An Ecological Characterization of the Salt River Bay National Historical Park and Ecological Preserve, U.S. Virgin Islands

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Cover Photograph

NOAA aerial photograph of Salt River Bay taken in 2000.

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M.S. Kendall[1], L.T. Takata[1], O. Jensen[1], Z. Hillis-Starr[2], and M.E. Monaco[1]

[1]NOAA, National Ocean Service
National Centers for Coastal Ocean Science
Center for Coastal Monitoring and Assessment
1305 East West Highway, N/SCI-1
Silver Spring, MD 20910
Matt.Kendall@noaa.gov

[2]National Park Service, Buck Island Reef National Monument
2100 Church Street #100
Christiansted, St. Croix, VI 00820-4611
Zandy_Hillis-Starr@nps.gov

Contributors:
Government of the Virgin Islands Department of Planning and Natural Resources (VIDPNR)
VIDPNR Coastal Zone Management Division
VIDPNR Division of Fish and Wildlife
VIDPNR Division of Environmental Protection
NOAA, Office of Oceanic and Atmospheric Research
NOAA, National Environmental Satellite, Data and Information Service
St. Croix Environmental Association, Virgin Islands ReLeaf

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Salt River Bay National Historical Park and Ecological Preserve (hereafter, SARI or the park) was created in 1992 to preserve, protect, and interpret nationally significant natural, historical, and cultural resources (United States Congress 1992). The diverse ecosystem within it includes a large mangrove forest, a submarine canyon, coral reefs, seagrass beds, coastal forests, and many other natural and developed landscape elements. These ecosystem components are, in turn, utilized by a great diversity of flora and fauna. A comprehensive spatial inventory of these ecosystems is required for successful management. To meet this need, the National Oceanic and Atmospheric Administration (NOAA) Biogeography Program, in consultation with the National Park Service (NPS) and the Government of the Virgin Islands Department of Planning and Natural Resources (VIDPNR), conducted an ecological characterization. The characterization consists of three complementary components: a text report, digital habitat maps, and a collection of historical aerial photographs. This ecological characterization provides managers with a suite of tools that, when coupled with the excellent pre-existing body of work on SARI resources, enables improved research and monitoring activities within the park (see Appendix F for a list of data products).

A collection 184 color, black and white, black and white infrared, and color infrared aerial photographs of the Salt River area from the 1970's to 2000 were obtained from several federal agencies for this assessment. Photographs from selected years were digitally oriented in geographic space (orthorectified) and then used to create several habitat maps of the park. The most current photographs, from year 2000, were used to create a map of fifty terrestrial and marine habitat types visible in the imagery. This map covers the entire land (145 hectares) and mangrove area (19 hectares) within the park, all of the benthic habitat within Triton, Sugar, and Salt River Bays, and much of the offshore benthic habitats (250 hectares). This map, created with a minimum feature size of 10 by 10 meters, is the first detailed spatial characterization of the SARI ecosystem. The time series of photographs were used to create maps of changes to seagrass and mangrove distributions that have occurred over the last three decades. This group of maps and images were used to frame the discussion of each major habitat type, faunal group, or environmental category in the text report for this ecological characterization.

The text portion of the report is divided into sections based on physical characteristics (e.g. geology, water quality, currents), habitat types (e.g. land cover, coral reefs, mangroves), and major faunal groups (e.g. fish, birds). Each section includes an overview, methods, results, and a discussion of linkages with other components of the SARI ecosystem and surrounding environment.

Physical characteristics of the SARI area described in this report include currents, climate, water quality, geology, and bathymetry. Water currents within the park are primarily wind and tidal driven. These play an important role in the transport of sediments along the shelf and canyon axis and consequently are a major control on reef characteristics of the canyon walls. The climate of the park is controlled primarily by the seasonal changes associated with the trade winds which are interrupted by weak cold fronts in winter and hurricanes in the summer and fall. Water quality within the bays is usually within acceptable values for Class B waters although dissolved oxygen, turbidity, and bacterial load of some sites farthest from the bay mouth are periodically in violation of allowable pollutant levels. The geology of the region has been well characterized including the underlying terrestrial and marine formations as well as the sediment accretion, erosion, and transport patterns of the bays and shelf. Bathymetry within the park has changed considerably over the last fifty years due to dredging activities and will likely continue to change at an accelerated rate relative to natural conditions due to development and erosion in the watershed.

Reef and hard bottom habitats in the canyon were once among the best studied and characterized coral structures in the world at the time the NOAA National Undersea Research Program (NURP) saturation diving facility was in operation at the site. Since the closing of this facility this is no longer the case. Reefs within SARI but outside of the canyon have received virtually no attention. Based on the year 2000 maps, total two-dimensional coral reef and hard bottom area within SARI covered 116.3 hectares, with over 41 species of coral documented in the canyon from existing literature.

Seagrass and algae communities within the canyon were also once studied intensively using the NOAA/NURP diving facility but have since gone largely unmonitored. Our maps indicate that seagrass distributions within the bays declined by ~13% overall from the 1970's to 1992 with the greatest apparent change occurring in the northwestern portion of Salt River Bay. By 2000, seagrass area had changed little from its 1992 extent.

The mangrove forests of the park were once among the most impressive in the region although they have undergone perhaps the most dramatic changes of any SARI ecosystem component in the last 30 years. Hurricane Hugo in 1989 killed over half of the 1988 mangrove stand, approximately 12 hectares of forest, and reduced the density of much of the remaining canopy. Despite this catastrophic loss, forests are recovering both naturally and with human assistance.

Notable evidence of past and recent human alteration, including dredging and construction, are noted in the grey literature, and are also visible in aerial photographs. Despite this and the expansive residentially zoned development areas within the park, forests dominate current (2000) terrestrial land cover, accounting for 106 hectares.

Fish communities within SARI are quite diverse considering the park's relatively small area. The presence of mangrove, seagrass, reef, bay, shelf edge, and access to offshore habitat within park boundaries all contribute to the high diversity of fish. Recent studies have noted 57 species in mangrove habitats, and nearly 200 on the walls of the canyon.

The bird fauna utilizing SARI are similarly diverse. The SARI area contains an array of potential avifauna habitat, including sandy beaches, mangrove stands, and mud flats. The most recent bird census data were collected by the Virgin Islands Division of Fish and Wildlife, but were not available during the preparation of this report.

The aerial imagery, habitat maps, and text report that make up this assessment are complimentary, together providing research, monitoring, and management tools for the park. The images can be used to map additional ground features, document historical changes, and serve as a baseline against which future imagery may be compared. Habitat and land cover maps will assist with the design of monitoring schemes, selection of research sites, and identification of potential habitat for species of interest. The discussion and analyses contained in the text highlight established knowledge, explore spatial aspects of prior research, and identify information gaps and threats that may guide future monitoring and research. Together, these components provide a variety of information that will facilitate the current and future stewardship of the diverse resources contained within SARI.

An Ecological Characterization of the Salt River Bay National Historical Park and Ecological Preserve, U.S. Virgin Islands

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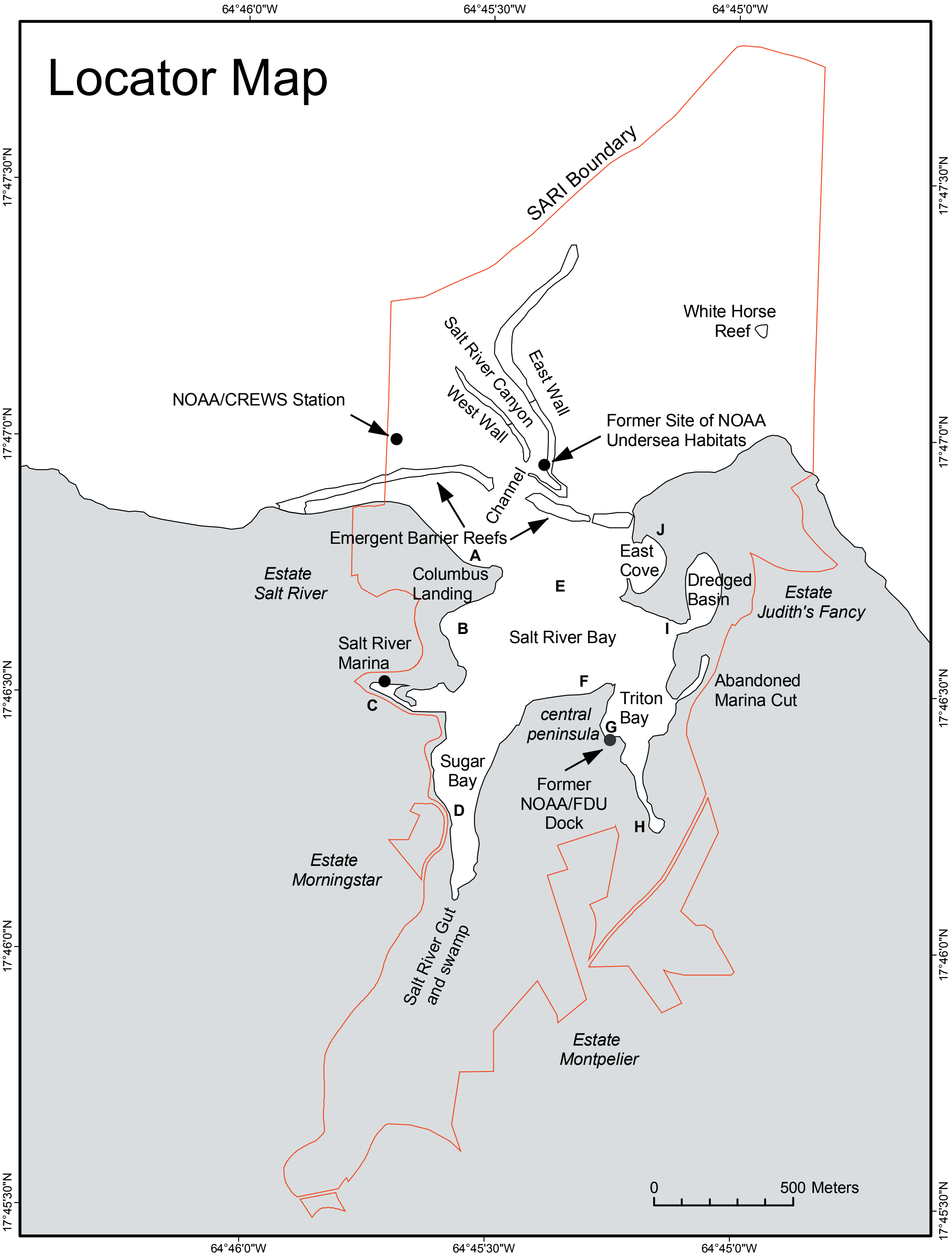

Figure 1.1. Features, sampling sites, and place names in and around SARI. Capital letters denote water quality sampling atations.

Figure 1.2. Aerial photograph of Salt River Bay, taken during 2000.

Section 1 Introduction

This report, associated maps, and aerial photographs provide an ecological characterization of the Salt River Bay National Historical Park and Ecological Preserve (hereafter, "SARI" or "the park"). It is the result of a partnership between the National Park Service (NPS) and the National Oceanic and Atmospheric Administration (NOAA) to provide a baseline characterization to enhance resource management of the park. The park is located along the north/central coast of St. Croix, United States Virgin Islands. Created in 1992, SARI was established to preserve, protect, and interpret nationally significant natural, historical, and cultural resources for the benefit of present and future generations (United States Congress 1992). The park's roughly 1015 acres encompass a combination of marine, estuarine, and terrestrial habitats including the largest remaining mangrove forest within the U.S. Virgin Islands, coral reefs, seagrass beds, and a submarine canyon.

Several excellent assessments of the cultural and ecological resources of the park have been conducted, most notably before and after the designation of park boundaries (National Park Service 1990; Island Resources Foundation 1993a, Island Resources Foundation 1993b), and for marina/hotel development proposals within smaller areas of SARI (Antillean Engineers Inc. 1983, Sugar Bay Land Development Ltd. 1986, Coastal Consultants 1987). These reports were typically compilations of prior research coupled with targeted collection of new data such as current surveys to document flushing potential for proposed marinas. Topics not addressed in the present assessment that have been described in detail elsewhere include the park's historical significance, land ownership and zoning, resource use and conflicts, and recommendations to preserve the park's ecosystems and cultural resources (e.g. National Park Service 1990; Island Resources Foundation 1993a, Island Resources Foundation 1993b). For example, the Area of Particular Concern reports on the Salt River watershed include a comprehensive list of management recommendations for preserving the ecological value of the site (Island Resources Foundation 1993a, Island Resources Foundation 1993b). Several studies have compiled qualitative species lists for terrestrial and marine flora and fauna of SARI (e.g. Gerhard and Bowman 1975, National Park Service 1990). Rather than repeat this information here, species lists were only included in the present assessment when either new data are available or a novel format and comparison are presented. For the most up to date information on the federally threatened or endangered species in the park, the US Fish and Wildlife Service should be consulted. In addition, the VI DPNR Division of Fish and Wildlife should be consulted for a current list of locally threatened or endangered species and associated monitoring activities.

Despite a diversity of prior assessments, a fine-scale, spatially explicit characterization of the park's ecological resources has not been conducted. Such an accounting of the spatial distribution of SARI's marine, estuarine, and terrestrial habitats is an important missing component of the park's ecological management plans.

The objective of this assessment is to provide the needed, spatially explicit inventory of park resources and discuss what is known about the park's ecology within this spatial framework. The present assessment is not intended to replace the previously completed assessments of the park (e.g. Island Resources Foundation 1993b), rather it is designed to build on and enhance the value of the information within them by providing habitat maps and related discussion regarding the spatial distribution of ecological resources.

There are three components to the present assessment: a text report, a time series of habitat maps, and data products such as aerial photographs and digital map files (see Appendix F). Since the 1940's, aerial photographs of St. Croix have been obtained periodically by Government agencies. Although photographs rarely targeted SARI directly, many such photography acquisitions include portions of the park. These images provide a unique record and time series of changes in land cover and benthic features within SARI from the 1940's, 1970's, shortly before and after Hurricane Hugo (1989), up to conditions in 2000. A collection of available hard copy and digital scans of these images are included as a part of this assessment. Unfortunately, the oldest images, acquired by the US Navy in 1947, were not made available at the time this report and data were compiled.

Aerial photographs were the basis of the second and perhaps most useful component of this ecological assessment; maps of land, estuarine, and benthic cover. The long time series of high quality photographs allowed maps to be created based on 1970's, 1988, 1992, and 2000 orthorectified images. Seagrass and mangrove coverage were mapped for all four years of imagery. Maps based on the most current imagery (2000) include these habitats as well as coral reef and hard bottom, sand and mud bottom, forest, development, and other land and marine cover types for a total of 50 map categories. These maps, valuable aids to management by themselves, frame the discussion of SARI's ecological resources in the report component of this characterization.

The report provides descriptions and interpretations of the image and map products in the context of previously completed environmental assessments and original research findings. A tremendous amount of research has been conducted within SARI, primarily within the submarine canyon due to the presence of the NOAA/NURP saturation diving facility, Hydrolab/Aquarius, from 1977 to 1989 (See Locator Map, figure 1.1) which was operated in conjunction with the West Indies Lab, Fairleigh Dickinson University. Only those studies most relevant for the ecological characterization were used. A more comprehensive list of research related to SARI is available from NOAA through the Coral Literature Education and Outreach program (Appendix A).

The present report is divided into sections based on major faunal groups (e.g. fish, birds), habitat types (e.g. land cover, coral reefs, mangroves), and environmental characteristics (e.g. geology, water quality, currents). Each section includes an overview, methods, results, and a discussion of linkages with other components of the SARI ecosystem and surrounding environment. All hard copy and electronic components of this ecological characterization are available from the National Park Service, Division of Resource Management in Christiansted, St. Croix, U.S. Virgin Islands.

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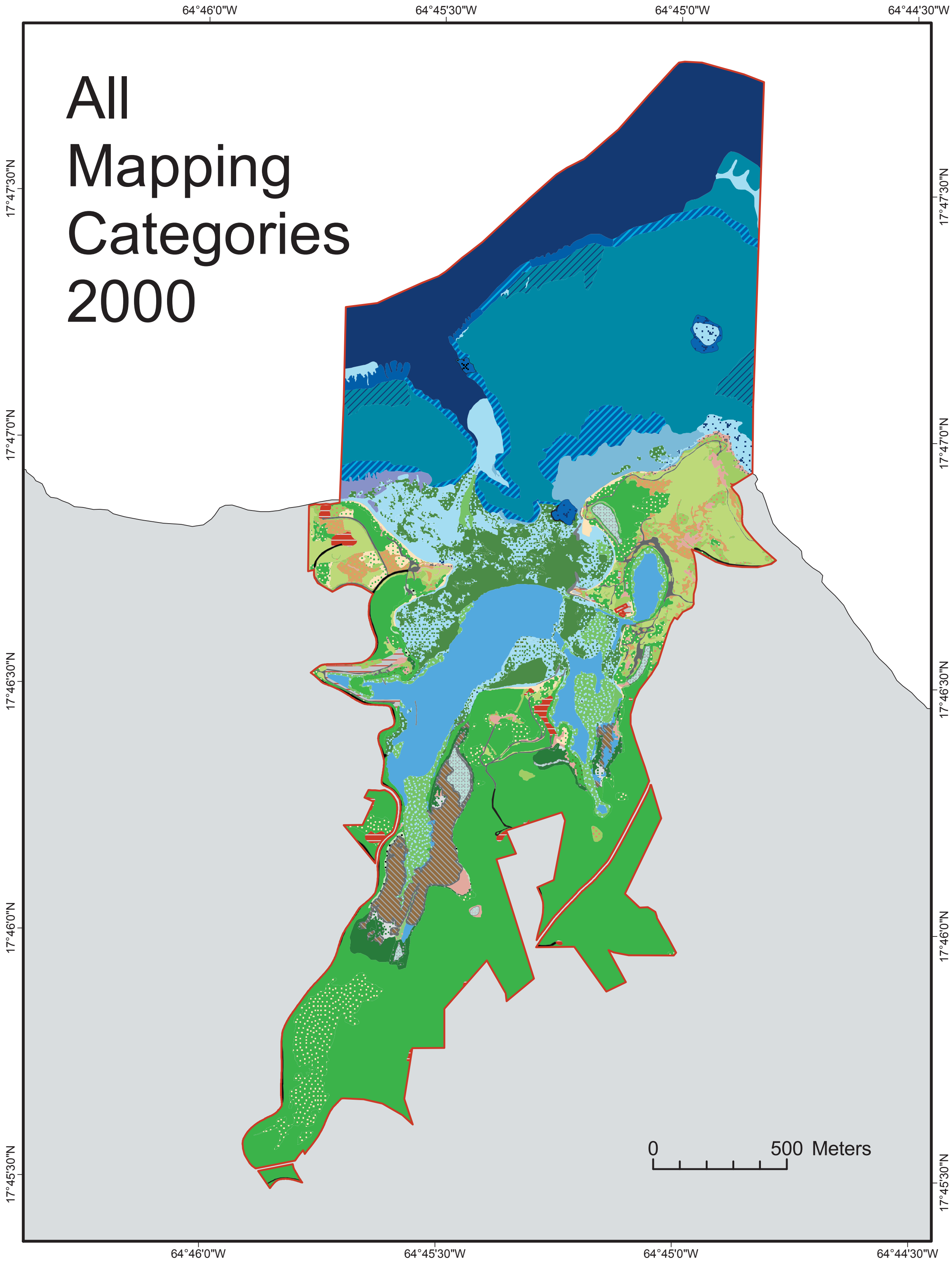

Figure 2.1. Map of all benthic, mangrove, and land cover map classifications in SARI based on 2000 aerial photograph.

Park Boundary

☐

Classification

- ⬛ Benthic, Artificial
- ▨ Coral Reef and Colonized Hardbottom, Aggregated Patch Reefs
- 🟦 Coral Reef and Colonized Hardbottom, Colonized Bedrock
- 🟦 Coral Reef and Colonized Hardbottom, Colonized Pavement
- ▨ Coral Reef and Colonized Hardbottom, Colonized Pavement with Sand Channels
- ▨ Coral Reef and Colonized Hardbottom, Linear Reef
- 🟦 Coral Reef and Colonized Hardbottom, Scattered Coral/Rock in Unconsolidated Sediment
- 🟦 Coral Reef and Colonized Hardbottom, Spur and Groove
- 🟦 Uncolonized Hardbottom, Reef Rubble
- 🟦 Uncolonized Hardbottom, Uncolonized Bedrock
- 🟪 Uncolonized Hardbottom, Uncolonized Pavement
- 🟩 Macroalgae, Continuous - 90% to 100% cover
- 🟩 Macroalgae, Patchy (Discontinuous) - 10% to less than 50% cover
- 🟩 Macroalgae, Patchy (Discontinuous) - 50% to less than 90% cover
- 🟩 Seagrass, Continuous - 90% to 100% cover
- 🟩 Seagrass, Patchy (Discontinuous) - 10% to less than 50% cover
- 🟩 Seagrass, Patchy (Discontinuous) - 50% to less than 90% cover
- 🟦 Benthic, Unconsolidated Sediments, Mud
- 🟦 Benthic, Unconsolidated Sediments, Sand
- 🟦 Benthic, Unknown
- 🟥 Land, Bare Areas, Other
- 🟫 Land, Bare Areas, Rock
- 🟨 Land, Bare Areas, Sand/Beach
- 🟥 Land, Bare Areas, Soil
- ▤ Developed, Commercial
- ▤ Developed, Residential
- ⬜ Inland Water Bodies, Freshwater Pond
- ⬜ Inland Water Bodies, Saltwater Pond
- 🟩 Forest/Trees, Closed - >65% canopy coverage
- 🟩 Forest/Trees, Open - 15%-65% canopy coverage
- 🟨 Forest/Trees, Sparse - 1%-15% canopy coverage
- 🟩 Shrubs/Bushes, Closed - >65% canopy coverage
- 🟩 Shrubs/Bushes, Open - 15%-65% canopy coverage
- 🟧 Shrubs/Bushes, Sparse - 1%-15% canopy coverage
- 🟩 Vegetated Field
- ⬛ Roads, Paved
- ⬛ Roads, Unpaved
- 🟩 Mangrove, Avicennia germanis, Closed - >65% canopy cover
- 🟩 Mangrove, Avicennia germanis, Open - 15%-65% canopy coverage
- ⬜ Mangrove, Avicennia germanis, Sparse - 1%-15% canopy coverage
- ▨ Mangrove, Dead
- 🟩 Mangrove, Laguncularia racemosa, Closed - >65% canopy cover
- 🟩 Mangrove, Laguncularia racemosa, Open - 15%-65% canopy coverage
- 🟨 Mangrove, Laguncularia racemosa, Sparse - 1%-15% canopy coverage
- 🟩 Mangrove, Mixed, Closed - >65% canopy cover
- 🟩 Mangrove, Mixed, Open - 15%-65% canopy coverage
- 🟫 Mangrove, Mixed, Sparse - 1%-15% canopy coverage
- 🟩 Mangrove, Rhizophora mangle, Closed - >65% canopy cover
- 🟩 Mangrove, Rhizophora mangle, Open - 15%-65% canopy coverage
- 🟥 Mangrove, Rhizophora mangle, Sparse - 1%-15% canopy coverage

Figure 2.1. (Cont.) Legend for map of all benthic, mangrove, and land cover map classifications in SARI.

Figure 2.2. Taking GPS data to orthorectify aerial photographs.

Section 2 Aerial Photographs & Mapping Methods

OVERVIEW

Benthic habitat, mangrove, and land cover maps were created to provide the park with a spatial inventory of its resources, and to enable an examination of changes in seagrass and mangrove distribution through time. A total of 184 aerial photographs were obtained of the Salt River study area. Maps were created from a subset of aerial photographs acquired from the 1970's through 2000. The most recent map provides a thorough inventory of park resources, covering 50 benthic, mangrove, and land cover classifications within SARI boundaries during 2000. That year, 2.50 km^2 of benthic habitat area, 1.45 km^2 of land cover area, and approximately 0.19 km^2 of mangrove area were mapped. During the 1970's, 1988, and 1992, only the 3 seagrass and 13 mangrove classes were mapped to examine distribution changes in those habitats beginning with the oldest year of imagery available, before and after the passage of Hurricane Hugo in 1989 up to conditions in 2000. Seagrass and mangrove coverage shifted notably in size and shape before and after the passage of the hurricane. In 2000, forest cover dominated terrestrial areas, and coral reef and colonized hard bottom dominated in benthic areas. These maps, as well as the orthorectified photo mosaics generated for them, will facilitate present inventory and monitoring efforts for the park, and can be utilized to direct future studies.

METHODS

A search was conducted to locate and obtain all aerial photographs of the study region. Several agencies were contacted through email or telephone, including the Federal Emergency Management Agency (FEMA), the U.S. Geological Survey (USGS), the U.S. Department of Agriculture (USDA), NOAA's National Geodetic Survey (NGS), and the U.S. Army Corps of Engineers (USACE). Local (St. Croix) contacts included the University of the Virgin Islands, the Island Resources Foundation, the Conservation Data Center, and the St. Croix Environmental Association. A complete set of these images is available at the National Park Service Office on St. Croix (see pg. 84 for contact information).

A subset of images taken by the National Geodetic Survey (NGS) were selected to construct georeferenced photographic mosaicks (images tiled together to form a single image), from which all habitat and land cover maps were constructed. Year 2000 images, the most recent available, were used to produce an inventory of the land and benthic features within the park. In order to examine changes in seagrass and mangrove habitats through time, both the oldest and most recent imagery available was used. In addition, due to the major impacts of Hurricane Hugo in 1989, the closest available images to before and after the storm's passage were also used. Photographs selected were from 1988, 1992, and 2000. The oldest available photographs taken in 1971 and 1977, did not cover the full extent of the study region during any single year. Therefore, a composite "1970s" mosaic covering the desired spatial extent for this assessment was constructed from a combination of both years of

Date	*Scale*	*Number of Photos*	*NOAA/NGS Roll Number*
1/20/2000	1:20,000	3	00ACN01
1/31/1992	1:20,000	3	92BCN02
11/24/1988	1:20,000	3	88ECN
11/14/1977	1;20,000	1	100-993
11/20/1971	1:30,000	3	100-722

Table 2.1. List of photographs used to create orthorectified photographic mosaics

photography (See Table 2.1. for information on the photographs used to produce each mosaic).

To produce mosaics, scans of selected photographs were "orthorectified" or linked to coordinates in geographic space. Geomatica OrthoEngine version 9.1.2 software was used to incorporate several pieces of data for the orthorectification process and mosaic construction. First, precise geographic coordinates (latitude/longitude) were obtained for landmarks within each image using survey grade GPS equipment. Approximately 10-15 of these landmarks, called "ground control points" (GCP's), were visually identified in each image. Most GCP's persisted from the 1970s through January of 2000, and were visible in nearly all photographs in all years. A small number of additional GCPs were also included in some photographs that had large gaps between the perennial GCPs. Calibration data from the cameras used to take the photographs was obtained to correct for lens distortion. USGS Digital Terrain Model data was also obtained to correct for terrain (elevation) effects. The three datasets were then processed with scans of aerial photographs using the Geomatica OrthoEngine software to produce mosaicks for each year.

A hierarchical classification scheme was created to map targeted habitats within the park boundary (Figure 2.1, Table 2.2). The 20 benthic habitat categories used in this assessment were based on a previous mapping effort in Puerto Rico and the Virgin Islands (Kendall et al. 2002), but were modified for the specific objectives of this assessment. Thirteen mangrove categories were adopted, based on knowledge of species observed at SARI (Gladfelter 1988, Knowles 1993), and canopy coverage categories defined by the Food and Agriculture Organization (DiGregorio and Jansen 2000). Similarly, the 17 land cover categories used were based on cover types utilized in other land cover mapping studies in semi-rural tropical areas (Vargas 1974, Smith and Brown 1992), and on land cover categories relating to resource use/development activities of concern to the health of the Salt River Bay watershed (USVI Department of Planning and Natural Resources 1993). The entire suite of 50 categories was mapped using the year 2000 mosaic (Table 2.2). During previous years, only the seagrass and mangrove classifications were utilized.

Maps were digitized from the orthorectified photo-mosaics using the Habitat Digitizer (Kendall et al. 2002) and Image Analysis software extensions in ArcView 3.2. On-screen digitizing was conducted at 1:1500 to maximize accuracy and polygon detail, while maintaining reasonable digitizing time. The minimum mapping unit (MMU) was restricted to 100 m^2, disallowing the digitization of smaller polygons which were difficult to discern given the scale and scanning resolution of the imagery. With the Habitat Digitizer extension activated, polygons were drawn around discreet, visually interpreted photographic signatures, and assigned a classification category. In addition to the original photographs, image diapositives and several pieces of collateral information were available to assist with habitat identification. Previous mapping efforts, descriptive references, hand-drawn maps included in regional studies, and field mapping of the St. Croix Environmental Association mangrove restoration plots aided with the digitization process (Kendall et al. 2002, Knowles 1993, USVI Department of Planning and Natural Resources 1993, Gladfelter 1988, Gerhard and Bowman 1975). Maps were based on two dimensional area and do not take into account vertical relief.

Some portions of the marine/estuarine environment were not directly interpretable in

	2000		1992		1988		1970's	
	# Polygons	Total Area (hectares)	# Polygons	Total Area (hectares)	# Polygons	Total Area (hectares)	# Polygons	Total Area (hectares)
Benthic Habitats								
Artificial	7	0.4						
Coral Reef and Hardbottom								
Coral Reef and Colonized Hardbottom								
Aggregated Patch Reefs	2	0.3						
Colonized Bedrock	2	1.3						
Colonized Pavement	5	80.7						
Colonized Pavement with Sand Channels	3	6.7						
Linear Reef	7	13.0						
Scattered Coral/Rock in Unconsolidated Sediment	2	0.1						
Spur and Groove	3	2.8						
Uncolonized Hardbottom								
Reef Rubble	3	7.1						
Uncolonized Bedrock	10	2.7						
Uncolonized Pavement	2	1.7						
Submerged Vegetation								
Macroalgae								
Patchy (discontinuous) – 10% to less than 50% cover	15	10.9						
Patchy (discontinuous) – 50% to less than 90% cover	6	0.4						
Continuous – 90% to 100% cover	2	0.8						
Seagrass								
Patchy (discontinuous) – 10% to less than 50% cover	76	7.3	63	6.2	56	5.9	55	8.9
Patchy (discontinuous) – 50% to less than 90% cover	59	9.5	45	12.9	65	12.2	49	13
Continuous – 90% to 100% cover	27	12.7	29	10.4	27	13.9	26	12.9
Unconsolidated Sediments								
Mud	24	25.1						
Sand	41	11.4						
Unknown	1	55.0						
Mangroves								
Avicennia germanis (Black Mangrove)								
Sparse – 1% to 15% canopy coverage	6	0.7	19	2.4	5	0.1	5	0.3
Open – 15% to 65% canopy coverage	14	1.8	19	3.1	21	3.2	10	3.1
Closed - >65% canopy coverage	7	3	1	< 0.1	11	10.9	12	8.3
Laguncularia racemosa (White Mangrove)								
Sparse – 1% to 15% canopy coverage	0	0	3	< 0.1	0	0	0	0
Open – 15% to 65% canopy coverage	8	0.6	8	0.8	1	< 0.1	3	0.1
Closed - >65% canopy coverage	0	0	0	0	2	< 0.1	0	0

Table 2.2. Heirarchical classification scheme used for mapping benthic, mangrove, and land cover habitats within SARI. Area mapped and number of polygons are given for each year and category mapped.

	2000		1992		1988		1970's	
	# Polygons	Total Area (hectares)	# Polygons	Total Area (hectares)	# Polygons	Total Area (hectares)	# Polygons	Total Area (hectares)
Mangroves (Continued)								
Rhizophora mangle (Red Mangrove)								
Sparse – 1% to 15% canopy coverage	4	0.1	16	0.9	0	0	3	0.1
Open – 15% to 65% canopy coverage	13	0.9	31	1.8	12	0.43	13	0.5
Closed - >65% canopy coverage	18	2.8	6	0.2	27	6.1	17	7.3
Mixed								
Sparse – 1% to 15% canopy coverage	0	0	3	0.2	0	0	0	0
Open – 15% to 65% canopy coverage	9	0.5	8	0.8	5	0.2	1	< 0.1
Closed - >65% canopy coverage	2	< 0.1	0	0	8	1.2	3	0.4
Dead	12	8.1	20	12	0	0	4	0.1
Land Cover								
Bare Areas								
Rock	7	0.5						
Sand/Beach	17	1.3						
Soil	32	2.1						
Developed								
Commercial	7	1.4						
Residential	14	1.7						
Inland Water Bodies								
Freshwater Pond	1	0.1						
Saltwater Pond	5	2.4						
Natural and Semi-Natural Areas								
Forest/Trees								
Sparse – 1% to 15% canopy coverage	11	1.5						
Open – 15% to 65% canopy coverage	60	16.8						
Closed - >65% canopy coverage	25	87.8						
Shrubs/Bushes								
Sparse – 1% to 15% canopy coverage	31	4.6						
Open – 15% to 65% canopy coverage	65	5.1						
Closed - >65% canopy coverage	10	1.4						
Vegetated Field	50	14.2						
Roads								
Paved	14	1.3						
Unpaved	8	2.9						

Table 2.2 (Continued). Heirarchical classification scheme used for mapping benthic, mangrove, and land cover habitats within SARI. Area mapped and number of polygons are given for each year and category mapped.

photographs due either to turbidity or depth. For example, benthic habitat at the bottom of Salt River Canyon and in the deep regions approximately 0.5 – 1 km north of the bay, could not be seen in aerial photographs. As a result, these areas were labeled as “unknown” bottom type. Also, a large region of high turbidity obscured portions of the bottom in the bays throughout all years of photography. The area encompassed deeper (>1.5 m) portions of the Salt River Bay, the Marina, Sugar Bay, the dredged basin, abandoned marina cut, and western and southern portions of Triton Bay. Though field investigation of the deep offshore areas was not feasible for this study, ground truthing was possible in the much shallower bays. Thirty two points distributed throughout the bays were checked, revealing that areas up to 2 m deep typically exhibited patchy (50% to less than 90%) algae cover (Appendix E). Areas deeper than 2 m consistently exhibited mud substrate, devoid of vegetation. These observations corroborate those of Gerhard and Bowman (1975), indicating that vegetative growth in Salt River Bay ceases at approximately 2 m. Therefore, sections of the turbid region less than 2 m deep were assigned the patchy algal cover (50% to less than 90%) classification, and sections over 2 m were designated as mud.

Following the completion of a draft map for 2000, features in the imagery that were difficult to interpret due to confusing signatures, shadows, or high turbidity were checked for accuracy. A GIS theme was created with points located within polygons in question, or across gradients between polygons. Points were loaded into a GPS unit, and visited in the field for ground validation of habitat type, with a total of 166 benthic, terrestrial, and mangrove forest/marsh locations visited. In the field, habitat type and depth where appropriate, was recorded, and used to revise draft maps (Appendix E).

Date	*Photo Type*	*Scale*	*Source*	*Count*
1940's	B&W	Unknown	US Navy	Unknown
1971	B&W	1:20,000	USDA	5
11/20/1971	color	1:30,000	NOAA, NGS	10
11/14/1977	B&W infrared	1;20,000	NOAA, NGS	3
11/14/1977	color	1:20,000	NOAA, NGS	9
11/14/1977	color infrared	1:20,000	NOAA, NGS	4
11/30/1977	color	1;50,000	NOAA, NGS	8
11/30/1977	color	1:30,000	NOAA, NGS	3
12/3/1977	color	1:50,000	NOAA, NGS	5
12/3/1977	color	1:30,000	NOAA, NGS	3
12/7/1977	color	1:4,000	NOAA, NGS	11
12/7/1977	color	1:20,000	NOAA, NGS	5
12/7/1977	color infrared	1:4,000	NOAA, NGS	18
12/7/1977	color infrared	1:20,000	NOAA, NGS	6
12/17/1977	B&W infrared	1:4,000	NOAA, NGS	22
12/17/1977	B&W infrared	1:20,000	NOAA, NGS	5
1/31/1985	B&W	1:40,000	USDA	3
11/24/1988	color	1:20,000	NOAA, NGS	7
1991	B&W	1:65,000	USDA	3
1/31/1992	color	1;20,000	NOAA, NGS	4
2/7/1999	color	1:20,000	NOAA, NGS	3
2/18/1999	color	1:20,000	NOAA, NGS	10
3/3/1999	color	1:20,000	NOAA, NGS	2
3/19/1999	color	1:20,000	NOAA, NGS	3
12/16/1999	color	1:20,000	NOAA, NGS	2
1/20/2000	color	1:19,500	NOAA, NGS	19
2/2/2000	color	1:20,000	NOAA, NGS	8
2/26/2000	color	1:20,000	NOAA, NGS	3

Table 2.3. List of all photographs obtained of the SARI area. Sources include NOAA, and FSA (USDA).

RESULTS

Prints, diapositives, and scans (25 micron resolution) for a total of 184 images of the SARI. Most photos were taken at a scale of 1:20,000, although scales ranged from 1:4,000 to 1:50,000. The majority (173) were obtained from NOAA’s NGS, including 115 color, 28 color infrared, and 30 black and white infrared photographs taken between 1971 and 2000. An additional 11 black and white photographs taken between 1971 and 1991 were obtained from the United States Department of Agriculture (USDA), Aerial Photography Field Office (Table 2.3). Copies of the 1947 US Navy photographs were unavailable at the time the data were compiled for this report.

Orthorectified photographs produced for the 1970s, 1988, 1992 and 2000 had a pixel size of 0.5 meters, and an average positional accuracy (root mean squared error) ranging from 1.09 – 2.59 m (Table 2.4.). For year 2000, a total of 747 polygons were drawn and classified for benthic, land cover and mangrove habitats. Approximately 2.50 km^2 of benthic habitat area, 1.45 km^2 of land cover area, and 0.19 km^2 of mangrove area were mapped within SARI's boundaries. Habitat polygons ranged in size from 100 m^2 (minimum mapping unit), to 664,413 m^2 (66 hectares) for a section of colonized pavement in 2000. During the 1970's, 1988, and 1992, a total of 201, 240 and 263 polygons respectively were drawn for mangrove and seagrass habitats.

Year	*X*	*Y*
2000	2.13	2.59
1992	1.53	1.20
1988	1.09	1.21
1977	1.83	1.86
1971	1.90	1.38

Table 2.4. Estimated horizontal spatial accuracy of orthorectified photo mosaicks by time period. Values are in meters.

In 2000, non-vegetated benthic habitats covered approximately 153 hectares. Of that, approximately 70% was coral reef and colonized hard bottom, 23% was unconsolidated sediment, and 7% was uncolonized hard bottom. Most of the coral reef and colonized hard bottom consisted of large regions of colonized pavement, located on the shelf to the east and west of Salt River Canyon. A large reef rubble beach and shore located on the north shore of Judith's Fancy, extended seaward approximately 100-150 meters from the beach, and accounted for much of the uncolonized hard bottom. See Section 8 for a quantitative description of reef habitats. The large area of muddy bottom in the middle of Salt River Bay accounted for 70% of the unconsolidated sediment.

Seagrass and algae patches shift in size, shape and position throughout the time series of maps. Notably, a large region of seagrass visible southwest of the channel to Salt River Canyon during the 70's, 1988, and 1992, is no longer present in 2000. A large, continuous area of seagrass in the north-central portion of the bay appears to persist between years, though its size and shape is variable. See Section 9 for a quantitative analysis of seagrass.

Dramatic changes in mangroves coincide with the passage of Hurricane Hugo in the fall of 1989. Large patches of red (*Rhizophora mangle*) and black mangroves (*Laguncularia racemosa)* mapped before the storm in1988 were largely denuded or destroyed by 1992. By 2000, Red and black mangroves appeared to be returning to some of these areas, however large areas of dead mangrove persisted, particularly in lower Sugar Bay. See Section 10 for a quantitative analysis of mangrove change.

Terrestrial cover during 2000 was dominated by the forests of the steeper mountainous areas in the southern portions of the park. Field and shrub cover were concentrated in northeastern and northwestern limits of land near the shore. Though much of the area has been designated as low or medium density residential (R-1 or R-3) or waterfront pleasure (W-1) (Island Resources Foundation 1993b), relatively few structures have been completely built. For a more complete description of land cover and land use, see Section 13.

MAP USES

The maps and orthorectified photography provide a foundation on which future monitoring and research projects within the National Park can be based. For example, the distribution of organisms based on preferred habitat characteristics may be related to mapped habitats, and habitat boundaries. Maps facilitate selection of study sites for targeted research in specific habitats or on specific organisms in the park. Maps also provide a baseline of information to which future natural changes, restoration activities, and human induced impacts may be compared.

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Figure 3.1. NOAA/AOML Coral Reef Early Warning System (CREWS) station.

Section 3 Climate

OVERVIEW

The trade winds dominate the weather pattern for SARI. Winds are most intense during the winter months and have an easterly or east-northeasterly orientation. Wind speeds decrease during spring but re-intensify during summer months while shifting to a more easterly or east-southeasterly orientation. Fall winds maintain the westward flow but achieve the lowest average intensity. These typical weather patterns are interrupted in the winter by weak cold fronts and in the summer and fall by tropical cyclones which dramatically change the direction and intensity of the dominant wind patterns. Wind generated waves drive water circulation patterns inside and along the mouth of Salt River Bay. Rainfall is seasonal with a late summer and early fall wet season during which most of the annual precipitation occurs, contrasting with a late winter and early spring dry season. Periods of heavy rain from thunderstorms and tropical storms cause the only occurrences of freshwater flow down Salt River Gut into Sugar Bay (Figure 1.1). Air temperatures usually range from ~26° to 30°C annually with a daily range of ~2°C.

METHODS

Climate data and information were obtained from two primary sources, the NOAA/ Atlantic Oceanographic and Meteorological Laboratory (NOAA/AOML) and through literature search. The NOAA/AOML data provide an hourly record of conditions at one site within SARI, whereas the literature search provided additional descriptive information on climate which was compiled and summarized (e.g. Island Resources Foundation 1977).

In 2002 NOAA/AOML installed a Coral Reef Early Warning System (CREWS) Station in SARI near the west wall of Salt River Canyon (17° 47.045’ N, 64° 45.689’ W) as one component of NOAA’s Coral Health and Monitoring Program. The station records several oceanic and atmospheric parameters on an hourly basis, including several of interest for characterizing climate at SARI such as air temperature, wind direction, and wind speed. At the time of this assessment, hourly data from the CREWS station were available for the period between April 2002 and October 2003. All parameters were not recorded on all dates and times due to periodic maintenance required by the instruments. Despite these interruptions, the station provides a tremendous volume of nearly continuous data on key parameters for characterizing environmental conditions at SARI. Only the most pertinent summary analyses are included in this report. A quality control procedure was used to check the data for clearly erroneous sensor values which were eliminated prior to analysis. Hourly wind direction, wind speed, and air temperature are plotted based on an average of all 18 months of available data. Minimum and Maximum monthly air temperatures are also plotted based on all available data. Raw wind direction data with outliers eliminated is plotted. Additional parameters on wind gust speed, direction, and duration where collected by the CREWS sensors, however, these data where not analyzed as part of this assessment.

RESULTS

St. Croix lies in the region of the Caribbean dominated by the trade winds. These easterly winds vary seasonally in magnitude and direction. During the winter weather period, roughly from December through February, the trade winds achieve their maximum intensity, 10 to more than 20 knots, and typically blow from east-northeast. During spring, roughly March through May, wind speed is reduced and is primarily out of the east. During the summer, June through August, winds typically increase to moderate intensity and typically blow from the east or east-southeast. In fall, September through November, winds typically achieve lowest velocities but maintain the dominant easterly or east-southeasterly orientation. During the summer and fall periods, thunderstorms and hurricanes can occur which have dramatic influence on local wind direction and intensity.

Tropical storms and hurricanes occur between June and November with a clear peak in abundance in August and September. Since the 1930's, twenty eight storms have passed within 60 nautical miles of St. Croix for an average occurrence of one every 2.6 years (Caribbean Hurricane Network). Four of those storms were category three or higher on the Saffir Simpson intensity scale (winds over 110 miles per hour). Hurricane Hugo passed directly over St. Croix in September of 1989. This slow moving category 4 storm had the most notable impacts on SARI of recent storms.

Rainfall in the assessment area is seasonably variable as well. Typical rainfall for the SARI area is 35-45 inches annually. Most occurs during the late summer and fall wet season from August to November during short, but intense thunderstorms. The dry season occurs in late winter and early spring, roughly from February through April.

Data from the CREWS Station used in the assessment included 9531 observations taken hourly between April 2, 2002 and October 3, 2003. This data represents a typical 18 month period of weather for the assessment site. Deviations from the usual weather pattern occurred during this period, providing examples of the natural variability of the climate in the region. Such deviations in the CREWS data are noted and discussed relative to more typical weather conditions.

A plot of average daily air temperature during this period indicates a seasonal fluctuation from a low of ~27 °C in February to a maximum of ~29 °C in September with a typical daily range of ~2 °C (Figure 3.2). When air temperatures were averaged by hour, the

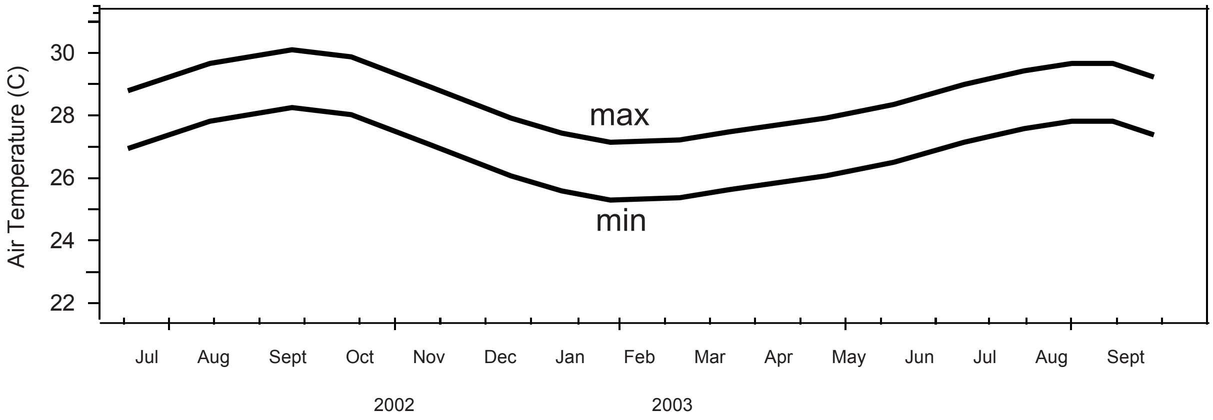

Figure 3.2. Minimum and maximum air temperature from April 2002 to October 2003.

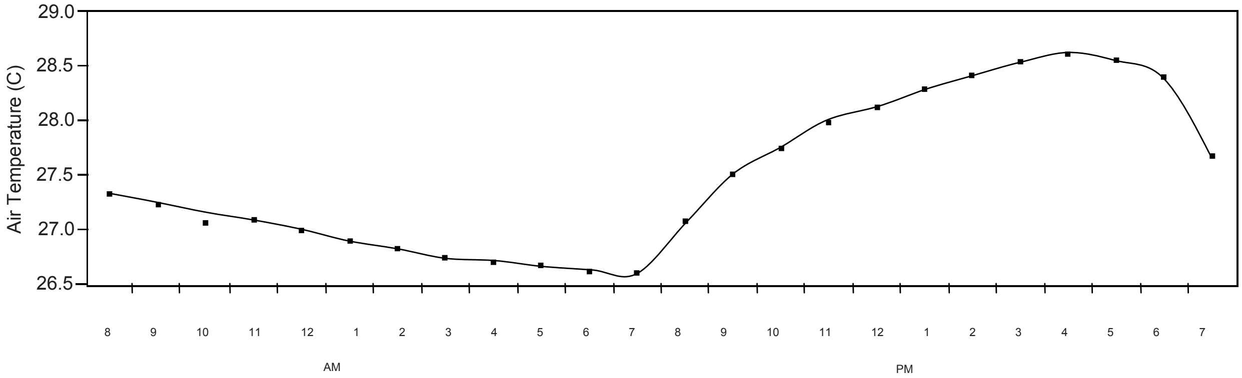

Figure 3.3. Mean hourly air temperature over the course of a 24 hour period, based on CREWS data pooled from April 2002 to October 2003.

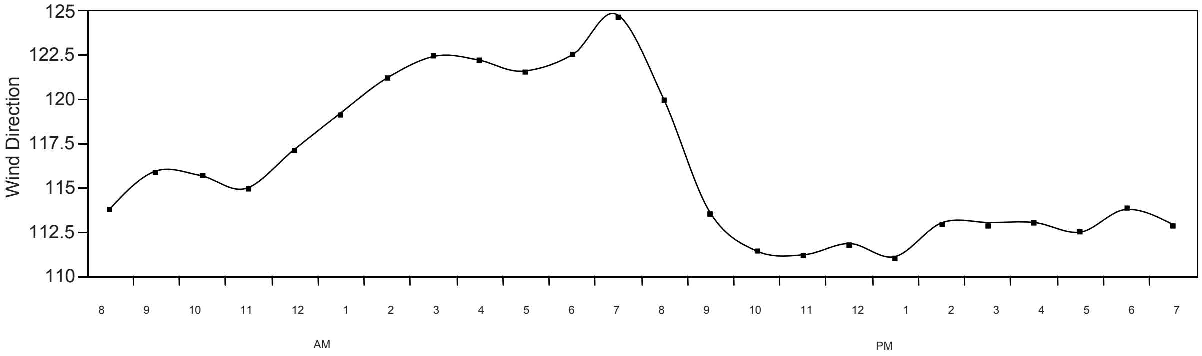

Figure 3.4. Mean hourly wind direction over the course of a 24 hour period, based on CREWS data pooled from April 2002 to October 2003.

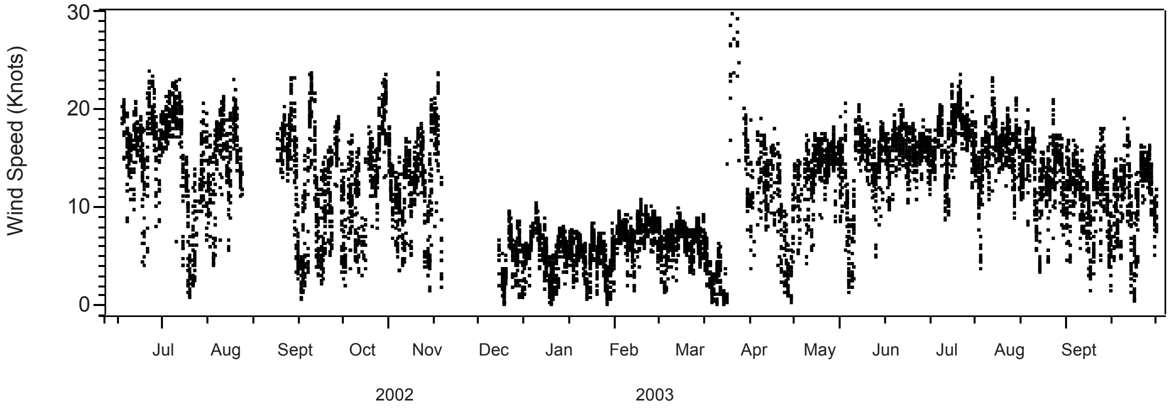

Figure 3.5. Wind speed plotted from raw CREWS data from June 2002 to October 2003.

lowest air temperatures were observed at ~7 AM (Atlantic Standard Time) around sunrise and the highest were observed at 4 PM prior to sunset (Figure 3.3).

Wind direction changed during the course of the day with winds blowing more directly out of the east during daylight hours and gradually shifting to east southeast at night (Figure 3.4). An abrupt change back to easterly winds occurs each morning around sunrise over a period of ~2 hours. This daily change in wind direction was consistent regardless of season. Wind intensity was highly variable throughout the year and depended on the timing of weak cold fronts during winter months (known locally as the “Christmas Winds”) and changes in the Bermuda High and Equatorial Trough during summer and fall. Such changes in wind intensity pattern occur on variable timescales but generally lasted a few days to a week. These periodic changes can be observed in the raw data plotted in Figure 3.5. Deviations from the typical weather pattern for this area included a winter period of unusually reduced and consistent wind intensity with typical speeds of less than 10 knots. Winds increased in spring to more typical intensity and variability during summer and fall with winds of 15-20 knots not uncommon.

Wind intensity also displayed a predictable pattern over the course of each day (Figure 3.6). Winds are generally the calmest during the few hours before dawn and increase sharply after sunrise to a maximum speed around mid-day. Winds gradually diminish through the evening hours and remain fairly low during the night. It should also be noted that the topography of the landforms around SARI are considerable. Depending on the specific location within the park, local wind speed and direction may deviate widely from the typical patterns described here.

ECOLOGICAL LINKAGES

Winds play the dominant role in controlling currents in Salt River Bay and along the bay mouth. The easterly direction of winds throughout the year maintains an east to west longshore current. This current plays the principle role in the gradual process of transporting shelf sediments into Salt River Canyon down the east canyon wall.

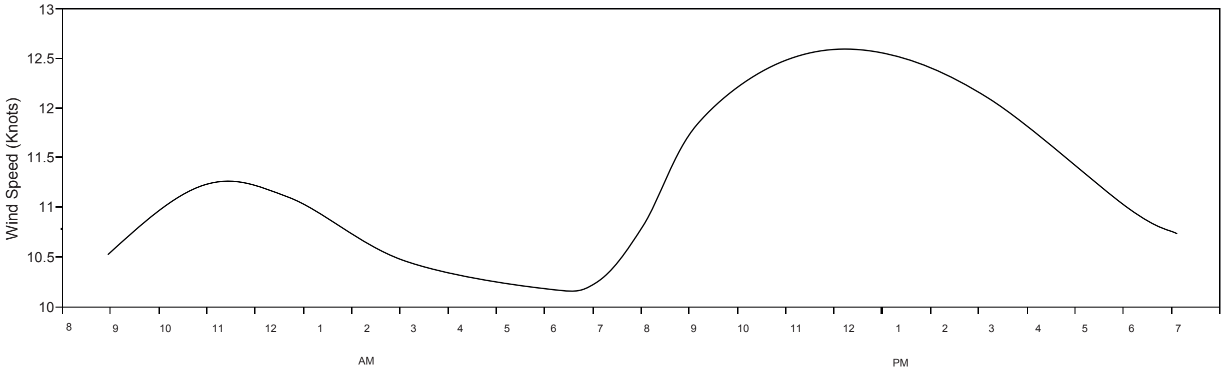

Figure 3.6. Mean hourly wind speed over the course of a 24 hour period, based on CREWS data pooled from April 2002 to October 2003.

Waves generated by the easterly winds refract around the Judith's Fancy headland and transport water over the reef crest and into Salt River Bay. This is the major driver of the current patterns within the assessment area (See Currents, Section 6).

Intense rain from hurricanes or even thunderstorms can cause flash flooding in the Salt River watershed and result in a large freshwater discharge down Salt River Gut into Sugar Bay. This can temporarily reduce salinity and aggravate already high turbidity levels in the assessment area.

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Figure 4.1. Beach composed of coral rubble.

Section 4 Geology

OVERVIEW

The geological formations of Salt River provide the foundation for the region's ecology. Limestone in the south and a variety of rock types in the northern portion of the drainage comprise the two main geologic formations. Holocene reef accretion has significantly modified the submerged topography of Salt River Canyon and greatly constricted the mouth of the estuary. The distribution of sediment types in the bays is controlled by depth and proximity to terrigenous sources and the bay mouth. Terrigenous sediments are flushed into the bays down the watershed's main drainage and by erosion of exposed headlands. Sediments are dominated by terrigenous types in the deepest and southernmost portions of the bays. Shallow northern portions of the bays are dominated by carbonate sediments primarily derived from calcareous algae. Sediments outside the bays in Salt River Canyon are almost exclusively carbonate and are primarily derived from bioerosion of reef corals. Longshore drift carries sediment from east to west along the shelf. The sediment budget within the canyon is characterized by gradual long term build up and sudden periodic purging by major storms. Even though prevailing conditions have likely occurred more than 95% of the time over the last century they are only responsible for about a third of the total sediment transport in and around Salt River Canyon.

METHODS

Literature on the geology and geological processes within the SARI area were compiled for both the bay and canyon/shelf areas. These sources often included maps and text descriptions on the extent of rock or sediment bodies and their relationship with the system's ecology. These diverse sources were then combined and condensed into a generalized description of the overall geological setting for SARI.

RESULTS

The major geologic formations for the Salt River watershed consist of two primary lithologic units (Justus et al 1975, Gill et al 2002a; Gill et al 2002b). Most of the drainage basin and area south of SARI is underlain by the Miocene Kingshill Formation. The northern portion of the basin including the exposed bedrock around the shoreline of SARI consists of the Cretaceous Judith's Fancy Formation. The Kingshill Formation is primarily limestone whereas the Judith's Fancy Formation is a mixture of volcanoclastics, sandstone, mudstone, and contains a few small dioritic or gabbroic intrusions. The main stream bed of Salt River consists of eroded surface sediments.

Sediment in Sugar and Salt River Bay consists of two distinct types. Carbonate sediments with course grain size (>4 phi) are typically located along the sides of Sugar Bay and the main body of Salt River Bay where water depth is less than ~2m. Finer sediments (<4 phi) such as terrigenous silt and clay with low carbonate content are primarily found in the southernmost reaches of Sugar Bay and in the deep, central axis of Sugar and Salt River Bays (Justus et al 1975). In addition to these differences in sediment type according to water depth, there is also a gradual change from mostly terrigenous sediments in the southernmost reaches of Sugar Bay to carbonate marine sediments toward the mouth of Salt River Bay. Triton Bay presumably exhibits a similar distribution of sediment types according to depth and proximity to the marine environment, although it has not been directly evaluated. The carbonate sediments within the bays are derived from calcareous algae such as *Halimeda* as well as a variety of benthic organisms such as mollusks, foraminifera, and echinoids. Terrigenous sediments originate primarily from upland erosion and subsequent transport to the bays by freshwater runoff down the Salt River streambed as well as from a few outcrops exposed to wave action (Gerhard and Petta 1974).

The abundance of terrigenous sediment declines abruptly seaward of the reef at the mouth of Salt River Bay. This indicates that the reef is generally an effective depositional barrier that separates bay from canyon and shelf sedimentation (Hubbard 1989). Exceptions to this general pattern have been observed following extreme events such as tropical storms or hurricanes, when carbonate sediments offshore have been observed to be covered with a thin layer of brown, terrestrially-derived sediment (Williams 1988). In general, however, the shelf and canyon environments of SARI are subject to sedimentary processes largely separate from those inshore of the bay mouth.

The sediment budget and geology of the shelf and canyon at Salt River have been studied extensively by Hubbard (1989, 1992). Sediments outside the bays are carbonate; primarily a product of bioerosion of corals. The dominant longshore drift in the area is east to west, driven by the trade winds. As a result, the shelf to the east serves as the major source of sediment to the floor of Salt River Canyon. Large quantities of material move from the shelf with the longshore current, down the east wall of the canyon to settle on the canyon floor. Once settled, sediments await flushing to deeper water through storm driven processes. Carbonate sediments produced on the wall and shelf to the west of the canyon are either carried away westward by longshore currents or are rapidly channeled to the canyon floor through the numerous vertical cuts in the reef along the west wall. Consequently, the west canyon wall receives much less sediment than does the east wall.

The floor of Salt River Canyon is composed primarily of medium to course grained carbonate sand (~0.27-0.99 mm) with sediments becoming increasingly finer down canyon. Normally the sand surface on the canyon floor is a featureless slope with occasional mounds of the burrowing shrimp *Callianassa* sp. During storms however, sand ripples form on the canyon floor which are then eroded by water rushing out of Salt River Bay (see Currents, Section 6).

The balance between sediment input and export in the canyon is controlled by gradual, long term accretion and brief, intense erosion processes. During predominant or non-storm weather conditions, there is gradual transport of 66,000 kg of sediment to the canyon floor per year, with only 18,000 kg of sediment exiting the base of the canyon annually. The gradual annual net increase of 48,000 kg of canyon sediment during predominant conditions is offset by massive erosion events associated with tropical storms and hurricanes (Williams 1988). Such erosion events last only a few hours and are due to the intense down canyon currents associated with storm surge exiting Salt River Bay along the axis of the canyon (see Currents, Section 6). For example, during normal, non-storm weather conditions, ~33 kg of sediment move over the shelf edge at Salt River Canyon on a day to day basis. Even heavy weather can increase this amount to ~440 kg/day. During a storm in 1979, ~350,000 kg of sand were removed in a single day, a quantity equal to 5-10 years of sediment accumulation. In a more extreme example, Hurricane Hugo moved ~2,000,000 kg of sand from Salt River Canyon into deeper water in a 4-6 hour period. Down canyon currents of up to 4 m/s occurred along the base of the western canyon wall during the passage of Hugo, removing up to 2 m of sand. This transport rate was 11 orders of magnitude above that measured during fair weather.

ECOLOGICAL LINKAGES

The sedimentary processes of SARI are linked to the ecology of the enclosed bay habitats as well as the canyon and reefs offshore. The prevalence of carbonate sediments in the bays in areas with water depth less than ~2m is due in part to the high turbidity of the system. The calcareous alga *Halimeda*, responsible for much of the carbonate sediments in the bay, doesn't receive sufficient light in water depths more than 2m. The turbidity not only influences the distribution of carbonate sediment with respect to depth, but probably also effects the position of carbonate sediments in the bays relative to proximity to the bay mouth. Waters become progressively less turbid in the bay from the southernmost reaches of Sugar and Triton Bays toward the reef at the mouth of Salt River Bay (see Water Quality, Section 7).

Carbonate sediments produced on the shelf and wall are primarily a result of bioerosion of corals due to parrotfish and other rasping grazers. To some extent, they are also the result of simple physical breakdown of the reef. The east to west longshore drift and associated transport of these sediments has a major influence on the morphology and benthic communities of the east versus west walls of the canyon. On the east slope, large quantities of sediment transported from the shelf into the canyon discourages extensive growth of hard corals (see Reef and Hardbottom, Section 8). In contrast, more vigorous coral growth and a steeper wall formation are observed on the west wall, where less sediment is received (see Currents, Section 6).

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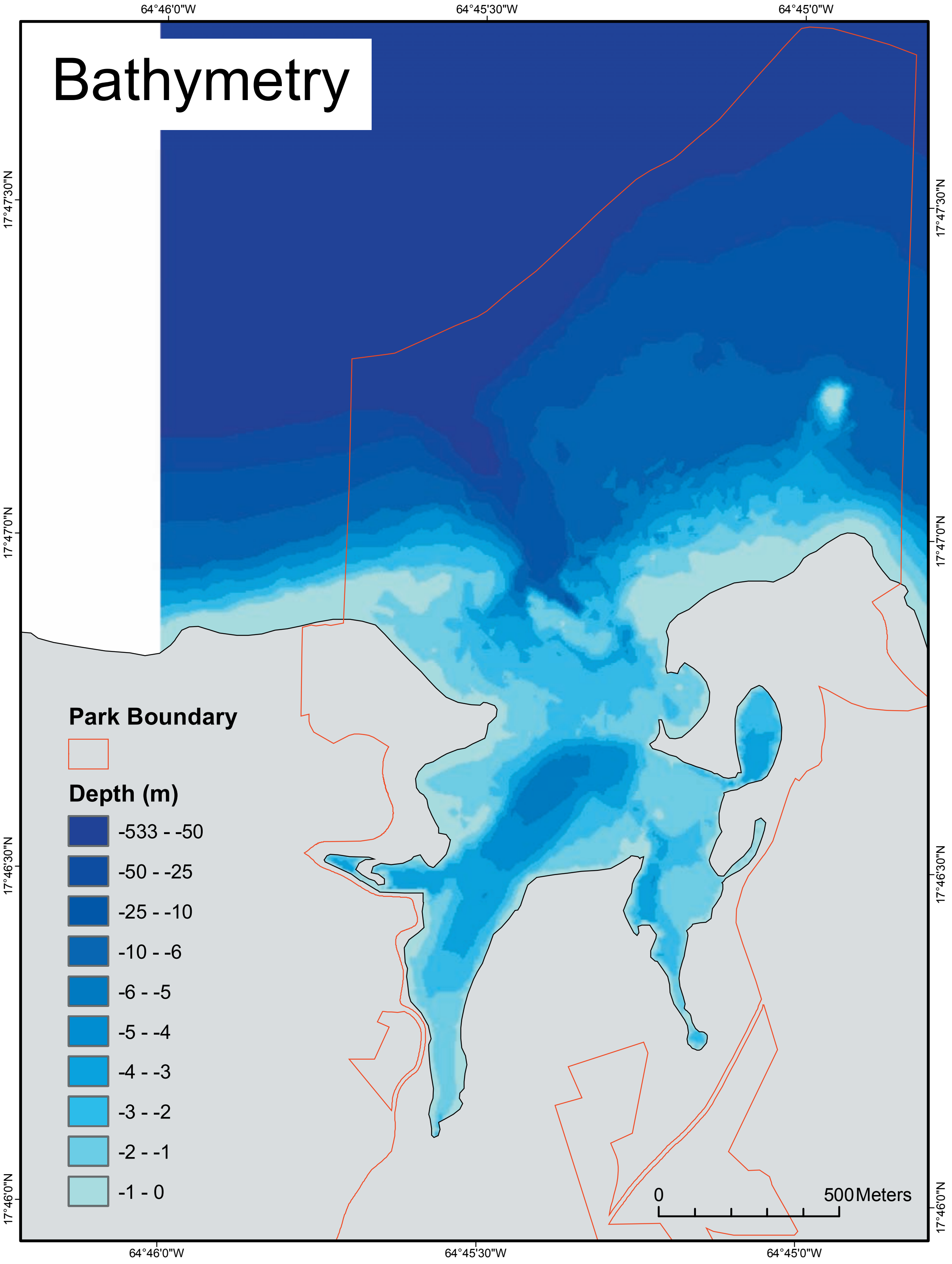

Figure 5.1. Interpolated bathymetry for SARI, based on the available soundings conducted in 1982 and 1977 from NOAA Geophysical Data System (GEODAS).

Section 5 Bathymetry

OVERVIEW

A bathymetry map for the Salt River Bay area was created based on soundings from NOAA hydrographic surveys. This map may be used for modeling, zoning, and research planning, but should not be used for navigation.

Although the accuracy assessment of this map is based on recently collected data, the soundings from which the map was created are more than 20 years old. Bathymetry can change over time due to natural processes such as deposition and sediment transport as well as anthropogenic factors such as dredging and filling which have had a large impact on the bathymetry of Salt River Bay in the past. The areas of Salt River Bay most influenced by these activities include the dredged areas of the marina, the channel to Triton Bay and the NOAA dock, the basin northeast of Triton Bay, and the abandoned marina cut on the east side of Triton Bay (Figure 1.1). Natural processes responsible for changes in bathymetry due to movement of sediments include sedimentation from runoff and removal of sediment from the bays and canyon during storms. Continuing development of the watershed is likely to increase erosion and sedimentation rates.

METHODS

Soundings data used in creating the bathymetry map were obtained from the GEOphysical DAta System (GEODAS) which is a compilation of all NOAA hydrographic survey data. Soundings available for the Salt River area were from surveys conducted in 1977 and 1982, with the majority (95%) of the data from the 1982 surveys. All soundings were adjusted to mean high water. Soundings used for accuracy assessment were obtained during a March 2004 field mission.

Soundings data were interpolated using the triangulated irregular network (TIN) method in the 3D-Analyst extension for ArcMap 8.3. This method involves automated creation of a network of non-overlapping triangles from all combinations of three nearest points. Each triangle is given a depth value based on the measured depths at each vertex of the triangle. Lines and polygons of known depth can also be used to increase the accuracy of the resulting bathymetry map. For this analysis, soundings were used as mass points (i.e. one dimensional point data) and a shoreline shapefile (derived from the 2000 aerial photograph) was used as a hard zero depth fill (i.e. a two-dimensional polygon for which depth was set to zero). Emergent reefs to the west of the mouth of Salt River Bay and Whitehorse Reef were digitized from the 2000 aerial photograph and used as hard fills with a value of 0.15m since they are barely submerged features where no depth sounding data were available. This forced the bathymetric model nearly to the surface in these areas to match the approximate depth of these reefs. The resulting TIN file (which is made up of triangles of various sizes) was converted to a 5m grid for analysis and display.

To assess the accuracy of the bathymetry map, 51 points randomly selected from the region shoreward of the barrier reef were sampled using a hand-held depth echosounder (Appendix E). The measured depth at these points was compared to the predicted depth at the same location from the bathymetry map. The correlation coefficient between the observed and predicted values was calculated to assess the overall map accuracy. In addition, the error distribution was examined in order to assess potential bias and to determine the reliability of predictions within different depth intervals. Although the accuracy of the bathymetry map is likely to vary between different areas of the study region (due to factors such as uneven distribution of soundings and differences in bottom slope), this spatial variation could not be estimated from the limited number of accuracy assessment points available.

RESULTS

The average mapped depth in Salt River

Bay (shoreward of the barrier reef) is 2.2m with a maximum depth of 5.4m found in mid-bay. The average depth within the park boundaries (including bay and canyon waters) is 23m. The deepest part of the canyon within the park boundaries is 289m. Using a tidal range of 0.3m, the total area of the intertidal zone within the bay is estimated to be 2.4 hectares (Figure 5.1).

Notable bathymetric features within the park boundaries include the canyon walls (the western wall is vertical or overhanging in some places and steeper than the eastern wall), the barrier reef extending across the mouth of Salt River Bay, and the channel through the barrier reef. Dredged areas include the Marina, the southern tip of Triton Bay, a channel through the sand bar at the mouth of Triton Bay, and the abandoned marina cut and dredged basin east of Salt River Bay (see Locator Map, Figure 1.1).

The accuracy assessment R^2 for the linear regression of predicted versus observed depth (Figure 5.2) was 0.82. In other words, the bathymetry map accounts for 82% of the observed variability in depth. The mean absolute error was 0.43m, with no apparent relationship between error and predicted or observed depth, i.e. the mean error of 0.43m is a reasonable estimate of the expected error at both deep and shallow sites within the bay. No estimate of accuracy is available for the canyon or other areas beyond the barrier reef.

ECOLOGICAL LINKAGES

Salt River, Triton, and Sugar Bays comprise a shallow estuary connected to a deep submarine canyon through a narrow break in the reef crest at the mouth of Salt River Bay. This unique geomorphology has important consequences for the ecology of the bay-canyon system and is responsible for Salt River Bay's value as a small protected harbor or "hurricane hole." The narrow channel between the bay and the canyon allows for flux of water, nutrients, and marine organisms between these two areas, while protecting the bay from waves.

The bay's bathymetric profile is responsible for many aspects of the

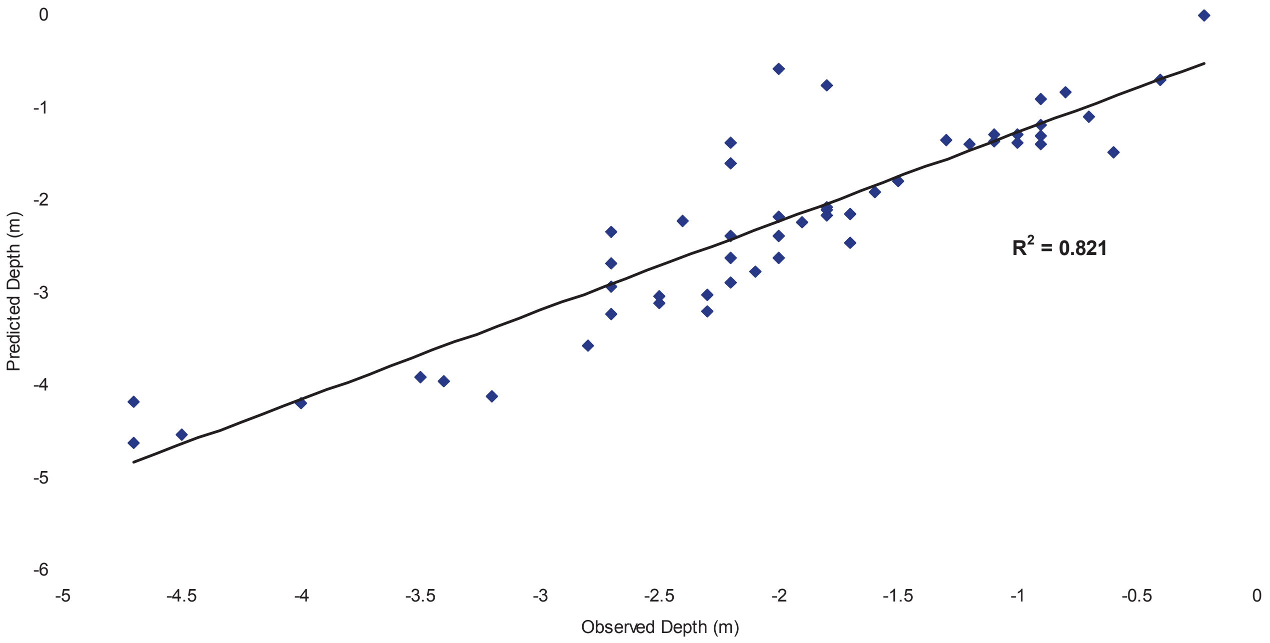

Figure 5.2.. Linear regression of predicted versus observed depth in SARI.

distribution of chemical and biological parameters. For example, the areas of the bay deeper than 2 m, where light availability at the substrate level is limited, are unsuitable for submerged aquatic vegetation. The deeper areas of the mid-bay are also more subject to anoxia and have limited biological communities (Gerhard and Bowman, 1975). The intertidal zone within the bay is an important foraging area for many wading birds (see bird section).

The contrasting bathymetric profiles of the east and west canyon walls are the result of the interplay between longshore currents, sediment transport, and coral growth. Higher sedimentation rates along the eastern wall discourage extensive coral growth and accounts for the occurrence of a more gradual slope on that side of the canyon (see currents, geology, and reefs sections). Lower sedimentation rates along the western wall result in more vigorous coral growth and the formation of steeper, often overhanging slopes. An excellent three dimensional sketch of the differing canyon walls can be found in Hubbard 1986.

Accurate GIS bathymetry maps provide a foundation for many different types of spatial analysis including benthic habitat delineation (e.g., Kendal et al., 2004) and habitat suitability modeling (e.g., Rubec et al., 1999). They are also useful for identifying depth strata for selection of stratified random sampling points. The map will facilitate such analyses and field investigations for continued monitoring and research conducted in SARI.

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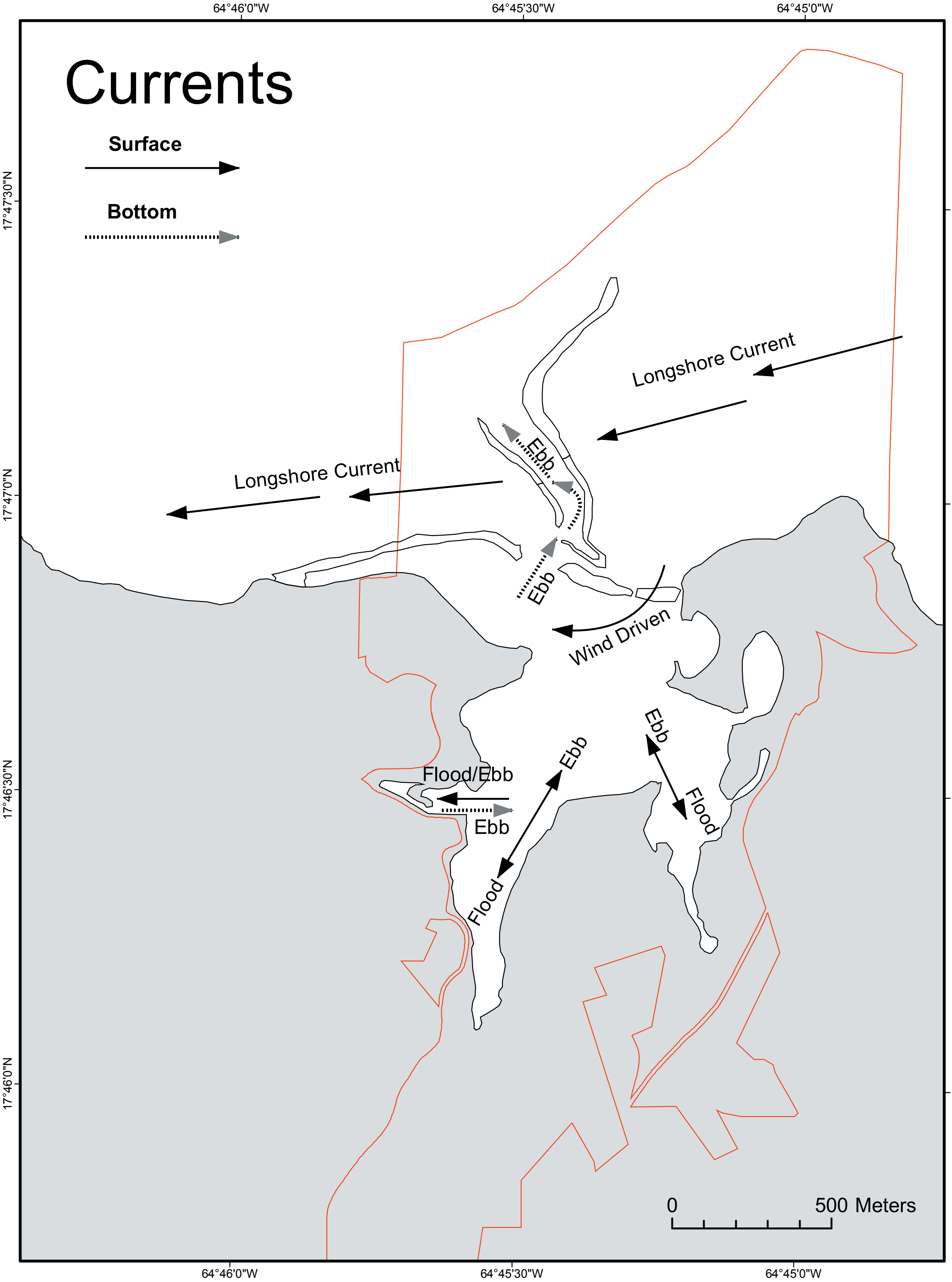

Figure 6.1. Map of generalized currents in SARI.

Section 6 Currents

OVERVIEW

Water currents in SARI are largely wind and wave driven with only a minor influence attributable to the small tides (less than 30 cm) in this part of the Caribbean. The dominant currents along the north coast of St. Croix run from east to west driven by easterly trade winds. Wind and waves transport surface water southward over the reef crest at the mouth of Salt River Bay. This causes water to accumulate within the bay until sufficient volume builds, tide ebbs, and/or winds relax causing water to flow out through the opening in the reef into the head of Salt River Canyon. Once in the canyon, currents oscillate up and down the axis of the canyon at low velocity (~10-15 cm/s) until the tide ebbs at which time current flows more regularly down canyon at a higher velocity (~20 cm/s). Despite these general patterns, bay, canyon, and longshore currents are highly variable, with intensities changing dramatically depending upon local wind conditions. For example, the intense winds and waves associated with Hurricane Hugo in 1989 transported a large volume of surface water into the bays, causing storm surge within them up to 1.0-1.5 m. When such a large volume of water exits the bays through the channel into the canyon, consistent down canyon current speeds of ~200 cm/s have been observed.

METHODS

Literature on the current patterns within the SARI area were compiled for both fair weather and storm conditions. Current patterns were rarely the sole subject under investigation, rather, studies addressed some component of SARI currents tangentially as they related to some other topic such as sediment transport, marina development, or algal growth. These sources often included maps and text descriptions of currents for discrete seasons, conditions, or portions of SARI (e.g. bay during summer vs. canyon during storm). These diverse sources were then combined and condensed to form the generalized description and map of overall SARI current patterns.

RESULTS

The Salt River system is not truly estuarine and does not display the typical current patterns of an estuary. For the last several decades an ephemeral stream has run into Sugar Bay only during times of heavy rainfall. Rainwater from the ~12 km^2 watershed flows down the streambed into the marsh south of Sugar Bay. The stream bed flattens into a sheet flow percolating through the marsh and mangroves and then reconcentrates most flow into a single discharge into Sugar Bay. During at least one period of heavy rain, a slight salt wedge was observed to form with surface waters exhibiting reduced salinity compared to waters deeper in the bay. Typically, however, the salinity of the bay approximates that of the open Caribbean to the north, or is slightly higher due to evaporation (Shepard and Dill 1977).

Currents within SARI are driven primarily by winds and to a lesser degree by tides. Tides in this part of the Caribbean are quite small, generally less than 30 cm and exhibit a diurnal pattern (one high and one low per day). Seaward of the reef, a fairly regular east-to-west current is driven by wind and waves breaking on the eastern end of the reef. The dominant trade winds from the northeast push water along the surface over the reef crest into Salt River Bay, before continuing westward. Typical wave height is 0.3-1 m with periods of 4-6 seconds. To compensate for the volume of water entering the bay over the reef crest, water exits through the channel connecting the bay and the head of Salt River Canyon. This flow through the reef cut and down the canyon is not continuous. Release of the water built up in the bay is triggered by the falling tide or relaxation of the trade winds. Once through the cut in the fringing reef, currents continue down the axis of the canyon especially during times when the bay water exhibits elevated salinity and therefore greater density than shelf waters (Shepard and Dill 1977). Currents in the canyon are highly oscillatory, alternating along the axis of the canyon at irregular intervals averaging about 30 minutes. A tidal cycle can be partially discerned in these oscillations, particularly during ebb tides when currents flow more consistently down canyon and achieve velocities higher than those of the oscillating currents. Down canyon currents follow a predicable flow pattern once through the reef. At first, currents in the head of the canyon move along the eastern wall. However, below a depth of 20 m, flow shifts to the western side of the canyon. During fair weather, currents within the canyon are slow, rarely exceeding ~10-15 cm/s during oscillating periods, and flowing faster during falling tides at ~20 cm/s. Longshore currents superimposed on this bay and canyon flow are typically weak (~5 cm/s) and move in a westerly direction along the north shore. Flow in Triton and Sugar Bays to the south reverse direction with the tides, resulting in exchange of water between the bay mouth and the southern reaches of these inner bays. Despite these general patterns, bay, canyon, and longshore currents are highly variable with intensities changing dramatically according to local wind conditions.

During storms, greater amounts of water are forced over the reef into the estuary by larger waves (Hubbard 1989), resulting in an exaggeration of the processes described above. Water levels can be elevated within Triton and Sugar Bays by more than 30 cm during small storms to over a meter during powerful hurricanes. As storms pass, or when winds forcing and holding water in the bays relax or change direction, water trapped within the bays is released through the channel in the barrier reef. Down canyon currents exceeding 50 cm/s have been measured during small storms (Williams 1988). This process was examined in detail during Hurricane Hugo in 1989 (Hubbard 1992) when water was piled against the shore and into the bays as the category 4 hurricane approached. Wave heights on the north coast reached 3.5 m. As Hugo approached, storm surge reached 1.0-1.5 m on the north shore of St. Croix. Wind direction changed as the storm passed overhead, and the mass of water in Salt River, Triton, and Sugar Bays was released into the head of the canyon through the reef cut. For a period of 4-6 hours, net down canyon currents reaching 200 cm/s and oscillatory flows up to 400 cm/s occurred along the base of the western canyon wall. Based on sediment scour patterns, the zone of maximum flow was probably confined to the west wall.

ECOLOGICAL LINKAGES

Down canyon currents driven by major hurricanes are an important mechanism for periodically flushing canyon sediments, and offsetting the usual imbalance between sediment import and export (Hubbard 1992). Water trapped within the bays by storm winds and waves flushes through the reef cut, carrying large quantities of sediment and organic debris down the canyon (See Geology, Section 4). This continually discourages coral growth along the lower portions of the western canyon wall where currents can be most intense (See Reef and Hardbottom, Section 8).

The east to west direction of longshore drift along the north shore of St. Croix is also suggested as a controlling mechanism on the faunal differences between the east and west walls of Salt River Canyon (Hubbard 1989)(See Reef and Hardbottom, Section 8). Over twice as much sediment is carried over the east wall into the canyon compared to the west wall (see Geology, Section 4), resulting in different benthic assemblages on each side of the canyon. On the east side, there is an abundance of algal covered cobbles, with sponges and gorgonians as the dominant benthic fauna. Corals are small and include mostly sediment tolerant species. In contrast, the west wall has much greater coral cover and larger colonies (See Reef and Hardbottom, Section 8).

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Figure 7.1. Sediment plume flowing from Sugar Bay, visible in 1970's aerial photograph.

Section 7 Water Quality

OVERVIEW

Waters within Salt River Bay are designated by the Virgin Islands Department of Environmental Protection (DEP) as Class B according to the EPA's Integrated Reporting format. Class B waters are designated for Primary Contact Recreation and Aquatic Life Use Support with allowable pollutant levels set according to the Virgin Islands Water Quality Standards (Division of Environmental Protection, 2002). Water quality in portions of Sugar and Triton Bays farthest from the mouth of Salt River Bay periodically have lower DO and higher turbidity levels than allowable for Class B waters. The marina has had low levels of DO during almost all sampling times and occasional spikes in bacterial load. These conditions will probably continue to occur periodically until the factors that influence these parameters have changed. Erosion and discharges in the watershed appear to be primary threats to water quality. Contaminants such as pesticides and heavy metals are not currently monitored at SARI.

METHODS

Water quality data for the ecological assessment were obtained from two primary sources, the NOAA/Atlantic Oceanographic and Meteorological Laboratory (NOAA/AOML) and the USVI/DPNR/Division of Environmental Protection (DEP). The NOAA/AOML data provide an hourly record of conditions at one site in the study area whereas the DEP data provide a monthly to annual record of conditions at 10 sites (see Locator Map, Figure 1.1). A recent inventory of water quality data was conducted for all National Parks including SARI by the NPS/Water Resources Division (NPS/WRD, 1999). Their search included all information in the EPA's data storage and retrieval system (STORET), discharges by industrial facilities, drinking water intakes, water gauges, and water impoundments. This search indicated no data types for SARI exist except for those in STORET. Since the primary purpose of the NPS/WRD report was to create in inventory of data holdings, not to create customized interpretation on water quality for any particular park, the report was used in this assessment only to cross-check data obtained directly from STORET.

As described in section 3 on climate, in 2002 NOAA/AOML installed a Coral Reef Early Warning System (CREWS) station in SARI near the west wall of Salt River Canyon (17 degrees 47.045 minutes N, 64 degrees, 45.689 minutes W) as one component of NOAA's Coral Health and Monitoring Program. The station records several parameters of interest for monitoring water quality such as water temperature, salinity, and both photosynthetically active radiation (PAR; μmol quanta $m^{-2}s^{-1}$) and ultra-violet (UVB; mW/cm^2) radiation at the water surface and 1 m depth. The hourly data is nearly continuous for April 2002 through October 2003, except for brief periods needed for instrument maintenance.

Maximum daily water temperature and salinity are plotted for all 18 months of available data. Values of PAR at the surface (PARS) and 1 m depth (PAR-1) were available only for April 2002 through Dec 2002. Mean PARS and PAR-1 were calculated hourly for this nine month period to examine how light patterns change in the area over the course of one day. Sufficient data are not yet available to examine the differences in PAR between seasons. UVB data were unavailable at the time this report was written.

DEP has collected several variables on water quality in SARI periodically since 1972 and more frequently after 1981. Variables include dissolved oxygen, fecal coliform, nutrients, salinity, temperature, and turbidity. Data were collected irregularly between 1 and 8 times a year at 2 to 10 stations throughout the bay. Data before 1981 were not considered in this analysis due to their age, extremely low sample size (in most cases, only one station visit annually), and inconsistent methodology. DEP data are periodically provided to the EPA and archived into the STORET system. A complete set of all DEP water quality data for SARI (Stations 33a-33j) (see Locator Map, Figure 1.1) collected after 1981 were obtained by accessing the STORET archives and cross checking those records against raw data sheets from DEP. A quality control procedure was used to check, reformat, and prepare the data for analysis. Data records not yet in STORET from 2000 to 2002 were entered into the database directly from DEP field sheets, and screened for obvious errors. No analyses were attempted for nutrients, pH, or total suspended solids since there were very few records for those variables. Mean and standard error are reported for dissolved oxygen, fecal coliform, turbidity, temperature, and salinity by station. Where sufficient data were present, yearly and seasonal trends were explored for each variable at key stations. Additionally, differences in mean value of these parameters before versus after Hurricane Hugo were explored. Differences in mean values of parameters among stations were examined using the Tukey-Kramer multiple means comparison procedure once values were transformed to meet statistical assumptions. Other observations on water quality based on this dataset that are relevant to the ecological assessment are provided.

RESULTS

Data from the CREWS Station used in the analysis included 9531 observations of the various parameters taken hourly between April 2, 2002 and October 3, 2003. A plot of water temperature from September 2002 to August 2003 indicates a seasonal fluctuation from ~27 °C in February/March to ~29.5 °C in September/October with an average daily range of 0.25-0.75 °C (Figure 7.2). Lowest hourly water temperatures were observed at ~7 AM (local time) around sunrise and the highest were observed at 5 PM around sunset.

Values of PARS and PAR-1 both followed a bell shaped pattern over the course of the day (Figure 7.3). PAR began increasing from zero at approximately 6AM (depending on the season), peaked at noon, and declined to zero again by 6PM. Peak PARS values were approximately two times higher than peak PAR-1 values.

Department of Environmental Protection water quality data used for analysis consisted

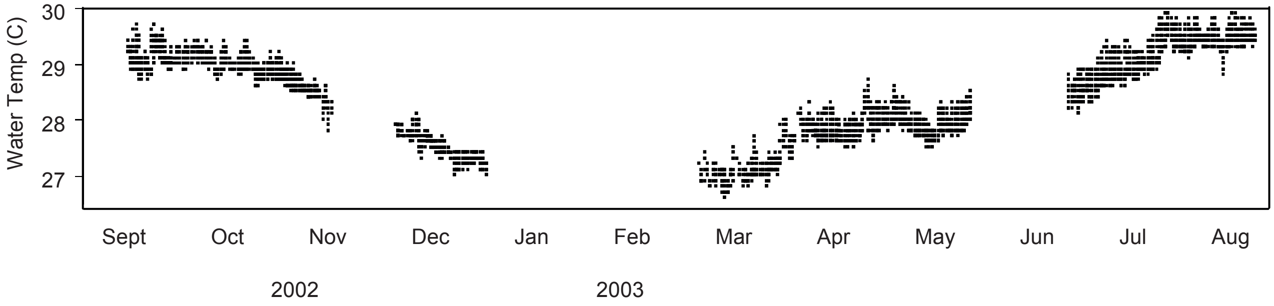


Figure 7.2. Water temperature (C) from CREWS station between September 2002 and August 2003.

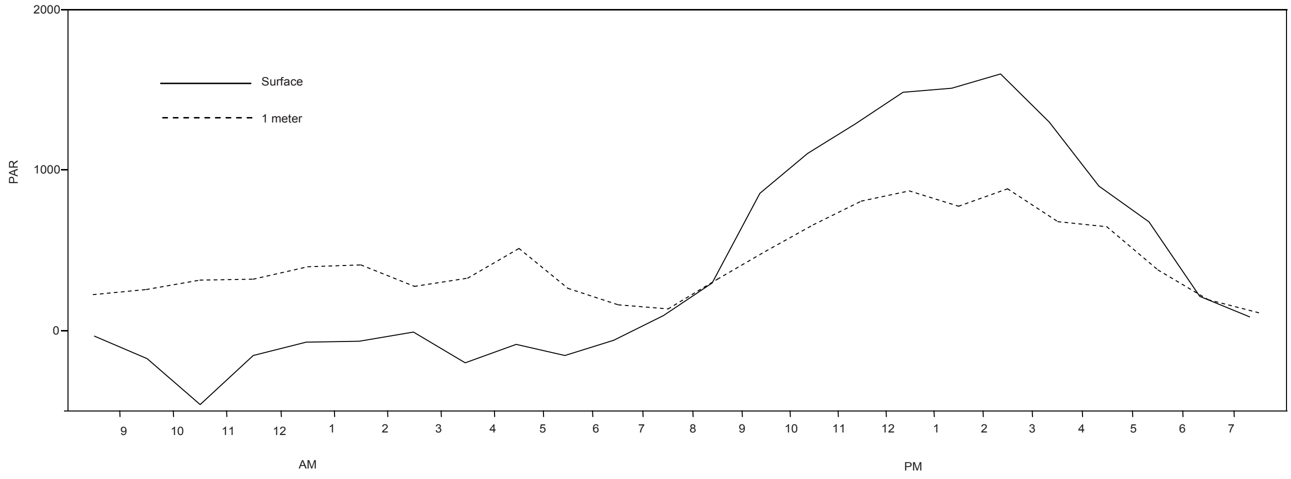


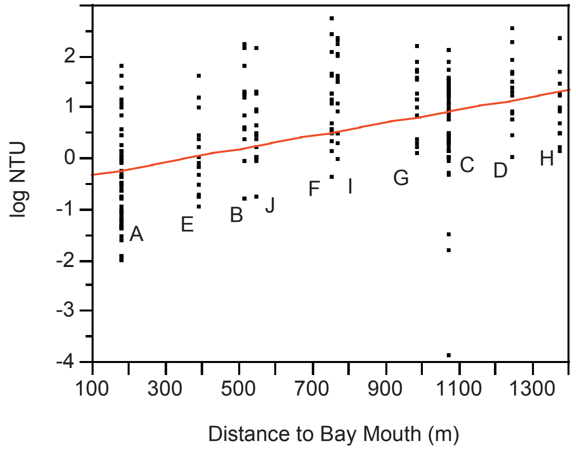
Figure 7.3. Mean hourly PAR (photosynthetically active radiation) at the surface (PARS) and at 1 meter (PAR-1) over the course of a 24 hour period. Averages are based on CREWS data pooled from April through December, 2002.

of 257 station visits and spanned 1981 to 2002. The number of visits and parameters recorded were highly variable among stations. Stations with the largest number of visits were the Columbus Landing (station A) and Marina (station C) with 58 and 66 respectively (see Locator Map, Figure 1.1). In contrast, other stations were only visited between 15 and 17 times over the 20 years of data collection. Further adding to the irregularities in sampling, not all variables were recorded during each station visit. As a result, comparisons among stations and variables must be interpreted with caution and should be used to design more robust sampling and investigation rather than to draw conclusions. An excellent summary of additional caveats for interpreting STORET data is given in the NPS/WRD (1999) report.

Average values of dissolved oxygen, fecal coliform, salinity, temperature, and turbidity are listed by station in Table 7.1 (see Locator map, Figure 1.1). Significant differences were found among stations for dissolved oxygen and turbidity according to distance from the mouth of the bay. When data across all seasons and years were pooled, stations nearest the bay mouth, namely Columbus Landing (station A) and Deep Grassbed (station E) had lowest

				Water Quality Parameters						
Station ID	***Description***	***Latitude***	***Longitude***	***Oxygen (% Sat.)***	***Oxygen (mg/l)***	***Fecal Coliform (#/100ml)***	***Fecal Coliform Filter***	***Salinity (PSU)***	***Temperature (C)***	***Turbidity (NTU)***
33A	Columbus Landing	-64.7589	17.7803	83.7 +/- 1.8	6.8 +/- 0.1	4.8 +/- 3.2	14.5 +/- 13.1	36.3 +/- 0.2	27.8 +/- 0.2	1.0 +/- 0.2
33B	Shallow Grassbed	-64.7589	17.7772	74.7 +/- 3.4	6.7 +/- 0.3	0.2 +/- 0.2	67.8 +/- 66.4	36.4 +/- 0.4	27.5 +/- 0.4	3.3 +/- 0.7
33C	Salt River Marina	-64.7619	17.7751	66.9 +/- 1.5	5.3 +/- 0.1	50.5 +/- 24.5	26.2 +/- 13.0	35.9 +/- 0.2	28.5 +/- 0.2	2.6 +/- 0.2
33D	Sugar Bay	-64.7592	17.7707	65.7 +/- 4.2	5.4 +/- 0.3	0.6 +/- 0.4	79.3 +/- 54.7	36.1 +/- 0.4	28.2 +/- 0.5	4.3 +/- 0.8
33E	Deep Grassbed	-64.7558	17.7785	81.4 +/- 1.2	6.9 +/- 0.2	0.2 +/- 0.2	33.0 +/- 30.7	36.3 +/- 0.4	27.4 +/- 0.3	1.3 +/- 0.3
33F	Beach	-64.7555	17.7753	77.7 +/- 2.6	6.6 +/- 0.2	0.0 +/- 0.0	62.3 +/- 34.0	36.5 +/- 0.4	27.8 +/- 0.5	4.2 +/- 1.0
33G	Old NOAA Dock	-64.7542	17.7739	70.2 +/- 3.2	5.8 +/- 0.2	42.8 +/- 41.4	63.4 +/- 38.7	36.4 +/- 0.4	28.1 +/- 0.4	3.6 +/- 0.5
33H	Bird Sanctuary	-64.7526	17.7708	69.5 +/- 3.2	5.5 +/- 0.2	0.3 +/- 0.3	59.9 +/- 56.8	36.2 +/- 0.4	28.3 +/- 0.5	3.0 +/- 0.6
33I	Steeple	-64.7521	17.7771	73.2 +/- 2.9	5.9 +/- 0.2	2.3 +/- 1.4	1.0 +/- 0.0	36.4 +/- 0.4	27.7 +/- 0.4	4.6 +/- 0.8
33J	East Cove	-64.7530	17.7799	81.0 +/- 4.0	6.6 +/- 0.2	0.2 +/- 0.2	58.3 +/- 57.0	36.7 +/- 0.4	27.7 +/- 0.3	2.1 +/- 0.5
	Grand Means:	**N/A**	**N/A**	**73.8 +/- 1.0**	**6.1 +/- 0.1**	**14.9 +/- 6.1**	**39.7 +/- 9.6**	**36.2 +/- 0.1**	**28.0 +/- 0.1**	**2.6 +/- 0.2**

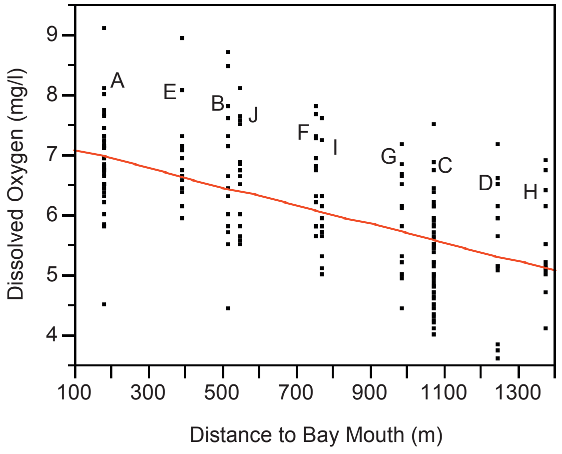
Table 7.1. Average values of dissolved oxygen, fecal coliform, salinity, temperature, and turbidity listed by station. DEP data was pooled from 1981-2002. Values are mean +/- SEM.



log NTU = -0.46336 + 0.0012875 Dist. (m)

Analysis of Variance Statistics
$R^2 = 0.236467$
$P < 0.001$

Figure 7.4. Log transformed NTU (nephelometric turbidity unit) data plotted against distance from the Salt River Bay mouth. Data pooled from all DEP sites sampled during 1981 to 2002 was used in this analysis. Letters denote sampling sites (see Locator Map, Figure 1.1).



Dissolved oxygen (mg/l) = 7.2504491 - 0.0015501 Dist. (m)

Analysis of Variance Statistics
$R^2 = 0.343154$
$P < 0.001$

Figure 7.5. Dissolved oxygen (mg/l) plotted against distance from the Salt River Bay mouth. Data pooled from all DEP sites sampled during 1981-2002 where used in this analysis. sites (see Locator Map, Figure 1.1).

levels of turbidity at 1.0 to 1.3 nephelometric turbidity units (NTU), presumably due to their proximity to clear oceanic water and their large distance from runoff sources (Figure 7.4). In contrast, stations farthest from the bay mouth such as Sugar Bay (station D) had over four times higher mean turbidity values. The 20 year average for turbidity at the Steeple (station I), Sugar Bay (station G), NOAA Dock, and Beach stations was higher than allowable levels for Class B waters (not to exceed 3 NTU) although the most recent values have been within acceptable limits.

Stations farthest from the bay mouth, including Marina, Sugar Bay, NOAA Dock, and Bird Sanctuary (see Locator Map, Figure 1.1) had lowest levels of dissolved oxygen with mean values of 5.0 to 5.7 mg/l (Figure 7.5). In contrast, the station closest to the bay mouth, Columbus Landing, had a mean dissolved oxygen value of 6.8 mg/l. For these areas, factors contributing to low dissolved oxygen probably include high turbidity, poor circulation, slightly higher mean temperature, and proximity to large areas of sediment with high organic content. The 20 year average of dissolved oxygen levels at the Marina is below allowable levels for Class B waters (less than 5.5 mg/l). In 1998, the DEP listed this station as having “Impaired Waters” with respect to dissolved oxygen due to erosion from derelict land, marina, boat, and residential discharges. Mean values in 2000 and 2001 remained below 5.5 mg/l indicating that unacceptably low oxygen levels most likely will continue to occur in the Marina until changes in practices that effect oxygen levels are implemented. Other sites, especially those far from the bay mouth such as the Bird Sanctuary and Sugar Bay, had average dissolved oxygen values very close to the lowest allowable level.

Temperature was the only variable with a consistent seasonal trend across all stations. Also of note, when selected stations were examined individually (listed in parenthesis) there were no significant seasonal or yearly trends in dissolved oxygen (Marina), fecal coliform (Marina), turbidity (Marina, Bird Sanctuary), or salinity (Sugar Bay). Interestingly, there was a significant decline in turbidity at Sugar Bay during the period for which data area available between 1984 and 1994. The NTU values declined from ~7.5 to ~1.5, despite the loss of the mangroves surrounding this site after Hurricane Hugo in 1989. A reduction in freshwater runoff from Salt River Gut is a possible influence on this trend that could be investigated further. The growth of mangroves planted to reforest areas lost during Hurricane Hugo is expected to further improve water quality around this site.

The parameters with the highest variability were fecal coliform concentration values. Variations were large among stations and even among dates at the same station. Lowest values for fecal coliform were at the Columbus Landing and East Cove stations which are both close to the bay mouth and are presumably well flushed relative to sites farther inside the bays. High spikes in fecal coliform occurred at several stations. While none of the stations were listed by the DEP as "Impaired" for bacterial load, and mean fecal coliform levels were below that designated for Class B (not to exceed 70/100ml), spikes in fecal coliform above 200 at several stations were not uncommon in the late 1980's and mid 1990's.

ECOLOGICAL LINKAGES

Many of the human uses and virtually all ecological processes are dependent on maintaining good water quality in SARI. Practices that promote water quality should be supported, such as the recent restoration of the mangrove forest in Sugar Bay which was justified in part to enhance water quality. Mangrove prop roots trap and stabilize sediments thereby reducing turbidity in some parts of SARI.

Poor flushing in the marina and inner reaches of the bays leave those areas particularly susceptible to low water quality and long residence time of pollutants once impaired. The presence and impact of toxins such as heavy metals in the water and sediments have been evaluated in the vicinity of the marina in the past but are not currently monitored.

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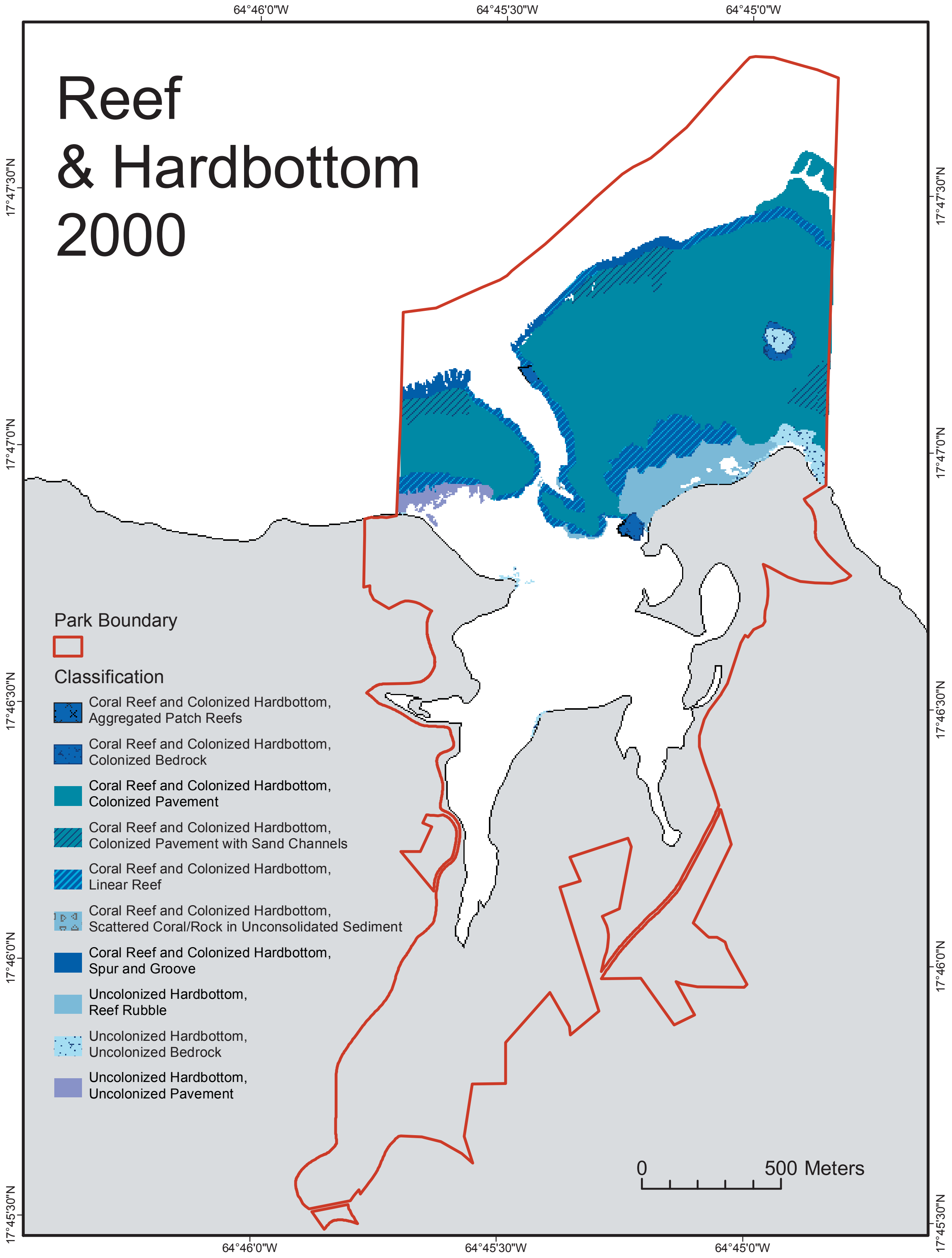

Figure 8.1. Map of colonized and uncolonized hardbottom in SARI during 2000

Section 8 Reef & Hardbottom

OVERVIEW

Over 116 hectares of reef and hard bottom were mapped within SARI for this assessment. This is an underestimate of the total area. The deep waters in the northern portion of SARI were mapped as 'unknown' because the extreme water depth precluded visual classification, but probably contain large areas of reef/hard bottom. Ten coral reef and hard bottom types were identified within SARI although additional types may occur in the deeper waters offshore. Virtually all field studies of SARI reefs have focused on the canyon walls, which were among the most studied reef systems in the world when the NOAA/NURP saturation diving facility was in operation at the site (1977-1989). Following Hurricane Hugo and the closing of these facilities, research on SARI reefs was virtually abandoned until 2001 when monitoring projects were reinitiated at two sites by UVI and VIDPNR. Over nearly three decades of research, 41 species of corals and 86 species of sponges have been found in the canyon. Percent cover of live coral and other sessile organisms in the canyon varies by depth and position on the walls. In general, the west wall is steeper and has greater coral coverage than the east wall. Species richness and diversity of corals decrease with depth along both walls. Extensive reefs are a key component of the tropical marine ecosystem within SARI boundaries. These reefs provide habitat for a diverse assemblage of fish and invertebrates and form a physical barrier which insulates the backreef and bay areas of SARI from waves and storms.

METHODS

Previous studies characterizing the reefs within the SARI area were compiled and condensed into a general description. A wide variety of studies on reef ecology have been conducted within the submarine canyon at SARI, however, only those that are most applicable to the present ecological characterization are included here. Material that is more geological in nature is summarized in the Geology section. Area and location of the different reef types was summarized based on the 2000 aerial photographs and maps created with this assessment. All area estimates are based on two dimensional maps, resulting in an underestimation of the area of vertical features such as shelf edges and canyon walls. Calculation of percentages excludes the area of deep water labeled as 'unknown' in the northern portion of SARI.

RESULTS

Total coral reef and hard bottom area within SARI mapped in this assessment was 116.3 hectares (Figure 8.1). This excludes the area of artificially constructed rock breakwaters and armored shorelines within the bay. This is an underestimate of the total hard bottom area within SARI since the aerial photos only allowed mapping to a depth of approximately 25 m and there are known reef habitats in the canyon and at the shelf edge within SARI that are deeper than this limit. Nearly 70% of the hard bottom within SARI was classified as colonized pavement. Area, number of polygons, and the percentage of the total hard bottom for each reef classification are presented in Table 8.1.

Despite comprising only ~3 hectares or less than 3% of the total hard bottom area within SARI, virtually all previous studies characterizing coral reefs in the park were conducted on the walls of the Salt River submarine canyon. These studies were typically associated with the NOAA/NURP saturation diving facility located at the head of the canyon, which offered excellent access to these habitats until it was closed following Hurricane Hugo in 1989. The studies examined many sections of the canyon walls using various survey methods, rarely at the same exact location, using inconsistent methods, and often resulting in widely different conclusions for the same general area. Virtually no studies have been conducted on reefs within SARI outside of the canyon. As a result, the

Coral Reef or Hardbottom Type	*Number of Polygons*	*Area (Hectares)*	*Percent of Total Reef Area*
Aggregated Patch Reefs	2	0.3	<1
Colonized Bedrock	2	1.3	1
Colonized Pavement	5	80.7	69
Colonized Pavement with Sand Channels	3	6.7	6
Linear Reef	7	13.0	11
Reef Rubble	3	7.1	6
Scattered Coral/Rock in Unconsolidated Sediment	2	0.1	<1
Spur and Groove	3	2.8	2
Uncolonized Bedrock	10	2.7	2
Uncolonized Pavement	2	1.7	1
TOTALS	**39**	**116.3**	**100**

Table 8.1. Area, number of polygons and percentage of total reef and hard bottom mapped during 2000.

following characterization is biased strongly toward describing only the canyon walls prior to Hurricane Hugo.

The east and west walls of Salt River submarine canyon have quite different morphologies and distributions of sessile biota. A total of 41 species of corals have been observed during studies in the canyon, 33 on the east wall and 38 on the west wall. An inventory of the coral species found during previous research and monitoring activities in the canyon is provided in Appendix B.

The southern half of the east wall is gently sloping with an unconsolidated cobble/boulder substrate. Percent cover of live coral in this area is relatively low, ranging from 0 to 7% (Boulon, 1978; Rogers et al. 1984). Farther toward the north, the wall becomes steeper, the substrate more solidified, and percent cover of live coral increases. At depths between 10 and 18 m, live coral cover is usually less than 10% and is dominated by *Diploria* and *Montastrea* species. Continuing northward along the east wall where depths reach between 19 and 21 m, live coral cover is higher, typically between 10 and 70% and is dominated by *Montastrea cavernosa* and *Agaricia* species. A depth of 18 m appears to have an optimal combination of light intensity, grazing pressure, and sedimentation rates for coral recruitment and survival on the east wall. Algal biomass was high at 9 m on the east wall (25 +/ -20 g/m^2) relative to other sites in the canyon (Rogers et al. 1984).

In contrast, the entire west wall is very steep and composed of solid substrate which forms overhanging cliffs separated by sediment-filled cuts that extend from the top of the wall to the canyon floor. Live coral cover along the west wall is typically between 20 and 60% (Boulon, 1978; Rogers et al., 1983; Rogers et al., 1984). The dominant species include *Porites* species, *Montastraea cavernosa*, *Madracis decactis,* and *Agaricia* species, with the latter being most dominant offshore and with increasing depth (Boulon 1978; Rogers et al. 1983). A depth of 9 m appears optimal for coral recruitment and survival on the west wall. Algal biomass was low at 9 m on the west wall (5 +/- 4 g/m^2) relative to other sites in the canyon (Rogers et al. 1984).

The west wall also contains numerous overhangs and caves, home to a diverse assemblage of sessile organisms including sponges, corals, bivalves, brachiopods, bryozoans, and serpulid worms. The abundant cave habitat and its corresponding biotic assemblage is different from exposed portions of the wall and further enhances the overall biodiversity of SARI. The sessile biota of these habitats between 15 and 40 m were characterized in 1982 (Rasmussen 1983; Rasmussen and Brett 1985). Total area of cave substrate covered with sessile biota increased with depth from 43% at 15 m to ~80% at the deeper caves. Demosponges were the dominant taxa at all depths covering between 30 and 54% of the substrate. Demosponges, ascidians, and sclerosponges all increased in coverage with depth. Diversity and richness levels were highest in caves at ~20 m and deeper.

Despite the differences mentioned above, the east and west walls also share several characteristics. Recruitment of corals is roughly even between the two walls, and tends to be associated with areas of low algal biomass and relatively high densities of urchins and fish (Rogers et al. 1984). Dead coral cover is highest at 9 m on both walls often exceeding 70% of the bottom, and is typically between 50 and 60% at other depths. *Agaricia lamarki* dominates deeper portions of both walls between 27 and 37 m. Cover of live coral at a depth of 37 m is lower than many shallower areas, generally below 10%. Species richness, evenness, and diversity of corals also decreases with depth along both walls (Rogers et al. 1984) although the east wall of the canyon is more diverse than the west wall at comparable depths (Coulston et al. 1990). *Diadema antillarum* density was highest in shallow areas (2.6 ind./m^2 at 9 m on the west wall) and decreased to 0 individuals at 37 m on both walls (Rogers et al. 1984).

Sponges are another important component of the sessile biota of SARI coral reef environments. The distribution of sponges at three sites, one on the west wall at 18 m and two on the east wall at 18 and 24 m, were assessed in 1983 (Targett and Schmahl 1984). Despite having different bottom characteristics and corresponding coral communities, the east and west canyon walls had similar abundance and types of sponges at the sites examined. Eighty-six species of sponges were found. All three sites had similar density and area coverage of sponges. Density was between 16 and 20 individuals per m^2. Coverage was typically between 20 and 30% of the substrate but was quite variable. No single species dominated the assemblage at any site.

Hurricane Hugo had a significant and easily measurable effect on some SARI features such as the mangroves in Sugar Bay (See Mangroves, Section 10) and the volume of sediment on the canyon floor (see Geology, Section 4). In contrast, overall changes to the coral coverage due to the storm were characterized as “minor” in a post-storm assessment, with most species losing only 2 to 14% coverage (Kesling 1990). Exceptions were *Dichocoenia stokesi* (81% loss, although this species was never abundant and limited to only shallow portions of the west wall prior to the storm), *Diploria clivosa* (28%), *Colpophyllia natans* (24%) (Kesling, 1990) and the complete devastation of an *Acropora cervicornis* patch (100%) (Coulston et al. 1990). Coral damage was patchy and mostly occurred along the east wall and shallow portions of the west wall. Sponges and gorgonians were more affected by the storm. Sponges decreased by 13% and gorgonians by 28% overall (Kesling 1990). Where living components of the reef were lost, they were replaced by bare rubble, sand, and algae-covered coral rubble. Monitoring data for the west wall at Salt River collected before and after Hurricane Allen in 1980 resulted in fewer significant changes in benthic cover (Rogers et al. 1983). In contrast, qualitative assessments indicate that extensive changes in benthic cover can be observed following such storms (Coulston et al. 1990). The techniques used to quantify changes have generally not supported such qualitative observations and probably need to be modified to improve sensitivity (Coulston et al. 1990) or confidence in the results.

In 2001, a new monitoring program using video transects was initiated with the objective of tracking changes in benthic cover at reef sites around St. Croix (Nemeth et al. 2003). The program includes one site each on the west (6 m deep) and east (12 m deep) canyon walls at Salt River. The data allow comparison with other reef sites around St. Croix. Fish are also surveyed regularly at these sites by the Division of Fish and Wildlife, VIDPNR, as part of a coral reef monitoring program (see Fish, Section 11). At the time this report was written, only the 2002 data and report were available and therefore discussion of the findings is limited. The real value of this activity is not the data in this first report, rather it will come from the long term dataset generated by continued semi-annual monitoring. A total of 24 surveys were conducted in 2001 and 2002, six each on the east and west walls per year. Coverage of live coral (~10%), dead coral with turf algae (70-80%), macroalgae (~5%), and sponges (~4%) were so similar between the two walls that the investigators recommend surveying only one of these sites in future monitoring. Coral bleaching was observed on 7-13% of colonies. Disease was observed on 2% of east wall colonies and 17% of west wall colonies.

ECOLOGICAL LINKAGES

Sedimentation is a major control on reef characteristics at SARI (see Geology, Section 4). Transport of shelf sediments and the potential mobility of the unconsolidated substrate on the southern portion of the eastern canyon wall during storms (Boulon 1978) serve to limit coral growth in that area. Apart from the canyon, other key reef features are the linear reefs, which form a physical barrier at the mouth of the bays. This barrier insulates seagrass, algae, and mangrove areas within the bays from potentially destructive wave energy. These habitats in turn insulate the reef from terrestrially borne sediments and runoff. The combination of reefs, mangroves, and seagrass beds within SARI provide an excellent combination of habitat types for a wide variety of aquatic organisms (see Fish, Section 11).

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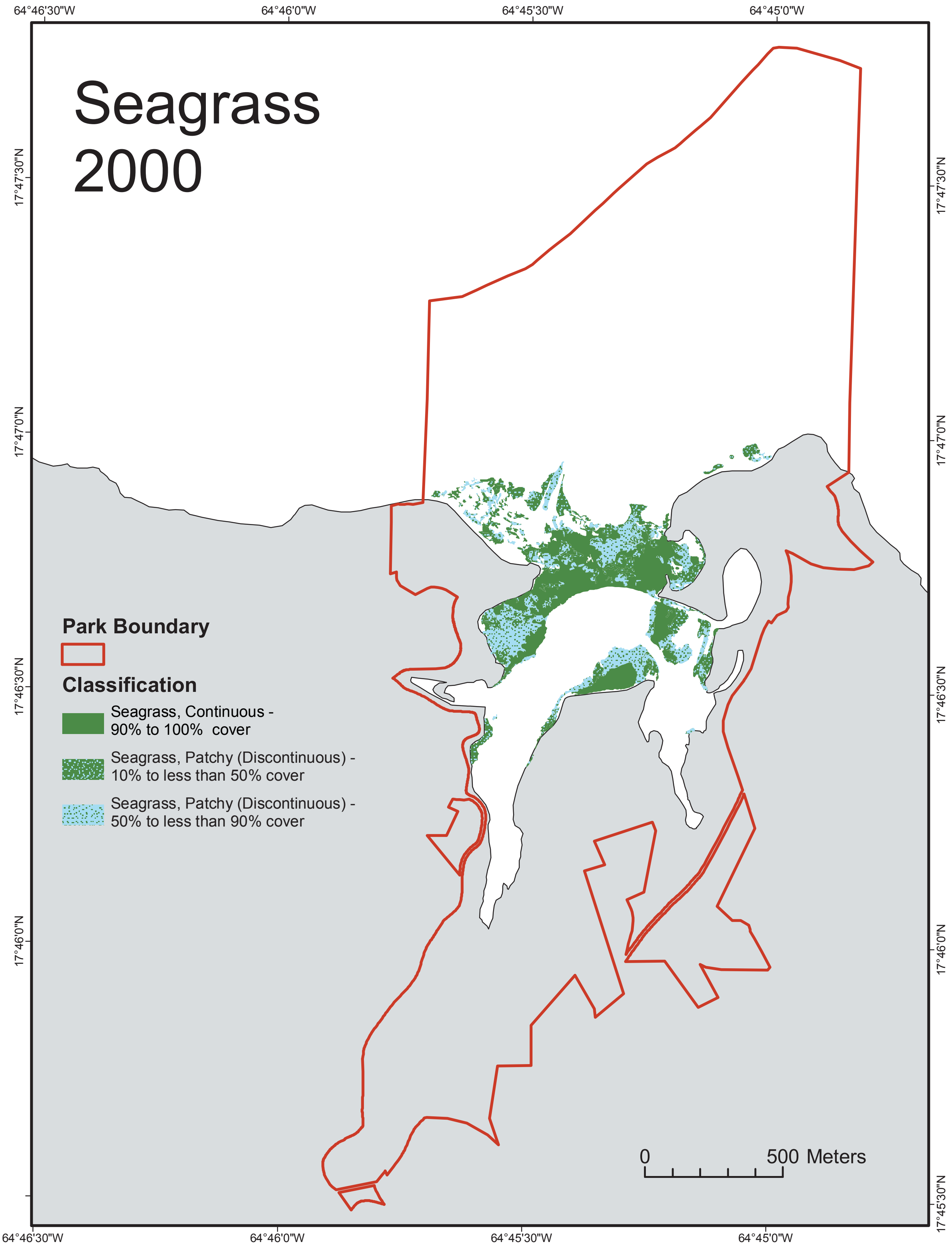

Figure 9.1. Map of seagrass distributions in SARI in 2000.

Section 9 Seagrass & Algae

OVERVIEW

The seagrass and algal communities of Salt River Canyon are among the better studied components of the SARI ecosystem as several NOAA/NURP Hydrolab/Aquarius missions during the 1980's were dedicated, at least partly, to those bottom types. The distribution of seagrass in the canyon was mapped at that time; however, the changes in distribution and present extent cannot be determined from aerial photos due to the depth of the canyon floor. Only algae and the seagrass *Halophila decipiens* are found growing on the canyon floor. Coverage there is seasonal with a peak during summer months. In contrast, the seagrass and algal communities of Salt River Bay have not received much *in situ* attention in the past, although their historical extent can be mapped using aerial photographs. Over the last three decades the seagrass areas of SARI have experienced major changes in distribution with a decline in total area. The most dramatic changes in coverage occurred behind the fringing reef west of the entrance to Salt River Bay. The area of seagrass present in the bays in 1970's covered 24.6 hectares. By 1988, a year prior to Hurricane Hugo, the area of seagrass remained relatively stable at 24.2 hectares. Three years after the passage of Hugo, the 1992 aerial photos indicated that coverage of seagrass was reduced by 12% to 21.3 hectares within the bays with most loss occurring in the western back reef area. By 2000, this coverage had changed little extending over 21.6 hectares.

METHODS

Extent of seagrass was digitized from orthorectified aerial photos acquired in the 1970's, 1988, 1992, and 2000. Submerged vegetation was mapped using a hierarchical classification scheme with attributes discriminating between seagrass and macroalgae, and degree of patchiness. The minimum mapping unit, scale of digitizing, and other details of the mapping process are described in Section 2, Aerial Photographs and Mapping Methods. Overall extent of seagrass in Salt River Bay from historical imagery (1970s, 1988, and 1992) was estimated using the simplifying assumption that actual seagrass coverage within patchy categories is at the mid point of each patchiness range. Seagrass coverage in the bay for each year was therefore calculated as:

1.0(polygon area labeled Continuous Seagrass)
0.3(polygon area labeled Patchy Seagrass 10% - 50%)
+ 0.7(polygon area labeled Patchy Seagrass 50% - 90%)
= Estimated total seagrass coverage

Unfortunately, no historical changes in vegetation distribution on the floor of Salt River Canyon could be determined from aerial photographs due to the depth of the canyon floor and difficulty determining meadow boundaries for sparse *Halophila decipiens* beds in water 30 feet deep. As a result, the canyon floor was mapped as sand. Therefore, the algae and seagrass in Salt River Canyon was characterized based on published reports from studies rather than maps. This literature was compiled from published literature and NOAA technical reports.

RESULTS

Seagrass coverage in Salt River Bay has declined slightly since the 1970's (Figure 9.1, Table 9.1). A 10-15% reduction in overall coverage from the 1970's meadow extent occurred between 1988 and 1992, coincident with the passage of Hurricane Hugo. The majority of the loss in seagrass coverage occurred between Columbus Landing and the cut in the reef at the mouth of Salt River Bay. Seagrass coverage by 2000 was only slightly greater than that observed in 1992 and remained 13% below 1970's coverage levels.

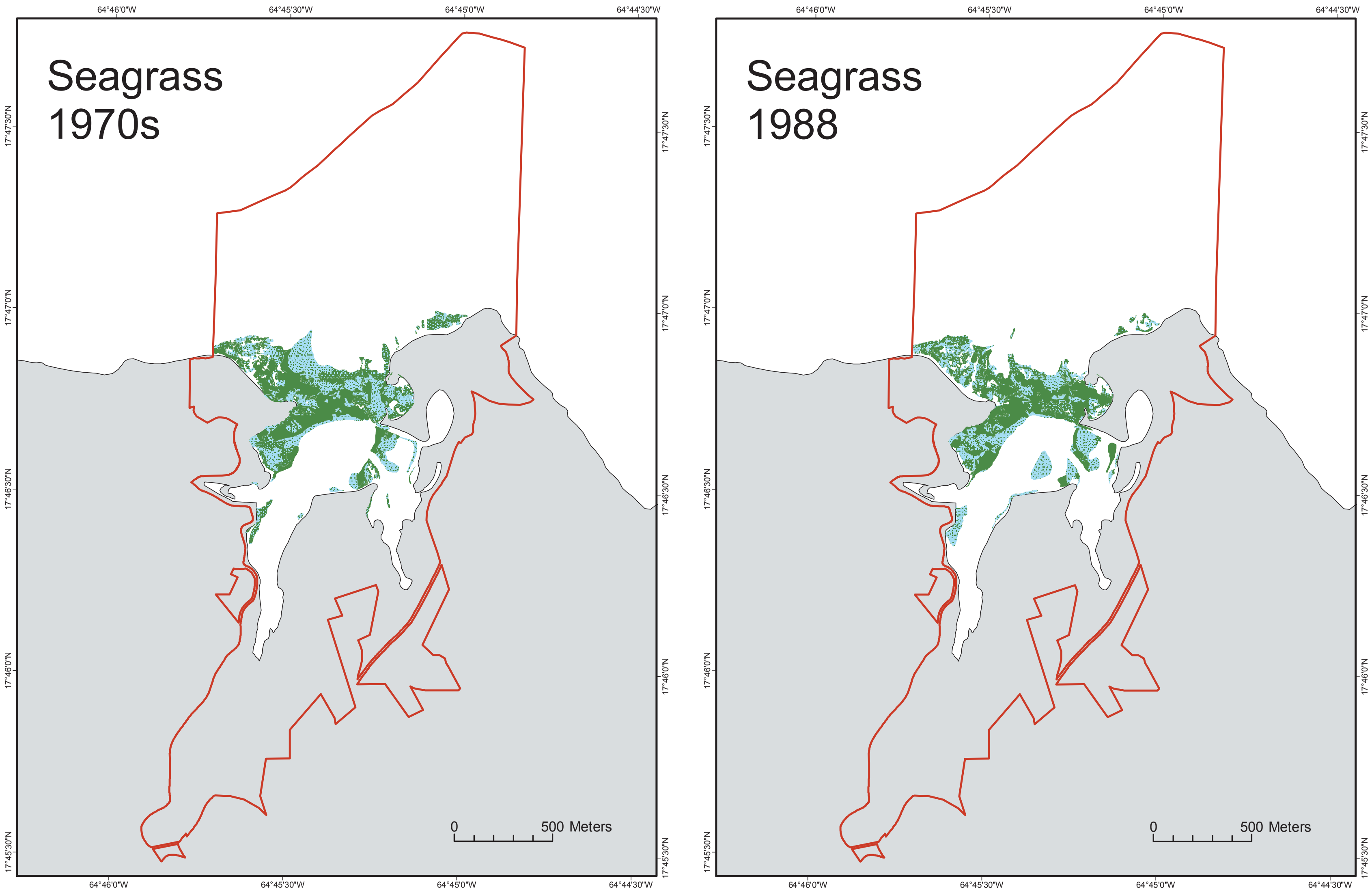

Figure 9.2. Map of seagrass distributions in SARI by time period.

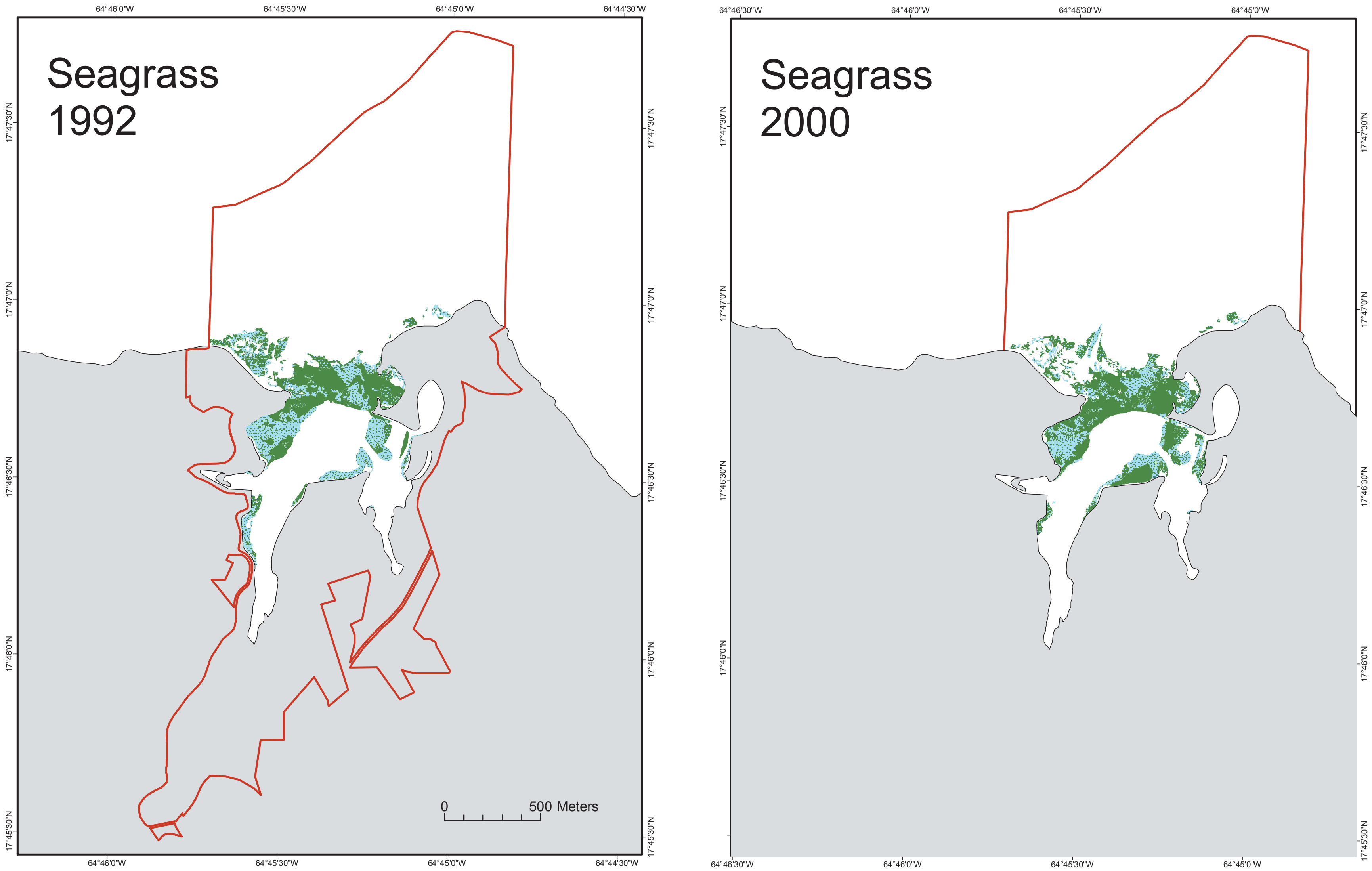

Figure 9.2. Map of seagrass distributions in SARI by time period.

	1970		***1988***		***1992***		***2000***	
	polygon	seagrass	polygon	seagrass	polygon	seagrass	polygon	seagrass
Continuous Seagrass	12.9	12.9	13.9	13.9	10.4	10.4	12.7	12.7
Patchy 50-90% Seagrass	13.0	9.1	12.2	8.5	12.9	9.0	9.5	6.7
Patchy 10-50% Seagrass	8.9	2.7	5.9	1.8	6.2	1.9	7.3	2.2
total seagrass coverage		24.6		24.2		21.3		21.6
% of 70's seagrass extent		n/a		98%		86%		87%

Table 9.1. Area of seagrass polygons, and estimated overall seagrass area by map classification and period of photography. Overall seagrass area was calculated by assuming that actual coverage of patchy categories was at the midpoint of each patchyness range.

An important caveat in quantifying any changes in seagrass coverage among years is that turbidity levels were not consistent among the four time periods of aerial photography used to create the maps. This was particularly apparent in the 1970's imagery which had higher turbidity levels in the southern portions of the bay than subsequent years. This limited the interpretation of submerged features in the southern and eastern portions of Salt River Bay and likely resulted in an underestimate of the seagrass coverage for this period. Most of the seagrass in the bays consists of two species, *Thalassia testudinum* and *Syringodium filiforme*, with lesser areas of *Halodule wrightii*.

Seagrass and algae in Salt River Canyon were studied intensively by several investigators between 1980 and 1989 on saturation dives using NOAA's Hydrolab. *Halophila decipiens*, seagrass detritus, and macroalgae were reported to be the major sources of primary production, organic matter, and vegetated habitat in Salt River Canyon. *H.decipiens* is the only seagrass that has been observed naturally growing on the canyon floor where it is the dominant macrophyte during summer. The canyon floor is below the depth/light limit for other Caribbean seagrass species. Presence of *H.decipiens* is seasonal. There is a fall/winter decline in coverage due to disturbance by cyclonic storms in the fall, lower irradiance levels associated with winter, and large swells characteristic of winter weather patterns which can disturb the sediment to a depth of 30 m (Williams 1988). For example, as a result of Tropical Storm Klaus (1984), *Halimeda incressata* declined to 58% of its density of the previous summer and 99% of *H.decipiens* and Caulerpa sp. were eliminated between 15 and 23 m. There is sufficient light for growth of *H.decipiens* only from April to August. A study in May, 1985, estimated that *H.decipiens* covered 37% of the canyon floor between depths of 14 and 32 m (Kenworthy et al 1989). Overall upper and lower depth limits of this species are approximately 8 and 40 m during summer months in Salt River Canyon. Measurements of biomass during summer range between 5-12 g dry weight per m^2 depending on year and depth.

Josselyn et al. (1983) studied composition and movements of the large amount of drift vegetation found in Salt River Canyon. Seagrass blades dominated the drifting vegetation. *Thalassia testudinum* and *Syringodium filiforme* were in the drift year round, whereas *Halodule wrightii* and *H.decipiens* were found only during the summer mission. Except for the *H.decipiens*, Salt River Bay is the primary source of this drifting vegetation. Residence time in the canyon for drift vegetation was highly variable, ranging from less than a day during storm conditions to several weeks during periods of calm. Net movement of the material is down canyon.

ECOLOGICAL LINKAGES

Salt River Canyon provides an ecological connection between Salt River Bay and the deep sea communities north of St. Croix. The dominant trade winds from the northeast push water along the surface over the reef crest into the bay. Water and the vegetation from within the bays which is carried with it, must then exit through the open channel at the head of Salt River Canyon (Josselyn et al 1983). Energy, in the form of high seagrass productivity in the shallow areas of the bay, is then funneled rapidly down canyon by currents and is made available to deep sea ecosystems (see Currents, Section 6). During summer months *H.decipiens* is one of the major sources of organic matter to the depths below 30 m (Josselyn et al 1986). Observations from a submersible revealed a large amount of detrital seagrass deposited in the ~3000 m depths off the canyon (Suchanek et al 1985).

Water quality in the bays may affect production of seagrass in the canyon (see Water Quality, Section 7). The solar irradiance that drives primary production on the canyon floor is influenced by weather and discharge from Salt River Bay. When strong onshore winds occur, bottom currents carry turbid water from the bay, through the channel in the fringing reef, and into the head of Salt River Canyon. Turbid waters are then diluted and cleared as they mix with clear offshore water farther down the canyon. Even though it is deeper in the middle of the canyon, the irradiance can be higher there than in the shallower head of the canyon due to this discharge of turbid water (Josselyn et al 1986).

The role that seagrass plays in stabilizing coastal sediments is well documented. Terrestrial runoff from the Salt River watershed flows across seagrass beds before exiting Salt River Bay. The seagrass beds trap some of these terrestrial sediments thereby partially protecting the coral reefs further offshore from the harmful effects of sedimentation.

The seagrass, algal beds, and associated epiphytes in both the canyon and bay are utilized by a diverse assemblage of organisms. Dozens of fish and invertebrate species utilize algae and seagrass as a direct or indirect source of food or as structural shelter during some stage of their life history (see Fish, Section 11). The seagrass meadows of SARI represent the only large patch of this bottom type along the northwestern third of St. Croix.

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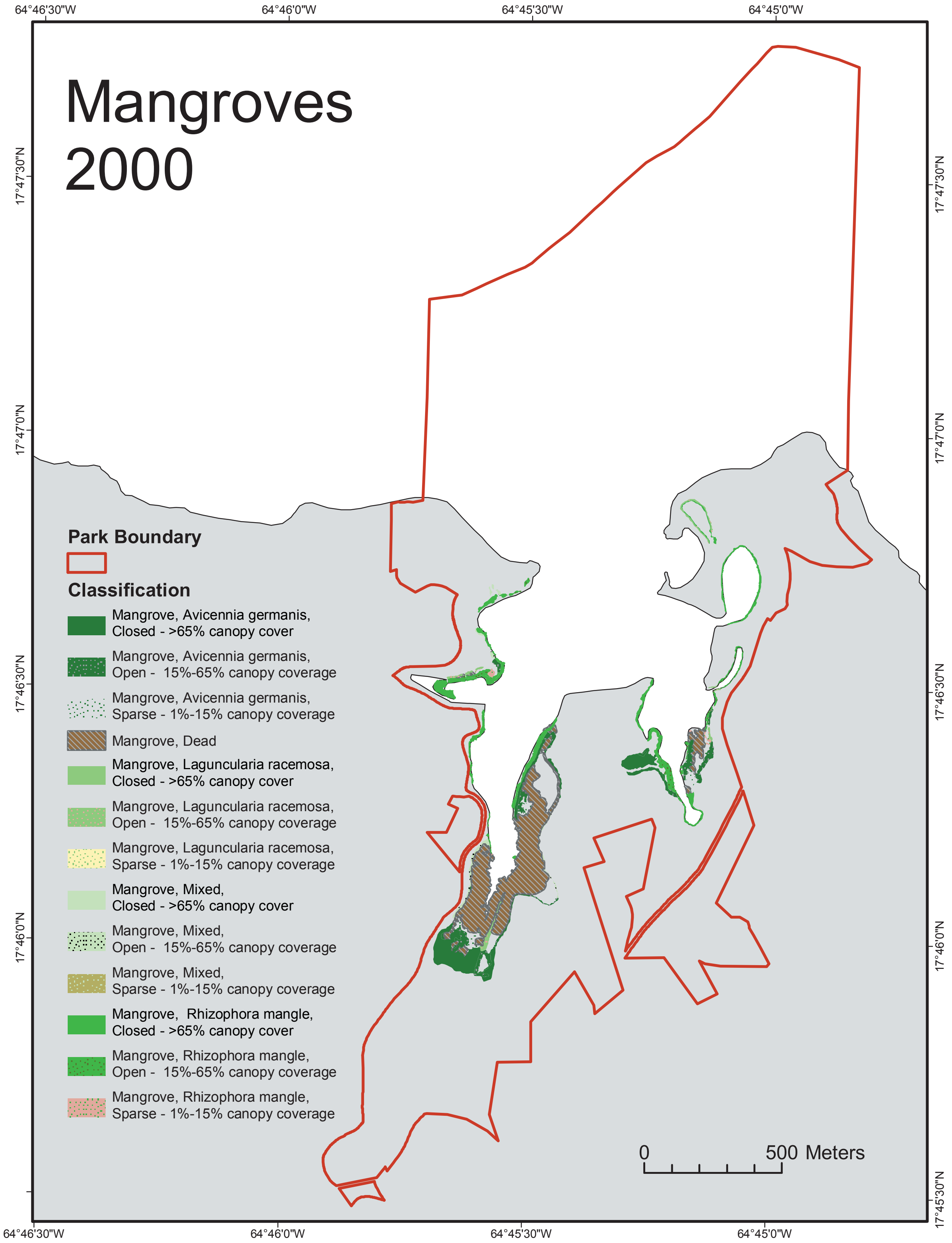

Figure 10.1. Map of mangrove distributions in SARI in 2000.

Figure 10.2. Restoration planted red mangrove seedling.

Section 10 Mangroves

OVERVIEW

The mangrove forests of SARI Bay were once considered the finest in the US Virgin Islands. However, over the last three decades these forests have experienced among the most dramatic changes of any terrestrial or benthic feature in St. Croix. Major losses in mangrove cover occurred primarily due to the devastating winds associated with Hurricane Hugo in 1989. Specifically, the area of mangrove forest present in 1970's photography covered 20.2 hectares and by 1988, a year prior to the devastation caused by Hugo, the area of this forest had increased to the maximum extent observed in this assessment, covering 22.2 hectares. Most of the mangroves prior to the storm occurred in mature, closed canopy forests from ~4 to 6 m tall. Three years after the passage of Hugo, the 1992 aerial photos indicated that 12 hectares of mangrove forest were dead with most remaining live mangrove canopies reduced to open or sparse coverage. Live mangroves in 1992 covered only 43% of their 1988 extent. Since 1992, gains in mangrove habitat have occurred as a result of both natural growth as well as a restoration project by the St. Croix Environmental Association which was initiated in 1999. As a result of the restoration effort, 1.4 hectares of the lost mangrove forest, primarily on the western side of Sugar Bay, have been replanted. Survival rate for restoration seedlings is estimated at 80%. Natural regrowth accounts for 0.9 hectares of forest since 1992. The most recent aerial photos of this area (2000) indicate that naturally occurring and restoration mangroves now cover 12 hectares or 54% of the extent of the 1988 forest.

METHODS

Extent of mangrove forests was digitized from orthorectified aerial photos acquired in the 1970s, 1988, 1992, and 2000 (Figure 10.1). Mangroves were mapped using a hierarchical classification scheme with attributes defining species and canopy density. Canopy density categories where based on the Florida Land Use and Land Cover Classification scheme (Smith 1992). Closed was defined as having a canopy that obscured more than 65% of the ground, typically with tree crowns interlocking, touching or very slightly separated. Open was defined as having a canopy that obscured 15-65% of the ground, with crowns not typically interlocking. Sparse was defined as having a canopy that obscures only 1-15% of the ground. The minimum mapping unit and scale of digitizing were consistent with that described in the general mapping section. Identification of the extent of different mangrove species from historical imagery (1970s, 1988, and 1992) was guided by an early map of the forest (NPS Lands Office), several narrative accounts (e.g. Knowles 1993), and by matching tone and texture signatures visible in the 2000 imagery for each species which were visited in the field.

Apart from two 100 m test plots, mangrove restoration activities were conducted between 1999 and 2001. Each year, thousands of red mangrove propagules were planted in three large rectangular plots on the western side of Sugar Bay. In addition to those large plots, a fringe planting of propagules was conducted along much of the eastern shore of Sugar

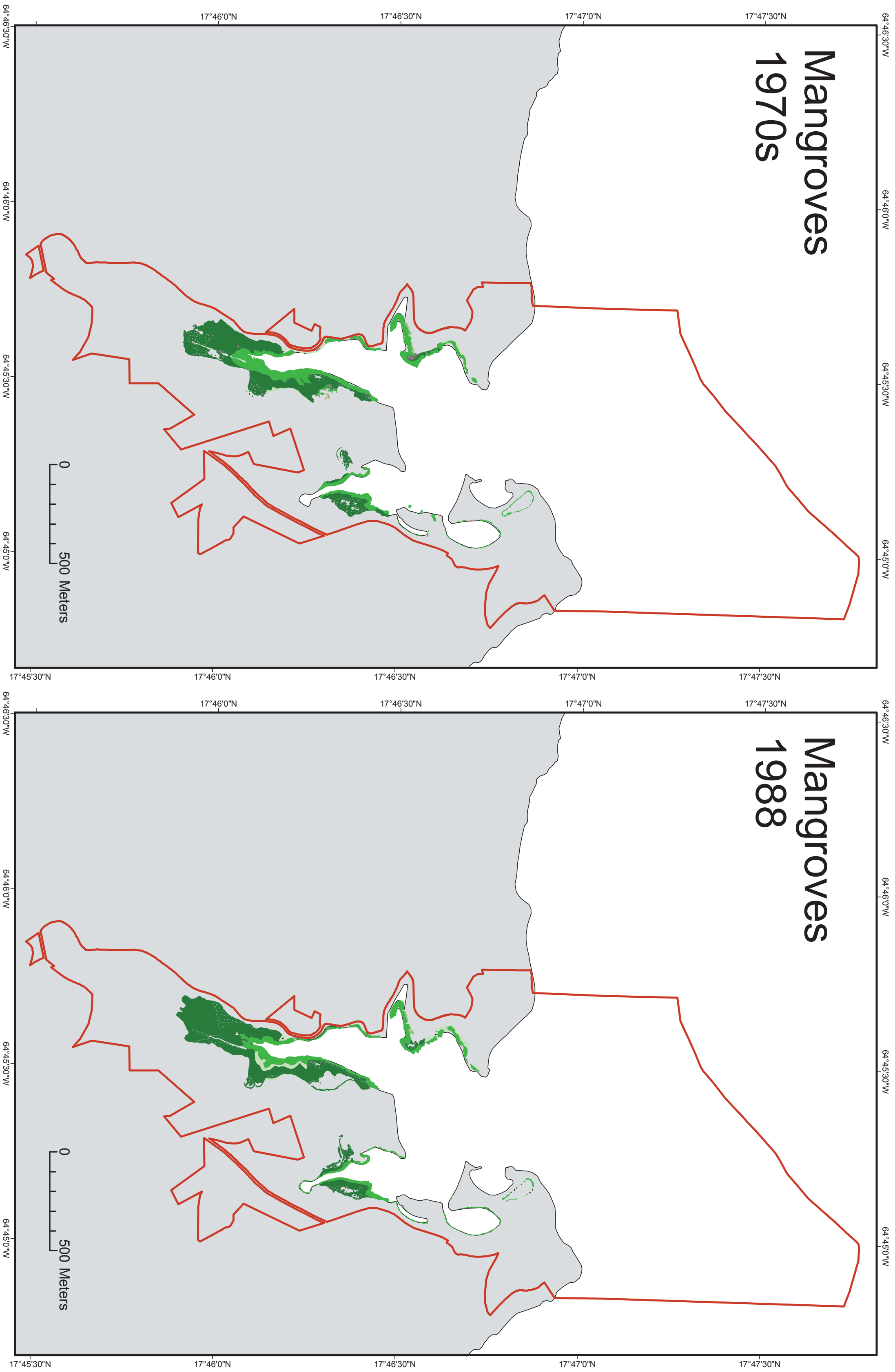

Figure 10.2. Map of mangrove distributions in SARI by time period.

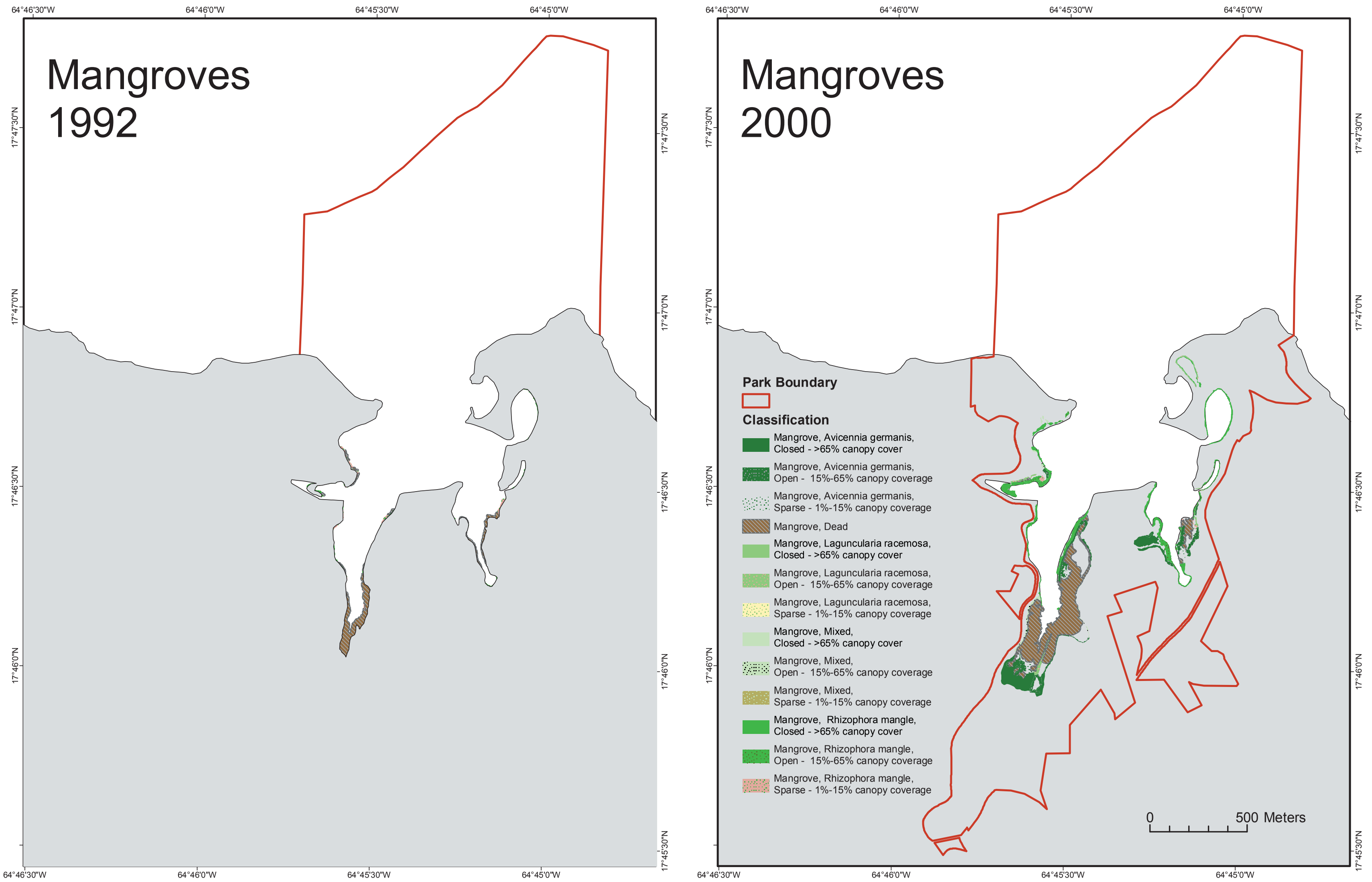

Figure 10.2. Map of mangrove distributions in SARI by time period.

Mangrove Restoration

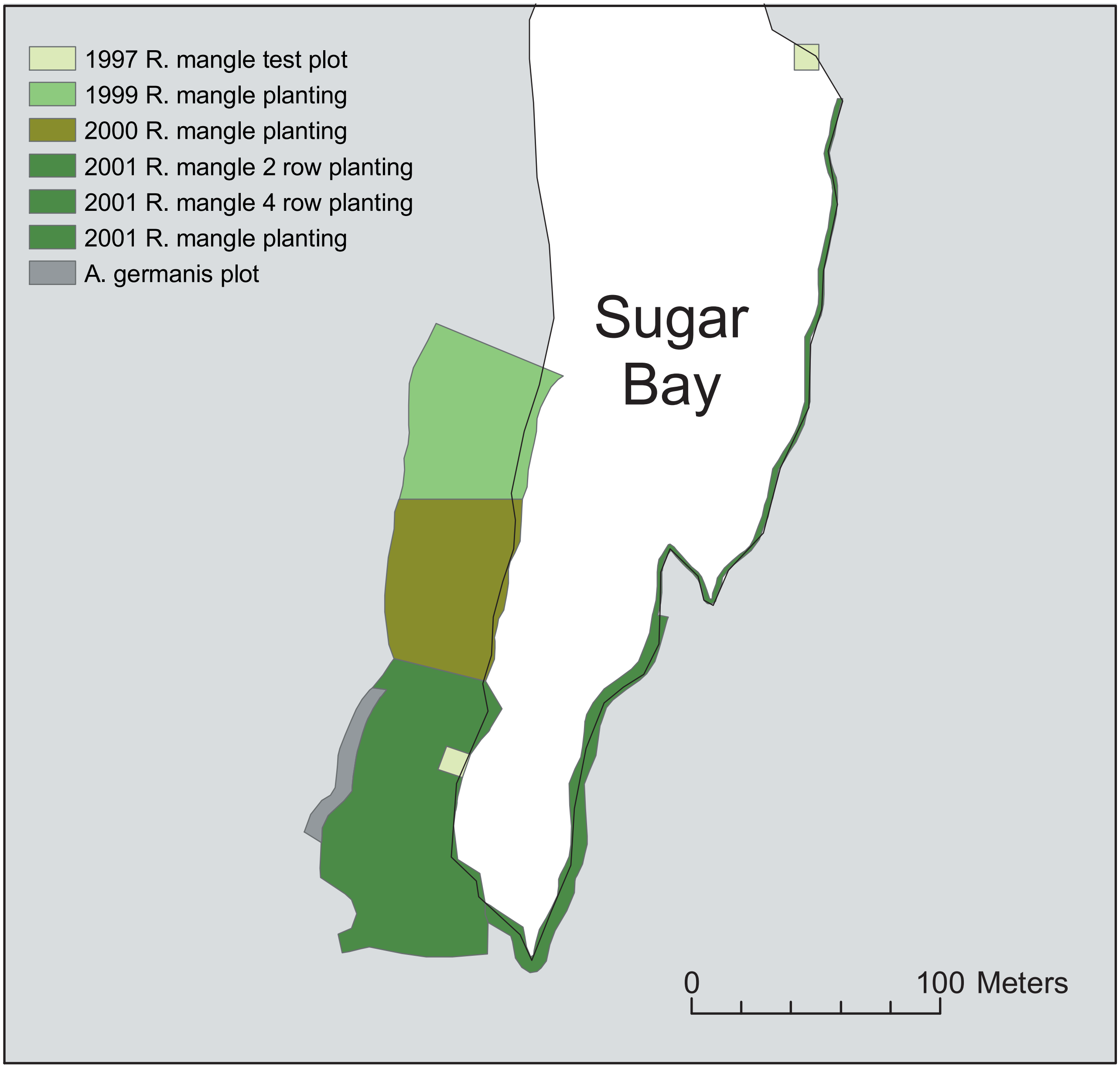

Figure 10.3. Map of St. Croix Environmental Association (SEA) mangrove restoration plots.

Bay. A small zone of black mangroves was also planted in 2001 although <1% survived long term. Detailed methods of restoration activities are available in Riley and Kent 1999 and SEA 2004. Restoration mangroves were not visible in the 2000 imagery due to the small size of individual seedlings. These plots were therefore delineated with the aid of GPS waypoints acquired by walking or kayaking around the perimeter of each plot. GPS positions were used as a guide to digitize the boundaries of the restoration areas and the results are presented on a separate map (Figure 10.3).

Figure 10.4. Two rows of seedlings were planted along a portion of the eastern side of Sugar Bay. Remains of the mangroves killed by Hurricane Hugo lie landward of the seedlings.

	Canopy Density	*1970*	*1988*	*1992*	*2000*
Avicennia germanis	Closed	82907	109043	551	29965
	Open	30801	31903	31068	18358
	Sparse	3153	967	24151	7453
	TOTAL	**116861**	**141913**	**55770**	**55776**
Laguncularia racemosa	Closed	0	645	0	0
	Open	1320	437	854	6150
	Sparse	0	0	0	0
	TOTAL	**1320**	**1082**	**854**	**6150**
Rhizophora mangle	Closed	73121	60614	2171	27620
	Open	4986	4309	18072	9288
	Sparse	932	0	8907	1157
	TOTAL	**79039**	**64923**	**29150**	**38065**
Mixed mangrove forest	Closed	4318	11780	0	383
	Open	421	2302	8346	5347
	Sparse	0	0	2344	0
	TOTAL	**4739**	**14082**	**10690**	**5730**
TOTALS (natural)	Closed	160346	182082	2722	57968
	Open	37528	38951	58340	39143
	Sparse	4085	967	35402	8610
Dead (not in Total below)		1076	0	120188	80556
Restoration (up to 2004)		0	0	0	13915
TOTAL natural and restoration		201959	222000	96464	119636
% of 1988 (max) total extent		91%	100%	43%	54%

Table 10.1. Estimated mangrove area for each map classification and time period of photography. Values are in m^2.

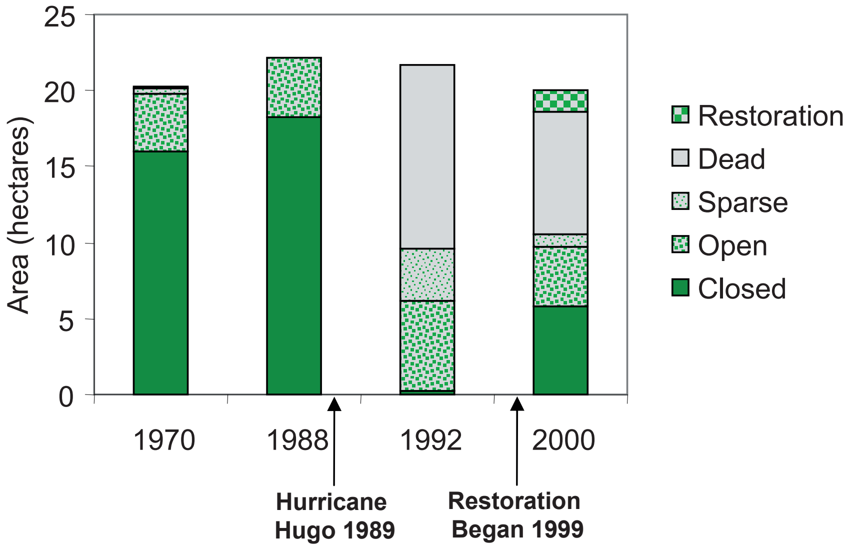

Figure 10.5. Graph of mangrove cover by cover classification and time period.

RESULTS

Changes in coverage for each species of mangrove are summarized by year in Table 10.1. Total mangrove forest area during the time periods covered by this assessment ranged from a high of 22.2 hectares in 1988 to a low of 9.6 hectares in 1992, a decline of 57%. Typical mangrove zonation patterns were observed in all years of imagery with red mangroves nearest the shoreline, white mangroves most inland, and black mangroves in between. In all years, black mangroves accounted for over half the total mangrove forest extent with red mangroves comprising another third of the total. Most of the remaining mangrove forest area was composed of a mixture of species. Only small areas were mapped as white mangroves in any year. This is at least partly due to the difficulties of discriminating between white mangroves and bordering upland coastal forests as these habitats rapidly transition on the steep slopes along this part of St.Croix's coast.

In the 1970's and in 1988 the forest was primarily classified as closed canopy (Figure 10.5, Table 10.1). Three years after Hurricane Hugo, approximately half the total mangrove forest was mapped as dead, and most of the remaining half was categorized as open or sparse canopy. The total area classified as open and sparse in 1992 had by 2000 become classified as closed and open respectively, indicating a slow recovery of the forest injured during Hugo (Figure 10.5, Table 10.1). The total area mapped as dead in 1992 was still extensive by 2000 although some areas were recovering naturally and others becoming reestablished from the restoration project.

ECOLOGICAL LINKAGES

The role that mangroves play in stabilizing coastal sediments is well documented. This was cited as one of the principle justifications for the Sugar Bay mangrove restoration. The watershed's main outlet from Salt River Gut into Sugar Bay flows through the center of the largest mangrove stand lost during Hurricane Hugo. The seagrass beds, coral reefs, and other benthic habitats on the insular shelf beyond this area benefit from a healthy mangrove forest which buffers the harmful effects of terrestrial runoff.

Mangroves also play a role in regulating water temperature on tidal flats. Before Hurricane Hugo defoliated and ultimately killed the extensive mangroves in Sugar and Triton Bays, the large tidal flats in those areas were insulated from intense sunlight. The changes from a shaded, cool water community in the once living mangrove root system to the current sun-exposed community have not been quantified. As the restoration mangroves continue to grow and form interlocking canopies and root systems that shade the tidal flat, community structure and water quality will presumably return to pre-Hugo conditions.

The physical structure provided by the mangroves is utilized by a diverse assemblage of terrestrial and aquatic organisms. Many bird species utilize the emergent portions for roosting and nesting (see Birds, Section 12). Dozens of fish species utilize the submerged portion of prop roots during some stage of their life history (see Fish, Section 11). A recent study by VIDPNR's Division of Fish and Wildlife recommended the reforestation of hurricane damaged mangroves to enhance fish nursery habitat in the Salt River area (Tobias et al 1996). A tremendous diversity of algae, sponges, tunicates, mollusks, and other sessile invertebrates also utilize the mangrove prop roots as a settlement substrate. These encrusting organisms are then used as food and habitat by a diversity of other organisms. Excellent summaries of the ecological role of mangroves in coastal systems are given in Hogarth (1999) and Tomlinson (1986). The mangroves of SARI represent the only large patch of this forest type along the northwestern quarter of St.Croix.

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Figure 11.1. Fish on a reef in Salt River National Historical Park and Ecological Preserve.

Section 11 Fish

OVERVIEW

SARI encompasses large areas of mangrove forest, seagrass meadows, and reefs within close proximity to each other. This variety of benthic habitats is required by many tropical marine fish to complete their life cycle (Christensen et al. 2003). Seagrass and sand areas are used by many larval fish as initial settlement sites when they transition from ocean drifting forms to bottom dwelling forms. The prop roots of red mangroves provide structural refuge and foraging habitat for juveniles of many species. A recent study at SARI found 57 species of fish utilizing mangrove habitat (Adams and Tobias 1994). Numerous reef types such as the east and west walls of the canyon provide habitat for perhaps the largest diversity of adult and juvenile fish species. Nearly 200 species of fish have been observed on SARI reefs to date (Kaufman and Ebersole 1984, Workman et al. 1985, Adams and Tobias 1994, Tobias 2002), and this despite nearly all sampling effort expended only on the canyon walls. The park also includes a large area of shelf edge habitat and easy access to offshore waters. This connection to pelagic environments further enhances the biodiversity of fishes within SARI and the ecological linkages with the adjacent oceanic ecosystem.

METHODS

Literature on the species and distribution of fish fauna within SARI were compiled for the bay, canyon/shelf, and pelagic areas. These sources often included species lists and discussion of the fish fauna's association with specific habitats or bottom types and their relationship with the region's ecology. Information in these published sources was combined and condensed into a generalized description of the ichthyofauna and their habitats at SARI. Appendix D lists the species observed on the most robust of these assessments. Distribution, area, and changes in key fish habitats are quantified based on the maps created for this assessment.

RESULTS

As with other resources in SARI, the studies of fish fauna can be divided into those focused outside the bays and those within. One study characterized the mangrove ichthyofauna for a period of several years after Hurricane Hugo. Several studies have been conducted on the fish communities occupying the east and west reef walls of the Salt River canyon. Two studies used fish attraction devices to at least partly examine pelagic species in the area.

Red mangrove prop-roots provide structural refuge and foraging habitat for a diverse community of fish. This habitat was sampled monthly at SARI between 1990 and 1993 using baited fish traps and visual transects (Adams and Tobias, 1994). Sites were spread around the Salt River Bay, Sugar Bay, and Triton Bay to cover a range of mangrove density, human impact, and turbidity levels. A total of 57 species were observed (Appendix D). Fish caught in traps included 40 species and 19 families, and those observed on transects included 48 species and 26 families. Most abundant families were Lutjanidae, Haemulidae, and Gerreidae which together accounted for 82% of the fish observed on transects and 72% of fish caught in traps. Length frequency histograms indicate that most of the fish caught were juveniles. Species richness was greater close to the Bay mouth relative to sites farther in Triton and Sugar Bay. The study highlighted the importance of Salt River mangroves as a nursery ground to many important recreational and commercial fish species, and emphasized that this habitat should be included in fisheries and habitat management plans. These data provide a useful reference dataset for comparison with future studies, particularly along the shoreline of the recent mangrove restoration in Sugar Bay (see Mangroves, Section 10).

The linear distance of tidal shoreline that is occupied by red mangroves should be monitored due to this habitat's role as an ichthyofaunal nursery (Tobias1996). Total length of tidal mangrove shoreline in maps from the present assessment was approximately 4180, 4625, 4420, and 4740 m based on 1970's, 1988, 1992, and 2000 imagery respectively. In 1970's and 1988 this length consisted entirely of live mangroves, whereas in 1992 and 2000 significant portions consisted of dead trees due to Hurricane Hugo. In 1992, 2860 m was live and 1560 was dead. In 2000, 3610 m was live and 1130 was dead (see Mangroves, Section 10). The recently completed mangrove restoration in Sugar Bay has resulted in the successful establishment of seedlings over most of the shoreline formerly occupied by dead trees. As these trees grow and form interlocking root structures, an extensive habitat for juvenile fish will be restored.

Studies of the fish outside the bay have primarily focused on the fish associated with the canyon walls (e.g. Bortone et al. 1978, Kaufman and Ebersole 1984). Kaufman and Ebersole (1984), based out of Hydrolab, used a timed-roving diver technique to census species along the east and west walls of the canyon at a depth of ~16 m. Species were categorized according to trophic group, coloration, and "defense mode". During 16 censuses, a total of 108 species were recorded (Appendix D). Species richness was higher on the west wall (86 species total) than on the east wall (65 species total). Species composition differed on the two walls, with 43 species found exclusively on the west wall and 22 species found only on the east. Trophic ratios were similar between the walls, the only difference being that there were more planktivores and fewer opportunistic feeders on the west wall compared to the east. More species employed the "seek shelter" mode of defense on the west wall whereas more fish on the east wall use the "run and dodge" mode. Differences in morphology of the west and east walls were used to explain much of the differences in distribution of trophic group, coloration, and defensive mode. The steeper drop off and higher density of hard corals and shelter resulted in more planktivores, shelter seeking species, and bold colored or barred fish on the west wall. The more gradual slope, lower density of hard corals and shelter sites on the east wall resulted in more species that are stripped and dodge and run as a means of predator avoidance. In separate studies, Rogers et al (1984) and Clavijo (1978) found that herbivorous fish declined in abundance along both walls with increasing depth.

Most recently, the VIDPNR Division of Fish and Wildlife (Toller 2002, Nemeth et al 2004) began monitoring programs using a variety of fish census techniques to survey fish communities around St.Croix including a site at the west canyon wall at SARI. The sites are also surveyed annually for benthic cover characteristics by the University of the Virgin Islands, Center for Marine and Environmental Studies, as part of a coral reef monitoring program (see Reef and Hardbottom, Section 8). While not intended to provide a comprehensive inventory of reef fish at SARI, the data allow comparison with several other reef sites around St.Croix. Point counts, belt transects, and roving diver surveys are all part of the monitoring program. At the time this report was written, only the 2002-2004 data and 2002-2003 reports (Toller 2002, Nemeth et al 2004) were available. The real value of this activity is not the data in these first years of monitoring, which have limited sample size, but instead will be the long term dataset generated by continued semiannual monitoring using multiple techniques. A total of 91 species have been observed in this program so far (Appendix D). A list of species observed, frequency of occurrence, abundance, and minimum/maximum/average size are provided for each time period and census technique.

In addition to these research and monitoring projects, the walls of Salt River Canyon are among the most popular recreational dive areas in St.Croix with several mooring buoys providing easy access to both the east and west walls. A volunteer based organization, the Reef Environmental Education Foundation (REEF), organizes and trains recreational divers to conduct fish surveys using a random swim technique. To date, REEF divers have documented a total of 185 species in 69 hours of survey time on dives conducted on both walls of the canyon (Appendix D). While these data are collected by individuals with limited training in fish identification, the large number of visitors to SARI involved in this program make it an important and growing dataset. Caveats for data interpretation, a complete description of the survey method, and summary data are available at http://www.reef.org/.

Despite the large amount of effort spent monitoring the fish community on the canyon walls of SARI, this habitat composes only 3 hectares or less than 3% of the total coral reef and hard bottom (two dimensional area) within SARI that was mapped in this assessment. This disproportionate survey effort is no doubt due to the access once afforded to these sites by NOAA/NURP's saturation diving facilities within the canyon, the current placement of mooring buoys which maintain easy access to these sites, and the fact that the canyon walls are among the most impressive reefs on St. Croix. Other reef types within SARI have received almost no attention despite their much larger extent (113 hectares or 97% of the total reef/hardbottom within SARI).

Pelagic fish have received less study but are a notable component of the fish assemblage of SARI due to its proximity to deep oceanic habitat. In fact, the deepest point within SARI is ~289 m, located along the steep, continuing drop off on the north side of St.Croix, making it likely that SARI is visited by a variety of open water species. Two studies using fish attraction devices (FADs) which tend to attract pelagic fish have been conducted in the area (Workman et al, 1985; Friedlander et al, 1994). One study which used hook and line to sample fish, most commonly caught 3 species: blackfin tuna (*Thunnus atlanticus*), little tunny (*Euthynnus alletteratus*), and dolphin (*Coryphaena hippurus*) which together accounted for 92% of the catch (Friedlander et al, 1994). Another study, which used FADs close to the reef and a variety of additional assessment techniques most frequently observed 3 different species: yellowtail snapper (*Ocyurus chrysurus*), creole wrasse (*Clepticus parra*), and mackerel scad (*Decapterus macarellus*) (Workman et al, 1985). Lack of controls, the biases associated with sampling pelagic fish, and the biases associated with the use of FADs limit the use of these studies as quantitative characterizations of the pelagic fish of SARI. Nevertheless, these studies document the presence of pelagic species in and around SARI.

ECOLOGICAL LINKAGES

A diverse assemblage of fish can find a suitable combination of habitats for larval settlement, juvenile growth, and adult life stages all within the relatively small boundaries of SARI. Inshore mangroves and seagrass beds provide an important nursery area for fish that ultimately migrate to the reefs outside the bay as adults. Seagrass beds enhance biodiversity of nearby reefs (Kendall 2003), and mangroves have been shown to enhance biomass of commercially important fish found on reefs nearby (Mumby et al, 2004). Mangroves, in particular have a limited distribution around St.Croix, with SARI containing one of the largest forests and mangrove shorelines on the island. This habitat may serve as an important nursery to juvenile fish that ultimately migrate to the reefs of SARI and elsewhere along the north shore of St.Croix.

Pelagic fish are frequent visitors to the canyon and shelf edge reef and provide an ecological link with open ocean habitats. Fifty-five hectares of the area within the SARI boundary was too deep to be mapped using aerial photography. Depths increase rapidly northward of the SARI boundary as well. Salt River Canyon links into the nearby Christiansted Canyon and continues down the steep St.Croix insular shelf such that water depths exceed 4000 m a mere 11 kilometers offshore from

SARI. The frequency, duration, and ecological impact of SARI interactions with pelagic fish are poorly understood.

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Figure 12.1. Pelicans roosting on dead mangrove stumps.

Section 12 Birds

OVERVIEW

SARI is utilized by a diverse assemblage of birds including year round residents, overwintering residents, and species stopping briefly at St. Croix during annual migrations. An accounting of these species has been conducted several times in recent decades, both before and after Hurricane Hugo, and continues to be the subject of ongoing research. Results are not presented here since they are published elsewhere. The most recent bird survey data for the area was collected by Department of Planning and Natural Resources (VIDPNR), Division of Fish and Wildlife (DFW), however, these data were not available during preparation of this report. DFW should be contacted directly for these surveys and data interpretation. Instead of summarizing the various avifaunal reports as has been done elsewhere, and given that the most recent bird survey information are not yet widely available, the focus of this portion of the ecological assessment is on important bird habitats within SARI. Namely, there is a ~200 m^2 heron rookery within a large patch of red mangroves near the marina, a ~4000 m^2 tern nesting beach west of Judith's Fancy, two freshwater ponds, ~12 hectares of natural and restoration mangroves, ~1 hectare of sand and mud salt flat, ~1.3 hectares of sandy beach, and an additional ~2.4 hectares of other intertidal foraging habitats for wading and shore birds. A recent publication describing habitat preferences for Virgin Island avifauna (Rodriguez 2002) coupled with the land and marine habitat maps provided here allow quantification of important habitats on a species by species basis for SARI.

METHODS

Literature review, discussions with local experts, and field observations were used to identify key locations within SARI for roosting, nesting, and foraging activities of several avifauna species. Particular attention is given to mangrove habitats and shore birds due to recent changes in the extent of these habitats, and the high visibility of these birds within SARI. Literature reviews were narrowly focused on the habitat components of each study rather than on providing a thorough inventory of bird species, due to the unavailability of the most recent survey data.

Nesting and roosting sites described in the literature were observed in the field, and the extent of those habitats was calculated based on the 2000 aerial photography. The area of intertidal foraging habitat for wading birds was estimated using the bathymetry model (see Bathymetry, Section 5).

RESULTS

The presence of avian bones in pre Columbian kitchen middens near Columbus Landing indicates that birds have been used by humans at SARI for centuries (Wetmore 1918). Interestingly, some of the bones present in the middens are from species not known to occur on St. Croix in present times. Whether these birds were captured locally and then extirpated or were captured elsewhere and then transported to SARI is not known.

Avifauna within portions of SARI, most notably the mangroves in Sugar Bay, have been studied intermittently by a number of researchers over the past several decades. Unfortunately, no consistent, long-term monitoring data are available for SARI mangroves, and virtually no information is available for inland avifauna at SARI. Instead, a few brief studies, some prior to Hurricane Hugo, and several broad scale assessments of the bird communities of the entire Virgin Islands have been conducted with limited specific reference to the Salt River Bay area.

Unfortunately, among the best avifauna information published in a peer reviewed journal for the area is based on surveys conducted prior to Hurricane Hugo in the formerly well developed mangrove forest of Sugar Bay (Wauer and Sladen, 1992). During the 12 surveys conducted between October 1986 and March 1987, 35 species were observed. Eight months after Hurricane Hugo, Wauer and Wunderle (1992) surveyed birds all over St. Croix and found no change in species richness, a minimal change in species composition, and a significant decline in average number of birds. Included in that study were before and after pictures taken at ground level of the damage to mangroves at Salt River, which illustrate the dramatic changes to that habitat. A quantitative examination of the impacts of the severe hurricane to these forests is included in the mangroves section of this report (Section 10).

Another report based on information for Salt River prior to Hurricane Hugo lists the bay as a nesting site for the Yellow-crowned Night-Heron (*Nyctanassa violacea*), Green Heron (*Butorides virescens*), Little Blue Heron (*Egretta caerulea*), Yellow Warbler (*Dendroica petechia*), and White-crowned Pigeon (*Columba leucocephala*) among others (Scott and Carbonell eds., 1986). Prior to Hurricane Hugo, Sladen (1988) noted that 26 of the 44 bird species known to breed on St. Croix nest at Salt River. SARI is currently a feeding and roosting site for Osprey (*Pandion haliaetus*), Brown Pelican (*Pelecanus occidentalis*), at least five species of herons, and many shorebirds. Cattle Egrets (*Bubulcus ibis*) and Little Blue Herons currently nest in a ~200 m^2 rookery within a much larger patch of red mangroves near Salt River Marina.

The most extensive bird survey information available for SARI is based on Virgin Islands Department of Planning and Natural Resources (VIDPNR), Division of Fish and Wildlife (DFW) surveys conducted between April 1989 and September 1995 which appear in a report, *Wildlife use of Saltwater Wetlands in the USVI*, prepared by DFW (1993). Additional surveys have since been conducted and are the subject of a report in preparation by the DFW, comparing historical to more recent data. The DFW has also marked a tern nesting site which covers ~4000 m^2 on the northeast side of SARI, west of Judith's Fancy. The area is composed of rock, coral rubble, sand, and other dredge spoil. VIDPNR/DFW should be contacted for the most recent data, nesting activity, and reports in press.

Another source with some Salt River avifauna data is the US Virgin Islands Rapid Bird Assessment (Rodrigues, 2002). This report provides a good summary of historical bird information, some new survey data, a species by species accounting of bird status in the USVI and worldwide, specific birding records by location within the USVI, and a list of preferred habitats for each species. The information on habitat preference could be used in combination with the land cover maps presented in this report (Section 13, Land Cover, Soils and Land Use) to quantify potential habitat for each bird species occurring within SARI.

ECOLOGICAL LINKAGES

The mangrove habitat at SARI has been shown to be of critical importance to locally breeding/nesting birds as well as overwintering and migrating North American songbirds (Wauer and Sladen, 1992). In 1989, Hurricane Hugo profoundly changed the characteristics of this important bird habitat (see Mangroves, Section 10). The restoration of Sugar Bay mangroves and gradual regrowth provides an opportunity for an interesting time series examining bird populations in a recovering mangrove forest.

The shallow mud, sand, and seagrass areas of Salt River provide a large foraging area for wading and shore birds. The size of this area is approximately 4.7 hectares. This was estimated as the combined area of the salt flats and beaches as delineated in the 2000 aerial photography plus the intertidal zone as derived in the bathymetry section of this report.

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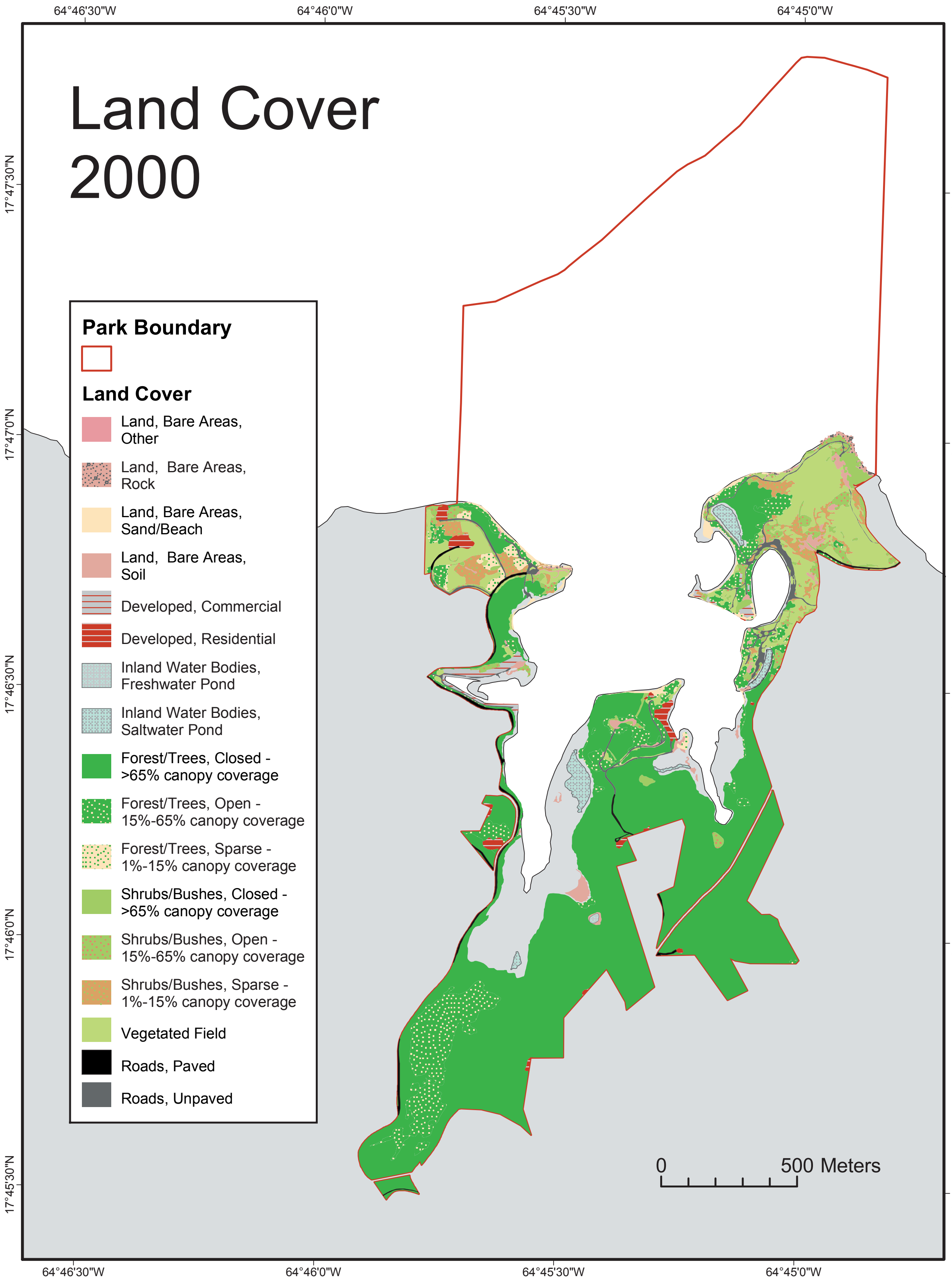

Figure 13.1. Map of land cover in SARI during 2000.

Figure 13.2. Salt River Bay from an upland forest overlook.

Section 13 Land Cover, Soils, & Land Use

OVERVIEW

The terrestrial environs within SARI were characterized based on aerial photographs, land cover maps produced in this assessment, and literature review. The park has been subject to notable human use, particularly dredging to enhance boat access, and commercial and residential construction. Dredging has altered the natural contours of the bays, and has as resulted in top soils containing salt where spoils have been deposited. However, although most parcels in the area are zoned for residential development or waterfront pleasure, only 7.3 hectares out of approximately 145 hectares land area were classified as developed in 2000. There is much visible evidence of past construction that in 2000 appears abandoned or incomplete. Topsoils consist primarily of loam of varying composition, and are not well suited for agriculture. The majority of terrestrial vegetation is forest of varying canopy cover (106 hectares), with vegetated fields and shrubs/ bushes also covering notable extents (14 and 11 hectares respectively). Eroded terrigenous soils dominated sediments in some areas of in the bays, demonstrating the influence that land activities can have on bay turbidity, reef development, and seagrass growth. In addition, periodic severe disturbance to forests and soils can be expected to occur in the hurricane-prone region, compounding existing human disturbance.

METHODS

Literature review and year 2000 aerial photography were the primary sources of information for the characterization of vegetation, land use, and soils in SARI. Seventeen mutually exclusive land cover types were mapped (See Aerial Photographs and Mapping Methods, Section 2). Areas reported here for vegetation, bare areas, and land use categories were calculated using this map (Figure 13.1). Vegetation maps created from 1995 aerial photographs and produced as part of the Rapid Ecological Assessment for St. Croix (University of the Virgin Islands 2000) were also referenced for this report. However, their maps and classification schemes were not incorporated directly, as the scope and scale of that effort differed from the intent of this characterization.

A large portion of the soil type descriptions included this report are based on a 1998 U.S. Department of Agriculture, National Resources Conservation Service (USDA/NRCS) soil survey of the U.S. Virgin Islands (USDA/ NRCS 1998). Additional sources of newer terrestrial soil data are scant, and even relatively recent reports (1990's) which contain regional descriptions mainly reference a previously conducted NRCS survey (Rivera et al. 1970). Additional information was obtained from field observations and literature review. Most reports were written during the mid 1990's or earlier. Therefore, wherever possible, evidence of current (2000) use or persistence of the effects of past use were verified in year 2000 aerial photo mosaicks, and during 2004 field surveys.

As with soils and land use, supplementary information on vegetation was obtained from previously published surveys and reports. Plant species observed in other surveys within the park were compiled in Appendix C, though all are over ten years old and the park is in need of a comprehensive survey of current flora. In this section, only terrestrial vegetation is discussed, and mangroves were not included. For information on mangroves in SARI, see the Mangroves, section 10.

Category	*Classification*	*Number of Polygons*	*Total Area (hectares)*	*Percent of Total*
Bare Areas	Rock	7	0.5	8%
	Sand/Beach	17	1.3	19%
	Soil	32	2.1	33%
Inland Water Bodies	Freshwater Pond	1	0.1	2%
	Saltwater Pond	5	2.4	38%
Total		**62**	**6.5**	**100%**

Table 13.1. Estimated area of natural and semi-natural unvegetated map classifications for year 2000.

RESULTS

Of the non-aquatic areas, unvegetated soil covered the most area, approximately 2 hectares. Sand/beach covered the second largest area, approximately 1 hectare, and bare rock covered 0.6 hectares (Table 13.1). Inland aquatic areas accounted for 2.5 hectares, mostly from five saltwater ponds (2.4 hectares). At least two of the ponds are man made; one on the northeastern side of East Cove, and the Abandoned Marina Cut (Figure 1.1). A single freshwater pond was located on the southeastern side of Sugar Bay, covering approximately 0.1 hectares. A berm approximately 10 feet above sea level prevents seawater from entering this pond during high tides or even during moderate storm surge conditions. While seepage from Sugar Bay or the adjacent salt flat may effect salinity in this pond, it is not a typical salt pond as may be suspected by casual inspection of the aerial photographs.

There are a total of 11 NRCS soil types of varying grade (slope) within the park (USDA/NRCS 1998) (Table 13.2.). The majority of top soils are approximately 0-9” deep, consisting of gravelly, sandy, stony, or clay loam. These include the Arawak, Cramer-Victory, Glynn, Solitude, and Victory-Southgate soil series (a family of soils with similar vertical structure, color, texture, composition and arrangement) and complexes (a mixture of two or more soil types that are either too intertwined or too patchy to map separately). Tidal areas around Sugar Bay and Triton Bay are flat (0-2% grade) sections of sandy clay loam and black muck (fine, well decomposed organic soil) from the Sandy Point/Sugar Beach series, and patches of gravelly fine sandy loam from the Solitude series. These are frequently flooded by the waters of the estuary, and typically contain some salt. The Salt River floodplain south of the Sugar Bay tidal region consists of clay loam from the Carib series, frequently flooded by freshwater from the upland watershed. Beaches are located on the northern facing shores, flanking the mouth of the bay. The eastern shore consists of fine sand formed from calcareous deposits, classified as the Jaucas series. The beach west of the mouth is also calcareous, but with a surface layer composed of large weathered coral pieces, characteristic of the Redhook series. A point that extends into the north western mouth of Triton Bay is also composed of Jaucas series sand. The majority of soils within the park are not well suited for crops (NPS 1990, USDA/NRCS 1998).

Dredge and fill activities have taken place since the 1960’s in various locations around the bays to create marinas and improve boat access. Although most projects were never completed, dredging resulted in dramatic alterations to the natural shape shoreline and bathymetry of the bays. Dredge disposal from these activities were deposited in several locations around the bay perimeter, creating new land and influencing soil characteristics. For instance, spoils have been deposited around the

Soil Series	***Soil Description***	***Total Area (hectares)***
Arawak	Gravelly loam, very stony	36.8
Carib	Clay loam, frequently flooded. Slightly saline to non-saline	16.1
Cramer-Victory Complex	Gravelly clay loam and loam (patchy)	33.9
Glynn	Gravelly loam, rarely flooded	5.7
Jaucas	Sand, on calcareous coastal beaches, rarely flooded	1.0
Pitts, Quarries	Areas where rock, gravel or sand have been removed by humans	0.1
Redhook	Extremely stony sand, rubbly, rarely flooded	2.3
Salt Flats	Flooded, unvegetated areas of saline flats, saline marshes and salt ponds	0.7
Sandy Point and Sugar Beach	Frequently flooded, sandy clay loam and black muck (patchy)	24.4
Solitude	Gravelly fine sandy loam, frequently flooded. Slightly to strongly saline	15.2
Southgate-Rock Outcrop Complex	Gravelly loam, extremely stony surface, exposed bedrock	0.5
Ustorthents	Altered from natural state by human activity	7.6
Victory-Southgate Complex	Very stony loam and gravelly loam (patchy)	20.7

Table 13.2. Soils found within SARI boundaries, summarized from the 1998 USDA/NRCS Soil Survey of the United States Virgin Islands.

Dredged Basin, and the soil there has been reported to contain elevated amounts of salt (NPS 1990). Additional locations of dredge fill are: on the peninsula between East Cove and the Dredged Basin, on the peninsula west of the Abandoned Marina Cut, and east of the salt pond located west of Estate Judith's Fancy. Along the western side of the bay extending from north of the Salt River Marina to just south of the Columbus Landing Site (Island Resources Foundation 1993) (Reference land marks on the "Locator Map", Figure1.1).

During land cover mapping, the only classification categories for human land use included roads (gravel and paved) and developed areas (commercial and residential). Of these, unpaved roads cover the most area, 2.9 hectares and are located primarily in the northwestern, central areas of the park, and around the dredged basin. Residentially developed areas accounted for approximately 1.7 hectares. Dwellings were scattered in the developments of Estate Salt River on the northwestern side of SARI, Estate Morningstar in the southwest quadrant, Estate Montpellier on the peninsula between Triton and Sugar Bay, and Estate Judith's Fancy on the northeastern side of the park. Commercial development, consisting of the Salt River Marina and the uncompleted resort at Estate Judith's Fancy, encompasses 1.4 hectares. Paved roads and account for approximately 1.3 hectares, concentrated primarily along the western length of the park (Table 13.3).

The bulk of the land within the boundaries of the park is zoned for low and medium density residential development, and for waterfront pleasure. Although large residentially zoned areas are owned by various corporations, most have not been developed. A handful of tracts show evidence of attempted development, but appear abandoned in 2000 aerial photography. The largest and most

Category	*Classification*	*Number of Polygons*	*Area (hectares)*	*Percent of Total*
Developed	Commercial	7	1.4	19%
	Residential	14	1.7	23%
Roads	Paved	14	1.3	18%
	Unpaved	8	2.9	40%
Total		**43**	**7.3**	**100%**

Table 13.3. Number of polygons and estimated area of roads and developed areas by map classification during 2000.

conspicuous of these is an abandoned resort located in Estate Judith's Fancy, on the peninsula between East Cove and the Dredged Basin. A number of hotel and marina developments have been attempted or proposed there, from the 1950's through the mid-1980's. (Island Resources Foundation 1993). Remnants of these efforts include the degrading remains of a hotel, a large pool, and several small cement pads scattered over the peninsula. There has also been more recent development that has occurred after the 2000 photographs were taken. For instance, during 2004 field activities, a multi-acre area of recently cleared land was observed on the bay side slopes of Judith's Fancy, apparently in preparation for residential development. The extent of these areas, however, could not be quantified for lack of more recent aerial photography.

Additional land use designations in the park include public (owned by federal or local government), and mixed waterfront-pleasure-industrial. The Columbus Landing site is owned by the Government of the Virgin Islands due to its historical and cultural significance. Once the site of a prehistoric ceremonial ball court and the 17th century French and Dutch fortification, Fort Sale, the five-acre area has been impacted by vehicular traffic and archaeological looting (Island Resources Foundation 1993). A second public area occupies the southeastern leg of the park, extending into the former 4.5 hectare Nature Conservancy Wildlife Sanctuary east of Triton Bay. Salt River Marina is located on the west side of the mouth to Sugar Bay. The facility includes 36 slips, a boat ramp, restaurant, and dive shop. To the east of the marina is Gold Coast Yachts, a boat construction facility. Together, the marina, boat yard and associated road cover approximately 1.4 hectares. On the western shore of Triton Bay, is the site of the former Fairleigh Dickinson University/West Indies Marine Research Laboratory where operations for the NOAA Undersea Research Program saturation diving facilities (Hydrolab and Aquarius) were once based. Currently, the majority of the peninsula (approximately 23 out of 25 hectares) is occupied by a private residence.

The 1998 NRCS survey identified two small soil areas as human-altered. A very small patch less than ½ hectare east of Judith's Fancy near the easternmost point of the park, was at one time excavated, probably for the purposes of mining gravel, sand, or stone for construction. The second patch, approximately 1 hectare, located in the upper Salt River floodplain, was the former site of a tropical fish hatchery for which mangroves were cleared over 15 years ago (NPS 1990). In year 2000 aerial photo mosaicks, half a dozen square "footprints" most likely from this operation are visible interrupting the forest cover. A raised dirt road was also constructed prior to 1977, from the area of the former hatchery, extending northwest into the southern tip of Sugar Bay. The roadway lies approximately 0.5 – 1.0 m above sea level, and is topped with bare packed soil and some upland vegetation. Today, much of the roadway persists though it is not used. Small, sparsely distributed white mangroves fringe its sides (See Mangroves, section 10).

Vegetation	*Cover*	*Number of Polygons*	*Area (hectares)*	*Percent of Vegetative Cover*
Forest/Trees	Closed - >65% canopy coverage	25	88	67%
	Open - 15%-65% canopy coverage	60	17	13%
	Sparse - 1%-15% canopy coverage	11	1	1%
Shrubs/Bushes	Closed - >65% canopy coverage	10	1	1%
	Open - 15%-65% canopy coverage	65	5	4%
	Sparse - 1%-15% canopy coverage	31	5	3%
Vegetated Field		50	14	11%
Total		**252**	**131**	**100%**

Table 13.4. Number of polygons and estimated area of natural and semi-natural vegetative land cover during 2000.

Agricultural activity was evident in 1992 aerial photographs in the southern Salt River floodplain. The area was used to grow feed for livestock (NPS 1990). Though northern portions of the plot closer to Sugar Bay are now overgrown, apparently because soil was too moist for tractor operation (NPS 1990), southern portions retain evidence of the agricultural use. In year 2000 aerial photographs, parallel crop rows oriented from the northwest to southwest remain visible across approximately 1.4 hectares.

Most of the natural and semi-natural cover in the park consists of forest (106 hectares). Approximately 83% of the forest canopy is closed, 16% is open, and 1% is sparse (see Aerial Photography and Mapping Methods, Section 2 for description of classifications). The bulk of forest cover is located in the southern inland portions of the park. Smaller patches exist in western portions of Estate Judith's Fancy, between the Columbus Landing Site and Salt River Marina, and along the northwestern ocean front shores (Figure 13.1). Due to the topography and relatively low rainfall, dry forest communities are characteristic of these areas, including semi-deciduous forest and gallery semi-deciduous forest (confined to riparian corridors where additional moisture is available from runoff) (University of the Virgin Islands, 2000). Vegetated fields covered approximately 14 hectares, the second most extensive natural and semi-natural cover in the park. Shrubs and bushes account for approximately 11 hectares, or 8% of the vegetated areas (Table 13.4). Most of the shrub and field cover is concentrated in the northeastern and northwestern portions of the park.

The Salt River watershed drains approximately 3000 acres, and although the "river" flows only intermittently, a freshwater wetland is located south of the mangrove line in Salt River Gut, prior to discharging in the mangrove marshes. Vegetation in the freshwater wetland is characterized by cattails *(Typha domingensis)*. The swamp fern *(Achrosticum danaefolium)* is also occasionally found in the area.

ECOLOGICAL LINKAGES

The Salt River watershed is the third largest on St. Croix. Rain events flush terrigenous sediments into the bays, particularly down the Salt River Gut, where they are deposited in the benthic sediments of the estuary (Gerhard and Bowman 1975) (See Geology, Section 4). Activities including building, road construction, dredging, and vegetation removal, will cause increases in sediment input and turbidity in the bay. These will in turn, influence benthic vegetation growth

(Gerhard and Bowman 1975) as well as coral recruitment and growth in and around Salt River Canyon (Hubbard 1989) (See Seagrass and Algae, and Reef and Hardbottom, Sections 9 and 8 respectively).

Activities which affect the hydrology of wetlands can influence vegetation communities, particularly in the freshwater and mangrove wetlands. The alteration of lands for agricultural activity in the lower Salt River floodplain, for example, has altered water flow to the wetland communities located nearby (Island Resources Foundation 1993).

Hurricanes are known to affect the development and succession of forest communities (see Climate, Section 3). Hurricane Hugo in 1989 had visible impacts on inland forest cover as seen in SARI aerial photographs (See Mangroves, Section 10) that were still evident in 2000. Organisms that utilize vegetation habitats (i.e. birds) are consequently impacted by these severe events. The effects of such storms can be compounded by anthropogenic forest alterations, such as clearing for agriculture or development (See Birds, Section 12).

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Figure 14.1. Mangrove prop roots damaged by an improperly moored vessel in Triton Bay.

Section 14 Data Gaps and Threats

Salt River Bay National Historical Park and Ecological Preserve contains a diverse cross section of habitats and ecosystems. Ideally, data would be available on the complete range of these resources to ensure that informed management decisions can be made. For this ecological characterization, every attempt was made to locate and incorporate all of the most relevant and recent data available on the park's resources. However, there have only been a limited number of studies conducted within SARI on a limited range of topics. As a result, the information in this and other park characterizations to date is cobbled together from a diversity of reports and studies intended for other uses, is rarely based on up to date conditions, is not comprehensive for the entire park, and is typically not even representative of all the habitats or biotic groups within the park. Compilation of this available data and the spatial characterization completed here highlight many information gaps that require additional study or monitoring.

Virtually all terrestrial and marine flora and fauna lack a comprehensive and systematic baseline inventory. Such programs fill a critical information gap in assessing resources, guiding future research and monitoring, and informing management actions. Particularly lacking have been studies on SARI reefs outside the canyon, algae and seagrass communities within the bays, and the mangrove and upland forest communities. Since the closure of the NOAA/NURP FDU facilities in the 1990's, canyon studies have been virtually abandoned. In addition to a lack of key assessment and monitoring programs within SARI, the import and export of biotic and abiotic material across SARI boundaries and reciprocal influences with outside ecosystems are even more poorly characterized.

Despite this, there are currently a handful of ongoing programs in place that will undoubtedly provide important, up-to-date data on some park resources. The aerial photographs compiled for this assessment and that will likely continue to be periodically obtained in the future, provide a valuable time series of data for use on a wide range of topics. In addition to the seagrass, mangrove, benthic, and land cover maps presented here, photographs also provide historical information on such topics as shoreline change, land use and development, and forest health and succession. The NOAA CREWS station provides nearly continuous point data on key atmospheric and marine parameters near the submarine canyon. Inside the bays, the VIDPNR/DEP continues to collect several key variables concerning water quality in the face of increasing human pressures. As the University of the Virgin Islands CMES and VIDPNR coral reef and fish monitoring program continues, important long-term data on fish diversity and abundance as well as benthic cover will be produced. These few existing monitoring programs should be maintained and, in many cases, expanded in spatial and temporal scope.

The human threats to the park's ecosystems are diverse. As noted in the water quality section of this and other reports, upland erosion from development and land clearing within the watershed can have adverse effects on the turbidity and sedimentation rates of park waters. Relict crop rows in the marsh south of Sugar Bay have affected the hydrology of the Salt River Gut and water flow to Sugar Bay.

Local government ACE projects redirect flow of runoff around nearby housing areas such as Mon Bijou which increases speed and volume of runoff reaching SARI. Spills or discharges of human waste in the vicinity of the marina and the many live-aboard boats in that region of the park contribute to the high bacterial load, hypoxia, and elevated turbidity that periodically occur in that area. Other human threats to park resources include more direct physical degradation of and damage to natural habitats. As observed during ground surveys, the prop roots of ~30m of red mangrove fringe in Triton Bay were recently crushed back to the shoreline, presumably by a large boat improperly moored. A portion of the upland area behind Sugar Bay is fenced with barbed wire to contain horses. Trash and other large debris including furniture, tires, entire automobiles, and derelict boats litter the mangroves and dirt roads behind Sugar Bay, as well as the beaches east and west of Salt River Bay. Fishing and dive moorings on the walls of Salt River Canyon have been installed to reduce anchor impacts to the reef, however, seagrass and algae within the bays are frequently damaged by vessel groundings and anchor/chain drag.

Harvest of natural resources is also intense. Over harvest of fish, conch, and lobster is pervasive in the region. The high density of land crab burrows in the swamp in Sugar Bay is matched by an equally high density of pipe traps. Informal surveys during ground truthing of the maps of this area revealed that virtually every land crab burrow was occupied by a trap.

The goal of this characterization was to compliment existing research and assessments on SARI ecology by providing new tools and products that managers may use to guide future science within the park (see Appendix F). It is hoped that the maps created, the aerial photographs collected, summary information provided, and the data gaps highlighted in the present assessment will facilitate the design of a formal stratified monitoring program for many of the park's habitats. The park has within its borders a wide variety of tropical ecosystem components including terrestrial, wetland, bay, and open water regions with diverse habitat types such as coastal forests, mangroves, algal and seagrass beds, mud and sand, and several types of coral reef and hard bottom. With the information provided in this characterization, park managers now have additional tools to aid in the stewardship of this diverse ecosystem.

Figure 14.2. Assorted catch of a Salt River fisherman.

Section 15 Additional Information

Additional information in the following subject areas is available from the web sites listed below.

http://www.nps.gov/sari/ ...for information on the National Park Service on St.Croix, general information on SARI, hard copy, and scans of aerial photographs of SARI, and all other data products in this report.
Written requests for information on other inquiries should be sent to...
2100 Church Street #100
Christiansted VI 00820-4611
or by phone at 340-773-1460
or fax at 340-773-2950
or by email at Zandy_Hillis-Starr@nps.gov

http://biogeo.nos.noaa.gov/ …for information on benthic and land cover maps in this report

http://geodesy.noaa.gov/ …for information on NOAA aerial photography

http://www.coral.noaa.gov/ …for information on NOAA's Coral Reef
Early Warning System

http://www.dpnr.gov.vi/ …for information on the local government involved in research and management at SARI. The site includes links to information on such topics as water quality and wildlife monitoring in the U.S. Virgin Islands.

http://www.coral.noaa.gov/ …for information on Comprehensive bibliography of Salt River research

Appendices

Appendix A: Coral Literature Education and Outreach Program Reference List

Year	*Principal Investigators*	*Title*	*Located*
1978	C. Birkeland and S. Neudecker	Comparative Study of Chaetodontid Foraging Patterns	X
1978	C. Smith and J. Tyler	Regulatory Mechanisms in Coral Reef Fish Communities	X
1978	D. Arneson and L. Meiklejohn	Diel and Depth Variation in the Population Densities of Commercially Important Carnivorous Fishes	
1978	D. Hubbard, J. Sadd, H. Tonnemacher, and C. Phips	Sediment Transport Processes of Salt River Submarine Canyon St. Croix, U.S. Virgin Islands	X
1978	I. Clavijo	Diel and Depth Variation in the Population Densities of Herbivorous Fishes	
1978	P. Colin, A. Arneson, and R. Boulon	Spawning of Western Atlantic Reef Fishes	
1978	P. Colin, A. Arneson, and R. Boulon	Coral Distribution in the Salt River Canyon	X
1978	P. Winkler and R. Bolton	Oxygen Consumption of Reef Fishes During Quiescent Periods of their Circadian Activity Cycles	
1978	R. Clarke and G. Dale	The Role of Light in Nocturnal/Diurnal Changeover Patterns of Certain Coral Reef Fishes	
1978	R. Hanlon and R. Hixon	Response of Squids to Night Lights and Reef Behavior of Octopuses	X
1978	R. Vaissiere, A Meinesy, C. Falconetti, and D. Bay	Comparison of Mediterranean and Caribbean Benthionic Biological Systems	X
1978	S. Bortone, R. Hastings, D. Siegel, R. Bolton	Quantification of Reef Fishes	X
1979	D. Hubbard, S. McGowan, H. Tonnemacher, J. Sadd	Geologic Development of Salt River Canyon	X
1979	D. Meyer, G. Minnery, C. Messing, L. Somers	The Comparative Feeding Behavior of Crinoids and Ophiuroids	X
1979	D. Olsen, K. Turbe, B. Friedman	Optimum Yield for Virgin Islands Black Coral Fishery	X
1979	E. Williams, J. Kimmel, R. Waldner, L.Williams	Manipulation of Large External Isopods (Genus Anilocra) on Brown and Blue Chromis	X
1979	J. Ogden, S. Miller, W. McFarland, N. Wolf, M. Shulman, J. Ebersole	The Settlement and Recruitment of Postlarval Fishes into the Coral Reef Community	X

Year	*Principal Investigators*	*Title*	*Located*
1979	W. Gladfelter, W. Johnson, J. Davidson	Structure of the Planktivorous Fish Community Along a Depth Gradient	
1980	A. Hurley, M. Josselyn, R. Cowen, S. Hawes, G. Cailliet, T. Niessen, J. Connor	The Sources, Dispersal, and Utilization of Benthic Drifting Plants in the Salt River Submarine Canyon	X
1980	D. Olsen, G. McCrain, B. Friedman	Characteristics of Black Coral Trees in Salt River Canyon: Management Data	X
1980	H. Lasker, M. Russel, M. Gottfried, D. Gordon	Resource Availability and Suspension Feeding by Gorgonians	X
1980	I. Clavijo, A. Bardales, L. Amador, J. Ramirez, J. Morell, A. Mendez	Diel Migrations of *Scarus Guacamaia* and *Scarus Coelestinus*	X
1980	M. Reaka, C. VanZant, N. Wolf, F. Pecora, J. Lansteiner	An Experimental Analysis of Ecological Processes That Structure Fish and Invertebrate Reef Communities	X
1980	P. Winkler, I. Szurley, and L. Greiner	In Situ Oxygen Consumption of Reef Fishes During Quiescence	
1980	S. Neudecker, W. Hamilton, P. Lobel	Social Behavior and Feeding Ecology of Caribbean Chaetodontids	X
1980	T. Suchanek, D. Duggins, B. Rivest, P. Banko	Influence of Sediment Bioturbators on the Success of Seagrass Communities	X
1980	W. Johnson, J. Davidson, V. Chase, F. Johnson, S. Hamilton	Resource Utilization Patterns in a Deep-Water Planktivorous Fish Community at Salt River Canyon	X
1980	Y. Sadovy, I. Clavijo, K. Boulon	Social Behavior in *Eupomacentrus partitus*	X
1981	C. Rogers, M. Gilnack, C. Fitz, J. Beets, J. Hardin	Relationship of Coral Recruitment and Grazing Intensity to the Distribution of Algae and Corals in Salt River Canyon	X
1981	D. Hubbard, J. Westerfield, J. Bayes, A. Miller, I. Gill, R. Burke	Geological Development of Salt River Submarine Canyon	X
1981	E. Reese, T. Hourigan, R. Stanton, B. Carlson, P. Motta	Feeding and Space-Related Behavior of Three Species of Pomacanthid Fishes	
1981	E. Williams, L. Williams, R. Waldner, M. Dowgiallo	Manipulation of Large External Isopods (Genus Anilocra) on Brown and Blue Chromis and Coneys	X
1981	G. Gitschlag	Development and Testing of Underwater Fish Marking and Release Techniques	X
1981	G. Helfman, J. Meyer, D. Dallmeyer, E. Bozeman	Trumpetfish Distribution and Predation	X
1981	G. Samson, E. Igleria, A. Lee, J. Arteaga	Fish Behavior in Relation to Commercial Fish Traps	

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1981	G. Samson, E. Igleria, A. Lee, J. Arteaga	Fish Behavior in Relation to Commercial Fish Traps	

Year	*Principal Investigators*	*Title*	*Located*
1982	R. Steneck	Role of Productivity and Herbivory in Structuring Tropical Algal Communities	X
1982	T. Suchanek	Competition Among Encrusting Colonial Invertebrates in Open Reef Habitats	X
1983	A. Szmant-Froelich	Role of Herbivorous Fish in Nitrogenous Regeneration of Coral Reefs	X
1983	C. Falconetti	Morphological Variation of Caulerpa: Study of Macrobenthic Species on the Shelf Bottom	
1983	D. Bay	Sociobiology and Sex Change of Labroid Fishes	
1983	E. Williams	Early Life History and Host Relationships of the Isopod *Anilocra chromis*	X
1983	I. Workman	Attraction of Pelagic Fishes to Midwater Structures	X
1983	J. Coyer	Influence of Fish Predators on Activity Patterns of *Diadema antillarum*	X
1983	M. Reaka	Patterns of Life History and Behavior in Coral Reef Organisms	
1983	M. Robblee, C. McIvor	Assessment of Deep *Halophila* Seagrass Meadow as Fish Habitat and Feeding Ground	
1983	N. Downing, C. Al-Zehar	Artificial Reef Utilization by Grouper Fish	
1983	N. Targett	Chemical Ecology and Histocompatibility of Sponges	
1983	R. Bray	Planktivorous Fish as Nutrient Importers in Tropical Reef Communities	
1983	S. Williams	Growth of Caulerpa spp. and its Relationship to Sediment Habitat	X
1983	T. Niesen	Ecological Function and Fishery Resources of *Halophila* Beds	
1984	A. Landry	Evaluation of Multilevel Artificial Structures in the Attraction of Deep Reef Fishes	
1984	A. Szmant-Froelich	Nutrient Regeneration in Coral Reef Sediments	
1984	C. Bouchon	Irradiance Measurements, Correlation Bathymetric Distribution of Scleractinian Corals in Salt River Canyon, St. Croix	

Year	*Principal Investigators*	*Title*	*Located*
1984	C. Smith and J. Tyler	Diversity and Relative Abundance of Fish Larval Stages	X
1984	D. Hubbard	Geological Development of Salt River Submarine Canyon	X
1984	E. William	Early Life History and Host Relationships of the Isopod Anilocra chromis	X
1984	I. Workman	Evaluation of the Potential of Using Fish-Attracting Devices to Attract Harvestable Concentrations of Coastal Pelagic Fishes Into Shallow Caribbean Waters	
1984	K. Sebens	Effect of Water Flow on Coral Respiration and Productivity	
1984	M. Coulston	Assessment of the Queen Conch (Strombus gigas) Population and Predation Studies of Hatchery-Reared Juveniles in Salt River Canyon, St. Croix, V.I.	X
1984	N. Targett	Chemical Ecology of Space Competition Between Sponges and Corals	
1984	R. Larson	Ecological Function and Fishery Resources of *Halophila* in the Caribbean	
1984	S. Williams	Diurnal Growth Patterns in *Halophila* and *Caulerpa*	
1984	W. Johnson	Role of Cleaning Stations in Overall Fish Community Organization Along a Depth Gradient at Salt River Canyon, St. Croix	
1985	C. Smith and J. Tyler	Growth and metamorphosis of coral reef fish larval stages in the Salt River canyon, St. Croix, USVI: Final Scientific Report Mission 85-5	X
1985	K. Sebens, M. Patterson, R. Olson	Effect of Water Flow on Coral Respiration and Productivity	
1985	M. Hay	Does the Tropical Seaweed Halimeda Reduce Herbivory by Growing at Night?: Diel Patterns of Growth, Nitrogen Content, Herbivory, and Chemical Versus Morphology Defenses	
1985	N. Targett, J. Porter	Chemical Interactions Between Sponges and Corals	
1988	C. Butman	Field Studies of the Roles of Spatial Scale and Boundary-Layer Flow Regime in Active Habitat Selection by Settling Larvae: Preliminary Sampling	
1988	G. King	Oxygen Dynamics and Anaerobic Metabolism in Sediments of Salt River Canyon	
1988	H. Foushee	An Observational and Survey Study of Crew Composition and Member Satisfaction in Subsea Habitats	
1988	J. Porter	The Energetics of Sediment Removal and Zooplankton Feeding in Caribbean Reef-Building Corals	

Year	*Principal Investigators*	*Title*	*Located*
1988	K. Sebens	Effect of Water Movement on Zooplankton Feeding by Corals	
1988	M. Patterson	Field Measurement of Diffusional Boundary Layers and Turbulent Enhancement in Scleractinian Reef Corals	
1988	R. Steneck	Patterns and Processes Structuring Tropical Algal Communities Along a Depth Gradient: The Dynamic Roles of Productivity and Herbivory	
1988	T. Fisher	Primary Productivity and Nutrient Fluxes of the Benthic Microflora of Coral Reef Sediments	
1989	A. Miller, M. Boardman, K. Parsons	Spatial Resolution and Taphonomic Gradients in Accumulating Molluscan Remains, Salt River, St. Croix: Postponed Due to Hurricane Hugo	
1989	C. Harvell	Chemical and Structural Defenses of Caribbean Gorgonians: Pattern and Process Over a Depth Gradient	X
1989	G. Helfman, L. Kaufman	Effects of Ontogeny and Refuge Quality on Threat-Sensitivity in Recently-Recruited Coral Reef Fishes	
1989	G. King	Effects of Animal Disturbance on Microbiological Processes in Sediments of Salt River Canyon	
1989	G. Wellington	Ultraviolet Light and its Effect on Reef-Building Corals	
1989	J. Ebersole, L. Kaufman	Adaptive Selection of Local Habitat and Passive Movement of Larvae as Factors Influencing Composition of Assemblages of Fishes on Coral Reefs	
1989	J. Woodley	The Trophic Impact of Deposit and Suspension-Feeding Ophiuroids on Recruitment of Other Coral Reef Organisms: A Feasibility Study	
1989	L. Madin	In Situ Studies of the Distribution, Behavior, and Community Ecology of Zooplankton, Micronekton, and Benthos at a Deep-Sea Station Near St. Croix, USVI	
1989	M. Coulston, O. Hewlett, Z. Hillis, M. Taylor, R. Simms, M. Herko	Environmental Monitoring in the Salt River Submarine Canyon	X
1990	C. Petersen	The Evolution of Mating Systems and Fertilization Rates in Hermaphroditic Fishes	

This list and some of the publications, are available online at the website of the NOAA/OAR/Atlantic, Oceanographic and Meteorological Laboratory (AOML), http://www.aoml.noaa.gov/general/lib/crews.htm.

Although a complete list (with the possible exception of 1985) of Hydrolab and Aquarius mission abstracts for Salt River was compiled, a complete collection of mission reports could not be located. Reports or related publications that were available or acquired for approximately 50 out of 103 missions, and are indicated with an X in the "Located" column.

Appendix B. List of coral species found during previous research and monitoring activities in Salt River Canyon

Coral Species	*East Wall*	*West Wall*	*References Cited*
Acropora cervicornis	x	x	a, e
Acropora palmata		x	a, e
Agaricia agaricites	x	x	a, c, d, e
Agaricia fragilis	x	x	a, e
Agaricia lamarcki	x	x	d, e
Colpophyllia natans	x	x	a, b, c, d, e
Dendrogyra cylindrus		x	b, e
Dichocoenia stokesii	x	x	a, b, c, d, e
Diploria clivosa	x	x	a, b
Diploria labyrinthiformis	x	x	a, b, c, d, e
Diploria strigosa	x	x	a, b, c, d, e
Eusmilia fastigiata	x	x	a, b, d, e
Favia fragum	x	x	a, e
Helioseris cucullata	x	x	a, d, e
Isophyllastrea rigida	x	x	d, e
Isophyllia sinuosa	x	x	d, e
Madracis decactis	x	x	a, c, d, e
Madracis mirabilis		x	c, e
Manicina areolata		x	e
Meandrina meandrites	x	x	a, b, c, d, e
Millepora alcicornis	x	x	a, b, c
Millepora complanata		x	b
Montastraea annularis	x	x	a, b, d, e
Montastraea cavernosa	x	x	a, b, c, d, e
Montastraea faveolata	x	x	c
Montastraea franksi	x		c
Mussa angulosa	x		a, e
Mycetophyllia aliciae	x	x	e
Mycetophyllia ferox	x	x	a, b, c, d, e
Mycetophyllia lamarckiana		x	a, e
Phyllangia americana		x	a
Porites astreoides	x	x	a, b, c, d, e
Porites furcata	x		a
Porites porites	x	x	b, c, d, e
Scolymia cubensis	x	x	a
Scolymia lacera		x	a
Siderastrea radians	x	x	a, b
Siderastrea siderea	x	x	a, b, c, d, e

Coral Species	*East Wall*	*West Wall*	*References Cited*
Stephanocoenia mechelinii	x	x	b, c, d, e
Stylaster roseus		x	a
Tubastraea aurea	x	x	a, b

References

a. Boulon, RH. 1978. Coral distributions in the Salt River Submarine Canyon, St.Croix, US Virgin Islands. Final Scientific Report NOAA Hydrolab; Mission 78-6B. Pp. 1-18.

b. Kesling, CA. 1990. Preliminary report: Effects of Hurricane Hugo on the benthic coral reef community of Salt River Submarine Canyon, St.Croix, US Virgin Islands. Final Scientific Report NOAA Aquarius; Mission 89-4C Pp. 1-20 and in Diving for Science; Proc. Of the 10th Annual American Academy of Underwater Sciences Diving Symposium. Japp, W., St. Petersburg, Fl.

c. Nemeth, RS, S Herzlied, M Taylor, S Harold, and W Toller. 2003. Video monitoring assessment of coral reefs in St.Croix, United States Virgin Islands. Year two final report to VI Department of Planning and Natural Resources. Pp. 1-9 and Appendices.

d. Rogers, CS, M Gilnak, and HC Fitz III. 1983. Monitoring of coral reefs with linear transects: A study of storm damage. Journal of Experimental Marine Biology and Ecology 66:285-300

e. Rogers, CS, HC Fitz III, M Gilnack, J Beets, and J Hardin. 1984. Scleractinian coral recruitment patterns at Salt River Submarine Canyon, St.Croix, US Virgin Islands. Coral Reefs 3:69-76

Appendix C. List of Plant Species Observed in Salt River National Historic Park and Ecological Preserve

Scientific Name	*Common Name*	*Reference Cited*
Acacia macrancantha	stink casha	d
Acacia tortuosa	casha	a, c, d
Achyranthes indica	man-better-man	d
Acrostichum daneaifolium	swamp fern	c, d
Agave eggersiana*	Egger's agave*	c
Agave spp.	century plant	e
Ageratum conyzoides	goat weed	d
Albizia lebbek	Tibet	e
Annona muricata	soursop	d
Annona squamosa	sugar apple	d
Antigonon leptopus	Mexican love	d
Bambusa vulgaris	bamboo	d
Batis maritima	saltwort	e
Bidens pilosa	beggarticks	a, d
Blutaparon vermiculare	salt weed	d
Boerhavia coccinea	boerhavia, hog weed	a
Borrichia aborescens	sea oxeye	e
Bourreria succulenta	pigeon-berry	d
Bucida buceras	gregre	a, d
Bursera simaruba	turpentine tree, gumbo-limbo	a, d
Caesalipinia bonduc / C. crista	grey knickers, nickerbean	d
Cakile lanceolata	searocket	a, d, e
Calotripis procera	giant milkweed	d
Canavalia maritima	baybean	d
Capparis cynophallophora	Jamaican caper	a, d
Capparis flexuosa	limber caper	a, d
Capparis frondosa	rat-bean	d
Capparis indica	caper	d
Carcia papaya	papaya	d
Cassia siamea	yellow cassia	d
Cassytha filiformis	love vine	e
Cenchrus echinatus	sandburr	d
Chrysophyllum pauciflorum	caimito de perr	d
Cissus sicyoides	pinekoop	a, d
Citharexylum fruticosa	pasture fiddle, fiddle wood	d
Cleome viscosa	tickweed, spider flower	d

Scientific Name	*Common Name*	*Reference Cited*
Clitoria ternatea	butterfly pea	a
Cocoloba uvifera	seagrape	d, e
Cocos nucifera	coconut palm	a, b, d, e
Commelina diffusa	blue day-flower	d
Commelina elegans		d
Comocladia dononaea	Christmas bush	d
Conocarpus erectus	buttonwood	b, c, d, e
Cordia alba	white manjack	a, b, d
Cordia collococca	red manjack	a, d
Corton rigidus	maran	a
Corton spp.	corton	d
Crescentia cujete	calabash	b
Crotalaria sp.	yellow sweet pea	a
Cryptostegia grandiflora	Indian rubber, rubber vine	d, e
Delonix regia	flamboyant tree	d
Distichlis spicata	beach grass	d
Epidendrum bifidum*		c
Epidendrum ciliare*	spider orchid*	c
Eugenia rhombea	spiceberry	d
Eugenia spp.	pencil bush	d
Ficus citrifolia	shortleaf fig	d
Guaicacum officinale*	lignumvitae*	d
Guapira fragrans	black mampoo	d
Hibiscus sp.	hibiscus	b
Hippomane mancinella	manchineel	a, c, d
Ipomoea pes-capre	beach morning glory	d, e
Ipomoea sp.	goats foot	a, d, e
Jacquinea arborea		a
Jatropha gossypifolia	physic nut, bellyache bush	a
Kalanchoe pinnata	leaf of life	d, e
Lantana camara	yellow sage	d
Lantana invulcrata	wild sage	d
Lantana spp.	sages	d
Laportea sp.	stinging nettle	a
Leucaena leucacephala	tan-tan	a, c, d, e
Ludwigia sp.		d
Malphigia infestissima*	stingbush*	a, c, d
Malphigia woodburyana*	cow-itch, cowage cherry*	a
Malvastrum corchorifolium	false mallow	e

Scientific Name	***Common Name***	***Reference Cited***
Malvastrum coromandelianum	threelobe false mallow	e
Mammilaria nivosa*	wolly nipple*	c
Mangifera indica	mango	d
Melicoccus bijugatus	genip	a, d, e
Merremia quinquefolia	merremia, merremia vine	a, e
Momordica charantia	maiden apple	d
Morinda citrifolia	painkller	e
Morisonia americana	rat-apple	d
Opuntia spp.		d
Panicum maxium	guinea grass	a, d
Petiveria alliacea	garlic weed	d
Pilosocereus royenii	pipe organ cactus	d
Piscidia piscipula	fish poision trees	d
Pisonia aculeata	prickly mampoo	d
Pithecellobium unguis-cati	bread and cheese	a, d, e
Pluchea symphitifolia	sweet scent	d
Portulaca oleracea	little hogweed, purslane	e
Psychotria nervosa	wild coffee	d
Randia aculeata	box-briar	d
Rhizophora mangle	red mangrove	a, b
Rivina humilis	cat's blood	a, d
Roystonea regia	royal palms	b
Sansevieria sp.	snake plant	a, e
Schaefferia frutescens	Florida boxwood	d
Schinus terebinthifolius	Christmasberry	e
Sesuvium portulacastrum	sea purslane	a, d, e
Sida acuta	broom weed	a, e
Spartina patens	salt grass	d
Stachytarpheta jamaicensis	blue porterweed	a
Suriana maritima	bay cedar	d
Tabebuia heterophylla	pink cedar	d, e
Tamarindus indica	tamarind	b
Tecoma stans	ginger thomas	a, d, e
Terminalia catappa	West Indian almond, tropical almond	a, d, e
Thespesia populnea	haiti-haiti, seaside maho	a, d, e
Triphasia trifolia	sweet lime, limeberry	a, d
Typha domingensis	cattail	d
Yucca aloifolia	spanish bayonet	e
Yucca spp.		a, d

Scientific Name	*Common Name*	*Reference Cited*
Zanthoxyllum flavum	satin wood	c
Zanthoxylum martinicense	white prickle	d
Zanthoxylum monophyllum	yellow prickle	d

* Indicates species is locally listed as threatened or endangered by The Virgin Islands Department of Planning and Natural Resources, Division of of Fish and Wildlife, 1991.

Documents cited:
a) Coastal Consultants, 1987. Environmental Assessment Report for Columbus Landing: A Marina, Restaurant Shopping and Office Complex at Estate Morningstar on Sugar Bay (Salt River). 64 pgs.

b) Haines Enterprises, Inc. 1983. Major Class I Environmental Assessment Report for the Proposed Docking Facility at Salt River Marina, Estate Salt River, Sugar Bay, St. Croix, United States Virgin Islands. 87 pgs.

c) Virgin Islands Department of Planning and Natural Resources, 1993. Salt River Bay and Watershed (APR) Area of Particular Concern (APC) and Area for Preservation and Restoration (APR), A Comprehensive Analytic Study. 60 pgs.

d) Government of the U.S. Virgin Islands. 1990. Alternatives Study and Environmental Assessment, Columbus Landing Site, St. Croix, U.S. Virgin Islands.

e) Sugar Bay Land Development, Ltd., 1986. Environmental Assessment Report Preliminary Submittal.

Appendix D. List of fish species found within the boundaries of SARI

Scientific Name	*Mangrove*	*Canyon Walls*	*Pelagic FAD*	*References Cited*
Abudefduf saxatilis	x	x		a, c, d, e
Acanthemblemaria aspera		x		d
Acanthemblemaria chaplini		x		d
Acanthemblemaria maria		x		d
Acanthemblemaria spinosa		x		d
Acanthostracion polygonia		x		c, d, e
Acanthostracion quadricornis		x		d, f
Acanthurus bahianus		x		c, d, e
Acanthurus chirurgus	x	x		a, c, d, e
Acanthurus coeruleus	x	x		a, c, d, e
Alectis ciliaris		x		f
Aluterus scriptus		x		d, e
Amblycirrhitus pinos		x		d
Anisotremus surinamensis		x		d
Anisotremus virginicus	x	x		a, d ,e
Antennarius multiocellatus		x		d
Apogon binotatus		x		c, d
Apogon lachneri		x		c, d
Apogon maculatus		x		d
Apogon townsendi		x		c, d, e
Archosargus rhomboidalis	x			a
Aulostomus maculatus		x		a, d, e
Balistes vetula		x		d, e
Bodianus rufus		x		c, d, e
Bothus lunatus		x		c, d, e
Bothus ocellatus		x		c
Calamus calamus		x		d
Cantherhines macrocerus		x		d, e
Cantherhines pullus		x		d, e
Canthidermis sufflamen		x		d, f
Canthigaster rostrata		x		c, d, e
Caranx bartholomaei		x		e
Caranx crysos		x		d, e
Caranx hippos		x		d
Caranx latus	x	x		a, e, f
Caranx ruber	x	x	x	a, b, c, d, e, f
Centropomus undecimalis	x			a
Centropyge argi		x		d

Scientific Name	***Mangrove***	***Canyon Walls***	***Pelagic FAD***	***References Cited***
Cephalopholis cruentatus		x		c, d, e
Cephalopholis fulvus		x		c, d, e
Chaenopsis limbaughi		x		d
Chaetodon aculeatus		x		c, d, e
Chaetodon capistratus	x	x		a, c, d, e
Chaetodon ocellatus		x		d, e
Chaetodon sedentarius		x		d
Chaetodon striatus	x	x		a, c, d, e
Chilomycterus antennatus		x		d
Chromis cyanea		x		c, d, e
Chromis insolata		x		d
Chromis multilineata		x		c, d, e
Chromis scotti		x		d
Clepticus parrae	x	x		a, c, d, e, f
Coryphaena hippurus			x	b
Coryphopterus dicrus		x		d
Coryphopterus eidolon		x		d
Coryphopterus glaucofraenum		x		c, d, e
Coryphopterus lipernes		x		c, d, e
Coryphopterus personatus/hyalinus		x		c, d, e
Cryptotomus roseus		x		c
Dactylopterus volitans		x		c
Dasyatis americana		x		c, d, e
Decapterus macarellus		x		d, f
Decapterus tabl		x		d
Diodon holocanthus		x		d
Diodon hystrix	x	x		a, c, d, f
Echeneis naucrates		x		e
Elagatis bipinnulata		x		d
Emblemaria pandionis		x		c, d
Emblemariopsis bahamensis		x		d
Emmelichthyops atlanticus		x		d
Enchelycore carychroa		x		d
Enneanectes altivelis		x		d
Enneanectes boehlkei		x		d
Epinephelus adscensionis		x		c, d, e
Epinephelus guttatus		x		c, d, e
Epinephelus itajara		x		c
Epinephelus striatus		x		d
Equetus acuminatus	x			a
Equetus punctatus	x	x		a, d, e
Eucinostomus jonesi	x			a

Scientific Name	*Mangrove*	*Canyon Walls*	*Pelagic FAD*	*References Cited*
Euthynnus alletteratus			x	f
Fistularia tabacaria		x		d
Garmannia saucra		x		d
Gerres cinereus	x	x		a, c, d, e
Ginglymostoma cirratum		x		e
Gnatholepis thompsoni		x		c, d
Gobiosoma chancei		x		d
Gobiosoma evelynae		x		d
Gobiosoma genie		x		c, d
Gobiosoma louisae		x		d
Gobiosoma pallens		x		d
Gobiosoma prochilos		x		d
Gobiosoma tenox		x		c
Gramma loreto		x		c, d, e
Gymnothorax funebris	x	x		a, d, e
Gymnothorax miliaris		x		d
Gymnothorax moringa		x		c, d
Gymnothorax vicinus		x		c
Haemulon aurolineatum	x	x		a, c, d, e
Haemulon carbonarium	x	x		a, d, e
Haemulon chrysargyreum	x	x		a, c, d
Haemulon flavolineatum	x	x		a, c, d, e
Haemulon macrostomum	x			a
Haemulon parra	x	x		a, d
Haemulon plumieri	x	x		a, c, d, e
Haemulon sciurus	x	x		a, c, d, e
Haemulon striatum	x			a
Halichoeres bivittatus	x	x		a, c, d, e
Halichoeres garnoti		x		c, d, e
Halichoeres maculipinna	x	x		a, c, d, e
Halichoeres pictus		x		c, d, e
Halichoeres poeyi		x		c
Halichoeres radiatus		x		c, d
Hemiramphus brasiliensis		x		f
Heteroconger longissimus		x		d
Heteropriacanthus cruentatus		x		d
Hirundichthys speculiger		x		d
Holacanthus bermudensis		x		d
Holacanthus ciliaris		x		c, d
Holacanthus tricolor		x		c, d, e
Holocentrus adscensionis		x		c, d, e
Holocentrus rufus		x		c, d, e

Scientific Name	*Mangrove*	*Canyon Walls*	*Pelagic FAD*	*References Cited*
Hypoplectrus chlorurus		x		d, e
Hypoplectrus guttavarius		x		d, e
Hypoplectrus indigo		x		d
Hypoplectrus nigricans		x		d, e
Hypoplectrus puella		x		d, e
Hypoplectrus unicolor		x		c, d, e
Inermia vittata		x		c, d, f
Katsuwonus pelamis			x	b
Kyphosus sectatrix/incisor		x		d, e
Labrisomus nuchipinnis	x			a
Lachnolaimus maximus		x		d
Lactophrys bicaudalis		x		c, d, e
Lactophrys triqueter		x		c, d, e, f
Liopropoma carmabi		x		d
Liopropoma rubre		x		c, d
Lucayablennius zingaro		x		c, d
Lutjanus analis	x	x		a, c, d, e
Lutjanus apodus	x	x		a, c, d, e
Lutjanus griseus	x	x		a, d
Lutjanus jocu	x			a
Lutjanus mahogoni	x	x		a, c, d, e
Lutjanus synagris	x	x		a, d
Malacanthus plumieri		x		d
Malacoctenus triangulatus		x		d
Melichthys niger		x		d, e, f
Microgobius carri		x		d
Microspathodon chrysurus	x	x		a, d, e
Monacanthus tuckeri		x		c, d
Mugil curema	x			a
Mulloidichthys martinicus	x	x		a, c, d, e
Mycteroperca bonaci		x		d
Mycteroperca interstitialis		x		d
Mycteroperca tigris		x		d
Mycteroperca venenosa		x		d
Myripristis jacobus		x		c, d, e
Neoniphon marianus		x		c, d, e
Nicholsina usta	x			a
Ocyurus chrysurus	x	x		a, c, d, e, f
Odontoscion dentex	x	x		a, c, d
Ophioblennius atlanticus		x		d
Opistognathus aurifrons		x		c, d
Paradiplogrammus bairdi		x		d

Scientific Name	*Mangrove*	*Canyon Walls*	*Pelagic FAD*	*References Cited*
Paranthias furcifer		x		d
Phaeoptyx conklini		x		c
Phaeoptyx pigmentaria		x		d
Phaeoptyx xenus		x		d
Platax orbicularis	x			a
Plectrypops retrospinis		x		d
Pomacanthus arcuatus		x		c, d, e
Pomacanthus paru	x	x		a, c, d, e
Priacanthus cruentatus		x		c
Priolepis hipoliti		x		c
Pseudupeneus maculatus		x		c, d, e
Ptereleotris calliurus		x		d
Ptereleotris helenae		x		c, d
Remora remora		x		d
Risor ruber		x		d
Rypticus bistrispinus		x		d
Rypticus saponaceus		x		c, d, e
Sargocentron coruscum		x		c
Sargocentron vexillarium		x		c, d
Scarus coeruleus		x		d
Scarus guacamaia		x		c, f
Scarus iserti	x	x		a, c, d, e
Scarus taeniopterus		x		c, d, e
Scarus vetula	x	x		a, c, d, e
Scomberomorus cavalla		x		f
Scomberomorus regalis		x		b, c, d, e, f
Scorpaena plumieri		x		c, d
Seriola dumerili		x		d
Serranus baldwini		x		c, d
Serranus tabacarius		x		c, d, e
Serranus tigrinus		x		c, d, e
Serranus tortugarum		x		d
Sparisoma atomarium		x		c, e
Sparisoma aurofrenatum	x	x		a, c, d, e
Sparisoma chrysopterum	x	x		a, c, d, e
Sparisoma radians	x			a
Sparisoma rubripinne	x	x		a, d, e
Sparisoma viride	x	x		a, c, d, e
Sphoeroides spengleri	x	x		a, c, d
Sphoeroides testudineus	x			a
Sphyraena barracuda	x	x	x	a, b, c, d, e, f
Sphyraena picudilla		x		d

Scientific Name	*Mangrove*	*Canyon Walls*	*Pelagic FAD*	*References Cited*
Stegastes adustus	x	x		a, c, d, e
Stegastes diencaeus		x		c, d
Stegastes leucostictus	x	x		a, d, e
Stegastes partitus	x	x		a, c, d, e
Stegastes planifrons		x		c, d, e
Stegastes variabilis	x	x		a, d
Synodus intermedius		x		c, d, e
Thalassoma bifasciatum		x		c, d, e
Thunnus atlanticus			x	b
Tylosurus crocodilus		x	x	b, d
Xyrichtys splendens		x		c, d

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Appendix E. Mapping Field Notes and Bathymetry Measurements from Sites Visited During Ground Truth Activities

Site	*Longitude*	*Latitude*	*Depth (m)*	*Field Notes*
1	-64.754959	17.775354	0.9	continuous seagrass
2	-64.755575	17.775571	1.3	seagrass
4	-64.753864	17.776698	2	
5	-64.754026	17.777177	1.1	
6	-64.753510	17.777275	0.7	Thalassia (seagrass)
7	-64.752949	17.777316	0.9	Halimeda (algae)
8	-64.757206	17.777837	1.8	
9	-64.757500	17.778006	0.4	
10	-64.757503	17.778358	0.5	seagrass
11	-64.755971	17.778615	1.6	
12	-64.755939	17.779168	1.7	
13	-64.753091	17.779637	0.7	
14	-64.754529	17.779647	1.8	
15	-64.754276	17.779749	1.5	Thalassia & Syringodium (seagrass)
16	-64.758710	17.780025	2	
17	-64.758293	17.780294	2.5	
18	-64.757053	17.780513	2	
19	-64.753441	17.772506	0.02	benthic: algae mat, Rhizophora mangle (red mangrove)
20	-64.758675	17.770331		mud
21	-64.759827	17.772779	0.7	algae
22	-64.759638	17.773741		seagrass
23	-64.752188	17.774306		algae
24	-64.756236	17.774937		continuous seagrass
25	-64.753257	17.775287	1.6	10-90% algae
26	-64.754073	17.775504		10-90% algae, seagrass approx 20 m NE
27	-64.758532	17.775824		algae shallower than 2 m, mud deeper
28	-64.754830	17.776538		algae
29	-64.754356	17.776697	1.9	algae
30	-64.754058	17.777643		seagrass
31	-64.759067	17.777738		seagrass
33	-64.753208	17.779056	2	seagrass
34	-64.758443	17.779335		seagrass wrack

Site	*Longitude*	*Latitude*	*Depth (m)*	*Field Notes*
35	-64.758728	17.779361		scattered bedrock
36	-64.757406	17.780485		Thalassia & Syringodium (seagrass)
38	-64.755772	17.780596	2.5	rubble patches with some seagrass
39	-64.754481	17.780716		live patch reef with wood planks and seagrass around margins
40	-64.756538	17.780948		mostly dead elkhorn, with seagrass growing on top. Some live coral
41	-64.757972	17.780993		patch reef or colonized bedrock
44	-64.757021	17.781306		large live elkhorn & dead and down coral
45	-64.757411	17.781320		algae
46	-64.758591	17.781442		sand
51	-64.756524	17.782275		scattered coral
54	-64.751322	17.782474		reef rubble
55	-64.751390	17.782712		seagrass ring. Approx 30 m E is also seagrass
58	-64.751537	17.782998		reef rubble
59	-64.749426	17.783171		reef rubble to bedrock @ point of land
60	-64.751209	17.783427		reef rubble from beach to just beyond breakers
61	-64.749187	17.783567		from cliff looks like bedrock
62	-64.748040	17.783890		from cliff looks like bedrock
63	-64.756405	17.783947		linear reef
64	-64.757508	17.785768		no algae/sg - patch reef
68	-64.756897	17.787760		reef with sand channels not oriented in any direction - patch reef?
69	-64.751274	17.787810		patches of dark red encrusting sponge
70	-64.756130	17.788557		linear reef
71	-64.747274	17.790327		linear reef
72	-64.750097	17.790987		no spur and groove. Linear reef
73	-64.749775	17.791391		linear reef
74	-64.748485	17.791911		not spur and groove
75	-64.758832	17.771059	0.6	algae shallower than 2 m, mud deeper
76	-64.759481	17.771279	0.7	no sand, no mangrove at adjacent land
77	-64.759619	17.772709	2.2	algae shallower than 2 m, mud deeper
79	-64.759453	17.773341	1.4	
80	-64.758057	17.773415	1.6	algae shallower than 2 m, mud deeper
81	-64.759133	17.773904	1.5	
82	-64.753304	17.774504	0.8	10-90% alage
83	-64.757242	17.774584	1.8	15m West is seagrass. Point is seagrass/algae mix 10-90%
84	-64.758466	17.775028	3.3	

Site	*Longitude*	*Latitude*	*Depth (m)*	*Field Notes*
85	-64.753901	17.775091	2.1	algae shallower than 2 m, mud deeper
86	-64.757176	17.775130	2.6	algae shallower than 2 m, mud deeper
87	-64.756494	17.775390	2	algae
88	-64.758248	17.775654	3	
90	-64.756532	17.775863	3.8	mud
92	-64.759861	17.777175	0.2	sand w/ seagrass around margins of water.
93	-64.752717	17.777357	1	seagrass/algae mix 10-90%
94	-64.755250	17.777546	4.5	
95	-64.751063	17.777695	2.5	mud
96	-64.750914	17.777843	2.3	mud
97	-64.750800	17.777973	2.3	mud
98	-64.755562	17.778067	4.3	
99	-64.755824	17.778114	4.5	sand. Northward goes to algae to algae/seagrass to seagrass
100	-64.756584	17.778129	2.1	mostly seagrass. Some algae
101	-64.752628	17.779653	0.8	algae
102	-64.756676	17.779878	1.8	mostly thalassia (seagrass)
104	-64.758291	17.780506	2.5	syringodium (seagrass)
105	-64.751275	17.779468	1.6	mangrove is Rhizophora mangle
106	-64.764084	17.763439		paved
107	-64.756162	17.764636		pt is paved.
108	-64.760123	17.765373		black mangrove
109	-64.750215	17.765928		was shrubs, now forest. Bare soil area is gone
110	-64.761631	17.766059		forest from rd to 17.76611 64.76147. Point is in forest.
111	-64.761115	17.768437		Likely paved. Abandoned car is blocking road
112	-64.755584	17.768885		paved, sorta
113	-64.754933	17.768898		Point is in forest. Rd. is paved
114	-64.760689	17.769132		Paved. Switches to gravel @ 17.77092 64.76176
115	-64.757781	17.769690		Fringe is mixed black and white approx 3 m wide
116	-64.759840	17.770016		Blk mangrove from water to 2m in. Point is not in mangrove
117	-64.760952	17.770145		forest
118	-64.752320	17.771944		black around fringe. Upland is forest
120	-64.756636	17.772304		Point is not paved. Switches from paved to gravel at 17.77028 64.75583
121	-64.754117	17.772706		Black from pond, north to road. Road is gravel.
122	-64.760328	17.772914		No mangrove at point or to road.
123	-64.759964	17.773547		No mangrove at point or to road.

Site	*Longitude*	*Latitude*	*Depth (m)*	*Field Notes*
124	-64.760582	17.774408		Unpaved
125	-64.751547	17.775103		Red mang around pond interspersed w/dead. Red along beach on bay side. White fringe along path to bay.
126	-64.763411	17.775103		Paved
127	-64.762432	17.775362		Unpaved (dark gravel)
129	-64.761523	17.776355		Unpaved (gravel). Switches to paved at 17.77683 64.76144
130	-64.750957	17.776695		Forest
131	-64.751000	17.777075		Vegetated field with some scattered shrubs
132	-64.750396	17.777286		Shrubs
133	-64.749274	17.777873		Switches from unpaved to paved away from the water
135	-64.760842	17.777978		Sparse forest just W of corner. Vegetated field at corner. Rd. is unpaved
136	-64.759560	17.778142		Point is in forest. But along road on both sides is black and white mangroves
137	-64.761711	17.778458		Vegetated field
138	-64.749630	17.778503		Shrubs
139	-64.760653	17.778532		Point is in sparse forest in vegetated field. Bushes along road.
140	-64.758511	17.778856		Vegetated field mixed with bushes.
141	-64.759400	17.778877		Unpaved
142	-64.750125	17.779041		vegetated field, was probably dead grass before
143	-64.749472	17.779724		Shrubs without leaves in vegetated field. Rd. is paved
144	-64.751342	17.780001		Point is in shrubs. Toward road is vegetated field.
145	-64.750960	17.780446		Shrubs without leaves in vegetated field.
146	-64.750707	17.780920		Trees bordered by shrubs without leaves
147	-64.747780	17.781190		Point is in shrubs. Road is paved.
148	-64.747426	17.781203		Shrubs interspersed with bare areas.
149	-64.752124	17.781409		Forest
150	-64.760235	17.764871		Upland forest
151	-64.760008	17.765765		Black mangrove on both sides of trail & around pond. White along road.
152	-64.761429	17.766028		Pt. is in black mangrove. From pt to rd. is also black. Lots of land crabs
153	-64.760718	17.766065		black mangrove
154	-64.760539	17.766911		black and white mixed
155	-64.759401	17.767305		white along dike
156	-64.760809	17.767339		point is in upland forest
157	-64.757336	17.767804		point is in forest, but black mangrove frings on land side of dead zone
158	-64.758797	17.767870		black mangrove fringe approx 4 m wide to upland forest transition

Site	*Longitude*	*Latitude*	*Depth (m)*	*Field Notes*
159	-64.760289	17.768165		Mostly white mangrove. Forest is approx 6 m wide along road.
160	-64.760096	17.769472		Point is on edge of mangrove/forest interface. From pt to water is black mangrove.
161	-64.759515	17.769904		Red is approx 3 m wide, switches to black and white mixed
162	-64.759635	17.769932		mostly black, mixed w/white.
163	-64.752715	17.771367		Red mangrove
164	-64.752603	17.771400		Red mangrove along fringe. No black or white
165	-64.758573	17.771433		Point is on red to black transition.Red along shore.
166	-64.758383	17.771495		Point is in black mangroves
167	-64.760317	17.771795		Red mangroves
168	-64.760167	17.771849		Red mangrove from point toward N. South along water there are no mangroves at all.
169	-64.753484	17.772256		Red mangrove. Black on fringe on W side of bare area
170	-64.754080	17.772416		All black mangrove around pond. Bare area is sand
171	-64.757450	17.772518		Black mangrove approx 10 m wide along fringe
172	-64.751928	17.772787		Black mangrove
173	-64.752738	17.772912		Red mangrove along water.
174	-64.753808	17.773214		Red mangrove fringe approx 8 m wide. Switches to sparse black
175	-64.760145	17.773355		Red mangrove
176	-64.751990	17.773389		Pt is on transition from red to white mang. No black mangrove
177	-64.757582	17.773403		Red mangrove along water. Switch to black mangrove around pond
178	-64.752032	17.774177		Pt. is on transition from blk mangrove to forest. Water's edge is red mangrove.
179	-64.754381	17.774457		Red mangrove.
180	-64.757056	17.774691		No mangrove or dead mangrove. Bedrock
181	-64.760783	17.775357		White mangrove along marina road about 3 m wide. Red from water to white mangrove.
182	-64.759795	17.775370		Point is at red mangrove. White fringe along road approx 3 m wide.
185	-64.751331	17.775675		Red mang.around margin of pond, some dead. Along path is 3 m fringe of white, red along beach at bay side.
186	-64.759522	17.775794		No mangrove around path to water
187	-64.759329	17.775925		Red mangrove by water
190	-64.759409	17.777971		Red mangrove from beach to 17.77802 64.75931
191	-64.758688	17.778137		Red mangrove from beach to about 7-10 m inland
193	-64.750368	17.778823		Red mangrove
194	-64.751707	17.780146		Not mangrove
195	-64.752576	17.781166		White mangrove 2-3 m toward land from water. Red and white mixed all the way around pond.

Appendix F. List of Data Products From This Project Available From NPS

Product Description	***Format (s)***
Aerial Photographs	hard copy prints, hard copy diapositives, digital
1970's Orthorectified Mosaic	imagine file
1988 Orthorectified Mosaic	imagine file
1992 Orthorectified Mosaic	imagine file
2000 Orthorectified Mosaic	imagine file
1970's map of seagrass and mangrove distribution	GIS shapefile
1988 map of seagrass and mangrove distribution	GIS shapefile
1992 map of seagrass and mangrove distribution	GIS shapefile
2000 map of benthic and land cover	GIS shapefile
Bathymetry Grid	grid file

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Carlos M. Gutierrez
Secretary

National Oceanic and Atmospheric Administration

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Under Secretary of Commerce for Oceans and Atmosphere

National Ocean Service

Richard W. Spinrad
Assistant Administrator for Ocean Service and Coastal Zone Management

United States Department of the Interior

Gale A. Norton
Secretary

National Park Service

Fran P. Mainella
Director

Southeast Regional Office

Patricia Hook
Director