser islands (see Section 4.3.1). These reefs harbor over 30 species of stony corals, including the US Endangered Species Act listed species: elkhorn coral (*Acropora palmata*), staghorn coral (*Acropora cervicornis*), pillar coral (*Dendrogyra cylindrus*), rough cactus coral (*Mycetophyllia ferox*), lobed star coral (*Orbicella annularis*), mountainous star coral (*Orbicella faveolata*), and boulder star coral (*Orbicella franksi*). In addition, the southern portion of VICR contains deeper habitats (>30 m depth) that are underexplored but are likely to contain dense mesophotic coral reefs with coral cover in excess of 30%. Coral cover has been declining since at least the 1980s, with degradation driven by climate change and thermal stress, regional overfishing, disease epizootics, land-based sources of pollution, and failure to recover after natural disturbances such as tropical storms.

Long spined sea urchins

The long spined sea urchin (*Diadema antillarum*) was one of the most important grazing herbivores in VIIS-VICR due to its ability to intensively overgraze reef surfaces keeping them free of coral competing species, such as macroalgae, and promoting coral recruitment (Edmunds and Carpenter 2001). The urchins were decimated by a Caribbean-wide epizootic of unknown cause in the early 1980s (Lessios 1988). Typical abundances on shallow coral reefs prior to the die-off were greater than 100 urchins per 100 m^2. From 2003 to 2018 abundance of urchins ranged between 0 and 9 per 100 m^2 at seven long-term monitoring sites (Figures 2.2.2.11 and 2.2.2.12). There appeared no trend of increase compared to historical abundances. Most recently, urchin abundances declined at most sites following the extensive damage to shallow water marine environments caused by Hurricane Irma on September 6, 2017.

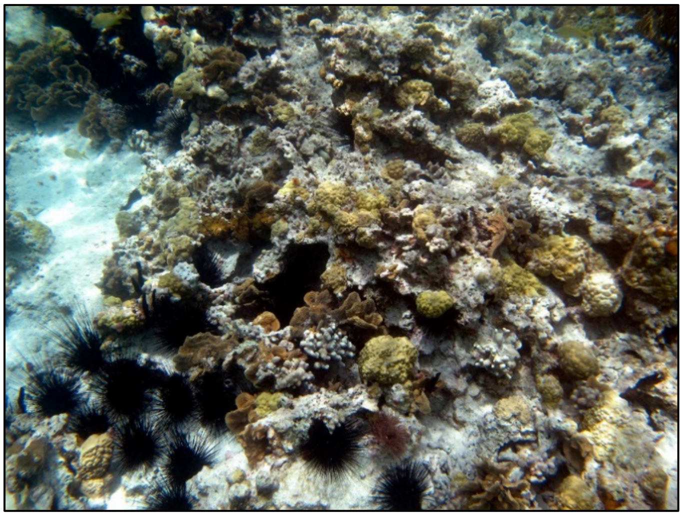

Figure 2.2.2.11. An aggregation of long-spined urchins at Salomon Bay, St. John (June 28, 2012; photo credit: Tyler B. Smith)

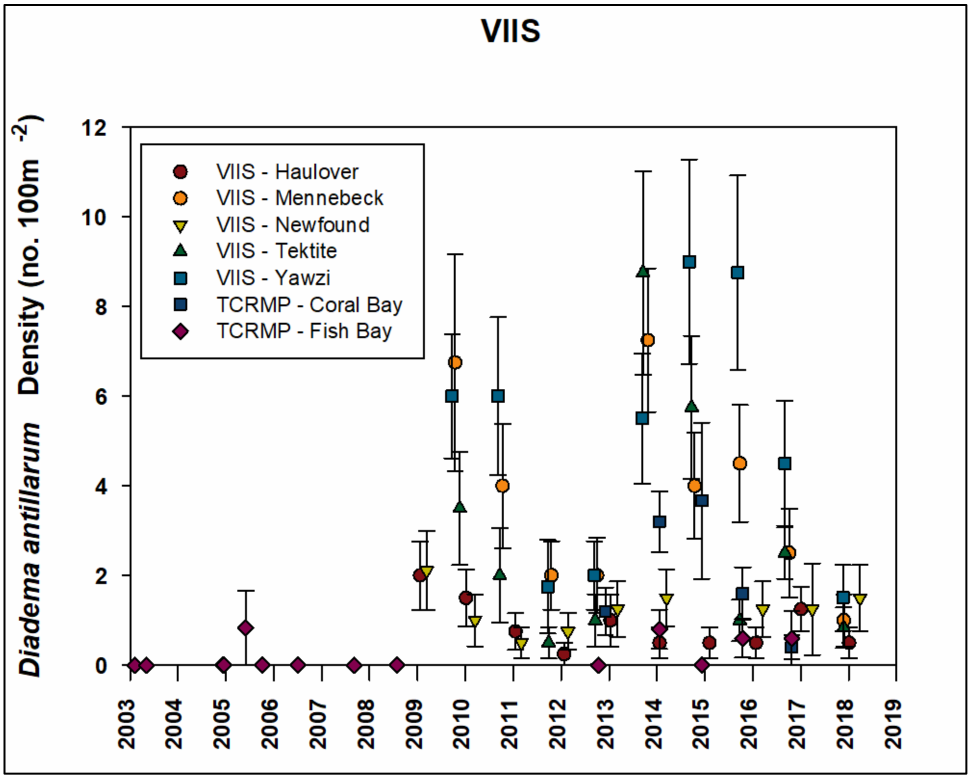

Figure 2.2.2.12. Density of the long-spined sea urchin (*Diadema antillarum*) at long-term coral reef monitoring sites in and around the VIIS and VICR. Urchin data taken along transects. Descriptions of the long-term sites provided in Section 4.3.1 of this report (Ennis et al. 2019).

Queen conch and Spiny Lobster

Caribbean spiny lobster (*Panulirus argus*) and queen conch (*Lobatus gigas*) have historically been important fisheries species in the USVI. Fish and shellfish population declines in the 1960s–1970s prompted fishing regulations to be signed into law in 1972 (Virgin Islands Code). Several amendments in the following years established further restrictions on lobster and queen conch, such as minimum size requirements and seasonal closures. However, the Virgin Islands National Park (VIIS) and Virgin Islands Coral Reef National Monument (VICR), established in 1956 and 2001, respectively, have provided protections for lobster and conch since their creation (Richter et al. 2018). Within the boundaries of the VIIS, recreational lobster and conch take follows the established territorial fishing regulations, but take is limited to two individuals per person per day (Richter et al. 2018). The VICR is a designated no-take zone.

Historically, lobster populations within the USVI were reported as quite high (Rogers and Teytaud 1988); however, in later years stocks had been severely depleted and even within the VIIS, fishing impacts on lobster populations could be observed (Olsen et al. 1975, Rogers and Teytaud 1988). Several reports from the 1990s documented declines in both population at some previously studied locations (Wolff 1998, Boulon 1999) and individual sizes (Wolff 1998) within the VIIS. More recent study has shown that lobster populations within the VIIS continue to be quite low and patchy (Richter et al. 2018). Continued monitoring of lobster occurs on randomly distributed transects during the biennial National Coral Reef Monitoring Program (NCRMP). The most recently completed sampling in 2017 found average lobster densities to be highest within the VICR and both St. John national parks had densities higher than areas open to territorial fishing regulations. Table 2.2.2.1 provides lobster and conch densities calculated from the National Coral Reef Monitoring Program sampling in 2017. Figure 2.2.2.13 shows the map of lobster and conch densities. However, populations were very patchy and on average 90% of locations surveyed within park boundaries contained no lobster. The maximum number of lobster observed at a single site was 3 individuals.

Table 2.2.2.1. Lobster and queen conch densities calculated from the National Coral Reef Monitoring Program sampling in 2017. Densities were calculated for the following management regimes in St. Thomas and St. John: open (open area – territorial fishing regulations), STEER (St. Thomas East End Reserves – no take zone), VICR (Virgin Islands Coral Reef National Monument – no take zone), and VIIS (Virgin Islands National Park – 2 individuals/person/day of legal size). STEER and open areas are shown for reference.

	Density (#/ha) ± SEM	
Management Regime	**Lobster**	**Conch**
Open	8.1 ± 4.7	73.2 ± 27.6
STEER	66.7 ± 51.9	100.0 ± 84.1
VICR	72.1 ± 32.0	153.2 ± 67.9
VIIS	18.2 ± 10.3	175.8 ± 97.4

Queen conch populations within the boundaries of the VIIS have been low as early as the 1980s, potentially attributed to habitat degradation and overfishing (Boulon 1987; Rogers and Teytaud 1988; Boulon 1999). Additionally, Friedlander (1996) stated that under the current management regulations, the conch fishery within the boundaries of the park was unsustainable. However, more recent surveys of conch populations recorded higher densities (35.3 conch/ha) than had been previously found (7.2 conch/ha) in the same areas (Gordon 2002, Gordon 2010, Richter 2015). Doerr and Hill (2007) found that juvenile conch can exhibit site fidelity in shallow nearshore habitats, and this behavior could make them more vulnerable to shoreline activities and habitat degradation (Doerr and Hill 2013). Finally, the most recently completed NCRMP surveys in 2017 found that conch densities were highest in both the VIIS and VICR compared to areas open to territorial fishing regulations.

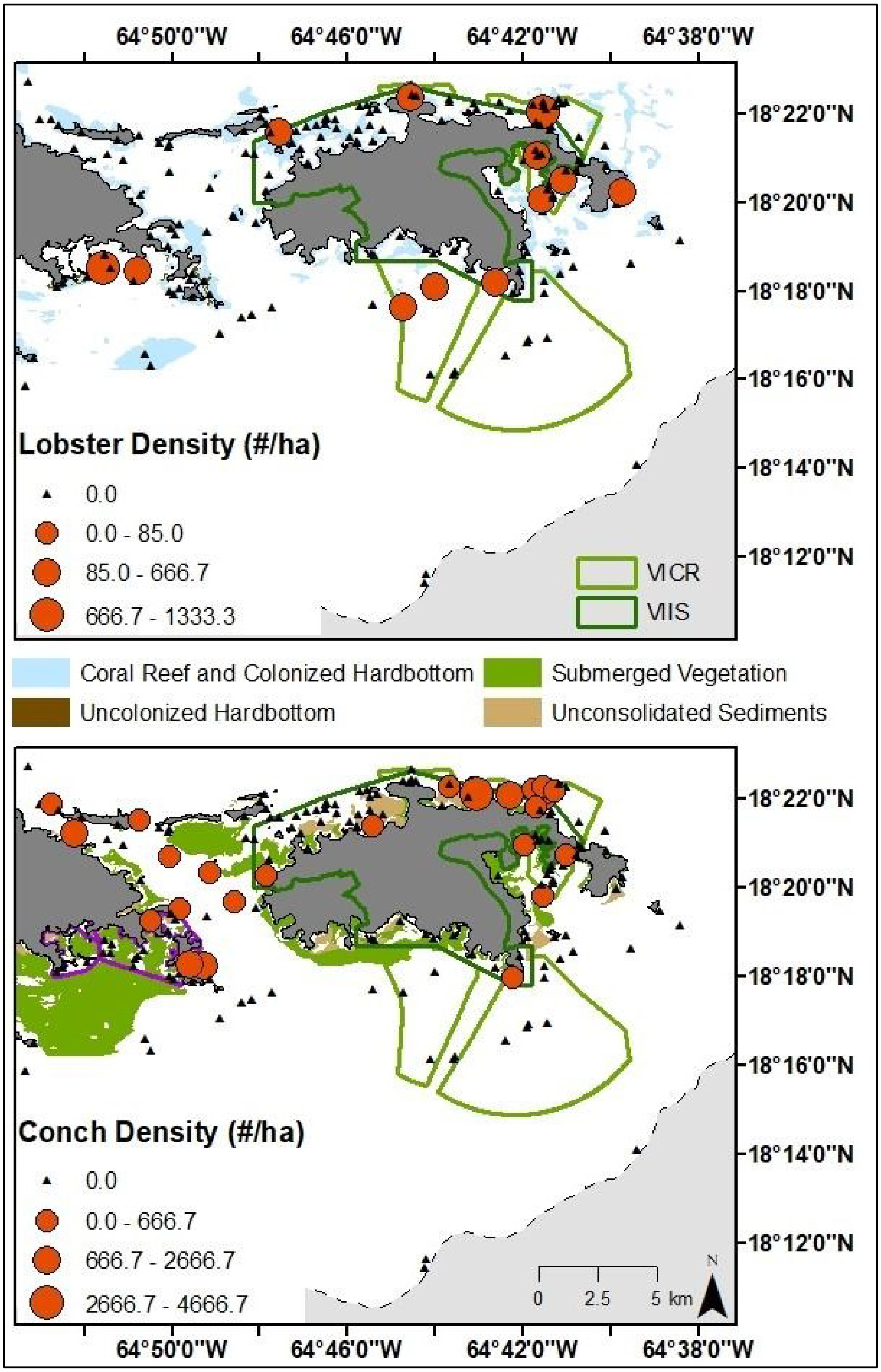

Figure 2.2.2.13. Map of lobster (top) and queen conch (bottom) densities (#/ha) calculated from the most recently completed National Coral Reef Monitoring Program (NCRMP) sampling (2017). VIIS = Virgin Islands National Park, VICR = Virgin Islands Coral Reef National Monument. Open areas also shown for reference.

Sponges

Sponges form a diverse component of the marine benthos in VIIS-VICR but are poorly characterized. In general, on coral reefs, sponges represent a minor component of the benthic cover and are typically less than 5% cover (see Section 4.3.1). However, on hard bottom habitats with low coral cover they may form an important component of benthic structure that shelters fishes and invertebrates.

Marine Vertebrates

Reef Fish

Multiple habitats within VIIS and VICR support high reef fish diversity, including seagrass and corals pictured in Figure 2.2.2.14. Data reported from studies of reef fish in VIIS include species, diversity, community composition, richness, and trophic groups, with earliest studies dating to the 1960s (Randall 1963). Other studies have investigated the stressors that affect fish communities in the park's reefs, the main one being the degradation of the marine ecosystem, including the impacts of fishing (Rogers and Beets 2001). An analysis of trends in reef fish communities in VIIS and VICR can be found in Section 4.4.1.

Figure 2.2.2.14. Schoolmaster snapper at Hurricane Hole Princess Bay. Photo credit: John Cassell.

Pelagic Fish

Thirteen species of pelagic fish were caught during a fish aggregation device study between 1986 and 1990 in both inshore and shelf edge waters near VIIS and VICR (Friedlander et al. 1994). Pelagic fish [e.g., bar jack (*Caranx ruber*), barracuda (*Sphyraena* spp.), and cero (*Scomberomorus regalis*)] are often observed during reef fish surveys within the boundaries of both VIIS and VICR (Figure 2.2.2.15). The three aforementioned species were also the most frequently observed species during the study by Friedlander et al. (1994). Pelagic fish have opportunistically been included in monitoring studies of reef fish within park boundaries.

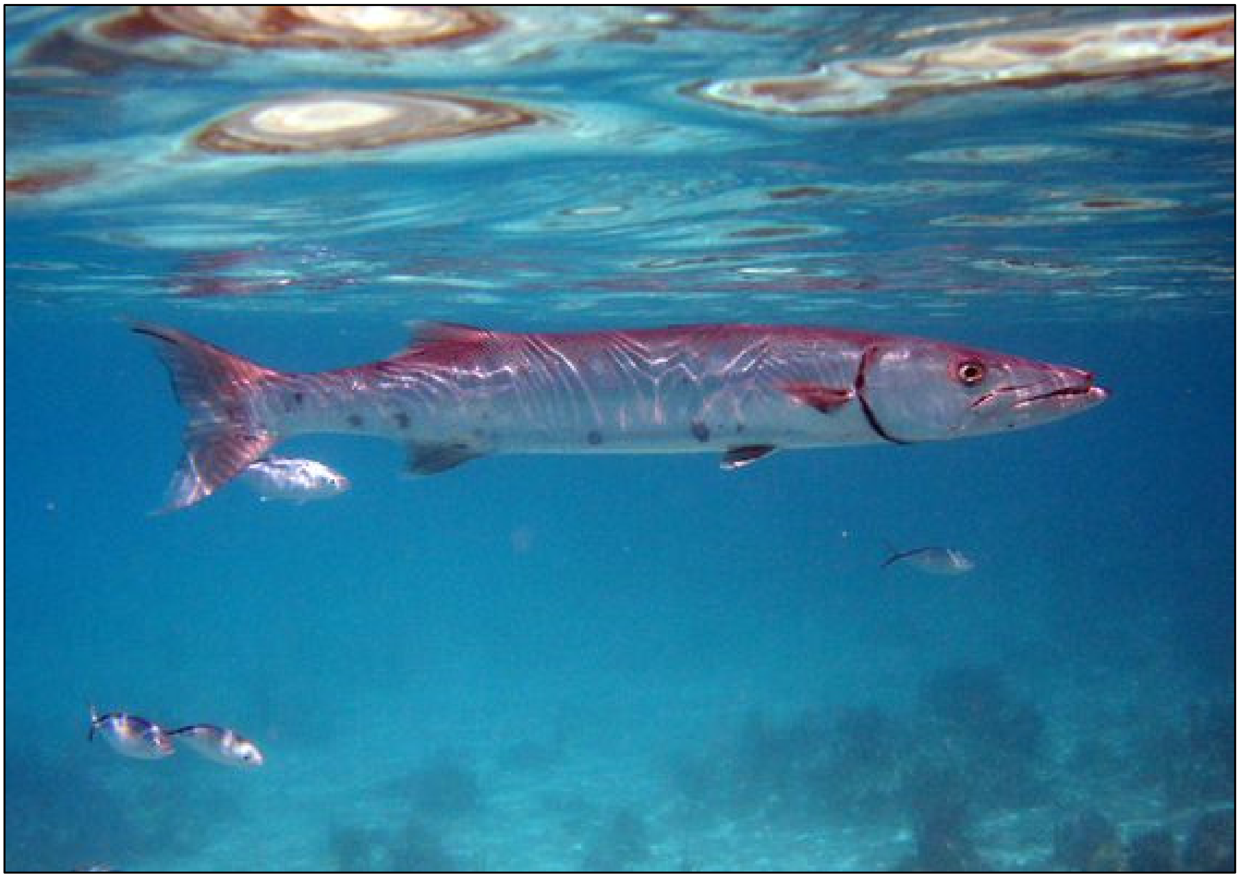

Figure 2.2.2.15. A barracuda and three bar jacks observed in VIIS. Photo credit: NPS (https://npgallery.nps.gov/AssetDetail/2D122962-1DD8-B71C-078D0125BCA2A182)

Sea Turtles

Historically, sea turtles in the USVI have played an important role in the local culture (e.g., as food and inspiring art) and economy (e.g., through the sale of green turtle meat and hawksbill jewelry). Throughout the USVI, sea turtle populations have declined because of habitat loss, hunting to meet the demand of restaurants, and nest predation by non-native mongooses and dogs (Nellis and Small 1983). The USVI prohibited the take of hawksbill (*Eretmochelys imbricata*) and leatherback (*Dermochelys coriacea*) turtles in 1972 prior to the 1973 U.S. Endangered Species Act that added protection for green turtles *(Chelonia mydas*) (Platenberg and Boulon 2011). Sea turtles continue to inspire local art and support the local economy through ecotourism. The Friends of the Virgin Islands National Park sponsor the St. John Sea Turtle Monitoring and Protection Program. Hawksbill turtles nest on St. John more often than any other species with peak nesting between August and November. An average of one leatherback sea turtle nest is found each year, and the first documented green sea turtle nest on St. John was found in 2017 (Figure 2.2.2.16).

No turtle sightings were recorded in either VIIS or VICR during surveys conducted as part of NOAA's reef fish monitoring program. Green and hawksbill turtles have been recorded by volunteers (a mix of both expert and novice fish observers) conducting surveys for the Reef Environmental Education Foundation (REEF) in VIIS from 1994 to 2017 and VICR from 2000 to

2015 (Table 2.2.2.2). Eighty-three surveys were conducted in VICR from 2000 to 2015, while 970 surveys were conducted in VIIS from 1994 to 2017.

Data are lacking on the effects of anthropogenic factors such as fisheries, pollution, habitat loss, and boating as well as the effects of natural disasters such as hurricanes on sea turtle populations in VIIS and VICR. Studies of foraging habitat use (both interesting and year-round) are needed to identify critical habitats and to identify ecosystem-based conservation goals.

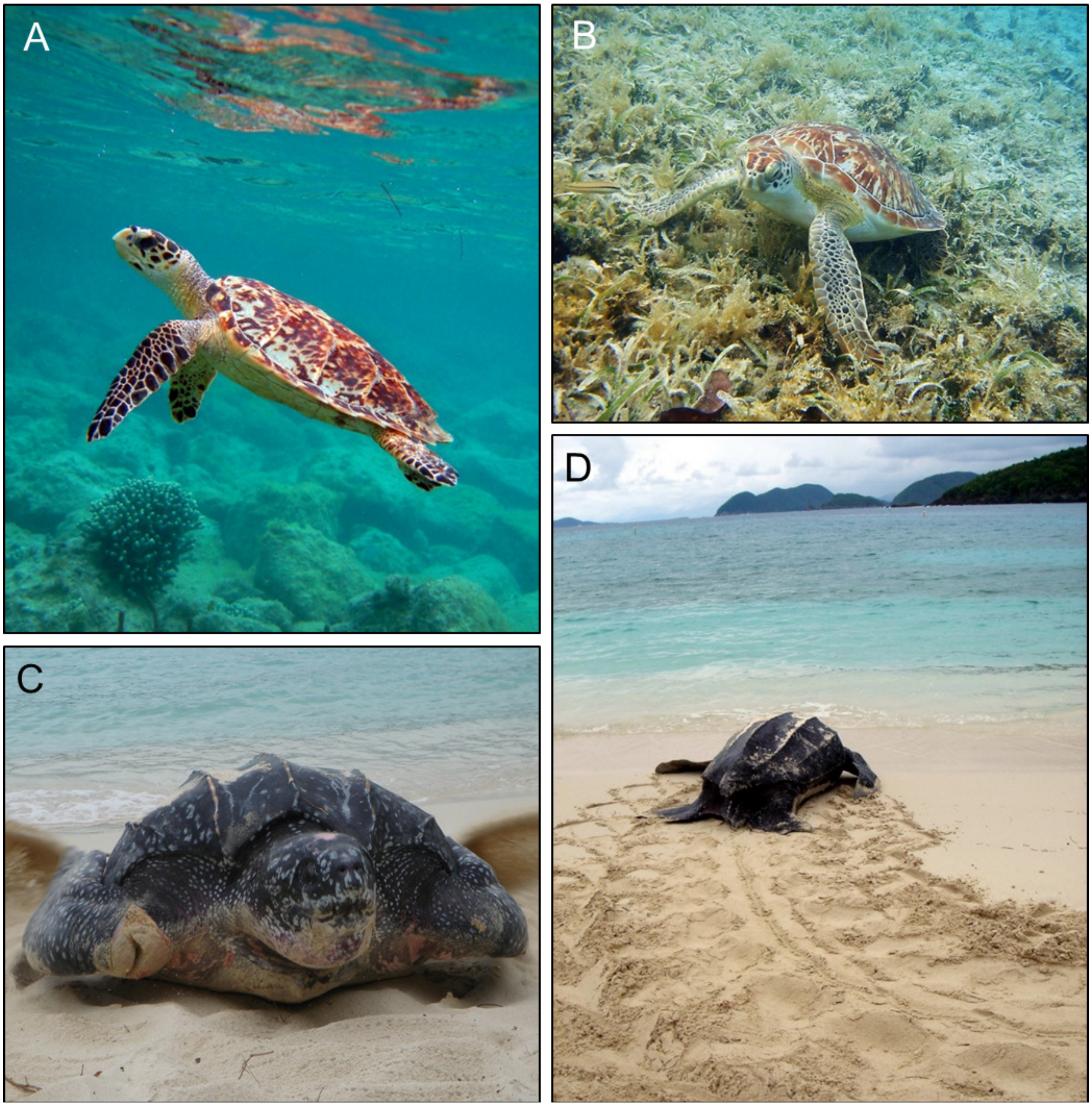

Figure 2.2.2.16. Sea turtles observed in VIIS: A) hawksbill turtle, B) green turtle resting on seagrass, C) leatherback turtle coming onshore to nest, and D) leatherback turtle returning to the ocean. Photo Credit: Caroline Rogers and NPS

Table 2.2.2.2. Sea turtle sightings during REEF surveys (1994–2017) and the mean number of turtles per survey calculated for each year in parentheses. (Data from REEF 2018).

Area	Year	Surveys	Unknown	Hawksbill	Green	Total Observed
VICR	2000	11	0 (0)	0 (0)	0 (0)	0 (0)
VICR	2001	1	0 (0)	0 (0)	0 (0)	0 (0)
VICR	2002	5	0 (0)	0 (0)	0 (0)	0 (0)
VICR	2003	1	0 (0)	1 (1)	0 (0)	1 (1)
VICR	2004	33	0 (0)	6 (0.18)	2 (0.06)	8 (0.24)
VICR	2005	1	0 (0)	0 (0)	0 (0)	0 (0)
VICR	2010	4	0 (0)	0 (0)	0 (0)	0 (0)
VICR	2011	16	0 (0)	0 (0)	0 (0)	0 (0)
VICR	2012	3	0 (0)	1 (0.33)	0 (0)	1 (0.33)
VICR	2015	8	0 (0)	0 (0)	0 (0)	0 (0)
VIIS	1994	17	0 (0)	0 (0)	0 (0)	0 (0)
VIIS	1995	11	0 (0)	0 (0)	0 (0)	0 (0)
VIIS	1996	95	0 (0)	0 (0)	0 (0)	0 (0)
VIIS	1997	9	0 (0)	0 (0)	0 (0)	0 (0)
VIIS	1998	159	0 (0)	0 (0)	0 (0)	0 (0)
VIIS	1999	217	0 (0)	0 (0)	0 (0)	0 (0)
VIIS	2000	47	0 (0)	0 (0)	0 (0)	0 (0)
VIIS	2001	10	0 (0)	1 (0.1)	0 (0)	1 (0.1)
VIIS	2002	86	2(0.02)	44 (0.51)	1 (0.01)	47 (0.55)
VIIS	2003	11	0 (0)	3 (0.27)	0 (0)	3 (0.27)
VIIS	2004	48	10 (0.21)	14 (0.29)	4 (0.08)	28 (0.58)
VIIS	2005	15	1(0.07)	4 (0.27)	0 (0)	5 (0.33)
VIIS	2006	4	0 (0)	0 (0)	0 (0)	0 (0)
VIIS	2007	43	0 (0)	3 (0.07)	1 (0.02)	4 (0.09)
VIIS	2008	45	2(0.04)	5 (0.11)	11 (0.24)	18 (0.4)
VIIS	2009	19	0 (0)	3 (0.16)	1 (0.05)	4 (0.21)
VIIS	2010	14	5 (0.36)	0 (0)	4 (0.29)	9 (0.64)
VIIS	2011	67	5 (0.07)	7 (0.1)	11 (0.16)	23 (0.34)
VIIS	2012	1	0 (0)	1 (1)	1 (1)	2 (2)
VIIS	2013	6	0 (0)	0 (0)	2 (0.33)	2 (0.33)
VIIS	2014	17	0 (0)	0 (0)	1 (0.06)	1 (0.06)
VIIS	2015	18	0 (0)	1 (0.06)	0 (0)	1 (0.06)
VIIS	2016	4	0 (0)	0 (0)	1 (0.25)	1 (0.25)
VIIS	2017	7	0 (0)	1 (0.14)	2 (0.29)	3 (0.43)

Sharks and Rays

No concerted efforts have been made to study sharks and rays within park and monument boundaries. However, multiple studies have identified the coastal bays off St. John as nursery habitat for multiple species including *Carcharhinus limbatus* (blacktip shark) and *Negaprion brevirostris* (lemon shark) (DeAngelis et al. 2008, Legare et al. 2015).

Bottom-longline and hand-gear sampling in Fish Bay (adjacent to VIIS) from eight sampling trips conducted June 2004 through December 2005 found primarily neonatal and young-of-the-year *Negaprion brevirostris* (lemon shark) and *Carcharhinus limbatus* (blacktip shark), as well as *Dasyatis Americana* (southern stingray), *Ginglymostoma cirratum* (nurse shark), *Carcharhinus acronotus* (blacknose shark), and *Rhizoprionodon porosus* (Caribbean sharpnose) (DeAngelis et al. 2008). The relative abundance of all species was significantly higher in summer than winter sampling seasons.

Passive acoustic tracking from 2006 to 2012 off St. John in Fish Bay and Coral Bay (also adjacent to VIIS) revealed high site fidelity across years for primarily young of the year blacktip sharks (42–69 cm) and lemon sharks (48–103 cm) in shallow nearshore habitats (Legare et al. 2015). The highest number of detections for both species occurred from May to August with a decrease in detections, attributed to emigration and/or mortality, from August to October. Although the passive acoustic tracking study was conducted in bays outside of VIIS and VICR, it highlights the importance of St. John's nearshore habitats for at least two species of sharks.

Few species of sharks and rays were observed in either VIIS and VICR during surveys conducted as part of NOAA's reef fish monitoring program. Between 2001 and 2011, nurse sharks were observed nine times in VICR and four times in VIIS, southern stingrays four times in VICR and once in VIIS, and a spotted eagle ray once in VICR (Table 2.2.2.3; Figure 2.2.2.17**).**

Table 2.2.2.3. Observations and size of sharks and rays observed during NOAA reef fish surveys from 2001 to 2011 (https://data.noaa.gov/datasetsearch/).

Unit	Survey Year	Count	Length ±SD (cm)	Count	Length ±SD (cm)	Count	Length ±SD (cm)
VICR	2003	1	120	0	–	0	–
VICR	2004	1	150	0	–	0	–
VICR	2005	0	–	1	120	0	–
VICR	2006	2	60 ±14.14	0	–	–	–
VICR	2007	1	100	1	135	1	170
VICR	2008	1	107	0	–	0	–
VICR	2009	1	60	1	61	0	–
VICR	2010	2	140 ±14.14	1	65	0	–
VIIS	2003	2	125 ±49.5	0	–	0	–
VIIS	2005	1	240	0	–	0	–

Table 2.2.2.3 (continued). Observations and size of sharks and rays observed during NOAA reef fish surveys from 2001 to 2011 (https://data.noaa.gov/datasetsearch/).

Unit	Survey Year	Count	Length ±SD (cm)	Count	Length ±SD (cm)	Count	Length ±SD (cm)
VIIS	2006	1	110	0	–	0	–
VIIS	2009	0	–	1	120	0	–

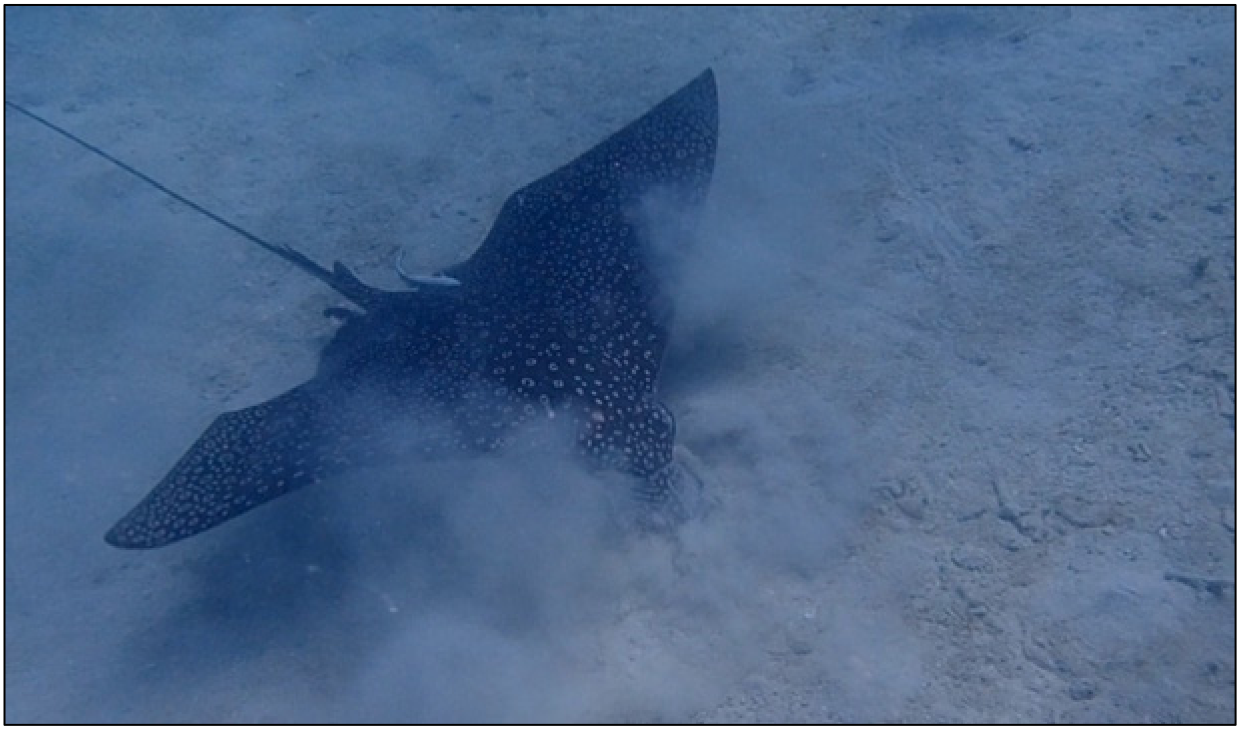

Figure 2.2.2.17. Eagle ray foraging in Maho Bay. Photo Credit: John Cassell

The potential impacts of increasing or decreasing shark populations can have cascading effects on ecosystems (e.g., Feretti et al. 2010; Heithaus et al. 2014). A targeted shark census would elucidate the potential effects of sharks on other park resources and identify critical nursery habitats that may require additional monitoring and management.

Mammals

The proximity of US. Virgin Islands to deep water provides access to resident and migrating cetaceans such as dolphins and humpback whales. However, no targeted research has been conducted on marine mammals within the boundaries of VIIS or VICR. A meta-analysis of published literature, unpublished reports, and fisher surveys between 1952 and 1989 on marine mammal sightings across the insular shelf occupied by Puerto Rico, the US Virgin Islands, and the British Virgin Islands reported sightings of 17 different species (Mignucci-Giannoni 1998). Subsequent surveys in the region reported sightings of 142 cetacean groups from 11 species, and audio recordings of humpback whales between the British Virgin Islands and St. Croix (Swartz et al. 2002). Pygmy killer whales

(*Feresa attenuate*), although not seen during surveys, also likely occupy waters near the parks. Following Hurricane Marilyn in 1995, five pygmy whales reportedly stranded in the British Virgin Islands (Mignucci-Giannoni et al. 2000). Similar species composition but lower encounter rates were reported for the 2001 surveys compared to prior surveys. More recent sighting data can be gleaned from the blogs and the social media of locals, tourists, and eco-tourism operators (e.g., Figure 2.2.2.18). Data on cetaceans within VIIS and VICR are lacking including estimates of species abundance, migratory patterns, feeding behaviors, and stressors such as disease, human impacts, and extreme weather events.

Figure 2.2.2.18. Tourists from Puerto Rico enjoying an encounter with a dolphin in Maho Bay, St. John. Photo credit: Gerald Singer 2009.

Terrestrial Communities

Terrestrial communities on St. John span several different physiognomic types, including grasslands, shrublands, woodlands and forests (Gibney et al. 2000). A wide diversity of plants and animals inhabit VIIS, over 50% of which is in forest and another 35% in woodland and shrubland (Figure 2.2.2.19; Thanawastien et al. 2015). At the time of Danish colonization in 1718, St. John was heavily forested, but within a decade all large trees had been harvested leaving a small-statured forest (Tyson 1984). By 1760, 98% of the land area was in plantations (Tyson 1987), however not all land was in cultivation at any one time. A land use map from the 1780s shows only ~35–40% of the lands cleared for sugar cultivation (Oxholm 1780), while the remaining ~60% likely was in secondary forest (Tyson 1984). This patchwork of cultivation and forest would have provided a continuous seed source for recolonization of abandoned parcels (Gibney 2004). The terrestrial communities found today face pressure from invasive plant and animal species, increased development (erosion), and climate change.

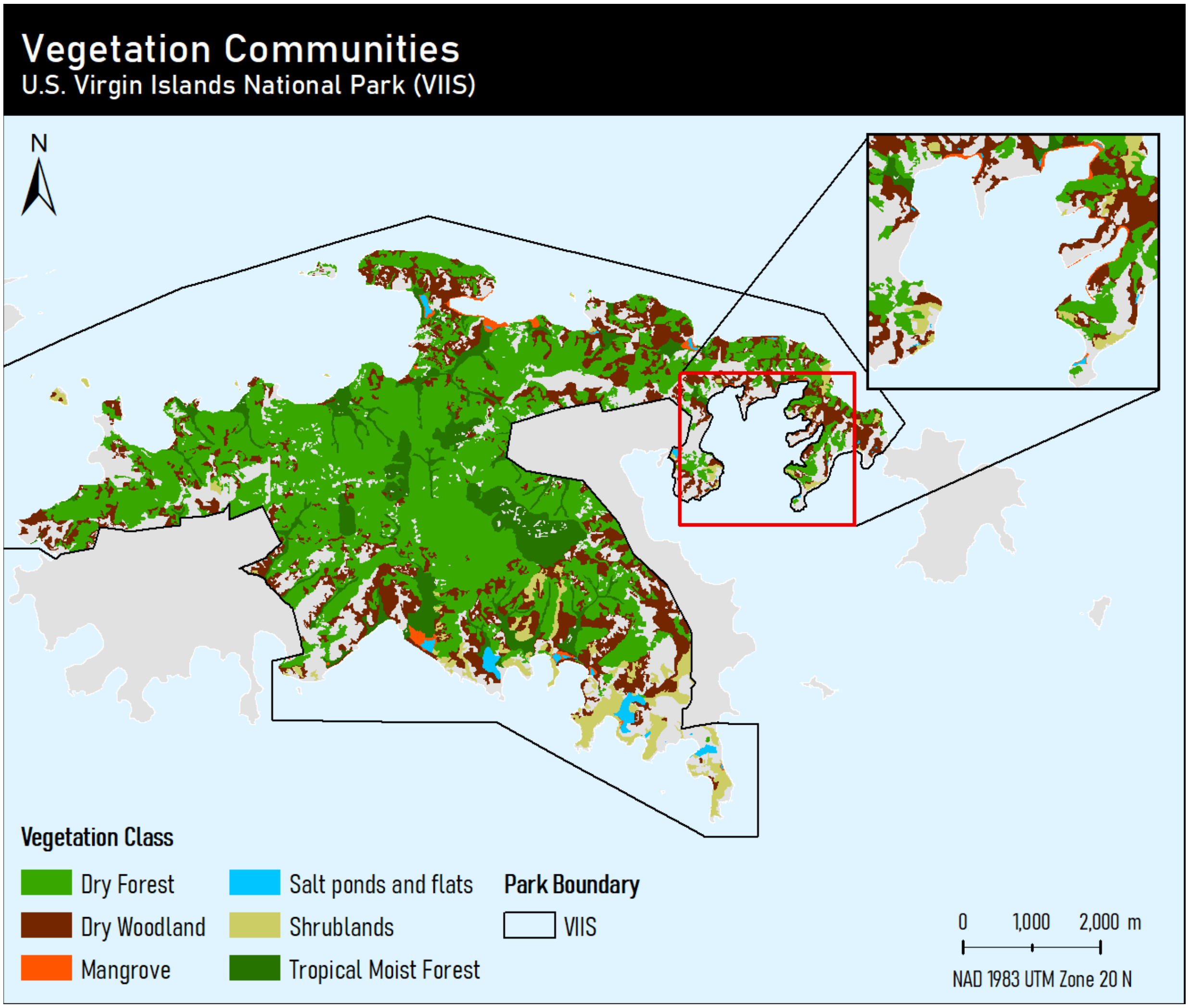

Figure 2.2.2.19. Map of vegetation communities referenced in this report aggregated from the Thanawastien et al. (2015) vegetation classification of Virgin Islands National Park. Inset shows location of fringing mangroves found in Hurricane Hole.

Terrestrial Plants

Vascular plants species on St. John include 747 native or naturalized species, of which, 642 are indigenous to the island (Acevedo 1996). Within VIIS, 712 vascular plant species have been documented, of which 83% are native (Appendix A). Two federally endangered plant species occur within VIIS: Thomas' lidflower, *Calyptranthes thomasiana*, and St. Thomas prickly ash, *Zanthoxylum thomasianum*. Populations of these evergreen shrubs are scarce (there is only one known occurrence of St. Thomas pickly ash) and are negatively impacted from non-native goats and sheep (NPS 2004). Additionally, a parasitic insect has been found to destroy the majority of seeds in the less than 20 individuals that remain of *Z. thomasianum* (Acevedo 1996). Two endemic species to

St. John occur within VIIS: Earhart's stopper, *Eugenia earhartti*, and *Machaonia woodburyana*. Both species could be considered threatened given their small population sizes and/or location (Acevedo 1996). Twenty-five species are Puerto Rican Bank endemics (Acevedo 1996), including the Tyre palm, *Cocothrinax alta*, which grows in both moist and dry forests and was used historically for bags, hats, roof thatch, and rope (Thomas and Devine 2005). The native bay rum tree, *Pimenta racemosa*, was important economically from the 1920–1940s for production of oil and is especially prevalent in Cinnamon Bay (Figure 2.2.2.20; Weaver 2006).

Several invasive exotic plant species are present throughout the park and have been targeted for eradication (Table 2.2.2.4). The dominant non-native species in the park include tan-tan, guinea grass and sweet lime (NPS 2006). Beginning in 2006, the Florida and Caribbean Exotic Plant Management Team (FLC-EPMT) has been working with VIIS to manage invasive plants and protect native species (Figure 2.2.2.21; NPS 2014). This work has included the erection of a fence in Battery Gut area to exclude non-native ungulates and domestic farm animals, cutting and herbicide treatment of exotics on America Hill, Henley, Ramgoat, Watermelon, and Trunk Cays, and construction of a gate across the trail to Nanny Point to exclude goats. Increased mapping and monitoring of invasive species, as well as efficacy of exotic treatment are needed (NPS 2016).

Figure 2.2.2.20. Bay rum trees are prevalent in the moist forest of the Cinnamon Bay plantation. Photo credit: D. Ogurcak, February 2017.

Table 2.2.2.4. Invasive plant species occurring within VIIS, treated by the FLC-EPMT (2006–2014).

Scientific Name	**Common Name**
Bromelia pinguin	pinguin
Leucaena leucocephala	tan-tan, lead tree
Melicoccus bijugatus	genip
Morinda citrifolia	pain killer
Oeceoclades maculata	ground orchid
Sansaveria trifasciata	mother-in-law's tongue
Triphasia trifolia	sweet lime
Urochloa maxima	Guinea grass

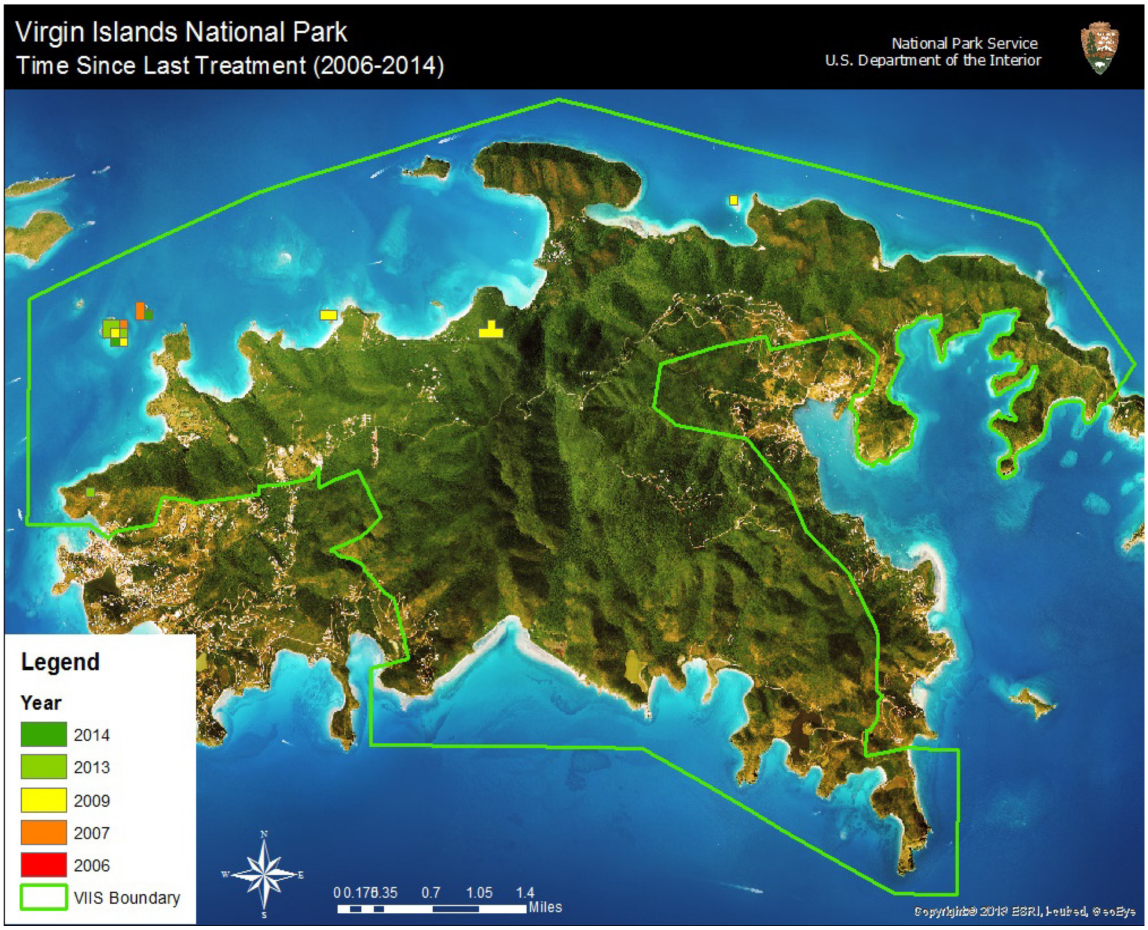

Figure 2.2.2.21. Time since last treatment grid displays the most recent year in which EPMT staff treated a particular area for exotic plant species within VIIS. Figure courtesy of FLC-EPMT 2014 report.

Mangroves

Approximately 60 acres of mangrove occur within the park boundary in forest, woodland, fringing, and shrubland classes (Figure 2.2.2.19; Thanawastien et al. 2015). These classes are defined on the basis of canopy height and tree density. Forests have a closed canopy of trees greater than 5 m in height, woodlands and fringing mangrove similarly contain trees taller than 5 m, but have sparser tree densities (10 to 60%), and individuals within shrublands reach heights of less than 5 m (Gibney et al. 2000). Three true mangrove species – red (*Rhizophora mangle*), black (*Avicennia germinans*), and white mangrove (*Laguncularia racemosa*) – are found within VIIS and are listed as US Virgin Islands Territorially protected (NPS 1999). Along with the mangrove-associate, *Conocarpus erectus,* these species dominate low elevation tidally-flooded zones in protected bays. Mangrove ecosystems provide a number of ecological functions and services including storm protection, carbon storage, and fish nurseries. Mangrove habitat within the USVI decreased by two-thirds between 1980 and 1990 (Ellison and Farnworth 1996). On St. John, combined mangrove and salt pond area has declined from 300 acres since the surveys of Woodbury and Weaver (1987). Hurricane Hole (Figure 2.2.2.22), which is part of the Monument, likely has the most pristine and greatest percentage of remaining mangroves on St. John and perhaps within the USVI (NPS 1999). These mangroves support a diversity of coral, at least 30 species of which have been identified (Rogers 2017). Mangroves on St. John were severely impacted from Hurricanes Irma and Maria (2017), as large decreases in basal area (63–100 % loss) and live standing biomass across all typologies (e.g. fringing, basin, salt pond associated) were documented, with very little post-storm regeneration observed more than 2 years following the impacts (Krauss et al. 2020).

Figure 2.2.2.22. Fringing red mangroves grow along the coastline of Princess Bay in Hurricane Hole. Photo credit: D. Ogurcak, February 2017.

Salt Pond Associated Vegetation

Salt ponds are common features of dry Caribbean coastlines and are typically hypersaline, but with varying connection to the sea (Jarecki and Walkey 2006). They are the dominant wetland type throughout the USVI (Stengle 1998). While they occupy only a small portion of the overall landscape (~ 70 acres in VIIS, Thanawastien et al. 2015) (Figure 2.2.2.19), they provide a prey base for shorebirds and serve as catchments for run-off and pollutants (Platenberg et al. 2005). All mangrove species can be found fringing the edge of salt ponds, but occurrence is dependent on pond salinity (Gangemi 2003). Sevreral salt-tolerant herbaceous species are commonly associated with salt flats, the coastal flats adjacent to mangroves, and salt ponds: *Sesuvium portulacastrum*, *Heliotropium curassavicum*, *Sporobolous virginicus*, *Blutaparon vermiculare* (Woodbury and Weaver 1987). Assessment of ponds has documented animal and plant species, water quality, and sedimentation (Stengle 1998; Gangemi 2003; Rennis et al. 2006). Salt ponds are often negatively impacted by sedimentation and nutrient contamination from upslope land management practices.

Tropical Dry Forest

Dry forests occupy the majority (48%) of the landscape within VIIS and are comprised of four classes, including semi-evergreen, semi-deciduous, gallery semi-deciduous, and drought deciduous forest types (Figure 2.2.2.19; (Thanawastien et al. 2015). If one considers dry woodlands (canopy closure < 60% resulting from recent agricultural abandonment), as merely a successional step toward dry forests, the class' occurrence on the landscape jumps to 65%. Permanent forest monitoring plots have been established throughout this community type. Beginning in the late 1980s, workers inventoried trees at five locations throughout the park including Mary Point, Cinnamon Bay, Caneel Hill, and Lameshur (Ray and Brown 1995) and Hawknest (Reilly et al. 1990). Estimated age of stands ranges from 35 to 125 years. Number of species observed over the course of inventories ranged from as many as 54 at Hawknest to eight species at the youngest site, Mary Point, which was dominated by the invasive legume, *L. leucocephala*. However, even older dry forests, like Hawknest (~70 years), can have considerable invasive exotics present; *M. bijugatus* was the most frequent species encountered during surveys in that plot (Reilly et al. 1990).

Tropical Moist Forest

Tropical moist forests in VIIS occupy 9% of the landscape and can be broken into three classes on the basis of their location: upland moist forest, gallery moist forests in guts, and basin moist forests near the coast (Figure 2.2.2.19) (Thanawastien et al. 2015). They are comprised of 75% or more evergreen-leaved tree species and are typified by higher moisture conditions (Thomas and Devine 2005). These are the tallest forests on the island with trees attaining heights of 25 to 30 m (Woodbury and Weaver 1987). While the majority of these forests are secondary forest, having regenerated after agriculture was abandoned, some near pristine stands have been observed in upland locations (Woodbury and Weaver 1987). Forest diversity and structure has been studied in permanent plots within Cinnamon Bay basin and gallery forest (Weaver 2006) and on Bordeaux and L'Esperance upland and gallery moist forest types (Reilly et al. 1990) in the 1980s to 2000s and during a one-time study in Reef Bay basin forest in 1975 (Forman and Hahn 1980). Estimated age of the stands studied ranged from ~30 to 125 years and the number of species observed ranged from 28 at Reef Bay to 80 at Cinnamon Bay. Differences in species composition and relative density of trees between sites are likely result of varying land use histories rather than differences between forest classes (Acevedo 1996).

Terrestrial Vertebrates and Invertebrates

Terrestrial wildlife occurring within VIIS includes indigenous, naturalized, and exotic species of birds, reptiles, amphibians, mammals, and invertebrates. Endangered, threatened, and species of special concern are described for each group and species lists are included as either tables or appendices.

Birds

The avifauna of VIIS is diverse with 174 species recorded across 20 orders (Appendix B). This includes seabirds, waterfowl, marsh and shorebirds, and land birds, including about two dozen breeding or permanent residents (Robertson 1962, NPS 1999). Annual monitoring with the Christmas Bird Count was initiated in 1981 (Patterson et. al 2008). Wintering neotropical migrants are abundant in VIIS and are found three times as often in moist forest compared to dry forest habitats (Askins and Ewert 1992). Of the numerous seabirds occurring within the park and monument, fifteen species breed here (NPS 1999, Platenberg et al. 2005). One federally threatened species, the roseate tern, *Sterna dougallii*, breeds on offshore islands within the USVI, and has been observed in large numbers (~130 post-breeding individuals including fledglings) just off the coast near Mary Point (FWS 1993). The species was first observed nesting in VIIS in 1997 (NPS 1999). The Kirtland's warbler, *Dendroica kirtlandii*, and piping plover, *Charadrius melodus*, are federally listed species that winter in the Caribbean, but neither has been documented in VIIS (NPS 2017a). Seven species are considered territorially endangered (Table 2.2.2.5), and the Caribbean brown pelican, *Pelecanus occidentalis*, is listed a species of special concern (Platenberg et al. 2005). De-listed in 2009, monitoring of brown pelican nesting sites continues within the USVI. The species nests on islets and cliffs on the north side of St. John and there are an estimated 325–425 breeding pairs in the USVI (Pierce 2009).

Table 2.2.2.5. USVI territorially endangered bird species (Platenberg et al. 2005). All species, except the Great blue heron, breed within VIIS (Brannick and Catanzara 2002).

Scientific Name	Common Name
Ardea alba	Great egret
Ardea herodias	Great blue heron
Egretta thula	Snowy egret
Nycticorax nycticorax	Black-crowned night heron
Patagioenas leucocepala	White-crowned pigeon
Sterna antillarum	Least Tern
Tachybaptus dominicus	Least Grebe

Herpetofauna

Thirty extant species of reptiles and amphibians occur within the USVI (Platenberg and Boulon 2006). Within VIIS, twelve species of non-marine reptiles and eight species of anurans have been recently recorded or are thought to occur within the boundaries of the park (Table 2.2.2.6). Four of the anuran species are non-natives, three of which were introduced from other islands within the Greater Antilles, including: *Eleutherodactylus coqui*, common coqui, from Puerto Rico, *E. lentus*, mute coqui, from St. Croix, and *Osteopilus septentrionalis*, Cuban treefrog. The cane or marine toad, *Bufo marinus,* is an exotic introduced from South America. While it has been recorded on St. John in the past and is currently present on nearby islands, a survey of amphibians by the USGS (2001–2003) did not detect this species (Rice et al. 2005). The most commonly observed species during these surveys was *E. antillensis*, Antillean coqui, found throughout most habitats, but especially in forested areas (Rice et al. 2005). Two species of anurans on the IUCN Red List, the Virgin Islands bo-peep, *E. schwartzi,* and the Puerto Rican crested toad, *B. lemur,* were previously recorded from St. John, but are now considered extirpated in the UVSI (Philibosian and Ynetma 1977, Platenberg and Boulon 2006).

Three species of anole, two species of gecko, one species of ground lizard, and the green iguana are commonly found throughout VIIS (Table 2.2.2.6). The Puerto Rican racer, *Alsophis portoricensis,* and the slipperback skink, *Mabuya sloanii,* have been likely extirpated on St. John and occur now only on offshore islands lacking the presence of the introduced Asian mongoose, *Herpestes javanicus* (Platenberg and Boulon 2006). Recent molecular work has split *M. sloanii,* a species found throughout the Caribbean, into several genera and species (Hedges and Conn 2012). Species distribution information within VIIS is lacking for *M. sloanii* and several other reptile species including: the Virgin Islands worm lizard, *Amphisbaena fenestrata*, the Puerto Rican garden snake, *Arrhyton exiguum,* Richard's blind snake, *Typhlops richardii*, and the red-footed tortoise, *Geochelone carbonari.* Additional surveys and ecological study are recommended (Platenberg and Boulon 2006). Both the red-footed tortoise and green iguana are introduced, possibly by pre-Columbian peoples, and have since become naturalized in the USVI and are not considered invasive (Platenberg 2007). In contrast, the more recent introduction of *Trachemys stricta* to the USVI in the last several decades is of management concern as the species is considered highly invasive (Platenberg and Boulon 2006).

Table 2.2.2.6. Reptile and amphibian species found in VIIS (NPSpecies; https://irma.nps.gov/NPSpecies/, Philobosian and Yntema 1976, Platenberg and Boulon 2006, Rice et al. 2005).

Scientific Name	**Common Names**
Amphisbaena fenestrata	Virgin Islands Worm Lizard
Alsophis portoricensis [2]	Puerto Rican Racer
Arrhyton exiguum	Puerto Rican Garden Snake
Hemidactylus mabouia [1]	Afro-American House Gecko, Cosmopolitan House Gecko
Anolis cristatellus	Crested Anole, Puerto Rican Crested Anole
Anolis pulchellus	Common Grass Anole
Anolis stratulus	Barred Anole
Iguana iguana [1]	Common Green Iguana, Green Iguana
Mabuya sloanii complex [2]	Slipperyback skink
Sphaerodactylus macrolepis	Common Dwarf Gecko

[1] Indicates non-native species.

[2] Indicates species likely extirpated in VIIS.

Table 2.2.2.6 (continued). Reptile and amphibian species found in VIIS (NPSpecies; https://irma.nps.gov/NPSpecies/, Philobosian and Yntema 1976, Platenberg and Boulon 2006, Rice et al. 2005).

Scientific Name	**Common Names**
Ameiva exsul	Puerto Rican Ground Lizard
Typhlops richardii	Richard's Blind Snake
Geochelone carbonaria [1]	Red-footed Tortoise
Trachemys scripta [1]	Red-eared slider
Bufo marinus [1]	Cane Toad, Giant Toad, Marine Toad
Eleutherodactylus antillensis	Antillean Coqui, Antillean Frog
Eleutherodactylus cochranae	Whistling Coqui, Whistling Frog
Eleutherodactylus coqui [1]	Common Coqui, Coqui
Eleutherodactylus lentus [1]	Mute Coqui, Mute Frog
Osteopilus septentrionalis [1]	Cuban Treefrog
Leptodactylus albilabris	Caribbean White-lipped Frog

[1] Indicates non-native species.

[2] Indicates species likely extirpated in VIIS.

Terrestrial Invertebrates

Terrestrial invertebrates occurring on St. John include representatives from five phyla: Platyhelminthes (1 species), Mollusca (32 species), Annelida (1 species), Onchyophora (1 species), and Arthropoda (1000 + species) (Muchmore 1987). Arachnids comprise the largest order. A species list, see Appendix C, was compiled from a combination of collections and literature surveys during 1974–1987 (Muchmore 1987). The inventories of Order Acarina and Class Insecta within the Phyla Arthropoda include representative forms only. An estimated 1,200 beetle species occur within the USVI, many of which occur in VIIS. Terrestrial decapods within VIIS include seven species of crabs, including two species of fiddler crab, *Uca rapax* and *U. burgersi*, the mangrove tree crab, *Aratus pisonii*, and great land crab, *Cardisoma guanhumi,* all of which can be found within mangrove forests and adjacent mud flats. Great land crabs are hunted for food where they are not protected.

Mammals

Mammals found within VIIS include six species of bat (all native) and 10 non-native species (Table 2.2.2.7). All bat species except *Artibeus jamaicensis* and *Molossus molossus* are considered locally data deficient according to the Virgin Island Endangered Species and Indigenous Species Act. Additionally, the red fruit bat (*Sternoderma rufum*) is listed as near threatened on the IUCN Red List of threatened species (IUCN 2017). Between 2003 and 2007, inventories were conducted in the park using a combination of mist or harp netting, Anabat™ detector systems, and visual inspection of roost sites. Maps of bat species detections (Figures 2.2.2.23 to 2.2.2.26) include these surveys, as well as surveys conducted in 1997 by Jim Petterson (Fly By Night, Inc. 2017). Land degradation and habitat loss are causes of bat decline in the USVI (Platenberg et al. 2005).

Non-native mammal species arrived at St. John during the period of European colonization. Most species were intentionally introduced as part of the plantation economy in the form of livestock and work animals (Tyson 1984) or as pest control. The small Asian mongoose, *Herpestes javanicus,* was introduced to control the rat population (Cock 1985). These non-native species have a serious impact on indigenous species on the island (NPS 2016). Deer, goats, and donkeys influence forest regeneration by over-browsing palatable plant species and wild hogs destroy vegetation through uprooting and accelerate erosion (NPS 2003). Introduced rodents, feral cats, and mongoose are threats to the island's native herpetofauna and bird species through predation pressure (NPS 2002). Data and planning needs include a deer population study, mapping non-native species, and deer and donkey management plans (NPS 2016).

Table 2.2.2.7. Mammal species documented in VIIS (Fly By Night, Inc. 2017; NPS 2017a) .

Scientific Name	**Common Name(s)**	**Status**
Artibeus jamaicensis	Jamaican fruit-eating bat	Native
Brachyphylla cavernarum	Antillean fruit-eating bat	Native
Molossus	Pallas' free-tailed bat, Pallas's mastiff bat	Native
Noctilio leporinus	Greater bulldog bat	Native
Stenoderma rufum	Desmarest's fig-eating bat, red fig-eating bat, red fruit bat	Native
Tadarida brasiliensis	LeConte's free-tailed bat	Native
Canis familiaris	feral dog	Non-native
Capra hircus	goat	Non-native
Equus asinus	feral ass	Non-native
Felis catus	feral cat	Non-native
Herpestes javanicus	Indian mongoose, Javan mongoose, small Asian mongoose	Non-native
Mus musculus	house mouse	Non-native
Odocoileus virginianus	white-tailed deer	Non-native
Rattus norvegicus	Norway rat	Non-native
Rattus	black rat	Non-native
Sus scrofa	feral hog	Non-native

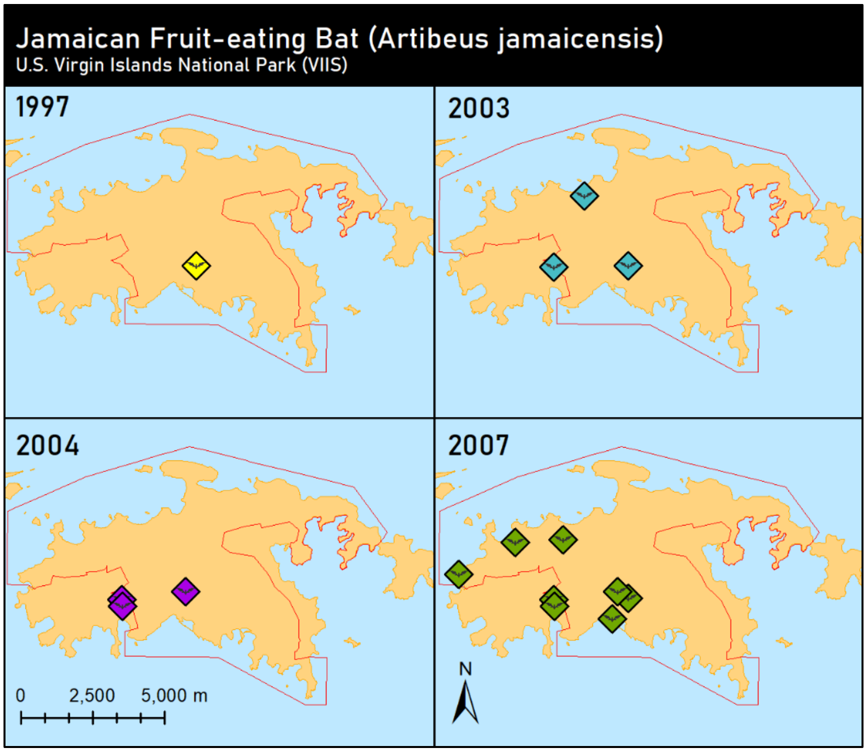

Figure 2.2.2.23. Detections of the Jamaican fruit-eating bat within VIIS 1997–2007 (Fly By Night, Inc. 2017).

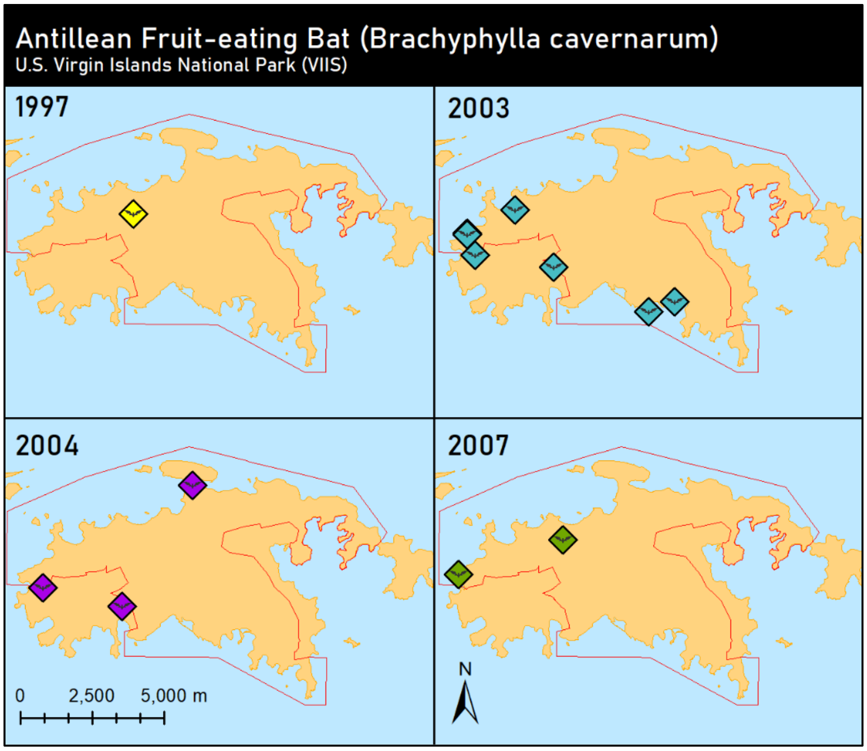

Figure 2.2.2.24. Detections of the Antilean fruit-eating bat within VIIS 1997–2007 (Fly By Night, Inc. 2017).

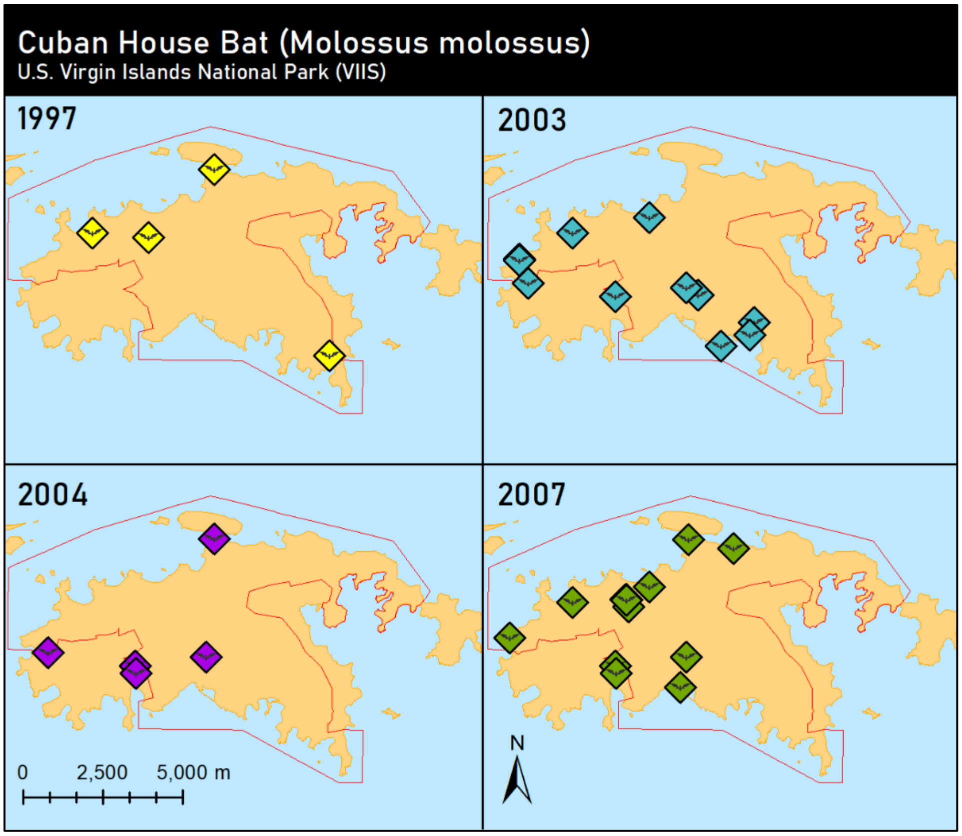

Figure 2.2.2.25. Detections of the Cuban house bat within VIIS 1997–2007 (Fly By Night, Inc. 2017).

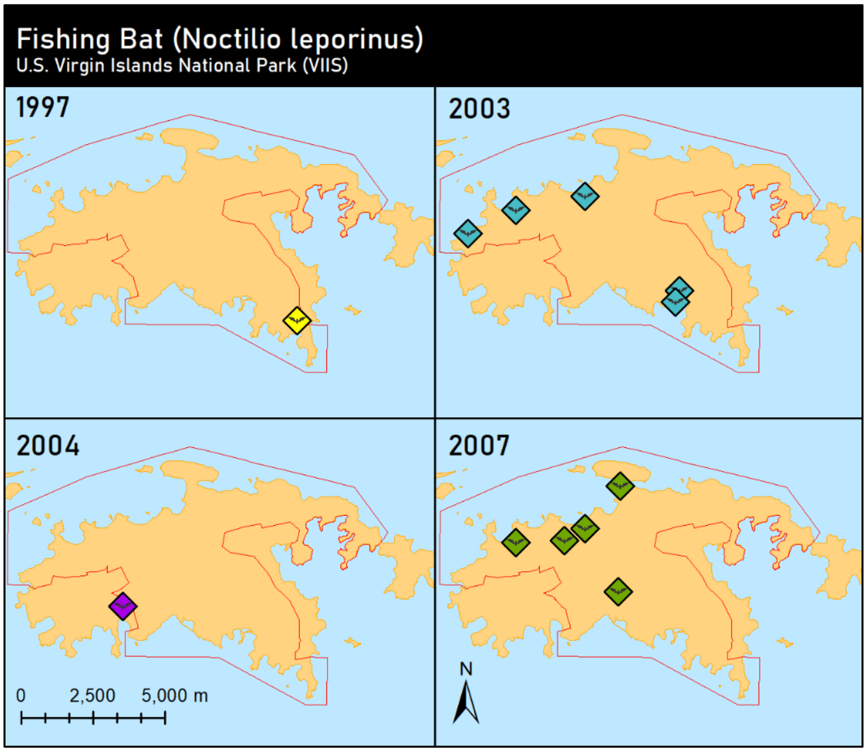

Figure 2.2.2.26. Detections of the Fishing bat within VIIS 1997–2007 (Fly By Night, Inc. 2017).

Other Resources

Soundscape

Quiet beaches and bays, hiking trails, and limited development are important features allowing visitors to experience natural sounds within the park and monument (NPS 2016). Threats to the soundscape include large ferries, small motorized boats, and trucks and invasive amphibians (NPS 2016). An investigation of vessels on underwater noise levels at reefs within the park found boat noise within 6–12% of samples (Kaplan and Mooney 2015). Exotic amphibian species like the Cuban treefrog and common coqui will change the natural sounds within the park as their numbers increase. Data needs include baseline data for natural sounds (NPS 2016).

Viewscape

Scenic resources in VIIS include cultural landscapes, historic structures, white sand beaches, blue seas, coral reefs, lush tropical vegetation, and scenic overlooks. These resources are an important feature of the park as stated in the enabling legislation (NPS 2016). Conditions throughout the park generally allow for unobstructed views of a mostly undeveloped landscape and seascape. However, Saharan dust can reduce visibility from ~125 miles to 40–60 miles (NPS 2016). Visibility as measured by haze index has been declining and the resource warrants significant concern (NPS 2010). Other threats include overgrowth of vegetation encroaching on scenic viewsheds, trash, pollution from trash burning on nearby Tortola, cell towers, wind generators, utility infrastructure, and increased light pollution. Artificial light from boats and outdoor lights on dwellings disrupt nighttime viewscape within the monument and park. Data needs include visual resource inventory, visitor use counts, and baseline data for dark skies (NPS 2016).

2.2.3. Resource Issues Overview

Resource condition threats or stressors identified as being "of concern" in terms of potential risk or harm to important park resources are explored in more detail in Chapter 4. Some threats have already been mentioned in Section 2.2 of this chapter. This section provides a brief introduction to other threats and stressors that are impacting or could potentially compromise the adequate condition of the VIIS + VICR complex's resources.

Human Interactions

The mission of Virgin Islands National Park is *to protect, manage, interpret and preserve the park's unique natural and scenic resources and nationally significant cultural resources and values unimpaired for the education, enjoyment, and aspiration of present and future generations* (NPS 2017b). Similarly, the purpose of Virgin Islands Coral Reef National Monument is *to preserve and protect coastal mangroves, shallow water reefs, and sea grass beds spanning from the bays of Hurricane Hole to the deep water coral reefs, fish, and bottom communities of the shelf edge surrounding St. John, U.S. Virgin Islands—furthering the protection and stewardship of the resources in Virgin Islands National Park* (NPS 2016).

Given that the stated purpose of the units include their use for education and enjoyment, it is indisputable that human interactions impact areas both inside and adjacent to areas of the park and the monument. The VIIS+VICR complex provides a number of valued resources and services to visitors. As per the VIIS and VICR Conceptual Model (Patterson et al. 2008, NPS 2019d), coral reefs are a resources of particular aesthetic value that further provides a highly productive habitat for fish and invertebrates. Equally productive are seagrass beds and mangroves which in turn contribute to shoreline protection. Existing wildlife, in particular unique and rare marine and terrestrial species, provide both recreational and educational opportunities for visitors, services that are fundamental for their wellbeing and intellectual advancement. VIIS offers a habitat important for migratory bird stopover. Finally, the establishment of VICR as a "No Take" marine reserve converts the Monument into a valued resource that serves as safe breeding grounds for numerous populations that can expand into fished areas (NPS 2019d). The following sections discuss threats related to human interactions with the resource, including boating, debris, and land use change.

Boat traffic and grounding

There are two ways to get to the park and monument, either by vessel or by land. Boats visiting the park or passing near its boundaries can negatively impact the natural habitats in many ways, such as oil or other discharges, spills, pumping of bilge water, release of toxic material contained in hull bottom paint (NPS 2019d). Another way of potentially harming coral reefs, seagrass beds and mangroves are by groundings, anchoring, inappropriate use of anchors, improper moorings, or by propeller or hull damage. To reduce damage to the coral reefs due to vessel anchoring, VIIS has instituted an offshore moorings system in various bays around the park. To minimize the risk of potential hazards to the marine habitats in VIIS only large vessels (125–210 ft) may be anchored and only in special locations within in VIIS (NPS 2017b). There is no anchoring permitted in VICR (NPS 2017c). Boats must be less than 60 ft in length to use moorings (NPS 2017b, c). During the passage of a hurricane, boats may take refuge at Hurricane Hole; the site has a maximum capacity of 126 vessels (NPS 2017c). Following Hurricanes Irma and Maria (2017), at least 90 derelict vessels washed up within the park and monument boundaries, many of which required removal and damaged coral reefs or fringing mangroves (Natural Parks Traveler 2017). Grounding of vessels due to poor navigation, loss of engine power, but also related to illegal smuggling and severe storm damage have been reported to occur around the island of St. John (NPS 2017b, c).

Debris, plastics, and microplastics

Debris resulting from human use of the VIIS+VICR complex may stress some of their natural resources, in particular in the marine environment. Marine debris consists mostly of floating manmade debris, remnants of fishing nets, and abandoned or lost fishing buoys. Fishing lines, nets, rope, and other type trash can wrap around animals and cause drowning, infection, or amputation. In addition, debris flows into various bays as a result of stormwater runoff from roads and driveways. In-land and marine debris can settle on hard bottom areas and kill coral colonies (Waddell et al. 2005).

One kind of debris that is rapidly increasing in tonnage in the ocean is plastics of all kinds. The total global production of plastics grew nearly 200 times in the last half century, from about 1.5 million tons in 1950 to 280 million tons in 2012 (Rochman et al. 2013). The degradation processes of plastic materials is very slow; therefore, plastics can become a major environmental hazard to the marine environment. Except for the tiny fraction that has been incinerated, all plastics ever manufactured are still on the planet (Jambeck et al. 2015). Plastic entanglement and ingestion by marine mammals, fish, birds, and reptiles that result in injury and even death are frequently reported (Derraik 2002; Lozano and Mouat 2009).

In a study done in 2013, Whitmire and his co-investigators studied the occurrence and distribution of small pieces of plastics in the southeastern coastal region of the United States (Whitmire et al. 2016). They analyzed sand samples collected from various coastal sites from eighteen National Park Service (NPS) parks in the Southeastern Region. Microplastics were isolated using density separation and counts of microplastic particles were compared among sites. In addition, the researchers developed a predictive model to understand the drift of plastics via ocean currents.

One of the sampling sites in this study was located along the northern shoreline of Virgin Islands National Park (Figure 2.2.3.1). A total of 10 sand samples were collected from the site between July and October 2013. The analysis of the samples yielded an average of 444 microplastics observed in 1 kg (2.2 lbs.) of sand. The percentage of microplastic items as pieces was 76.6% and that as fibers was 23.4%. The average length of the microplastic fibers was 2.65 cm (1.04 inches). The yield of plastics pieces was relatively high, compared to other sites in the US southeastern coast. Considering that there is very little development in the area immediately surrounding the site and no large river nearby to transport wastewater to it, the microplastic found must have been transported via local coastal marine currents or come from plastic debris being disintegrated near the site (Whitmire et al. 2016).

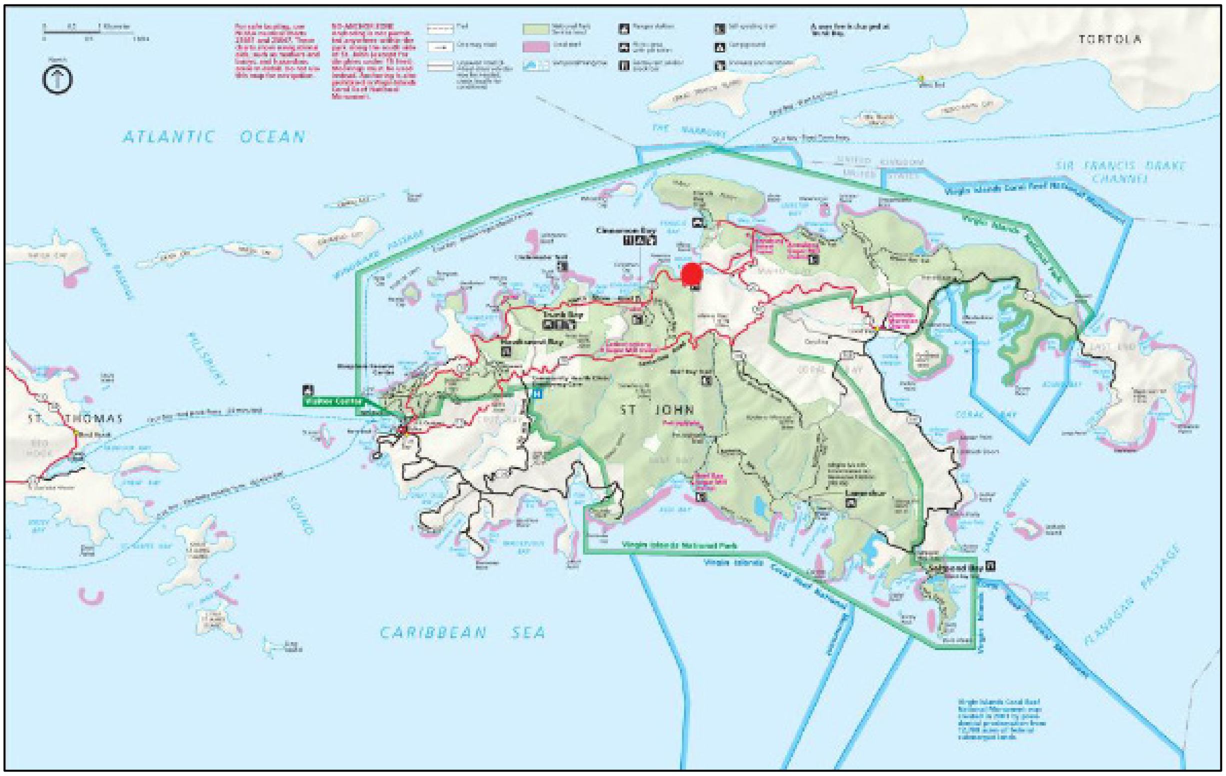

Figure 2.2.3.1. Map of St. John depicting the plastic sampling site (red dot on the northern coast) of the Whitmire et al. study (2016). The green line represents the border of VIIS and blue line the border of VICR. (Image from Whitmire et al. 2016).

In summary, over the last decade microplastics have been found in marine waters worldwide and accumulate in environments such as sandy beaches and marine sediments, even in remote and protected areas (Cozar et al. 2014, Turra et al. 2014, Lusher 2015). At the rate of increase of this type of debris, without waste management infrastructure improvements in coastal regions and a cultural change within the sailing community, the cumulative quantity of plastic waste available to enter the ocean from land as predicted by Jambeck et al. (2015), will increase by an order of magnitude by 2025.

Poaching and Looting

VIIS and VICR law enforcement duties include ensuring the park's resources (natural and historical) protection, as well as visitor safety. Park rangers are tasked with enforcement of all park rules and regulations, which includes the "no-take" policy, beach closings for sensitive species' nesting seasons, no wake zones, the "pack-it-in/pack-it-out" policy, anchoring and mooring area, among other responsibilities. In addition, park rangers are to work to prevent poaching of natural resources or looting of historical sites and address any such cases inland in in the sea (NPS 2017b). Furthermore, both VIIS and VICR units are experiencing increased drug smuggling cases and illegal immigration traffic (NPS 2017c). Due to staffing limitations and funding constraints, law enforcement presence is not provided on a full-time basis (NPS 2017b, 2017c).

Consequently, poaching episodes occur within the various parks in the Virgin Islands. Invertebrates, such as conch and lobster have suffered poaching and poaching of bird eggs still occurs on offshore remote areas (NPS 2016). Sea turtle and seabird eggs (e.g., brown pelican, Figure 2.2.3.2) in isolated parts of the park may continue to be exploited by human poaching (Collini and O'Rourke 2007). Information on poaching or looting episodes, in particular prior to the passage of Hurricane Irma, is not available in written format. No statistics could be found on the extent of poaching or looting in the park. Data on enforcement are needed.

Figure 2.2.3.2. Brown pelican (*Pelecanus occidentalis*) perched on the edge of a dock. Photo credit: Gerald Singer 2016.

Land Use Changes

The land cover maps for VIIS presented in this section were derived from the NOAA Coastal Change Analysis Program (C-CAP) national standardized land cover and change products for the coastal regions of the U.S. C-CAP products inventory coastal intertidal areas, wetlands, and adjacent uplands with the goal of monitoring changes in these habitats. The timeframe for this data is 2005, 2007, or 2012 (depending on the exact date of imagery used). These maps are developed through the automated classification of high-resolution National Agriculture Imagery Program (NAIP) imagery, available Lidar digital elevation data, and assorted ancillary information (NOAA 2005, 2007, 2012).

Figure 2.2.3.3 depicts the VIIS land cover in 2005, 2007, and 2012. The comparison of these three maps for the different years show that there are very few small detectable changes in land cover within the boundary of VIIS over the time period 2005–2012 (Figure 2.3.3.4). Based on the NOAA (2005, 2007, 2012) products, forests (deciduous and evergreen) cover the majority of VIIS averaging 83% of the land use of the park from 2005 to 2012. Over this period, there was a decrease in forested land of approximately 2.75 ha. Wetlands occupy 3% of the territory of the park and no major changes in cover were observed over the time period. Grasslands, scrubland, shrubs, and other herbaceous vegetation covered approximately 8.3% of VIIS and showed a slight increase in surface of less than 2.0 ha from 2005 to 2012. Developed, open, and impervious surface increased by 2.3 ha during the study period.

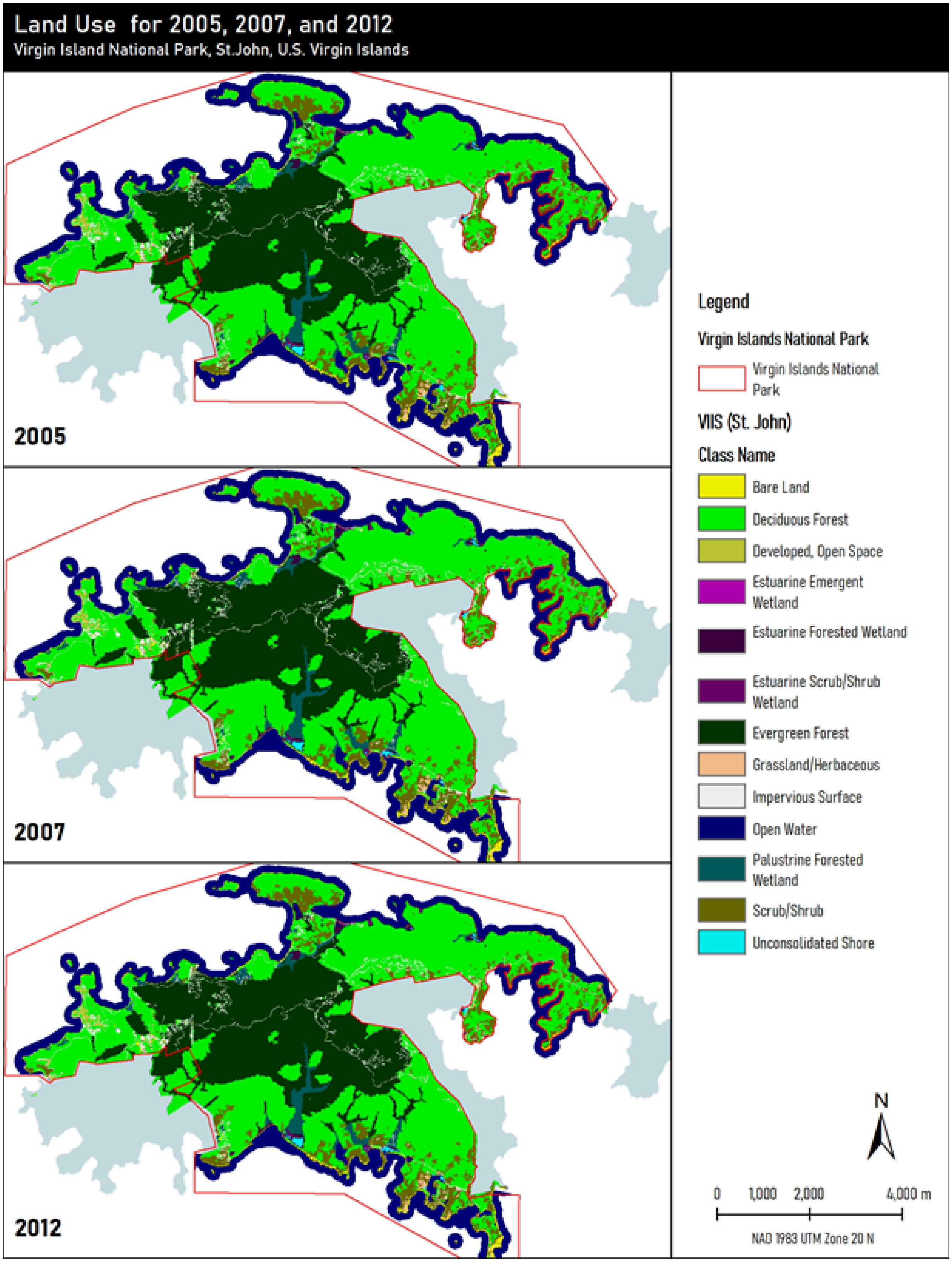

Figure 2.2.3.3. Virgin Islands National Park (VIIS) land cover in 2005 (upper panel), 2007 (middle panel), and 2012 (lower panel). Land cover data from NOSS C-CAP, 2005, 2007, 2012).

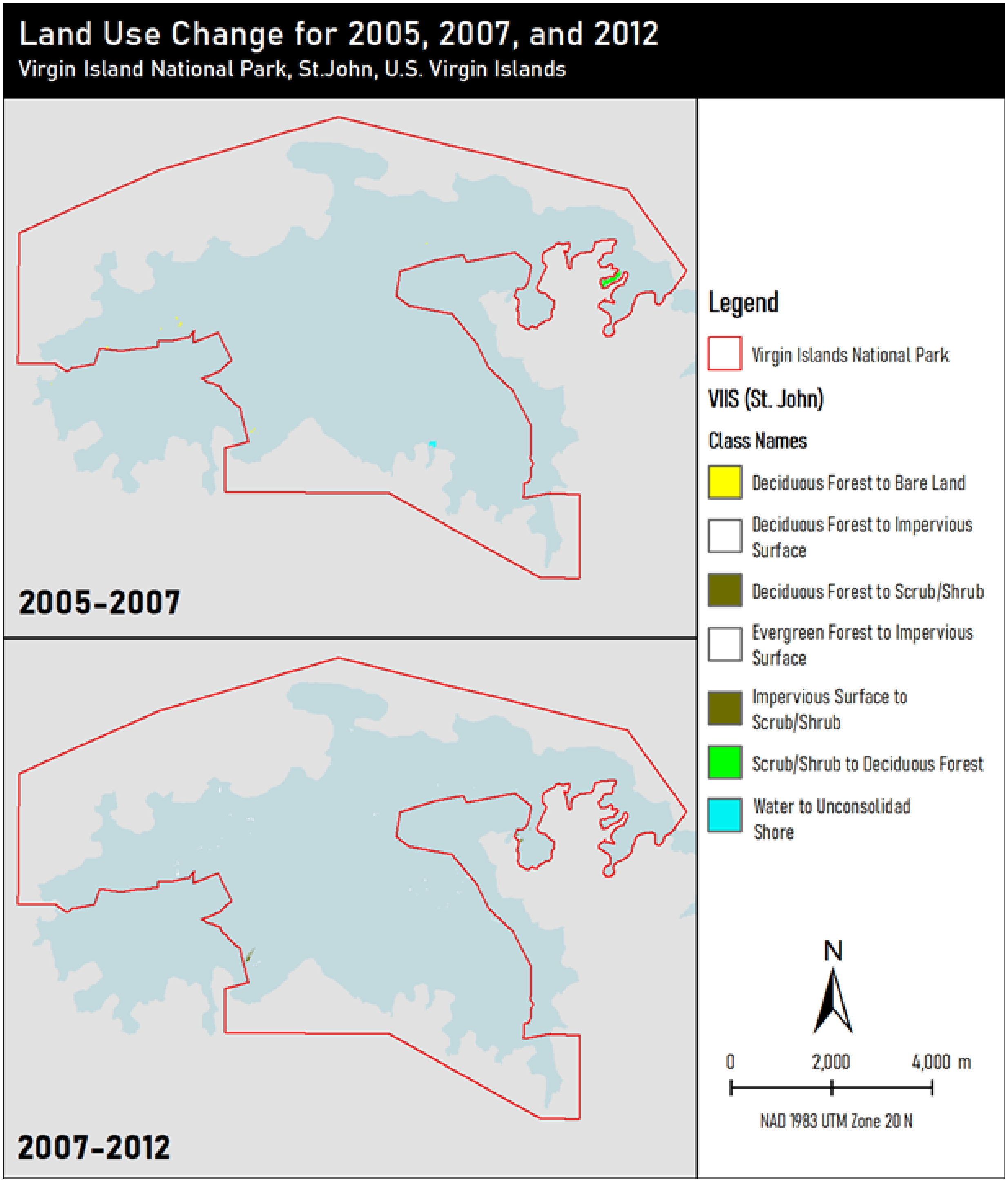

Figure 2.2.3.4. Changes in land use/cover within Virgin Islands National Park (VIIS) over the period 2005–2007 (upper panel) and 2007–2012 (lower panel). Land cover data from NOAA C-CAP, 2005, 2007, and 2012.

Unfortunately, since 2012 there have been no further land cover datasets developed consistent with those used in the present analysis. Similarly, since the end of Phase III of the VIIS vegetation mapping project in 2011 (Thanawastien et al. 2015, unpublished), there has been no other major program to carry out a detailed mapping of the vegetation of the park. Continued development outside the park boundaries, although not included in the analysis, has impacts on the terrestrial and marine resources of the park. The majority of development on the island in concentrated in Cruz Bay and Coral Bay (Figure 2.2.3.5).

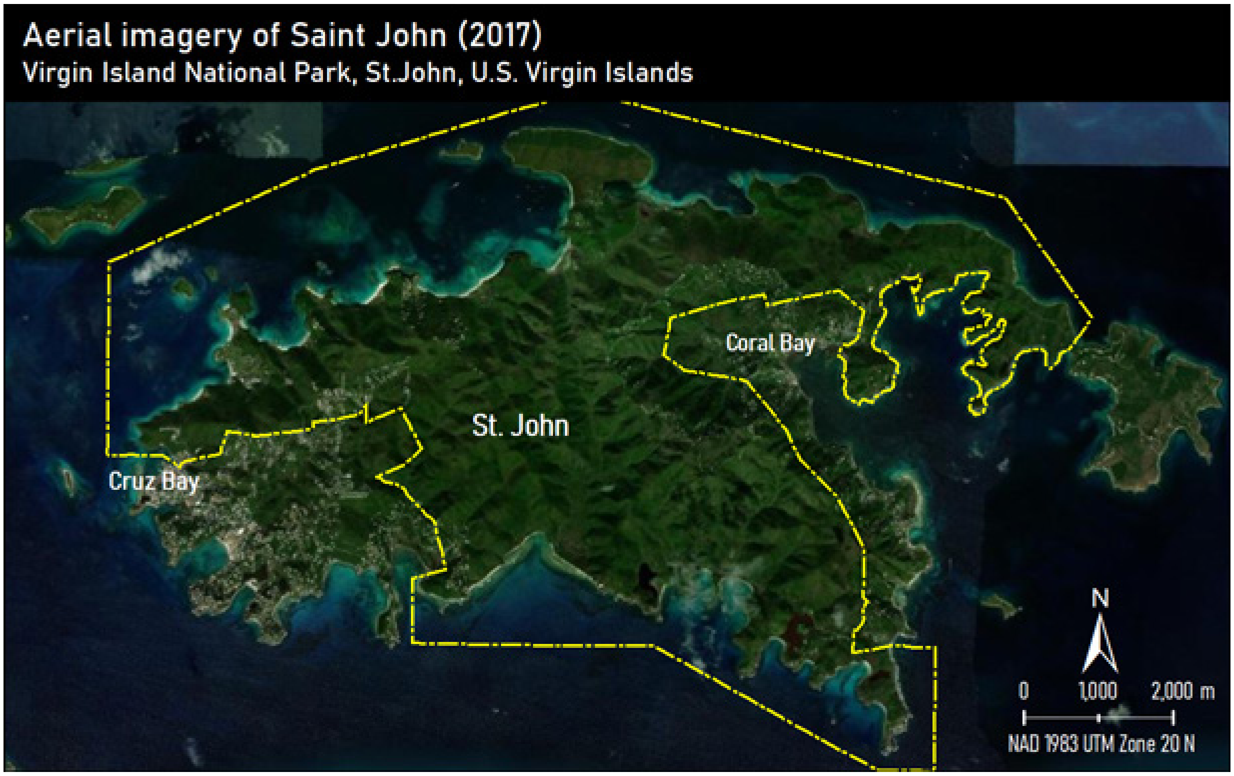

Figure 2.2.3.5. Aerial imagery of Virgin Islands National Park (VIIS) showing locations of Cruz Bay and Coral Bay, VIIS boundary depicted with yellow dashed line.

Hurricanes and Tropical Storms

Because of a warming global atmosphere, and increasingly prolonged warming phases of sea-surface waters, there is a possibility of higher frequency of strong tropical storm events in the western Atlantic and Caribbean basins (Bengtsson et al. 2007). However, current high-resolution models do not support increase in overall number of tropical storms, but rather predict fewer tropical storms for the Atlantic Basin, with the number of category 4 and 5 storms slightly increasing or not significantly changing (Bengtsson et al. 2007; Yoshida et al. 2017). The potential of fewer but stronger storms will increase the probability of destructive storm surges and wave activity, which in combination with heavy precipitation could further erode the beaches on Buck Island. Hurricane frequency by category shows that between 1900 and 2018, 38 tropical storms came within 50 nmi (nautical miles) of VIIS, 17 storms did not reach hurricane strength and 5, 5, 3, 5, and 3, storms reached hurricane categories 1 through 5, respectively, while they were located within 50 nmi of VIIS (Landsea and Franklin 2013) (Table 2.2.3.1; Figure 2.2.3.6).

Table 2.2.3.1. Tropical storm and hurricane frequency by decade. Storm categories were are determined by maximum strength gained within 50 nmi of VIIS. TS = Tropical Storm, H1 = Hurricane Category 1, H2 = Hurricane Category 2, H3 = Hurricane Category 3, H4 = Hurricane Category 4, H5 = Hurricane Category 5. Best Track Data (HURDAT2) provided by NOAA https://www.nhc.noaa.gov/data/ (Landsea and Franklin 2013).

Decade	Storm Category						Total
	TS	H1	H2	H3	H4	H5	
1900–1909	2	–	–	–	–	–	2
1910–1919	1	–	3	–	–	–	4
1920–1929	2	–	1	1	–	1	5
1930–1939	2	2	–	–	1	–	5
1940–1949	3	–	–	–	–	–	3
1950–1959	–	–	–	–	–	–	0
1960–1969	–	–	–	1	–	–	1
1970–1979	2	–	–	–	–	–	2
1980–1989	2	–	–	–	1	–	3
1990–1999	1	2	1	1	1	–	6
2000–2009	1	1	–	–	1	–	3
2010–2018	1	–	–	–	1	2	4
Total	17	5	5	3	5	3	38

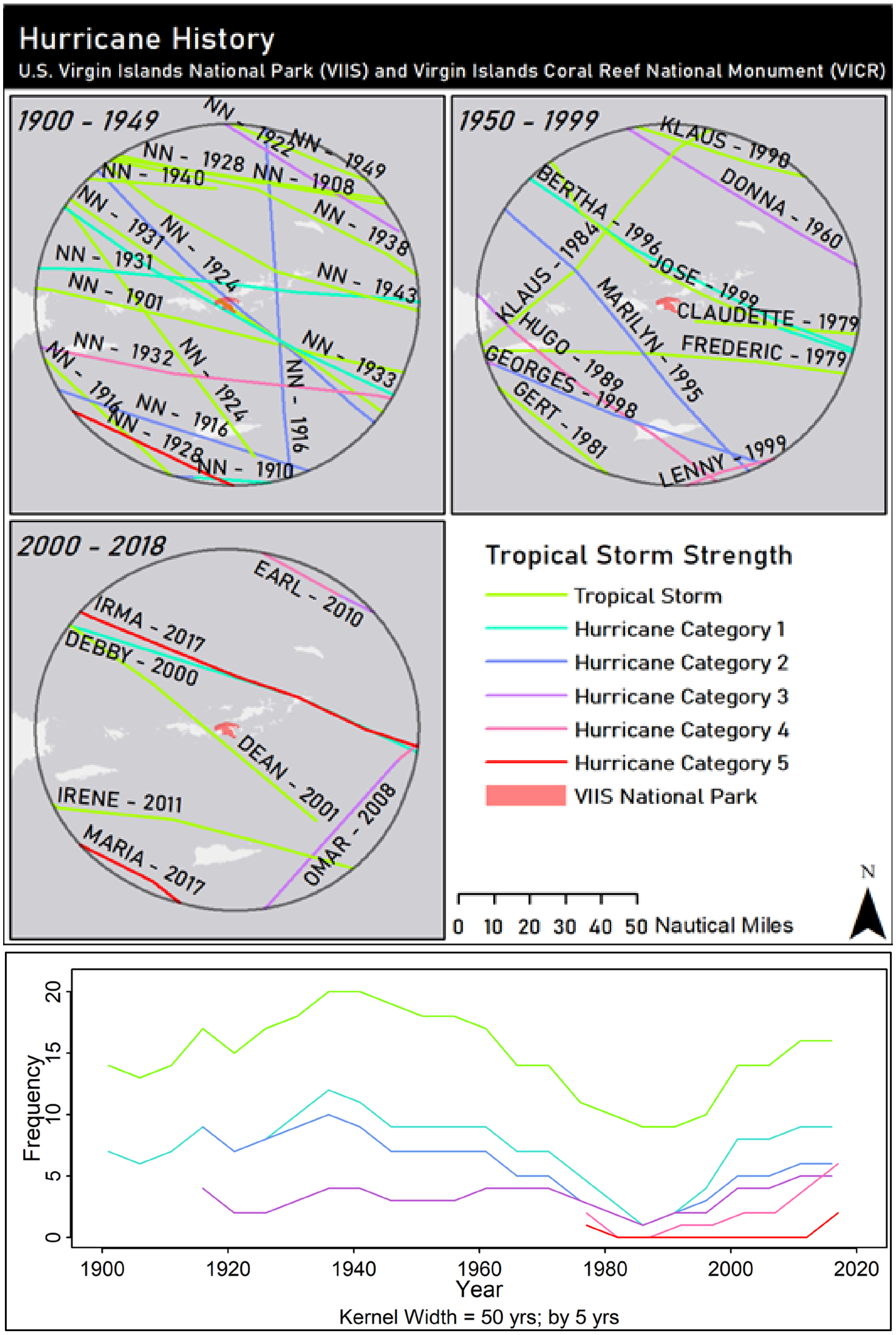

Figure 2.2.3.6. Top: Tropical storm and hurricane history for VIIS. Tropical storm track labels indicate storm name and year. NN = No Name was given or is known for the storm. Bottom: Tropical storm frequency by category estimated for a 50-year moving window, predicted at 5-year intervals. Graphs generated with Zoo package in R (Zeileis and Grothendieck 2005). Data source: Best Track Data (HURDAT2) provided by NOAA https://www.nhc.noaa.gov/data/ (Landsea and Franklin 2013).

2.3. Resource Stewardship

2.3.1. Management Directive and Planning Guidance

In December 2016, the National Park Service published the Foundation Document for the Virgin Islands National Park (VIIS) and Virgin Islands Coral Reef National Monument (VICR). The Foundation Document outlines the purposes, significance, resources, and planning principles for the national park and national monument.

The purpose of the Virgin Islands National Park is "to preserve and protect for public benefit and inspiration outstanding scenic features, Caribbean tropical marine and terrestrial ecosystems in their natural conditions, and cultural heritage from pre-Columbian through Danish colonial times" (NPS 2016).

The purpose of the Virgin Islands Coral Reef National Monument is "to preserve and protect coastal mangroves, shallow-water reefs, and sea grass beds spanning from the bays of Hurricane Hole to the deep water coral reefs, fish, and bottom communities of the shelf edge surrounding St. John, U.S. Virgin Islands—furthering the protection and stewardship of the resources in Virgin Islands National Park" (NPS 2016).

The National Park Service has identified fundamental resources and values that constitute a central management priority for the VINP and VINM:

- Marine Ecosystems
- Terrestrial Ecosystems
- Hurricane Hole
- Evidence of Pre-Columbian Taino Indians
- Diverse Historic Landscape
- Hassel Island
- Scenic Viewscape
- Dark Night Skies and Natural Sounds

In addition, the NPS identified the most pressing issues facing resource managers and planners in the VINP and VINM. They are:

- Land acquisition and protection
- Transportation
- Education on and enforcement of park regulations
- Caneel Bay Lease
- Climate Change
- Lack of Baseline Monitoring of Critical Resources

2.3.2. Status of Supporting Science

To adequately manage the national parks, the National Park Service must have adequate knowledge of the condition of natural resources. Therefore, park managers require scientifically sound information that will allow them to acquire a broad-based understanding of the status and trends of park resources as a basis for making decisions and working with other agencies and the public for the long-term protection of park ecosystems. To acquire the needed information the South Florida and Caribbean Inventory and Monitoring Network (SFCN) worked in putting together a long-term monitoring program. At the individual park level, the program aims to monitor a set of key resources defined as the park's vital signs. "Vital signs," as defined by the NPS, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources or elements that have important human values (Patterson et al. 2008). Table 2.3.2.1 shows the SFCN Vital Signs selected for monitoring within VIIS and VICR.

To facilitate the identification and prioritization of vital signs, SFCN divided the ecosystems in the South Florida and Caribbean parks into seven ecological zones and developed conceptual models for each as well as a region-wide overview and a marine benthic communities sub-model. The biological communities in these ecological zones are assumed to be affected by similar physical drivers and the same general set of stressors. The conceptual model for VIIS/VICR can be found at https://irma.nps.gov/DataStore/DownloadFile/4699889.

For the present assessment, available data and reports varied significantly by focal resource. Datasets available from monitoring and inventory efforts used to assess condition and to develop reference conditions are described within each indicator summary in Chapter 4. Data and documents were obtained from numerous sources, including SFCN personnel, VIIS-VICR staff, academic researchers with prior or ongoing research programs within the park and monument, and publicly available datasets.

Table 2.3.2.1. SFCN Vital signs selected for monitoring in VIIS-VICR (Patterson et.al. 2008).[1]

Category	Vital Sign	Type 1	Type 2	Type 3	No Monitoring Planned
Air Quality	Air Quality-Deposition	–	x	–	–
	Air Quality-Mercury	–	–	x	–
Geology and Soils	Coastal Geomorphology	x	–	–	–
Water	Surface Water Hydrology	–	x	–	–
	Estuarine salinity patterns	–	–	x	–
	Water Chemistry	–	x	–	–
	Nutrient Dynamics	–	x	–	–
	Periphyton (Freshwater)	–	–	–	x
	Phytoplankton (Marine)	–	–	x	–
Biological Integrity	Invasive/Exotic Animals	–	x	–	–
	Invasive/Exotic Plants	x	–	–	–
	Marine Benthic Communities	x	–	–	–
	Mangrove-Marsh Ecotone	x	–	–	–
	Wetland Ecotones and Community Structure	–	–	–	x
	Forest Ecotones and Community Structure.	x	–	–	–
	Marine Exploited Invertebrates	x	–	–	–
	Aquatic invertebrates in wet prairies & marshes	–	–	–	x
	Marine Fish Communities	x	–	–	–
	Focal Fish Species	–	x	–	–
	Freshwater Fish and large macro-invertebrates	–	–	x	–
	Amphibians	x	–	–	–
	Colonial Nesting Birds	–	x	–	–
	Marine Invertebrates-Rare, Threatened, and Endangered	x	–	–	–
	Sea Turtles	–	x	–	–
	Protected Marine Mammals	–	–	x	–
Human Use	Visitor Use	–	x	–	–
Landscapes (Ecosystems Pattern and Processes)	Fire Return Interval	–	–	–	x
	Vegetation Communities Extent & Distribution	x	–	–	–
	Benthic Communities Extent & Distribution	x	–	–	–
	Land Use Change	x	–	–	–

[1] Type 1 represents Vital Signs for which the network will develop protocols and implement monitoring; Type 2 represents Vital Signs that are monitored by VIIS+VICR, another NPS program, or by another federal or state agency using other funding; Type 3 represents Vital Signs for which monitoring cannot be currently implemented because of limited staff and funding but will likely be done in the future.

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3. Study Scoping and Design

The NRCA is a collaborative project between Florida International University, the University of the Virgin Islands (UVI), and the National Park Service (NPS). Stakeholders on this project include Buck Island Reef National Monument management and staff, as well as NPS Interior Region 2 – South Atlantic Gulf managers, the NPS South Florida/Caribbean Network (SFCN) scientists, and other NPS staff linked to the Virgin Islands sites.

This chapter describes the study scoping process, introduces the hierarchical indicator framework used in the assessment, and summarizes the general approach and types of methods used to evaluate and report condition findings reported in chapters 4 and 5.

3.1. Preliminary Scoping

3.1.1. Initial planning and scoping

During the initial stage of Phase I of the study, several in-person meetings and conference calls took place between the FIU Principal Investigator (Anna Wachnicka) and NPS staff. A preliminary scoping meeting took place on December 12, 2016, where the FIU project team met with staff from the NPS South Florida/Caribbean Network (SFCN) and the acting coordinator of the Regional NRCA and RSS Programs. The objective of the meeting was to identify (a) projects conducted by SFCN in the USVI parks; (b) reports, papers and data available at the SFCN office that could be used for the present project; (c) potential data gaps; and (d) important drivers of ecological change in the selected sites based on the research done in the parks.

The meeting started with a discussion of the vital signs being monitored by SFCN and partners in the Virgin Islands parks. A preliminary subset of physical, chemical, and biological elements and processes of the park ecosystems were identified as important for the present NRCA, but it was agreed that the final list would be determined during the on-site scoping meetings planned for February 2017. As a result of the discussion, a number of reports and papers were highlighted, as well as data sets available at the SFCN headquarters and in other NPS data centers. Information available from partner agencies and institutions was also identified. The names of potential contacts were provided to the FIU team. A preliminary list of identified documents and datasets and their online location was to be prepared by NPS.

Following the preliminary scoping meeting, the FIU project team met with the acting coordinator of the Regional NRCA and RSS Programs to plan future actions, in particular as it referred to the on-site park visits and scoping meetings. In the course of the meeting, it was reiterated that the purpose of the NRCA was to evaluate and report on current conditions for important park natural resources, and to identify critical data and knowledge gaps and potential factors that are influencing park resource conditions. As with other NRCAs, constraints were set on this assessment, namely: (a) the NRCA was to be performed utilizing available data sets and information; (b) the identification of data needs and gaps should be guided by the framework categories selected for the project; (c) as possible and appropriate, description and evaluation of conditions in each unit would be completed using GIS coverages and map products; and (d) study design and reporting products would follow national NRCA guidelines and standards (FIU 2017).

3.1.2. Onsite scoping and meetings with VIIS-VICR NPS staff

The FIU project team arrived to the island of St. John on February 12, 2017. During the visit, the FIU team discussed the scope of work for condition assessments for resources within Virgin Islands National Park (VIIS) and visited field sites. Additionally, during the course of the discussions with NPS staff, it was agreed that the NRCA would be extended to include the Virgin Islands Coral Reef National Monument (VICR).

The logistics of the scoping activities began with meetings with NPS staff organized during the first part of the week (February 13 and 14 of 2017), while the on-site visits to the parks were planned for the middle of the week, with a debriefing meeting at the end (Appendix D). During the first two days of meetings, the participants accomplished series of tasks:

- Discuss the methodology to be used in the assessment and revise the dates set for the implementation of the three phases of the project;
- Confer with a preliminary scope of the content of the individual NRCA for the complex;
- Jointly concur to a preliminary list of focal resources or components to be assessed in full or in a limited manner, based on the available information and data sets for each park, as per the knowledge of the meeting participants;
- Complete draft scoping tables reflecting the results of the deliberations of the participants; and
- Identify existing information and data sets in-situ that would be provided to the FIU team before the conclusion of their visit or sent to them on a later time.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

The framework used in the study of VIIS-VICR is adapted from that presented in the H. John Heinz III Center for Science's "State of Our Nation's Ecosystems 2008" (Heinz Center 2008). The framework defines a way to organize the various resources that are considered important to the park in a hierarchal manner. The framework considers regional and landscape context, as well as historic condition influences, and constitutes a mechanism to summarize current natural resources conditions, risk factors, and critical data gaps.

The proposed framework encompasses two major categories, namely the Supporting Environment and Biological Integrity. In turn, Supporting Environment is subdivided into the following categories: Coastal Dynamics and Chemical/Physical and Biological Integrity into Terrestrial Plants, Marine Plants, Terrestrial Vertebrates/Invertebrates, Marine Vertebrates, and Marine Invertebrates.

The primary features in the selected framework are focal resource components, indicators, measures, stressors, and reference conditions. Resource "Components" in this process are defined as natural resources (e.g., lizards), natural processes or patterns (e.g., coastal dynamics), or specific features or values (e.g., water quality) that are considered important to current managers. Each focal resource or component can be characterized by one or more "indicators". The term "indicator" is used in our assessment to refer to “a specific, well-defined, and measurable variable that reflects some key characteristic of a component that can be tracked through time” (Heinz Center 2008) to signal what is happening to the specific resource. Each indicator has one or more “measures” that best define the current condition of a resource being assessed in the NRCA. “Measures” are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a resource. In addition to measures, current condition of resources may be influenced by certain “stressors,” which are also considered during assessment. A “stressor” is defined as any agent that imposes adverse changes upon a component. These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as hurricanes, floods, or predation (adapted from Amberg et al. 2014).

A “reference condition” is a benchmark to which current values of a given measure can be compared to determine the condition of that resource component. A reference condition may be a historical condition (e.g., species composition of seagrass in the 1980s), an established ecological threshold (e.g., predefined standards for water quality), or a targeted management goal/objective (e.g., abundance of reptiles) (adapted from Amberg et al. 2014 and Stoddard et al. 2006).

During the scoping process in VIIS-VICR, key resources were identified by NPS staff. These are represented as “components” in the NRCA framework. The list of components was not a comprehensive list of all the resources in the park and monument. Rather, a selection of components was made which included resources and processes that were of greatest concern or highest management priority and for which there existed sufficient datasets to conduct assessments. One or more indicators and respective measures for each, as well as known or potential stressors, were identified in collaboration with NPS staff.

Table 3.2.1.1 provides the framework for the VIIS-VICR NRCA, including the list of focal resources considered, along with the associated condition indicators used to assess each focal resource. Full assessments were conducted for all focal resources. Authors responsible for each section are listed next to their respective focal resource.

Table 3.2.1.1. VIIS-VICR NRCA framework table.

Framework Category	Focal Resource	Assessment Level	Section Author	Indicators and Measures
Supporting environment – Chemical / physical	Water quality	Full assessment	T. Smith	• Fecal indicator bacteria (1 measure) • Dissolved oxygen (1 measure) Total suspended solids – TSS (1 measure) • Turbidity (1 measure) • Dissolved Nutrients (3 measures) • Chlorophyll (1 measure) • Terrestrial Sediments (1 measure) • Contaminants (1 measure)

Table 3.2.1.1 (continued). VIIS-VICR NRCA framework table.

Framework Category	Focal Resource	Assessment Level	Section Author	Indicators and Measures
Biological integrity – Marine plants	Macroalgae	Full assessment	T. Frankovich E. Whitman	• Macroalgae community extent (1 measure)
	Seagrass	Full assessment	E. Whitman T. Frankovich	Seagrass community extent (2 measures)
Biological integrity – Marine invertebrates	Corals	Full assessment	T. Smith	• Stony coral cover (1 measure) • Stony coral health (1 measure) • Seawater temperature (1 measure)
Biological integrity – Marine vertebrates	Reef fish	Full assessment	A. Duran	• Community and population status (3 measures)

3.2.2. Reporting Areas

VIIS-VICR includes areas of both submerged and dry lands. The reporting area was treated as one unit and, depending of the resource being analyzed, encompassed the entire acreage within VIIS-VICR's maritime or terrestrial boundaries unless otherwise noted in a specific focal resource section.

3.2.3. General Approach and Methods

This assessment includes the collection and review of available literature, datasets, as well as other types of existing information (maps, photographs, etc.) for each of the relevant resource identified in the framework. New data were not collected for this study. Existing data were analyzed to present summaries of the resource condition(s) and to compare with the reference condition(s). New spatial representations and maps were created as needed. Once all relevant information for each component was considered, a qualitative statement of the overall current condition was provided and compared to the reference condition wherever possible.

Data Gathering

Data, literature and overall information mining began with the collection of information during the scoping process. Information gathered includes NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data and charts, GIS data, photographs, maps, which were either provided by NPS staff or obtained through personal communication with researchers and online bibliographic literature searches and inquiries.

Data analysis and assessment

Data analysis and development of the assessment was particular to each focal component identified in the framework and was based on the amount of existing information and recommendations provided by NPS staff and other experts. The methodology applied for each resource is defined in the corresponding section within Chapter 4 of this report.

Researchers and experts

Researchers and subject matter experts from FIU, NPS, and partner entities of these two organizations were consulted while developing the NRCA for VIIS-VICR. Consultations were in the form of individual and group visits, correspondence via email or phone, virtual meetings, and reviews of resource sections. A list of the team of researchers and experts contributing to the assessment of each focal resource can be found in the respective chapter 4.

Summary Indicator Symbols

The "Indicator" and "Measurement" assessments for each component will be presented in a standard format throughout the document. This standard format is consistent with State of the Park reporting (NPS 2012). Condition/trend/level of confidence tables will be used for each resource to provide a representation of the condition assessment in a concise visual manner. The level of confidence will be depicted as high, medium or low, and will infer how confident the assessment is based on the information used to evaluate the condition. A detailed account will be provided in the various sections of chapter 4 of this report under the heading "Condition and Trend" for each resource.

Table 3.2.3.1 shows the "Condition/trend/level of confidence" scorecard to be used to describe the overall condition, trend, and level of confidence of the analysis assigned to each indicator for a focal resource. The color of the circles indicates the condition based upon the chosen indicators/measures and the reference conditions. Red circles imply that a resource is of significant concern; yellow circles denote that a resource is of moderate concern; and green circles signify that an indicator and/or measure are/is currently in good condition. A circle without any color, (which is almost always associated with the low confidence symbol-dashed line), signifies that there is insufficient information to make a statement about condition of the indicator, consequently, condition is unknown. The arrows within the circles represent the trend of the indicator/measure condition. Arrows pointing upward refer to an indicator which is improving; horizontal left-right pointing arrows express that the indicator's condition is currently unchanging; and arrows pointing downward indicate that the indicator's condition is deteriorating. Circles with no arrows denote that the trend of the indicator's condition is currently unknown. Table 3.2.3.2 provides example indicator symbols and descriptions of how to interpret them in the assessment summary tables.

Table 3.2.3.1. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

Condition Status		Trend in Condition		Confidence in Assessment	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
🟢	Resource is in Good Condition	⇧	Condition is Improving	◯	High
🟡	Resource warrants Moderate Concern	⇔	Condition is Unchanging	○	Medium
🔴	Resource warrants Significant Concern	⇩	Condition is Deteriorating	⬚	Low

Table 3.2.3.2. Example indicator symbols and descriptions of how to interpret them in the assessment summary tables.

Symbol Example	Verbal Description
🟢⇧	Resource is in good condition; its condition is improving; high confidence in the assessment.
🟡⇔	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
🔴	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
⬚	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Overall condition tables are presented for each focal resource in Chapter 5. To arrive at an overall status and trend for each focal resource, we followed the rules for combining multiple status and trends as outlined in the NPS-NRCA Guidance Update date January 20, 2014. Specifically, a combined condition score for a focal resource was determined by assigning any red symbol a value of 0, any yellow symbol a value of 50, and any green symbol a value of 100, summing the values of all indicators for each focal resource and dividing by the number of indicators/measures. Deviation from this method to arrive at the overall status was done on a case-by-case basis at the discretion of the resource assessment author and is noted in chapter 5 when applicable.

The overall trend for a focal resource was determined by adding the number of up arrows and subtracting the total number of down arrows. Calculated trend values greater than 2 were considered an increasing trend while values less than −2 were considered a negative trend. All values in between were considered no trend. In the case when there were less than three indicators for a particular focal resource and both trends for indicators/measures were the same, the overall trend took on the same value.

However, when only two indicators/measures were present for a focal resource and the status or trend was not in agreement between the two, the author of each focal resource assessment made a judgement as to whether one indicator should be more highly weighted. The condition and trend of the more highly weighted measure was used to represent the overall status of a focal resource. The rationale for this is described on a case by case basis when applicable in chapter 5.

Overall confidence level corresponded to the level most often indicated for a resource if indicators were equally weighted. In the case when indicators were not equally weighted, the confidence level of the higher weighted indicator was used for the overall indicator. The focal resource assessment author has noted which indicator was weighted more highly and has provided their reasoning in the text of chapter 5.

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was carried out by FIU and UVI analysts and researchers. Though the project team, analysts, and researchers, rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also played a role in providing insights into the direction for analysis and assessment of each component.

Subsequent to the initial scoping engagements and general undertakings described above, the process of developing draft documents for each component began with a project team brainstorming session, followed by knowledge-sharing and planning meeting. In addition, personal and e-mail conversation among the members of the project team and an individual or multiple individuals considered local experts on the resource components under examination took place throughout the draft assessment development process. These conversations were a way for the project team members to verify the most relevant data and literature sources that should be used and to formulate ideas about current condition with respect to the NPS staff opinions. Throughout the draft assessment development process, the project team maintained communication, to the extent possible, with NPS staff, in particular with the acting coordinator of Regional NRCA and RSS Programs. Upon completion, draft assessments were forwarded to NPS component experts for initial review and comments.

Final Component Assessments

Final resource component assessments were made by incorporating comments provided by NPS staff, resource experts, and reviewers during the review of draft chapters. As a result of this process, and based on the recommendations and insights provided to the authors, the final component assessments were written. These final resource component assessments represent the most relevant and timely information and data available for each component and the insight and knowledge of park resource staff, researchers, external resources experts, and assessment writers.

Format of the focal resource assessment sections presented in chapter 4

All focal resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description

This section describes the relevance of the resource component to the individual park and explains its characteristics. This section also refers to any existing interrelations that exist between the featured component and other resources components referenced in the assessment. Emphasis is to be given to issues that make the component a unique feature of the park, a key process or resource in the park ecology, or a resource that is of high management priority in the park.

Data and Methods

This section refers to the datasets used in the analysis as well as any type of information utilized in the assessment. The methods used for processing or evaluating the data are also discussed herein where applicable. The indicators and corresponding measures are presented in this section as well, describing to the best of our knowledge how each indicator was measured or qualitatively assessed the natural resource topic.

Reference Conditions/Values

This section describes the reference conditions that were used to evaluate each resource component as it is delineated in the framework. Also, discussions of available data and documents that describe the reference conditions are located in this section. This section provides an explanation as to why specific reference conditions are appropriate or logical to use in this assessment.

Condition and Trend

This section provides and discusses key findings regarding the existing condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component is presented and interpreted in this section.

Threats and Stressors

This section presents the major threats and stressors that may affect the resource and influence to the current condition of a resource component based on a combination of available data and literature, and discussions with experts and NPS staff.

Data Needs/Gaps

In this section, critical data needs or gaps for the resource component are reported. It also refers to how these data needs/gaps, if addressed, would provide further insight in determining the current condition or trend of a given component in future assessments. The section is expected to help NPS staff seeking to prioritize monitoring or data gathering efforts.

Overall Condition

This section renders a qualitative summary statement of the current condition that was determined for the resource component. This determination is established based on the analysis and review of available literature, data, and any insights from NPS staff and experts, or other subject matter experts.

The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that authors attribute to the condition of the resource component. In addition, this section includes the condition assessment table.

Sources of Expertise

Individuals who provided data or references, or were consulted for the focal study resources, will be listed in this section. A short paragraph presenting their title and affiliation with offices or programs is also included.

Literature Cited

This is a list of formal citations for literature or datasets used in the analysis and assessment of condition for the resource component. When possible, links to websites are also included. Citations used in appendices and plates referenced in each section (component) of Chapter 4 are listed in that section's "Literature Cited" section.

3.3. Literature cited

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4. Natural Resource Conditions

4.1. Chemical /Physical

4.1.1. Water Quality

This section reviews the condition of water quality in the Virgin Islands National Park and Virgin Islands Coral Reef National Monument (VIIS-VICR). The condition assessment considers data provided by the US National Park Service and the USVI Department of Planning and Natural Resources Division of Environmental Protection (1988–2019), and individual research assessments between 2012 and 2015. The condition of seawater quality is typically evaluated using metrics that detect changes away from conditions suitable for the maintenance and propagation of marine and aquatic life and for human contact recreation. The condition metrics selected for this resource assessment include fecal indicator bacteria, dissolved oxygen, total suspended solids, turbidity, dissolved nutrients, water column chlorophyll and contaminants. Temporal trends in condition metrics were evaluated for time-series measurements.

Description

Water quality in VIIS-VICR is variable across space and time, reflecting seasonality and responses to episodic events, such as storms. Conditions range from very clear oceanic waters offshore to highly turbid and occasionally contaminated inshore waters. Water quality can be estimated from numerous variables that are measurable on site, remotely, or from collected samples that are analyzed in a laboratory (Table 4.1.1.1). These variables can indicate acceptable conditions for human health, such as fecal indicator bacteria that suggest the epidemiological risk for human contact-based development of gastrointestinal illness. These variables may also indicate suitability of water for maintenance of certain forms of marine life or deviation of conditions away from natural, unperturbed ecosystems. Of high relevance to VIIS-VICR are water quality variables and their associated values that support sensitive ecosystems, such as coral reefs. These include the variables turbidity, contaminants, and free water chlorophyll.

Data and Methods

In the USVI, marine water bodies are classified into three categories of regulation based on their ability to affect wildlife and aquatic life and human health (USVI 2019). Classifications are: Class A. Waters are of exceptional recreational, environmental, or ecological significance; Class B. Designated for maintenance and propagation of desirable species of wildlife and aquatic life, contact recreation; Class C. waters are those waters which are located in industrial harbors and ports and have less stringent water quality standards for certain parameters than Class B waters (USVI 2019). Most marine waters of VIIS-VICR are Class B and are subject to standards with the purpose of maintaining aquatic life and human health. However, the area around Trunk Bay and the Snorkel Trail are classified as Class A waters. Class A waters are defined as "Outstanding natural resource waters" with "exceptional recreational, environmental, or ecological significance" and "The quality of these waters cannot be altered except towards natural conditions. No new or increased dischargers shall be permitted." Thus, the expectation is that water quality around Trunk Bay is as unaltered from a pristine natural condition." Water quality included in this assessment were taken from publicly available databases and published and unpublished sources.

Table 4.1.1.1. Common water quality indicators used in this assessment. When available, each unit is listed with its standard upper or lower limit for the maintenance and activity of aquatic life, or deviation from natural conditions as determined by local regulations. For chlorophyll a, literature surveys served as a guideline for when values exceed oligotrophic conditions associated with coral reefs.

Variable	**Unit**	**Standards or guidelines**	**Source**
pH	None	<7, >8.3	USVI 2019
Temperature	°C	Dependent on taxa; <29°C for corals/<32°C elsewhere	see Section 4.4 for corals; USVI 2019
Dissolved Oxygen	mg L^{-1}	>4.8 mg L^{-1}; >5.5 mg L^{-1}	Prince and Goodyear (2006); USVI 2019
Total Suspended Solids	mg L^{-1}	None	–
Turbidity	Nephelometric turbidity units	<1 NTU reduction from oceanic clarity for coral reefs/<3 NTU maximum in general[1]	Smith et al. 2013 and USVI 2019
Ammonia	µg L^{-1}	None	–
Nitrate	µg L^{-1}	None	–
Phosphate	µg L^{-1}	None	–
Chlorophyll a	mg L^{-1}	<0.4 µg L^{-1}	Smith et al. 2013; Furnas et al. 2005
Fecal Indicators	Colony forming units per 100 mL seawater	<30 CFU (30 day geo. Mean), <110 CFP (<10% samples for 30 days)	USVI 2019

Common water quality metrics

Common water quality indicators included in this assessment with their standards for maintenance of aquatic life (where developed) are listed in Table 4.1.1.1. Temperature has high relevance to coral stress and is presented and discussed later in the Section 4.4.1. Dissolved oxygen (DO) is important for maintenance of respiration in aquatic animals and can affect animal growth and movement (Prince and Goodyear 2006), with values lower than 4.8 mg L^{-1} indicative of impairment (USEPA 2000) and a level of 5.5 mg L^{-1} as the legal standard for the USVI (USVI 2019). Total suspended solids (TSS) can indicate both endogenous particles related to biological activities in the water column, such as plankton, and exogenous particles potentially related to pollution. There are no US Environmental Protection Agency (USEPA) nor local USVI aquatic life standards for TSS (USEPA 2019; USVI 2019). Turbidity is a measure of water clarity, with values greater than 1 nephelometric turbidity unit (NTU) associated with waters of limited clarity that are less aesthetically pleasing and indicate impairment for coral reef environments of the USVI (USVI 2019). Less stringent standards of <3 NTU are listed for other Class B areas without coral reefs.

Nutrients and phototrophs

Dissolved inorganic nutrients are important and essential for aquatic life by supporting the growth of phytoplankton and benthic phototrophs, such as macroalgae. However, excessive nutrients can promote growth of unwanted types or abundance of phototrophs. For example, phytoplankton stimulated by nutrients can decrease light penetration to the benthos and some species are implicated in harmful algal blooms (Anderson et al. 2002). Excessive nutrients can stimulate overabundance benthic plants at the expense of desired and natural foundational species, such as corals and seagrasses, particularly when herbivory is naturally or artificially low (McCook 1999). This includes competition with juvenile and adult stony corals for space.

Important dissolved nutrients that support pelagic and benthic plant growth are ammonia, nitrate, and phosphorous (orthophosphorous). Nutrient criteria have been developed for USVI Class B waters for Total Phosphorous and Total Nitrogen with limits set at 50 $\mu g\ L^{-1}$ and 207 $\mu g\ l^{-1}$, respectively. Data were available for ammonia, nitrate, and phosphorous (orthophosphorous). Reporting limits (minimum acceptable values) for these molecules in USVI waters are the following: ammonia (10 $\mu g\ l^{-1}$), nitrate (1.5 $\mu g\ l^{-1}$), and phosphate/orthophosphate (7 $\mu g\ l^{-1}$) (Smith et al. 2013). Values that are close to these reporting limits are reasonably likely to indicate low concentrations (oligotrophic) conditions for that nutrient in reference to stimulation of phototrophs.

Chlorophyll concentrations and deviations from mean conditions can be important indicators of nutrient pollution in tropical waters. In general, dissolved nutrients in oligotrophic tropical seawater are rapidly taken up and used by pelagic and benthic phototrophs for growth, thus, free water dissolved nutrient concentrations are very low (Furnas et al. 2005). For this reason, water column chlorophyll, the concentration of photosynthetic pigments indicating phytoplankton abundance, is often used as a proxy for dissolved nutrients (Furnas et al. 2005). Chlorophyll a values greater than about 0.4 $\mu g\ L^{-1}$ are indicative of enrichment above oligotrophic oceanic conditions based on research conducted south of St. John (Smith et al. 2013) and are similar to values found on the Great Barrier Reef (Furnas et al. 2005).

Fecal indicator bacteria

Fecal indicator bacteria, such as enterococcus, can indicate human and animal waste contamination and are used to assess the suitability of marine water for contact-based activities. Values that exceed 35 colony forming units 100 ml^{-1} (CFU) are associated with marine waters considered at higher risk for development of human illness (at a rate of 36 per 1000 persons; USEPA 2012). The USVI standard indicates the 30 day geometric mean of enterococci should not exceed 30 CFU for 30 consecutive days or values of 110 CFU should not be found in more than 10% of 30 samples.

Data used in this assessment for the above water quality variables were taken from published sources and online databases. Smith et al. (2013) assessed the water quality in Fish Bay, Lameshur Bay, Reef Bay, Coral Bay, and an offshore reference site off the south coast of St. John from February 2012 – July 2013. Fish Bay, Lameshur Bay, and Coral Bay were divided into inner/outer, east/west quadrants and three sampling sites were randomly chosen for each month of sampling. Multimeter samples were taken at a depth of 0.5 m and analyzed for salinity, temperature, DO, and fluorometric turbidity and chlorophyll. Dissolved oxygen and chlorophyll are presented in this assessment. In addition, a horizontal Niskin sampler was used to retrieve a water sample from 0.5 m depth at the same spot. Bottled samples were tested for TSS and dissolved nutrients.

The US Environmental Protection Agency (USEPA) stores publicly available water quality data at https://www.waterqualitydata.us. This database was queried on September 10, 2019, for all data related to the St. John district. This query resulted in 37 unique water quality areas (Figure 4.1.1.1, Table 4.1.1.2) representing 9,082 individual sampling events from a variety of research and monitoring programs, including the USEPA, USVI Department of Planning and Natural Resources, TetraTech, Cadmus, and the US National Park Service (Table 4.1.1.2). Twenty-four of these sites were entirely or partially in VIIS-VICR waters (Table 4.1.1.2). Data taken from the same general area at multiple stations were condensed into a single station (e.g., Caneel Bay and Caneel Beach were aggregated and treated together as Caneel Bay). Where multiple stations were aggregated the geographic coordinates (Figure 4.1.1.1) were taken from the average latitude and longitude or, where averages produced unreasonable values on land, a central coordinate was chosen. Offshore sampling stations (>1 km from shore) that should represent the oceanic water quality conditions are also represented for comparison to nearshore data. Data were visually inspected for consistency. NPS turbidity data were excluded because of unusually high values that may indicate sensor and/or calibration issues. In addition, duplicate data reporting was common and removed from the final database. Site mean or median, standard deviation, and maximum value (or minimum for DO) were calculated for represented variables, including DO, TSS, turbidity, nutrients, fecal indicator bacteria, and chlorophyll. All suites of variables were not represented at each site. Dissolved nutrients included ammonia, nitrate, phosphorous and orthophosphorous. Although phosphorous and orthophosphorous are often considered synonymous, the differences in the USEPA database were not specified and so were left as separate data for this assessment.

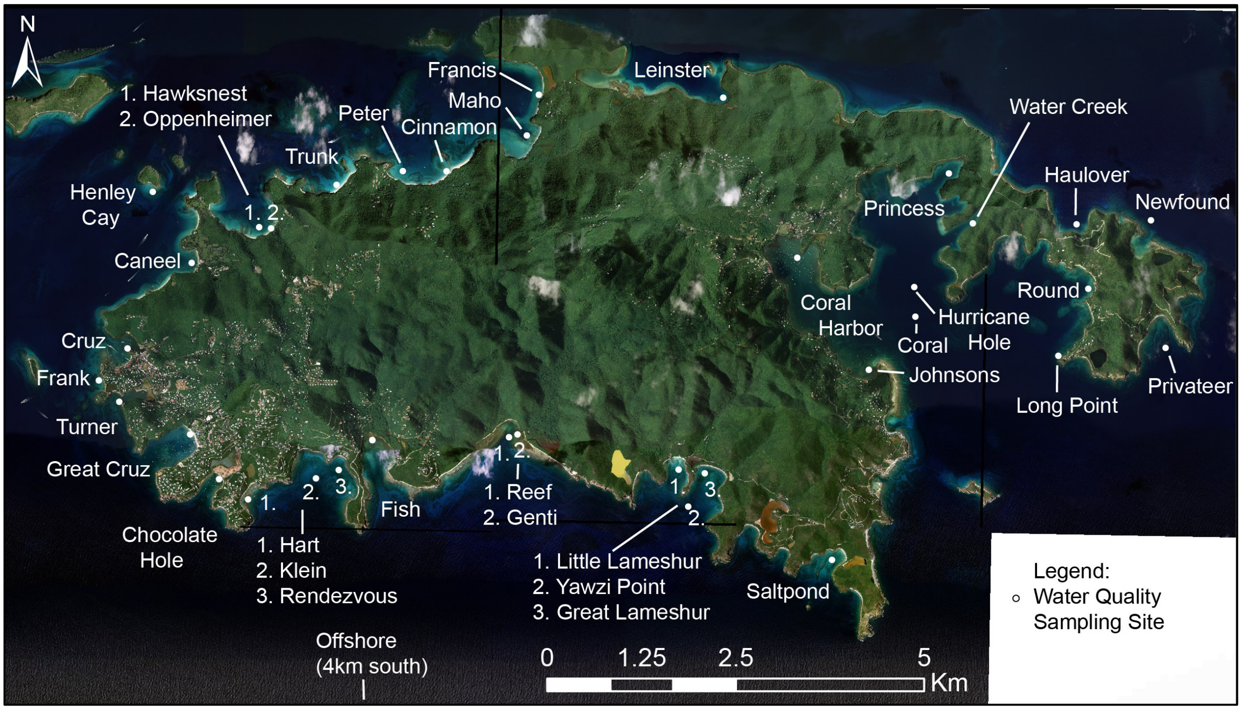

Figure 4.1.1.1. Map of water quality sampling stations around St. John and used in the assessment. The word “Bay” has been omitted from applicable sites names to make labels less cluttered. Aerial photos taken in 2007, source OCM Partners 2021.

Table 4.1.1.2. Sites sampled for water quality, their central coordinates, range of dates sampled, and number of individual sampling events (N). Individual samplings include at least one of the variables examined in this report. Data were extracted from https://www.waterqualitydata.us for the region US/USVI/St. John.

Location	Latitude	Longitude	Start	End	N
Caneel Bay[1]	18.34276	−64.78737	1/28/88	4/21/16	137
Chocolate Hole	18.31770	−64.78411	1/28/88	5/28/19	658
Cinnamon Bay[1]	18.35447	−64.75605	1/28/88	5/28/19	143
Coral Bay[1]	18.33835	−64.69820	1/28/88	3/22/10	180
Coral Harbor	18.34449	−64.71163	3/18/99	5/28/19	29
Cruz Bay[1]	18.33272	−64.79559	1/28/88	5/28/19	1285
Fish Bay[1]	18.32235	−64.7651	1/28/88	12/28/98	165
Francis Bay[1]	18.36367	−64.74479	1/28/88	5/28/19	394
Frank Bay	18.32893	−64.79859	1/28/88	5/28/19	646
Genti Bay[1]	18.32302	−64.74680	7/23/04	12/17/18	45
Great Cruz Bay	18.32259	−64.78776	3/18/99	5/28/19	863
Great Lameshur Bay[1]	18.31854	−64.72387	1/28/88	5/28/19	129
Hart Bay	18.31493	−64.78118	1/28/88	5/28/19	533
Haulover Bay[1]	18.34842	−64.67694	7/23/04	1/7/15	168
Hawksnest Bay[1]	18.34722	−64.77972	1/28/88	5/28/19	225
Henley Cay[1]	18.35189	−64.79292	1/28/88	12/28/98	93
Hurricane Hole[1]	18.34045	−64.69832	8/14/04	12/28/09	15
Johnson Bay	18.33137	−64.70368	1/28/88	5/28/19	553
Klein Bay	18.31741	−64.77239	7/23/04	8/7/17	500
Leinster Bay[1]	18.36322	−64.72108	1/28/88	12/28/98	94
Little Lameshur Bay[1]	18.31883	−64.72663	1/28/88	5/28/19	129
Long Point	18.33262	−64.67884	1/28/88	3/22/10	98
Maho Bay[1]	18.35856	−64.74569	1/28/88	12/28/98	100
Newfound Bay	18.34919	−64.66800	10/10/91	12/28/98	60
Offshore (CaRA VI1)	18.2505	−64.7625	12/10/04	9/30/15	12
Oppenheimer[1]	18.34665	−64.77840	7/28/04	12/17/18	697
Peter Bay[1]	18.35417	−64.76225	1/28/88	2/13/97	84
Princess Bay[1]	18.35719	−64.69325	1/28/88	2/13/97	83
Privateer Bay	18.33481	−64.66562	12/10/04	5/28/19	39
Reef Bay[1]	18.32303	−64.74731	1/28/88	12/28/98	93
Rendezvous Bay	18.31856	−64.76956	1/28/88	5/28/19	156
Round Bay[1]	18.34108	−64.67528	8/14/04	5/28/19	42
Saltpond Bay[1]	18.30846	−64.71102	1/28/88	5/28/19	144
Trunk Bay[1]	18.35233	−64.76997	1/28/88	5/28/19	150

[1] indicates site within VIIS-VICR boundaries.

Table 4.1.1.2 (continued). Sites sampled for water quality, their central coordinates, range of dates sampled, and number of individual sampling events (N). Individual samplings include at least one of the variables examined in this report. Data were extracted from https://www.waterqualitydata.us for the region US/USVI/St. John.

Location	Latitude	Longitude	Start	End	N
Turner Bay	18.32658	−64.79672	1/28/88	5/28/19	154
Water Creek[1]	18.35117	−64.68939	1/28/88	12/28/98	93
Yawzi Point[1]	18.31408	−64.72583	1/28/88	12/28/98	93

[1] indicates site within VIIS-VICR boundaries.

Time series analysis of water quality was not possible because of changing sampling frequency across locations and limited time periods of assessment. Visual analysis of existing data across time did not indicate strong patterns for any variable. Changing water quality over time was inferred from spatial patterns (e.g., turbidity in embayments exposed to more severe run off) and from frequency of deviation away from standards consistent with maintenance of marine life and human health (Table 4.1.1.1).

Reference Conditions/Values

Historically, the waters around St. John were noted for their clarity (Clifton and Phillips 1975), but areas of Coral Bay were naturally turbid in the early 1960s (Kumpf and Randall 1961). Active sample-based water quality monitoring did not start in the USVI until the late 1980s and has not been consistent through time until more recently. However, because of high water clarity it can be expected that vital plant nutrients, total suspended solids, chlorophyll, and turbidity were low in concentration in most areas of VIIS-VICR, with the specific exception of areas in Coral Bay and Cruz Bay.

Current Condition and Trend

In general water quality is good in VIIS-VICR, with exceptions for areas adjacent to highly populated areas and some indication of sporadic fecal contamination.

Fecal indicators

Over the data period, 57% of the 37 EPA STORET sampling sites (Table 4.1.1.2; Figure 4.1.1.1) had one or more periods when indicators of mammalian fecal bacteria (Enterococcus and fecal coliform) were above EPA guidelines of 35 cfu 100 ml^{-1} (Table 4.1.1.3). Most sites only had a small number of cases of potential contamination; however, some areas of VIIS had more persistent evidence of fecal contamination. These sites included Caneel Bay (11% of samplings), Coral Bay (12%), Cruz Bay (19%), Hurricane Hole (33%; note only 3 separate samplings), Oppenheimer (13%), and Salt Pond Bay (9%).

Table 4.1.1.3. Mean values (colony forming units per 100 ml) of Enterococcus and fecal coliform indicator bacteria, and chlorophyll for sites inside and outside of the VIIS-VICR. The standard deviation (SD), maximum values recorded at the site, and the number of samples (N) are also given. Fecal indicator values above 35 cfu 100 ml^{-1} suggest marine waters with elevated risk for contact-related human illness. Only sites sampled for fecal indicator bacteria and/or chlorophyll are shown in the table. NS = not sampled. Summarized from USEPA STORET data.

	Enterococcus (cfu 100 ml^{-1})			**Fecal Coliform (cfu 100 ml^{-1})**			**Total Fecal**	**Chlorophyll (µg l^{-1})**		
Location	**Median**	**SD**	**N**	**Median**	**SD**	**N**	**> 35 cfu 100 ml**	**Mean**	**SD**	**N**
Caneel Bay[1]	3.8	236	29	1	7	41	11%	–	–	–
Chocolate Hole	2	96	558	0	6	54	11%	–	–	–
Cinnamon Bay[1]	10	114	29	1	9	37	5%	0.8	0.0	2
Coral Bay[1]	10	12	39	3	194	29	12%	0.6	0.9	33
Coral Harbor	1	3	21	1	7	25	0%	2.0	0.6	4
Cruz Bay[1]	8	394	934	1	36	221	19%	–	–	–
Fish Bay[1]	1	11	55	1	16	49	3%	0.2	0.0	2
Francis Bay[1]	1	43	285	1	9	34	7%	–	–	–
Frank Bay	3	856	645	–	–	–	13%	–	–	–
Genti Bay[1]	10	6	29	0	1	27	0%	–	–	–
Great Cruz Bay	2	247	751	1	38	55	13%	–	–	–
Great Lameshur Bay[1]	10	5	29	1	1	27	0%	–	–	–
Hart Bay	4	149	533	–	–	–	20%	–	–	–
Haulover Bay[1]	–	–	–	–	–	–	–	–	–	NS
Hawksnest Bay[1]	10	17	30	1	0	37	2%	–	–	–
Henley Cay[1]	–	–	–	–	–	–	–	–	–	NS
Hurricane Hole[1]	12	16	2	153.75	210	2	33%	0.4	0.3	12
Johnsons Bay	3	249	468	0	3	22	13%	–	–	–
Klein Bay	1	147	499	–	–	–	10%	–	–	–
Little Lameshur Bay[1]	10	5	29	0	1	27	0%	–	–	–
Long Point	0	–	1	0.5	1	2	0%	0.2	–	1
Maho Bay[1]	2	4	7	–	–	–	0%	–	–	–
Newfound Bay	–	–	–	–	–	–	–	–	–	NS
Offshore	0	30	12	0	0	8	8%	–	–	–
Oppenheimer[1]	3	77	695	–	–	–	13%	–	–	–
Peter Bay[1]	–	–	–	–	–	–	–	–	–	NS
Princess Bay[1]	–	–	–	–	–	–	–	–	–	NS
Privateer Bay	10	114	39	0	4	19	3%	–	–	–
Reef Bay[1]	–	–	–	–	–	–	–	–	–	NS
Rendezvous Bay	1	5	55	0	106	49	3%	0.2	0.0	4

[1] indicates site within VIIS-VICR boundaries.

Table 4.1.1.3. (continued) Mean values (colony forming units per 100 ml) of Enterococcus and fecal coliform indicator bacteria, and chlorophyll for sites inside and outside of the VIIS-VICR. The standard deviation (SD), maximum values recorded at the site, and the number of samples (N) are also given. Fecal indicator values above 35 cfu 100 ml^{-1} suggest marine waters with elevated risk for contact-related human illness. Only sites sampled for fecal indicator bacteria and/or chlorophyll are shown in the table. NS = not sampled. Summarized from USEPA STORET data.

	Enterococcus (cfu 100 ml^{-1})			**Fecal Coliform (cfu 100 ml^{-1})**			**Total Fecal**	**Chlorophyll (μg l^{-1})**		
Location	**Median**	**SD**	**N**	**Median**	**SD**	**N**	**> 35 cfu 100 ml**	**Mean**	**SD**	**N**
Round Bay[1]	10	5	35	0	4	17	0%	0.7	0.6	3
Salt Pond Bay[1]	10	145	31	1	16	29	9%	0.2	0.0	4
Trunk Bay[1]	10	168	31	1	2	37	5%	–	–	–
Turner Bay	0.5	7	51	1	39	53	7%	–	–	–
Water Creek[1]	–	–	–	–	–	–	–	–	–	NS
Yawzi Point[1]	–	–	–	–	–	–	–	–	–	NS

[1] indicates site within VIIS-VICR boundaries.

Dissolved oxygen

Dissolved oxygen is nearly always well above that required for aquatic life (Table 4.1.1.4). Low minimum values indicating impairment were seen in VIIS-VICR at Caneel Bay, Cinnamon Bay, Coral Bay, Fish Bay, Francis Bay, Hawksnest Bay, Johnsons Bay, Salt Pond Bay, and Trunk Bay. However, the percentage of deviations were less than 5% for all sites and membrane oxygen sensors are sensitive to calibration changes, which can lead to spurious values. Generally high and sufficient levels of dissolved oxygen were also seen in Reef Bay, Lameshur Bay, Fish Bay, and Coral Bay, with mean values greater than offshore, reflecting higher water column photosynthesis in nearshore areas (Figure 4.1.1.2).

Table 4.1.1.4. Mean values of dissolved oxygen, total suspended solids, and turbidity for sites inside and outside of the VIIS-VICR. The standard deviation (SD), maximum values recorded at the site, and the number of samples (N) are also given for total suspended solids and turbidity. Summarized from USEPA STORET data. For dissolved oxygen, the percentage of values that fall below 4.8 mg l^{-1}, the EPA value indicating impairment (USEPA 2000), are presented.

	Dissolved Oxygen (mg l^{-1})				**Total Suspended (mg l^{-1})**				**Turbidity (NTU)**			
Location	**Mean**	**SD**	**<4.8**	**N**	**Mean**	**SD**	**Max**	**N**	**Mean**	**SD**	**Max**	**N**
Caneel Bay[1]	6.4	0.8	2%	105	6.5	5.9	23.4	20	1.1	1.6	6.63	44
Chocolate Hole	7.3	0.9	2%	128	5.0	3.9	21.8	60	1.8	1.9	10.8	245
Cinnamon Bay[1]	6.5	0.7	2%	117	4.8	4.0	15.0	29	0.9	1.7	9.1	51
Coral Bay[1]	6.4	0.9	3%	150	8.7	10.2	56.3	60	2.5	2.6	15.2	75
Coral Harbor	6.7	1.5	8%	13	7.8	6.9	23.9	22	2.7	1.5	5.7	28
Cruz Bay[1]	6.3	0.8	3%	443	6.8	7.6	76.0	219	2.5	2.3	18	668

[1] indicates site within VIIS-VICR boundaries.

Table 4.1.1.4 (continued). Mean values of dissolved oxygen, total suspended solids, and turbidity for sites inside and outside of the VIIS-VICR. The standard deviation (SD), maximum values recorded at the site, and the number of samples (N) are also given for total suspended solids and turbidity. Summarized from USEPA STORET data. For dissolved oxygen, the percentage of values that fall below 4.8 mg l^{-1}, the EPA value indicating impairment (USEPA 2000), are presented.

	Dissolved Oxygen (mg l^{-1})				Total Suspended (mg l^{-1})				Turbidity (NTU)			
Location	**Mean**	**SD**	**<4.8**	**N**	**Mean**	**SD**	**Max**	**N**	**Mean**	**SD**	**Max**	**N**
Fish Bay[1]	6.9	1.2	3%	129	6.2	4.2	20.4	60	3	6.1	49.2	69
Francis Bay[1]	6.5	0.7	2%	114	5.3	3.8	16.8	28	1.8	2.2	15.6	141
Frank Bay	–	–	–	–	2.2	0.7	3.0	3	1.5	1.6	19	312
Genti Bay[1]	8.0	1.3	0%	33	5.1	4.2	21.6	29	0.9	1.5	7.18	41
Great Cruz Bay	6.5	0.8	2%	131	6.3	4.7	20.7	63	3.2	3.7	27.3	439
Great Lameshur Bay[1]	6.9	0.9	0%	109	5.8	4.4	16.5	29	0.5	0.6	27.3	439
Hart Bay	–	–	–	–	16.2	13.7	31.9	3	3.1	3.1	19.9	198
Haulover Bay[1]	6.7	0.6	0%	97	2.9	2.7	13.0	64	–	–	–	–
Hawksnest Bay[1]	6.4	0.6	1%	193	5.2	6.0	30.9	29	0.7	1.3	7.1	53
Henley Cay[1]	6.4	0.4	0%	83	1.3	0.9	3.0	6	–	–	–	–
Hurricane Hole[1]	5.7	0.5	0%	10	2.0	–	2.0	1	0.9	0.2	1.1	4
Johnsons Bay	6.8	0.6	0%	105	5.6	5.0	26.0	46	1.6	2.2	21.1	298
Klein Bay	–	–	–	–	2.2	1.3	3.7	3	1.5	1	6.6	169
Leinster Bay[1]	6.5	0.4	0%	83	2.0	0.6	2.5	6	–	–	–	–
Little Lameshur Bay[1]	6.8	1.0	0%	109	6.0	5.5	23.8	27	0.6	0.7	2.8	43
Long Point	6.6	0.6	0%	88	2.2	1.1	3.7	7	0.9	1.2	3	5
Maho Bay[1]	6.4	0.4	0%	83	1.9	0.7	3.0	6	–	–	–	–
Newfound Bay	7.0	0.7	0%	48	2.2	0.8	3.6	6	–	–	–	–
Offshore	7.9	2.3	0%	8	12.7	6.1	20.5	12	0.4	0.4	1.5	12
Oppenheimer[1]	–	–	–	–	7.9	6.7	15.6	3	1.9	2.2	21.3	363
Peter Bay[1]	6.5	0.5	0%	77	–	–	–	–	–	–	–	–
Princess Bay[1]	6.6	0.5	0%	76	–	–	–	–	–	–	–	–
Privateer Bay	6.9	1.0	3%	29	4.8	5.1	23.1	39	0.4	0.4	1.9	39
Reef Bay[1]	7.9	0.7	0%	82	3.3	2.7	7.7	6	–	–	–	–
Rendezvous Bay	7.0	0.7	0%	122	4.8	5.0	28.5	54	0.7	0.9	5	69
Round Bay[1]	6.6	0.7	0%	32	4.8	4.3	18.2	36	0.6	0.9	5	40
Salt Pond Bay[1]	6.8	1.0	2%	119	4.6	3.6	16.7	37	0.5	0.5	2.3	45
Trunk Bay[1]	6.4	0.6	2%	122	4.9	5.3	22.2	35	0.9	1.7	9.2	53
Turner Bay	6.9	0.9	1%	122	5.0	4.2	19.2	53	1	1	4.5	71
Water Creek[1]	6.5	0.7	0%	83	3.3	2.6	8.5	6	–	–	–	–
Yawzi Point[1]	6.5	0.5	0%	82	1.8	1.2	4.0	6	–	–	–	–

[1] indicates site within VIIS-VICR boundaries.

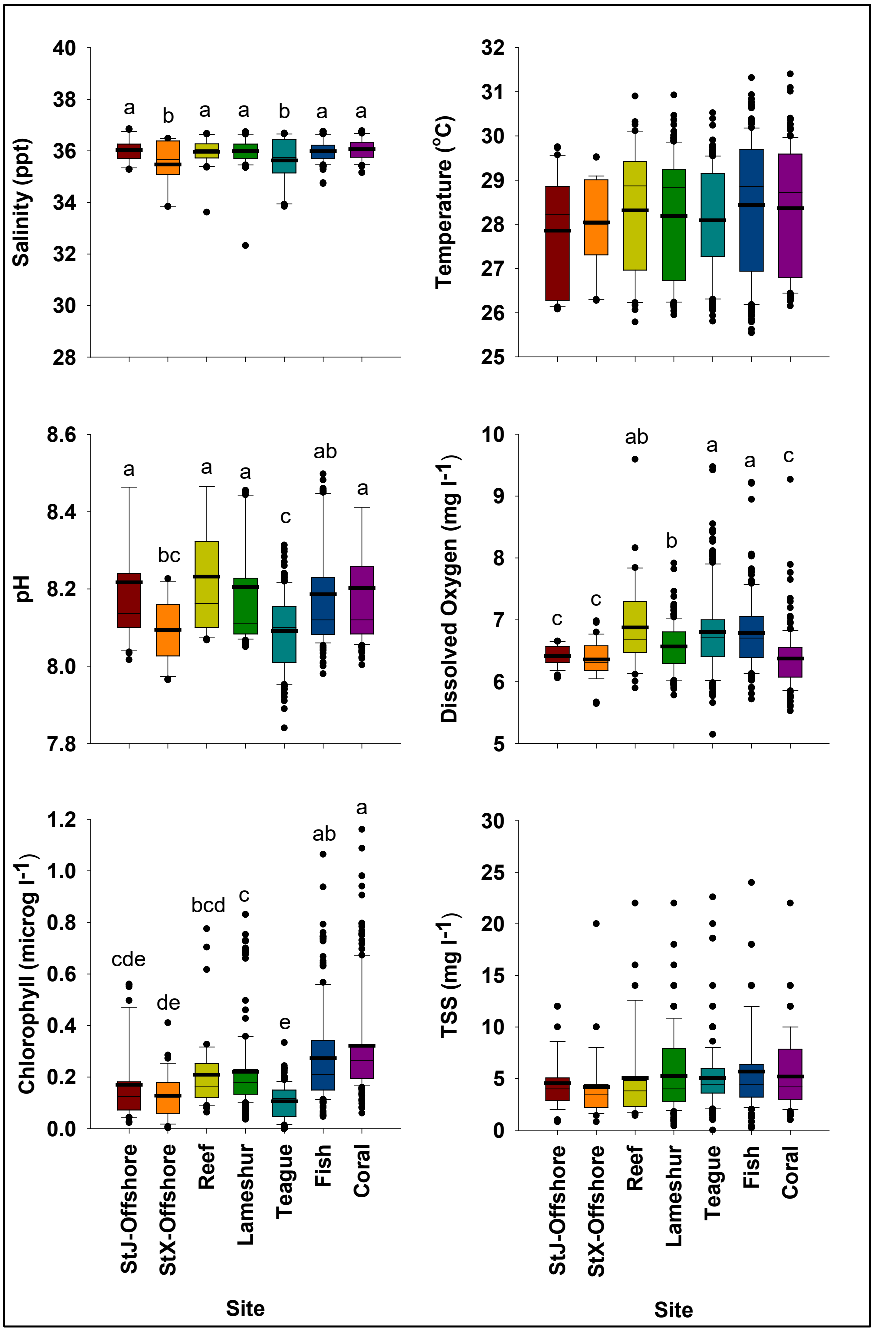

Figure 4.1.1.2. Water quality at various sampled locations on St. John (Reef Bay, Lameshur Bay, Fish Bay, and Coral Bay, and StJ-Offshore) and two additional reference sites on St. Croix (Teague Bay and StX-Offshore) for temperature, salinity, pH, dissolved oxygen (DO), chlorophyll, and total suspended solids (TSS). Figures represent box plots (mean – thick line, median – thin line, 25/75 percentile – box, 5/95 percentile – whiskers, outliers – points). Letters above plots represent Tukeys Post-Hoc test results between sites when among sites test was significant (see Smith et al. 2013 for full details).

Total suspended solids and turbidity

Total suspended solids were low in general, but the highest values outside the park were seen in areas such as Coral Harbor, which has high inputs of terrestrial run-off (Gray et al. 2012). Turbidity was recorded as high (>1 NTU) in many locations, however, this may indicate multimeter sensors of insufficient sensitivity to record the low turbidity values in most waters around the USVI, as was found in the research of Smith et al. (2013). Typical values of turbidity taken with oceanographic quality fluorometers on the south shore of St. Thomas, USVI, showed a polluted area with mean turbidity of about 1.2 NTU, whereas unpolluted nearshore and offshore waters were <1 NTU (Ennis et al. 2016) and below the legal standard for coral reefs in the USVI (USVI 2019). Water clarity, as measured by transmittance of photosynthetically active radiation, drops in association with rainfall in Lameshur Bay, which is away from human development (Edmunds et al. 2018). This suggests that higher turbidity values are associated with terrestrial runoff and could be subject to surges with increased discharge below developed and developing watersheds.

Dissolved nutrients and phototrophs

Dissolved nutrients in the water column are typically low in concentration throughout VIIS-VICR. Ammonia, nitrate, orthophosphate, and phosphate typically had means that were near, but below reporting limits for most sites (Table 4.1.1.5; Figure 4.1.1.3). There can be episodic values that are higher (see high outliers in Figure 4.1.1.3), but all indications suggest that even areas that might be under the influence of excess nutrient inputs they tend to have low nutrients in general (such as Fish Bay and Coral Harbor that are just outside VIIS-VICR boundaries). This is not unexpected, as nutrients in oligotrophic seawater are rapidly scavenged by phytoplankton and benthic phototrophs and can be detected by measuring chlorophyll (Furnas et al. 2005). Typical offshore values for chlorophyll south of St. John were less than 0.2 $\mu g\ l^{-1}$ (Smith et al. 2013). Only nine sites in the EPA STORET database presented data for chlorophyll (Table 4.1.1.3). However, the turbid and potentially polluted Coral Harbor site near VIIS-VICR boundaries did show high values (2.0 $\mu g\ l^{-1}$), possibly indicating nutrient enrichment. This was corroborated by Smith et al. (2013) who showed that the Coral Harbor zone within the larger Coral Bay area, had significantly higher chlorophyll. They also found that potentially impacted areas of inner Fish Bay, near to the VIIS-VICR boundary to the east, also had significantly higher chlorophyll concentrations. Coral and Fish Bays were also significantly elevated in chlorophyll compared to offshore areas and the VIIS sites Reef Bay and Lameshur Bay (Figure 4.1.1.3).

Terrestrial sediments

Terrestrial sediments are important sources of stress for stony corals growing in nearshore areas (Rogers 1990, Fabricius 2005). Existing data suggests that terrestrial sediments are elevated in areas sharing the same catchment as human development, such as Fish Bay and Coral Bay, relative to lightly developed areas, such as Lameshur Bay (Rogers and Beets 2001, Brooks et al. 2007, Gray et al. 2008, Gray et al. 2012, Brooks et al. 2015). Runoff is a potentially serious problem given steep hillsides and rapid residential and commercial development outside park lands (Rogers and Teytaud 1988; Whitall et al. 2015). Even embayments, such as Hawksnest Bay, which is not adjacent to land development can be impacted from activities far up the watershed (Rogers and Teytaud 1988). Periods with tropical storms and heavy rainfall can see large, transient increases in background rates of sedimentation, even in areas away from human development (Edmunds and Gray 2014). There is continued land-clearing, road building, and development in areas outside of park boundaries and this will likely further increase terrestrial sediment loading into park embayments and adjacent waters (Ramos-Scharrón and MacDonald 2007).

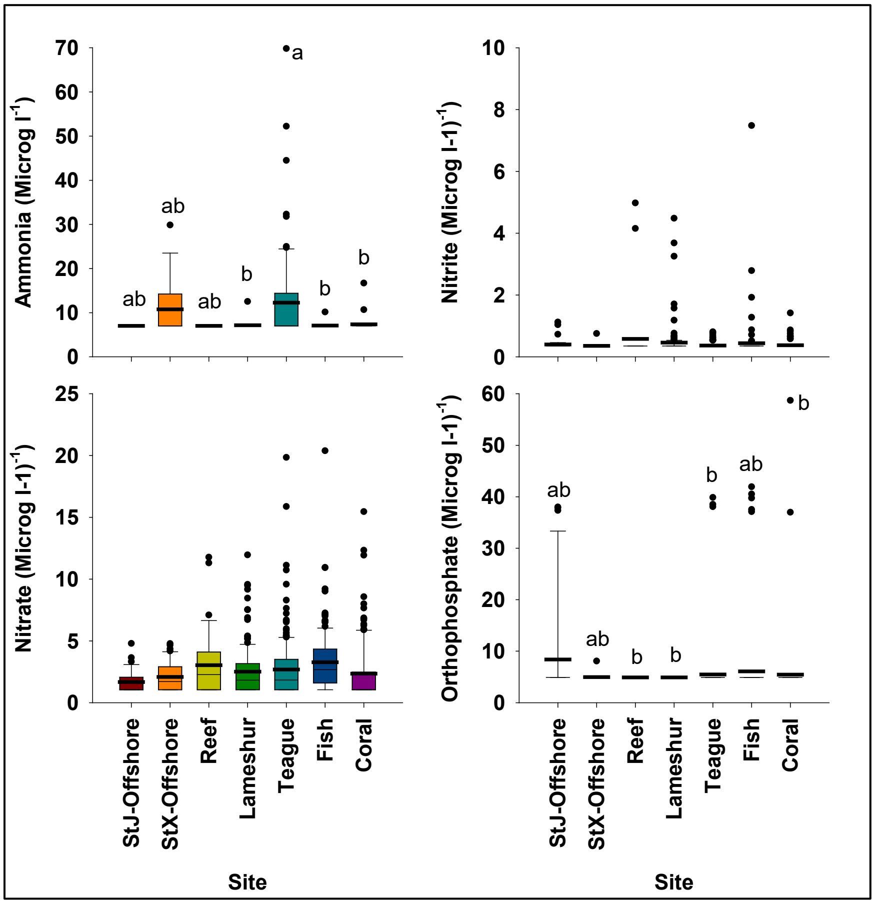

Figure 4.1.1.3. Water quality at various sampled locations on St. John (Reef Bay, Lameshur Bay, Fish Bay, and Coral Bay, and StJ-Offshore) and two additional reference sites on St. Croix (Teague Bay and StX-Offshore) for the dissolved nutrients ammonia, nitrite, nitrate, and orthophosphate. Figures represent box plots (mean – thick line, median – thin line, 25/75 percentile – box, 5/95 percentile – whiskers, outliers – points). Letters above plots represent Tukeys Post-Hoc test results between sites when among sites test was significant (see Smith et al. 2013 for full details).

Table 4.1.1.5. Mean values of dissolved ammonia, nitrate, orthophosphate, and phosphate for sites inside and outside of the VIIS-VICR. The standard deviation (SD), maximum values recorded at the site, and the number of samples (N) are also given. Summarized from USEPA STORET data.

	Ammonia ($\mu g\ l^{-1}$)				**Nitrate ($\mu g\ l^{-1}$)**				**Orthophosphate ($\mu g\ l^{-1}$)**				**Phosphate ($\mu g\ l^{-1}$)**			
Location	**Mean**	**SD**	**Max.**	**N**	**Mean**	**SD**	**Max.**	**N**	**Mean**	**SD**	**Max.**	**N**	**Mean**	**SD**	**Max.**	**N**
Caneel Bay[1]	–	–	–	–	2.1	2.7	11.6	24	5.6	4.0	17.5	24	–	–	–	–
Chocolate Hole	–	–	–	–	2.2	1.5	5.3	23	4.0	2.3	8.4	22	20.2	19.8	79.0	22
Cinnamon Bay[1]	4.0	0.0	4.0	4.0	3.0	2.0	8.1	26	4.2	1.8	7.7	26	15.9	22.3	88.0	17
Coral Bay[1]	11.5	4.2	18.0	11.5	2.7	3.5	12.4	32	5.1	3.2	12.0	62	42.5	46.0	170	52
Coral Harbor	10.5	2.1	12.0	10.5	–	–	–	–	4.0	1.9	6.1	3	10.8	3.3	15.1	4
Cruz Bay[1]	–	–	–	–	2.6	3.9	32.4	79	4.7	2.5	11.5	79	20.3	19.8	78.0	88
Fish Bay[1]	9.7	0.0	9.7	9.7	1.9	1.9	8.7	34	3.5	2.2	8.4	34	25.4	29.2	130	24
Francis Bay[1]	–	–	–	–	1.5	1.9	6.8	25	5.1	5.5	29.7	25	15.4	20.9	79.0	15
Genti Bay[1]	–	–	–	–	–	–	–	–	–	–	–	–	15.5	21.4	79.0	15
Great Cruz Bay	–	–	–	–	2.1	2.9	13.6	31	3.8	2.2	8.4	31	21.0	18.6	68.0	22
Great Lameshur Bay[1]	–	–	–	–	2.2	1.9	8.1	24	4.4	2.6	10.5	24	16.2	22.1	76.0	15
Haulover Bay[1]	–	–	–	–	2.5	2.4	11.1	49	3.8	2.3	13.0	49	–	–	–	–
Hawksnest Bay[1]	–	–	–	–	2.1	2.4	12.8	48	4.7	2.2	10.2	48	15.1	21.0	78.0	15
Henley Cay[1]	–	–	–	–	2.4	1.9	9.1	32	3.8	1.7	7.4	32	–	–	–	–
Hurricane Hole[1]	6.8	4.2	16.0	6.8	3.7	0.7	4.6	10	4.8	1.5	6.3	15	10.2	4.6	26.0	15
Johnsons Bay	–	–	–	–	2.7	1.5	6.3	24	4.1	2.6	10.8	24	19.4	20.9	83.0	21
Leinster Bay[1]	–	–	–	–	1.6	2.6	12.8	33	3.3	1.7	7.1	33	–	–	–	–
Little Lameshur Bay[1]	–	–	–	–	1.5	1.4	6.2	24	4.6	3.7	15.2	24	16.9	22.4	78.0	15
Long Point	10.8	6.7	15.5	10.8	1.8	1.4	7.1	32	3.5	2.6	11.0	37	9.7	2.1	12.2	4

[1] indicates site within VIIS-VICR boundaries.

Table 4.1.1.5 (continued). Mean values of dissolved ammonia, nitrate, orthophosphate, and phosphate for sites inside and outside of the VIIS-VICR. The standard deviation (SD), maximum values recorded at the site, and the number of samples (N) are also given. Summarized from USEPA STORET data.

	Ammonia (µg l^{-1})				**Nitrate (µg l^{-1})**				**Orthophosphate (µg l^{-1})**				**Phosphate (µg l^{-1})**			
Location	**Mean**	**SD**	**Max.**	**N**	**Mean**	**SD**	**Max.**	**N**	**Mean**	**SD**	**Max.**	**N**	**Mean**	**SD**	**Max.**	**N**
Maho Bay[1]	–	–	–	–	1.5	2.0	9.2	32	3.5	2.1	9.0	32	–	–	–	–
Newfound Bay	–	–	–	–	2.3	1.3	5.1	33	3.7	2.1	7.7	32	–	–	–	–
Offshore	–	–	–	–	–	–	–	–	–	–	–	–	50.0	–	50.0	4
Peter Bay[1]	–	–	–	–	2.0	2.0	9.0	24	4.4	2.0	9.0	24	–	–	–	–
Princess Bay[1]	–	–	–	–	1.6	2.2	9.9	23	5.6	5.5	26.0	22	–	–	–	–
Privateer Bay	–	–	–	–	–	–	–	–	–	–	–	–	19.3	21.0	90.0	22
Reef Bay[1]	–	–	–	–	2.2	1.7	8.5	32	3.6	2.5	9.8	30	–	–	–	–
Rendezvous Bay	7.0	1.1	7.9	7.0	2.0	1.9	7.1	27	4.2	2.6	13.0	27	17.2	17.9	76.0	26
Round Bay[1]	8.2	1.6	9.4	8.2	1.9	0.0	1.9	2	3.2	1.8	5.4	6	19.0	24.5	110	27
Salt Pond Bay[1]	9.2	2.9	11.7	9.2	2.2	1.9	7.8	36	3.6	2.2	8.4	36	14.7	19.7	77.0	19
Trunk Bay[1]	–	–	–	–	2.0	1.8	9.7	32	3.8	3.6	21.1	32	16.6	20.2	73.0	15
Turner Bay	–	–	–	–	3.4	3.0	14.6	22	7.4	9.0	44.8	22	19.8	19.1	76.0	22
Water Creek[1]	–	–	–	–	2.1	3.0	15.7	32	4.0	2.6	12.1	32	–	–	–	–

[1] indicates site within VIIS-VICR boundaries.

Contaminants

Contaminants that have been tested in waters of VIIS-VICR were low in general, but with some exceptions. Whitall et al. (2015) sampled marine sediments for over 140 contaminants with possible effects on organisms in a mix of targeted and random sites in and adjacent to park and monument waters of the areas of Fish Bay and Coral Bay. In the park waters sampled there were detections of a range of sediment contaminants, but none at levels associated with changes in biota due to toxicity. In areas adjacent to the park, copper was found in Coral Harbor and at one site in the inner portion of Fish Bay to be at levels above which effects on organisms could occur (effective range low; Whitall et al. 2015). Chlordane was also found above effective range low in inner portions Coral Harbor. Downs et al. (2016) looked at potential contamination of park waters with UV blocking components founds in human sunscreens (benzophenone-3) near heavy recreational water use areas of VIIS. Concentrations in water were detected near heavy wading and snorkeling areas of Hawksnest Bay and Trunk Bay and above potential values associated with impacts on coral (75–95 ppbillion around elkhorn coral *Acropora palmata* spurs in Hawksnest and 1.4 ppmillion near the Trunk Bay snorkel trail). There was no detection in Caneel Bay with relatively little in-water recreation. As covered in Section 4.4.1, colonies of the threatened stony coral *A. palmata* are being evaluated for negative effects on reproduction potentially associated with sunscreen exposure.

Threats and Stressors

The main sources of reduced water quality for recreation and marine life likely stem from terrestrial activities and recreational activities. Temperature increases are a major threat to coral reef ecosystems, and this is covered in section 4.4.1. Terrestrial activities reducing water quality around St. John likely include land clearing for residences and roads, which can promote the liberation of clay soils during rain events (Ramos-Scharrón and MacDonald 2007). These small particles can impair water quality and are particularly damaging to sensitive coral reef ecosystems (Weber et al. 2012). In addition, poorly maintained septic systems and fecal material from feral animals could be a source of fecal indicator bacteria in nearshore marine waters. There are areas just outside or partially inside VIIS-VICR near residential areas that are known to have impacts from run off, such as Coral Bay and Fish Bay (Gray et al. 2008, Gray et al. 2012). In addition, Cruz Bay, which is located at the center of activity for St. John, is likely impacted by run off, and indications from water quality sampling suggest this is the case. Lastly, localized exposure to contaminants may be impacting corals in areas of heavy use by bathers.

Data Needs and Gaps

The USVI Department of Planning and Natural Resources maintains an ambient water quality monitoring program that samples within and around VIIS-VICR and provides valuable information on water quality. However, the program is not comprehensive and has periodic lapses in sampling, potentially missing key acute events that impact water quality, such as storm derived run off. A water quality sampling program utilizing sample collection and the deployment of sensors at areas known or suspected to be impacted by run off of terrestrial soils or potential human and animal waste would be valuable. Such a program would allow a better determination of the temporal and spatial scale of the problem. Target areas could include Cruz Bay, Coral Bay, and Fish Bay, and should be supplemented with control samples from non-impacted offshore areas and nearshore areas (e.g., Lameshur Bay). In addition, continued and strengthened cooperation with sampling efforts of the territorial government could assist in understanding and mitigating the impacts of pollutants and threats to water quality from adjacent non-park waters and lands. In particular, confirming periods of fecal contamination and tracking the sources of contamination could lead to mitigation strategies. Further, in high recreational use areas confirming the impacts on corals and other biota of personal hygiene products washed off of bathers, such as UV sunscreens, seems prudent given preliminary data. A more robust sampling program for water column chlorophyll, which is relatively cheap using in situ fluorometric sensors (episodic and continuous sampling), could replace a more expensive and less informative program examining dissolved nutrients. In addition, remote sensing approaches using satellite-based sensors and calibrated water color products (turbidity, chlorophyll, phytoplankton species determination) could give near continuous and wide-scale assessments of general water quality around VIIS-VICR. A calibration of satellite sensors was recently conducted for the northern USVI, including sampling in Lameshur Bay. This project could be a starting point for monitoring using remote sensing tools (Brandt et al. 2019).

Overall Condition

The water quality of VIIS-VICR is generally good, with some exceptions at the periphery of the park near population centers (Table 4.1.1.6). Continued human development in upland areas of St. John outside the park will continue to impact water quality and is likely to continue to degrade water quality. In addition, indicators of fecal contamination from sewage and livestock are not uncommon and are cause for concern, as are potential contaminants (sunscreens) associated with bathers in high use areas of VIIS-VICR.

Table 4.1.1.6. Graphical summary of status and trends for Water Quality.

Component	**Indicator**	**Condition Status /Trend**	**Rationale and Reference Conditions**
Water Quality	Fecal Indicator Bacteria	🟡⇩	There are indications of fecal contamination for some sites that periodically exceed values considered a risk for human contact. Continued development and poor enforcement of septic discharge may contribute to increasing incidences of fecal contamination.
	Dissolved Oxygen	🟢⇔	Values are nearly universally high in areas sampled and there is no indication of declines in concentration over time.
	Total Suspended Solids	🟢	Total suspended solids are low in areas away from human development. There is insufficient information to understand if concentrations are changing.
	Turbidity	🟢	Turbidity is low in areas away from human development. There is insufficient information to understand if concentrations are changing.

Table 4.1.1.6 (continued). Graphical summary of status and trends for Water Quality.

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Water Quality (continued)	Dissolved Nutrients	🟢 ⇔	These are typically near detection limits in most areas. However, they may be a poor metric of nutrient loading.
	Chlorophyll	🟢	Chlorophyll was low in a few areas that were assessed, but elevated near human activities, indicating nutrient loading. There is insufficient information to understand if phytoplankton abundance is changing.
	Terrestrial sediments	🟡 ⇩	Terrestrial sediments have been noted as affecting water quality in multiple areas of the park below human development. Continued development and road building under VI codes does not prevent increasing delivery of terrestrial sediments to nearshore marine environments.
	Contaminants	🟡 ⇔	There are some indications of sediment contaminants in areas adjacent to park waters and personal hygiene product contamination in high use areas

Source(s) of Expertise

- Benjamin Keularts, Division of Environmental Protection, USVI Department of Planning and Natural Resources
- Anthony Pait, National Oceanic and Atmospheric Administration

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4.2. Marine Plants

4.2.1. Macroalgae

This section reviews the condition of macroalgae in VICR and VIIS. The condition assessment considers 33 years of data (Edmunds 2013 for data from 1987–2011; NOAA's Center for Coastal Monitoring and Assessment, 2005, 2007 (NCCOS 2009); South Florida/Caribbean Network coral reef monitoring program 1999–2018 (data provided by Lee Richter), Miller et al. 2007; National Coral Reef Monitoring Plan (NCRMP) of the NOAA Coral Reef Conservation Program 2013, 2015, 2017, 2019 (data available from https://www.coris.noaa.gov/monitoring); Clark et al. 2015; Bramanti et al. 2017; Smith et al. 2017; Territorial Coral Reef Monitoring Program 2017 (TCRMP data available from https://sites.google.com/site/usvitcrmp/available-data)) to assess the status of the macroalgae resource. The status of the macroalgae is evaluated using metrics that detect change in abundance and occurrence. The condition metric selected to assess this resource is percent cover.

Description

Seagrass and macroalgae are significant primary producers in many shallow marine systems (Duarte and Cebrian 1996) including back reefs and lagoons of the Virgin Islands (Williams 1990). The combined 11,597 ha of diverse submerged coastal habitats in VIIS and VICR include algal plains and fields of rhodolith rubble (Menza et al. 2006, Friedlander et al. 2013). Of the 53 km^2 benthic habitat surrounding St. John (including VIIS and VICR) as mapped by Zitello et al. (2009), 74% was predominantly covered by algae. Within VICR, the proportion was 84% (Table 4.2.1.1).

Table 4.2.1.1. Area and proportion of area predominantly covered by seagrass and algae from surveys of acoustic and remotely sensed imagery of the marine habitats in 2005 and 2007 (Zitello et al. 2009).

		Seagrass		Algae	
Unit	**Total area (ha)**	**Area (ha)**	**Proportion**	**Area (ha)**	**Proportion**
VICR	5625.21	22.49	0.004	4720.67	0.84
VIIS	5971.95	382.81	0.064	1284.18	0.22

Macroalgae is often found in mixed seagrass meadows and, along with filamentous algae, on coral rubble inside fringing coral reefs (Zitello et al. 2009). Rhodolith beds, fields of unattached fragments of layered coralline red algae, are found in moderate-depths relative to surrounding habitats. Algae provide habitat structure (Wilson et al. 1990) and are the base of food webs (Simenstad and Wissmar 1985) for diverse ecosystems. Protected and commercially important fish species such as Nassau grouper (*Epinephelus striatus*) use macroalgae as near-shore nursery habitat (Sadovy et al. 2018).

However, algae also colonize dead coral structures and can remain dominant for decades, preventing coral recruitment (Bruno et al. 2014). Coral disease and mortality, nutrient additions to the system and losses of herbivorous fish and urchins perpetuate the algal-dominated state (Precht et al. 2019). *Ramicrusta textilis* (Pueschel and Saunders 2009) is an invasive encrusting peyssonnelid algal crust (PAC) aggressively spreading on Caribbean reefs, including those in the Virgin Islands. *Ramicrusta* can grow on bare hard substrate and corals and sponges (Eckrich and Engel 2013, Edmunds et al. 2019). Genetic analyses revealed the PAC in St. John to be *Ramicrusta textilis* (Wilson et al. 2020), a taxon recently described from Jamaica. The invasive algae may capitalize on coral bleaching events and prevent recolonization by coral (Smith et al. 2017). Because algae can have both positive and negative effects on marine communities and ecosystem function, they are among the major taxonomic groups targeted for monitoring with VIIS.

Data and Methods

The Center for Coastal Monitoring and Assessment (CCMA) used acoustic imagery to assess the status, abundance, and distribution of moderate-depth marine habitats in VICR in 2005. In 2007 a visual interpretation of remotely sensed imagery was used to map and assess the nearshore benthic habitats off St. John. To calculate benthic cover for each habitat type within the park boundaries, we combined the 2005 and 2007 data sets. Where data overlapped spatially, the most detailed information was retained and surveyed habitats within the park boundaries were extracted for analysis. The unit boundaries used for mapping and polygon analysis were sourced from the National Park Service database.

This report also summarizes macroalgae observations and cover estimates produced during coral reef monitoring surveys conducted according to the National Coral Reef Monitoring Plan (NCRMP) of the NOAA Coral Reef Conservation Program (Clark et al. 2015). Benthic composition was surveyed by diver observation during 2013, 2015, 2017, and 2019 during the months of July and August at 81–97 locations using line point-intercept (LPI) surveys. The transect sites differed between years. Macroalgae percent cover was estimated as the number of algal occurrence observations at 100 points spaced at 20 cm intervals along a 20 m linear transect. Each sample point was identified to predetermined major functional categories, 10–11 of which were algal categories. The occurrence and cover of the following algal categories were recorded: *Cyanophyta* spp., *Dictyota* spp., *Halimeda* spp., *Lobophora* spp., other calcareous macroalgae, other "fleshy" macroalgae, *Peyssonnelia* spp., *Ramicrusta* spp., Rhodophyta crustose spp. (other), turf algae with sediment, and turf algae free of sediment. For this report, only total algae percent cover and percent cover of *Ramicrusta* sp., a putative invasive exotic alga (Eckrich and Engel 2013) recorded since 2017 are discussed.

Smith et al. (2017) described the benthic communities including cyanobacteria, epilithic algae and macroalgae at the Territorial Coral Reef Monitoring Program (TCRMP) sites. Only two sites, Coral Bay and Fish Bay were located off St. John, but neither within VIIS or VICR boundaries. They also investigated the status of the invasion of *Ramicrusta* spp. red algae. The presence, abundance, and impacts of each functional group were estimated from the TCRMP benthic cover dataset.

Random point-intercept benthic algae cover data, produced by the South Florida / Caribbean Network (SFCN) from 10 m permanent video transect surveys (Miller et al. 2007) and conducted annually at Yawzi Reef (1999–2017), Mennebeck Reef (2000–2017), Haulover Reef (2003–2018), and Tektite Reef (2005–2017) (Figure 4.2.1.1) are summarized as time series plots of abundance (mean number of point observations per transect). Nine categories of benthic algae cover were observed at these reefs: turf algae (dead coral w/ turf algae), other macroalgae (macro algae), *Dictyota* spp., cyanobacteria, crustose coralline algae, *Halimeda* spp., *Lobophora variegata*, *Sargassum* spp., and *Amphiroa* spp.

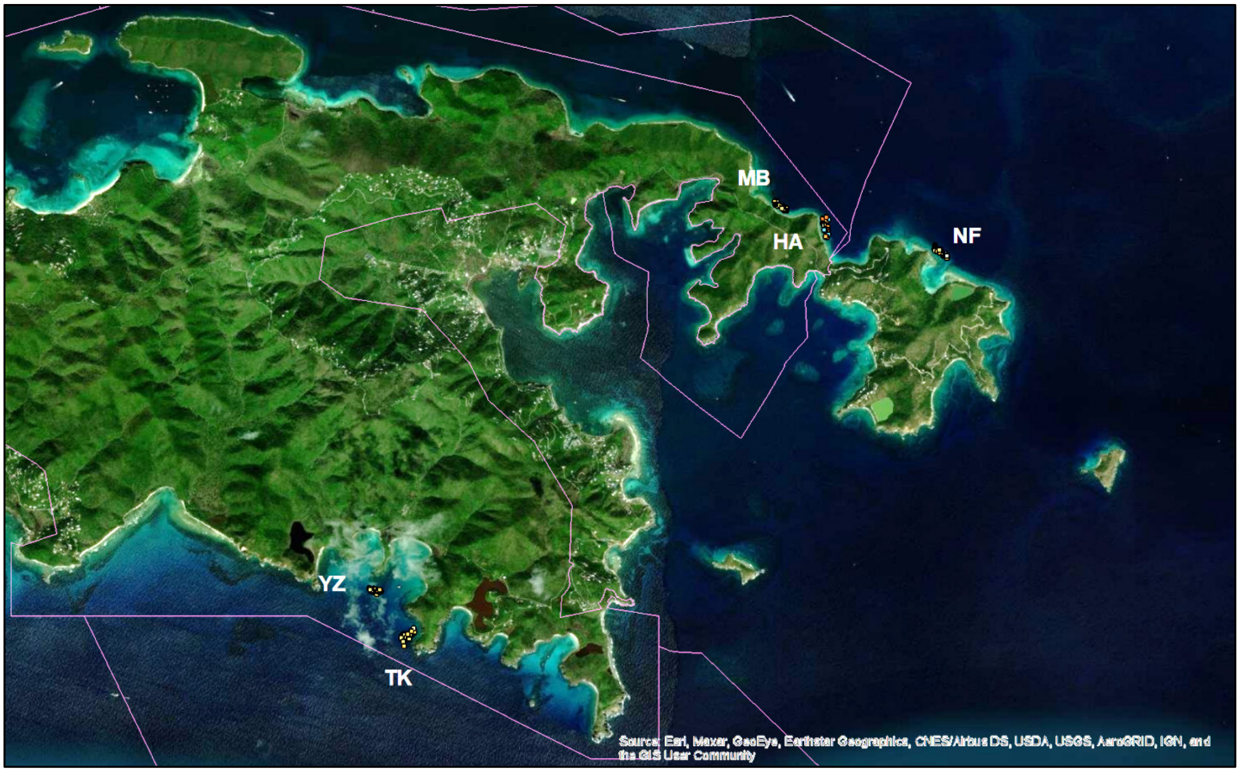

Figure 4.2.1.1. Location map of Yawzi Reef (YZ), Mennebeck Reef (MB), Haulover Reef (HA), and Tektite Reef (TK) video reef transects within Virgin Islands National Park and Newfound Reef (NF, outside Park boundary) (Miller et al. 2007).

Edmunds (2013, 2019) quantified the effects of hurricanes on reefs off St. John. Data were analyzed from plots at Yawzi Point and Tektite where three 10-m permanent transects were surveyed over 31 years. The data include identification of substratum and cover of coral, macroalgae, and CTB (crustose coralline algae, algal turf, and bare space) from 1m^2 photo quadrats.

Bramanti et al. (2017) conducted 50 m video surveys along shallow reefs off St. John's southern coast and quantified the benthic cover of an encrusting macroalgae. Identified as *Peyssonnelia stoechas*, the macroalgae has similar physical and growth characteristics to *Ramicrusta* spp. Still frames from the videos were extracted and given a score for *P. stoechas* dominance using a 25 square grid.

Reference Conditions/Values

Multiple disturbances to the benthos including hurricanes, anchoring, and the appearance of the non-native seagrass *Halophila stipulacea* (Willette et al. 2014, 2020) have led to shifting baselines of algal abundance in VIIS and VICR. In this report, the conditions of algal functional groups are assessed relative to disturbances and broadly by comparing the condition observed in benthic surveys conducted in the 1980s to the condition observed in recent surveys. The results of the 2005 and 2007 CCMA surveys are used to assign the pre-*H. stipulacea* invasion condition of algae in VICR and VIIS. Anchoring in seagrass and coral habitats was discontinued in 2000. A die-off of sea urchin

(*Diadema antillarum*) in 1983–1984 led to a 30-fold increase in algal biomass off St. John (Levitan 1988; Carpenter 1990).

Early trends in macroalgae (primarily *Dictyota* spp.) on Lameshur reef off of Yawzi Point in southern VIIS were documented as increasing from 7.3% to 33.5% following Hurricane Hugo in 1989 (Rogers and Miller 2006). The macroalgae replaced coral that was lost during the hurricane, and then hindered or prevented the growth of adult corals. The subsequent persistence of algae cover and lack of recovery by corals was attributed to reduced herbivory associated with overfishing of herbivorous fishes and herbivorous fish habitat degradation following the hurricane (Rogers and Miller 2006).

Turf and crustose algae have been the most abundant of all algae observed in the USVI. Off St. John, turf and crustose algae comprised a mean of 30.4% ± 1.7% of the benthos compared to 13.9% ± 0.9% mean cover of macroalgae and 1.7% ± 0.4% mean cover of filamentous algae and cyanobacteria (Rogers et al. 2008). The most common macroalgae observed off St. John were *Dictyota* spp., *Lobophora variegata*, and *Halimeda* spp.

Current Condition and Trend

Edmunds (2013, 2019) reports large increases in macroalgae cover over the 28-year period from April 1989 to July 2017 at Yawzi Point and Tektite. At Yawzi Point, macroalgae increased in abundance from 4.2% ± 0.7% in April 1989 to 41.6% ± 3.1% in July 2017. Similarly, at Tektite, macroalgae increased from 8.4% ± 1.6% to 40.5% ± 1.2% over the same time period (Figure 4.2.1.2).

Macroalgae observations and cover estimates produced from coral reef monitoring surveys conducted according to the National Coral Reef Monitoring Plan (NCRMP) revealed a steady increase in mean total algae percent cover from 2013 to 2019 (Figures 4.2.1.3–4.2.1.6). Mean total algae percent coverage observed during transect surveys in 2013, 2015, 2017, and 2019 (Figures 4.2.1.3–4.2.1.6) were 45%, 49%, 57%, and 63%, respectively. Turf algae with sediment was the most frequently observed algal category during all survey years and comprised 33–47% of all algae observations and was the largest contributor to the increase in total algae cover between 2013 and 2019. The mean percent cover of turf algae with sediment was 20%, 23%, 19%, and 27% in 2013, 2015, 2017, and 2019, respectively. *Ramicrusta* spp. were not recorded until 2017 when it was added as a new algal category for monitoring. Observations prior to 2017, if any, may have been recorded in a different category (e.g. *Peyssonnelia* spp.). In 2017, *Ramicrusta* spp. occurred in 16% of the transects surveyed and exhibited a mean percent cover of 1.2% (Figure 4.2.1.7). In 2019, the mean percent cover of *Ramicrusta* spp. decreased to 0.6%, but the frequency of occurrence among transects increased to 25% (Figure 4.2.1.8).

Macroalgae observations from random point-intercept video transect surveys produced by the South Florida / Caribbean Network (SFCN) on Yawzi Point, Mennebeck, Haulover, and Tektite reefs indicates a similar dominance of turf algae among the reef algal community (Figure 4.2.1.9). Time series plots of macroalgae abundance at Yawzi Point (1999–2017), Mennebeck (2000–2017), Haulover (2003–2018), and Tektite (2005–2017) reveal considerable inter-annual variability for the abundance of the algal groups with the exception of Haulover Reef which exhibited lower total algal abundance and relatively less inter-annual variation within the algal groups (Figure 4.2.1.9). Long-term temporal trends over the period of record for most algal groups are not readily evident, but *Dictyota* spp. abundance increased greatly in 2017 (Yawzi Point, Mennebeck, and Tektite) and in 2018 (Haulover) following Hurricane Irma in the fall of 2017. Algae abundances increased 140–300% above period of record means.

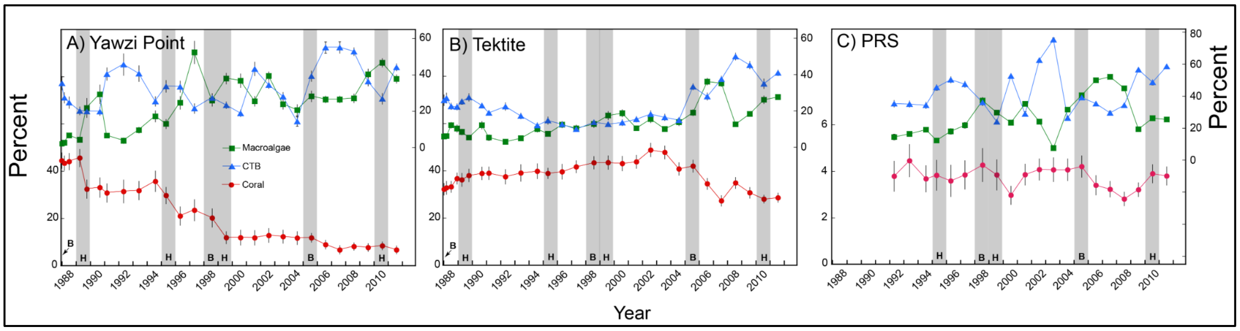

Figure 4.2.1.2. Trends in benthic community structure estimated from photo quadrats on three reef habitats within VIIS: A) Yawzi Point, B) Tektite, and C) multiple random sites pooled to represent a single habitat type. Left scale: scleractinian corals, Right scale: macroalgae and CTB (combined crustose coralline algae, algal turf and bare space). Gray bars represent disturbances: bleaching (B) and hurricanes (H). (Figure courtesy of P.J. Edmunds)

In 2016 *Ramicrusta* spp. was observed at ca. 60% of the sites surveyed for benthic cover by TCRMP in the USVI (Smith et al. 2017). The invasive algae comprised less than 25% at most sites but up to 98.25% at a site off the west coast of St. Thomas. None of the sites surveyed were within VIIS or VICR. The two sites surveyed off St. John, Fish Bay and Coral Bay, had less than 25% cover.

The mean cover of encrusting macroalgae *P. stoechas* was significantly greater on coral reefs at 3 m depths (8.5 ± 1.3%) compared to 5 m (3.4 ± 0.6%) and 7 m (1.0 ± 0.2%) depths (Bramanti et al. 2017). Further review of photographs from previous studies suggests that the encrusting algae began to dominate some areas of the benthic substrate in 2011 and 2012.

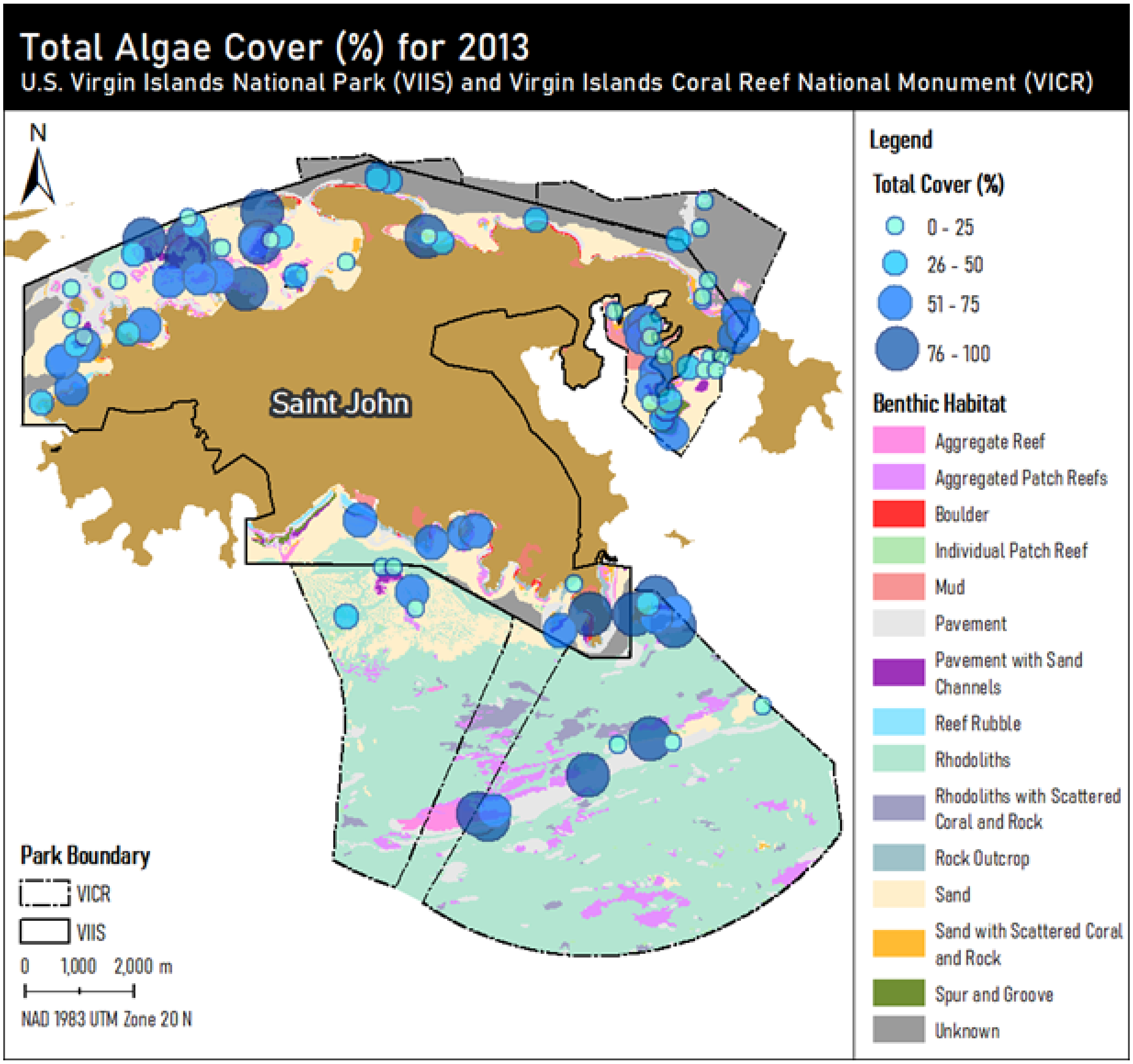

Figure 4.2.1.3. Total algae percent cover, U.S. Virgin Islands National Park and Virgin Islands Coral Reef National Monument, 2013 (NCCOS-SEFSC 2021). Habitat data source: NPS-NCRMP-UVI program. Habitat cover from Costa et al. 2009.

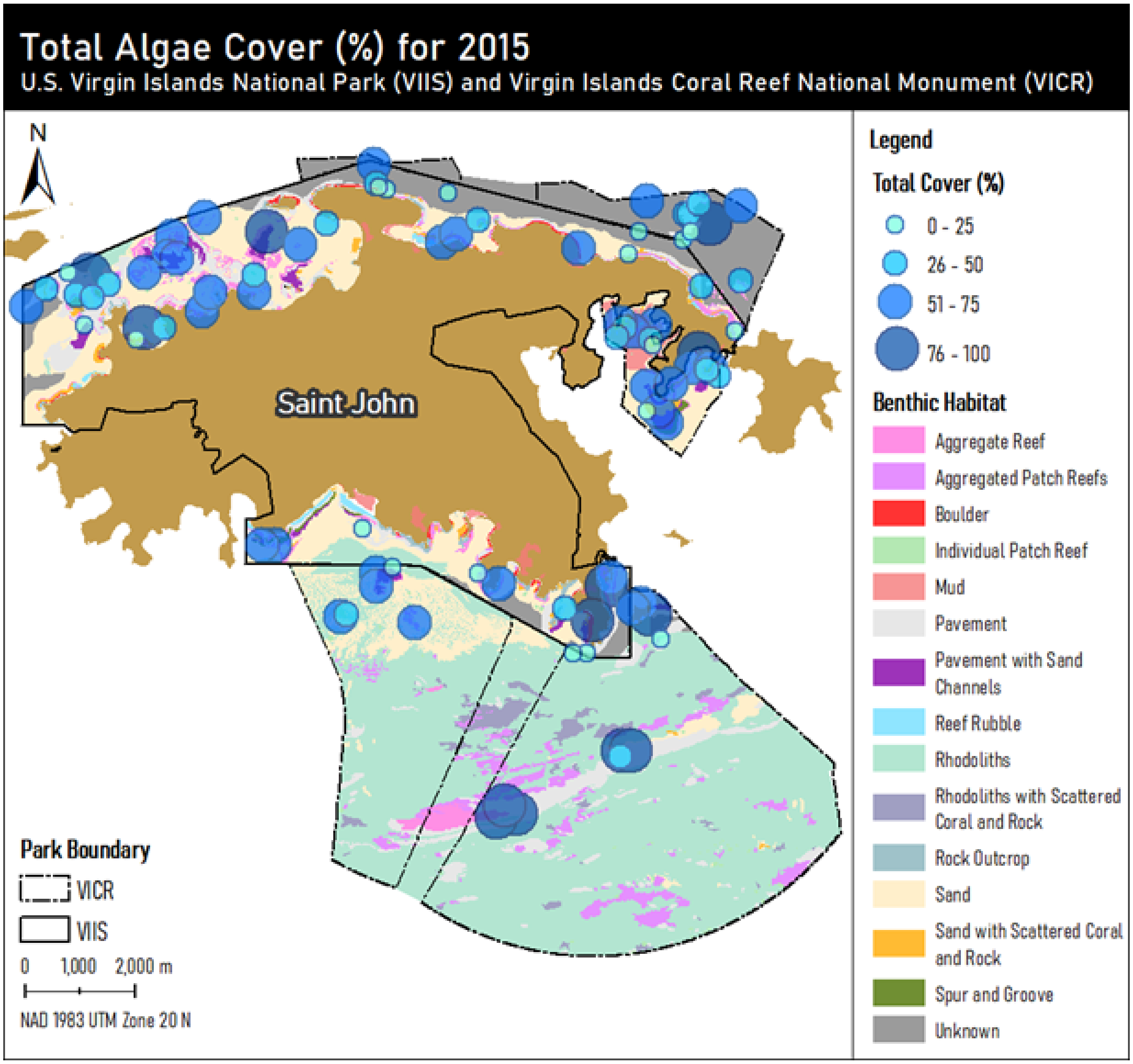

Figure 4.2.1.4. Total algae percent cover, U.S. Virgin Islands National Park and Virgin Islands Coral Reef National Monument, 2015 (NCCOS-SEFSC 2021). Habitat data source: NPS-NCRMP-UVI program. Habitat cover from Costa et al. 2009.

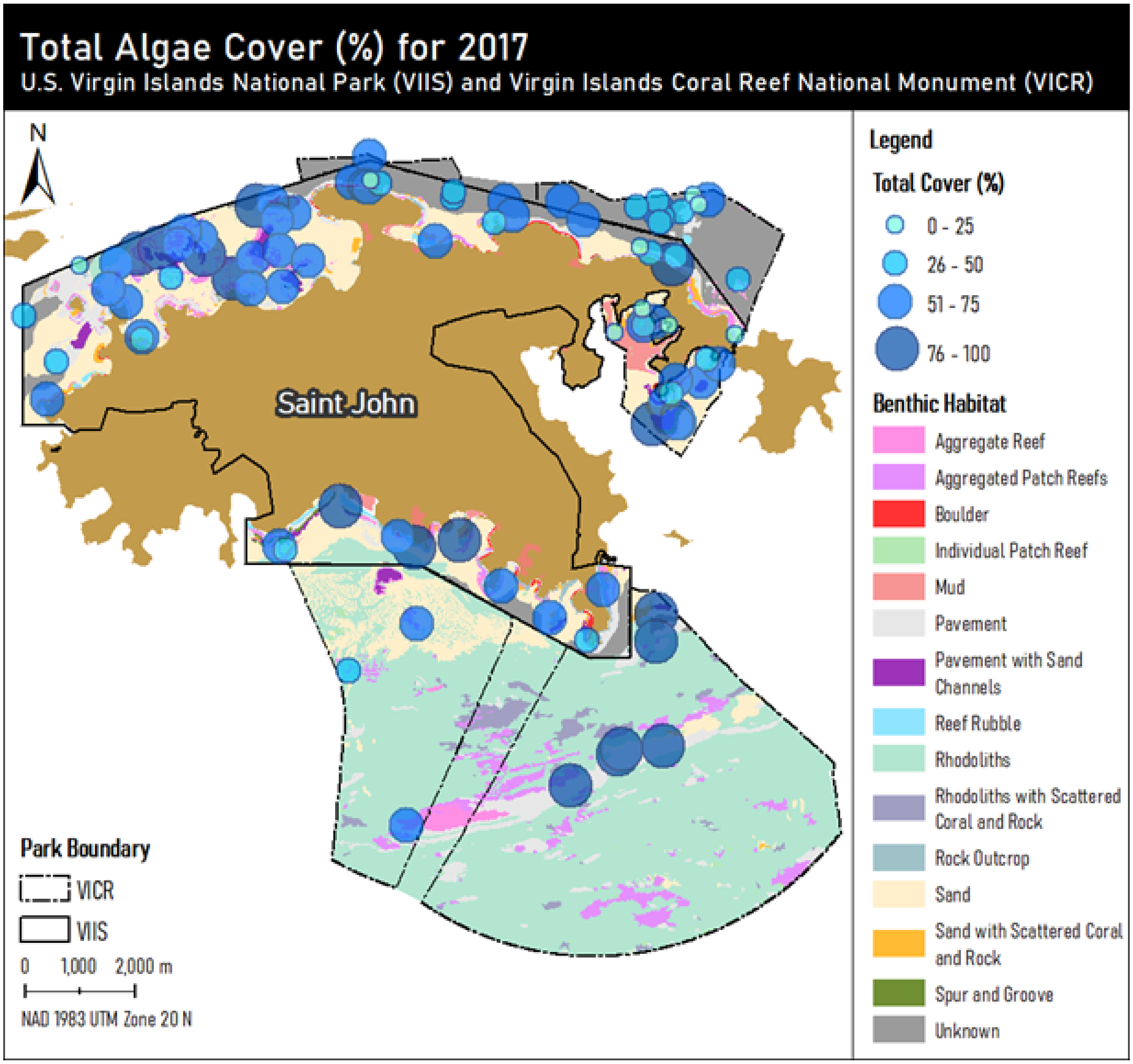

Figure 4.2.1.5. Total algae percent cover, U.S. Virgin Islands National Park and Virgin Islands Coral Reef National Monument, 2017 (data provided by Lee Richter, NPS). Habitat data source: NPS-NCRMP-UVI program. Habitat cover from Costa et al. 2009.

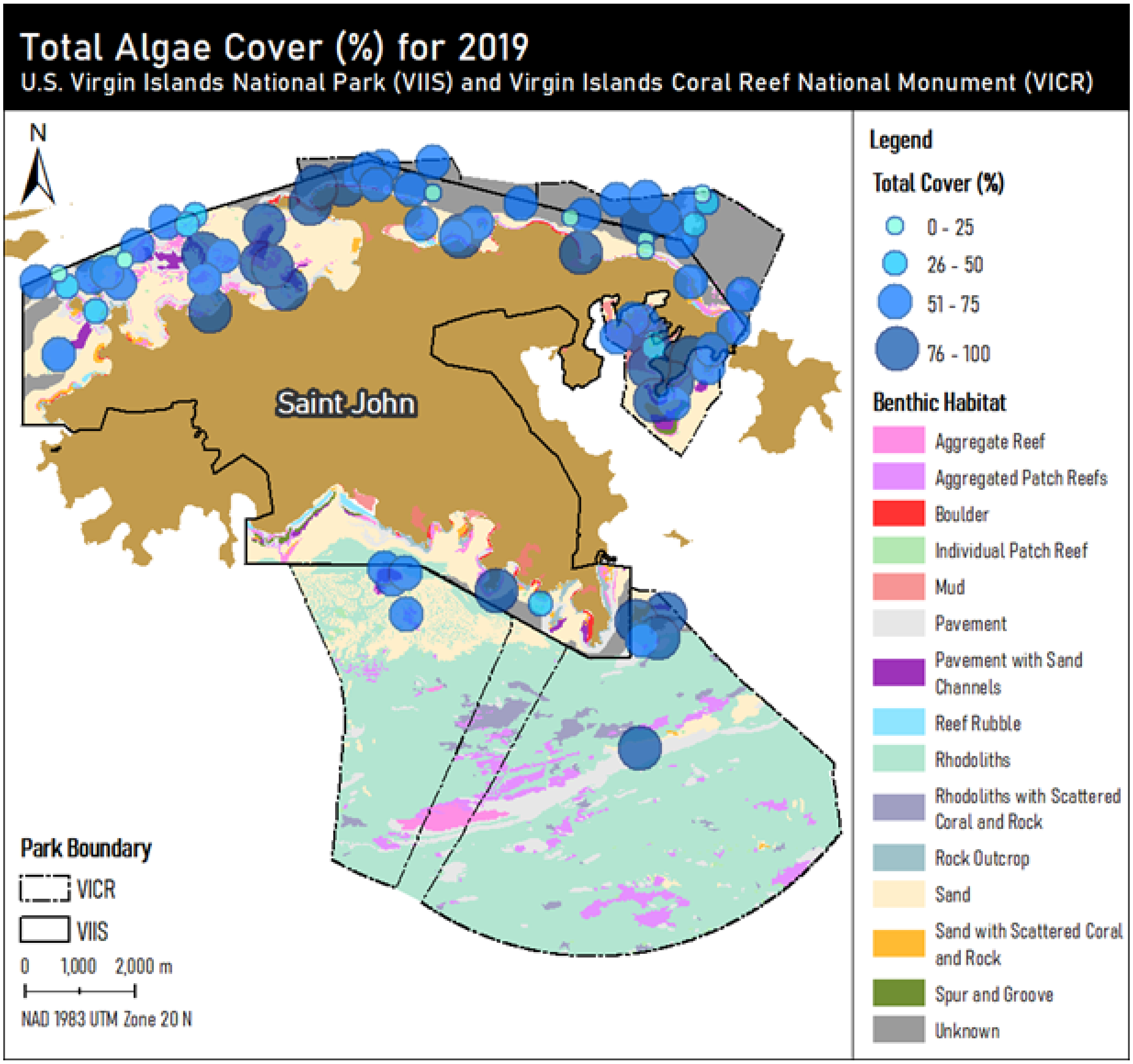

Figure 4.2.1.6. Total algae percent cover, U.S. Virgin Islands National Park and Virgin Islands Coral Reef National Monument, 2019 (data provided by Lee Richter, NPS). Habitat data source: NPS-NCRMP-UVI program. Habitat cover from Costa et al. 2009.

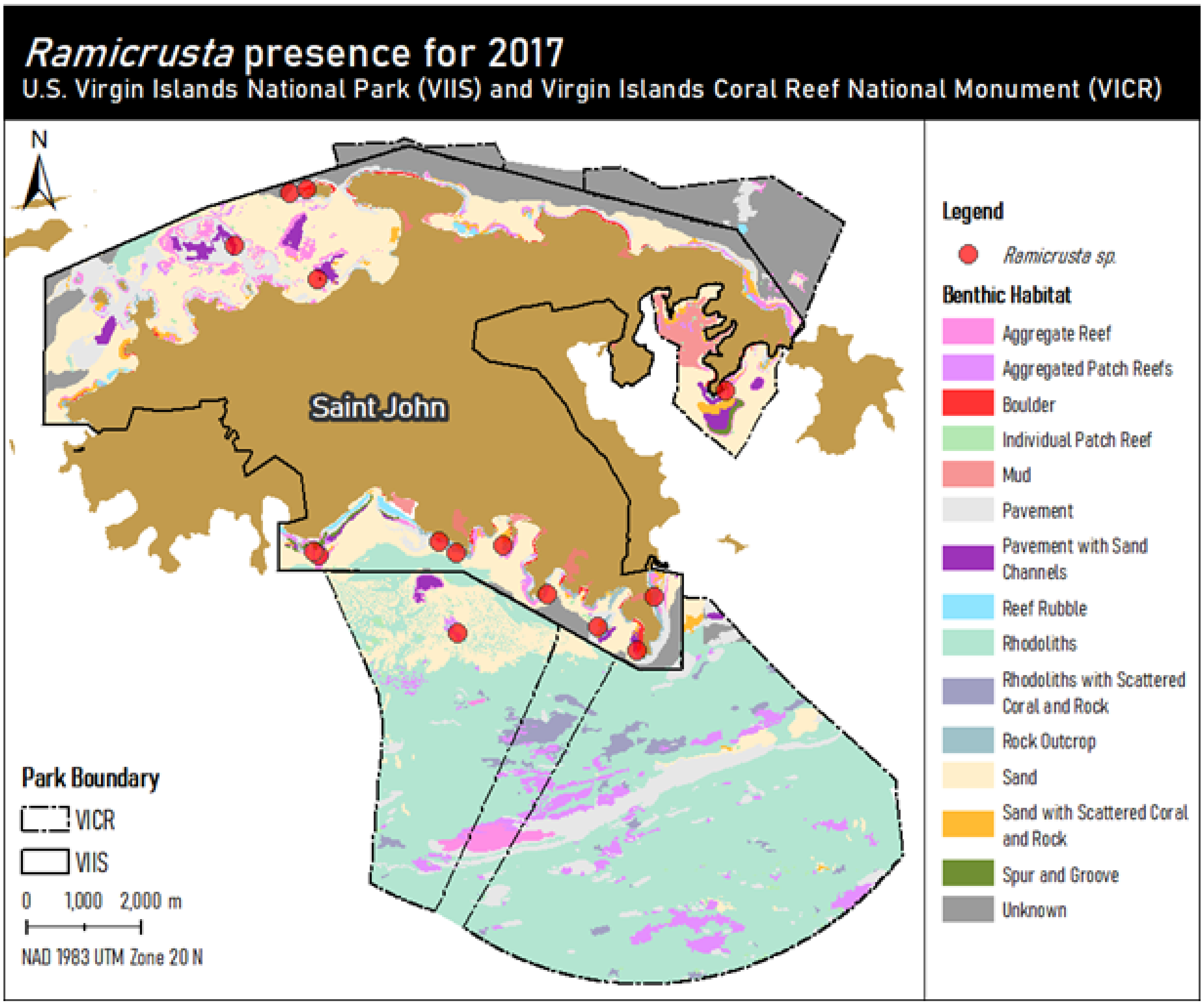

Figure 4.2.1.7. *Ramicrusta* presence, U.S. Virgin Islands National Park and Virgin Islands Coral Reef National Monument, 2017 (data provided by Lee Richter, NPS). Habitat data source: NPS-NCRMP-UVI program. Habitat cover from Costa et al. 2009.

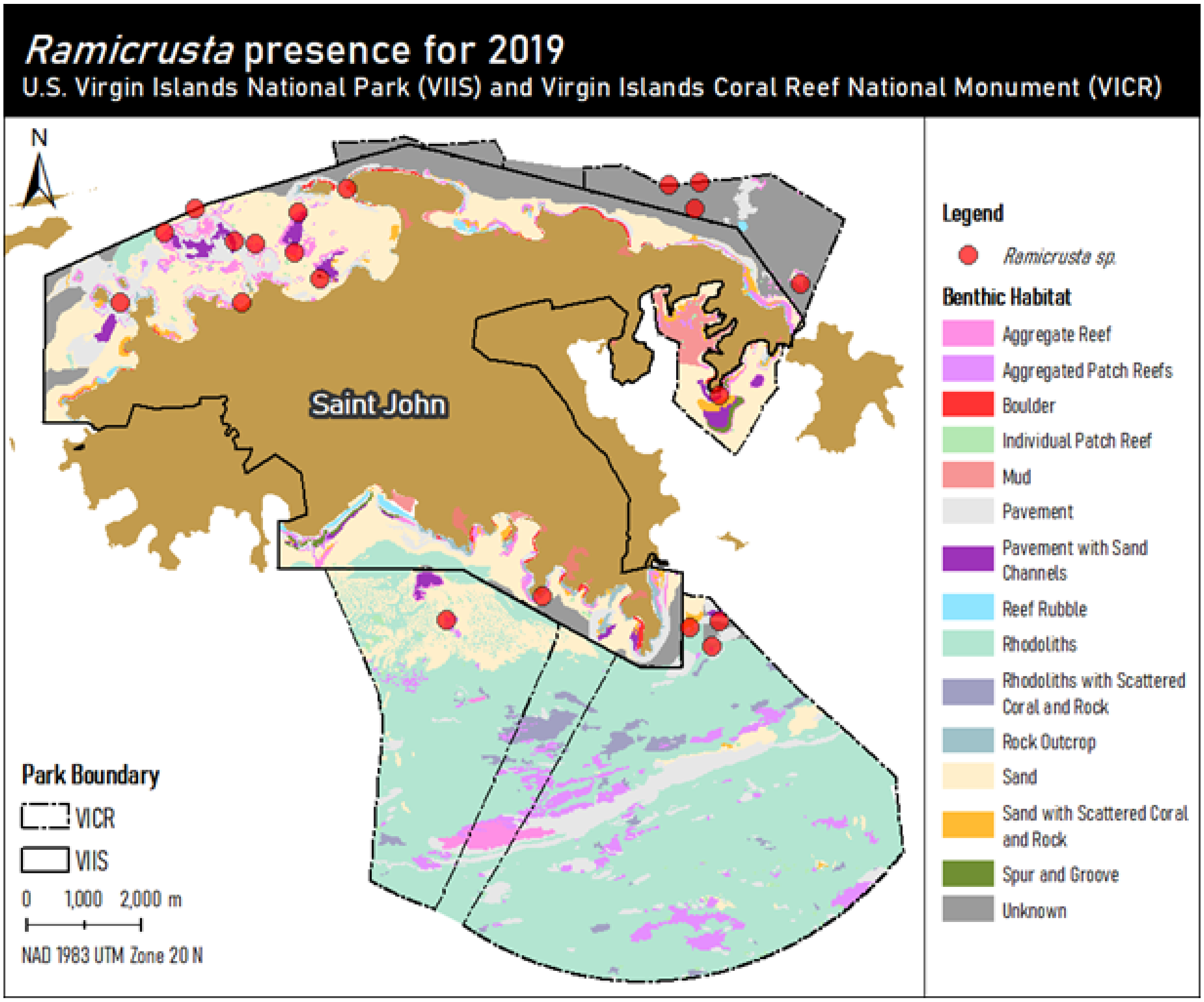

Figure 4.2.1.8. *Ramicrusta* presence, U.S. Virgin Islands National Park and Virgin Islands Coral Reef National Monument, 2019 (data provided by Lee Richter, NPS). Habitat data source: NPS-NCRMP-UVI program. Habitat cover from Costa et al. 2009.

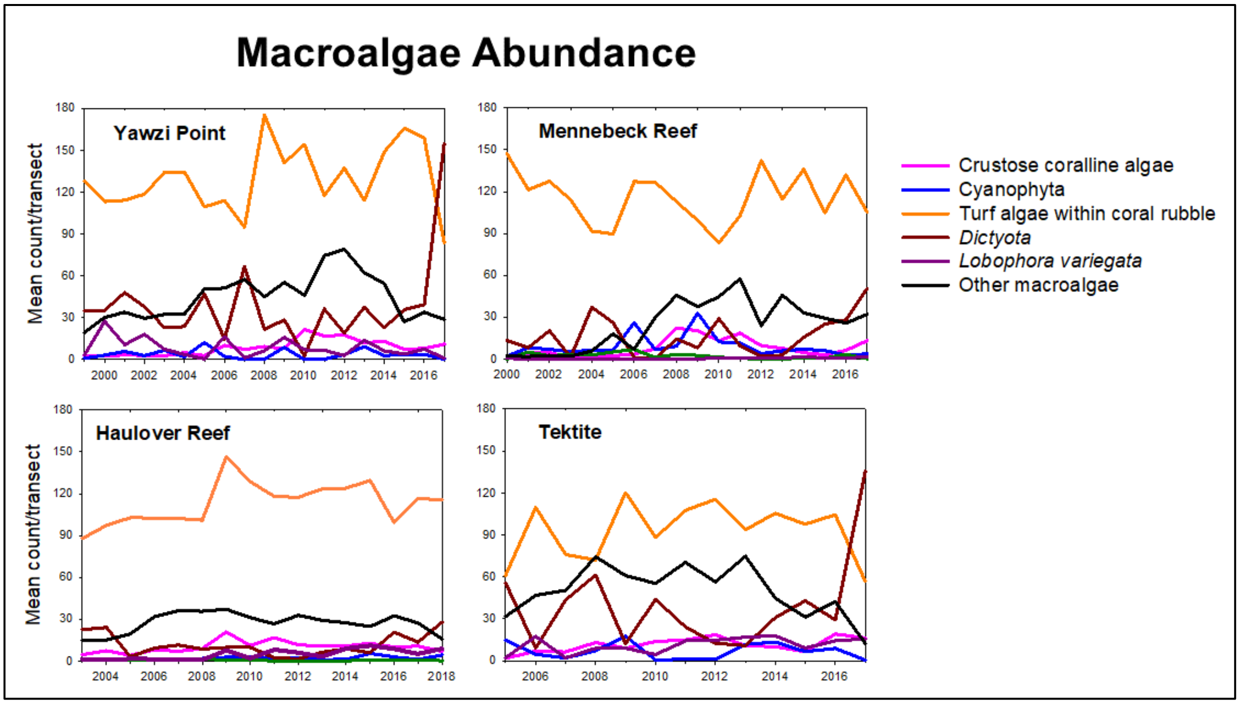

Figure 4.2.1.9. Time series of macroalgae abundance at Yawzi Point, Mennebeck Reef, Haulover Reef, and Tektite Reef (South Florida/Caribbean Network; Miller et al., 2007; Lee Richter, NPS).

Threats and Stressors

Multiple disturbances have the potential to affect algae abundance. The invasive seagrass *Halophila stipulacea* can form extensive monospecific beds leaving little room for other seagrass or macroalgae species (Ruiz and Ballantine 2004). Boat anchors and wave action during extreme weather events such as hurricanes can uproot macroalgae and seagrass (Fourqurean and Rutten 2004). Algal blooms could become more common as development of the highly sloped terrestrial habits increases nutrient enrichment from runoff, cruise ships, and seepage from septic tanks (Patterson et al. 2008). Recovering populations of herbivorous sea urchins may reduce algal abundances.

Sargassum natans and *S. fluitans* are pelagic brown macroalgae from the North Atlantic (Guiry and Guiry 2021) that accumulate in windrows and form large floating offshore rafts. These *Sargassum* “islands” within the pelagic ocean support a rich ecosystem consisting of animals from 11 different phyla and over 100 species (Stoner and Greening 1984). Easterly winds move these accumulations onshore and onto eastern Atlantic beaches where the beached *Sargassum* supports the production of crustacean and insect prey used by shorebirds (Schlacher et al. 2017). From 2011 to the present (June 2021), the equatorial Atlantic has experienced a large increase in *Sargassum* production and tropical beaches were inundated with tons of *Sargassum* (Franks et al. 2011; Figure 4.2.1.10) disrupting the tourisms industry (Higgins 2016). It is hypothesized that increased nutrient availability promoted the recent blooms, though specific mechanisms that may be responsible such as Amazon River discharge, climatic variations, hurricanes, and coastal upwelling (Wang et al. 2019) have not been unequivocally identified (Oviatt et al. 2019). The recent recurrent *Sargassum* blooms may continue to disrupt the economy and ecology of Caribbean, including the Virgin Islands.

Figure 4.2.1.10. *Sargassum natans* and *S. fluitans*, pelagic brown algae, washed up on a U.S. Virgin Islands beach in 2017. Photo: David Horner (National Park Service, St. John USVI, https://www.nps.gov/viis/learn/nature/sargassum.htm).

Data Needs and Gaps

The irregular inundations of the brown algae *Sargassum* spp. have the potential to negatively affect coastal ecosystems and tourism. Studies of the long-term effects on coastal ecosystems are lacking. The invasive seagrass *Halophila stipulacea* (Figure 4.2.1.11) can tolerate a wide range of temperature (Georgiou et al. 2016), light (Schwarz and Hellblom 2002) and can spread via fragmentation (Smulders et al. 2017). It has the potential to settle in areas where seagrasses have previously not competed with macroalgae. Monitoring of the species composition of seagrass and algae communities is needed to elucidate the effects of the invasive seagrass on native primary producers. The invasive encrusting red algae *Ramicrusta* spp. is rapidly increasing at sites in the USVI with the potential to devastate stony corals (Figure 4.2.1.12). Data on the interactions between *Ramicrusta* spp., other disturbances, and local herbivores are needed to assess the potential impacts that the invasion may have on coral reefs in the USVI.

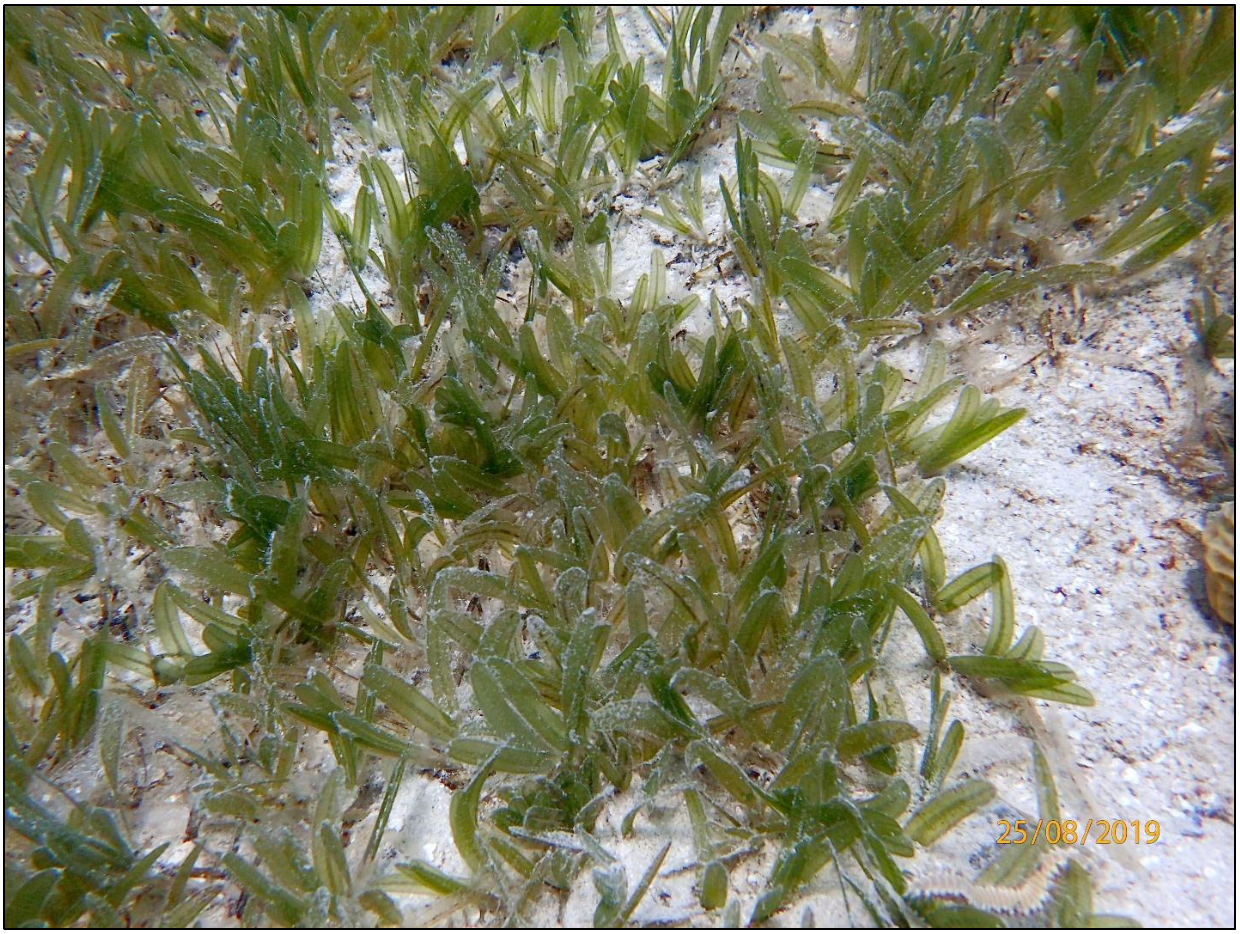

Figure 4.2.1.11. *Halophila stipulacea*, invasive exotic seagrass, St. John. Photo: John Cassell.

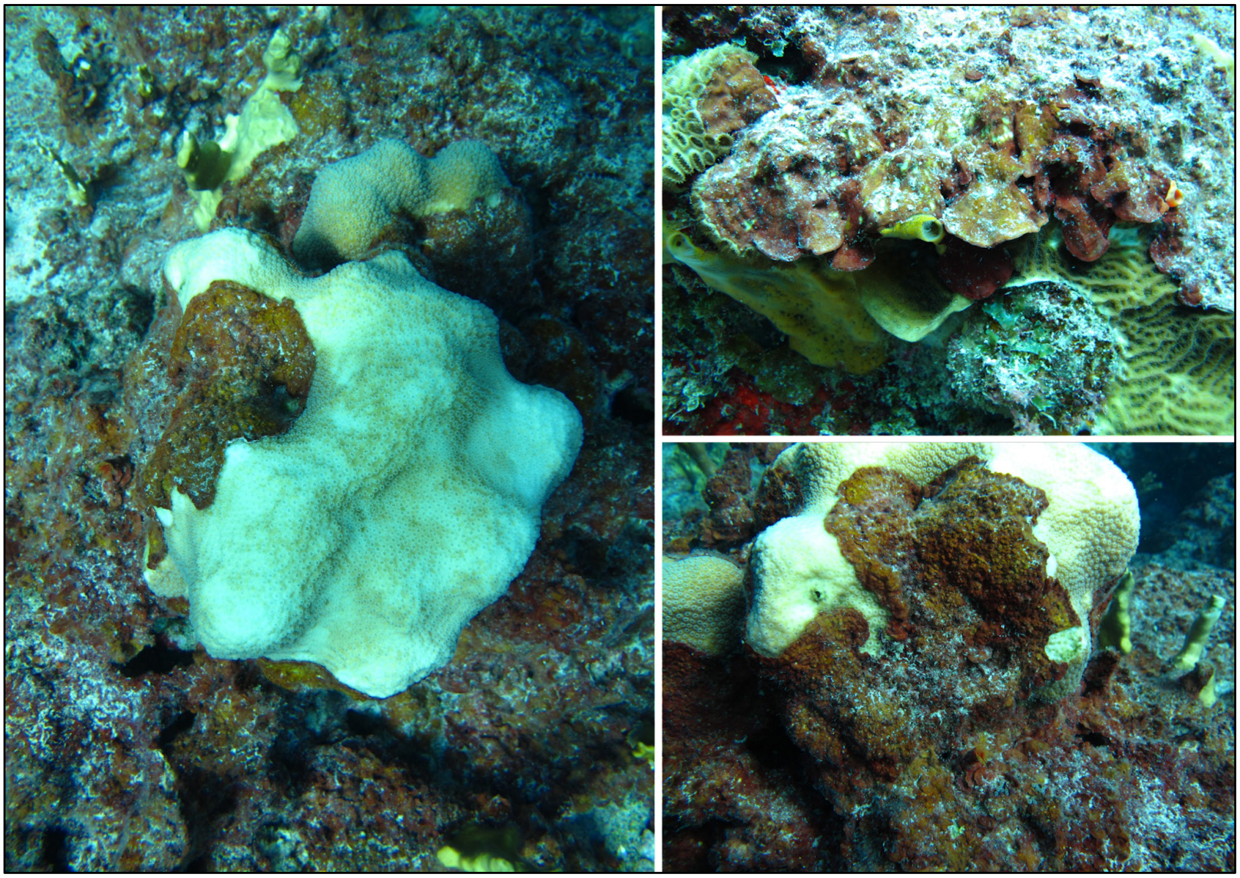

Figure 4.2.1.12. *Ramicrusta* spp. from the west coast of St. Thomas. Photo credit: Rosmin Ennis.

Overall Condition

Macroalgae have increased in occurrence and abundance post-disturbances (e.g., urchin die-off, hurricanes, coral bleaching) and their increasing presence is considered an indicator of deteriorating condition for benthic resources in the VIIS and VICR (Table 4.2.1.2).

Table 4.2.1.2. Graphical summary of status and trends for macroalgae.

Component	**Indicator**	**Condition Status /Trend**	**Rationale and Reference Conditions**
Macroalgae	Percent cover	⬇	Algae abundance has increased since the die-off of sea urchins in the early 1980s, post-hurricane damage to corals and seagrass, and after coral bleaching events.

Source(s) of Expertise

- Peter J. Edmunds, PhD, California State University, Northridge, CA
- Lee J. Richter, Marine Biological Scientist, NPS, So. Fl / Caribbean Network, St. John, USVI

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4.2.2. Seagrass

This section reviews the condition of seagrass in VICR and VIIS. The condition assessment considers seagrass measures produced during the period 1959 through 2016 and includes 1) aerial imagery 1959–1991 (Rogers and Beets 2001), 2) acoustic imagery 2005, 2007 (NCCOS 2009), and 3) seagrass shoot density 2000–2016 (Willette et al. 2020) to assess the status of the seagrass natural resources. The status of the seagrasses is evaluated using metrics that detect change in abundance and occurrence. The condition metrics selected for this resource are species composition and density.

Description

Seagrass meadows serve as the base of food webs, habitat for fish and invertebrates, and an important atmospheric carbon sink. Protected and commercially and economically important species such as juvenile Nassau grouper (*Epinephelus striatus*, Sadovy et al. 2018) and green turtles (*Chelonia mydas*) rely on seagrass meadows for shelter and foraging habitat during multiple life stages. Some species of parrotfish, grunts, and snappers rely on seagrass meadows for all or some of their habitat requirements (Garrison 1998), and seagrass loss is linked to decreases in the abundance of both juvenile finfish and shellfish (Heck et al. 2003). Blacktip and lemon sharks off St. John also use disparate seagrass habitats as nurseries (Legare et al. 2015). *Thalassia testudinum* is the dominant climax seagrass species in VIIS and the Caribbean. *Syringodium filiforme*, *Halophila decipiens*, and *Halodule wrightii* are also often found in mixed beds with *T. testudinum*. The invasive seagrass *Halophila stipulacea* was first documented off St. John at Mennebeck Reef in a mixed bed of native seagrasses and subsequently at multiple sites within both VIIS and VICR (Willette et al. 2014; Figure 4.2.2.1).

The 2007 natural resource assessment of VIIS and VICR reported that seagrass community composition was ranked fourth among the top 32 indicators with a high level of importance to park management and with some monitoring occurring as of 2007 (Collini and O’Rourke 2007, Patterson et al. 2008, Davis et al. 2019).

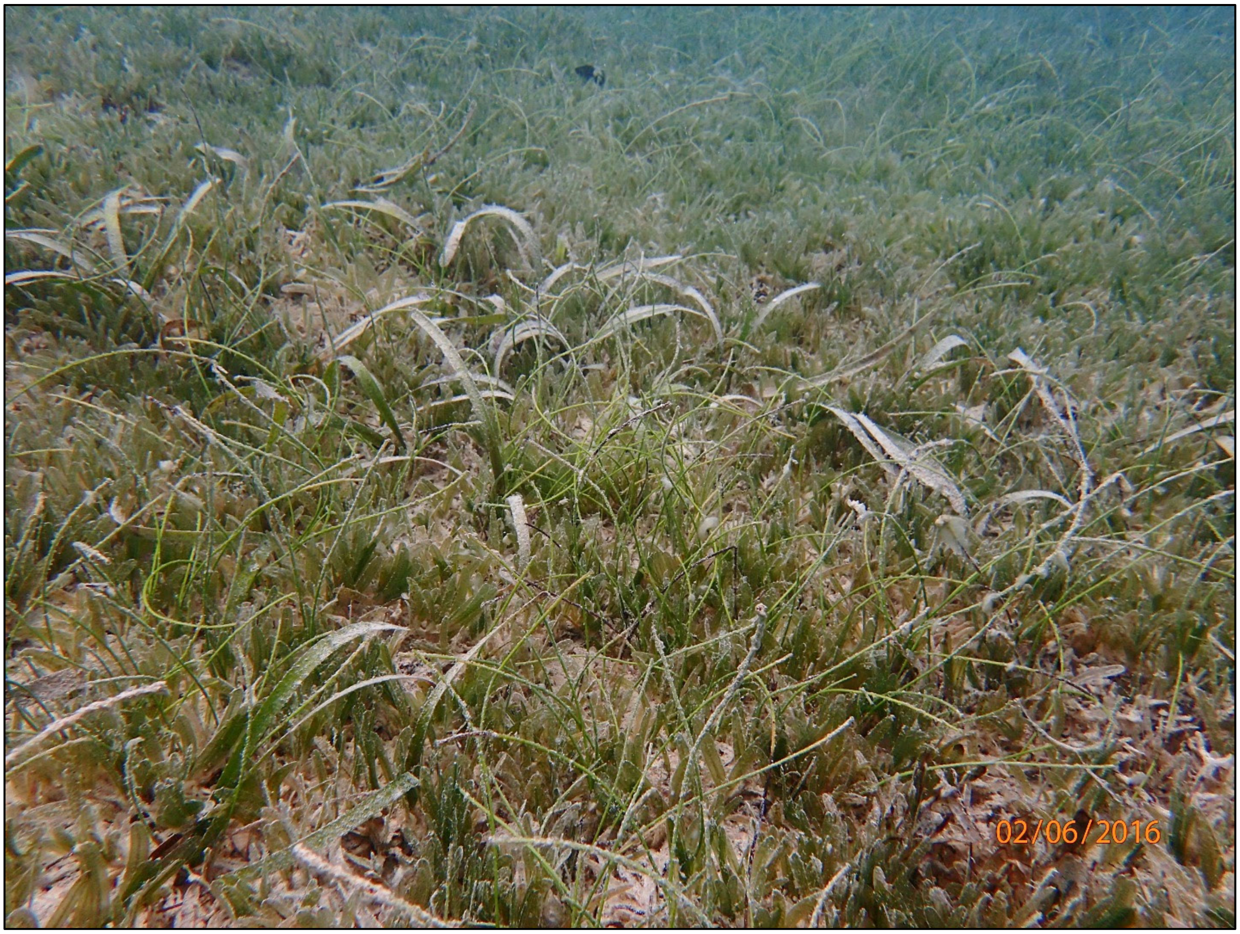

Figure 4.2.2.1. A mixed seagrass meadow in Hurricane Hole of invasive *H. stipulacea* (short paddle-shaped leaves) and natives *S. filiforme* (long cylindrical leaves) and *T. testudinum* (long, flat leaves). Photo Credit: John Cassell.

Data and Methods

The reference condition for seagrass was established by Rogers and Beets (2001) who summarized the analysis of aerial photo analysis starting in 1959 through 1991 for subsections of VIIS.

The Center for Coastal Monitoring and Assessment (NOAA) used acoustic imagery to assess the status, abundance, and distribution of moderate-depth marine habitats in VICR in 2005. In 2007, a visual interpretation of remotely sensed imagery was used to map and assess the nearshore benthic habitats off St. John (Zitello et al. 2009). Mapping was conducted primarily using digital orthophotos from 2007, but 2000 and 2005 IKONOS multispectral satellite imagery was used where digital orthophotography wasn't suitable for habitat delineation. A minimum mapping unit (MMU) of 1000 m^2 was used with heads-up digitizing for map creation at a scale of 1:2000. The results of the 2005 and 2007 surveys are used in this analysis to assign the pre-*H. stipulacea* invasion condition of seagrass in VICR and VIIS.

Anchoring in seagrass and coral habitats was discontinued in 2000 and the “National Park Service USVI: Buoy Seagrass Shoot Count” was implemented to survey recovery of seagrasses where mooring buoys were deployed in Leinster, Francis, Maho, and Hawksnest Bays (Willette et al. 2020). Five mooring buoys were selected in each bay (only four in Francis Bay) at places where seagrasses historically occurred. At each buoy, four 25 m transects were established, extending out from the mooring anchor in 4 compass headings (33°, 87°, 124°, and 205°), and along each transect, ten 20 cm x 20 cm quadrats were randomly placed for seagrass monitoring.

Reference Conditions/Values

The reference condition was established by Rogers and Beets (2001) who summarized the analysis of aerial photo analysis starting in 1959 through 1991 for subsections of VIIS. Maps from 1959 and 1961 indicated expansive seagrass meadows covering the majority of the benthic surface up to a water depth of 19 m. Aerial photos from 1962 and 1983 revealed declines in seagrass coverage, most notably in areas with high anchorage. Photo analysis of Great Lameshur Bay and Little Lameshur Bay revealed decreases of 0.068 km^2 and 0.022 km^2, respectively, in seagrass cover between 1971 and 1991. Shoot density in Maho and Francis Bays decreased for *T. testudinum* between 1986 and 1997 and for both *T. testudinum* and *S. filiforme* in Great Lameshur Bay between 1990 and 1999 (Williams 1988).

Current Condition and Trend

Following the documented decline in seagrass cover (Rogers and Beets 2001), Zitello et al. (2009) reported large increases in seagrass development from 1999 to 2007 along the south shore of St. John (Figure 4.2.2.2). The increased seagrass coverage was of much greater magnitude than the losses observed in the previous decades. Seagrass cover increases in Reef Bay, Europa Bay, and Little Lameshur Bay similar to that detailed for Rendezvous Bay (outside of VIIS and VICR, but also on the St. John south shore). Seagrass cover in Rendezvous Bay increased by 0.52 km^2 over that same period.

The decreases in benthic cover of native seagrasses from the mid to late 1900s has been attributed to severe weather events and damage from human activities (e.g., anchoring) (Rogers and Beets 2001). More recent losses of native seagrass cover have been attributed to competitive exclusion demonstrated to result from the invasion of *Halophila stipulacea* in Caribbean seagrass beds (Smulders et al. 2017; Sheibling et al. 2018; Willette and Ambrose 2012). However, the rapidly spreading non-native seagrass *H. stipulacea* can settle in both bare sediment and in already established seagrass meadows and is likely to increase overall seagrass cover. Monitoring of species composition and benthic extent will elucidate the potential positive and/or negative consequences of the spread of *H. stipulacea*.

Prior to the invasion of *H. stipulacea,* the total benthic area containing seagrasses, across substrates, was 22.49 ha in VICR and 382.81 in VIIS (Figure 4.2.2.2). Ninety-eight percent of these areas were sand-dominated. Because the data are from acoustic and remote-sensing imagery, seagrass species composition is unknown. Results from surveys of seagrass shoot density and community composition in areas transitioned from anchorage to mooring fields suggest some recovery of native *S. filiforme* in Hawksnest and Maho Bays (Muthukrishnan et al. 2020; Willette et al. 2020; Figures 4.2.2.3 and 4.2.2.4). Impacts from Hurricane Marilyn in 2005 and the appearance and rapid expansion of *H. stipulacea* since 2011 correspond with decreases in some native seagrasses.

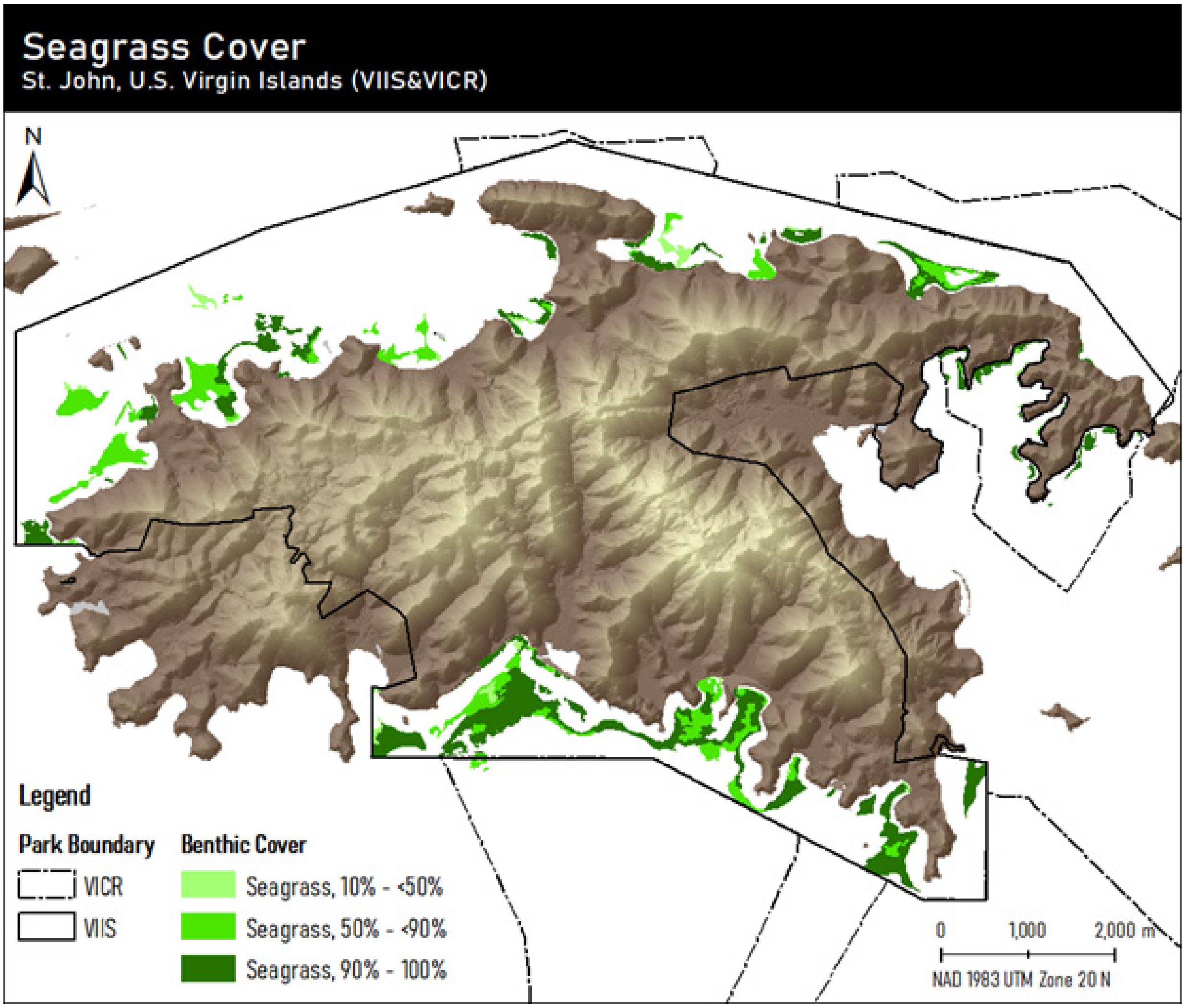

Figure 4.2.2.2. Seagrass cover classification in Virgin Islands Coral Reef NM and Virgin Islands NP (Zitello et al. 2009).

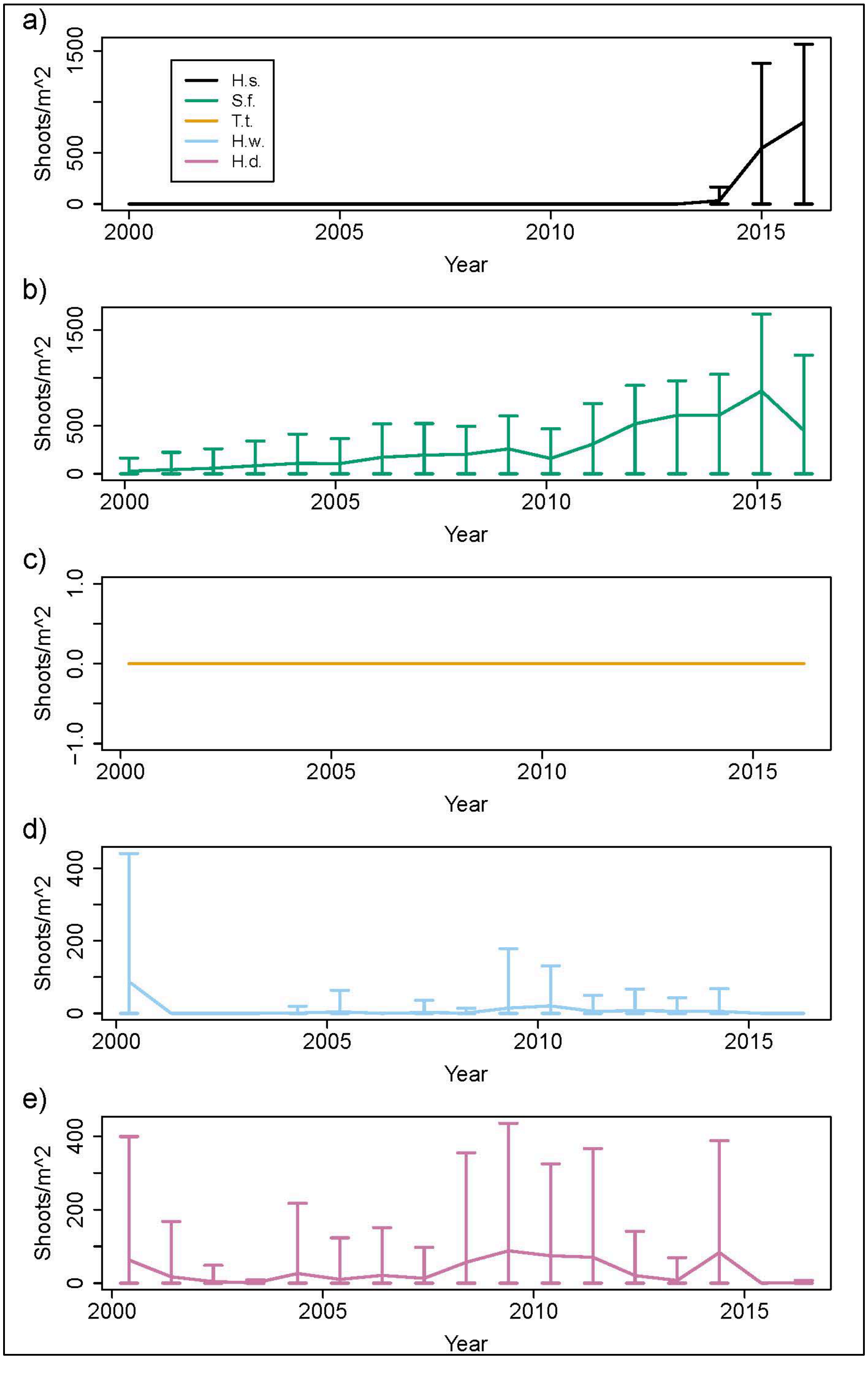

Figure 4.2.2.3. Trends in shoot density (shoots / m^2) of a) *H. stipulacea,* b) *S. filiforme,* c) *T. testudinium,* d) *H. writghtii,* and e) *H. decipiens* within mooring fields (established in 2000) in Hawksnest Bay (Figure courtesy of Ranjan Muthukrishnan). See Figure 4.1.1.1 in Section 4.1.1 for location of Hawksnest Bay.

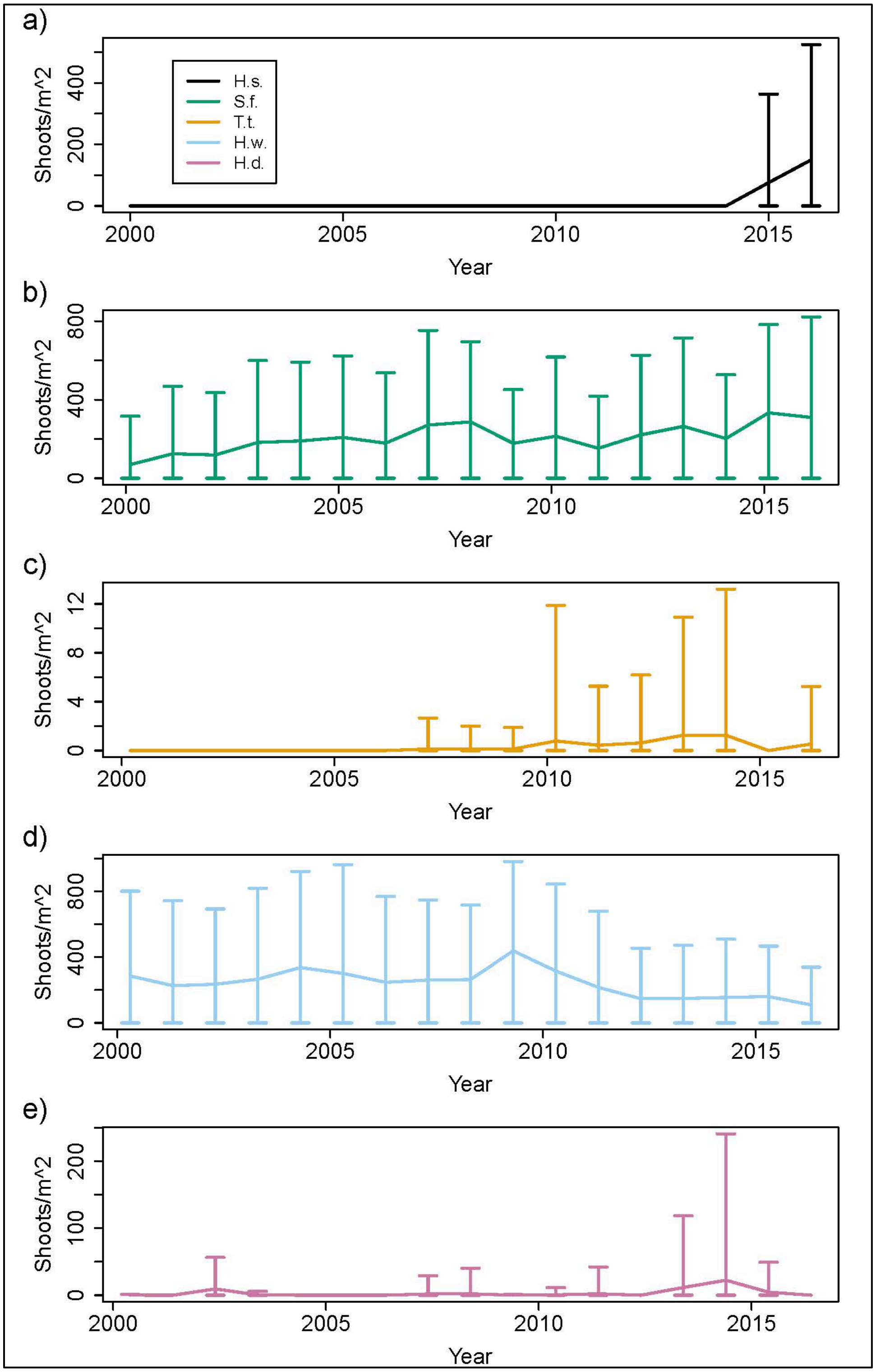

Figure 4.2.2.4. Trends in shoot density (shoots / m^2) of a) *H. stipulacea,* b) *S. filiforme,* c) *T. testudinium,* d) *H. writghtii,* and e) *H. decipiens* within mooring fields (established in 2000) in Maho Bay (Figure courtesy of Ranjan Muthukrishnan). See Figure 4.1.1.1 in Section 4.1.1 for location of Maho Bay.

Threats and Stressors

Seagrass meadows in VIIS are directly damaged by anchors, boat groundings, and inexperienced snorkelers and divers (Allen 1992). Anchoring in seagrasses can damage meadows by uprooting seagrasses when anchors are pulled and by effectively "mowing" seagrass meadows, removing leaf biomass and decreasing photosynthetic capacity, as anchor chains are pulled across the benthos as boats swing with winds and currents. A survey of small water craft (boats with 45 ft mean length) found that 46% of the boats had anchored in either coral or seagrass habitats and 23 percent of those "severely disrupted" the benthos (Allen 1992). Anchoring is currently restricted to two designated anchorages within VIIS: Offshore Francis Bay and Lind Point. Excessive anchoring can damage seagrass meadows by uprooting macrophytes and creating propagating fragments of the invasive seagrass H. stipulacea (Figure 4.2.2.5).

Figure 4.2.2.5. Anchor in Hurricane Hole uprooting the invasive seagrass *H. stipulacea* (short paddle-shaped leaves) and native *S. filiforme* (narrow cylindrical leaves). Photo Credit: John Cassell.

The invasive exotic seagrass *Halophila stipulacea* has spread throughout the Caribbean including the Virgin Islands since its first observation in Grenada in 2002 (Willette et al. 2014, Ruiz et al. 2017). The invasion of the seagrass *Halophila stipulacea* is changing the composition of many seagrass communities in the eastern Caribbean, and there is concern about potential loss of some ecosystem functions of seagrass meadows because of structural differences between the invasive and native seagrasses (Willette and Ambrose 2012). The seagrass, *H. stipulacea*, is native to the Indian Ocean, has successfully spread to the Mediterranean and Caribbean and is one of only two known invasive seagrass species to have transoceanic establishment (Ruiz and Ballantine 2004). *H. stipulacea* was first documented in St. John at Mennebeck Reef as a monospecific bed at a depth of 5 m (Willette et al. 2014).

Green turtles whose primary food source in the Caribbean is seagrass (Bjorndal 1985), are endangered on a global scale (Jackson 2001; Seminoff et al. 2007), but as a result of focused conservation and management efforts, some regional populations are increasing (Mazaris et al. 2017). As grazers, green turtles have the potential to affect seagrass communities. In multiple ocean basins, seagrass communities have begun to collapse under heavy turtle grazing pressure where predator populations have been greatly reduced (Fourqurean et al. 2010; Christianen et al. 2014; Heithaus et al. 2014). Studies of habitat use of local sea turtle and shark populations are needed to identify the potential interactions in VIIS.

Increases in pollution and nutrients from boat effluent, land use runoff, septic tank seepage, and increased trash production can affect water quality and indirectly affect seagrasses (Allen 1992). Extreme weather events such as hurricanes are becoming increasingly severe and also have the potential to affect seagrass communities by physically removing seagrass biomass, increasing runoff, decreasing water quality (e.g., pollution and salinity changes). Moderate disturbance from storms can increase seagrass community diversity by creating disturbed patches for pioneer (or invasive) species to populate, but storms with severe wave action can uproot large meadows that can take years to recover if at all (Fourqurean and Rutten 2004). Long-term impacts caused by changes in water quality from runoff and increases in suspended sediments, phytoplankton blooms and dissolved organic matter are potentially more damaging to seagrass meadows than the immediate physical impacts (Carlson et al. 2010). Increased rainfall can lead to declines in salinity and increased water runoff that can carry pollutants and terrestrial nutrients. Increases in suspended solids and chlorophyll a can threaten seagrasses by decreasing water clarity and limiting the amount of sunlight that reaches the benthos, thus decreasing photosynthetic capacity.

Data Needs and Gaps

Analysis of aerial photography has not been conducted since the invasion of *H. stipulacea*. However, data on the extent and rate of spread of *H. stipulacea* is needed for effective management of seagrass ecosystems. Changes to overall seagrass cover and community composition since the invasion outside of the heavily disturbed areas (Muthukrishnan et al. 2020, Willette et al. 2020) would be valuable info for the park management and in building knowledge of the effects of *H. stipulacea* on seagrass communities across the Caribbean. The NPS Inventory and Monitoring network has recently developed, but has yet to implement, a protocol to assess and quantify seagrasses in VIIS (Davis et al. 2019).

Overall Condition

The seagrass communities surrounding St. John, like others in the Caribbean, are likely experiencing changes in species composition, density, and benthic cover because of the appearance of the rapidly spreading non-native *H. stipulacea* (Table 4.2.2.1). Estimates of an overall condition for seagrasses with in VIIS and VICR based solely on data collected prior to the invasion would be misleading.

Post-invasion surveys are needed to appropriately assess the condition of seagrass communities. Given the lack of park and monument-wide monitoring are confidence in the assessment is low.

Table 4.2.2.1. Graphical summary of status and trends for seagrass species composition and density within VIIS/VICR.

Component	**Indicator**	**Condition Status /Trend**	**Rationale and Reference Conditions**
Seagrass	Species composition	🔴⇩	The non-native seagrass H. stipulacea appears to be replacing native seagrasses in heavily disturbed areas. No species composition data available for park-wide assessment outside of disturbed areas.
	Density	🔴	Historical photo analysis and in-water density surveys reveal declining trends in both percent cover and shoot density prior to 2000, but increased coverage through 2007. More recent estimates of seagrass density are not available. The spread of non-native H. stipulacea is increasing total shoot density in previously disturbed areas.

Source(s) of Expertise

- Thomas Kelley, Natural Resource Manager, VIIS/VICR, St. John, US Virgin Islands
- Demian Willette, PhD, Loyola Marymount University, Los Angeles, CA
- Ranjan Muthukrishnan, PhD, Boston University, Boston, MA

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4.3. Marine Invertebrates

4.3.1. Coral

This section reviews the condition of the stony corals and coral reefs in Virgin Islands National Park (VIIS) and Virgin Islands Coral Reef National Monument (VICR), hereafter collectively referred to as VIIS-VICR. The condition assessment considers data provided by the South Florida and Caribbean Inventory and Monitoring Network of the US National Park Service (SFCN data was accessed via irma.nps.gov/DataStore/) (1999–2018), the USVI Territorial Coral Reef Monitoring Program (NCRMP, data available from https://www.coris.noaa.gov/monitoring) (TCRMP data available from https://sites.google.com/site/usvitcrmp/available-data) (2001–2016), the National Coral Reef Monitoring Program (2015, 2017, 2019), as well as data sets from numerous individual researchers (1968–2017). The condition of stony corals is typically evaluated using metrics that detect changes in abundance/benthic cover, skeletal growth, coral health (bleaching, disease, partial mortality, reproduction), and temperature. The condition metrics selected for this resource assessment include benthic cover, coral health (bleaching, disease, reproduction), and sea water temperature. Abundance, skeletal growth, and reproduction were not included in this assessment due to lack of data. Temporal trends in condition metrics were evaluated for time-series measurements.

Description

VIIS-VICR contains diverse coral reef environments (Rogers and Teytaud 1988, Figure 4.3.1.1, Figure 4.3.1.2). Upon the founding of marine protections of VIIS in 1962, the National Park Service (NPS) noted the clear waters and the coral reefs as a significant ecological reserve (Kumpf and Randall 1961) and the coral reef environments of VIIS and VICR were fundamental to their founding (NPS 2016). Coral reef types include fringing nearshore reefs, nascent barrier reefs, offshore submerged shelf reefs, a limited number of shallow and intermediate depth patch reefs, and even coral communities growing within and on mangroves (Kumpf and Randall 1961, Rogers and Teytaud 1988; Rogers 2017). Coral communities historically included high coral cover fringing elkhorn coral reefs (Figure 4.3.1.3) and fringing and submerged star coral reefs (Figure 4.3.1.4), as well as low abundance, but diverse, communities of corals growing on igneous rocks (Figure 4.3.1.5) (Rogers and Teytaud 1988, Edmunds 2002). Areas of soft sediment, dominated by seagrass, macroalgae, or sand communities, typically surround reefs on the seaward sides (Kumpf and Randall 1961). Early descriptions of submerged biota were facilitated by Kumpf and Randall (1961), Randall (1963), and the Tektite I and II underwater habitat missions in Lameshur Bay, St. John (1969–1970) (Clifton et al. 1970).

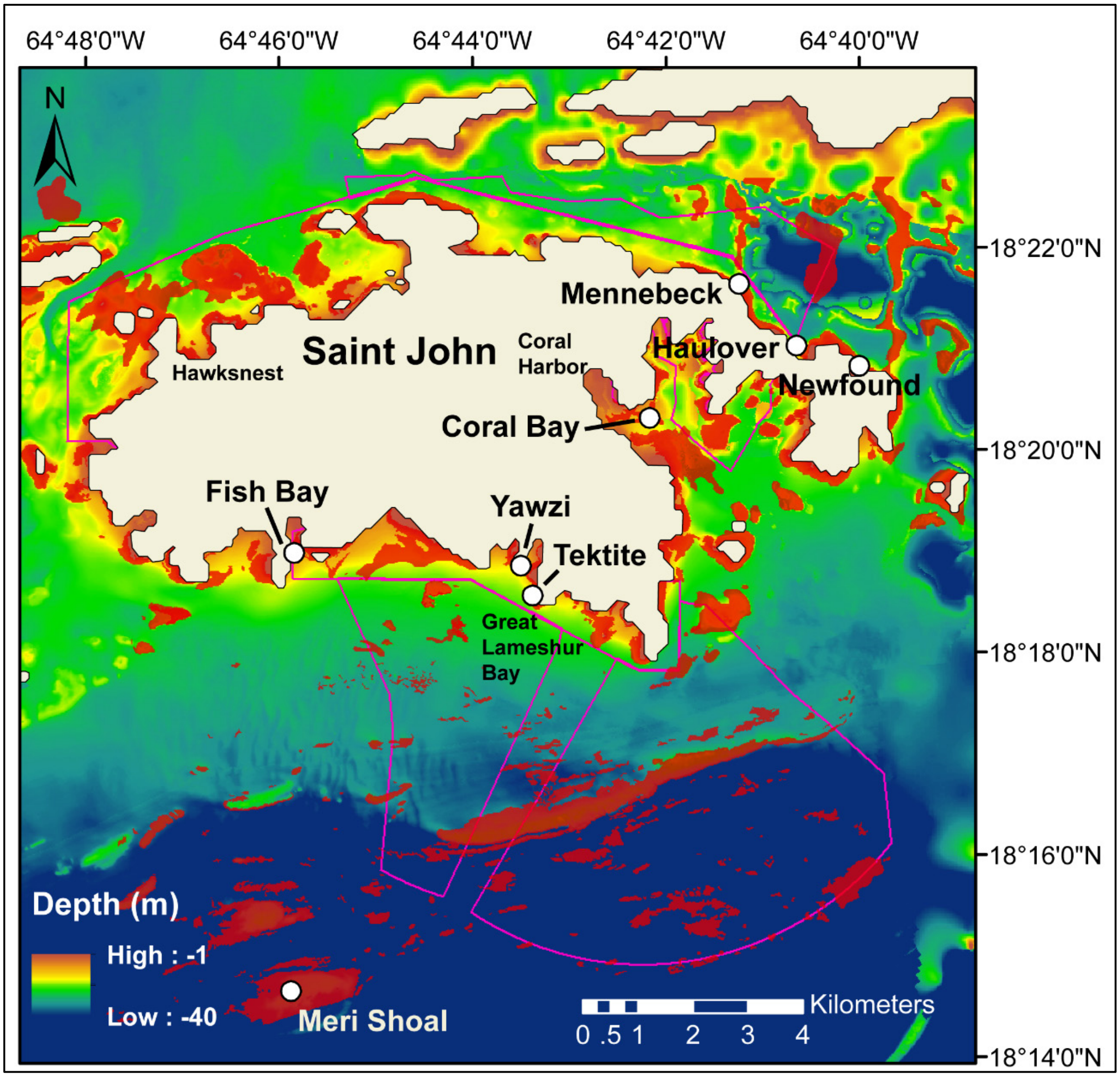

Figure 4.3.1.1. Map of St. John, U.S. States Virgin Islands showing locations of permanent monitoring sites of the NPS South Florida Caribbean Inventory & Monitoring Network, USVI Territorial Coral Reef Monitoring Program, and Peter Edmunds (California State University Northridge). Areas in bright red are coral reef or hardbottom habitats that support large populations of stony corals. SFCN sites include Yawzi, Tektite, Mennebeck, Haulover, and Newfound. TCRMP sites include Fish Bay, Meri Shoal, and Coral Bay. Edmunds sites include Yawzi and Tektite. Other locations mentioned in text are also noted. Note that coral reef and hardbottom habitat coverage estimates are not represented for the British Virgin Islands (upper left of map). Bathymetry and habitat designations accessed from NOAA (August 8, 2019; https://products.coastalscience.noaa.gov/collections/benthic/default.aspx)

Figure 4.3.1.2. Lettuce coral and fish community at Salomon Bay, St. John (June 28, 2012; photo credit: Tyler B. Smith)

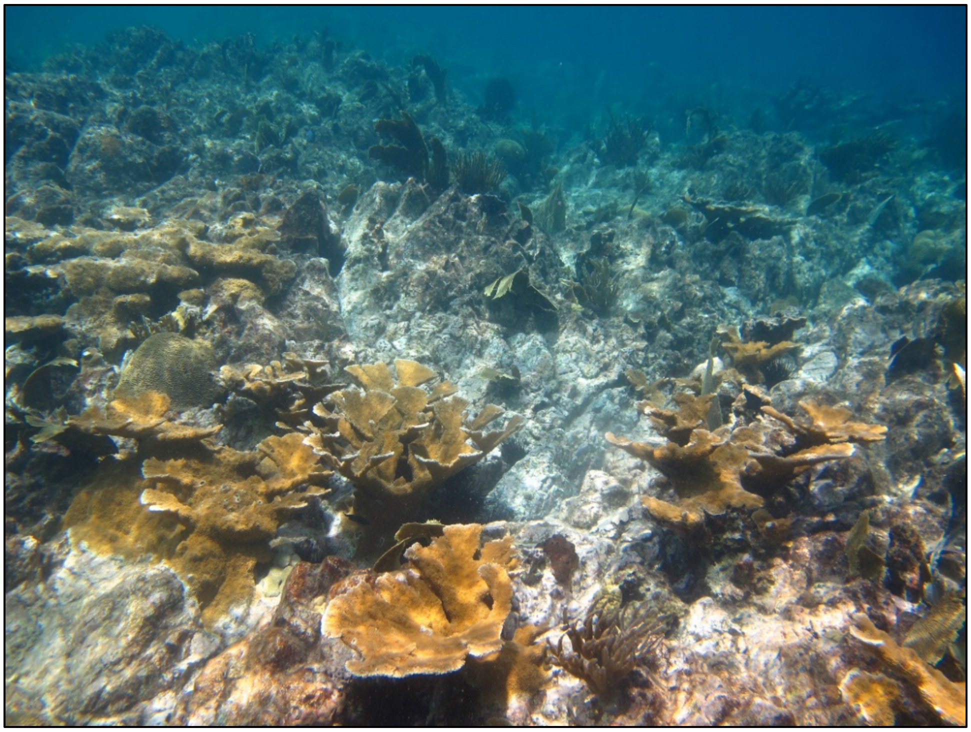

Figure 4.3.1.3. Elkhorn corals (*Acropora palmata*) growing on shallow water (3–4 m depth) igneous rocks at Yawzi Point, St. John (June 29, 2012; photo credit: Tyler B. Smith)

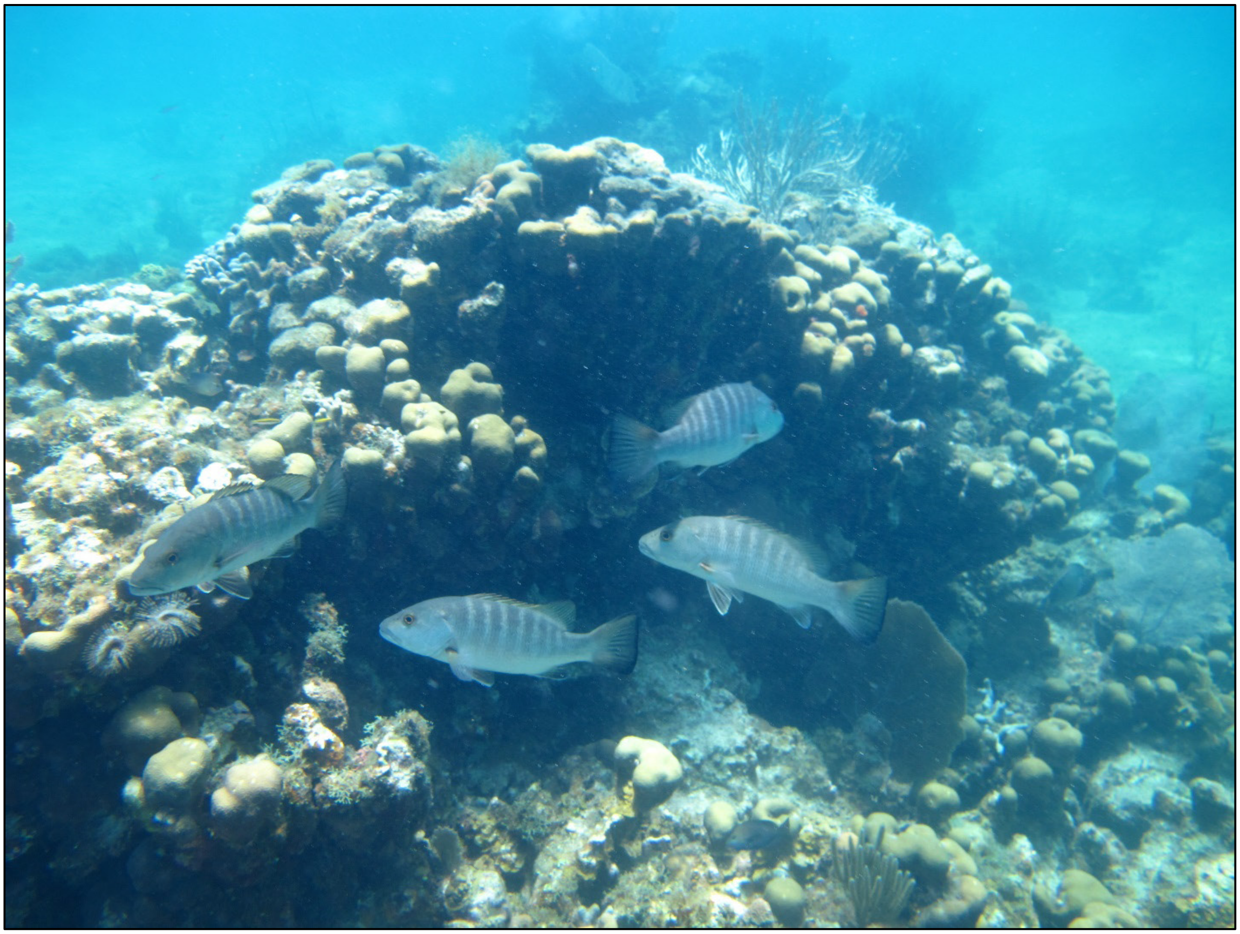

Figure 4.3.1.4. Boulder star corals (*Orbicella annularis*) sheltering a school of juvenile cubera snapper (*Lutjanus cynaoptera*) at Yawzi Point, St. John (June 29, 2012; photo credit: Tyler B. Smith).

Figure 4.3.1.5. A diverse coral community growing on igneous rocks in 4 m depth off Yawzi Point, St. John. At least 11 species are visible in the image, including the pillar coral (*Dendrogyra cylindrus*; center), boulder star coral (*Orbicella annularis*; top right), and fire coral (*Millepora alcicornis*). (June 29, 2012; photo credit: Tyler B. Smith)

Data and Methods

In situ observations of and experiments with coral reefs of VIIS have been made since the late 1950's (Kumpf and Randall 1961; Randall 1963; Earle 1971; Mathieson et al. 1971). These assessments were typically for purposes of characterization and provide important qualitative and quantitative information on reef condition prior to many of the more recent anthropogenic impacts affecting coral reefs. These observations were concentrated on nearshore areas of Great Lameshur Bay on the southern central coast of St. John (Figure 4.3.1.1).

Long-term studies, utilizing longitudinal sampling design, repeatedly over the same reef areas were not started until the late 1980s (Rogers and Zullo 1987; Edmunds 2002; Edmunds 2013; Rogers and Miller 2006). A summary of sampling sites and their locational data is presented in Table 4.3.1.1. Early monitoring by the NPS (Rogers and Miller 2006) was instituted along five permanent chain transects at Yawzi Point, Lameshur Bay (9 m depth) from 1989–2002 and at Newfound reef on northeast St. John (7.6 m depth) from 1990–2002.

Table 4.3.1.1. Coral reef monitoring sites of the NPS South Florida/Caribbean Inventory & Monitoring Network (SFCN), Peter J. Edmunds, and the USVI Territorial Coral Reef Monitoring Program (TCRMP).

Program	Island	Site	Latitude	Longitude	Depth (m)
NPS-SFCN	St. John	Haulover	18.35128	−64.67951	6
NPS-SFCN	St. John	Mennebeck	18.35338	−64.68413	6
NPS-SFCN	St. John	Newfound	18.34864	−64.66764	8
NPS-SFCN	St. John	Tektite	18.30918	−64.72270	13
NPS-SFCN	St. John	Yawzi	18.31391	−64.72597	13
TCRMP	St. John	Coral Bay	18.33797	−64.70402	9
TCRMP	St. John	Fish Bay	18.31417	−64.76408	6
TCRMP	St. John	Meri Shoal	18.24447	−64.75862	30
Edmunds	St. John	Yawzi-Edmunds	18.31520	−64.72500	9
Edmunds	St. John	Tektite-Edmunds	18.30970	−64.72285	14

Peter Edmunds (California State University Northridge) installed permanent photoquadrat monitoring at Yawzi Point and Tektite reef in 1987 and monitored an additional subset of randomly located areas ("pooled random sites") in greater Lameshur Bay from 1992 onwards. A representative photo of the Tektite reef is shown in Figure 4.3.1.6. Photoquadrats used by Edmunds allowed tracking of benthic cover and coral demographics by following individual corals annually. These data are not presented graphically in this report, but were recently summarized in Edmunds (2013), Tsounis and Edmunds (2017), and Edmunds (2019).

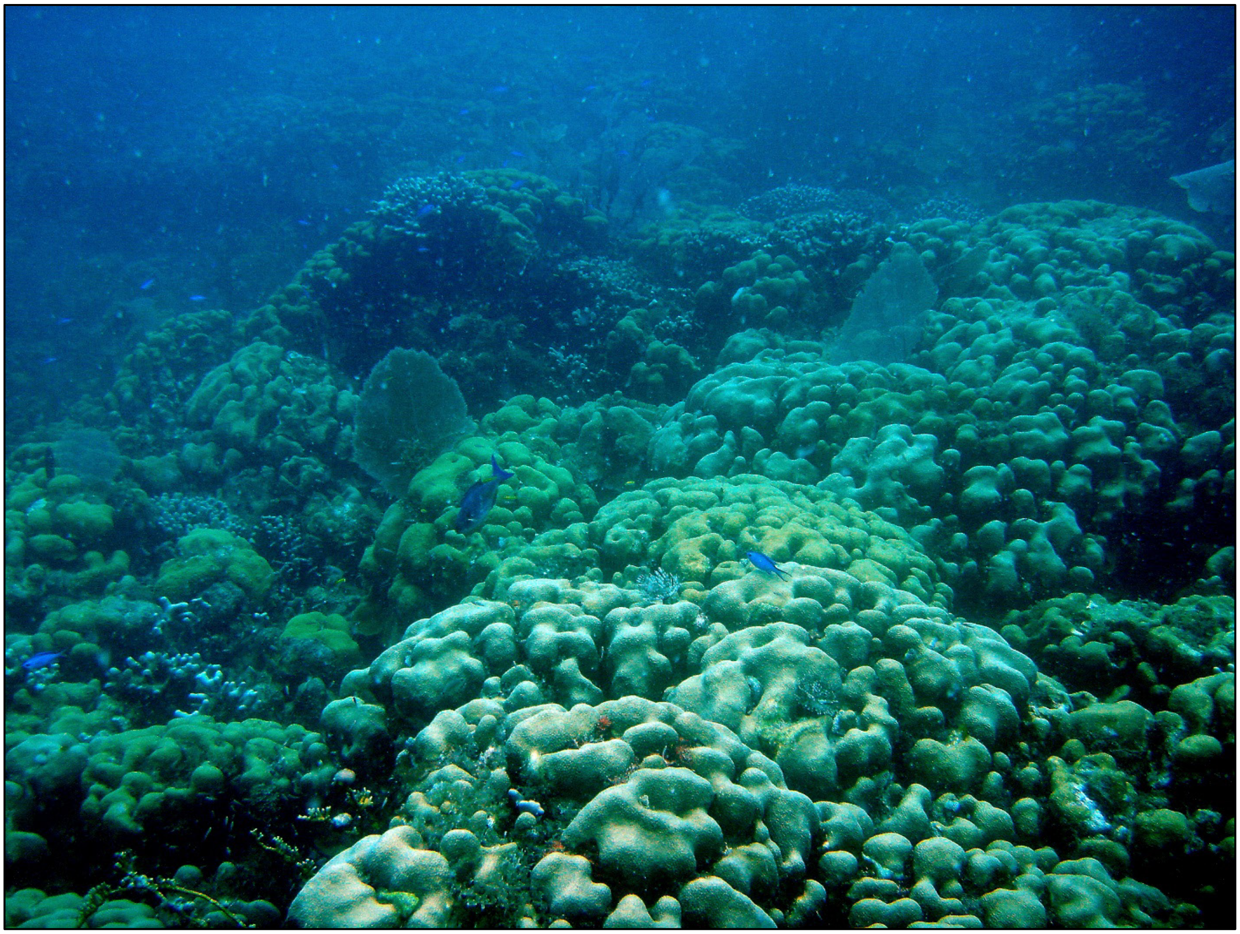

Figure 4.3.1.6. A representative photo of the Tektite coral reef, Lameshur Bay, St. John dominated by the boulder star coral (*Orbicella annularis*) (November 2, 2009; photo credit: Tyler B. Smith).

Additional comprehensive long-term data sets using video along permanently marked transects were initiated by the National Park Service Southeast Florida and Caribbean Inventory and Monitoring Network (SFCN) in 1999 (SFCN 2019). These data overlapped (1999–2002) and then replaced the earlier monitoring along chain transects (Rogers and Miller 2006) at Yawzi and Newfound, as well as adding additional sites. New sites included Tektite, Haulover, and Mennebeck (Table 4.3.1.1). Monitoring protocols are described for SFCN here https://www.nps.gov/im/sfcn/index.htm.

The USVI Territorial Coral Reef Monitoring Program (TCRMP) monitored coral reefs just outside of VIIS-VICR at three sites (Smith et al. 2011, 2018; Table 4.3.1.1; Figure 4.3.1.1). The sites Fish Bay (est. 2001, Figure 4.3.1.7) and Coral Bay (est. 2009, Figure 4.3.1.8) are very close to National Park boundaries (<500m) and represent areas impacted by land-based sources of pollution, specifically sediment-laden run-off (Gray et al. 2012b). The site Meri Shoal (est. 2005, Figure 4.3.1.9) is west of the VICR and represents an offshore *Orbicella* mesophotic reef. Monitoring protocols are described for TCRMP here https://sites.google.com/site/usvitcrmp/.

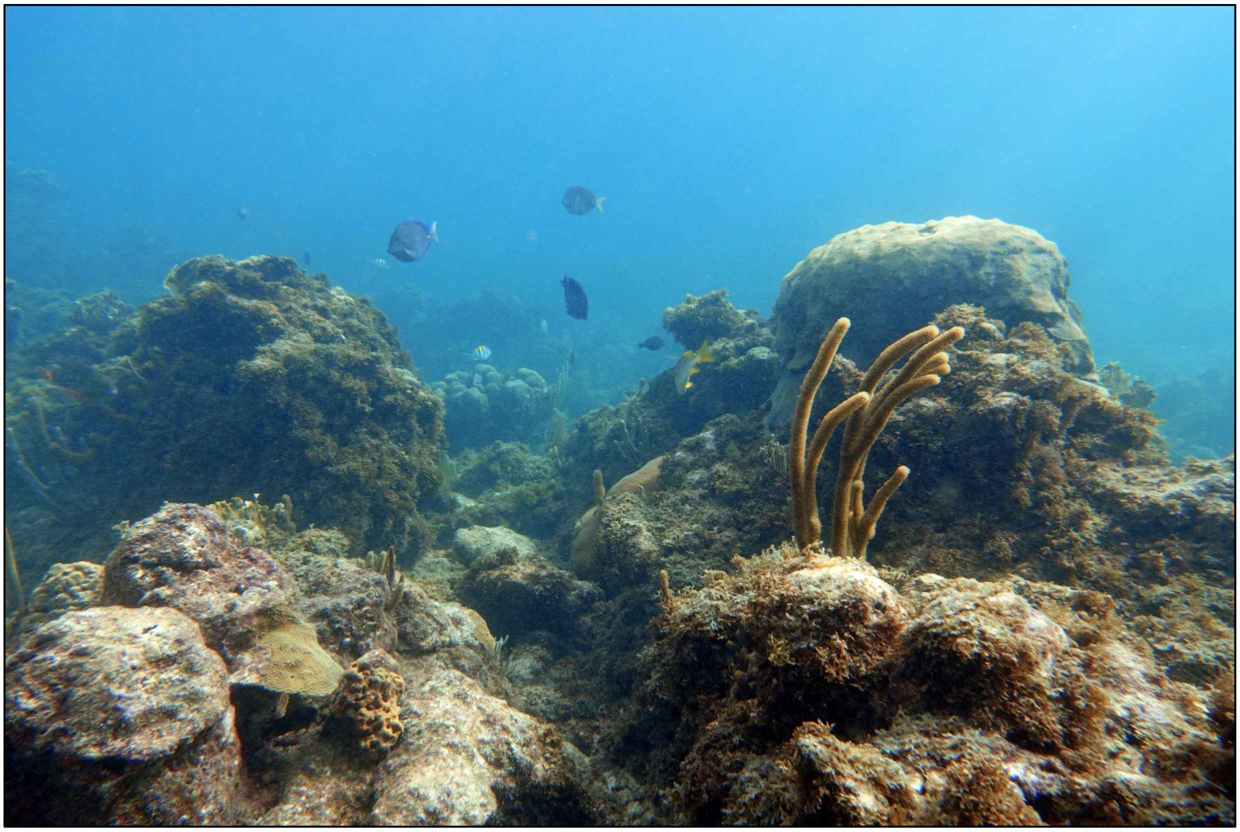

Figure 4.3.1.7. A representative photo of the western fringing reef of Fish Bay, St. John at the Territorial Coral Reef Monitoring Program research site (October 5, 2018; photo credit: Elizabeth Kadison)

SFCN monitors 20 transects at each site, each initially randomly placed, but then permanently marked. TCRMP used 6 permanent transects per site. At each site temporary transects lines are stretched between permanent marking stakes. Divers swimming with a downward pointing digital video camera films the benthos. From the images, non-overlapping still frames are captured and processed to quantify benthic cover (Kohler and Gill 2006). Stony coral summaries include the cover of the hydrocoral *Millepora* spp. since this genus can be ecologically important. In addition, along TCRMP transects, each coral colony intercepted by the transect line is assessed for health indicators following a modified Atlantic and Gulf Rapid Reef Assessment protocol (Kramer et al. 2005, Smith et al. 2016). Benthic cover (%) was calculated for major sessile epibenthic organisms. Relative coral cover among taxa was calculated from all available data across all years of monitoring. Caution should be used in comparing total species richness across sites, since sampling effort was unequal due to length of the record (i.e., sites monitored for longer periods may have more species recorded).

Figure 4.3.1.8. A representative close up photo of the patch reef of Coral Bay, St. John at the Territorial Coral Reef Monitoring Program research site near the mouth of Coral Harbor (December 4, 2012; credit Tyler B. Smith).

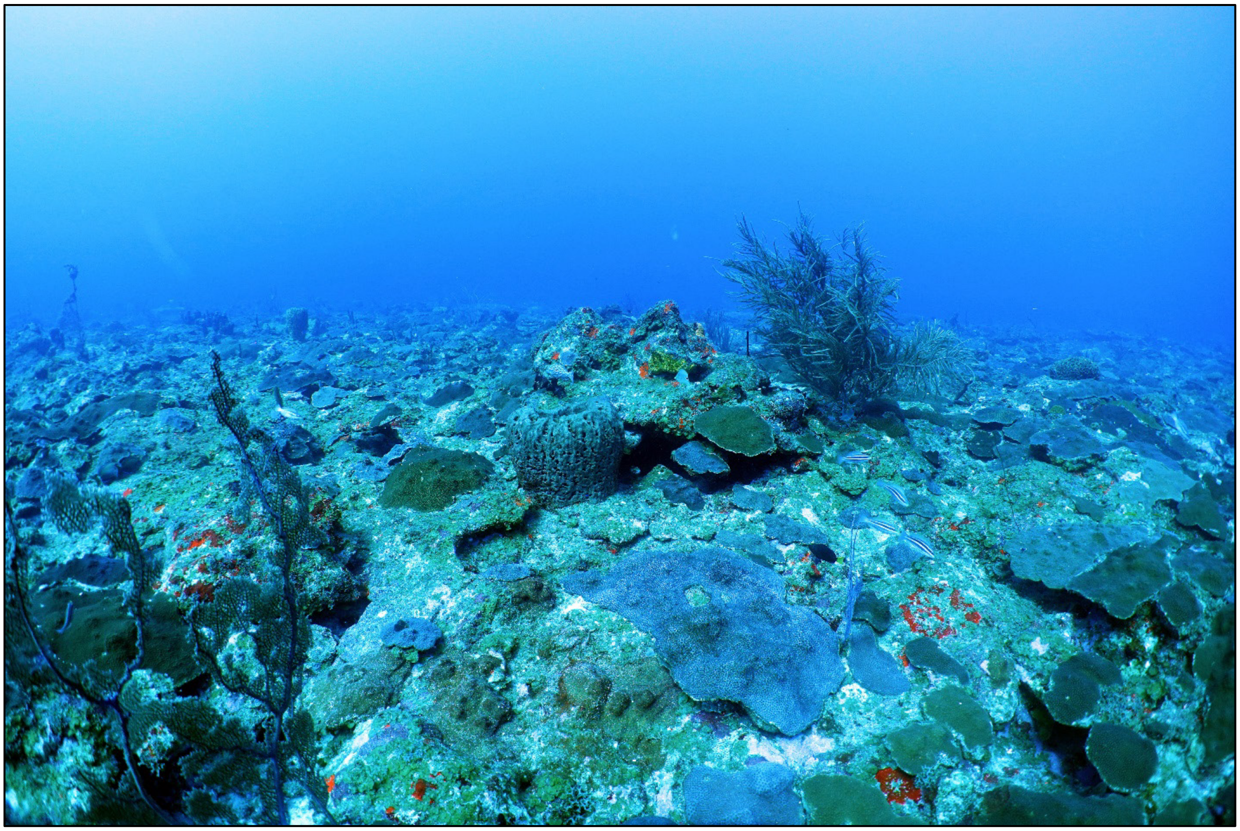

Figure 4.3.1.9. A representative photo of the mesophotic bank reef Meri Shoal, St. John at the Territorial Coral Reef Monitoring Program research site (December 12, 2018; credit: Sarah Heidmann).

Reference Conditions/Values

The earliest observations of the waters of the VIIS around St. John note exceptional conditions for coral reefs and healthy fringing reef systems (Figure 4.3.1.10). Nearly six decades ago clear water quality around VIIS was noted by Kumpf and Randall (1961), although turbid waters were found inside Coral Bay. Estimates of coral cover as high as 30–50% and macroalgal cover less than 10% were recorded on fringing reefs in Lameshur Bay that were dominated by boulder star corals as late as Hurricane Hugo in 1989 (Rogers and Miller 2006; Edmunds 2013). It should be noted that not all areas in Lameshur with hard bottom had high coral cover; Edmunds (2013) found that six randomly sited areas had coral cover of <4.5% in 1992 and suggest this was the background coral cover for these areas. Across St. John colonies of elkhorn (*Acropora palmata*) and staghorn (*Acropora cervicornis*) corals were ubiquitous, and there were a more limited number of dense elkhorn reefs (Rogers et al. 2003). Pictures taken during the Tektite mission also indicate that large head corals exhibited very complete tissue coverage with low evidence of partial mortality (Figure 4.3.1.10).

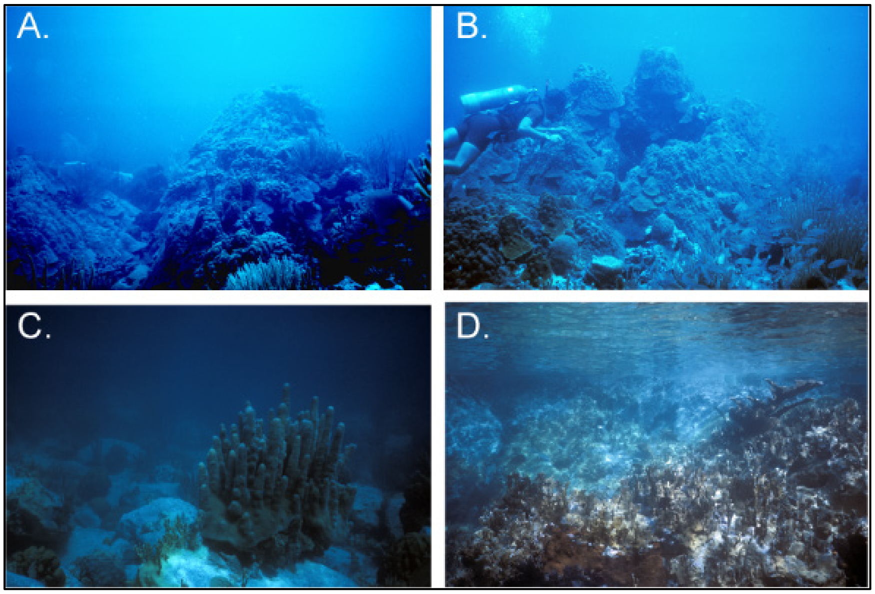

Figure 4.3.1.10. Historical photos of the reef near the Tektite habitat from April 1970. (A) Colonies of mountainous star coral (*Orbicella faveolata*) with extensive live tissue cover. (B) Colonies of mountainous star coral with diver in photo for scale. (C) Shallow storm susceptible bedrock and boulder areas with colonies of blade fire coral (*Millepora complanata*) in the foreground and a colony of elkhorn coral (*A. palmata*) in the background. (D) Bedrock and boulder area with a solitary colony of pillar coral (*Dendrogyra cylindrus*) surrounded by isolated colonies of mountainous star coral (photo credit: H. Edward Clifton; U.S. Geological Survey, Coastal and Marine Geology, Emeritus & Tektite Aquanaut)

Macroalgae were minor space occupiers on coral reefs prior to 1980. Observations of Tektite habitat scientists (1969–1970) underscore the paucity of algae on reefs prior to Hurricane Hugo:

- "In most cases the algae were restricted to cracks and crevices and they were diminutive in size." (Mathieson et al. 1971).
- "Perhaps the most striking aspect of plant life on a coral reef is the general lack of it. It seems anomalous to even the casual observer that tropical reefs, notable for their dazzling profusion of animal life, are almost devoid of conspicuous plants" (Earle 1971).

Thus, up until the 1980s most well-developed coral reefs of St. John had high water clarity, high coral cover, and very low macroalgal cover.

Current Condition and Trend

Coral Reefs prior to and just after Hurricane Hugo in 1989

Mixed coral assemblages

Coral reefs of VIIS-VICR have undergone significant degradation since the 1980s. The long-term data sets of Rogers and Miller (2006) and Edmunds (2013, 2019) allow managers to see when and where deviations from reference conditions occurred. While there was likely some degradation of coral reefs from storms prior to Hurricane Hugo on September 18, 1989 (Rogers and Zullo 1987), it was after this particular storm when reefs apparently began to show low to no recovery. Long-term reef monitoring initiated before Hurricane Hugo also showed that there was spatial heterogeneity in storm impacts. The southern Yawzi site in Great Lameshur Bay was heavily impacted, losing about 35–40% of its coral cover (Rogers et al. 1991, Edmunds and Witman 1991). However, even within Lameshur Bay and less than a kilometer away, the slightly deeper study plots on Tektite reef (9 versus 14 m) were largely unaffected by the storm (Edmunds and Witman 1991). Tektite is in the lee of Cabrite Horn point and this, and the slight increase in depth, may have helped buffer storm impacts. Hurricane Hugo also marked the initiation of higher benthic cover of macroalgae in Lameshur Bay. Cover of macroalgae was less than 10% prior to the storm but increased to between 10–40% after the storm (Rogers et al. 1991; Edmunds and Witman 1991). This level of macroalgae has been maintained, with Edmunds (2019) indicating a 4–8 fold increase in macroalgal cover over a 28 year period ending in July 2017 (just prior to more recent major hurricane impacts).

Acropora

In the period through the late 1970's to mass bleaching in 2005, populations of *A. palmata* and *A. cervicornis* were greatly affected by white band disease and hurricanes (Rogers et al. 2003). White band was uncommon but present in early 1984, but large dead stands of *A. palmata* may have indicated recent impacts from the disease (Beets et al. 1986). Both Hurricanes David (1979) and Hugo (1989) caused damage to *A. palmata* populations on the south shore of St. John (Beets et al. 1986; Rogers et al. 2003). In addition, localized impacts from algae, corallivores, bleaching, and physical breakage impacted populations in Hawksnest Bay (Rogers et al. 1988).

Coral Reefs prior to Mass Bleaching in 2005

Mixed coral assemblages

In the period between Hurricane Hugo in 1989 and severe thermal stress in 2005, a survey of five coral reef monitoring sites by the NPS-SFCN in and around VIIS-VICR showed that coral cover typically remained steady or declined, but with increases at one site.

Yawzi

The Yawzi study sites failed to recover coral cover lost in Hurricane Hugo. The Yawzi site monitored by Rogers and Miller (2006) showed no apparent recovery of coral after declining to about 10% total coral cover. This paper only reported up to 2002, but a continuation of the data sets indicates that coral cover remained low (Figure 4.3.1.11). The stony coral community at Yawzi was composed largely of star corals in the genus *Orbicella*, with a high overall stony coral species richness of 32 species identified in transects (Figure 4.3.1.12). This site also had a relatively high cover of pillar coral (*Dendrogyra cylindrus*) but only a single colony provided the overall coverage (W.J. Miller 2020, personal observation). An additional site monitored at Yawzi still had greater than 30% coral cover after Hurricane Hugo, but cover declined precipitously to about 20% cover by 2005 (Edmunds 2013). A large drop in coral cover occurred around Hurricane Marilyn (September 15, 1995) and Hurricane Georges (Sep. 21, 1998) (Edmunds 2013), underscoring the sensitivity of this site to storm damage. In contrast, the nearby Tektite reef had stable to slightly increasing coral cover of about 40% between 1989 and 2005 and randomly placed coral monitoring sites had low (~4%) and stable coral cover (Edmunds 2013).

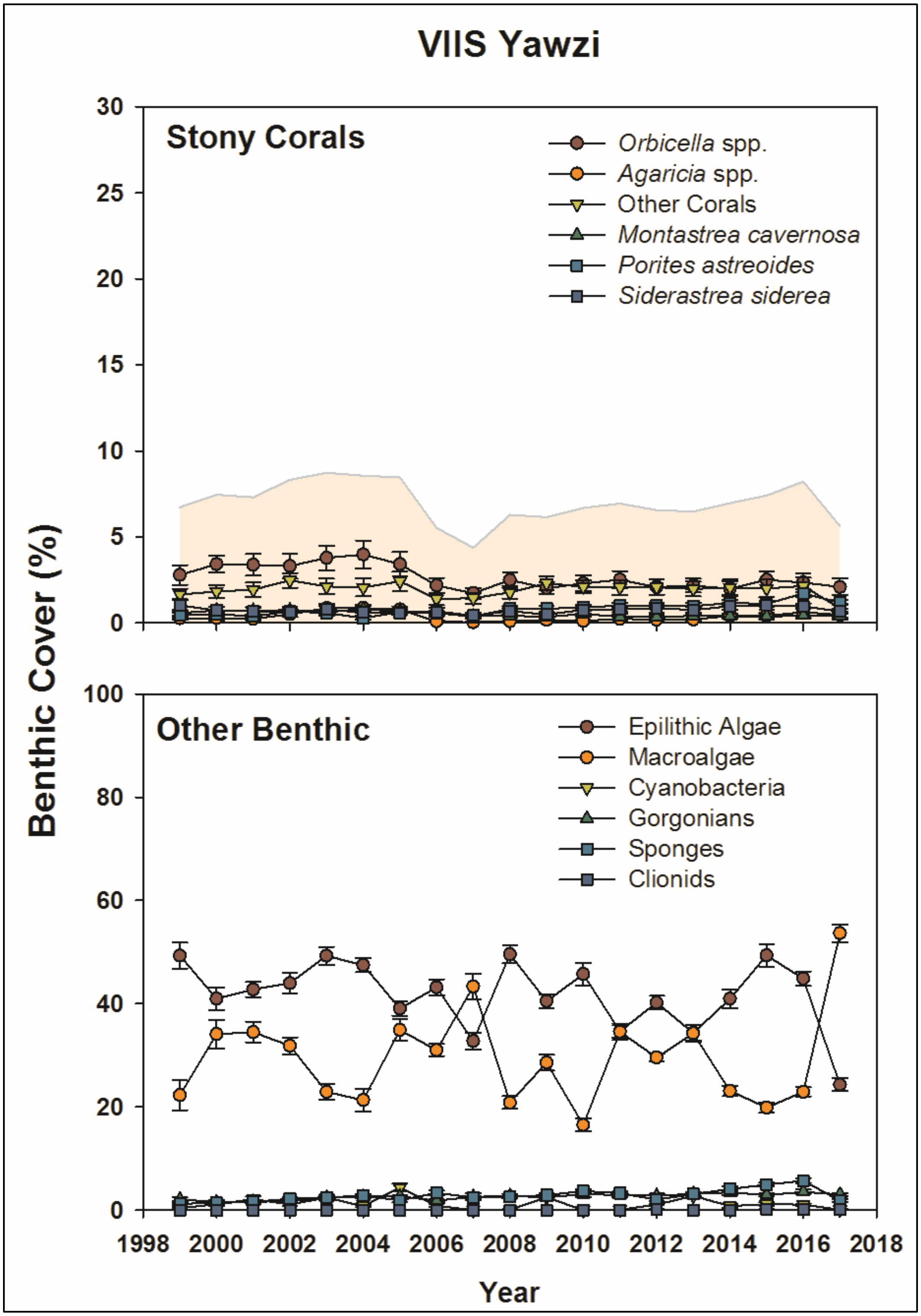

Figure 4.3.1.11. Cover of sessile epibenthic organisms (±SE) through time at the SFCN Yawzii site. (Top) Cover of stony corals. Total coral cover indicated by shaded area, then the most abundant individual species from the full data set indicated as separate markers and lines. (Bottom) Other benthic organisms.

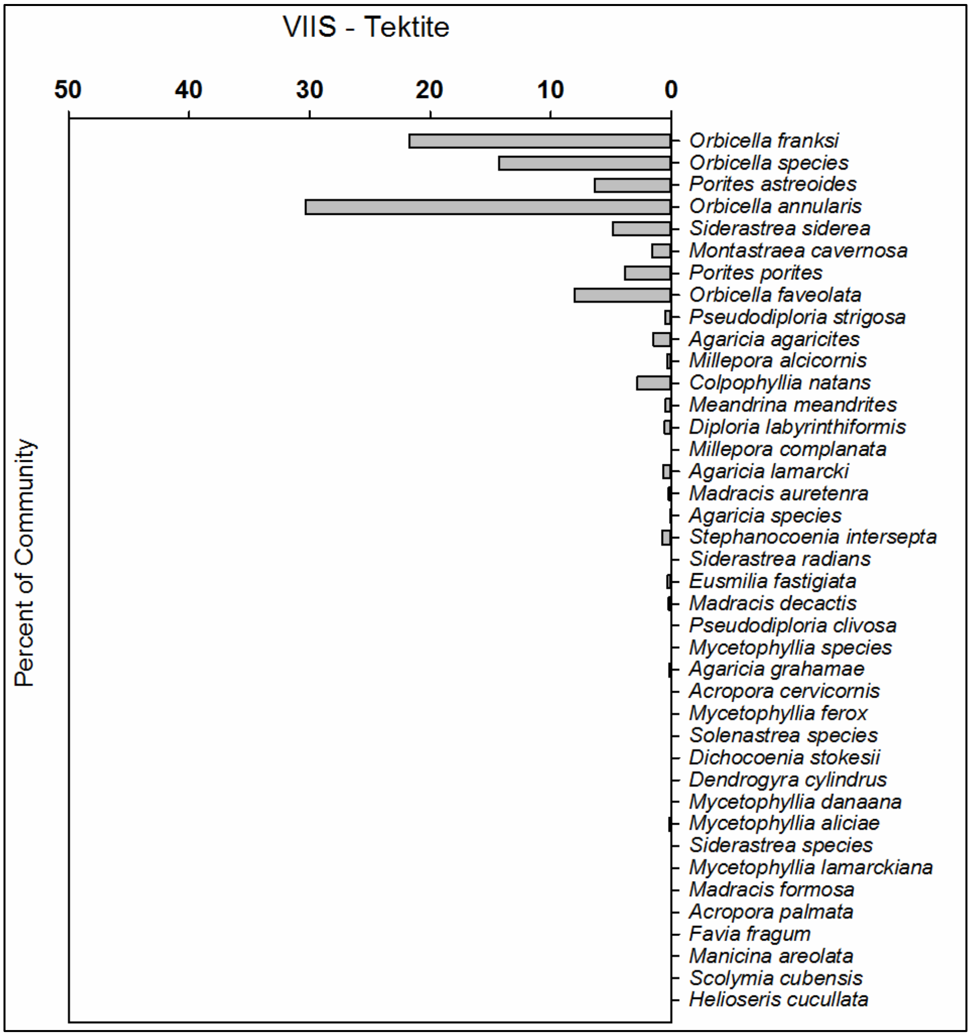

Figure 4.3.1.12. Relative abundance of coral species by benthic cover at SFCN Yawzi site. Coral species are ordered by the rank abundance (descending rightward) according to abundance across the TCRMP shallow water sites outside park areas (26 sites).

Newfound and Mennebeck

On the northeast shore of St. John, the Newfound reef site monitored by SFCN between 1999 and 2017 showed a drop in coral cover between 1999 and 2000, which was attributed to white plague coral disease (Rogers and Miller 2006), but coral cover was then stable until 2005 (Figure 4.3.1.13). Newfound was dominated by *Orbicella annularis* and unidentified *Orbicella* spp., which composed over half of the living coral cover, and had a total of 18 stony coral species identified in transects (Figure 4.3.1.14). The nearby Mennebeck reef site monitored by SFCN between 2000 and 2017 also had stable coral cover of about 20% prior to 2005 (Figure 4.3.1.15). This site was highly dominated by *Orbicella* spp. (almost 80% of the relative coral cover), particularly *O. annularis*, but also had 25 other species (Figure 4.3.1.16).

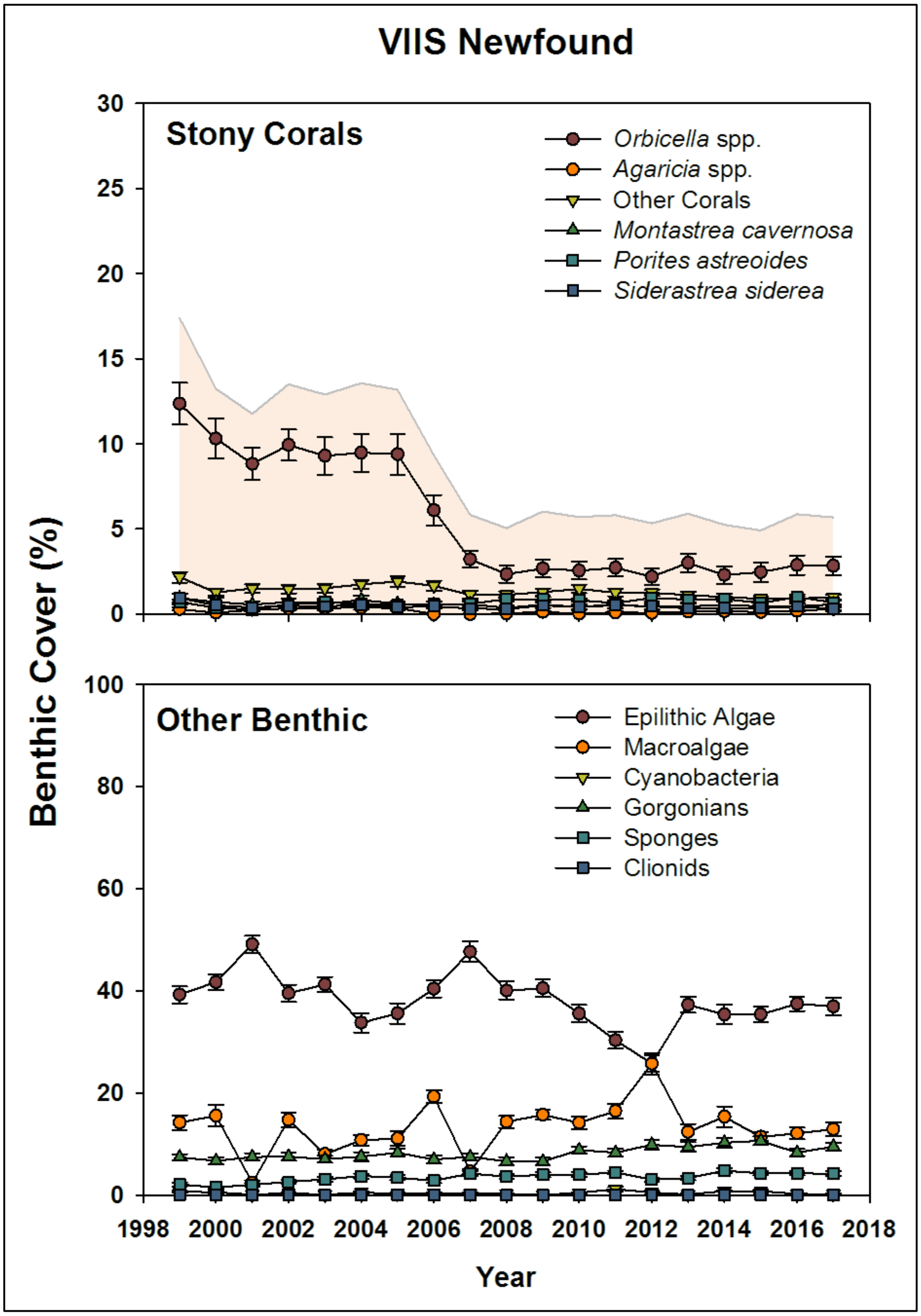

Figure 4.3.1.13. Cover of sessile epibenthic organisms (±SE) through time at the SFCN Newfound site. (Top) Cover of stony corals. Total coral cover indicated by shaded area, then the most abundant individual species from the full data set indicated as separate markers and lines. (Bottom) Other benthic organisms.

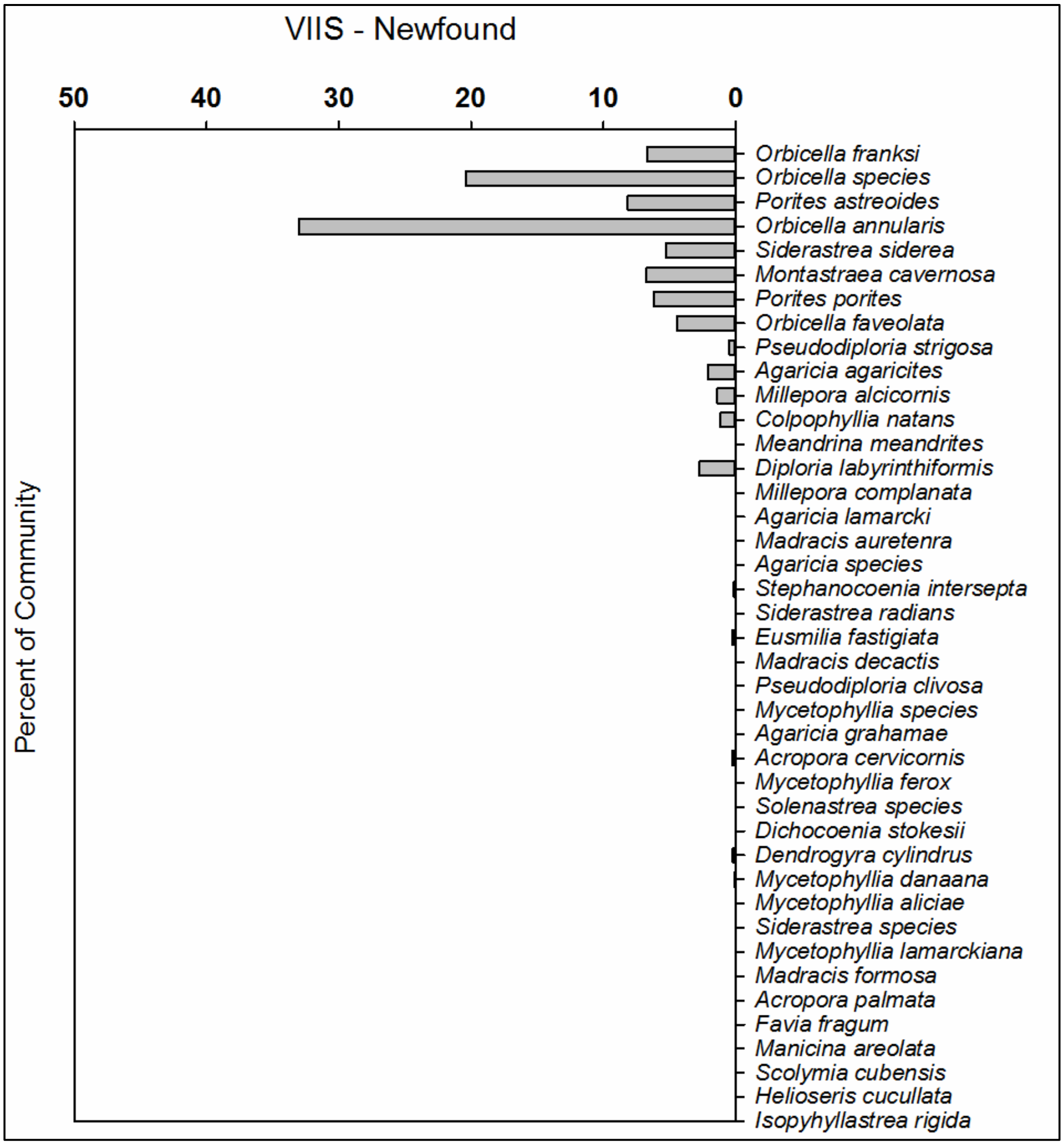

Figure 4.3.1.14. Relative abundance of coral species by benthic cover at SFCN Newfound site. Coral species are ordered by the rank abundance (descending rightward) according to abundance across the TCRMP shallow water sites outside park areas (26 sites).

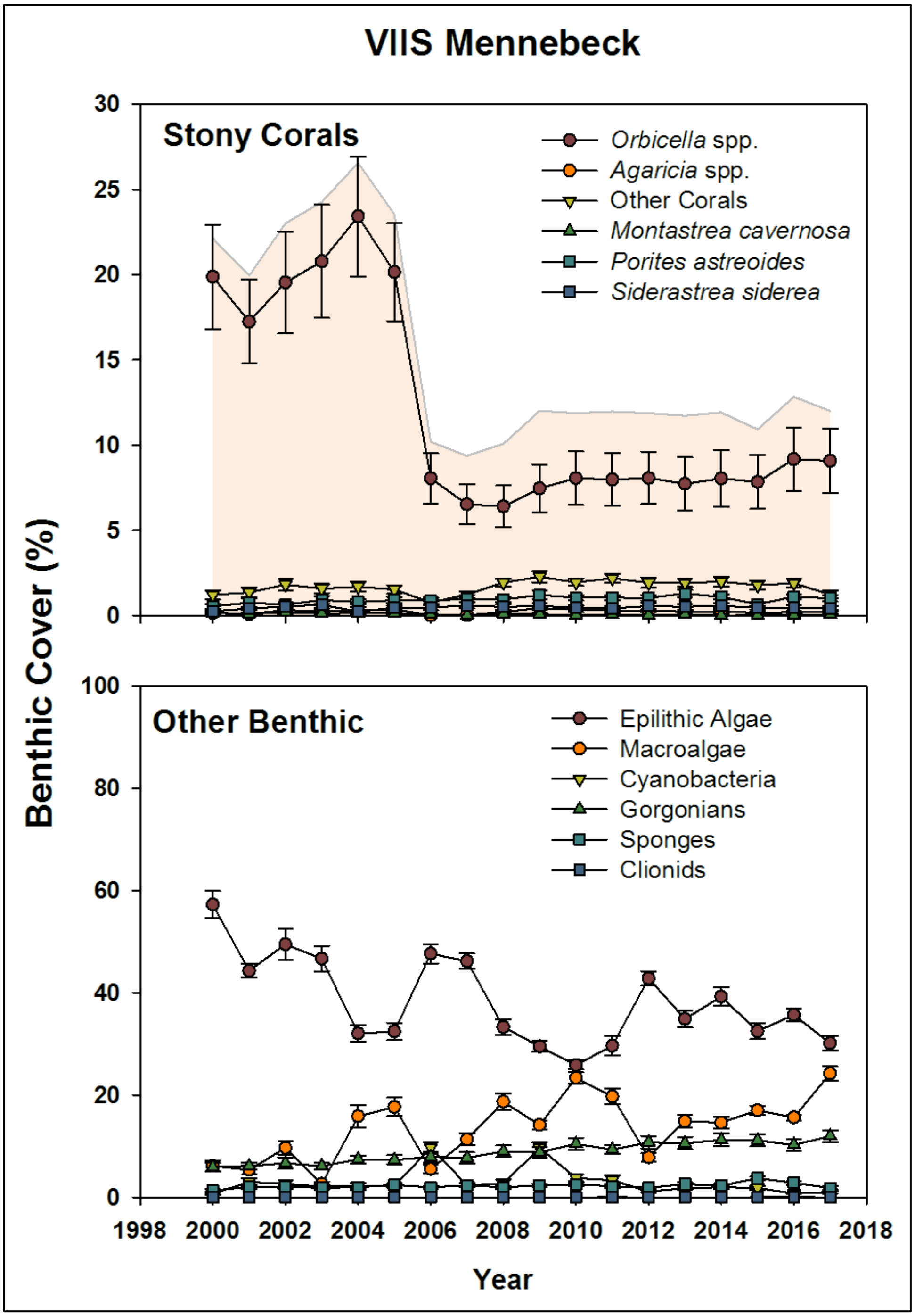

Figure 4.3.1.15. Cover of sessile epibenthic organisms (±SE) through time at the SFCN Mennebeck site. (Top) Cover of stony corals. Total coral cover indicated by shaded area, then the most abundant individual species from the full data set indicated as separate markers and lines. (Bottom) Other benthic organisms.

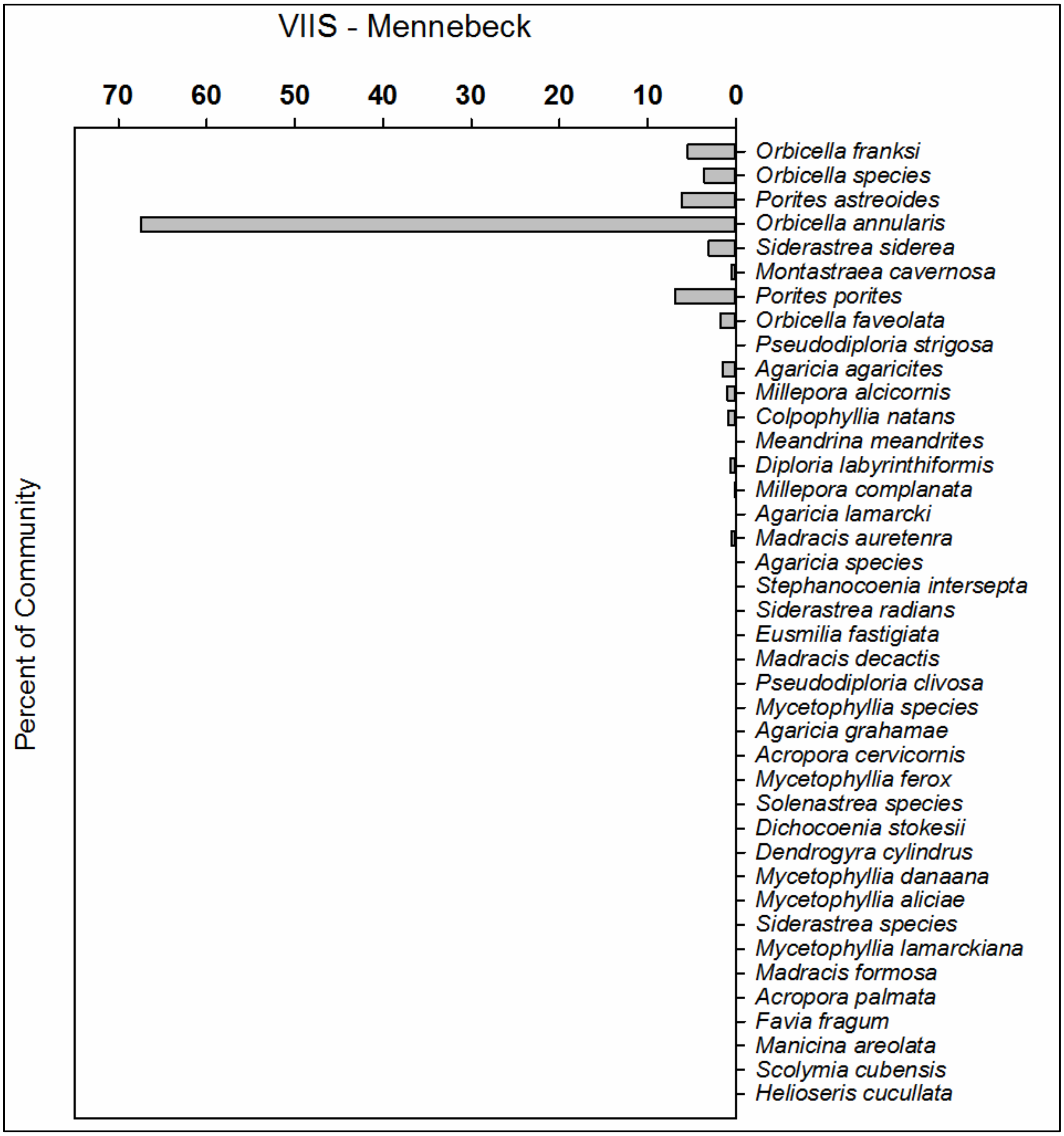

Figure 4.3.1.16. Relative abundance of coral species by benthic cover at the SFCN Mennebeck site. Coral species are ordered by the rank abundance (descending rightward) according to abundance across the TCRMP shallow water sites outside park areas (26 sites). Note that cover of many species is too low to be resolved on figure.

Fish Bay

Just outside of the southwestern park boundary the TCRMP monitored a site within Fish Bay that exhibited stable cover between 2001 and 2005 (Figure 4.3.1.17). However, this site has been under the influence of land-based pollution in the form of silt-laden run-off from construction and unpaved roads from a large catchment prior to the initiation of monitoring (Rogers and Zullo 1987, Ramos-Scharrón and LaFevor 2016). Rogers and Zullo (1987) monitored a 11 m depth site on the east side of Fish Bay and found a community that was almost half composed of *Agaricia agaricites* with a total stony coral cover as of their final data point in November 1985 of about 18%. The western site monitored by TCRMP was about 13% coral cover in 2001 (Figure 4.3.1.17) and had 20 species of stony corals in transects (Figure 4.3.1.18). However, this site had *Orbicella* spp., primarily *O. faveolata*, as the dominant coral group, and *A. agaricites* composed less than 4% of the living coral cover, with numerous standing dead corals heavily covered in macroalgae evident within transects (T. Smith, unpub. obs.). This suggests a decline in coral, particularly *A. agaricites*, prior to initiation of the TCRMP program in 2001.

In summary, for mixed coral assemblages, prior to 2005 and after Hurricane Hugo in 1989, a monitoring site had increasing coral cover (e.g., Tektite) if it had high initial coral cover and was buffered from storm disturbances; and a site had declining coral cover when coral cover was already reduced and there were storm impacts (Yawzi) or when coral cover was high and there were disease impacts (Newfound). A site had stable coral cover if already reduced in cover and there were co-occurring stressors (Fish Bay) or where cover of coral was high and there were low co-occurring stressors (Mennebeck).

Acropora

In surveys around St. John between 2000 and 2005 about 2,300 colonies of *A. palmata* were assessed on snorkel with handheld GPS providing a partial distribution map of living colonies Rogers et al. (2003). Particularly dense stands of colonies were present on the north coast in Hawksnest Bay (438 colonies), Leinster Bay/Waterlemon Bay (185), and an area east of Brown Bay (179). Populations of *A. cervicornis* in VIIS-VICR were less well documented in this period, but colonies tended to occur across as isolated colonies in low density with some areas of higher density on the east end of St. John (Rogers et al. 2003).

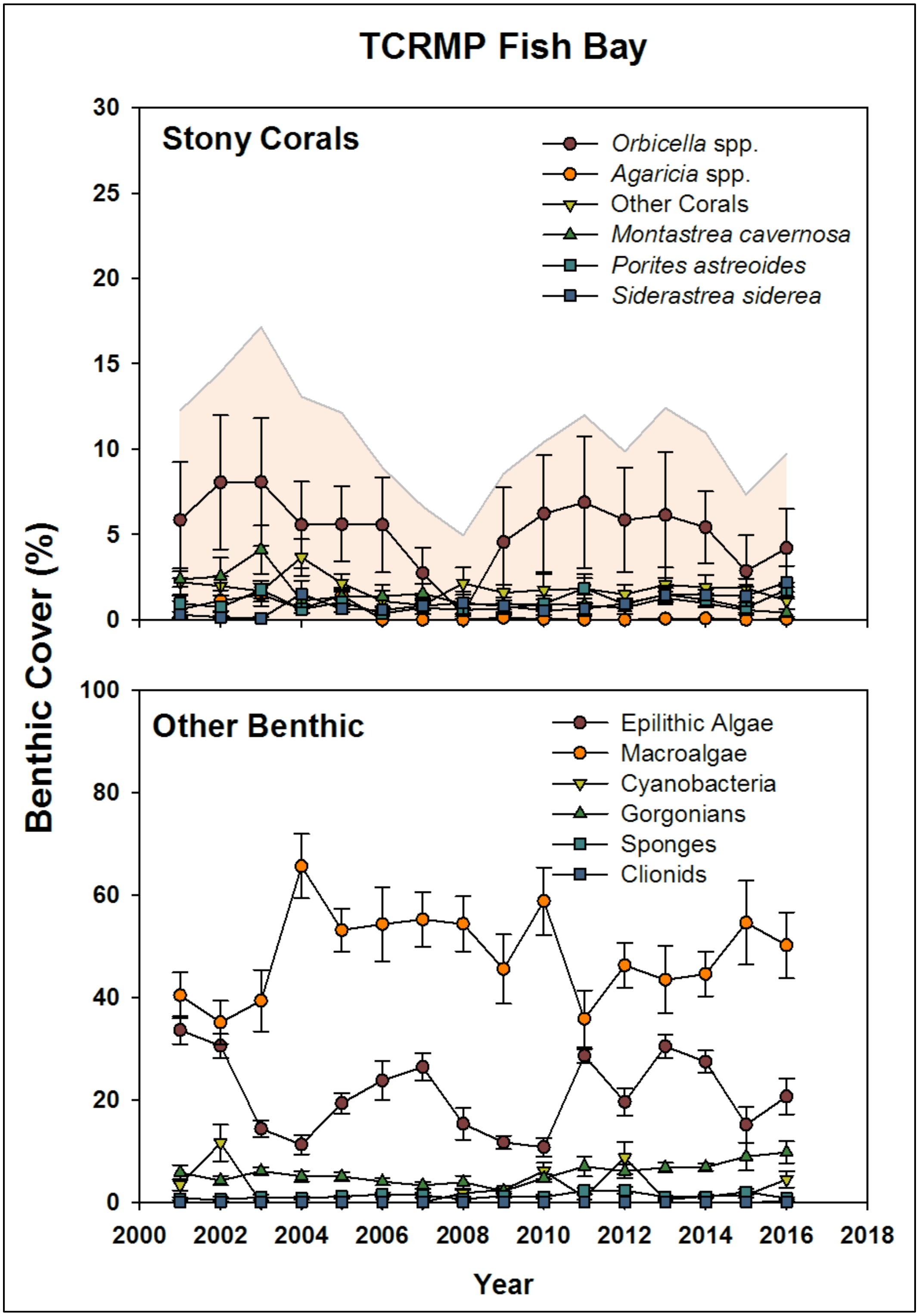

Figure 4.3.1.17. Cover of sessile epibenthic organisms (±SE) through time at the TCRMP Fish Bay site. (Top) Cover of stony corals. Total coral cover indicated by shaded area, then the most abundant individual species from the full data set indicated as separate markers and lines. (Bottom) Other benthic organisms.

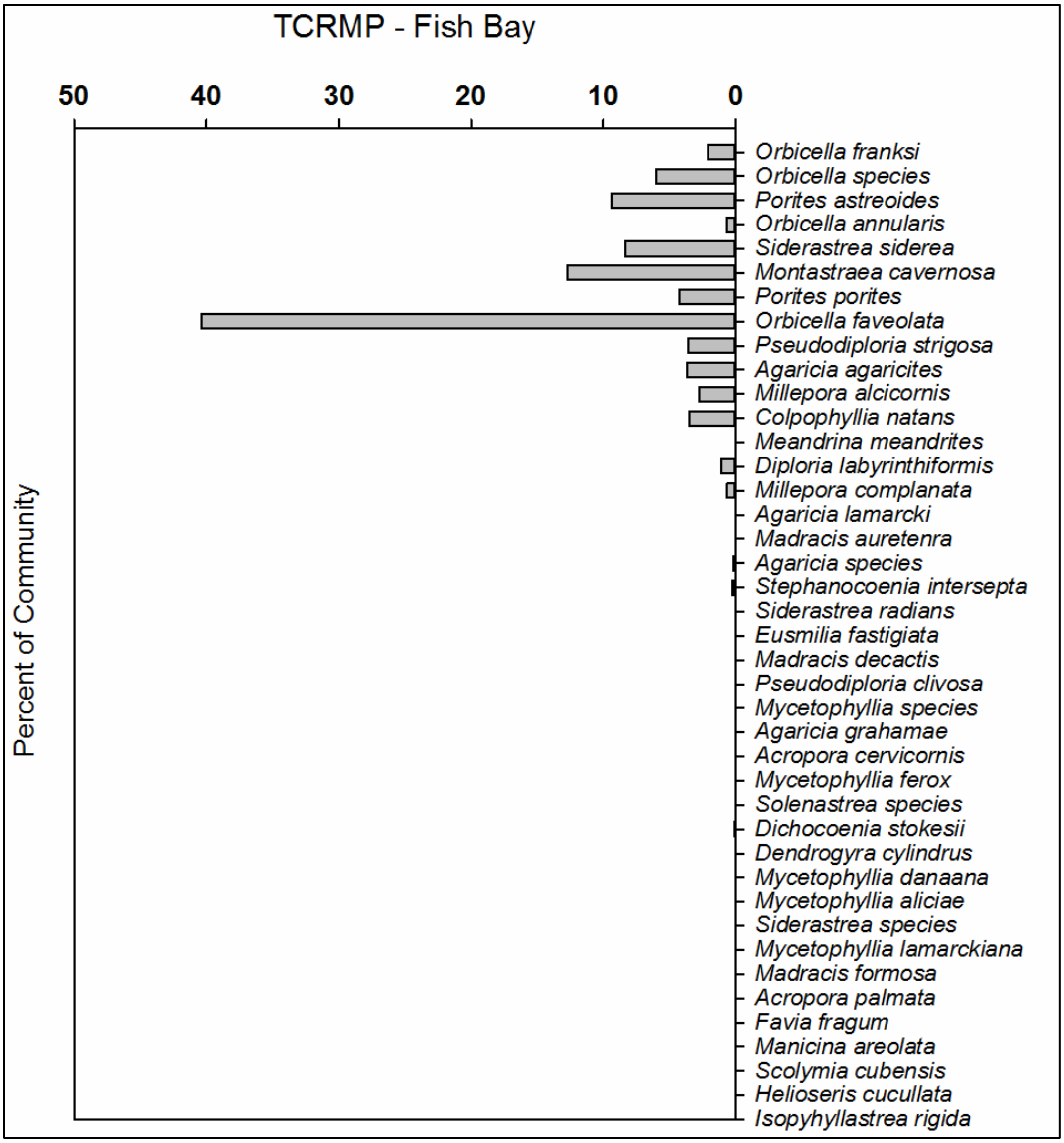

Figure 4.3.1.18. Relative abundance of coral species by benthic cover at the TCRMP Fish Bay site. Coral species are ordered by the rank abundance (descending rightward) according to abundance across the TCRMP shallow water sites outside park areas (26 sites).

Coral Reefs from Mass Bleaching in 2005 to 2017

The year 2005 saw the highest sustained sea surface temperatures recorded in the northeastern Caribbean (Donner et al. 2007), with high levels of coral thermal stress, and widespread coral bleaching (loss/reduction of intracellular algal symbionts), disease, and mortality (Eakin et al. 2010). This event strongly impacted all shallow to mesophotic coral reefs in the USVI (Miller et al. 2009, Smith et al. 2013, Smith et al. 2016, Figure 4.3.1.19). These included reef in VIIS-VICR (Figure 4.3.1.20) where minimum estimates of bleached of coral cover ranged from 50–85% (Figure 4.3.1.19). Discussion of the thermal environments of VIIS-VICR coral reef sites is discussed more extensively in the following section.

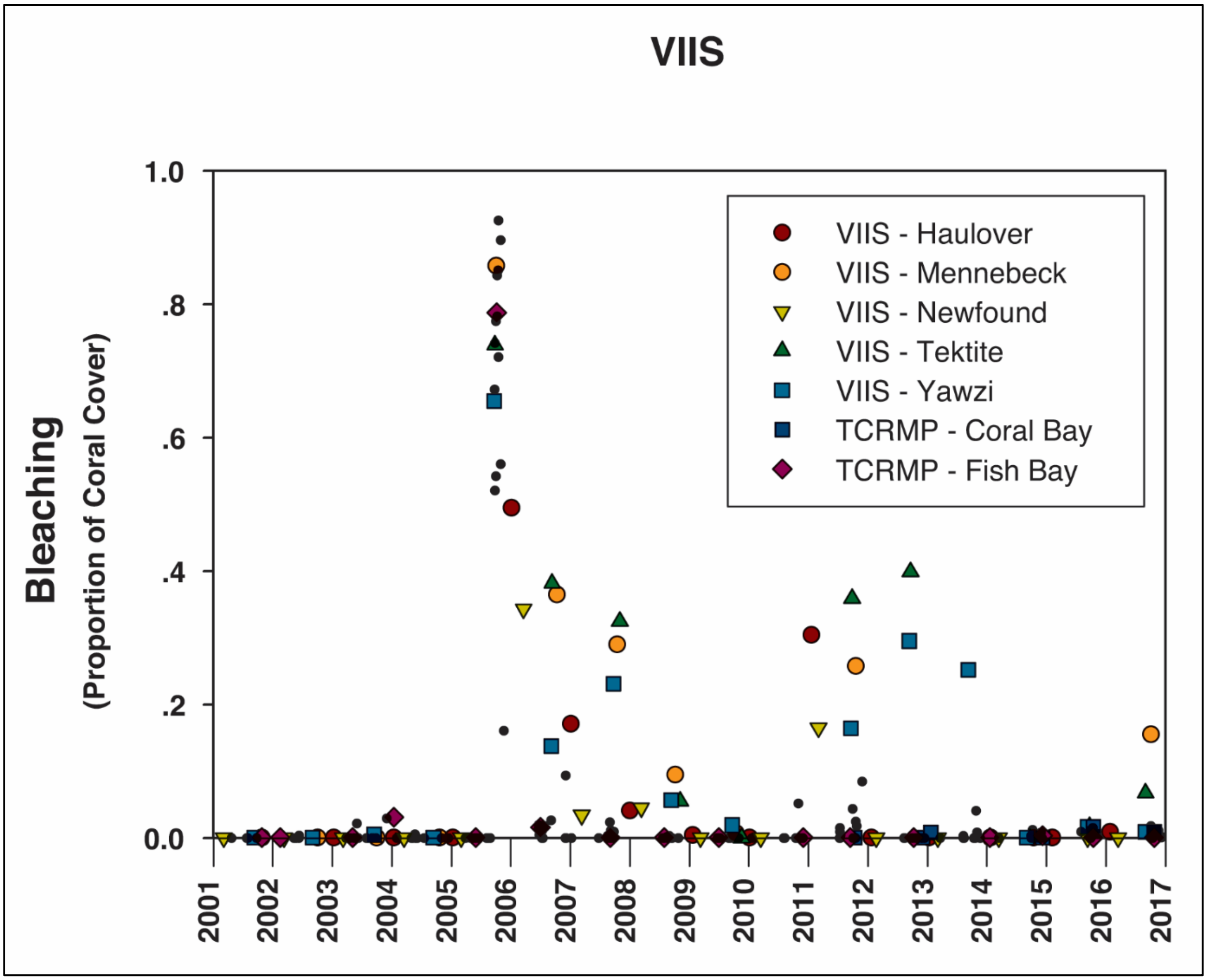

Figure 4.3.1.19. Proportion of coral cover bleached at the SFCN VIIS monitoring sites and the TCRMP Fish Bay and Coral Bay sites. Note that Coral Bay was not monitored before 2011. Another mesophotic TCRMP site Meri Shoal is not shown on the figure, but had 5.2% of coral cover bleached on October 6, 2019. Black dots are estimates from 23 other shallow water sites of the Territorial Coral Reef Monitoring Program outside park boundaries shown for reference. Estimates from captured digital video.

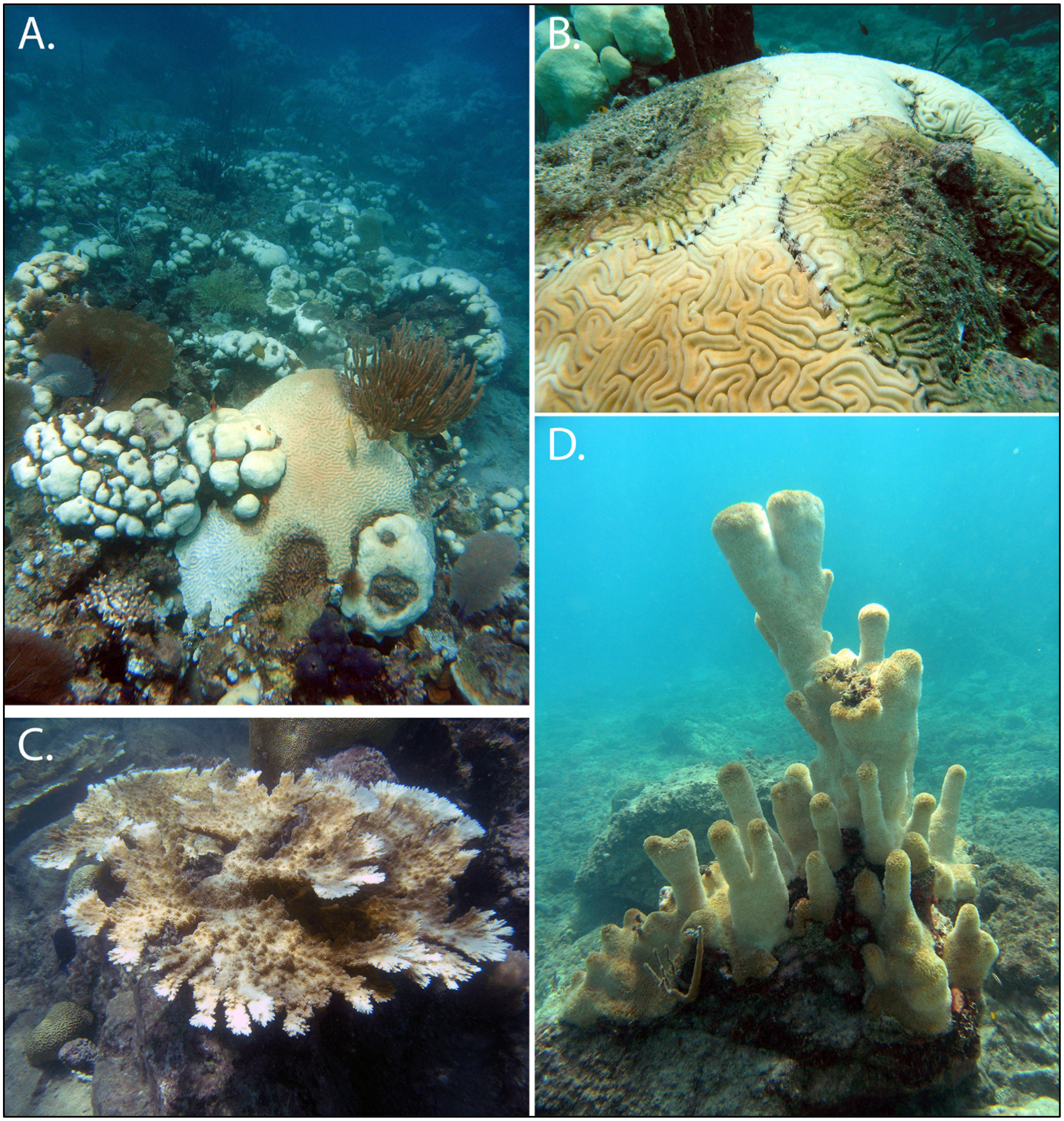

Figure 4.3.1.20. Bleaching, disease, and mortality of corals at Yawzi point, Great Lameshur Bay, St. John during the 2005 thermal stress and coral bleaching event. (A) Bleached colonies of star corals (*Orbicella annularis*) and boulder brain coral (*Colpophyllia natans*) (approx. 10 m depth). (B) Close-up view of a grooved brain coral (*Diploria labyrinthiformis*) that is partially bleached and suffering from black band disease exhibiting multi-focal lesions (approx. 3m depth). (C) A partially bleached colony of elkhorn coral (*Acropora palmata*) (2 m depth). (D). A partially bleached colony of pillar coral (*Dendrogyra cylindrus*). All photos taken on October 6, 2005. (Photo credit: Tyler B. Smith)

Mixed coral assemblages

The coral reefs of VIIS-VICR that were dominated by *Orbicella* spp. had particularly large losses of coral cover (Smith et al. 2011, SFCN 2019). These included the aforementioned reef monitoring sites at Yawzi (Figure 4.3.1.11), Newfound (Figure 4.3.1.13), Mennebeck (4.3.1.15), and Fish Bay (4.3.1.17). The impacts on coral cover were also severe at Tektite reef in the SFCN site established with 20 randomly placed transects just prior to the bleaching event. The reef lost about 60% of its coral cover (Figure: 4.3.1.21), which was composed of about 75% relative living cover of *Orbicella* spp. and had high species diversity, with 25 recorded stony coral species (Figure 4.3.1.22). Edmunds (2013) also saw losses at his monitoring site at Tektite, but the coral cover values started higher (42%) and declined less (~28% loss). Additional reef monitoring sites added by SFCN and TCRMP just prior to the 2005 bleaching event add additional information on the extent and impacts of the bleaching event. The Haulover monitoring site on northeastern St. John established in 2003 had coral cover of about 22%, but declined precipitously with bleaching and disease, with a loss of stony coral cover of about 54% (Figure 4.3.1.23; Miller et al. 2009, SFCN 2019). The Haulover site was also dominated by *Orbicella* spp., at about 79% relative living coral cover, and had a species rich community of 31 species, most of which were in very low abundance (Figure 4.3.1.24).

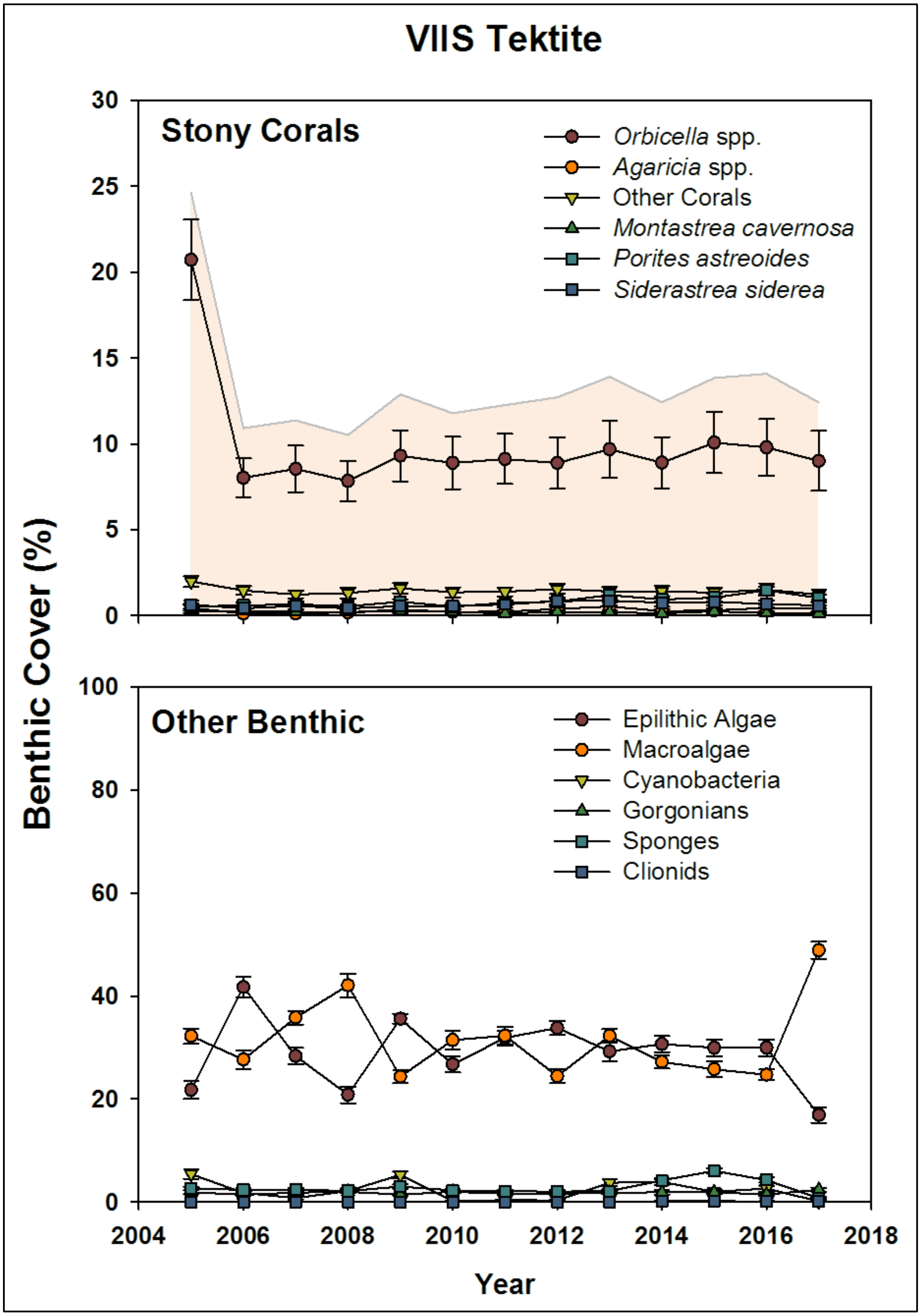

Figure 4.3.1.21. Cover of sessile epibenthic organisms (±SE) through time at the SFCN Tektite site. (Top) Cover of stony corals. Total coral cover indicated by shaded area, then the most abundant individual species from the full data set indicated as separate markers and lines. (Bottom) Other benthic organisms.

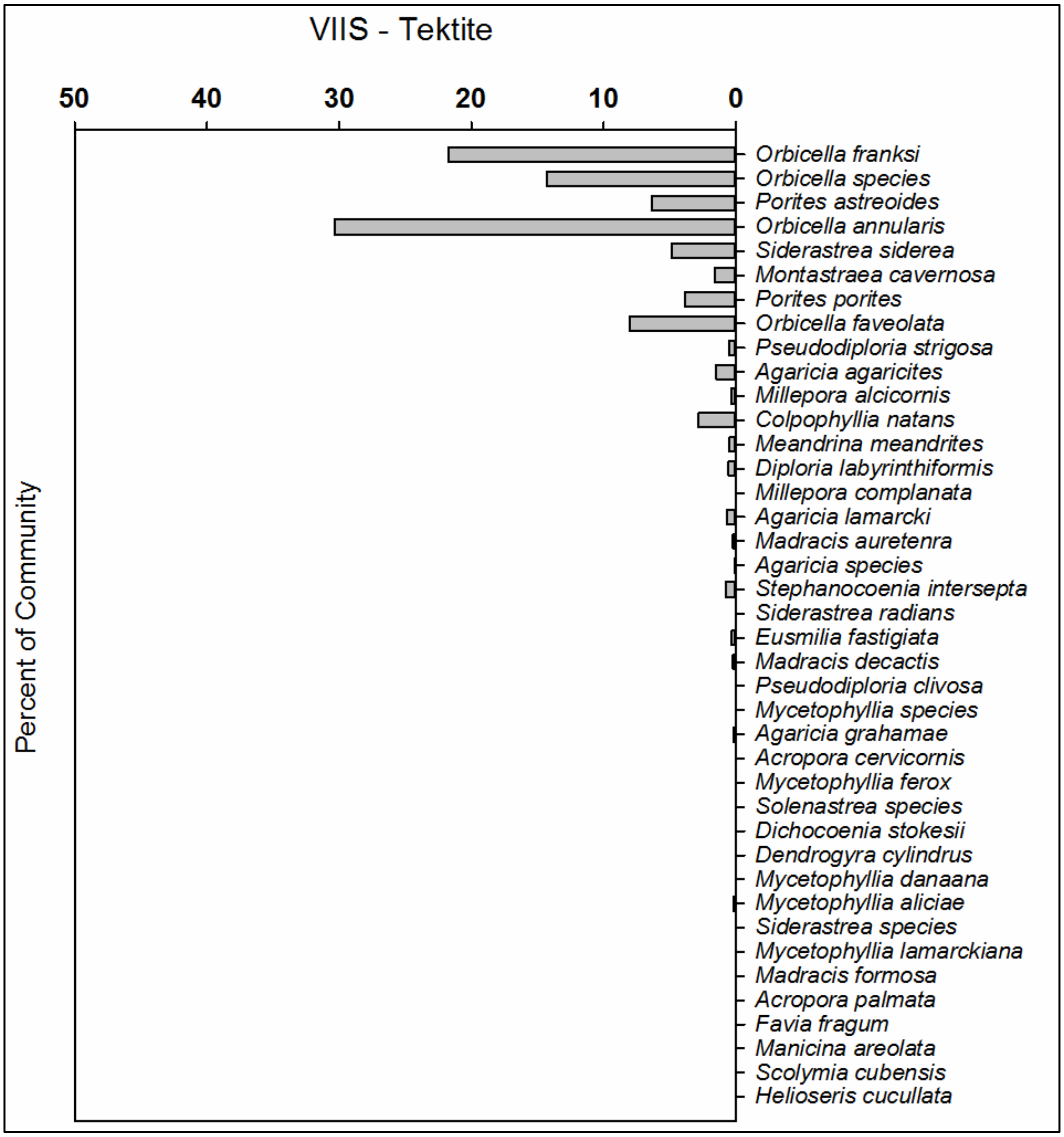

Figure 4.3.1.22. Relative abundance of coral species by benthic cover at the SFCN Tektite site. Coral species are ordered by the rank abundance (descending rightward) according to abundance across the TCRMP shallow water sites outside park areas (26 sites). Note that cover of many species is too low to be resolved on figure.

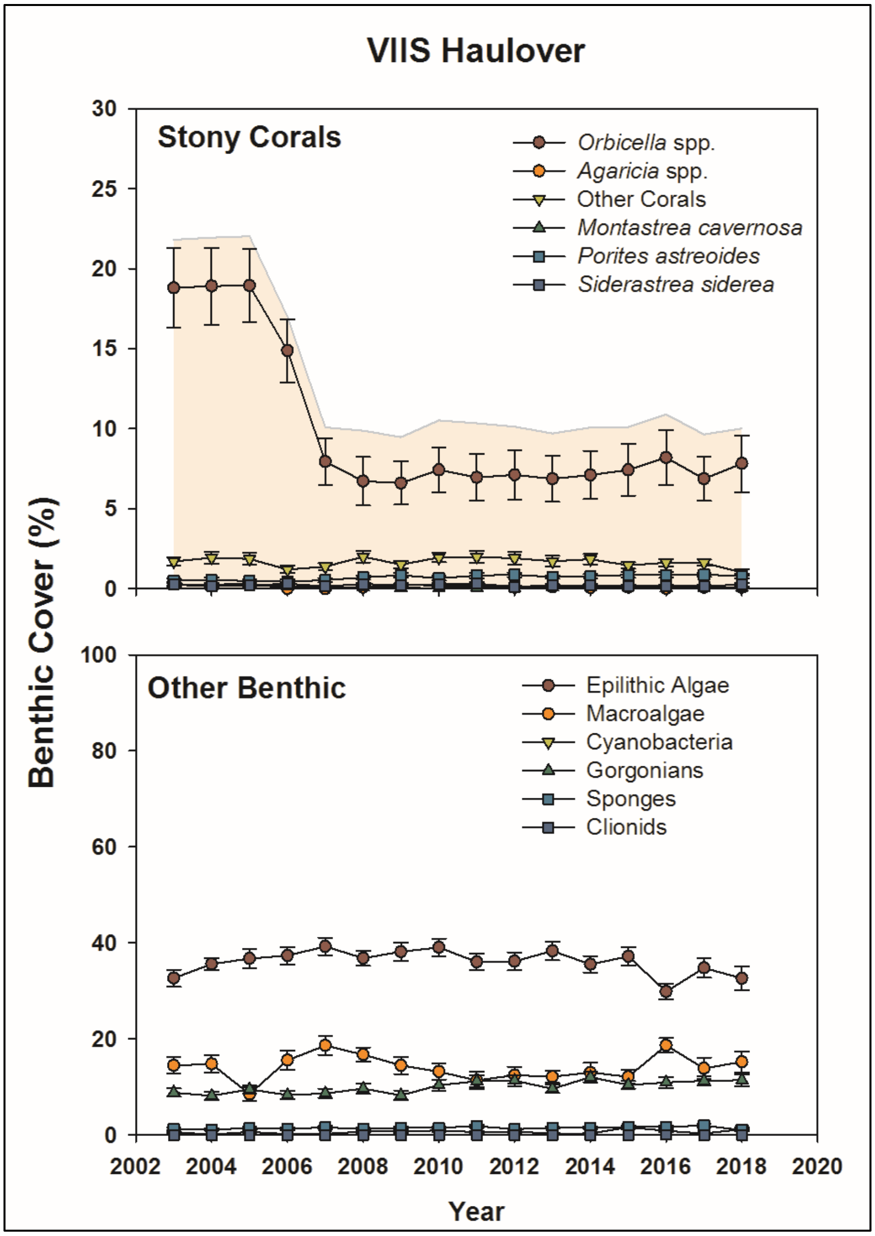

Figure 4.3.1.23. Cover of sessile epibenthic organisms (±SE) through time at the SFCN Haulover site. (Top) Cover of stony corals. Total coral cover indicated by shaded area, then the most abundant individual species from the full data set indicated as separate markers and lines. (Bottom) Other benthic organisms.

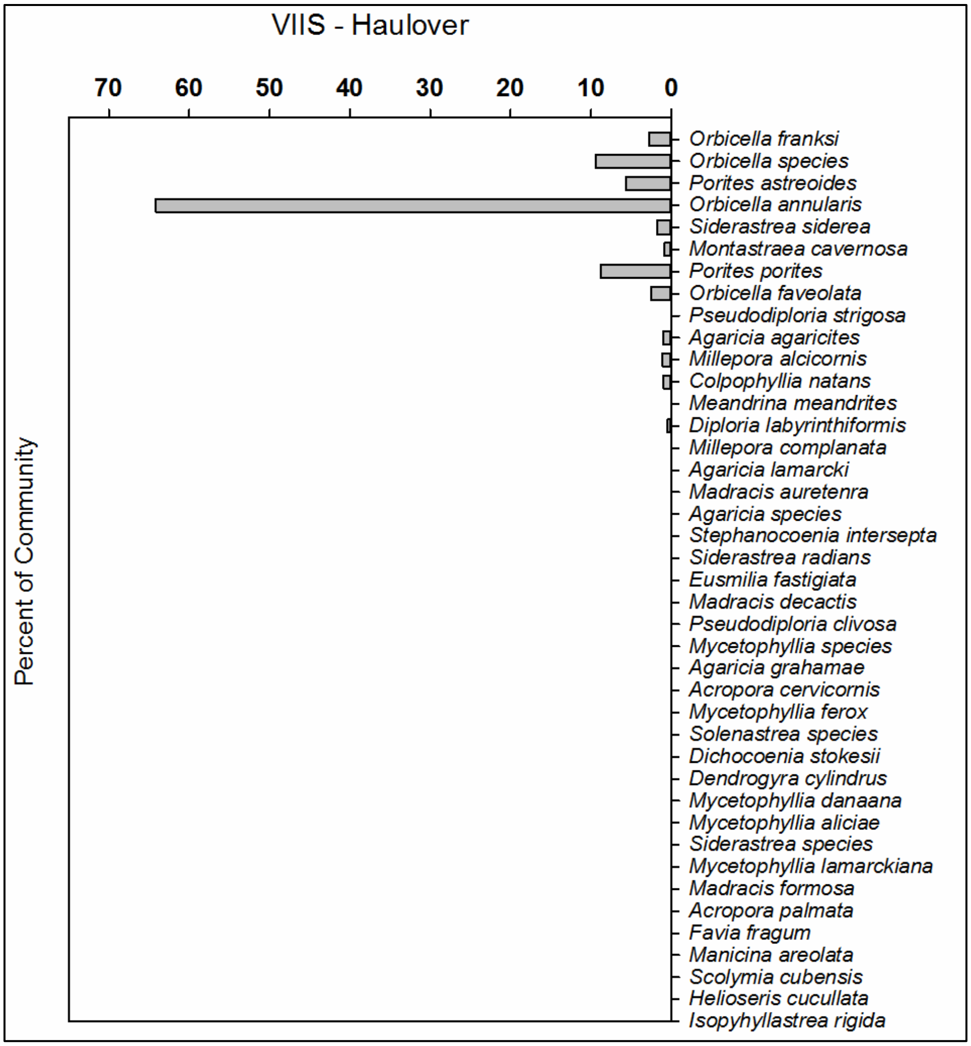

Figure 4.3.1.24. Relative abundance of coral species by benthic cover at the SFCN Haulover site. Coral species are ordered by the rank abundance (descending rightward) according to abundance across the TCRMP shallow water sites outside park areas (26 sites). Note that cover of many species is too low to be resolved on figure. Note that cover of many species is too low to be resolved on figure.

An upper mesophotic reef complex (referred to Mid-shelf reef #1 in Menza et al. 2007), included the TCRMP Meri Shoal site at 30 m water depth. This site was about 2 km southwest of the VICR boundary and was established by TCRMP during the 2005 bleaching event. Meri Shoal bleached (Smith et al. 2016) and saw a subsequent 33% decline in coral cover from a high of 52% in 2005 (Figure 4.3.1.25). This high coral cover mesophotic site was exceptionally dominated by *Orbicella* spp., at 95% relative living stony coral cover, but also supported a total of 23 stony coral species in permanent transects (4.3.1.26). Prior to bleaching in February 2005 this reef was surveyed by remotely operated vehicle along a single transect and evidence of recent mortality on the deeper slopes of the shoal (> 37 m) suggested relative losses of coral cover of 20–60% due to an unknown cause (Menza et al. 2007). This suggests other localized coral mortality events can occur on mesophotic reefs near VIIS-VICR and need further investigation.

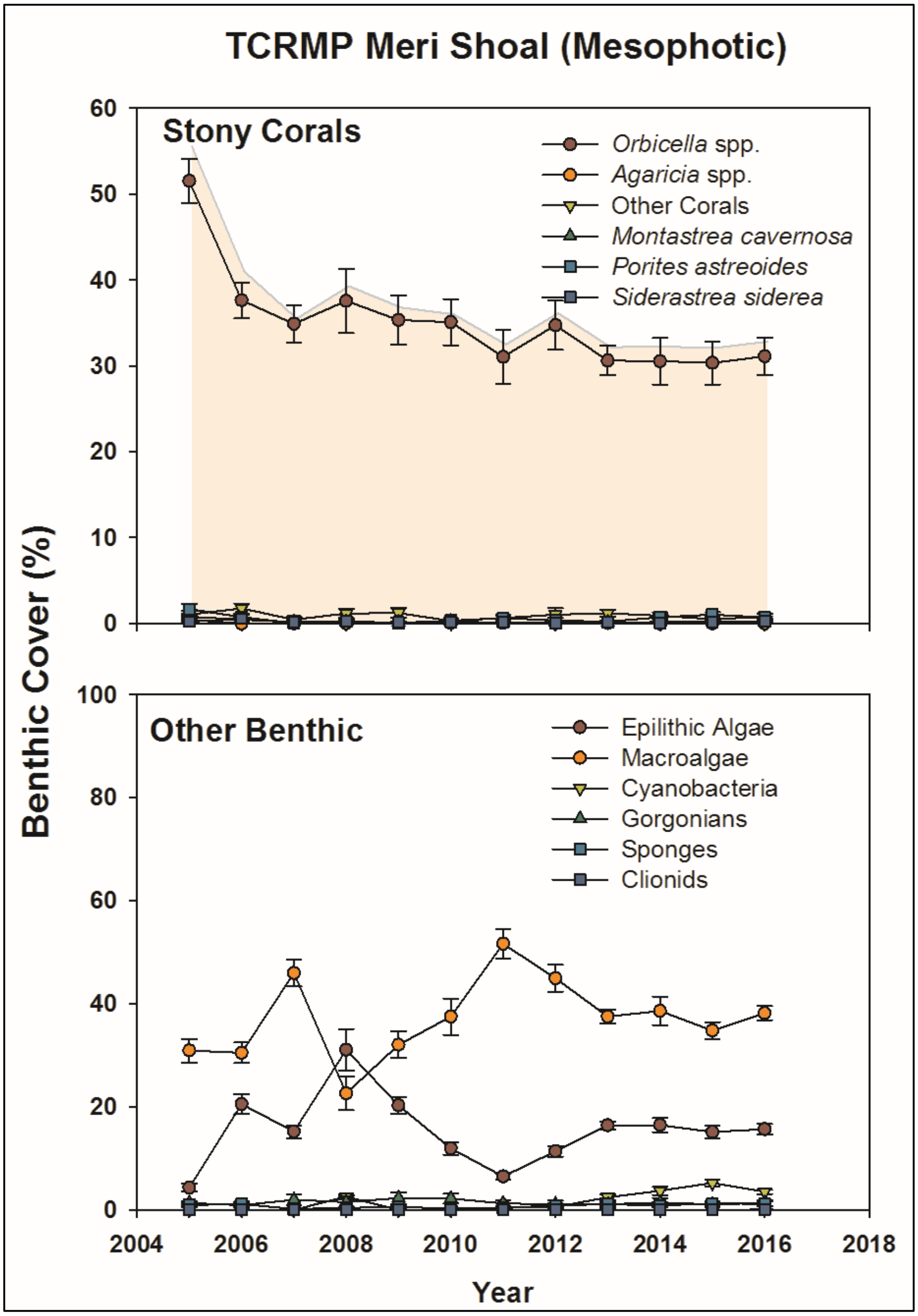

Figure 4.3.1.25. Cover of sessile epibenthic organisms (±SE) through time at the TCRMP Meri Shoal site. (Top) Cover of stony corals. Total coral cover indicated by shaded area, then the most abundant individual species from the full data set indicated as separate markers and lines. (Bottom) Other benthic organisms.

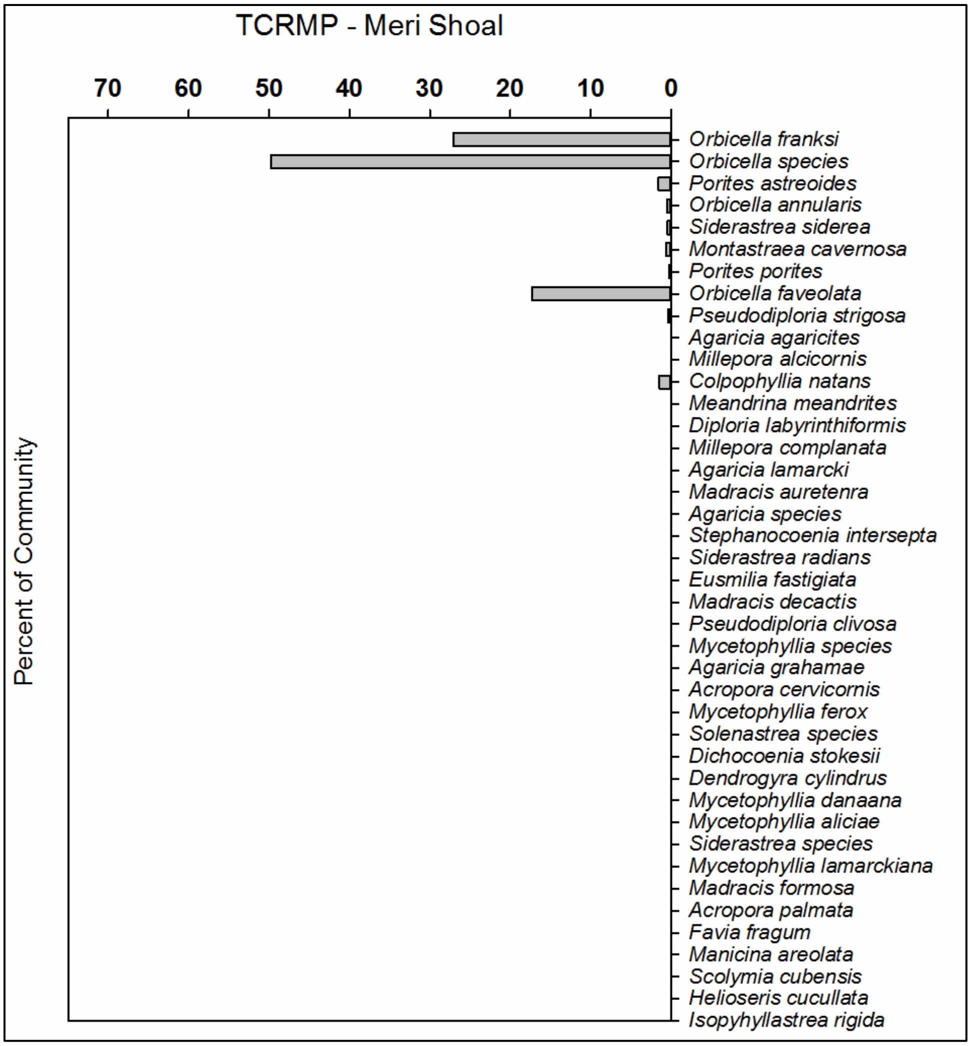

Figure 4.3.1.26. Relative abundance of coral species by benthic cover at the TCRMP Meri Shoal site. Coral species are ordered by the rank abundance (descending rightward) according to abundance across the TCRMP shallow water sites outside park areas (26 sites).

Since 2007, after bleaching and subsequent disease impacts in 2005–2006, mixed assemblage coral reefs sites have shown low rates of recovery (SFCN 2019 and figures referenced above). The Tektite and Mennebeck SFCN sites showed very limited recovery to 2017, but recovered coral cover was still a fraction of what was lost in 2005 and 2006 (SFCN 2019; Figure 4.3.1.11, Figure 4.3.1.15). All other sites had a flat recovery or declined. For example, the mesophotic Meri Shoal site continued to lose coral cover from 2007 onwards (Figure 4.3.1.25), a likely consequence of persistent occurrence of white plague disease in this dense coral community (Smith et al. 2018; Chaves-Fonnegra et al. 2021). Another TCRMP site established in 2009, Coral Bay, also showed declines in coral cover to 2016 (Figure 4.3.1.27). This site is located at the mouth of Coral Harbor, an area with high amounts of terrestrial run off and boating activity (see Section 4.1.1; Gray et al. 2012a), and impacts from pollution may be causing loss of coral cover. TCRMP Coral Bay is already dominated by weedier species that are more resistant to stress, such as *Porites astreoides*, and show faster rates of recover following disturbance, such as *Agaricia* spp. (Figure 4.3.1.28), suggesting previous and ongoing inpacts from pollution.

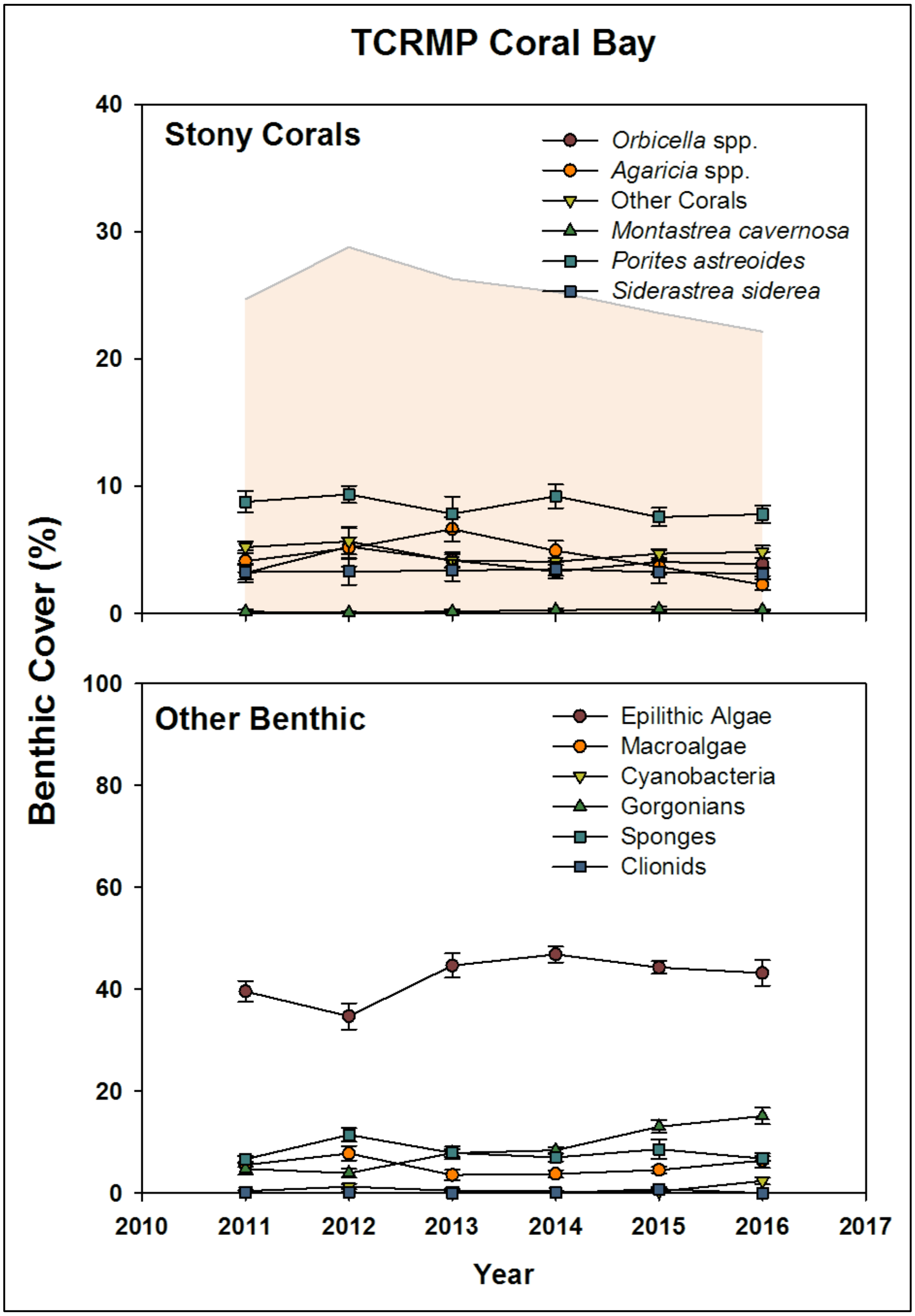

Figure 4.3.1.27. Cover of sessile epibenthic organisms (±SE) through time at the TCRMP Coral Bay site. (Top) Cover of stony corals. Total coral cover indicated by shaded area, then the most abundant individual species from the full data set indicated as separate markers and lines. (Bottom) Other benthic organisms.

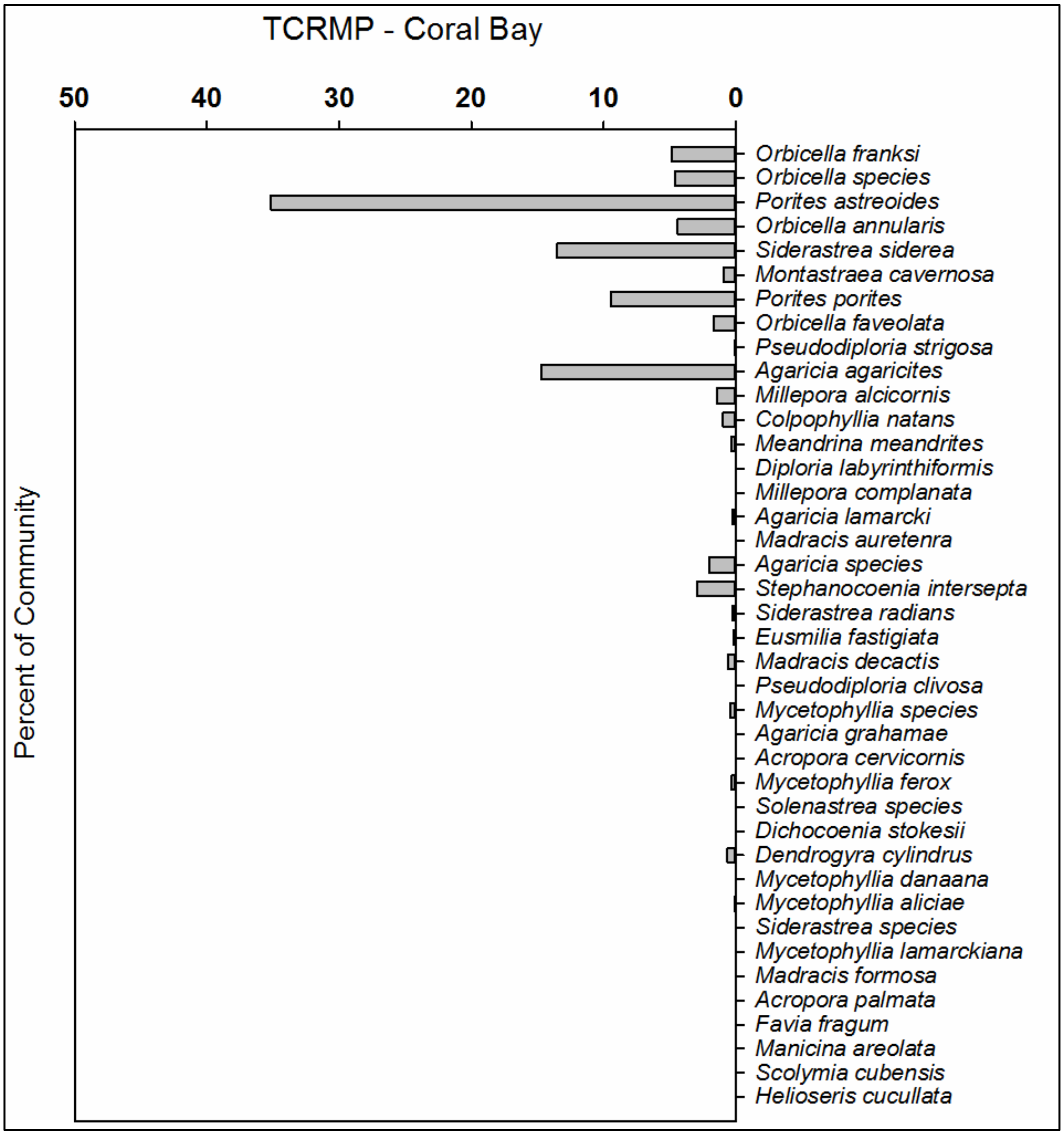

Figure 4.3.1.28. Relative abundance of coral species by benthic cover at the TCRMP Coral Bay site. Coral species are ordered by the rank abundance (descending rightward) according to abundance across the TCRMP shallow water sites outside park areas (26 sites).

Mangrove associated coral communities

A significant feature of VICR is the mangrove communities of Hurricane Hole (NPS 2016) and their exceptional associated coral communities (Yates et al. 2014, Rogers 2017). These mangrove prop roots and the carbonate seafloor support up to 30 stony coral species, including rare forms for shallow water and six of seven ESA listed Caribbean coral species (Rogers 2017). These areas might also serve as refuges from thermal stress and ocean acidification (Yates et al. 2014). However, the mangroves that shade these corals and provide some of the structural habitat were severely damaged in Hurricanes Irma and Maria, September 2017 (Rogers 2019). Stony corals were also heavily damaged and their recovery may depend upon reestablishment of the mangrove canopy and prop root structure and then recruitment back into the embayments (Rogers 2019).

Acropora

Branching elkhorn and staghorn coral populations suffered under the 2005 bleaching event and subsequent diseases and have declined to very low abundance (Muller et al. 2008; Rogers and Muller 2012). Since 2005, diseases (Muller and van Woesik 2014), and physical damage (Bright et al. 2016) continue to impact populations. While there have been some encouraging signs (Muller et al. 2013), it is unclear if upward trends can be sustained with increasing seawater temperatures and local human population pressures.

Distribution of recent coral cover

Although there have been numerous impacts to coral communities in VIIS-VICR over the last 40 years, surveys from the National Coral Reef Monitoring Program show that stony corals are still widely spread over St. John, with some of the highest remaining coral cover sites within park and monument boundaries (Figure 4.3.1.29). These surveys indicate abundant coral reefs and coral communities that are valuable sites for protection and restoration and could serve as sources of larvae for regeneration of degraded areas.

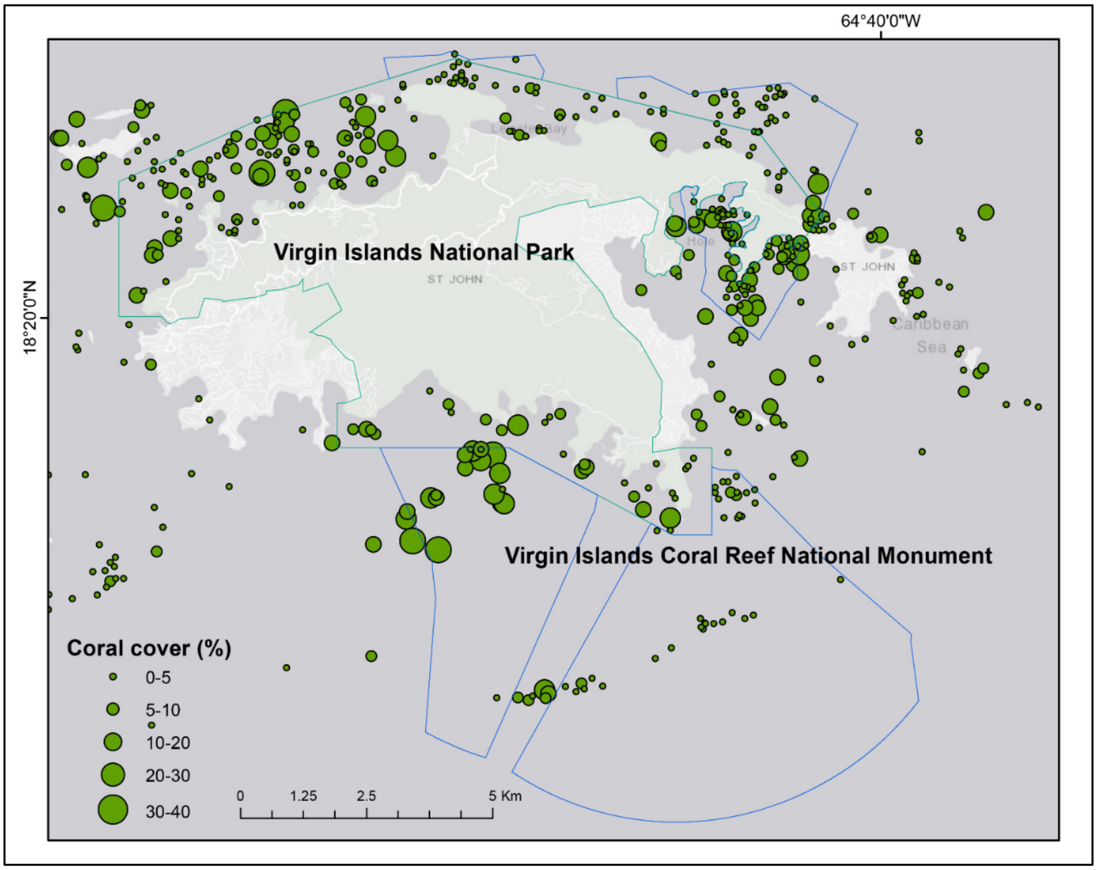

Figure 4.3.1.29. Stony coral cover recorded at randomly selected hardbottom sites around St. John. Data from the National Coral Reef Monitoring Program covering years 2015, 2017, and 2019 (data and map courtesy of Sarah Groves, NOAA, Sep. 4, 2020). Note that surveys are limited to water depths <30 m and so under-represent coral cover found in deeper water, particularly on the south coast of St. John. Map is oriented true north up.

Threats and Stressors

The coral reefs of VIIS-VICR are threatened and stressed by climate change, disease outbreaks, storms, fishing, invasive species, and, for VIIS, land-based sources of pollution.

Thermal stress

The ocean water surrounding VIIS-VICR is warming at a rate of about 0.006°C per year and this is leading to repeated temperatures surpassing coral bleaching thresholds (Figure 4.3.1.30). A clear trend to nearly annual incidences of potential coral thermal stress is evident in this record and is also reported for the wider Caribbean (Muñiz-Castillo et al. 2019), with severe annual bleaching by the mid-twenty first century possible for the wider Caribbean and the USVI under business as usual human emissions scenarios (van Hooidonk et al. 2015). As presented above, warming oceans linked to climate change (Donner et al. 2007) contributed to the 2005 coral bleaching event in the NE Caribbean Sea (Eakin et al. 2010). This event caused a 50–60% decline in living shallow water coral cover in the US Virgin Islands (Miller et al. 2009, Smith et al. 2013) and about a 28% decline in corals deeper than 30 m depth (Smith et al. 2016). Degree heating weeks (DHW) are one of the most common metrics of heat stress on corals. They are calculated as the 12-week rolling sum of temperatures exceeding 1°C over the monthly maximum mean temperature (NOAA 2006), also called the bleaching threshold. DHW values above 4 are associated with the onset of bleaching, and above 8 with the onset of mass bleaching and coral mortality (https://www.coral.noaa.gov/crews-icon/icon.html). The regional estimate of heat stress in 2005 for the USVI based on SST was 10.2 DHW (50km product, NOAA 2019, Figure 4.3.30), with values >8 DHW associated with mass bleaching and widespread mortality of reef building corals (NOAA 2006). Between 1998 and 2019, temperatures at the five SFCN sites around St. John surpassed the regional bleaching threshold (29.5°C) in 17 of 22 years (SFCN 2019) and mirrored the regional trends (Figure 4.3.1.30).

Using reef depth loggers, VIIS coral heat stress was high between 1988 to 2004 (Miller et al. 2009). Site-specific reef depth temperature and estimates of coral thermal stress are presented for the monitoring sites Yawzi, Newfound, Haulover, Tektite, Mennebeck, and a boat anchor damage site, Windspirit (Figures 4.3.1.31–36). Lower impact shallow water thermal stress events also occurred after 2005 but predicted reef level stress values did not exceed 5–6 DHW, which suggests sub-lethal stress for most corals. As mentioned above, in response to thermal stress corals bleached extensively at the monitoring sites in and around VIIS-VICR in 2005 and continuing into 2006 (Figure 4.3.1.10, Figure 4.3.1.11). Lower intensity coral bleaching also occurred sporadically between 2010 and 2014 and in 2016 and 2019. Future global warming as the result of human emissions will likely increase the incidence of heat stress (van Hooidonk et al. 2015) and will continue to be the leading ultimate cause of coral decline in VIIS-VICR (but see the following section on coral diseases and stony coral tissue loss disease).

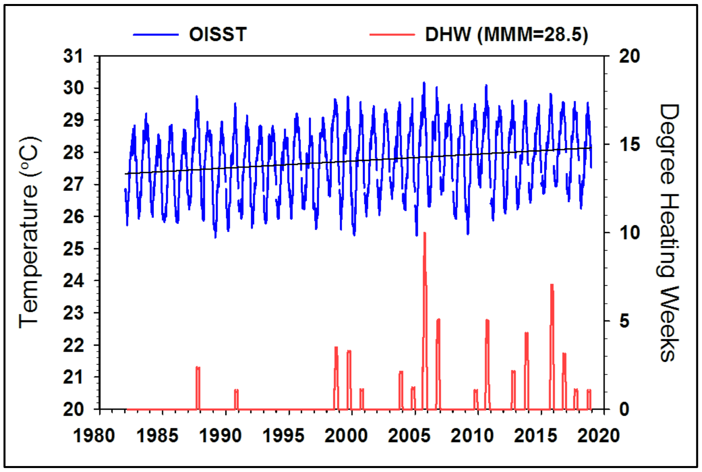

Figure 4.3.1.30. Optimum Interpolation Sea Surface Temperature (OISST; blue line, left vertical axis) and degree heating weeks (red line, right vertical axis) for the USVI. The black line is a linear fit of the OISST data and shows about 0.007°C increase in temperature per year (y = 0.000669/year*x – 25.545). Degree heating weeks (DHW) are calculated as the 12 week rolling sum of temperatures exceeding 1°C over the monthly maximum mean temperature, which is estimated at 28.5°C for the USVI (NOAA 2006). OISST values averaged from coordinates 17.5N/65.5W, 17.5N/64.5W, 18.5N/65.5W 18.5N/64.5W from https://www.ncdc.noaa.gov/oisst; Accessed June 6, 2019.

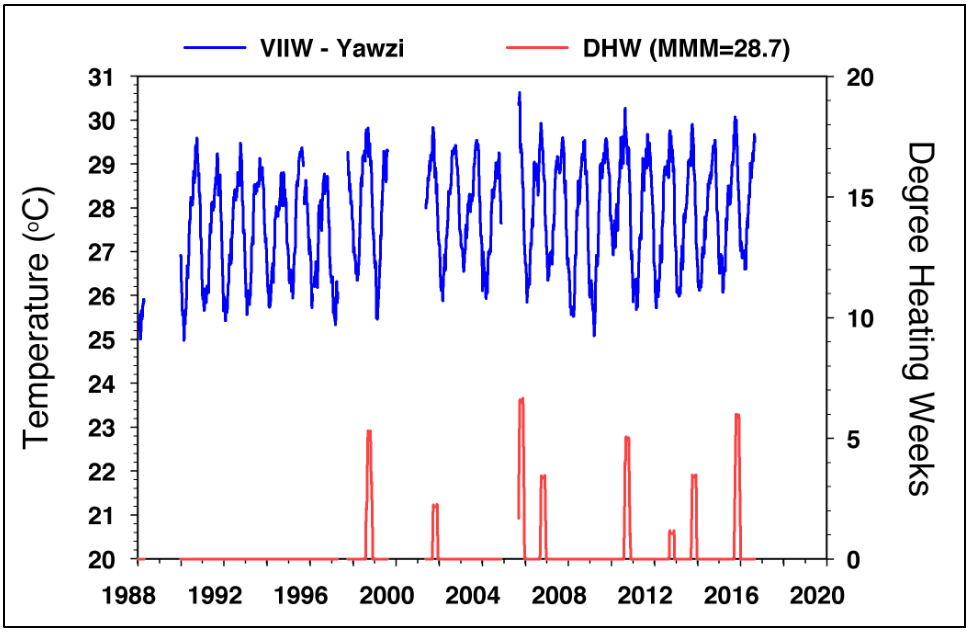

Figure 4.3.1.31. Water temperature (blue line, left vertical axis) and degree heating weeks (red line, right vertical axis) at the SFCN Yawzi site. Note that temperatures were not recorded in the first part of the 2005 thermal stress event, leading to lower estimates of DWH than were actually experienced by corals. Data from the South Florida/Caribbean Inventory & Monitoring Network.

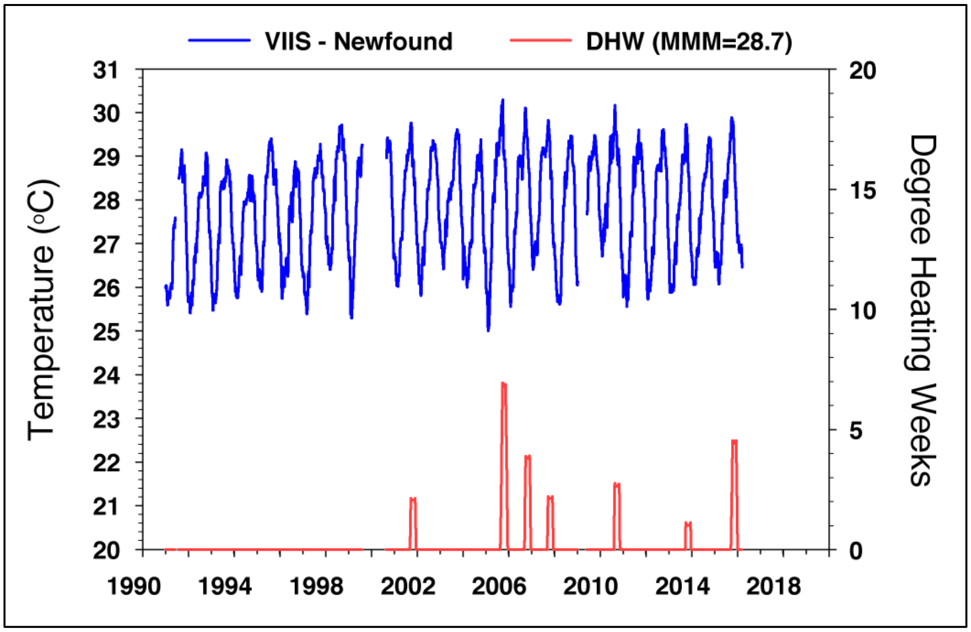

Figure 4.3.1.32. Water temperature (blue line, left vertical axis) and degree heating weeks (red line, right vertical axis) at the SFCN Newfound site Data from the South Florida/Caribbean Inventory & Monitoring Network.

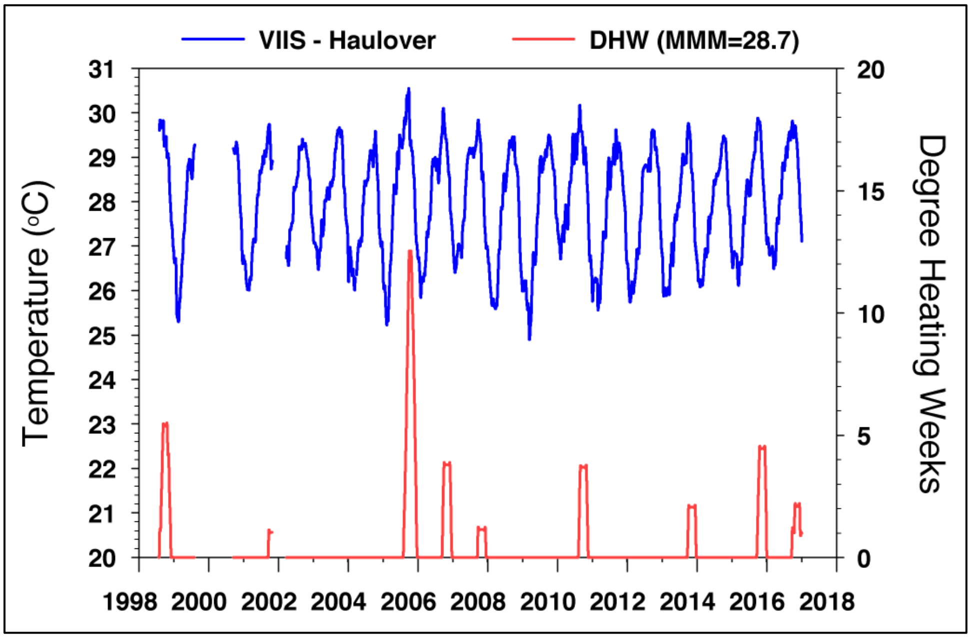

Figure 4.3.1.33. Water temperature (blue line, left vertical axis) and degree heating weeks (red line, right vertical axis) at the SFCN Haulover site. Data from the South Florida/Caribbean Inventory & Monitoring Network.

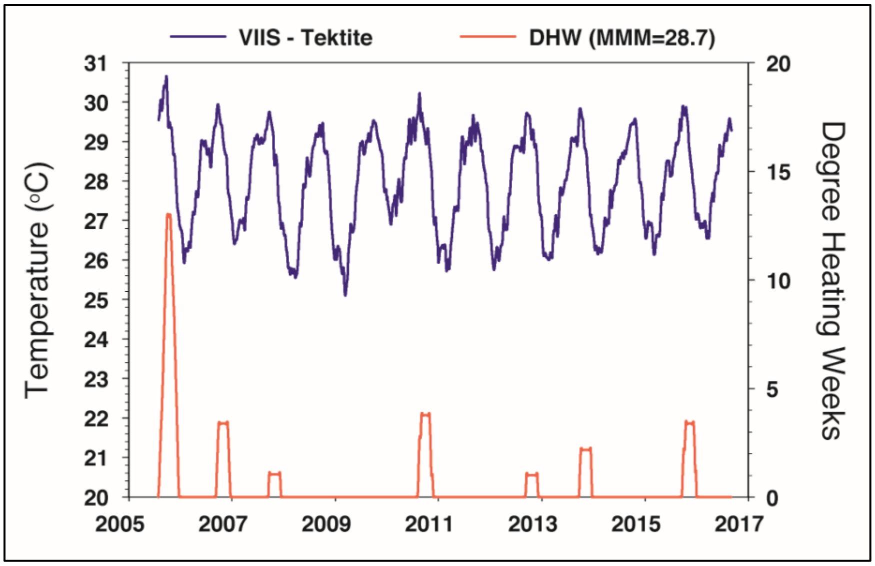

Figure 4.3.1.34. Water temperature (blue line, left vertical axis) and degree heating weeks (red line, right vertical axis) at the SFCN Tektite site. Data from the South Florida/Caribbean Inventory & Monitoring Network.

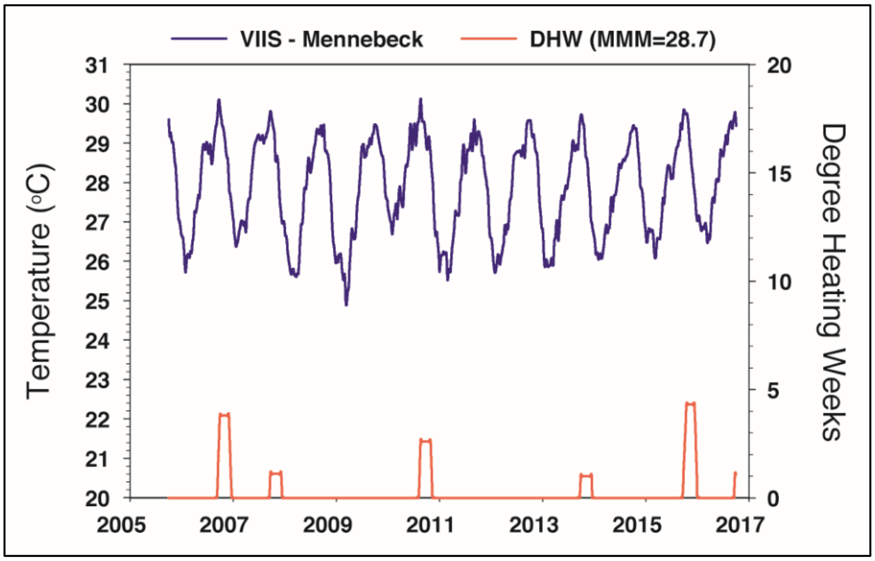

Figure 4.3.1.35. Water temperature (blue line, left vertical axis) and degree heating weeks (red line, right vertical axis) at the SFCN Mennebeck site. Data from the South Florida/Caribbean Inventory & Monitoring Network.

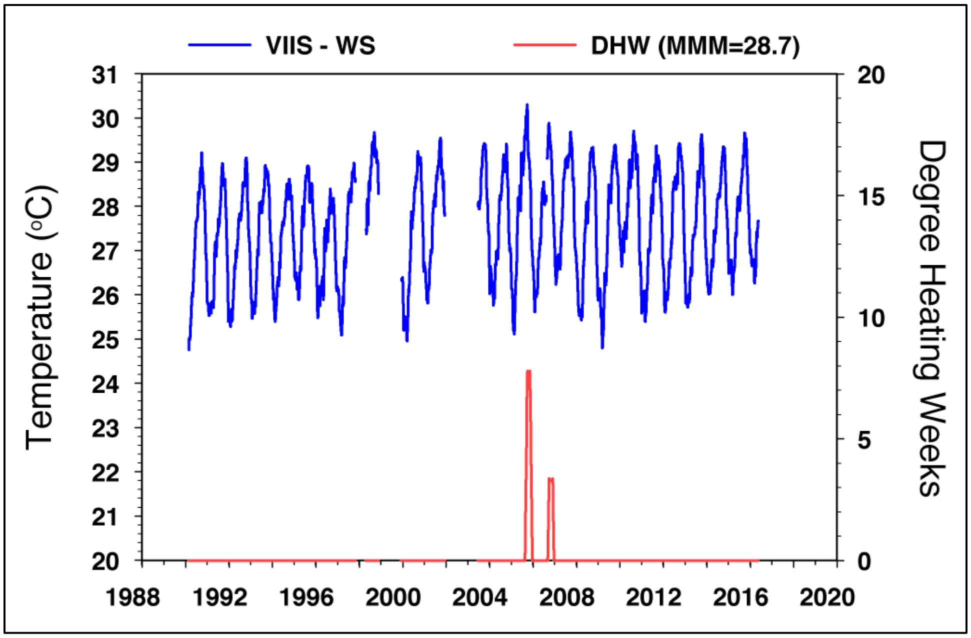

Figure 4.3.1.36. Water temperature (blue line, left vertical axis) and degree heating weeks (red line, right vertical axis) at the SFCN Winspirit site. This is the site of reef structural damage from a dragged cruise ship anchor (depth = 12m; coordinates: 18.365602, −64.76181; Rogers and Garrison 2001). Data from the South Florida/Caribbean Inventory & Monitoring Network.

Coral disease

Coral diseases also pose a continued stress to corals in VIIS-VICR. Initial outbreaks of disease occurred during the white band epizootics that affected elkhorn and staghorn corals as early as the 1970s in St. Croix (Gladfelter 1982), with the disease noted in VIIS by 1984 (Beets et al. 1986) and is likely to have caused degradation of large stands of *A. palmata* inside the park (Rogers et al. 2003). In the 1990s other diseases were being noted on massive head corals with greater frequency, including black band disease (Edmunds 1991) and white plague (Rogers and Miller 2006). White - pox disease became to be a major influence of elkhorn populations by the 2000s (Rogers et al. 2008; Muller and van Woesik 2014). The 2005 thermal stress and coral bleaching event contributed to unprecedented white disease outbreaks (possibly white plague) on reef-building star corals (Miller et al. 2006; Miller et al. 2009; Smith et al. 2013) and contributed to higher white-pox prevalence on *A. palmata* and a higher area of affected tissue on bleached colonies (Muller et al. 2008).

Furthermore, Stony Coral Tissue Loss Disease (Precht et al. 2016; Walton et al. 2018) was first reported from St. Thomas in January 2019. It has subsequently spread eastward to St. John (February 2020) and into VIIS (March 2020) (Lee Richter, NPS, 2020, pers. obs.; https://www.vicoraldisease.org/sctld-disease-tracking). This disease most severely affects brain and star corals (genera: *Dendrogyra*, *Dichocoenia*, *Diploria*, *Eusmilia*, *Meandrina*, *Montastraea*, *Orbicella*, *Pseudodiploria*; from Walton et al. 2018; Muller et al. 2020; M. Brandt, unpub. data for USVI). Unlike most other diseases, whole colony mortality (loss of coral genotype from the reef) is the typical outcome for highly susceptible species (Sharp et al. 2020). The initial site of occurrence at St. Thomas, Flat Cay, lost over half of its coral cover between January and May 2019 (TCRMP, unpub. data). By June 2020, the disease was confirmed at many locations around VIIS-VICR including Johnson's Reef and had extended past St. John into the nearby British Virgin Islands. Evidence from Florida suggests severe impacts on the coral community unless aggressive intervention is implemented and sustained. Interventions are being conducted by volunteer research divers under the guidance of the NPS and a multi-agency VI Coral Reef Advisory Group within selected sites of VIIS-VICR. In most treatments, amoxicillin mixed with a paste carrier is applied topically. Results have been encouraging in halting loss of reef biodiversity at treated sites (M. Brandt 2020, personal communication), but the treatments require extensive human resources.

Storms

Storms have also been a driver of coral cover loss in the VIIS (Edmunds and Witman 1991, Rogers et al. 1991). Presumably, the deeper coral communities of VICR are more buffered from storm impacts by their depth. Storm magnitude is likely to increase with climate change (Knutson et al. 2015) and climate change may already be producing wetter storms, including the major Hurricanes Irma and Maria that impacted the USVI in 2017 (Patricola and Wehner 2018). Many modern reef coral communities in VIIS-VICR may be less impacted by storms because they have already been so degraded and susceptible colonies have been killed (Edmunds 2019). However, branching and columnar species, such as threatened *Acropora* spp. and *Dendrogyra cylindrus*, may continue to have inhibited recovery due increasing storm impacts.

Fishing

Fishing has long been implicated as a factor impacting the coral reefs of St. John (Randall 1963, Beets and Rogers 2000). While no-take fisheries closures and fisheries restrictions have been implemented as part of VIIS-VICR management (e.g., VIIS enacted as a no-take fishery zone in 2003; National Park Service 2016), there has not been substantial recovery (Rogers et al. 2008; Friedlander et al. 2013). Possible reasons include insufficient time to see recovery or recovery is compromised by other factors, such as extirpation of spawning stock, Allee effects, and poaching. Changes in fish community structure due to fishing, pollution, of habitat loss can have negative impacts on coral reefs. In some cases large herbivorous fish species, such as blue parrotfish (*Scarus coeruleus*), midnight parrotfish (*Scarus coelostinus*) and rainbow parrotfish (*Scarus guacamaia*) that were seen in Lameshur Bay before 1980 (Randall 1963; Earle 1971) are no longer present or are exceedingly rare (Friedlander et al. 2013). This and a general decline in herbivorous fishes (Beets and Rogers 2000) may be contributing to higher macroalgae cover on coral reefs (Edmunds 2019), even in areas of VIIS with very low plant nutrients (Rogers and Miller 2006).

Pollution

Land-based sources of pollution in the form of enhanced run-off of loose, fine-grained tropical soils are a threat to VIIS. While most of the submerged waters of the park are adjacent to land that is under park management and, thus, potentially less impacted by terrigenous sediments (but see Edmunds and Gray 2014), other areas are in or near developing watersheds (e.g., Fish Bay and Coral Bay) or are connected to more distant upland development by ephemeral streams (Hawksnest Bay) and have seen impacts from run-off (Hubbard et al. 1987; Rogers and Zullo 1987; Gray et al. 2008). As noted above, degradation in Fish Bay and Coral Bay reefs may be the result of heavy development in the watershed. In addition to land-based sources of pollution, other localized pollutants can impact coral communities, including chemicals introduced into the water through recreational activities. Pollutants, such as sunscreens, could be particularly important in areas of VIIS that have heavy visitation by waders. Benzophenones likely associated with sunscreens were detected at levels of 75–95 ppbillion around *A. palmata* spurs in Hawksnest and 1.4 ppmillion near the Trunk Bay snorkel trail, whereas no benzophenones were detected in the much less frequently visited Caneel Bay (Downs et al. 2016). Work to understand potential reproductive effects on corals within these locations is ongoing (C. Woodley 2021, personal communication), and is an area of future needed research.

Data Needs and Gaps

Corals in VIIS are exceptionally well monitored in both time and space relative to most coral reefs globally. These efforts should be prioritized and maintained. The data sets of Peter Edmunds are exceptional for their detail (e.g., demographics, recruitment, physical oceanography) and the information they provide on drivers of coral trajectories on selected study plots. However, they are managed by one individual and there is a risk of failure to sustain this unique ecological data set. The park should seek ways to ensure the continuity of core data streams in the event that Edmunds cannot. In addition, there are no established longitudinal (fixed site) long-term monitoring data for VICR. The deeper coral reefs in VICR (Figure 4.3.1.1) may have different reef composition and responses to stressors, if the TCRMP Meri Shoal site detailed above is any indication. At least one fixed site station on a coral reef, such as the southern mid-shelf complex, would be a valuable addition to determining trajectories of corals and drivers of change.

Overall Condition

Based on historical condition of coral reefs in VIIS, the condition of coral reefs presently is moderate to poor and is trending downward (Table 4.3.1.2), with most increases in coral cover due to more ephemeral, weedy species and not major reef building species, such as *Orbicella* spp. Coral cover continues to decline and macroalgae now compromise the major benthic coverage category for sessile epibenthic organisms. The incidence of bleaching and disease is increasing on corals in and around VIIS-VICR.

Table 4.3.1.2. Graphical summary of status and trends for coral reefs within the framework category Marine Invertebrates, including rationale and reference condition.

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Stony Corals	Coral Cover	⬇	Coral cover has declined at all monitoring sites in and around VIIS-VICR over the last two decades
	Coral Disease and Bleaching	⬇	The incidence of coral bleaching events and coral disease epizootics has increased and is likely to continue increasing in the near future (e.g., introduction of Stony Coral Rapid Tissue Loss Disease)
	Seawater Temperature	⬇	Between 2004 and 2017 seawater temperatures have exceeded site-specific bleaching thresholds 6–10 times in conjunction with general warming of the Caribbean

Source(s) of Expertise

- Caroline S. Rogers, Research Biologist, United States Geological Survey
- Peter J. Edmunds, Professor, California State University Northridge
- Michael Feeley, South Florida Caribbean Network, National Park Service
- William J. Miller, South Florida Caribbean Network, National Park Service
- Robert Waara, South Florida Caribbean Network, National Park Service

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4.4. Marine Vertebrates

4.4.1. Reef Fish

Description

Decades of exploitation and habitat degradation has led to establishing fishing regulations and marine protected areas across the United States Virgin Islands (Bryan et al. 2013). USVI fishery regulations include year-round prohibition (e.g., Nassau and goliath grouper), seasonally permitted (e.g., mutton and lane snapper July 1–March 31), size limited (e.g., 12 in total length minimum for yellowtail snapper), and gear restrictions (e.g., tarpon and bonefish catch and release with hook and line only). Virgin Islands National Park (VIIS) and Virgin Islands Coral Reef National Monument represent examples of a governmental effort to further protect valuable areas from fishing and other local anthropogenic pressures. Virgin Islands National Park was established in 1962. All commercial fishing is prohibited, while other fishing methods such as pots or traps of conventional Virgin Islands design (not larger than five feet) are permitted (DPNR 2018). In VIIS, while highly regulated, the extraction of baitfish, Caribbean spiny lobster, and queen conch are permitted. All fishing is prohibited in VICR, except for baitfish, which needed to be authorized by the National Park Service (DNPR 2018). While these areas share some regulations to protect their habitats (e.g., anchoring prohibition), fishing regulations are further restricted in VICR compared to VIIS.

To evaluate the current status and effectiveness of regulations within VIIS and VICR, temporal analysis of long-term data is crucial. A multiagency effort, encompassing National Park Services (NPS), National Oceanic Atmospheric Administration, and the University of Virgin Islands (UVI), here referred to as National Coral Reef Monitoring Program (NPS-NCRMP-UVI), has conducted several surveys since 2001. This report focuses on reef fish communities, for which density, biomass, and richness are indicators of past and current status. Years covered by the datasets considered in this analysis include the following: 2001–2012 (data provided by Jeremiah Blondeau, NOAA), 2013–2019 (NOAA NCCOS 2018).

Data and Methods

Surveys used in this report were conducted on hardbottom habitats, including aggregated reef (AGRF), bedrock (BDRK), hardbottom (HARD), patch reef (PTRF), pavement (PVMT), and scattered coral/rock (SCR) between 2001–2019 using two different methodologies (Table 4.4.1.1). Data sets are available from the NOAA National Centers for Environmental Information at https://data.noaa.gov/datasetsearch/. Surveys from 2001–2015 were carried out along 25 m x 4 m belt transects (100 m^2). During each survey, the number of individuals by species and length were recorded from which we can obtain density (ind. 100 m^{-2}) and richness (the number of species). Fish surveys conducted in 2017 and 2019 followed Reef Visual Census (RVC, Bohnsack and Bannerot 1986) within a 15 m diameter imaginary cylinder (~177 m^2). Reef visual census includes stationary counts rather than counts along the transect and the order of fish parameter collection (first round species list and later number of individuals and length). Fish density for 2017 and 2019 is expressed as the number of individuals per sampling unit. Data (individual fish length) from both methods were used to estimate individual weight using weight (W) length (L) relationships ($W=aL^b$, “a” and “b” are species-specific morphometric coefficients) obtained from (Bohnsack and Harper 1988). Few exceptions (less than 1% of individuals) in which equations from similar species (e.g., *Hypoplectrus* sp.) were used. Biomass (g 100 m^{-2}) was calculated using individual weights by sampling area for belt transect. Biomass for 2017 and 2019 surveys is expressed as g per sampling unit. Given the methodological differences between the two data sets, all graphical and statistical analyses are separated from 2001–2015 and 2017–2019.

Table 4.4.1.1. Number of surveys conducted in Virgin Islands National Park (VIIS) and Virgin Islands Coral Reef National Monument (VICR) by year and method from 2001 to 2019.

		Number of Surveys	
Year	**Method**	**VICR**	**VIIS**
2001	Belt transect	3	12
2002	Belt transect	10	25
2003	Belt transect	37	22
2004	Belt transect	40	27
2005	Belt transect	51	19
2006	Belt transect	49	18
2007	Belt transect	54	15
2008	Belt transect	51	11
2009	Belt transect	51	22
2010	Belt transect	53	15
2011	Belt transect	53	11
2013	Belt transect	44	54
2015	Belt transect	43	46
2017	RVC	37	56
2019	RVC	50	57

Besides total density, biomass, and richness, we also analyzed these parameters by trophic level as follows: (H = herbivore, I = invertivore, Pl = planktivore, P = piscivore). Herbivore included all species of scarids (family Scaridae), acanthurids (family Acanthuridae), and other species such as the Bermuda chub (*Kyphosus sectratix*). Invertivores comprised many reef fishes within families Haemulidae, Lutjanidae, and Pomacanthidae, whereas fewer planktivorous species included the blue chromis (*Chromis cyanea*) and creole wrasse (*Clepticus parrae*). Piscivores contained large and medium-sized predators such as barracuda (*Sphyraena barracuda*), multiple species of serranids (family Serranidae), and jack (family Carangidae).

For statistical reasons, large and mobile shark observations (family Carcharinidae and Ginglymostomatidae) were removed from the analysis. Similarly, herrings (*Jenkinsia* spp.) that form large fish schools were not considered because it skews density data distributions. Here we report the R^2 values from linear models used to evaluate temporal trends from 2001–2015. We use one-way

ANOVA to compare between 2017–2019. Dispersion in all graphs and text descriptions is expressed as standard error.

Reference Conditions/Values

Reef fish research in VIIS began with Dr. Jack Randall. He began recording coral reef observations and reef fish as early as the late 1950s and publishing his results in the 1960s, including his masterwork on feeding habits of Caribbean reef fishes (Randall 1967). Since then, many studies and monitoring efforts have targeted reef fish communities, including the National Marine Fisheries Service's Tektite Program, an underwater laboratory setup in Lameshur Bay in 1969–1970. At least nine studies related to reef fish ecology were conducted through the Tektite Program, including Dr. Sylvia Earle's study of herbivores' effects on marine plants (Collette 1996). However, although valuable, the data collected during the Tektite Program is spatially restricted and not directly comparable to larger-scale surveys of reef fish communities.

In the 1990s and early 2000s, several research works indicate noticeable fish decline resulting from fishing (Appeldoorn et al. 1992; Beets 1996; Rogers and Beets 2001). However, in an analysis of reef fish data collected inside and outside VIIS and VICR boundaries between 1988 and 2000, no differences were observed between number of species and biomass of reef fish within and outside of VIIS boundaries (Beets and Friedlander 2003). The same analysis also revealed that several species declined in abundance and frequency during the study period. Rogers et al. (2008) presented a history of fisheries in the Virgin Islands and trends in reef fish assemblages from 1989–2006. Declines in reef fish communities, attributed to fishing pressure, likely occurred decades before the monitoring program began in 1989, so the baseline for trend analyses may be inherently low for several species.

Pittman et al. (2014) presented trends for several metrics for reef fish populations inside NPS boundaries and adjacent areas. The data were collected from 2002 through 2011 and revealed no significant increases in 15 fish metrics within VIIS and VICR. Adult parrotfish density and redband parrotfish (*Sparisoma aurofrenatum)* biomass decreased significantly within VIIS. Total fish biomass, herbivore biomass, adult grouper density, coney grouper (*Cephalopholis fulva)* biomass, and ocean surgeonfish (*Acanthurus bahianus)* biomass decreased significantly within VICR.

Current Condition and Trend

Virgin Islands National Park

Between 2001–2015, the average total fish density fluctuated greatly from 325.9 ± 43.8 ind. 100 m^{-2} in 2002 to as low as 125.1 ± 16.1 ind. 100 m^{-2} in 2010 with a slight (lm, YEAR, $R^2 = 0.01$, $p = 0.050$) decline over the study period (Figure 4.4.1.1 A). 2017–2019 averaged 245.7 ± 23.1 ind. 100 m^{-2} of total fish density with no difference between the years (Figure 4.4.1.1 B). Total fish biomass displayed no temporal trends (2001–2015) or differences between 2017–2019 (Figure 4.4.1.1 C&D). On the contrary, with an average of 21.5 ± 0.4 species per survey, richness showed a significant decline over the years (lm, YEAR, $R^2 = 0.04$, $p < 0.001$, Figure 4.4.1.1 E) that was more evident when comparing 2017 with 32.1 ± 1.1 species) to 2019 with 26.8 ± 1.35 species (Figure 4.4.1.1 F).

Fish density of herbivores and invertivores declined between 2001–2015, whereas planktivores and piscivores did not show any trend (Figure 4.4.1.2). We observed an approximated 50% reduction in herbivore density from 2017 (43.1 ± 3.5 ind. sampling unit^{-1}) to 2019 with 22.3 ± 2.1 ind. sampling unit^{-1} (Figure 4.4.1.2 B). Similarly, despite large yearly fluctuation, herbivorous fish biomass decreased between 2001 to 2015, while biomass of invertivores and planktivores did not change over time (Figure 4.4.1.3 A-F). Biomass of piscivorous fish increased approximately sixfold from 2001 (367. 0 ± 181 g. 100 m^{-2}) to 2015 with 2304.9 ± 1033.1 g. 100 m^{-2} (Figure 4.4.1.3 G&H).

While collectively herbivore density decreased over time, neither parrotfish (lm, $R^2 = 0.001$, $p = 0.651$) nor surgeonfish (lm, $R^2 = 0.006$, $p = 0.217$) showed changes over time between 2001 and 2015. Analysis of fish density by species revealed no general trend of individuals by species of scarids (Figure 4.4.1.4). However, the decline of herbivore biomass can be partially explained by a decline in the parrotfish biomass from 2001 to 2015 (lm, $R^2 = 0.02$, $p = 0.012$). The two most common parrotfish species, *Scarus iseri* (lm, $R^2 = 0.08$, $p < 0.001$) and *Sparisoma aurofrenatum* (lm, $R^2 = 0.06$, $p < 0.001$) showed evidence of biomass lost over the years. Density and biomass of surgeonfishes, another important family of Caribbean herbivorous fishes, did not change from 2001–2015. The significant increase of piscivorous fish biomass could be attributed to the presence of large groups of jacks (family Carangidae) in 2015, averaging 2747 g 100m^{-2}, yet not statistically significant (lm, $R^2 = 0.04$, $p = 0.090$).

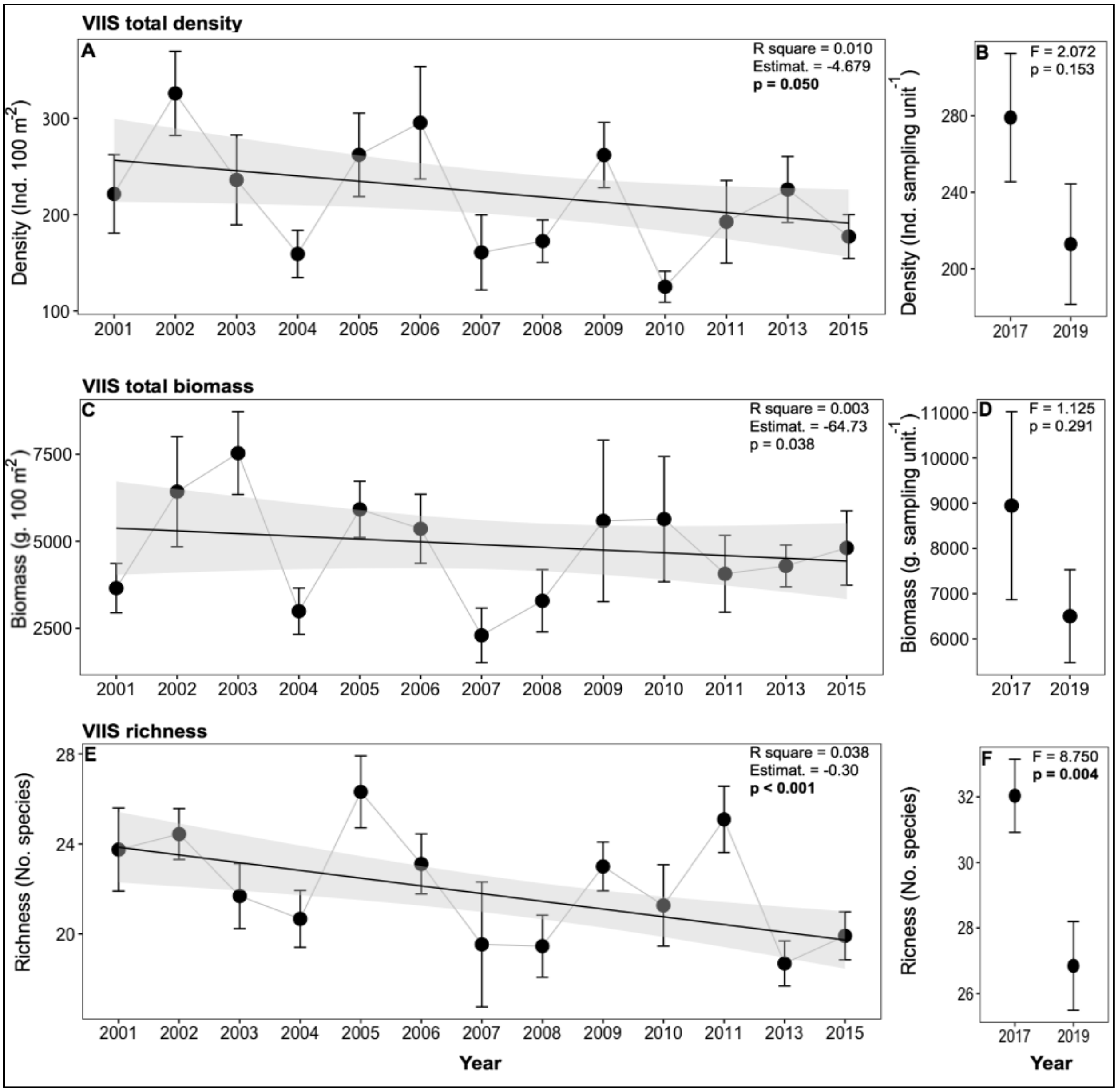

Figure 4.4.1.1. Density, biomass, and richness of reef fish in Virgin Islands National Park from 2001 to 2019. Surveys from 2001 to 2015 were conducted using belt transect, while surveys in 2017 and 2019 used Reef Visual Census. Mean ± SE. Bold letters indicate statistical significance. Data source: NPS-NCRMP-UVI program

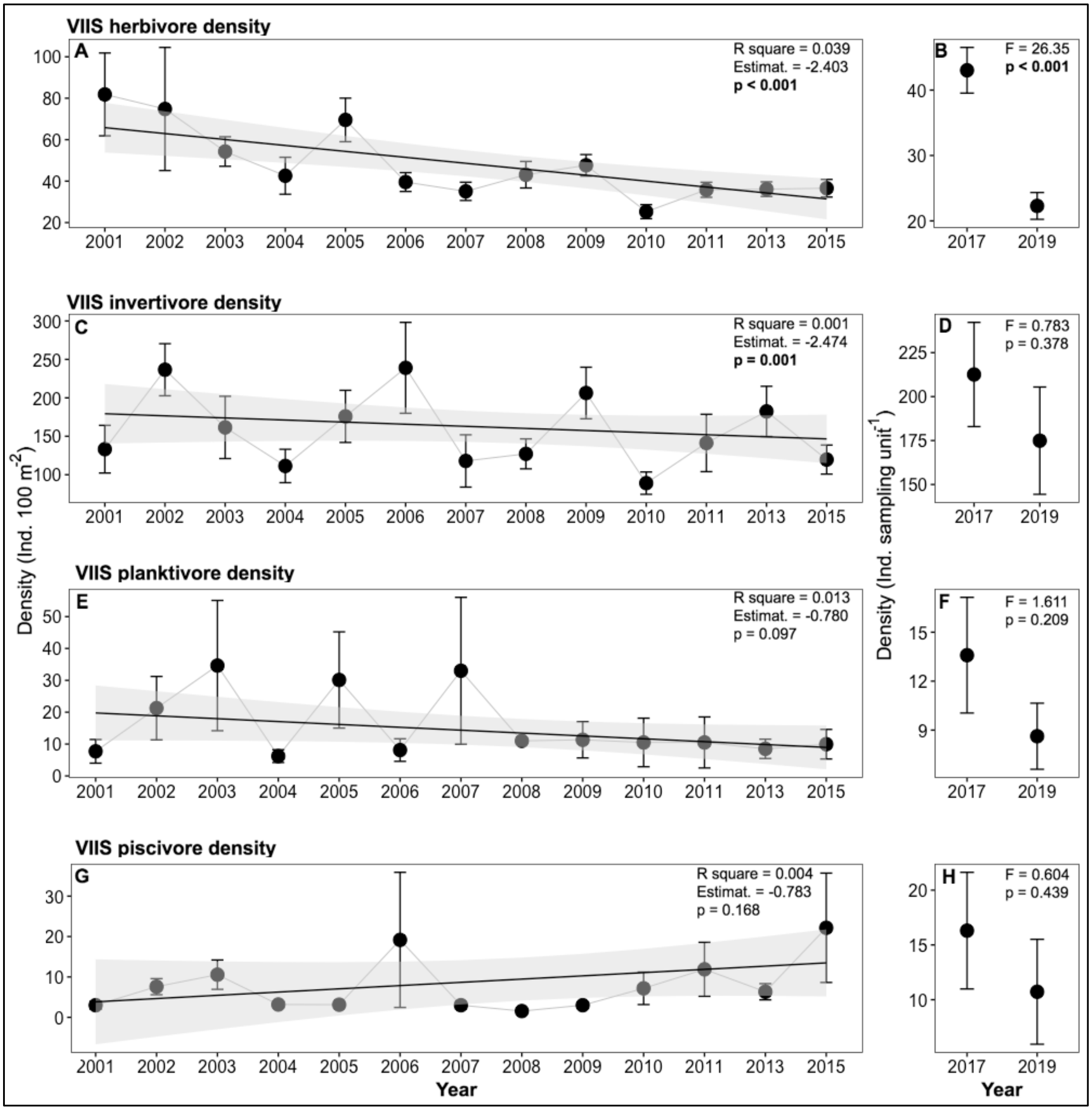

Figure 4.4.1.2. Fish density by trophic group: A&B – herbivores, C&D – invertivores, E&F – planktivore, and G&BH – piscivore in Virgin Islands National Park from 2001 to 2019. Surveys from 2001 to 2015 were conducted using belt transect, while surveys in 2017 and 2019 used Reef Visual Census. Mean ± SE. Bold letters indicate statistical significance. Data source: NPS-NCRMP-UVI program

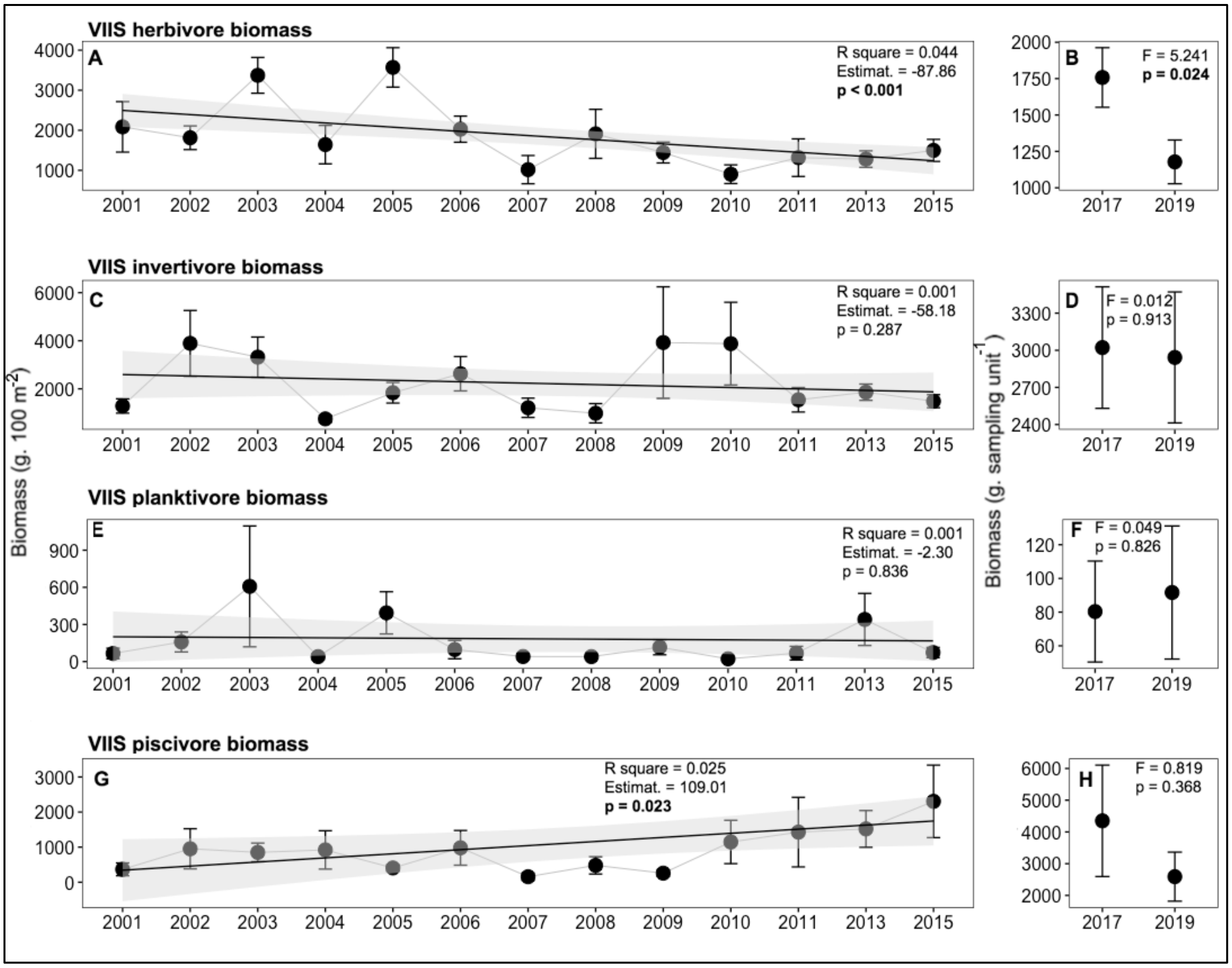

Figure 4.4.1.3. Fish biomass by trophic group: A&B – herbivores, C&D – invertivores, E&F – planktivore, and G&H – piscivore in Virgin Islands National Park from 2001 to 2019. Surveys from 2001 to 2015 were conducted using belt transect, while surveys in 2017 and 2019 used Reef Visual Census. Mean ±SE. Bold letters indicate statistical significance. Data source: NPS-NCRMP-UVI program

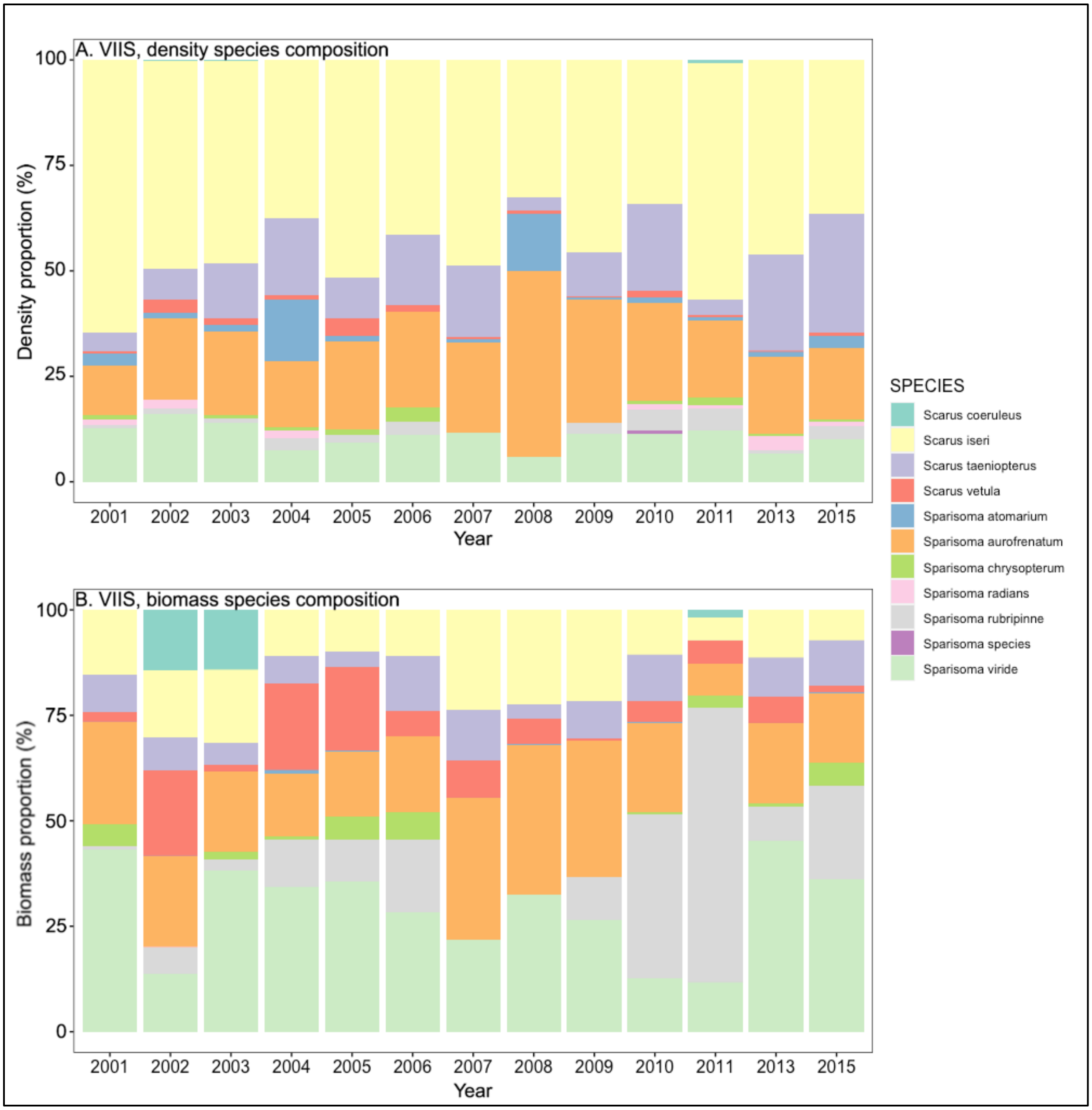

Figure 4.4.1.4. Species composition, as percentages of density (A) and biomass (B) of parrotfishes (family Scaridae) in Virgin Islands National Park from 2001 to 2015. Data source: NPS-NCRMP-UVI program

Virgin Islands Coral Reef National Monument

In VICR, total fish density and total biomass averaged 223.9 ± 7.5 ind. 100 m^{-2} and 6394.5 ± 327.0 g. 100 m^{-2}, respectively, and declined from 2001 to 2015 (Figure 4.4.1.5 A&B), corroborating the biomass results reported by Pittman et al. 2014. Fish richness also decreased during 2001–2015 (Figure 4.4.1.5 E), averaging 17.6 species per survey in 2013, three species less than 2007, the lowest richness year (this report and Pittman et al. 2014). No differences in density, biomass, or richness were observed between 2017 and 2019, RVC survey methodology (Figure 4.4.1.5 B, D, and F). The analysis of fish density by trophic level revealed that, except piscivores, all other trophic groups' density decreased between 2001–2015 (Figure 4.4.1.6 A-H). However, only the biomass of herbivorous fish decreased over the years (Figure 4.4.1.7 A-H), which corresponds with the findings by Pittman et al. 2014. Neither density nor biomass by trophic groups showed differences between 2017 and 2019.

Fish density of the two most important herbivorous fish families in the Caribbean, parrotfish (31.5 ind. 100 m^{-2}) and surgeonfish (31.5 Ind. 100 m^{-2}), decreased from 2001 to 2015 (parrotfish, lm, $R^2 = 0.02$, $p = 0.003$, surgeonfish, lm, $R^2 = 0.02$, $p = 0.002$). Likewise, biomass of both families decreased over time (parrotfish, lm, $R^2 = 0.08$, $p = 0.004$, surgeonfish, lm, $R^2 = 0.02$, $p = 0.002$). As in VIIS, we did not find evidence of changes in density or biomass for specific major species of herbivores (Figure 4.4.1.8), except for ocean surgeonfish (*Acanthurus bahianus*). Pittman et al. (2014) reported a similar negative trend for the *Acanthurus bahianus*.

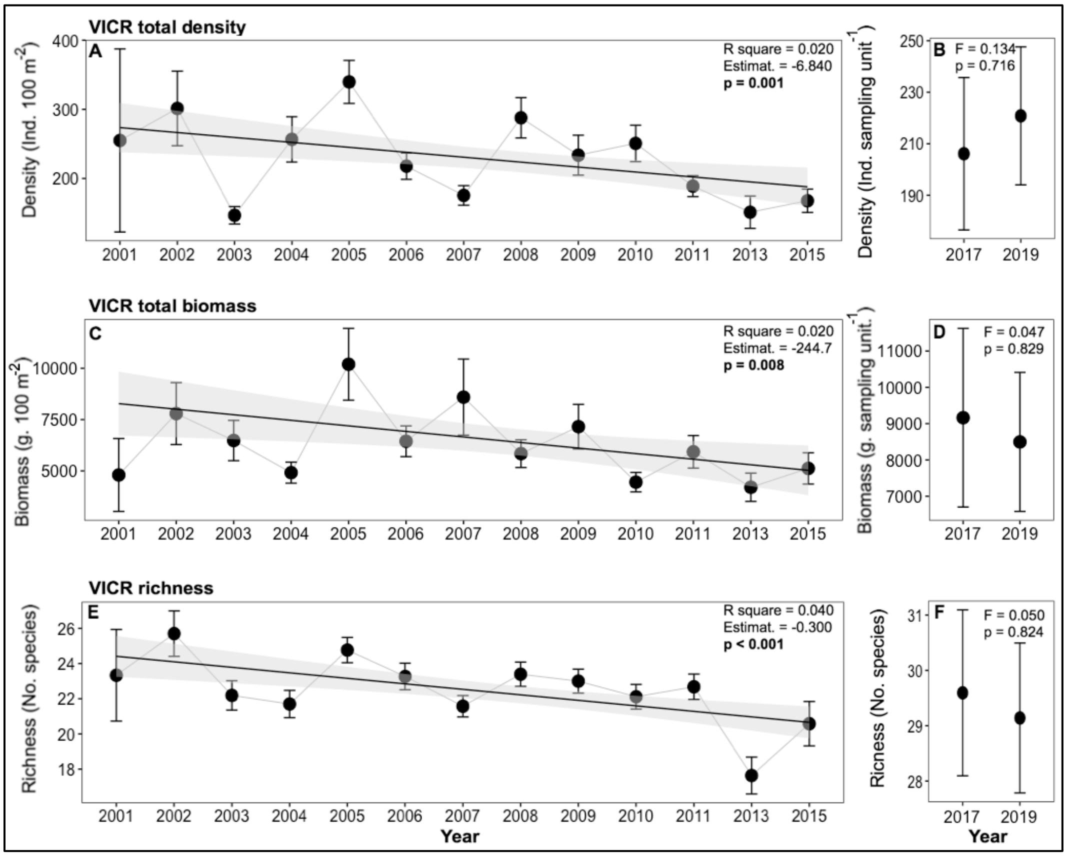

Figure 4.4.1.5. Density, biomass, and richness of reef fish in Virgin Islands Coral Reef National Monument from 2001 to 2019. Surveys from 2001 to 2015 were conducted using belt transect, while surveys in 2017 and 2019 used Reef Visual Census. Mean ± SE. Bold letters indicate statistical significance. Data source: NPS-NCRMP-UVI program

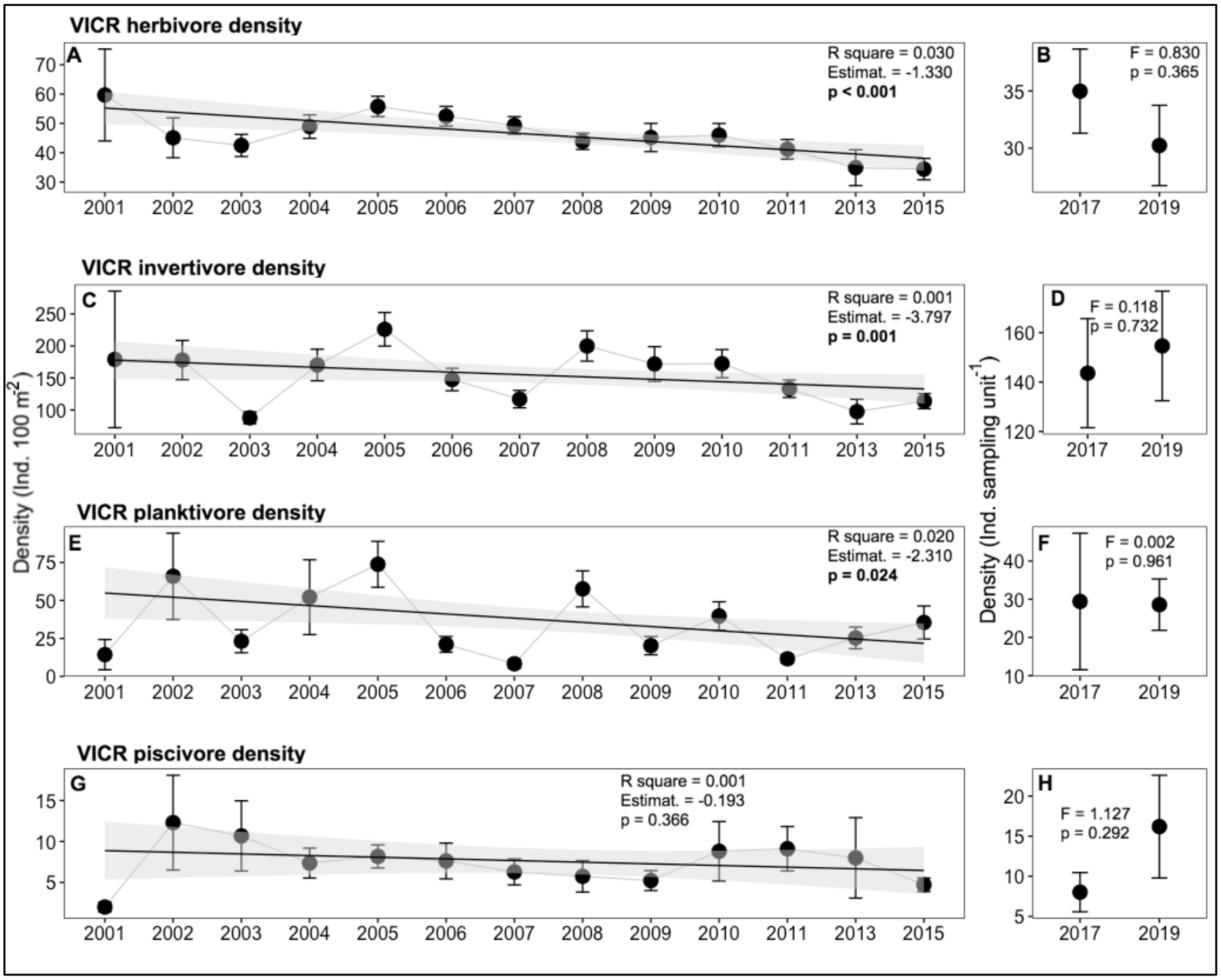

Figure 4.4.1.6. Fish density by trophic group: A&B – herbivores, C&D – invertivores, E&F – planktivore, and G&H – piscivore in Virgin Islands Coral Reef National Monument from 2001 to 2019. Surveys from 2001 to 2015 were conducted using belt transect, while surveys in 2017 and 2019 used Reef Visual Census. Mean ± SE. Bold letters indicate statistical significance. Data source: NPS-NCRMP-UVI program

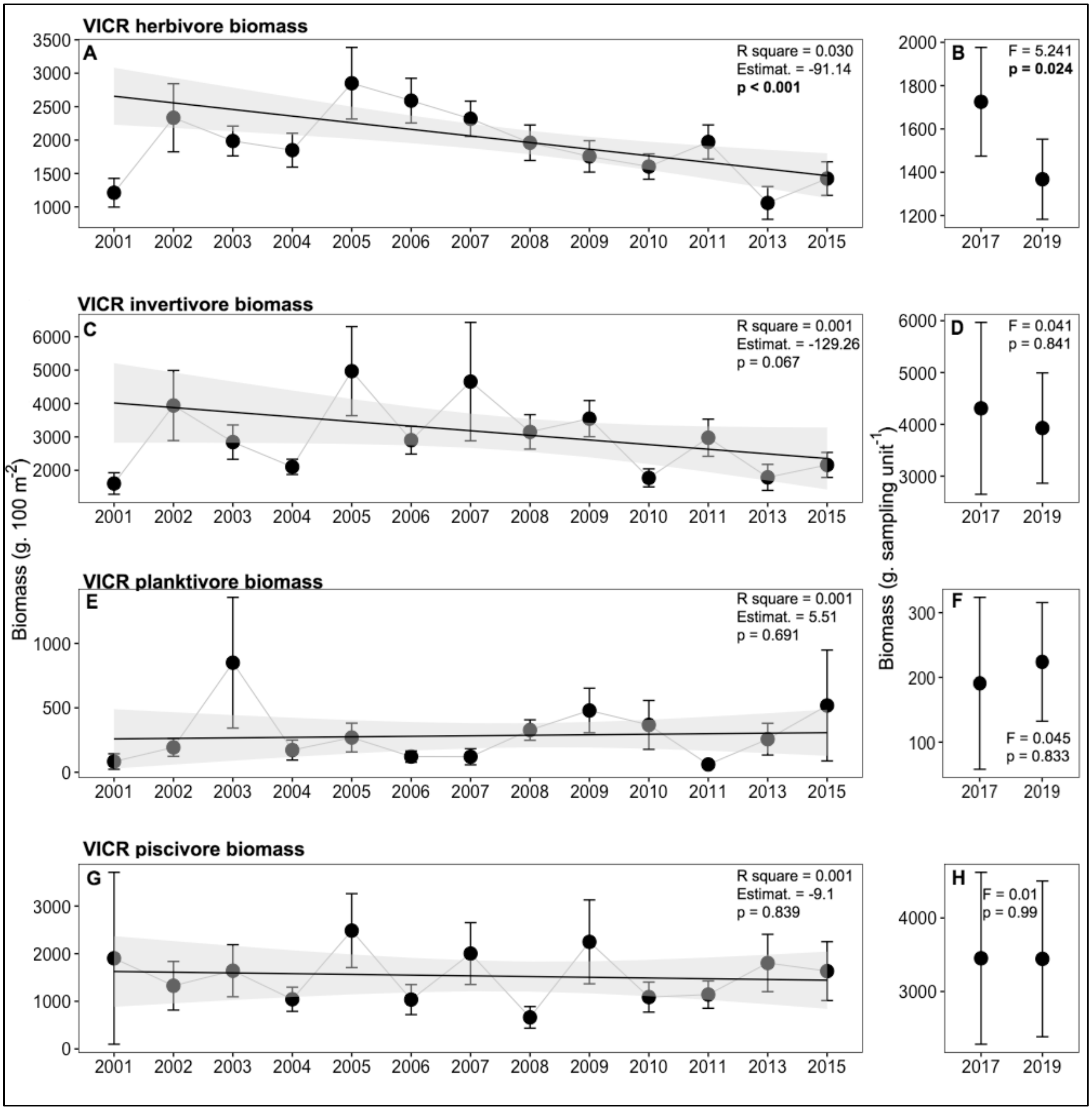

Figure 4.4.1.7. Fish biomass by trophic group: A&B – herbivores, C&D – invertivores, E&F – planktivore, and G&BH – piscivore in Virgin Islands Coral Reef National Monument from 2001 to 2019. Surveys from 2001 to 2015 were conducted using belt transect, while surveys in 2017 and 2019 used Reef Visual Census. Mean ± SE. Bold letters indicate statistical significance. Data source: NPS-NCRMP-UVI program

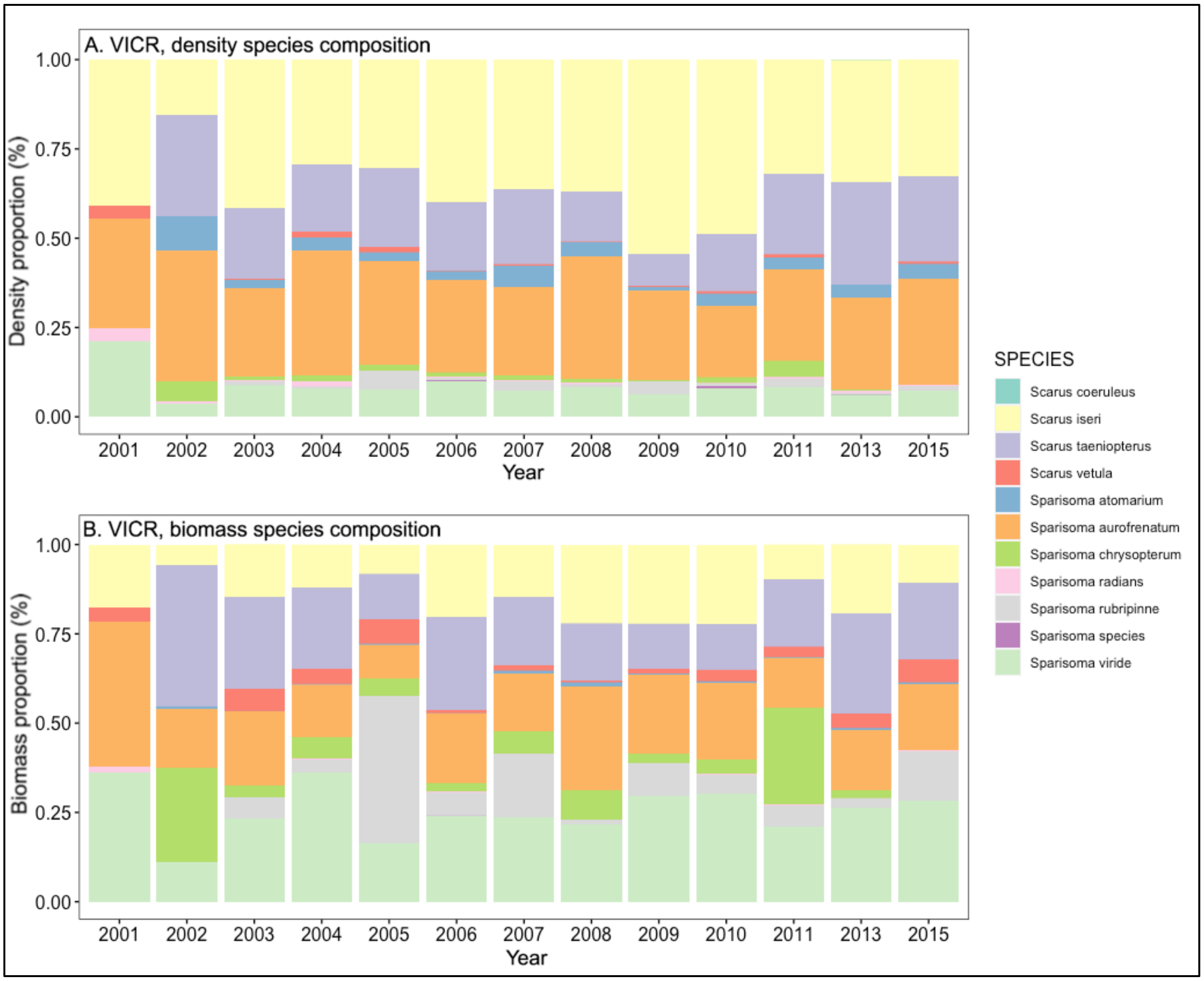

Figure 4.4.1.8. Species composition, as percentages of density (A) and biomass (B) of parrotfishes (family Scaridae) in Virgin Islands Coral Reef National Monument from 2001 to 2015. Data source: NPS-NCRMP-UVI program.

To illustrate the spatial distribution of reef fish within both VIIS and VICR, we created two maps with the most recent monitoring data collected in 2017 and 2019. There are not clear spatial patterns of total fish density (Figure 4.7.1.9) and total fish biomass (Figure 4.7.1.10), and further analysis is needed to investigate spatial distribution.

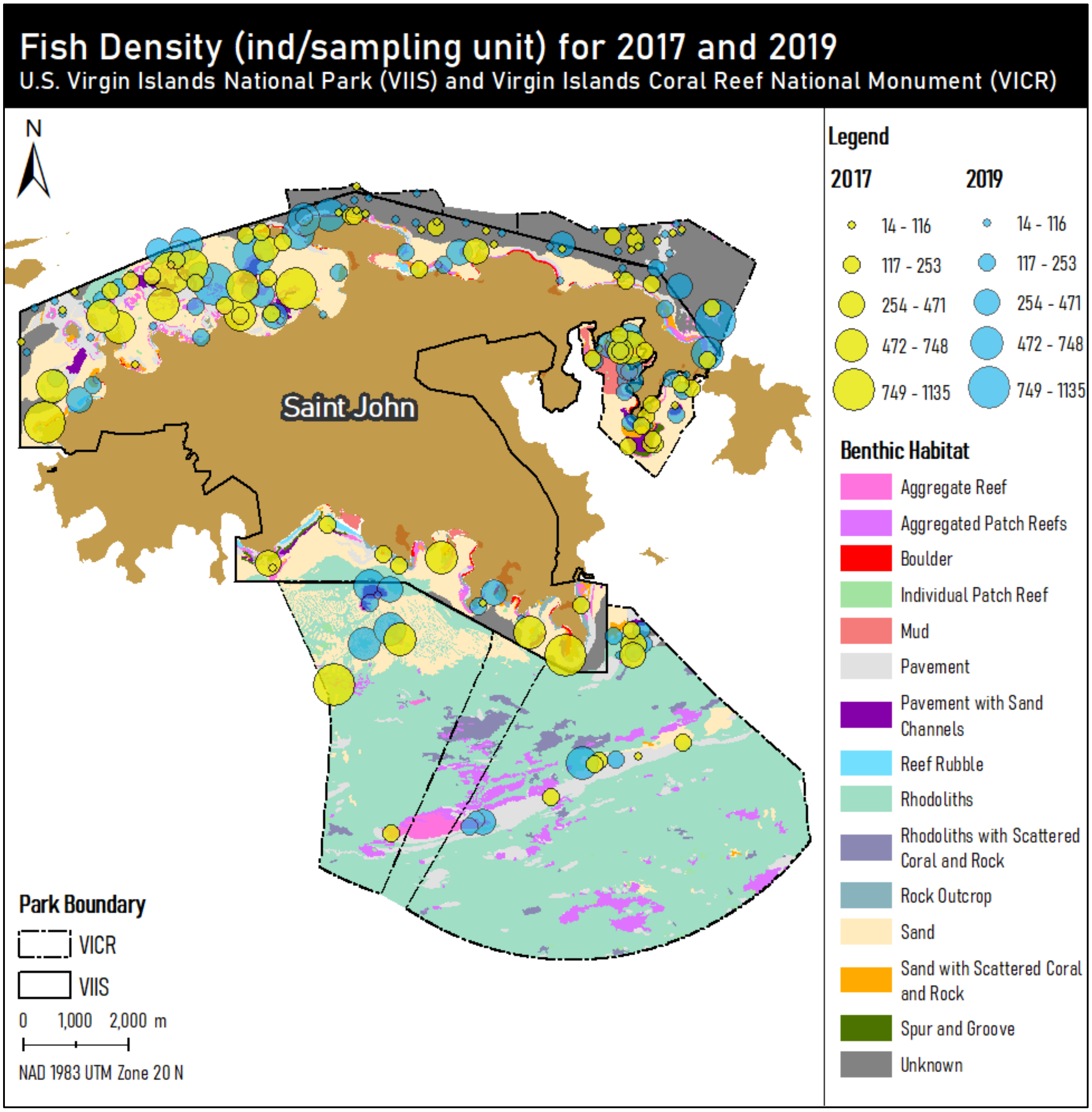

Figure 4.4.1.9. Mean total fish density (ind. sampling unit^{-1}) estimated from 2017 (yellow circles) and 2019 (blue circles) surveys conducted in Virgin Islands National Park and Virgin Islands Coral Reef Monument. Habitat data source: NPS-NCRMP-UVI program. Habitat cover from Costa et al. 2009.

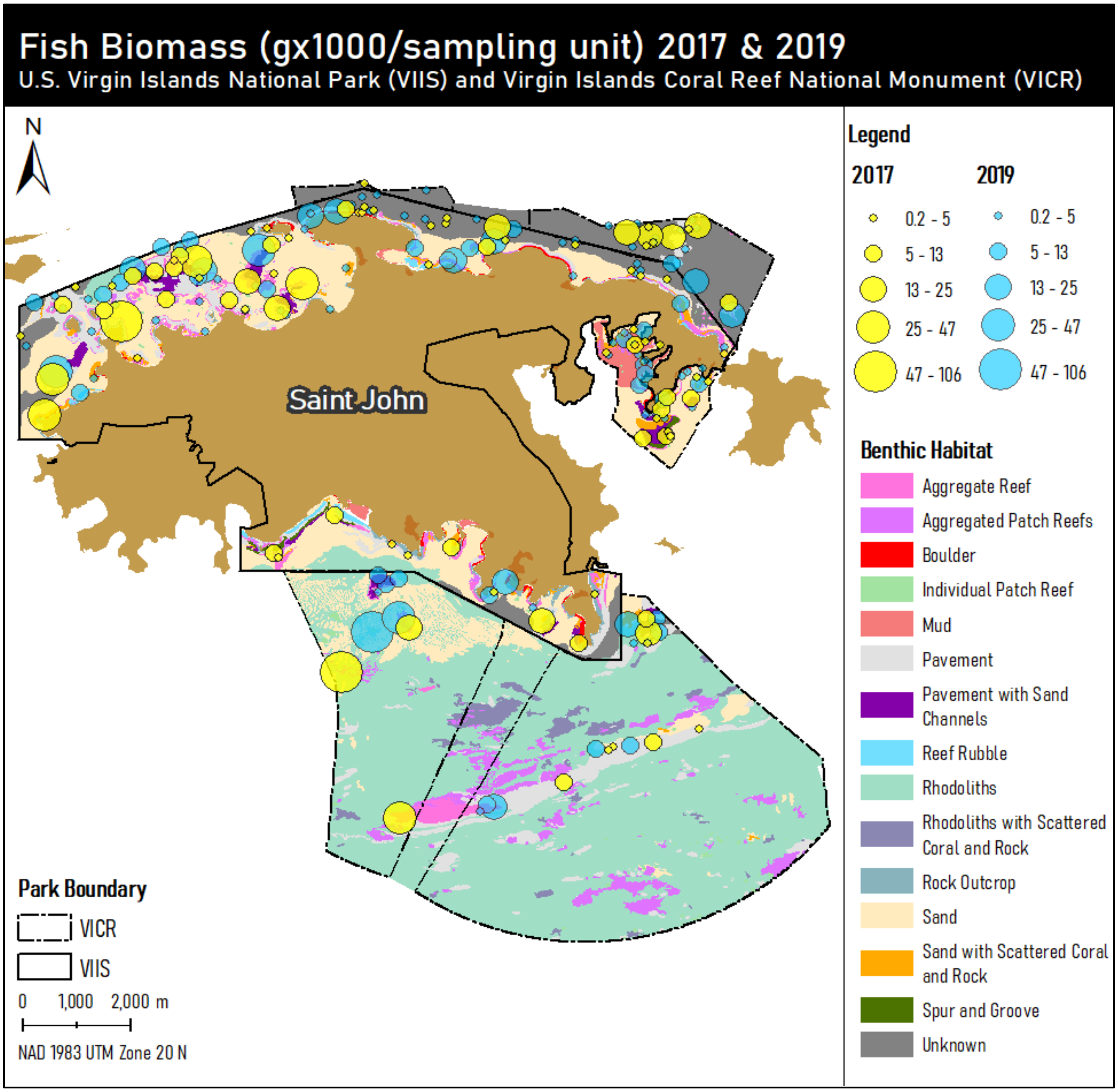

Figure 4.4.1.10. Mean total fish biomass (g. sampling unit^{-1}) estimated from 2017 (yellow circles) and 2019 (blue circles) surveys conducted in Virgin Islands National Park and Virgin Islands Coral Reef Monument. Habitat data source: NPS-NCRMP-UVI program. Habitat cover from Costa et al. 2009.

Threats and Stressors

The reef fish community's characteristics in VIIS and VICR reflect the long-term effect of fishing with no signs of recovery. Large fish species such as Nassau grouper (*Epihnephelus striatus*), dog snapper (*Lutjanus cyanopterus*), hogfish (*Lachnolaimus maximus*), and large parrotfishes (*Scarus guacamaia*, *Sc. coelestinus,* and *Sc. coeruleus*) are rarely seen in both areas (Table 4.4.1.2). Increased piscivore biomass was driven by increases in Carangidae's biomass, a transient species group. We did not find information on illegal fishing activities, but the lack of reef fish recovery might result from illegal fishing, mostly trapping. Indeed, parrotfish biomass, species usually caught in fish traps, declined in both parks (Clark et al. 2012). The absence of fish species frequently targeted by fishermen has also been reported by Pittman et al. 2014 and Kadison et al. 2017. However, it is worth noting a greater number of these species in 2017 and 2019 compared to previous years (Table 4.4.1.2), which can be statistically validated once a cross-method study is conducted.

The invasive Indo-Pacific lionfish (*Pterois volitans*) also pose a recognized threat to native reef fish because they can rapidly consume a large number of prey. The species was first reported in the northern USVI in early 2011, two years after the first sighting off St. Croix. The low number of sightings (Table 4.4.1.2) in the past years suggests that local efforts to control the population have been effective. Anecdotal reports by divers and fishers agree with sighting results from TCRMP surveys suggesting that the population is reduced from the initial estimates in 2011–2013 (Smith et al. 2017).

Table 4.4.1.2. Total number of individuals observed in Virgin Islands National Park (VIIS) and Virgin Islands Coral Reef National Monument (VICR) from surveys conducted between 2001–2019.

	VICR					**VIIS**				
Species	**pre-2011**	**2013**	**2015**	**2017**	**2019**	**pre-2011**	**2013**	**2015**	**2017**	**2019**
Scarus coeruleus	0	0	0	0	0	3	0	0	0	0
Scarus coelestinus	0	0	0	0	0	1	0	0	0	0
Lutjanus cyanopterus	0	0	0	0	0	0	0	3	2	0
Lutjanus jocu	7	1	0	6	9	3	2	1	11	8
Epinephelus striatus	9	0	0	3	2	0	0	0	7	7
Myteroperca tigris	0	0	0	2	1	0	0	0	0	1
Lachnolaimus maximus	6	0	2	1	3	3	4	3	2	3
Pterois volitans	0	1	1	4	2	0	2	3	5	4

The rapidly spreading non-native seagrass *H. stipulacea* alters juvenile fish communities in the US Virgin Islands (Olinger et al. 2017). For example, some species (e.g., adult grunts) use seagrass habitat as nocturnal foraging habitat but shelter by day on coral reefs (Beets and Friedlander 2003), and changes to their foraging habitat could force fish to shift their behaviors to consume new species or use alternative habitats. Similarly, habitats lost or degraded by increasingly intense hurricanes, coastal development, or pollution will not support the current reef fish abundance and diversity.

Data Needs and Gaps

A continuation of the current monitoring program is necessary to identify trends in reef fish communities adequately. A cross-validation study that allows data comparison before and after 2015 is crucial at this point. Such a study is currently underway with funding from NOAA NMFS (M. Feeley 2021, personal communication). A first approach could be standardizing fish density and biomass given the survey surface area (belt transect 100 m^2 vs. RVC 15 m diameter), considering that RVC produces more accurate metric estimates (Colvocoresses and Acosta 2007). Our preliminary trials indicate that fish richness could be the most difficult metric to compare between methods, given that RVC surveys produce a significantly higher number of species. Nevertheless, the negative trends of richness from 2001–2015 could be masked by the change in survey methodology beginning in 2017.

Information on legal and illegal fishing is needed to estimate fishing pressure and the level of law enforcement. This information is crucial to understand the temporal and current status of reef fish communities in both parks. Additionally, surveys designed to target specific species (e.g., large-bodied grouper and snapper) are needed to address species-specific trends and design informed recovery and community education efforts.

Overall Condition

Within VIIS, total fish biomass showed no significant trend over the time period of data analyzed. However, a decrease in reef fish richness was observed over the time period. Within VICR, all three indicators of reef fish community and population status declined between 2001 and 2015. However, no differences were observed between the most recent sampling dates (2017 and 2019) using the RVC survey methodology. Overall, values for indicators have declined or have failed to improve compared to reference conditions, leading us to consider the resource as warranting significant concern (Table 4.4.1.3).

Table 4.4.1.3. Graphical summary of status and trends for reef fish richness, biomass, diversity, and density.

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Reef fish	Density	🔴↔	Reef fish density warrants significant concern because a lack of positive trends after decades of fishing pressure suggests factors are still negatively affecting reef fish communities.
	Biomass	🔴↔	Biomass did not change in VIIS and decreased in VICR between 2001–2015. The metric warrants significant concern as a known indicator of reef fish community health. A similar trend was reported by Pittman et al. 2014.
	Richness	🔴↔	Reef fish richness warrants significant concern because of the negative trend between 2001–2015, potentially as a result of decades of fishing pressure.

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5. Discussion

5.1 Reporting Category Condition Summaries

Resource condition summaries for each focal resource assessed in chapter 4, along with the indicators used in each, are presented in Tables 5.1.1 to 5.1.5. These include focal resources pertaining to the supporting environment of VIIS (water quality, Table 5.1.1), as well as focal resources falling within the framework category of biological integrity, specifically algae, seagrass, corals, and reef fish (Tables 5.1.2 to 5.1.5). We present an overall summary of all focal resources in Table 5.1.6. The overall summary table provides an overview of the condition, trend, and confidence in the assessment of all focal resources in a single table. Unless otherwise stated, we follow the methods for combining condition and trends for individual indicators as outlined in the NPS-NRCA Guidance Update from January 20, 2014.

Table 5.1.1. Indicator summary for Water Quality focal resource.

Indicators of Condition	**Measures or Criteria**	**Condition Status /Trend**	**Rationale**
Fecal Indicator Bacteria	USVI 2019 Amended Water Quality Standards Rules and Regulations	⇩	There are indications of fecal contamination for some sites that periodically exceed values considered a risk for human contact. Continued development and poor enforcement of septic discharge may contribute to increasing incidences of fecal contamination.
Dissolved Oxygen	USVI 2019 Amended Water Quality Standards Rules and Regulations	⇔	Values are nearly universally high in areas sampled and there is no indication of declines in concentration over time.
Total Suspended Solids	NA	●	Total suspended solids are low in areas away from human development. There is insufficient information to understand if concentrations are changing.
Turbidity	USVI 2019 Amended Water Quality Standards Rules and Regulations	●	Turbidity is low in areas away from human development. There is insufficient information to understand if concentrations are changing.
Dissolved Nutrients	NA	⇔	These are typically near detection limits in most areas. However, they may be a poor metric of nutrient loading.
Chlorophyll	Enrichment above oligotrophic oceanic conditions	◌	Chlorophyll was low in a few areas that were assessed, but elevated near human activities, indicating nutrient loading. There is insufficient information to understand if phytoplankton abundance is changing.

Table 5.1.1 (continued). Indicator summary for Water Quality focal resource.

Indicators of Condition	Measures or Criteria	Condition Status /Trend	Rationale
Terrestrial Sediments	Annual number of events associated with high rainfall	🟡⇩	Terrestrial sediments have been noted as affecting water quality in multiple areas of the park within watersheds with human development. Continued development and road building under VI codes does not prevent increasing delivery of terrestrial sediments to nearshore marine environments.
Contaminants	Detection of compounds used as UV filters	🟡⇔	There are some indications of sediment contaminants in areas adjacent to park waters and personal hygiene product contamination in high use areas.
Water Quality overall	–	🟡⇩	–

Table 5.1.2. Indicator summary for Macroalgae focal resource.

Indicators of Condition	Measures or Criteria	Condition Status /Trend	Rationale
Change in abundance and occurrence of algae	Percent cover	🔴⇩	Algae abundance has increased since the die-off of sea urchins in the early 1980s, following hurricane damage to corals and seagrass, and after coral bleaching events. Larges increases in algae abundance indicate a deteriorating resource condition.
Macroalgae overall	–	🔴⇩	–

Table 5.1.3. Indicator summary for Seagrass focal resource.

Indicators of Condition	**Measures or Criteria**	**Condition Status /Trend**	**Rationale**
Change in abundance and occurrence of seagrass	Species composition	🔴⬇	The non-native seagrass *H. stipulacea* appears to be replacing native seagrasses in heavily disturbed areas. No species composition data are available for park-wide assessment outside of disturbed areas.
Change in abundance and occurrence of seagrass	Density	🔴	Historical photo analysis and in-water density surveys reveal declining trends in both percent cover and shoot density prior to 2000, but increased coverage through 2007. More recent estimates of seagrass density are not available. The spread of non-native *H. stipulacea* is increasing total shoot density in previously disturbed areas. Data was not sufficient to determine a trend in condition.
Seagrass overall	–	🔴⬇	–

Table 5.1.4. Indicator summary for Corals focal resource.

Indicators of Condition	**Measures or Criteria**	**Condition Status /Trend**	**Rationale**
Stony coral coverage	Percent of benthic cover	🔴⬇	Coral cover has declined at all monitoring sites in and around VIIS-VICR over the last two decades
Stony coral health	Percent coral bleaching and incidence of disease	🔴⬇	The incidence of coral bleaching events and coral disease epizootics has increased and is likely to continue increasing in the near future (e.g., introduction of Stony Coral Rapid Tissue Loss Disease)
Seawater temperature	Number of degree heating weeks above bleaching threshold	🔴⬇	Between 2004 and 2017 seawater temperatures have exceeded site-specific bleaching thresholds 6–10 times in conjunction with general warming of the Caribbean
Corals overall	–	🔴⬇	–

Table 5.1.5. Indicator summary for Reef Fish focal resource.

Indicators of Condition	**Measures or Criteria**	**Condition Status /Trend**	**Rationale**
Community and population status	Density	🔴⬄	Reef fish density warrants significant concern as density of fish remains low compared to estimated historic levels, despite several decades of management.
Community and population status	Biomass	🔴⬄	Biomass did not change in VIIS and decreased in VICR between 2001–2015. The metric warrants significant concern as a known indicator of reef fish community health. A similar trend was reported by Pittman et al. 2014.
Community and population status	Richness	🔴⬄	Reef fish richness warrants significant concern because of the negative trend between 2001–2015.
Reef fish overall	–	🔴⬄	–

Table 5.1.6. Overall resource-level summary table.

Resource Category	**Focal Resource**	**Condition Status /Trend**	**Rationale**
Supporting Environment	Water Quality	🟡⇩	Fecal indicator bacteria, terrestrial sediments, and contaminants from recreational activities (personal care products) are present and potentially increasing. Other aspects of water quality (turbidity, nutrients, dissolved oxygen) are suitable for sensitive ecosystems.
Biological Integrity	Algae	🔴⇩	Algae abundance is high and has increased since the die-off of sea urchins in the early 1980s, following hurricane damage to corals and seagrass, and after coral bleaching events.
	Seagrass	🔴⇩	Historical photo analysis and in-water density surveys reveal declining trends in both percent cover and shoot density prior to 2000, but increased coverage through 2007. More recent estimates of seagrass density are not available. The spread of non-native *H. stipulacea* is increasing total shoot density in previously disturbed areas.
	Corals	🔴⇩	Coral cover and abundance is declining, thermal stress events are more common, disease is more common and novel diseases are appearing. Impacts are felt in shallow and deep coral populations.

Table 5.1.6 (continued). Overall resource-level summary table.

Resource Category	Focal Resource	Condition Status /Trend	Rationale
Biological Integrity (continued)	Reef fish	↔	A lack of positive trend in reef fish density, biomass, or richness after decades of management suggests factors, including fishing pressure, are still negatively affecting these communities.

A comparison of the five focal resources assessed in this report shows that the majority of resources, four of five (80%), were considered to be of significant concern. Only the supporting environment resource, water quality, was of moderate concern, and no resources were found to be in good condition. The focal resources assessed in this report are all marine resources, so we make no judgement of the many terrestrial resources found within the park boundaries. The overall condition of the marine resources of VIIS/VICR suggests a system under a wide range of threats. Equally concerning is the trajectory of condition for these focal resources, with four of the five having deteriorating conditions. Only reef fish were considered to be in an unchanging condition. Taken as whole, the assessment suggests that the marine resources of VIIS/VICR are experiencing degraded conditions compared to reference conditions for these resources. Deteriorating conditions for seagrass and corals combined with a lack of recovery of the reef fish communities are especially concerning. The current conditions for these resources appear to have resulted from the result of the interaction of disturbance events and anthropogenic impacts, including extent of hurricane damage, increasing sea surface temperatures, contaminants, introduction of invasive species and continued fishing pressure.

Increasing algae cover in our assessment serves as an indicator of worsening conditions for the coral resources, and perhaps seagrass, but that it unclear, suggesting long-term change in these ecosystems. While algae have both negative and positive effects within the marine environment, increased presence of algae on coral reefs is alarming. Algae compete with coral for space and inhibit recolonization of damaged reefs by corals. Minimal presence of macroalgae was noted on the reefs St. John prior to the 1980s (Rogers and Miller 2006, Edmunds 2013). Large increases in the cover of macroalgae were observed following the loss of urchins from the system (1983–84, *Diadema antillarum* die-off) (Levitan 1988; Carpenter 1990) and then again following disturbance from Hurricane Hugo (1989) which severely damaged much of the coral reefs. Coral bleaching from high thermal stress combined coral diseases are an additional stress reducing coral coverage. Declines in herbivorous fish species may also be contributing to a reduced grazing pressure on macroalgae. Additionally, the presence of the invasive encrusting red algae *Ramicrusta* spp. in VIIS-VICR is concerning and the threat it poses is great given the rapid expansion of this species throughout the Caribbean and its known ability to overgrow corals.

Water quality as a supporting environmental resource is an important driver of change in the condition of biological integrity. All indicators of condition status for water quality were not considered equally weighted. Instead, fecal indicator bacteria, terrestrial sediments, and contaminants were more highly weighted and as a result, the overall status and trend is reflective of their influence. This decision to weight some indicators of water quality more heavily than others was due to the potential linkage of those specific indicators to coral degradation. Additionally, increasing development outside the park in St. John is likely to result in increases in fecal indicator bacteria from leaky septic systems and boat dumping, as well as from terrestrial run-off. On a positive note, recent territorial bans on potential endocrine disruptors in sunscreens may alleviate those contaminants. There was insufficient data to determine whether levels of chlorophyll, turbidity, and total dissolve solids are changing over time, but they were considered to be indicators of good condition since values for each were low, but only in areas sampled away from development and human activity.

5.2 Reporting Category Information Gaps

A medium level of confidence was assigned to the majority of focal resources, with individual indicators of the resources primarily of medium confidence. The assessment of the seagrass focal resource has assigned low confidence. The only assessment having high confidence was for the coral focal resource. This suggests that for all focal resources except coral, assessments of condition are constrained by a lack of recent data, insufficient temporal or spatial coverage of datasets, or differences between survey methods for datasets compared. Important information gaps with some suggestions for future data acquisition are listed for each focal resource in Table 5.2.1.

Additional research and data collection are needed to answer questions related to how non-native invasive species are changing these ecosystems. The non-native invasive seagrass *Halophila stipulacea* and the encrusting red algae *Ramicrusta* spp. are concerns for seagrass and coral reefs respectively. *Halophila stipulacea* has the potential to settle in areas where seagrasses have previously not competed with macroalgae. *Ramicrusta* spp. is rapidly increasing at sites in the USVI with the potential to devastate stony corals. Data are needed to understand interactions between colonization of these invasive species and other disturbances, and their potential impacts on the native species. For reef fish, the recent arrival (first reported in the USVI in 2011) of the invasive Indo-Pacific lionfish (*Pterois volitans*) is another potential threat, as lionfish consume a large amount of prey species and subsequently reduce recruitment of coral-reef fish (Albins and Hixon 2008).

An integrated approach to monitoring and data collection of the assessed marine focal resources of VIIS/VICR is suggested as a way to capture changes in these resources and better understand causes impacting the nearshore marine system. A monitoring approach could consist of metrics (like water quality, coral health and abundance, seagrass cover, and the presence of non-native invasive species) collected relative to one another in time and space. The designs for such a sampling scheme are various but should build on existing datasets and infrastructure. Research on the use of the marine resources by visitors and residents alike are suggested to estimate benefits from ecosystem services provided, as well as amount of anthropogenic pressure on the resource. Information on both legal and illegal fishing would allow for estimates of fishing pressure, which is crucial to understand the temporal and current status of reef fish communities. Finally, rapid responses and management intervention are needed to combat coral diseases like stony coral tissue loss and newly emergent invasive species threats.

Table 5.2.1. Summary of important information gaps for each focal resource.

Resource Category	Focal Resource	Important Information Gaps
Supporting Environment	Water Quality	A comprehensive water quality sampling program, that includes sensitive coral reef ecosystems, would provide much more information on status and trends of water quality. Areas adjacent to or in the park that are of particular concern (Coral Bay, Fish Bay, Trunk Bay) are particularly important to assess, since they may be upstream sources of pollutants and each area is likely to see continued watershed and marina development. A water quality sampling program, led by NPS, could include deployed sensors for continuous measurements, discreet sampling for contaminants, and establishment of satellite based remote sensing stations to measure water optical properties (turbidity, chlorophyll, colored dissolved organic matter) and benthic cover.
Biological Integrity	Algae	Surveys and experiments to determine the effects of *Sargassum* accumulation on littoral communities are recommended. Experiments are also recommended to elucidate the relationships between herbivory and disturbance on the spread of invasive *Ramicrusta* spp.
	Seagrass	New aerial imagery seagrass surveys are recommended to determine current seagrass coverage within the park. Concurrent field surveys of seagrass are also recommended to ground-truth aerial imagery.
	Corals	Monitoring of iconic elkhorn coral populations is currently lacking. Monitoring of corals within high recreational use areas is lacking. The potential of evidence-based coral restoration to rehabilitate coral habitats and threatened species needs to be assessed.
	Reef fish	A continuation of the current monitoring program is necessary to adequately identify trends in reef fish communities, as is employing cross-validation methods among disparate datasets (underway). Additionally, surveys designed to target specific species (e.g., large-bodied grouper and snapper) are needed to address species-specific trends and design informed recovery. Finally, information on legal and illegal fishing is needed to estimate fishing pressure and the level of law enforcement.

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Appendix A.

Plant species in VIIS are listed in Table A-1.

Table A-1. Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Acanthaceae	*Asystasia gangetica*	Chinese violet	Uncommon	Non-Native
Acanthaceae	*Avicennia germinans*	black mangrove	Common	Native
Acanthaceae	*Barleria lupulina*	hophead Philippine violet	Uncommon	Non-Native
Acanthaceae	*Blechum pyramidatum*	Browne's blechum	Common	Native
Acanthaceae	*Dicliptera sexangularis*	sixangle foldwing	Uncommon	Native
Acanthaceae	*Justicia carthagenensis*	woodland water-willow	Uncommon	Native
Acanthaceae	*Justicia mirabiloides*	West Indian water-willow	Uncommon	Native
Acanthaceae	*Justicia pectoralis*	freshcut	Uncommon	Non-Native
Acanthaceae	*Justicia periplocifolia*	tropical waterwillow	Common	Native
Acanthaceae	*Oplonia microphylla*	thicketwort	Common	Native
Acanthaceae	*Oplonia spinosa*	pricklybush	Common	Native
Acanthaceae	*Ruellia coccinea*	yerba maravilla	Uncommon	Native
Acanthaceae	*Ruellia tuberosa*	minnieroot	Uncommon	Native
Acanthaceae	*Siphonoglossa sessilis*	tropical tube tongue	Uncommon	Native
Acanthaceae	*Stenandrium tuberosum*	mata espiritista	Rare	Native
Acanthaceae	*Thunbergia fragrans*	whitelady	Uncommon	Non-Native
Aizoaceae	*Cypselea humifusa*	panal	Uncommon	Native
Aizoaceae	*Sesuvium portulacastrum*	shoreline seapurslane	Common	Native
Aizoaceae	*Trianthema portulacastrum*	desert horsepurslane	Uncommon	Native
Amaranthaceae	*Achyranthes aspera*	devil's horsewhip	Common	Non-Native
Amaranthaceae	*Alternanthera brasiliana*	Brazilian joyweed	Uncommon	Non-Native
Amaranthaceae	*Alternanthera caracasana*	washerwoman	Uncommon	Native
Amaranthaceae	*Alternanthera tenella*	sanguinaria	Uncommon	Native
Amaranthaceae	*Amaranthus crassipes*	spreading amaranth	Common	Native
Amaranthaceae	*Amaranthus dubius*	spleen amaranth	Common	Non-Native
Amaranthaceae	*Amaranthus viridis*	slender amaranth	Common	Native
Amaranthaceae	*Atriplex cristata*	crested saltbush	Rare	Native
Amaranthaceae	*Blutaparon vermiculare*	silverhead	Uncommon	Native
Amaranthaceae	*Celosia nitida*	West Indian cock's comb	Uncommon	Native
Amaranthaceae	*Chenopodium ambrosioides*	Mexican tea	Uncommon	Non-Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Amaranthaceae	*Gomphrena serrata*	arrasa con todo	Uncommon	Non-Native
Amaranthaceae	*Iresine angustifolia*	white snowplant	Common	Native
Amaryllidaceae	*Crinum zeylanicum*	Ceylon swamplily	Uncommon	Non-Native
Amaryllidaceae	*Hymenocallis caribaea*	Caribbean spiderlily	Uncommon	Native
Amaryllidaceae	*Hymenocallis speciosa*	green-tinge spiderlily	Uncommon	Non-Native
Anacardiaceae	*Anacardium occidentale*	cashew	Uncommon	Non-Native
Anacardiaceae	*Comocladia dodonaea*	poison ash	Common	Native
Anacardiaceae	*Mangifera indica*	mango	Common	Non-Native
Anacardiaceae	*Schinus terebinthifolius*	Brazilian peppertree	Uncommon	Non-Native
Anacardiaceae	*Spondias mombin*	hogplum	Uncommon	Unknown
Annonaceae	*Annona glabra*	pond apple	Uncommon	Native
Annonaceae	*Annona muricata*	soursop	Common	Non-Native
Annonaceae	*Annona reticulata*	custard apple	Uncommon	Native
Annonaceae	*Annona squamosa*	sugar apple, sweet sop	Uncommon	Native
Apiaceae	*Cyclospermum leptophyllum*	marsh parsley	Uncommon	Non-Native
Apocynaceae	*Asclepias curassavica*	scarlet milkweed	Common	Native
Apocynaceae	*Calotropis procera*	roostertree	Common	Native
Apocynaceae	*Catharanthus roseus*	Madagascar periwinkle	Uncommon	Non-Native
Apocynaceae	*Cryptostegia grandiflora*	Palay rubbervine	Common	Non-Native
Apocynaceae	*Matelea maritima*	beach milkvine	Common	Native
Apocynaceae	*Nerium oleander*	oleander	Uncommon	Non-Native
Apocynaceae	*Pentalinon luteum*	hammock viper's-tail	Uncommon	Native
Apocynaceae	*Plumeria alba*	nosegaytree	Common	Native
Apocynaceae	*Prestonia agglutinata*	babeiro	Uncommon	Native
Apocynaceae	*Rauvolfia nitida*	glasswood	Common	Native
Apocynaceae	*Rauvolfia viridis*	milkbush	Common	Native
Aquifoliaceae	*Ilex nitida*	Puerto Rico holly	Occasional	Native
Aquifoliaceae	*Ilex urbaniana*	Urban's holly	Uncommon	Native
Araceae	*Anthurium cordatum*	Organ Mountain laceleaf	Common	Native
Araceae	*Anthurium crenatum*	scalloped laceleaf	Uncommon	Native
Araceae	*Anthurium X selloum*	large laceleaf	Uncommon	Native
Araceae	*Dieffenbachia seguine*	dumbcane	Uncommon	Native
Araceae	*Lemna aequinoctialis*	lesser duckweed	Uncommon	Native
Araceae	*Philodendron giganteum*	giant philodendron	Rare	Native
Araceae	*Philodendron scandens*	heartleaf philodendron	Uncommon	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Araceae	*Pistia stratiotes*	tropical duckweed	Uncommon	Native
Araceae	*Syngonium podophyllum*	arrowhead vine	Uncommon	Non-Native
Araliaceae	*Schefflera morototonii*	Octopus tree	Common	Native
Arecaceae	*Coccothrinax alta*	–	Common	Native
Arecaceae	*Cocos nucifera*	coconut palm	Uncommon	Non-Native
Arecaceae	*Roystonea borinquena*	Puerto Rico royal palm	Rare	Native
Aristolochiaceae	*Aristolochia odoratissima*	fragrant dutchman's pipe	Uncommon	Native
Aristolochiaceae	*Aristolochia trilobata*	bejuco de santiago	Uncommon	Non-Native
Asparagaceae	*Agave missionum*	corita	Common	Native
Asparagaceae	*Sansevieria trifasciata*	viper's bowstring hemp	Uncommon	Non-Native
Asparagaceae	*Yucca aloifolia*	aloe yucca	Uncommon	Non-Native
Aspleniaceae	*Asplenium pumilum*	dwarf spleenwort	Uncommon	Native
Asteraceae	*Acanthospermum hispidum*	hispid starburr	Common	Native
Asteraceae	*Ageratum conyzoides*	tropical whiteweed	Occasional	Native
Asteraceae	*Bidens alba* var. *radiata*	bidens, romerillo	Common	Native
Asteraceae	*Bidens cynapiifolia*	West Indian beggarticks	Common	Native
Asteraceae	*Chaptalia nutans*	heal and draw	Occasional	Native
Asteraceae	*Chromolaena corymbosa*	Caribbean thoroughwort	Uncommon	Native
Asteraceae	*Chromolaena odorata*	Jack in the bush	Common	Native
Asteraceae	*Chromolaena sinuata*	wavyleaf thoroughwort	Uncommon	Native
Asteraceae	*Conyza bonariensis*	flaxleaved fleabane	Uncommon	Native
Asteraceae	*Cyanthillium cinereum*	little ironweed	Common	Native
Asteraceae	*Eclipta prostrata*	yerba de tajo	Common	Native
Asteraceae	*Elephantopus mollis*	soft elephantsfoot	Uncommon	Native
Asteraceae	*Emilia fosbergii*	Florida tasselflower	Uncommon	Native
Asteraceae	*Emilia sonchifolia*	lilac tasselflower	Uncommon	Non-Native
Asteraceae	*Erigeron cuneifolius*	wedgeleaf fleabane	Uncommon	Native
Asteraceae	*Gnaphalium domingense*	Dominican cudweed	Rare	Native
Asteraceae	*Lagascea mollis*	acuate, silkleaf	Uncommon	Native
Asteraceae	*Launaea intybacea*	achicoria azul	Uncommon	Native
Asteraceae	*Mikania cordifolia*	Florida Keys hempvine	Uncommon	Native
Asteraceae	*Neurolaena lobata*	sepi	Rare	Native
Asteraceae	*Parthenium hysterophorus*	ragweed parthenium	Uncommon	Native
Asteraceae	*Pectis humifusa*	yerba de San Juan	Rare	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Asteraceae	*Pectis linifolia*	narrowleaf lemonweed	Rare	Native
Asteraceae	*Piptocoma antillana*	Antilles velvetshrub	Common	Native
Asteraceae	*Pluchea carolinensis*	cure for all	Common	Native
Asteraceae	*Pluchea odorata* var. *odorata*	marsh fleabane	Common	Native
Asteraceae	*Pseudelephantopus spicatus*	dog's-tongue	Uncommon	Native
Asteraceae	*Pterocaulon virgatum*	wand blackroot	Uncommon	Native
Asteraceae	*Sonchus oleraceus*	common sowthistle	Uncommon	Non-Native
Asteraceae	*Sphagneticola trilobata*	Bay Biscayne creeping-oxeye	Uncommon	Non-Native
Asteraceae	*Synedrella nodiflora*	nodeweed	Common	Native
Asteraceae	*Tagetes erecta*	Aztec marigold	Uncommon	Non-Native
Asteraceae	*Tridax procumbens*	cadillo chisaca	Common	Native
Asteraceae	*Verbesina alata*	capitaneja	Occasional	Native
Asteraceae	*Vernonia sericea*	longshoot	Common	Native
Asteraceae	*Wedelia fruticosa*	coastal plain creepingoxeye	Uncommon	Native
Basellaceae	*Anredera vesicaria*	Texas madeiravine	Uncommon	Native
Bataceae	*Batis maritima*	saltwort	Uncommon	Native
Bignoniaceae	*Amphitecna latifolia*	black calabash	Uncommon	Native
Bignoniaceae	*Arrabidaea chica*	cricketvine	Uncommon	Native
Bignoniaceae	*Crescentia cujete*	common calabash tree	Common	Non-Native
Bignoniaceae	*Crescentia linearifolia*	higuerito	Common	Native
Bignoniaceae	*Cydista aequinoctialis*	guard withe	Uncommon	Native
Bignoniaceae	*Macfadyena unguis-cati*	catclaw vine, claw vine	Common	Native
Bignoniaceae	*Spathodea campanulata*	African tuliptree	Uncommon	Non-Native
Bignoniaceae	*Tabebuia heterophylla*	white cedar	Common	Native
Bignoniaceae	*Tecoma stans*	yellow elder	Common	Native
Blechnaceae	*Blechnum occidentale*	hammock fern	Uncommon	Native
Brassicaceae	*Cakile lanceolata*	coastal searocket	Uncommon	Native
Brassicaceae	*Lepidium virginicum*	peppergrass	Common	Native
Bromeliaceae	*Aechmea lingulata*	West Indian livingvase	Uncommon	Native
Bromeliaceae	*Bromelia pinguin*	pinguin	Uncommon	Native
Bromeliaceae	*Catopsis floribunda*	Florida strap airplant	Uncommon	Native
Bromeliaceae	*Pitcairnia angustifolia*	–	Uncommon	Native
Bromeliaceae	*Tillandsia fasciculata*	giant airplant	Uncommon	Native
Bromeliaceae	*Tillandsia lineatispica*	pinon	Rare	Unknown

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Bromeliaceae	*Tillandsia recurvata*	ballmoss, small ballmoss	Uncommon	Native
Bromeliaceae	*Tillandsia utriculata*	spreading airplant	Uncommon	Native
Burseraceae	*Bursera simaruba*	gumbo limbo	Common	Native
Cactaceae	*Cereus uruguayanus*	Peruvian apple	Uncommon	Native
Cactaceae	*Hylocereus trigonus*	strawberry-pear	Uncommon	Native
Cactaceae	*Mammillaria nivosa*	woolly nipple cactus	Rare	Native
Cactaceae	*Melocactus intortus*	Turk's cap	Uncommon	Native
Cactaceae	*Opuntia cochenillifera*	cochineal cactus	Uncommon	Non-Native
Cactaceae	*Opuntia repens*	roving pricklypear	Uncommon	Native
Cactaceae	*Opuntia rubescens*	sour pricklypear	Uncommon	Native
Cactaceae	*Opuntia stricta* var. *dillenii*	erect pricklypear	Common	Non-Native
Cactaceae	*Pereskia aculeata*	Barbados shrub	Uncommon	Unknown
Cactaceae	*Pilosocereus royenii*	Royen's tree cactus	Uncommon	Native
Cactaceae	*Selenicereus grandiflorus*	queen of the night	Uncommon	Non-Native
Calophyllaceae	*Mammea americana*	mamey	Uncommon	Native
Campanulaceae	*Hippobroma longiflora*	madamfate	Uncommon	Native
Canellaceae	*Canella winteriana*	wild cinnamon	Uncommon	Native
Cannabaceae	*Celtis iguanaea*	iguana hackberry	Uncommon	Native
Cannabaceae	*Celtis trinervia*	almex	Rare	Native
Cannabaceae	*Trema micranthum*	Florida trema	Common	Native
Cannaceae	*Canna indica*	Indian shot	Uncommon	Native
Capparaceae	*Capparis amplissima*	burro blanco	Common	Native
Capparaceae	*Capparis baducca*	caper, church blossom	Uncommon	Native
Capparaceae	*Capparis cynophallophora*	black caper	Common	Native
Capparaceae	*Capparis flexuosa*	limber caper	Common	Native
Capparaceae	*Capparis hastata*	broadleaf caper	Uncommon	Native
Capparaceae	*Capparis indica*	linguam	Common	Native
Capparaceae	*Morisonia americana*	ratapple	Common	Native
Caricaceae	*Carica papaya*	papaya, pawpaw	Uncommon	Non-Native
Celastraceae	*Cassine xylocarpa*	marbletree	Uncommon	Native
Celastraceae	*Crossopetalum rhacoma*	Florida crossopetalum	Uncommon	Native
Celastraceae	*Maytenus laevigata*	white cinnamon	Uncommon	Native
Celastraceae	*Schaefferia frutescens*	Florida boxwood	Uncommon	Native
Chrysobalanaceae	*Chrysobalanus icaco*	coco plum	Uncommon	Native
Cleomaceae	*Cleome gynandra*	spider whisp	Uncommon	Non-Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Cleomaceae	*Cleome spinosa*	spiny spiderflower	Uncommon	Native
Cleomaceae	*Cleome viscosa*	Asian spiderflower	Common	Non-Native
Clusiaceae	*Clusia rosea*	Florida clusia	Uncommon	Native
Combretaceae	*Buchenavia tetraphylla*	fourleaf buchenavia	Common	Native
Combretaceae	*Bucida buceras*	gregorywood	Common	Native
Combretaceae	*Conocarpus erectus*	button mangrove	Common	Native
Combretaceae	*Laguncularia racemosa*	white mangrove	Common	Native
Combretaceae	*Quisqualis indica*	Rangoon creeper	Uncommon	Non-Native
Combretaceae	*Terminalia catappa*	tropical almond	Uncommon	Native
Commelinaceae	*Callisia fragrans*	basketplant	Uncommon	Non-Native
Commelinaceae	*Callisia repens*	creeping inchplant	Uncommon	Non-Native
Commelinaceae	*Commelina erecta*	erect dayflower	Common	Native
Commelinaceae	*Tradescantia spathacea*	oyster plant	Uncommon	Non-Native
Commelinaceae	*Tradescantia zebrina*	inchplant	Uncommon	Non-Native
Convolvulaceae	*Convolvulus nodiflorus*	aguinaldo blanco	Common	Native
Convolvulaceae	*Cuscuta americana*	American dodder	Uncommon	Non-Native
Convolvulaceae	*Cuscuta umbellata*	flatglobe dodder	Rare	Native
Convolvulaceae	*Evolvulus convolvuloides*	bindweed dwarf morning-glory	Uncommon	Native
Convolvulaceae	*Evolvulus filipes*	Maryland dwarf morning-glory	Uncommon	Native
Convolvulaceae	*Evolvulus nummularius*	agracejo rastrero	Uncommon	Native
Convolvulaceae	*Ipomoea eggersii*	Egger's morning-glory	Uncommon	Native
Convolvulaceae	*Ipomoea hederifolia*	scarlet creeper, scarletcreeper	Uncommon	Native
Convolvulaceae	*Ipomoea indica*	oceanblue morningglory	Uncommon	Native
Convolvulaceae	*Ipomoea nil*	whiteedge morningglory	Uncommon	Non-Native
Convolvulaceae	*Ipomoea ochracea*	fence morningglory	Uncommon	Non-Native
Convolvulaceae	*Ipomoea pes-caprae*	bayhops	Common	Native
Convolvulaceae	*Ipomoea repanda*	bejuco colorado	Common	Native
Convolvulaceae	*Ipomoea setifera*	bejuco de puerco	Uncommon	Native
Convolvulaceae	*Ipomoea triloba*	littlebell	Common	Native
Convolvulaceae	*Ipomoea violacea*	beach moonflower	Common	Native
Convolvulaceae	*Jacquemontia cumanensis*	thicket clustervine	Uncommon	Native
Convolvulaceae	*Jacquemontia havanensis*	Havana clustervine	Uncommon	Native
Convolvulaceae	*Jacquemontia pentanthos*	skyblue clustervine	Common	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Convolvulaceae	*Jacquemontia solanifolia*	cambustera de costa	Uncommon	Native
Convolvulaceae	*Merremia aegyptia*	hairy woodrose	Uncommon	Native
Convolvulaceae	*Merremia dissecta*	noyau vine	Uncommon	Native
Convolvulaceae	*Merremia quinquefolia*	rock rosemary	Common	Native
Convolvulaceae	*Merremia tuberosa*	Spanish arborvine	Uncommon	Non-Native
Convolvulaceae	*Merremia umbellata*	hogvine	Uncommon	Native
Convolvulaceae	*Stictocardia tiliifolia*	spottedheart	Uncommon	Native
Cordiaceae	*Cordia alliodora*	cypre, Spanish elm	Uncommon	Native
Cordiaceae	*Cordia collococca*	red manjack	Common	Native
Cordiaceae	*Cordia laevigata*	smooth manjack	Uncommon	Native
Cordiaceae	*Cordia polycephala*	black-sage	Uncommon	Native
Cordiaceae	*Cordia rickseckeri*	San Bartolome	Uncommon	Native
Cordiaceae	*Cordia sebestena*	largeleaf geigertree	Uncommon	Native
Cordiaceae	*Cordia sulcata*	mucilage manjack	Common	Native
Crassulaceae	*Kalanchoe pinnata*	cathedral bells	Common	Non-Native
Cucurbitaceae	*Cayaponia americana*	American melonleaf	Uncommon	Native
Cucurbitaceae	*Cucumis anguria*	West Indian gherkin	Uncommon	Non-Native
Cucurbitaceae	*Doyerea emetocathartica*	coralfruit	Uncommon	Native
Cucurbitaceae	*Melothria pendula*	drooping melonnettle	Uncommon	Non-Native
Cucurbitaceae	*Momordica charantia*	balsampear	Uncommon	Non-Native
Cyatheaceae	*Cyathea arborea*	West Indian treefern	Uncommon	Native
Cymodoceaceae	*Syringodium filiforme*	manatee grass	Uncommon	Native
Cyperaceae	*Abildgaardia ovata*	flatspike sedge	Uncommon	Native
Cyperaceae	*Bulbostylis pauciflora*	fewflower hairsedge	Rare	Native
Cyperaceae	*Cyperus compressus*	poorland flatsedge	Uncommon	Native
Cyperaceae	*Cyperus distans*	Piedmont flatsedge	Uncommon	Native
Cyperaceae	*Cyperus elegans*	sticky flatsedge	Common	Native
Cyperaceae	*Cyperus flexuosus*	Vahl's flatsedge	Common	Native
Cyperaceae	*Cyperus ligularis*	Alabama swamp flatsedge	Common	Native
Cyperaceae	*Cyperus nanus*	Indian flatsedge	Uncommon	Native
Cyperaceae	*Cyperus planifolius*	flatleaf flatsedge	Uncommon	Native
Cyperaceae	*Cyperus surinamensis*	tropical flatsedge	Uncommon	Native
Cyperaceae	*Eleocharis geniculata*	Canada spikesedge	Common	Native
Cyperaceae	*Fimbristylis dichotoma*	forked fimbry	Uncommon	Native
Cyperaceae	*Fimbristylis ferruginea*	West Indian fimbry	Common	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Cyperaceae	*Fimbristylis spathacea*	hurricanegrass	Common	Native
Cyperaceae	*Kyllinga odorata*	fragrant spikesedge	Uncommon	Native
Cyperaceae	*Rhynchospora nervosa* ssp. *ciliata*	yerba de estrella	Uncommon	Native
Cyperaceae	*Scleria lithosperma*	Florida Keys nutrush	Common	Native
Cyperaceae	*Scleria pterota* var. *melaleuca*	–	Common	Native
Cyperaceae	*Scleria scindens*	hairy nutrush	Common	Native
Dioscoreaceae	*Dioscorea pilosiuscula*	bulbous yam	Uncommon	Native
Ehretiaceae	*Bourreria succulenta*	bodywood, pigeon berry	Common	Native
Ehretiaceae	*Rochefortia acanthophora*	greenheart ebony	Uncommon	Native
Erythroxylaceae	*Erythroxylum brevipes*	brisselet	Uncommon	Native
Euphorbiaceae	*Acalypha poiretii*	Poiret's copperleaf	Uncommon	Non-Native
Euphorbiaceae	*Adelia ricinella*	wild lime	Uncommon	Native
Euphorbiaceae	*Argythamnia candicans*	sharpleaf silverbush	Uncommon	Native
Euphorbiaceae	*Argythamnia fasciculata*	broom silverbush	Common	Native
Euphorbiaceae	*Argythamnia stahlii*	bluntleaf silverbush	Uncommon	Native
Euphorbiaceae	*Chamaesyce articulata*	jointed sandmat	Common	Native
Euphorbiaceae	*Chamaesyce hirta*	pillpod sandmat	Common	Native
Euphorbiaceae	*Chamaesyce hypericifolia*	graceful sandmat	Common	Native
Euphorbiaceae	*Chamaesyce hyssopifolia*	hyssopleaf sandmat	Common	Native
Euphorbiaceae	*Chamaesyce mesembrianthemifolia*	coastal beach sandmat	Common	Native
Euphorbiaceae	*Chamaesyce ophthalmica*	Florida hammock sandmat	Common	Native
Euphorbiaceae	*Chamaesyce prostrata*	ground spurge	Uncommon	Native
Euphorbiaceae	*Chamaesyce serpens*	matted sandmat, serpent spurge	Common	Native
Euphorbiaceae	*Chamaesyce thymifolia*	gulf sandmat	Common	Native
Euphorbiaceae	*Croton astroites*	wild marrow	Common	Native
Euphorbiaceae	*Croton betulinus*	beechleaf croton	Common	Native
Euphorbiaceae	*Croton fishlockii*	Fishlock's croton	Rare	Native
Euphorbiaceae	*Croton lobatus*	lobed croton	Common	Native
Euphorbiaceae	*Croton ovalifolius*	yerba	Common	Native
Euphorbiaceae	*Croton rigidus*	yellow balsam	Common	Native
Euphorbiaceae	*Dalechampia scandens*	spurgecreeper	Uncommon	Native
Euphorbiaceae	*Euphorbia heterophylla*	Mexican fireplant	Common	Native
Euphorbiaceae	*Euphorbia oerstediana*	West Indian spurge	Uncommon	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Euphorbiaceae	*Euphorbia petiolaris*	manchineel berry	Common	Native
Euphorbiaceae	*Euphorbia tirucalli*	Indiantree spurge	Uncommon	Non-Native
Euphorbiaceae	*Gymnanthes lucida*	oysterwood	Common	Native
Euphorbiaceae	*Hippomane mancinella*	manchineel	Common	Native
Euphorbiaceae	*Hura crepitans*	sandbox tree	Uncommon	Native
Euphorbiaceae	*Jatropha gossypiifolia*	bellyache bush	Uncommon	Native
Euphorbiaceae	*Pedilanthus tithymaloides*	redbird flower	Uncommon	Non-Native
Euphorbiaceae	*Ricinus communis*	castor bean	Uncommon	Non-Native
Euphorbiaceae	*Sapium caribaeum*	gumtree	Uncommon	Native
Euphorbiaceae	*Tragia volubilis*	fireman	Common	Native
Fabaceae	*Abrus precatorius*	crab's eye	Common	Non-Native
Fabaceae	*Acacia macracantha*	long-spine acacia	Common	Native
Fabaceae	*Acacia muricata*	spineless wattle	Common	Native
Fabaceae	*Acacia retusa*	catch and keep	Uncommon	Native
Fabaceae	*Acacia tortuosa*	twisted acacia	Common	Native
Fabaceae	*Adenanthera pavonina*	coral bean tree	Uncommon	Non-Native
Fabaceae	*Aeschynomene americana*	shyleaf	Uncommon	Native
Fabaceae	*Albizia lebbeck*	woman's tongue	Uncommon	Non-Native
Fabaceae	*Andira inermis*	bastard mahogany	Common	Native
Fabaceae	*Caesalpinia bonduc*	grey nicker	Uncommon	Native
Fabaceae	*Caesalpinia ciliata*	mato	Uncommon	Native
Fabaceae	*Caesalpinia pulcherrima*	dwarf poinciana	Uncommon	Non-Native
Fabaceae	*Canavalia rosea*	baybean	Common	Native
Fabaceae	*Centrosema virginianum*	wist vine	Common	Native
Fabaceae	*Chamaecrista glandulosa* var. *swartzii*	Swartz's Jamaican broom	Common	Native
Fabaceae	*Chamaecrista nictitans* ssp. *nictitans*	partridge pea	Common	Native
Fabaceae	*Clitoria ternatea*	Asian pigeonwings	Unknown	Non-Native
Fabaceae	*Coursetia caribaea*	anil falso	Uncommon	Native
Fabaceae	*Crotalaria incana*	shakeshake	Common	Native
Fabaceae	*Crotalaria lotifolia*	cascabelillo axilar	Common	Native
Fabaceae	*Crotalaria pallida* var. *obovata*	smooth rattlebox	Common	Non-Native
Fabaceae	*Crotalaria retusa*	rattleweed	Common	Non-Native
Fabaceae	*Crotalaria verrucosa*	blue rattlesnake	Common	Non-Native
Fabaceae	*Dalbergia ecastaphyllum*	coinvine	Uncommon	Native
Fabaceae	*Desmanthus virgatus*	wild tantan	Common	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Fabaceae	*Desmodium glabrum*	zarzabacoa dulce	Uncommon	Native
Fabaceae	*Desmodium incanum*	tickclover	Uncommon	Native
Fabaceae	*Desmodium procumbens*	western trailing tickclover	Uncommon	Native
Fabaceae	*Desmodium triflorum*	threeflower ticktrefoil	Common	Native
Fabaceae	*Erythrina eggersii*	cock's spur	Rare	Native
Fabaceae	*Galactia dubia*	West Indian milkpea	Common	Native
Fabaceae	*Galactia eggersii*	Eggers' milkpea	Uncommon	Native
Fabaceae	*Galactia striata*	Florida hammock milkpea	Common	Native
Fabaceae	*Gliricidia sepium*	quickstick	Uncommon	Non-Native
Fabaceae	*Hymenaea courbaril*	stinkingtoe	Common	Native
Fabaceae	*Indigofera suffruticosa*	indigobush	Common	Native
Fabaceae	*Indigofera tinctoria*	true indigo	Uncommon	Non-Native
Fabaceae	*Inga laurina*	sacky sac bean	Common	Native
Fabaceae	*Lablab purpureus*	hyacinthbean	Uncommon	Non-Native
Fabaceae	*Leucaena leucocephala*	lead tree	Common	Non-Native
Fabaceae	*Machaerium lunatum*	palo de hoz	Common	Non-Native
Fabaceae	*Macroptilium lathyroides*	wild bushbean	Uncommon	Native
Fabaceae	*Mimosa ceratonia*	black ambret	Uncommon	Native
Fabaceae	*Mimosa pudica*	shameplant	Uncommon	Native
Fabaceae	*Parkinsonia aculeata*	Jerusalem thorn	Uncommon	Non-Native
Fabaceae	*Peltophorum pterocarpa*	yellow poinciana	Uncommon	Non-Native
Fabaceae	*Phaseolus peduncularis*	–	Uncommon	Native
Fabaceae	*Pictetia aculeata*	fustic	Common	Native
Fabaceae	*Piscidia carthagenensis*	stinkwood	Uncommon	Native
Fabaceae	*Pithecellobium unguis-cati*	catclaw blackbead	Common	Native
Fabaceae	*Poitea florida*	wattapama	Common	Native
Fabaceae	*Pueraria phaseoloides*	tropical kudzu	Uncommon	Non-Native
Fabaceae	*Rhynchosia minima*	least snoutbean	Common	Native
Fabaceae	*Rhynchosia reticulata*	habilla	Common	Native
Fabaceae	*Samanea saman*	raintree	Uncommon	Non-Native
Fabaceae	*Senna bicapsularis*	Christmasbush	Common	Non-Native
Fabaceae	*Senna obtusifolia*	Java-bean	Common	Native
Fabaceae	*Senna occidentalis*	wild coffee	Common	Native
Fabaceae	*Senna siamea*	Siamese cassia	Uncommon	Non-Native
Fabaceae	*Sesbania sericea*	papagayo	Uncommon	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Fabaceae	*Sophora tomentosa*	yellow necklacepod	Uncommon	Native
Fabaceae	*Stylosanthes hamata*	cheesytoes	Common	Native
Fabaceae	*Tamarindus indica*	tamarind	Uncommon	Non-Native
Fabaceae	*Tephrosia cinerea*	ashen hoarypea	Common	Native
Fabaceae	*Tephrosia senna*	anil racimillo	Uncommon	Native
Fabaceae	*Teramnus labialis*	blue wiss	Common	Native
Fabaceae	*Vigna luteola*	hairypod cowpea	Common	Native
Fabaceae	*Zapoteca portoricensis*	white stickpea	Common	Native
Goodeniaceae	*Scaevola plumieri*	gullfeed	Uncommon	Native
Heliotropiaceae	*Argusia gnaphalodes*	sea rosemary	Common	Native
Heliotropiaceae	*Heliotropium angiospermum*	scorpionstail, scorpion's-tail	Common	Native
Heliotropiaceae	*Heliotropium curassavicum*	seaside heliotrope	Common	Native
Heliotropiaceae	*Heliotropium indicum*	India heliotrope, Indian heliotrope	Uncommon	Native
Heliotropiaceae	*Heliotropium ternatum*	bushy heliotrope	Uncommon	Native
Heliotropiaceae	*Tournefortia bicolor*	niguita	Uncommon	Native
Heliotropiaceae	*Tournefortia filiflora*	cold withe	Rare	Native
Heliotropiaceae	*Tournefortia hirsutissima*	chiggery grapes	Common	Native
Heliotropiaceae	*Tournefortia volubilis*	twining soldierbush	Uncommon	Native
Hydrocharitaceae	*Thalassia testudinum*	–	Uncommon	Native
Hypoxidaceae	*Hypoxis hirsuta*	common goldstar	Uncommon	Native
Lamiaceae	*Clerodendrum aculeatum*	haggarbush	Uncommon	Native
Lamiaceae	*Hyptis capitata*	false ironwort	Common	Non-Native
Lamiaceae	*Hyptis pectinata*	French Tea	Common	Native
Lamiaceae	*Hyptis suaveolens*	pignut	Common	Native
Lamiaceae	*Hyptis verticillata*	John Charles	Common	Native
Lamiaceae	*Leonotis nepetifolia*	Christmas candlestick	Common	Non-Native
Lamiaceae	*Leonurus sibiricus*	honeyweed	Uncommon	Non-Native
Lamiaceae	*Ocimum campechianum*	least basil	Common	Native
Lamiaceae	*Salvia micrantha*	Yucatan sage	Common	Native
Lamiaceae	*Salvia occidentalis*	West Indian sage	Uncommon	Native
Lamiaceae	*Salvia serotina*	littlewoman	Common	Native
Lauraceae	*Cinnamomum elongatum*	laurel avispillo	Common	Native
Lauraceae	*Licaria parvifolia*	Puerto Rico cinnamon	Uncommon	Native
Lauraceae	*Licaria triandra*	pepperleaf sweetwood	Common	Native
Lauraceae	*Ocotea coriacea*	lancewood	Common	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Lauraceae	*Ocotea floribunda*	laurel espada	Uncommon	Native
Lauraceae	*Ocotea leucoxylon*	loblolly sweetwood	Uncommon	Native
Lauraceae	*Ocotea patens*	capberry	Uncommon	Native
Lindsaeaceae	*Odontosoria aculeata*	thicket creepingfern	Occasional	Native
Loganiaceae	*Spigelia anthelmia*	West Indian pinkroot	Uncommon	Native
Lomariopsidaceae	*Nephrolepis exaltata*	Boston swordfern	Uncommon	Native
Lomariopsidaceae	*Nephrolepis multiflora*	Asian swordfern	Common	Non-Native
Loranthaceae	*Dendropemon caribaeus*	four-angle leechbush	Common	Native
Lythraceae	*Ammannia coccinea*	purple ammannia	Uncommon	Native
Lythraceae	*Ammannia latifolia*	pink redstem	Uncommon	Native
Lythraceae	*Ginoria rohrii*	bastard gregre	Common	Native
Malpighiaceae	*Bunchosia glandulosa*	cafe forastero	Common	Native
Malpighiaceae	*Byrsonima lucida*	Long Key locustberry	Common	Native
Malpighiaceae	*Byrsonima spicata*	doncella, Maricao cimarron	Uncommon	Native
Malpighiaceae	*Heteropteris purpurea*	bull withe	Common	Native
Malpighiaceae	*Malpighia coccigera*	Singapore holly	Rare	Native
Malpighiaceae	*Malpighia linearis*	bastard cherry	Uncommon	Native
Malpighiaceae	*Malpighia woodburyana*	Woodbury's stingingbush	Uncommon	Native
Malpighiaceae	*Stigmaphyllon emarginatum*	monarch Amazonvine	Common	Native
Malpighiaceae	*Stigmaphyllon floribundum*	woolly Amazonvine	Common	Native
Malvaceae	*Abutilon umbellatum*	umbrella Indian mallow	Common	Native
Malvaceae	*Ayenia insulicola*	dwarf ayenia	Uncommon	Native
Malvaceae	*Bastardia viscosa* var. *sanctae-crucis*	viscid mallow	Common	Native
Malvaceae	*Bastardia viscosa* var. *viscosa*	viscid mallow	Common	Native
Malvaceae	*Ceiba pentandra*	kapoktree	Uncommon	Non-Native
Malvaceae	*Corchorus aestuans*	jute	Uncommon	Native
Malvaceae	*Corchorus hirsutus*	jackswitch	Common	Native
Malvaceae	*Corchorus siliquosus*	slippery burr	Uncommon	Native
Malvaceae	*Gossypium barbadense*	Creole cotton	Uncommon	Non-Native
Malvaceae	*Guazuma ulmifolia*	bastardcedar	Common	Native
Malvaceae	*Helicteres jamaicensis*	screwtree	Uncommon	Native
Malvaceae	*Herissantia crispa*	bladdermallow	Uncommon	Native
Malvaceae	*Malachra alceifolia*	yellow leafbract	Uncommon	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Malvaceae	*Malvastrum americanum*	Indian Valley false mallow	Uncommon	Native
Malvaceae	*Malvastrum corchorifolium*	false mallow	Common	Native
Malvaceae	*Malvastrum coromandelianum*	threelobe false mallow	Uncommon	Native
Malvaceae	*Melochia nodiflora*	bretonica prieta	Common	Native
Malvaceae	*Melochia pyramidata*	pyramidflower	Uncommon	Native
Malvaceae	*Melochia tomentosa*	teabush	Common	Native
Malvaceae	*Pavonia spinifex*	gingerbush	Uncommon	Native
Malvaceae	*Quararibea turbinata*	swizzlestick tree	Common	Native
Malvaceae	*Sida acuta*	common wireweed	Common	Native
Malvaceae	*Sida ciliaris*	bracted fanpetals, bracted sida	Uncommon	Native
Malvaceae	*Sida cordifolia*	`ilima	Uncommon	Native
Malvaceae	*Sida glabra*	smooth fanpetals	Uncommon	Native
Malvaceae	*Sida glomerata*	clustered fanpetals	Common	Native
Malvaceae	*Sida glutinosa*	sticky fanpetals	Uncommon	Native
Malvaceae	*Sida jamaicensis*	Jamaican fanpetals	Uncommon	Native
Malvaceae	*Sida repens*	Javanese fanpetals	Uncommon	Native
Malvaceae	*Sida spinosa*	prickly sida	Uncommon	Native
Malvaceae	*Sida urens*	tropical fanpetals	Uncommon	Native
Malvaceae	*Sidastrum multiflorum*	manyflower sandmallow	Common	Native
Malvaceae	*Theobroma cacao*	cacao	Uncommon	Non-Native
Malvaceae	*Thespesia populnea*	Portia tree, seaside mahoe	Common	Native
Malvaceae	*Triumfetta lappula*	grandcousin	Uncommon	Native
Malvaceae	*Triumfetta semitriloba*	Sacramento burbark	Uncommon	Non-Native
Malvaceae	*Urena lobata*	Caesarweed	Common	Native
Malvaceae	*Waltheria indica*	basora-prieta, uhaloa	Common	Native
Malvaceae	*Wissadula amplissima*	big yellow velvetleaf	Uncommon	Native
Malvaceae	*Wissadula periplocifolia*	white velvetleaf	Common	Native
Melastomataceae	*Miconia laevigata*	smooth johnnyberry	Common	Native
Melastomataceae	*Tetrazygia angustifolia*	stinkingfish	Uncommon	Native
Melastomataceae	*Tetrazygia elaeagnoides*	krekre	Uncommon	Native
Meliaceae	*Cedrela odorata*	Spanish cedar	Uncommon	Native
Meliaceae	*Melia azedarach*	chinaberry	Common	Non-Native
Meliaceae	*Swietenia mahagoni*	West Indian mahogany	Uncommon	Non-Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Menispermaceae	*Cissampelos pareira*	pareira brava, velvetleaf	Common	Native
Menispermaceae	*Hyperbaena domingensis*	forest snakevine	Uncommon	Native
Molluginaceae	*Mollugo nudicaulis*	nakedstem carpetweed	Uncommon	Non-Native
Moraceae	*Ficus citrifolia*	shortleaf fig, wild banyantree	Common	Native
Moraceae	*Ficus trigonata*	jaguey blanco	Common	Native
Myrtaceae	*Calyptranthes thomasiana*	Thomas' lidflower	Rare	Native
Myrtaceae	*Eugenia axillaris*	white stopper	Uncommon	Native
Myrtaceae	*Eugenia biflora*	blackrodwood	Uncommon	Native
Myrtaceae	*Eugenia confusa*	redberry stopper	Uncommon	Native
Myrtaceae	*Eugenia cordata*	lathberry	Common	Native
Myrtaceae	*Eugenia earhartii*	Earhart's stopper	Rare	Native
Myrtaceae	*Eugenia ligustrina*	privet stopper	Common	Native
Myrtaceae	*Eugenia monticola*	birdcherry	Common	Native
Myrtaceae	*Eugenia procera*	rockmyrtle	Uncommon	Native
Myrtaceae	*Eugenia pseudopsidium*	Christmas cherry	Common	Native
Myrtaceae	*Eugenia sessiliflora*	sessileleaf stopper	Uncommon	Native
Myrtaceae	*Myrcia citrifolia* var. *imrayana*	red rodwood	Uncommon	Native
Myrtaceae	*Myrcianthes fragrans*	twinberry stopper	Common	Unknown
Myrtaceae	*Myrciaria floribunda*	guavaberry	Uncommon	Native
Myrtaceae	*Pimenta racemosa* var. *racemosa*	bayrumtree	Uncommon	Unknown
Myrtaceae	*Psidium amplexicaule*	mountain guava	Uncommon	Native
Myrtaceae	*Psidium guajava*	guava	Uncommon	Non-Native
Nyctaginaceae	*Boerhavia coccinea*	scarlet spiderling	Common	Native
Nyctaginaceae	*Boerhavia diffusa*	red spiderling	Common	Native
Nyctaginaceae	*Boerhavia erecta*	erect spiderling	Common	Native
Nyctaginaceae	*Boerhavia scandens*	climbing spiderling	Common	Native
Nyctaginaceae	*Guapira fragrans*	black mampoo	Uncommon	Native
Nyctaginaceae	*Neea buxifolia*	saltwood	Uncommon	Native
Nyctaginaceae	*Pisonia aculeata*	pullback	Uncommon	Native
Nyctaginaceae	*Pisonia subcordata*	water mampoo	Common	Native
Ochnaceae	*Ouratea littoralis*	abey amarillo	Uncommon	Native
Oleaceae	*Chionanthus compactus*	bridgotree	Common	Native
Oleaceae	*Forestiera eggersiana*	inkbush	Uncommon	Native
Oleaceae	*Jasminum fluminense*	Brazilian jasmine	Uncommon	Non-Native
Oleaceae	*Jasminum multiflorum*	star jasmine	Common	Non-Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Onagraceae	*Ludwigia octovalvis*	Mexican primrosewillow	Common	Native
Ophioglossaceae	*Ophioglossum reticulatum*	netted adderstongue	Uncommon	Native
Orchidaceae	*Cyclopogon cranichoides*	cranichis-like ladies'-tresses	Rare	Native
Orchidaceae	*Cyclopogon elatus*	tall ladies'-tresses	Rare	Native
Orchidaceae	*Epidendrum anceps*	brown-flower butterfly orchid	Rare	Native
Orchidaceae	*Epidendrum ciliare*	fringed star orchid	Uncommon	Native
Orchidaceae	*Oeceoclades maculata*	ground orchid, monk orchid	Uncommon	Non-Native
Orchidaceae	*Ponthieva racemosa*	hairy shadow witch	Rare	Native
Orchidaceae	*Prescotia oligantha*	small Prescott orchid	Uncommon	Native
Orchidaceae	*Psychilis macconnelliae*	island peacock orchid	Common	Native
Orchidaceae	*Tetramicra canaliculata*	serpentine wallflower orchid	Uncommon	Native
Orchidaceae	*Tolumnia prionochila*	tropical dancing-lady orchid	Uncommon	Native
Orchidaceae	*Tolumnia variegata*	harlequin dancing-lady orchid	Uncommon	Native
Orchidaceae	*Vanilla barbellata*	wormvine orchid	Uncommon	Native
Orchidaceae	*Vanilla planifolia*	vanilla	Uncommon	Non-Native
Oxalidaceae	*Oxalis corniculata*	creeping oxalis	Uncommon	Native
Papaveraceae	*Argemone mexicana*	Mexican prickly poppy	Common	Non-Native
Passifloraceae	*Passiflora foetida*	stinking passionflower	Uncommon	Native
Passifloraceae	*Passiflora laurifolia*	golden bellapple	Common	Native
Passifloraceae	*Passiflora multiflora*	whiteflower passionflower	Uncommon	Native
Passifloraceae	*Passiflora rubra*	dutchman's laudanum	Common	Native
Passifloraceae	*Passiflora suberosa*	corky passionflower	Common	Native
Passifloraceae	*Turnera diffusa*	damiana	Common	Native
Passifloraceae	*Turnera ulmifolia*	ramgoat dashalong	Uncommon	Native
Pentaphylacaceae	*Ternstroemia peduncularis*	–	Uncommon	Native
Phyllanthaceae	*Flueggea acidoton*	simpleleaf bushweed	Rare	Native
Phyllanthaceae	*Margaritaria nobilis*	bastard hogberry	Common	Native
Phyllanthaceae	*Phyllanthus acidus*	Tahitian gooseberry tree	Uncommon	Non-Native
Phyllanthaceae	*Phyllanthus amarus*	carry me seed	Common	Native
Phyllanthaceae	*Phyllanthus niruri*	cane piece senna	Common	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Phytolaccaceae	*Petiveria alliacea*	guinea henweed	Common	Native
Phytolaccaceae	*Rivina humilis*	bloodberry rougeplant	Uncommon	Native
Phytolaccaceae	*Trichostigma octandrum*	hoopvine	Common	Native
Piperaceae	*Peperomia glabella*	cypress peperomia	Uncommon	Native
Piperaceae	*Peperomia humilis*	Polynesian peperomia	Uncommon	Native
Piperaceae	*Peperomia magnoliifolia*	spoonleaf peperomia	Uncommon	Native
Piperaceae	*Peperomia myrtifolia*	myrtleleaf peperomia	Uncommon	Native
Piperaceae	*Peperomia pellucida*	man to man	Uncommon	Native
Piperaceae	*Piper amalago*	higuillo de limon	Uncommon	Native
Plantaginaceae	*Bacopa monnieri*	coastal waterhyssop	Uncommon	Native
Plantaginaceae	*Plantago major*	broadleaf plantain	Uncommon	Native
Plantaginaceae	*Scoparia dulcis*	licorice weed	Uncommon	Native
Plumbaginaceae	*Plumbago scandens*	doctorbush, plumbago	Common	Native
Poaceae	*Andropogon bicornis*	West Indian foxtail	Uncommon	Native
Poaceae	*Anthephora hermaphrodita*	oldfield grass	Uncommon	Native
Poaceae	*Aristida cognata*	spreading threeawn	Uncommon	Native
Poaceae	*Arthrostylidium farctum*	old man's beard	Uncommon	Native
Poaceae	*Axonopus compressus*	broadleaf carpetgrass	Uncommon	Native
Poaceae	*Bambusa vulgaris*	common bamboo	Uncommon	Non-Native
Poaceae	*Bothriochloa pertusa*	pitted beardgrass	Common	Non-Native
Poaceae	*Bouteloua americana*	American grama	Uncommon	Native
Poaceae	*Cenchrus echinatus*	common sandbur	Uncommon	Native
Poaceae	*Chloris barbata*	swollen fingergrass	Common	Native
Poaceae	*Cynodon dactylon*	Bermudagrass	Uncommon	Non-Native
Poaceae	*Dactyloctenium aegyptium*	Durban crowsfoot grass	Common	Non-Native
Poaceae	*Digitaria ciliaris*	southern crabgrass	Uncommon	Native
Poaceae	*Digitaria hitchcockii*	shortleaf crabgrass	Uncommon	Native
Poaceae	*Digitaria horizontalis*	Jamaican crabgrass	Uncommon	Native
Poaceae	*Digitaria insularis*	sourgrass	Common	Native
Poaceae	*Echinochloa colona*	jungle ricegrass	Uncommon	Non-Native
Poaceae	*Eleusine indica*	crowsfoot grass	Uncommon	Native
Poaceae	*Eragrostis ciliaris*	gophertail lovegrass	Uncommon	Non-Native
Poaceae	*Eragrostis tenella*	Japanese lovegrass	Uncommon	Non-Native
Poaceae	*Eriochloa punctata*	Louisiana cupgrass	Uncommon	Native
Poaceae	*Heteropogon contortus*	tanglehead	Uncommon	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Poaceae	*Lasiacis divaricata*	smallcane	Uncommon	Native
Poaceae	*Lasiacis ligulata*	thicket tribisee	Uncommon	Native
Poaceae	*Lasiacis sorghoidea*	woodland tribisee	Uncommon	Native
Poaceae	*Leptochloa virgata*	tropic sprangletop	Uncommon	Native
Poaceae	*Olyra latifolia*	carrycillo	Uncommon	Native
Poaceae	*Oplismenus hirtellus*	bristle basketgrass	Uncommon	Native
Poaceae	*Panicum diffusum*	West Indian panicgrass	Rare	Native
Poaceae	*Paspalidium geminatum*	Egyptian panicgrass	Uncommon	Native
Poaceae	*Paspalum conjugatum*	herbe creole	Uncommon	Native
Poaceae	*Paspalum fimbriatum*	Panama crowngrass	Common	Native
Poaceae	*Paspalum laxum*	coconut paspalum	Uncommon	Native
Poaceae	*Paspalum molle*	soft paspalum	Uncommon	Native
Poaceae	*Paspalum notatum*	Bahia grass	Uncommon	Native
Poaceae	*Paspalum vaginatum*	seashore paspalum	Uncommon	Native
Poaceae	*Pennisetum clandestinum*	Kikuyu grass	Uncommon	Non-Native
Poaceae	*Pharus lappulaceus*	Cape Francais stalkgrass	Common	Native
Poaceae	*Schizachyrium sanguineum*	crimson bluestem	Uncommon	Native
Poaceae	*Setaria setosa*	West Indian bristlegrass	Common	Native
Poaceae	*Setaria utowanaea*	Caribbean bristlegrass	Uncommon	Native
Poaceae	*Spartina patens*	saltmeadow cordgrass	Uncommon	Native
Poaceae	*Sporobolus indicus*	Rattail smutgrass	Uncommon	Native
Poaceae	*Sporobolus virginicus*	seashore dropseed	Uncommon	Native
Poaceae	*Tragus berteronianus*	spiked burrgrass	Uncommon	Non-Native
Poaceae	*Uniola virgata*	–	Uncommon	Native
Poaceae	*Urochloa adspersa*	Dominican signalgrass	Uncommon	Native
Poaceae	*Urochloa fasciculata*	browntop signalgrass	Common	Native
Poaceae	*Urochloa maxima*	guineagrass	Uncommon	Non-Native
Polygonaceae	*Antigonon leptopus*	coral vine	Common	Non-Native
Polygonaceae	*Coccoloba krugii*	whitewood	Common	Native
Polygonaceae	*Coccoloba microstachya*	puckhout	Common	Native
Polygonaceae	*Coccoloba swartzii*	Swartz's pigeonplum	Uncommon	Native
Polygonaceae	*Coccoloba uvifera*	seagrape	Uncommon	Native
Polygonaceae	*Coccoloba venosa*	false chiggergrape	Common	Native
Polypodiaceae	*Campyloneurum latum*	birdwing fern	Occasional	Native
Polypodiaceae	*Campyloneurum phyllitidis*	long strapfern	Occasional	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Polypodiaceae	*Phlebodium aureum*	golden polypody	Occasional	Native
Polypodiaceae	*Pleopeltis astrolepis*	starscale fern	Occasional	Native
Portulacaceae	*Portulaca oleracea*	common purslane	Common	Native
Portulacaceae	*Portulaca quadrifida*	chickenweed	Uncommon	Native
Portulacaceae	*Portulaca rubricaulis*	redstem purslane	Uncommon	Native
Primulaceae	*Ardisia obovata*	Guadeloupe marlberry	Uncommon	Native
Primulaceae	*Jacquinia arborea*	braceletwood	Uncommon	Native
Primulaceae	*Jacquinia berteroi*	Bertero's barbasco	Common	Native
Psilotaceae	*Psilotum nudum*	whisk fern	Common	Native
Pteridaceae	*Acrostichum danaeifolium*	inland leatherfern	Rare	Native
Pteridaceae	*Adiantum fragile* var. *fragile*	fragile maidenhair	Common	Native
Pteridaceae	*Adiantum fragile* var. *rigidulum*	fragile maidenhair	Occasional	Native
Pteridaceae	*Adiantum tenerum*	fan maidenhair	Uncommon	Native
Pteridaceae	*Doryopteris pedata*	digit fern	Uncommon	Native
Pteridaceae	*Pityrogramma calomelanos*	Dixie silverback fern	Occasional	Native
Pteridaceae	*Pityrogramma chrysophylla* var. *gabrielae*	island goldback fern	Occasional	Native
Pteridaceae	*Pteris biaurita*	thinleaf brake	Occasional	Native
Pteridaceae	*Pteris vittata*	Chinese brake	Occasional	Native
Putranjivaceae	*Drypetes alba*	cafeillo	Rare	Native
Rhamnaceae	*Colubrina arborescens*	coffee colubrina	Uncommon	Native
Rhamnaceae	*Colubrina elliptica*	soldierwood	Common	Native
Rhamnaceae	*Gouania lupuloides*	whiteroot	Common	Native
Rhamnaceae	*Krugiodendron ferreum*	ironwood	Common	Native
Rhamnaceae	*Reynosia guama*	guama	Uncommon	Native
Rhizophoraceae	*Rhizophora mangle*	red mangrove	Uncommon	Native
Rosaceae	*Prunus pleuradenia*	Antilles cherry	NA	Native
Rubiaceae	*Chiococca alba*	West Indian milkberry	Uncommon	Non-Native
Rubiaceae	*Chione venosa*	fatpork	Rare	Native
Rubiaceae	*Coffea arabica*	Arabian coffee	Uncommon	Non-Native
Rubiaceae	*Diodia ocymifolia*	slender buttonweed	Uncommon	Native
Rubiaceae	*Erithalis fruticosa*	blacktorch	Common	Native
Rubiaceae	*Exostema caribaeum*	Caribbean princewood	Common	Native
Rubiaceae	*Faramea occidentalis*	false coffee	Unknown	Native
Rubiaceae	*Genipa americana*	jagua	Uncommon	Non-Native
Rubiaceae	*Geophila repens*	corrida yerba de guava	Rare	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Rubiaceae	*Gonzalagunia hirsuta*	mata de Mariposa	Uncommon	Native
Rubiaceae	*Guettarda odorata*	cucubano de vieques	Uncommon	Native
Rubiaceae	*Guettarda scabra*	roughleaf velvetseed	Common	Native
Rubiaceae	*Ixora ferrea*	palo de hierro	Common	Native
Rubiaceae	*Machaonia woodburyana*	alfilerillo	Rare	Native
Rubiaceae	*Morinda citrifolia*	Indian mulberry	Common	Non-Native
Rubiaceae	*Palicourea croceoides*	yellow-cedar	Uncommon	Native
Rubiaceae	*Psychotria brownei*	Browne's wild coffee	Uncommon	Native
Rubiaceae	*Psychotria domingensis*	cheakyberry	Uncommon	Native
Rubiaceae	*Psychotria microdon*	thicket wild coffee	Uncommon	Native
Rubiaceae	*Psychotria nervosa*	Seminole balsamo	Uncommon	Native
Rubiaceae	*Randia aculeata*	white indigoberry	Common	Native
Rubiaceae	*Rondeletia pilosa*	cordobancillo peludo	Uncommon	Native
Rubiaceae	*Scolosanthus versicolor*	Puerto Rico devilbrush	Uncommon	Native
Rubiaceae	*Spermacoce assurgens*	woodland false buttonweed	Uncommon	Native
Rubiaceae	*Spermacoce confusa*	river false buttonweed	Uncommon	Native
Rubiaceae	*Spermacoce prostrata*	prostrate false buttonweed	Common	Native
Ruppiaceae	*Ruppia maritima*	widgeongrass	Uncommon	Native
Rutaceae	*Amyris diatrypa*	hairy torchwood	Uncommon	Native
Rutaceae	*Amyris elemifera*	torchwood	Common	Native
Rutaceae	*Citrus aurantifolia*	–	Uncommon	Non-Native
Rutaceae	*Murraya exotica*	Chinese box	Uncommon	Non-Native
Rutaceae	*Pilocarpus racemosus*	aceitillo	Rare	Native
Rutaceae	*Triphasia trifolia*	limon-China	Uncommon	Non-Native
Rutaceae	*Zanthoxylum flavum*	West Indian satinwood	Rare	Native
Rutaceae	*Zanthoxylum martinicense*	white pricklyash	Uncommon	Native
Rutaceae	*Zanthoxylum monophyllum*	yellow prickle	Common	Native
Rutaceae	*Zanthoxylum thomasianum*	St. Thomas pricklyash	Rare	Native
Salicaceae	*Casearia decandra*	wild honeytree	Common	Native
Salicaceae	*Casearia guianensis*	Guyanese wild coffee	Common	Native
Salicaceae	*Casearia sylvestris*	crackopen	Common	Native
Salicaceae	*Prockia crucis*	guasimilla	Uncommon	Native
Salicaceae	*Samyda dodecandra*	guayabilla	Uncommon	Native
Salicaceae	*Xylosma buxifolia*	mucha-gente	Uncommon	Native
Sapindaceae	*Allophylus racemosus*	palo de caja	Uncommon	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Sapindaceae	*Cardiospermum corindum*	faux persil	Uncommon	Native
Sapindaceae	*Cardiospermum halicacabum*	balloonvine, love in a puff	Uncommon	Native
Sapindaceae	*Exothea paniculata*	inkwood	Uncommon	Native
Sapindaceae	*Melicoccus bijugatus*	Spanish lime	Common	Non-Native
Sapindaceae	*Serjania polyphylla*	basketwood	Common	Native
Sapotaceae	*Chrysophyllum bicolor*	star apple	Rare	Native
Sapotaceae	*Chrysophyllum pauciflorum*	–	Common	Native
Sapotaceae	*Manilkara bidentata*	bulletwood	Uncommon	Native
Sapotaceae	*Pouteria multiflora*	bullytree	Uncommon	Native
Sapotaceae	*Sideroxylon foetidissimum*	false mastic	Uncommon	Native
Sapotaceae	*Sideroxylon obovatum*	breakbill	Common	Native
Sapotaceae	*Sideroxylon salicifolium*	white bully	Common	Native
Schoepfiaceae	*Schoepfia obovata*	white beefwood	Rare	Native
Schoepfiaceae	*Schoepfia schreberi*	gulf graytwig	Uncommon	Native
Scrophulariaceae	*Bontia daphnoides*	white alling	Uncommon	Native
Scrophulariaceae	*Capraria biflora*	goatweed	Common	Native
Simaroubaceae	*Picrasma excelsa*	bitter-ash	Uncommon	Native
Smilacaceae	*Smilax coriacea*	Everglades greenbrier	Uncommon	Native
Solanaceae	*Brunfelsia americana*	American brunfelsia	Common	Native
Solanaceae	*Capsicum frutescens*	–	Common	Native
Solanaceae	*Cestrum laurifolium*	–	Common	Native
Solanaceae	*Datura inoxia*	angel's trumpet	Uncommon	Native
Solanaceae	*Datura stramonium*	jimsonweed	Uncommon	Non-Native
Solanaceae	*Physalis angulata*	cutleaf groundcherry	Common	Native
Solanaceae	*Physalis cordata*	heartleaf groundcherry	Uncommon	Native
Solanaceae	*Physalis turbinata*	thicket groundcherry	Uncommon	Native
Solanaceae	*Solanum americanum*	American black nightshade	Common	Native
Solanaceae	*Solanum conocarpum*	maron baccora	Rare	Native
Solanaceae	*Solanum erianthum*	mullein nightshade, potatotree	Uncommon	Non-Native
Solanaceae	*Solanum lanceifolium*	lanceleaf nightshade	Common	Native
Solanaceae	*Solanum polygamum*	cakalaka berry	Uncommon	Native
Solanaceae	*Solanum racemosum*	canker berry	Common	Native
Solanaceae	*Solanum torvum*	devil's fig	Uncommon	Non-Native
Surianaceae	*Suriana maritima*	bay cedar	Common	Native

Table A-1 (continued). Plant species (organized alphabetically by family) documented in VIIS (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Family	Scientific Name	Common Name	Abundance	Nativity
Symplocaceae	*Symplocos martinicensis*	Martinique sweetleaf	Uncommon	Native
Talinaceae	*Talinum fruticosum*	Verdolaga-Francesa	Common	Native
Talinaceae	*Talinum paniculatum*	big talinum	Uncommon	Native
Thelypteridaceae	*Thelypteris dentata*	downy maiden fern	Occasional	Non-Native
Thelypteridaceae	*Thelypteris hispidula*	roughhairy maiden fern	Occasional	Native
Thelypteridaceae	*Thelypteris kunthii*	Kunth's maiden fern	Common	Native
Thelypteridaceae	*Thelypteris poiteana*	darkgreen maiden fern	Occasional	Native
Thelypteridaceae	*Thelypteris tetragona*	freetip maiden fern	Occasional	Native
Thymelaeaceae	*Daphnopsis americana*	burn nose	Uncommon	Non-Native
Urticaceae	*Cecropia schreberiana*	pumpwood	Uncommon	Native
Urticaceae	*Laportea aestuans*	West Indian woodnettle	Uncommon	Native
Urticaceae	*Pilea microphylla*	rockweed	Common	Native
Urticaceae	*Pilea nummulariifolia*	creeping charlie	Uncommon	Native
Urticaceae	*Pilea sanctae-crucis*	Virgin Island clearweed	Common	Native
Urticaceae	*Pilea tenerrima*	musgo	Uncommon	Native
Verbenaceae	*Bouchea prismatica*	prism bouchea	Common	Native
Verbenaceae	*Citharexylum fruticosum*	Florida fiddlewood	Uncommon	Native
Verbenaceae	*Duranta erecta*	golden dewdrops	Uncommon	Native
Verbenaceae	*Lantana camara*	largeleaf lantana	Uncommon	Non-Native
Verbenaceae	*Lantana involucrata*	buttonsage	Common	Native
Verbenaceae	*Lantana urticifolia*	nettleleaf shrubverbena	Uncommon	Native
Verbenaceae	*Priva lappulacea*	catstongue	Uncommon	Non-Native
Verbenaceae	*Stachytarpheta jamaicensis*	light-blue snakeweed	Common	Native
Verbenaceae	*Stachytarpheta strigosa*	West Indian porterweed	Uncommon	Native
Vitaceae	*Cissus obovata*	spoonleaf treebine	Uncommon	Native
Vitaceae	*Cissus trifoliata*	sorrelvine	Common	Native
Vitaceae	*Cissus verticillata*	seasonvine	Common	Native
Vitaceae	*Vitis tiliifolia*	West Indian grape	Uncommon	Native
Xanthorrhoeaceae	*Aloe vera*	aloe vera	Uncommon	Non-Native
Ximeniaceae	*Ximenia americana*	tallow wood, tallowwood	Uncommon	Native
Zygophyllaceae	*Guajacum officinale*	lignum-vitae	Uncommon	Native
Zygophyllaceae	*Kallstroemia maxima*	big caltrop	Common	Native
Zygophyllaceae	*Kallstroemia pubescens*	Caribbean caltrop	Common	Native

Literature Cited

National Park Service (NPS). 2017. NPSpecies online application. Available at: https://irma.nps.gov/NPSpecies/ (accessed 26 March 2018)

Appendix B.

Bird species at VIIS are listed in Table B-1.

Table B-1. Bird species (organized alphabetically by Order) documented in VIIS from species inventories (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Order	Scientific Name	Common Names
Accipitriformes	*Accipiter striatus*	Sharp-shinned Hawk
Accipitriformes	*Buteo jamaicensis*	Red-tailed Hawk
Accipitriformes	*Circus cyaneus*	Northern Harrier
Accipitriformes	*Pandion haliaetus*	Osprey, Western Osprey
Anseriformes	*Anas acuta*	Northern Pintail
Anseriformes	*Anas americana*	American Wigeon
Anseriformes	*Anas bahamensis*	Bahama Duck, White-cheeked Pintail
Anseriformes	*Anas clypeata*	Northern Shoveler
Anseriformes	*Anas crecca*	Green-winged Teal
Anseriformes	*Anas discors*	Blue-winged Teal
Anseriformes	*Aythya affinis*	Lesser Scaup
Anseriformes	*Aythya collaris*	Ring-necked Duck
Anseriformes	*Dendrocygna arborea*	West Indian Whistling-Duck
Anseriformes	*Lophodytes cucullatus*	Hooded Merganser
Anseriformes	*Mergus serrator*	Red-breasted Merganser
Anseriformes	*Oxyura jamaicensis*	Ruddy Duck
Apodiformes	*Chaetura pelagica*	Chimney Swift
Apodiformes	*Anthracothorax dominicus*	Antillean Mango
Apodiformes	*Eulampis holosericeus*	Green-throated Carib
Apodiformes	*Orthorhyncus cristatus*	Antillean Crested Hummingbird
Caprimulgiformes	*Caprimulgus carolinensis*	Chuck-will's-widow
Caprimulgiformes	*Chordeiles gundlachii*	Antillean Nighthawk
Caprimulgiformes	*Chordeiles minor*	Common Nighthawk
Charadriiformes	*Charadrius semipalmatus*	Semipalmated Plover
Charadriiformes	*Charadrius vociferus*	Killdeer
Charadriiformes	*Charadrius wilsonia*	Wilson's Plover
Charadriiformes	*Pluvialis dominica*	American Golden Plover, Lesser Golden-Plover
Charadriiformes	*Pluvialis squatarola*	Black-bellied Plover, Grey Plover
Charadriiformes	*Haematopus palliatus*	American Oystercatcher
Charadriiformes	*Anous stolidus*	Brown Noddy
Charadriiformes	*Chlidonias niger*	Black Tern

[a] Indicates species probably present

Table B-1 (continued). Bird species (organized alphabetically by Order) documented in VIIS from species inventories (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Order	Scientific Name	Common Names
Charadriiformes	*Larus argentatus*	European Herring Gull, Herring Gull
Charadriiformes	*Larus atricilla*	Laughing Gull
Charadriiformes	*Larus delawarensis*	Ring-billed Gull
Charadriiformes	*Larus ridibundus*	Black-headed Gull, Common Black-headed Gull
Charadriiformes	*Sterna anaethetus*	Bridled Tern
Charadriiformes	*Sterna antillarum*	Least Tern
Charadriiformes	*Sterna dougallii*	Roseate Tern
Charadriiformes	*Sterna fuscata*	Sooty Tern
Charadriiformes	*Sterna hirundo*	Common Tern
Charadriiformes	*Sterna maxima*	Royal Tern
Charadriiformes	*Sterna nilotica*	Gull-billed Tern
Charadriiformes	*Sterna paradisaea*	Arctic Tern
Charadriiformes	*Sterna sandvicensis*	Sandwich Tern
Charadriiformes	*Himantopus mexicanus*	Ae'o, Black-necked Stilt, Hawaiian Stilt
Charadriiformes	*Actitis macularius*	Spotted Sandpiper
Charadriiformes	*Arenaria interpres*	Ruddy Turnstone
Charadriiformes	*Bartramia longicauda*	Upland Sandpiper
Charadriiformes	*Calidris alba*	Sanderling
Charadriiformes	*Calidris alpina*	Dunlin
Charadriiformes	*Calidris canutus*	Red Knot
Charadriiformes	*Calidris fuscicollis*	White-rumped Sandpiper
Charadriiformes	*Calidris himantopus*	Stilt Sandpiper
Charadriiformes	*Calidris mauri*	Western Sandpiper
Charadriiformes	*Calidris melanotos*	Pectoral Sandpiper
Charadriiformes	*Calidris minutilla*	Least Sandpiper
Charadriiformes	*Calidris pusilla*	Semipalmated Sandpiper
Charadriiformes	*Catoptrophorus semipalmatus*	Willet
Charadriiformes	*Gallinago delicata*	Wilson's Snipe
Charadriiformes	*Limnodromus griseus*	Short-billed Dowitcher
Charadriiformes	*Numenius phaeopus*	Whimbrel
Charadriiformes	*Tringa flavipes*	Lesser Yellowlegs
Charadriiformes	*Tringa melanoleuca*	Greater Yellowlegs
Charadriiformes	*Tringa solitaria*	Solitary Sandpiper
Charadriiformes	*Stercorarius pomarinus*	Pomarine Jaeger, Pomarine Skua
Columbiformes	*Columba livia*	Common Pigeon, Rock Dove, Rock Pigeon

[a] Indicates species probably present

Table B-1 (continued). Bird species (organized alphabetically by Order) documented in VIIS from species inventories (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Order	Scientific Name	Common Names
Columbiformes	*Columbina passerina*	Common Ground Dove
Columbiformes	*Geotrygon montana*	Ruddy Quail-Dove
Columbiformes	*Geotrygon mystacea*	Bridled Quail-Dove
Columbiformes	*Patagioenas leucocephala*	White-crowned Pigeon
Columbiformes	*Patagioenas squamosa*	Scaly-naped Pigeon
Columbiformes	*Zenaida asiatica*	White-winged Dove
Columbiformes	*Zenaida aurita*	Zenaida Dove
Coraciiformes	*Ceryle alcyon*	Belted Kingfisher
Cuculiformes	*Coccyzus americanus*	Yellow-billed Cuckoo
Cuculiformes	*Coccyzus minor*	Mangrove Cuckoo
Cuculiformes	*Crotophaga ani*	Smooth-billed Ani
Falconiformes	*Falco columbarius*	Merlin
Falconiformes	*Falco peregrinus*	Peregrine Falcon
Falconiformes	*Falco sparverius*	American Kestrel
Galliformes	*Numida meleagris*	Helmeted Guineafowl
Galliformes	*Gallus gallus*	Red Junglefowl
Gruiformes	*Fulica americana*	American Coot
Gruiformes	*Fulica caribaea*	Caribbean Coot
Gruiformes	*Gallinula chloropus*	Common Moorhen
Gruiformes	*Porzana carolina*	Sora
Gruiformes	*Rallus longirostris*	Clapper Rail
Passeriformes	*Passerina caerulea*	Blue Grosbeak
Passeriformes	*Passerina cyanea*	Indigo Bunting
Passeriformes	*Pheucticus ludovicianus*	Rose-breasted Grosbeak
Passeriformes	*Piranga olivacea*	Scarlet Tanager
Passeriformes	*Spiza americana*	Dickcissel
Passeriformes	*Coereba flaveola*	Bananaquit
Passeriformes	*Hirundo rustica*	Barn Swallow
Passeriformes	*Petrochelidon pyrrhonota*	Cliff Swallow
Passeriformes	*Progne dominicensis*	Caribbean Martin
Passeriformes	*Riparia riparia*	Bank Swallow, Sand Martin
Passeriformes	*Stelgidopteryx serripennis*	Northern Rough-winged Swallow
Passeriformes	*Tachycineta bicolor*	Tree Swallow
Passeriformes	*Dolichonyx oryzivorus*	Bobolink
Passeriformes	*Icterus galbula*	Baltimore Oriole, Northern Oriole

[a] Indicates species probably present

Table B-1 (continued). Bird species (organized alphabetically by Order) documented in VIIS from species inventories (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Order	Scientific Name	Common Names
Passeriformes	*Icterus icterus*	Troupial
Passeriformes	*Molothrus bonariensis*	Shiny Cowbird
Passeriformes	*Margarops fuscatus*	Pearly-eyed Thrasher
Passeriformes	*Mimus polyglottos*	Northern Mockingbird
Passeriformes	*Dendroica caerulescens*	Black-throated Blue Warbler
Passeriformes	*Dendroica castanea*	Bay-breasted Warbler
Passeriformes	*Dendroica coronata*	Yellow-rumped Warbler
Passeriformes	*Dendroica discolor*	Prairie Warbler
Passeriformes	*Dendroica dominica*	Yellow-throated Warbler
Passeriformes	*Dendroica fusca*	Blackburnian Warbler
Passeriformes	*Dendroica magnolia*	Magnolia Warbler
Passeriformes	*Dendroica palmarum*	Palm Warbler
Passeriformes	*Dendroica pensylvanica*	Chestnut-sided Warbler
Passeriformes	*Dendroica petechia*	American Yellow Warbler, Yellow Warbler
Passeriformes	*Dendroica striata*	Blackpoll Warbler
Passeriformes	*Dendroica tigrina*	Cape May Warbler
Passeriformes	*Dendroica virens*	Black-throated Green Warbler
Passeriformes	*Geothlypis trichas*	Common Yellowthroat
Passeriformes	*Helmitheros vermivorum*	Worm-eating Warbler
Passeriformes	*Limnothlypis swainsonii*	Swainson's Warbler
Passeriformes	*Mniotilta varia*	Black-and-white Warbler
Passeriformes	*Oporornis formosus*	Kentucky Warbler
Passeriformes	*Parula americana*	Northern Parula
Passeriformes	*Protonotaria citrea*	Prothonotary Warbler
Passeriformes	*Seiurus aurocapilla*	Ovenbird
Passeriformes	*Seiurus motacilla*	Louisiana Waterthrush
Passeriformes	*Seiurus noveboracensis*	Northern Waterthrush
Passeriformes	*Setophaga ruticilla*	American Redstart
Passeriformes	*Vermivora chrysoptera*	Golden-winged Warbler
Passeriformes	*Vermivora peregrina*	Tennessee Warbler
Passeriformes	*Vermivora pinus*	Blue-winged Warbler
Passeriformes	*Wilsonia citrina*	Hooded Warbler
Passeriformes	*Passer domesticus*	House Sparrow
Passeriformes	*Loxigilla noctis*	Lesser Antillean Bullfinch
Passeriformes	*Tiaris bicolor*	Black-faced Grassquit

[a] Indicates species probably present

Table B-1 (continued). Bird species (organized alphabetically by Order) documented in VIIS from species inventories (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Order	Scientific Name	Common Names
Passeriformes	*Catharus fuscescens*	Veery
Passeriformes	*Elaenia martinica*	Caribbean Elaenia
Passeriformes	*Myiarchus antillarum*	Puerto Rican Flycatcher
Passeriformes	*Tyrannus dominicensis*	Gray Kingbird, Grey Kingbird
Passeriformes	*Vireo altiloquus*	Black-whiskered Vireo
Passeriformes	*Vireo flavifrons*	Yellow-throated Vireo
Passeriformes	*Vireo griseus*	White-eyed Vireo
Passeriformes	*Vireo olivaceus*	Red-eyed Vireo
Pelecaniformes	*Ardea alba*	Great Egret
Pelecaniformes	*Ardea herodias*	Great Blue Heron
Pelecaniformes	*Botaurus lentiginosus*	American Bittern
Pelecaniformes	*Bubulcus ibis*	Cattle Egret
Pelecaniformes	*Butorides virescens*	Green Heron
Pelecaniformes	*Egretta caerulea*	Little Blue Heron
Pelecaniformes	*Egretta rufescens*	Reddish Egret
Pelecaniformes	*Egretta thula*	Snowy Egret
Pelecaniformes	*Egretta tricolor*	Tricolored Heron
Pelecaniformes	*Ixobrychus exilis*	Least Bittern
Pelecaniformes	*Nyctanassa violacea*	Yellow-crowned Night Heron
Pelecaniformes	*Nycticorax nycticorax*	Black-crowned Night Heron
Pelecaniformes	*Pelecanus occidentalis*	Brown Pelican
Pelecaniformes	*Plegadis falcinellus*	Glossy Ibis
Phaethontiformes	*Phaethon aethereus*	Red-billed Tropicbird
Phaethontiformes	*Phaethon lepturus*	White-tailed Tropicbird
Piciformes	*Sphyrapicus varius*	Yellow-bellied Sapsucker
Podicipediformes	*Podilymbus podiceps*	Pied-billed Grebe
Podicipediformes	*Tachybaptus dominicus*	Least Grebe
Procellariiformes	*Oceanites oceanicus*	Wilson's Storm Petrel
Procellariiformes	*Oceanodroma leucorhoa*	Leach's Storm Petrel
Procellariiformes	*Puffinus gravis*	Greater Shearwater
Procellariiformes	*Puffinus lherminieri*	Audubon's Shearwater
Psittaciformes	*Aratinga pertinax* [a]	Brown-throated Parakeet
Strigiformes	*Megascops nudipes*	Puerto Rican Screech Owl
Suliformes	*Fregata magnificens*	Magnificent Frigatebird
Suliformes	*Phalacrocorax auritus*	Double-crested Cormorant

[a] Indicates species probably present

Table B-1 (continued). Bird species (organized alphabetically by Order) documented in VIIS from species inventories (NPSpecies 2017; https://irma.nps.gov/NPSpecies/).

Order	Scientific Name	Common Names
Suliformes	*Sula dactylatra*	Masked Booby
Suliformes	*Sula leucogaster*	Brown Booby
Suliformes	*Sula sula*	Red-footed Booby

[a] Indicates species probably present

Literature Cited

National Park Service (NPS). 2017. NPSpecies online application. Available at: https://irma.nps.gov/NPSpecies/ (accessed 26 March 2018)

Appendix C.

Table C-1. Terrestrial invertebrates documented in VIIS from species inventories and literature reviews, organized by Phyla (Muchmore 1987).

Phylum	Class	Order	Species	Common name
Platyhelminthes	Rhabditophora	Tricladida	*Rhynchodemus* cf. *sylvaticus*	land planarian
Mollusca	Gastropoda	Archaeogastropoda	*Alcadia foviata*	–
	Gastropoda	Archaeogastropoda	*Alcadia striata*	–
	Gastropoda	Mesogastropoda	*Littorina angulifera*	mangrove periwinkle
	Gastropoda	Mesogastropoda	*Littorina ziczac*	zebra periwinkle
	Gastropoda	Mesogastropoda	*Nodilittorina tuberculata*	common prickly-winkle
	Gastropoda	Mesogastropoda	*Tectarius muricatus*	bearded periwinkle
	Gastropoda	Mesogastropoda	*Chondropoma newcombiana*	–
	Gastropoda	Mesogastropoda	*Megalomastoma petiti*	–
	Gastropoda	Mesogastropoda	*Truncatella scalaris*	–
	Gastropoda	Basommatophora	*Melampus coffeus*	coffee bean shell
	Gastropoda	Systellommatophora	*Leidyula kraussi*	slug
	Gastropoda	Systellommatophora	*Leidyula floridana*	slug
	Gastropoda	Stylommatophora	*Guppya gundlachi*	–
	Gastropoda	Stylommatophora	*Bulimulus guadalupensis*	tall tree snail
	Gastropoda	Stylommatophora	*Bulimulus diaphanus*	–
	Gastropoda	Stylommatophora	*Drymaeus virgulatus*	–
	Gastropoda	Stylommatophora	*Polydontes incertus*	round tree snail
	Gastropoda	Stylommatophora	*Caecilioides gundlachi*	–
	Gastropoda	Stylommatophora	*Caecilioides consobrinus*	–
	Gastropoda	Stylommatophora	*Hemitrochus nemoralinus*	palm snail
	Gastropoda	Stylommatophora	*Plagioptycha euclasta*	–
	Gastropoda	Stylommatophora	*Varicella terebraeformis*	–
	Gastropoda	Stylommatophora	*Gastrocopta pellucida*	pupa snail
	Gastropoda	Stylommatophora	*Hyalosagda subaquila*	–
	Gastropoda	Stylommatophora	*Lacteoluna selenina*	–
	Gastropoda	Stylommatophora	*Streptaxis glaber*	–
	Gastropoda	Stylommatophora	*Gulella bicolor*	–
	Gastropoda	Stylommatophora	*Beckianum beckianum*	–
	Gastropoda	Stylommatophora	*Lamellaxis gracilis*	–
	Gastropoda	Stylommatophora	*Lamellaxis micra*	–

Table C-1 (continued). Terrestrial invertebrates documented in VIIS from species inventories and literature reviews, organized by Phyla (Muchmore 1987).

Phylum	Class	Order	Species	Common name
Mollusca (continued)	Gastropoda	Stylommatophora	*Opeas pumilum*	–
	Gastropoda	Stylommatophora	*Subulina octona*	slender-spired snail
Annelida	Oligochaeta	Haplotaxida	*Lumbricus* sp.	earthworm
Onchyphora	Udeonychophora	Euonychophora	*Peripatus juliformis danicus*	peripatus
Arthropoda	Crustacea	Isopoda	*Ligia baudiniana*	sea roach
	Crustacea	Isopoda	*Philoscia culebrae*	woodlouse
	Crustacea	Isopoda	*Ligia panzeri*	white woodlouse
	Crustacea	Isopoda	*Venezillo culebrae*	pill bug
	Crustacea	Isopoda	10+ other species	–
	Crustacea	Amphipoda	*Platorchestia platensis*	beach flea
	Crustacea	Amphipoda	*Tethorchestia antillensis*	beach flea
	Crustacea	Decapoda	*Coenobita clypeatus*	hermit crab
	Crustacea	Decapoda	*Grapsus grapsus*	sally lightfood crab
	Crustacea	Decapoda	*Pachygrapsus transversus*	–
	Crustacea	Decapoda	*Aratus pisonii*	mangrove tree crab
	Crustacea	Decapoda	*Sesarma ricordi*	–
	Crustacea	Decapoda	*Cardisoma guanhumi*	great land crab
	Crustacea	Decapoda	*Ocypode quadrata*	ghost crab
	Crustacea	Decapoda	*Uca burgersi*	fiddler crab
	Crustacea	Decapoda	*Uca rapax*	fiddler crab
	Arachnida	Scorpionida	*Heteronebo yntemai*	scorpion
	Arachnida	Scorpionida	*Microtityus waeringi*	scorpion
	Arachnida	Scorpionida	*Centruroides griseus*	scorpion
	Arachnida	Pseudoscorpionida	*Pseudochthonius* sp.	–
	Arachnida	Pseudoscorpionida	*Paraliochthonius* sp.	–
	Arachnida	Pseudoscorpionida	*Tyrannochthonius* sp.	pseudoscorpion
	Arachnida	Pseudoscorpionida	*Caribchthonius butleri*	pseudoscorpion
	Arachnida	Pseudoscorpionida	*Lechytia* sp.	–
	Arachnida	Pseudoscorpionida	*Ideoblothrus* sp.	–
	Arachnida	Pseudoscorpionida	*Nannobisiurn* sp.	–
	Arachnida	Pseudoscorpionida	*Typhloroncus coralensis*	pseudoscorpion
	Arachnida	Pseudoscorpionida	*Pachyolpium* sp.	pseudoscorpion
	Arachnida	Pseudoscorpionida	*Aphelolpium longidigitatum*	–
	Arachnida	Pseudoscorpionida	*Novohorus incertus*	–
	Arachnida	Pseudoscorpionida	*Garypus* sp.	pseudoscorpion
	Arachnida	Pseudoscorpionida	*Idiogaryops* sp.	–

Table C-1 (continued). Terrestrial invertebrates documented in VIIS from species inventories and literature reviews, organized by Phyla (Muchmore 1987).

Phylum	Class	Order	Species	Common name
Arthropoda (continued)	Arachnida	Pseudoscorpionida	*Cheiridium* sp.	–
	Arachnida	Pseudoscorpionida	*Neocheiridium* sp.	–
	Arachnida	Pseudoscorpionida	*Lustrochernes* sp.	–
	Arachnida	Pseudoscorpionida	*Bituberochernes jonensis*	pseudoscorpion
	Arachnida	Pseudoscorpionida	*Dinocheirus altimanus*	pseudoscorpion
	Arachnida	Pseudoscorpionida	*Epactiochernes* sp.	–
	Arachnida	Pseudoscorpionida	*Parachelifer parvus*	pseudoscorpion
	Arachnida	Amblypygida	*Phrynus longipes*	large amblypygid
	Arachnida	Amblypygida	*Charinides levii*	small amblypygid
	Arachnida	Opilionida	*Metacynortoides obscura*	harvestman
	Arachnida	Opilionida	*Stygnomma* sp. 1	–
	Arachnida	Opilionida	*Stygnomma* sp. 2	–
	Arachnida	Opilionida	*Kimula* sp.	–
	Arachnida	Opilionida	*Paraconomma* sp.	harvestman
	Arachnida	Opilionida	*Sarnoinae gen. et* sp.	–
	Arachnida	Opilionida	*Martibianta virginsulana*	harvestman
	Arachnida	Araneida	*Obaerarius insulanus*	–
	Arachnida	Araneida	*Phaeoclita* sp.	–
	Arachnida	Araneida	*Diplura macrura*	–
	Arachnida	Araneida	*Avicularia laeta*	–
	Arachnida	Araneida	*Cyrtopholis bartholomei*	tarantula
	Arachnida	Araneida	*Ischnocolus shoemakeri*	–
	Arachnida	Araneida	*Aysha tenuis*	–
	Arachnida	Araneida	*Antillognatha lucida*	–
	Arachnida	Araneida	*Argiope argentata*	–
	Arachnida	Araneida	*Cyclosa oculata*	–
	Arachnida	Araneida	*Eustala* sp.	–
	Arachnida	Araneida	*Gasteracantha cancriformis*	–
	Arachnida	Araneida	*Gasteracantha tetracantha*	–
	Arachnida	Araneida	*Larinia coamensis*	–
	Arachnida	Araneida	*Lariniacantha crewi*	–
	Arachnida	Araneida	*Leucauge argyra*	–
	Arachnida	Araneida	*Leucauge regnyi*	orchard spider
	Arachnida	Araneida	*Metepeira virginensis*	–
	Arachnida	Araneida	*Nephila clavipes*	golden silk spider
	Arachnida	Araneida	*Tetragnatha subextensa*	–

Table C-1 (continued). Terrestrial invertebrates documented in VIIS from species inventories and literature reviews, organized by Phyla (Muchmore 1987).

Phylum	Class	Order	Species	Common name
Arthropoda (continued)	Arachnida	Araneida	*Wixia serrallesi*	–
	Arachnida	Araneida	*Caponina* sp.	–
	Arachnida	Araneida	*Nops blandus*	–
	Arachnida	Araneida	*Corinna abnormis*	–
	Arachnida	Araneida	*Corinna cleonei*	–
	Arachnida	Araneida	*Filistatoides* sp.	–
	Arachnida	Araneida	*Camillina elegans*	–
	Arachnida	Araneida	*Microsa chickeringi*	–
	Arachnida	Araneida	*Zimiromus rnuchmorei*	–
	Arachnida	Araneida	*Grammonota* cf. *calcarata*	–
	Arachnida	Araneida	*Loxosceles virgo*	–
	Arachnida	Araneida	*Theotima minutissima*	–
	Arachnida	Araneida	*Theotima* sp.	–
	Arachnida	Araneida	*Oecobius concinnus*	–
	Arachnida	Araneida	*Heteroonops spinirnanus*	–
	Arachnida	Araneida	*Ischnothyreus peltifer*	–
	Arachnida	Araneida	*Oonops balanus*	–
	Arachnida	Araneida	*Oonops castellatus*	–
	Arachnida	Araneida	*Oonops ronoxus*	–
	Arachnida	Araneida	*Oonops* sp.	–
	Arachnida	Araneida	*Opopaea lutzi*	–
	Arachnida	Araneida	*Scaphiella kalunda*	–
	Arachnida	Araneida	*Stenoonops lucradus*	–
	Arachnida	Araneida	*Stenoonops nitens*	–
	Arachnida	Araneida	*Stenoonops noctucus*	–
	Arachnida	Araneida	*Stenoonops reductus*	–
	Arachnida	Araneida	*Harnataliwa* sp.	–
	Arachnida	Araneida	*Oxyopes salticus*	–
	Arachnida	Araneida	*Otiothops pentucus*	–
	Arachnida	Araneida	*Micrornerys* sp.	–
	Arachnida	Araneida	*Modisimus coeruleolineatus*	–
	Arachnida	Araneida	*Modisimus glaucus*	–
	Arachnida	Araneida	*Modisimus montanus*	–
	Arachnida	Araneida	*Modisimus sexoculatus*	–
	Arachnida	Araneida	*Beata octopunctata*	–
	Arachnida	Araneida	*Corythalia iridescens*	–

Table C-1 (continued). Terrestrial invertebrates documented in VIIS from species inventories and literature reviews, organized by Phyla (Muchmore 1987).

Phylum	Class	Order	Species	Common name
Arthropoda (continued)	Arachnida	Araneida	*Emathis* sp.	–
	Arachnida	Araneida	*Hentzia antillana*	–
	Arachnida	Araneida	*Metacyrba taeniola*	–
	Arachnida	Araneida	3 new genera	–
	Arachnida	Araneida	*Scytodes fusca*	–
	Arachnida	Araneida	*Ariadna arthuri*	–
	Arachnida	Araneida	*Selenops lindborgi*	–
	Arachnida	Araneida	*Olios antiguensis*	–
	Arachnida	Araneida	*Stasina portoricensis*	–
	Arachnida	Araneida	*Monoblernma muchmorei*	–
	Arachnida	Araneida	*Argyrodes caudatus*	–
	Arachnida	Araneida	*Argyrodes elevatus*	–
	Arachnida	Araneida	*Argyrodes nephilae*	–
	Arachnida	Araneida	*Argyrodes obtusus*	–
	Arachnida	Araneida	*Argyrodes quasiobtusus*	–
	Arachnida	Araneida	*Chindellum cybele*	–
	Arachnida	Araneida	*Coleosoma floridanurn*	–
	Arachnida	Araneida	*Spintharus flavidus*	–
	Arachnida	Araneida	*Theridion rufipes*	–
	Arachnida	Araneida	*Thymoites guanicae*	–
	Arachnida	Araneida	*Misumenops insulanus*	–
	Arachnida	Araneida	*Miagrammopes ciliatus*	–
	Arachnida	Araneida	*Miagrammopes pinopus*	–
	Arachnida	Schizomida	*Schizomus portoricensis*	schizomid
	Arachnida	Palpigradida	*Eukoenenia berlesei virginea*	microwhipscorpion
	Arachnida	Solpugida	*Ammotrechella pallida*	windscorpion
	Arachnida	Acarina	*Opilioacarus* sp.	–
	Arachnida	Acarina	Argasidae (family)	–
	Arachnida	Acarina	Ixodidae (family)	–
	Arachnida	Acarina	*Trombidium* sp.	velvet mites
	Arachnida	Acarina (Orbatida)	–	beetle mites
	Chilopoda	Scolopendromorpha	*Scolopendra alternans*	scolopendra centipede
	Chilopoda	Scolopendromorpha	*Cormocephalus impulsus*	–
	Chilopoda	Scolopendromorpha	*Otostigmus caraibicus*	–
	Chilopoda	Scolopendromorpha	*Cryptops* sp.	–

Table C-1 (continued). Terrestrial invertebrates documented in VIIS from species inventories and literature reviews, organized by Phyla (Muchmore 1987).

Phylum	Class	Order	Species	Common name
Arthropoda (continued)	Chilopoda	Scolopendromorpha	*Newportia virginensis*	–
	Chilopoda	Geophilomorpha	several species	centipede
	Chilopoda	Scutigeromorpha	*Scutigera linceci*	centipede
	Diplopoda	Polyxenida	*Lophoturus longisetis*	millipede
	Diplopoda	Stemmiulida	*Prostemmiulus wheeleri*	millipede
	Diplopoda	Spirobolida	*Rhinocricus arboreus*	arboreal millipede
	Diplopoda	Spirobolida	*Rhinocricus monilicornis*	–
	Diplopoda	Siphonophorida	*Siphonophora albiceps*	millipede
	Diplopoda	Polydesmida	*Asiomorpha coarctata*	millipede
	Diplopoda	Polydesmida	*Prosopodesmus jacobsoni*	millipede
	Diplopoda	Polydesmida	*Poratioides virginalis*	millipede
	Symphyla	Cephalostigmata	*Hanseniella orientalis*	symphylan
	Pauropoda	Tetramerocerata	*Allopauropus* sp.	–
	Insecta	Collembola	–	springtails
	Insecta	Thysanura	*Lepisma saccharina*	silverfish
	Insecta	Odonata	*Erythrodiplax umbrata*	band-winged dragonlet
	Insecta	Orthoptera	*Schistocerca americana*	American grasshopper
	Insecta	Orthoptera	*Acheta assimilis*	Jamaican field cricket
	Insecta	Dictyoptera	*Periplaneta americana*	American cockroach
	Insecta	Dermaptera	*Anisolabis maritima*	seaside earwig
	Insecta	Isoptera	*Nasutitermes costalis*	arboreal termite
	Insecta	Mallophaga	*Myrsidea coerebicola*	bananaquit louse
	Insecta	Hemiptera	*Dysdercus andreae*	love bug
	Insecta	Homoptera	*Aphis* sp.	plant lice
	Insecta	Coleoptera	*Anelaphus nanus*	beetle
	Insecta	Neuroptera	*Myrmeleon insertus*	antlion
	Insecta	Lepidoptera	*Danaus plexippus*	monarch
	Insecta	Lepidoptera	*Dione vanillae*	gulf fritillary
	Insecta	Lepidoptera	*Heliconius charitonius*	butterfly
	Insecta	Lepidoptera	*Ascia monuste*	great southern white
	Insecta	Lepidoptera	*Battus polydamus*	polydamus swallowtail
	Insecta	Lepidoptera	*Urbanus proteus*	long-tail skipper
	Insecta	Lepidoptera	*Composia sybaris*	sybaritic beauty
	Insecta	Lepidoptera	*Horama pretus*	wasp moth
	Insecta	Lepidoptera	*Ascalapha odorata*	black witch
	Insecta	Lepidoptera	*Perigonia lusca*	half-blind sphinx

Table C-1 (continued). Terrestrial invertebrates documented in VIIS from species inventories and literature reviews, organized by Phyla (Muchmore 1987).

Phylum	Class	Order	Species	Common name
Arthropoda (continued)	Insecta	Diptera	*Culex guinguefasciatus*	house mosquito
	Insecta	Diptera	*Culicoides furens*	sand fly
	Insecta	Diptera	*Musca domestica*	house fly
	Insecta	Siphonaptera	*Ctenocephalides canis*	dog flea
	Insecta	Hymenoptera	*Solenopsis geminata*	ant
	Insecta	Hymenoptera	*Polistes crinitus*	wasp
	Insecta	Hymenoptera	*Apis mellifera*	honey bee
	Insecta	Hymenoptera	*Xylocopa mordax*	carpenter bee

Literature Cited

Muchmore, W. B. 1987. Terrestrial invertebrate animals of the Virgin Islands National Park, St. John, U.S.V.I.: an annotated checklist. Unpublished Report, University of Rochester, Rochester, NY.

Appendix D.

On site visit to VIIS/VICR (February 13–16, 2017)

AGENDA

NATURAL RESOURCE CONDITION ASSESSMENT SCOPING MEETING

ST. JOHN, USVI

VIRGIN ISLANDS NATIONAL PARK (VIIS)

and

VIRGIN ISLANDS CORAL REEF NATIONAL MONUMENT (VICR)

Schedule for the Visit:

- **Monday Feb 13–14** – VIIS scoping meeting and supplemental data transfers (Table D-1)
    - Meeting at the Headquarters (1300 Cruz Bay Crk., St. John, USVI)

Participants (in person):

Dave Worthington (NPS Chief of Resource Management and Interpretation VIIS), Thomas Kelley (NPS Natural Resource Management VIIS), Devon Tyson (NPS), Jean Schiffer (NPS), Dale McPherson (NPS Natural Resource Program Manager), Caroline Rogers (USGS), Anna Wachnicka (Research Assistant Professor FIU), Maria C. Donoso (Research Associate Professor FIU), Danielle E. Ogurcak (Postdoctoral Associate FIU), W. Jeff Miller (NPS SFCN – joined the second day)

Participants (joining by phone):

Mike Feeley (NPS SFCN), Kevin Whelan (NPS SFCN), Daniel Gann (Research Associate FIU)

- **Wednesday-Friday Feb 15** –Park and Monument site visit with focus on natural resource issues (land and boat; snorkeling encouraged)
    - Team meets at **8:30 AM** (Park HQ); Tour ends at **4:00 PM**
- Friday Feb 16 – Departure

Table D-1. Agenda.

DATE	TIME	TOPICS FOR FEB 13–15 MEETING & ACTIVITIES
February 13th Meeting (Park HQ)	**8:00**	• Room set-up
	9:00–9:15	• Arrival/Introductions
	9:15–9:45	• Introduction to NRCA (Dale) • Project Schedule & Meeting Expectations (Anna)
	9:45–12:00	• Setting expectations for the VIIS NRCA reports • Reviewing park resources, threats/stressors, issues, and gaps that will be used for populating the Heinz framework tables; Completing scoping tables for the parks • Developing a list of priority resource interests (going through an initial draft of the scoping table and discussing resource priorities) • Identifying experts; collecting data info on experts
	12:00–1:00	• Lunch Break
	1:00–4:30	• Continuation of the scoping meeting; completing scoping tables for the parks
February 14th Meeting (Park HQ)	**8:30**	• Anna & Dale meet to set up computer and webinar
	9:00–12:00	• Continuation of the scoping meeting; completing scoping tables for the parks
	12:00–1:00	• Lunch Break
	1:00–4:30	• Discussion on data management/ArcGIS files storage and management, including sensitive data • Supplemental data transfers • Consolidating info on literature sources (reports/papers) available for writing the reports • Final remarks/comments/Q & A
	4:30	• Meeting concludes
February 15th Field Visit and Final	**8:30–4:30**	• Field Visit
	5:00–6:00	• Debriefing meeting

NPS 161/181610, 663/181610, June 2022

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
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