National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Buck Island Reef National Monument

Natural Resource Report NPS/BUIS/NRR—2022/2380

ON THE COVER
Buck Island as viewed from the water off the west shore, looking toward the east
Photo credit: Laura Palma

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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. Buck Island Reef National Monument (BUIS) is a 19,015 acre unit located within the Caribbean, situated just north of the island of St. Croix. Consisting of both marine and terrestrial components, environments of BUIS range from the deepest water in the NPS (1812 m below sea level) to an elevation of just over 100 m above sea level in the dry tropical forest. Marine communities include soft bottom habitats predominantly occupied by seagrasses and hardbottom habitats dominated by patch reefs. Terrestrial habitats are dominated by shrublands and forests, with beaches that stretch from northwest to southwest corner of the island. The forest on Buck Island is mainly lowland tropical/subtropical semi-deciduous forest, whereas the shrubland is mostly covered by low stature tropical/subtropical broad-leaved evergreen shrubland.

The BUIS NRCA considers 12 focal resources within the Monument categorized as either pertaining to the supporting environment or biological integrity. These include shoreline dynamics and water quality, in the framework category of supporting environment, and dry tropical forest, coastal forest, terrestrial reptiles, seagrass, corals, reef fish, and sea turtles, both green and hawksbill, in the framework category of biological integrity. Full assessments were conducted for all above-listed resources except for lobsters and queen conch which were restricted to limited assessments due to a lack of data. 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 Monument are discussed separately and include impacts of hurricanes/tropical storms, landcover/landuse changes, and human interactions related to boat traffic, marine debris, and poaching.

Assessment of the focal resources in BUIS resulted in the majority being considered as warranting moderate concern. Three focal resources warranted significant concern, including reef fish, corals, and shoreline dynamics. Only water quality and queen conch were found to be in good condition. Trends in condition were more evenly split across focal resources between unchanging, deteriorating, and improving conditions. Deteriorating trends were recorded for seagrass, corals, and coastal forest. Whereas improving trends were recorded for terrestrial reptiles, dry tropical forest, conch, and green sea turtles. Trends for both supporting environment resources, water quality and shoreline dynamics, were assessed as unchanging. Lobsters, reef fish, and hawksbill sea turtles were also considered to have stable, unchanging trends in condition. The low number of resources recorded as being in good condition, combined with several resource showing deteriorating conditions suggests that resources of BUIS are significantly threatened and in need of continued monitoring and management.

Improving conditions for conch and green sea turtles are encouraging and may suggest that implementation of local and regional policies and conservation strategies have made positive impacts on these populations. However, a lack of improving condition in for the BUIS reef fish community suggests that the multiple stressors that impact recovery have not been sufficiently addressed,

including illegal harvesting, habitat degradation, and the impact of introduced species. The continued decline of coral coverage and condition is alarming, especially given the increase in the number of thermal stress events observed and appearance of novel diseases. The improved conditions found for dry tropical forest and terrestrial lizards are very likely attributable to management interventions related to exotic plant and animal control and a successful translocation program. The planned work for reforestation following the 2017 hurricane season is promising but expanded forest monitoring and continued exotics management will be necessary to maintain the improving conditions of these focal resources.

A moderate level of confidence was assigned to the majority of resources, with individual indicators varying between low, medium, and high. The only focal resources having assessments with high levels of confidence were corals and the St. Croix ground lizard, both having datasets with high spatial and temporal coverage. Low confidence assessments were restricted to terrestrial vegetation focal resources. Given that a minority of focal resources had high confidence in the assessments, the majority of assessments were constrained to some degree by either a lack of recent data, insufficient temporal or spatial coverage of datasets, or differences between survey methods for data used in the assessments. Therefore, 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 BUIS, 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 impact of visitor use of the marine and terrestrial resources to estimate benefits from ecosystem services provided and amount of anthropogenic pressure on the resource, 3) expansion of a permanent plot network throughout the terrestrial vegetation focal resources to understand long-term changes in species assemblages and abundances, and 4) expansion of a shoreline dynamics monitoring program that captures seasonal and inter-annual variability of sediment transport and changes to areal extent of beach. Expansion of monitoring programs will add to the large body of research already conducted within BUIS 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.

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The authors would like to acknowledge personnel at Buck Island Reef National Monument, especially Z. Hillis-Starr, C. Pollock, and K. Ewen, for their input and expertise during the writing of this report. 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. 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.

[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

Buck Island Reef National Monument (BUIS) was established by Presidential Proclamation No. 3443 by President John F. Kennedy in 1961 to protect Buck Island and "its adjoining shoals, rocks, and under-sea coral reef formations," which "possess one of the finest marine gardens in the Caribbean Sea" (Presidential Proclamation No. 3443).

Recognizing that Buck Island's "unique natural area and the rare marine life which are dependent upon it are subject to constant threat of commercial exploitation and destruction," Proclamation 3443 prohibits unauthorized persons from appropriating, injuring, destroying, defacing, or removing any feature of the Monument, or from locating or settling upon any of the lands reserved for the Monument. In 2001, Presidential Proclamation No. 7392 expanded the park's protected area, creating one of the few "no take" marine reserve zones in the U.S. National Park System.

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. 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), 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.

The Buck Island Reef National Monument (BUIS) occupies the entirety of Buck Island and part of the surrounding sea (Figure 2.1.2.1). BUIS consists of 19,015 land and water acres north of the island of St. Croix in the USVI. The park supports many terrestrial and marine threatened and/or endangered species and also contains important cultural resources, including remains from prehistoric occupation, wrecks of two eighteenth century slave ships – the Mary and General Abercrombie – and archeological sites from Danish rule in the eighteenth and nineteenth centuries.

The BUIS is accessible only by boat. Buck Island has white sand beaches and a land-based nature trail. There is an underwater trail for snorkeling and scuba diving. The irregular arc of reef surrounding Buck Island's northern and eastern shore creates a lagoon between reef and island. Wide and shallow lagoon waters seldom exceed 12 feet deep.

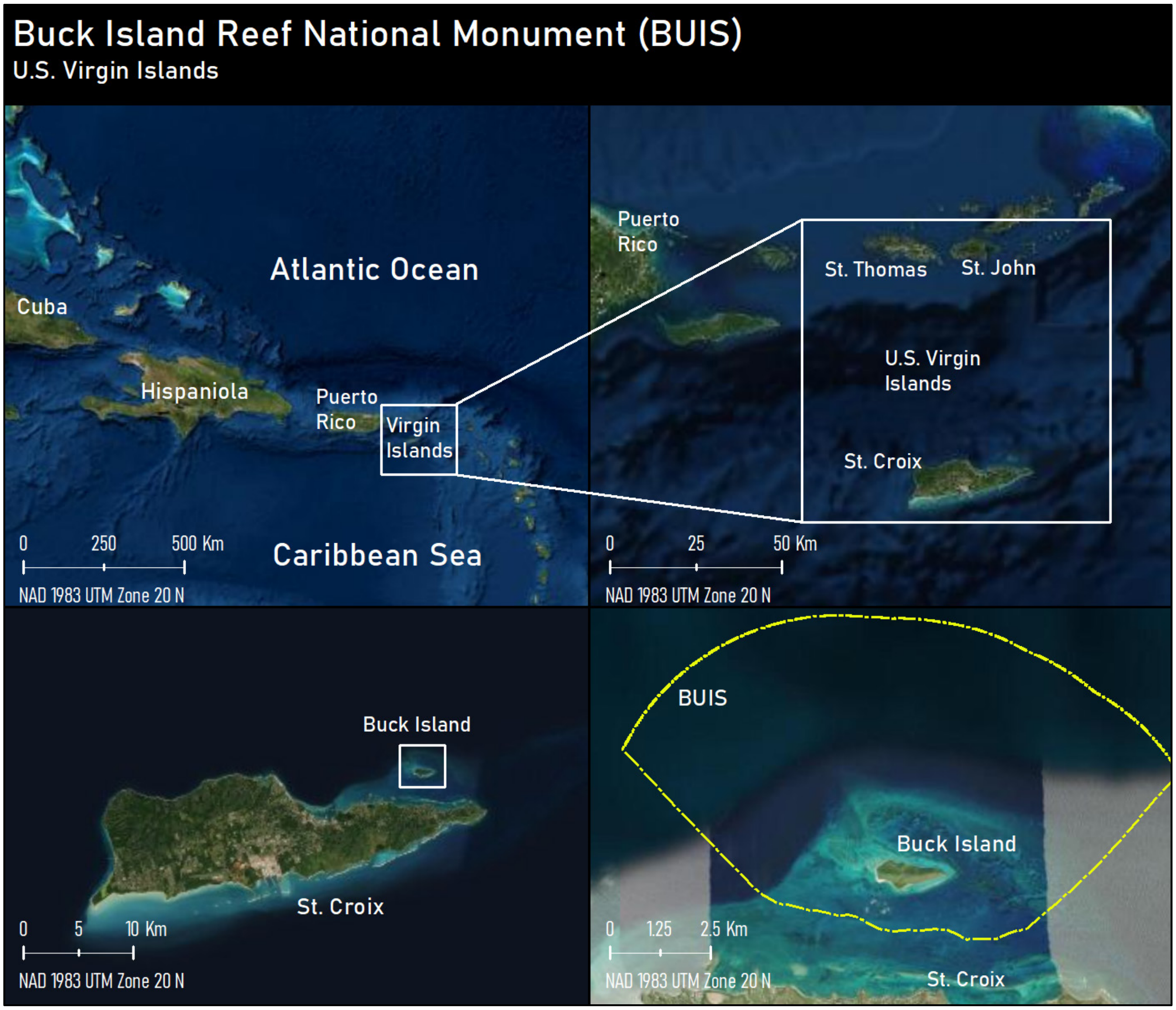

Figure 2.1.2.1. Location of the Buck Island Reef National Monument (BUIS). Geographic location of the US Virgin Islands in the Caribbean (upper panels). In relation to the island of St. Croix (lower panel left). Demarcation of the territory that encompasses BUIS (lower panel right).

2.1.3. Visitation Statistics

From 1962 to 2019, BUIS has had 2,538,468 visitors (Figure 2.1.3.1) (NPS 2019a); most visits occurred between the months of February and May (NPS 2019a). The average number of recreational visitors to the Monument from 1962–2019 was 50,185 visitors per year (NPS 2019a). Visitation in the Monument has declined over the years, from average annual visitations of around 67,700 in the late 70s and 80s, to 50,300 in the 90s and a little under 40,000 in this century. The entirety of Buck Island provides areas that allow visitors to enjoy nature and learn about the various ecosystems present in the park. Some popular activities include snorkeling the coral reefs, swimming, SCUBA diving, daily boat trips, hiking, bird watching, sunbathing and picnicking. A marked hiking trail from either Diedrichs Point or the West Beach picnic area crosses the island (NPS 2019b).

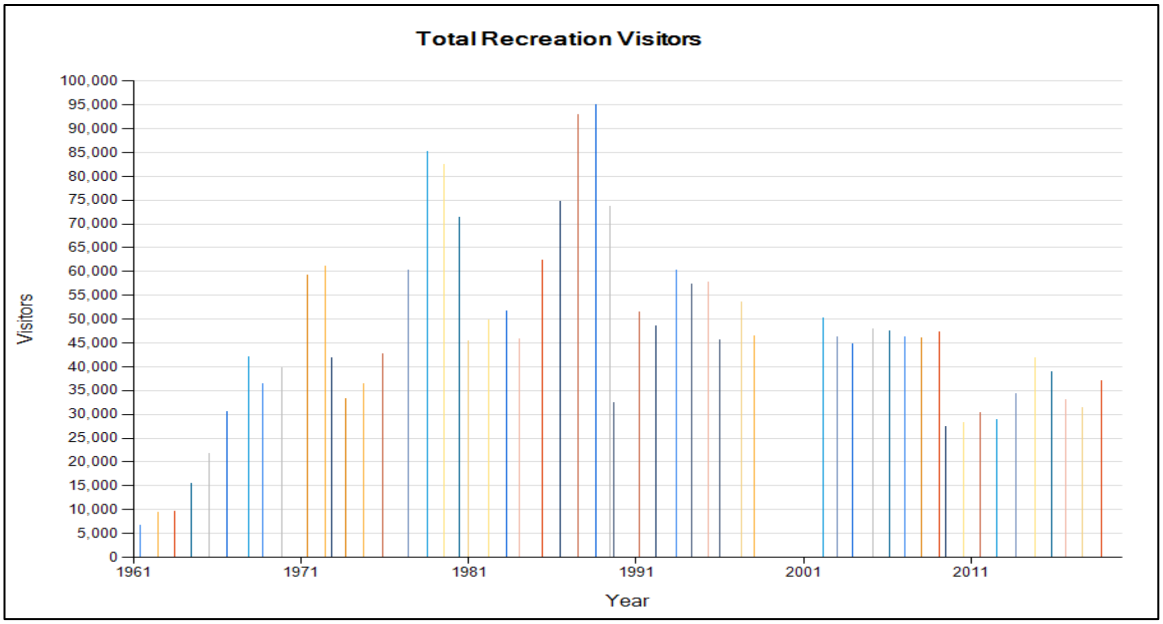

Figure 2.1.3.1. Total Recreation Visits to the Buck Island Reef National Monument for the period 1962 to 2019. Data from https://irma.nps.gov/Stats/

2.2. Natural Resources

2.2.1. Ecological Units and Watersheds

Located north-east of St. Croix, Buck Island Reef National Monument (BUIS) is composed of terrestrial (<1 %) and benthic (>99 %) habitats (Table 2.2.1.1, Figure 2.2.1.1). Benthic habitats are mostly comprised of areas deeper than 30 m. BUIS boasts the deepest water in the NPS at 1,812 m (NOAA 2018). The benthic areas can be divided into two types: bank/shelf and shelf escarpment. The bank/shelf is mostly made of hardbottom habitats with cover dominated by turf, fleshy, coralline or filamentous algae. However, covering about a quarter of the benthic habitats (24.3%), live corals covered between 10 to less than 50% of the benthos. The shelf escarpment occupies the majority of the benthos. The escarpment area is dominated by habitats of uncolonized sand and mud, the latter being mostly present in deeper areas. Steep slopes in these areas result in low sediment accumulation and high bedrock exposure. Although the area mostly lacks benthic cover, some sparse mesophotic corals were recorded in these areas (Costa et al. 2012).

Ecological Units

Benthic habitats

Unconsolidated sediments (mud) are mostly present in moderate to deep-water habitats with little or no benthic cover. Rock/Boulder refers to coral reef and hardbottom areas, which are mostly present in moderate to deep-water habitats (Figure 2.2.1.1). Sand represents unconsolidated sediment with little cover or some presence of algae, and mostly present in moderate and shallow habitats. Reefs including aggregated, aggregated patch, and individual patch reefs are mostly present in shallow and moderate deep habitats (bank/shelf). The benthic cover in these habitats is mostly algae. Pavement with sand channels are an important component of this ecological unit followed by areas covered by algae. Pavement is mostly present in shallow and moderate depth habitats, composed of coral reef and hardbottom. The main benthic cover in both shallow and moderate depth habitats is algae. Sand with Scattered Coral and Rock habitat is mostly present in shallow and moderate deep habitats (bank/shelf). Composed of unconsolidated sediments. In general, the benthic cover in shallow habitats is a mosaic of algae and seagrass. While in moderate deep habitats, the benthic cover tends to be inexistent, and most likely because of the low amount of solar radiation reaching the bottom. Aggregated Reefs are present mostly in shallow habitats such as bank/shelf, back reef, channel, lagoon, fore reef, reef crest, and reef flat, and are composed of coral reef and hardbottom. The main benthic cover is algae. Rhodoliths habitats are present in shallow and moderate deep habitats (bank/shelf), and are composed of coral reef and hardbottom, and mostly covered by algae. Rhodoliths with Scattered Coral and Rock are present in shallow areas (bank/shelf). The major structural component in these areas is coral reef and hardbottom, and benthic cover is algae. Unknown habitats are uncharacterized ecological units mostly present in moderate and deep habitats. Artificial areas refer to man-made structures. The area covered by these is very small (Costa et al. 2012).

Table 2.2.1.1. Major ecological units for Buck Island Reef National Monument (BUIS). Data source: Data collected in 2005–2006, processed 2011 (Costa et al., 2012). Terrestrial data from Moser et al. 2010.

Location	Ecological Unit	Area (ha)	% Cover
Benthic	Mud	2,340.16	30.46
	Rock/Boulder	1,703.90	22.18
	Sand	1,371.74	17.85
	Pavement	1,247.90	16.24
	Aggregated Patch Reefs	341.05	4.44
	Unknown	189.89	2.47
	Pavement with Sand Channels	131.62	1.71
	Sand with Scattered Coral and Rock	122.89	1.60
	Aggregate Reef	61.85	0.81
	Individual Patch Reef	43.45	0.57
	Rhodoliths	39.19	0.51
	Reef Rubble	22.16	0.29
	Rhodoliths with Scattered Coral and Rock	0.43	0.01
	Artificial	0.01	0.00
	Total Area (ha)	**7,616.24**	**–**
Terrestrial	Shrubland	35.29	50.30
	Forest	21.42	30.53
	Woodland	9.17	13.07
	Sparse Vegetation	4.26	6.08
	Total Area (ha)	**70.15**	**–**

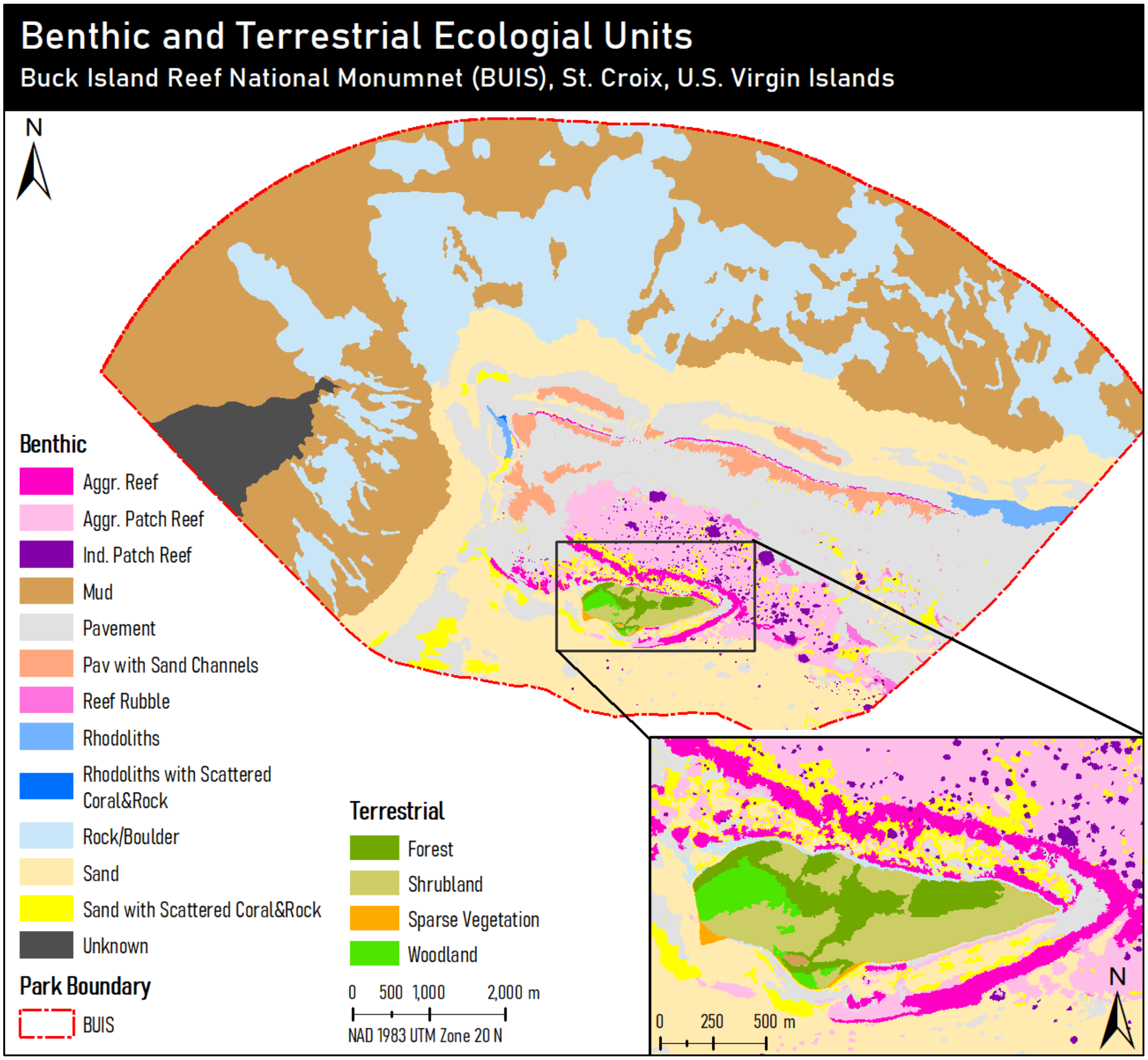

Figure 2.2.1.1. Benthic and terrestrial Ecological Units for Buck Island Reef National Monument (BUIS). Benthic data collected in 2005–2006, processed 2011 (Costa et al. 2012). Terrestrial data from Moser et al. 2010. Park boundary red hatch line.

Terrestrial

The forest on Buck Island is mainly lowland tropical/subtropical semi-deciduous forest, with presence of semi-evergreen forest, and gallery semi-deciduous forest. The shrubland is mostly covered by low stature tropical/subtropical broad-leaved evergreen shrubland. This habitat also presents lowland drought deciduous shrubland, mangrove shrubland, mixed dry shrubland, coastal hedge, and seasonally flooded/saturated tropical/subtropical broad-leaved evergreen shrubland. The woodland is dominated by tropical or subtropical semi-deciduous woodland, and semi-evergreen woodland. The sparse vegetation is present in mostly intermittently flooded sand beaches and shores, cliffs with sparse vascular vegetation, intermittently flooded mud flat, including salt pond, rock pavement, and beach dunes (Moser et al. 2010, Figure 2.2.1.1).

Watersheds

There are no watersheds that form permanent streams on Buck Island. However, intermittent streams form during storms or periods of heavy rain. In some areas, the erosion caused by heavy rains can deliver important amounts of sediment from the land area to the coast.

2.2.2. Resource Descriptions

Coastal Dynamics

Many processes contribute to significant changes in the distribution and morphology of coastal landforms and habitats. The Virgin Islands are located in the center of the trade wind belt where oceanic and atmospheric processes are highly affected by the Bermuda High in the north and the Equatorial Trough to the south. As a result, the winds create a strong east to west longshore drift (Hubbard 1980). Maximum wind speeds occur during the winter months; trade winds then decrease in intensity during the spring. In the summer, trade winds and barometric pressure both increase, and together with warming Atlantic and Caribbean waters, lead to the generation of tropical storms and hurricanes that can and have had an important effect on the coastal geomorphology of the island (KellerLynn 2011). More recently, rising sea levels along with intensifying wind, waves, and currents have been identified as a cause for concern with respect to geologic resources. The sandy beaches and rocky shorelines at the national monument are vulnerable to sea level rise and a potential increase of the intensity of coastal storms is likely to further impact the coastline (KellerLynn 2011).

Changes in the intensity of these atmospheric systems especially during the winter months is likely to have an important effect on the strength of the winds and currents on the islands (Hubbard 1979). However, warming of the ocean during the summer and early fall can also lead to tropical storms and hurricanes with potentially devastating effects to the islands. Around the island, current speeds are not strong, and current circulation within the lagoons is mostly wind and wave driven (Hubbard 1979), which emphasizes the importance of wind to the coastal dynamics. About 60% of the waves reach from the east. The maximum wave intensity occurs around February. In general, the tidal range in the U.S. Virgin Islands area is small (20 cm), thus wind and waves are the dominant forces of shelf and coastal currents. Rain events are characterized by being short but very intense, which increases erosion and runoff. Climatic projections for the area predict an increase in the number of heavy rain events (Karl et al. 2009). Although the island presents no permanent streams or rivers, the intense rain events can result in intermittent streams that can cause significant erosion given the steep slopes of the island and the storm water runoff can significantly affect the nutrient and sedimentation processes of the marine ecosystems. The temperature of the seawater in the Monument is relatively consistent at 26–29.5 °C. However, climatic projections for the Caribbean predict an increase in ocean temperatures, which is likely to negatively affect marine ecosystems (Karl et al. 2009).

Since the coastal dynamics of the Monument are primarily driven by currents resulting from wind and wave activity, an increase of sea level is likely to magnify the effects of the wind and wave action to shoreline dynamics. For instance, increase in wave action can result in redistribution of sediment, which would result in changes to the shoreline morphology, particularly of concern for sandy beaches, which are important nesting habitats for sea turtles. However, rocky shorelines are also at risk because of flooding which is of concern because of the destruction it could bring to bird nesting grounds. Sea-level rise also is likely to increase the effect of storm surge along the shorelines further modifying their dynamics and morphology.

<u>Coastal Geomorphology</u>
Buck Island originated from deep-marine sediment composed of the Upper Cretaceous Caledonia Formation, which was later reworked by deep ocean currents (Nagle and Hubbard 1989). This formation makes up most of the coast on the island, except along the west end (Figure 2.2.2.1). The largest section of the rocky shore surrounding much of the island is composed of consolidated carbonate sand (Nagle and Hubbard 1989). The rest of the Monument is made up by coral reef, hardbottom, and unconsolidated sediment, and submerged vegetation. At just 1.8 km in length and a width of 0.67 km, the island reaches an elevation of 104 m above sea level. Although Buck Island consists of steeps slopes, most being steeper than 30%, two sandy beaches, Diedrichs Point on the south side of the island and West Beach on the western end of the island, are fairly level (KellerLynn 2011).

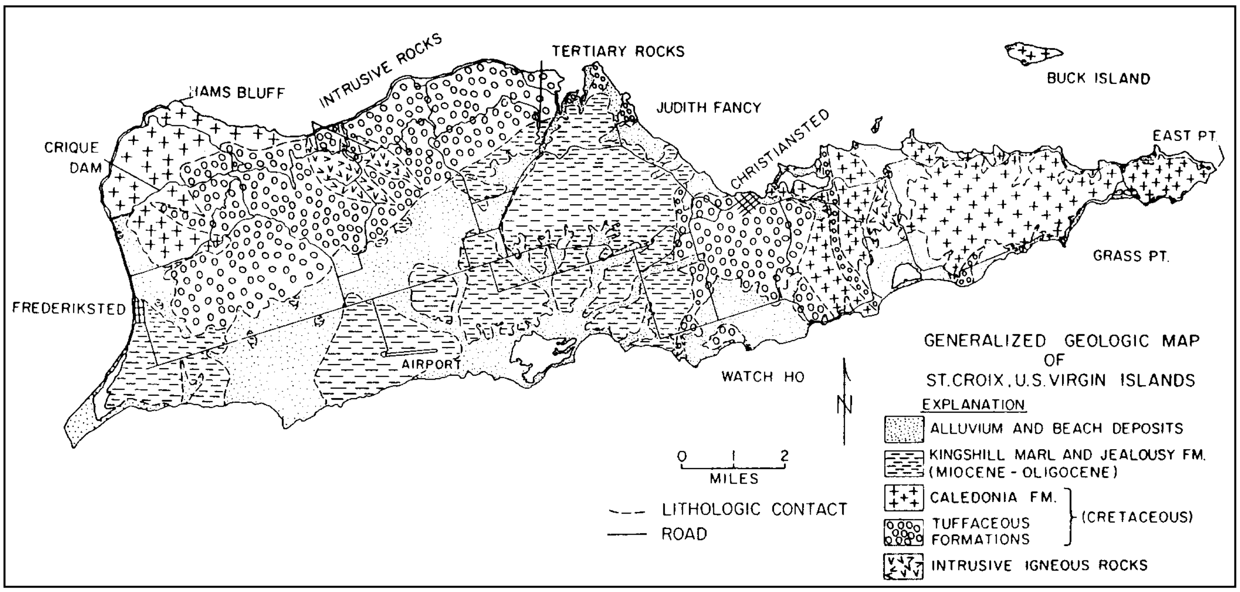

Figure 2.2.2.1. Generalized geologic map of St. Croix. After Whetten (1966) (in: Nagle and Hubbard 1989).

Previous studies in the western end of Buck Island showed some seasonality associated with the sediment movement (Hubbard 1980), with onshore sediment movements occurring in late fall to late spring, and off-beach transport (net loss) occurring during the summer and early fall. Overlaying these processes there is a seasonal shift of sediment between the western and southwestern beaches, where the sediment moves counterclockwise during late fall, winter, and spring from western beach to southwestern beach. The sediment returns to the western beach (clockwise direction) during summer and early fall (Hubbard 1980). Within the Buck Island Channel, the sediment is mostly fine-grained carbonated sands, with some open areas of coarse-grained and poorly sorted sand (Gerhard and Cross 2005). In the lagoon of Buck Island, the sediments are considered bi-modal and poorly sorted (Levin 1978) with presence of some terrestrial detritus (Hubbard 1979).

Grass beds and algal mats present in both lagoon and in the open shelf habitats function as effective substrate stabilizers. However, during storms, wave-generated currents can move large quantities of sediment off the shelf (Hubbard 1980). In addition to sediment, Kendall et al. (2004) suggested that storms also have a positive effect on seagrass by enhancing seed and seagrass fragment dispersal. Given the morphological characteristics of the different environments, the factors driving sediment transport vary. Along the shoreline the physical processes dominate the sediment movement. In the lagoons, bioturbation caused by grazers and burrowers greatly affect the characteristics of the sediment. Some of this sediment becomes suspended and then transported around nearshore via wave action. In the outer shelf, currents generated by waves dominate the processes of sediment transport.

Erosion in Buck Island is a concern for both terrestrial and marine systems. For instance, heavy rains can negatively affect terrestrial trails and historical sites (prehistoric and archeological sites), which are of great value, and maintenance of the terrestrial infrastructure can be costly. Rain runoff can also affect coral reef communities by initially increasing the amount of suspended sediment in the water column which is likely to diminish photosynthetic activity of aquatic vegetation by reducing the amount of light penetrating the water column and later, by increasing sediment deposition smothering the coral reef and seagrass beds (Pinet 1992, Hall 2005). The effects of rain runoff at Buck Island seem to be concentrated in two areas: along the south shore and western beach (Hall 2005). However, revegetation programs, which started in 2003, have reduced the presence of non-native species in favor of regrowth of native species and subsequently reduced the risk of high sediment runoff (Hall 2005).

Major storms such as hurricanes are likely to have a significant impact on terrestrial and coastal habitats. However, Hubbard (1980) suggested that storm-induced beach erosion is just part of the seasonal erosion-deposition processes of the island. The island shoreline might have evolved in response to the typical path taken by the storms, where the western and southwestern parts of the island are more protected from the strongest waves. However, significant wave damage has been observed in these areas (Hubbard 1980). Even if the impacts of the storms are considered part of the coastal dynamics, co-occurrence of storms and animal nesting events can significantly affect the reproduction of endangered species.

Buck Island Reef National Monument is also influenced by external factors that can impact both terrestrial and marine systems. For instance, the area of Buck Island is affected by atmospheric deposition of Sahara Dust, the transport of eroded particles from Sahara Desert and the Sahel of West Africa (Kellogg and Griffin 2003). The dust particle journey across the Atlantic can take five to seven days, but dust concentrations vary temporally and spatially (Kellogg and Griffin 2003, Garrison et al. 2011). The Saharan dust in a mixture of nutrients, microorganisms (virus, bacteria, and fungi), organic pollutants, toxic substances among others that can have a strong negative effect on both the people of the area but also the environment (Kellogg and Griffin 2003). Previous studies related to the effect of the Saharan dust on the U.S Virgin Islands have shown a direct link between the decline of some marine species and the Saharan dust pulses (Kellogg and Griffin 2003) but also no direct causal link (Garrison et al. 2011). As a result, further work is required to clarify these dichotomous conclusions. Given the link between West Africa and the U.S. Virgin Islands, it is key to understand the climatic predictions for West Africa. For instance, a reduction in rainfall can result in drought that can increase the intensity and frequency of Saharan dust pulses.

Bathymetry assessments for Buck Island Reef National Monument show that areas around Buck Island generally present depths between 0 to 6 m. Shallow waters play an important role in preventing shoreline erosion by reducing wave action energy. However, Buck Island presents very active sediment movement, which results in important changes in the beach area and coastal dynamics (see Chapter 4.1.1). Beyond the shallow waters north of the island, a large area with different types of reefs is protected by a pavement barrier with shallow water that forms an arch that extends from the northwest shelf to northeast of the island. The central and northern areas of the park are dominated by deep water, ranging from −100 to −1000 m (Figure 2.2.2.2). However, in 2018, NOAA Mission Océano Profundo determined the existence of depths as great as 1812 m (https://oceanexplorer.noaa.gov/okeanos/explorations/ex1811/welcome.html).

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 the density function in ggplot2 (RStudio, version 1.2.1335). The range in water depths for the Monument is large, ranging from 0 to −1000 m, with a large portion of the park presenting depths equal or deeper than −1000 m. Shallow waters are also an important component of the park and occur mostly around the island (Figure 2.2.2.2 & 2.2.2.3). Bathymetry data was obtained from National Centers for Coastal Ocean Science, 2021 https://www.fisheries.noaa.gov/inport/item/38815 (NCCOS 2021).

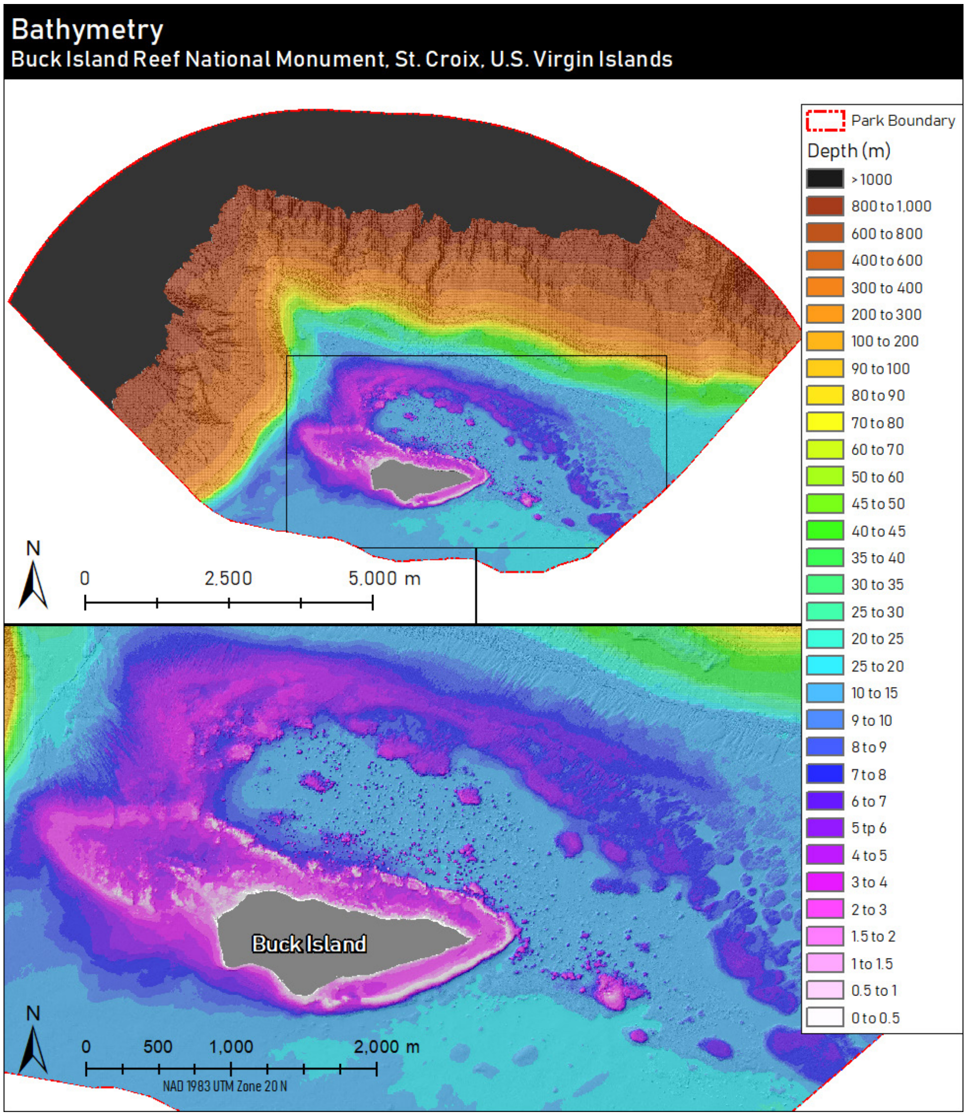

Figure 2.2.2.2. Bathymetry for Buck Island Reef National Monument (BUIS, NCCOS 2021). Park boundary in hatched red. Data sources: Bathymetry data from National Centers for Coastal Ocean Science, 2021 https://www.fisheries.noaa.gov/inport/item/38815 (NCCOS 2021).

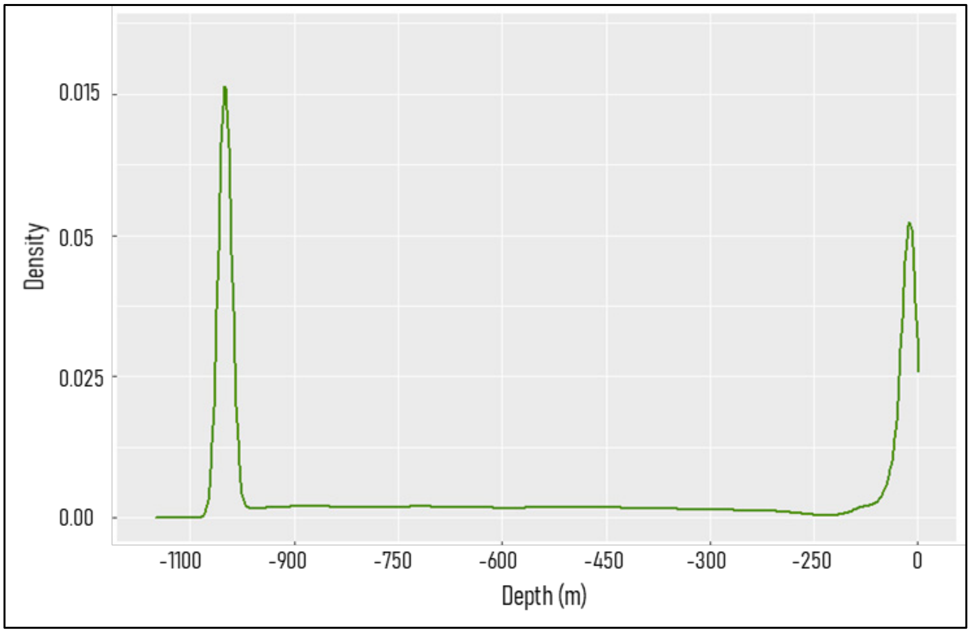

Figure 2.2.2.3. Density distribution for bathymetry estimates for Buck Island Reef National Monument (BUIS, NCCOS 2021). Higher density values represent higher occurrence.

Shoreline

The shoreline of Buck Island can be divided into three sections: the sand beaches along the western and southern shoreline, the northern rock coast with steep drop-offs interspersed with small gravel beaches and the more gently sloped rocky coast with gravel beaches along the eastern and southeastern coast (Figure 2.2.2.4). The coastal shoreline sections that are pre-dominantly affected by seasonal dynamics are the 1.6 km of sand beaches, which represents about 39 % of the total shoreline as of 2018 (Table 2.2.2.1). The beaches are a crucial resource for sea turtles, specifically the hawksbill (*Eretmochelys imbricate*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), and loggerhead (*Caretta caretta*) sea turtles (Pollock et al. 2009, Hart et al. 2013) (Section 4.7.2). This makes the sand beaches a high-priority resource to park management (NPS Management Policies NPS Organic Act Coastal Zone Management Act Virgin Islands Code, Title 12 Section 910).

Of major concern are the long-lasting erosion effects caused by tropical storms and to some degree the seasonal erosion patterns that shape beach extent, shape, and topographic profile of the beaches throughout the year. Erosion that leads to permanent loss of overall nesting habitat is mainly driven by storm events. Whereas seasonal effects of local redistribution patterns of sediment are of interest during the turtle-nesting season between June and September (Section 4.7.2).

Table 2.2.2.1. Coastal shoreline length by shoreline type as identified in aerial photography of 2018 (Method described in Section 4.1.1).

Type	Length (m)	Length (%)
Beach – Sand	1,605	39.1
Beach – Gravel	252	6.1
Cliff	2,243	54.7
Total	**4,100**	**100**

Figure 2.2.2.4. Beach sand at Turtle Bay. Whetten (1966) mapped recent surficial deposits surrounding Buck Island. These deposits include beach sand composed of fragments of coral and mollusks. National Park Service photograph courtesy Zandy Hillis-Starr (St. Croix and Buck Island (Caption and image from nrr-2011-462)

Chemical / Physical Conditions

Water Quality

The clear blue waters that bathe Buck Island and the surrounding coral reefs and seagrass beds are one of the main attractions of BUIS. Because BUIS is a small, uninhabited, and vegetated island, located over 2km from the main island of St. Croix and is surrounded by offshore currents, there are no strong sources of land-run off that impact water quality. There are occasional periods with higher concentrations of particulates (e.g., marine snow) that may be related to natural processes, such as swell-generated sediment resuspension during rough seas. Nutrients, chlorophyll, turbidity, and fecal coliform tend to be low, dissolved oxygen tends to be high, and pH, total suspended solids, and salinity are all within ranges that would support coral reefs and seagrass communities. There is the potential of acute periods of reduced water quality associated with boating and recreational activity, but impacts should be localized. Therefore, BUIS has water quality consistent with maintenance of marine life and support of recreational activities. A detailed analysis of the quality of water at BUIS is presented in Section 4.2.1.

Weather and Climate

The climate in the Virgin Islands is tropical. In BUIS, the average high temperature ranges between 84°F and 89°F, with lows between 73°F and 80°F (23°C to 27°C). The temperatures of 98°F (37°C) and 51°F(11°C) are respectively the maximum and minimum temperatures registered for the period March 1951 to December 2019 at the Christiansted Hamilton Field Airport located less than 2 miles from BUIS on the neighboring island of St. Croix (NOAA 2020). The coolest months in the year occur from December to March. Average temperatures in the winter are around 73°F (23°C). August through October is the hottest time of the year, with average high temperatures in the upper 80s and low 90s (29°C to 32°C) (NPS 2019b).

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. 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 millimeters (mm) to 1,200 mm (40 to 47 inches) per year and is generally slightly more abundant on the northern slopes of Buck Island. The maximum 24 hour rainfall registered for the period March 1951 to December 2019 at the Christiansted Hamilton Field Airport is St. Croix was 457 mm (about 18 in) (Figure 2.2.2.5). This precipitation was recorded during the passage of Hurricane Frederick in early August 1979. NOAA (2020) daily rainfall records show that during the passage of Hurricane Maria on September 20, 2017, the precipitation reached over 130 mm (5 inches) prior to the instrument being damaged by strong winds. Thus, the total amount of rainfall associated with the storm was not recorded. 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 from August to October. A detailed discussion of hurricanes can be found further on in this chapter.

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. Maximum average daily wind speed is 27.74 miles per hour (mi/hr), and the fastest 2-minute wind speed, registered for the period August 2000 to December 2019, was 61 mi/hr, as recorded at the Christiansted Hamilton Field Airport in St. Croix (NOAA 2020).

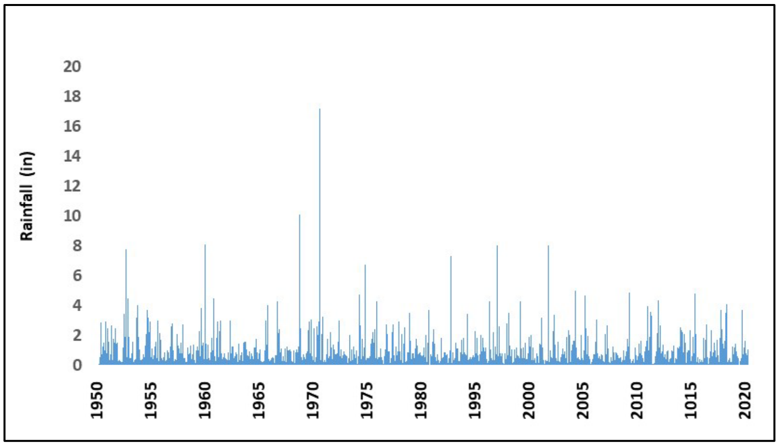

Figure 2.2.2.5. Maximum daily rainfall registered for the period March 1951 to December 2019 at the Christiansted Hamilton Field Airport on the neighboring Island of St. Croix located less than 2 miles from BUIS (NOAA 2020)

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 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 (Campbell et al. 2011, Henareh et al. 2016), 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.

Buck Island, 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 2.2.2.6 shows a simulation of the extent of flooding on Buck Island during high tide.

Figure 2.2.2.7 shows the impact on of a 4 ft (1.2 m) sea level rise (SLR) above mean higher high water (MHHW) in Buck Island. 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 Mean Higher High Water (MHHW) and do not take into consideration future erosion, subsidence, or man-made alterations of the shoreline.

Figure 2.2.2.6. High Tide Flooding 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/)

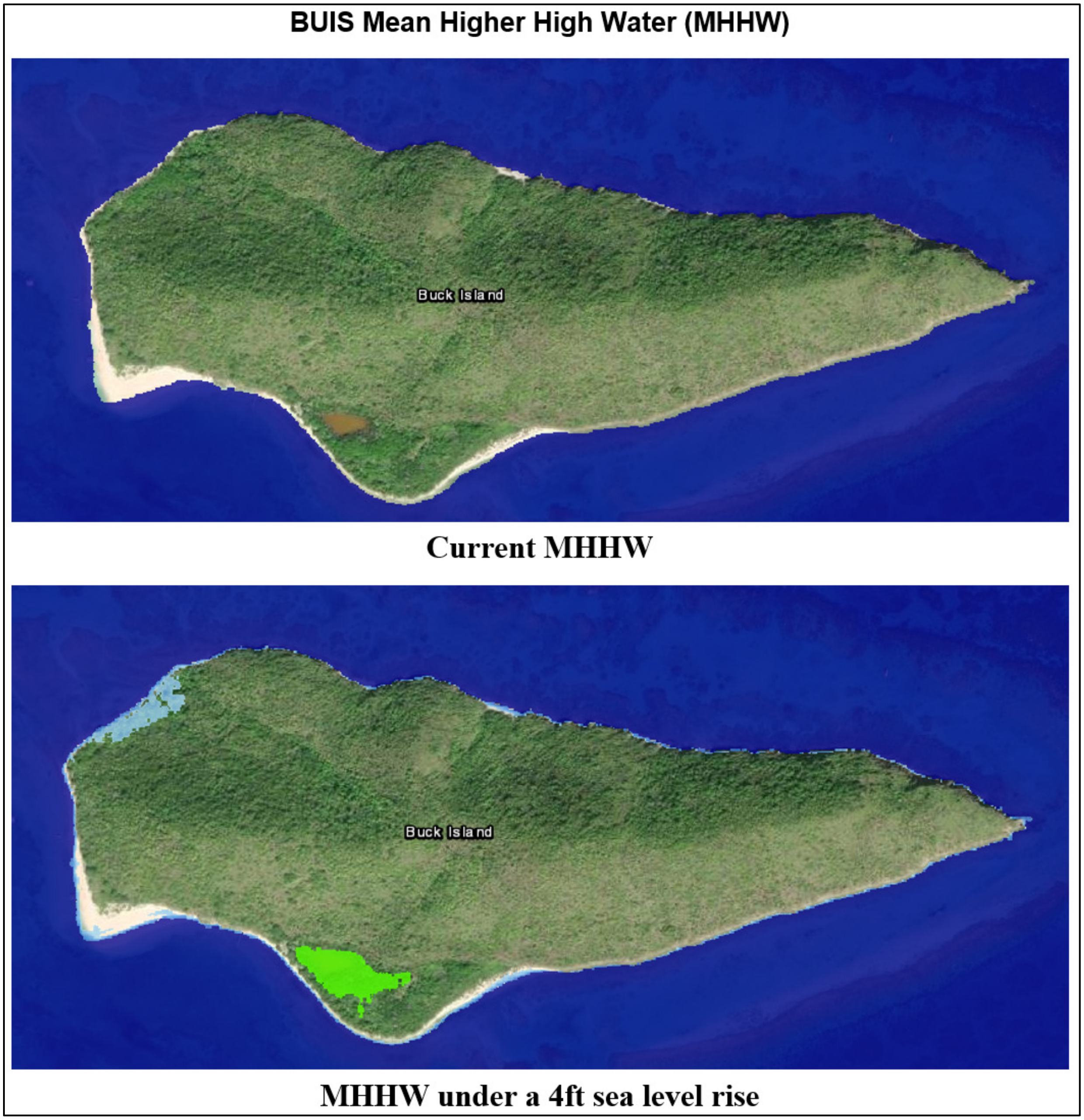

Figure 2.2.2.7. SLR BUIS. Upper panel BUIS present coastline. Lower panel BUIS coastline for a 4 feet rise corresponding to the estimated sea level in 2080. Low-lying areas, displayed in green, are hydrologically "unconnected" areas that may flood. Graphic display under this scenario derived using the NOAA SLR and Coastal Flooding Impacts Viewer (https://coast.noaa.gov/slr/#/layer/slr/0/).

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, nutrients, metals, and persistent organic pollutants (e.g., pesticides, PAHs, PCBs) (Garrison et al. 2011, Kellogg and Griffin 2003). 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, a particular soil fungus detected, *Aspergillus sydowii*, causes sea fan disease and results in widespread coral mortality (Kellogg and Griffin 2003).

Certain chemicals transported by the wind may also have harmful effects on surface waters, marine environments, and vegetation similar to those found in BUIS. 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).

African dust or human-caused haze from fine particles of air pollution may also affect visibility. There is no permanent air quality monitoring station in BUIS, but observations made in nearby stations in St. Croix indicate a reduction of the average natural visual range from about 120 mi (without pollution) to about 65 mi on days with pollution. During high pollution days, the visual range can be reduced to below 40 mi (NPS 2019d) (Figure 2.2.2.8).

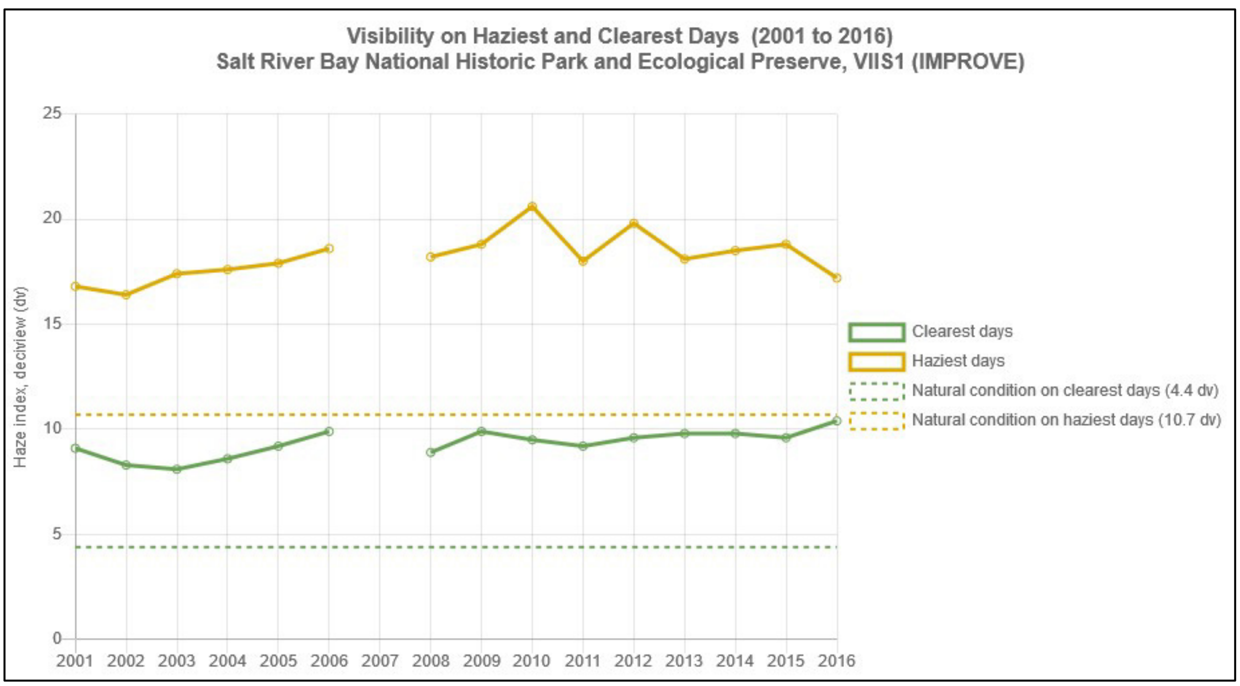

Figure 2.2.2.8. Visibility on haziest and clearest days at the Salt River National Historic and Ecological Preserve located on the north side of St. Croix during the period 2001–2016 (NPS 2019d).

Surface Hydrology

There are no rivers or permanent streams in BUIS (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). Storm water runoff can cause considerable erosion which in turn can have profound effects on local marine sedimentation (Hubbard et al. 1981, KellerLynn 2011).

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 in) 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 of BUIS, the speed of the current is of the order off 10 cm (4 in) per second. These currents are not as intense as those in the central portions of the Caribbean or on the western side of neighboring St. Croix, where much stronger currents are observed. Figure 2.2.2.9 shows a schematic of the ocean currents in the waters of the Greater Caribbean Region.

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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)

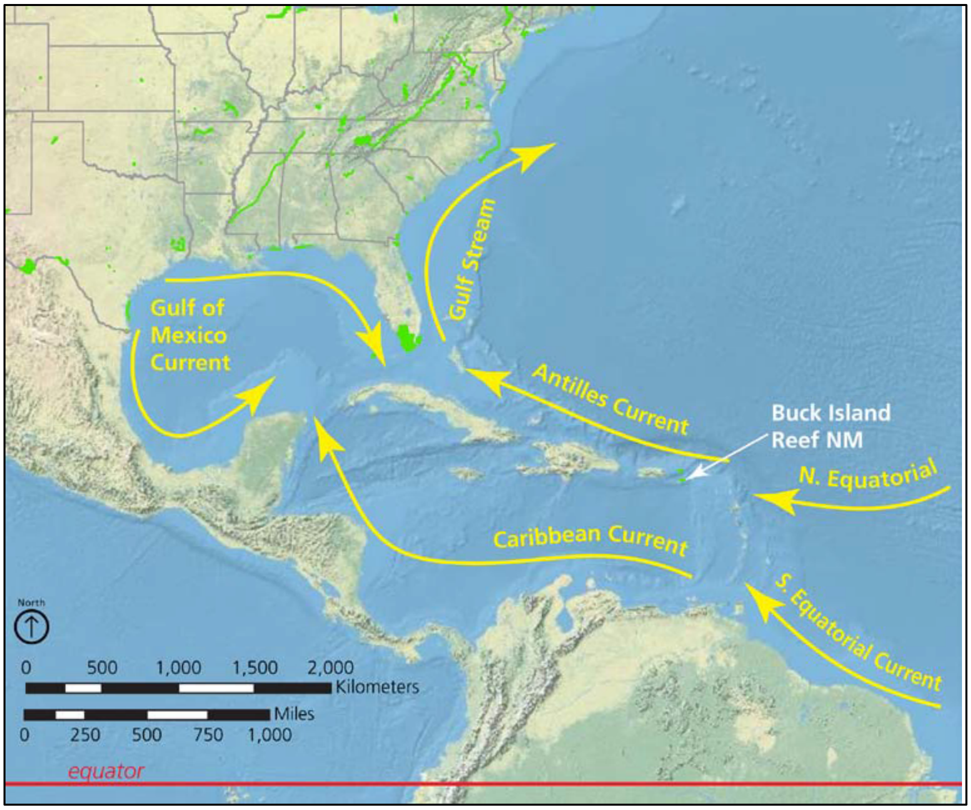

Figure 2.2.2.9. Major oceanographic currents Global circulation around the equator drives oceanographic currents in the Caribbean. Currents around Buck Island Reef National Monument flow from east to west. Current directions after Hubbard (1989). Aerial imagery from ESRI Arc Image Service, USA Prime Imagery, compiled by Jason Kenworthy (NPS Geologic Resources Division). Image and caption from KellerLynn (2011).

Marine Communities

Marine Plants

Soft bottom habitats located to the south of Buck Island are predominantly occupied by continuous (90% to 100% cover) or patchy (50% to <90% cover) cover of seagrasses. Seagrass meadows at this site are dominated by *Thalassia testudinum* (turtle grass) but support a mixed assemblage of *Syringodium filiforme* (manatee grass) and *Halodule wrightii* (shoal grass) (Figure 2.2.2.10). A non-native seagrass species, *Halophila stipulacea*, was first found in BUIS seagrass meadows in 2017 (Gulick et al. 2020). The relative dominance of each species varies with depth and according to Kendall et al. (2004), deep seagrass meadows found in the Buck Island Channel are dominated by *S. filiforme*. BUIS seagrass meadows provide habitat and forage for an array of marine organisms, including a recovering population of green turtles (*Chelonia mydas*) (Hart et al. 2017, Gulick et al. 2020).

The hard-bottom areas of BUIS located mostly north of Buck Island encompass patchy coral reef dominated by turf algae (Figure 2.2.2.11). Long-term benthic surveys of fore reefs and spur and groove reefs show low abundance of macroalgae (Pittman et al. 2014). However, species composition and relative abundance of reef macroalgal assemblages has not been evaluated.

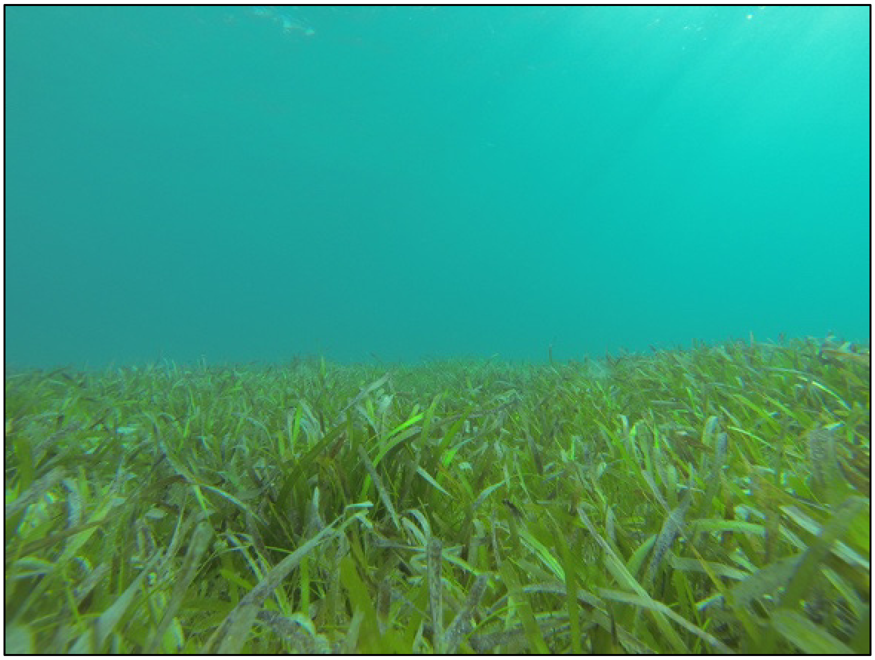

Figure 2.2.2.10. Seagrass meadows at BUIS are dominated by *Thalassia testudinum* (turtle grass). Photo credit: Alexandra Gulick.

Figure 2.2.2.11. Benthic composition of hard bottom areas found at BUIS. Photo credit: S. Pershern.

Marine Invertebrates

Corals

Stony corals (Order Scleractinia) are the most important habitat forming species in BUIS and coral reefs support the highest diversity of marine plants, animals, and microorganisms. Coral reefs and coral communities cover the majority of the shallow (< 30 m) benthic substrate in BUIS. A map of BUIS and the coral reef monitoring locations is presented in Section 4.6.1 of this report. These reefs harbor at least 43 species of scleractinian corals, including US federally 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*) (NOAA 2014). Critical habitat has been established for *Acorpora* spp. and has been proposed for the balance of those aforementioned. The deeper areas of BUIS on the northern extent have highly developed mesophotic *Orbicella* bank reefs that are phenomenally intact coral communities relative to the USVI and wider Caribbean. Coral cover has been declining since at least the 1980s, with degradation driven by climate change and thermal stress, regional overfishing, disease epizootics, and failure to recover after natural disturbances such as tropical storms (Rogers et al. 1982).

Long spined urchins

The long spined sea urchin (*Diadema antillarum*) was one of the most important grazing herbivores in BUIS 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. Figure 2.2.2.12 presents the density of the long-spined sea urchin (*Diadema antillarum*) at long-term coral reef monitoring sites in and around the Buck Island National Monument. From 2002 to 2018 abundances of urchins was between 0 and 1.4 per 100 m^2 at three long-term monitoring sites, with most sites showing no recorded urchins in annual surveys (Figure 2.2.2.12). Urchin data were taken along 25 x 2 m belt transects. Descriptions of the long-term sites are provided in Section 4.6.1. There appeared no trend of increase (recovery) to historical abundances.

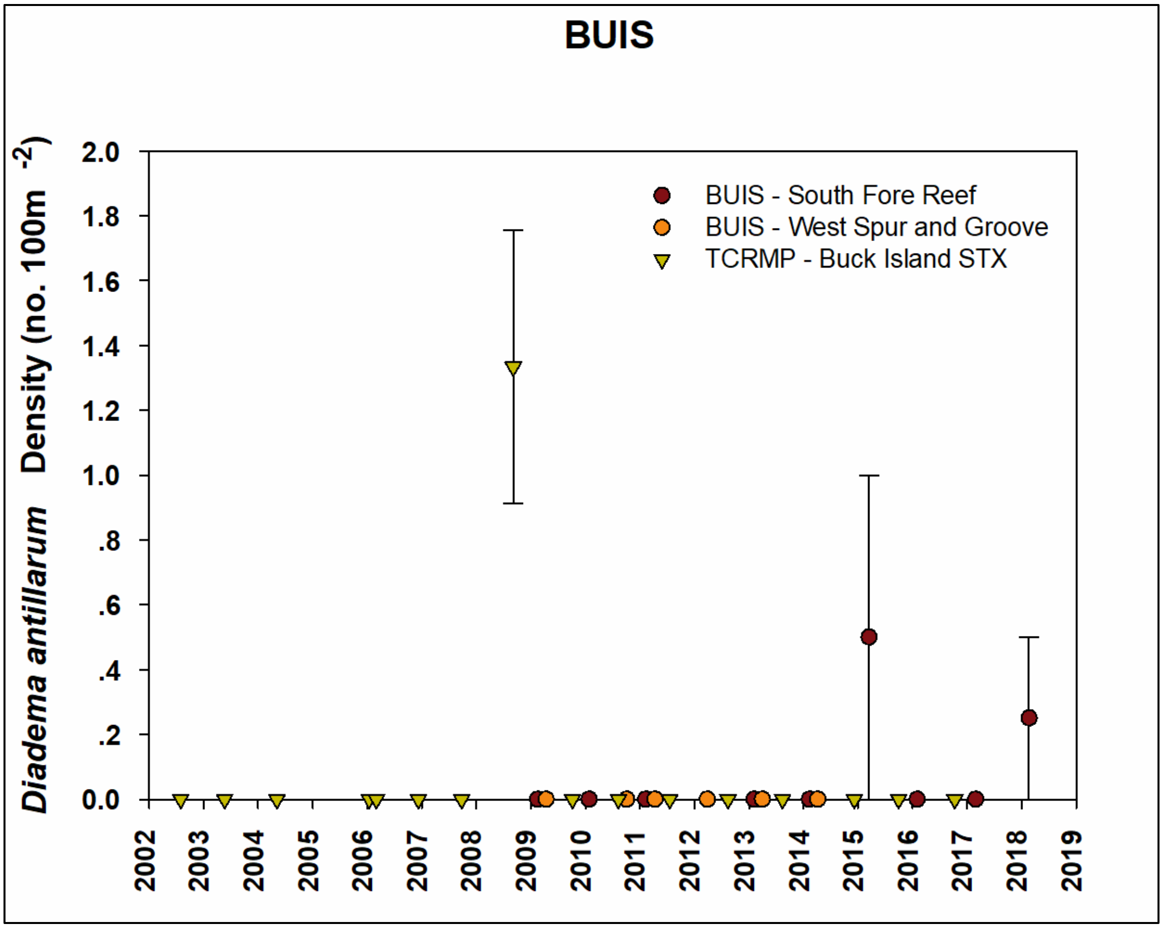

Figure 2.2.2.12. Long-spined sea urchin in BUIS: Density of the long-spined sea urchin (*Diadema antillarum*) at long-term coral reef monitoring sites in and around the Buck Island National Monument (data from South Florida/Caribbean Inventory & Monitoring Network and the USVI Territorial Coral Reef Monitoring Program).

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. Since the establishment of Buck Island National Park (BUIS) in 1961, spiny lobster and conch populations have been protected for almost 60 years (Richter et al. 2018).

Despite low abundance, lobster populations as a whole within the park boundaries have been found to be both larger and more numerous than those found in similar habitats outside the park (Cox et al. 2009). Additionally, reproductively active females were more common inside the protection of the BUIS (Cox et al. 2009). The biennial sampling conducted by the National Coral Reef Monitoring Program (NCRMP) in 2017 found lobster densities within the BUIS to be higher than in areas open to fishing around St. Croix. However, populations were very patchy as 95% of all sites, on average, had no lobster present (Figure 2.2.2.13).

Restrictions on anchoring within park boundaries have preserved large areas of seagrass habitat suitable to both juvenile and adult queen conch. The NCRMP sampling in 2017 found conch densities in the BUIS to be the second highest in St. Croix (Figure 2.2.2.13; See section 4.6.2); however, the methodology of the NCRMP most likely underestimates population sizes as it only samples on hardbottom habitat. Additionally, Doerr and Hill (2018) found conch populations were denser inside the park (302 conch/ha) compared to nearby habitats outside the park, and that the current management approach has allowed for a stable and potentially recovering conch population. This is noteworthy because population densities within the BUIS were also higher than elsewhere in the USVI and Puerto Rico, and Pittman et al. (2008) suggested that this population may be of significant regional importance.

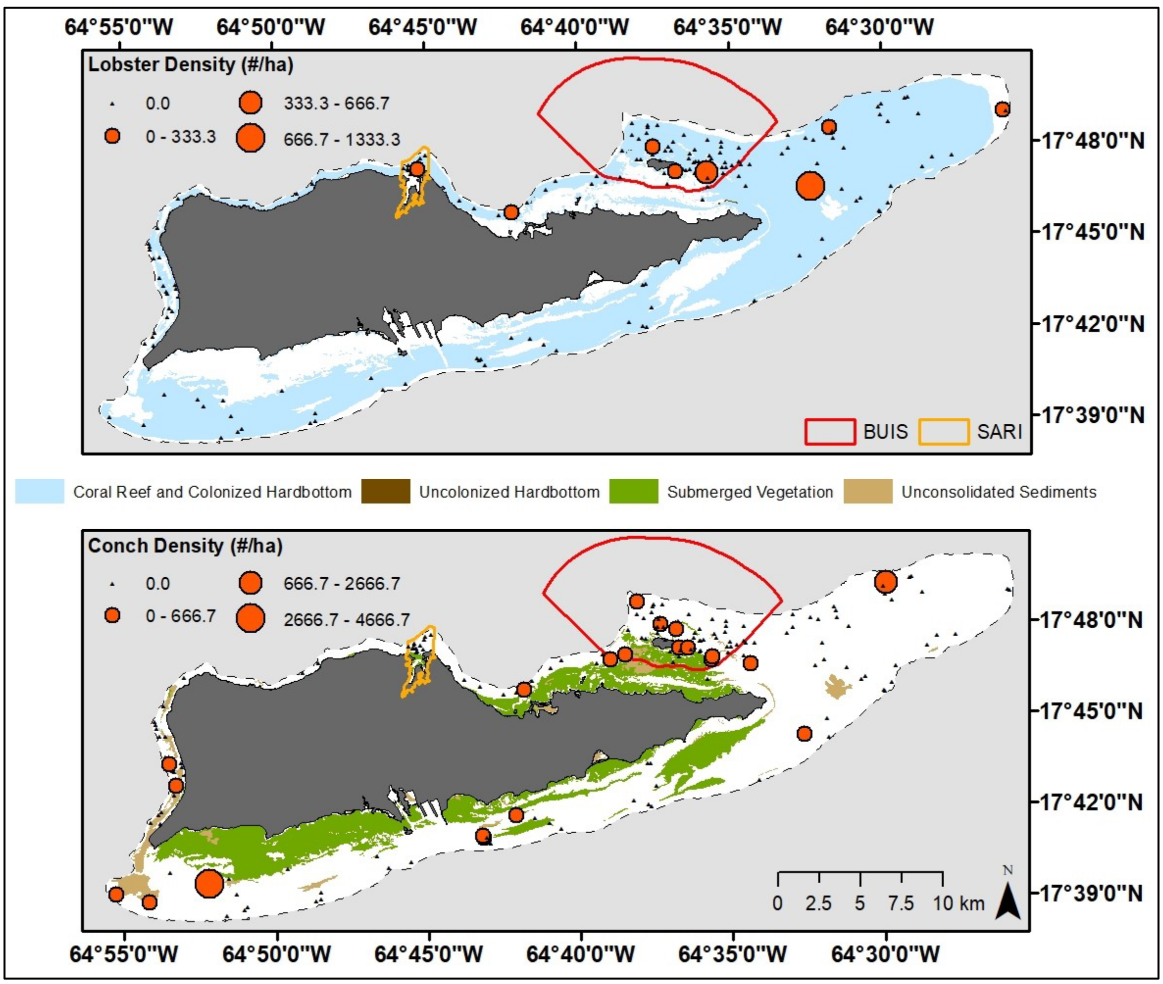

Figure 2.2.2.13. Lobster and queen conch densities in BUIS from 2017 sampling (data from NCRMP).

Marine Vertebrates

Reef Fish

The current boundaries of Buck Island Reef National Monument (BUIS) encompass approximately 47% of coral reef and hardbottom areas that shelter multiple reef fishes. Early studies (Gladfelter et al. 1977) reported high abundance (density) for some species within families Serranidae (groupers), Lutjanidae (snappers), Haemulidae (grunts) and Scaridae (parrotfishes). Despite the early (1975) establishment and subsequent increase in size and regulation of BUIS, fish communities have been in decline. Indeed, back in 2001, Rogers and Beets called for stronger protection in Marine Protected Area (MPA) of the U.S. Virgin Islands as they showed significant decreases in fish size and abundance, particularly of those, target species such as groupers and snappers. The most recent, detailed study of fish communities in the BUIS shows no difference in multiple metrics (species richness, fish biomass of different groups) between sites inside and outside BUIS (see Section 4.7.1) (Figure 2.2.2.14).

Figure 2.2.2.14. SCUBA diver conducting fish visual surveys on BUIS reefs. Photo credit: Ian Lundgren.

Pelagic Fish

Several species of inshore-pelagic fish (highly mobile species, usually occurring in schools) such as jacks (family Carangidae) and mackerels (family Scombridae) are present in BUIS. Data used in this report show that Bar jack (*Caranx ruber*) is one of the most abundant species in the family while cero (*Scomberomorus regalis*) is rarely present. Anecdotal information indicates that fishermen trolling deep (500 m) waters along the west and north boundaries of BUIS catch wahoo (*Acanthocybium solandri*) and mahi (*Coryphaena hippurus*). No information was found regarding offshore-pelagic species such as billfishes [families Istiophoridae (marlin and sailfish) and Xiphiidae (swordfish)]. However, based on the popularity of offshore sport fishing in the area (see https://caribbeanseaadventures.com/tour/fishing/), it is reasonable to think, billfishes are present and abundant at certain levels. Monitoring catch per unit effort, even from catch and release effort, could provide useful information about these species.

Lionfish

Lionfish (Figure 2.2.2.15) is a species complex (*Pterois volitans/miles*) endemic from the Indo-Pacific Ocean which, according to NOAA, was first reported in Florida in the mid-1980s as a few individuals. However, in the 1990s, lionfish dramatically spread throughout the Caribbean posing a serious threat to native fish communities (Johnston and Purkis 2011). The predatory behavior of this species complex has been associated with as much as 79% decline of native fish recruitment on coral reefs (Albins and Hixon 2008). Reports of lionfish in BUIS started in 2008 but control through permitted spearfishing has controlled the population in check. Data from a reef site surveyed since 2003 show the first individual in 2012 and in 2019 its density was lower than 0.3 individuals 100 m^{-2} (see Section 4.7.1).

Figure 2.2.2.15. Invasive lionfish (*Pterois volitans/miller*), an Indo-Pacific species spread throughout the Caribbean. Photo credit: Alain Duran.

Sea Turtles

Sea turtles are large marine reptiles with a global distribution, although most species are found in subtropical / tropical marine habitats. All seven sea turtle species are currently listed as Threatened or Endangered under the Endangered Species Act. BUIS provides critical developmental habitat for hawksbill turtles (*Eretmochelys imbricata*), foraging grounds for juvenile and adult green turtles

(*Chelonia mydas*), and nesting beach habitat for hawksbill, green, leatherback (*Dermochelys coriacea*), and loggerhead turtles (*Caretta caretta*) (Phillips and Hillis-Starr 2002). Long-term monitoring programs for nesting and in-water sea turtle populations at BUIS have played an important role in the localized recovery of sea turtles in the park, particularly for hawksbill and green turtles (Figure 2.2.2.16) (Hillis-Starr and Phillips 1998, Hart et al. 2017). Notably, the Buck Island Sea Turtle Research Program (est. 1987–present) is one of the longest running saturation-tagging programs for sea turtles in the world, serving as an invaluable tool for evaluating the status of the BUIS sea turtle population.

Figure 2.2.2.16. (Left) Recently emerged hawksbill hatchlings make their way to the water. (Right) An adult green turtle grazes in a seagrass meadow at BUIS. Photo credits: A. Gulick.

Sharks and Rays

Despite the lack of quantitative information regarding the presence and abundance of sharks and rays, individuals of several species are present in BUIS. Figure 2.2.2.17 shows pictures of two different species of sharks patrolling softbottom (left) and hardbottom (right) areas in BUIS. In the single-site yearly survey used for long-term analysis in section 4.7.1 of this report, two individuals of southern stingray (*Dasyatis Americana*) are reported. Given the general evasive behavior, territory size, and seasonal migration of these species, particularly shark, their abundances obtained via visual surveys are usually underestimated. Other methods such as Baited Remote Underwater Video (BRUV) used worldwide (see https://globalfinprint.org) can provide more accurate information on shark populations in BUIS.

Figure 2.2.2.17. (Left) A tiger shark (*Galeocerdo cuvier*) swims over a seagrass meadow. (Right) A reef shark (*Carcharhinus* sp.) patrols a hardbottom reef at BUIS. Photo credits: Alexandra Gulick (left); Kemit-Amon Lewis (right).

Mammals

Dolphins are frequently seen in BUIS (Figure 2.2.2.18). Indeed, it is one the main attractions sold by concessions taking tourists in scuba diving and snorkeling trips. However, quantitative information in regard to individual identification and the size of the resident population is not available. Other marine mammals such as manatees (Buck Island Reef National Monument Facebook post May 9th 2018) can be present in BUIS but no detailed information was available. Acoustic monitoring in the Monument from 2014 to 2018 has detected the presence of humpback whales (*Megaptera novaeanglieae*), which have been documented vocalizing during the months of January through April (Haver et al. 2019).

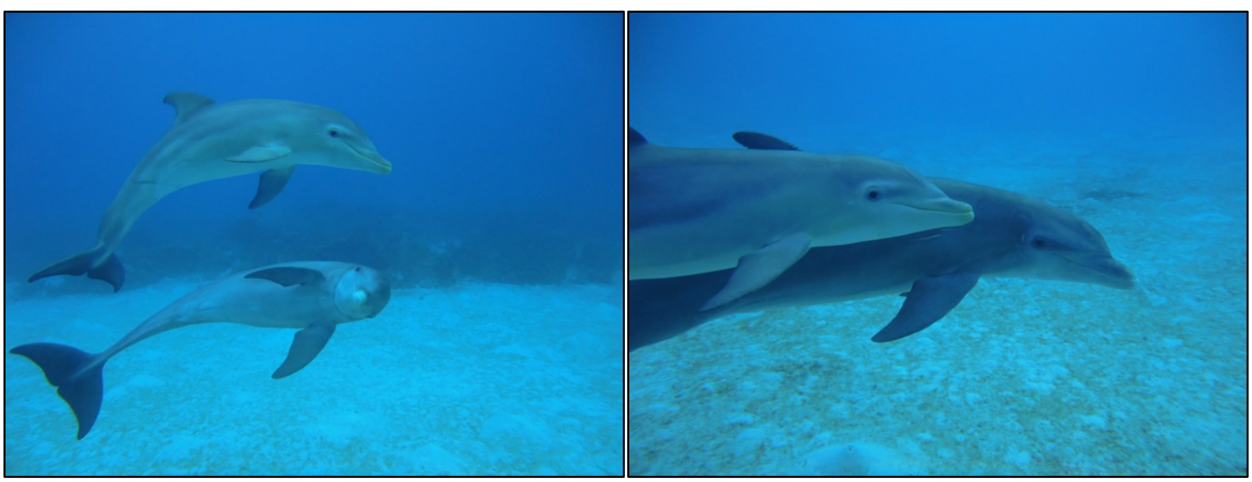

Figure 2.2.2.18. Bottlenose dolphins (*Tursiops truncatus*) at BUIS. Photo credits: Tessa Code.

Terrestrial Communities

Terrestrial communities located in Buck Island Reef National Monument range from sandy beaches and rock pavement at the water's edge to dry forests at the island's highest elevation, just over 100 meters above sea level. Prior to European colonization, most of Buck Island was likely covered by dry tropical forest; however, settlement of the island, which began in the mid-1600s, altered the landscape through clearing for logging, cultivation, and goat and sheep grazing (Woodbury and Little

1976). Based on the study carried out in 2009, shrubland dominates the landscape (50%) and the forest and woodland communities comprise approximately 40% of the island (Figure 2.2.2.19) (Moser et al. 2010). Mangrove forest is restricted to the area immediately surrounding the salt pond on the south side of the island. Sparsely vegetated cliffs form the perimeter of much of the north and southeast sides, while sandy beaches are found along the western edge. The island supports a handful of native reptiles, nesting birds, frugivorous bats, and numerous invertebrates. Establishment of non-native mammals and plants have created challenges to the management of the native flora and fauna.

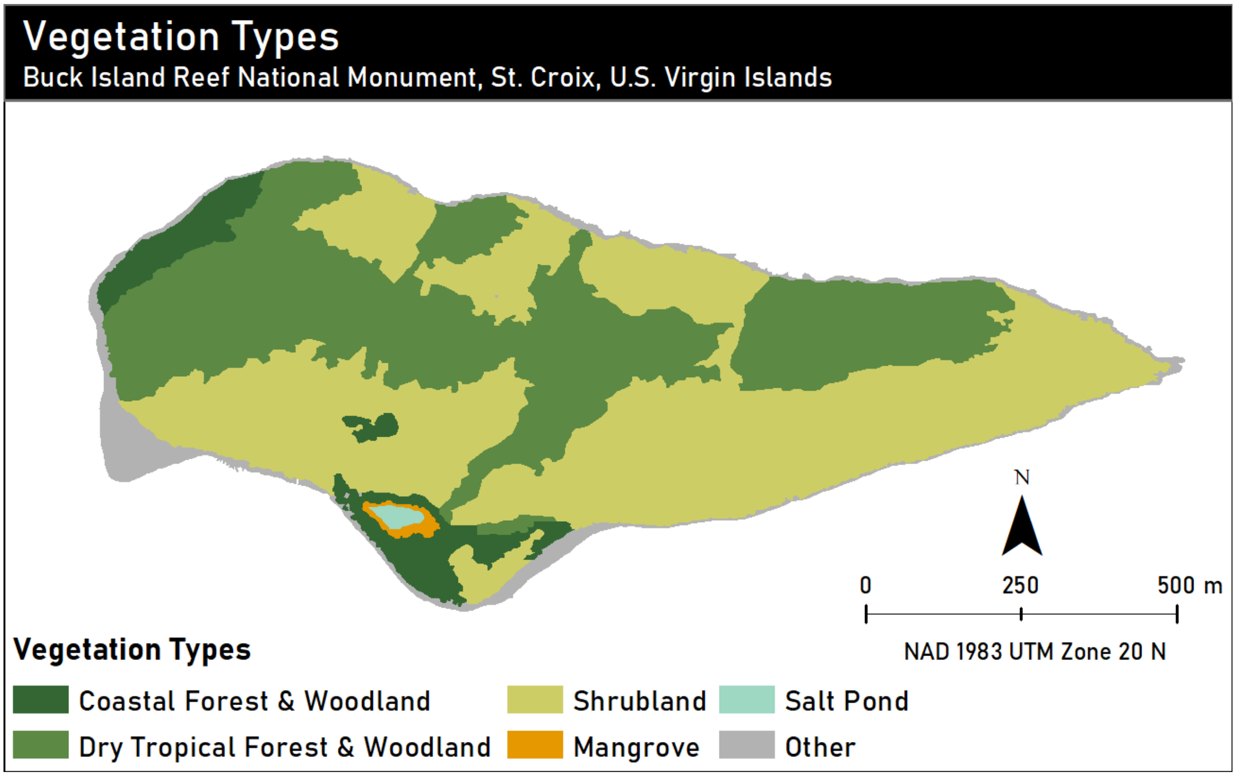

Figure 2.2.2.19. Land cover classification of major vegetation types on Buck Island, classes aggregated from Moser et al. (2010). Spatial dataset available from USGS 2009.

Terrestrial Plants

The flora of BUIS includes approximately 250 species of terrestrial vascular plants, of which nearly 60% are trees or shrubs, over 30% are herbs, and the remainder are vines, epiphytes and parasites (Woodbury and Little 1976) (Appendix A). No ferns occur on the island. Woodbury and Little (1976) noted the dry character of the flora and documented 228 species, including 17 non-natives during several surveys of the island between 1966 and 1970. While subsequent floristic inventories by Gibney (1996) and Ray (2003) added additional species to the flora, both remark on the absence of many species observed by Woodbury and Little and suggest impacts from climatic events (hurricanes and drought) and invasive species as proximal causes. Ray (2003) estimates that the current number of plant species on Buck Island is closer to 200.

Rare and endemic species include *Malphigia infestissima*, stinging bush, a tree restricted to Buck Island and St. Croix, and *Croton rigidus,* a weedy shrub, which is confined to the Virgin Islands and Puerto Rico (Woodbury and Little 1976). Stinging bush is fairly common throughout the island (Gibney 1996). Five plant species are listed as territorially endangered (Table 2.2.2.2) according to the USVI Endangered and Indigenous Species Act of 1990 (NPS 2012). The wooly nipple cactus, *Mammilaria nivosa,* has been observed in two locations on the island (Ray 2003). While the cactus is found throughout the West Indies, it is typically confined to rocky shorelines on small cays. Lignum vitae was prevalent throughout the Caribbean prior to European settlement but was extirpated from Buck Island due to logging for its valuable wood (NPS 2012). The species has since been reintroduced to the island (NPS 2012). *Opuntia tricanta* is a medium-sized cactus found throughout the Caribbean and south Florida. Populations of this cactus are threatened by the introduction of the non-native cactus moth, *Cactoblastis cactorum*, from South America. The endangered Egger's century plant, *Agave eggersiana*, native to the eastern end of St. Croix, was out-planted on BUIS in 2010, and as of March 2020, 36 individuals were found along the trail behind Dietrich (Z. Hillis-Starr 2021, personal communication). All but one of the individuals was healthy and no signs of agave snout weevil were observed.

Table 2.2.2.2. Vascular plant species of concern on Buck Island Reef National Monument (NPS 2012).

Scientific Name	Common Name	Territory Status
Guaiacum officinale	Lignum vitae	Endangered
Malphigia infestissima	Stinging bush	Endangered
Mammilaria nivosa	Woolly nipple cactus	Endangered
Opuntia tricantha	Spanish lady	Endangered
Psychillis macconnelliae	Butterfly orchid	Endangered

During the twentieth century, introduced mammals heavily impacted the native flora, decreasing reproduction of native species through extensive seed and fruit consumption and pruning trees by gnawing (Ray 2003). The eradication of the Indian mongoose, *Herpestes auropunctatus*, and tree rat, *Rattus rattus*, from the island has ameliorated these impacts (Ray 2003). The extent of invasive exotic plants is less than that of other islands, as large monocultures of exotics are mostly absent (NPS 2012). However, a couple exotic species have established on the island, especially in the dry tropical forest and shrubland. The NPS Exotic Plant Management Program began removing and chemically treating ten priority species in 2003 (Table 2.2.2.3), the most widespread being African guinea grass, *Urochloa maximum*, and wild tan-tan, *Leucaena leucocephala* (Clarke and Hillis-Starr 2004).

Table 2.2.2.3. List of invasive exotic plant species on Buck Island Reef National Monument targeted for island-wide removal (Clark and Hillis-Starr 2004) and the percent of grid cells in which each species was recorded as occurring, according to the BUIS plant inventory by Gary Ray in 2001 (Ray 2003).

Scientific Name	Common Name	% of grid cells with species present
Aloe vera	aloe	3%
Boerhavia erecta	boerhavia	9%
Bromelia pinguin	wild pineapple	3%
Leucaena leucocephala	wild tan-tan	56%
Meliococcus bijugatus	kenip	6%
Morinda citrifolia	noni	6%
Tamarindus indica	tamarind	24%
Tecoma stans	ginger thomas	24%
Thespesia populnea	seaside maho	12%
Urochloa maximum	African guinea grass	74%

Mangroves

Mangroves cover less than one acre of BUIS, surrounding the salt pond located on the south side of the island (Moser et al. 2010) (Figure 2.2.2.19). The community consists of both fringing and shrubland types and is comprised of two species, *Laguncularia racemosa* (white mangrove) and *Avicennia germinans* (black mangrove), with the notable absence of *Rhizophora mangle* (red mangrove) (Moser et al. 2010). Fringing mangroves reach a height of 20–25 m (Woodbury and Little 1976), whereas the mangrove shrubland are less than 2 m tall (Moser et al. 2010). Associated species in this community include seagrape, *Cocoloba uvifera,* and fingergrass, *Chloris barbata*. Several species of herons, egrets, and ducks frequent the mangrove-fringed salt pond. Mangroves provide potential nesting sites for birds.

Tropical Dry Forest

Tropical dry forests on BUIS are dominated by *Bursera simarouba* and *Pisonia subcordata*, both with individuals older than 100 years, as well as *Bourerria succulenta*, *Cordia dentata, Adelia ricinella*, and *Piscidia carthagenesis* (Woodbury and Little 1976, Gibney 1996). *Guapira discolor*, *Krugiodendron ferreum*, and *Tabebuia heterophylla* are found in moister locations (Gibney 1996). We consider the following Level 4 classes (Moser et al. 2010) as constituting tropical dry forest on BUIS: gallery semi-deciduous forest, semi-deciduous forest, *Bursera simarouba – Pisonia subcordata* forest association, *Rochefortia acanthophora – Pisonia subcordata* forest association, and *Pisonia subcordata – Bursera simarouba* woodland association. This forest community is found primarily in ravines, directly adjacent to the coastal forest, and on north-facing slopes on Buck Island (Gibney 1996) (Figure 2.2.2.19).

Coastal Vegetation

Large manchineel trees, *Hippomane manchineel*, dominate the coastal forest. Associated large trees in this forest include *Pisonia subcordata, Coccoloba uvifera*, *Ficus citrifolia*, and the introduced *Tamarindus indica* (Woodbury and Little 1976). This forest type is primarily found on the western and southern shores of the island (Figure 2.2.2.19). The coastal forest classification consists of the following Level 4 forest and woodland alliances/associations on BUIS (Moser et al. 2010): *Pisonia subcordata – Hippomane mancinella* forest, *Hippomane mancinella* forest, semi-evergreen forest, *Acacia tortusa – Pisonia subcordata* woodland, *Pisonia subcordata* woodland, and *Hippomane mancinella – Sideroxylon obovatum* woodland. This forest has been heavily impacted by hurricanes, including Hurricanes Hugo (1989) and Marilyn and Luis (1995), leading to mortality of large trees and rapid beach erosion (Gibney 1996).

Terrestrial Vertebrates and Invertebrates

Terrestrial vertebrates on BUIS include more than 50 species of birds, five reptiles, and three mammals. Invertebrates dominate the animal life on the island. Species lists are provided in tables or appendices and endemic and threatened species are noted.

Birds

Fifty-three species of birds have been recorded within the monument (National Audubon Society 2010, eBird 2017, NPS 2017) (Appendix B). USVI territory listed species include the brown pelican, *Pelecanus occidentalis*, white-crowned pigeon, *Columba leucocephala*, white-cheeked pintail, *Anas bahamensis*, Wilson's plover, *Charadrius wilsonia*, and least tern, *Sterna antillarum* (Watson 2003). The peregrine falcon, *Falco peregrinus*, is a rare winter visitor (Watson 2003). Seabird monitoring of pelican and least terns was initiated in 1969 (Patterson et al. 2008). These two species nest within the Monument and are high management priority. The Caribbean brown pelican was federally de-listed in 2009 but remains territorially endangered (NPS 2012). Twenty to forty individuals nest annually between September and February at the rookery located on north side of the island (Clark and Hillis-Starr 2004). While yearly nesting effort is quite variable, the average annual number of nests on BUIS decreased from a high in the 1970s to a low in the 1990s, with a subsequent reversal of this trend following eradication of the non-native roof rat, *Rattus rattus*, from BUIS (Figure 2.2.2.20).

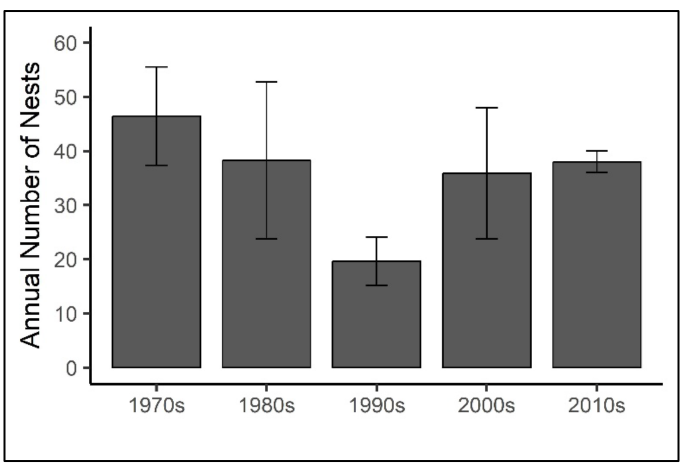

Figure 2.2.2.20. Average annual nesting effort by decade ± SE for the brown pelican. Data from 1969 is included in the 1970s average. Data provided by BUIS Resource Management staff (1969–2013).

A colony of 20 to 80 least terns nested at West Beach until 2005, but the site was abandoned until recently, when the colony returned and successfully fledged 40 chicks in 2019 (K. Ewen 2021, personal communication). While the reason for their absence following 2005 is unknown (NPS 2012), a high percentage of nest predation and/or abandonment was noted in both 2004 and 2005 from BUIS survey data, with nests being washed out by the tide or disturbed by sea turtle nesting. Least terns arrived again in April/May 2020 with 75–100 birds in the colony. Unfortunately, nesting was rather unsuccessful with only 3 chicks observed and low numbers were partially attributed to human activity observed within the closed off area of the beach (K. Ewen 2021, personal communication). Wilson's plovers' nests have been observed on West Beach in 2004 and 2005. Threats to both pelicans and least terns include resource limitation, predators, availability and quality of nesting habitats, and interactions with park visitors.

Avian monitoring is conducted annually via the Audubon Christmas Bird Count, with a total of 25 species observed during the last three counts (2013, 2014, and 2017) (National Audubon Society 2010). The successful removal of mongoose and rats from BUIS has likely promoted nesting success and increased the availability of forage resources. Documentation of resident and migratory bird nesting and foraging activity on the island has been identified as a management objective (Watson 2003).

Reptiles

Five species of terrestrial reptiles are found on Buck Island, including three geckos, one anole, and the critically endangered St. Croix ground lizard, *Pholidoscelis polyps* (Table 2.2.2.4). No amphibians are present on the island (NPS 2012). Three of reptile species are endemic to St. Croix and the surrounding cays. All are native to Buck Island except for the introduced house gecko, *H. mabouia*. All species, except *P. polops* and *Sphaerodactylus beattyi*, were observed during surveys conducted in 2001 (Waddell and Rice 2002). In 2008, *P. polops* was re-introduced to the Buck Island from a population on Green Cay in the National Wildlife Refuge (Treglia and Fitzgerald 2010). Fifty-seven adult lizards were translocated (25 males and 32 females) to the western coastal forest. Since that time, the population has expanded to occupy the entirety of the island and the most recent abundance surveys conducted in 2019 indicate a population on BUIS ranging between 10,000 and 12,000 individuals (K. Ewen 2020, personal communication). Trends in status and condition of the population are discussed in section 4.5.1.

Table 2.2.2.4. Terrestrial reptiles occurring on BUIS (NPS 2017).

Scientific Name	Common Name	Status
Pholidoscelis polops	St. Croix ground lizard	Endemic to St. Croix (Federally endangered)
Anolis acutus	St. Croix anole	Endemic to St. Croix
Hemidactylus mabouia	House gecko	Introduced
Sphaerodactylus beattyi	Cotton ginner gecko	Endemic to St. Croix
Sphaerodactylus macrolepis	Dwarf gecko	Restricted to Puerto Rico and the U.S. and British Virgin Islands

Terrestrial Invertebrates

Invertebrates are the most abundant animal group on the island (Platenburg et al. 2005). Surveys for beetles, conducted from 1993–1997 by Michael Ivie, documented 126 species of coleopteran (NPS 2012) (Appendix C), including several endemic, and two species new to science (Pollock and Ivie 1996). A terrestrial invertebrate survey conducted on the island in 1996 documented the presence of several groups of terrestrial invertebrates: *Blattaria*, Millipeds, *Orthoptera*, *Lepidoptera*, *Dipteria*, *Hemiptera*, *Acari*, *Hymenoptera*, *Neuroptera*, *Odonata*, and *Arachnida* (NPS 2012). During six weeks of invertebrate sampling in 2008, over 5000 individuals, within 21 orders, were captured in pitfall traps in the coastal forest (Treglia 2010). Crabs are found throughout all habitats on the island and include the following species: *Coenobita clypeatus* (hermit crab), *Ocypode quadrata* (ghost crab), *Cardisoma guanhumi* (great land crab), *Gecarcinus ruricola* (land crab), and *Aratus pisonii* (mangrove crab). Ghost and hermit crabs are an important food source for shorebirds (NPS 2012).

Mammals

The island has a long history of non-native mammal occupants. Goats and sheep were brought to the island at the time of colonial settlement and were grazed for several hundred years until 1925 (NPS 2012). Mongoose were introduced in 1912 and eradicated by 1985 (NPS 2012). As result of mongoose removal, the population of non-native tree rats exploded (Witmer et al. 2007). A concerted effort to remove the rats was made from 1998 to 2000 with an island-wide grid of elevated bait stations containing rodenticide (Witmer et al. 2007) (Figure 2.2.2.21). Post-treatment monitoring from 1999 through 2005 resulted in zero rat captures, indicating successful eradication of rats from the monument. However, monitoring did reveal a growing population of the house mouse, *Mus musculus*, and the impacts of this remaining non-native mammal are being investigated.

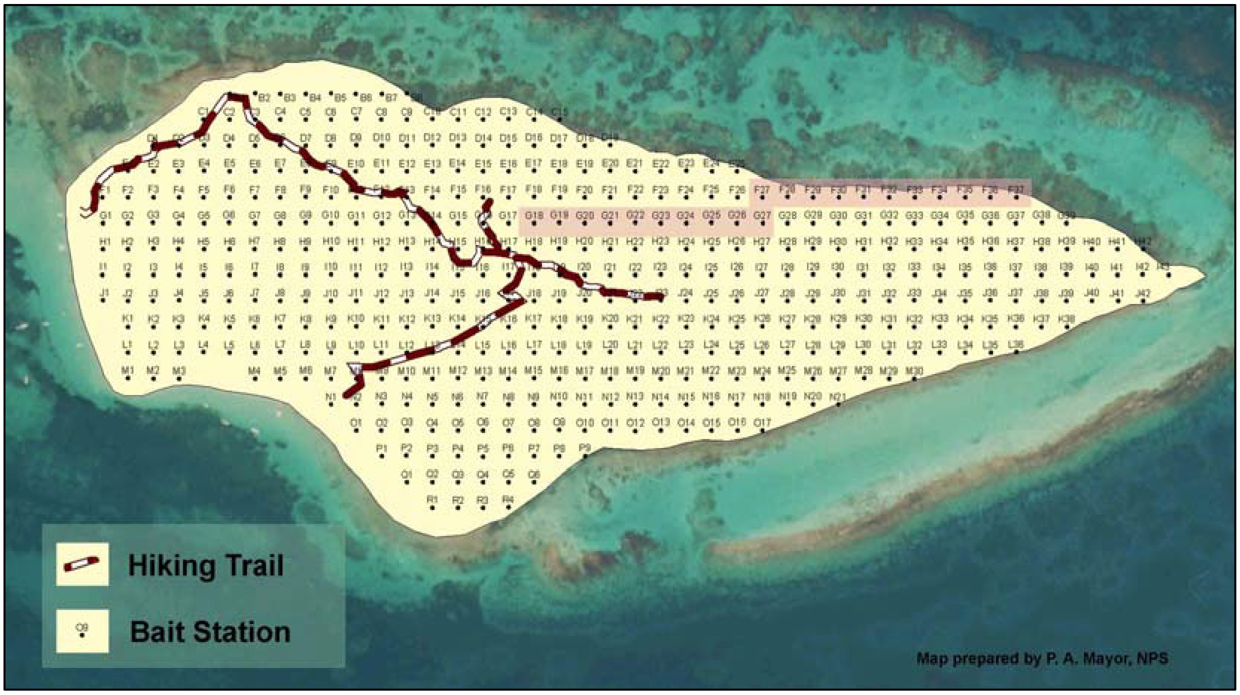

Figure 2.2.2.21. Sixty-meter grid of rodenticide bait stations (numbered points) reprinted from the 2004 BUIS Environmental Assessment (Clark and Hillis-Starr 2004). Highlighted areas indicate where bait was thrown due to steep terrain.

The only native mammals on Buck Island include two species of frugivorous bats, *Molossus molossus* and *Tadarida brasiliensis* (Figure 2.2.2.22) documented during Anabat surveys in 2003 and 2007 (Fly By Night 2017). While few individuals were observed during these surveys, some were seen foraging during the wet season (NPS 2012). Several large-fruited plant species are bat-dispersed, including *Cassine xylocarpa* and *Cordia ricseckeri*, and vegetation recovery should proceed with increased visitation by bats to the island (Ray 2003).

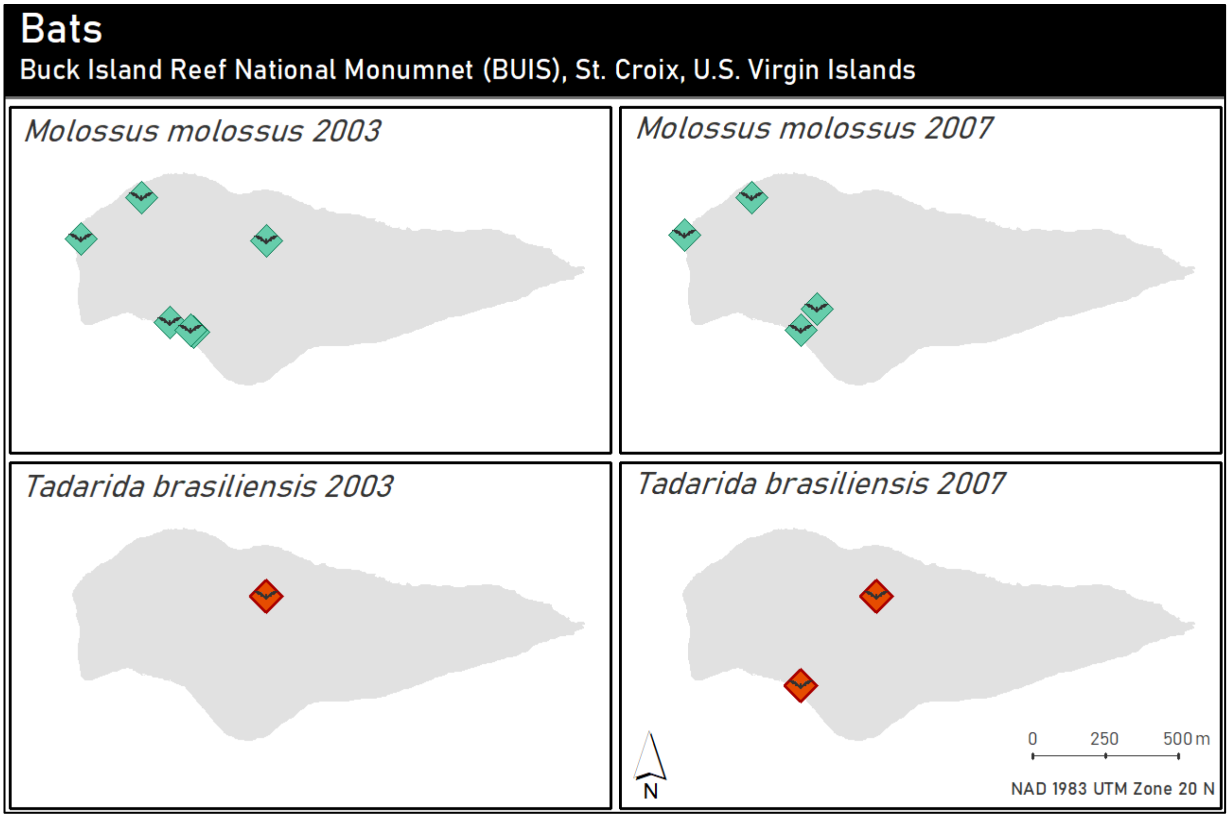

Figure 2.2.2.22. Detections of the Cuban house bat (*Molossus molossus*) and LeConte's free-tailed bat (*Tadarida brasiliensis*) within BUIS during 2003 and 2007 Anabat surveys (Fly By Night 2017).

Other Resources

Sound scape

The natural soundscape of BUIS consists primarily of sound produced by wind and waves and animals, including birds, insects and geckos (NPS 2012). Human-produced sounds include those associated with motorized boating activity and visitor use, especially in the West Beach area. The intensity of human-produced sound varies by season and weekday/weekend and has not been measured in the park (NPS 2012). BUIS is one of 12 sites within the NOAA/NPS Ocean Noise Reference Station Network, which uses passive acoustic recorders to quantify levels and trends in ocean noise within the U.S. Exclusive Economic Zone (Haver et al. 2018, Haver et al. 2019). Acoustic data is available for the BUIS site beginning in November 2016. Marine vessel noise, humpback whale vocalizations, and wind noise, including that generated from Hurricanes Irma and Maria in 2017, have all been documented as part of the monitoring (Haver et al 2019). BUIS participated as one of 17 locations within the NPS in a project to record the response of the vocalizing biological community to the total solar eclipse of August 21, 2017 (https://www.nps.gov/orgs/1207/08-17-2017-eclipse.htm). Although BUIS was not in the path of totality, it did experience a partial solar eclipse. Acoustic monitoring was conducted in subtropical dry forest between August 18 and August 25, 2017 (E. Brown 2021, personal communication).

View scape

Scenic resources of the park include white beaches, blue water, dry tropical forest, and underwater communities of coral and seagrass, with little human development (NPS 2012). The viewshed toward Buck Island, looking from St. Croix is primarily natural, while that from Buck Island toward St. Croix is a substantially greater built environment (NPS 2012). The Monument boasts incredible night skies and dark conditions are maintained by minimal artificial lighting from boats anchored in designated areas.

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 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 condition of BUIS' resources.

Human Interactions

The mission of the Buck Island Reef National Monument clearly states that its existence is for the "education, enjoyment, and inspiration of present and future generations" (NPS 2012). Consequently, it is indisputable that human interactions occur and will continue to occur in the premises and vicinity of the Monument. BUIS provides a number of valued resources and services to visitors. As per the BUIS Conceptual Model (Patterson et al. 2008), coral reefs are a resource of particular aesthetic value which in turn provide a highly productive habitat for fish and invertebrates and equally productive are seagrass beds. Wildlife, and in particular, unique and rare marine and terrestrial species, provide both recreational and educational opportunities for visitors, a service that is fundamental for the wellbeing and intellectual advancement of humans. Finally, the establishment of BUIS as a "No Take" marine reserve allows the Monument to serve as a valued resource, providing a safe breeding grounds for numerous populations that can expand into fished areas (NPS 2018).

Boat traffic and grounding

There are two ways to get to the park, either by private vessel or with park concession operators. Vessels for hire are prohibited within the park without authorization. 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 or sloughing of toxic material contained in bottom paint (NPS 2012). Another way of potentially harming coral reefs and seagrass beds is through groundings, anchoring, inappropriate use of anchors, or by propeller or hull damage. During the past three decades, there have been several vessel groundings due to poor navigation and loss of engine power, as well as related to illegal smuggling. There are also safety concerns of getting to the beach from offshore moorings. An anchoring permit is required for all vessels, and anchoring is only allowed in a designated area near West Beach in deep sand (Figure 2.2.3.1). To minimize the risk of potential hazards to the marine habitats in the park, the size of boats entering BUIS is limited and their length cannot exceed 150 feet, but those sailing into the lagoon need to be 42 feet in length. In addition, on the east side of Buck Island, up to twelve moorings are available at the site of the underwater trail, of which two are for SCUBA diving (NPS 2012).

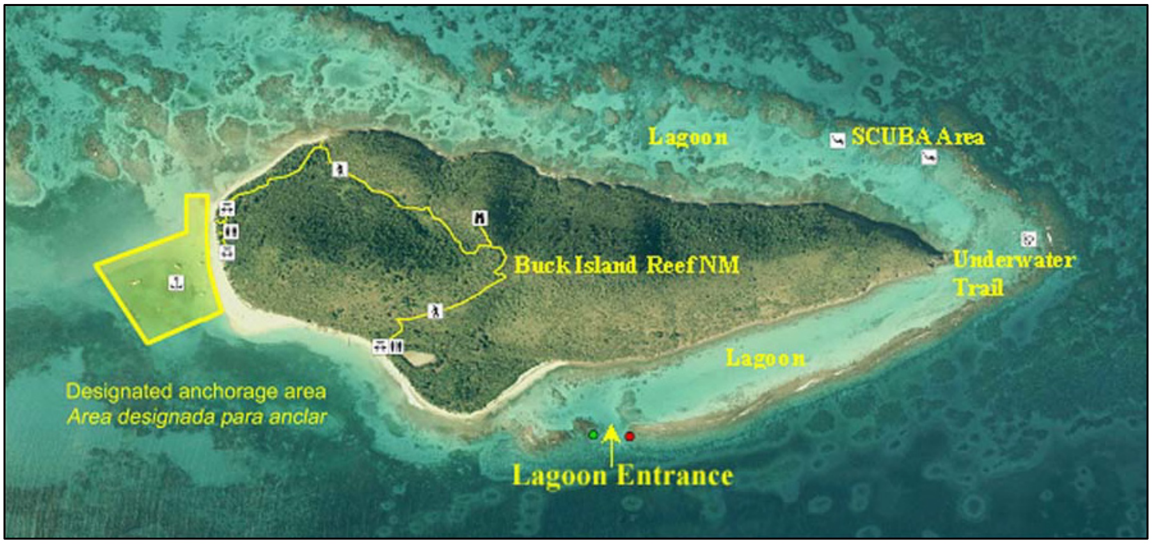

Figure 2.2.3.1. Map of BUIS depicting the designated anchorage and areas associated with different recreational activities (Adapted from KellerLynn 2011).

Debris, plastics, and microplastics

Debris resulting from human use of the park may stress some park resources, in particular in the marine environment. Marine debris consists mostly of floating manmade debris, remnants of fishing nets, abandoned or lost fishing buoys, and abandoned fish traps. Fishing lines, nets, rope, and other types of trash can wrap around animals and cause drowning, infection, or amputation. Furthermore, debris can settle on hard bottom areas and kill coral colonies (Waddell, et al. 2005). In an attempt to remove abandoned traps, the park staff has an ongoing fish trap removal at BUIS. In addition, debris found along the shoreline or on the reef is removed on a periodic and opportunistic basis (NPS 2012).

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).

Small plastic pieces less than five millimeters long, known as microplastics, are a type of debris of most emerging concern in marine environments. These are small enough to be ingested by a vast group of marine organisms. Furthermore, microplastics can adsorb and transport a variety of toxins because they have relatively large surface areas which are hydrophobic.

In a study done in 2013, Whitmire and his co-investigators studied the occurrence and distribution of microplastics in the southeastern coastal region of the United States. They analyzed sand samples collected from various coastal sites from eighteen units within NPS Southeastern Region. Microplastics were isolated using density separation and counts of microplastic particles were compared among sites. In addition, they 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 western shoreline of BUIS (see Figure 2.2.3.2). 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 102 microplastic pieces in 1 kg (2.2 lbs.) of sand. The percentage of microplastic items as pieces was 39.2% and that as fibers was 60.8%. The average length of the microplastic fibers was 2.65 cm (1.04 in). The yield of microplastics was relatively low, but 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 ocean currents or come from plastic debris being disintegrated near the site (Whitmire et al. 2016).

Figure 2.2.3.2. Location of the microplastics study site on BUIS. Coordinates of the study site: 17°47'23.14", −64°37'32.34" (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

BUIS law enforcement duties include ensuring the park's resource 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 and address any such cases on land or in the sea. Due to staffing limitations and funding constraints, law enforcement presence is not provided on a full time basis. Consequently, poaching episodes occur within the various parks in the Virgin Islands (NPS 2012). Information on poaching episodes, in particular prior to the passage of hurricanes Maria and Irma, is not available in written format. Conversations with park rangers during the scoping visits for the development of this report yielded information attesting to the that poaching episodes in BUIS compared to other parks, such as the Virgin Islands National Park (VIIS), were rare because of its offshore location. Notwithstanding, there is a need to increase park ranger presence on Buck Island, park waters, and provide consistency (NPS 2012).

Land Cover Change

Land cover maps for BUIS presented in this section were derived from the NOAA Coastal Change Analysis Program (C-CAP), nationally 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 2002, 2007, and 2012. 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 2002, 2007, 2012).

Figure 2.2.3.3 depicts BUIS land cover in 2002, 2007, and 2012. The comparison of these three maps show that there are negligible changes in these landcover classes within Monument over the period of 2002–2012. Figure 2.2.3.4. shows the extent of vegetated cover in BUIS as of 2019 (basemap obtained from ESRI), indicating that the majority of the island remains vegetated. Given that the classification system used by C-CAP exists to compare change across a regional landscape and is not specific to the Virgin Islands or Caribbean, we refer the reader to Section 4.3.1 and 4.3.2 of the report for information on vegetation classes found on BUIS as described in Moser et al. (2010). A lack of available C-CAP mapping after 2012 precludes an analysis of more recent change, which is especially needed following the 2017 hurricane season which damaged tree canopies across the island (Z. Hillis-Starr 2020, personal communication). Similarly, since the product of the BUIS vegetation mapping project became available in 2009 (Moser et al. 2010), there has been on other major program to carry out a detailed mapping of the vegetation of the park.

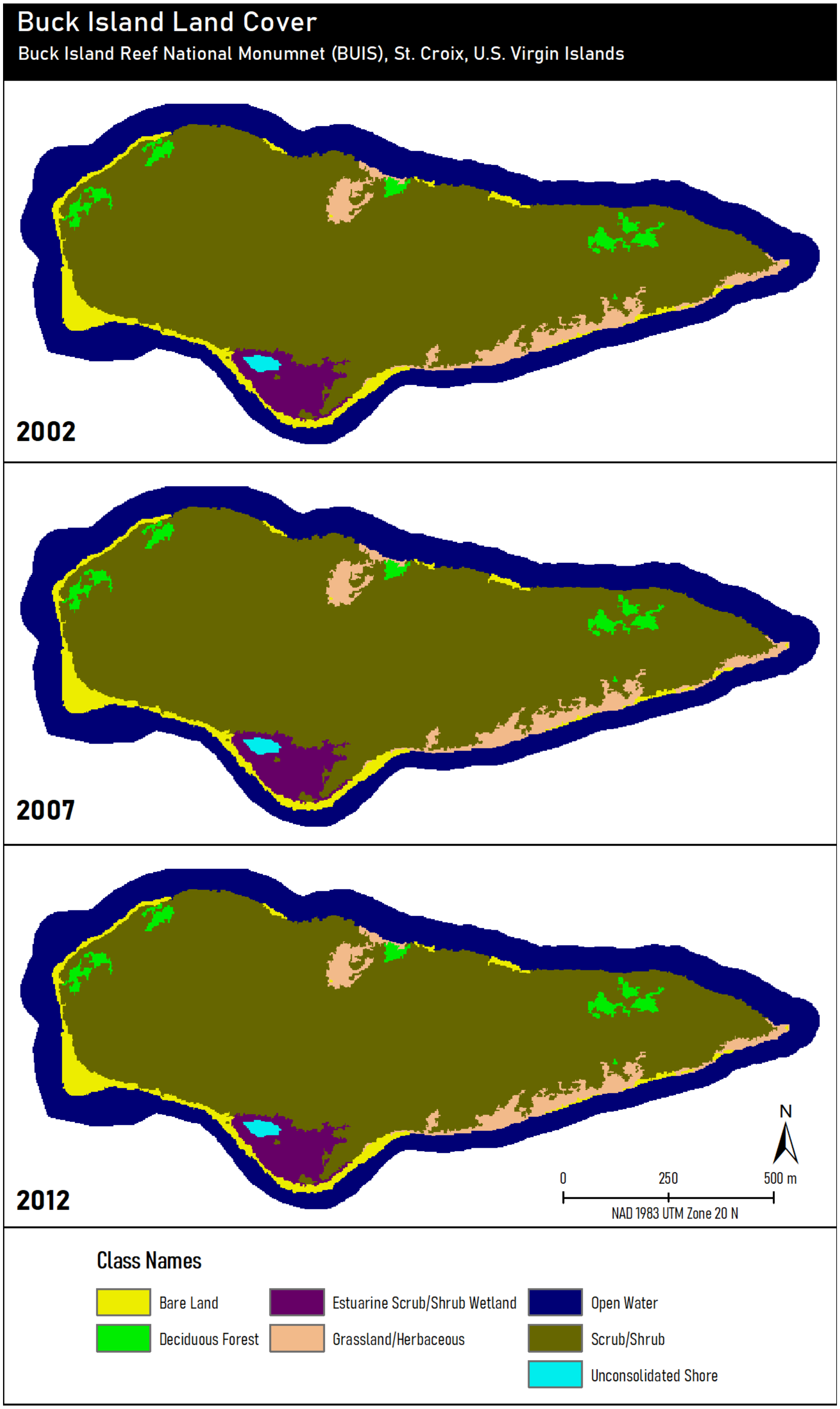

Figure 2.2.3.3. BUIS land cover in 2002 (upper panel), 2007 (middle panel), and 2012 (lower panel). Land cover data from NOSS C-CAP, 2002, 2007, 2012.

Figure 2.2.3.4. Buck Island Reef National Monument Satellite image from ESRI.

Hurricanes and Tropical Storms

Hurricanes and tropical storms are a frequent component of the Caribbean climate, bringing high winds, storm surge, and torrential rainfall with impacts to both the terrestrial and nearshore environments. However, 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). A recent study indicates that while there is a trend of increasing frequency of tropical storm activity in the Atlantic basin since the 1980s, long-term projections are not possible, because of the Atlantic Multidecadal Variability or Oscillation (AMV or AMO) (Murakami et al. 2020). In fact, including track records since the early 1900s an increase in overall number of tropical storms is not supported, but rather fewer tropical storms were registered 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). Reliable long-term projections of frequency and strength of hurricane trends is not possible at this point in time (Murakami et al. 2020).

An increase of stronger storms would increase the probability of destructive storm surges and wave activity, which in combination with heavy precipitation could further erode the beaches on Buck Island and damage coastal forest habitat. Hurricane frequency by category shows that between 1900 and 2018, 35 tropical storms came within 50 nmi of BUIS, 15 of these storms did not reach hurricane strength and 6, 7, 4, and 3, storms reached hurricane categories 1, 2, 4, and 5, respectively while they were located within 50 nmi of BUIS (Landsea and Franklin 2013) (Table 2.2.3.1, Figure 2.2.3.5).

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

	Storm Category						
Decade	**TS**	**H1**	**H2**	**H3**	**H4**	**H5**	**Total**
1900–1909	2	1	–	–	–	–	3
1910–1919	2	–	3	–	–	–	5
1920–1929	1	–	1	–	–	1	3
1930–1939	1	2	–	–	1	–	4
1940–1949	1	–	–	–	–	–	1
1950–1959	1	–	1	–	–	–	2
1960–1969	–	–	–	–	–	–	0
1970–1979	2	–	–	–	–	–	2
1980–1989	1	–	–	–	1	–	2
1990–1999	–	2	2	–	1	–	5
2000–2009	2	1	–	–	1	–	4
2010–2018	2	–	–	–	–	2	4
Total	**15**	**6**	**7**	**0**	**4**	**3**	**35**

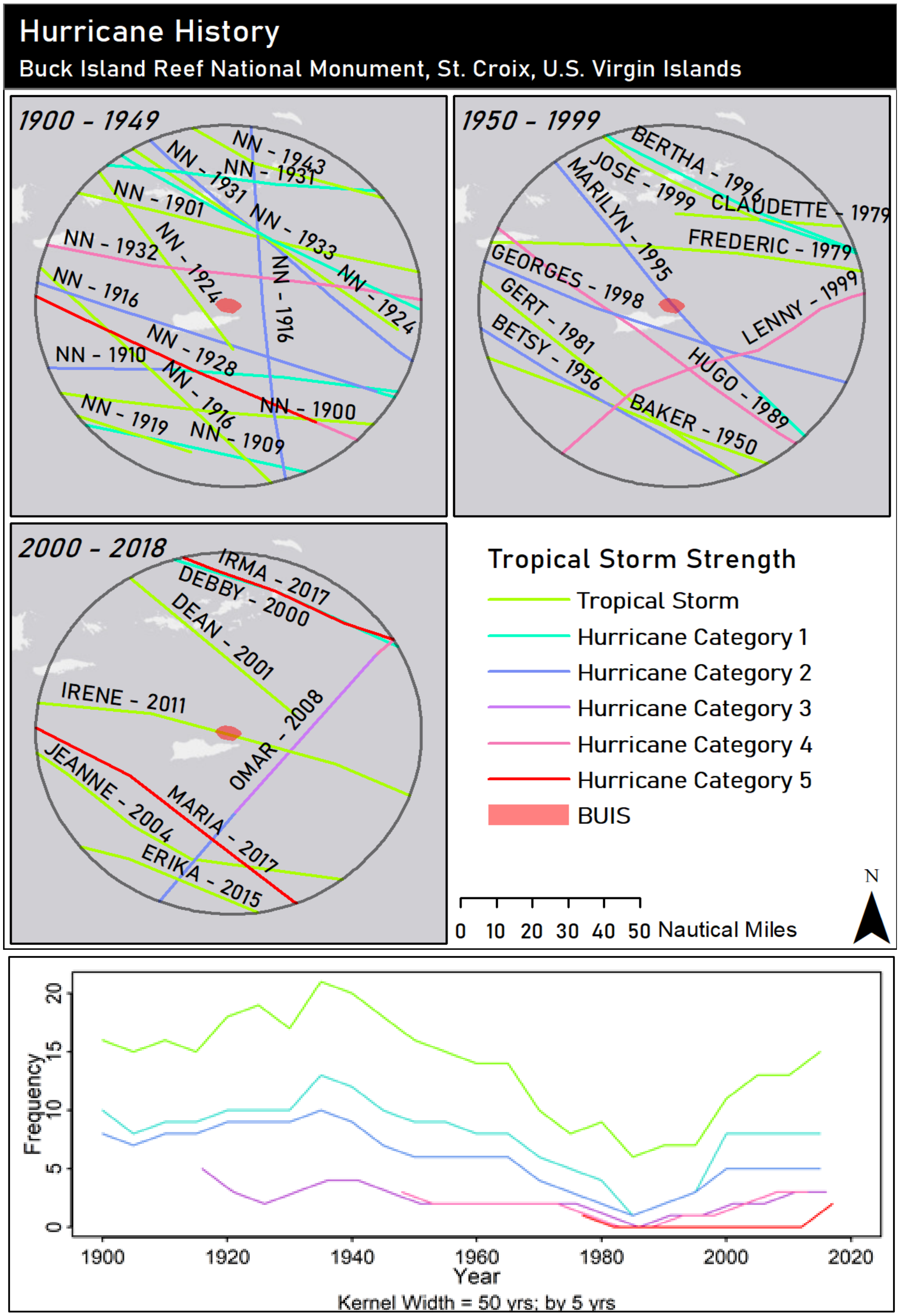

Figure 2.2.3.5. Top: Tropical storm and hurricane history within 50 nm of BUIS. Tropical storm track labels indicate storm name and year. NN = No Name was given or is known for the storm. Bottom: Tropical storm frequency by category estimated for a 50-year moving window, predicted at 5-year intervals. Graphs generated with the 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

"The mission of Buck Island Reef National Monument is to protect, preserve, manage, and interpret the monument's seascapes, scenic views, and unique natural and cultural resources unimpaired for the education, enjoyment, and inspiration of present and future generations" (NPS 2012). In 2012, the National Park Service developed the General Management Plan / Environmental Impact Statement (2012 GMP) for Buck Island Reef National Monument.

The GMP (2012) establishes the purposes of the Buck Island Reef National Monument for future planning guidance (NPS 2012 p. 1–13):

- *Preserve and protect the island and tropical marine ecosystem, including coral reefs, seagrass beds, octocoral hardbottom, sand communities, algal plains, shelf edge, and oceanic habitats;*
- *Protect threatened and endangered species and enhance their habitats and survivability;*
- *Enhance the health and diversity of fisheries resources through their protection;*
- *Protect and manage terrestrial and submerged cultural resources;*
- *Preserve this area of outstanding scientific, aesthetic, and educational importance for the benefit and enjoyment of the people now and for the future.*

The GMP also identifies several significance statements which capture the Monument's importance in terms of natural and cultural heritage. The statements also describe the distinctiveness of BUIS and by doing so, function to place the Monument in its regional, national, and international context. Establishing significance statements further assist park managers in making decisions about resources that are in line with the purpose of the Monument (from NPS 2012, p 1–14):

- *Buck Island and its surrounding coral barrier reef formations constitute one of the finest marine gardens in the Caribbean and support countless species of reef fishes, invertebrates, plants, sea birds, and marine mammals and reptiles.*
- *The Monument's tropical marine ecosystems are a continuum of coral reefs (patch, spur and groove, deep and wall), unusual "haystacks" of elkhorn coral, seagrass beds, octocoral hardbottom, sand, algal plains, shelf edge, and open ocean, and provide habitats that are essential for sustaining fragile communities of plants and animals.*
- *Several threatened and endangered species forage, breed, nest, rest, or calve in the waters within the monument, including humpback whales, pilot whales, dolphins, brown pelicans, least terns, and the hawksbill, leatherback, loggerhead, and green sea turtles. Buck Island is the only completely protected habitat that will support the globally endangered St. Croix ground lizard.*
- *The monument contains the wrecks of two eighteenth century slave ships, the Mary and General Abercrombie, other yet unidentified shipwrecks, and terrestrial archeological sites associated with Danish sovereignty in the eighteenth and nineteenth centuries.*
- *The monument offers outstanding opportunities for education and scientific research due to the diversity, complexity, and relationship of the natural resources and provides a dynamic laboratory for study and learning.*

Four management alternatives were considered in the development of the 2012 GMP. The management alternative chosen emphasizes resource protection, civic engagement and partnering programs, and requirements addressed in the Presidential Proclamations. The GMP calls for the establishment of four management zones:

- Recreation Zone
- Marine Hazard Zone
- Resource Protection Zone
- Island Discovery Zone

These management zones were established to optimize resource protection while maintaining visitor use and park experiences. The 2012 GMP utilizes zone-specific planning directives to enhance management and inter-agency coordination.

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 BUIS.

To facilitate the identification and prioritization of vital signs, SFCN divided the ecosystems occurring within the South Florida and Caribbean units of the NPS 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 the Buck Island Reef National Monument (BUIS) can be found at https://irma.nps.gov/DataStore/DownloadFile/469988.

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, BUIS staff, academic researchers with prior or ongoing research programs within the Monument, and publicly available datasets.

Table 2.3.2.1. SFCN Vital signs selected for monitoring in BUIS (Patterson et al. 2008)[a] (x = selected).

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 (Ecosystem and Pattern Processes)	Fire Return Interval	–	–	–	x
	Vegetation Communities Extent & Distribution	x	–	–	–
	Benthic Communities Extent & Distribution	x	–	–	–
	Land Use Change	–	–	–	x

[a] Type 1 represents Vital Signs for which the network will develop protocols and implement monitoring; Type 2 represents Vital Signs that are monitored by BUIS, 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 (Ania 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 BUIS NPS staff

The Buck Island Reef National Monument (BUIS) was the first of the three NPS units visited (Appendix D). The FIU team traveled to St. Croix on February 5, 2017. On Monday, Feb. 6, a joint team of NPS staff and FIU staff carried out the Buck Island Reef National Monument (BUIS) site visit. During the site visits, the team focused on identifying the major natural resources in the parks and the issues that were impacting these, both positively and negatively. In relation to the Monument, the team observed the effects of sedimentation and erosion processes while surveying the reefs. The impact of Hurricane Hugo on the area was discussed in length. A brief set of notes of the visit to the BUIS site is provided in the Phase I project Report (FIU 2017).

During these meetings, the participants accomplished series of tasks, namely (FIU 2017):

- Revisit the most important issues examined during the site visits. Follow-up and/or clarify matters that required further discussion.
- Discuss the methodology to be used in the assessment and revise dates set for the implementation of the phases of the project.
- Confer with a preliminary scope of the content of the individual NRCAs for the units.
- Jointly concur to a preliminary list of focal resources 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.
- Agree on the responsibility of the different actors, in addition to the FIU team (NPS on-site staff, NPS in mainland staff, South Florida/Caribbean Network, others) and their expected information and data input and datelines.
- Complete the draft scoping tables reflecting the results of the deliberations of the participants.
- 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 BUIS 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 BUIS, 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 Monument. Rather, a selection of components was made which included resources and processes that were of greatest concern or highest management priority. 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 BUIS 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 except for queen conch and lobster. Authors responsible for each section are listed next to their respective focal resource.

Table 3.2.1.1. BUIS NRCA framework table.

Framework Category	Focal Resource	Assessment Level	Section Author	Indicators and Measures
Supporting environment	Shoreline Dynamics	Full assessment	D. Gann	• Shoreline change (2 measures)
	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)
Biological integrity – terrestrial plants	Tropical dry forest	Full assessment	D. Ogurcak	• Vegetation community extent (2 measures)
	Coastal forest	Full assessment	D. Ogurcak	• Vegetation community extent (2 measures)
Biological integrity – Marine Plants	Seagrass	Full assessment	A. Gulick, E. Whitman	• Seagrass community extent (1 measure)
Biological integrity – terrestrial vertebrates	Reptiles (St. Croix ground lizard)	Full assessment	D. Ogurcak	• Population status (3 measures)
Biological integrity – marine vertebrates and invertebrates	Corals	Full assessment	T. Smith	• Stony coral cover (1 measure) • Stony coral health (1 measure) • Seawater temperature (1 measure)
	Queen conch	Limited assessment	R. Ennis	• Community extent (1 measure)
	Lobster	Limited assessment	R. Ennis	• Community extent (1 measure)
	Reef fish	Full assessment	A. Duran	• Community and population status (3 measures)
	Sea turtles – Hawksbill	Full assessment	A. Gulick	• Population status (7 measures)
	Sea turtles – Green	Full assessment	A. Gulick	• Population status (7 measures)

3.2.2. Reporting Areas

BUIS includes areas of both submerged and dry lands. The reporting area was treated as one unit and depending on the resource being analyzed encompassed the entire acreage within BUIS'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 was not collected for this study. Existing data was 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 BUIS. 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.

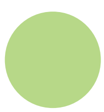
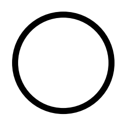
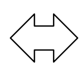
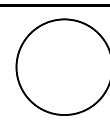
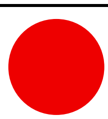
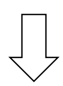
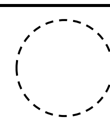
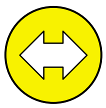
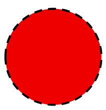
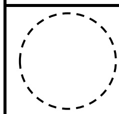
Condition Status		**Trend in Condition**		**Confidence in Assessment**	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		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 was 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 with 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, as well as 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 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. Coastal Dynamics

4.1.1. Shoreline Dynamics

This section reviews the condition of the shoreline and sandy beach extent of Buck Island. The condition assessment is made on the basis of historic aerial photography and satellite data. The data sets that were considered are panchromatic aerial photography from 1954 (U.S. Geological Survey [USGS]), 1977 (National Centers for Coastal Ocean Science 2020), and true color (RGB) aerial photography of 1999 (National Centers for Coastal Ocean Science 2020), 2004 (U.S. Department of Agriculture [USDA] 2004), 2004 and 2007 (USGS 2009), 2007 (U.S. Army Corps of Engineers [USACOE] 2008), and 2011–2012 (USACOE 2012). Digital Globe's World View 1 panchromatic data product was used for 2015 and pan-sharpened panchromatic and multi-spectral 8-band satellite data were used for the 2017 and 2018 assessment periods. The condition of the shoreline and its sandy beaches was evaluated using metrics that measure changes in beach surface area, and the migration of the shoreline and vegetation edge that is bordering the beach. Temporal trends in condition metrics for island size and sandy beach area, as well as temporal variability of shoreline sections were evaluated in a spatially explicit fashion.

Description

The temporal variability of the sandy beach shoreline is a function of wind, wave and sea current pattern and was evaluated on the basis of four years of shoreline survey data (2017–2020) provided by the National Park Service (NPS). Shorelines were surveyed by NPS staff using a Trimble Geo 7x GPS unit with TerraSync, and data were post-processed using the GPS Pathfinder Office GNSS post-processing tool. Shoreline seasonality could not be evaluated due to lack of consistent data collection throughout the four-year period, leading to unbalanced samples across seasons of the evaluated years. The record was too short to establish long-term trends.

Buck Island is situated towards the southern edge of the Buck Island Reef National Monument (Figure 2.1.2.1 – general reference map). Buck Island has steep topographic gradients along the northern coast (> 30%) and gentle slopes along the southern and western shores. The shoreline of Buck Island can be divided into three types. The largest portion of shoreline consists of 2.2 km of rocky shore (Table 4.1.1.1) composed of consolidated carbonate sand that originated from deep-marine sediment composed of the Upper Cretaceous Caledonia Formation (Nagle and Hubbard 1989). The rocky coast with steep drop-offs along the northern section and less steep gradients along the eastern shore, is interspersed with about 252 m of small sedimentary rock and coral sand beaches (Table 4.1.1.1). The coastal shoreline sections that are predominantly affected by seasonal wind and wave dynamics are the 1.6 km of sand beaches along the western and southern shoreline (Table 4.1.1.1). This section represents about 39 % of the total shoreline length as of February 2018. The beaches are predominantly composed of recent surficial deposits (also referred to as alluvium) which are made up of fragments of coral and mollusks, beach rock (sand and gravel cemented with calcium carbonate), and stream deposits (Whetten 1966) (Photograph of beach sand at Turtle Beach Figure 2.2.2.4.

Table 4.1.1.1. Coastal shoreline length by shoreline type as identified in aerial photography of February 5, 2018 (Figure 4.1.1.3; see section Data and Methods).

Type	Length (m)	Length (%)
Beach – Sand	1,605	39.1
Beach – Gravel	252	6.1
Cliff	2,243	54.7

The sandy beaches are a high-priority resource to park management, because of competing interests of several migratory and resident species that use the beaches for nesting and breeding and the recreational use of the beaches by human visitors. Of major concern are primarily the long-lasting erosion effects caused by tropical storms (Section 2.2.3) and, to some degree, the seasonal erosion patterns that shape beach extent, shape, and topographic profile of the beaches throughout the year. Erosion that leads to permanent loss of overall island surface area reduces coastal forests, affects nesting habitat of several species, and constrains visitor use areas. Changes in sand beach surface area are mainly driven by storm events, however seasonal effects of local redistribution patterns of sediment are of interest for the seasonal uses of the open beach area by least terns and sea turtles.

Seasonal redistribution patterns of sediments have been attributed to wind, waves, currents, and to some degree sea level rise (KellerLynn 2011). Sediments are redistributed mainly between the southwestern and western beaches on Buck Island. Between October and June, an onshore sedimentation transport can be observed, which possibly originates in the nearshore area west and northwest of the island (Figure 4.1.1.1, blue arrows). From the summer to the beginning of the fall, an off-beach transport leads to a net loss of sediments on the same beaches (Hubbard 1980) (Figure 4.1.1.1, orange arrows). The southwest portion of the beach, where the pier is located (Figure 2.1.2.1 – reference map), is a rocky shore during the month of September, gradually shift to a sand beach during the winter, and then erodes once again as summer approaches (Gladfelter et al. 1977). West Beach builds and extends southwestward developing a large sand spit (Figure 4.1.1.2b). The seasonal variability of beach areal extent and steepness of the western and southern shoreline was supported by beach profile surveys that were conducted in 1976 and 1977 (Gladfelter et al. 1977). The surveys indicated that, during the winter months, this section becomes shorter and steeper, and during spring it broadens in shape. More recently, the beach surveys conducted with GPS technology confirmed the uneven redistribution of sediments along the shoreline of West Beach. Fifteen GPS shoreline surveys conducted between September 2017 and November 2020 (Table 4.1.1.2) indicate that the redistribution of sediments along the shoreline of West Beach is highly variable. A kernel density estimate (Silverman 1986) of the 15 survey lines acquired between 2017 and 2020, using a search radius of 10 m (number of lines within a 10 m search radius), shows that over the 4-year period, the variability of the shoreline was highest along the southwestern tip of West Beach (Figure 4.1.1.1). The seasonal erosion and deposition patterns along the shoreline could not be assessed quantitatively because of inconsistency of survey dates across years. Twelve of the 15 surveys were conducted between July and November, and only three between December and June (Table 4.1.1.3).

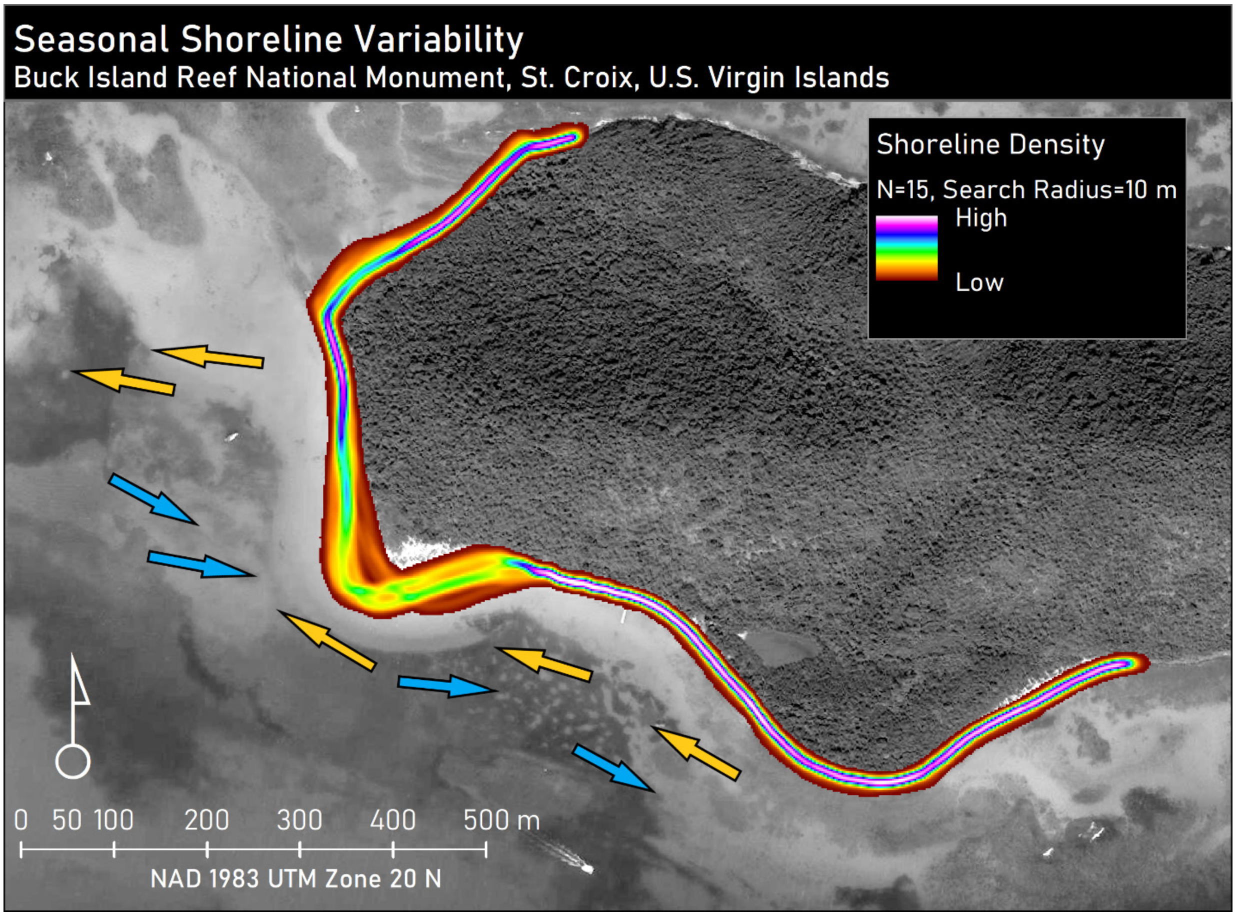


Figure 4.1.1.1. Sediment transport at Buck Island Reef National Monument. Seasonal wind and wave patterns direct sediment from onshore to offshore at Buck Island, as well as between the western and southwestern beaches, resulting in a high variability of the shoreline. Highest variabilities along the shoreline are observed at the southern tip of West Beach. Shoreline variability was generated using a kernel density estimator for 15 shoreline surveys within a search radius of 10 m. Arrows adopted from Hubbard (1980), indicating wind and sediment transport pattern for fall-spring (blue) and summer and early fall (yellow). Data source: GPS Shoreline surveys, NPS, 2021, background image is the February 5, 2018 mosaic of pan-chromatic WorldView 2 data copyright (DigitalGlobe, Inc.).

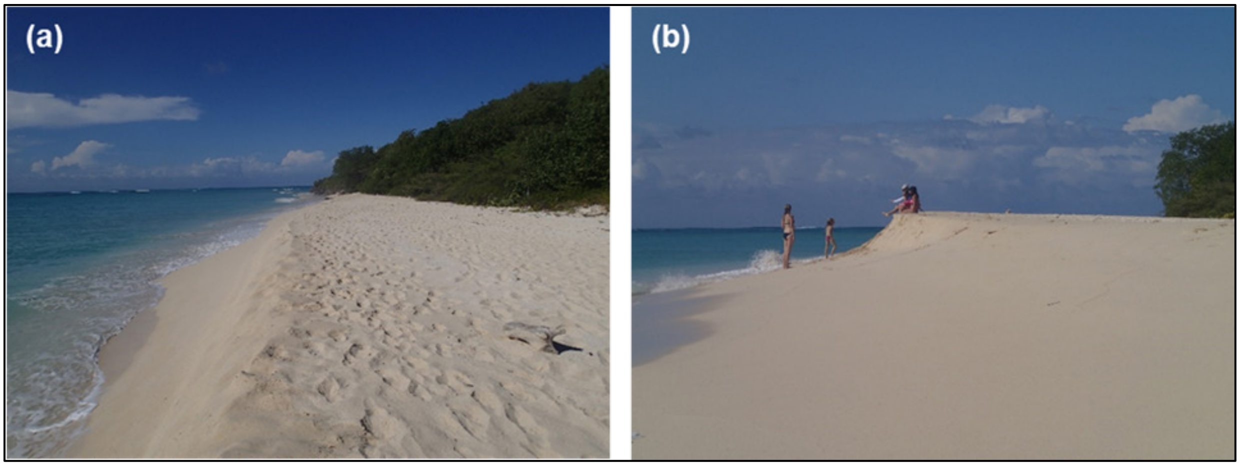


Figure 4.1.1.2. Wind and ocean currents drive the seasonal sedimentation patterns of West Beach (Figure 4.1.1.1) shown in these photos. Onshore accumulation of sediments on November 3, 2012 (a) along the northwestern segment and (b) at the southern section of West Beach (Photo credits: National Park Service, Zandy Hillis-Starr).

Table 4.1.1.2. Shoreline survey dates between September 2017 and November 2020. Survey data were used to visualize the shoreline density (Figure 4.1.1.1) as an indicator for temporal variability of shoreline migration. Data source: (GPS Shoreline surveys, provided by Z. Hillis-Starr, NPS, 2021).

Year	Month	Date
2017	9	1-Sep-2017
2017	9	12-Sep-2017
2017	10	2-Oct-2017
2018	3	30-Mar-2018
2018	5	31-May-2018
2018	8	9-Aug-2018
2018	9	17-Sep-2018
2019	7	2-Jul-2019
2019	8	27-Aug-2019
2020	3	2-Mar-2020
2020	7	2-Jul-2020
2020	7	31-Jul-2020
2020	9	16-Sep-2020
2020	10	13-Oct-2020
2020	11	17-Nov-2020

Table 4.1.1.3. Frequency of GPS shoreline surveys between 2017 and 2020 by month across the four survey years. Data source: (GPS Shoreline surveys, provided by Z. Hllis-Starr, NPS, 2021).

Month	Count	Years
1	0	–
2	0	–
3	2	2018, 2020
4	0	–
5	1	2018
6	0	–
7	3	2019, 2020 (2)
8	2	2018, 2019
9	4	2017 (2), 2018, 2020
10	2	2017, 2020
11	1	2020
12	0	–

The wide-open sand beach and highly variable sand spit area of West Beach provides large open areas for visitor's recreational use on the island. Recreational activities along the seashore attract boaters and beachgoers year-round (Section 2.1.3) which can have disruptive effects on turtle and least tern nesting behavior and breeding success. Along this section of the coastline, sea turtles nest year-round and least terns (*Sternula antillarum antillarum*) nest between April and June/July (Z. Hillis-Starr and C. Pollock 2020, personal communications). The sand beaches provide critical nesting habitat for four species of sea turtle, specifically the hawksbill (*Eretmochelys imbricata*), green (*Chelonia mydas*), loggerhead (*Caretta caretta*), and leatherback (*Dermochelys coriacea*) sea turtles (Pollock et al. 2009, Hart et al. 2013) (Section 4.7.2). The seasonal changes can make turtle access to the beach more difficult and reduce nesting habitat along some stretches of the island, while also enhancing nesting habitat for other sections by flattening and broadening the surface area of beaches. Early leatherback sea turtles and least terns arrive in spring when West Beach is usually at its largest extent. The seasonal shifts of sediments along the southern section of West Beach affects the least terns because they tend to nest and breed along this most variable stretch of the beach (Figure 4.1.1.1). How the seasonal and inter-annual shoreline variability affects nesting behavior and breeding success of least terns and sea turtles has not been investigated.

Data and Methods

The metrics that were assessed to evaluate the condition and long-term trends of shoreline changes of the sand beach habitat are total surface area of Buck Island and the extent of beach area, which is a function of seasonal shoreline variability and a more permanent landward migration pattern. For the long-term trends, the timeframe of evaluation encompasses 1954 to 2018. The reference conditions for the Monument's shoreline dynamics were the shoreline and vegetation boundary digitized from a 1954 panchromatic aerial photograph (USGS 1954), the earliest available aerial photography of BUIS. Current condition was established from a satellite dataset acquired on February 5, 2018

(DigitalGlobe, Inc. 2018). The long-term trends of beach surface area and beach migration were assessed with 10 additional data points between the 1954 reference and the 2018 current condition (Table 4.1.1.4). For consistency of high-waterline interpretation and digitization we digitized beach and interior land area polygons from geometrically corrected aerial photography and panchromatic or multi-spectral pan-sharpened WorldView data (Table 4.1.1.4). We geo-referenced each aerial photograph and WV2 satellite dataset in ArcGIS using pseudo-invariant features that were recognizable in all aerial photographs and satellite images. The baseline image for geo-referencing was the highest resolution aerial photograph of 2011 (USACOE 2012) (Figure 4.1.1.3). The multi-spectral and panchromatic WV data were geometrically corrected in reference to the 2011 image with a less than 5-m root mean square error (RMSE) across all images.

The digitization scale was 1:500 with a minimum distance of vertices of ~10 m. Sources of uncertainty of the digitization process can be attributed to two major components. Since seasonal and inter-annual sediment transport (Figure 4.1.1.1) majorly modifies the shoreline configuration, aerial photography and satellite data acquisition at a specific day of year only capture snapshots of the described processes and, depending on time of year, the process is captured at different stages of the sediment transport process. In addition to the day of the year and shifts in seasonal weather patterns, it is crucial to consider the time of day, because each aerial photograph and satellite image was acquired at different tidal stages, which complicates the interpretation of the high-water mark in every image. Seasonal variability of shoreline morphology affects the estimate of the projected surface area of the beach, and the time of day adds uncertainty in the interpretation of the high-water mark. Both aspects contribute to uncertainty in the change-detection analysis, and since each image sets the baseline of change for the next image derived change, all these factors need to be considered when interpreting the changes in reference to the baseline and for every time-step in the analysis. To minimize digitization error when interpreting the high-water line, the tide schedules for Christiansted were used to interpolate water levels for acquisition date and time for the WV2 data. For the aerial photographs, time of day was unknown, but since the spatial resolution of the imagery is higher, the interpretation of high-water marks was easier. In addition, we consulted a report by Gray and Messman (2012) as reference for digitization of some shoreline segments. For interpretation of shoreline morphology and areal fluctuations of island and beach extents in relation to tropical storm activity in the vicinity of Buck Island, storm tracks with intensity estimates were acquired from the National Hurricane Center (Section 2.2.3.4) (Landsea and Franklin 2013).

Reference Conditions/Values

Reference conditions of island and beach surface area were determined from the digitized shoreline and vegetation boundary from the aerial photograph of 1954, which is the reference year for this assessment. The size of the island was 74 ha (183 acres), with the beach surface occupying 3.3 ha (8 acres) (Figure 4.1.1.3, Table 4.1.1.4).

Table 4.1.1.4. Changes in beach, interior and total island surface area in hectares (ha) between 1954 and 2018. Area change in each row is calculated by subtracting area of prior row from that of the current row. Cumulative (Cum.) change is calculated relative to the reference condition of 1954 (first row). Image types: AP = aerial photography, WV = WorldView, pan = panchromatic, RGB = Red Green Blue.

Year	Image Type	Acquisition Date	Hurricane Name	Beach Area (ha)	Beach Area Change (ha)	Beach Cum. Change (ha)	Interior Area (ha)	Interior Area Change (ha)	Interior Cum. Change (ha)	Island Area (ha)	Island Area Change (ha)	Island Cum. Change (ha)
1954	pan AP	1954	Pre-Betsy	3.25	–	–	70.75	–	–	74.00	–	–
1977	pan AP	12/7/1977	Post-Betsy / Pre-Hugo	2.34	−0.91	−0.91	69.94	−0.81	−0.81	72.28	−1.72	−1.72
1999	RGB AP	2/7/1999	Post-Hugo	3.81	1.47	0.56	67.39	−2.55	−3.36	71.20	−1.08	−2.80
2004	RGB AP	9/21/2004	–	2.94	−0.86	−0.31	68.27	0.88	−2.48	71.22	0.02	−2.78
2007	RGB AP – Mosaic	2006–2007	–	2.31	−0.63	−0.94	67.84	−0.44	−2.91	70.15	−1.07	−3.85
2011	RGB AP – Mosaic	2011–2012	–	2.84	0.53	−0.41	67.62	−0.21	−3.13	70.47	0.32	−3.53
2015	pan-sharpened WV2	2/5/2015	–	2.15	−0.70	−1.10	67.73	0.11	−3.02	69.88	−0.59	−4.12
2017	pan-sharpened WV2	8/31/2017	Pre-Irma	2.00	−0.15	−1.25	67.30	−0.43	−3.45	69.30	−0.57	−4.69
2017	pan WV1	9/18/2017	Post-Irma / Pre-Maria	2.03	0.03	−1.22	67.74	0.43	−3.01	69.77	0.46	−4.23
2017	pan-sharpened WV2	9/24/2017	Post-Maria	2.48	0.45	−0.77	67.35	−0.39	−3.40	69.82	0.05	−4.18
2017	pan-sharpened WV2	11/26/2017	–	2.64	0.16	−0.61	67.34	0.00	−3.41	69.98	0.16	−4.02
2018	pan-sharpened WV2	2/5/2018	–	2.37	−0.26	−0.88	67.47	0.12	−3.28	69.84	−0.14	−4.16

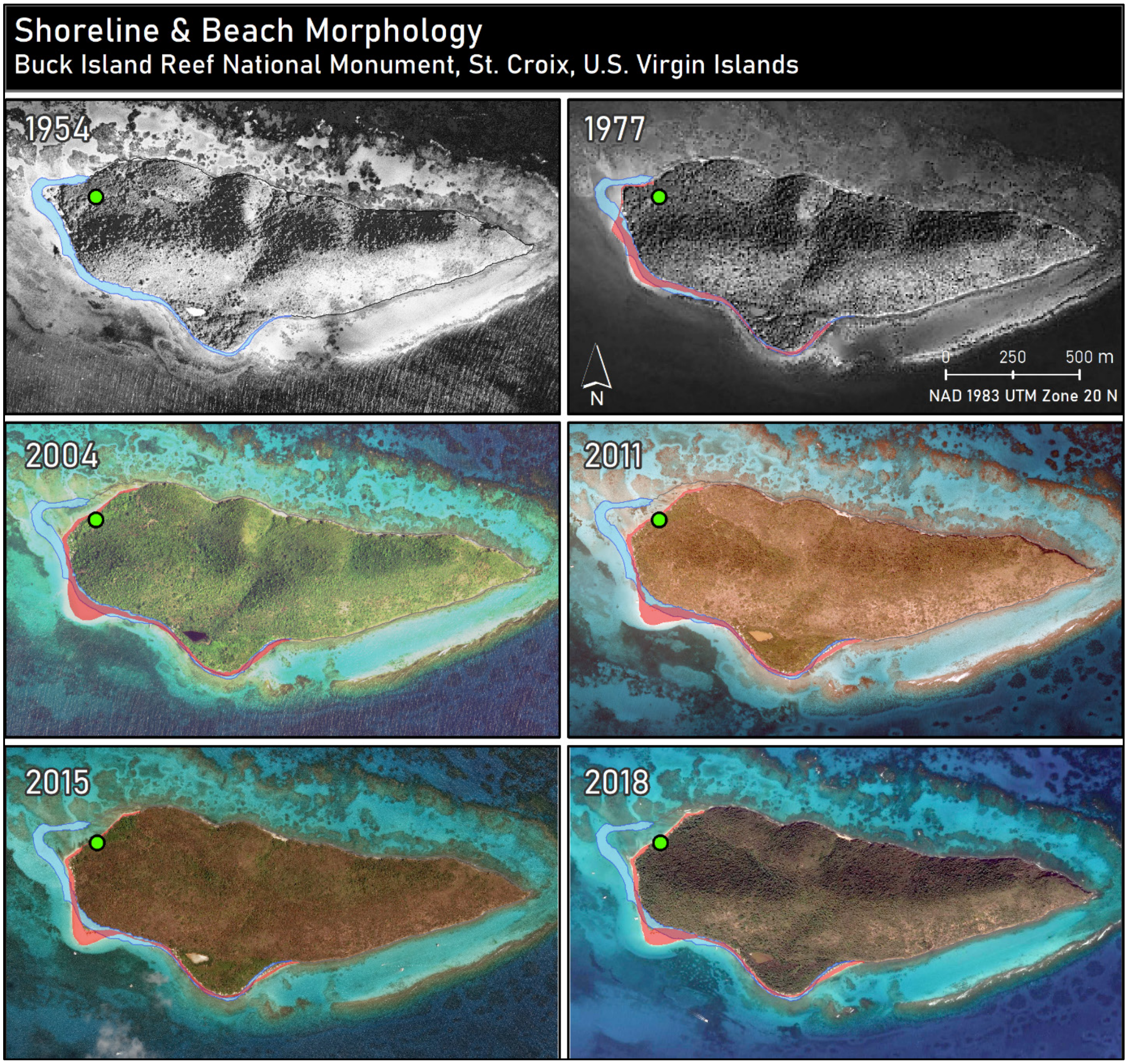


Figure 4.1.1.3. Shoreline morphology and beach surface extent. Baseline condition of 1954 in light blue in every map and each year's beach location in light red; permanent vegetation plot of the Manchineel Forest represented as green point. Images: 1954 panchromatic aerial photograph (USGS), 1977 panchromatic aerial photograph (National Centers for Coastal Ocean Science), 2004 RGB aerial photograph (USDA), 2011 RGB aerial photograph (US Army Corps of Engineers), 2015 and 2018 (mosaic of pan-sharpened true color WorldView 2 imagery copyright DigitalGlobe, Inc.).

Condition and Trend

The current extent of Buck Island as estimated from WV 2 data of February 5, 2018 is 69.8 ha (172.6 acres) with a sand beach surface area of 2.4 ha (5.9 acres), which constitutes a net loss of 4.2 ha (10.3 acres) of the island, a 5.7% reduction. During the same 64-year period, the beach surface area was reduced by 0.9 ha (2.2 acres), constituting a 28% net loss of the beach surface area (Figure 4.1.1.3, Table 4.1.1.4). The four major storm events during the assessment period were hurricane category 2

Betsy in 1956, category 4 hurricane Hugo in 1989, and category 5 Hurricanes Irma and Maria in 2017 (Figure 2.2.3.5).

The largest island area loss occurred within the 17-year assessment period from 1954 to 1977. By 1977, 21 years after hurricane Betsy in 1956, the land surface area had been reduced by 1.7 ha (4.3 acres) predominantly due to the loss of a large section of former Turtle Beach (currently named West Beach) in the northwestern tip of the island (Figure 4.1.1.3 Frame 1977, Table 4.1.1.4). Hurricane Betsy could have been at least partially responsible for this loss. Between 1977 and 1999, Hurricane Hugo impacted the island in 1989, and could very well be responsible for the loss of an additional island surface area of 2.8 ha (6.9 acres), removing the entire northwest tip of the island (Figure 4.1.1.3: Frames 1977 & 2004). During the 23-year period between 1954 and 1977, more than 12 years before Hugo made landfall on St. Croix, the beach area extent had been reduced by 0.9 ha (2.2 acres). In contrast, ten years after Hugo, in 1999, the beach area covered a 1.47 ha (3.63 acres) larger area than in 1977, a 0.6 ha (1.5 acres) net gain in reference to 1954. The same surface area was lost again by the next evaluation date in 2004 (Figure 4.1.1.3: Frames 1977, 2004; Table 4.1.1.4). Since 1999, the beach surface area fluctuated between 2.9 ha (7.3 acres) and 2.0 ha (5.0 acres) in 2017 with the greatest loss of 0.7 ha (1.72 acres) between 2011 and 2015 (Table 4.1.1.4). There is no observable net loss of beach area since 1977 (Table 4.1.1.4).

Fluctuations of beach surface area could be the result of acquisition dates of the aerial photography capturing seasonal or inter-annual variability of the shoreline (Figure 4.1.1.1) that are driven by wind and wave patterns. The major reduction of island size, most likely caused by Betsy and Hugo, is predominantly a loss of coastal forest habitat along the northwestern shoreline and a landward migration of the coastal vegetation line. The current edge of the Manchineel forest is over 100 m further inland than it was in 1954 (Figures 4.1.1.3 and 4.1.1.4 green marker). The effect of the closer shoreline on the coastal vegetation is that many trees of the Manchineel forest are more frequently inundated (Section 4.3.2 Coastal Forest).

Figure 4.1.1.4. Oblique aerial photograph (Fritz Henle 1960s) with view onto West Beach (orientation southwest to northeast). The green point marks the location of the Manchineel forest, the main reference point for change analysis.

Threats and Stressors

Oceanographic and meteorological variables of interest to the management of the Buck Island shoreline are frequency and intensity of tropical storm events, ocean currents, wind patterns, precipitation, waves and tides and their modified patters under different global climate change and sea-level rise scenarios.

This analysis supports the hypothesis that tropical storms are major contributors to continued erosion of the Buck Island shoreline and a landward migration of the beaches, consuming coastal forest in the process. This erosion results in permanent losses to the island surface area. Hurricane frequency by category shows that between 1900 and 2018, 35 tropical storms came within 50 nmi of Buck Island, 15 storms did not reach hurricane strength and 6, 7, 4, and 3, storms reached hurricane categories 1, 2, 4, and 5, respectively while they were located within 50 nmi of BUIS (Landsea and Franklin 2013) (Table 2.2.3.1, Figure 2.2.3.5). It has been noted by park staff witnessing decades of tropical storms and hurricanes that storm track determines the impact to the Buck Island shoreline; some tropical storms can pass 150 miles to the north or south or further and still have a significant impact on coastal conditions at Buck Island. Beach conditions especially at West Beach can change from one day to the next with either significant sand deposition or loss within 24 hours (Z. Hillis-Starr 2020, personal communication). However, although the most recent category 5 hurricanes to impact BUIS, Hurricanes Maria and Irma, came within 43 and 25 nm of Buck Island respectively, no noticeable erosion was observed from the satellite data (comparing February 8, 2018 to February 2, 2015) (Table 4.1.1.4), despite sustained wind speeds of 155 and 150 miles/hour.

Effects of tropical storm events and seasonal sediment redistribution pattern are exacerbated by rising sea levels and local effects of climate change. Warming global atmosphere, and increasingly prolonged warming phases of sea-surface waters, suggest that 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 an 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). While there is a trend of increasing frequency of tropical storm activity in the Atlantic basin since the 1980s, long-term projections are not possible, because of the Atlantic Multidecadal Variability or Oscillation (AMV or AMO) (Murakami et al. 2020). The potential of fewer but stronger storms increases the probability of destructive storm surges and wave activity, which in combination with heavy precipitation could further erode the beaches on Buck Island and permanently moving the shoreline further landward. Storm surges will also more frequently impact the human waste facilities that are close to the shore, washing human waste products into the nearby reefs and seagrass beds.

Ocean warming and sea level rise has been identified as a major source of concern in the resource management of marine and terrestrial habitats as well as other resources at Buck Island Reef National Monument (KellerLynn 2011). Ocean temperature has increased by about 1.1 degrees Celcius since 1901 and sea levels have risen by 2.5 cm per decade (Environmental Protection Agency 2016). Regional predictions of sea-level rise by Hall et al. (2016) range from 64 cm (2.1ft) in 2050 to 201 cm (6.6 ft) in 2100, but no local sea-level models and predictions for BUIS are known to exist.

As a result of sea-level rise, storm surges will push ocean water ever further into the coastal forest areas, leading to longer inundation periods and submersion of coastal vegetation. Long-term effects could include shifting sandy beaches even further landward and destroying valuable coastal forest habitat on the gentler slopes in the western and southern parts of the island. Constant reduction of coastal forest habitat also affects other coastal forest habitat species like the St. Croix Ground Lizard (*Pholidoscelis polops*) (See Section 4.5.1). Once the landward migration of beaches reaches steeper slopes, the long-term effect of erosion will lead to major reductions of beach surface areas, negatively affecting the vital nesting habitats of sea turtles, least terns, brown pelicans and other visiting coastal bird species. The landward migration of beaches and eventual loss of sandy beach habitat will also affect the primary recreational use of beaches by day visitors. Support facilities including picnic areas, grills, comfort stations and vault toilets close to the beaches (Figure 2.2.3.1) will be lost to the rising sea, unless they are relocated further inland and on higher elevation.

Projections of climate-change induced precipitation patterns predict an increase in the number of heavy rain events (Karl et al. 2009), which would lead to increased erosion risk and sediment runoff from beaches. The island presents no permanent streams or rivers, but the intense rain events can result in intermittent streams that can cause significant erosion given the steep slopes of the island and the storm water runoff, washing out beaches and significantly affecting the nutrient and sedimentation processes of the marine ecosystems. This increase in mass movement of sediments could affect coral and seagrass beds. Reefs are more protected to the east of Buck Island, but they are open in the west and the increased sediment transport leads to an increase in the amount of suspended sediment in the water column, diminishing photosynthetic activity of aquatic vegetation, and increasing sediment deposition and burying of coral reef and seagrass beds (Pinet 1992, Hall 2005).

Data Needs and Gaps

Some fluctuations in island and beach surface estimates can be attributed to several factors. Data quality of the early aerial photography, human error in the geometric referencing and correction of the imagery, and the subjective process of digitization (line tracing) are the main sources of error and uncertainty. Secondly, acquisition date and time-of-day of imagery are crucial metadata. The date is important since the effects of seasonal sediment transport between different shoreline sections of the island (see seasonal dynamics of beach morphology in Section 2.2.2) cannot be accounted for if the aerial photographs were acquired at different times of the year, or if magnitude and pattern of sediment transport does not occur systematically across years. The time-of-day when the imagery was acquired is important to best interpret the high-water mark in reference to the tidal water levels as seen in the photograph.

A monitoring program that captures the seasonal transport and the inter-annual variability of the transport patterns can be useful in decomposing long-term sediment and areal extent of beach loss from patterns of seasonal variability. Several methods could be implemented individually or in combination.

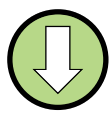
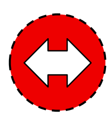
1. Frequently acquired beach profiles throughout the year can provide rough estimates of intra- and inter-annual beach morphology patterns. Continuation of monthly GPS shoreline surveys as they are currently conducted since July 2020 will augment the existing record that started in 2017. However, a crucial aspect is the even distribution of surveys across the year to observe long-term shifts in seasonal patterns.
2. Using high-resolution satellite data in combination with digital image processing techniques that include automated classification algorithms can be employed to detect classes of a very simple classification scheme that includes only sand, water and vegetation. This approach would reduce the human introduced error in line digitization and is very efficient and economical to implement. Tidal difference between image acquisitions, however, cannot be eliminated with this approach since the acquisition schedule of satellites is fixed.
3. Airborne photography with the use of unmanned aerial systems (UAS technology) could eliminate the tidal-phase source of variability in the data and, in addition, would provide much higher-resolution data, which increases the precision of areal cover and change estimates, but this method is more costly due to maintenance of UAS, expensive photogrammetric software, data gathering and data processing time.
4. Terrestrial LiDAR scans in strategic scan locations could provide not only 2-D estimates of surface extent change, but also volumetric estimates of sediment transport between scan dates. This method like the UAS solution would require purchase and maintenance of equipment and proprietary software.

5. To establish vulnerability and risk for the shoreline of Buck Island concerning sea-level rise a vulnerability and risk assessment needs to be conducted. The aspects of the assessment should cover geologic and geomorphological factors including slope of the terrain. This assessment should also include the exposure of human-build structures, especially toilets and other solid waste deposition facilities. Physical processes that should be considered in the risk assessment are relative sea level, wave height, tidal range, and coastal erosion rate in the context of worst-case scenarios of category 5 hurricanes and the compounding effects of sea-level rise, adding increased erosion risks of storm surge, tidal extremes and wave activity.

Overall Condition

The condition of shoreline dynamics in BUIS was assessed using two indicators: percent change in island area and percent change in beach area (Table 4.1.1.5). Overall, the change in island area constituted a minor loss over the time period, leading us to assess the component as being in good condition with a declining trend. However, the change in beach location over the time period was assessed as being of significant concern due to continued loss of low-elevation island surface area with a landward-migrating shoreline. This process could ultimately result in the loss of sandy beach as the coastline gets increasingly steep.

Table 4.1.1.5. Graphical summary of status and trends for shoreline dynamics within the framework category Coastal Dynamics.

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Shoreline Dynamics	% island area change		Reduction of 5.7% or 4.16 ha (10.3 acres) of the island area since 1954 (reference condition).
Shoreline Dynamics	% beach area		Reduction of 28% or 0.88 ha (2.2 acres) sand beach area between 1954 (reference condition) and 2018 (current condition), but no net loss in beach surface area since 1977, because beaches shifted land inward and seasonally southwestern beaches experience higher amounts of sand depositions.

Sources of Expertise

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- Laura Messman, Oberlin College
- Clayton Pollock, National Park Service, biologist Dry Tortugas National Park

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4.2. Chemical /Physical

4.2.1. Water Quality

This section reviews the condition of water quality in the Buck Island Reef National Monument (BUIS). The condition assessment considers data provided by the US National Park Service (1975–1996), the USVI Department of Planning and Natural Resources Division of Environmental Protection (2000–2019), and individual research assessments between 2012 and 2018 (May and Woodley 2016, Bayless 2019). 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 includes fecal indicator bacteria, dissolved oxygen, total suspended solids, turbidity, and pollution indicator assays. There was insufficient information to evaluate trends in dissolved and total nutrients, chlorophyll, and specific contaminants. Temporal trends in condition metrics were evaluated for time-series measurements.

Description

Clear water is listed prominently as a fundamental resource of BUIS by the NPS (NPS 2020). Water quality guidelines under VI Code specify the area within 0.5 miles of the boundaries of Buck Island's Natural Barrier Reef Buck Island as one of only two Class A waterbodies in the USVI (USVI DPNR 2015). 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 Buck Island is as unaltered from a pristine natural condition."

Buck Island sits approximately 2.5 km from St. Croix and largely up-current from land-based sources of pollution due to development on the main island (sediment, bacteria, and toxins). Thus, the waters of BUIS are typically clear and direct influences of terrestrial sources of pollution are likely to be low in most cases. However, currents do not always flow westward with the trade winds and it is possible for land-based sources of pollution to reach Buck Island episodically. In addition, during storms large amounts of run off and sediment resuspension could distribute pollution to BUIS. Potential sources of pollution also relate to shipping traffic in the area and local activity associated with recreational activities (boating, swimming, etc.). Recreational activities could have high localized impacts since BUIS receives 40,000–50,000 annual visitors (1995–2008; Pittman et al. 2014) and in water activities are concentrated around the Underwater Trail inside the Buck Island Lagoon and West Beach (NPS 2020). Therefore, it is unlikely that the waters surrounding Buck Island are in a pristine natural condition.

Water quality data can be used to indicate conditions that are potentially harmful to human contact and for the maintenance of desirable ecological systems and processes. These data can be obtained from numerous variables that are measurable on site, remotely, or from collected samples that are analyzed in a laboratory. Different variables and their expected values indicating potential problems with water quality are detailed in the Data and Methods section. Of high relevance to BUIS are water quality variables indicative of impacts to coral reefs. The USVI maintains standards of water quality and contaminants for territorial marine waters (USVI 2019).

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). All marine waters within 0.5 miles (0.8 km) of the Buck Island natural barrier reef are classified as Class A. Water quality included in this assessment were taken from publicly available databases and published and unpublished sources.

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 4.2.1.1. Temperature has high relevance to coral stress and is presented and discussed more fully later in the section 4.6.1. Dissolved oxygen (DO) is important for maintenance of respiration in aquatic animals and can affect animal growth and movement (Prince and Goodyear 2006). 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 (T.B. Smith unpublished observations, Smith et al. 2013).

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). Alternatively, 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.

Enrichment of waters with inorganic and organic nutrients can have detrimental effects on oligotrophic marine ecosystems, such as coral reefs, by favoring the growth of phytoplankton and benthic phototrophs, such as macroalgae. Phytoplankton can decrease light penetration to the benthos and benthic algae may compete with juvenile and adult stony corals for space. Important dissolved nutrients that support pelagic and benthic plant growth are ammonia, nitrate, and phosphorous (orthophosphorous). There are no standards for these nutrients in USVI waters. An example of reporting limits (minimum acceptable values) for these molecules in USVI waters are ammonia (10 μg l^{-1}), nitrate (1.5 μg l^{-1}), phosphate/orthophosphate (7 μg l^{-1}) (Smith et al. 2013). However, as mentioned above, 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 and enrichments is hard to detect (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 values greater than about 0.4 mg L^{-3} are indicative of enrichment above oligotrophic oceanic conditions based on research conducted south of St. John (Smith et al. 2013).

Table 4.2.1.1. Common water quality indicators used in this assessment. When available, each unit is listed with its standard 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

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 a published source (Gladfelter et al. 1977) and online databases (see below). Reference condition values were taken from water clarity observations presented in Gladfelter et al. (1977).

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 an area encompassing BUIS and up through the year 2016, the last year of reporting. This query resulted in five unique water quality stations representing 343 individual sampling events from a variety of research and monitoring programs, including the USVI Department of Planning and Natural Resources (DPNR), Cadmus, and the US National Park Service (Table 4.2.1.2). The most recent data in the database was from 2016. Data were visually inspected for consistency (e.g., lack of outliers and large deviations from mean conditions). Site mean or median, standard deviation, and maximum value (or minimum for DO and pH) 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. The variables salinity and pH were not reported from the DPNR site data because of suspect values in the database. The Cadmus site presents a wider range of variables than the NPS or DPNR data; however, it is not broadly representative of long-term conditions. The data are from only four sampling days on 9/21/09, 10/19/09, 11/10/09, and 12/30/09.

Reference Conditions/Values

The waters around BUIS were typically very clear, with vertical clarity in the 1970s never less than 15 m visibility (Gladfelter et al. 1977). Periods of lower water clarity only occurred in episodic periods with westerly winds or storms that produced a large northern swell (Gladfelter et al. 1977). For reference, the USVI standard for water clarity is based on a horizontal secchi disk reading of 15 m depth or visibility of bottom if depth is less than 15 m (USVI 2019). This suggests no chronic impairment of water clarity during the reference period. NPS and DPNR time series data that extend into the 1970s show excellent conditions for marine life for variables consistently measured (Figure 4.2.1.1).

Table 4.2.1.2. Sites sampled for water quality, their central coordinates, range of dates sampled, and number of individual sampling events. Individual samplings include at least one of the variables examined in this report. Data were extracted from https://www.waterqualitydata.us/portal. A query was run for a 1.75 mi radius circle centered on 17.798565°N, 64.616390°W for any available water quality data. Water physical values were retrieved for five stations that were sampled between years 1975 to 2016.

Station	ID	Latitude	Longitude	Start	End	Sampling events	Description
11NPSWRD_WQX-BUIS_NPS_6	NPS 6	17.79444	−64.63667	1/1/75	3/29/96	105	West BUIS about 0.8 km from coral station WSG
11NPSWRD_WQX-BUIS_NPS_7	NPS 7	17.78919	−64.61047	1/1/75	3/29/96	104	Inside northeast Buck Island barrier reef
CADMUS-STCR-0004	CADMUS	17.7825	−64.6228	9/21/09	12/30/09	4	Buck Island south point
USVIST-(_WQX)-STC-6	DPNR 6	17.78665	−64.62793	6/30/00	5/4/19	77	Buck Island southwest beach
USVIST-(_WQX)-STC-7	DPNR 7	17.78982	−64.61367	6/30/00	5/4/19	77	Inside northeast Buck Island barrier reef at anchorage

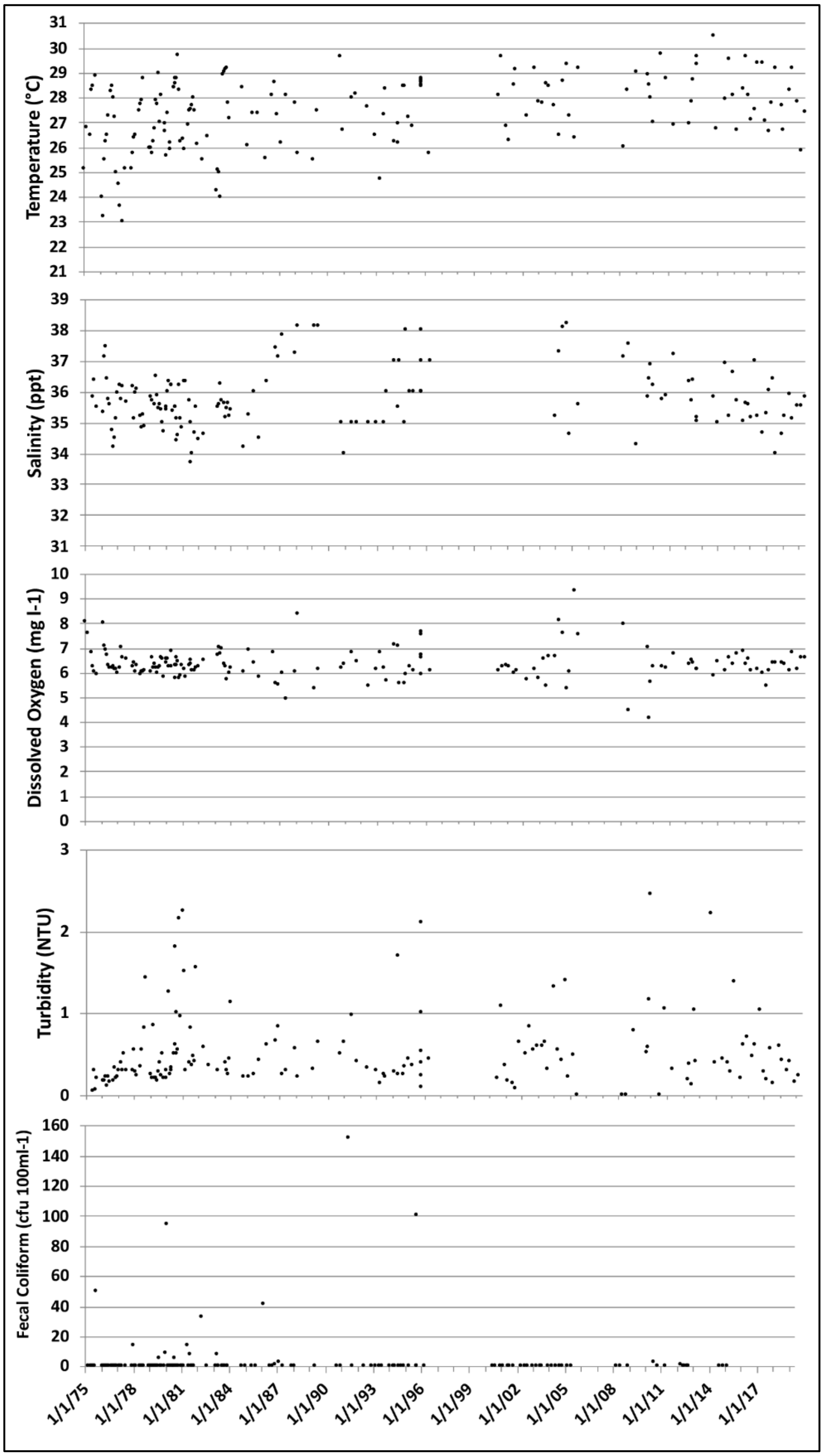

Figure 4.2.1.1. Water quality time series for temperature, salinity, dissolved oxygen, turbidity, and fecal coliform bacteria sampled between 1975 and 2019. Water quality time series is a compendium from BUIS sites listed in Table 4.2.2. Because of few indications of poor water quality sites were aggregated from around BUIS in the time series. However, for each site-specific conditions are given in Table 4.2.3. NPS sites were sampled from 1975–1996 and DPNR sites were sampled from 2000–2016.

Current Condition and Trend

In general, available data and observations indicate that water quality around BUIS remains good relative to other coastal waters in the USVI. Long term time series show no apparent changes over time (Figure 4.2.1.1) and mean and extreme values were nearly always within acceptable values for maintenance of marine life and contact recreation (Table 4.2.1.3, Figure 4.2.1.1). There was very little sampling for nutrients and chlorophyll, but available data (Table 4.2.1.4) indicates low values that are consistent with good water quality conditions for coral reefs. There was one period of over 100 samplings with dissolved oxygen values below 4.8 mg l^{-1}; however, the low DO values occurred at both DPNR sampling sites, which could indicate a sensor issue. Fecal coliform values at the NPS 6 sampled station had about 5% of periods out of 97 with measurements above 35 cfu $100ml^{-1}$, the EPA standard (USEPA 2012). Exceedance readings were reported episodically five times from 1975 to 1995 (sampling at the site ceased in 1996). This site is located over a kilometer west of Buck Island and over 3 kilometers from the main island of St. Croix, so it is not clear why fecal indicator bacteria would be present. All samplings of DPNR sites sampled from 2000–2016 showed no evidence of fecal coliform bacteria. Sedimentation rate data could not be found, but given the offshore location of BUIS, it is expected that total sediment flux is low and suitable for coral reefs (Smith et al. 2008). The exception to high water quality at BUIS is a generally increasing sea surface temperature that is negatively impacting stony corals and is covered in the section 4.6.1.

Table 4.2.1.3. Mean (or median for fecal coliform), standard deviation (SD), and sample size (N) given variable sampled at four water quality stations at BIUS (Table 4.2.2). The table presents dissolved oxygen, total suspended solids, turbidity, fecal coliform bacteria, salinity, and pH. Maximum values are presented for total suspended solids and turbidity and minimum for pH. For dissolved oxygen, the percentage of values that fell below 4.8 mg l^{-1}, the EPA value indicating impairment (USEPA 2000), are presented. Fecal indicator values above 35 cfu 100 ml^{-1} suggest marine waters with elevated risk for contact-related human illness (USEPA 2012) but note that the new standard for USVI waters is lower (Table 4.2.1). NPS sites were sampled 1975–1996. DPNR sites were sampled 2000–2016.

	Dissolved Oxygen (mg l^{-1})				Total Suspended Solids (mg l^{-1})				Turbidity (NTU)				Fecal Coliform (cfu 100 ml^{-1})				Salinity (ppt)			pH			
Location	**Mean**	**SD**	**<4.8**	**N**	**Mean**	**SD**	**Max**	**N**	**Mean**	**SD**	**Max**	**N**	**Median**	**SD**	**>35**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**Min.**	**N**
NPS 6	6.31	0.58	1%	105	3.17	3.75	7.5	3	0.60	0.62	3.3	95	0	26.39	5%	97	35.74	1.00	95	8.21	0.13	7.8	59
NPS 7	6.36	0.61	1%	104	2.96	1.90	5.8	5	0.35	0.33	2.0	95	0	22.49	1%	94	35.72	1.04	96	8.20	0.14	7.8	62
DPNR 6	7.77	10.60	0%	48	5.35	4.55	22.5	33	0.67	0.60	2.2	51	0	0.42	0%	50	–	–	–	–	–	–	–
DPNR 7	7.91	11.91	0%	48	3.96	3.07	18.6	33	0.36	0.47	3.2	51	0	0.57	0%	50	–	–	–	–	–	–	–

Table 4.2.1.4. Water quality measurements at a single site south of Buck Island in BUIS from four different dates between 9/21/2009 to 12/30/2009.

Variable	Mean	SD	Max
Ammonia	0.01 mg L^{-1}	0.00	–
Carbon	0.21 mg L^{-1}	0.07	–
Chlorophyll a [(a)]	0.56 µg L^{-1}	–	–
Dissolved oxygen	5.76 mg L^{-1}	1.22	–
Nitrite	0.001 mg L^{-1}	0.00	–
Nitrogen	0.11 mg L^{-1}	0.01	–
Organic carbon	2.15 mg L^{-1}	0.79	–
Orthophosphate	0.003 mg L^{-1}	0.00	–
pH	7.82	0.25	–
Phosphorus	0.01 mg L^{-1}	0.00	–
Salinity	36.32 ppt	0.44	–
Total suspended solids	4.60 mg L^{-1}	–	–
Turbidity	0.76 NTU	0.29	1.16

[a] corrected for pheophytin

Indirect measurements of water quality indicate marine conditions that would favor the normal development and maintenance of sensitive ecosystems, such as coral reefs. Bayless (2019) measured foraminferal index scores and $\delta^{13}C$ from sediments and reported values indicating oceanic sediment input as opposed to terrestrial sediment input, with low levels of heavy metals. In addition, skeletal analysis of corals showed uptake of more oceanic upwelling nutrients as opposed to heavy metals.

However, despite a generally a generally good picture of mean water quality there may be issues with pollutants/contaminants associated with recreational park use. Indirect measurements of water quality based on biological assays involving fertilization and embryo development of the sea urchin *Lytechinus variegatus* showed that embryos exposed to sediment porewater from the area of the BUIS underwater trail had significant retardation of development relative to seawater controls in June 2015 (May and Woodley 2016). Only 24% of embryos showed normal development after exposure, opposed to about 90% normal in seawater control. Purification of porewater through a C18 column that removes non-polar and moderately polar compounds significantly reduced the negative impacts to embryos (68.5% normal) suggesting chemical contaminants which could include hydrocarbons (e.g., from boat engines), antifoulants, and/or personal care products, such as sunscreens (May and Woodley 2016). Five other sites tested around BUIS showed no significant impacts on urchin embryo development (West Beach, Scuba Mooring, South Lagoon, South Forereef, BI Site 3 to the east of barrier reef; see map in May and Woodley 2016). On the other hand, Bayless (2019) found reduced urchin fertilization and normal embryo development at a wider range of sites at the South Lagoon, Underwater Trail, and two sites outside and to the north and northwest of the Buck Island barrier reef. She also found elevated levels unionized ammonia at the South Lagoon and Underwater Trail sites, potentially indicating sewage pollution from boats or pit toilet

(Bayless 2019). Detectible levels of UV filters associated with sunscreens have been found in surface waters in 2015 and 2017 [oxybenzone (up to 0.233 μg/L), avobenzone (up to 0.031 μg/L), and octocrylene (up to 0.044 μg/L); C. Woodley, personal communication in Bayless 2019]. Testing of elkhorn coral (*Acropora palmata*) biopsies two weeks prior to spawning periods in August 2013 revealed the possibility of low reproduction of corals near the underwater trail that could be consistent with toxic impacts from substances such as UV sunscreens and other personal hygiene products (C. Woodley, unpub. data).

Threats and Stressors

The marine habitats around BUIS are not threatened by poor water quality due to run-off from land in general because they are fairly isolated from the main island of St. Croix, although acute run-off from Buck Island during high-intensity rainfall events occur 1–4 times per year (Z. Hillis-Starr 2019, personal communication). Localized threats from recreational activity are more of a concern, particularly around the heavily visited area of the snorkel trail (May and Woodley 2016, Bayless 2019). Here hydrocarbons from combustion engines and wash off of personal care products on bathers, such as deodorants and sunscreens (Downs et al. 2016), could pose a threat to coral development. Other threats to the water quality at BUIS come from global factors related to greenhouse gas driven global warming and increasing carbon dioxide absorbed into seawater. Seawater temperature is detailed in section 4.6.1. Ocean acidification is an emerging issue that will be a larger threat to stony corals and other calcifying organism in the future.

Data Needs and Gaps

The USVI Department of Planning and Natural Resources maintains an ambient water quality monitoring program that samples two sites within BUIS and provides valuable information on water quality. However, the program is not comprehensive, nor consistent, and potentially misses key acute events that impact water quality. An NPS led water quality sampling program with deployed sensors and discreet water samples would be a valuable addition to establish trends in water quality for BUIS. Sampling could include areas that have higher relevance for the wider assemblage of animals and plants across the park, as opposed to the West Beach and Underwater trail where the water quality focus is on human health. Sampling could include deployed sensors for chlorophyll and turbidity and the use of remote sensing to detect water color. A calibration of satellite sensors was recently conducted for the northern USVI. This project could be a starting point for monitoring using remote sensing tools (Brandt et al. 2019). Furthermore, measurement of pH, alkalinity, and other variables related to the carbonate chemistry and aragonite/calcite saturation state would assist in understanding the emerging threat of ocean acidification to the calcifying organisms of BUIS. Lastly, given preliminary data suggesting contaminants in high use areas such as the Underwater Trail (May and Woodley 2016; C. Woodley 2019, personal communication) a robust research study to establish the types of contaminants and the impact of contaminates is important and could lead to a monitoring and mitigation plan to protect nesting sea turtles and corals.

Overall Condition

The water quality of BUIS is good, but with indications of localized impacts from unknown contaminants and threats derived from regional and global changes associated with human-induced climate change and ocean acidification. Therefore, the majority of indicators were assessed as being in good condition with the exception of contaminants which warrant significant concern (Table 4.2.1.5).

Table 4.2.1.5. 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 spurious indications of fecal contamination and but no violations for contact recreation in the last two decades
	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. There is insufficient information to understand if concentrations are changing.
	Turbidity		Turbidity is low. There is insufficient information to understand if concentrations are changing.
	Dissolved Nutrients		These are typically near low detection limits in most areas but have not been extensively.
	Chlorophyll		Chlorophyll was low in a few areas that were assessed. There is insufficient information to understand if phytoplankton abundance is changing.
	Terrestrial sediments		Terrestrial sediments have not been directly measured, but other research suggests that values should be low and with no cause for increases.
	Contaminants		There are worrying signs of possible contaminants and biological effects on corals in localized areas that deserve further investigation

<u>Sources of Expertise</u>

- Benjamin Keularts, Division of Environmental Protection, USVI DPNR
- Cheryl M. Woodley, National Oceanic and Atmospheric Administration
- William J. Miller, South Florida and Caribbean Network, National Park Service

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4.3. Terrestrial Plants

4.3.1. Dry Tropical Forest

This section reviews the condition of the dry tropical forest in BUIS. The condition assessment considers data for the years 2001 and 2004–2012, provided by Gary Ray (2001), the South Florida Caribbean Network (2008–2009), and the NPS Florida/Caribbean Exotic Plant Management Team (2004–2012) to assess the status of the dry tropical forest. The condition of upland forests is typically evaluated using metrics that detect changes in species composition, forest structure, fragmentation and habitat loss, diversity, percent cover of invasive species, and mortality/damage. The condition metrics selected for this resource include change in species composition and change in percent cover of invasive exotic species. Temporal trends in condition metrics were evaluated.

Description

In this treatment, dry tropical forests on Buck Island include all subtropical semi-deciduous forests and woodlands not dominated by *Hippomane mancinella* nor found along the coast. As defined, this class covers 38% of the island (Figure 4.3.1.1) (Moser et al. 2010). Today these forests are dominated by *Bursera simaruba*, gumbo limbo, and *Pisonia subcordata*, water mampoo, and contain species typical of seasonal deciduous forests in the Caribbean (Gibney 1996). More than two centuries of heavy grazing, cultivation, exotic species introduction, and logging of valuable hardwood species (e.g., lignum vitae) likely changed the structure and composition of the forest (Woodbury and Little 1976). In the late 1960s, the forest was described as relatively open and composed of 6 m high trees with average diameter at breast height of 30 cm (Woodbury and Little 1976).

By the mid-1990s, the impact to native vegetation from the non-native roof rat population, *Rattus rattus*, was substantial and included the chewing of young branches and foliage and consumption of a large portion of fruits and seed mast (Gibney 1996). Eradication efforts conducted between 1998 and 2001 were successful in eliminating the rats from the island (Witmer et al. 2007). Continued monitoring using bi-annual snap-trap line assessments has resulted in an occasional individual tree rat capture, but a reproductive population has not re-established on the island (K. Ewen 2020, personal communication). A floristic inventory and survey of vegetation communities during 2001 documented the recovery of vegetation and the distribution of species on the island, including non-native invasive species, establishing a baseline from which to assess future community change (Ray 2003). Control of invasive plants on BUIS began in 2004. The removal of ten invasive exotic plant species by the Florida/Caribbean Exotic Plant Management Team (FLCEPMT) during 2004 to 2008 had achieved 80% control of the invasion (NPS 2020). Methods of treatment made use of the established grid system and included both manual removal of exotic species and herbicide application.

Treatment of exotic plants on the island is ongoing annually barring hurricane years which postpone or impact treatment schedules (NPS 2014). In 2017, impacts from two Category 5 hurricanes, Hurricane Irma (September 6th–7th, 2017) and Hurricane Maria (September 18th–19th, 2017) resulted substantial damage to the forest with foliage loss, downed and damaged trees, and subsequent quick recolonization of invasive plant species (NPS 2020). A forest restoration plan for BUIS, based on the results of pollen coring in the salt pond, identified 37 highly recommended woody species, 9 of which are rare or extirpated from BUIS, for future out-planting efforts (Geographic Consulting LLC 2017). These efforts should help to restore native species diversity to Buck Island as part of the NPS Tropical Dry Forest Project (BUIS 178837, 2017–2019) (Z. Hillis-Starr 2020, personal communication).

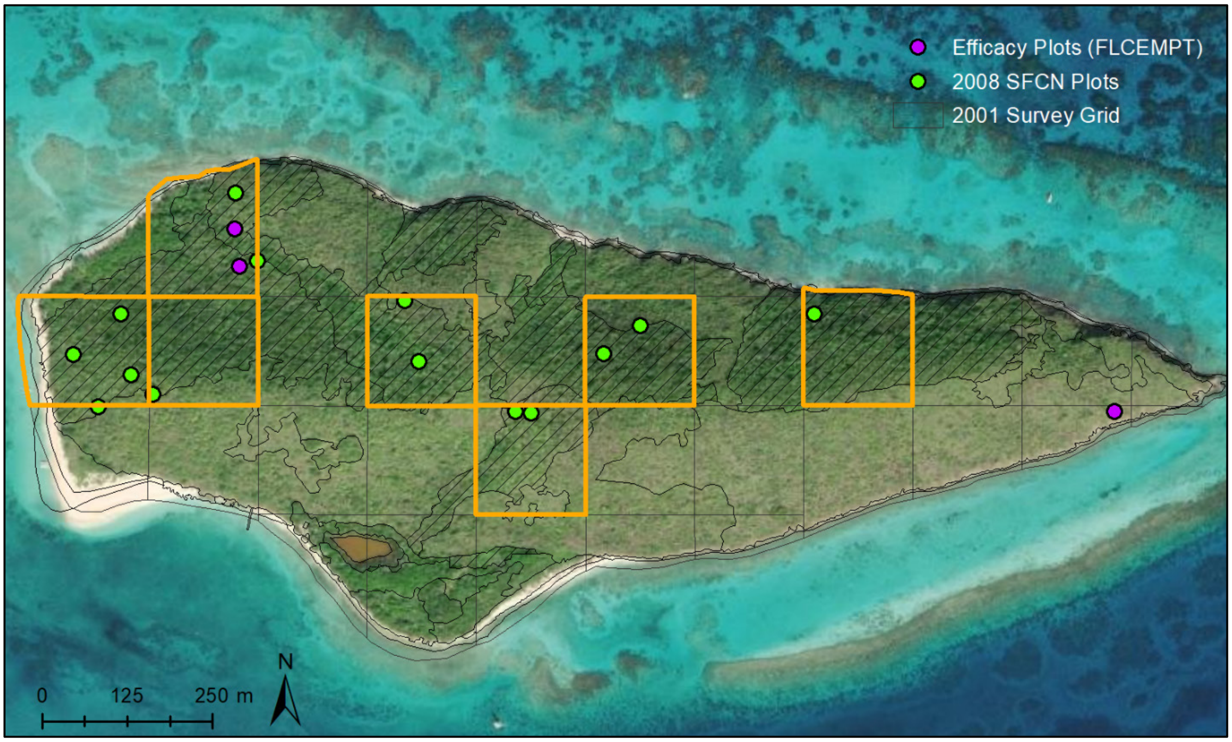


Figure 4.3.1.1. Location of 14 SFCN circular plots located in dry tropical forest from BUIS vegetation map (hashed polygons) and 7 cells (orange outlines) of the island-wide grid system considered in change of species composition on BUIS. Location of exotic species treatment efficacy plots (FLCEMPT) indicated.

<u>Data and Methods</u>

The indicator used to assess the dry tropical forest component is community extent and includes two measures: the change in species composition and change in percent cover of exotic species. Datasets used for analysis include the following:

1. an island-wide species inventory and community assessment conducted in 2001 of the entire island, divided into 160 m by 160 m square plots based on the Braun-Blanquette cover abundance scale (Table 4.3.1.1) (Ray 2003),
2. a list of dominant species noted in fourteen 300 m2 circular plots visited in 2008/2009 as part of the accuracy assessment for the BUIS Vegetation Mapping Project (Moser et al. 2010),

   a geodatabase of species-specific treatment locations of invasive plants on BUIS from 2004–2012 from the NPS Florida/Caribbean Exotic Plant Management Team (FLCEPMT), and

3. treatment efficacy monitoring data for three 6 m radius plots surveyed in 2007 and again in 2011/2012 located in areas of high invasive species occurrence from the NPS Florida/Caribbean Exotic Plant Management Team (FLCEPMT).

Table 4.3.1.1. Braun-Blanquet cover class categories for estimation of percent species cover as used during the Buck Island Vegetation Survey and Mapping Project (Ray 2003).

Cover Class	Percent Cover
1	< 1%
2	1–5%
3	6–25%
4	26–50%
5	51–75%
6	76–95%
7	>95%

Change in species composition

Given the large differences in assessment methodologies (e.g., size of plots and metrics considered), we limited our analysis to consider the frequency in which species were recorded from plots in each survey and to a qualitative judgment regarding species recorded as dominant or common (Moser et al. 2010) or having a percent cover class (3 or higher) (Ray 2003). The island-wide grid system from the 2001 survey uses grid cells that each covers an approximate area of 26,000 m^2 and includes multiple vegetation community types within each cell. For this analysis, we include data from cells in the 2001 surveys that meet the following criteria: 1) the majority of the cell is comprised of the dry tropical forest vegetation class, 2) the cell overlaps plots from the sampling effort in 2008/2009 by botanists from the South Florida Caribbean Network (SFCN) (Figure 4.3.1.1). This resulted in 7 of the grid cells from the Ray study being considered in our analysis, specifically cells (orange grid cells in Figure 4.3.1.1). We calculated a relative frequency for all dry forest cells by converting cover class codes to presence/absence for each species. In the tables presented, to match up better with the 2008/2009 methodology, we focus only on species that would have been considered more common, having been given cover class values of 3 or greater in at least 1 of the grid cells.

As the aim of the work completed by SFCN in 2009 was field assessment to aid in vegetation mapping, exhaustive species lists were not created for each plot. Instead, only the dominant and common species were listed. Specifically, the data collected for each plot included an estimate of total percent cover, average canopy height, identification of the first and second most prevalent species by strata, and a short list of common species. Also recorded was the magnitude of hurricane damage from Hurricane Omar which impacted Buck Island on October 16, 2008. In order to compare with the 2001 dataset, we similarly calculated relative frequency for each species observed across the 14 (~300 m^2) plots.

To assess change in non-native invasive species cover we qualitatively compared island-wide frequency and percent cover of non-native invasive species across all 34 grid cells as assessed in

2001 (Ray 2003) to treatment and eradication effort from 2004 through 2012. We also report on efficacy of invasive plant treatment based on data from three 6 m radius plots which were surveyed during 2007 and again in 2011/2012 (Figure 4.3.1.1). Because a large percentage of the island is in dry tropical forest or in close proximity to the community type, the distribution of exotic species island-wide has the capacity to negatively impact this component and therefore we did not restrict our assessment to the boundaries of the community as designated by the 2009 vegetation map. We qualitatively compare the 2001 distribution and percent cover across the entirety of the island-wide grid system for the following species: *Leucaena leucocephala* (tan-tan), *Tecoma stans* (ginger thomas), *Tamarindus indica* (tamarind), and *Urochloa maximum* (guinea grass). We overlay those maps with the species-specific treatment points as indicated by the FLCEPMT for the following years: 2004, 2007, and 2012. While exotic treatment was conducted in 2010, species-specific information was not available. Therefore, we do not include 2010 points in species overlays, but do consider the points in the treatment effort for all species combined.

Change in species cover of non-native exotic species

To assess change in non-native invasive species cover we qualitatively compared island-wide frequency and percent cover of non-native invasive species across all 34 grid cells as assessed in 2001 (Ray 2003) to treatment and eradication effort from 2004 through 2012. We also report on efficacy of invasive plant treatment based on data from three 6 m radius plots which were surveyed during 2007 and again in 2011/2012 (Figure 4.3.1.1). Because a large percentage of the island is in dry tropical forest or in close proximity to the community type, the distribution of exotic species island-wide has the capacity to negatively impact this component and therefore we did not restrict our assessment to the boundaries of the community as designated by the 2009 vegetation map. We qualitatively compare the 2001 distribution and percent cover across the entirety of the island-wide grid system for the following species: *Leucaena leucocephala* (tan-tan), *Tecoma stans* (ginger thomas), *Tamarindus indica* (tamarind), and *Urochloa maximum* (guinea grass). We overlay those maps with the species-specific treatment points as indicated by the FLCEPMT for the following years: 2004, 2007, and 2012. While exotic treatment was conducted in 2010, species-specific information was not available. Therefore, we do not include 2010 points in species overlays, but do consider the points in the treatment effort for all species combined.

Treatment efficacy plots were established in 2007 in areas heavily impacted by guinea grass in both dry tropical forest and adjacent shrubland. As these plots are intended to show efficacy of management intervention, the plots are found in areas that were chemically treated and with easy access to the trail system. They were not randomly selected, but rather situated using best professional judgement. Percent cover was estimated for all observed species in three height strata: 1) vegetation <= 1 m, 2) vegetation > 1 m but not including tree species >= 1.3 m, and 3) all tree species >= 1.3 m. Cover classes are as follows: 1) 0–5%, 2) 6–25%, 3) 26–50%, 4) 51–75%, 5) 76–95%, and 6) 96–100%. The midpoint of each class was used to compare cover estimates between 2007 and 2011/2012 for guinea grass and the dominant tree species in the plots. Density of trees greater than 1 cm dbh was recorded at the time of survey.

Reference Conditions/Values

The reference conditions date to 2001 when the first spatially explicit plant community assessment of BUIS was conducted by Gary Ray (Ray 2003). Eradication effort leading to control of non-native invasive mammals (tree rats) had been completed in the year prior to this survey (Witmer et al. 2007).

Current Condition and Trend

Species Composition

In Table 4.3.1.2 we list the relative frequency of species recorded in dry forest for each sampling effort (2001 vs. 2008–09) for all species recorded in greater than 10% of plots. In 2001, within the dry tropical forest grid cells considered in this analysis (Figure 4.3.1.1), 131 species were recorded. The species with the greatest relative frequency consisted primarily of native tree and shrub species, cacti, and the notable presence of the invasive guinea-grass, *Urochloa maxima*. In 2008/2009, 21 dominant and common species were recorded from the 14 (~300 m^2) plots visited. Given the differing plot sizes and methods of survey, we are cautious to interpret change over the 7-year period and do not directly compare relative frequency values between surveys. However, some general conclusions can be made from the data: 1) guinea grass was greatly reduced in its frequency between surveys, 2) several of the same tree and shrub species are recorded as common or dominant in both surveys, and 3) *Bursera simaruba*, gumbo limbo, has likely increased in its importance in the forest.

Table 4.3.1.2. Relative frequency of species in 2001 (Ray 2003) and 2008/2009 surveys (Moser et al. 2010) in dry tropical forest. Letters following species name indicate life form: cactus (C), herb (H), shrub (S), tree (T), or vine (V). Species are listed from most to least frequent for all species occurring in > 10 % of plots.

Survey Years	Species	Rel. Freq (%)
2001	*Acacia tortuosa* (S)	100
	Lantana involucrata (S)	100
	Pilosocereus royenii (C)	100
	Pisonia subcordata (T)	100
	Rochefortia acanthophora (S)	100
	Tournefortia volubilis (V)	100
	Urochloa maxima (H)	100
	Chromolaena sinuatum (S)	85.7
	Flueggea acidoton (S)	85.7
	Bourreria succulenta (T)	85.7
	Oplonia spinosa (S)	85.7
	Tabebuia heterophylla (T)	57.1
	Plumbago scandens (S)	14.3

Table 4.3.1.2 (continued). Relative frequency of species in 2001 (Ray 2003) and 2008/2009 surveys (Moser et al. 2010) in dry tropical forest. Letters following species name indicate life form: cactus (C), herb (H), shrub (S), tree (T), or vine (V). Species are listed from most to least frequent for all species occurring in > 10 % of plots.

Survey Years	Species	Rel. Freq (%)
2008 / 2009	*Bursera simaruba* (T)	78.6
	Pilosocereus royenii (C)	71.4
	Pisonia subcordata (T)	71.4
	Rochefortia acanthophora (S)	50.0
	Acacia tortuosa (S)	42.9
	Bourreria succulenta (T)	35.7
	Plumeria alba (T)	35.7
	Capparis cynophallophora (T)	21.4
	Piscidia carthagenesis (T)	14.3
	Tillandsia utricultata (H)	14.3

Damage to the dry tropical forest from Hurricane Omar (2008) was qualitatively assessed in the 14 ~300 m^2 plots during 2008/2009 and was nearly equally split between minor damage (6 plots) and moderate damage (8 plots). Canopy height ranged from 5 to 9 meter, averaging 6.8 m and canopy closure ranged as low as 20% in a moderately damaged plot to 80% in a plot recorded as having minor damage.

Percent cover of invasive exotic species

The number of invasive exotic species on the landscape decreased subsequent to herbicide treatment and manual removal of invasive plants. While all invasive exotic species were targeted for eradication, efforts focused on the two most widespread species, *Urochloa maximum* and *Leucaena leucocephala*. A list of all species treated via herbicide or removed by hand during the time period are listed in Table 4.3.1.3. Figure 4.3.1.2. shows the number of invasive species present in each grid cell in 2001 compared to all treatment points classified by year.

During the Ray 2001 survey, *U. maximum* was found across ~75% of the island, with large congregations in the northwest corner (Figure 4.3.1.3a). A comparison of *L. leucocephala* and *U. maximum* extent in 2001 to the treatment effort indicates that the initial widespread distribution of these two species have been addressed (Figure 4.3.1.3a and 4.3.1.3b). Percent cover of guinea grass was considerably reduced in all efficacy plots between 2007 and 2011/2012 (Figure 4.3.1.4a). Percent cover of native species increased slightly for plots 1 and 2 (Figure 4.3.1.4b). Additionally, in plot 1, the number of trees with dbh > 1 cm increased from a single individual to 3. Nearly two dozen individuals of *T. stans* were treated in the woodland and shrub areas on the east and west end of the island (Figure 4.3.1.3c). Large individuals of *T. indica* remain on the island (Figure 4.3.1.3d). This is in line with management goals to preserve several individuals associated with historic settlements on the north and west sides of the island, while saplings and seedlings were targeted for removal (Clark and Hillis-Starr 2004).

Table 4.3.1.3. Invasive exotic species treated during 2004, 2007, and 2012 work by FLCEPMT.

Species	**Common Name**	**Number of treatment points**
Abrus precatorius	crab's eye	6
Aloe vera	aloe	3
Boerhavia erecta	boerhavia	4
Bromelia pinguin	wild pineapple	3
Cocos nucifera	coconut palm	1
Leucaena leucocephala	wild tan-tan	81
Meliococcus bijugatus	kenip	1
Morinda citrifolia	noni	4
Scaveola sericea	beach naupaka	2
Tamarindus indica	tamarind	9
Tecoma stans	ginger thomas	23
Thespesia populnea	seaside maho	1
Urochloa maximum	African guinea grass	195

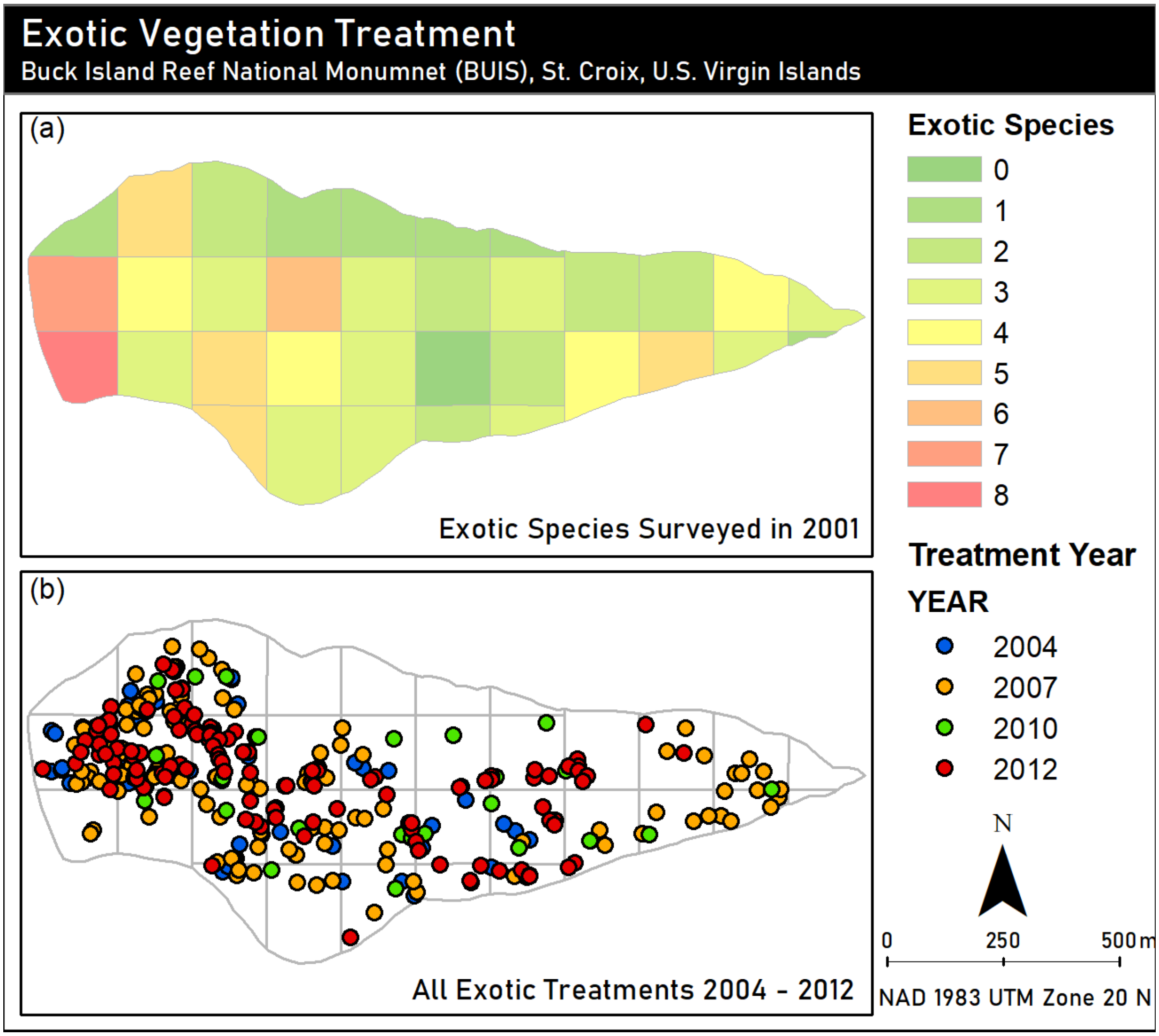


Figure 4.3.1.2. Exotic species distribution and treatment effort as a) the total number of introduced exotic species present in each grid cell as inventoried in 2001 (Ray 2003) and b) the location of treatment points for all exotic species for years 2004, 2007, 2010, and 2012 (data provided by FLCEMPT).

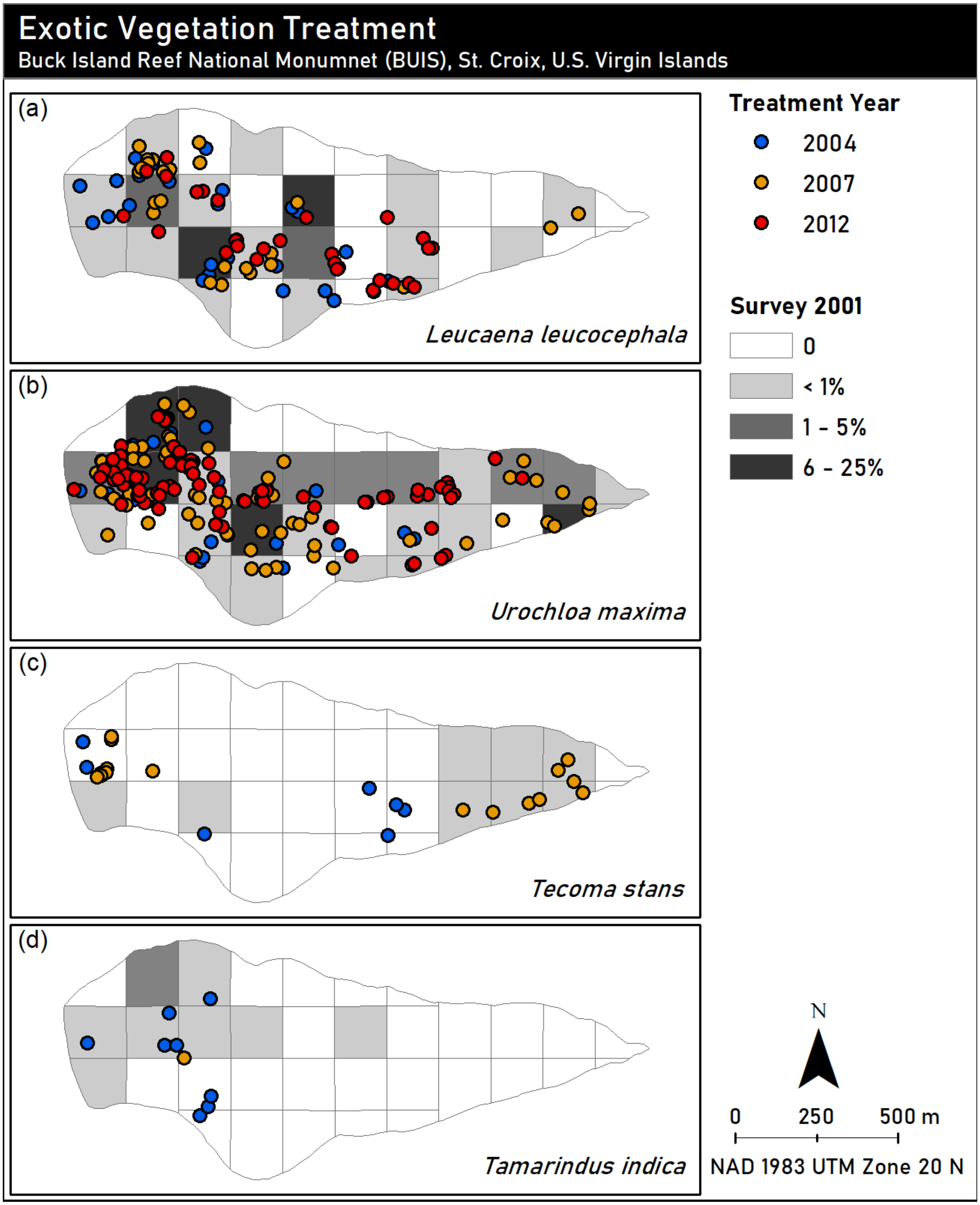


Figure 4.3.1.3. Percent cover of a) *L. leucocephala,* b) *U. maximum*, c) *T. stans* and d) *T. indica* in 2001 (Ray 2003) compared to locations of exotic treatment for each species in 2004, 2007, and 2012 (data provided by FLCEMPT).

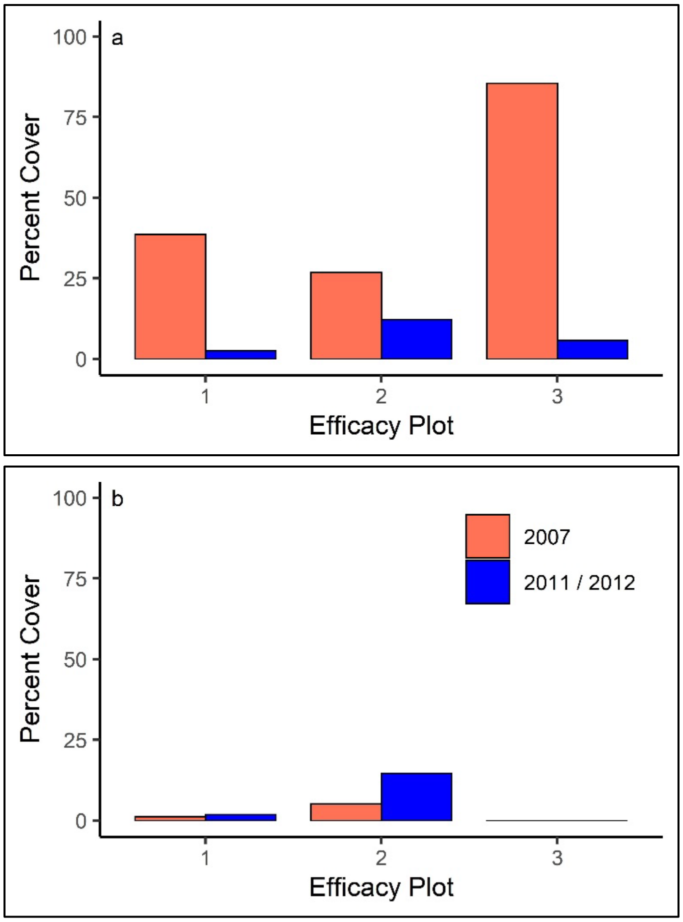


Figure 4.3.1.4. Percent cover of a) *U. maximum* and b) native tree cover in 3 treatment efficacy plots surveyed in 2007 and 2011/2012.

Threats and Stressors

Threats and stressors to dry tropical forests within BUIS include the effects of extreme weather events (e.g., hurricanes, drought, and fire), erosion along hiking trails, and potential reintroduction of non-native plant and animal species. Hurricanes cause mortality and structural damage to trees, resulting in open canopies and soil erosion. Hurricane Omar in 2008, resulted in minor to moderate damage of the dry forest. The impact from the 2017 hurricane season, Hurricanes Irma and Maria, resulted in extensive damage to the forests on BUIS including wind damage to mature trees, loss of cover across patchy areas which opened up areas to the spread of non-native invasive plants (Z. Hillis-Starr 2020, personal communication). Disturbance impacts can often increase the potential for re-establishment of aggressive non-native species that can take advantage of disturbed conditions.

Data Needs and Gaps

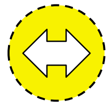
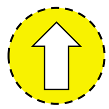
Establishment of a permanent plot network throughout all vegetation subclasses contained within the dry forest and woodland type is recommended. This would provide the opportunity to robustly assess changes in plant species composition and forest structure and should include tagging of all stems, and estimates of tree height, understory density, and litter cover. Continued monitoring and treatment of invasive plant species is imperative to limit the impact on native flora that may be outcompeted. As dry tropical forest occurs at higher elevations on Buck Island compared to the low-lying coastal forest, it will serve as an important refugia for the endangered St. Croix ground lizard as sea level rises. Habitat monitoring and assessment of environmental conditions within the forest would provide an important component of management for the endangered St. Croix ground lizard which is found throughout the dry forest.

Overall Condition

Given the long history of anthropogenic disturbance and non-native mammal and plant infestations, the recent progress made in the recovery of the dry tropical forest is encouraging. To assess the condition of the forest, we used community extent as an indicator and considered two metrics: change in species composition and change in percent cover of invasive exotic species (Table 4.3.1.4). Given non-compatibility of data sources, we are not confident in the extent of change in species composition in the component beyond the clear impact that removal of invasive species following several years of management has had. However, it appears the overall species assemblage is quite similar between surveys, and therefore, we give a trend of unchanging for species composition. It is also not clear how the current assemblage compares to island-wide species list of 228 (17 non-native species), as described in the work of Woodbury and Little (1976). Although it is most certainly less species diverse based on the 2001 inventory which documented 163 species island-wide, 21 of which were non-native (Ray 2003).

Unfortunately, after the 2017 hurricane season, some of the gains made in the control of invasive species were lost as a result of severe disturbance and recolonization by these species. We consider the condition of the resource based on percent cover metric to be of moderate concern. The condition was considered to be improving as decreases in percent cover of invasive species, most notably *U. maxima*, were accompanied by slight increases in the percent cover of native tree species in efficacy plots. However, we have low confidence in the assessment of change in percent cover of non-native invasives because of the non-random location of plots and the lack of data assessing the impacts of disturbance caused by the 2017 hurricane season. The addition of more plots across the component would increase confidence of future assessments.

Table 4.3.1.4. Graphical summary of status and trends for Tropical Dry Forest within the framework category Terrestrial Vegetation, including rationale and reference condition.

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Tropical Dry Forest	Community Extent (Change in species composition)		Overall species composition of the island is likely similar to the 2001 reference conditions. However, confidence in the trend and condition is low given the available data. The current forest enrichment project should serve to increase species diversity, hopefully leading to a future positive trend in condition.
	Community Extent (Change in percent cover of exotic species)		Since the 2001 inventory, the percent cover of invasive non-native species has likely decreased following several years of treatment for exotic species. The percent cover of native flora has likely increased in response to treatment for invasive plants and eradication of roof rats. However, confidence in trend detection is low given the differences between survey methodologies and the occurrence of hurricanes after the most recent survey data. Impacts from 2017 hurricane season have reportedly resulted in forest damage and recolonization of some invasive species.

<u>Sources of Expertise</u>

- Kristen Ewen, biological technician, National Park Service BUIS
- Eleanor Gibney, St. John, USVI
- Gary Ray, St. John Land Conservancy, St. John, USVI
- Brooke Shamblin, NPS South Florida/Caribbean I & M Network, Palmetto Bay, FL
- Kevin Whelan, PhD, NPS South Fl Caribbean I & M Network, SFCN, Palmetto, Bay, FL
- Zandy Hillis-Starr, NPS Resource Manager BUIS (retired)

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4.3.2. Coastal Forest

This section reviews the condition of the coastal forest in BUIS. The condition assessment considers data for the years 2001 and 2008–2016, provided by Gary Ray (2001) and the South Florida Caribbean Network (2008–2009, 2010, 2012, and 2016) to assess the status of the dry tropical forest. The condition of upland forests is typically evaluated using metrics that detect changes in species composition, forest structure, fragmentation and habitat loss, diversity, percent cover of invasive species, and mortality/damage. The condition metrics selected for this resource include change in species composition and change in percent cover. Temporal trends in condition metrics were evaluated.

Description

Coastal forest and woodland include the tallest trees on the island and is found on the northwestern and southern sandy coastal plain a few meters above sea level. It is dominated by the manchineel tree, *Hippomane mancineel*, but also includes water mampoo, *Pisonia subcordata*, mastic, *Sideroxylon obovatum*, the introduced tamarind, *Tamarindus indica*, and several other tropical hardwoods. The community was likely cleared for cultivation historically (Woodbury and Little 1976). The coastal forest serves as important habitat for the endangered St. Croix ground lizard. Past hurricanes, including Hurricanes Hugo (1989), Marilyn and Luis (1995), Georges (1998), Lenny (1999), Omar (2008), and Irma (2017) have greatly impacted this vegetation community. While large swaths of the forest were leveled after Hurricane Hugo (all mature trees were damaged and died in place), subsequent regeneration by the dominant species maintained similar species composition (Gibney 1996; Z. Hillis-Starr 2020, personal communication). Coverage by non-native and invasive plant species is minimal (Ray 2003). Beginning in 2004, NPS undertook the eradication of non-native invasive plants in the coastal environment. This was done to prepare the coastal habitat for translocation and release of the St. Croix Ground Lizard and reduce potential conflict between management actions: protect newly released lizards vs control of exotic plants through herbicide use (Z. Hillis-Starr 2020, personal communication).

Data and Methods

The indicator used to assess the coastal forest component is community extent and includes two measures: the change in species composition and change in percent cover. Datasets used for analysis include the following:

1. an island-wide species inventory and community assessment conducted in 2001 based on the Braun-Blanquet cover abundance scale (Table 4.3.2.1) (Ray 2003),
2. a list of dominant species noted in eleven 300 m^2 circular plots visited in 2008/2009 as part of the BUIS Vegetation Mapping Project (Moser et al. 2010), and
3. a single 300 m^2 circular permanent plot, located in coastal forest on the northwest side of island, which was established in 2008, expanded in 2010, and partially resurveyed in 2016 (data provided by South Florida Caribbean Network).

Table 4.3.2.1. Braun-Blanquet cover class categories for estimation of percent species cover as used during the Buck Island Vegetation Survey and Mapping Project (Ray 2003).

Cover Class	Percent Cover
1	< 1%
2	1–5%
3	6–25%
4	26–50%
5	51–75%
6	76–95%
7	>95%

Change in species composition

Given the large differences in assessment methodologies (e.g., size of plots and metrics considered), we limited our analysis to consider the relative frequency in which species were recorded from plots in each survey and to a qualitative judgment regarding species recorded as dominant or common (Moser et al. 2010) or having a percent cover class (2 or higher) (Ray 2003). The island-wide grid system from the 2001 includes multiple vegetation community types within each cell. We selected two cells from the 2001 surveys that are dominated by coastal forest habitat and cover an approximate area of 15,000 m^2 (Figure 4.3.2.1). This resulted in 2 of the grid cells from the Ray study being considered as coastal forest (orange outlined cells in Figure 4.3.2.1). We calculated a relative frequency for all coastal forest cells by converting cover class codes to presence/absence for each species. In the tables presented, to match up better with the 2008/2009 methodology, we focus only on species that would have been considered occasional or common, having been given cover class values of 2 or greater in at least 1 of the grid cells.

As the aim of the work completed by SFCN in 2009 was field assessment to aid in vegetation mapping, exhaustive species lists were not created for each plot. Instead, only the dominant and common species were listed. Specifically, the data collected for each plot included an estimate of total percent cover, average canopy height, identification of the first and second most prevalent species by strata, and a short list of common species. Also recorded was the magnitude of hurricane damage from Hurricane Omar which impacted Buck Island on October 16, 2008. In order to compare with the 2001 dataset, we calculated relative frequency for each species observed across the 11 (~300 m^2) plots falling within coastal forest as mapped by Moser et al. 2010 (Figure 4.3.2.1).

Change in species cover and hurricane damage

To assess change in species cover, we used data from a permanent plot established in the coastal forest vegetation type in 2008. The original plot (5-meter radius) was established within a week of passage of Hurricane Omar and all stems greater than 2 cm dbh were measured. The plot was expanded to a 10-meter radius plot in 2010 and all stems having a height greater than 1 m were measured and tagged (stems of *Capparis flexuosa* were tagged only within a portion of the plot). All trees within the plot were identified to species, dbh, height, and location within the canopy or understory recorded, and a condition code was assigned (0 = no damage, 1 = minor damage, limb breakage, 2 = moderate damage, 3 = severe damage, including tipped up, or 4 = severe damage with loss of canopy or snapped tree). During the partial resurvey in 2016, trees were designated as being wet from tidal flooding or dry. We comment on the extent of hurricane damage by species (2008/2010) and subsequent erosion extent (2016).

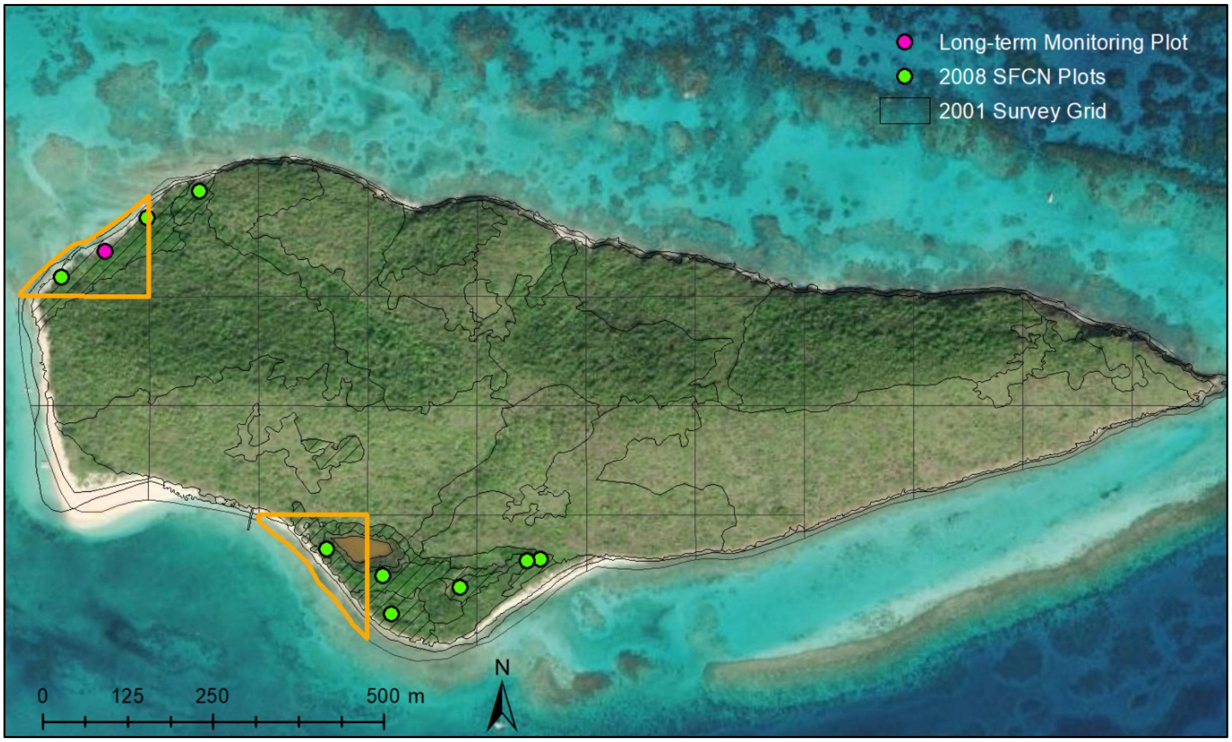


Figure 4.3.2.1. Location of 11 SFCN circular plots, including the SFCN long-term monitoring plot, located within coastal forest habitat as mapped by Moser et al. (2010) (hashed polygons). Two grid cells (orange outlines) of the 2001 island-wide grid system (Ray 2003) were considered as being dominated by coastal forest for comparison between the two datasets.

Reference Conditions/Values

Reference conditions for coastal forest date to 2001 when the first spatially explicit plant community assessment of BUIS was conducted by Gary Ray. However, given differences in extent of inventories, it is not possible to determine changes in percent cover compared to the 2001 dataset. Instead, we report on the amount of hurricane damage by species in 2008/2010 and the extent of tidal inundation to the permanent plot as of 2016.

Current Condition and Trend

Species Composition

In Table 2, we list the relative frequency of species recorded in coastal forest for each sampling effort (2001 vs. 2008–09) for all species recorded in at least 10% of plots. In 2001, within the two grid cells dominated by coastal forest (Figure 4.3.2.1), 73 species were recorded, and most could generally be described as characteristic of the habitat type. However, black and white mangroves, *Avicennia germinans* and *Laguncularia racemosa*, were both found within the same grid cells along the salt pond and as such are included in the list (Table 4.3.2.2). In 2008/2009, 23 dominant and common species were recorded from the 11 plots visited by SFCN in coastal forest vegetation. As a result of the differing plot sizes and methods of survey, we are cautious to interpret change over the 7-year period between surveys. And most differences are more likely attributable to differences in extent and methodology. However, several species are common to both lists, and two species in particular were found with relatively high frequency in both: *Hippomane mancinella* and *Acacia tortosa*. Species recorded in both surveys were primarily native tree and shrub species. However, low coverage (< 1 %) of the following non-native species was documented during the 2001 surveys (Ray 2003): *Agave missionum*, *Chloris barbata*, *Cocos nucifera, L. leucocephala, T. indica,* and *U. maxima*.

Table 4.3.2.2. Relative frequency (Rel. Freq.) of species occurrence in 2001 and 2008/2009 surveys in coastal forest. Letters following species name indicate life form: herb (H), shrub (S), tree (T), or vine (V). Species are listed from most to least frequently encountered.

Survey Years	Species	Rel. Freq. (%)
2001	*Acacia tortuosa* (S)	100
	Cocoloba uvifera (T)	100
	Comocladia dodanaea (S)	100
	Ernodea littoralis (H)	100
	Heliotropium angiospermum (H)	100
	Hippmane mancinella (T)	100
	Pisonia subcordata (T)	100
	Rochefortia acanthophora (S)	100
	Sideroxylon obovatum (T)	100
	Avicennia germinans (T)	50
	Flueggea acidoton (S)	50
	Heliotropium ternatum (S)	50
	Heteropterys purpurea (V)	50
	Laguncularia racemosa (T)	50
	Tephrosia cinerea (H)	50
2008 / 2009	*Hippmane mancinella* (T)	81.8
	Acacia tortuosa (S)	36.4
	Capparis cynophallophora (T)	36.4
	Krugiodendron ferreum (T)	27.3
	Pisonia subcordata (T)	27.3
	Bursera simaruba (T)	18.2
	Cocoloba uvifera (T)	18.2
	Comocladia dodanaea (S)	18.2
	Gymnanthes lucida (T)	18.2
	Pilosocereus royenii (C)	18.2
	Sideroxylon obovatum (T)	18.2
	Bourreria succulenta (T)	9.1
	Caesalpinia ciliata (S)	9.1
	Capparis indica (T)	9.1
	Cissus trifoliata (V)	9.1

Table 4.3.2.2 (continued). Relative frequency (Rel. Freq.) of species occurrence in 2001 and 2008/2009 surveys in coastal forest. Letters following species name indicate life form: herb (H), shrub (S), tree (T), or vine (V). Species are listed from most to least frequently encountered.

Survey Years	Species	Rel. Freq. (%)
2008 / 2009 (continued)	*Duranta erecta* (S)	9.1
	Erithalis fruticosa (T)	9.1
	Ernodea littoralis (H)	9.1
	Eugenia procera (T)	9.1
	Jacquinia arborea (S)	9.1
	Paspalum laxum (H)	9.1
	Piscidia carthagenesis (T)	9.1
	Pithecellobium unguis-cati (S)	9.1

Damage to the coastal forest related to Hurricane Omar as recorded in the ~300 m^2 plots in 2008 and 2009 ranged from minor (7 plots) to severe (1 plot), with the remaining plots recorded as having moderate damage. Height of the tree canopy was 5 to 7 m tall and the canopy cover ranged from 30% in the severely damaged plot to 85% canopy closure.

Percent cover and 2008 hurricane damage of permanent plot

A total of 287 stems were tagged within the 10 m radius plot dominated by *Hippomane mancinella*, which contributes to 78% of the stem total. A little more than 50% of the 224 manchineel stems in the plot can be characterized as saplings (dbh < 5cm), while the other half is primarily composed of individuals having a dbh between 5 and 15 cm (Figure 4.3.2.2). The tallest trees in the plot reach heights near 11m with ~50% of stems in the plot having tree heights of 5 to 10 meters. The majority of trees in the plot (84%) had little to no damage as a result of Hurricane Omar, but damage varied greatly by species (Table 4.3.2.3). Results of a partial re-visit to the plot in 2016 found that trees located at a distance of 21 to 26 m from shoreline as mapped in 2009 were wet at the base of the trunk from repeated flooding and a clear water line was visible (K. Whelan 2020, personal communication), implicating inundation from tides. As such, tidal flooding and erosion currently impacts approximately half of the plot.

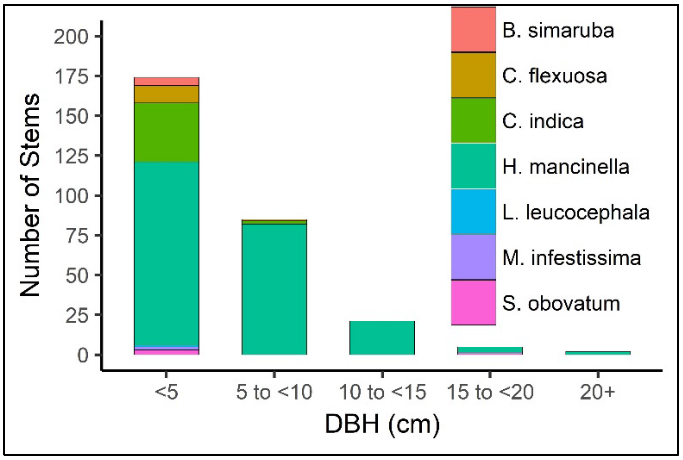


Figure 4.3.2.2. Total number of stems in each 5 cm DBH category by species in the 10-meter radius permanent plot (data collected by SFCN in 2008/2010).

Table 4.3.2.3. Total number of stems of each species occurring within the 10 m radius permanent plot and the percentage of those stems having moderate (2) or major (3,4) damage from Hurricane Omar as assessed by SFCN (2008/2010).

Species	Number of Stems	Percent Damaged (%)
Bursera simaruba	5	60
Capparis flexuosa [a]	12	0
Capparis indica	39	46
Hippomane mancinella	224	9
Leucaena leucocephala	1	0
Malpighia infestissima	2	100
Sideroxylon obovatum	4	75

[a] stems of *C. flexuosa* were only tagged for approximately half of the permanent plot area

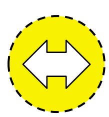
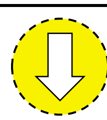
Threats and Stressors

Threats and stressors include habitat loss from coastal erosion, extreme weather events, including windstorms, droughts, hurricanes, sea level rise, tsunamis, and continued introduction of non-native invasive plant species. Of these, the most pressing include the combined impacts of sea level rise and storm surge events. The low elevation and coastal proximity of the forest make it extremely vulnerable to these threats, which result in inundation and erosion. The limited area of this forest (< 4 ha) makes any loss in extent significant. Non-native invasive species, especially *L. leucocephala* and *U. maxima*, are of particular concern as they are still present on the island in adjacent habitats. Disturbance from hurricanes and storm-washed debris from St. Croix have continued to bring exotic landscape plants to the island, resulting in further competition in this limited habitat (Z. Hillis-Starr 2020, personal communication). Additionally, extensive overgrowth of a vine, *Cissus* sp., has been observed smothering mature trees along northwest coastal area following damage from Hurricanes Irma and Maria (Z. Hillis-Starr 2020, personal communication). Potential future expansion of mangrove species into coastal forest is likely in areas adjacent to the salt pond as sea level continues to rise.

<u>Data Needs and Gaps</u>
Currently, only one 10-meter radius permanent plot has been established in the northwest area of coastal forest on BUIS. The establishment of additional plots in this community is recommended and would allow for future change detection of species composition and percent cover. The recent decreases in the extent of the community is very concerning given the limited remaining amount of this habitat on Buck Island. Impacts to the forest from the 2017 hurricane season exposed areas for re-colonization of non-native invasive species and will be addressed in newly funded project in FY 2020/2021 (NPS 2020). Treatment will enable NPS to re-quantify the extent and condition of non-native invasive plants on BUIS and provide information to reduce the potential for further spread of these species into the native plant community.

<u>Overall Condition</u>
To assess the condition of the coastal forest, we used community extent as an indicator and considered two metrics: change in species composition and change in percent cover. Based on the results of plot-level species occurrence and cover data, we conclude that the species composition of the coastal forest has changed little between the reference year (2001) and the most recent inventory in 2010 (Table 4.3.2.4). However, the differences between survey methodologies constrain the likelihood of change detection for this metric and our confidence in any trend is low. For the percent cover metric, we consider the condition to be moderate but deteriorating. However, we have low confidence in the assessment as it was not possible to directly compare percent cover between the 2001 and the 2008 surveys. The observed impacts to the forest from tidal inundation are very concerning and require expanded monitoring to quantify the extent of loss.

Table 4.3.2.4. Graphical summary of status and trends for Coastal Forest within the framework category Terrestrial Plants, including rationale and reference condition.

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Coastal Forest	Community Extent (Change in species composition)		Species composition appears similar to the 2001 reference conditions. The forest remains dominated by manchineel. However, confidence in trend detection is low given the differences between survey methodologies.
	Community Extent (Change in cover)		Percent cover has declined since 2001 as a result of tidal inundation and subsequent erosion. The magnitude of the decrease has not yet been quantified.

<u>Sources of Expertise</u>
- Eleanor Gibney, St. John, USVI
- Gary Ray, St. John Land Conservancy, St. John, USVI
- Brooke Shamblin, NPS South FL Caribbean I & M Network (SFCN), Palmetto Bay, FL

- Kevin Whelan, PhD, NPS South FL Caribbean I & M Network (SFCN), Palmetto, Bay, FL
- Zandy Hillis-Starr, Resource Manager BUIS

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Moser, J. G., K. R. T. Whelan, R. B. Shamblin, A. J. Atkinson, and J. M. Patterson. 2010. Buck Island Reef National Monument, U.S. Virgin Islands, vegetation mapping project, 2009. Natural Resource Technical Report. NPS/SFCN/NRTR-2010/293. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2020. Florida/Caribbean EPMT Fiscal Year 2020 Project Application: Buck Island Reef National Monument – Post-Hurricane Re-Treatment 2020. 6 pp.

Ray, G. 2003. Vascular plant inventory and mapping of Buck Island Buck Island Reef National Monument St. Croix, U.S. Virgin Islands. Cooperative agreement between the University of the Virgin Islands and U.S. Department of the Interior National Park Service South Florida / Caribbean Network. DRAFT.

Woodbury, R., and E. Little. 1976. Flora of Buck Island Reef National Monument (U.S. Virgin Islands). USDA Forest Service Research Technical Paper ITF-19. Institute of Tropical Forestry, Rio Piedras, Puerto Rico.

4.4. Marine plants

4.4.1. Seagrasses

This section reviews the condition of seagrasses at Buck Island Reef National Monument (BUIS). The condition assessment considers 10 years of data, collected by NOAA (2001–2010) (Caldow et al. 2015), to assess the status of seagrasses in the park. The condition of seagrasses is typically evaluated using metrics that detect changes in abundance (percent cover), productivity, and composition. Temporal trends for seagrass abundance (percent cover) during the referred period were evaluated; temporal trends in productivity and composition could not be evaluated due to lack of data, but baseline values are provided in this report.

Description

Seagrasses create a foundation for some of the most productive ecosystems in the world (Duarte and Chiscano 1999), providing habitat and forage for an array of marine organisms (Adams et al. 2006), including green turtles (Figure 4.4.1.1; See Ch. 4.7.2 Sea Turtles). Several ecosystem services are provided by seagrass meadows, including sediment stabilization (thus protecting shorelines from storms, reducing water turbidity for adjacent ecosystems like coral reefs, etc.), long-term carbon storage, and developmental habitat for several U.S. commercial fishery species (Adams et al. 2006, Fourqurean et al. 2012), including the Queen Conch (See Ch. 4.6.2 Queen Conch).

Seagrass ecosystems in the Caribbean are typically dominated by *Thalassia testudinum* (turtle grass), but also support mixed assemblages of *Syringodium filiforme* (manatee grass), *Halodule wrightii* (shoal grass), and in some areas, the invasive seagrass, *Halophila stipulacea* (Green and Short 2003, Willette et al. 2014). Species composition and productivity of seagrass meadows varies spatially and temporally (Fourqurean et al. 2001) but, if not subjected to major and frequent disturbances (e.g., hurricanes, boat anchor damage, invasive species), can exhibit consistent, long-term coverage. Thus, measures of seagrass abundance (percent cover), productivity, and composition can be useful indicators of ecosystem condition.

Figure 4.4.1.1. (Left) Seagrass meadows within the marine protected area at Buck Island Reef National Monument (BUIS) support *Thalassia testudinum* (turtle grass), *Syringodium filiforme* (manatee grass), and *Halodule wrightii* (shoal grass). (Right) BUIS seagrass meadows provide habitat and forage for an array of marine organisms, including a recovering population of protected/threatened (ESA listed) green turtles. (Photo credits: Alexandra Gulick).

Approximately 66.5% of the colonized soft bottom (4.06 km^2) at Buck Island Reef National Monument (BUIS) is occupied by seagrass (Costa et al. 2012), with the largest extent of seagrass meadows found to the south of Buck Island. Seagrass coverage at BUIS is classified as continuous (90% to 100% cover) or patchy (10% to <90% cover) (Caldow et al. 2015); with coverage area potentially associated with the presence of nearby reefs (KellerLynn 2011). Percent cover data obtained from seagrass monitoring surveys is a useful resource for evaluating temporal changes and responses to disturbance.

Data and Methods

Changes in seagrass abundance (percent cover) were evaluated using data collected by NOAA between 2001 and 2010 (Caldow et al. 2015); these data are accessible via this link. This dataset has been used in multiple NOAA Technical Memorandums for BUIS, including Pittman et al. (2008) and Costa et al. (2012). Benthic data (percent cover) was collected *in situ* using a 1 m^2 quadrat (Caldow et al. 2015). Geo-referenced observations of three seagrass habitat types [Patchy (10% to 50%), Patchy (50% to 90%) and Continuous (>90%)] produced in 1999 and 2011 by Caldow et al. (2015) are used in the Geographic Analysis (GIS) for this report. Due to the incomplete coverage area of more recent aerial photographs, changes in percent cover of seagrasses at BUIS were not evaluated past 2011 for this report.

Reference Conditions/Values

Baseline data for assessing percent coverage of seagrass meadows at BUIS consists of a set of aerial images captured in 1971 by the NOAA National Ocean Service. Kendall et al. (2004) used this imagery to quantify changes in the spatial distribution of seagrass meadows in the Buck Island Channel (~ 2km to the south of Buck Island) from 1971 to 1999. Kendall et al. (2004) reported approximately 1.33 km^2 (15% of the bottom in the study area) of seagrass coverage in 1971 and 4.34 km^2 (48% of the bottom in the study area) in 1999; a three-fold increase in seagrass coverage area (Figure 4.4.1.2).

Baseline data for assessing seagrass structural complexity (shoot density, biomass, above- and below-ground morphology) and productivity at BUIS was collected during 2017–2018 by Gulick et al. (2020, 2021). A summary of these indicators, in addition to environmental data (benthic water temperature, light access, nutrient availability) for BUIS seagrass meadows during the study period, can be referenced in Gulick et al. (2020) (See Tables 1–3). Baseline data for assessing seagrass community composition (diversity, richness, evenness) is being analyzed and is not yet available to the public domain (Gulick et al. unpublished data).

Invasion of the non-native seagrass, *Halophila stipulacea*, was first documented at BUIS in 2017 (Gulick et al. unpublished data). The invasive seagrass was observed opportunistically at 10 locations (depth range, 1–12m), with patch size ranging from 1m^2 to >100m^2. These locations included native seagrass meadows, the shallow lagoon on the south side of the Buck Island, and just outside the south fore-reef. Estimates of total coverage area of *H. stipulacea* at BUIS have not been determined.

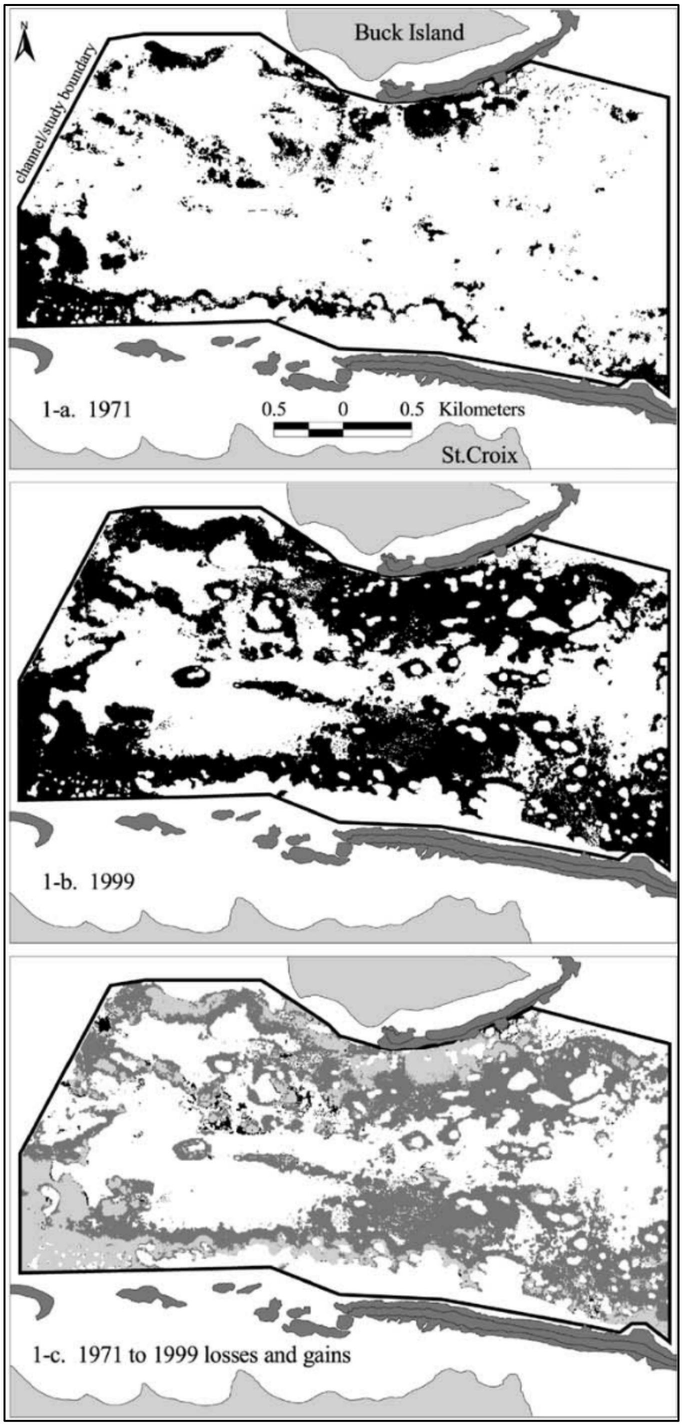


Figure 4.4.1.2. Reference maps of seagrass cover in the Buck Island Channel during 1971 and 1999 (Figure included from Kendall et al. 2004, by permission from Matt Kendall).

Current Condition and Trend

Average percent cover of seagrasses (all species) in soft-bottom habitats was 23.6 % ± 1.6 % across all years sampled (2001–2010) (data provided by Caldow et al. 2015). Seagrass coverage in soft-bottom habitats during this time frame was greater than other benthic species, including hard coral (scleractinian) (16.3 ± 12.0 %), turf algae (10.3 ± 2.6 %), and macroalgae (6.0 ± 0.5 %). During 2001 and 2010, the abundance of seagrass in soft bottom areas averaged 22.4 ± 1.5 % with broad yearly fluctuations in coverage (min 7.4 ± 2.4 % in 2009; max 40.5 ± 4.0 % in 2001; Figure 4.4.1.3). Seagrass (all species) abundance in soft-bottom habitat appears to have decreased overall from 2001–2010, with an average coverage area of 9.43 ± 3.8 % in 2010 (Figure 4.4.1.3). However, differences in sampling frame and distribution could not be accounted for when generating this estimate.

At a larger spatial scale, the GIS analysis reveals little or no changes in seagrass distribution between 1999 and 2011 (Figure 4.4.1.4). Costa et al. (2012) also reported relatively little change in total seagrass cover between 2001 (2.89 km^2) and 2011 (2.702 km^2). However, the seagrass cover reported for 2011 (2.702 km^2) by Costa et al. (2012) is substantially lower than the cover reported for 1999 (4.34 km^2) by Kendall et al. (2004). This comparison cannot be seen as conclusive evidence of seagrass decline in BUIS for multiple reasons (i.e., the deep seagrass meadows in the Buck Island Channel assessed by Kendall et al. (2004) were not included in the 2011 survey; increases in green turtle grazing is also reducing seagrass cover (Gulick et al. 2020, 2021) but does emphasize the need for further monitoring and finer resolution data for BUIS seagrasses.

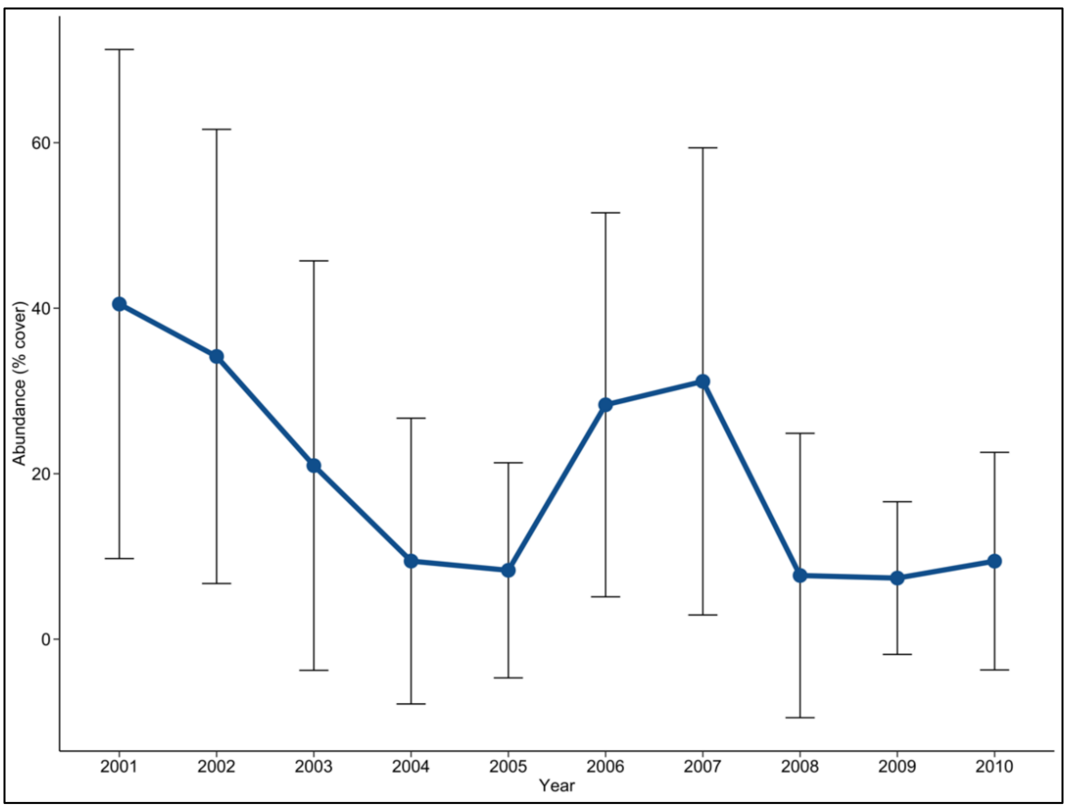


Figure 4.4.1.3. Mean annual abundance of seagrass in soft-bottom habitats at BUIS during 2001–2010. Dataset provided by NOAA (Caldow et al. 2015).

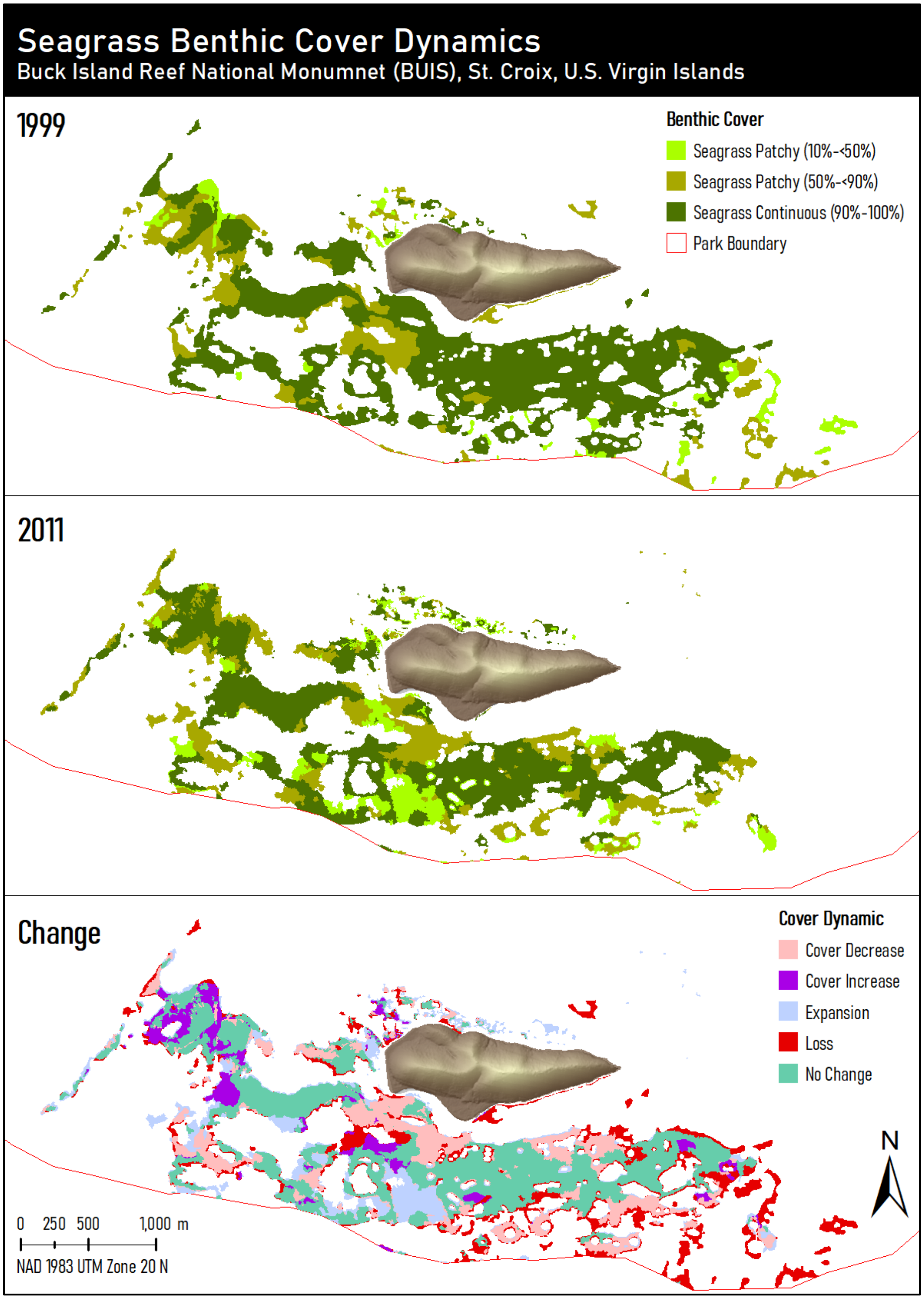


Figure 4.4.1.4. Distribution of seagrass habitat type in 1999 (A) and 2011 (B) and cover change (C) analyzed using Geographic Analysis (GIS). Spatial data provided by NOAA (Caldow et al. 2015).

Threats and Stressors

Hurricanes are one of the major threats to seagrass meadows in the Virgin Islands (Rogers and Beets 2001). From 1979 to 2001, the severe impacts of eight hurricanes on marine ecosystems in St. John and St. Croix were thoroughly documented (Rogers and Beet 2001, Table 1). Although the increased frequency of storms during this time frame had substantial impacts on coral reefs in the area, the seagrass meadows at BUIS did not appear to experience any deleterious effects; perhaps due to the meadows occupying benthic habitats in deeper waters (Kendall et al. 2004). In 2017, Hurricane Maria and Hurricane Irma (the strongest storm recorded in the Atlantic) passed by St. Croix and Virgin Gorda causing catastrophic damage to many marine ecosystems (Rogers 2019). However, seagrasses at BUIS were largely spared from the damage, with moderate burial occurring only in meadows at the shallowest (<2 m) depths (NPS, unpublished data). Although seagrass ecosystems are adapted to withstand periodic disturbance events like hurricanes, the increased frequency of major hurricanes due to anthropogenic climate change in recent years, poses a major threat to the stability and resilience of these ecosystems (Short and Neckles 1999, Rogers 2019).

Increases in water temperature due to anthropogenic climate change is also a potential threat to seagrasses (Collier and Waycott 2014) and has been linked to widespread loss in some areas (Thomson et al. 2015). Although the reference data collected for benthic water temperature at BUIS is within the tolerance range of the native species (Gulick et al. 2020), continued monitoring of this environmental parameter (in addition to irradiance, salinity, and nutrient availability) is essential for documenting seagrass responses to environmental changes.

Recent documentation of a non-native seagrass species (*Halophila stipulacea*) at BUIS in 2017 (Gulick et al. unpublished data), in addition to Salt River Bay National Historical Park and Ecological Preserve in 2015 (National Park Service 2015), poses a significant threat to native seagrass meadows in the St. Croix parks. *Halophila stipulacea* is a stress-tolerant species that can maintain productivity over a wide range of salinity (Oscar et al. 2018), water depth (Sharon et al. 2011), and light availability (Sharon et al. 2011); allowing it to successfully outcompete native seagrass species (Willette et al. 2014). Invasion of *H. stipulacea* in Caribbean seagrass communities has been linked to the degradation of ecosystem services provided by seagrass meadows, including reduced sediment stabilization (James et al. 2020) and potentially decreased forage quality for green turtles (Christianen et al. 2019). This shift in seagrass species dominance to a non-native species will undoubtedly continue to have potentially severe implications for the conservation and management of Caribbean seagrass ecosystems, including those at BUIS.

Green turtle populations are recovering in many areas due to long-term conservation efforts (Mazaris et al. 2017), including the Caribbean, and at BUIS (See Ch. 4.7.2 Sea Turtles). The recovery of green turtles has resulted in the return of some seagrass meadows to a natural grazed state, raising concerns for overgrazing (Fourqurean et al. 2019). Green turtle grazing fulfills an important role in regulating the productivity of Caribbean seagrass meadows, including those at BUIS (Gulick et al. 2020, 2021). Although seagrass meadows at BUIS are able to support current levels of grazing intensity (Gulick et al. 2020, 2021), continued monitoring is necessary, particularly since the invasion of *H. stipulacea* will likely degrade the quality of green turtle foraging habitats (Christianen et al. 2019).

Boat anchoring and physical damage via anthropogenic activity is another potential factor affecting seagrass meadows at BUIS, particularly near the southern and eastern boundary. However, the expansion of the BUIS boundary in 2001 and the establishment of a restricted anchoring zone has helped mitigate these effects.

Data Needs and Gaps

A long-term seagrass monitoring program is necessary to effectively assess the temporal and spatial dynamics of seagrass ecosystems at BUIS. SFCN recently published a seagrass protocol for conducting long-term stratified random surveys in all parks in the Virgin Islands – seagrass surveys will occur every three years at BUIS. A monitoring program will assist managers with evaluating the effectiveness of current regulations, impacts of visitor-use (anchoring vs. no-anchoring), and the impacts of threats/stressors (e.g., hurricanes, water quality issues, increasing ocean temperatures, and invasive species (*Halophila stipulacea*)).

The following data needs and gaps have been identified for seagrasses at BUIS:

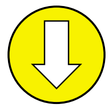
1. Current benthic habitat surveys and aerial photographs with complete coverage of soft-bottom habitats are necessary to assess changes in native seagrass abundance beyond 2011.
2. Additional data collection is needed to assess the status and trend of the other condition metrics identified for native seagrass meadows, including measures of seagrass structural complexity (e.g., shoot density, morphology, biomass), productivity, and community composition (diversity, richness, evenness).
3. Additional data collection of environmental conditions known to affect the productivity and stability of seagrass meadows (benthic water temperature, light access at canopy-level, nutrient availability) will be important in assessing long-term trends in seagrass condition.
4. A current assessment (benthic surveys) of the distribution of H. stipulacea to document the extent of the invasion in native seagrass meadows.
5. Continued monitoring of grazing pressure by the recovering green turtle population (See Ch. 4.7.2 Sea Turtles) will be important to further evaluate the sustainability of increased grazing intensity and its potential role in facilitating the H. stipulacea invasion.

   The establishment of a mooring field near the southern and eastern boundaries would nearly eliminate the effects of boat anchoring in seagrass meadows.

Overall Condition

Overall, the state of seagrasses at BUIS warrants moderate concern with a degree of uncertainty associated with the assessment (Table 4.4.1.1). Upon evaluating existing datasets for seagrass abundance and distribution at BUIS (provided by Kendall et al. 2004 and Caldow et al. 2015), results suggest that overall, the abundance of seagrasses at BUIS has declined from 1971 to 2011. Given the impending threat associated with the recent invasion of *Halophila stipulacea*, recent impacts of two major hurricanes (Rogers 2019), and changes in natural grazing pressure (Gulick et al. 2020), additional monitoring is warranted for assessing the current condition of seagrasses at BUIS. The lack of comparative data for evaluating the other indicators of seagrass health (i.e., productivity, diversity, etc.), limits the ability to identify mechanisms behind the decline in seagrass abundance and assess the current condition of seagrasses with full confidence.

Table 4.4.1.1. Graphical summary of the status and trend for seagrass abundance (percent cover).

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Seagrass	Abundance (% Cover)		The cover of seagrasses increased from 1971 (1.33 km^2) to 1999 (4.34 km^2) and declined to (2.70 km^2) in 2011. The lack of comparative data to evaluate the other indicators of seagrass health, limits the ability to assess potential mechanisms behind this decline in seagrass abundance. Due to the impending threat associated with the invasion of *Halophila stipulacea*, impacts of two major hurricanes, and changes in natural grazing pressure by seagrass herbivores, additional monitoring is critical to assessing the current status of seagrass meadows at BUIS.

<u>Sources of Expertise</u>

- Matt Kendall, PhD, NOAA/NOS/NCCOS/Marine Spatial Ecology Div, Silver Spring, MD
- Alexandra Gulick, PhD Candidate, University of Florida, Gainesville, FL

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4.5. Terrestrial Vertebrates

4.5.1. Reptiles

This section reviews the condition of the terrestrial reptiles in BUIS. The condition assessment considers data for the years 2008, 2013–2015, and 2019, as reported by Lee Fitzgerald et al. (2015), Nicole Angeli et al. (2016, 2018), and Kristen Ewen (2020) to assess the status of the St. Croix Ground lizard, *Pholidoscelis polyps*. The condition of reptile populations is typically evaluated using metrics that detect changes in abundance, distribution, and reproductive success. The condition metrics selected for this resource includes those listed above. Temporal trends in condition metrics were evaluated.

<u>Description</u>

The critically endangered *Pholidoscelis polyps,* St. Croix ground lizard, is one of five species of terrestrial reptiles found on Buck Island. Ameivas are whiptailed lizards in the family Teiidae. The St. Croix ground lizard is a small-sized Ameiva with a maximum snout to vent length of 64 mm in males and 69 mm in females (Schwartz and Henderson 1991) (Figure 4.5.1.1). It is an active forager, eating a variety of invertebrates, and spends a large portion of time on thermoregulation (Meier et al. 1993). The species is a habitat generalist but prefers open-forested habitat, which provides a mix of sun and shade and abundant leaf litter (McNair 2003, McNair and Lombard 2004). Considered among the rarest lizards in the world, they are endemic to St. Croix and the surrounding cays (Schwartz and Henderson 1991). No longer found on St. Croix, the last individual was observed on the west end in 1968 (Philobosian and Ruibal 1971), and remnant populations now occur on the cays surrounding St. Croix: Ruth Cay, Protestant Cay, Green Cay, and Buck Island.

Although not historically recorded from Buck Island, *P. polops* quite possibly occurred on the island prior to introduction of the Indian mongoose, *Herpestes auropunctatus*, in 1912 (Philibosian and Ruibal 1971). In 1968, following removal of mongoose from the west end of Buck Island, 16 individuals were introduced from nearby Protestant Cay and began breeding on the island (Philibosian and Ruibal 1971). However, by 1974 after cessation of mongoose trapping in 1970, no individuals could be located (Philibosian and Yntema 1976). In 1977, the species was federally listed as endangered (USFWS 1977) and the subsequent species recovery plan recommended translocation to Buck Island following predator removal (USFWS 1984). During the 1980s and 1990s, the NPS and USFWS undertook an extensive program to remove mongoose from BUIS (Z. Hillis-Starr 2020, personal communication). Exotic predators, including the mongoose and later the tree rat, *Rattus rattus*, were eliminated from the island by 2001 (Witmer and Hillis-Starr 2002, Witmer et al. 2007). While bi-annual snap-trap line assessments have resulted in an occasional individual tree rat capture, a reproductive population has not re-established on the island (K. Ewen 2020, personal communication). In 2008, *P. polops* was re-introduced to the Buck Island from a population on Green Cay in the National Wildlife Refuge (Treglia and Fitzgerald 2010). Individuals were placed in eight 10 x 10 m enclosures, located in coastal forest habitat in the northwest corner of the island, to facilitate habituation and enable daily monitoring of the translocated population (Figure 4.5.1.2).

Figure 4.5.1.1. St. Croix ground lizard, *Pholidoscelis polops*, on Buck Island. Photo credit: Nicole Angeli.

Data and Methods

The indicator used is population, which includes three measures: abundance, distribution, and reproductive success. Abundance includes current and future population estimates. The 2013 population estimate was based on patterns of presence and absence and the number of individuals observed at randomly selected monitoring sites five years after translocation during a 63-day period between March and May 2013 (Fitzgerald et al. 2015). Future abundance was predicted using an N-mixture model with a negative binomial distribution (Angeli et al. 2018). The distribution metric considered expansion of the population across the island beyond locations of initial release in 2008. Patterns of dispersal were quantified using percent occupancy at sites (40 m diameter circular plots) during five biannual / annual surveys (May 2013–October 2015) (Figure 4.5.1.2). Surveys used a double-observed methodology and all sites were samples five times over the course of three days in each sampling season (Angeli et al. 2018). The future spatial distribution of the population was predicted from the 2013 population estimate with spatial interpolation in ArcGIS 10.1 on 30 m grid cells using a model that included environmental covariates including habitat type (Angeli et al. 2018). Reproductive success was assessed by estimating the number of generations required to reach the observed number of individuals as assessed during the 2013 surveys. (Fitzgerald et al. 2015). In October 2019, a random subset (n = 15) of the sites surveyed during the 2013–2015 study were resampled for lizard occupancy and abundance and estimates of current lizard abundance and occupancy were modeled using the new data (K. Ewen 2020, personal communication) (Figure 4.5.1.3).

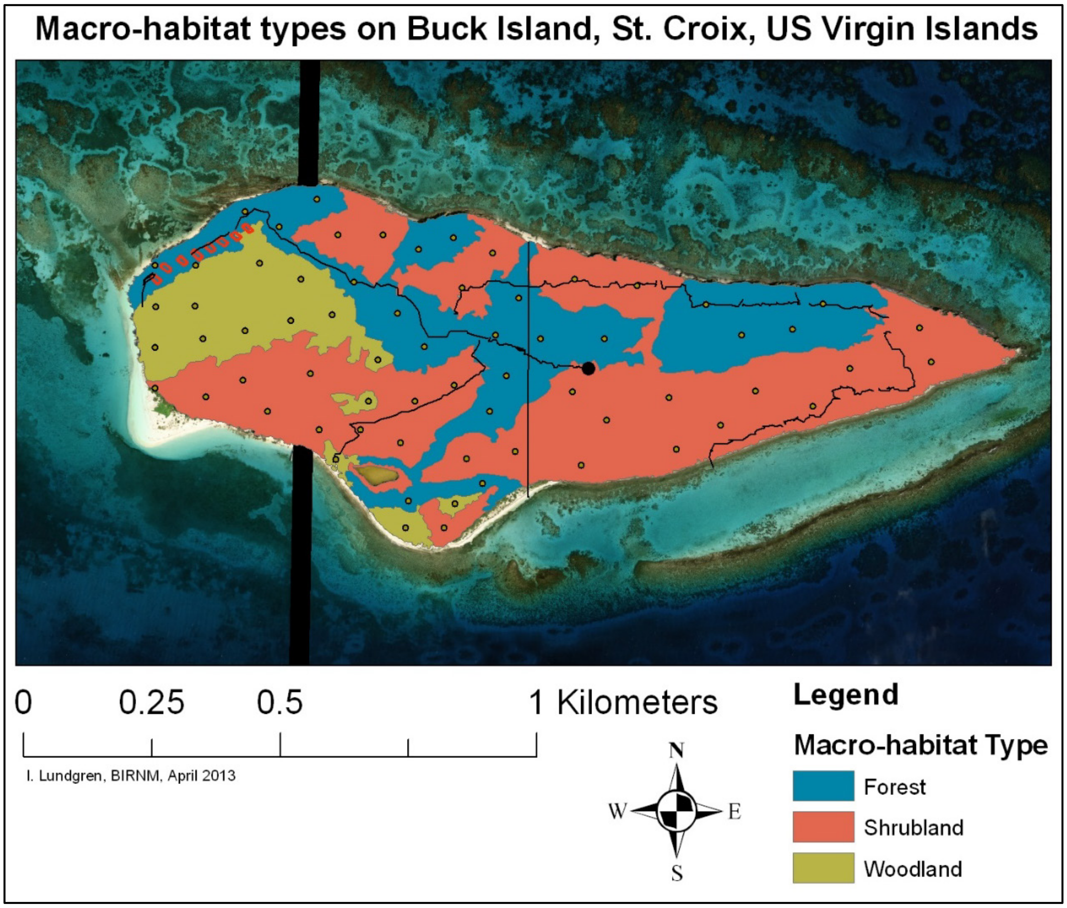


Figure 4.5.1.2. Enclosure locations (8 red rectangular polygons on west side of BUIS) and occupancy monitoring survey locations (yellow points) for *P. Polops* re-introduction monitoring (Angeli 2013).

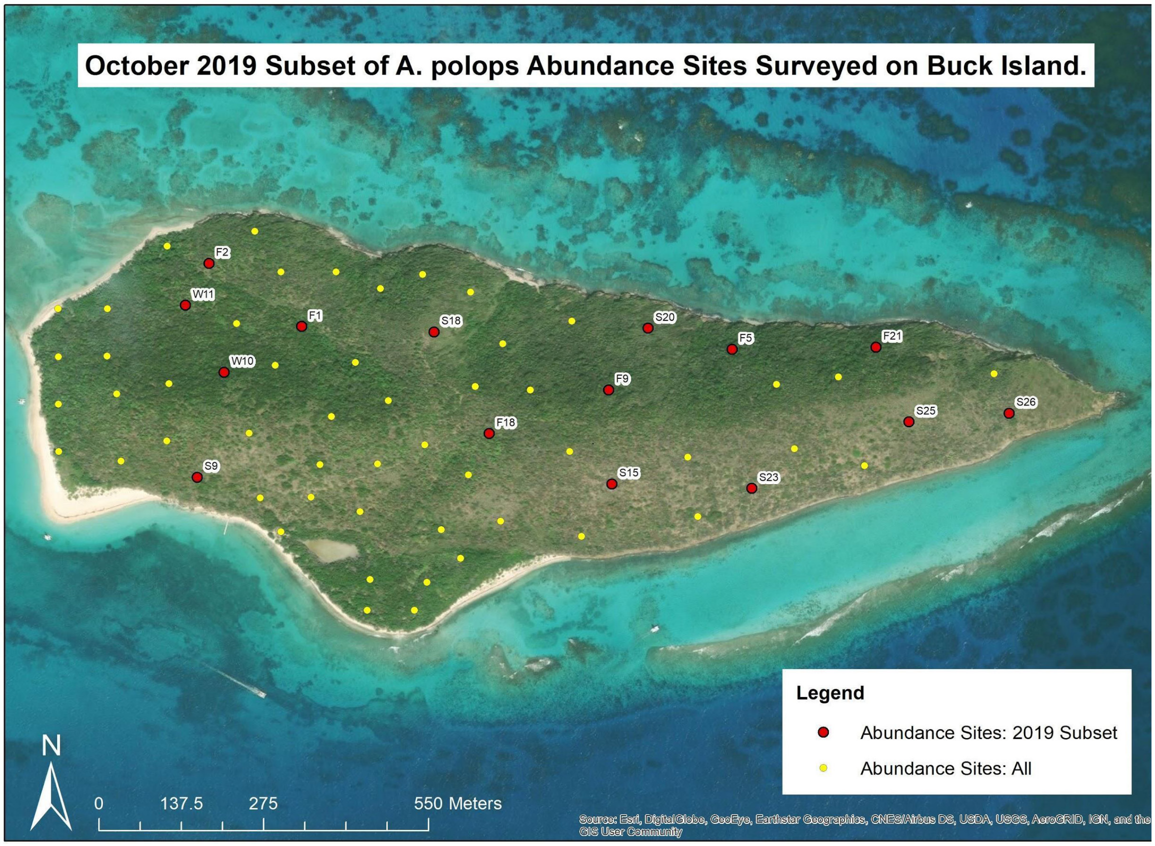


Figure 4.5.1.3. Ground lizard abundance survey locations (2013–2015) with the randomly-selected 2019 survey locations indicated in red. Map provided by K. Ewen.

Reference Conditions/Values

The reference condition is the population abundance and distribution at the time of translocation in 2008. Fifty-seven adult lizards (25 males and 32 females) were translocated to the coastal forest in the northwest corner of Buck Island from the population on Green Cay in the National Wildlife Refuge (Treglia and Fitzgerald 2010). Some females were gravid at time of translocation.

Current Condition and Trend

Abundance of *P. polyps* has steadily increased from the time of re-introduction. As of May 2013, the population was estimated at 1,473 (CI: 940–1,802) individuals (Fitzgerald et al. 2015). Modeling results predicted a post-dispersal population on BUIS reaching 8,336 individuals (95% CI, 6,590–10,501) (Angeli et al. 2018). The current population on Buck Island is larger than the combined estimates from the three other islands where *P. polops* is located (Meier et al. 1993, McNair 2003, McNair and Lombard 2004, McNair and Mackay 2005) (Figure 4.5.1.4). Potential future population size could be up to five-fold of the current population estimate with individuals inhabiting a large proportion of the island (Angeli et al. 2018). Models predict that the carrying capacity for the St. Croix Ground Lizard on Buck Island will range between 6,590–10,501 individuals (Angeli 2016, Angeli et al. 2018). Species abundance was negatively correlated with island elevation, perhaps explained by the dry and hot conditions present at ridge tops, but also indicative of species dispersal pattern from the release sites (Angeli et al. 2018). Initial results of modeling from the most recent abundance surveys conducted in 2019 indicate a population on BUIS ranging between 10,000 and 12,000 individuals (K. Ewen 2020, personal communication).

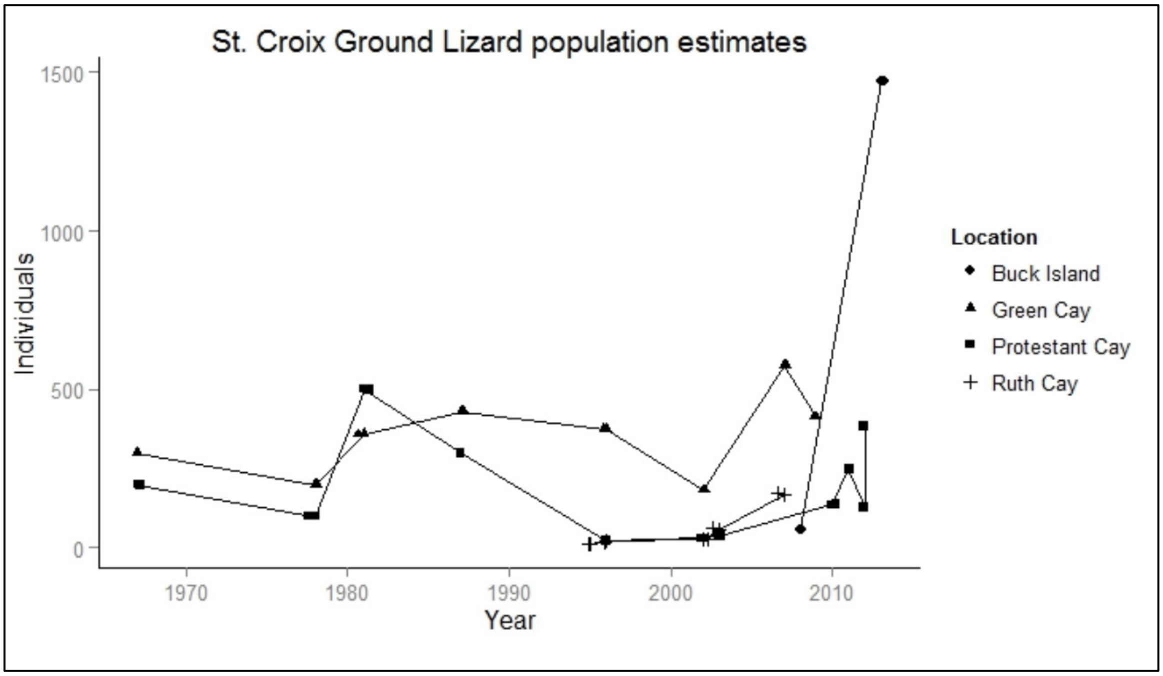


Figure 4.5.1.4. Population estimates of the St. Croix Ground Lizard by island (from Angeli 2016).

Distribution across the island of *P. polyps* increased from 41% site occupancy in May 2013 to 87% site occupancy as of October 2015 and dispersal is predicted to all habitats on Buck Island (Angeli et al. 2018) (Figure 4.5.1.5). Population is increasing its range by 5–10% every six months. While individuals were observed in all habitat types during the aforementioned surveys (2013–2015), they were found more often in wetter woodland sites (41%), compared to forest (34.3%) and shrubland (24.7%), which were typically drier. A negative relationship between elevation and distance to release site in that study indicated that the species dispersed around rather than over the drier, hotter peaks of the island (Angeli et al. 2018). Results the 2019 abundance surveys indicate that the species now occupies the entirety of the island, as individuals were found at all sites, including sites where they were previously not observed (K. Ewen 2020, personal communication). Additionally, it is likely that individuals are having to disperse to less suitable habitats as intraspecies competition for space increases; juveniles have been observed in locations directly adjacent to the beach (K. Ewen 2020, personal communication).

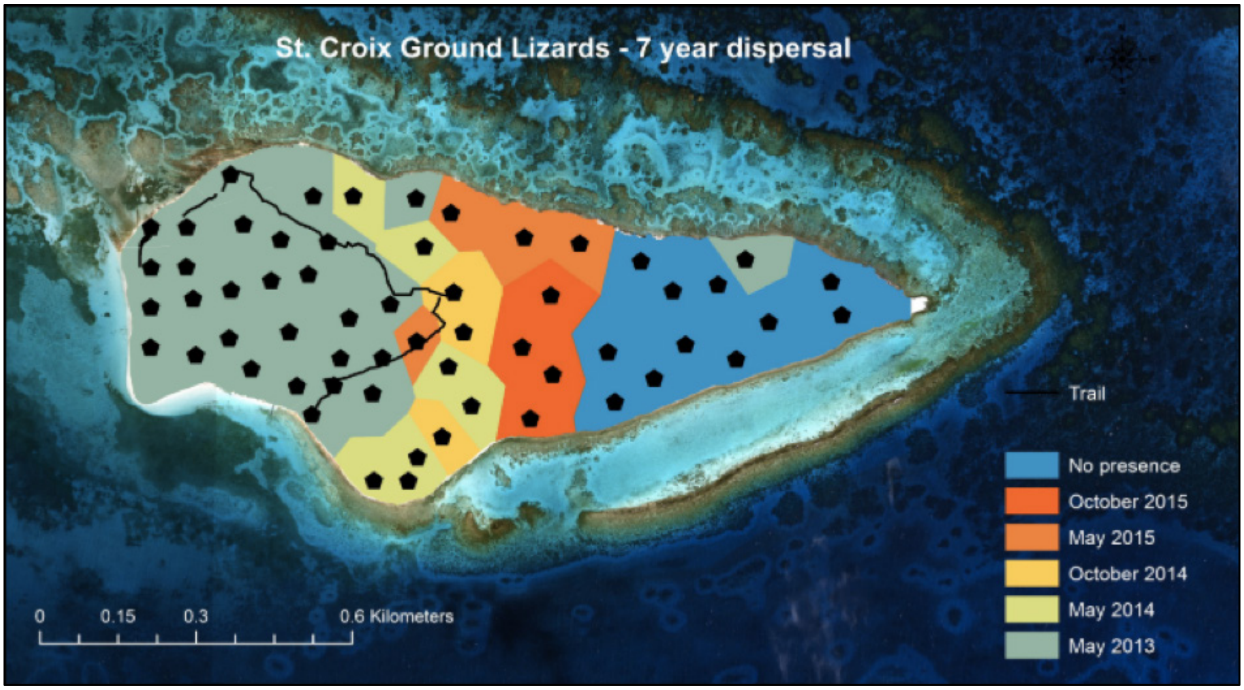


Figure 4.5.1.5. Dispersal of St. Croix Ground Lizard across BUIS from May 2013 to October 2015 (from Angeli 2016).

Reproductive success, while not explicitly quantified, can be roughly estimated given the number and life stage of individuals observed in 2013: 354 individuals observed, 24% of which were juveniles and 74% adults. Assuming a generation time of 18 to 24 months, at least 2 generations had been produced since re-introduction (Fitzgerald et al. 2015). The increase in abundance and eastward dispersal of individuals into new habitat, and now across the entirety of the island, suggest the population is reproducing at a rate sufficient to maintain itself.

Threats and Stressors

Limited habitat, potential re-introduction of non-native predators, fire, droughts, hurricanes and associated storm surge threaten the species. Habitat condition is decreased by hurricane damage to coastal forests and dry tropical forests. Given the restriction of the species to a small island, competition for resources will put an upper limit on population expansion. Individuals will be forced to disperse into less suitable habitats, including those frequented by humans. Visitor interaction surveys, conducted in 2019, documented indirect interactions between humans and lizards. The results of this study indicated that visitors to BUIS are not currently negatively impacting the health or success of the translocated population (K. Ewen 2020, personal communication).

Data Needs and Gaps

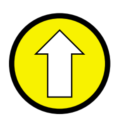
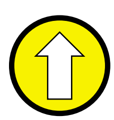
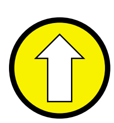
Continued monitoring of population abundance and distribution is recommended given the globally endangered status of the species and the vulnerable condition of the coastal forest (ground lizard's preferred habitat). Angeli et al. (2018) recommend abundance monitoring at least every 5 years. Ongoing habitat restoration efforts which include the removal of invasive trees and grasses, and continued efforts to increase native tree diversity across the island as part of the NPS Tropical Dry

Forest Project (BUIS 178837, 2017–2019) will be important for providing the optimal habitat conditions. Continued monitoring for the presence of non-native mammalian predators with snap-trap surveys and the addition of pneumatic traps (2019) will provide information on early detection of exotic species threats (K. Ewen 2020, personal communication). Studies are currently underway to evaluate any potential impacts that visitor use may have on the ground lizard habitat use and behavior.

<u>Overall Condition</u>

To assess the condition of the St. Croix ground lizard, we used population as an indicator and considered three metrics: abundance, distribution, and reproductive success. Based on the results of intensive post-translocation population monitoring, we concluded that the resource is of moderate concern (Table 4.5.1.1). The trend in condition based on abundance, distribution, and reproductive success metrics has improved since the time of translocation (57 adults to current estimate of over 10,000 individuals that have colonized island wide). We have high confidence in the assessment of all indicators. The results of multi-year monitoring and population modeling is very encouraging. However, given the species' globally endangered status and the existence of populations on only four small islands surrounding St. Croix, continued monitoring of the species will prove essential. Current and future threats to the species, especially those resulting from impacts to species' habitat, e.g., coastal forest loss from hurricanes and sea level rise, necessitate close monitoring and continued native plant restoration of coastal and dry tropical forests on the island to ensure available habitat.

Table 4.5.1.1. Graphical summary of status and trends for the St. Croix ground lizard within the framework category Terrestrial Vertebrates.

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
St. Croix ground lizard	Population (Abundance)		Abundance of individuals is increasing throughout all habitats. Estimates are robust and based on double observer surveys of sites located throughout the entirety of the island. As a result of the success of reintroduction efforts on BUIS, but given the species' globally endangered status, we classify it as of moderate concern.
	Population (Distribution)		Individuals have dispersed across the island beyond the original release location and are predicted to inhabit all areas of the island given environmental conditions on BUIS.
	Population (Reproductive Success)		The population is reproducing, leading to dispersion across the island and an increase in abundance to a current estimate of more than 10,000 individuals. However, net reproductive rates for the species have not been determined.

Sources of Expertise

- Nicole Angeli, Ph.D., dissertation research at Texas A&M, Director of Department of Planning and Natural Resources, USVI
- Kristen Ewen, National Park Service, Technician BUIS
- Lee Fitzgerald, Ph.D., Texas A&M University
- Zandy Hillis-Starr, National Park Service, Resource Manager BUIS
- Michael Treglia, master's research at Texas A&M, The Nature Conservancy

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Witmer, G. W., F. Boyd., and Z. Hillis-Starr. 2007. The successful eradication of introduced roof rats (*Rattus rattus*) from Buck Island using diphacinone, followed by an irruption of house mice (*Mus muculus*). Wildlife Research 34:108–115.

4.6. Marine Invertebrates

4.6.1. Coral

This section reviews the condition of the stony corals and coral reefs in BUIS. The condition assessment considers data provided by the South Florida and Caribbean Inventory and Monitoring Network of the US National Park Service (2000–2017) (SFCN data was accessed via irma.nps.gov/DataStore/), the USVI Territorial Coral Reef Monitoring Program (2001–2016) (TCRMP data available from https://sites.google.com/site/usvitcrmp/available-data), the National Coral Reef Monitoring Program (2015, 2017, 2019) (NCRMP, data available from https://www.coris.noaa.gov/monitoring), as well as data sets from individual researchers in the areas immediately surrounding Buck Island and its eastern barrier reefs (1976–2000). 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 includes benthic cover, coral health (bleaching, disease, partial mortality, reproduction), and temperature. Abundance and skeletal growth were not included in this assessment due to lack of data. Temporal trends in condition metrics were evaluated for time-series measurements.

Description

The Buck Island Reef National Monument (BUIS) was specifically established in recognition of the surrounding vibrant coral reefs. In particular, the large stands of elkhorn coral (*Acropora palmata*) that create the well-developed bank-barrier reef on the eastern two-thirds of the island and extensive coral hard bottom habitat extending along the north side of Buck Island as well as highly complex and diverse deep patch reefs to the south of Buck Island (Figure 4.6.1.1). The emergent barrier reef surrounding Buck Island creates a shallow sand bottom lagoon and intricate shallow coral grottos which have provided visitors the opportunity to visit and experience the coral reef safely through daytime boat/snorkel trips guided by park concessionaires. These daily trips bring up to 40,000 visitors to the monument annually (NPS 2016). Snorkeling and underwater observations of the natural marine life along the Buck Island Reef underwater trail and SCUBA areas are a major focus of these trips.

In addition to the barrier reef, the expanded BUIS protected area supports a wide variety of reef types, including patch reefs, spur and groove formations, and shallow to relatively deep mesophotic star coral reefs. Hardbottom pavement habitats are also common and have been mapped from shallow to deep areas of the monument. They are composed of a Pleistocene-Holocene antecedent pavement overlain with sessile epibenthic organisms, such as corals, sponges, and gorgonians. This condition assessment evaluates conditions of corals and coral reef resources in BUIS from approximately 1970 to 2017.

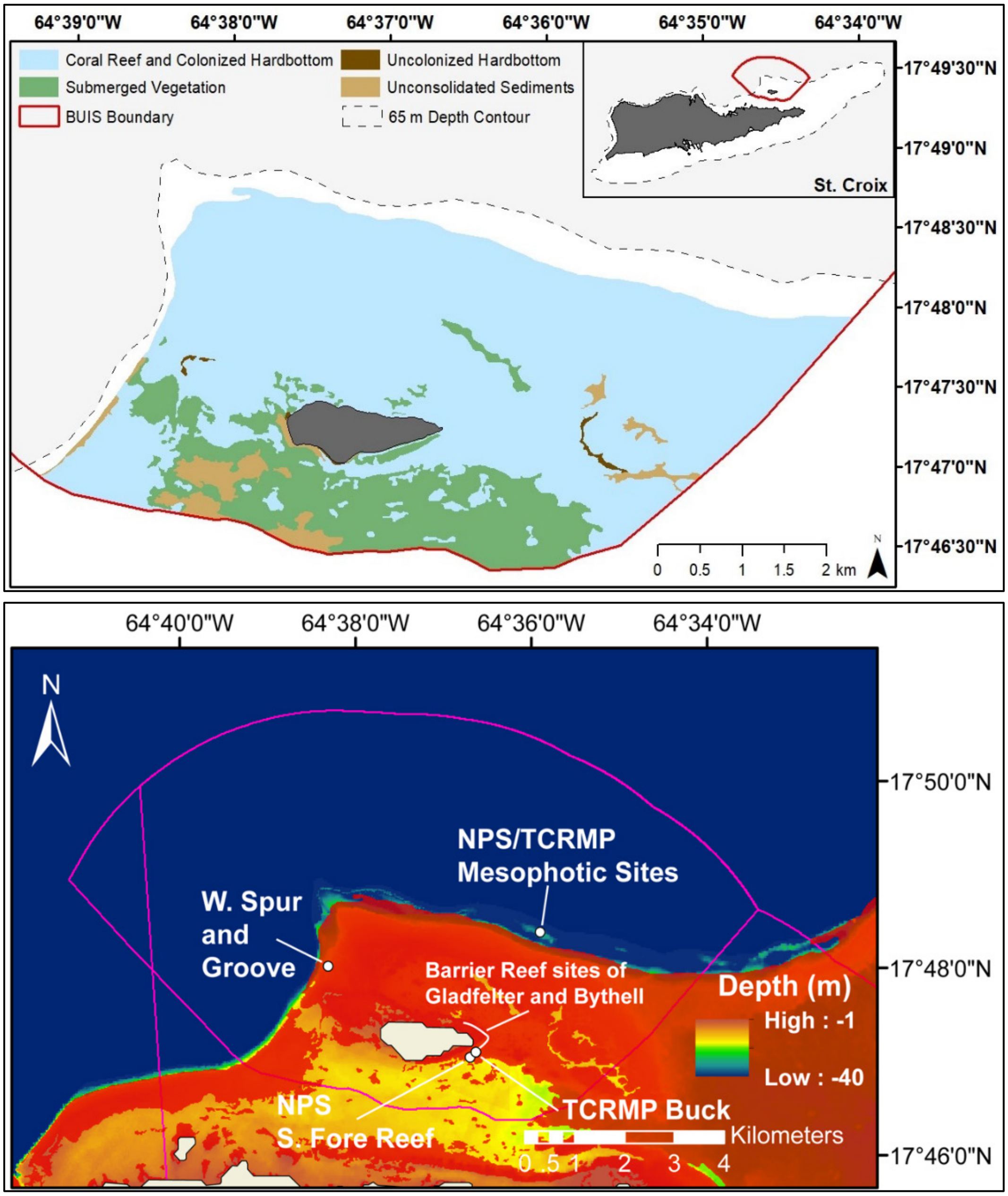


Figure 4.6.1.1. The Buck Island National Park (BUIS) (top), U.S. States Virgin Islands boundary (inset), with major benthic cover categories designated. Map of BUIS (bottom), showing locations of permanent monitoring sites of the NPS South Florida Caribbean Inventory & Monitoring Network and the USVI Territorial Coral Reef Monitoring Program. Areas in bright red are coral reef or hardbottom habitats overlain on shallow water bathymetry. These hardbottom areas support large populations of stony corals. Areas in blue are deeper than 40 m. Pink boundaries are the Buck Island National Monument (center) and the St. Croix East End Marine Park (below). Areas deeper than 30 m are poorly mapped and characterized. Bathymetry and habitat designations accessed from NOAA (August 8, 2019; https://products.coastalscience.noaa.gov/collections/benthic/default.aspx)

Data and Methods

This section describes the data types and methods used in establishing coral reference values as well current conditions and trends. There have been numerous short- and long-term monitoring efforts for corals in BUIS since the 1970s (Figure 4.6.1.1, Figure 4.6.1.2, Table 4.6.1.1).

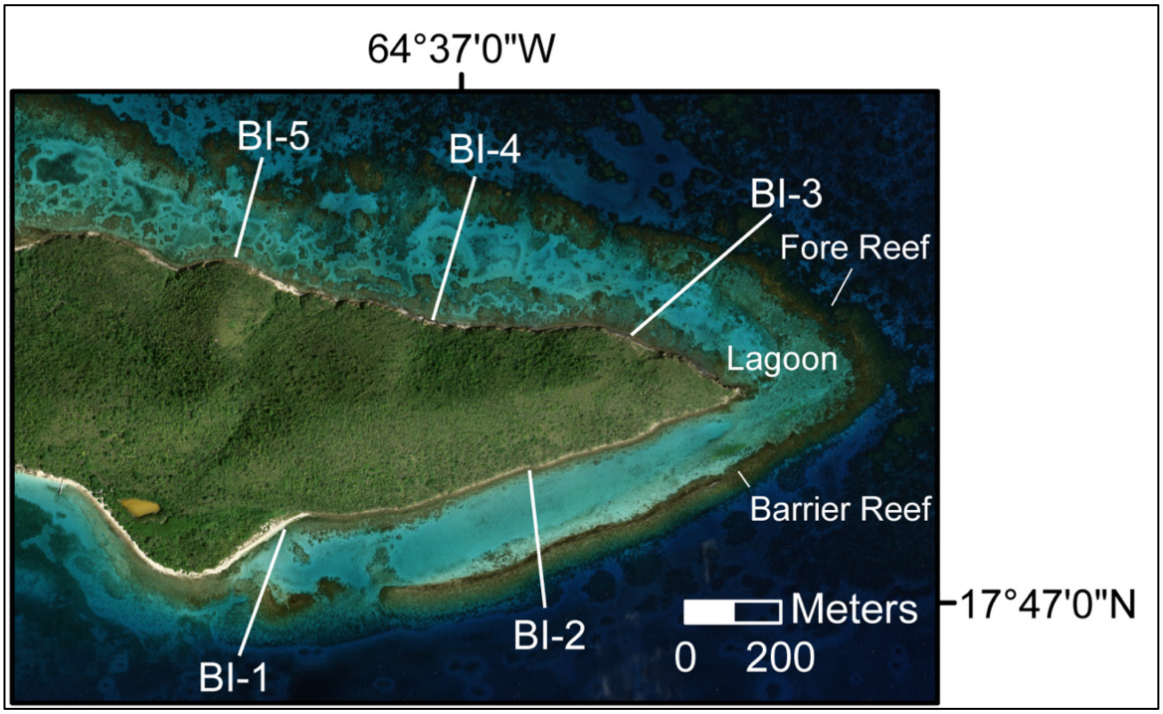


Figure 4.6.1.2. Close up aerial photograph of Buck Island showing locations of transects established by Gladfelter et al. (1977). Transects extended from the shoreline across the barrier reef. Imagery from NOAA 2006–2007 natural color orthophotos covering the islands of Puerto Rico, Culebra, Vieques, St. Thomas, St. John, and St. Croix (ads40_pr_rgb).

Table 4.6.1.1. Coral reef monitoring sites of the NPS South Florida/Caribbean Inventory & Monitoring Network (SFCN) and the USVI Territorial Coral Reef Monitoring Program (TCRMP).

Program	Island	Site	Latitude	Longitude	Depth (m)
NPS-SFCN	St. Croix	Buck Mesophotic 1	17.80542	−64.59779	31
NPS-SFCN	St. Croix	Buck Mesophotic 2	17.80480	−64.59623	34
NPS-SFCN	St. Croix	Buck Mesophotic 3	17.80632	−64.59853	33
NPS-SFCN	St. Croix	Buck Mesophotic 4	17.80669	−64.60041	33
NPS-SFCN	St. Croix	South Fore Reef	17.78456	−64.60960	13
NPS-SFCN	St. Croix	West Spur and Groove	17.79962	−64.63603	9
TCRMP	St. Croix	Buck Island-St. Croix	17.78500	−64.60917	15
TCRMP	St. Croix	Buck Island-MCE	17.80659	−64.59935	33

Acropora monitoring

Assessments of *A. palmata* and staghorn coral (*Acropora cervicornis*) populations have been conducted within BUIS starting in 1976 (Gladfelter et al. 1977, Rogers et al. 2003). Subsequent to the excellent summary of *Acropora* trends in St. Croix by Rogers et al. (2003), further assessments were conducted to understand the distribution of elkhorn coral and white band disease (Mayor et al. 2006), the response of elkhorn to thermally induced bleaching in 2005 (Lundgren and Hillis-Starr 2008), and the distribution of elkhorn and staghorn corals and their long-term trajectories (Smith et al. 2014).

Discontinued and spatially randomized monitoring efforts

A few programs started but stopped prior to 2017. The work of the NPS and researchers at the West Indies Laboratory of Fairleigh Dickinson University (1972–1989) provided a great deal of information on coral reefs of BUIS prior to some of the major events that degraded coral abundance starting in the late 1970s. The programs are used in the resource condition assessment to establish reference conditions and to show evidence of early degradation of some coral resources. Most of the data are from around the eastern barrier reef of Buck Island and the adjacent lagoon and fore reef (Figure 4.6.1.1, Figure 4.6.1.2). Long-term projects included the establishment of five monitoring sites across the eastern Buck Island barrier in 1976 (Figure 4.6.1 2, Sites B-1 to B-5) which served as focal areas for transect studies of benthic structure and coral diversity (Gladfelter et al. 1977). Gladfelter et al. (1977) initially surveyed these five sites by collecting data from 15–35 haphazardly chosen 1 m^2 quadrats or contiguous 1 m^2 quadrats per site to record benthic cover and coral abundance (frequency). These transects formed the basis of subsequent studies using slightly different methodologies in 1985 (Anderson et al. 1986) and 1988 (Bythell et al. 1989). Bythell et al. established three permanent monitoring sites in these same areas using four marked 20 m transects that estimated coral cover using the chain transect methodology (Bythell et al. 2000). The transects established by Bythell et al. were monitored from 1990–2000.

Additional monitoring resources include the NOAA National Coral Reef Monitoring Program (NCRMP) and the NOAA Biogeography Program (National Centers for Coastal Ocean Science), which conducted randomized site surveys within BUIS. They were conducted after reference conditions were established and are less appropriate for characterizing coral trends. However, they can portray spatial distribution of coral resources during the period of monitoring.

Ongoing long-term monitoring

Additional long-term programs have assessed stony coral and benthic cover within BUIS since 2001 to 2017. These programs are used in the resource condition assessment to show trends in coral condition after the reference conditions were established. These programs utilized fixed permanent transects to assess coral reef resources over time (longitudinal monitoring).

The NPS South Florida/Caribbean Inventory & Monitoring Network (SFCN) quantified benthic community trends at three sites in BUIS (Figure 4.6.1.1, Table 4.6.1.1). Monitoring protocols are described for SFCN here https://www.nps.gov/im/sfcn/index.htm. SFCN established 20, 10 m long transects at each site, with the exception of the BUIS Mesophotic Coral Ecosystem site, which had 16 transects. Each transect was randomly placed initially and then permanently marked. The site

West Spur and Groove was monitored from 2000–2014 and was located about 1.5 km to the northwest of Buck Island at 9 m depth and represents habitats of this area (26,365 m^2). The site was a low stony coral cover, but diverse, hardbottom habitat dominated by epilithic algal turfs and gorgonians. Monitoring frequency was reduced (from annual to periodic) due to persistent low coral cover. Another site approximately 300 m southeast of Buck Island, BUIS South Fore Reef, has been monitored by SFCN since 2002. This site is located in 13 m water depth and is primarily composed of boulder star corals (*Orbicella annularis*) surrounded by patches of sand and represents a surrounding habitat of 40,753 m^2. About 2.5 km northeast of Buck Island lies a mesophotic (> 30 m water depth) bank reef complex that is very well-developed. SFCN maintains four randomly selected sites, each with 4, 10 m long transects, that represent the BUIS MCE site (99,416 m^2; 27–41 m depth). This site is dominated by the knobby star coral *Orbicella franksi*. These sites were established in April 2017.

USVI Territorial Coral Reef Monitoring Program (TCRMP) quantified benthic community trends at 2 sites in BUIS (Figure 4.6.1.1, Table 4.6.1.1). Monitoring protocols are described for TCRMP here https://sites.google.com/site/usvitcrmp/. TCRMP established 6, 10 m long permanent transects per site. TCRMP Buck Island was established in August 2001, approximately 100 m from SFCN BUIS South Fore Reef site (Figure 4.6.1.3), in a similar habitat and depth (15 m) and is also dominated by *O. annularis*. The site was initially established with 3 transects radiating out from a single point, and these were augmented with 3 additional transects in 2003. Co-located with the SFCN BUIS MCE site is the TCRMP Buck MCE site (33 m depth; Figure 4.6.1.4). The TCRMP Buck MCE shares many of the same characteristics of the BUIS MCE site and was established in partnership with SFCN to augment their data collection (e.g., coral health). This TCRMP site was also established in 2017.

At each of the SFCN and TCRMP sites similar methodologies are used to monitor benthic cover. Temporary transect lines are stretched between permanent marking stakes. Divers swim with a downward pointing digital video camera along the transect to film the benthos in a 40–60 cm wide swath. Digital video quality has been improved through the lives of these programs as technology has improved, resulting in more detailed images. From the images, non-overlapping still frames are captured and analyzed to quantify benthic cover (Kohler and Gill 2006). Benthic cover (%) was calculated for major sessile epibenthic organisms. 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. 2016a).

Benthic cover trends of dominant stony coral taxa and other living sessile organisms are presented in this assessment to evaluate long-term changes after reference conditions were established. In addition, to understand coral community composition at each site, the relative coral cover among coral taxa (cover of species X/total stony coral cover) were 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 by chance).

Figure 4.6.1.3. Representative photo of the boulder star coral (*Orbicella annularis*) community at Buck Island, St. Croix monitoring site of the Territorial Coral Reef Monitoring Program. (Depth 14m; Nov. 1, 2018; Photo credit: Rosmin Ennis)

Figure 4.6.1.4. Representative photo of the knobby star coral (*Orbicella franksi*) community at Buck Island Deep, St. Croix monitoring site of the Territorial Coral Reef Monitoring Program. (Depth: 33m; Nov. 1, 2018; Photo credit: Rosmin Ennis)

Reference Conditions/Values

When monitoring started in 1976 the coral reefs around BUIS were exceptionally healthy and well-developed (Rogers et al. 2008, Steneck 2014). In general, there was high coral cover and low algal cover. The latter indicates well grazed surfaces and limited coral-algal competition for benthic space. According to Gladfelter et al. (1977), the areas monitored during this time period were within three major zones, the lagoon between the Buck Island barrier reef and the island shore, the bank barrier reef shelf, and the bank proper seaward of the barrier reef. In 1976, the lagoon was largely sediment and hardbottom with scattered massive coral heads (Figure 4.6.1.2, Table 4.6.1.2). However, there was an extensive population of the hybrid *Acropora prolifera* in the western lagoon with a benthic cover of ~60%. Algal cover here was about 20%. The lagoon edge of the barrier reef was more diverse and well developed than inside the lagoon, and was dominated by *Pseudodiploria strigosa*, *Pseudodiploria clivosa*, and *Porites astreoides* (Table 4.6.1.2). Algal cover was about 10% along the lagoon edge. The turbulent seaward side of barrier reef was a true elkhorn reef, with >50% total coral cover and >30% *A. palmata* cover, and lesser amounts of the hydrocoral *Millepora complanata* (Table 4.6.1.2). The seaward bank reefs were a more diverse reef community of about 27% coral cover, that was co-dominated by *Orbicella annularis*, *Siderastrea siderea*, and *Porites porites* (Table 4.6.1.2). Also apparent from photographs of the seaward bank zone were commingled colonies and thickets of *Acropora cervicornis* that had coverage of 1.7% (Gladfelter et al. 1977). Algal coverage within the seaward bank zone was 20%.

Table 4.6.1.2. Benthic cover of select areas of Buck Island in 1976. Sites as described in Figure 4.6.1.1. Top three stony coral or hydrocoral species (by cover) shown and presented as absolute benthic coverage. Data adapted from Gladfelter et al. 1977. Estimates are from 15–35 haphazardly or sequentially placed 1 m^2 quadrats.

Zone	Location/coral species	Coral cover (%)	# colonies per quadrat	H'	# 1 m^2 quadrats/ depth (m)
Lagoon	**South Shore**	**7.0**	–	1.8	15 / 1–3
	Porites astreoides	3.7	2.7	–	–
	Pseudodiploria strigosa	1.6	1.2	–	–
	Siderastrea radians	1.0	2.7	–	–
	Head Coral (n. cut)	**18.1**	–	1.8	20 / 2–3
	Pseudodiploria strigosa	7.9	1.4	–	–
	Pseudodiploria clivosa	7.2	1.7	–	–
	Porites astreoides	1.5	1.8	–	–
	Head Coral (s. reef)	**11.8**	–	1.7	20 / 2–3
	Pseudodiploria strigosa	5.2	2.0	–	–
	Pseudodiploria clivosa	4.7	2.5	–	–
	Siderastrea radians	0.9	0.5	–	–

Table 4.6.1.2 (continued). Benthic cover of select areas of Buck Island in 1976. Sites as described in Figure 4.6.1.1. Top three stony coral or hydrocoral species (by cover) shown and presented as absolute benthic coverage. Data adapted from Gladfelter et al. 1977. Estimates are from 15–35 haphazardly or sequentially placed 1 m^2 quadrats.

Zone	Location/coral species	Coral cover (%)	# colonies per quadrat	H'	# 1 m^2 quadrats/ depth (m)
Reef	**Forereef Slope (n.)**	**52.2**	–	1.4	20 / 0–15
	Acropora palmata	30.8	3.2	–	–
	Millepora complanata	8.5	0.4	–	–
	Porites astreoides	6.5	3.0	–	–
Bank	**Rich Bank (n)**	**27.0**	–	3.1	35 / 8–15+
	Orbicella annularis	6.6	0.2	–	–
	Siderastrea siderea	4.5	1.7	–	–
	Porites porites	6.9	0.4	–	–

Current Condition and Trend

Overall, since the 1970s the conditions of coral reef resources have typically declined for reasons that will be fully covered in the Threats and Stressor Factors section. Despite this, recent coral cover values from randomized surveys show some of the highest densities of higher coral cover reefs (>20%) in the waters of BUIS (Figure 4.6.1.5). This suggests that BUIS continues to be a reservoir of some of the most important coral reef habitats around St. Croix.

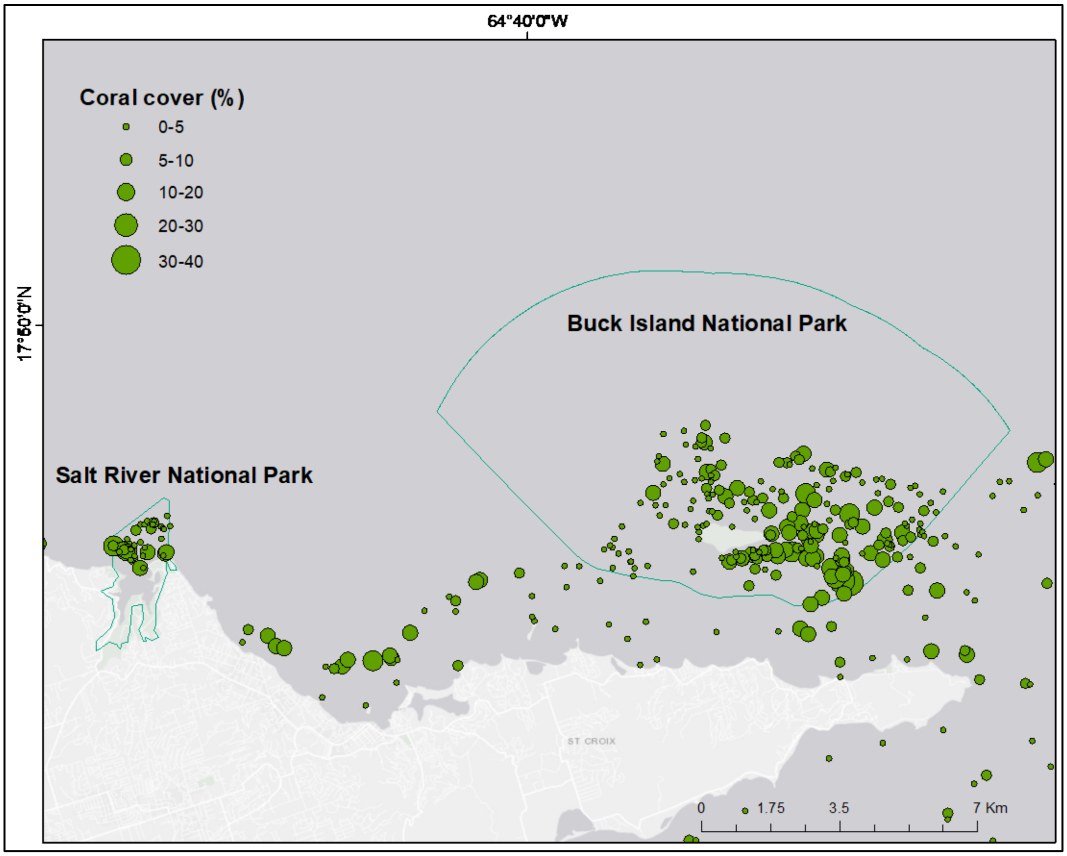


Figure 4.6.1.5. Stony coral cover recorded at randomly selected hardbottom sites for northeastern St. Croix and BUIS. Data from the National Coral Reef Monitoring Program covering years 2015, 2017, and 2019 (data and map courtesy of Sarah Groves, NOAA, Sep. 4, 2020).

Condition and trends of Acropora

Since reference conditions were established in 1976 diseases have taken an enormous toll on the corals of BUIS and specifically on populations of acroporid corals. White band disease was first described from the *A. palmata* and *A. cervicornis* monitored around Buck Island in the late 1970s (Gladfelter 1982). Subsequently, this disease went on to cause a precipitous decline in acroporid corals throughout the Caribbean (Aronson and Precht 2001). Combined with impacts from storms and lack of recovery, the losses for the wider Caribbean by 2002 were estimated at 80–90% of the population (Bruckner 2003). The Buck Island lagoon and barrier reef sites surveyed by Gladfelter et al. (1977) showed there was near total loss of living acroporid corals within these areas by 1985 (Bythell et al. 1989), with only their skeletal remnants surviving today. Losses also included the unique haystack formations of *A. palmata* seaward of the barrier reef. The lagoon population of *A. prolifera* was reduced to about 5% cover from 60% in 1976. The northeastern to southeastern populations of *A. palmata* from reef crest to fore reef (0–15 m) declined to less than 3% live coral cover by 1985 (Transects BI-1 to 4 in Figure 4.6.1.2; Gladfelter et al. 1977). However, there were still relatively intact populations (~20% cover) on the northern outer barrier reef (Transect BI-5 in Figure 4.6.1.2; in Gladfelter et al. 1977). In 1985 *A. palmata* was rare below 3–4 m depth (Bythell et al. 1989). More restricted populations of *A. cervicornis* on the fore reef slope in 1976 were nearly gone by 1986. It is not possible to prove that these dramatic reductions were solely due to white band disease, as direct tracking of coral cover fate was not conducted and there were impacts from Hurricane David in 1979 (see below; Rogers et al. 1979). However, similar declines in *Acropora* in relation to white band disease seen across the Caribbean in areas without storms and other evident localized stressors suggest the major driver was white band disease.

The decline in *Acropora* populations at BUIS continued in the following decades as the result of storms and continued disease. There were impacts from Hurricane David in 1979, particularly in shallow water (<3 m) (Rogers et al. 1982). Hurricane Hugo, a powerful category 4 Cape Verde-type storm, traversed across St. Croix from southeast to northwest on the night of September 18–19, 1989. There was damage to *A. palmata* populations across Buck Island, particularly on the south barrier reef, but much of the losses had already occurred from white band disease (Rogers et al. 2003). Permanent monitoring sites established in 1988 in the same areas as shown in Figure 4.6.1.2 showed continued decline of these remnant populations of *A. palmata* up to the year 2000, when the monitoring ended (Bythell et al. 2000). Eight areas on the eastern end of St. Croix, including Buck Island, showed that *A. palmata* cover that was 32% ± 5.7 SEM in the mid 1970's had dropped to 1.1% ± 0.4 SEM by 2002 (Adapted from Table 1 in Rogers et al. 2003). In addition, colonies that were present in 2002 were more often diminutive and encrusting, without the large three-dimensional structure that typified pre-white band disease impacted populations (Rogers et al. 2003).

Despite reductions in abundance of *A. palmata* in BUIS in the late 1970s and early 1980s, the species was recovering across much of the park in 2004. Mayor et al. (2006) conducted spatially randomized surveys along 25 x 10 m transects at 617 sites in water shallower than 10 m across the former and expanded monument. They found living *A. palmata* in 76% of transects, with a total of 2,492 colonies recorded and an estimated 115,801 large colonies present within BUIS. White band continued to be persistent in the population, with a prevalence of 3.2%. In September–October 2005, the northeastern Caribbean was severely impacted by a warm water event that caused coral bleaching and approximately 10.2 Degree Heating Weeks in the USVI (Eakin et al. 2010). Lundgren and Hillis-Star (2008) monitored *A. palmata* populations at 68 sites across BUIS across the bleaching event. Approximately 60% of colonies showed some bleaching, with colonies inside the lagoon suffering the worst (~80%). The 2005 bleaching event was the first time that *A. palmata* was recorded to have bleached in the USVI (Muller et al. 2008). Subsequent to bleaching about 40% of colonies experienced tissue loss, and among three more intensively monitored sites the whole colony mortality ranged from 64.7% in the lagoon, 36.4% at the north bar (about 1.5 km north of the barrier reef) and 18.8% at the southern barrier forereef.

More recent trends in *Acropora* spp. since 2005 were less well documented. Both *A. palmata* and *A. cervicornis* were listed as Threatened under the Endangered Species List in 2006 (NOAA 2014). In response, two efforts that incorporated demographic monitoring of *A. palmata* in BUIS were launched and followed protocols developed by NOAA (Williams et al. 2006). Although not monitored consistently, the NPS established 30 random demographic monitoring sites in BUIS in 2009 (Figure 4.6.1.6). These sites were monitored at least one other time, but the data was not obtainable as of the creation of this condition assessment. These sites are permanently marked and could be reused in a future monitoring program. A second program, the Acropora Monitoring and Mapping Program (AMMP) was started by NOAA in 2012 and conducted by the University of the Virgin Islands. This program established a fixed site (named AMMP BUIS 422) within BUIS at 17.7974N, 64.6039W (North Bar) with three 7 m radius circular plots (462 m^2) (methods following Williams et al. 2006) and was monitored once in 2012 (Smith et al. 2014). Within the plot there were 66 colonies of *A. palmata* with an average largest planar width of 49.7 cm and approximately 30% dead colony area. More recently there have been signs of recruitment and recovery of elkhorn coral around the park (Z. Hillis-Starr, unpub. obs.).

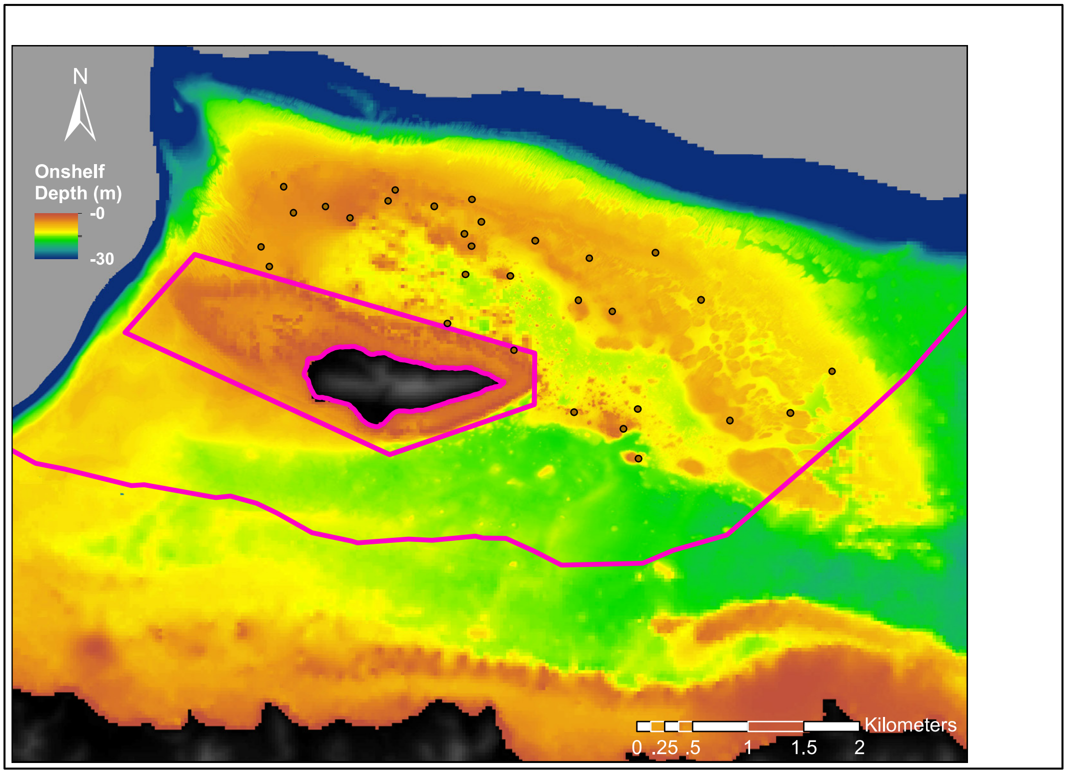


Figure 4.6.1.6. Acropora Monitoring and Mapping Program long-term demographic sampling plots that have not been continually monitored. These sites had subsurface mooring pins established to mark plots and could be reused in a future monitoring program.

In addition, AMMP conducted a spatially stratified random synoptic survey of *Acropora* on all hardbottom areas of St. Croix in waters shallower than 18 m (following protocol of Miller et al. 2011*).* Of the sites, 29 of 261 sites were sampled inside BUIS (Figure 4.6.1.7). Within these 29 sites, 10 sites had *A. palmata* within the survey area and 5 sites had colonies that fell within a randomly placed 15x1 m transect and densities of 0.1–0.3 m^2. In addition, 2 of the 29 sites contained *A. cervicornis*. Overall, from these suites of data it is clear that *Acropora* populations have been extremely negatively impacted by disease, storms, and bleaching since the mid-1970s. However, remnant colonies are widespread and sexual reproduction is occurring (Steneck 2014), indicating that recovery of populations is still possible with targeted management.

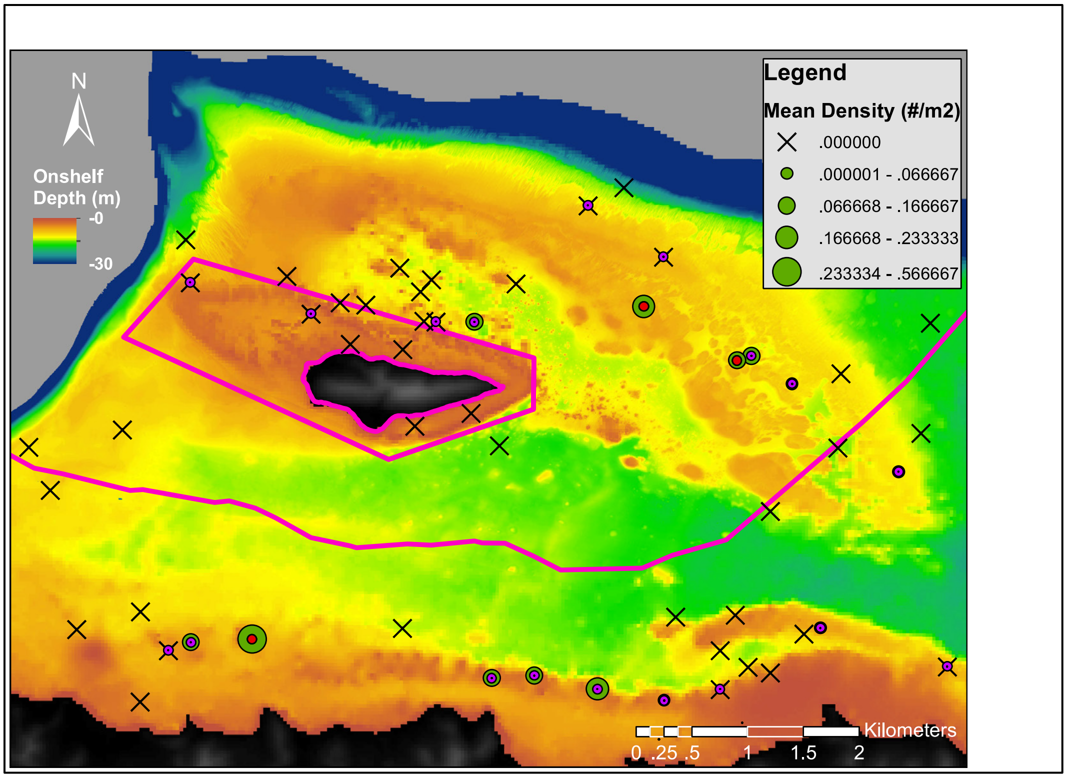


Figure 4.6.1.7. A map of northeastern St. Croix showing sampling stations of the Acropora Monitoring and Mapping Program in 2012–2013. Spatially stratified random sites in waters shallower than 18 m were surveyed for acroporids along two 15x1 m transects and noted as present or absent outside of transects. An "X" indicates no *Acropora* found in transects, a green circle indicates *Acropora* in transect with the size dependent on the density, a lavender circle indicates *A. palmata* present at site only outside of transect, and a red circle indicates *A. palmata* and *A. cervicornis* present outside the transect. Date from Smith et al. 2014.

Condition and trend of other coral species

Other, non-acroporid coral species fluctuated in abundance between the 1970s and the 2005 bleaching event. Some species, such as *P. astreoides*, may have increased in abundance following the population collapse of *A. palmata* (Bythell et al. 1989), mirroring its general increase in the wider Caribbean (Green et al. 2008). Other species showed declines that could be attributed to storms followed by recovery. Hurricane Hugo was destructive to the south barrier fore reef on St. Croix (Hubbard et al. 1991) and inside the Buck Island lagoon (Bythell et al. 2000). Areas on the south barrier fore reef (8–10 m depth) dominated by the boulder star coral (*Orbicella annularis*) and finger coral (*Porites porites*) declined by 35% during Hurricane Hugo in 1989 but recovered almost completely to 23% absolute cover by 1995 (Bythell et al. 2000). An area in the Buck Island lagoon (4 m depth) dominated by knobby brain coral (*Pseudodiploria clivosa*) and the symmetrical brain coral (*Pseudodiploria strigosa*), only declined by about 6% over Hurricane Hugo, but then increased by 23% to an absolute cover of 37% in 1995 (Bythell et al. 2000).

SFCN and TCRMP programs established in the early 2000s captured the impacts of the 2005 bleaching event and coral reef dynamics up to the writing of this assessment. The SFCN site BUIS

Western Spur and Groove lost about 40% of its cover in the 2005 thermal stress event (Figure 4.6.1.8). The stony coral community was dominated by *M.* cavernosa, *Siderastrea siderea*, and *P. strigosa* (Figure 4.6.1.9). The site The SFCN site BUIS South Fore Reef lost about 84% of its coral cover (19.7% to 3.1%) in the 2005 thermal stress event to bleaching and a subsequent disease outbreak (Miller et al. 2009; Figure 4.6.1.10). The decline was largely due to the loss of much of the *O. annularis* living cover. The site showed steady recovery with slow regrowth of *O. annularis* to 8.9% total coral cover by 2017. The site had generally low macroalgal cover and a higher abundance of epilithic algae, which has increased through time. Overall, the stony coral community at South Fore Reef was dominated by *O. annularis*, *Orbicella franksi*, and *Orbicella faveolata* (Figure 4.6.1.11). The TCRMP Buck Island site was also severely affected by the 2005 thermal stress event and lost about 60% of its cover, led by a decline in *O. annularis*, from bleaching and subsequent disease (Figure 4.6.1.12). In contrast to BUIS South Fore Reef, TCRMP Buck Island has not recovered since bleaching, and has had stable to declining coral cover. Prior to bleaching mortality much of the benthic cover was composed of epilithic algae; however, this declined after coral mortality with concomitant increases in macroalgae and filamentous cyanobacteria. The stony coral community was dominated by *O. annularis*, *O. franksi*, and *P. porites* (Figure 4.6.1.13).

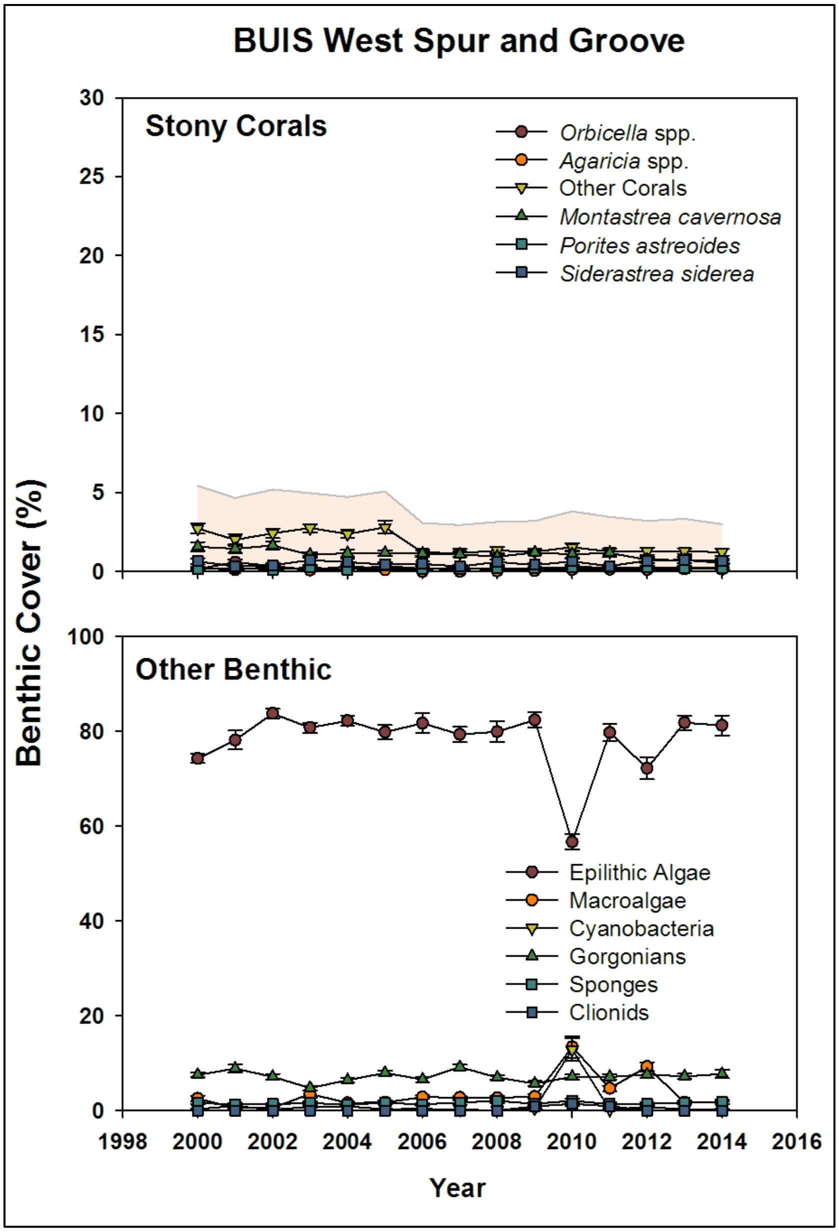


Figure 4.6.1.8. Cover of sessile epibenthic organisms (±SE) through time at the SFCN West Spur and Groove site. Cover of stony corals (top). Total coral cover indicated by shaded area, then the most abundant individual species from the full data set indicated as separate markers and lines. Other benthic organisms (bottom). (Data from South Florida/Caribbean Inventory & Monitoring Network.)

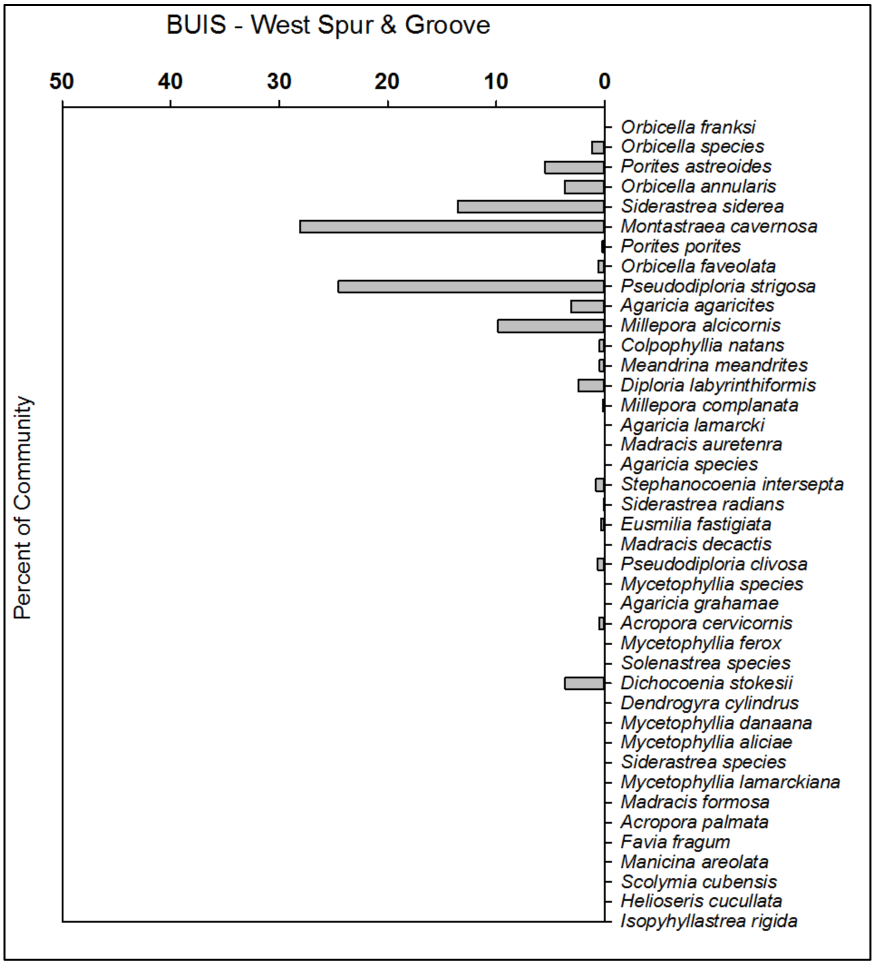


Figure 4.6.1.9. Relative abundance of coral species by benthic cover at SFCN West Spur and Groove site. Coral species are ordered by the rank abundance (top to bottom) according to abundance across the TCRMP shallow water sites outside park areas (26 sites).

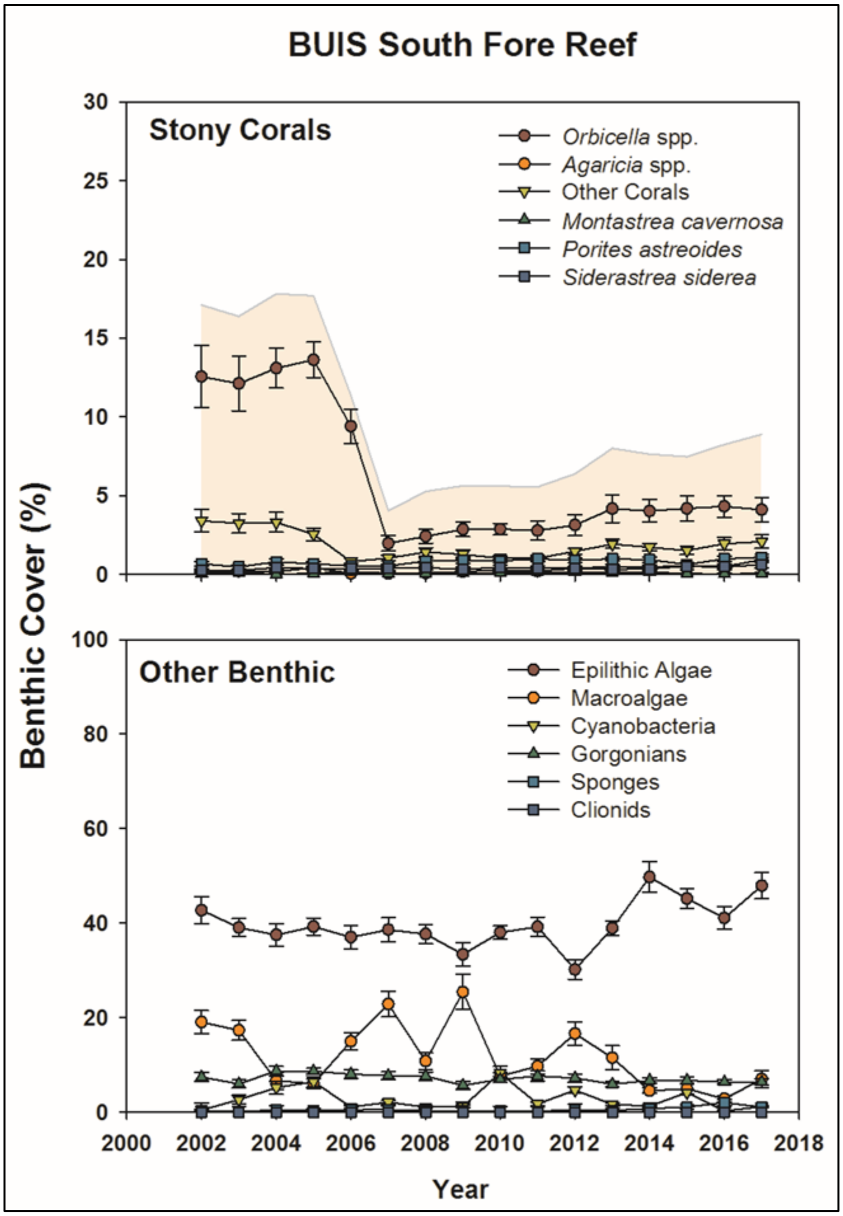


Figure 4.6.1.10. Cover of sessile epibenthic organisms(±SE) through time at the SFCN Southeast Forereef site. Cover of stony corals (top). Total coral cover indicated by shaded area, then the most abundant individual species from the full data set indicated as separate markers and lines. Other benthic organisms (bottom). (Data from South Florida/Caribbean Inventory & Monitoring Network.)

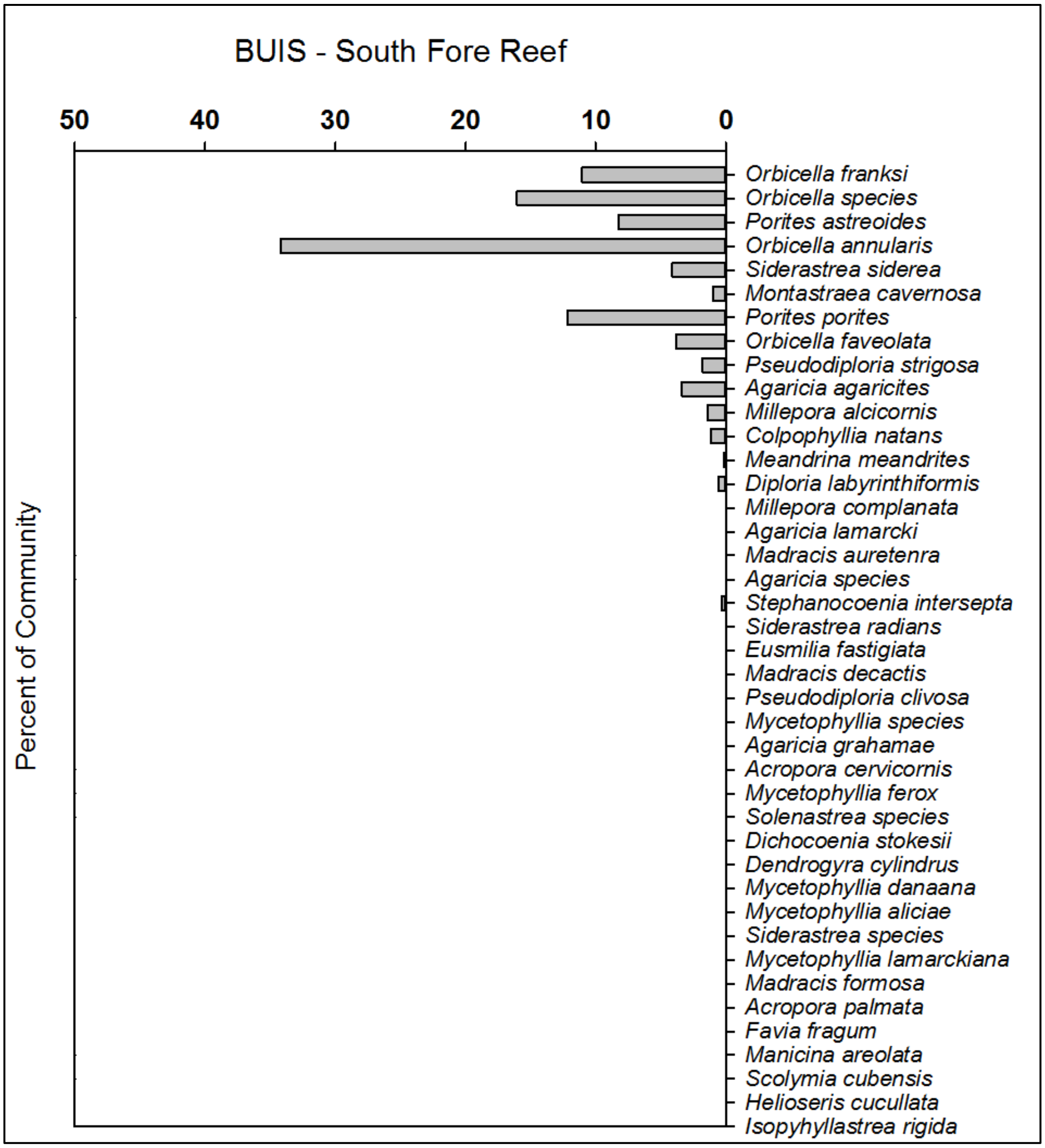


Figure 4.6.1.11. Relative abundance of coral species by benthic cover at SFCN Southeast Forereef site. Coral species are ordered by the rank abundance (top to bottom) according to abundance across the TCRMP shallow water sites outside park areas (26 sites).

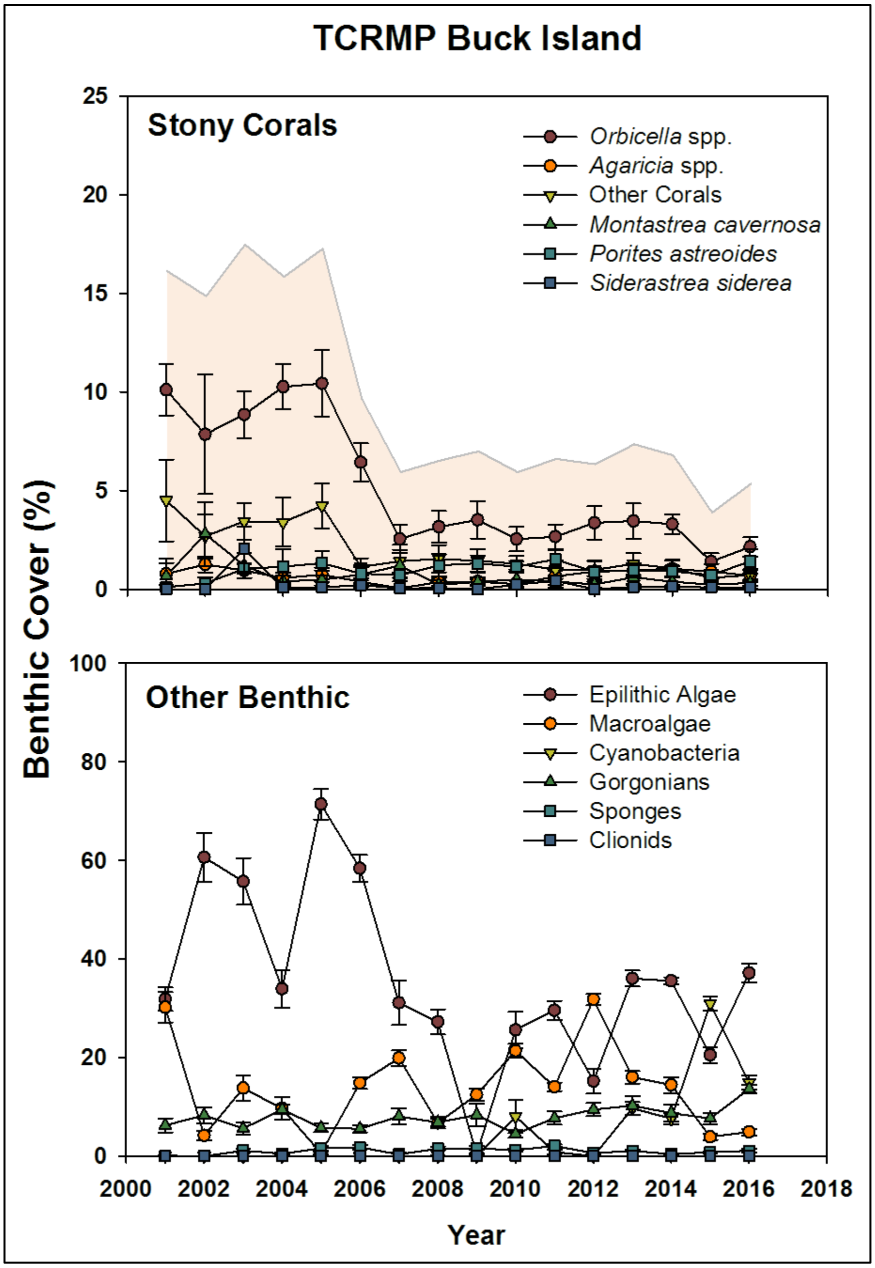


Figure 4.6.1.12. Cover of sessile epibenthic organisms (±SE) through time at the TCRMP Buck Island site. Cover of stony corals (top). Total coral cover indicated by shaded area, then the most abundant individual species from the full data set indicated as separate markers and lines. Other benthic organisms (bottom). (Data from USVI Territorial Coral Reef Monitoring Program.)

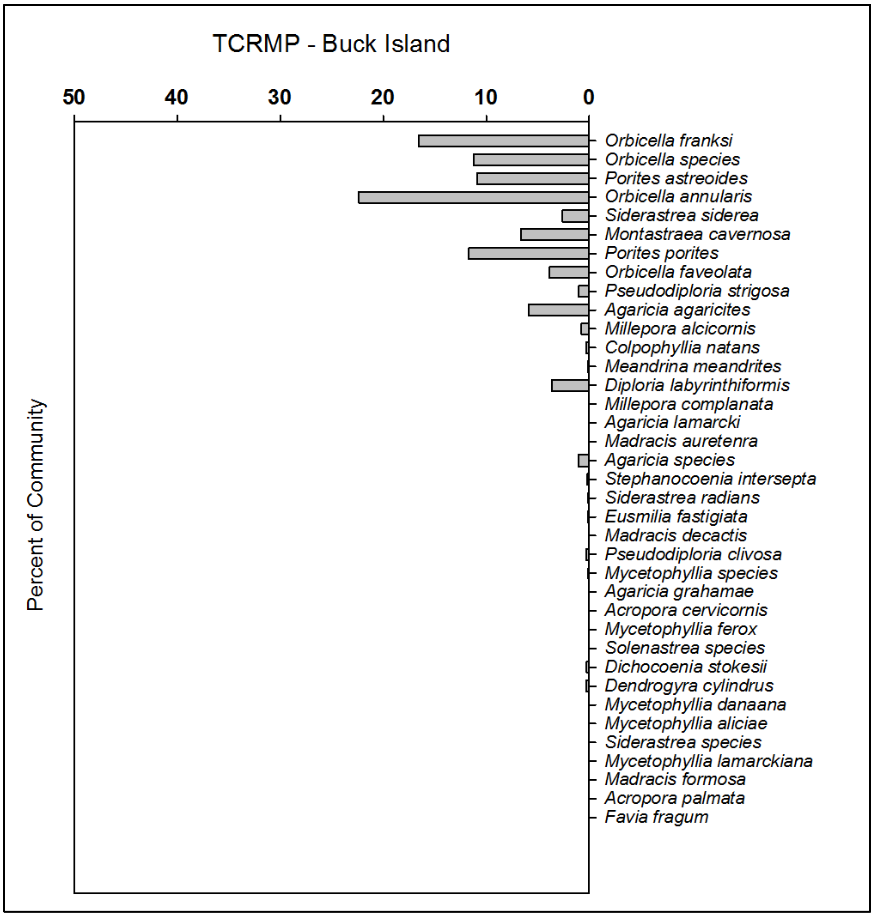


Figure 4.6.1.13. Relative abundance of coral species by benthic cover at the TCRMP Buck Island site. Coral species are ordered by the rank abundance (top to bottom) according to abundance across the TCRMP shallow water sites outside park areas (26 sites).

Although most coral reef monitoring at BUIS has historically focused on the areas immediately surrounding Buck Island, mesophotic coral ecosystems are also a conspicuous component of hardbottom habitats. Extensive areas in mesophotic depth ranges (30–100 m) are present on the north side of the monument (Smith et al. 2019) and cover approximately 11% of the BUIS area. Drop camera surveys indicate a patchy, but well developed, bank dominated by star corals (*Orbicella* spp.) in the 30–40 m depth range (V. Brandtneris, unpub. data). Permanent monitoring sites were established by SFCN and TCRMP in 2017 which recorded coral cover of greater than 30% (Smith et al. 2018; Smith et al. 2019; SFCN 2019; Figure 4.6.1.4). This coral cover is likely the highest for any coral reef system at BUIS (22–42%; SFCN 2019). Although cover is high, there was a greater than 1% prevalence of white disease (Smith et al. 2018), which is a continued threat to mesophotic *Orbicella* banks in the USVI (Smith et al. 2019). It is possible that on the deeper northern seaward slope at 50–90 m there are lettuce coral (*Agaricia* spp.) reefs. However, the relatively gentle slope might limit development because of interactions of corals with sediment (Sherman et al. 2010).

Threats and Stressors

The coral reefs of BUIS are primarily threatened by climate change and disease outbreaks, with more localized impacts from marine accidents (vessel groundings), overfishing and recreation (e.g., sunscreens, incidental coral breakage). Global climate change is causing increasing sea surface temperatures and marine heat waves (Holbrook et al. 2019) resulting in phenomena such as coral bleaching (Hughes et al. 2017), coral disease outbreaks (Bruno et al. 2007), and increases in storm frequency and strength (Knutson et al. 2015). Carbon dioxide emissions also contribute to ocean acidification (Feely et al 2009). This can lower aragonite saturation states of water (aragonite is the common mineral used when corals deposit their limestone skeleton) and decrease whole reef calcification to the potential detriment of coral growth (Albright et al. 2016).

Thermal stress

The surface waters surrounding BUIS are warming at a rate of about 0.007°C per year and this is leading to repeated temperatures surpassing coral bleaching thresholds (Figure 4.6.1.14). 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 forming deeper than 30 m depth (Smith et al. 2016b). 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). DHW values above 4 are associated with the onset of bleaching, and above 8 with the onset of mass bleaching and coral mortality. The regional estimate for the USVI based on SST was 10.2 DHW (50 km product; NOAA 2019), a level associated with mass bleaching and mortality of reef building corals (NOAA 2006). At BUIS in situ loggers on the lagoon back reef and fore reef showed thermal stress was high and supported regional estimates of Degree Heating Weeks in 2005 (Lundgren and Hillis-Starr (2008). Lower-impact, shallow-water thermal events also occurred in 2010, 2015, and 2016 with stress values of about 6 degree heating weeks (Figure 4.6.1.15).

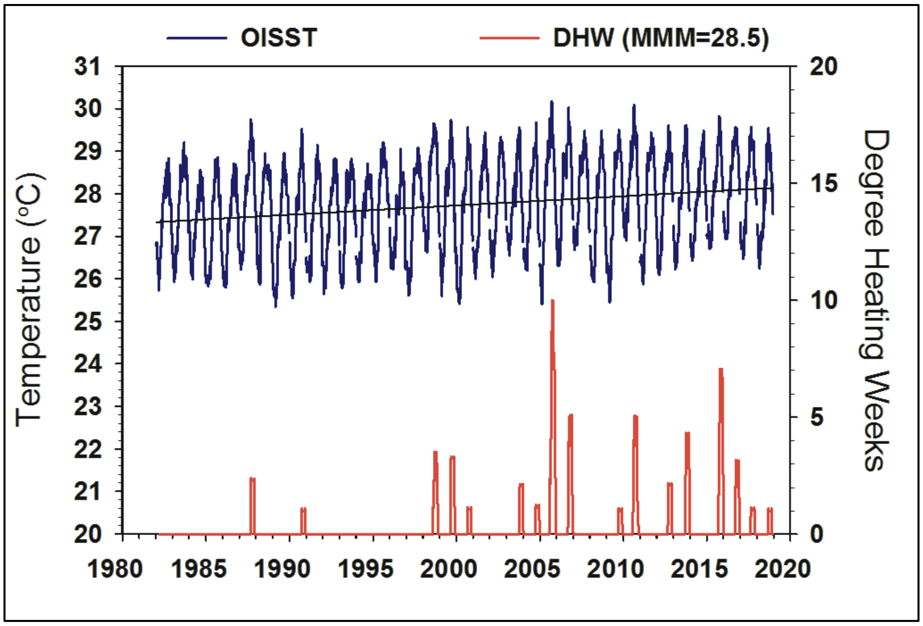


Figure 4.6.1.14. Optimum Interpolation Sea Surface Temperature (OISST; blue line, left vertical axis) and degree heating weeks (red line, right vertical axis) for the USVI. The black line is a linear fit of the OISST data and shows about 0.007°C increase in temperature per year (y = 0.000669/year*x − 25.545). 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 6/6/19 (data processing credit: Doug Wilson, Caribbean Wind LLC).

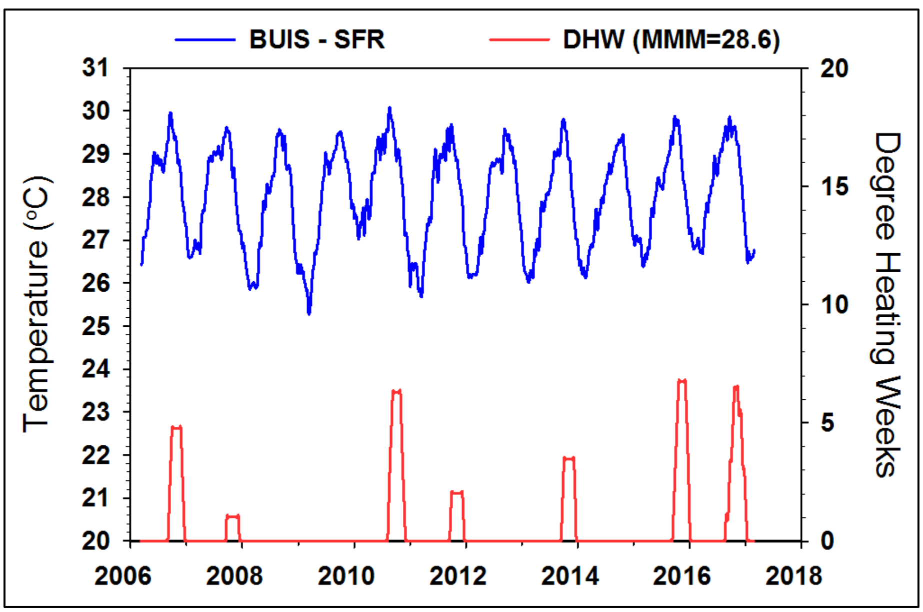


Figure 4.6.1.15. Water temperature (blue line, left vertical axis) and degree heating weeks (red line, right vertical axis) at the TCRMP Buck Island site. Degree heating weeks (DHW) are calculated as the 12 week rolling sum of temperatures exceeding 1°C over the monthly maximum mean temperature (NOAA 2006). The monthly maximum mean for Buck Island was estimated from the depth dependent formula in Smith et al. (2016b). 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).

Coral bleaching

Corals around BUIS in 2005 showed extensive impacts from warm water. As mentioned above, *A. palmata* colonies showed severe prevalence of bleaching and over 50% whole colony mortality in some areas (Lundgren and Hillis-Starr (2008). At non-acroporid monitoring sites, both the BUIS & TRCRMP South Fore Reef sites and BUIS Western Spur and Groove, experienced high prevalence of bleaching in 2005 and subsequent coral disease that resulted in significant coral loss. Only the BUIS South Fore Reef site had monitoring at the height of the 2005 bleaching (Figure 4.6.1.16) but impacts across the BUIS can be inferred from photographic reports (Figure 4.6.1.17) and disease and coral cover loss in 2006 (Figure 4.6.1.8, Figure 4.6.1.10, Figure 4.6.1.12; SFCN 2019, Smith et al. 2016a). The cumulative impact from thermal stress over the years can be inferred from the slow recovery of coral cover loss after the catastrophic 2005 coral bleaching event (Figure 4.6.1.8, Figure 4.6.1.10, Figure 4.6.1.12). Much lower but elevated incidence of bleaching was also recorded in 2006, 2007, 2010, 2011 and 2019 (SFCN 2019, Figure 4.6.1.16).

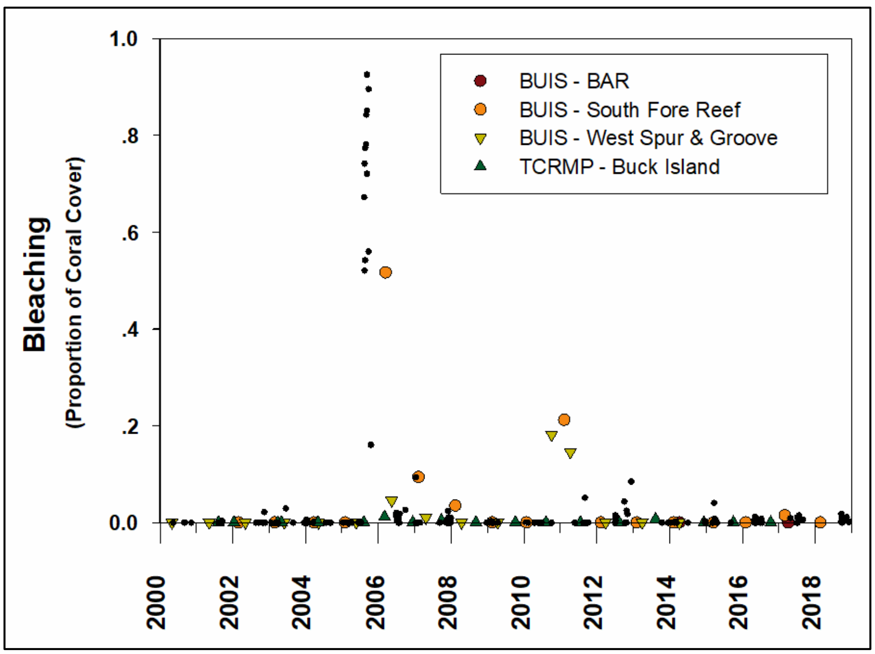


Figure 4.6.1.16. Proportion of coral cover bleached at the SFCN BUIS West Spur and Groove, BUIS South Forereef, and BUIS BAR (mesophotic), and the TCRMP Buck Island sites. Black dots are estimates from 23 other shallow water sites of the Territorial Coral Reef Monitoring Program outside park boundaries shown for reference. Estimates from captured digital video.

Figure 4.6.1.17. Bleached colonies of *Diploria labyrinthiformis* (left) and *Orbicella faveolata* (right) at the TCRMP Buck Island monitoring site (Nov. 21, 2005, depth 13 m). These corals bleached at the thermal maximum of the 2005 bleaching event in October and are showing some recovery of pigment. (Photo credit: Tyler B. Smith)

Coral diseases

Coral diseases also pose an ongoing threat to corals in BUIS. The epizootics of white band disease affecting acroporid corals are well documented and impacts from white band and another disease termed white pox disease (Sutherland and Ritchie 2004) are a continuing problem in the USVI in general (Muller et al. 2008, Rogers and Muller 2012) and particularly BUIS (Mayor et al. 2006). In addition, the impacts of white plague disease after bleaching were large drivers of coral cover loss after bleaching in 2005 (Miller et al. 2009, Smith et al. 2013, Smith et al. 2016b). Non-acroporid corals have also seen impacts from disease in BUIS, such as Caribbean yellow band and dark spots (Miller et al. 2009, Smith et al. 2016a, Randall et al. 2018). While the causes for most all of these diseases are not known, management of disease through direct treatment is an emerging area of research (e.g., Randall et al. 2018) that could be used for proactive management of coral population within BUIS. Furthermore, Stony Coral Tissue Loss Disease (SCTLD, Precht et al. 2016) was reported from St. Thomas in January 2019, St. John in February 2020, and St. Croix in May 2020, and is rapidly spreading (https://www.vicoraldisease.org/sctld-disease-tracking). It has not yet been reported from BUIS, but it is anticipated that it will spread there in the very near future. SCTLD would have profound negative impacts on coral abundance and diversity at BUIS.

Storm impacts

The impacts of storms on BUIS are also well-documented (Rogers et al. 1982, Bythell et al. 2000; and see *Current Condition and Trend* section) and likely to increase (Knutson et al. 2015). Slow recovery has also been documented after storm impacts, but a greater frequency of high magnitude storms may contribute to a general increase in disturbances limiting population recovery of shallow water stony corals.

Pollution

BUIS is situated away from human population centers but may be exposed to pollution from in-water recreational activities and boating. Potential pollutants are covered in Section 4.2. Potential effects of pollutants on corals come from detectable levels of oxybenzone associated with artificial sunscreens used by bathers in the eastern areas of Buck Island inside and outside the barrier reef (C. Woodley, unpub. data). Around the snorkel trail inside the eastern barrier reef, only 10% of colonies of *A. palmata* showed the presence of ovaries and spermaries during the reproductive period, whereas areas away from the snorkel trail and outside the barrier reef showed 60–80% of colonies with ovaries and spermaries present (C. Woodley, unpub. data). This may indicate reproductive effects of chemicals such as the detected sunscreens.

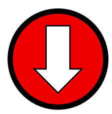
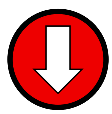
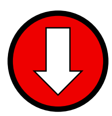
Data Needs and Gaps

The loss of ecosystem services, including shoreline protection and fish-habitat provision (Kuffner and Toth, 2016), from reef degradation in BUIS warrants consideration of interventions such as managed relocation of coral species to select sites. The population of elkhorn corals (*A. palmata*) surrounding Buck Island were a major factor in the creation of the national park by President John F. Kennedy in 1961 and subsequent expansion of the marine monument by President William J. Clinton in 2001. A clear gap is a consistent monitoring program for the populations of *A. palmata* and *A. cervicornis* in BUIS. Subsurface moorings were established at 30 sites in 2009 and 2012 and a subset of these could be used as sites for a reconstituted monitoring program (Figure 4.6.1.6). In addition, historical areas of the Buck Island barrier reef first surveyed by Gladfelter et al. (1977) and subsequently by Bythell et al. (2000) would be excellent permanent monitoring sites (Figure 4.6.1.2). Monitoring could incorporate coral genotyping, coral recruitment (low/high natural recovery) and accretion monitoring to facilitate optimized restoration activities. Preliminary evidence of pollution from recreational activities and its impacts on corals suggests the need for more involved studies to assess the true impacts on coral populations in BUIS. In addition, rapid response monitoring should be considered for the arrival of SCTLD, future bleaching events, and the spatial distribution and impacts of the nuisance alga *Ramicrusta* spp. (Edmunds et al. 2019).

Overall Condition

Based on historical condition of coral reefs at BUIS prior to the 1980s, the condition of coral reefs presently is moderate to poor and is trending downward (Table 4.6.1.3). Massive stands of elkhorn coral, the impetus for the park's creation, have been decimated. While there have been signs of continued recruitment and recovery of these coral populations, which could be harnessed for restoration activities, they are still a shadow of their historical abundance. Many other dominant coral species, such as *Orbicella* spp., have also declined precipitously since the 1980s, driven by combinations of diseases, bleaching, hurricanes, and historical overfishing prior to MPA creation in 2001. Coral cover continues to decline on all monitored reefs, with the exception of slow recovery BUIS SFR. One positive sign is that high abundance of certain algal types on open substrates, such as short filamentous turfs, indicate high levels of grazing. This can set up the potential for coral recruitment that facilitated reef recovery. Mesophotic banks are doing well but there are signs of disease which have degraded similar bank reefs near St. Thomas, USVI. The incidence of bleaching and disease events is increasing on corals in and around BUIS as seawater temperatures exceed bleaching thresholds with more regularity, particularly since the 1998. This is leading to significant loss of coral cover without documented recovery between disturbance events. The lack of long-term monitoring, specifically for the major foundation species of *Acropora*, is a significant knowledge gap within the current data framework.

Table 4.6.1.3. 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 BUIS over the last two decades. Only BUIS SFR has shown statistically significant increase since 2006. Only mesophotic reefs maintain relatively high living coral cover but are declining. There are concerns of potential degradation due to coral disease
	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

<u>Sources of Expertise</u>

- Vicktor Brandtneris, University of the Virgin Islands
- Mike Feely, South Florida Caribbean Inventory & Monitoring Network, National Park Service
- Ilsa Kuffner, United States Geological Survey
- William J. Miller, South Florida Caribbean Inventory & Monitoring Network, National Park Service
- Erinn Muller, Mote Marine Lab
- Cheryl Woodley, National Oceanic and Atmospheric Administration

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4.6.2. Queen Conch

Description

Conch have been harvested at Buck Island Reef National Monument for over 2000 years. In the early 1970s archeologists documented a conch midden located on the northwest corner of the island that was documented at over 1800 years old. Specimens of Queen conch and milk conch were large and thick-shelled. Today, Queen conch (*Lobatus gigas*) continue to be commonly found in near shore and deeper seagrass meadows, macroalgal plains, and vast sand areas surrounding the Monument; these habitats account for about 23% of the benthic habitat within the Monument. The densest seagrass beds are found south and west of Buck Island (Figure 4.6.2.1). The species has historically been an important fishery in the USVI; however, populations in the territory have substantially declined since the 1970–1980s (Doerr and Hill 2013). With the 2001 expansion BUIS became the first fully protected marine area in both the United States and the Caribbean (Proclamation No. 7392; Pittman et al. 2008). Therefore, it has recently been the focus of several studies to determine the impact of closed areas on the queen conch fishery.

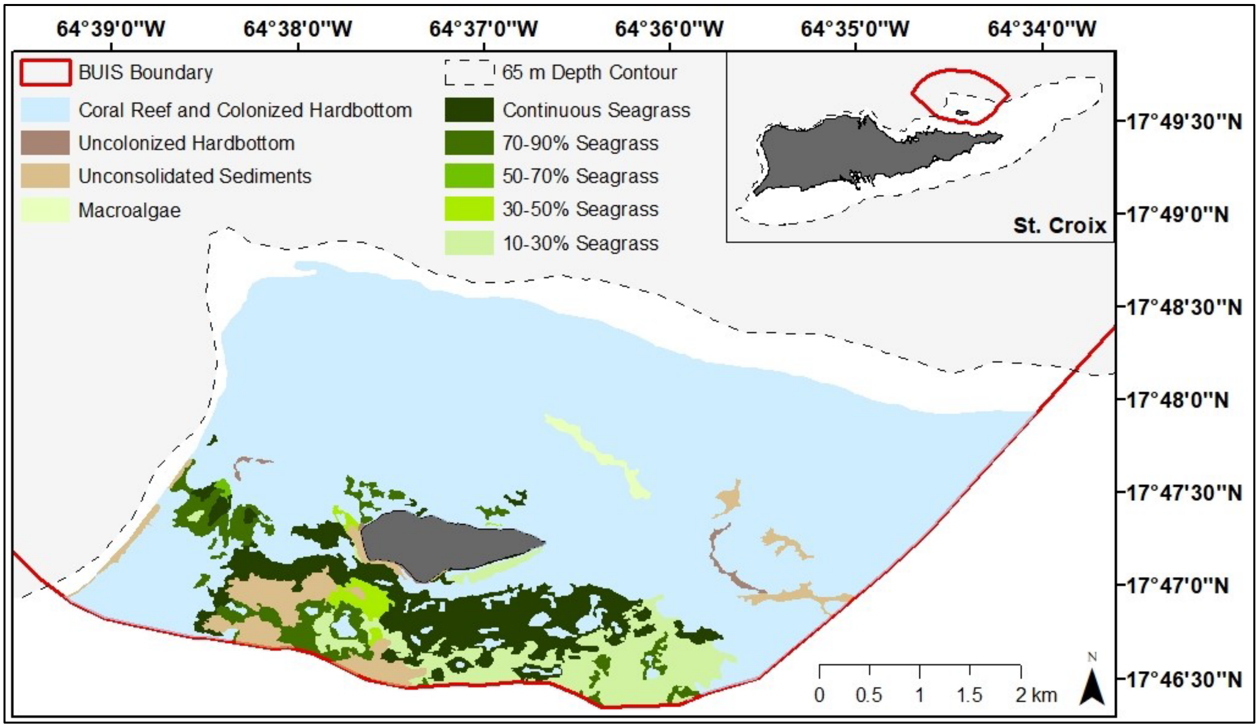


Figure 4.6.2.1. The Buck Island Reef National Monument (BUIS) location and boundary (inset). Major benthic cover categories within the BUIS are displayed.

Data and Methods

All data used for historical assessments of conch populations at BUIS were obtained through literature review. Tobias et al. (1988) used parallel 332 x 4 m belt transects targeting the western seagrass beds to quantify both juvenile and adult conch populations per hectare. These surveys were conducted monthly for six months.

The current condition of conch populations within the monument was obtained through both literature review and datasets provided by NOAA from the National Coral Reef Monitoring Program (NCRMP). From 2003–2006, Pittman et al. (2008) conducted conch assessments on 25 x 4 m belt transects around Buck Island stratified randomly by both substrate type and management regime (i.e., inside or outside BUIS). However, Doerr and Hill (2013, 2018) used radial transects (total area of 314 m^2) around Buck Island stratified by benthic habitat, depth, and management regime to quantify conch populations per hectare. During NCRMP conch population surveys, individuals are counted along 15 x 2 m belt transects stratified by depth, hardbottom habitat type, and management regime. NCRMP only assesses hardbottom habitats in waters shallower than 30 m.

Reference Conditions/Values

Early study of queen conch in the USVI focused primarily on biological aspects of the species (see Randall 1964, Berg 1975). However, queen conch has long been an important fishery throughout the USVI, and decreased catch and populations had been reported as early as the 1970s most likely due to overexploitation (Wood and Olsen 1983, Doerr and Hill 2013). Therefore, commercial fishing regulations were signed into law in 1972 (Virgin Islands Code), which would eventually include protections such as minimum shell length and lip thickness, commercial and recreational take limits, and seasonal closures during queen conch spawning periods. Subsequent research shifted to focus on management actions to stabilize the fishery and the potential for fishery replenishment through juvenile outplanting (Wood and Olsen 1983, Coulston et al. 1987). However, these studies were not specific to BUIS.

Within the boundaries of BUIS, Tobias et al. (1988) conducted conch population surveys along belt transects established in the western seagrass beds. They found juvenile conch populations (1370.4 conch/ha) to be more dense than adult conch (30.1 conch/ha) during all survey periods (Tobias et al. 1988). However, at the time of the surveys, fishing regulation within the BUIS allowed take of two conch per person per day without minimum size requirements. The authors cautioned about the potential of both recreational and commercial conch fishing to contribute to future population declines. They recommended full protection of marine resources within the BUIS but stated that populations may not recover even when relieved of fishing pressures (Tobias et al. 1988).

Current Condition and Trend

Until recently, the primary data source for queen conch population studies in the USVI had been reported fisheries landings. However, Pittman et al. (2008) performed benthic habitat, fish, and macroinvertebrate surveys both within and outside BUIS boundary from 2003–2006. They found that juvenile and adult conchs were most commonly observed in seagrass within the park boundary (Pittman et al. 2008, Figure 4.6.2.2).

Several years later, Doerr and Hill (2013) performed fishery-independent radial surveys on comparable habitats both within and outside BUIS to characterize conch populations and assess the park's effectiveness as a marine reserve. Preliminary analysis found juvenile conch to be far more dense (233.7 conch/ha) than adults (68.6 conch/ha) and that both groups preferred seagrass habitats. It should be noted that juvenile queen conch densities recorded by Doerr and Hill (2013) were substantially lower than those found by Tobias et al (1988), but adult densities were more than double. Although suitable habitat was the strongest predictor of conch densities, juvenile conch were also positively impacted by the protection of BUIS while adult densities were more influenced by deeper water. Overall conch densities were not different inside compared to outside BUIS boundary (Doerr and Hill 2013). More in-depth analysis of the dataset revealed both juvenile and adult densities were higher inside BUIS boundary, and there was evidence of successful larval conch recruitment. They concluded that the seagrass habitat found within BUIS is valuable nursery habitat and that BUIS is providing sufficient protection to allow recovery of conch populations (Doerr and Hill 2018).

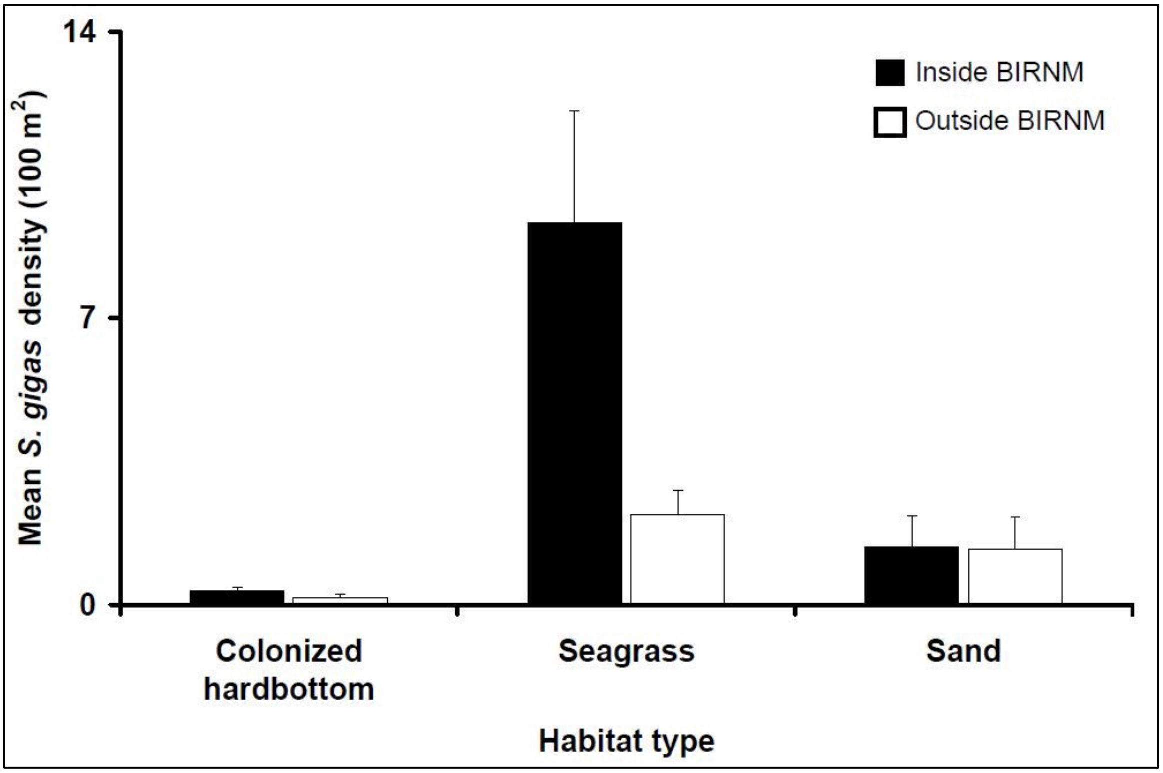


Figure 4.6.2.2. Queen conch inside and outside BUIS by dominant habitat types in the study region (northeastern St. Croix) between 2004 and 2006 (from Pittman et al. 2008).

Continued monitoring for queen conch at BUIS occurs biennially as part of the National Coral Reef Monitoring Program (NCRMP). Queen conch abundance is also recorded on transects at randomly stratified locations throughout St. Croix during the same NCRMP effort. The most recently completed NCRMP sampling (2017) recorded a density of 56.5 ± 20.0 queen conch per hectare within the boundaries of BUIS. However, the NCRMP most likely underestimates its assessment of queen conch populations, as surveys are performed only on hardbottom habitat and, on average, 90% of locations surveyed in St. Croix had no conch present. The South Florida Caribbean Network (SFCN) intends to record density of queen conch during upcoming planned seagrass surveys (M. Feeley 2021, personal communication).

Threats and Stressors

The largest threat to queen conch populations in St. Croix is overfishing; however, this does not necessarily apply to populations within the boundaries of BUIS since it is a designated no-take zone. Conch is poached illegally and at present the impact/effect is not fully known. NPS has documented the take of queen conch in the monument (2017, 2019) finding harvested conch shells on the bottom, abandoned after illegal take. Additionally, destruction or loss of seagrass habitat in which queen conch spend the majority of their life could lead to population declines. BUIS does not allow anchoring without permit inside the park boundaries, which substantially limits benthic habitat destruction as anchoring negatively impacts seagrass (Rogers and Beets 2001). A recent invasion of the Indo-Pacific seagrass *Halophila stipulacea* in the USVI (Willette et al. 2014) could have unknown consequences on queen conch; *H. stipulacea* was discovered within BUIS in 2017 (Gulick et al. 2020; see seagrass section 4.4.1). This invasive seagrass can displace native seagrass (Willette and Ambrose 2012) and invasive populations may change the ecology of queen conch (Becking et al. 2014). Queen conch do not avoid meadows of *H. stipulacea* (Becking et al. 2014), but it is not clear if they derive the same nutritional benefit from consuming *H. stipulacea* and its epiphytes. Apart from understanding how *H. stipulacea* impacts queen conch populations, queen conch inside BUIS are relatively protected from territorial threats and stressors under the current management regime.

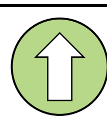
<u>Data Needs and Gaps</u>

Historical baseline population data for queen conch populations within BUIS are lacking. Tobias et al. (1988) provided one population assessment while fishing regulations still allowed take of queen conch within the Monument. However, there is no assessment of queen conch populations immediately after the close of fishing within the Monument boundaries, potentially making it difficult to accurately determine the state of recovery of the population. Current studies appear to provide a comprehensive assessment of adult queen conch populations across multiple different habitat types and depths. Juvenile queen conch populations are likely underestimated due to their tendency to remain buried in sediments, making them difficult to observe during surveys. Future monitoring should not solely be conducted during the NCRMP as sampling is only performed on hardbottom habitats shallower than 30 m, and efforts should be made to continue monitoring the seagrass beds for population recovery.

<u>Overall Condition</u>

Although historical data is lacking, queen conch populations reported during recent surveys appear to indicate that recovery is occurring (Table 4.6.2.1). The protection of the extensive seagrass beds within BUIS in addition to the established no-take zone will potentially allow for continued recovery barring the illegal poaching with the park has documented.

Table 4.6.2.1. Graphical summary of status and trends for queen conch within the framework category queen conch, including rationale and reference condition.

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Queen Conch	Abundance		Abundances appear to be relatively high and possibly increasing, with evidence of juvenile queen conch recruitment.

<u>Sources of Expertise</u>

- Lee Richter, Marine Biological Technician, South Florida Caribbean Inventory & Monitoring Network, National Park Service
- Jennifer Doerr, Research Fishery Biologist, Galveston Laboratory of the Southeast Fisheries Science Center, National Oceanic and Atmospheric Administration

- William Tobias, Division of Fish and Wildlife, USVI Department of Planning and Natural Resources (ret.)

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4.6.3. Lobster

This section reviews the condition of the spiny lobster (*Panulirus argus*) in the BUIS. The condition assessment considers data for the years 2017 and 2019 provided by the National Coral Reef Monitoring Program and the National Park Service Caribbean Spiny Lobster Monitoring Program, respectively, to assess the status of the spiny lobster. The condition of the spiny lobster population is typically evaluated using metrics that detect changes in abundance, size, and sex ratio.

<u>Description</u>

BUIS contains several coral reef habitats ranging from shallow emergent barrier and isolated patch reefs to deeper mesophotic reefs, in addition to sand and seagrasses meadows and other forms of submerged vegetation. Many threatened, endangered, or commercially important species including Caribbean spiny lobster (*Panulirus argus*) are found within the now fully protected Monument.

Caribbean spiny lobsters are most commonly found in a variety of hardbottom and coral reef habitats, which account for about 31% of the benthic habitat at Buck Island Reef NM (Figure 4.6.3.1). Although this species was not historically targeted as a major commercial fishery, there has been an exponential increase in its demand over the last 50 years presumably due to tourism (Richter et al. 2018). However, the expansion of Buck Island Reef NM in 2001 created one of the first marine protected “no-take” areas in both the United States and the Caribbean (Pittman et al. 2008) and provided additional protections to many vulnerable marine species for almost 20 years.

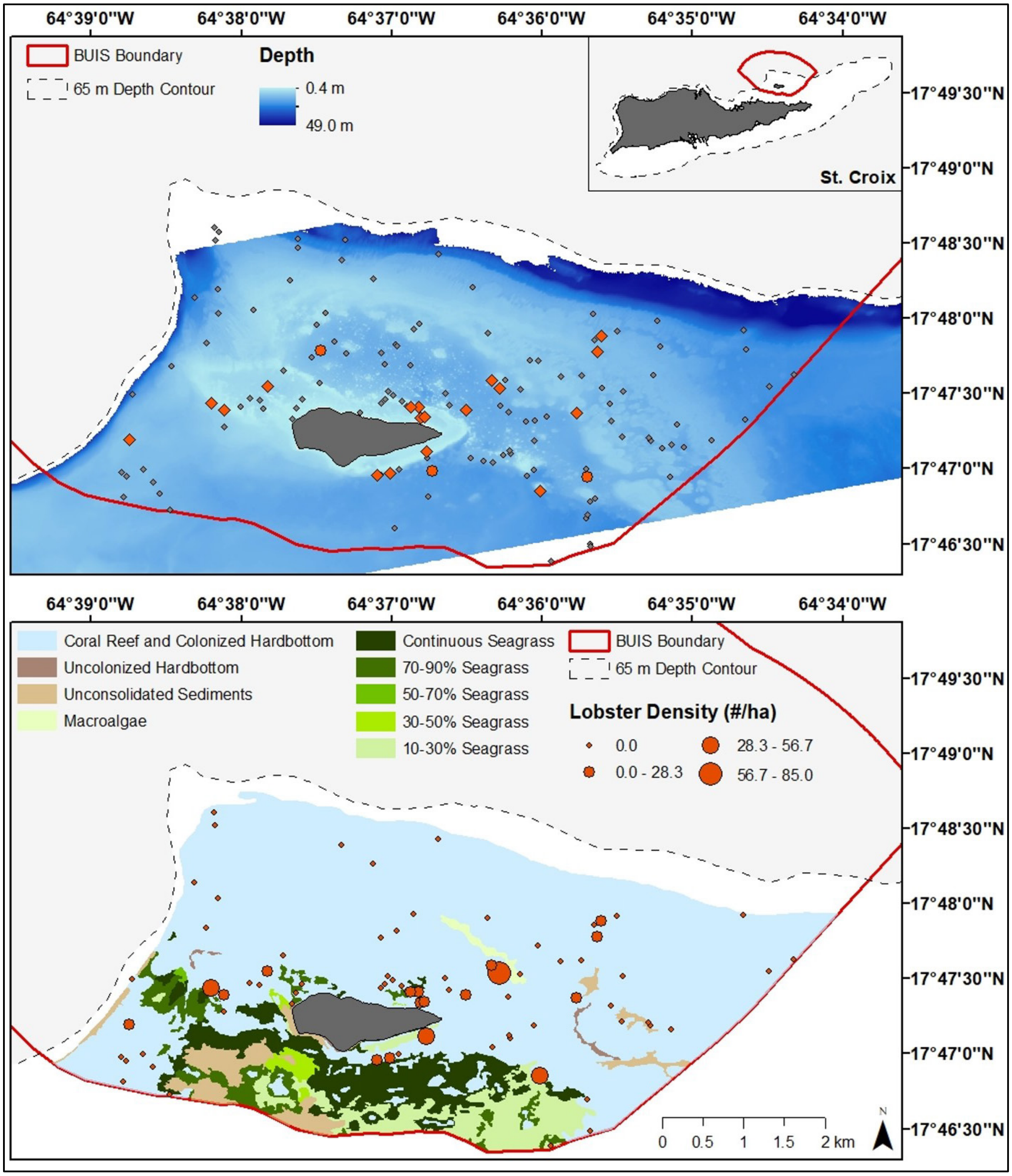


Figure 4.6.3.1. The Buck Island Reef National Monument location and boundary (inset). Top: presence (orange) or absence (gray) of lobster recorded during NCRMP (circle) or NPS (diamond) surveys. Depth within the BUIS is also displayed. Bottom: lobster density (#/ha) calculated from NPS spiny lobster monitoring surveys. Major benthic cover categories within the BUIS are displayed.

<u>Data and Methods</u>

All data used for historical assessments of lobster populations at BUIS were obtained through literature review. Tobias et al. (1988) conducted 15 minute searches for both spiny lobster and spotted lobster (*P. guttatus*) at three reef locations within the BUIS. Lobsters were counted and spiny lobster were categorized by size (≥3.5 or <3.5 in carapace length, representing the minimum legal capture limit cut-off for lobster in the USVI; Virgin Islands Code). These surveys were conducted monthly from November 1985 to June 1986. Mateo and Tobias (2002) analyzed historical fishing data obtained from the National Marine Fisheries Service from 1995–1999 in addition to biological metrics collected at ports to provide a characterization of lobster populations for the island of St. Croix, just 1–2 miles to the south of BUIS. Olsen et al. (2018) provided information regarding the Virgin Islands lobster fishery from 1975 to 2017 through analysis of historical landings data, port sampling, and tag and recapture studies.

Current estimates of spiny lobster populations were derived from datasets provided by NOAA from the National Coral Reef Monitoring Program (NCRMP) and the National Park Service (NPS) Caribbean Spiny Lobster Monitoring Program. During NCRMP sampling in 2017, lobster surveys were conducted on 15 x 2 m belt transects at randomly selected sites over several hardbottom habitat, depth, and management regime strata to obtain abundance estimates. In April 2019, the South Florida Caribbean Network Present-day baseline conditions of spiny lobster within the BUIS were obtained through literature review. From 2003–2006, Pittman et al. (2008) conducted lobster assessments on 25 x 4 m belt transects around Buck Island stratified randomly by management regime (i.e., inside or outside the BUIS). Lobsters were counted if they were found within the transect area but were not actively searched for under structure (Pittman et al. 2008). Cox et al. (2009) conducted 60 minute searches for lobster at randomly selected sites over a variety of reef habitats and depths from 2004–2007. During surveys, lobsters were counted, reproductive metrics for female lobster were recorded, and individuals were assessed for the presence of the PAV1 virus. Additionally, post-larval lobster collectors were installed in April 2004 and sampled monthly for one year to determine abundance of post-larval lobster (Cox et al. 2009).

(NPS) initiated a long-term Caribbean spiny lobster monitoring effort in BUIS, to be repeated every four years (Richter et al. 2018). The protocol uses stratified-random design based on the NCRMP sample frame. At each sample point, paired 7.5 m radius search plots are searched, where all lobster encountered are counted, sized, and assessed for several reproductive metrics (SFCN 2019).

Reference Conditions/Values

Spiny lobster were not a historically significant part of the Virgin Islands commercial fishery until about the 1980s when landings began to increase to meet the demands of tourism (Figure 4.6.3.2; Richter et al. 2018). Olsen et al. (2018) reported that total spiny lobster landings for the Virgin Islands in the 1970s were less than 5,000 kg annually, a fraction of present-day annual landings (about 45,000 kg). In 1985, several amendments to the original fishing regulation laws from 1972 (Virgin Islands Code) placed restrictions on lobster take, such as size restrictions and seasonal closures, and within the BUIS additional restrictions limited recreational take of lobster to two legal individuals per person per day. Around this point of increase, Tobias et al. (1988) conducted surveys for lobster from November 1985 to June 1986 at three reef locations within the BUIS – west patch, north patch, and south fringe –to estimate the impact of commercial fishing on lobster populations. They found that total spiny lobster densities ranged from 8.9–111.1 individuals per hectare with an overall density of 44.5 ± 16.5 (SEM) individuals per hectare (Table 4.6.3.1). There were lower densities of juveniles than adult legal size (3.5 in carapace length) lobster at all study locations. The authors cautioned about the potential of both recreational and commercial lobster fishing to contribute to future population declines within the BUIS, but noted that their observations of population decline were consistent with reef ecosystems in the US Virgin Islands as a whole. They recommended full protection of marine resources within the BUIS in the hope that they might provide a source of both larvae and adults to repopulate reefs outside the protected area, but stated that populations may not recover even when relieved of fishing pressures due to the small size of the protected zone (Tobias et al. 1988).

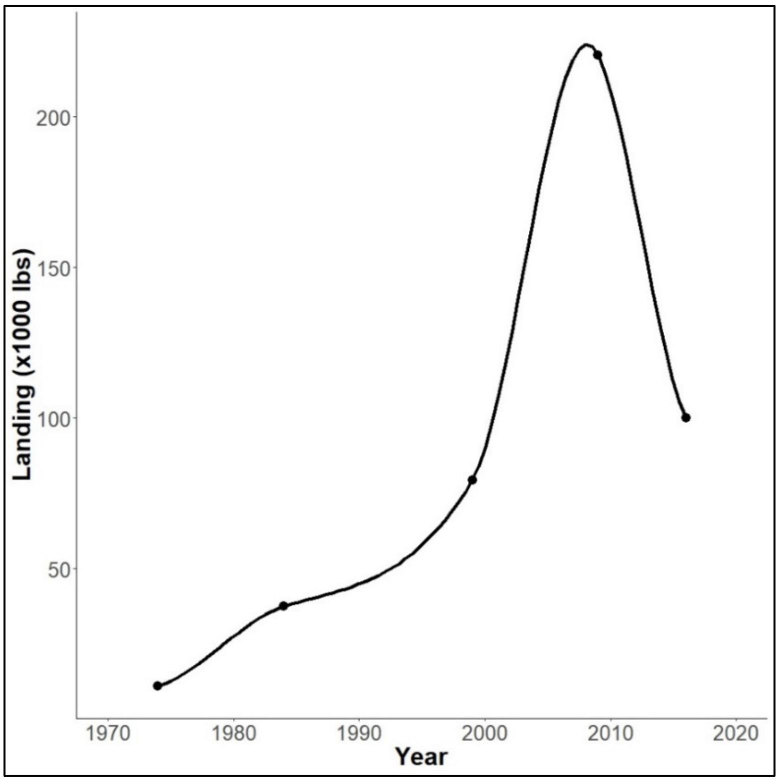


Figure 4.6.3.2. Commercial lobster landings in the US Virgin Islands from 1974–2016. Data were obtained from Richter et al. (2018).

Table 4.6.3.1. Summary of historical and current lobster population information within BUIS unless otherwise noted. All values are for Caribbean spiny lobster (*Panulirus argus*) unless otherwise noted and adult is defined as of legal size (≥89 mm). Average carapace lengths are for adult lobster only, while the carapace length range includes juveniles. Sex ratio is male:female.

Metric	Category	Historic Value	Current Value
Density (#/ha± SEM)	Total	44.5 ± 16.5 [a]	4.1 ± 2.7 [c] 22.6 ± 13.6 [e] 8.6 ± 2.0 [f]
	Adult	35.7 ± 12.8 [a]	5.6 ± 1.5 [f]
	Juvenile	12.1 ± 5.4 [a]	3.0 ± 1.0 [f]
	Spotted Lobster	37.0 ± 13.3 [a]	17.5 ± 3.9 [f]
Carapace Length (mm ± SEM)	Average	–	97.6 ± 5.5 [f]
	Male	108.4 [b]	121.0 (n=1) [f]
	Female	103.4 [b]	104.3 ± 3.5 [f]
	Range	75.0–190.0 [b]	28.0–168.0 [d] 48.0–121.0 [f]
Sex Ratio	M : F	1 : 0.7 [b]	1 : 0.8 [d] 1 : 4 [f]

[a] Source: Tobias et al. (1988). Values reported from Tobias et al. (1988) may be biased due to selection of optimal lobster habitat for sampling.

[b] Source: Mateo and Tobias (2002). Values reported from Mateo and Tobias (2002) were obtained from fisheries data and were not specific to BUIS.

[c] Source: Pittman et al. (2008).

[d] Source: Cox et al. (2009).

[e] Values were calculated using data from National Coral Reef Monitoring Program.

[f] Values were calculated using data from NPS Caribbean spiny lobster monitoring.

A decade after Tobias et al. (1988) conducted their study, Mateo and Tobias (2002) examined commercial fishing landings for the island of St. Croix from 1995–1999 to provide information about spiny lobster populations, estimate growth and mortality parameters, and determine the level of exploitation of the fishery. Based on landing data, the amount of lobster being removed from St. Croix waters due to commercial fishing increased by about 420% from 1978–1998 (Mateo and Tobias 2002). Over the course of their study, they reported a carapace length range of 75–190 mm (2.75–7.48 in) with a significant decline in average carapace length of males. They determined a sex ratio of 1.5 males to 1 female (Table 4.6.3.1), though they noted this ratio most likely is skewed due to no take restrictions on females with eggs. Additionally, exploitation rates of both males and females calculated from a variety of methods exceeded acceptable levels and the calculated maximum sustainable yield was exceeded in almost every year in the study period (Mateo and Tobias 2002). Based on these metrics, the authors concluded that the St. Croix lobster population was overfished at the time of their study. However, they noted that their reliance on voluntarily supplied landing information could provide an underestimate of exploitation, while migration of larger adult lobster to deeper water could provide an overestimation of population exploitation given that the St. Croix fishery relies primarily on diving for lobster harvest.

Current Condition and Trend

In 2001, the borders of the BUIS were expanded substantially, during which the Monument in its entirety became a “no take” zone (Pittman et al. 2008). After this restriction, Pittman et al. (2008) performed benthic habitat, fish, and macroinvertebrate surveys both within and outside the BUIS boundary from 2003–2006. Based upon the number of sites completed and the total number of lobster observed, densities inside and outside the borders of the BUIS were calculated to be 4.1 ± 2.7 (SEM) and 2.9 ± 1.1 (SEM) lobster per hectare, respectively. Although there appeared to be no difference in the density of lobster between the two management regimes, the authors note that these counts were most likely substantially underestimated, as they did not actively search for cryptic lobster during their surveys and about 98% of surveyed sites had no observed lobster (Pittman et al. 2008).

During about the same time period, Cox et al. (2009) conducted a study examining multiple aspects of spiny lobster population characteristics to provide a baseline of information to evaluate the effectiveness of the BUIS as a marine reserve. The objectives of this study were five-fold: to evaluate and compare lobster populations within and outside the BUIS, to assess breeding activity within and outside the BUIS, to record abundance of post-larval lobster to assess the BUIS as juvenile settlement habitat, to examine individuals for the virus PAV1, and to provide recommendations for future lobster monitoring. Results of search surveys suggest that lobster are both more abundant and larger within the boundaries of BUIS though statistical comparisons of metrics between the two management regimes were limited due to patchiness and variability of lobster observed (Table 4.6.3.1; Cox et al. 2009). Reproductive females were more frequently observed within the BUIS, especially in deeper habitats, than outside the protected area; however, statistical comparison was not possible due to low sample sizes.

Abundance of post-larval lobster collected around the BUIS was higher than that typically observed in Florida and the north side of the BUIS collected significantly more post-larval lobster than those on the south side. Despite high abundances, a lack of optimal settling habitat around the BUIS could increase predation of juveniles and the authors speculated it could limit the overall abundance of lobster in St. Croix. Finally, although the virus PAV1 was confirmed in St. Croix, sample size was too low to fully characterize the distribution and impact of the virus. The authors acknowledged the challenges and limitations of this study due to small sample sizes and patchiness in abundance. Based on their work, they recommended using a mix of both areal transect surveys and timed search surveys in targeted habitats and depths over a longer time period to maximize potential sample size and meaningful comparisons. However, despite limitations, they concluded that the BUIS appears to have a positive effect on lobster abundance, size, and breeding activity (Cox et al. 2009).

The National Coral Reef Monitoring Program (NCRMP) observed very few lobsters within the BUIS during the 2017 survey period. Although lobster density within the BUIS was higher than that in areas with no additional catch restrictions (Table 4.6.3.2), populations were very patchy and about 95% of sites surveyed had no lobster present (Figure 4.6.3.1). Densities calculated from the NCRMP data were higher than those reported by Pittman et al. (2008), but, like Pittman et al. (2008), lobster densities most likely do not reflect true populations sizes due to similar methodological constraints and should be used cautiously.

Table 4.6.3.2. Mean spiny lobster density per hectare (±SEM) calculated from the National Coral Reef Monitoring Program sampling in 2017. Densities were calculated for the following management regimes in St. Croix: open (open area – territorial fishing regulations), BUIS (Buck Island National Park – no take zone), EEMP (St. Croix East End Marine Park – partial no take zone), and SARI (Salt River Bay National Historic Park and Ecological Preserve – no take zone).

Management Regime	Total Spiny Lobster
Open	12.7 ± 7.2
BUIS	22.6 ± 13.6
EEMP	53.3 ± 53.3
SARI	27.8 ± 27.8

The South Florida Caribbean Network (NPS) initiated long-term monitoring of spiny lobster in BUIS, completing the first round of sampling in April 2019 (Richter et al. 2018). Average lobster densities observed during these surveys were lower than those from the National Coral Reef Monitoring Program (Table 4.6.3.1) but were comparable to the lower bound of the range reported by Tobias et al. (1988). Despite active search for lobster during surveys, populations were still patchy and about 75% of locations surveyed had no lobster present (Figure 4.6.3.1). Carapace lengths for all lobster recorded during surveys ranged from 48.0–121.0 mm (1.9–4.8 inches), while average lengths for adult lobster were 104.3 ± 3.5 mm (4.1 ± 0.1 inches, females) and 121.0 mm (4.8 inches [n = 1], males).

<u>Threats and Stressors</u>

Overall lobster populations in St. Croix are threatened by overfishing (Mateo and Tobias 2002). While this does not necessarily apply to populations within the boundaries of the BUIS because it is a designated no-take zone, illegal harvest and poaching of spiny lobster does occur and is considered a valid threat to populations within the BUIS (Hillis-Starr and Pollock 2020, personal communications). Destruction or loss of critical habitat due to either natural or anthropogenic influences could negatively impact future lobster populations by either increasing time to recovery or preventing recovery altogether. Lobsters depend on seagrass and macroalgae-dominated hardbottom habitats post settlement through juvenile life stages after which they transition to reef structures for protection as adults (Richter et al. 2018). The BUIS does not allow anchoring without permit inside the park boundaries, which could substantially limit direct benthic habitat destruction. However, it should be noted that the island of St. Croix in general lacks suitable settlement habitat for spiny lobster, which has been speculated to directly influence to the population's ability for recovery (Cox et al. 2009). Under the current management regime, lobster populations in the BUIS are relatively protected from direct threats; however, illegal harvest and the potential for habitat loss due to climate change impacts, such as increased water temperature and more destructive hurricanes, remain ever present threats.

<u>Data Needs and Gaps</u>

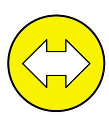
Historical data for lobster populations within the BUIS appear to provide a general baseline for the resource; however, the earliest data specific to the BUIS was from 1985 at which point commercial landings has already begun to increase. While Olsen et al. (2018) provides information regarding the lobster fishery prior to 1985, it is for the island of St. Croix as a whole. If possible, an examination of fisheries data specific to the BUIS prior to this first time point could be beneficial to establish a potentially more accurate baseline lobster population. Additionally, results of current landings data analyses should be incorporated to provide a current status of the fishery in general and serve as a point of comparison to current monitoring programs.

Initial monitoring through the NPS Caribbean Spiny Lobster Monitoring Program covered a relatively large number of survey locations in a short amount of time (76 sites over 7 days) and appeared to have the best success rate observing lobster during surveys. The continuation of this monitoring program would be beneficial to understanding current and future populations within the BUIS. However, the lack of similar surveys outside protected areas does not allow for any relative comparisons of lobster populations, as the data collected by the NCRMP is likely not representative of true populations and must be used cautiously for comparative purposes. Additionally, surveys of deeper reefs within the BUIS could provide more complete information about lobster populations since adults frequently migrate deeper, a trend observed by Cox et al. (2009).

<u>Overall Condition</u>

An examination of current estimates of lobster density relative to those reported in historical datasets indicate that density is still much lower than original populations. However, densities from the SFCN (NPS) Caribbean spiny lobster monitoring are higher than those recorded by Pittman et al. (2008), who surveyed shortly after the BUIS expanded, and this potentially indicates an increase in population since the establishment of the BUIS as a fully protected no-take area. We consider the condition of the spiny lobster as warranting moderate concern, with no trend (Table 4.6.3.3).

Table 4.6.3.3. Graphical summary of status and trends for lobster within the framework category Marine Invertebrates including rationale and reference condition.

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Lobster	Abundance		There is medium confidence in the assessment due to lack of consistent sampling and methodologies not optimized for lobster. Values indicate the potential for overfishing and poaching, but with stabilized or increasing populations within BUIS.

Sources of Expertise

- Lee Richter, Marine Biological Technician, South Florida Caribbean Inventory & Monitoring Network, National Park Service
- Clayton Pollock, Biologist, National Park Service
- Zandy Hillis-Star, Supervisory Resource Management Specialist (ret.), National Park Service

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Cox, C., A. Zito, R. Bertelsen, and J. H. Hunt. 2009. Buck Island National Monument Lobster Population Study. Final Summary Report. Florida Fish and Wildlife Conservation Commission, Marathon, FL. 29pp.

Mateo, I., and W. J. Tobias. 2002. Preliminary estimations of growth, mortality, and yield per recruit for the spiny lobster, *Panulirus argus*, in St. Croix, USVI. GCFI 53:58–75

Olsen, D. A., J. Nowlis, and D. Bryan. 2018. A study of the Virgin Islands spiny lobster fishery: growth, population size, and mortality. GCFI 70:210–217

Pittman, S. J., S. D. Hile, C. F. G. Jeffrey, C. Caldow, M. S. Kendall, M. E. Monaco, and Z. Hillis-Starr. 2008. Fish assemblages and benthic habitats of Buck Island National Monument (St. Croix, U.S. Virgin Islands) and the surrounding seascape: A characterization of spatial and temporal patterns. NOAA Technical Memorandum NOS NCCOS 71. Silver Spring, MD. 96 pp.

Richter, L. J., M. W. Feeley, A. J. Atkinson, J. M. Patterson, A. D. Davis, and J. Miller. 2018. Long-term monitoring of Caribbean spiny lobster (*Panulirus argus*): Protocol narrative. Natural Resource Report NPS/SFCN/NRR–2018/1850. National Park Service, Fort Collins, Colorado.

South Florida/Caribbean Network (SFCN). 2019. SFCN 2019 Caribbean Spiny Lobster Monitoring – Resource Brief. National Park Service

Tobias, W., E. Telemaque, and M. Davis. 1988. Buck Island Fish and Shellfish Populations. Virgin Islands Resource Management Cooperative Biosphere Reserve Research Report No. 26. 27pp.

Virgin Islands Code, Title 12, Chapter 9A, §§301–326.

4.7. Marine Vertebrates

4.7.1. Reef fish

Description

Caribbean coral reefs have experienced intense artisanal overfishing, particularly of ecologically and commercially important species such as parrotfishes (Figure 4.7.1.1 (left), family Scaridae) and groupers (Figure 4.7.1.1 (right), family Serranidae). The result has been a region-wide decline of fish biomass with catastrophic consequences for these ecosystems (Jackson et al. 2014, Kadison et al. 2017). Marine protected areas are among the most effective tools to assure protection of reef fish and their ecological roles (e.g., Palumbi 2004, Mumby and Steneck 2008, McCook et al. 2010 but also see Bruno and Valdivia 2016).

Buck Island Reef National Monument (BUIS) was founded in 1961, originally including 704 acres of water-protected area. National Park Service (NPS) has provided since then protection for marine resources with the Monument boundaries, initially with the "Marine Garden," excluding fishing within eastern two-thirds of the Monument's original park boundaries and limiting extraction of conch and lobster. The Monument boundaries were expanded in 1975 and for a second time in 2001, encompassing over 19,000 acres making BUIS one of the first fully protected marine areas in the national park system. The MPA Interim Regulations established in 2003 eliminated fishing and restricted anchoring within the Monument. However, enforcement of these regulations has been difficult as a consequence of insufficient funding to expand Visitor and Resource Protection staff (National Park Service 2012).

Figure 4.7.1.1. Ecologically and commercially important Caribbean reef fishes. Large parrotfishes (*Scarus coelestinus, Sc. guacamaia*, and *Sc. coeruleus*) grazing on a Florida coral reef (left). Nassau grouper (*Epinephelus striatus*) sheltering on a Bahamian coral reef (right). Photo credits: Alain Duran

Approximately 47% of BUIS encompasses coral reefs and hardbottom habitats that shelter multiple reef fish species. Despite the historical and current protection efforts, various indicators (e.g., fish richness, biomass, density, and size of large species) of fish community status indicate no evidence of improvement within BUIS compared to outside areas (Pittman et al. 2008). This report elaborates on past reports (e.g., Pittman et al. 2008, 2014) and uses newly available data sets collected by

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) to evaluate the trends and current status of BUIS reef fish. 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 within BUIS, 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 4.7.1.1). 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, Brandt et al. 2009, Bryan et al. 2013) within a 15 m diameter imaginary cylinder (~177 m^2). The method differs from the belt transect in several aspects, including stationary counts, count along the transect, and 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) (Bohnsack and Harper 1988, Stevens et al. 2019). There were a 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.

We also analyzed fish density and biomass by trophic level: (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.

Table 4.7.1.1. Number of surveys conducted in Buck Island Reef National Monument by year and survey method from 2001 (01) to 2019 (19). (Data from NPS-NCRMP-UVI program).

Year	Method	Number of Surveys
2001	Belt transect	79
2002	Belt transect	72
2003	Belt transect	79
2004	Belt transect	56
2005	Belt transect	86
2006	Belt transect	99
2007	Belt transect	50
2008	Belt transect	86
2009	Belt transect	89
2010	Belt transect	42
2012	Belt transect	64
2015	Belt transect	66
2017	RVC	57
2019	RVC	113

Reference Conditions/Values

Fish density of some reef fishes reported by Gladfelter and Gladfelter in 1979 are listed and compared to data from Pitman et al. from 2001–2006 (Pitman et al. 2008, Table 12). Almost one-third of the species listed (n=23) by Pittman et al. (2008) displayed negative trends compared to 1979, with no records of Nassau grouper (*Epinephelus striatus*), tiger grouper (*Mycteroperca tigris*), or yellowfin grouper (*M. venenosa*).

Pittman et al. (2014) studied 15 fish community metrics within BUIS and outside BUIS. Eight of those metrics showed no sign of change between 2003–2010 (positive or negative). Total fish biomass inside the park did not change while species richness decreased. Biomass and density of ecologically important groups such as herbivorous fish did not change during that period. Pittman et al. (2014) suggest that further studies are needed to investigate these trends, including the absence of large-bodied fishes such as Nassau (*Epinephelus striatus*) and yellowfin grouper (*Mycteroperca venenosa*).

Current Condition and Trend

Despite high annual variation, total fish density (175.3 ± 216.9 Ind. $100m^{-2}$) and total fish biomass (6334.5 ± 276.0 g. $100m^{-2}$), displayed no positive or negative trends from 2001–2015 (Figure 4.7.1.2 A&C, lm, density, $R^2 = 0.003$, $p = 0.098$, biomass, $R^2 = 0.004$, $p = 0.078$). Likewise, total fish density, total fish biomass, and richness calculated from surveys conducted in 2017–2019 exhibited no year differences (Figure 4.7.1.2 B&D). Our results concur with Pittman et al. (2014), who reported no changes in total fish biomass between 2003–2010. The number of species found per survey in 2001–2015 averaged 18.7 with no clear trends (Figure 4.7.1.2 E). On average, ten more species were found in the 2017–2019 point count surveys (Figure 4.7.1.2 F). Notice that the higher number of species per survey is likely a response to survey methodology differences.

Except for the negative trends of planktivores (2001–2015) and piscivores (2017–2019), fish density of other groups was low and did not change through time (Figure 4.7.1.3). Notice that herbivore fish density (parrotfishes, surgeonfishes, yellowtail damselfish) averaged 48.4 ± 1.8 Ind. $100m^{-2}$ in 2001–2015 and 49.4 ± 3.7 Ind. $100m^{-2}$ in 2017–2019. Given that RVC surveys usually yield higher fish densities than belt transect, these similar density values with both methodologies are worth more in-depth analysis. Only biomass of invertivorous fish displayed a positive (positive) trend in 2001–2015 (Figure 4.7.1.4). The absence of a trend in herbivorous fish biomass (2001–2015 average 3933.9 ± 228.6 g. $100m^{-2}$) matches the findings by Pittman et al. 2014.

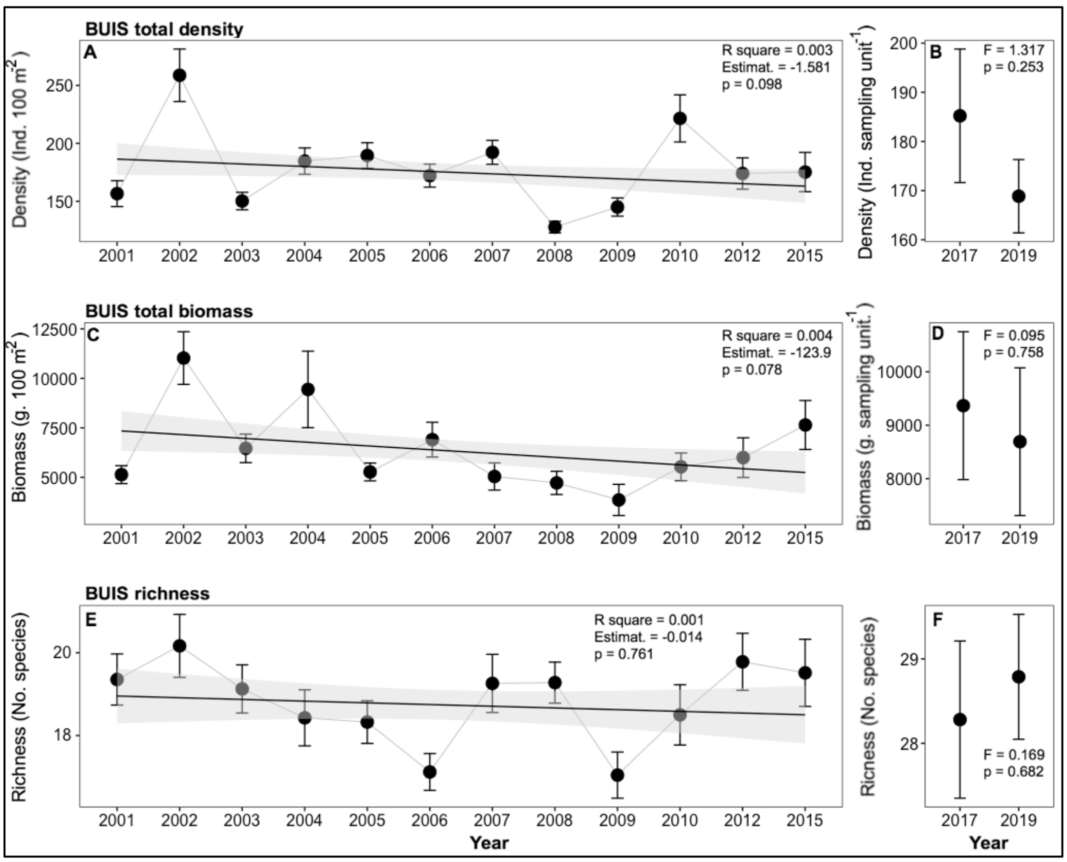


Figure 4.7.1.2. Density, biomass, and richness of reef fish in Buck Island Reef National Monument (BUIS) from 2001 to 2019 (data source: NPS-NCRMP-UVI program). Surveys from 2001 to 2015 were conducted using belt transect, while surveys in 2017 and 2019 used Reef Visual Survey. Mean ± S.E. Bold letters indicate statistical significance.

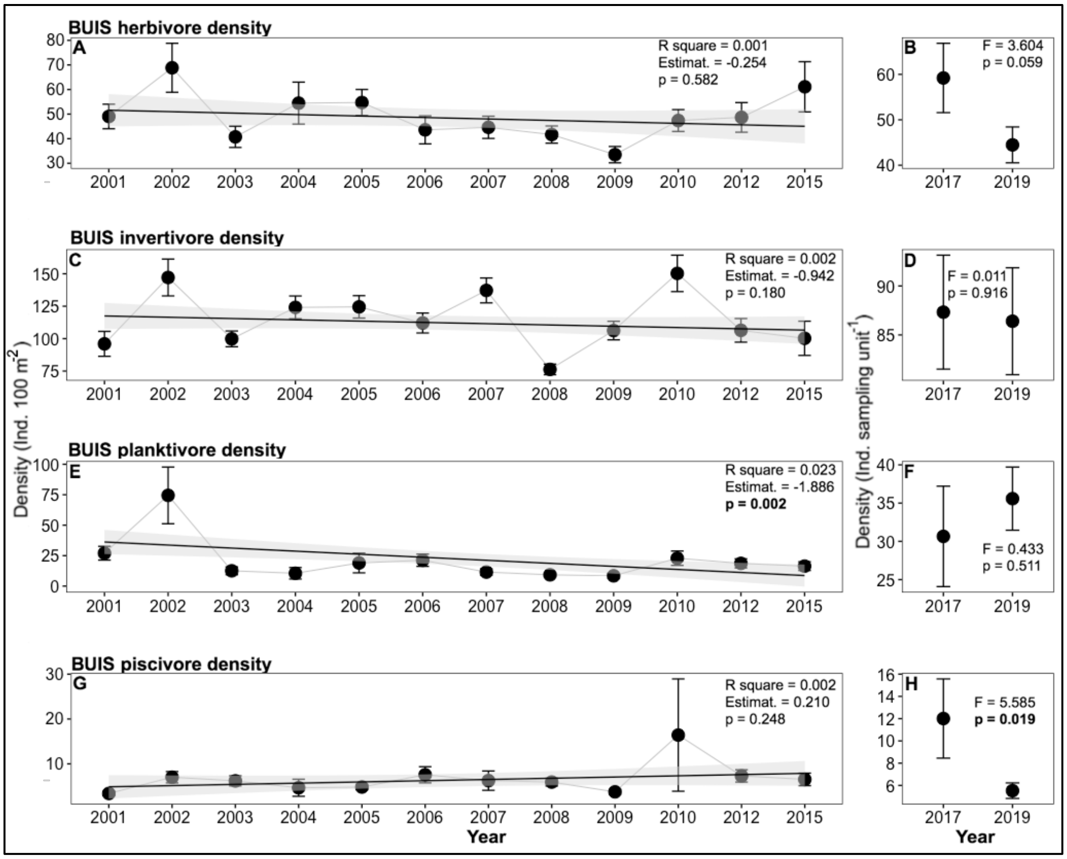


Figure 4.7.1.3. Fish density by trophic group: A&B – herbivores, C&D – invertivores, E&F – planktivore, and G&BH – piscivore in Buck Island Reef National Monument (BUIS) from 2001 to 2019 (data source: NPS-NCRMP-UVI program). Surveys from 2001 to 2015 were conducted using belt transect, while surveys in 2017 and 2019 used Reef Visual Survey. Mean ± S.E. Bold letters indicate statistical significance.

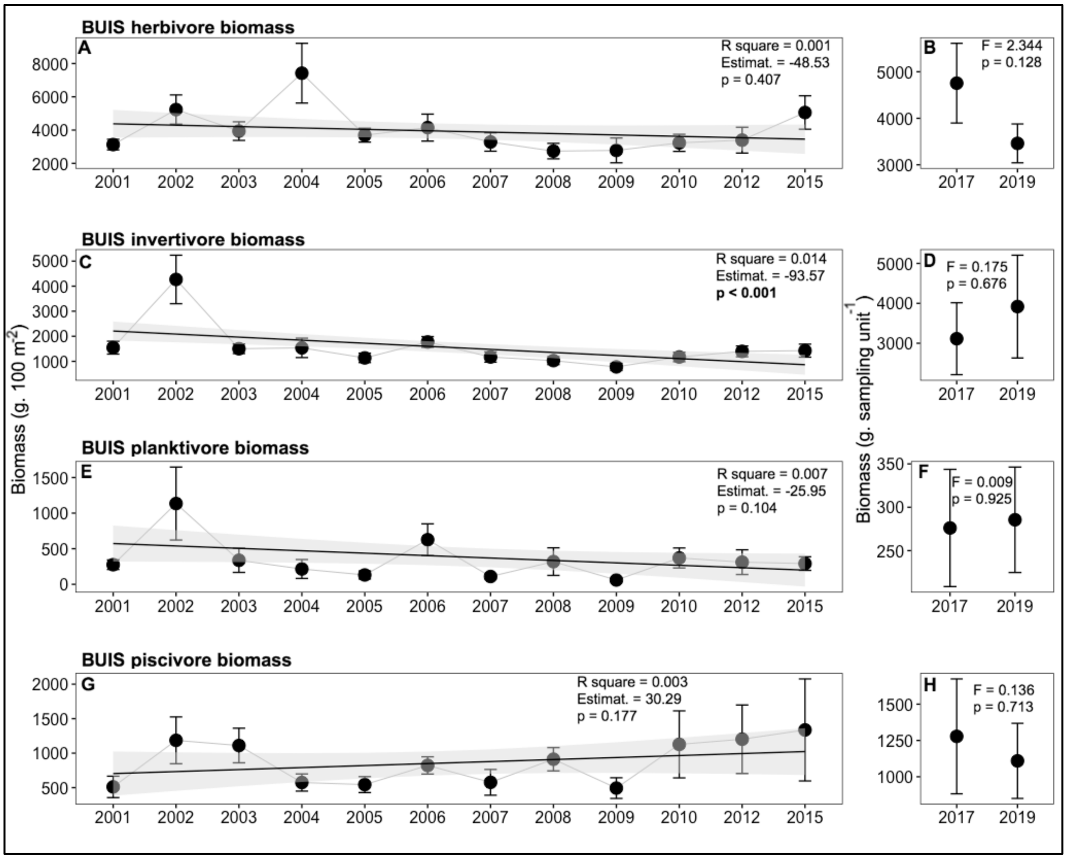


Figure 4.7.1.4. Fish biomass by trophic group: A&B – herbivores, C&D – invertivores, E&F – planktivore, and G&BH – piscivore in Buck Island Reef National Monument (BUIS) from 2001 to 2019 (data source: NPS-NCRMP-UVI program). Surveys from 2001 to 2015 were conducted using belt transect, while surveys in 2017 and 2019 used Reef Visual Survey. Mean ± S.E. Bold letters indicate statistical significance.

Density of the two major Caribbean herbivorous fish families, surgeonfish (family Acanthuridae) and parrotfish (family Scaridae), averaged 26.3 ± 1.5 Ind. 100 m^{-2} and 20.9 ± 0.7 Ind. 100 m^{-2}, respectively, with no trend in 2001–2015 (Figure 4.7.1.5 A). As reported by Pitman et al. 2014, densities of groupers (family Serranidae, 4.1 ± 0.1 Ind. 100 m^{-2}) and snappers (family Lutjanidae, 2.9 ± 0.3 Ind. 100 m^{-2}) are very low in BUIS, where groupers continued declining in 2001–2015 (Figure 4.7.1.5 A, lm, $R^2 = 0.02$, $p = 0.005$). Groupers were also the only family displaying negative fish biomass trends (Figure 4.7.1.5 B, lm, $R^2 = 0.02$, $p < 0.001$). To illustrate the spatial distribution of reef fish in the Monument, 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 4.7.1.6) and total fish biomass (Figure 4.7.1.7), but further analysis is needed to investigate spatial distribution.

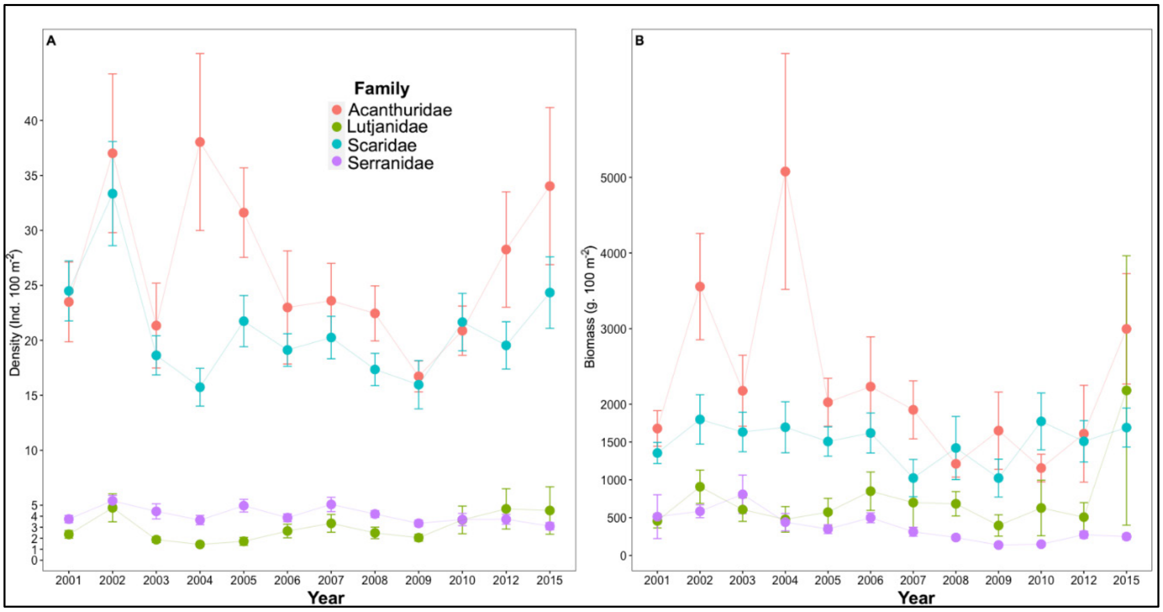


Figure 4.7.1.5. Fish density (A) and biomass (B) of some reef fish families in Buck Island Reef National Monument (BUIS) from 2001 to 2015 (data source: NPS-NCRMP-UVI program).

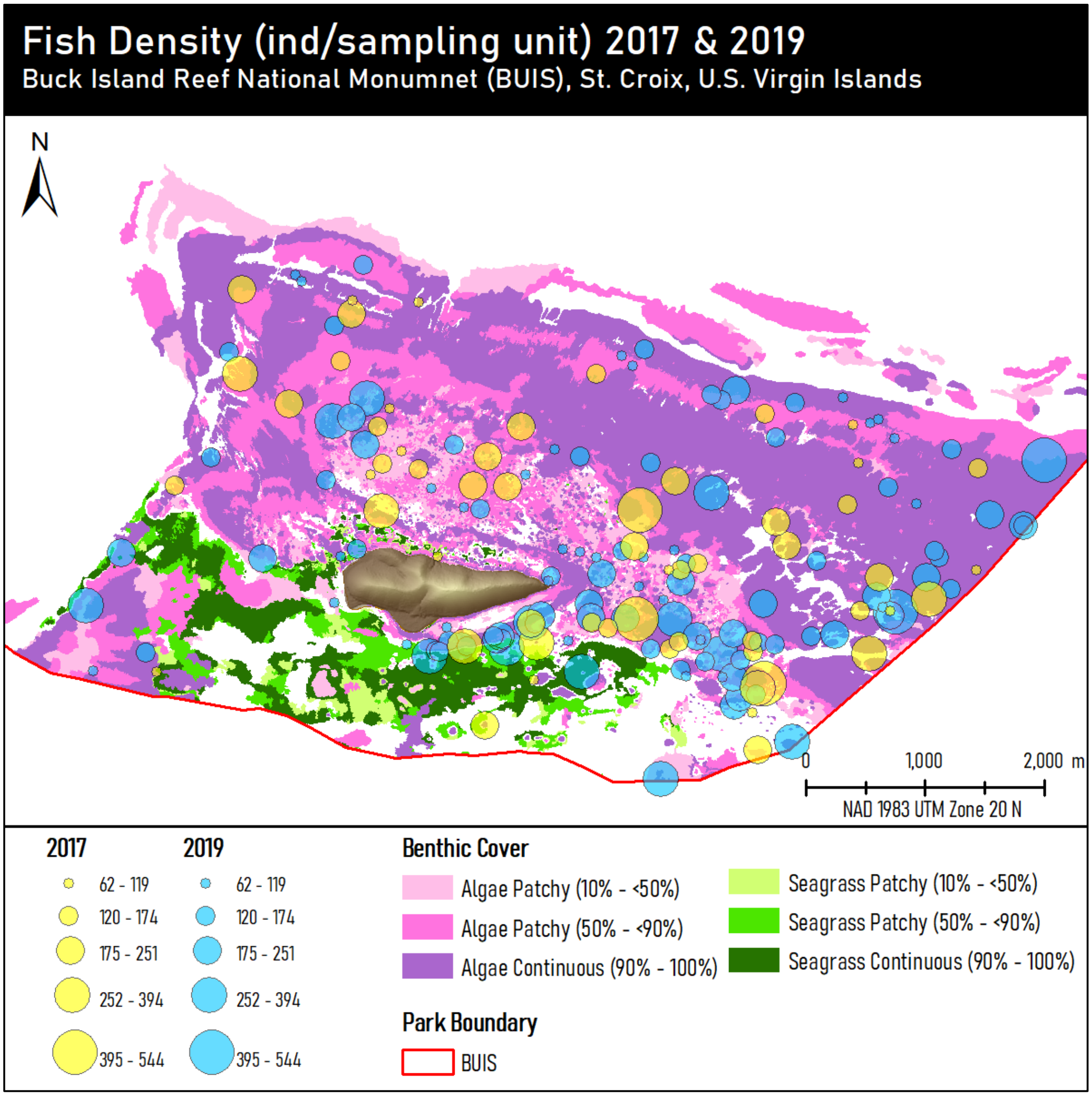


Figure 4.7.1.6. Mean total fish density (Ind. sampling unit^{-1}) estimated from 2017 (yellow circles) and 2019 (blue circles) surveys conducted in Buck Island National Monument (BUIS). Data source: NPS-NCRMP-UVI program. Habitat cover obtained from Costa et al. 2012.

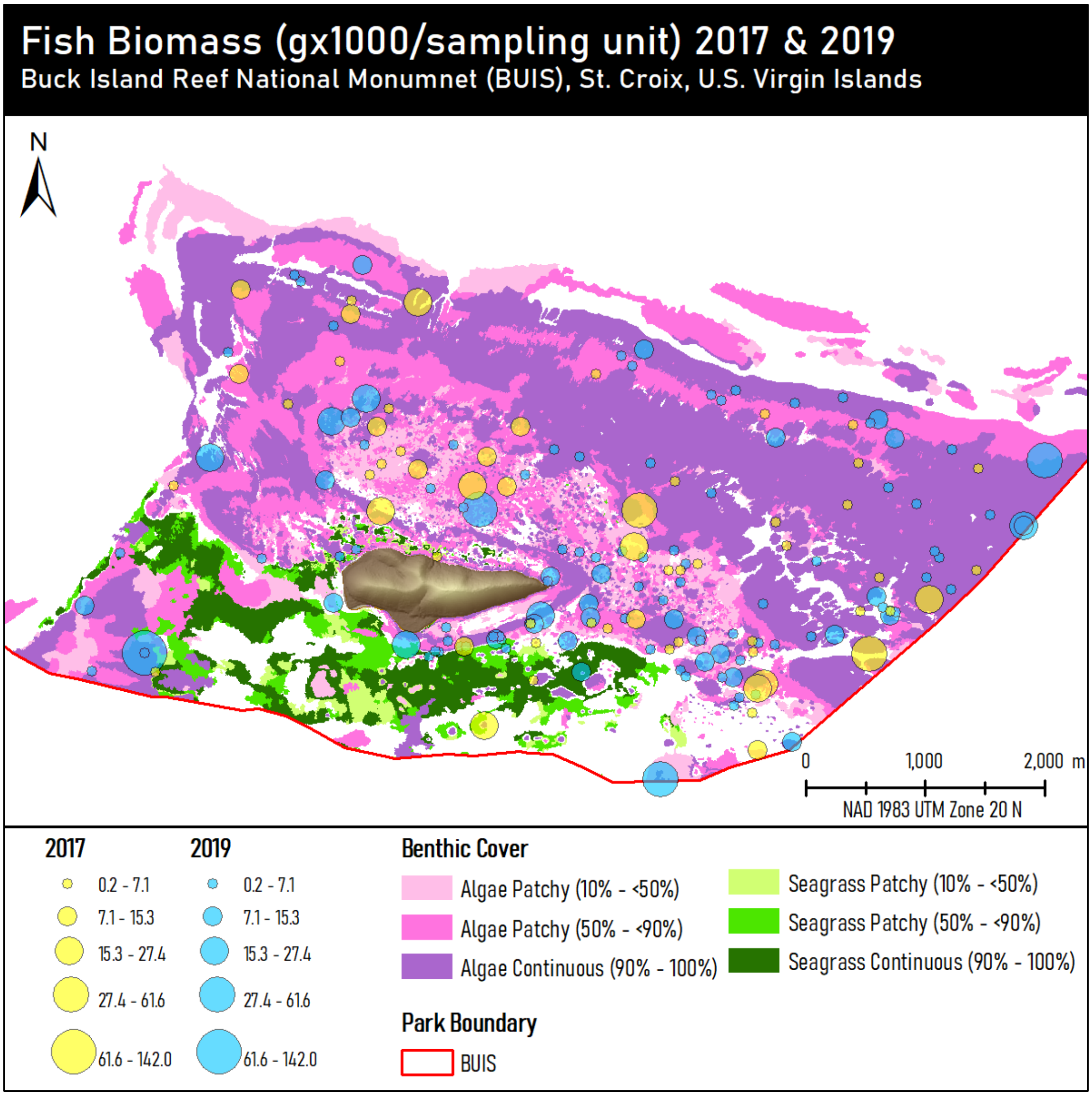


Figure 4.7.1.7. Mean total fish biomass (g. sampling unit^{-1}) estimated from 2017 (yellow circles) and 2019 (blue circles) surveys conducted in Buck Island National Monument (BUIS). Data source: NPS-NCRMP-UVI program. Habitat cover obtained from Costa et al. 2012.

<u>Threats and Stressors</u>

In the 1960s and 1970s, coral reefs located within today's Monument boundaries were dominated by corals that provided high physical complexity for a highly diverse fish community (Galdfelter et al. 1977, Bythell et al. 1989). Galdfelter et al. (1977) report the presence of large species, including midnight parrotfish (*Scarus coelestinus*), rainbow parrotfish (*Sc. guacamaia*), and blue parrotfish (*Sc. coeruleus*) that were already absent in the early 2000s (Pittman et al. 2008). However, several parrotfish have been observed recently during sea turtle patrols in Fall 2017 and via UAS in April 2018 (C. Pollock 2021, personal communication). Our findings, which include no trends in density, biomass, and richness from 2001 to 2019, adds to the list of reports pointing out concerns regarding BUIS reef fish communities (Kadison et al. 2017, Rincon-Diaz et al. 2018). Several stressors can be associated with this failure of reef fish recovery, including illegal harvesting (Valdés-Pizzini et al. 2010), habitat degradation (Bythell et al. 1989), and the impact of introduced species.

In 2001, Rogers and Beets published an analysis of BUIS reef fish communities from 1989–2000 that revealed significant decreases in fish size and abundance, particularly fishermen' target species such as groupers and snappers (Rogers and Beets 2001, p. 318). They concluded that BUIS, one of the oldest marine protected areas in the Caribbean, has not been effective and called for more active law enforcement. Pittman et al. (2008) studied BUIS reef fish from 2001 to 2006 and reported very few (3%) large (>35cm) groupers and snappers even though they indicate improvement in law enforcement. More than 70% of groupers, parrotfish, and surgeonfish were under 20 cm in length, explaining the low fish biomass in our data. Collectively, our information and past reports point out that there is still illegal fishing in the area. The only substantial evidence of the unlawful fishery in BUIS comes from Valdes-Pizzini et al. (2010), who described up to ten illegal traps used by "*weekend warriors*." Thus, this uncounted fishing pressure could well be the primary limiting factor on reef fish recovery. Along with more enforcement, outreach and environmental education programs are critical. According to Valdes-Pizzini et al. (2010), a large proportion of the fishermen do not recognize the benefits of the protection and feel that they have been "*squeezed out*" with the BUIS expansion. Stoffle et al. (2009) show that St. Croix communities depend almost exclusively on local fishing (100% of the catch is sold and consumed on the island), where jobs outside the fishing industry are hard to find. Thus, along with improved enforcement and better educational programs, fishers' economic alternatives are needed to make BUIS an effective marine protected area.

As early as 1975, Walter Adey describes areas around BUIS dominated by extensive coral reefs and algal ridges (Adey 1975). In the 1970s, *Acropora plamata* covered over 50% of the reef crest, and by 1985 several disease events reduced their population to less than 12% (Bythell et al. 1989). Rogers and Beets (2001, table 1) present a chronological list of stress events, hurricanes, diseases, and bleaching events, that have impacted coral communities in BUIS until 2000. The last significant events were Hurricanes Maria and Irma in 2017 that were impactful in coastal regions of St. John (Rogers 2019), but no information was found for BUIS. Habitat degradation is likely to be another limiting factor on reef fish recovery, as shown in other reef areas (Wilson et al. 2010). More studies are needed to evaluate the relationship between habitat degradation and fish community in BUIS and other factors such as fish larval recruitment and fish movement (but see Becker et al. 2020 and Novak et al. 2020).

The invasive Indo-Pacific lionfish (*Pterois volitans*) also pose a recognized threat to native reef fish because they can rapidly consume large numbers of prey. The species was first reported in the northern USVI in early 2011, two years after the first sighting off St. Croix. In BUIS, eleven individuals were reported in 2012 surveys, whereas only nine, three each survey year, were observed in 2015, 2017, and 2019. Thus, it seems local efforts to control the lionfish are effective.

Data needs/gaps

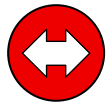
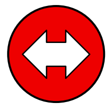
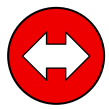
There is an urgent need to continue monitoring fish communities. Reef fish communities are naturally diverse and dynamic and susceptible to multiple factors, including fishing, reef structure, recruitment, survivorship, hurricanes, and many others. Thus, at least once a year, monitoring fish communities inside and outside BUIS is highly recommended to assess current regulations' effectiveness and act accordingly (adaptive management). 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. The negative trends of richness from 2001–2015 could be masked by the change in survey methodology beginning in 2017.

There is also a need for data collection on illegal fishing and compliance with park regulations. These are the dominant factors limiting reef recovery. Additionally, some research questions could help assist in management decisions, including what level of connectivity (closed or open populations) are the fish populations currently experiencing in BUIS? For example, each year, the red hind (*Epinephelus guttatus*) travels 5–18 km to its spawning aggregation site in BUIS, Lang Bank (Nementh et al. 2007). This migration pattern and fish movement denote the connectivity within BUIS and its potential as a core area for replenishing fish stock inside and outside its boundaries (spillover). See also the work by Bryan et al. (2019) on the movement of queen triggerfish (*Balistes vetula*) in and out of BUIS.

Unfortunately, decreased fish length and skewed sex ratio indicate that Lang Bank has failed to recover even after years of temporal closure protection (Nemeth et al. 2006). These findings alone justify the need for better protection in BUIS. Other questions of interest for management include whether habitat restoration promotes fish replenishment and whether large-bodied fishes absent from BUIS because of life-history traits that slow or prevent their full recovery.

<u>Overall condition</u>
Overall, there are no significant changes from 2001 to 2019. Based on early records, BUIS reef fish communities were heavily impacted in the 1980s and 1990s and have failed to recover (Table 4.7.1.2). Illegal harvesting and poor regulation compliance are likely limiting recovery.

Table 4.7.1.2. Graphical summary of status and trends for several metrics of reef fish communities.

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Reef fish	Total 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.
	Total fish biomass		Reef fish biomass warrants significant concern because a lack of positive trends after decades of fishing pressure suggests factors are still negatively affecting reef fish communities.
	Number of species		Reef fish richness warrants significant concern because a lack of positive trends after decades of fishing pressure suggests factors are still negatively affecting reef fish communities.

<u>Sources of Expertise</u>

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4.7.2. Sea Turtles

This section reviews the condition of sea turtles at Buck Island Reef National Monument (BUIS). The condition assessment considers 31 years of monitoring data for nesting and foraging aggregations, provided by the NPS Buck Island Sea Turtle Research Program (1988–2019), to assess the status of sea turtles in the park. The condition of sea turtle populations is typically evaluated using metrics that detect changes in abundance, productivity, and reproductive success. The condition metrics selected for this resource include measures of abundance (nesting females, in-water relative abundance), reproductive success (nest abundance, hatching success, hatchling emergence success, clutch size, hatchling sex ratio), size class, and genetic composition. Condition metrics were evaluated separately for nesting and foraging aggregations, and for each sea turtle species. Please note that some condition metrics could not be evaluated for some species due to lack of data. Temporal trends for each condition metric were evaluated for the referred period (1988–2019) when sufficient data was available.

Description

Sea turtles are large marine reptiles with a global distribution, but most species are found in temperate and tropical latitudes. Sea turtles fulfill important roles as consumers in marine ecosystems (i.e., coral reefs, mangroves, seagrass meadows) (Jackson 1997, Bjorndal and Jackson 2003), while also interacting with terrestrial systems via the use of beaches and coastal forest as nesting habitats. These reptiles are long-living, slowly maturing organisms with complex life history strategies, all of which are globally imperiled.

Sea turtles utilize separate habitats for foraging and nesting activities, which are connected by migration corridors that often span large geographic areas and jurisdictions of multiple countries (Wallace et al. 2011). Successful conservation and management of sea turtle populations requires international cooperation and large-scale strategies to mitigate threats (i.e., fisheries bycatch, direct harvesting) and prevent habitat loss (Wallace et al. 2011, Rees et al. 2016). All seven species of the world's sea turtles are protected under the Endangered Species Act (est. 1971) and are currently classified by the IUCN as endangered or critically endangered species (Seminoff et al. 2015, Valdivia et al. 2019).

BUIS provides critical nesting habitat for four sea turtle species: hawksbill (*Eretmochelys imbricata*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), and loggerhead (*Caretta caretta*) (Hillis-Starr and Phillips 1998). In particular, BUIS is the primary index nesting beach under U.S. jurisdiction for the critically endangered hawksbill sea turtle (Figure 4.7.2.1) and is the only fully protected site in the Caribbean where hawksbills forage and nest (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1993). BUIS also provides important year-round in-water developmental habitat for hawksbill and green turtles (Figure 4.7.2.1) (Hart et al. 2017, 2019). Sea turtles interact with and fulfill important roles in several BUIS ecosystems, including coral reefs, seagrass meadows, and coastal habitats. As federally listed species, sea turtles at BUIS are of high management priority (BIRNM General Management Plan 2010).

The National Park Service began monitoring sea turtle nesting activity at BUIS in 1980 (Zullo 1986). NPS park rangers conducted day patrols of the beaches to document the number of sea turtle tracks and nests. Sea turtle populations at BUIS were extremely low throughout the 1980s, with almost all documented nests being either predated by mongoose or poached by humans (Zullo 1986). NPS established the Buck Island Sea Turtle Research Program (BISTRP) in 1987 (Phillips and Hillis-Starr 2002), with the goal of using saturation tagging and long-term monitoring to evaluate the status of sea turtle populations in the Monument. The focus of BISTRP initially was to document nesting activity, but after the issue of the U.S. Hawksbill Recovery Plan was issued in 1993 (NMFS and USFWS 1993), the program was expanded to incorporate monitoring of in-water (foraging) populations (Phillips and Hillis-Starr 2002a). BISTRP has been monitoring sea turtles at BUIS since 1987 and has been recognized as one of the most intensive and successful sea turtle monitoring programs in the world, particularly for hawksbill sea turtles. This condition assessment utilizes thirty-one years of data collected by BISTRP to assess the condition of sea turtle populations at BUIS.

The status and condition of sea turtle populations are evaluated using established metrics (i.e., vital rates) that detect changes in abundance, productivity, and reproductive success. Condition metrics selected by NPS for this resource assessment include the following: abundance (nesting females, relative abundance in-water), size class, reproductive success (nest abundance, hatching success, hatchling emergence success, clutch size), genetic composition, and hatchling sex ratio.

Condition metrics were evaluated separately for nesting and foraging populations, and for each species. All report sections that follow are divided into separate components for each population, respectively.

Figure 4.7.2.1. Buck Island Reef National Monument (BUIS) provides critical nesting and foraging habitat for sea turtles. (Left) BUIS hosts the primary index population of critically endangered hawksbills under U.S. jurisdiction. (Right) A green turtle grazes in a shallow seagrass meadow at BUIS. (Photo credits: National Park Service, A. Gulick).

<u>Data and Methods</u>
Size class is the only condition metric that was evaluated for the entire population (including in-water and nesting) of a species. This was completed only for hawksbill and green turtles because these are the only species known to utilize both nesting and foraging grounds at BUIS. To characterize the overall size structure of each species, a size class frequency distribution was created using the most recent measurement of curved-carapace length (CCL) for each individual. CCL (cm) was measured from the nuc to the tip of the carapace (see protocol, Phillips and Hillis-Starr 2002b).

Temporal trends in condition metrics were evaluated separately for nesting and in-water sea turtle populations, and at the species level (when data was available). Temporal trends in the following metrics were evaluated for nesting populations: nesting female abundance, size class, reproductive success (nest abundance, hatching success, hatchling emergence success, clutch size), and hatchling sex ratio. Temporal trends in the following metric were evaluated for in-water populations: size class. Please note that temporal trends for some condition metrics could not be evaluated due to the lack of comparative data (e.g., relative abundance for in-water), but reference values are available (see Reference Values/Conditions).

Nesting population
Data collected during 1988–2019 by the NPS Buck Island Sea Turtle Research Program (BISTRP) (see protocol by Phillips and Hillis-Starr 2002b), was used to evaluate temporal trends in female abundance, size class, and reproductive success for hawksbill and green turtles. Temporal trends for loggerheads and leatherbacks could not be evaluated because of low sample size. Alternatively, summary statistics of condition metrics for these two species are provided in Table 4.7.2.1.

Loggerhead nesting at BUIS is very rare (Pollock et al. 2009). And although leatherbacks do occasionally nest on BUIS beaches, this site does not serve as a primary nesting beach nor do monitoring efforts overlap with the seasonal peak for nesting activity. Leatherback nesting activity that occurs at BUIS is typically spill-over from nearby primary nesting beaches: Sandy Point National Wildlife Refuge (St. Croix) and Culebra Island (Puerto Rico).

Table 4.7.2.1. Summary statistics of condition metrics for nesting sea turtle populations at BUIS during 1988–2019. Curved carapace length (CCL) was measured from the nuc to tip of the carapace (NPS-BUIS BISTRP dataset, unpublished).

Species	Condition metric	Mean (± SD)	Range
Hawksbill	# females year^{-1}	42 ± 21	11–78
	Female CCL (cm)	88.4 ±4.7	63.6–120.5
	# confirmed nests year^{-1}	150 ± 60	79–301
	Hatch success (%)	69.4 ± 26.6	0.0–100.0
	Emergence success (%)	63.1 ± 29.0	0.0–100.0
	Clutch size (# eggs clutch^{-1})	142 ± 33	5–273
Green	# females year^{-1}	11 ± 11	0–35
	Female CCL (cm)	108.7 ± 5.8	89.0 ± 170.0
	# confirmed nests year^{-1}	45 ± 42	3–144
	Hatch success (%)	75.5 ± 24.7	0.0–100.0
	Emergence success (%)	70.5 ± 26.9	0.0–100.0
	Clutch size (# eggs clutch^{-1})	110 ± 27	10–235
Leatherback	# females year^{-1}	0.2 ± 0.4	0–2
	Female CCL (cm)	149.5 ± 4.3	146.0–158.5
	# confirmed nests year^{-1}	6 ± 5	0–19
	Hatch success (%)	72.5 ± 24.4	0.0–99.2
	Emergence success (%)	67.7 ± 24.9	0.0–99.2
	Clutch size (# eggs clutch^{-1})	81 ± 20	34–136
Loggerhead	# females year^{-1}	0.3 ± 0.5	0–2
	Female CCL (cm)	103.5 ± 1.2	101.8–106.2
	# confirmed nests year^{-1}	0.9 ± 1.9	0–8
	Hatch success (%)	50.9 ± 35.6	0.0–98.1
	Emergence success (%)	46.0 ± 35.5	0.0–96.9
	Clutch size (# eggs clutch^{-1})	119 ± 32	19–165

All metrics for hawksbill and green turtles were assessed using data collected during 1988–2019. Abundance of nesting females was assessed by determining the number of individuals encountered in each year, while accounting for catch-per-unit-effort (CPUE). CPUE was calculated for each year by dividing the number individuals encountered by the number of patrol nights conducted. Temporal trends in female size class (CCL, measured nuc to tip) and reproductive parameters (nest abundance, hatchling success, hatchling emergence success, clutch size) were evaluated using the annual mean and variance (±SD) for each metric. CPUE was accounted for when evaluating nest abundance by dividing the number of nests encountered by the number of patrol nights conducted in a single season. Trends in hatchling sex ratio for hawksbills was evaluated using values from published literature.

In-water population

Condition metrics for in-water populations of sea turtles at BUIS were assessed for hawksbills and green turtles only. Leatherbacks and loggerheads are not known to use BUIS as a foraging area, although, an adult male loggerhead was recently documented foraging at BUIS (Hart et al. unpublished data). Data collected by NPS during 1993–2002 (see protocol, Phillips and Hillis-Starr 2002a) and by USGS during 2012–2019, was used to assess the size class of in-water populations; summary statistics for each species are provided. Relative abundance for in-water populations could not be evaluated at this time due to the lack of comparative data.

Reference Conditions/Values

Nesting population

NPS monitoring efforts of sea turtle nesting activity at BUIS began in 1980, in the form of day patrols conducted by park rangers (Zullo 1986). Forty-two sea turtle nests were documented in 1980, all of which were hawksbill (Zullo 1986). Nineteen of those nests (45%) hatched successfully, nine were predated (21%), one was poached (2%), and the status of thirteen (31%) were inconclusive. Green turtle (n = 8) and leatherback (n = 3) nests were not documented on BUIS until 1983 (Zullo 1986). The success of those specific nests could not be determined, although records show that the majority of sea turtle nests on BUIS in 1983 were either predated by mongoose or poached by humans. Monitoring efforts of sea turtle activity at BUIS varied significantly through the 1980s (Zullo 1986), but it can be inferred from existing records that the sea turtle nesting population at BUIS was extremely low at the time were enduring severe predation and poaching. Documentation of predation by exotic mammals (Zullo 1986, Witmer et al. 2007) and poaching by humans led to significant management actions to protect sea turtle nesting at Buck Island in the 1980s and early 1990s. The significantly greater numbers of sea turtle nests found at BUIS today, when compared to those reported by Zullo (1986), is a direct result of nesting beach protection through increased ranger patrols, establishment of long-term monitoring and research of nesting activity, successful eradication of invasive predators, enforcement of conservation laws, and local education/outreach (Hillis-Starr and Phillips 1998).

Reference conditions for the genetic composition of the BUIS hawksbill nesting population are provided by Hill et al. (2018). Using mitogenomic haplotypes, Hill et al. (2018) determined that female hawksbills nesting at BUIS are genetically distinct from other females that utilize nearby nesting beaches on St. Croix. This analysis supports the concept that the BUIS hawksbill population is a unique management unit. Similarly, the frequency divergence in haplotypes for green turtles nesting at BUIS, when compared to other populations in the Greater Caribbean, suggests that the BUIS rookery is demographically isolated (Shamblin et al. 2012), thus warranting its own management unit status. To our knowledge, the genetic composition of the leatherback and loggerhead nesting populations have not been evaluated. Tissue samples have been collected to evaluate the genetic composition of the leatherback and loggerhead nesting populations, but have not been analyzed (NPS unpublished data, Hart et al. unpublished data).

The sex ratio of hawksbill hatchlings was initially evaluated in 1994 by Wibbels et al. (1999). The ratio was strongly biased, with over 96% of individuals sampled being female (Wibbels et al. 1999). The impacts of multiple severe storms resulted in the loss of vegetation cover and increased exposure of dark soil nesting habitat to solar radiation; this shift in quality of nesting beach habitat was linked to the strong female bias found in the hawksbill hatchling sex ratios (Wibbels et al. 1999). To our knowledge, hatchling sex ratios has not been evaluated for green, leatherback, or loggerhead turtles at BUIS. Given the female-biased sex ratios documented for hawksbills at BUIS, it is hypothesized that a similar bias likely exists for other sea turtle species.

In-water population

Reference values of effort-corrected relative abundance for hawksbill and green turtles at BUIS are provided by Pollock (2013). During 2012, relative abundance (mean ± SD) of hawksbill turtles (all size classes) was 0.53 ± 0.12 turtle sightings km^{-2}, with the greatest relative abundance of hawksbills occurring in habitats dominated by reef and colonized hard-bottom (1.44 ± 0.94 turtle sightings km^{-2}). Relative abundance of green turtles (all size classes) was 1.22 ± 0.19 turtle sightings km^{-2}, with the greatest abundance occurring in habitats dominated by seagrass (6.98 ± 1.71 turtle sightings km^{-2}). For both species, relative abundance of each size class varied across benthic habitat type. For further information and reference values for habitat-use patterns of each species at BUIS, please see Pemberton (2000) and Hart et al. (2013).

Reference values for the size class of the hawksbill in-water population during 1994–1999 were provided by Hart et al. (2013). A total of 75 individuals were captured and mean (±SD) CCL was 47.4 (±13.0) cm and ranged from 23.2–77.7 cm. Reference values for the size class of the green turtle in-water population during 1998–2002 was provided by NPS (using the BISTRP database). A total of 29 green turtles were captured during the study period; CCL was measured for one individual (87.0 cm).

Reference conditions for the genetic composition of the hawksbill in-water population at BUIS are provided by Bowen et al. (2007). All hawksbill nesting populations in the Caribbean, including BUIS, are genetically distinct, meaning each population has unique haplotypes. However, a considerable mixing of haplotypes has been found among juvenile hawksbills that recruit to foraging areas (Bowen et al. 2007). The number of juveniles contributed to foraging areas appears to be largely driven by the size of nearby nesting colonies. Nesting colonies in Cuba, and BUIS and Mona Island (Puerto Rico) to a lesser extent, are the primary source populations for the hawksbill in-water population at BUIS (Bowen et al. 2007). Tissue samples have been collected for evaluating the genetic composition of the green turtle in-water population at BUIS, but these samples have not been analyzed (Hart et al. unpublished data).

Condition and Trend

Size class frequency distributions of curved carapace length (CCL) for hawksbill and green turtle populations (including in-water and nesting) are provided in Figure 4.7.2.2. These figures do not allow temporal trends to be evaluated for this condition metric but do provide a general overview of population size structure. Future assessments should evaluate size class frequency distributions to detect potential changes in the composition of in-water and nesting populations.

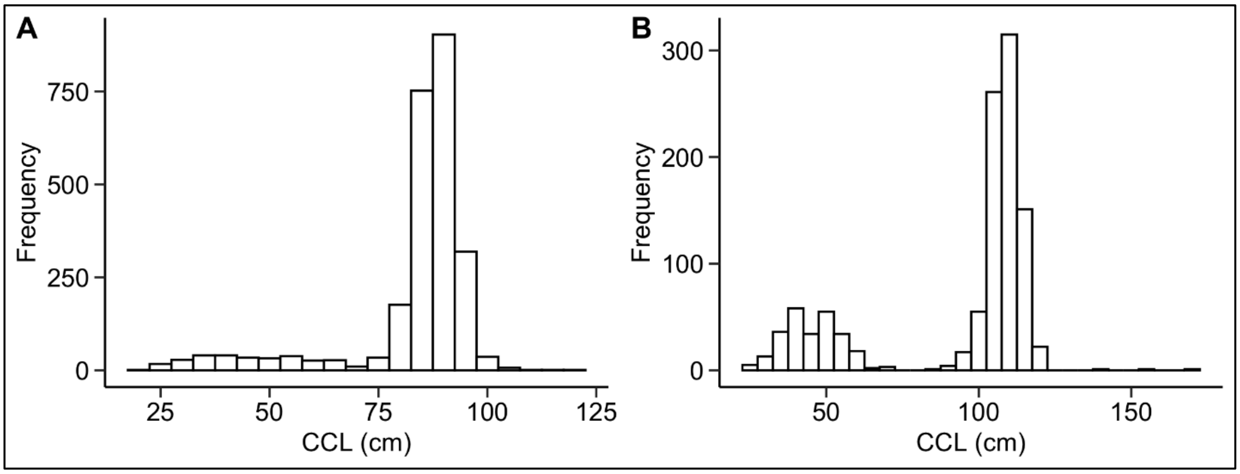


Figure 4.7.2.2. Graphical summary of the size class frequency distributions for (A) hawksbill and (B) green turtles. Frequency distributions include individuals from nesting and in-water populations. Curved carapace length (CCL) was measured from the nuc to tip of the carapace.

Nesting population

Overall, abundance of hawksbill females and nests increased during the study period (1988–2019) (Figures 4.7.2.3, 4.7.2.4), exhibiting a dramatic recovery from the reference condition reported for 1980 (Zullo 1986, Hillis-Starr and Phillips 1998). However, female abundance and nest abundance do appear to consistently decline after the 2013 nesting season, and nest abundance does not track with female abundance after 2010 (Figure 4.7.2.4). This decline appears to be maintained during years with consistent effort (Figure 4.7.2.3). Hatch success, emergence success, and clutch size have increased compared to the reference condition in 1980 but are quite consistent from 1988–2019 (Figure 4.7.2.4). Mean (±SD) CCL of nesting females is also consistent throughout the study period (88.4 ± 4.7 cm) (Figure 4.7.2.4, Table 4.7.2.1). The implications of these patterns are discussed below in detail.

During 1994, the sex ratio of hawksbill hatchlings at BUIS was strongly skewed toward female, with 96% of hatchlings sampled being female (Wibbels et al. 1999). During 2019, the temperature of all hawksbill nests sampled exceeded the threshold required to produce females (29.32 °C), with an overall mean (±SD) of 31.76 °C (±1.67) (Lyons 2020). Of the eggs sampled by Lyons (2020) in 2019, 94.5% were predicted to produce females. Lyons (2020) did not detect a statistical relationship between the temperature of nests and hatching (or emergence) success.

In contrast to hawksbills, female and nest abundance for green turtles exhibit a recovery trend during 1988–2019 (Figure 4.7.2.5). Notably, this overall trend seems to be maintained during nesting seasons that experienced major hurricanes (e.g., 2017) and/or changes in effort (Figure 4.7.2.3). Hatch success, emergence success, and clutch size are consistent after 2001 (Figure 4.7.2.5); a point at which there was a suitable sample size of nests to evaluate those metrics. Mean (±SD) CCL of nesting females is also maintained throughout the study period (108.7 ± 5.8 cm) (Figure 4.7.2.5., Table 4.7.2.1). No data is available to assess hatchling sex ratios for green turtles at BUIS.

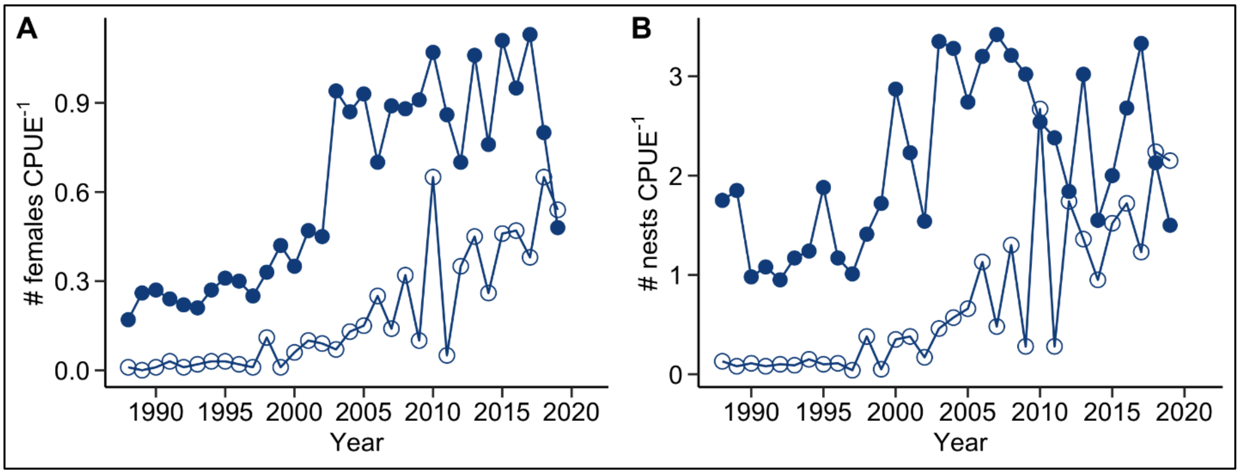


Figure 4.7.2.3. Graphical summary of annual (A) female abundance and (B) nest abundance per unit effort for hawksbill (closed points) and green (open points) turtles. CPUE is the number of females (or nests) encountered per patrol night.

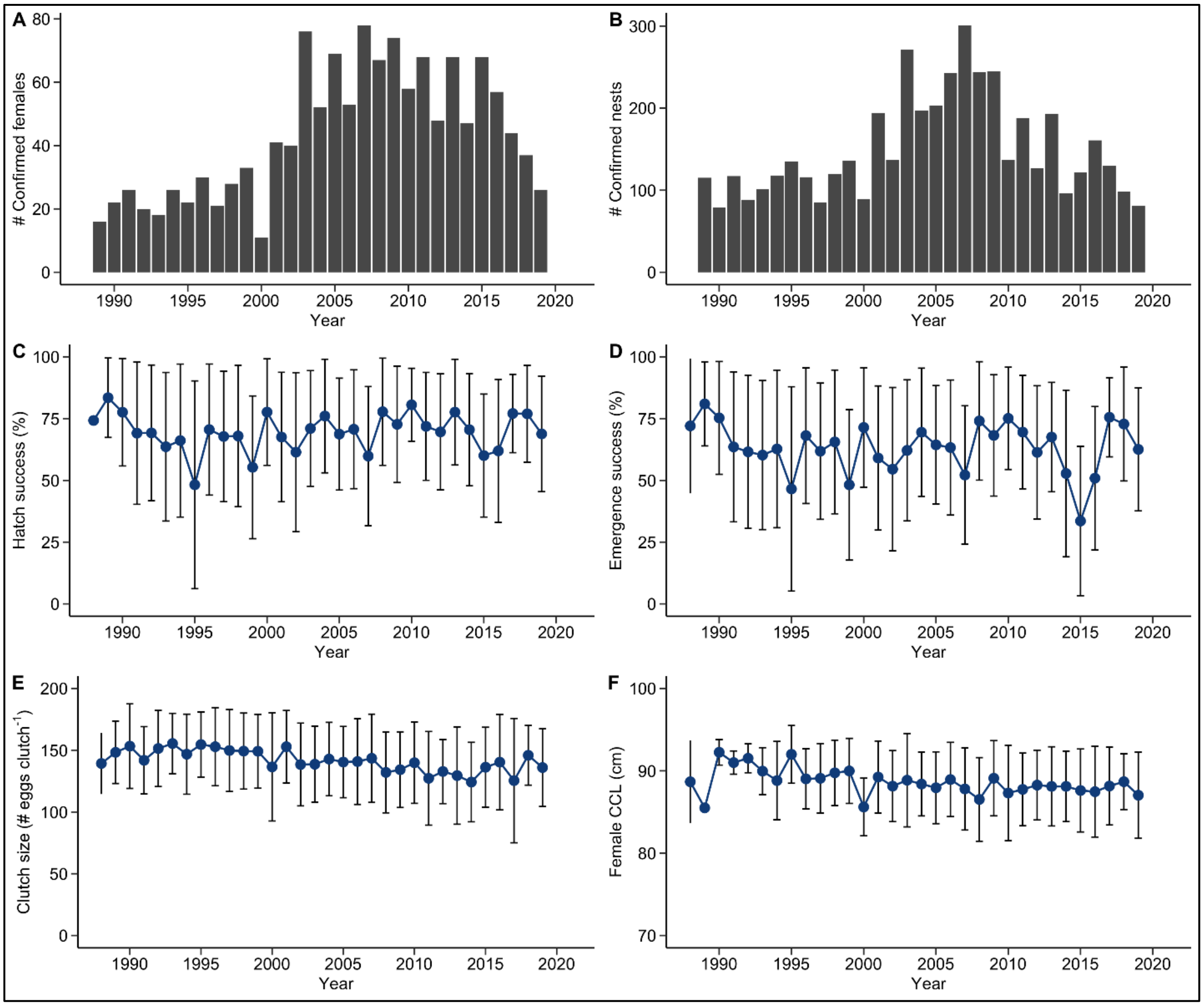


Figure 4.7.2.4. Graphical summary of temporal trends in condition metrics for the hawksbill nesting population at BUIS during 1988–2019. (A-B) Data represent annual counts of the confirmed number of individual females and nests. (C-F) Points and error bars represent the annual mean (±SD) for each metric. Curved carapace length (CCL) of nesting females was measured from nuc to tip.

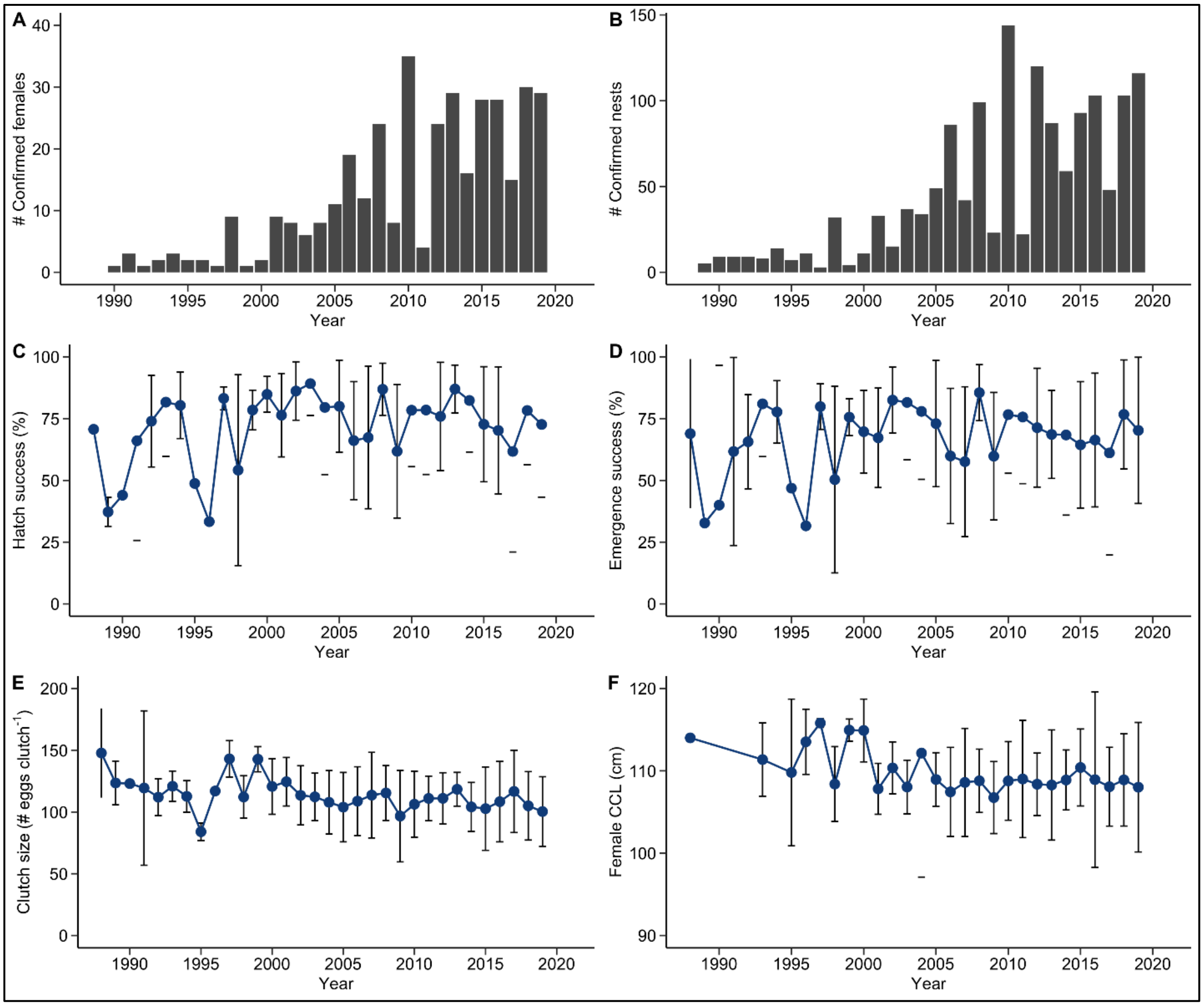


Figure 4.7.2.5. Graphical summary of temporal trends in condition metrics for the green turtle nesting population at BUIS during 1988–2019. (A-B) Data represent annual counts of the confirmed number of individual females and nests. (C-F) Points and error bars represent the annual mean (±SD) for each metric. Curved carapace length (CCL) of nesting females was measured from nuc to tip.

Several factors should be considered when interpreting trends in condition metrics for both sea turtle species. These factors include hurricanes, changes in monitoring effort, habitat loss and degradation, and biologically driven factors that can be indicative of changes in female productivity (e.g., longer remigration intervals, reduced growth rates). The abundance of hawksbill females and nests increase from 1988–2013, but appear to decline after this point, even after accounting for CPUE. Two major hurricanes occurred during 2017, substantially impacting NPS monitoring efforts (Figure 4.7.2.3) and the availability of nesting beach habitat (see Ch 4.1.1 Shoreline Dynamics). Saturation tagging effort was also reduced during 2018–2019 with increased effort put into day patrols, thereby affecting detectability of individual females (Hart et al. unpublished data). However, these factors alone do not explain the decline in female and nest abundance after 2013, particularly the mis-tracking of nest abundance with the number of females. This pattern suggests that nesting females may be utilizing other nesting beaches in close proximity to BUIS (Iverson et al. 2016, Hart et al. 2019), could be experiencing increased mortality (e.g., legal and illegal harvesting, interactions with fisheries), and/or remigration intervals may be increasing. The latter could potentially decrease female productivity, including the number of clutches produced by each female during a single season. The strongly female-biased sex ratio of hawksbill hatchlings also poses a significant threat to the productivity of the nesting population. The overall decline in female and nest abundance for hawksbills over the last decade, despite consistent hatch and emergence success, warrants significant concern, particularly since this decline is not observed in the green turtle nesting population.

In-water population

The in-water survey data was not sufficient to provide temporal trends in size class of in-water populations. Alternatively, summary statistics for each species is provided for comparison and use in future resource assessments. The size class of the hawkbill in-water population was assessed by comparing values for straight carapace length (SCL) collected by USGS during 2012–2019, to reference values collected during 1994–1999 by Hart et al. (2013). During 2012–2019, a total of 111 hawksbills were captured; mean (±SD) SCL was 44.1 (±12.7) cm and ranged from 18.8–81.6 cm. These SCL values are within the range of the reference CCL values for the population during 1994–1999 (Hart et al. 2013): 75 individuals were captured and mean (±SD) CCL was 47.4 (±13.0) cm and CCL ranged from 23.2–77.7 cm. However, the use of different methods for measuring size class (SCL vs. CCL) should be noted and taken into account when making comparisons. A size class distribution of the hawksbill population (in-water and nesting) is provided in Figure 4.7.2.2.

The size class of the green turtle in-water population was assessed by comparing values collected by USGS during 2012–2019, to reference values collected by BISTRP during 1998–2002. During 2012–2019, a total of 475 green turtles were captured; mean (±SD) SCL was 44.6 (±9.9) cm and ranged from 24.3–94.6 cm. These SCL values cannot be adequately compared to the single CCL value (87.0 cm) available for the 1998–2002 reference period, as the differing metrics for size class should also be accounted for. There is a notable increase in the number of green turtles captured (n = 29 during 1998–2002; n = 475 during 2012–2019); although, this is likely an artifact of increased capture effort. A size class distribution of the green turtle population (in-water and nesting) is provided in Figure 4.7.2.2.

<u>Threats and Stressors</u>

Although NPS has provided protection for one of the most well-managed sea turtle populations in the Caribbean, a myriad of factors still pose a threat to sea turtle nesting and in-water populations at BUIS. The impacts of hurricanes on nesting activity at BUIS have been well documented (Fortuna et al. 1997, Hillis-Starr and Phillips 1998, Storch et al. 2006). However, increases in frequency of hurricanes due to climate change, combined with changes in shoreline dynamics (see Ch 4.1.1 Shoreline Dynamics), will undoubtedly have persistent impacts on hatching success and availability of quality nesting habitat. Increased frequency of hurricanes and sea level rise will also continue to cause significant damage to sea turtle in-water habitats at BUIS, including coral reefs (e.g., declining accretion rates) and seagrass meadows (Rogers 2019).

Anthropogenic-driven climate change is also increasing global ocean and atmospheric temperatures, as well as having adverse effects on sea turtles (Hamann et al. 2013). Increases in air temperature will impact sea turtle nesting populations by creating female-biased sex ratios and potentially lethal environments for incubating nests. Given that the sex ratio of hawksbill hatchlings at BUIS is currently female-biased (Wibbels et al. 1999, Geis et al. 2003, Lyons 2020) and lethal temperatures have previously impacted hatch success (Wibbels et al. 1999, Lundgren 2009), further increases in temperature will undoubtedly have adverse effects on the productivity of this population. Increases in water temperature are also contributing to the degradation of important in-water habitats for sea turtles, including coral reefs and seagrass meadows (Hamann et al. 2013). Degradation in the quality of foraging habitats has been indirectly linked to the decrease in growth rates and productivity of hawksbill and green turtle populations in the Northwest Atlantic (Bjorndal et al. 2016, 2017).

Invasive species in nesting and in-water habitats also pose a threat to sea turtles. Although invasive predators (i.e., mongoose, tree rat, domestic cats and dogs) have been eradicated or are controlled/prohibited in the terrestrial habitats of BUIS, continued monitoring will be essential to ensure that this result is maintained. The invasive seagrass, *Halophila stipulacea*, recently invaded the native seagrass beds at BUIS (see Ch 4.4.1 Seagrasses). This invasion has the potential to degrade green turtle foraging habitat, which, could impact the grazing dynamics (Gulick et al. 2020, 2021) and recovery of the BUIS green turtle population (Hart et al. 2017).

Poaching of sea turtles and their eggs is no longer considered a threat to sea turtles at BUIS. However, there is potential for BUIS sea turtles to overlap with areas that have a legal harvest (e.g., British Virgin Islands), either during migration or while utilizing foraging areas.

Lastly, dwindling financial support for long-term saturation tagging and monitoring efforts poses an indirect, albeit serious threat to the effective conservation and management of sea turtles at BUIS.

Data Needs and Gaps

Nesting population

The overall decline of the hawksbill nesting population at BUIS warrants significant concern. In addition to continued monitoring of all condition metrics and vital rates for this nesting population, collection of environmental variables (i.e., nest temperature, changes in nesting beach availability) should also prioritized. Consistent collection of environmental data and continued tagging and sampling of individual nesting females will be critical to identifying potential factors contributing to this decline.

The recovery trend of green turtles at BUIS (Hart et al. 2017), and in the Caribbean (Chaloupka et al. 2008, Mazaris et al. 2017), is indicative of successful conservation efforts. However, consistent monitoring of nesting populations will be essential to ensure the continued recovery of the BUIS population. Several impending threats (e.g., increasing temperatures, nesting habitat availability, impacts of invasive seagrass in foraging areas) are likely to impact the success of green turtles at BUIS, therefore, metrics like hatchling sex ratios and nest temperatures should also be evaluated for this species.

In-water population

BUIS provides critical recruitment and foraging habitat for hawksbill and green turtles (Hart et al. 2013, 2017, 2019; Gulick et al. 2020). Much of the research and monitoring efforts for sea turtle in-water populations at BUIS has largely focused on habitat-use and movement patterns (Starbird et al. 1999; Pemberton 2000; Hart et al. 2013, 2017, 2019; Selby et al. 2019; Griffin et al. 2020). However, a current assessment of effort-corrected relative abundance is needed to evaluate the status of sea turtle in-water populations at BUIS. Several stressors identified in other areas of this report (e.g., see Ch 4.1.1 Coastal Dynamics, Ch 4.4.1 Seagrasses, Ch 4.5.1 Coral Reefs) have the potential to impact in-water populations. As these habitats continue to degrade at BUIS, further habitat-use studies and estimates of relative abundance for sea turtles will be needed to document the stress-related impacts.

The genetic composition of the in-water hawksbill population should also continue to be evaluated, since changes in contribution from source populations (i.e., nesting colonies) could be indicative of population-level changes. For similar reasons, the genetic composition of the green turtle in-water needs to be assessed (Hart et al. unpublished data). Identifying source populations for the in-water aggregation of green turtles at BUIS will be important in continuing the recovery trend of green turtles in the park.

Overall Condition

Condition metrics were evaluated separately for nesting and in-water populations, for hawksbill and green turtles (Table 4.7.2.2). Overall, hawksbill nesting populations have increased compared to the reference condition in 1980 (Zullo 1986). However, female and nest abundance have been in decline since 2014, warranting significant concern. In contrast, green turtle nesting populations are exhibiting a trend indicative of recovery, which is consistent with the population trend for the Caribbean region. The status in-water populations (hawksbill and green) could not be evaluated, although reference conditions are provided (Pollock 2013).

Table 4.7.2.2. A graphical summary of status and trend for condition metrics for hawksbill and green sea turtles.

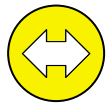
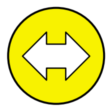
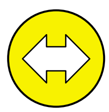
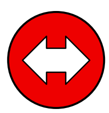
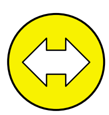
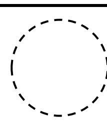
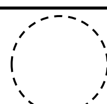
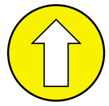
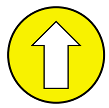
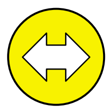
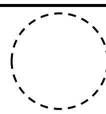
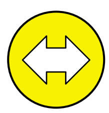
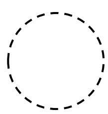
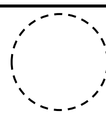
Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Sea turtles (Hawksbill)	Nesting female abundance		Current analyses indicate that female abundance has significantly increased when compared to the reference condition in 1980 (Zullo 1986). However, abundance appears to be decreasing during 2014–2019, despite consistent monitoring efforts. This inexplicable decline of this critically endangered species warrants concern and additional data is needed to identify the factor(s) behind this decline.
	Nest abundance		Current analyses indicate that female abundance has significantly increased when compared to the reference condition in 1980 (Zullo 1986). However, abundance appears to be decreasing during 2014–2019, despite consistent monitoring efforts. This inexplicable decline of this critically endangered species warrants concern and additional data is needed to identify the factor(s) behind this decline.
	Hatch success Emergence success Clutch size		Current analyses indicate that these metrics have been stable from 1988–2019, while having significantly improved from the reference condition in 1980 (Zullo 1986). However, several impending threats are likely to impact these parameters and additional data and monitoring efforts are needed to ensure that these metrics continue to improve.
	Hatchling sex ratio		Hatchling sex ratios reported during 2019 (Lyons 2020) appear to be strongly female biased, similar to the reference condition reported in 1994 (Wibbels et al. 1999). However, nest temperatures continue to increase and will continue to produce female-dominated clutches and are likely to produce lethal conditions for incubating nests.
	Size class (Nesting / In-water)		Current analyses indicate that this metric has been stable from 1988–2019. However, several impending threats are likely to impact this parameter and additional data and monitoring efforts are needed to ensure that this metric continues to improve. Reference conditions are not available.
	Genetic composition (Nesting / In-water)		Reference conditions are provided by Hill et al. (2018) for the nesting population and Bowen et al. (2007) for the in-water population. However, source populations for the hawksbill nesting colony at BUIS has not been evaluated.
	Relative abundance (In-water)		Reference condition for 2012 is provided by Pollock (2013). However, this metric cannot be evaluated due to the lack of current relative abundance data.

Table 4.7.2.2 (continued). A graphical summary of status and trend for condition metrics for hawksbill and green sea turtles.

Component	Indicator	Condition Status /Trend	Rationale and Reference Conditions
Sea turtles (Green)	Female abundance		Current analyses indicate that this metric has increased significantly, when compared to the reference condition reported in 1980 (Zullo 1986). However, continued monitoring and research efforts will be imperative to ensuring the continued recovery of green turtles at BUIS.
	Nest abundance		Current analyses indicate that this metric has increased significantly, when compared to the reference condition reported in 1980 (Zullo 1986). However, continued monitoring and research efforts will be imperative to ensuring the continued recovery of green turtles at BUIS.
	Hatch success Emergence success Clutch size		Current analyses indicate that these metrics have been stable from 1988–2019, while having significantly improved from the reference condition in 1980 (Zullo 1986). However, several impending threats are likely to impact these parameters and additional data and monitoring efforts are needed to ensure that these metrics continue to improve.
	Hatchling sex ratio		Cannot be assessed. Reference conditions and current data are not available.
	Size class (Nesting / In-water)		Current analyses indicate that this metric has been stable from 1988–2019. However, several impending threats are likely to impact this parameter and additional data and monitoring efforts are needed to ensure that this metric continues to improve.
	Genetic composition (Nesting / In-water)		Reference conditions are provided by Shamblin et al. (2012) for the nesting population, but have not been evaluated for the in-water population. Need additional data.
	Relative abundance (In-water)		Reference condition for 2012 is provided by Pollock (2013). However, this metric cannot be evaluated due to the lack of current relative abundance data.

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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 5.1.12. These include focal resources pertaining to the supporting environment of BUIS, specifically shoreline dynamics and water quality (Tables 5.1.1 and 5.1.2), as well as focal resources falling within the framework category of biological integrity, including dry tropical forest, coastal forest, terrestrial reptiles, seagrass, corals, reef fish, and sea turtles (Tables 5.1.3 to 5.1.12). We present the sea turtle focal resource as two separate tables divided by the two species evaluated, the hawksbill and green sea turtle, as the trends reported for some of the indicators vary by species. We present an overall summary of all focal resources in Table 5.1.13. 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 status and trends for individual indicators as outlined in the NPS-NRCA Guidance Update from January 20, 2014.

Table 5.1.1. Indicator summary for Shoreline Dynamics focal resource.

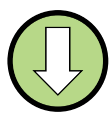
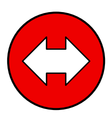
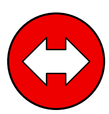
Indicators of Condition	Measures or Criteria	Condition Status /Trend	Rationale
Shoreline Change	Percent change in island area		The island has undergone a reduction in area of 5.7 % or 4.16 ha (10.3 acres) the since 1954.
Shoreline Change	Percent change in beach area		Reduction of 28% or 0.88 ha (2.2 acres) sand beach area between 1954 and 2018, but no net loss in beach surface area since 1977, because beaches shifted inward and seasonally southwestern beaches experience higher amounts of sand deposition.
Shoreline Dynamics Overall	–		–

Table 5.1.2. Indicator summary for Water Quality focal resource.

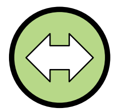
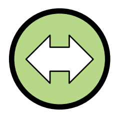
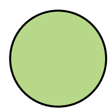
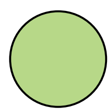
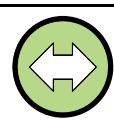
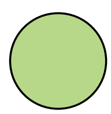
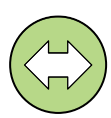
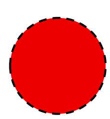
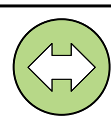
Indicators of Condition	Measures or Criteria	Condition Status /Trend	Rationale
Fecal Indicator Bacteria	USVI 2019 Amended Water Quality Standards Rules and Regulations		There are spurious indications of fecal contamination but no violations for contact recreation in the last two decades
Dissolved Oxygen	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. There is insufficient information to understand if concentrations are changing.
Turbidity	USVI 2019 Amended Water Quality Standards Rules and Regulations		Turbidity is low. There is insufficient information to understand if concentrations are changing.
Dissolved Nutrients	NA		These are typically near low detection limits in most areas but have not been extensively studied.
Chlorophyll	Enrichment above oligotrophic oceanic conditions		Chlorophyll was low in a few areas that were assessed. There is insufficient information to understand if phytoplankton abundance is changing.
Terrestrial Sediments	Annual number of events associated with high rainfall		Terrestrial sediments have not been directly measured, but other research suggests that values should be low and with no cause for increases.
Contaminants	Indirect measurements based on biological assays; detection of compounds used as UV filters		There are worrying signs of possible contaminants and biological effects on corals in localized areas that deserve further investigation
Water Quality Overall	–		–

Table 5.1.3. Indicator summary for Tropical Dry Forest focal resource.

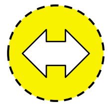
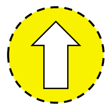
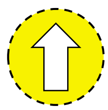
Indicators of Condition	Measures or Criteria	Condition Status /Trend	Rationale
Vegetation Community Extent	Species Composition / Richness		Overall species composition of the island is likely similar to the 2001 reference conditions. However, differences in available datasets results in low confidence in the assessment. The current forest enrichment project should serve to increase species diversity and hopefully lead to a future positive trend in condition.
Vegetation Community Extent	Percent Cover		Since 2001, percent cover of invasive non-native plant species has likely decreased following several years of exotics treatment. The percent cover of native flora has likely increased in response to both treatment for invasive plants and eradication of roof rats. However, confidence in trend detection is low given the differences between survey methodologies and the occurrence of hurricanes after the most recent survey data. Impacts from 2017 hurricane season have reportedly resulted in forest damage and recolonization of some invasive species.
Tropical Dry Forest Overall	–		–

Table 5.1.4. Indicator summary for Coastal Forest focal resource.

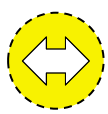
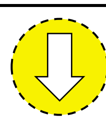
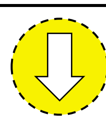
Indicators of Condition	Measures or Criteria	Condition Status /Trend	Rationale
Vegetation Community Extent	Species Composition / Richness		Species composition appears similar to the 2001 reference conditions. The forest remains dominated by manchineel. However, confidence in trend detection is low given the differences between survey methodologies.
Vegetation Community Extent	Percent Cover		Percent cover has declined since 2001 as a result of tidal inundation and subsequent erosion. The magnitude of the decrease has not yet been quantified.
Coastal Forest Overall	–		–

Table 5.1.5. Indicator summary for Seagrass focal resource.

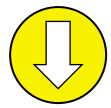
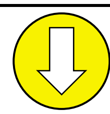
Indicators of Condition	**Measures or Criteria**	**Condition Status /Trend**	**Rationale**
Seagrass Community Extent	Percent Cover		The cover of seagrasses increased from 1971 (1.33 km2) to 1999 (4.34 km2) and declined to (2.70 km2) in 2011. The lack of comparative data to evaluate other indicators of seagrass health, limits the ability to assess potential mechanisms behind this decline in seagrass abundance. Due to the impending threat associated with the invasion of *Halophila stipulacea*, impacts of two major hurricanes, and changes in natural grazing pressure by seagrass herbivores, additional monitoring is critical to assessing the current status of seagrass meadows at BUIS.
Seagrass Overall	–		–

Table 5.1.6. Indicator summary for St. Croix Ground Lizard focal resource.

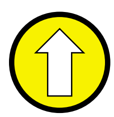
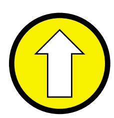
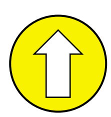
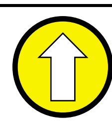
Indicators of Condition	**Measures or Criteria**	**Condition Status /Trend**	**Rationale**
Population Status	Abundance (estimated # of individuals)		Abundance of individuals is increasing throughout all habitats. Estimates are robust and based on double observer surveys of sites located throughout the entirety of the island. As a result of the success of reintroduction efforts on BUIS, but given the species' globally endangered status, we classify it as of moderate concern.
Population Status	Distribution (Percent site occupancy)		Individuals have dispersed across the island beyond the original release location and are predicted to inhabit all areas of the island given environmental conditions on BUIS.
Population Status	Reproduction		The population is reproducing, leading to dispersion across the island and an increase in abundance to a current estimate of more than 10,000 individuals. However, net reproductive rates for the species have not been determined.
St. Croix Ground Lizard Overall	–		–

Table 5.1.7. Indicator summary for Corals focal resource.

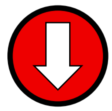
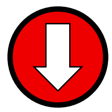
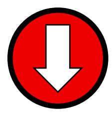
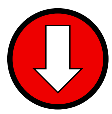
Indicators of Condition	**Measures or Criteria**	**Condition Status /Trend**	**Rationale**
Stony coral coverage	Percent of benthic cover		Coral cover has declined at all monitoring sites in and around BUIS over the last two decades. Only BUIS SFR has shown statistically significant increase since 2006. Only mesophotic reefs maintain relatively high living coral cover, but are declining. There are concerns of potential degradation due to coral disease.
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 5.1.8. Indicator summary for Queen Conch focal resource.

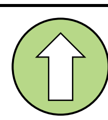
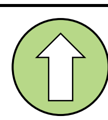
Indicators of Condition	**Measures or Criteria**	**Condition Status /Trend**	**Rationale**
Community Extent	Density		Abundances appear to be relatively high and possibly increasing, with evidence of juvenile queen conch recruitment.
Queen Conch Overall	–		–

Table 5.1.9. Indicator summary for Spiny Lobster focal resource.

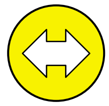
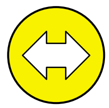
Indicators of Condition	Measures or Criteria	Condition Status /Trend	Rationale
Community Extent	Density		There is medium confidence in the assessment due to lack of consistent sampling and methodologies not optimized for lobster. Values indicate the potential for overfishing and poaching, but stabilized or increasing populations are found within BUIS.
Spiny Lobster Overall	–		–

Table 5.1.10. Indicator summary for Reef Fish focal resource.

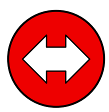
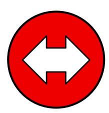
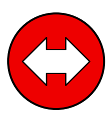
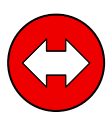
Indicators of Condition	Measures or Criteria	Condition Status /Trend	Rationale
Community and population status	Density		Reef fish density warrants significant concern because a lack of positive trends after decades of fishing pressure suggests factors are still negatively affecting reef fish communities.
Community and population status	Biomass		Reef fish biomass warrants significant concern because a lack of positive trends after decades of fishing pressure suggests factors are still negatively affecting reef fish communities.
Community and population status	Richness		Reef fish richness warrants significant concern because a lack of positive trends after decades of fishing pressure suggests factors are still negatively affecting reef fish communities.
Reef fish Overall	–		–

Table 5.1.11. Indicator summary for Hawksbill Sea Turtle focal resource.

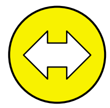
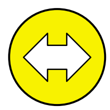
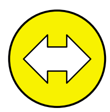
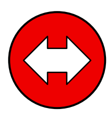
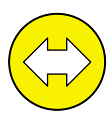
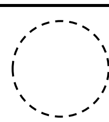
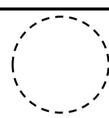
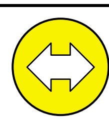
Indicators of Condition	**Measures or Criteria**	**Condition Status /Trend**	**Rationale**
Population Status	Nesting female abundance		Female abundance has significantly increased compared to 1980. However, abundance appears to be decreasing between 2014–2019. This inexplicable decline of this critically endangered species warrants concern and additional data is needed to identify the factor(s) behind this decline.
Population Status	Nest abundance		Female abundance has significantly increased compared to 1980. However, abundance appears to be decreasing during 2014–2019. This inexplicable decline of this critically endangered species warrants concern and additional data is needed to identify the factor(s) behind this decline.
Population Status	Hatch success Emergence success Clutch size		Hatch success, emergence, and clutch size have been stable from 1988–2019, having significantly improved from the reference condition in 1980. However, several impending threats are likely to impact these parameters and additional data and monitoring efforts are needed.
Population Status	Hatchling sex ratio		Hatchling sex ratios reported during 2019 appear to be strongly female biased, similar to the those reported in 1994. However, nest temperatures continue to increase and will continue to produce female-dominated clutches. Additionally, high temperatures are likely to produce lethal conditions for incubating nests.
Population Status	Size class (Nesting / In-water)		This metric has been stable from 1988–2019. However, several impending threats are likely to impact this parameter and additional data and monitoring efforts are needed to ensure that this metric continues to improve. Reference conditions are not available.
Population Status	Genetic composition (Nesting / In-water)		Although reference conditions are available for the nesting and in-water populations, source populations for the hawksbill nesting colony at BUIS have not been evaluated.
Population Status	Relative abundance (In-water)		While a reference condition is available for 2012, this metric cannot be evaluated due to the lack of current relative abundance data.
Sea turtle (Hawksbill) Overall	–		–

Table 5.1.12. Indicator summary for Green Sea Turtle focal resource.

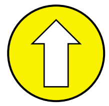
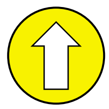
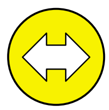
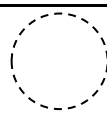
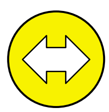
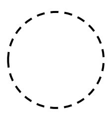
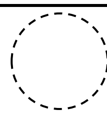
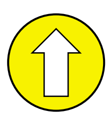
Indicators of Condition	**Measures or Criteria**	**Condition Status /Trend**	**Rationale**
Population Status	Nesting female abundance		Abundance of nesting females has increased significantly when compared to the reference condition reported in 1980. However, continued monitoring and research efforts will be imperative to ensuring the continued recovery of green turtles at BUIS.
Population Status	Nest abundance		Nest abundance has increased significantly when compared to the reference condition reported in 1980. However, continued monitoring and research efforts will be imperative to ensuring the continued recovery of green turtles at BUIS.
Population Status	Hatch success Emergence success Clutch size		These metrics have been stable from 1988–2019, while having significantly improved from the reference condition in 1980. However, several impending threats are likely to impact these parameters and additional data and monitoring efforts are needed to ensure that these metrics continue to improve.
Population Status	Hatchling sex ratio		Cannot be assessed. Reference conditions and current data are not available.
Population Status	Size class (Nesting / In-water)		Size class has been stable from 1988–2019. However, several impending threats are likely to impact this parameter and additional data and monitoring efforts are needed to ensure that this metric continues to improve.
Population Status	Genetic composition (Nesting / In-water)		Reference conditions are available for the nesting population, but they have not been evaluated for the in-water population. Need additional data.
Population Status	Relative abundance (In-water)		Reference condition for 2012 is available, but the metric cannot be evaluated due to the lack of current relative abundance data.
Sea turtle (Green) Overall	–		–

Table 5.1.13. Overall resource-level summary table.

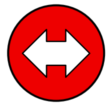
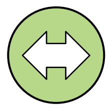
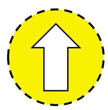
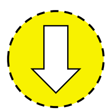
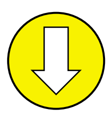
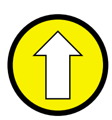
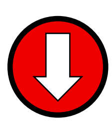
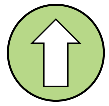
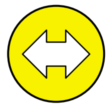
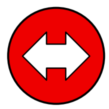
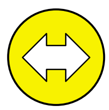
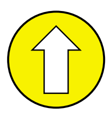
Resource Category	Focal Resource	Condition Status /Trend	Rationale
Supporting Environment	Shoreline Dynamics		The island area has experienced only a small reduction since 1954. However, this trend is likely to continue. The beach area decreased about 28% between 1954 and 2018. Although there has been no net loss in beach surface area since 1977, this has been because the beaches have shifted inward and southwestern beaches experience higher amounts of sand deposition.
	Water Quality		Waters tend to be clear, low in nutrients, and unpolluted. However, localized contaminants (hydrocarbons and personal care products) associated with recreational activities may be impacting corals. Water quality does not appear to be declining, but there is only medium confidence in the overall assessment because assessments by the USVI Division of Environmental Protection are limited in frequency and scale (only two sites).
Biological Integrity	Dry Tropical Forest		Species assemblages of native plants have likely not changed in past two decades. However, given the datasets available, the confidence in the assessment is low. Island-wide efforts to eradicate non-native plants and rats have been largely successful in decreasing these threats and improving the condition of dry tropical forest.
	Coastal Forest		Species composition has stayed relatively unchanged over decade, but differences in survey methodologies result in low confidence of assessment. The small amount of coastal forest on the island, combined with recent documented loss from tidal inundation and impacts from 2017 hurricanes suggest a declining trend.
	Seagrass		Seagrass cover increased from 1971 to 1999, but then declined by 2011. The lack of comparative data to evaluate the other indicators of seagrass health, limits the ability to assess potential mechanisms behind this decline in seagrass abundance.
	St. Croix Ground Lizard		Increases in abundance, distribution, and site occupancy since translocation of the species are encouraging. However, given the species globally endangered status and restricted distribution, we consider the focal resource to be of moderate concern requiring continued monitoring and management, including non-native animal trapping.
	Corals		Coral cover and abundance are declining, thermal stress events are more common, disease is more common and novel diseases are appearing. Localized impacts from contaminants may also be impacting corals in areas of high recreational use.

Table 5.1.13 (continued). Overall resource-level summary table.

Resource Category	Focal Resource	Condition Status /Trend	Rationale
Biological Integrity (continued)	Conch		Abundances of adults appear to be high, with indications of increases since the establishment of the no-take fisheries closure. There is evidence of juvenile recruitment.
	Lobster		Densities of spiny lobsters relative to historical baselines indicate low abundance. However, populations may be showing some level of recovery after the institution of no-take protected areas.
	Reef Fish		A lack of positive trend in reef fish density, biomass, or richness after decades of management suggests several factors, including fishing pressure, are still negatively affecting these communities.
	Sea Turtles (Hawksbill)		The abundance of hawksbill females and nests substantially increased during 1988–2013, but have been declining since 2014. Female-biased sex ratios, reduced growth rates, and increased remigration intervals further suggest that productivity of this population will continue to decrease. Rigorous data collection of all condition metrics will be imperative to preventing the loss of a critical index population for the species.
	Sea Turtles (Green)		The abundance of female green turtles and nests has substantially increased during 1988–2019. Although this recovery trend is encouraging, the lack of data for condition metrics that can provide insight for changes in productivity hinder effective management of the population.

Upon comparing the status of the 12 focal resources assessed in this report, more than 50% of the focal resources (7 of 12) were considered to be of moderate concern. Reef fish and corals were assessed as warranting significant concern, as was shoreline dynamics. Only water quality and queen conch were found to be in good condition. Trends in condition were more evenly split across focal resources between unchanging, deteriorating, and improving conditions. Deteriorating trends were recorded for seagrass, corals, and coastal forest, whereas improving trends were recorded for terrestrial reptiles, dry tropical forest, conch, and green sea turtles. Trends for both supporting environment resources, water quality and shoreline dynamics, were assessed as unchanging. Lobsters, reef fish, and hawksbill sea turtles were also considered to have stable, unchanging trends in condition. The low number of resources recorded as being in good condition, combined with several resources showing deteriorating conditions suggests that resources of Buck Island are threatened and in need to continued monitoring and management.

The overall condition status and trend for several resources was calculated in a manner that weighted particular indicators of condition more highly than others for a particular resource. For shoreline dynamics, percent change in beach area was weighted more heavily than percent change in island area, given that changes to beach area drive changes in island area. This resulted in an overall status for shoreline dynamics as warranting significant concern due to continued loss of low-elevation island surface area with a landward-migrating shoreline. This process could ultimately result in the loss of sandy beach as the coastline gets increasingly steep. As a supporting environment focal resource, changes in shoreline dynamics have important consequences for biological focal resources, including sea turtles that nest on the beaches of BUIS, as well as nesting shorebirds, including least terns. Changes to the shoreline, including loss of sandy beach area, are only likely to increase with accelerating sea level rise and increase frequency of strong hurricanes in the Atlantic basin (Bengtsson et al. 2007, USGCRP 2018).

For terrestrial vegetation focal resources, the trend in condition for the indicator related to percent cover was weighted more heavily than species composition/richness, resulting in the overall trend for each resource taking on the one associated with percent cover. For coastal forests the reasoning was related to the outsized importance of overall area loss and declining percent cover stemming from tidal inundation and impacts from hurricanes. For dry tropical forest, the increasing trend for percent cover was considered of greater importance given the impact that the management for invasive plant and animal species has likely had have on improved conditions for native tree and shrub species.

For sea turtles, key differences between species resulted in condition status and trend being assigned separately for each species. Whereas the status and trend assigned to hawksbill sea turtles corresponds to the value generated by the standardized formula, generating the overall status and trend for green turtles used unequal weighting of indicators. Green turtle nest abundance and female abundance were weighted more heavily than the other condition metrics, and as a result the overall trend is an upward one reflecting the recovery trend of the green turtle population in the Monument.

Improving conditions for conch and green sea turtles are encouraging and may suggest that implementation of local and regional policies and conservation strategies have made positive impacts on these populations. However, a lack of improving condition in for the BUIS reef fish community suggests that the multiple stressors that impact recovery have not been sufficiently addressed, including illegal harvesting (Valdés-Pizzini et al. 2010), habitat degradation (Bythell et al. 1989), and the impact of introduced species. The continued decline of coral coverage and condition is alarming, especially given the increase in the number of thermal stress events observed and appearance of novel diseases.

The improved conditions found for dry tropical forest and terrestrial lizards are attributable to management interventions related to exotic plant and animal control and a successful translocation program. The planned work for reforestation following the 2017 hurricane season is promising, but expanded forest monitoring and continued exotics management will be necessary to maintain the improving conditions of these focal resources.

5.2. Reporting Category Information Gaps

A moderate level of confidence was assigned to the majority of resources, with individual indicators varying between low, medium, and high. The only focal resources having assessments with high levels of confidence were corals and the St. Croix ground lizard, both having datasets with high spatial and temporal coverage. Low confidence assessments were restricted to terrestrial vegetation focal resources. Given that a minority of focal resources had high confidence in their assessments, 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 in this assessment. Important information gaps with some suggestions for future data acquisition are listed for each focal resource in Table 5.2.1.

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

Resource Category	Focal Resource	Important Information Gaps
Supporting Environment	Shoreline Dynamics	Given the dynamics of the sediment transport in Buck Island, it is recommended to establish a monitoring program that captures seasonal and inter-annual variability of sediment transport patterns to determine the long-term sediment and areal extent of beach and/or sediment loss. Several methods could be implemented individually or in combination. A vulnerability and risk assessment for the shoreline of Buck Island concerning sea-level rise is recommended.
	Water Quality	Only two consistent monitoring sites are assessed in BUIS for water quality and at these sites the variables assessed are centered on safety of human contact recreation, not sensitive marine ecosystems. A more consistent and widespread sampling program led by NPS would fill in this gap and allow for a wider assessment of trends and potential problems. Such a program 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	Dry Tropical Forest	Disturbance from the 2017 hurricane season led to canopy gaps and recolonization of non-native plants species, the extent of which is unknown. Establishment of a permanent plot network within the dry tropical forest would allow for higher confidence in future assessments, including improved tracking of success of invasive plant removal treatments.
	Coastal Forest	The extent of structural damage from the 2017 hurricane season and subsequent re-establishment of exotic species needs to be documented. Extent of loss of coastal forest from tidal inundation and erosion in unknown and annual monitoring is suggested.

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

Resource Category	Focal Resource	Important Information Gaps
Biological Integrity (continued)	Seagrass	Detailed data collection is necessary to collectively assess the temporal and spatial dynamics of seagrass relative abundance, productivity, and community composition (including macroalgae and sessile invertebrates). A long-term monitoring program is needed to assess the current status of seagrasses and to evaluate the impacts of local anthropogenic (e.g., water quality, anchor damage) and environmental (e.g., hurricanes, invasion of a non-native seagrass, *Halophila stipulacea*) threats.
	St. Croix Ground Lizard	Continued monitoring of species abundance and distribution across the island is recommended to occur at least every 5 years. Monitoring and trapping for non-native mammals should occur annually.
	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.
	Conch	There needs to be a consistent and standardized program for monitoring populations of conch if their status and trends are to be adequately understood.
	Lobster	Recent lobster assessments are not optimized to find and document spiny lobster abundance and other demographic variables (e.g., size structure, reproductive status). An episodic monitoring program optimized for spiny lobster would allow assessment of no-take protections in improving the population.
	Reef Fish	Reef fish community and population status should continue to be monitored annually, both inside and outside the boundaries of the Monument. A cross-validation study is recommended to allow for comparison of different monitoring methodologies. Additionally, studies evaluating the relationship between habitat degradation and fish community condition are suggested.
	Sea Turtles	Rigorous data collection for condition metrics and vital rates will be necessary to identify the underlying mechanisms of changes to sea turtle abundance, productivity, and reproductive success. The continuation of a monitoring program (i.e., the Buck Island Sea Turtle Research Program), with an emphasis on population demographics and metrics that can provide insight for changes in productivity, will be essential in mitigating threats and effectively managing sea turtle populations.

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 is needed to understand interactions between colonization of these invasives and other disturbances, and their potential impacts on the native species. For reef fish, the recent arrival (first reported in 2012 in BUIS) 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 BUIS 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 expand upon existing datasets and infrastructure. Research on the use of the marine and terrestrial resources by visitors are suggested to estimate benefits from ecosystem services provided, as well as amount of anthropogenic pressure on the resource. Expanded study into both legal and illegal fishing in and around the Monument (Valdes-Pizzini et al. 2010) would allow for estimates of fishing pressure, which is crucial to understand the temporal and current status of reef fish communities. Rapid responses and management intervention are needed to combat coral diseases like stony coral tissue loss and newly emergent invasive species threats.

For terrestrial resources, expansion of a permanent plot network throughout the terrestrial vegetation focal resources will be necessary to understand long-term changes to species assemblages and abundances related to expansion of invasive species, future hurricane disturbance, and increasing temperatures and changing rainfall patterns expected in a warming climate. For shoreline dynamics, methods useful in evaluating temporal changes in beach sediments include conducting GPS shoreline surveys at regular set intervals throughout the year and the use of high-resolution satellite data for automated classification schema of sand, water and vegetation. More advanced and precise method options include airborne photography with the use of unmanned aerial systems (UAS technology) and terrestrial LiDAR scans to capture beach profiles.

5.3. Literature Cited

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U.S. Global Change Research Program (USGCRP). 2018. Fourth National Climate Assessment. Volume II: Impacts, Risks, and Adaptation in the United States. https://nca2018.globalchange.gov/

Appendix A.

Table A-1. Plant species documented in BUIS organized alphabetically by family. Compiled from the following sources: NPS 2017, Moser et al. 2010, Ray 2003, Woodbury and Little 1976.

Family	Scientific Name	Common Name (USVI)
Acanthaceae	*Avicennia germinans*	black mangrove
Acanthaceae	*Justicia periplocifolia*	tropical waterwillow
Acanthaceae	*Oplonia spinosa*	Pricklybush
Acanthaceae	*Siphonoglossa sessilis*	tropical tube tongue
Agavaceae	*Agave eggersiana*	Egger’s century plant
Agavaceae	*Agave missionum*	Corita
Aizoaceae	*Sesuvium portulacastrum*	cencilla, shoreline seapurslane
Amaranthaceae	*Achyranthes aspera*	devil’s horsewhip
Amaranthaceae	*Alternanthera crucis*	West Indian joyweed
Amaranthaceae	*Amaranthus crassipes*	spreading amaranth
Amaranthaceae	*Amaranthus viridis*	slender amaranth
Amaranthaceae	*Blutaparon vermiculare*	silverhead
Amaranthaceae	*Celosia nitida*	West Indian cock’s comb
Amaranthaceae	*Iresine angustifolia*	white snowplant
Amaryllidaceae	*Hymenocallis caribaea*	Caribbean spiderlily
Anacardiaceae	*Comocladia dodonaea*	poison ash
Apocynaceae	*Cynanchum grisebachianum*	Grisebach’s swallow-wort
Apocynaceae	*Matelea maritima*	beach milkvine
Apocynaceae	*Plumeria alba*	nosegaytree
Apocynaceae	*Prestonia agglutinata*	babeiro
Apocynaceae	*Rauvolfia viridis*	matteroot, milkbush
Arecaceae	*Cocos nucifera*	coconut palm
Asphodelaceae	*Aloe vera*	aloe vera
Asteraceae	*Bidens pilosa*	beggar’s ticks, Spanish needles
Asteraceae	*Borrichia arborescens*	tree seaside tansy
Asteraceae	*Chromolaena sinuatum*	wavyleaf thoroughwort
Asteraceae	*Launaea intybacea*	achicoria azul
Asteraceae	*Pectis humifusa*	yerba de San Juan
Asteraceae	*Pectis linifolia*	narrowleaf lemonweed
Asteraceae	*Pluchea odorata* var. *odorata*	marsh fleabane
Asteraceae	*Wedelia fruticosa*	coastal plain creepingoxeye
Bataceae	*Batis maritima*	saltwort, turtleweed
Bignoniaceae	*Distictis lactiflora*	liana fragante
Bignoniaceae	*Macfadyena unguis-cati*	catclaw vine

Family	**Scientific Name**	**Common Name (USVI)**
Bignoniaceae	*Tabebuia heterophylla*	white cedar
Bignoniaceae	*Tecoma stans*	Ginger Thomas
Boraginaceae	*Bourreria succulenta*	bodywood, pigeon berry
Boraginaceae	*Rochefortia acanthophora*	greenheart ebony
Boraginaceae	*Tournefortia volubilis*	twining soldierbush
Brassicaceae	*Cakile lanceolata*	coastal searocket
Bromeliaceae	*Bromelia pinguin*	pinguin
Bromeliaceae	*Tillandsia recurvata*	small ballmoss
Bromeliaceae	*Tillandsia utriculata*	spreading airplant
Burseraceae	*Bursera simaruba*	gumbo limbo, West Indian birch
Cactaceae	*Mammillaria nivosa*	woolly nipple cactus
Cactaceae	*Melocactus intortus*	Turk’s cap
Cactaceae	*Opuntia repens*	jumping cactus
Cactaceae	*Opuntia rubescens*	sour pricklypear
Cactaceae	*Opuntia stricta* var. *dillenii*	erect pricklypear
Cactaceae	*Opuntia triacantha*	Spanish lady
Cactaceae	*Pilosocereus royenii*	Royen’s tree cactus
Canellaceae	*Canella winteriana*	cinnamonbark, wild cinnamon
Cannabaceae	*Celtis iguanaea*	iguana hackberry
Capparaceae	*Capparis cynophallophora*	Jamaican caper
Capparaceae	*Capparis flexuosa*	limber caper
Capparaceae	*Capparis indica*	linguam
Capparaceae	*Morisonia americana*	ratapple
Casuarinaceae	*Casuarina equisetifolia*	Australian pine
Celastraceae	*Crossopetalum rhacoma*	Florida crossopetalum
Celastraceae	*Schaefferia frutescens*	Florida boxwood
Cleomaceae	*Cleome viscosa*	Asian spiderflower
Clusiaceae	*Clusia rosea*	Florida clusia
Combretaceae	*Conocarpus erectus*	button mangrove
Combretaceae	*Laguncularia racemosa*	white mangrove
Commelinaceae	*Commelina virginica*	Virginia dayflower
Convolvulaceae	*Convolvulus nodiflorus*	aguinaldo blanco
Convolvulaceae	*Cuscuta indecora*	bigseed alfalfa dodder
Convolvulaceae	*Ipomoea alba*	tropical white morningglory
Convolvulaceae	*Ipomoea eggersii*	Egger’s morning glory
Convolvulaceae	*Ipomoea pes-caprae* ssp. *brasiliensis*	Brazilian bayhops
Convolvulaceae	*Ipomoea steudelii*	Steudel’s morningglory
Convolvulaceae	*Ipomoea triloba*	littlebell

Family	**Scientific Name**	**Common Name (USVI)**
Convolvulaceae	*Jacquemontia pentanthos*	skyblue clustervine
Cordiaceae	*Cordia alba*	white manjack
Cordiaceae	*Cordia angustifolia*	basora
Cordiaceae	*Cordia polycephala*	black-sage
Cordiaceae	*Cordia rickseckeri*	San Bartolome
Cucurbitaceae	*Melothria pendula*	drooping melonnettle
Cyperaceae	*Cyperus ligularis*	Alabama swamp flatsedge
Cyperaceae	*Cyperus nanus*	Indian flatsedge
Cyperaceae	*Cyperus planifolius*	flatleaf flatsedge
Cyperaceae	*Scleria lithosperma*	Florida Keys nutrush
Erythroxylaceae	*Erythroxylum rotundifolium*	ratwood
Euphorbiaceae	*Adelia ricinella*	wild lime
Euphorbiaceae	*Argythamnia candicans*	sharpleaf silverbush
Euphorbiaceae	*Chamaesyce articulata*	jointed sandmat
Euphorbiaceae	*Chamaesyce hirta*	pillpod sandmat
Euphorbiaceae	*Chamaesyce mesembrianthemifolia*	coastal beach sandmat
Euphorbiaceae	*Chamaesyce prostrata*	blue weed, prostrate sandmat
Euphorbiaceae	*Croton astroites*	wild marrow
Euphorbiaceae	*Croton betulinus*	beechleaf croton
Euphorbiaceae	*Croton discolor*	lechecillo
Euphorbiaceae	*Croton rigidus*	yellow balsam
Euphorbiaceae	*Euphorbia heterophylla*	Mexican fireplant
Euphorbiaceae	*Euphorbia leucocephala*	Christmas bush
Euphorbiaceae	*Flueggea acidoton*	simpleleaf bushweed
Euphorbiaceae	*Gymnanthes lucida*	oysterwood
Euphorbiaceae	*Hippomane mancinella*	manchineel
Euphorbiaceae	*Jatropha gossypiifolia*	bellyache bush
Euphorbiaceae	*Tragia volubilis*	fireman
Fabaceae	*Abrus precatorius*	crab’s eye
Fabaceae	*Acacia retusa*	catch and keep
Fabaceae	*Acacia tortuosa*	twisted acacia
Fabaceae	*Caesalpinia bonduc*	yellow nicker
Fabaceae	*Caesalpinia ciliata*	small yellow nicker
Fabaceae	*Canavalia rosea*	baybean
Fabaceae	*Centrosema virginianum*	butterflypea
Fabaceae	*Chamaecrista glandulosa* var. *swartzii*	Swartz’s Jamaican broom
Fabaceae	*Coursetia caribaea* var. *caribaea*	anil falso
Fabaceae	*Crotalaria incana*	shakeshake

Family	**Scientific Name**	**Common Name (USVI)**
Fabaceae	*Crotalaria lotifolia*	cascabelillo axilar
Fabaceae	*Crotalaria retusa*	rattleweed
Fabaceae	*Crotalaria saltiana*	African rattlebox
Fabaceae	*Dalbergia ecastaphyllum*	coin vine
Fabaceae	*Desmanthus virgatus*	wild tantan
Fabaceae	*Desmodium glabrum*	zarzabacoa dulce
Fabaceae	*Galactia dubia*	West Indian milkpea
Fabaceae	*Galactia striata*	Florida hammock milkpea
Fabaceae	*Indigofera suffruticosa*	indigobush
Fabaceae	*Leucaena leucocephala*	tan-tan, lead tree
Fabaceae	*Piscidia carthagenensis*	stinkwood
Fabaceae	*Pithecellobium unguis-cati*	catclaw blackbead
Fabaceae	*Rhynchosia minima*	least snoutbean
Fabaceae	*Rhynchosia reticulata*	habilla
Fabaceae	*Senna occidentalis*	coffee senna
Fabaceae	*Stylosanthes hamata*	cheesytoes
Fabaceae	*Tamarindus indica*	tamarind
Fabaceae	*Tephrosia cinerea*	ashen hoarypea
Fabaceae	*Teramnus labialis*	blue wiss
Goodeniaceae	*Scaevola plumieri*	gullfeed
Goodeniaceae	*Scaevola sericea*	beach naupaka
Heliotropiaceae	*Argusia gnaphalodes*	sea rosemary
Heliotropiaceae	*Heliotropium angiospermum*	scorpion's tail
Heliotropiaceae	*Heliotropium ternatum*	bushy heliotrope
Lamiaceae	*Clerodendrum aculeatum*	haggarbush
Lauraceae	*Cassytha filiformis*	devil's gut
Loranthaceae	*Dendropemon caribaeus*	four-angle leechbush
Malpighiaceae	*Bunchosia glandulosa*	cafe forastero
Malpighiaceae	*Heteropterys purpurea*	bull withe
Malpighiaceae	*Malpighia infestissima*	cowhage cherry
Malpighiaceae	*Stigmaphyllon emarginatum*	monarch Amazonvine
Malvaceae	*Abutilon umbellatum*	umbrella Indian mallow
Malvaceae	*Ayenia insulicola*	dwarf ayenia
Malvaceae	*Corchorus hirsutus*	jackswitch
Malvaceae	*Helicteres jamaicensis*	Cowbush
Malvaceae	*Hibiscus tiliaceus*	mahoe, sea hibiscus
Malvaceae	*Malvastrum corchorifolium*	false mallow
Malvaceae	*Melochia tomentosa*	teabush

Family	Scientific Name	Common Name (USVI)
Malvaceae	*Sida abutifolia*	prostrate sida
Malvaceae	*Sida acuta*	common wireweed
Malvaceae	*Sida ciliaris*	bracted fanpetals
Malvaceae	*Sida glabra*	smooth fanpetals
Malvaceae	*Sida repens*	creeping mallow
Malvaceae	*Sida salviifolia*	escoba parada
Malvaceae	*Sidastrum multiflorum*	manyflower sandmallow
Malvaceae	*Thespesia populnea*	Portia tree, seaside mahoe
Malvaceae	*Waltheria indica*	basora-prieta, uhaloa
Melastomataceae	*Tetrazygia elaeagnoides*	krekre
Molluginaceae	*Mollugo nudicaulis*	nakedstem carpetweed
Molluginaceae	*Mollugo verticillata*	green carpetweed
Moraceae	*Ficus citrifolia*	shortleaf fig, wild banyantree
Myrtaceae	*Eugenia axillaris*	white stopper
Myrtaceae	*Eugenia cordata*	lathberry
Myrtaceae	*Eugenia ligustrina*	privet stopper
Myrtaceae	*Eugenia procera*	–
Myrtaceae	*Eugenia rhombea*	red stopper
Nyctaginaceae	*Boerhavia diffusa*	red spiderling
Nyctaginaceae	*Boerhavia erecta*	–
Nyctaginaceae	*Boerhavia scandens*	climbing spiderling
Nyctaginaceae	*Guapira fragrans*	black mampoo
Nyctaginaceae	*Pisonia subcordata*	water mampoo
Oleaceae	*Forestiera eggersiana*	inkbush
Orchidaceae	*Psychilis macconnelliae*	island peacock orchid
Passifloraceae	*Passiflora suberosa*	corkystem passionflower
Passifloraceae	*Turnera diffusa* var. *diffusa*	damiana
Passifloraceae	*Turnera ulmifolia*	ramgoat dashalong
Phyllanthaceae	*Phyllanthus amarus*	carry me seed
Phytolaccaceae	*Petiveria alliacea*	guinea henweed
Phytolaccaceae	*Rivina humilis*	bloodberry rougeplant
Piperaceae	*Peperomia humilis*	Polynesian peperomia
Plumbaginaceae	*Plumbago scandens*	wild plumbago
Poaceae	*Anthephora hermaphrodita*	oldfield grass
Poaceae	*Aristida adscensionis*	sixweeks threeawn
Poaceae	*Aristida cognata*	spreading threeawn
Poaceae	*Bothriochloa pertusa*	pitted beardgrass
Poaceae	*Bouteloua americana*	three-awn

Family	Scientific Name	Common Name (USVI)
Poaceae	*Cenchrus echinatus*	common sandbur
Poaceae	*Chloris barbata*	swollen fingergrass
Poaceae	*Chloris ciliata*	fringed windmill grass
Poaceae	*Chloris radiata*	radiate fingergrass
Poaceae	*Dactyoctenium aegyptium*	Egypt grass
Poaceae	*Digitaria insularis*	sourgrass
Poaceae	*Eleusine indica*	crowsfoot grass
Poaceae	*Eragrostis ciliaris*	gophertail lovegrass
Poaceae	*Leptochloa filiformis*	–
Poaceae	*Panicum chapmani*	panic grass
Poaceae	*Panicum laxum*	lax panicgrass
Poaceae	*Panicum reptans*	–
Poaceae	*Paspalum laxum*	coconut paspalum
Poaceae	*Setaria setosa* var. *leiophylla*	West Indian bristlegrass
Poaceae	*Setaria setosa* var. *setosa*	West Indian bristlegrass
Poaceae	*Setaria utowanaea*	Caribbean bristlegrass
Poaceae	*Spartina patens*	saltmeadow cordgrass
Poaceae	*Sporobolus indicus*	Rattail smutgrass
Poaceae	*Sporobolus virginicus*	seashore dropseed
Poaceae	*Tragus berteronianus*	spiked burr grass
Poaceae	*Urochloa maxima*	African guinea grass
Polygonaceae	*Coccoloba microstachya*	Uvilla
Polygonaceae	*Coccoloba swartzii*	Swartz's pigeonplum
Polygonaceae	*Coccoloba uvifera*	seagrape
Portulacaceae	*Portulaca oleracea*	common purslane
Portulacaceae	*Portulaca pilosa*	kiss-me-quick
Primulaceae	*Jacquinia arborea*	braceletwood
Primulaceae	*Jacquinia berteroi*	bois bande
Rhamnaceae	*Colubrina arborescens*	coffee colubrina, greenheart
Rhamnaceae	*Colubrina elliptica*	soldierwood
Rhamnaceae	*Krugiodendron ferreum*	leadwood
Rubiaceae	*Antirhea lucida*	palo iloron
Rubiaceae	*Erithalis fruticosa*	blacktorch
Rubiaceae	*Ernodea littoralis*	coughbush
Rubiaceae	*Exostema caribaeum*	Caribbean princewood
Rubiaceae	*Guettarda odorata*	cucubano de vieques
Rubiaceae	*Morinda citrifolia*	painkiller
Rubiaceae	*Psychotria microdon*	thicket wild coffee

Family	Scientific Name	Common Name (USVI)
Rubiaceae	*Psychotria nervosa*	Seminole balsamo
Rubiaceae	*Randia aculeata*	white indigoberry
Rubiaceae	*Spermacoce confusa*	river false buttonweed
Rutaceae	*Amyris elemifera*	torchwood
Rutaceae	*Citrus aurantifolia*	–
Rutaceae	*Zanthoxylum monophyllum*	yellow prickle
Rutaceae	*Zanthoxylum spinifex*	niaragato
Salicaceae	*Samyda dodecandra*	guayabilla
Sapindaceae	*Melicoccus bijugatus*	Spanish lime
Sapindaceae	*Serjania polyphylla*	basketwood
Sapotaceae	*Sideroxylon obovatum*	breakbill
Scrophulariaceae	*Capraria biflora*	goatweed
Solanaceae	*Capsicum frutescens*	–
Solanaceae	*Solanum racemosum*	canker berry
Surianaceae	*Suriana maritima*	bay cedar
Talinaceae	*Talinum paniculatum* var. *paniculatum*	big talinum
Verbenaceae	*Citharexylum fruticosum*	Florida fiddlewood
Verbenaceae	*Duranta erecta*	golden dewdrops
Verbenaceae	*Lantana involucrata*	buttonsage
Verbenaceae	*Lantana urticifolia*	nettleleaf shrubverbena
Verbenaceae	*Stachytarpheta jamaicensis*	light-blue snakeweed
Violaceae	*Hybanthus linearifolius*	chancleta
Vitaceae	*Cissus trifoliata*	sorrelvine
Vitaceae	*Cissus verticillata*	pudding vine
Zygophyllaceae	*Guajacum officinale*	lignum-vitae

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Appendix B.

Table B-1. Bird species organized alphabetically by Order documented in BUIS from species inventories (National Audubon Society 2010, eBird 2017, NPSpecies 2017).

Order	Scientific Name	Common Name
Accipitriformes	*Buteo jamaicensis*	red-tailed hawk
Accipitriformes	*Pandion haliaetus*	osprey
Anseriformes	*Anas bahamensis*	bahama duck, white-cheeked pintail
Anseriformes	*Oxyura jamaicensis*	ruddy duck
Apodiformes	*Eulampis holosericeus*	green-throated carib
Apodiformes	*Orthorhyncus cristatus*	antillean crested hummingbird
Caprimulgiformes	*Caprimulgus carolinensis*	chuck-will's-widow
Charadriiformes	*Actitis macularius*	spotted sandpiper
Charadriiformes	*Arenaria interpres*	ruddy turnstone
Charadriiformes	*Calidris pusilla*	semipalmated sandpiper
Charadriiformes	*Charadrius vociferus*	killdeer
Charadriiformes	*Charadrius wilsonia*	wilson's Plover
Charadriiformes	*Haematopus palliatus*	american oystercatcher
Charadriiformes	*Himantopus mexicanus*	black-necked Stilt
Charadriiformes	*Larus atricilla* [a]	laughing Gull
Charadriiformes	*Larus delawarensis*	ring-billed gull
Charadriiformes	*Onychoprion fuscatus*	sooty turn
Charadriiformes	*Pluvialis squatarola*	black-bellied plover, gray plover
Charadriiformes	*Sterna antillarum*	least tern
Charadriiformes	*Sterna maxima*	royal tern
Charadriiformes	*Thalasseus sandivicensis*	sandwich tern
Charadriiformes	*Tringa flavipes*	lesser yellowlegs
Columbiformes	*Columbina passerina*	common ground-dove
Columbiformes	*Patagioenas leucocephala*	white-crowned pigeon
Columbiformes	*Patagioenas squamosa*	scaley-naped pigeon
Columbiformes	*Zenaida aurita*	zenaida dove
Columbiformes	*Zenaida macroura*	mourning dove
Coraciiformes	*Ceryle alcyon*	belted kingfisher
Cuculiformes	*Coccyzus minor*	mangrove cuckoo
Cuculiformes	*Crotophaga ani*	smooth-billed ani
Falconiformes	*Falco peregrinus*	peregrine falcon
Falconiformes	*Falco sparverius*	american kestral
Hirundinidae	*Hirundo rustica*	barn swallow
Passeriformes	*Coereba flaveola*	bananaquit

Order	Scientific Name	Common Name
Passeriformes	*Dendroica petechia*	yellow warbler
Passeriformes	*Elaenia martinica*	caribbean elaenia
Passeriformes	*Loxigilla noctis*	lesser antillean bullfinch
Passeriformes	*Margarops fuscatus*	pearly-eyed thrasher
Passeriformes	*Mimus polyglottos*	northern mockingbird
Passeriformes	*Passer domesticus*	house sparrow
Passeriformes	*Seiurus aurocapilla*	ovenbird
Passeriformes	*Tiaris bicolor*	black-faced grassquit
Passeriformes	*Tyrannus dominicensis*	gray kingbird
Passeriformes	*Vireo altiloquus*	black-whiskered vireo
Pelecaniformes	*Ardea alba*	great egret
Pelecaniformes	*Bubulcus ibis*	cattle egret
Pelecaniformes	*Egretta caerulea*	little blue heron
Pelecaniformes	*Egretta thula*	snowy egret
Pelecaniformes	*Nyctanassa violacea*	yellow-crowned night heron
Pelecaniformes	*Pelecanus occidentalis*	brown pelican
Phaethontiformes	*Phaethon lepturus*	white-tailed tropic bird
Suliformes	*Fregata magnificens*	magnificent frigatebird
Suliformes	*Sula leucogaster*	brown booby

[a] Species probably present.

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Appendix C.

Table C-1. Coleopteran species, organized alphabetically by Family/Subfamily, documented during inventory on BUIS (1993–1997 by M. Ivie). Status codes are as follows: I = Introduced, E = Endemic, N = Native, ? = Uncertain.

Family/Subfamily	Species	Status
Aderidae	*Cnopus* sp. #2	N
Aderidae	*Pseudariotes* sp.	N
Anobiidae	*Anobiidae* sp. #1	N
Anobiidae	*Cryptorama carinatum*	N
Anobiidae	*Cryptorama megalops*	N
Anobiidae	*Petalium puertoricensis*	N
Anobiidae	*Prosteca* sp.	N
Anobiidae	*Tricorinus* sp. #1	N
Anobiidae	*Tricorinus* sp. #2	N
Anthribidae	*Ormiscus* sp.	N
Anthribidae	*Toxonotus* sp.	N
Bostrichidae	*Amphicerus cornutus*	I
Bostrichidae	*Melalgus femorale*	N
Bostrichidae	*Xylomeira tridens*	N?
Brentidae	*Exopleura monilis*	N
Buprestidae	*Polycesta porcata*	N
Carabidae	*Selenophorus discopunctatus*	N
Carabidae	*Selenophorus integer*	N
Carabidae	*Selenophorus sinuatus*	N
Carabidae	*Stylulus n.*sp.#1	E
Cerambycidae	*Anelaphus nanus*	N
Cerambycidae	*Ataxia alboscutellata*	N
Cerambycidae	*Curtomerus flavus*	I
Cerambycidae	*Eburia decemmaculata*	N
Cerambycidae	*Elaphidion glabratum*	N
Cerambycidae	*Elaphidion irroratum*	N
Cerambycidae	*Lagocheirus araeniformis*	N
Cerambycidae	*Leptostyloides similis*	N
Cerambycidae	*Merostenus attenuatus*	N
Cerambycidae	*Methia necydalea*	N
Cerambycidae	*Styloleptus inermis*	N
Cerylonidae	*Euxestes erithacus*	N
Chrysomelidae	*Acanthoscelides* sp.	N

Family/Subfamily	Species	Status
Chrysomelidae	*Amblycerus schwarzi*	N
Chrysomelidae	*Chaetocnema brunnescens*	N
Chrysomelidae	*Chalcosicya crotonis*	N
Chrysomelidae	*Cryptocephalus krugi*	N
Chrysomelidae	*Homoschema nigriventre*	N
Chrysomelidae	*Longitaris milleri*	E
Chrysomelidae	*Longitaris zandae*	E
Chrysomelidae	*Pachybrachis mendicus*	N
Chrysomelidae	*Syphrea sanctaecrucis*	N
Ciidae	*Ciicae* sp.	N
Ciidae	*Cis creberrimus*	N
Ciidae	*Cis melliei*	N
Coccinellidae	*Decadiomus hubbardi*	–
Coccinellidae	*Diomus ochroderus*	–
Coccinellidae	*Diomus* sp. #2	–
Coccinellidae	*Psyllobora lineola*	N
Coccinellidae	*Zagloba* sp.	N?
Colydiidae	*Bitoma* sp.	N
Corylophidae	*Colrylophidae* sp.	N
Corylophidae	*Hoplicnema sallaei*	N
Curculionidae	*Anchonus* sp. #1	N
Curculionidae	*Anchonus* sp. #2	N
Curculionidae	*Anthonmus macromalus*	N
Curculionidae	*Anthonomus aestuans*	N
Curculionidae	*Anthonomus* sp. *nr. homunculus*	N
Curculionidae	*Cossoninae* sp. #1	N
Curculionidae	*Cossoninae* sp. #2	N
Curculionidae	*Decuanellus brevicrus*	E
Curculionidae	*Lachnopus valgus*	N
Curculionidae	*Lembodes* sp.	N
Curculionidae	*Neomastix numerus*	N
Curculionidae	New genus, new species #1	N
Curculionidae	New genus, new species #2	N
Curculionidae	*Polydrosini* sp. #1	N
Elateridae	*Conoderus castanipes*	N
Elateridae	*Conoderus sticturus*	N
Elateridae	*Ischiodontus* sp.	N
Histeridae	*Acritus komai*	N

Family/Subfamily	**Species**	**Status**
Histeridae	*Epierus* sp. *nr. antillarum*	N
Histeridae	*Histeridae* sp. 1	?
Histeridae	*Omalodes laevigatus*	N
Jacobsoniidae	*Derolathrus n.*sp.	N
Laemophloeidae	*Lathropus* sp.	I?
Languriidae	*Loberus testaceus*	N
Lathridiidae	*Cortilena picta*	?
Lathridiidae	*Metophthalmus iviei*	N
Leiodidae	*Zeodolopus nr. puertoricensis*	N
Melyridae	*Melyrodes* sp.	N
Mordellidae	*Glipostenoda guana*	N
Mordellidae	*Mordellistena lineata*	N
Mycetophagidae	*Berginus* sp.	N?
Mycetophagidae	*Typhea stercorea*	I
Nitidulidae	*Carpophilus* sp.	I?
Nitidulidae	*Cybocephalus n.* sp. #1	N
Nitidulidae	*Stelidota ruderata*	N
Oedemeridae	*Hypasclera* sp. #1	E?
Oedemeridae	*Hypasclera* sp. #2	E?
Oedemeridae	*Oxycopis desecheonis*	N
Phalacridae	*Ochrolitus tristriatus*	N
Pselaphinae	*Melba clypeata*	N
Pselaphinae	*Minibi insularis n.* sp.	E
Ptiliidae	*Acrotrichinae* sp.	N
Ptiliidae	*Ptiliini* sp.	N
Ptininae	*Ptinus strangulatus*	N?
Scaphidiinae	*Baeocera* sp. “small eyes”	N
Scaphidiinae	*Baeocera unicolor*	N
Scaphidiinae	*Scaphisoma* sp. #4	E?
Scaphidiinae	*Scaphisoma* sp. #5	N
Scarabaeidae	*Cyclocephala immaculata*	N
Scarabaeidae	*Ligyrus cuniculus*	N
Scarabaeidae	*Phyllophaga microphylla*	N
Scarabaeidae	*Strategus talpa*	N
Scolytinae	*Cryptocarenus seriatus*	N
Scolytinae	*Hypothenemus* sp. #1	N
Scolytinae	*Hypothenemus* sp. #2	N
Scolytinae	*Hypothenemus* sp. #3	N

Family/Subfamily	**Species**	**Status**
Scolytinae	*Scolytinae* sp. #1	N
Scolytinae	*Xyleborus ferrugineus*	?
Smicripidae	*Smicrips* sp.	N
Tenebrionidae	*Adelina pici*	N
Tenebrionidae	*Adelonia* sp.	–
Tenebrionidae	*Blapstinus dominicus*	N
Tenebrionidae	*Blapstinus opacus*	N
Tenebrionidae	*Blapstinus punctatus*	–
Tenebrionidae	*Cymatothes tristis*	–
Tenebrionidae	*Diastolinus clathratus*	N
Tenebrionidae	*Hymenorus* sp. *nr. wolcotti*	N
Tenebrionidae	*Nautes* sp. #2	N
Tenebrionidae	*Phaleria testacea*	N
Tenebrionidae	*Phaleria thinophila*	N
Tenebrionidae	*Sellio tibidens*	N
Zopheridae	*Aspanthines aeneus ovatus*	N
Zopheridae	*Hyporhagus marginatus*	N

Appendix D.

Agenda for site visit to BUIS and SARI (February 6–10, 2017)

AGENDA

NATURAL RESOURCE CONDITION ASSESSMENT SCOPING MEETING
ST. CROIX, USVI (BUIS/SARI)

Schedule for the Visit:

- **Monday Feb 6** – Buck Island Reef National Monument (BUIS) site visit with focus on natural resource issues:
    - Team meets at **8:30 AM** in front of Fort Christiansvaern at Christiansted National Historic Site (Table D-1)
- **Tuesday Feb 7** – Salt River Bay National Historical Park and Ecological Preserve (SARI) site visit with focus on natural resource issues
    - Team meets at **8:30 AM** at Headquarters (2100 Church Street #100 Christiansted, St. Croix, USVI) (Table D-1)
- **Wednesday-Friday Feb 8–10** – BUIS/SARI NRCA scoping and supplemental data transfers
    - Meeting at the Headquarters (2100 Church Street #100, GCW (first floor), Christiansted, St. Croix, USVI) (Table D-1)

Participants (in person):

Nathaniel Hanna (NPS), Clayton Pollock (NPS), Tessa Code (NPS Technician), Zandy Hillis-Starr (NPS Chief of Resource Management BUIS), Dale McPherson (NPS Natural Resource Program Manager), Elizabeth Whitman (PhD Candidate FIU), Daniel Gann (Research Associate FIU), Anna Wachnicka (Research Assistant Professor FIU)

Participants (joining by phone):

Maria C. Donoso (Research Associate Professor FIU), Danielle E. Ogurcak (Postdoctoral Associate FIU), Mike Feeley (NPS SFCN)

Table D-1. Agenda.

Date	Time	Topics for Feb 8–9 Meeting & Feb 9–10 Activities
February 8th Meeting (Park HQ)	**8:30–9:00**	• Room set-up
	9:00–9:15	• Arrival/Call-in/Introductions
	9:15–9:45	• Introduction to NRCAs (Dale) • Project Schedule & Meeting Expectations (Anna)
	9:45–12:00	• Setting expectations for the BUIS and SARI 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 • Collecting contact information for experts identified in framework table
	12:00–1:00	• Lunch Break
	1:00–4:30	• Continuation of the scoping meeting; completing scoping tables for the parks (Discussion between FIU team & Park representatives)
February 9 Meeting and Activities (Park HQ)	**8:20**	• Room set-up
	8:30–12:00	• Continuation of the scoping meeting; completing scoping tables for the parks (Discussion between FIU team & Park representatives)
	12:00–1:00	• Lunch Break
	1:00–4:30	• Discussion on data management/ArcGIS files storage and management, including handling of any sensitive data • Supplemental data transfers • Consolidating info on literature sources (reports/papers) available for writing the reports
February 10 Activity and Closing Meeting (Park HQ)	**8:30–12:00**	• Supplemental data transfers
	12:00–1:00	• Lunch Break
	1:00–4:00	• Supplemental data transfers • Final remarks/comments/Q & A

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 163/180359, May 2022

National Park Service
U.S. Department of the Interior

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