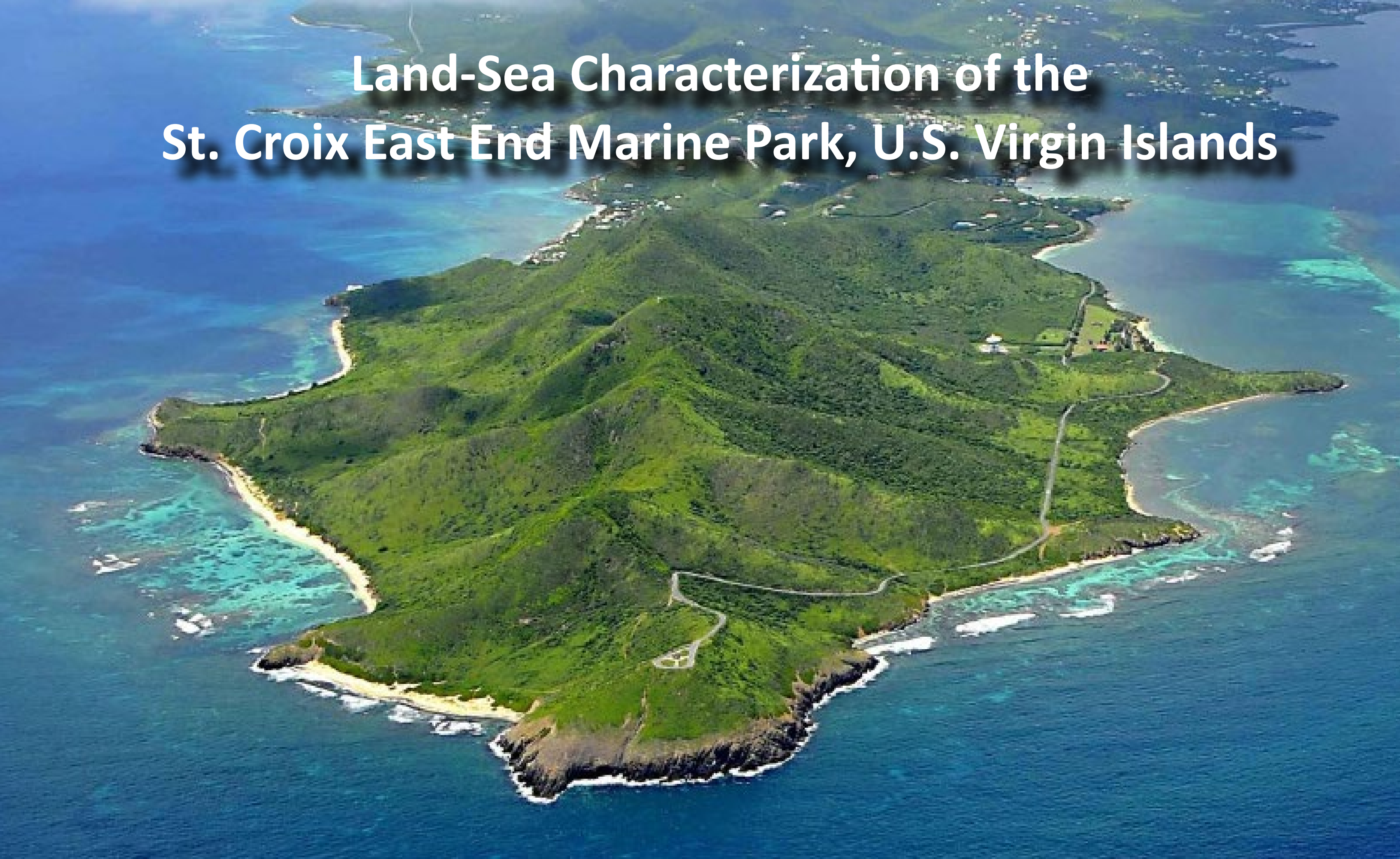
Land-Sea Characterization of the St. Croix East End Marine Park, U.S. Virgin Islands



NOAA National Centers for Coastal Ocean Science
Center for Coastal Monitoring and Assessment

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Land-sea characterization of the St. Croix East End Marine Park, U.S. Virgin Islands

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About This Document

This report provides a detailed spatial characterization of landscape and adjacent seascape condition within the St. Croix East End Marine Park (STXEEMP). This characterization is presented to highlight the potential influence of landscape patterns on nearshore coral reef ecosystems and to document the diversity, condition and composition of biological communities within each of the distinct park zones. The data includes new field data collected as part of this project to address a data gap on marine communities, particularly for the southern portion of the park. This synthesis is intended to support local management priority setting for conservation of coral reef ecosystems by identifying and mapping potential threats to coral reef health from land-based sources of pollution and also to help managers and the local community develop a more detailed understanding of the types, variety and condition of marine flora and fauna within the park.

The information was compiled as a contribution to the project "Land-sea characterization of STXEEMP to evaluate zones and support management plan review" funded by NOAA Coral Reef Conservation Program (CRCP). It addresses the CRCP goal to improve the use and effectiveness of marine protected areas (MPAs) by conducting science in support of MPA design and adaptive management.

Related report:

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

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Executive Summary

Photo courtesy of NOAA/NOS/NCCOS/CCMA Biogeography and U.S. Army Corps of Engineers

Executive Summary

BACKGROUND

The St. Croix East End Marine Park (STXEEMP) was established in 2003 as the first multi-use marine park managed by the U.S. Virgin Islands Department of Planning and Natural Resources. It encompasses an area of approximately 155 km^2 and is entirely within Territorial waters which extend up to 3 nautical miles from shore. As stated in the 2002 management plan, the original goals were to: protect and maintain the biological diversity and other natural values of the area; promote sound management practices for sustainable production purposes; protect the natural resource base from being alienated for other land use purposes that would be detrimental to the area's biological diversity; and to contribute to regional and national development (The Nature Conservancy, 2002). At the time of its establishment, there were substantial data gaps in knowledge about living marine resources in the St. Croix, and existing data were inadequate for establishing baselines from which to measure the future performance of the various management zones within the park.

In response to these data gaps, National Centers for Coastal Ocean Science (NCCOS), Center for Coastal Monitoring and Assessment, Biogeography Branch (CCMA-BB) worked with territorial partners to characterize and assess the status of the marine environment in and around the STXEEMP and land-based stressors that affect them. This project collected and analyzed data on the distribution, diversity and landscape condition of marine communities across the STXEEMP. Specifically, this project characterized (1) landscape and adjacent seascape condition relevant to threats to coral reef ecosystem health, and (2) the marine communities within STXEEMP zones to increase local knowledge of resources exposed to different regulations and stressors.

METHODS

We analyzed data on land cover and the distribution of dirt roads for use as proxy variables to characterize spatial patterns in land-based stressors that could correlate with observed distribution patterns of benthic habitats, coral reef sea floor "benthic" composition, and reef fish assemblages. Near-shore areas where impacts from land based sources of pollution were greatest were highlighted as watershed impact zones. These watershed impact zones were then classified to indicate where impacts were likely to be most intense.

We also analyzed GIS and field-based data on the distribution of marine habitats, benthic composition, and fish species assemblages to characterize watershed impact zones and management zones within the STXEEMP. GIS data on benthic habitats were digitized from high resolution aerial photographs (Kendall et al., 2002). In situ data on benthic composition and fish assemblages were collected by NOAA NCCOS Coral Reef Ecosystem Monitoring Project (2002-2010), and also as part of this project (2009-2010). We also reviewed published literature to identify and select coral species that were likely to be sensitive to land-based sources of pollution. Presence-absence data (i.e., observed in situ locations) of these sensitive species were analyzed to determine if their spatial patterns correlated with spatial patterns in land-based stressors.

MAJOR FINDINGS AND RECOMMENDATIONS:

Landscape -seascape linkages

- There were significant differences in the distribution and composition of benthic habitats among low, medium, and high watershed impact zones. Coral reef and hardbottom habitat types had greater extents (acreage) in medium and low impact zones than in high impact watershed zones.

- A management prioritization strategy based on information from this report should be developed to begin identifying direct causes of poor water quality in areas with priority marine communities with ESA listed acroporid corals, diverse coral reef, and areas with high potential to increase coral diversity. Areas identified as having high density of dirt roads and high Landscape Development Index (LDI) should be managed specifically to limit and reduce development of dirt roads and highly impervious surfaces, to reduce sediment and storm water run-off. Sediment run-off from dirt roads will negatively impact corals communities, and high levels of storm run-off are likely to increase land-based sources of pollution (LBSP), and thereby negatively impact the goals of the STXEEMP.

- The areas up-slope of the watershed impact zones which are identified as containing sensitive species should be managed to insure that conditions in these environments are sustainable. Our analyses highlighted greatest potential impact to water quality for Yellowcliff and Coakley Bays and Teague and Knight Bays on the northshore; and Robin and Great Pond Bays on the southshore. Yellowcliff, in particular, supports nearshore coral reefs with a high number of sensitive coral species, including Acropora palmata and high fish species richness.

- Regular monitoring of benthic habitats and critical species should be implemented in order to create an adaptive management process relative to the goals and targets of the management plan. Permanent monitoring sites should be established at coral hotspot areas (i.e., cluster of high coral cover sites), such as the fringing reef along the north shore, to monitor the impact of water quality on coral health, abundance and community composition.

- Priority sites for benthic monitoring should include the several reefs within medium and high watershed impact zones in order to determine if LBSP are negatively impacting the natural resources of the STXEEMP.

STXEEMP zonation, biotic patterns and expectations of MPA performance

- No-Take zones were dominated by small-bodied and juvenile fishes that are not primary target species of the fishery. Habitats in No-Take areas may not offer suitable habitats for larger-bodied adult fish, which occur at highest densities in the Take Zone. This finding suggests that the current zoning design of STXEEMP will contribute only a minor role in replenishment of fished populations. Future fish surveys (i.e., five or 10 years since enforcement) will be required to determine the ecological performance of areas closed to fishing.

- Of the harvested families of fish, the STXEEMP will likely offer partial protection for grunts based on the higher densities of adult grunts in No-Take and Recreation zones. However, several species of grunt are known to forage widely and undertake ontogenetic shifts across the shelf to deeper water reefs preferred as adult habitat. For example, tagged bluestriped grunts in the U.S. Virgin Islands had mean home ranges of 14,087 $m^{2,}$ and maximum of 29,944 m^2 (Hitt et al., 2011), while a single white grunt traversed a distance of 6.2 km in a year (Friedlander et al., 2013; Pittman et al., submitted).

- No-Take zones are likely to be too small to offer adequate protection for highly mobile animals during their life history movements, and this potentially has serious implications for the effectiveness of the STXEEMP No-Take zones.

- Data collections on the macro invertebrates provided insufficient data to describe their abundance and distribution patterns. Additional data collection methods are needed to adequately survey and describe distributions and abundance of spiny lobster, sea urchins and queen conch throughout the park.

Executive Summary

Introduction

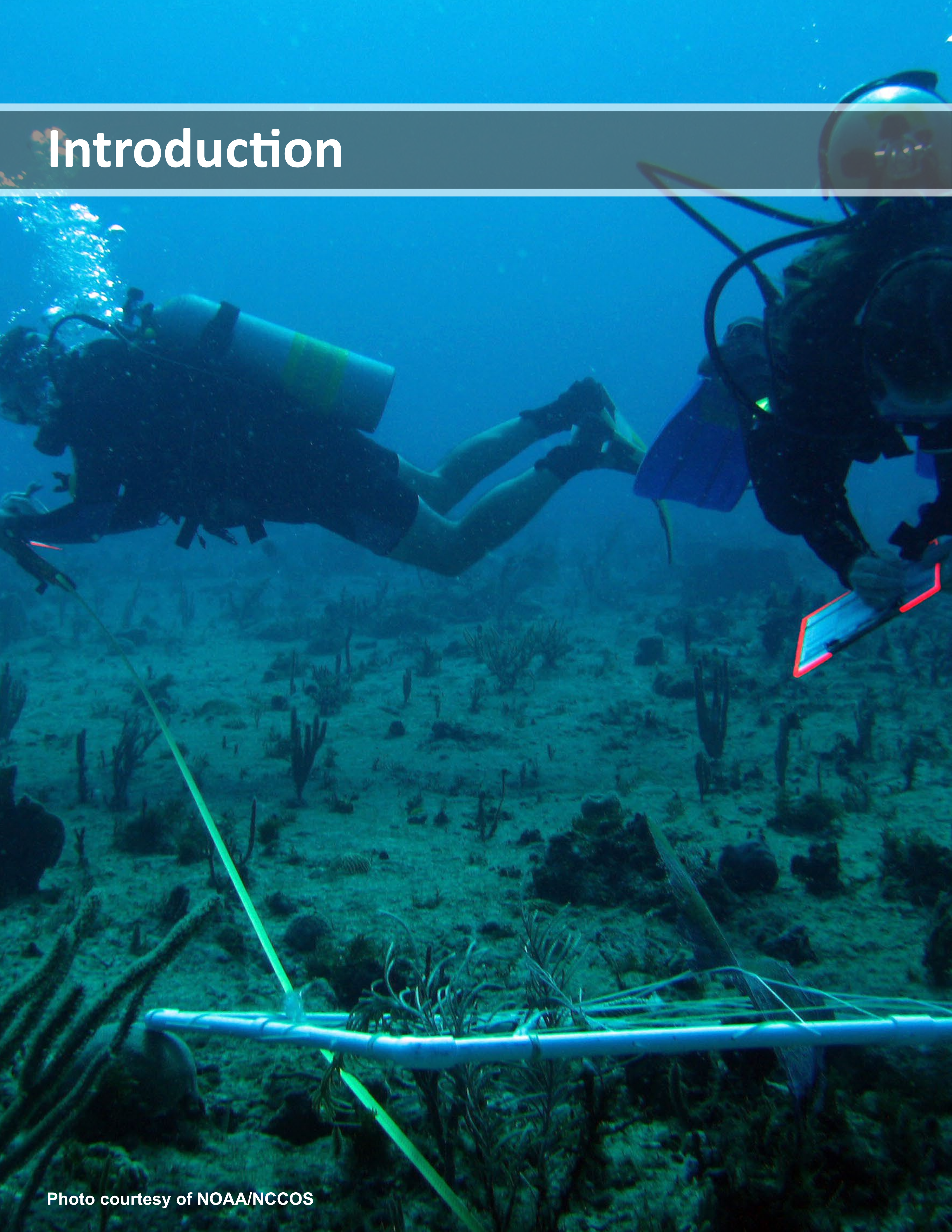


Photo courtesy of NOAA/NCCOS

Introduction

1.1 BACKGROUND

Figure 1.1. Photo of St. Croix East End Marine Park (STXEEMP). Photo credit: Friends of the St. Croix East End Marine Park.

St. Croix East End Marine Park (STXEEMP) was formally established on January 9th 2003 to become the first multi-use marine park managed by the U.S. Virgin Islands (USVI) Department of Planning and Natural Resources (DPNR), in collaboration with The Nature Conservancy (TNC) and NOAA Coral Reef Conservation Program (CRCP; Figure 1.1). The Park encompasses an area of approximately 155 km^2 and is entirely within Territorial waters up to the 3-nautical mile Territorial boundary. It is therefore under the jurisdiction of the USVI Government where it forms a major element of the U.S. Virgin Islands Coral Reef Initiative in response to the National Action Plan to Conserve Coral Reefs. According to the first management plan, the goals of the STXEEMP are to: protect and maintain the biological diversity and other natural values of the area; promote sound management practices for sustainable production purposes; protect the natural resource base from being alienated for other land use purposes that would be detrimental to the area's biological diversity; and to contribute to regional and national development (The Nature Conservancy, 2002).

The Park has four main types of managed areas, or zones, with regulations intended to provide protection for territorially significant marine resources, to promote sustainability of marine ecosystems and preserve significant natural areas for the use and benefit of future generations. The types of management areas include: No-Take zones, a Turtle Wildlife Preserve Zone, Recreation Zones, and large areas open to fishing. The No-Take, Wildlife Preserve and Recreational zones were established to ensure the protection of Park resources (The Nature Conservancy, 2002). The placement of Park boundaries and classification of zone types was designed based on known areas of high priority for protection, some of which were existing Areas of Particular Concern (APCs; Island Resources Foundation, 2002). The designation of STXEEMP unified and extended the APCs of Great Pond Bay, Jack Bay-Isaac Bay, Point Udall and Coakley Bay into one Territorial Marine Park that was considered to "represent healthy nearshore habitats which are likely to interact with Lang Bank, part of the most extensive coral reef system on the Puerto-Rican/Virgin Islands shelf." The process was guided by local community workshops, a review of literature on the biological resources, and the NOAA benthic habitat map released in 2001. Workshop participants considered current resource use, presence of sensitive marine habitat, connectivity between different habitat types, and presence of threatened species as the primary factors when designating these areas. Fishermen participating in the community workshops identified the two proposed No-Take areas as light fishing areas and agreed that these areas would be appropriate as No-Take zones.

At the time of park planning, however, substantial data gaps existed, with most priority sites having either no information available on fish, benthos, and human/natural impacts, or only general descriptions (Island Resources Foundation, 2002). Underwater surveys of marine communities were few and did not provide a comprehensive spatial coverage for the entire management area. In particular, very little was known about the southeast corner of St Croix. This also meant that no adequate data were available to establish an ecological baseline from which to measure the future performance of STXEEMP zones for their intended purpose to protect, replenish and sustain healthy populations of key species, habitats and biodiversity. Such information is required to support the adaptive management of STXEEMP and will be essential to inform the management plan review process and the review of park rules and regulations which is mandated to take place at 5 year intervals (Virgin Islands Code 12 V.I.C. Section 98(d)(3)).

Introduction

The Park management plan recognizes three primary types of threat to the health of marine biological communities: incompatible upland development, recreation impacts and incompatible fishing practices. The land that borders the Park is entirely within the coastal zone (first tier); therefore, any development activity is subject to approval by the Virgin Islands Coastal Zone Commission. Previous research has determined that development of the watersheds that feed into STXEEMP has resulted in increased runoff of terrestrial soils and freshwater into the park (WRI, 2006; Oliver, 2011). Geographical patterns of predicted erosion suggest that the eastern half of St. Croix is more seriously impacted than the west. The eastern half is also where considerable long-term investments have been made to protect coral reef ecosystems through establishment of marine protected areas (MPAs) by Federal and Territorial governments supported by non-governmental organizations and community groups. In response to concerns about impacts from land-based sources of pollution, NOAA has funded projects to reduce soil erosion and runoff and better manage watersheds for coral reef ecosystem health. The previous suite of projects focused on tackling problems on land to support management decision making had not investigated proximity and potential impact to sensitive marine communities. This project addresses an information gap on the distribution, diversity and condition of marine communities across the STXEEMP and highlights areas where landscape condition may negatively impact and pose a threat to seascape condition and the ecological performance of STXEEMP.

1.2 OBJECTIVES

This project will ensure that STXEEMP managers have the best available high quality, spatially accurate and comprehensive biophysical and ecological data to evaluate management practices and zoning strategies and identify threats to marine ecosystem health to support effective management prioritization and inform the management plan review process. The information will allow managers to determine if existing zones will be likely to meet the objectives for which they were designated and determine if important priority areas exist outside of the existing zones (Figure 1.2). The identification of potential threats from watershed development relative to priority marine species/habitats will help prioritize conservation actions for land and sea. For instance, if a high density of *Acropora* colonies or a coral diversity hotspot exists in close proximity to a watershed with high development, then this will be highlighted as an area of concern. If the abundance of priority fished species is considerably higher in fishable areas than in no-take zones then alternative strategies may be required to achieve objectives for conserving priority species. In general, the use of spatially explicit biological data will support ecologically meaningful decision making in future management actions, establish baselines from which to measure performance, help target monitoring efforts and support educational needs. This project provides information to support implementation of the Fishery Local Action Strategy developed by DPNR in collaboration with staff from NOAA National Marine Fisheries Service (NMFS), NOAA CRCP, TNC, National Park Service and others.

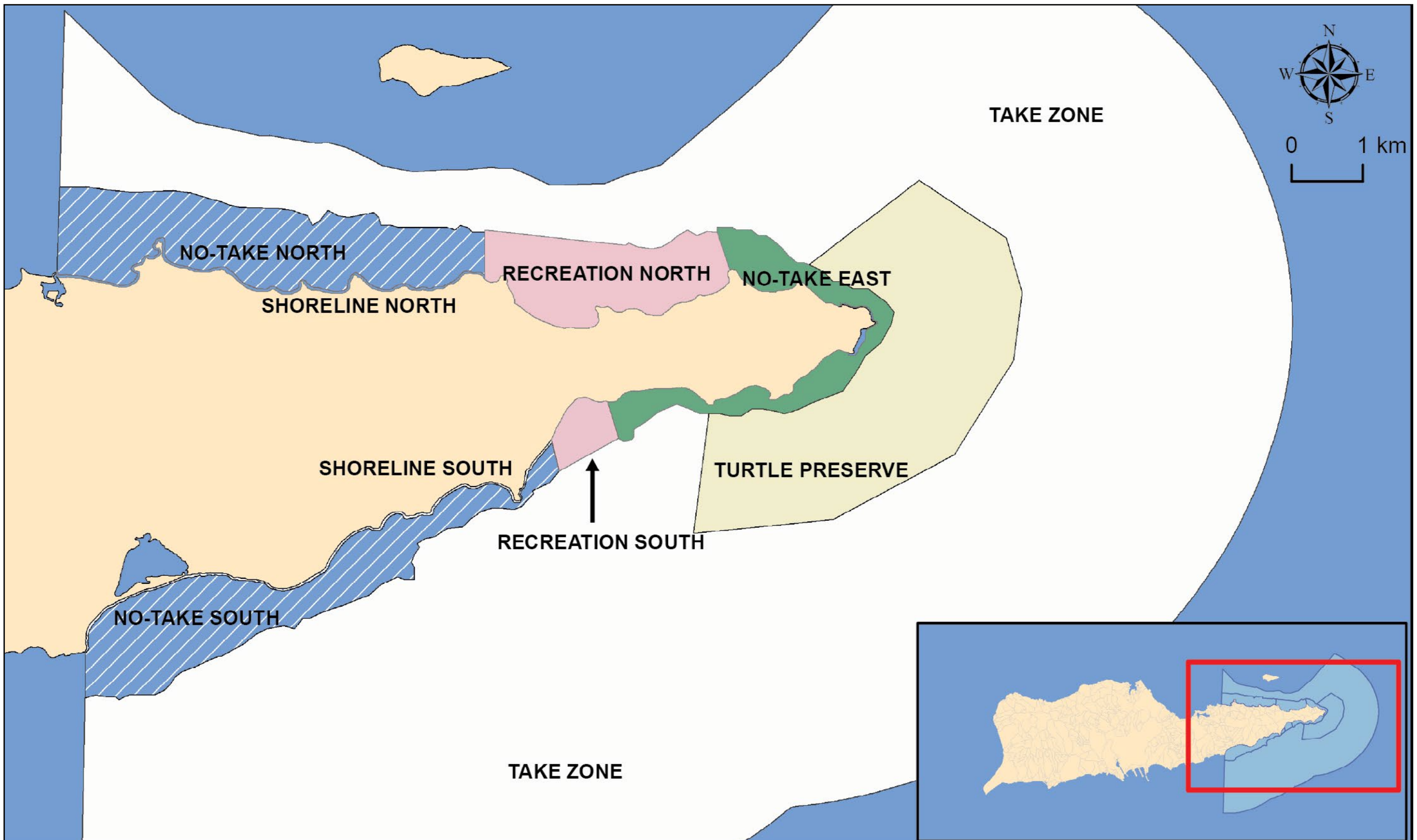
Primary objectives:

1. Characterize landscape and adjacent seascape condition relevant to threats to coral reef ecosystem health from terrestrial runoff around STXEEMP
2. Characterize the marine communities within STXEEMP zones to increase local knowledge of resources exposed to different regulations and stressors

The project also supports development and application of several CRCP programmatic performance measures (http://coralreef.noaa.gov/aboutcrcp/howwework/resources/crcp_perf-measures.pdf) including:

1. Establishing baselines for future comparison of fish biomass in STXEEMP zones to address CRCP Performance Measure F2 PM1: Stable or increasing biomass (g/m^2) of key taxa in MPAs.
2. Quantifying the amount of coral reefs and priority species inside STXEEMP zones to determine if sufficient coral reefs are being protected. This will help to establish a baseline with which to assess future performance to address CRCP Performance Measure F2 PM3: Number of acres of coral reefs effectively conserved within designated MPAs.

3. The project will provide critical information to resource managers to improve monitoring capabilities and assess effectiveness relevant to the CRCP MPA Management Assessment Checklist.



Park Wide Regulations			
• Removal, injury, or possession of any coral or live rock not allowed • Alteration or construction on the sea bed not allowed • Discharge or deposit of materials such as oil or trash not allowed • Use of a vessel in a manner that damages marine habitats not allowed • All vessels must be anchored or moored in accordance with marine park regulations • Diving without a flag not allowed • Damage or removal of markers not allowed • Commercial activity, scientific research, or other activity that involves extraction, alteration, or addition requires a permit			
Turtle Wildlife Preserve Area	**No-Take Zone**	**Recreational Zone**	**Open Fishing Area**
Gill and trammel nets* not allowed Additional regulations may be implemented at a future date	Vessels longer than 150 feet not allowed Fishing not allowed Removal of, or injury to, any living marine resource not allowed Personal watercraft, airboats, and waterskiing not allowed	Recreational activities such as, but not limited to, swimming, snorkeling, diving, kite boarding, windsurfing, and boating, allowed Catch and release guide fishing allowed Cast netting to catch bait fish allowed All other traditional fishing methods not allowed	Existing territorial regulations apply Removal of coral or live rock not allowed
* In response to concerns from fishermen and fishery managers (Toller & Tobias 2007), a gill and trammel net ban began in 2006 for the USVI when Governor Charles Turnbull signed into law a revision of Title 12, Chapter 9A, Section 321-1 of the VI Code.			

Figure 1.2. Map of zoning and table of select rules and regulations for STXEEMP. Map: S.J. Pittman.

Landscape Characterization

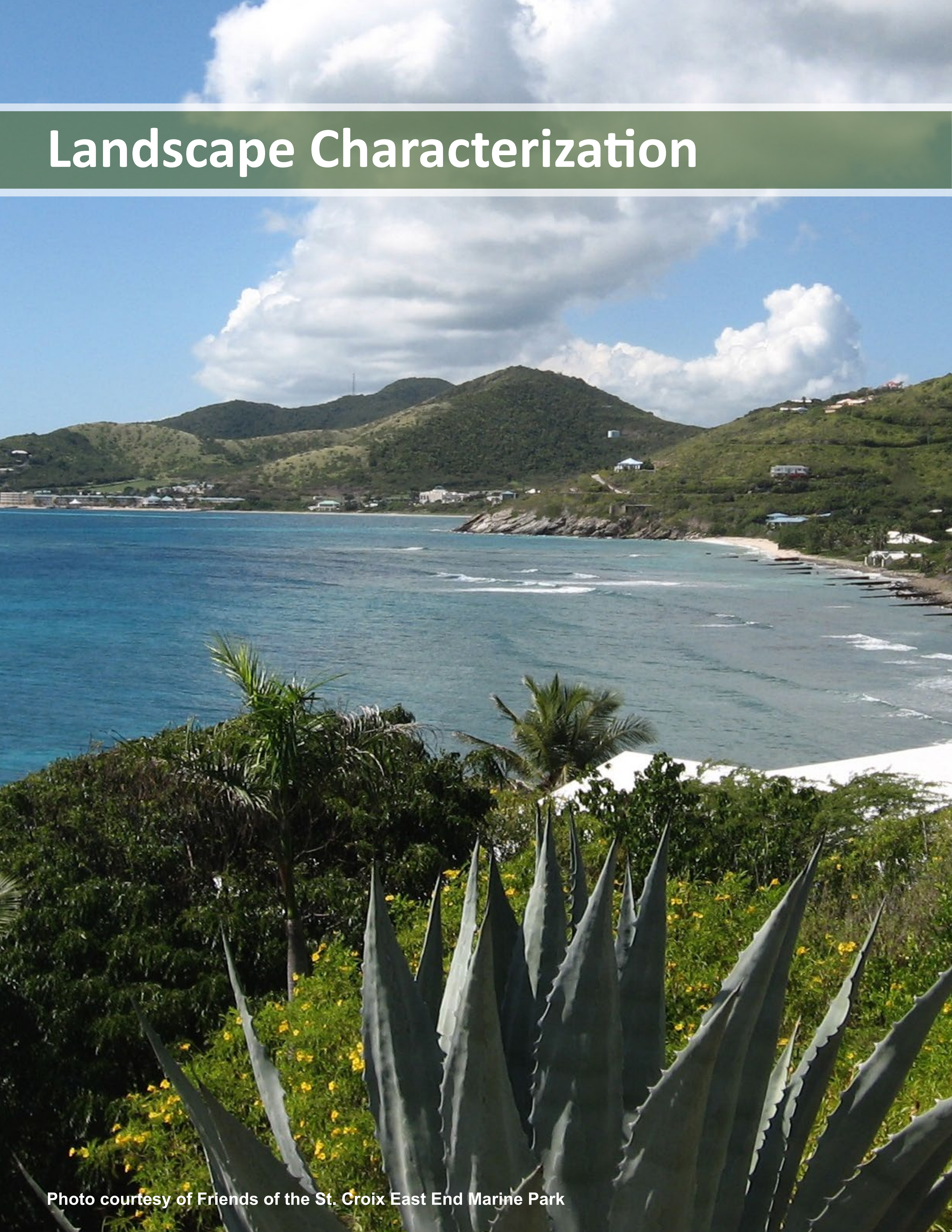


Photo courtesy of Friends of the St. Croix East End Marine Park

2.1 BACKGROUND

This section of the project seeks to highlight potential linkages between land-based sources of pollution (LBSP) and the condition of coral reef ecosystems for the STXEEMP. Alteration of the natural landscape for development, road construction, or agriculture can have adverse impacts on coral reefs through increased delivery of sediment and pollution to coastal waters. The threat associated with land clearing is higher in areas of steep relief, intense precipitation, and where soils are erosive in nature (WRI, 2006). Reporting on geographical distribution and intensity of land-based threats across the Virgin Islands is not new and this study builds on previous efforts to help managers prioritize actions and guide local action strategies. Few studies, however, have examined landscape condition and threats to coral reefs together with assessment of ecological condition of coral reef ecosystems in waters adjacent to watersheds. In this report, we quantify and map watershed condition in the landscapes in closest proximity to the STXEEMP and then examine condition relative to the patterns of marine communities and species distributions of potentially vulnerable species using a decade of underwater survey data collected by NOAA (and partners) scientific divers.

The "Reefs at Risk Revisited report", on threats to coral reef ecosystems, categorized USVI as experiencing "high" levels of exposure to threats from local human activities (Burke, 2011; Figure 2.1). This was determined using an analysis of coastal development, watershed-based pollution, marine pollution and damage, and overfishing. Threats increased even further when projected climate change stressors (sea temperature and acidification)

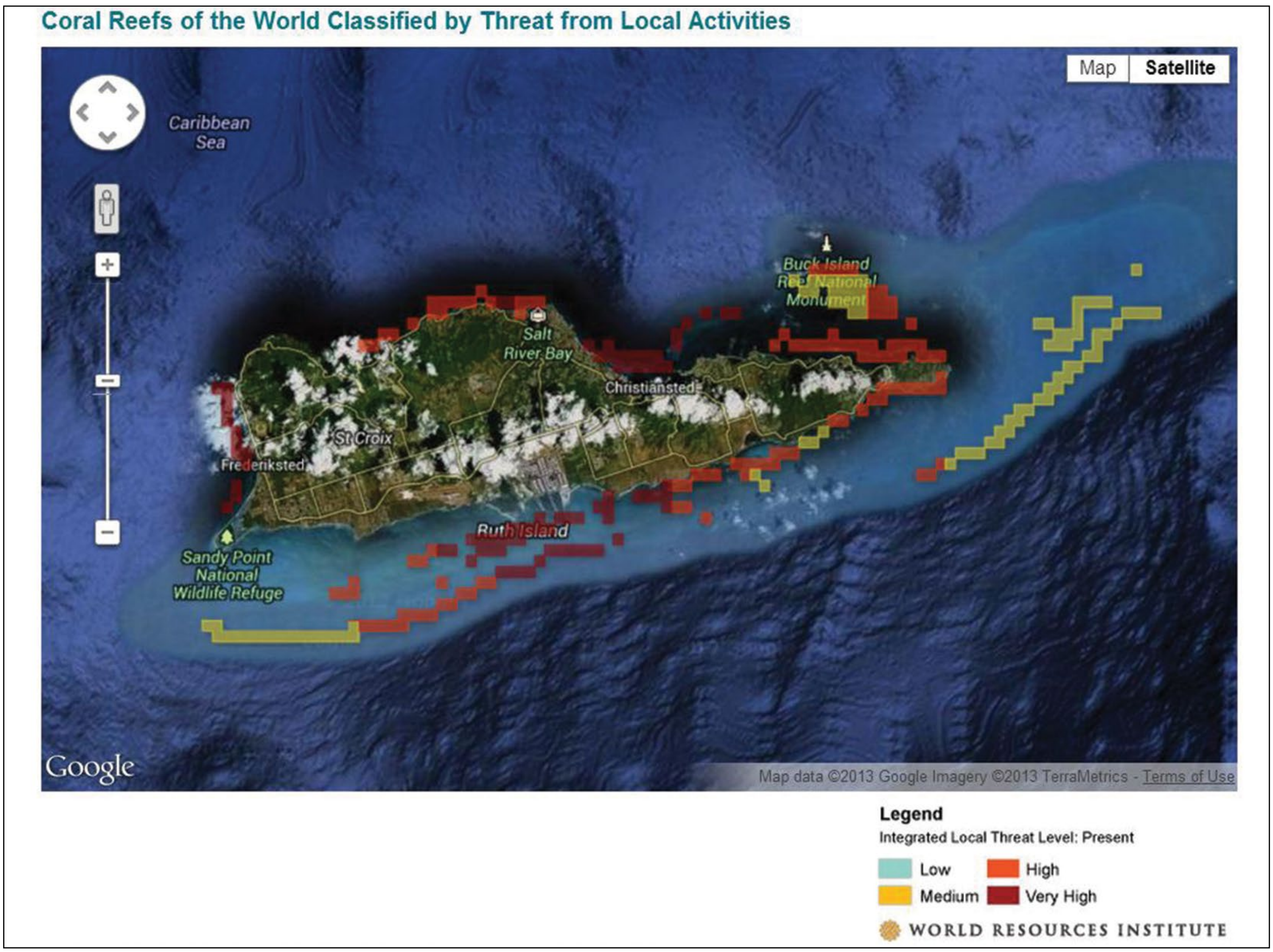


Figure 2.1. Magnitude and distribution of threats to coral reef ecosystems from accumulative local human activities. Adapted from Reefs at Risk Revisited, Burke et al., 2011. Source: Google Imagery and TerraMetrics, http://www.wri.org/publication/reefs-at-risk-revisited/global-reefs-map

were included in the risk assessment. Although the mapped threat level was a relatively coarse assessment, limited by local data availability, the World Resources Institute (WRI) also developed a report, "Land-based Sources of Threat to Coral Reefs in the USVI (WRI and NOAA, 2006)." This report analyzed both the relative erosion potential of each watershed and the estimated erosion from roads indicating that the majority of the eastern end of St. Croix had high vulnerability to land erosion (Figure 2.2).

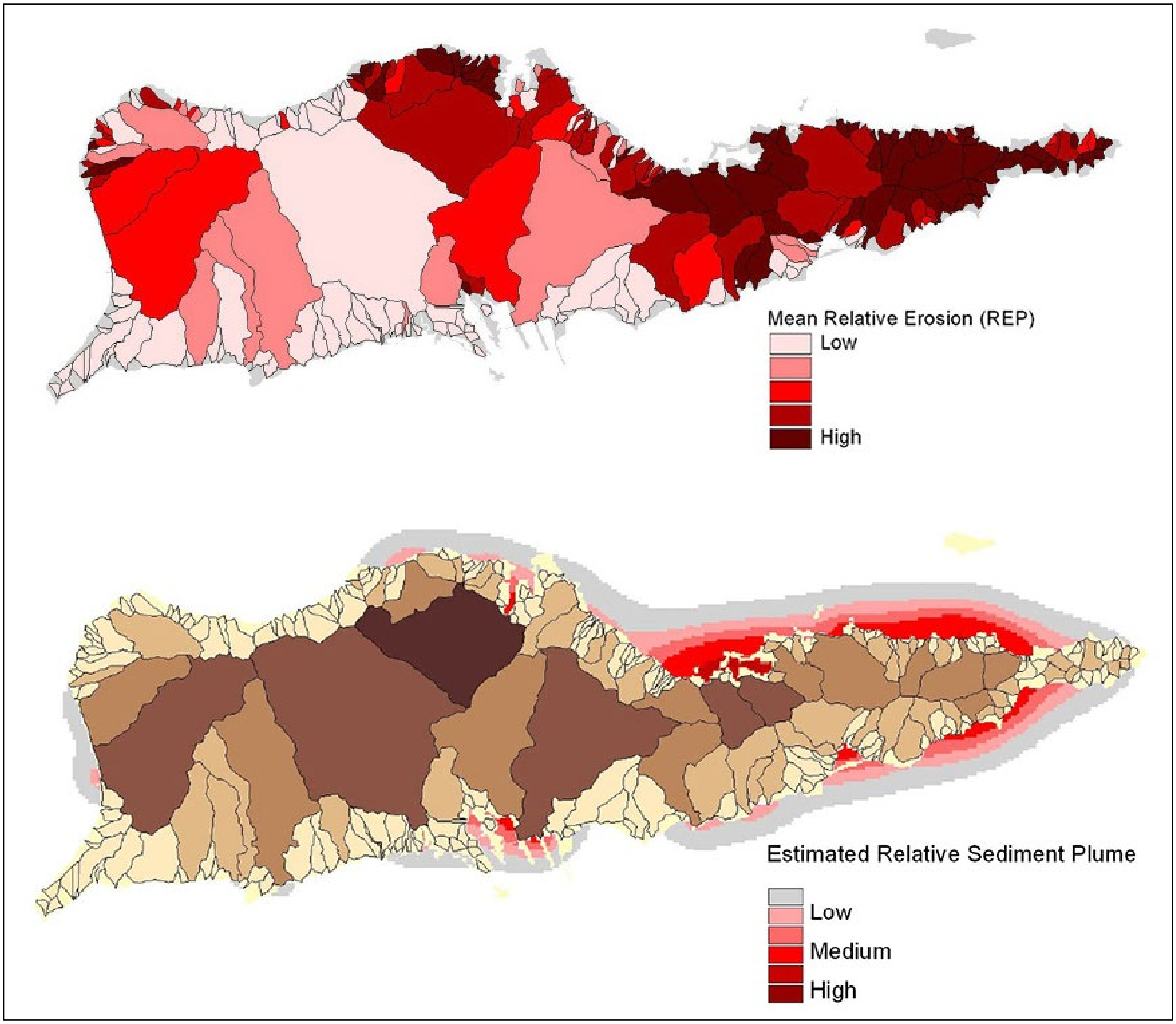


Figure 2.2. Estimated mean relative erosion potential and relative sediment plume for St. Croix highlighting highest threat to coral reef ecosystems on the East End portion of the island. Adapted from the report "Land Based Sources of Threat to Coral Reefs in the U.S. Virgin Islands" (WRI, 2006).

To address increasing concerns about watershed condition, NOAA CRCP commissioned projects by Horsley Witten Group Inc. Two reports were produced in 2011. 1) St. Croix East End Watersheds Existing Conditions Report (Horsley Witten Group, 2011a). This report identified basic watershed characteristics such as soils, rainfall, land use, and infrastructure. It also examined individual sites, the potential for reduction in land-based sources of pollution, and feasibility of implementing restoration projects. Several restoration projects are highlighted as priorities for implementation. Building on the ARRA watershed restoration activities, NOAA CRCP, DPNR, U.S. Department of Agriculture (USDA) and TNC are coordinating comprehensive watershed restoration plans for six watersheds surrounding the STXEEMP, some of which are 303(d) listed impaired waterbodies. 2) The second report is the St. Croix East End Watersheds Management Plan (Horsley Witten Group, 2011b). One of the objectives of this report was to protect marine resources by reducing the negative impacts of land-based sources of pollution by reducing sediment and nutrient loads. The St. Croix East End Watersheds Management Plan focuses on actions which can be taken on land to reduce negative impacts to marine ecosystems and natural resources. In 2011, a team of scientists with U.S. Environmental Protection Agency (EPA) related landscape development to near-shore marine ecosystem conditions (Oliver et al., 2011). This paper focused on the relationship between impervious surfaces and marine ecosystem conditions, specifically: stony coral colony density, taxa richness, coral colony size, and total coral cover. Here we adapt and apply the techniques developed by Oliver et al. (2011) and expand them to include additional variables of human disturbance and marine ecosystem condition. The current report will also make use of a decade of NOAA coral reef ecosystem biotic surveys to highlight areas of concern where human-impacted terrestrial conditions exist in close proximity to high priority marine species, habitats and biodiversity hotspots.

2.2 METHODS

The Territory of the USVI recognizes six watersheds, encompassing a total area of 3,145 ha, which make up the land adjacent to the STXEEMP(Figure 2.3a). These watersheds range in size from 807 ha for Great Pond Bay to 281 ha for Turner Hole. In order to tie LBSP directly to the conditions of coral reef ecosystems, we developed a set of finer scale analytical units. These units were developed by combining 121 catchment units from the U.S. Geological Survey's (USGS) National Hydrography Dataset (NHD). These catchment units were combined into 42 analytical units using the stream network and aerial photographs as a guide. The resulting 42 analytical units represent fine scale watersheds. These analytical units are shown overlaid on high resolution aerial photographs (Figure 2.3b) and nested within the recognized watersheds (Figure 2.3c).

One of the primary contributors to LBSP is erosion from land cover conversion. To analyze the potential contribution to sedimentation for each analytical unit we analyzed the land cover data developed in 2007 by the NOAA Coastal Service Center Coastal Change Analysis Program (Figure 2.4). Our analysis applied the Landscape Development Intensity Index (LDI) developed by the Center for Environmental Policy of the University of Florida (Brown and Vivas, 2005; Table 2.1). The LDI is intended to serve as an index of human disturbance. The LDI tracks impervious surfaces, agriculture, and other land cover types to create a value which indicates the potential of an area to contribute to LBSP (Figure 2.5). Oliver et al., (2011) were able to relate the LDI to coral reef condition along the coast of St. Croix. The researchers found that the LDI index was more robust than other indicators of human activity, exhibiting negative correlations with stony coral colony density, taxa richness, colony size, and total coral cover. They concluded that the LDI index is an effective landscape indicator of human impacts on St. Croix corals, highlighting the link between land-based human activity and marine ecosystems. Using a more recent land cover product and finer scale watershed units focused only on STXEEMP, we apply similar methods here to determine the expected contribution each analytical unit may make towards LBSP (Figure 2.5). We analyzed LDI within each watershed analytical unit, then identified areas where high LDI is likely to indicate deleterious effects on marine species and habitats.

We established a 300 meter buffer zone adjacent to each watershed analytical unit to represent the nearshore area where land based impacts are expected to be greatest. This area we call the watershed impact zone. We then identified the intensity of impact to the nearshore environment expected based on the LDI.

Landscape Characterization

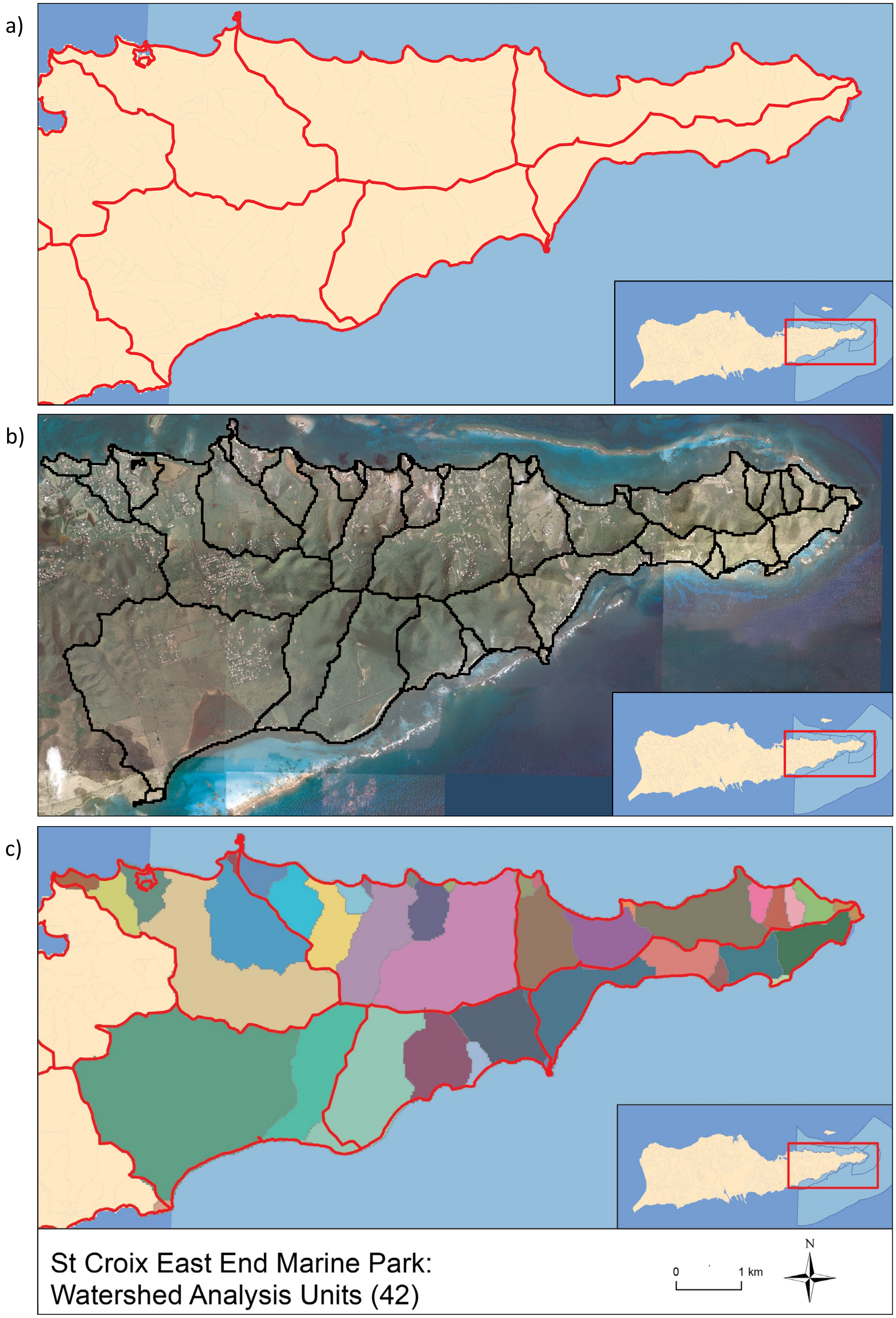


Figure 2.3. Defining watershed analysis units. Maps of a) the six watershed units conventionally used by the U.S. Virgin Islands (USVI) Territorial government; b) 42 fine scale analysis units overlaying high resolution aerial photographs; and c) fine scale analysis units shown nested within recognized watershed boundaries.

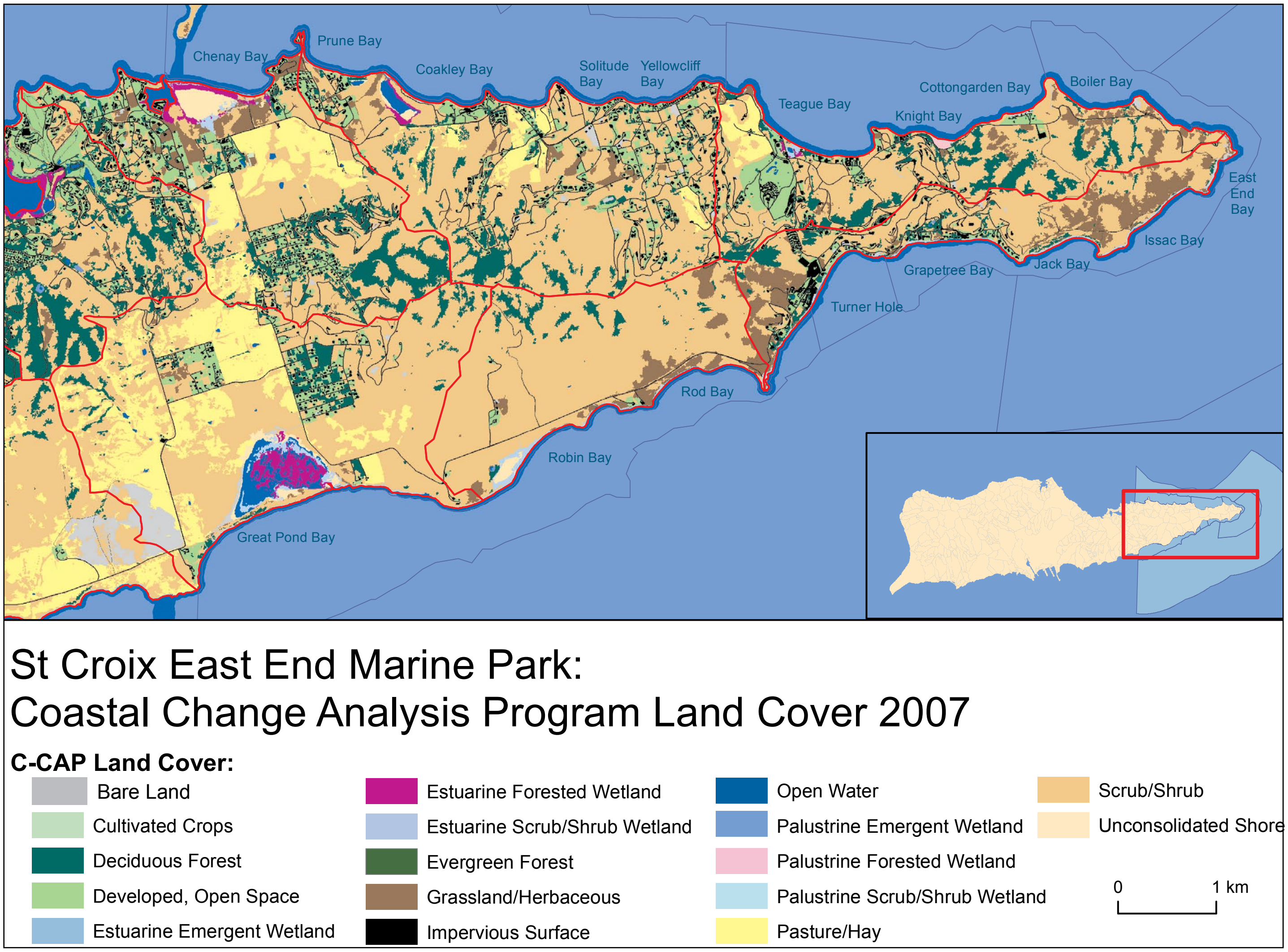


Figure 2.4. Land cover map developed by NOAA's Coastal Service Center Coastal Change Analysis Program (C-CAP). *http://www.csc.noaa.gov/digitalcoast/data/ccapregional.*

Table 2.1. Coefficients employed in developing the Landscape Development Index (LDI; Brown and Vivas, 2005).

Landcover Class	LDI coefficient	Landcover Class	LDI coefficient
Impervious Surface	8.28	Palustrine Scrub/Shrub Wetland	1.00
Pasture/Hay	3.03	Palustrine Emergent Wetland	1.00
Grassland/Herbaceous	2.06	Estuarine Forested Wetland	1.00
Scrub/Shrub	2.06	Estuarine Scrub/Shrub Wetland	1.00
Bare Land	1.85	Estuarine Emergent Wetland	1.00
Developed, Open Space	1.85	Unconsolidated Shore	1.00
Deciduous Forest	1.00	Open Water	1.00
Palustrine Forested Wetland	1.00		

Landscape Characterization

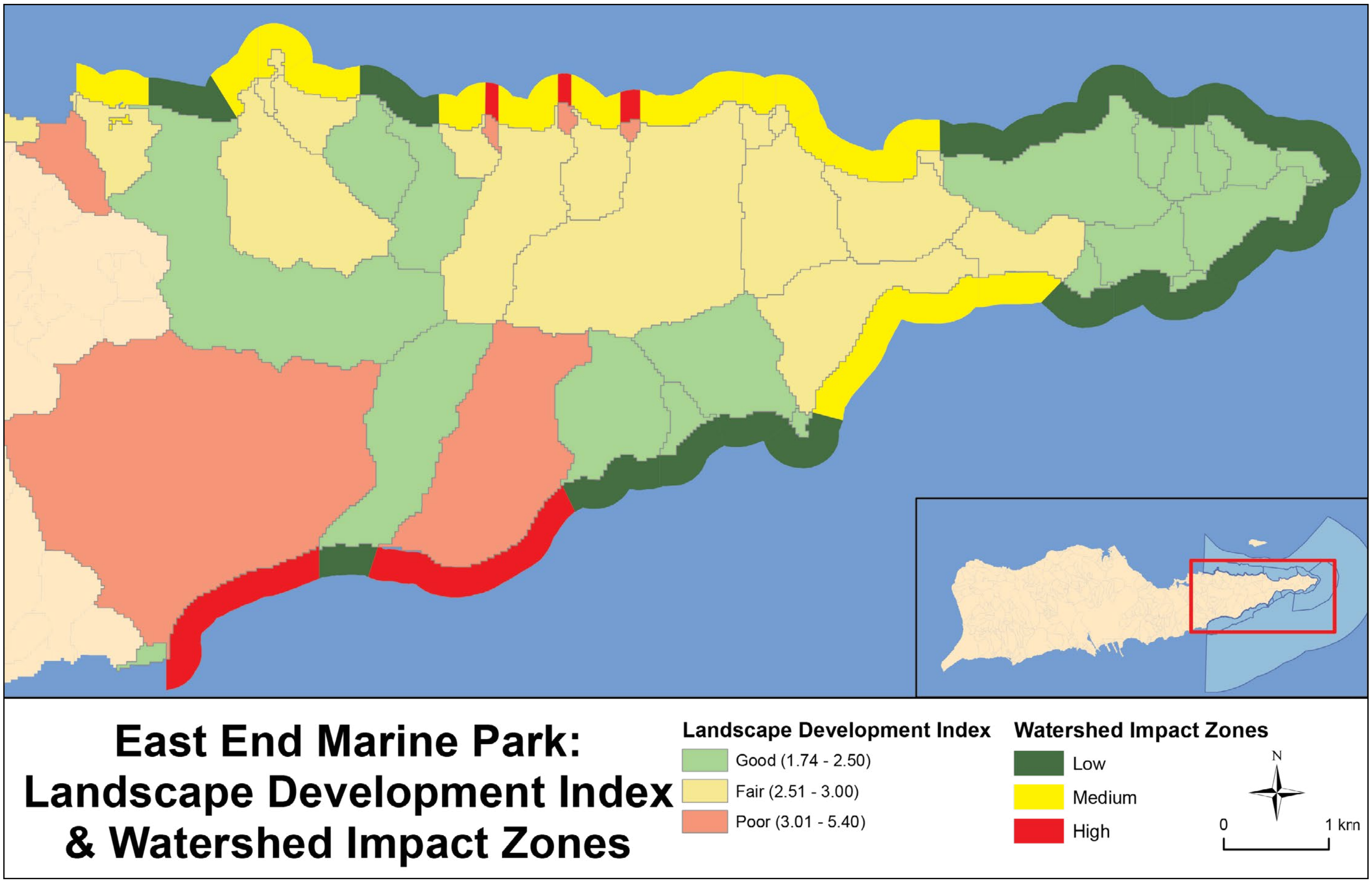


Figure 2.5. Landscape Development Intensity Index applied to project analysis units within the STXEEMP. Also represented are watershed impact zones and the expected level of impact (low, medium, high) based on the LDI.

The LDI provides one measure of the expected threat to coastal ecosystems from watershed-based pollution. Another expected threat is soil erosion from dirt roads. This threat is not captured by the LDI and so was analyzed independently. We tracked the area of dirt roads for each analytical unit in order to relate this to coastal condition. Dirt roads were mapped by Horsley Witten, Inc. The results are shown below in Figure 2.6, with nearshore areas highlighted by their expected impacts due to dirt roads.

We combine the results of the LDI and the dirt road assessments to create a single metric tracking anticipated negative impacts to nearshore habitats. The result is shown in Figure 2.7. The process we employed for deriving terrestrial impacts to watershed impact zones is outlined in Figure 2.8.

Man-made or hardened shorelines can also have deleterious effects on nearby coastal ecosystems by promoting the flow rate of runoff. To track this effect we applied the Shoreline Classification from NOAA's Environmental Sensitivity Index. We extracted the man-made shoreline types from this dataset and measured their contribution to the shores of each of the zones established by the STXEEMP (Figure 2.9).

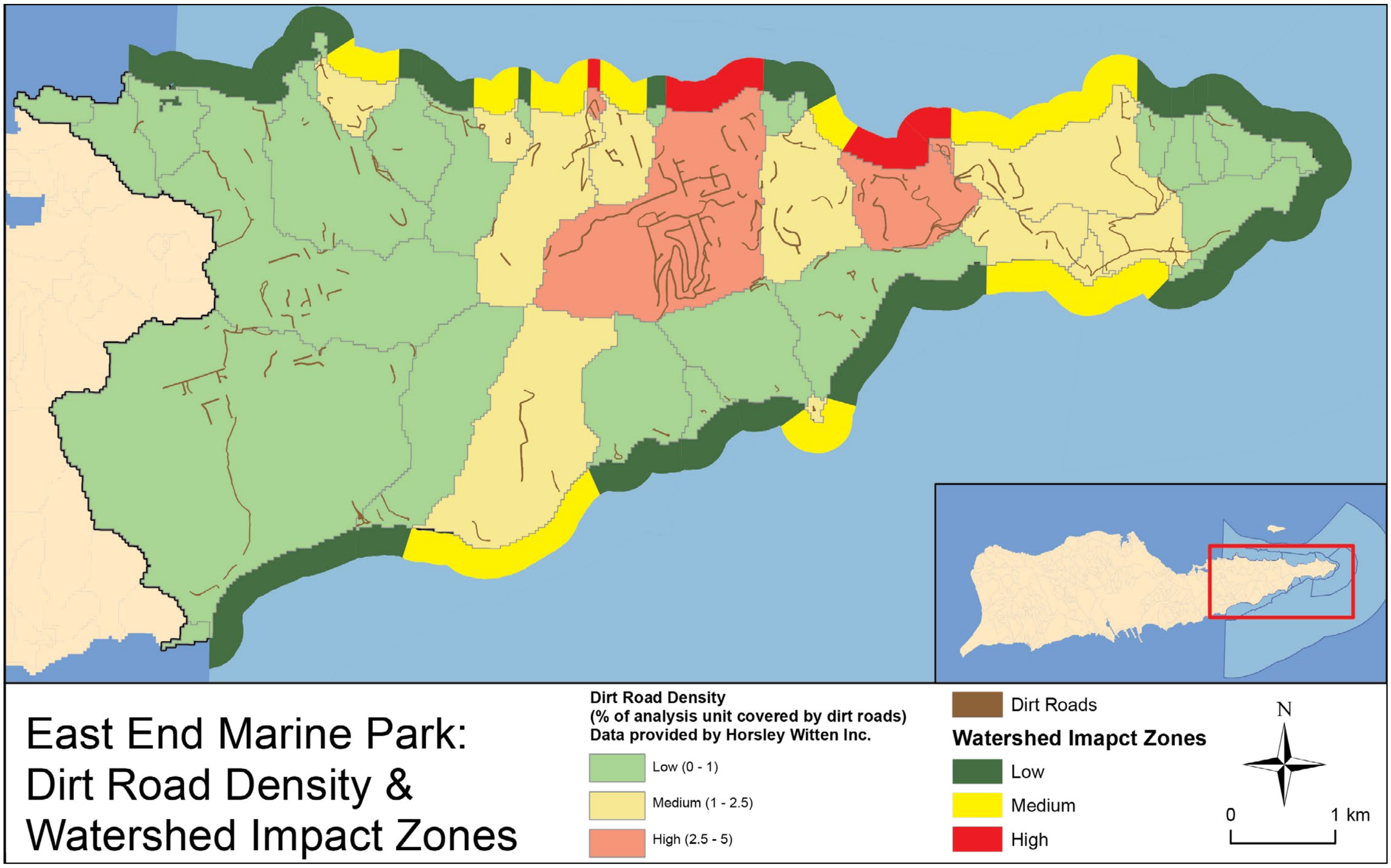


Figure 2.6. Road density for each analysis unit (area of dirt roads as a percentage of analysis unit area) within the STXEEMP. Dirt road information was developed by Horsley Witten, Inc.

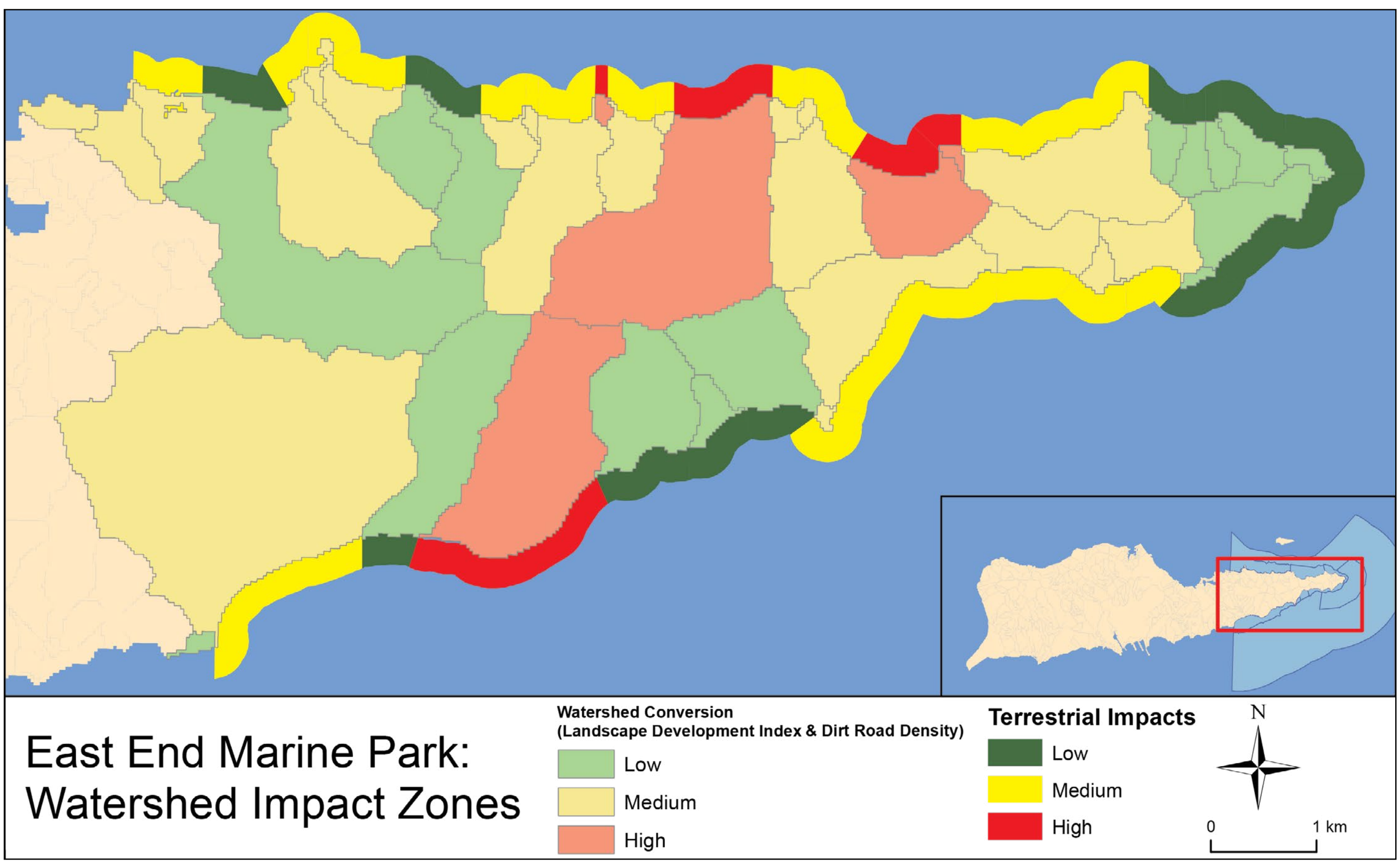


Figure 2.7. LDI and dirt road assessments combined to create a single metric tracking terrestrial impacts to watershed impact zones.

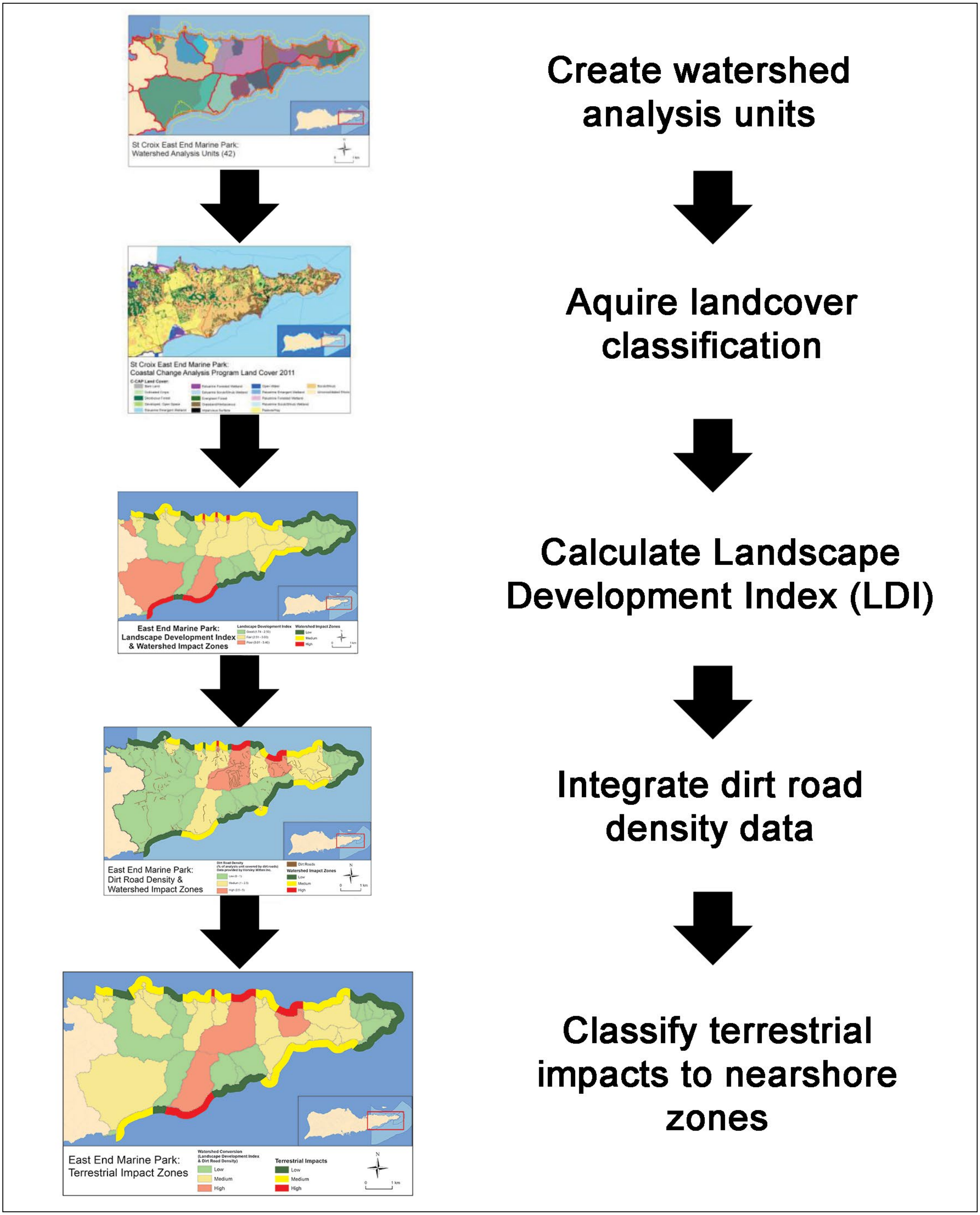


Figure 2.8. The key data sets and analytical process used to classify determine areas in the nearshore marine environment which are likely to experience negative effects due to land-based source of pollution resulting from different patterns of land use.

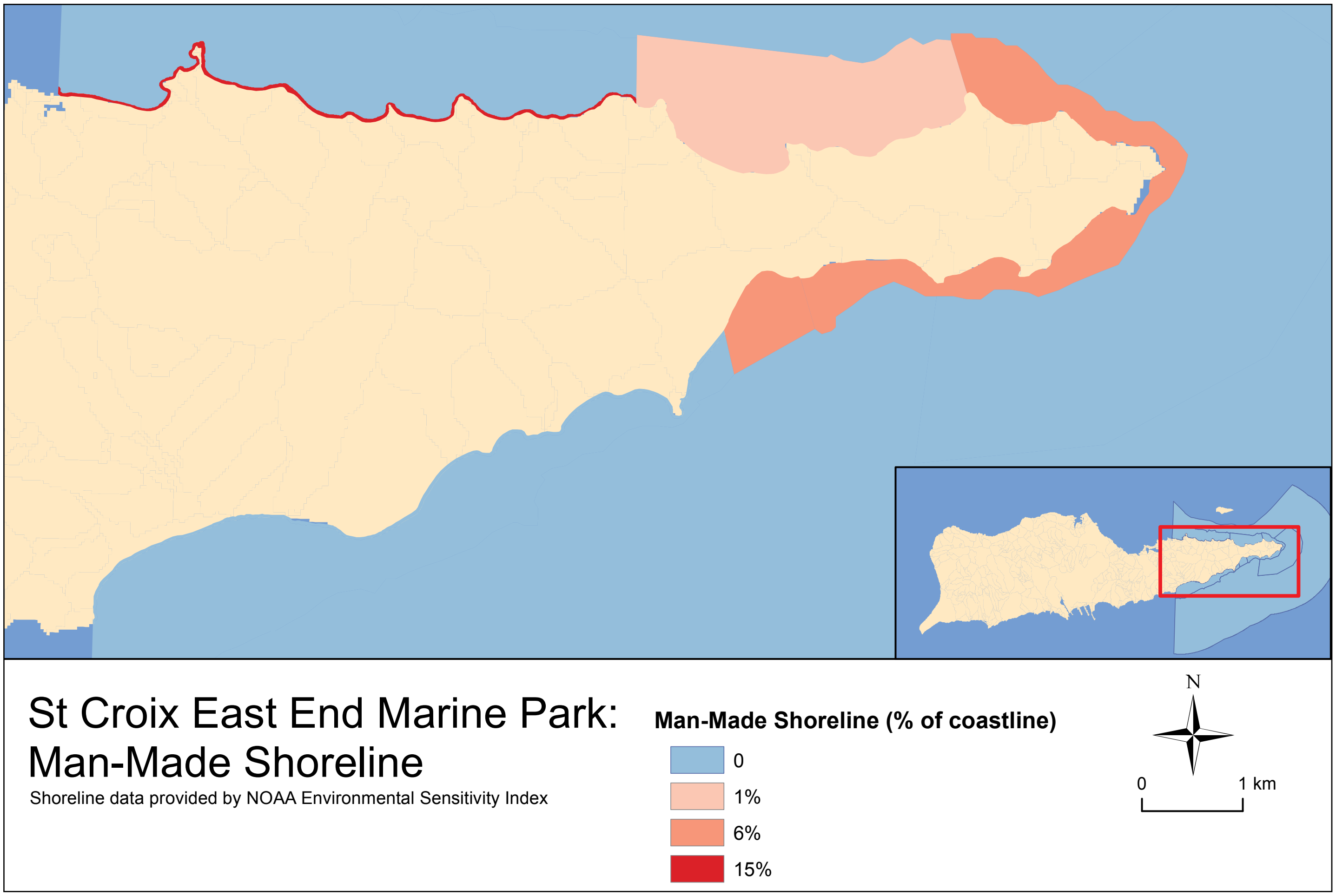


Figure 2.9. Man-made shorelines within STXEEMP. Source data: NOAA Environmental Sensitivity Index.

Marine Benthic Communities

Photo courtesy of NOAA/NOS/NCCOS/CCMA Biogeography Branch

Marine Fish and Benthic Communities

3.1 BACKGROUND

In the absence of ecological data, marine zones based on social and political criteria often are irreconcilable with ecologically-based objectives and goals. At present, 8.6% of STXEEMP is no-take (11 % if recreational areas are included), and 81% of the park is open to fishing. The STXEEMP management plan states that "no-take areas are designed to encompass large, contiguous diverse habitats" intended to "provide natural spawning, nursery, and permanent residence areas for the replenishment and genetic protection of marine life."

Our analyses aims to determine the species and communities located in each zone offering a spatial characterization to inform future management decision making. Based on the type, size and distribution of biota, we offer recommendations on the performance potential for the no-take zones. These data provide a baseline that can be used to evaluate future trends in populations. Data include periods prior to implementation of no-take areas and can therefore contribute to future evaluations of MPA performance. Geographical gaps in the sampling of marine communities across the STXEEMP are highlighted in the map of sampling locations (Figure 3.1).

Our data address some key questions relevant for Park management: Where are the Endangered Species Act (ESA) listed species within the park? Which coral reefs support highest biodiversity? Which reefs have highest coral cover? Where are the preferred areas for species of management concern, such as parrotfish and groupers? What is the seascape composition (amount of reef, seagrass, sand) in each zone? Which species are using the no-take zones? Finally,are no-take areas protecting fish species vulnerable to fishing? This is important because MPA's with areas closed to fishing (i.e., no-take) are typically evaluated on their performance in rebuilding the population biomass of previously fished species.

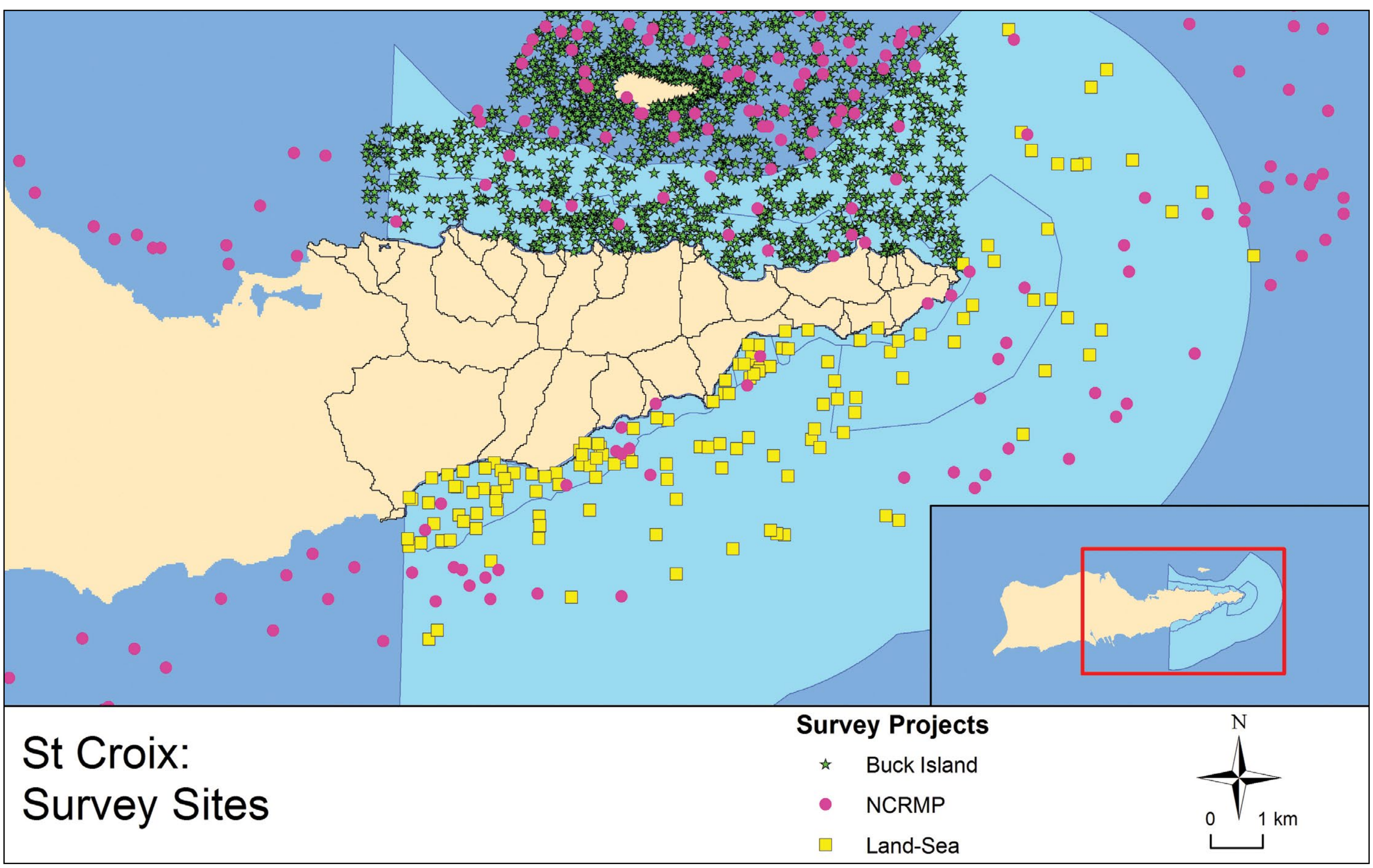


Figure 3.1. Map of all of the surveys used for benthic and fish maps and analyses. Buck Island sites are associated with the Caribbean Coral Reef Ecosystem Monitoring (CREM) project from 2002-2010; NCRMP sites are associated with the National Coral Reef Monitoring Plan (NCMP) in 2012; Land-Sea sites are associated with the project St. Croix, USVI Land-sea characterization of St. Croix East End Marine Park to evaluate zones and support management plan from 2010 and 2011.

Marine Fish and Benthic Communities

3.2 METHODS

To assist in monitoring coral reef ecosystem resources and to achieve a better understanding of fish-habitat relationships in the U.S. Caribbean, NOAA's National Center for Coastal Ocean Science, Center for Coastal Monitoring and Assessment's Biography Branch (CCMA-BB) developed a fish and benthic communities monitoring protocol to provide precise, quantitative and spatially explicit data, needed to comprehensively assess faunal populations and communities (Menza et al., 2006). Initially, samples were randomly located within two strata (hard and soft surficial seafloor characteristics from benthic habitat maps) to achieve the: 1) study objectives, 2) parsimony in the approach, and 3) results from statistical analyses of variance (Menza et al., 2006). The "hard" stratum comprised bedrock, pavement, rubble and coral reefs. The "soft" stratum comprised sand, seagrasses and macroalgal beds.

Sampling was carried out through three distinct, but coordinated projects funded primarily by NOAA CRCP. Consistent field survey techniques were used for each project. The majority of data came from the long-term monitoring of the Caribbean Coral Reef Ecosystem Monitoring (CREM) project. Data were selected from 2002-2010 (n=1961 sites). Data were also provided by the new National Coral Reef Monitoring Plan (NCRMP) from 2012 (n=290), which sampled around the entire island of St. Croix and the current project, named "Land-sea characterization of East End Marine Park to evaluate zones and support management plan review", which included a sampling component focused on STXEEMP in October of 2010 and 2011 (n= 140 sites; Figure 3.1).

All data are quality checked and available to the public via an online database, "Coral Reef Ecosystem and Assessment Database." A subsample of survey sites from all monitoring data were analyzed for STXEEMP by selecting only sites that were located within the boundary of the STXEEMP. For fish metrics, we show simple metrics of diversity and abundance for the entire fish community surveyed within STXEEMP boundaries and focal fish families, and species that are either listed in the management plan as priorities or are known to be of local or national ecological and economic importance. Because fishing impacts are of concern to management, we also include density of adults for many fished species.

3.2.1. Field survey methods

There are two complementary components to the biological field methods: (1) benthic habitat composition surveys, and (2) fish surveys (Figure 3.2). For detailed methodology for these two methods see Appendix A. Mission reports provide greater detail on the findings from these surveys (Appendix B).

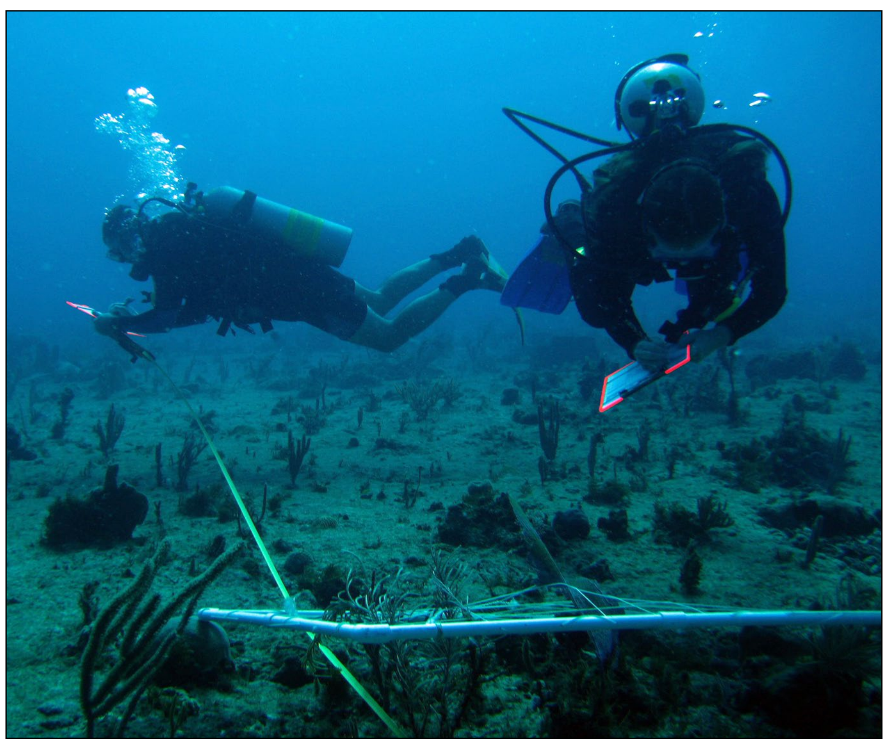


Figure 3.2. Photo of divers conducting benthic and fish surveys. Source: NOAA/NOS/NCCOS/CCMA/Biogeography Branch.

A stratified random sampling design was used to optimize the allocation of samples among four strata within the STXEEMP to allow rigorous inferences to the entire study area. Two benthic strata (hardbottom and softbottom substrates) and two cross-shelf strata (nearshore and offshore) were selected. The nearshore stratum included all the STXEEMP management zones that abut the shoreline, whereas the offshore, strata comprised all remaining areas further offshore but within the STXEEMP. Sites were selected and allocated among strata based on the approach used by Menza et al., 2006.

3.2.2. Analysis methods

In addition to the information collected from benthic surveys, information from NOAA's benthic habitat maps were analyzed to quantify the composition and area of habitat types (i.e. seagrasses, coral reef, sand etc.) in each zone. These data provide managers with information on the proportions of each habitat type within each management unit. Benthic habitats were digitized from high resolution aerial photographs and their accuracy was assessed using underwater validation surveys (Kendall et al., 2002).

Sensitive coral species were selected based on published literature (Bak and Elgershuizen, 1976; Rogers, 1983; Pastorok and Bilyard, 1985; Gleason, 1998; Nemeth and Sladek Nowlis, 2001; Pait et al., 2007). Whilst observed seagrass species were not considered sensitive species to contamination or sedimentation, when introduced to nutrient enrichment and/or eutrophication events, there are changes in growth rates and dominance within seagrass beds when other seagrass species are present (Fourquresan et al. 1995; Ferdie and Fourqurean, 2004; Burkholder et al, 2007).

3.2.2.1. Benthic Habitats

Benthic habitats were evaluated using two distinct data sets. The first was direct observation conducted by underwater surveys. The second was through the evaluation of the benthic habitat maps which were developed through the CRCP's national mapping effort. A total of 190 surveys were conducted within the 300 meter watershed impact zones (Figure 3.3).

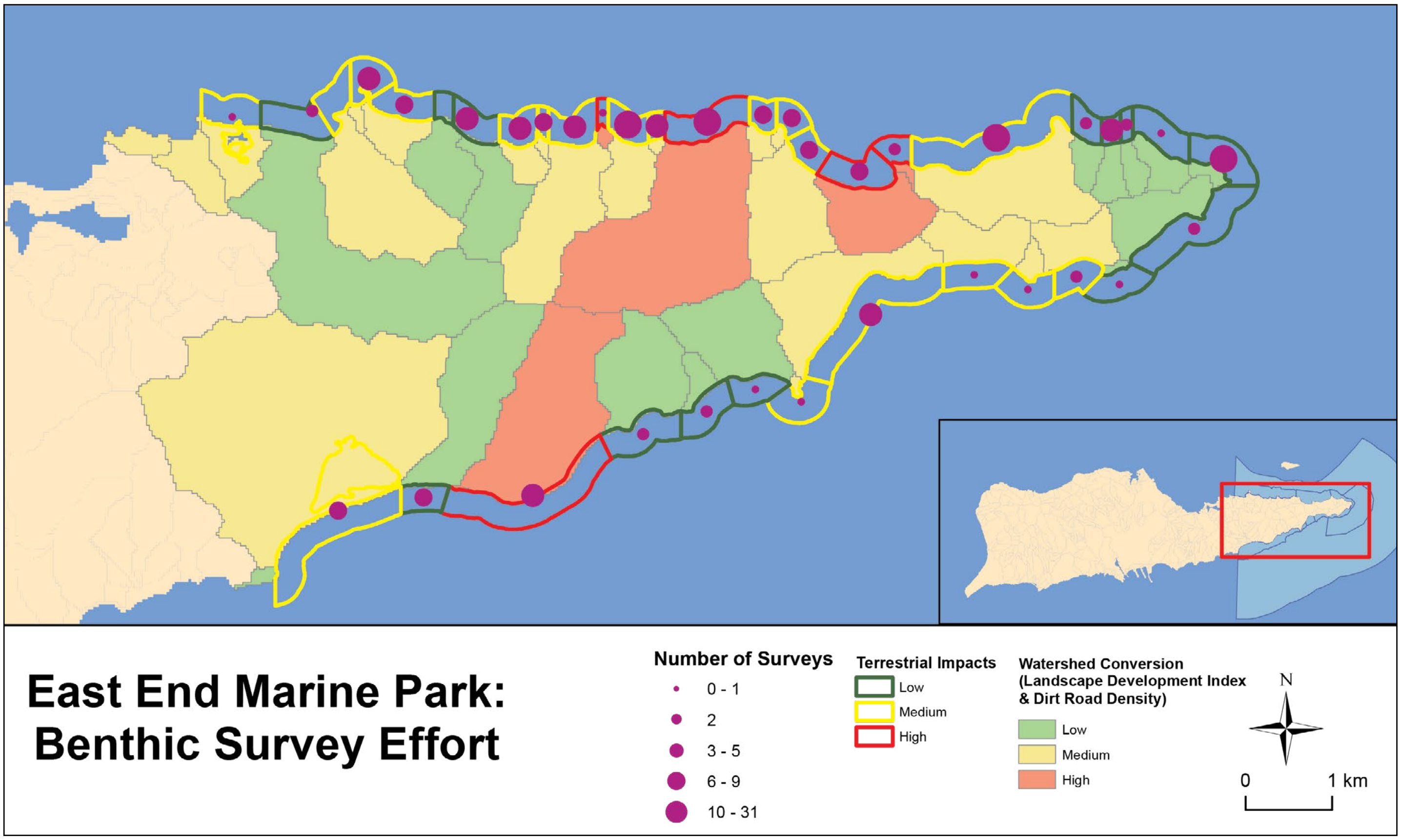


Figure 3.3. Map of benthic survey effort within 300 meter buffer along the coast of STXEEMP.

Marine Fish and Benthic Communities

We developed nearshore marine analysis units to characterize the areas adjacent to the watersheds of the STXEEMP (Figure 2.7). These were constructed using a 300 meter buffer along the coast of the park which was then subdivided into areas immediately adjacent to individual watershed units (Figure 2.7). These units, referred to here as "watershed impact zones", were then used to group and analyze the marine biota expected to be exposed to the influence of runoff. In the absence of any quantitative guidance on the seaward extent of LBSP impacts, a buffer of 300 m was selected based on the likelihood that impacts to marine biota would exert greatest detectable effect within 300 m of the land-sea interface. We acknowledge that LBSP can also influence a broader geographical extent due to local water movements that disperse materials offshore and alongshore, but due to dilution effects the impacts may decreases with increasing distance from shore. We also conducted a Wilcoxon statistical test to determine if there were significant differences in the benthic habitat composition between watershed impact zones.

3.2.2.2. Characterization of marine fish in STXEEMP zones

Fish survey sites from the three sampling projects were grouped by STXEEMP zones forming analysis units to examine the biota associated with individual STXEEMP zones and zone types, as defined in the management plan. Geographical Information System tools were used to select sites that were contained within each individual zone (n=10 analysis units); and were then also summarized by zone type (n=4 analysis units; Table 3.1; Figure 1.1).

Table 3.1. Number of surveys conducted within each zone type in St. Croix East End Marine Park (STXEEMP).

Zone type	Number of surveys	Individual zones	Number of surveys
No-take	320	Take	502
Take	502	No-take north	208
Recreation	124	No-take east	51
Turtle preserve	38	No-take south	61
		Turtle preserve	38
		Recreation north	103
		Recreation south	13
		Shoreline north	6
		Shoreline south	2

3.3. RESULTS

3.3.1. Marine communities in the watershed impact zones

3.3.1.1. Benthic communities

Based on the underwater surveys, the 300 meter buffer contains primarily algae and seagrasses (Figures 3.4 and 3.6). There is very little coral reef found within the watershed impact zones. The highest coral cover is found in Teague Bay and Boiler Bay. Benthic habitat composition as revealed by summing the results of the surveys across the terrestrial impact classes of the watershed impact zones is reported in Table 3.2 and Figures 3.5 and 3.6.

We found significant differences among impacts for three habitat types (Table 3.3). These are Coral Reef and Colonized Hardbottom occurring on hard substrate, Turf Algae on hard substrate and Coral Reef and Colonized Hardbottom in areas dominated by soft substrate. For Coral Reef and Colonized Hardbottom occurring on hard substrate, $p = 0.0294$ was found, indicating significant differences between classes. In particular, the difference between medium impact and low impact was most significant, with $p = 0.0284$. This indicated that Coral Reef and Colonized Hardbottom habitats were more abundant in areas classified as having medium terrestrial impact. The difference between medium and high impact classes was nearly significant with $p=0.0548$. Both of these results were driven by a single site with nearly 33% coral cover occurring in an area classified as medium impact. This site is found in Boiler Bay. For Turf Algae on hard substrate, a p value of 0.0175 was obtained indicating significant differences between classes. In particular, differences were significant between high and low classes ($p = 0.0085$) and between high and medium classes ($p = 0.0074$). Turf Algae distribution was greater in low and medium classes than in high. In areas dominated by soft bottom substrate, significant differences were found between Coral Reef and Colonized Hardbottom classes ($p = 0.0227$). Specifically, the difference was significant between high and low classes ($p = 0.036$) and between medium and low classes ($p = 0.0157$). For high impact zones, the difference was driven largely by a single site with nearly 2% Coral Reef and Colonized Hardbottom cover. Results from the Wilcoxon statistical tests are summarized below (Tables 3.3-3.6).

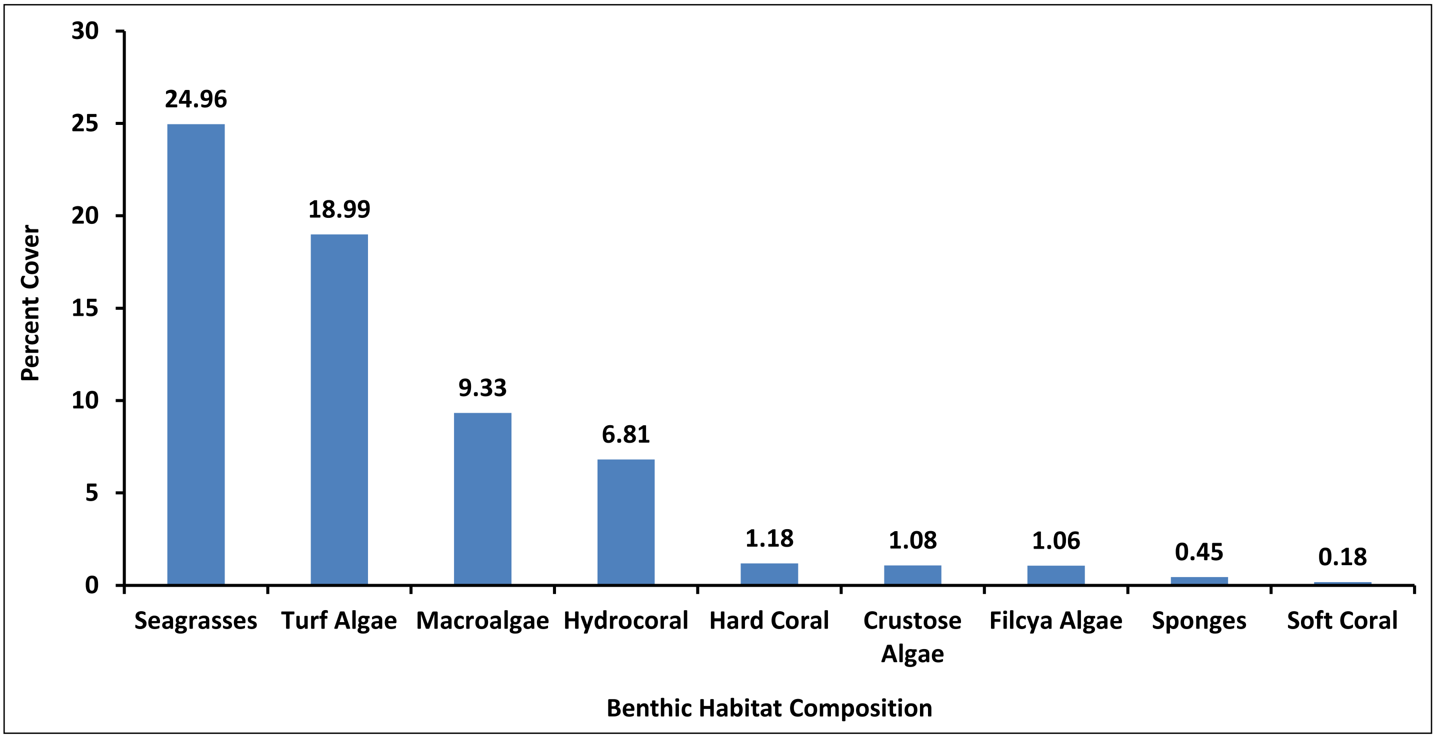


Figure 3.4. Benthic habitat composition as derived from in-situ surveys for the near-shore analysis zone. Filcya – Filamentous algae and cyanobacteria.

Table 3.2.Benthic habitat composition within Watershed Impact Zone categories of terrestrial influence.

Impact	Hard Corals	Hydrocorals	Macroalgae	Turf Algae	Crustose Algae	Filamentous Algae/ Cyanobacteria	Seagrass	Sorf Coral	Sponge
High	0.566	0.113	8.224	5.977	0.314	1.727	26.569	0.149	0.504
Medium	1.336	0.045	8.395	16.553	1.175	0.750	27.763	0.170	0.354
Low	1.274	0.091	12.588	35.469	1.439	1.328	16.601	0.245	0.682

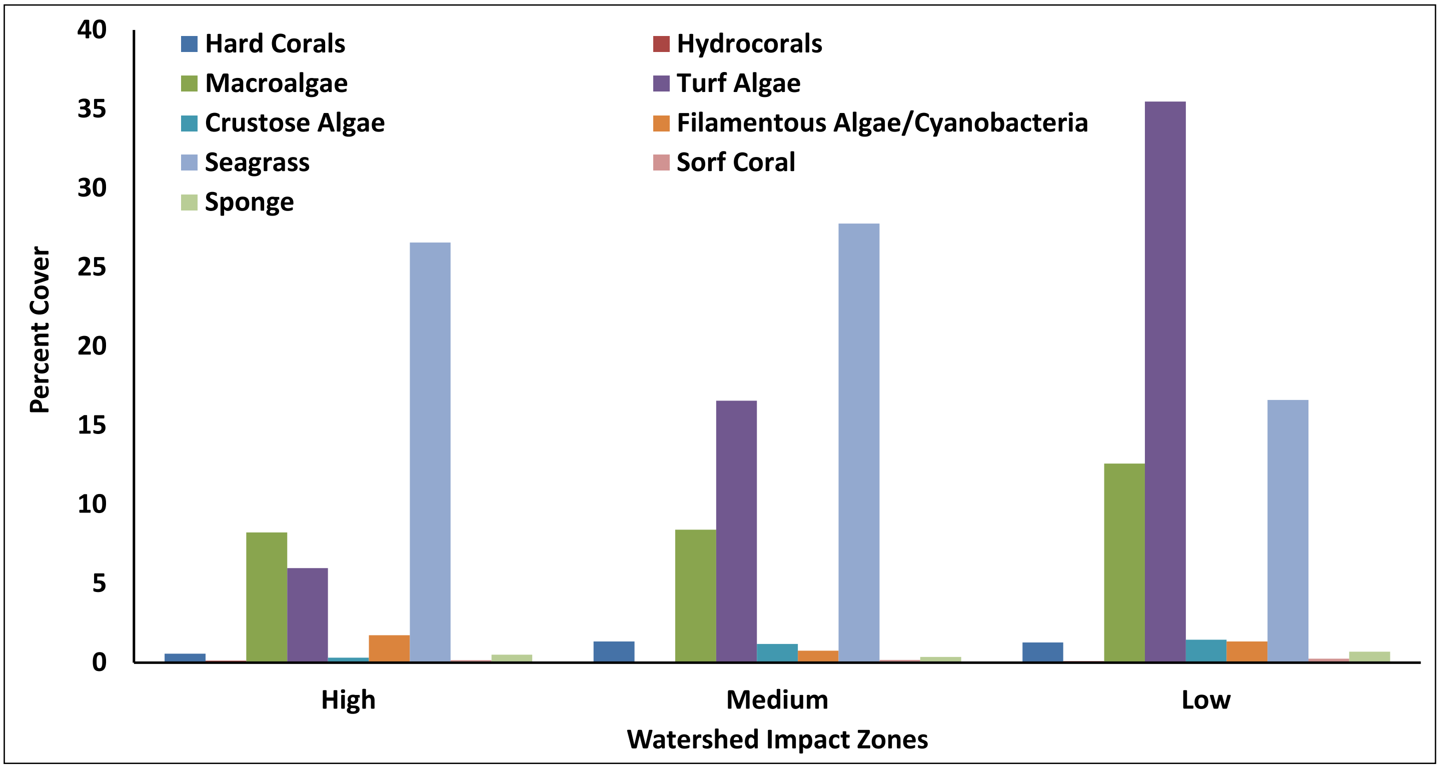


Figure 3.5. Benthic habitat composition within Watershed Impact Zone categories (low, medium, high) of terrestrial influence.

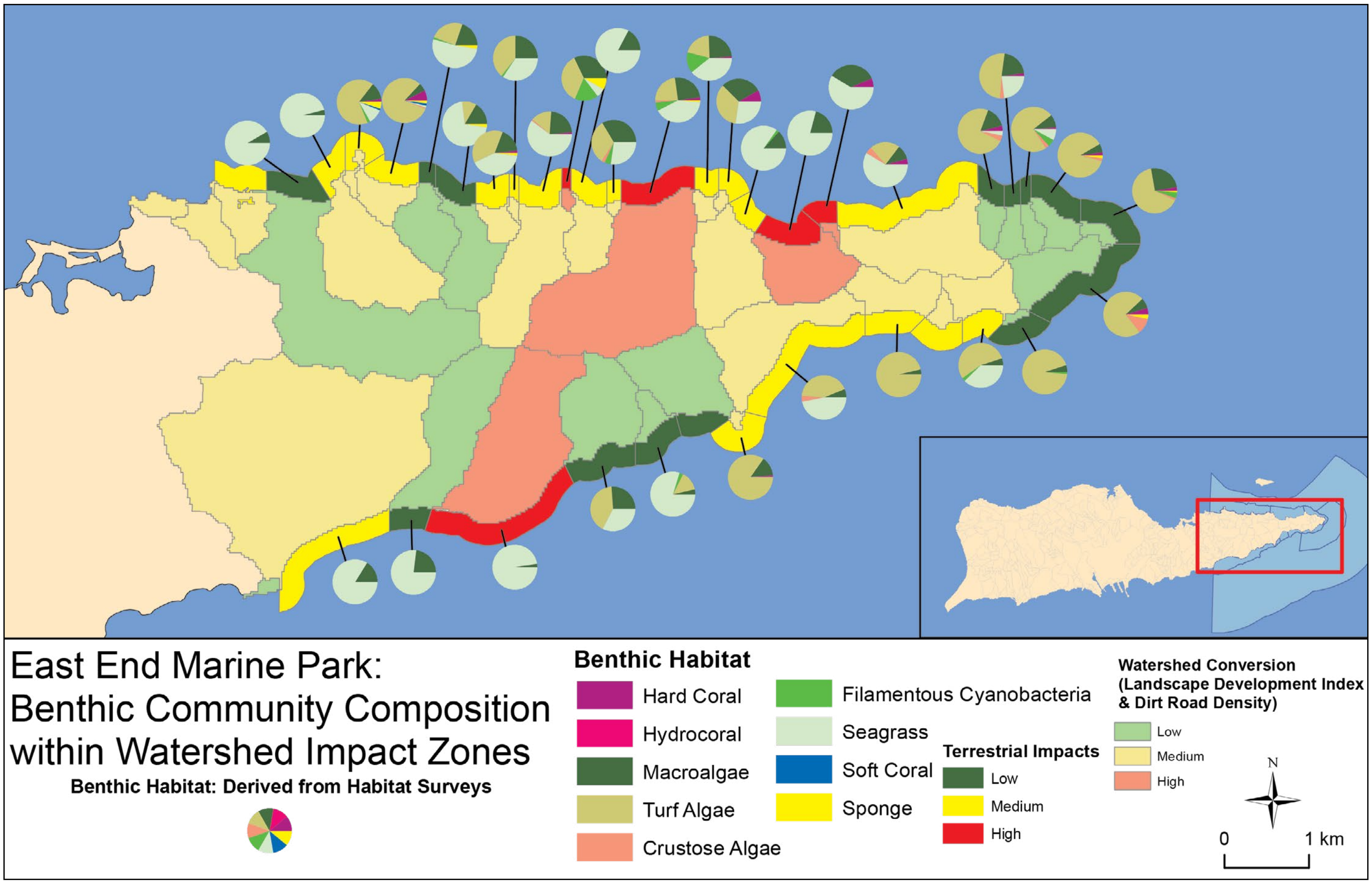


Figure 3.6. Map of benthic community composition derived from diver survey data collected at NOAA survey sites within the watershed impact zones (300 m buffer) STXEEMP.

Table 3.3. Wilcoxon values for significant variations of benthic habitats within terrestrial impact classes from survey data.

Habitat	ChiSquare	DF	Prob>ChiSq
Coral Reef and Colonized Hardbottom (hard substrate)	7.0561	2	0.0294
Turf Algae (hard Substrate)	8.0939	2	0.0175
Coral Reef and Colonized Hardbottom (soft substrate)	7.5703	2	0.0227

Table 3.4. Wilcoxon pairwise values for Coral Reef and Colonized Hardbottom in hard substrate.

Level	Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL
Medium	Low	10.307	4.704	2.191	0.028	0.82	0.09	1.98
High	Low	-4.767	4.333	-1.100	0.271	-0.3	-1.2	0.88
High	Medium	-9.219	4.800	-1.920	0.055	-1.02	-2.84	0.06

Table 3.5. Wilcoxon pairwise values for Turf Algae in hard substrate.

Level	Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL
Medium	Low	0.155	4.704	0.033	0.974	0.455	-13.24	14
High	Low	-11.411	4.333	-2.633	0.008	-29.41	-52.72	-8.38
High	Medium	-12.851	4.800	-2.677	0.007	-32.53	-51.8	-10.13

Table 3.6. Wilcoxon pairwise values for Coral Reef and Colonized Hardbottom in soft substrate.

Level	Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL
High	Medium	-1.239	2.741	-0.452	0.651	0	0	0
High	Low	-4.670	2.227	-2.097	0.036	0	0	0
Medium	Low	-9.558	3.955	-2.417	0.016	0	0	0

Analysis of the benthic habitat maps indicates that coral areas are concentrated along the eastern end of the park, while seagrasses and macroalgae dominate the western side (Figure 3.7). Benthic habitat composition as revealed by the benthic habitat maps is reported in Tables 3.7 and 3.8.

We analyzed benthic habitat composition as reported from the benthic habitat maps for differences among the impact classes (Figure 3.8 and Table 3.9). We found significant difference between high, medium and low impact classes for the distribution of Coral Reef and Colonized Hardbottom (p = 0.323) and Submerged Aquatic Vegetation (SAV) habitats (p = 0.0335; Tables 3.10-3.12). For Coral Reef and Colonized Hardbottom, there was a significant difference between high and low impact classes (p=0.0296), with low impact areas having higher cover. For SAV, the most significant difference was between high and low classes, with high impact areas having greater amounts of SAV.

3.3.1.2. Coral reef community

Several coral species are known to be sensitive to impacts from land-based sources of pollution (Figure 3.9). Here we consider the distribution of several of these species within the watershed impact zone (300 meter coastal buffer).

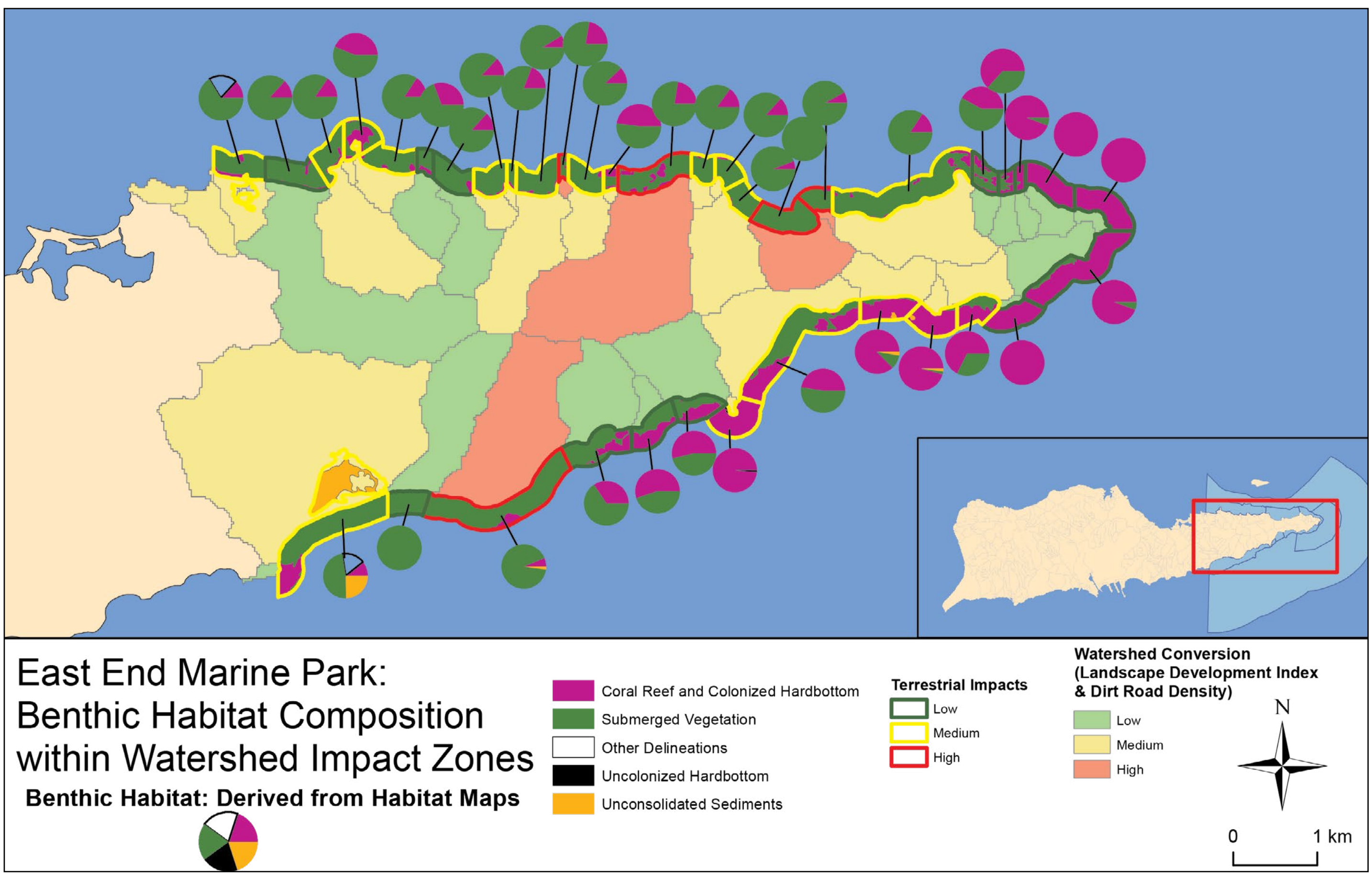


Figure 3.7. Map of benthic substrates derived from habitat maps for STXEEMP.

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Table 3.7. Seascape composition and area of habitat types in the watershed impact zones (≤300 m of the shoreline) quantified from NOAA's benthic habitat maps.

Benthic Habitat	Hectares
Coral Reef and Colonized Hardbottom	332.95
Other Delineations	21.97
Submerged Aquatic Vegetation	518.70
Uncolonized Hardbottom	0.35
Unconsolidated Sediments	26.67

Table 3.8. Description of the habitat composition types within Coral Reef and Hardbottom benthic habitat.

Habitat Type	Hectares	% of area
Colonized Bedrock	56.25	16.89
Colonized Pavement	137.32	41.24
Colonized Pavement w/ Sand Channels	33.64	10.1
Linear Reef	77.52	23.28
Patch Reef (Aggregated)	7.02	2.11
Scattered Coral/Rock in Unconsol. Sed.	21.20	6.37

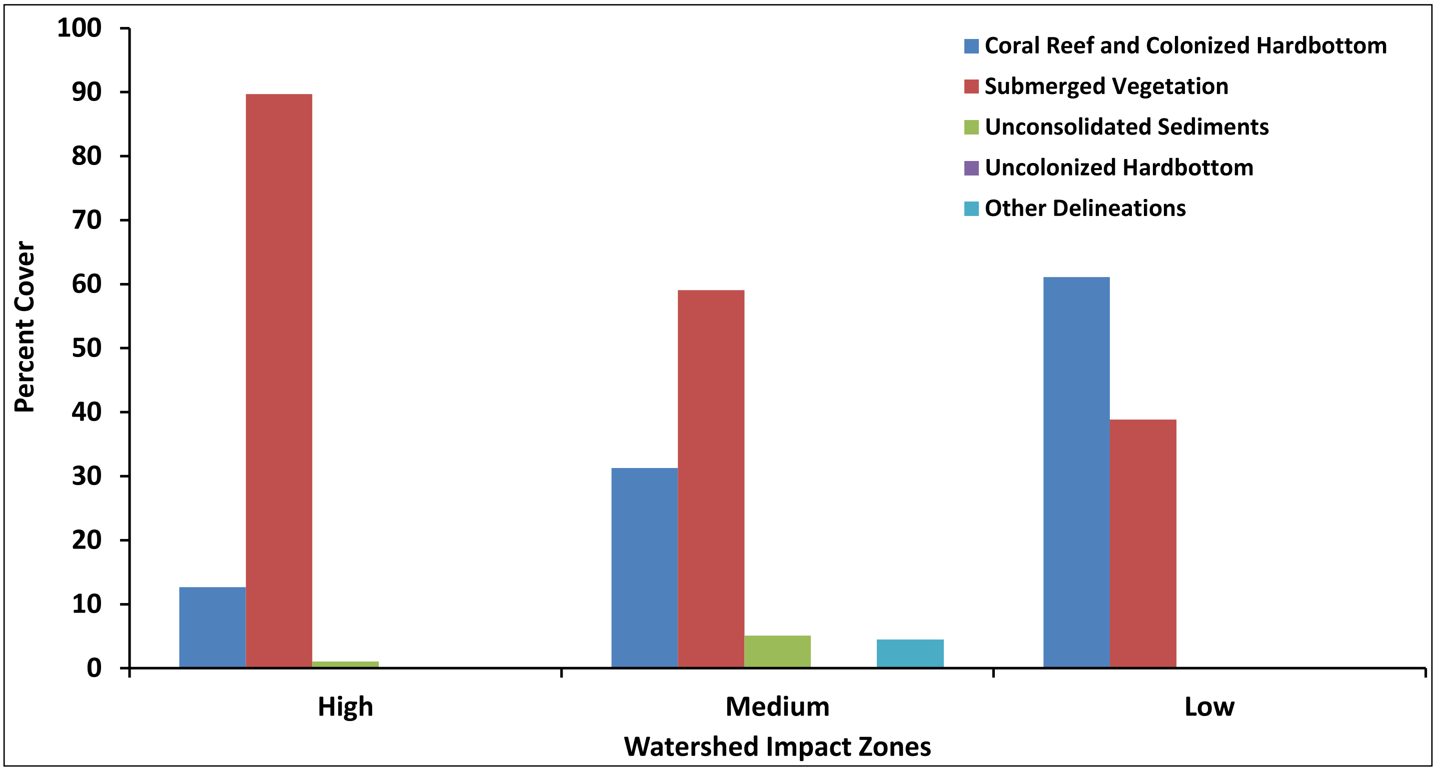

Figure 3.8. Benthic habitat composition within Watershed Impact Zones, based on terrestrial impact category. Derived from benthic habitat maps.

Table 3.9. Benthic habitat composition within Watershed Impact Zones, based on terrestrial impact category. Derived from benthic habitat maps.

Habitat Type	High	Medium	Low
Coral Reef and Colonized Hardbottom	12.67	31.29	61.1
Submerged Aquatic Vegetation	89.69	59.06	38.84
Unconsolidated Sediments	1.04	5.1	0.06
Uncolonized Hardbottom	0	0.07	0
Other Delineations	0	4.47	0

Table 3.10. Results from Wilcoxon test for difference of Submerged Aquatic Vegetation (SAV) among impact classes within the watershed impact zone.

Habitat	ChiSquare	DF	Prob>ChiSq
Coral Reef and Colonized Hardbottom	6.8659	2	0.0323
Submerged Aquatic Vegetation	6.7912	2	0.0335

Table 3.11. Results from pair wise Wilcoxon test for differences between terrestrial impact classes of Coral Reef and Colonized Hardbottom habitats.

Impact Level	Impact Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL
High	Medium	-5.305	3.554	-1.493	0.136	-9.486	-47.996	6.852
Medium	Low	-6.141	3.406	-1.803	0.071	-20.989	-49.758	1.876
High	Low	-6.379	2.932	-2.176	0.030	-41.462	-88.004	-5.112

Table 3.12. Results from pair wise Wilcoxon test for differences between terrestrial impact classes of SAV habitats.

Impact Level	Impact Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL
High	Low	6.379	2.927	2.180	0.029	41.473	4.910	85.997
High	Medium	6.316	3.554	1.777	0.076	15.128	-3.364	51.932
Medium	Low	5.397	3.405	1.585	0.113	17.384	-3.803	47.961

Very few observations of ESA listed staghorn coral (*Acropora cervicornis*) have been made by the scientific divers within the STXEEMP. None occurred within the watershed impact zone (Figure 3.10). In contrast, colonies of Elkhorn coral (*Acropora palmata*; Figure 3.9a) were sighted within the impact zone, primarily concentrated on the eastern tip of the island where human impacts are minimal (Figure 3.11). Brain coral (*Diploria strigosa*; Figure 3.9b) was observed in 20 of 38 surveyed near-shore analysis units (Figure 3.12). Golfball coral (*Favia fragum*) were observed in 12 impact zone units along the north shore (Figure 3.13), and Boulder star coral (*Montastraea annularis* complex; Figure 3.9c) were observed in six units along the north shore (Figure 3.14). Yellow pencil coral (*Madracis mirabilis*) was not observed within the impact zone (Figure 3.15). Finger coral (*Porites porites;* ; Figure 3.9d) and mustard hill coral (*Porites astreoides*) were observed within 20 and 17 of the surveyed impact zone units respectively (Figures 3.16 and 3.17).

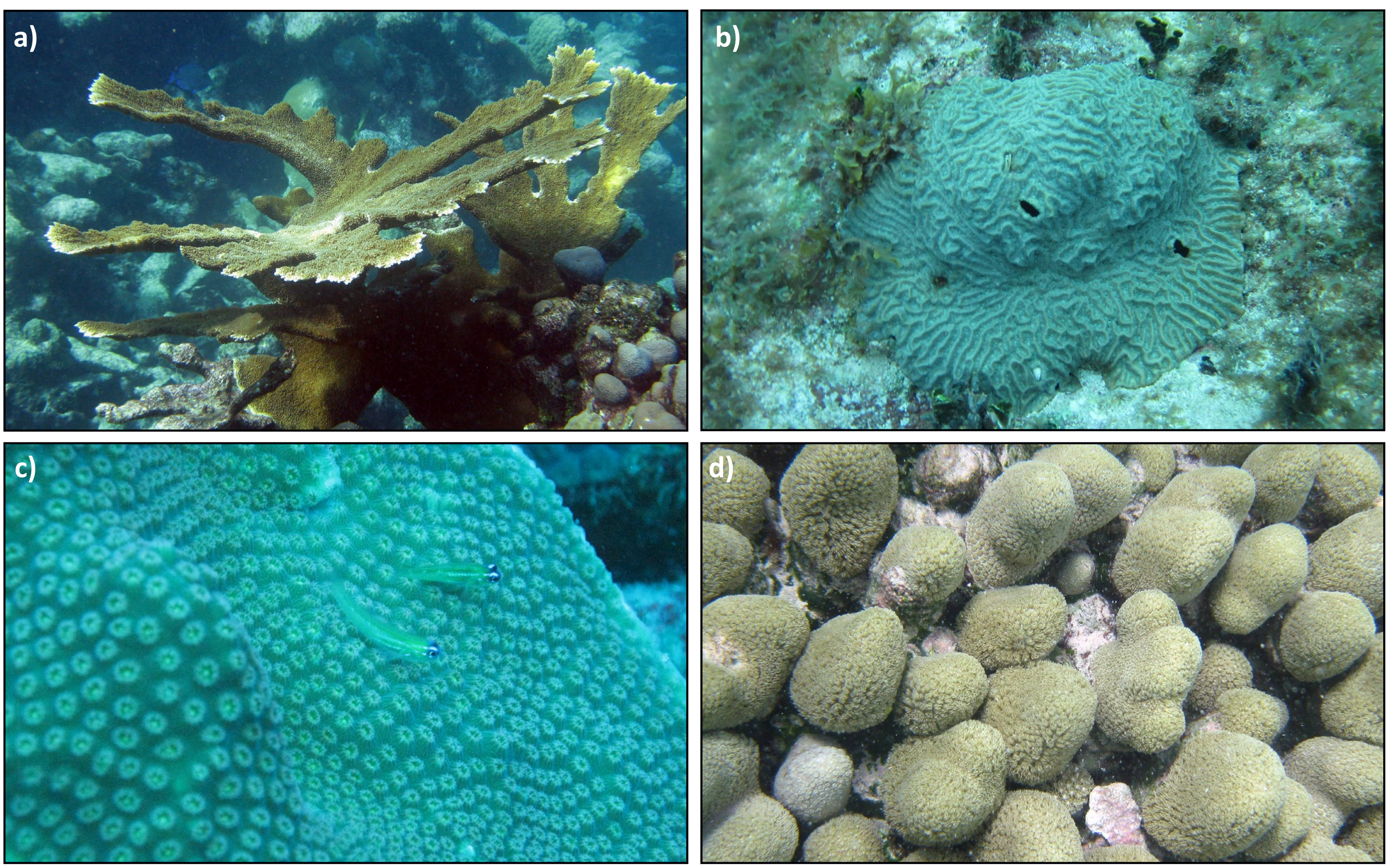

Figure 3.9. Photos of coral species present in STXEEMP: a) Acropora palmata*, b)* Diploria strigosa*, c)* Montastraea annularis *complex, and d)* Porites porites*. Photo credits: NOAA/NOS/NCCOS/CCMA Biogeography Branch.*

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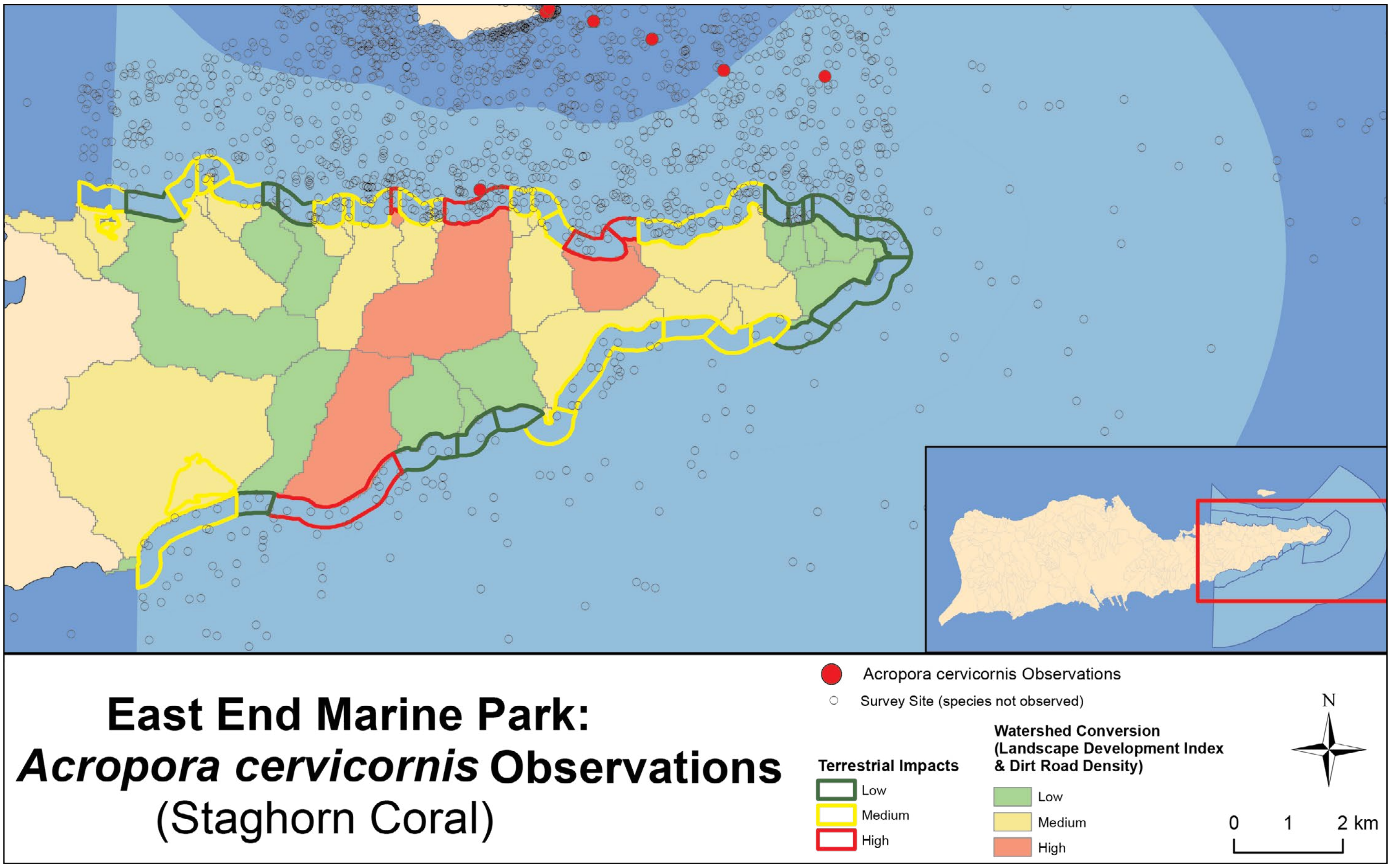

Figure 3.10 Map of Acropora cervicornis *(staghorn coral) sightings within and around STXEEMP*

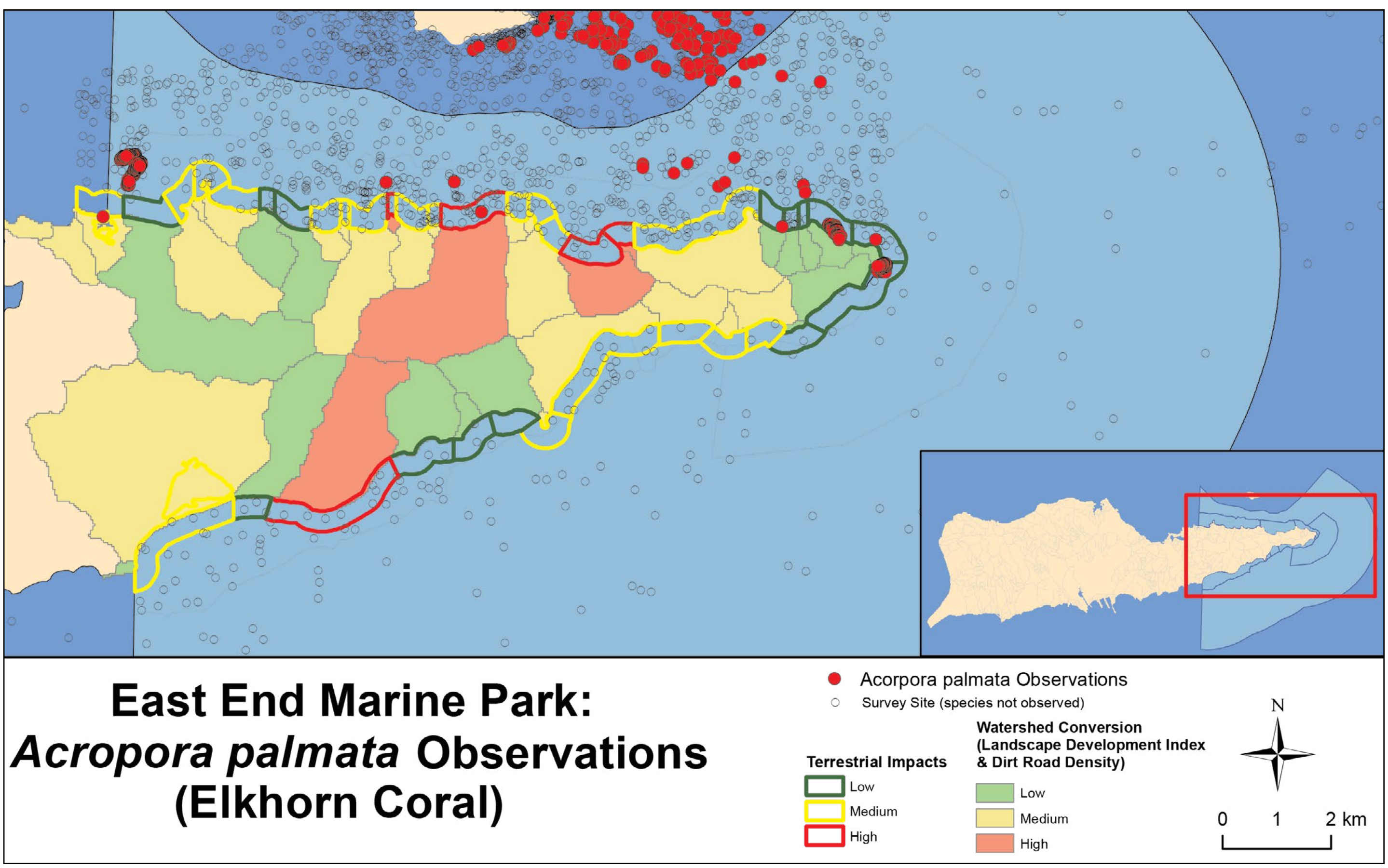

Figure 3.11. Map of Acropora palmata *(elkhorn coral) sightings within and around STXEEMP.*

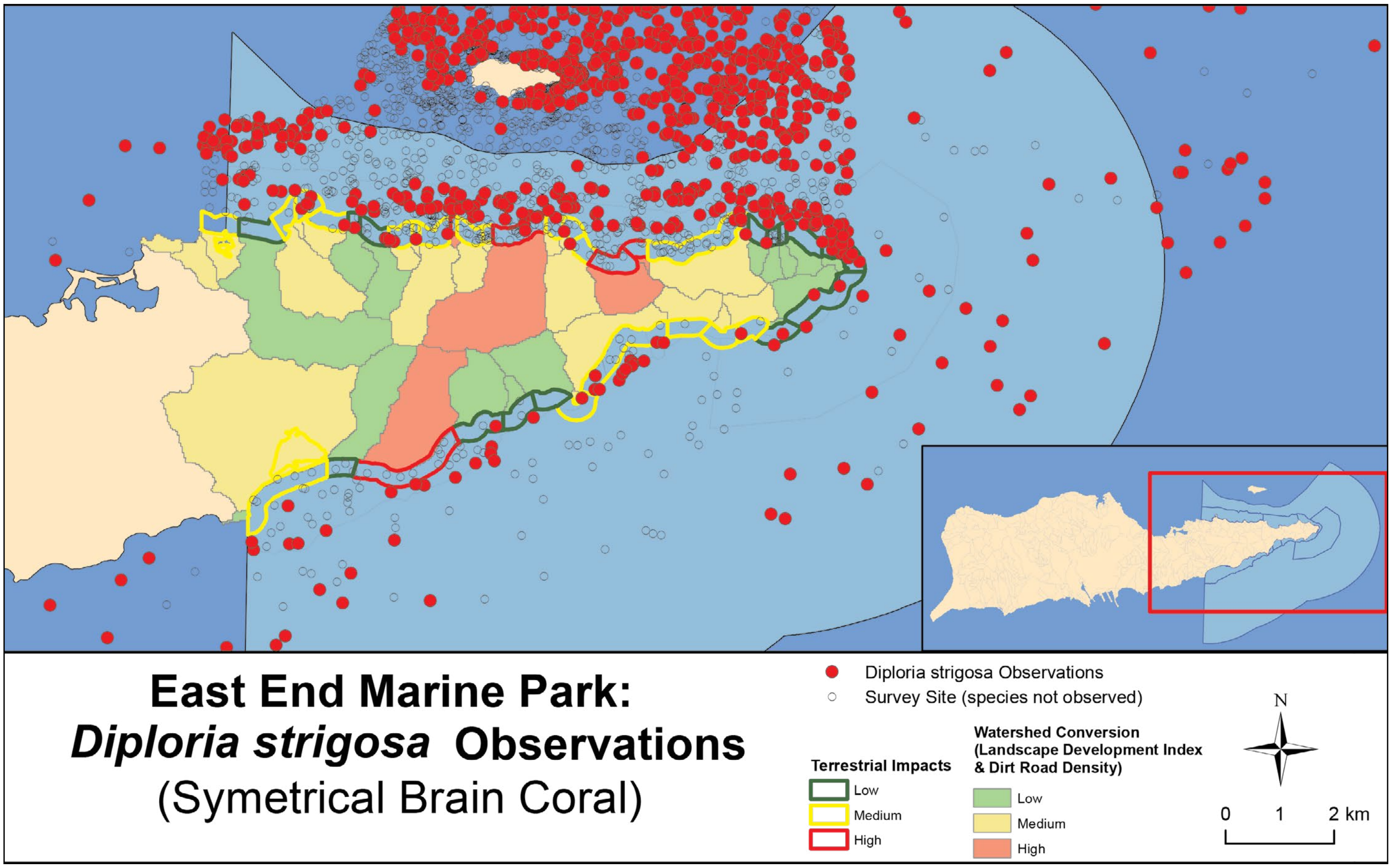

Figure 3.12. Map of Diploria strigosa *(symmetrical brain coral) sightings within and around STXEEMP.*

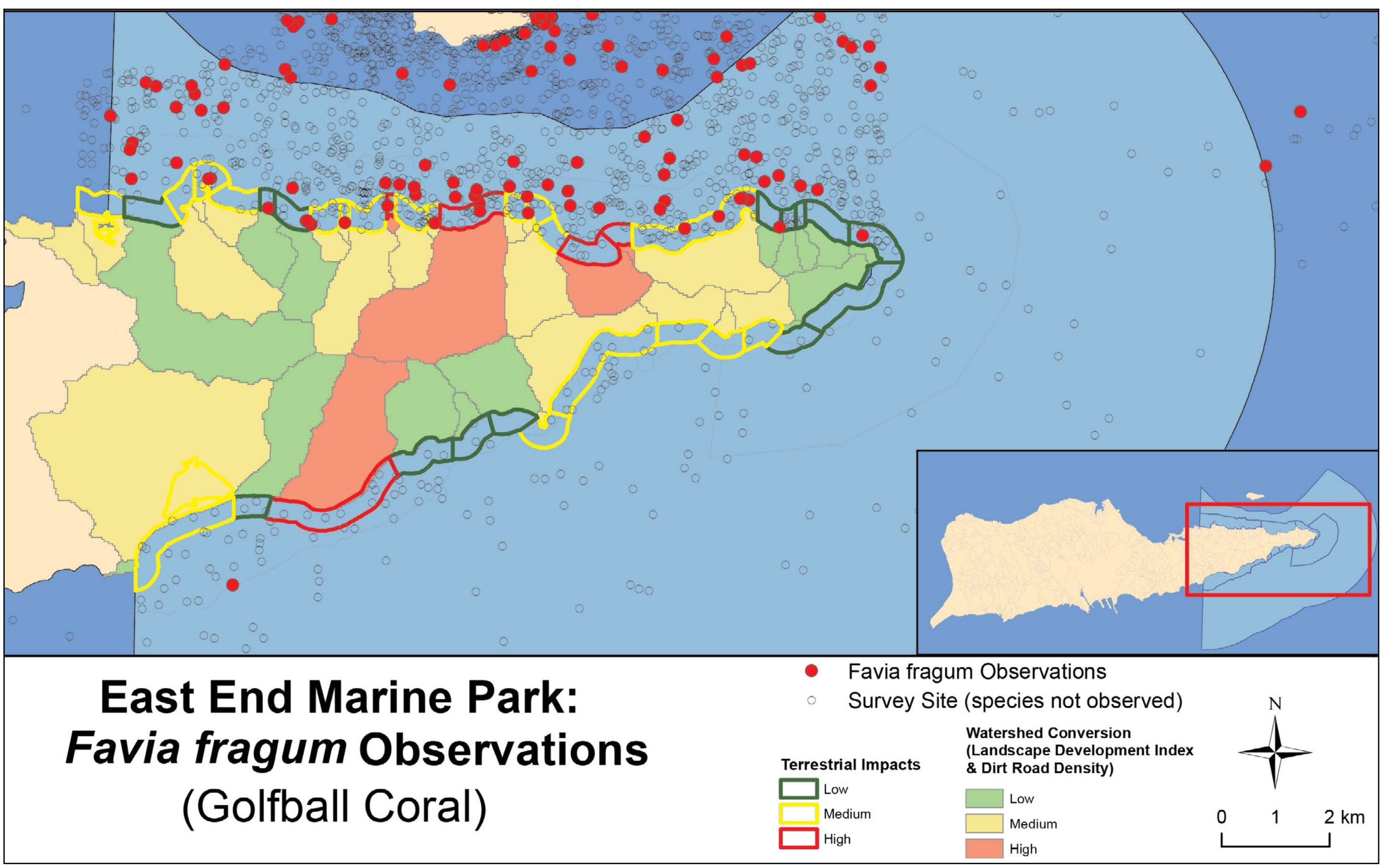

Figure 3.13. Map of Favia fragum *(golfball coral) sightings within and around STXEEMP.*

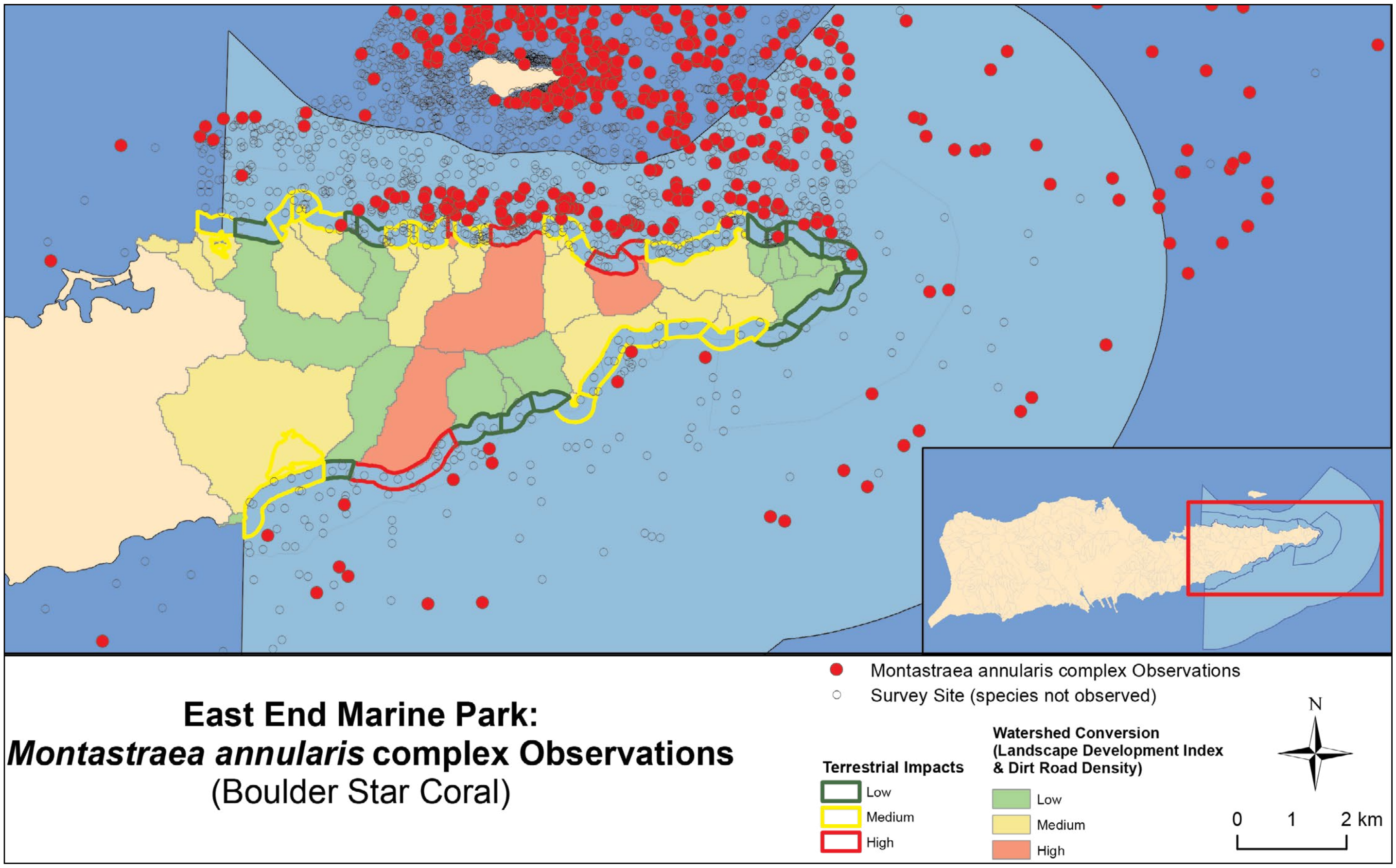

Figure 3.14. Map of Montastraea annularis *complex (boulder star coral) sightings within and around STXEEMP.*

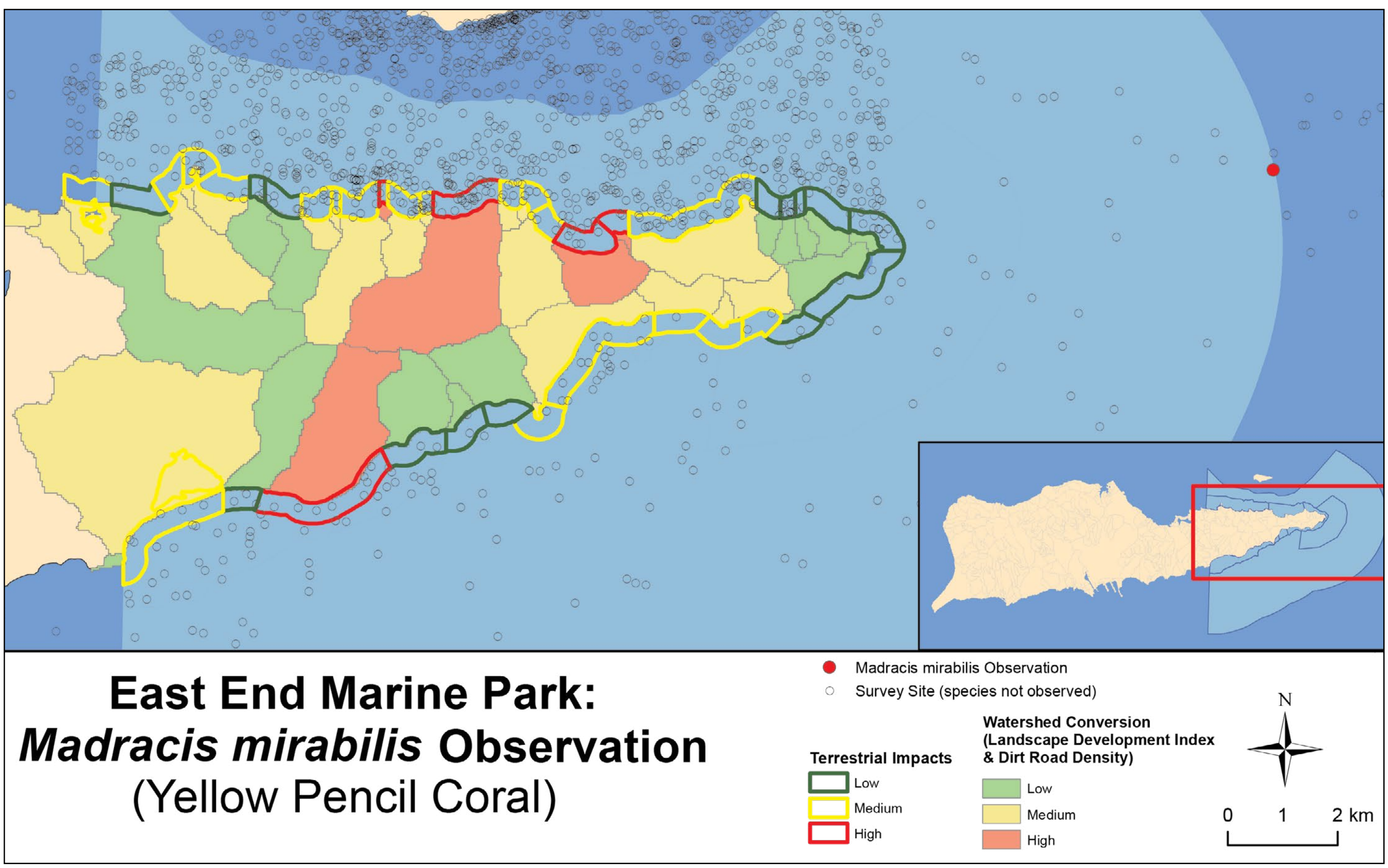

Figure 3.15. Map of Madracis mirabilis *(yellow pencil coral) sightings within and around STXEEMP.*

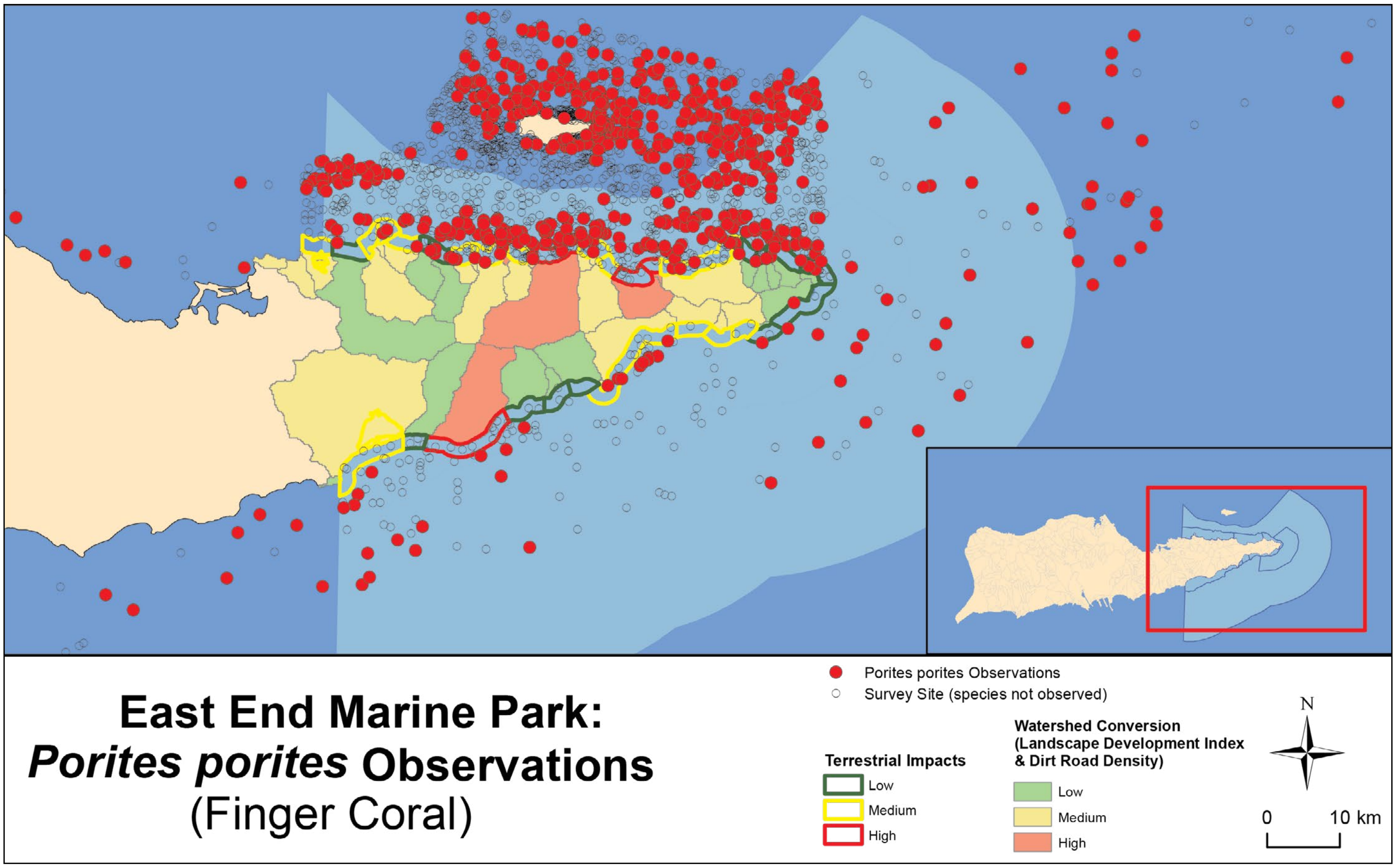

Figure 3.16. Map of Porites porites *(finger coral) sightings within and around STXEEMP.*

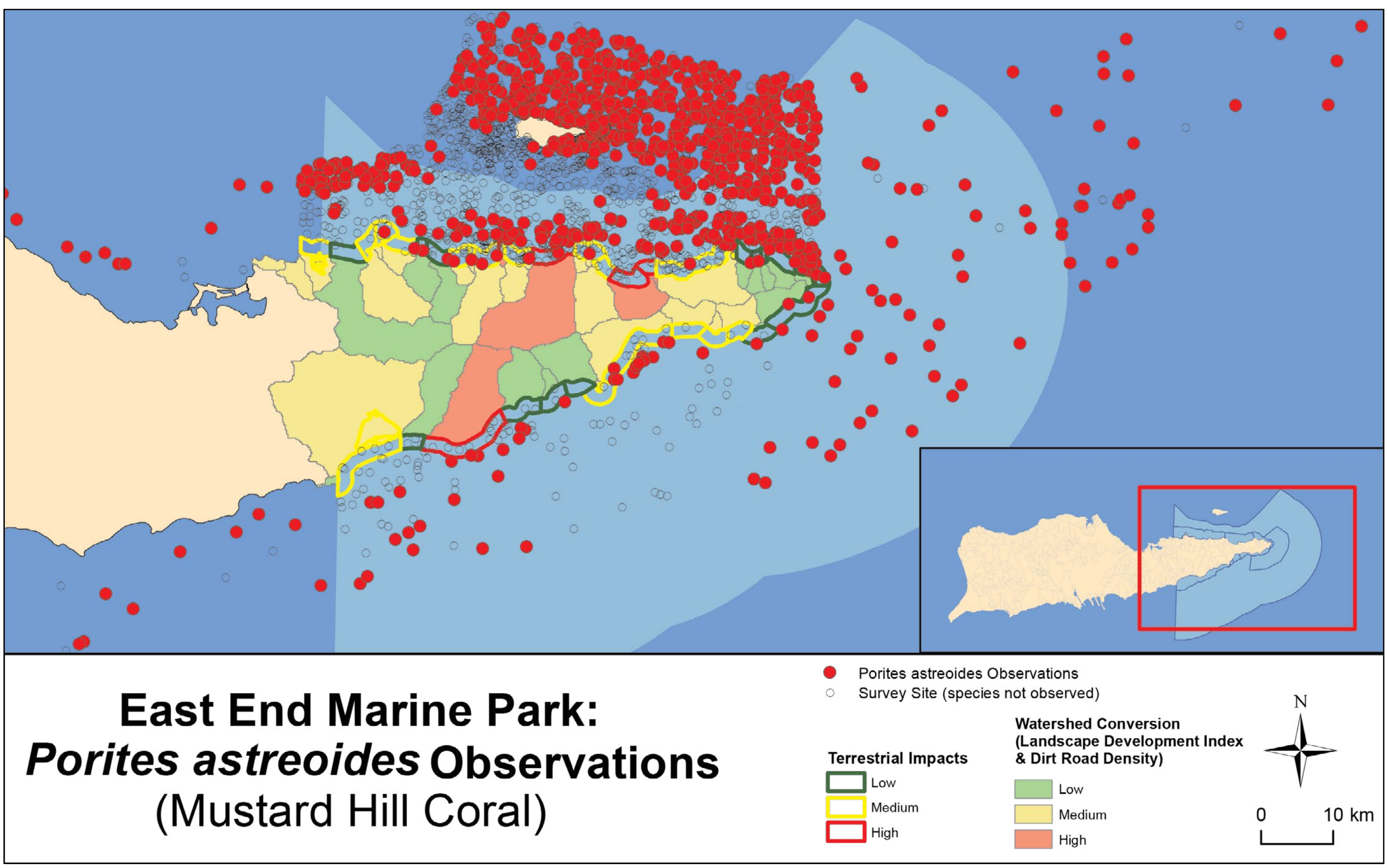

Figure 3.17. Map of Porites astreoides *(mustard hill coral) sightings within and around STXEEMP.*

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3.3.1.3. Seagrasses

Shoalgrass (*Halodule wrightii*) was observed in three watershed impact zone units (Figure 3.19). Paddle grass (*Halophila decipiens*) is known to be sensitive to land-based sources of pollution and was not observed in any of the analysis units (Figure 3.20). Manatee grass (*Syringodium filiforme*) was observed in 27 analysis units (Figure 3.21). Turtle grass (*Thalassia testudinum*) was widely distributed within watershed impact zones (Figures 3.18 and 3.22).

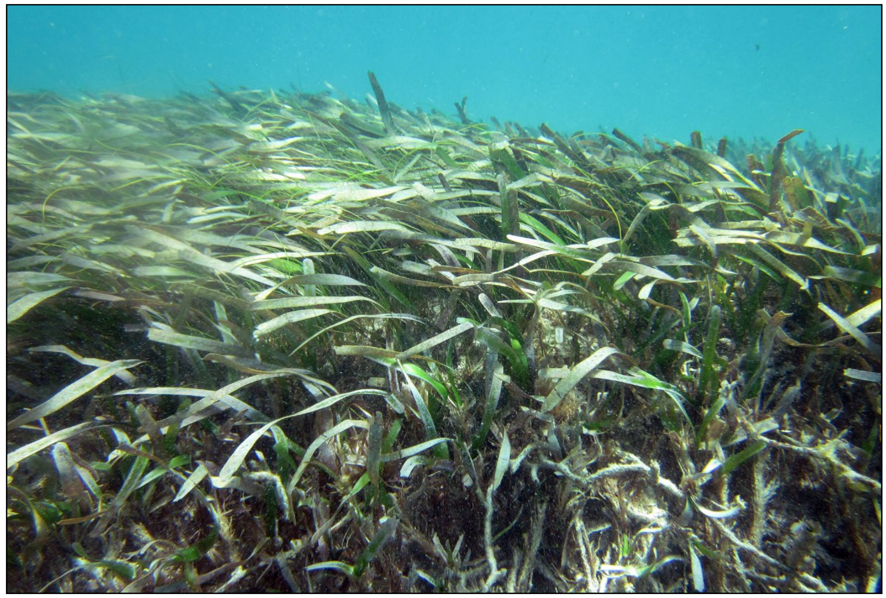


*Figure 3.18. Photo of turtle grass (*Thalassia testudinum*) within STXEEMP. Photo credit: NOAA/NOS/NCCOS/CCMA Biogeography Branch.*

Many of the near shore marine analysis units contained species which are known to be sensitive to sedimentation and land-based sources of pollution. Certain areas have higher species richness for species which are known to be sensitive to sedimentation and pollution. Those areas are highlighted in Figure 3.23

We analyzed the distribution of combined coral cover for several of the sensitive species (*Acropora palmata*, *Diploria strigosa*, *Favia fragum*, *Montastraea annularis* complex, *Porites astreoides*, and *Porites porites*) by impact class using a Wilcoxon test. The results showed no statistically significant differences.

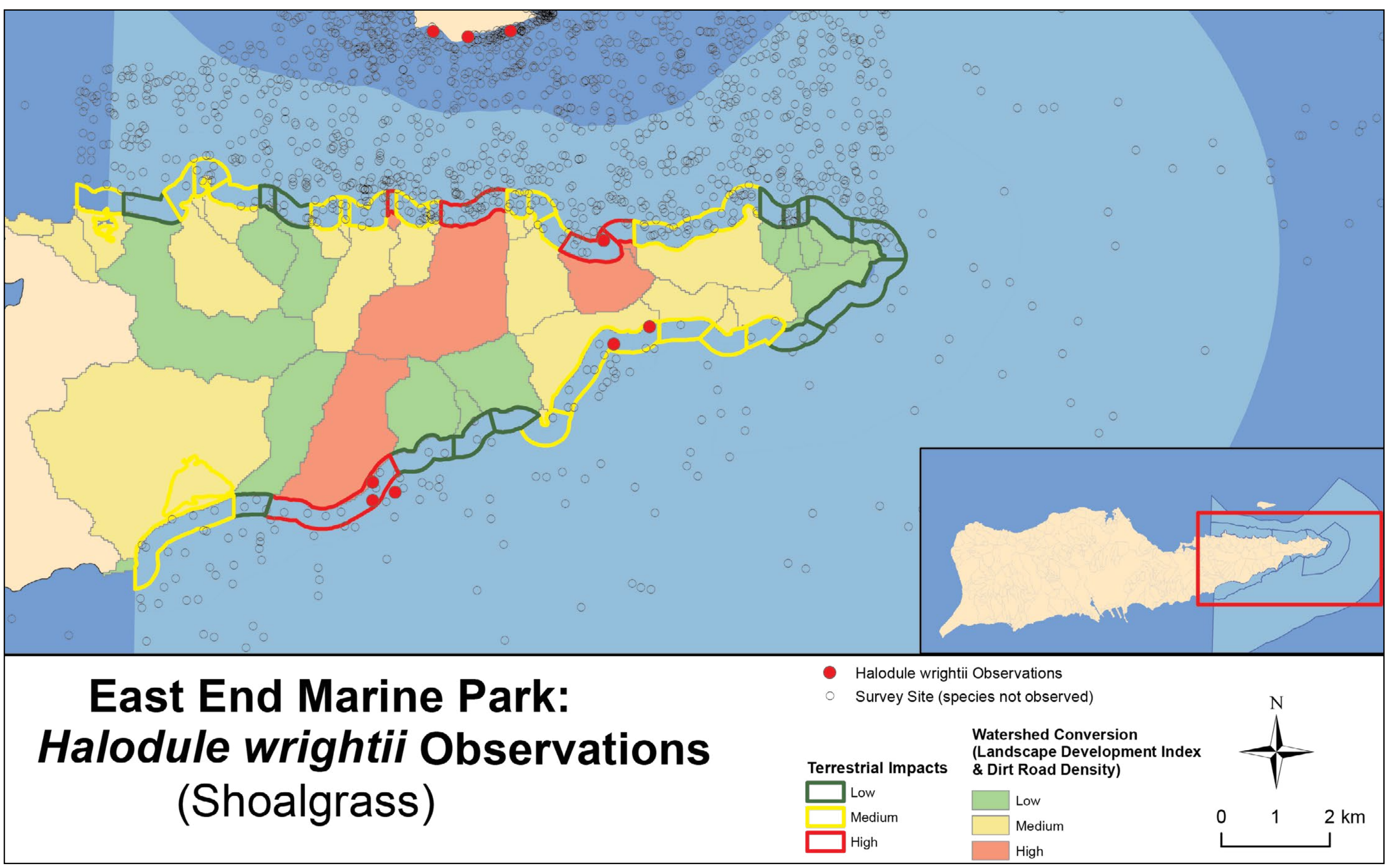


Figure 3.19. Map of Halodule wrightii *(shoalgrass) sightings within and around STXEEMP.*

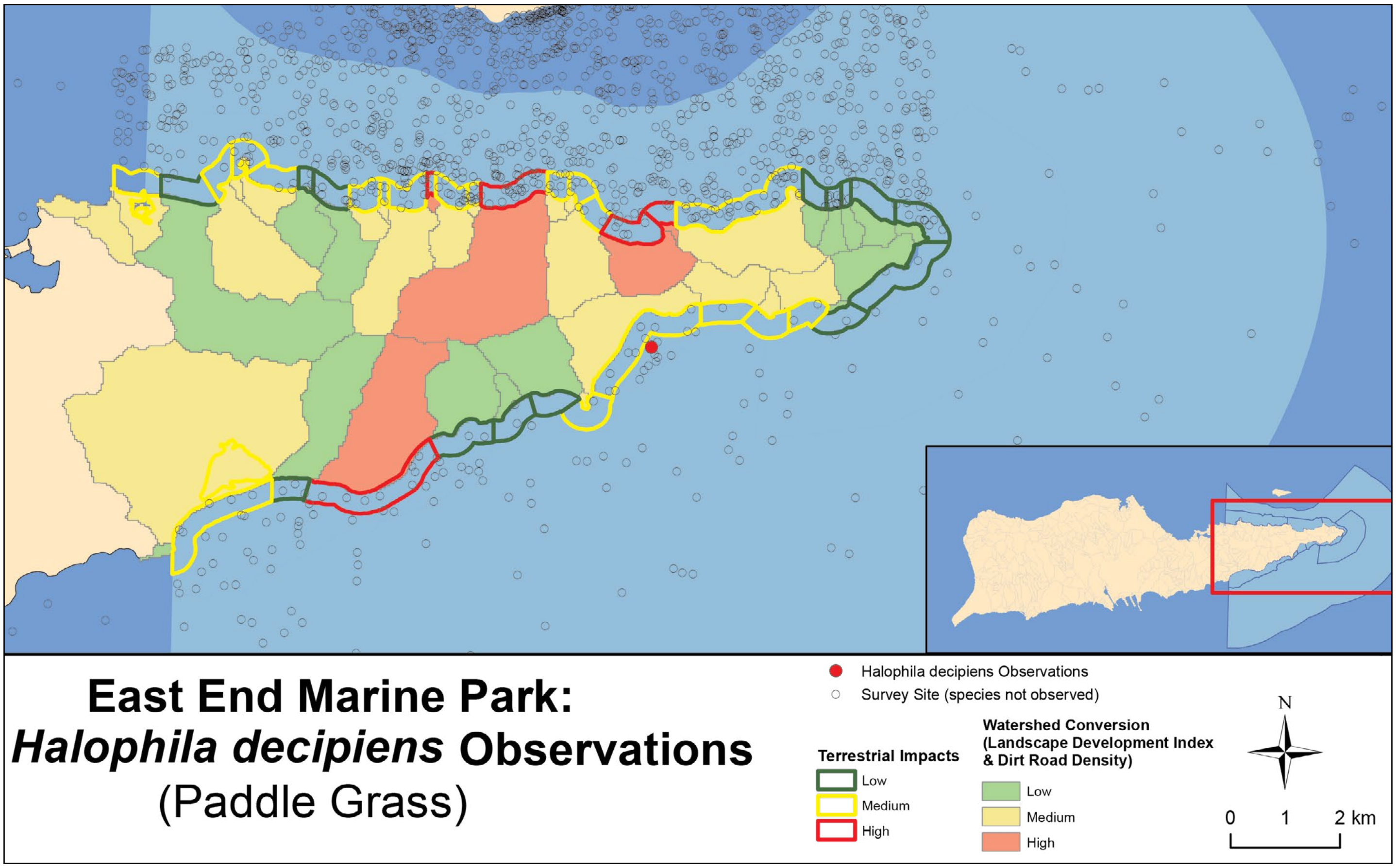


Figure 3.20. Map of Halophila decipiens *(paddle grass) sightings within and around STXEEMP.*

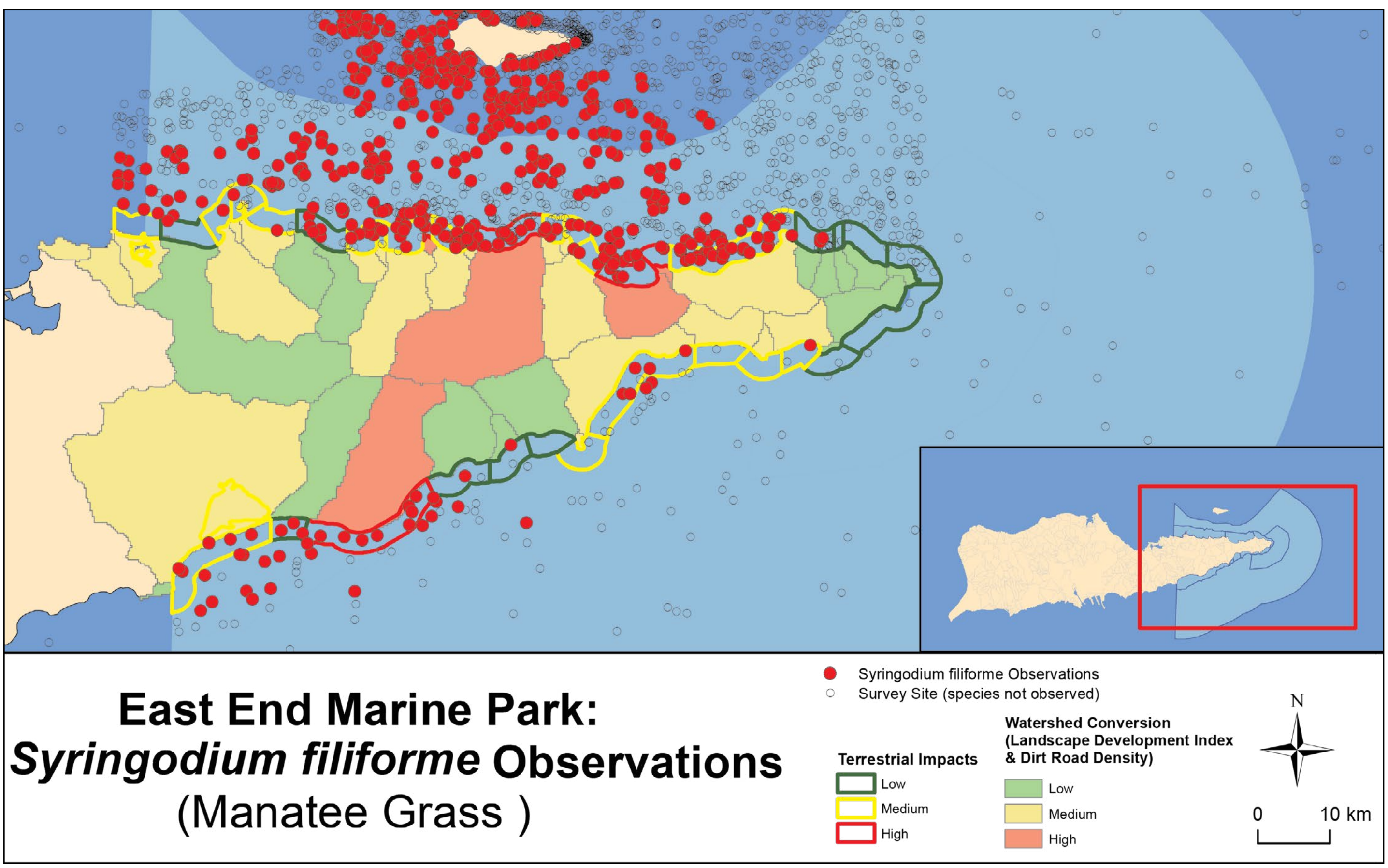


Figure 3.21. Map of Syringodium filiforme *(manatee grass) sightings within and around STXEEMP.*

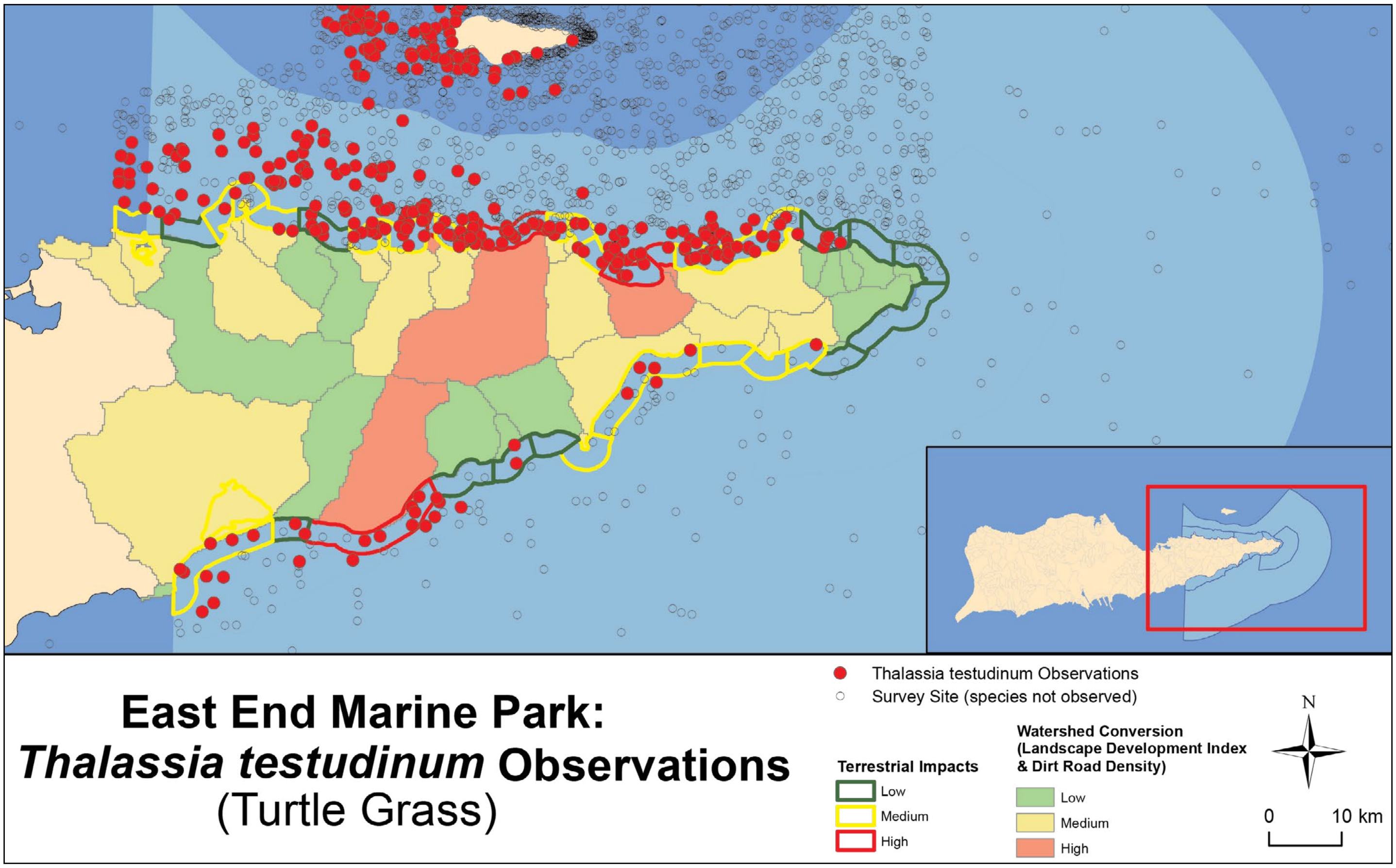


Figure 3.22. Map of Thalassia testudinum *(turtle grass) sightings within and around STXEEMP.*

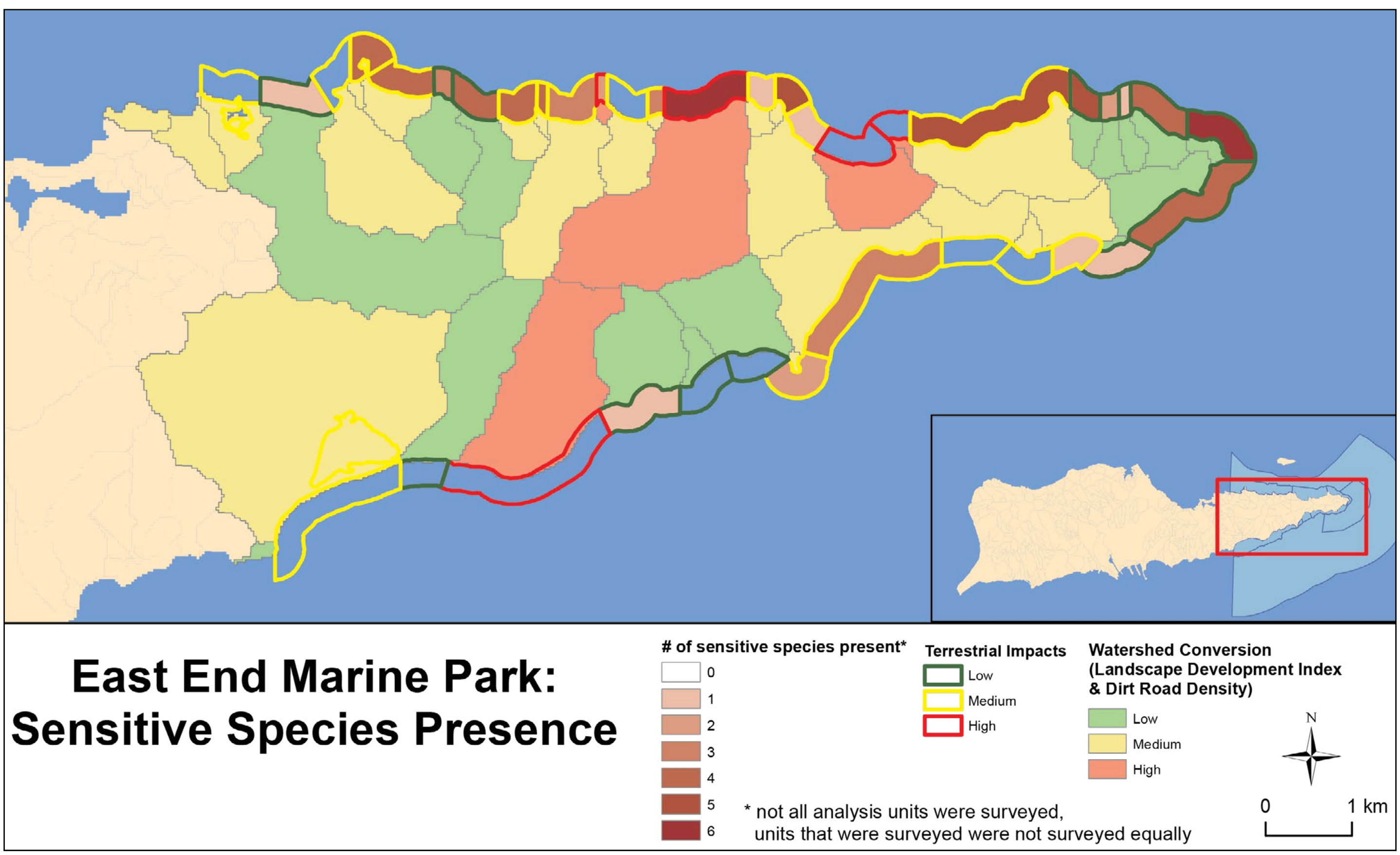


Figure 3.23. This map indicates the total number of sensitive species present within each watershed analysis unit.

3.3.1.4. Fish communities

Based on the 190 benthic surveys conducted within the watershed impact zone analysis units (Figure 3.24), we show here the maximum number of fish species recorded within a single survey (fish species richness per 100 m^2) and the mean of species richness for each of the analysis units (Figures 3.25 and 3.26). It is important to note that survey effort is not consistent, with greater effort focused on the north shore. Regardless, diverse fish assemblages currently exist in the northern watershed impact zone that are expected to be experiencing medium – high impact from land-based sources of pollution. The direct consequences of this exposure on fishes is unknown, nor do we know much about the impact of habitat suitability. This potential threat to species rich fish assemblages requires closer investigation.

Figure 3.24. Photo of a diver conducting a fish survey within an assemblage of juvenile grunts in Teague Bay of STXEEMP. Photo credit: NOAA/NOS/NCCOS/CCMA Biogeography Branch.

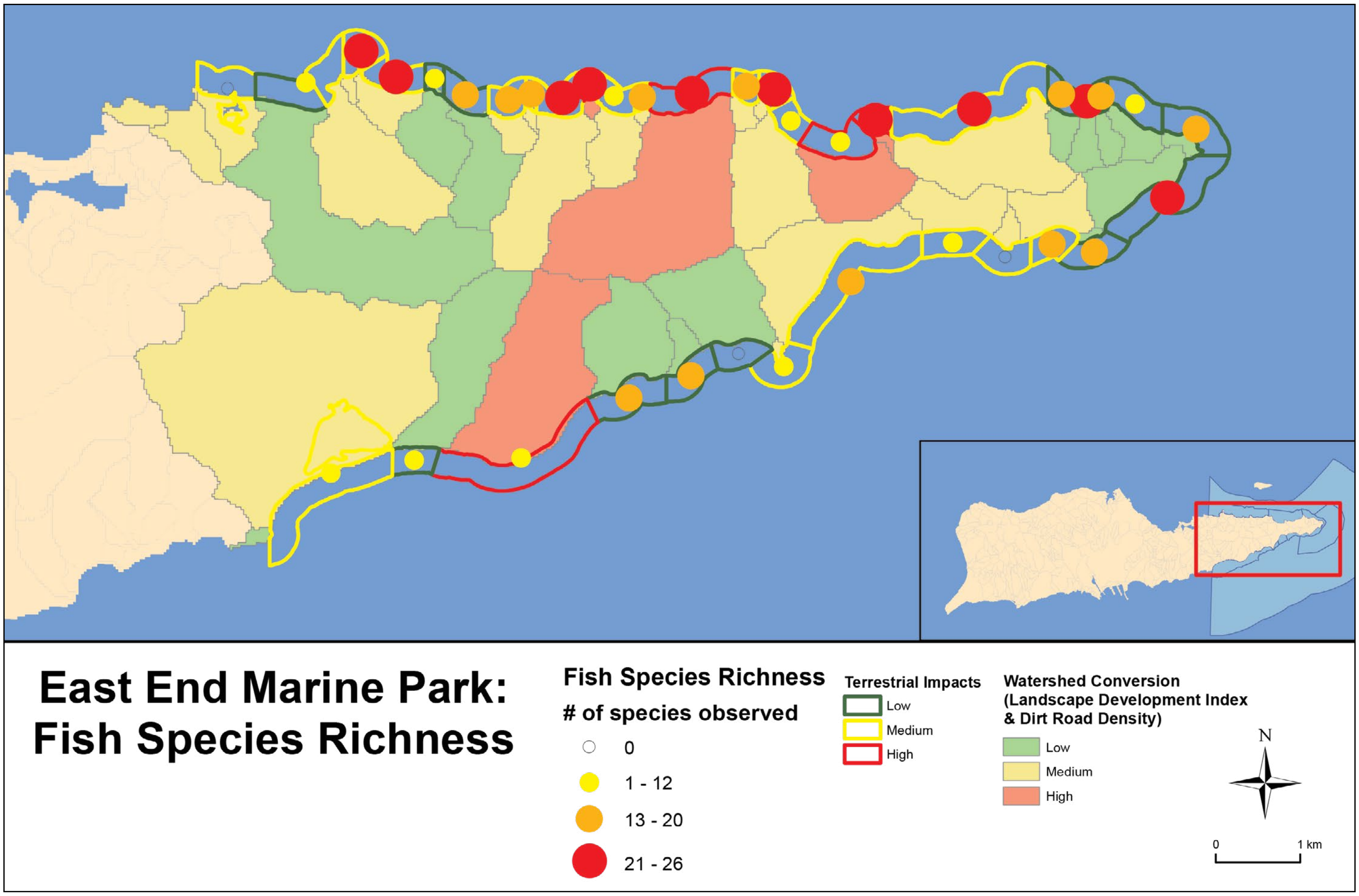


Figure 3.25. Distribution of maximum fish species richness (per 100 m^2) within the watershed impact zone of STXEEMP.

Marine Fish and Benthic Communities

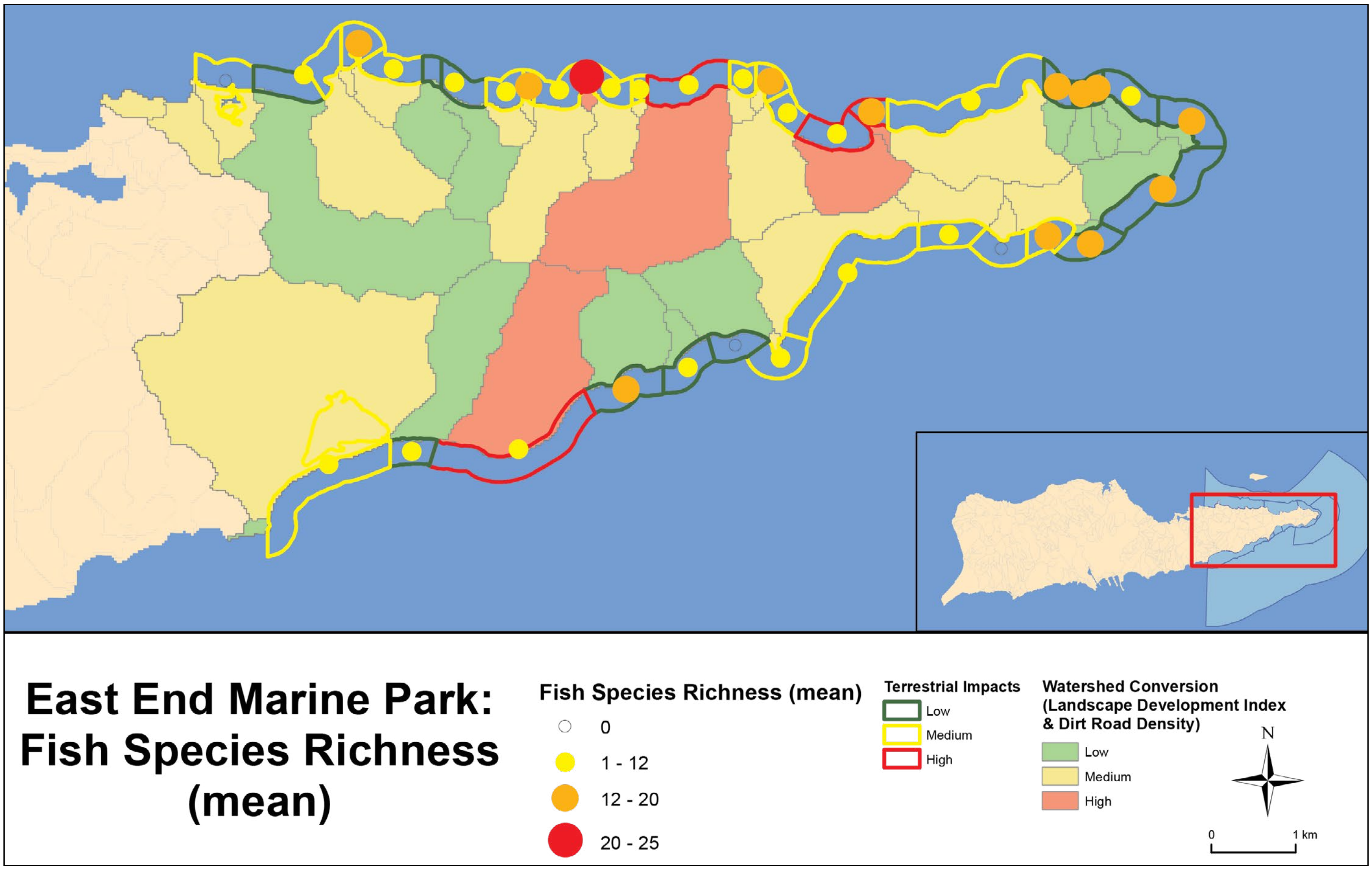


Figure 3.26. Mean fish species richness within each analysis unit of the watershed impact zone around STXEEMP.

3.3.2 Characterization of marine park zones

3.3.2.1. Benthic habitats

We quantified the benthic habitat composition of the different zones within the STXEEMP using two distinct datasets. The first dataset was the distribution of mapped benthic habitats from NOAA benthic habitat maps (Figure 3.27). The total area of each habitat type was determined using the benthic habitat map (Table 3.13). A chart, table, and map show the area of each habitat class within the zones of the STXEEMP (Table 3.14, Figures 3.27 and 3.28). Note that this value is based only on the mapped portions of the Park. Twenty-nine percent of STXEEMP comprising deeper water areas >35 m remain unmapped.

Table 3.13. Total benthic habitat composition of zones from benthic habitat map of the STXEEMP.

Benthic Habitat	Hectares
Coral Reef and Colonized Hardbottom	8000
Other Delineations	4040
Submerged Vegetation	2331
Uncolonized Hardbottom	8
Unconsolidated Sediments	277

Table 3.14. Table indicating the number of hectares for each habitat type within zone type for STXEEMP. Note that 29 % of the zone without regulations (Take) is unmapped.

EEMP Zones	Coral Reef & Col. Hardbottom	Unmapped	Submerged Vegetation	Uncolonized Hardbottom	Unconsolidated Sediments
No Take	578	4	700	4	2
Take	6398	4035	1217	2	246
Recreation	136	0	274	2	5
Sea Turtle Reserve	888	0	140	0	25

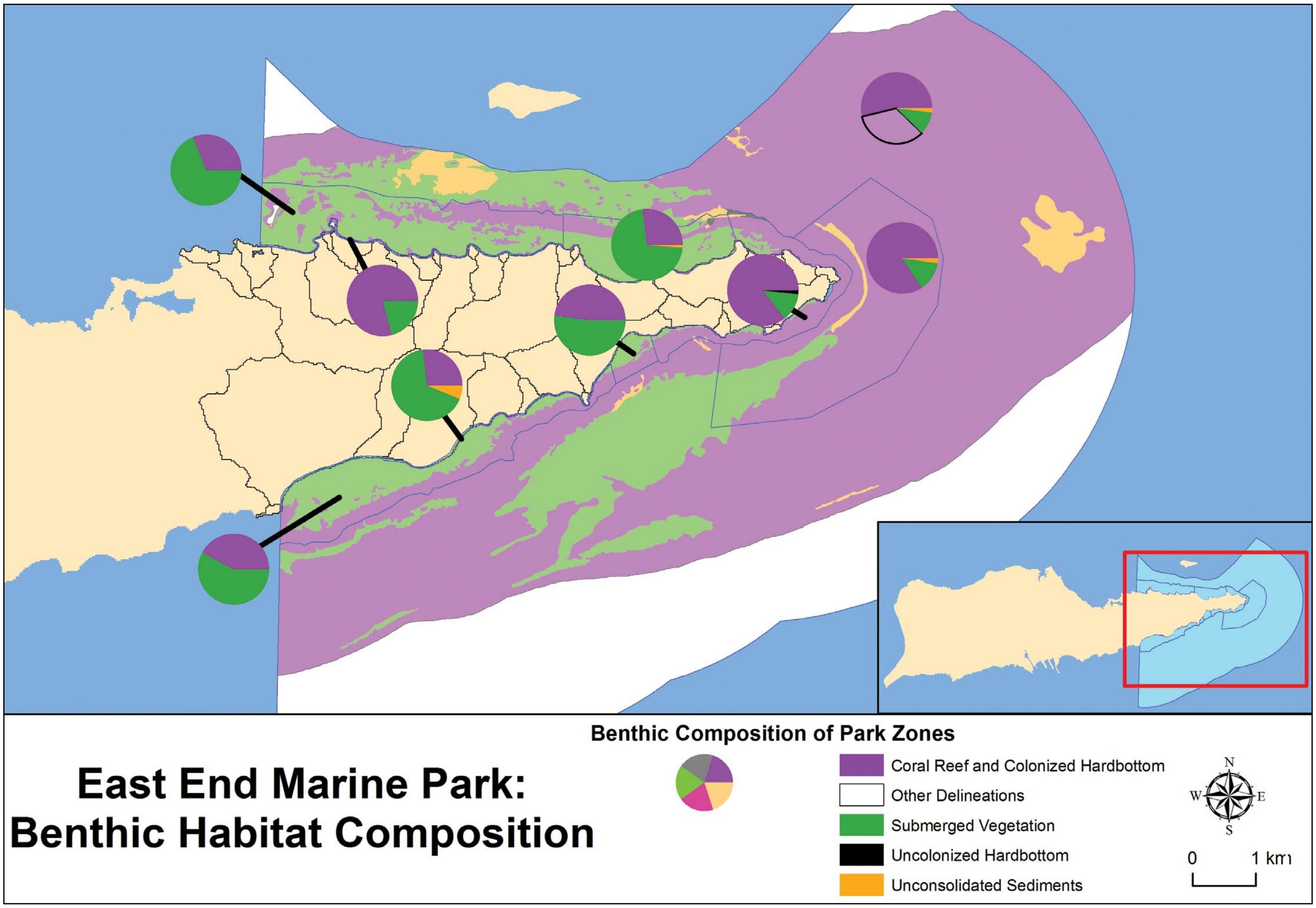


Figure 3.27. Benthic habitat composition by zones in STXEEMP.

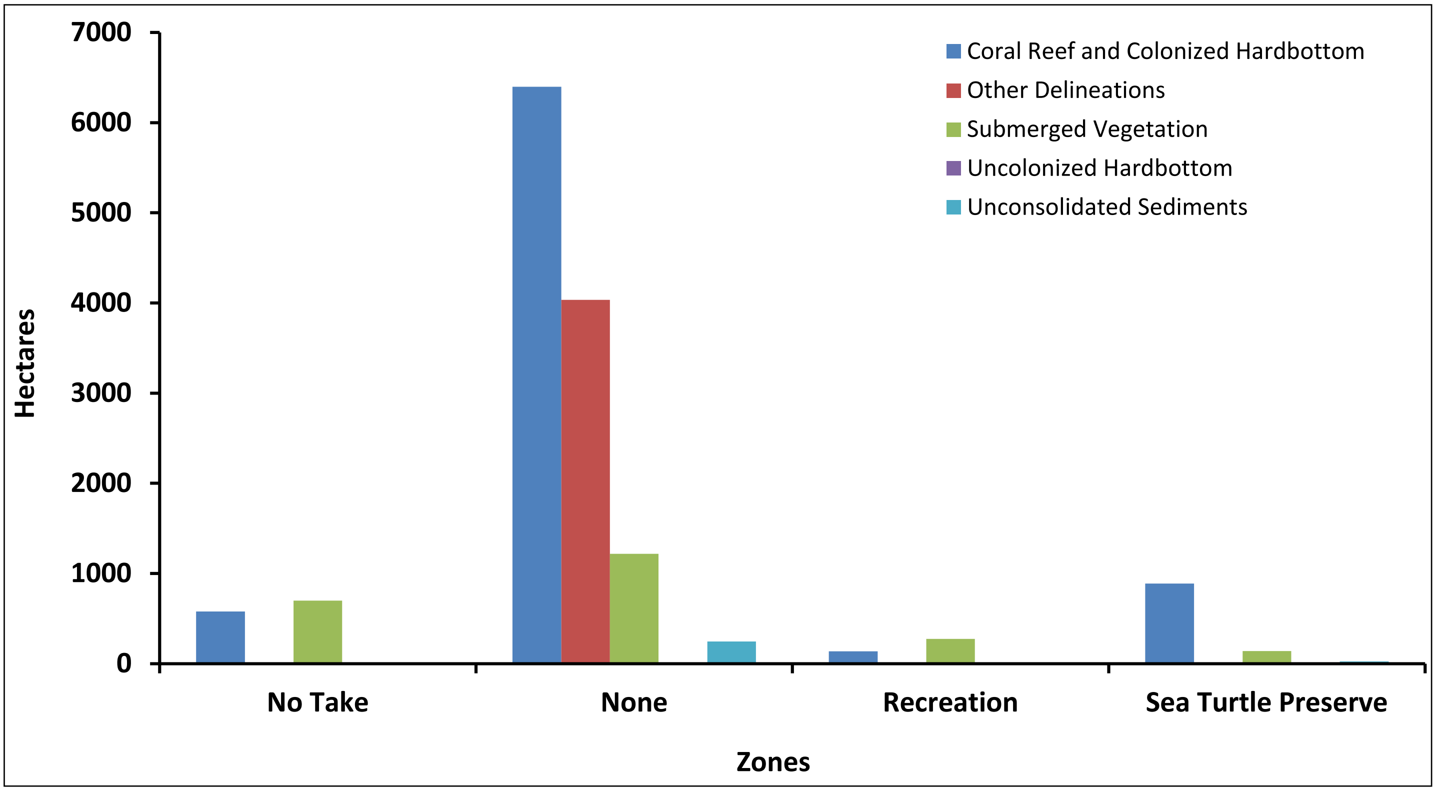


Figure 3.28. Mapped benthic habitat composition by zones in STXEEMP.

Marine Fish and Benthic Communities

The second dataset analyzed was the benthic habitat surveys conducted by scientific divers using five random 1 m^2 quadrats for each fish transect as described in section 3.2.1. We combined the results of surveys within each zone to produce an overall estimate of benthic habitat composition by zone type (Table 3.15). Since surveys only cover a small percentage (sub-samples) of the available habitat, these numbers should be taken as estimates only. The results from these surveys are shown in Figure 3.29 and in Figure 3.30.

Table 3.15. Percent of each benthic habitat within zone type based on survey information.

Zone	Hard Coral	Hydrocoral	Macroalgae	Turf Algae	Crustose Algae	Filamentous Algae/ Cyanobacteria	Seagrass	Soft Coral	Sponge
No Take	1.43	0.10	10.39	22.54	1.07	1.44	14.16	0.30	0.58
Take	1.54	0.18	8.54	24.01	0.82	7.71	2.97	0.87	1.83
Recreation	1.76	0.06	8.96	17.60	0.83	0.51	19.96	0.48	0.40
Sea Turtle Preserve	1.35	0.12	11.45	34.03	0.80	9.96	0.00	1.22	1.41

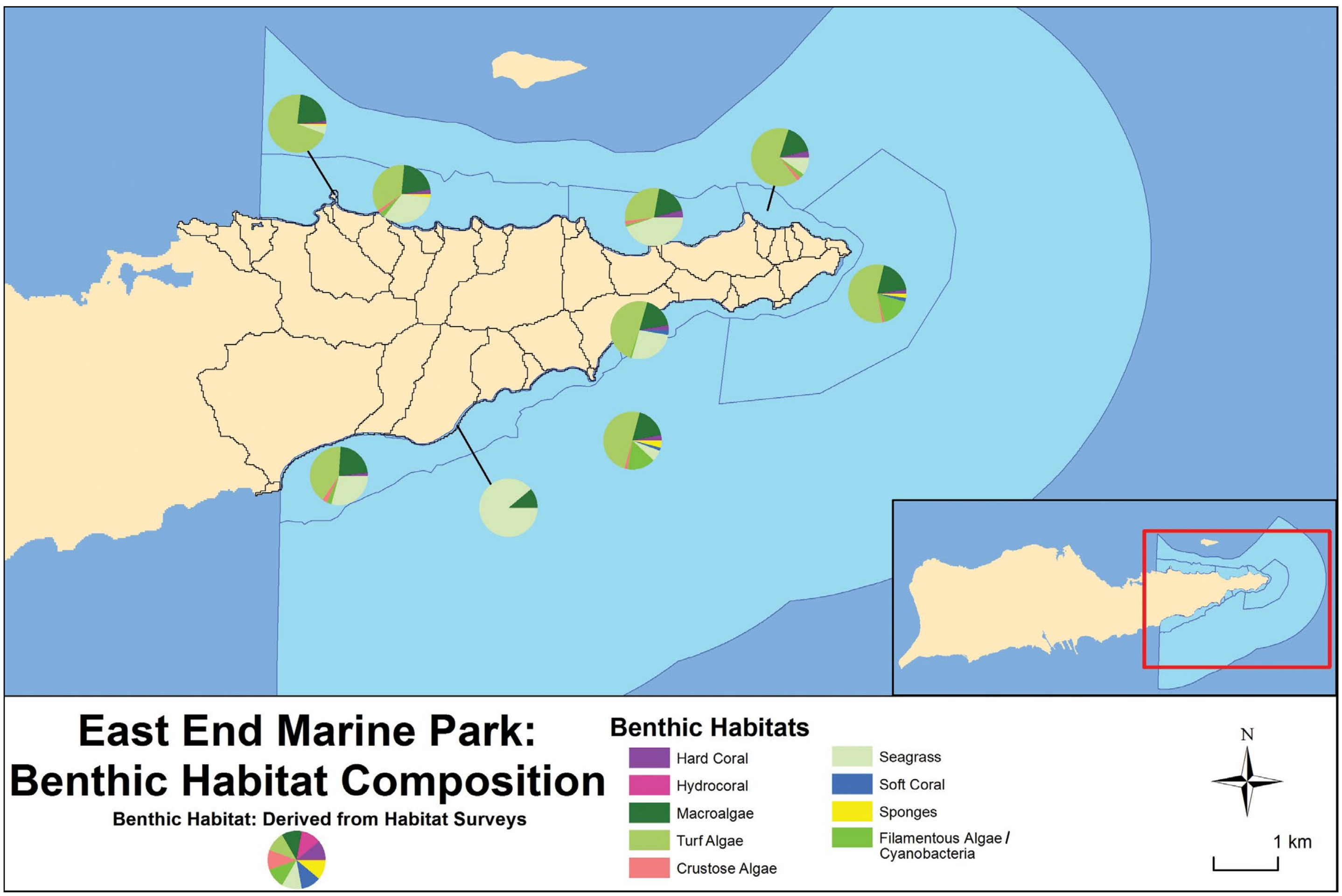


Figure 3.29. Benthic habitat composition by zones in STXEEMP.

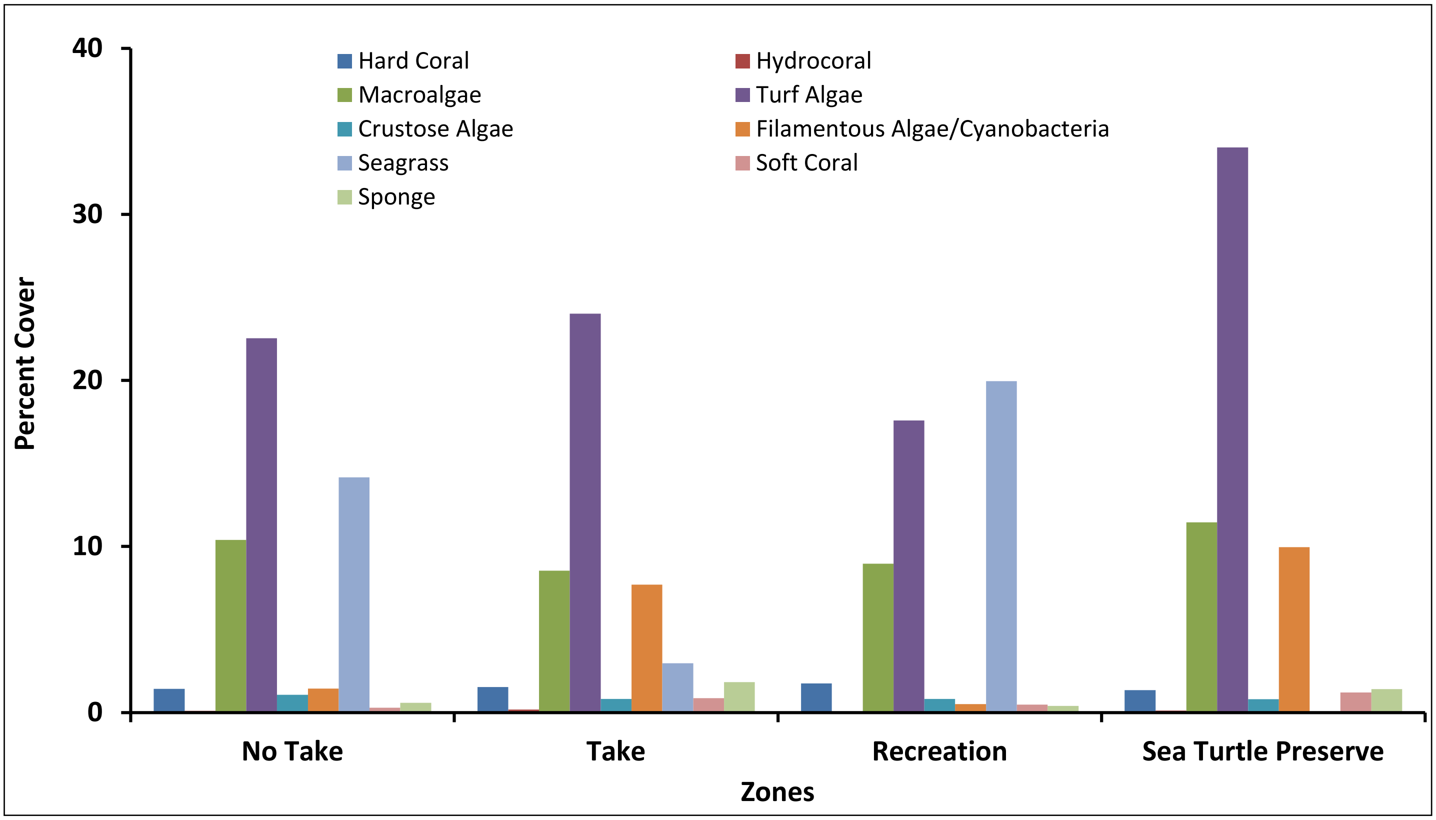


Figure 3.30. Mapped benthic habitat composition by zones in STXEEMP. Note: The class of Other Delineations (not shown) includes unclassified areas.

We examined the benthic habitat survey information within zones by conducting a Wilcoxon statistical test and a Wilcoxon pair wise test. These results are presented in Tables 3.16-3.19.

For habitats occurring in hard substrate, we found significant differences for nearly all habitat types (Table 3.16). Fewer habitats in soft substrate showed significant variation between park zone types (Table 3.17). Examined individually, many of the habitats in both hard and soft substrate showed significant variations between park zone types (Tables 3.18 and 3.19).

Differences in benthic composition are shown in Figures 3.31 and 3.32.

Table 3.16. Results from Wilcoxon test on benthic habitats on hard substrate within park zones.

Benthic Habitat	ChiSquare	DF	Prob>ChiSq
Crustose Algae	2.8709	3	0.412
Filamentous Algae/Cyanobacteria	34.743	3	<.0001
Hard Coral	20.849	3	0.0001
Hydrocoral	52.3625	3	<.0001
Macroalgae	33.107	3	<.0001
Seagrass	45.8176	3	<.0001
Soft Coral	53.8208	3	<.0001
Sponge	157.0581	3	<.0001
Turf Algae	5.4712	3	0.1404

Table 3.17. Results from Wilcoxon test on benthic habitats on soft substrate within park zones.

Benthic Habitat	ChiSquare	DF	Prob>ChiSq
Crustose Algae	14.4228	3	0.0024
Filamentous Algae/Cyanobacteria	1.3988	3	0.7058
Hard Coral	10.709	3	0.0134
Hydrocoral	0.2815	3	0.9635
Macroalgae	2.3814	3	0.4971
Seagrass	106.8829	3	<.0001
Soft Coral	10.8734	3	0.0124
Sponge	25.3508	3	<.0001
Turf Algae	5.7969	3	0.1219

Table 3.18. Results from Wilcoxon pair wise test of benthic habitats on hard substrate within park zones. Significant results are in the gray boxes.

Benthic Habitat	Park Zone	Take	Recreation	No Take
Hard Coral	Take			0.3866
	Recreation	<.0001		0.0002
	Sea Turtle Preserve	0.6434	0.0004	0.3439
Crustose Algae	Take			0.9867
	Recreation	0.1075		0.1644
	Sea Turtle Preserve	0.4707	0.4976	0.6354
Filamentous Algae / Cyanobacteria	Take			<.0001
	Recreation	<.0001		0.1041
	Sea Turtle Preserve	0.4257	0.0005	0.0027
Hydrocoral	Take			<.0001
	Recreation	<.0001		0.6862
	Sea Turtle Preserve	0.0275	0.1885	0.2246
Macroalgae	Take			<.0001
	Recreation	<.0001		0.1541
	Sea Turtle Preserve	0.641	0.0169	0.0649
Seagrass	Take			<.0001
	Recreation	<.0001		0.0572
	Sea Turtle Preserve	0.4589	0.0049	0.0425
Soft Coral	Take			<.0001
	Recreation	0.133		0.0349
	Sea Turtle Preserve	0.3276	0.075	<.0001
Sponge	Take			<.0001
	Recreation	<.0001		0.7888
	Sea Turtle Preserve	0.0177	<.0001	<.0001
Turf Algae	Take			0.0595
	Recreation	0.1176		0.7304
	Sea Turtle Preserve	0.2712	0.8637	0.7388

Table 3.19. Results from Wilcoxon pair wise test of benthic habitats on soft substrate within park zones.. Significant results are in the gray boxes.

Benthic Habitat	Zone	None	Recreation	No Take
Seagrass	None			<.0001
	Recreation	<.0001		0.8351
	Sea Turtle Preserve	0.0184	<.0001	<.0001
Turf Algae	None			0.388
	Recreation	0.0231		0.0934
	Sea Turtle Preserve	0.6315	0.0275	0.4162
Macroalgae	None			0.8203
	Recreation	0.1679		0.2207
	Sea Turtle Preserve	0.5986	0.3485	0.7581
Crustose Algae	None			0.1438
	Recreation	0.0092		0.0736
	Sea Turtle Preserve	0.0843	<.0001	0.0048
Filamentous Algae / Cyanobacteria	None			0.4802
	Recreation	0.5622		0.2417
	Sea Turtle Preserve	0.9874	0.8993	0.8602
Hard Coral	None			0.2531
	Recreation	0.0023		0.025
	Sea Turtle Preserve	0.189	0.5641	0.2705
Hydrocoral	None			0.8633
	Recreation	0.7976		0.6922
	Sea Turtle Preserve	0.7428	0.8059	0.7254
Soft Coral	None			0.0347
	Recreation	0.0165		0.2104
	Sea Turtle Preserve	0.5148	0.0008	0.0462
Sponge	None			0.0002
	Recreation	<.0001		0.2657
	Sea Turtle Preserve	0.0752	0.7291	0.4458

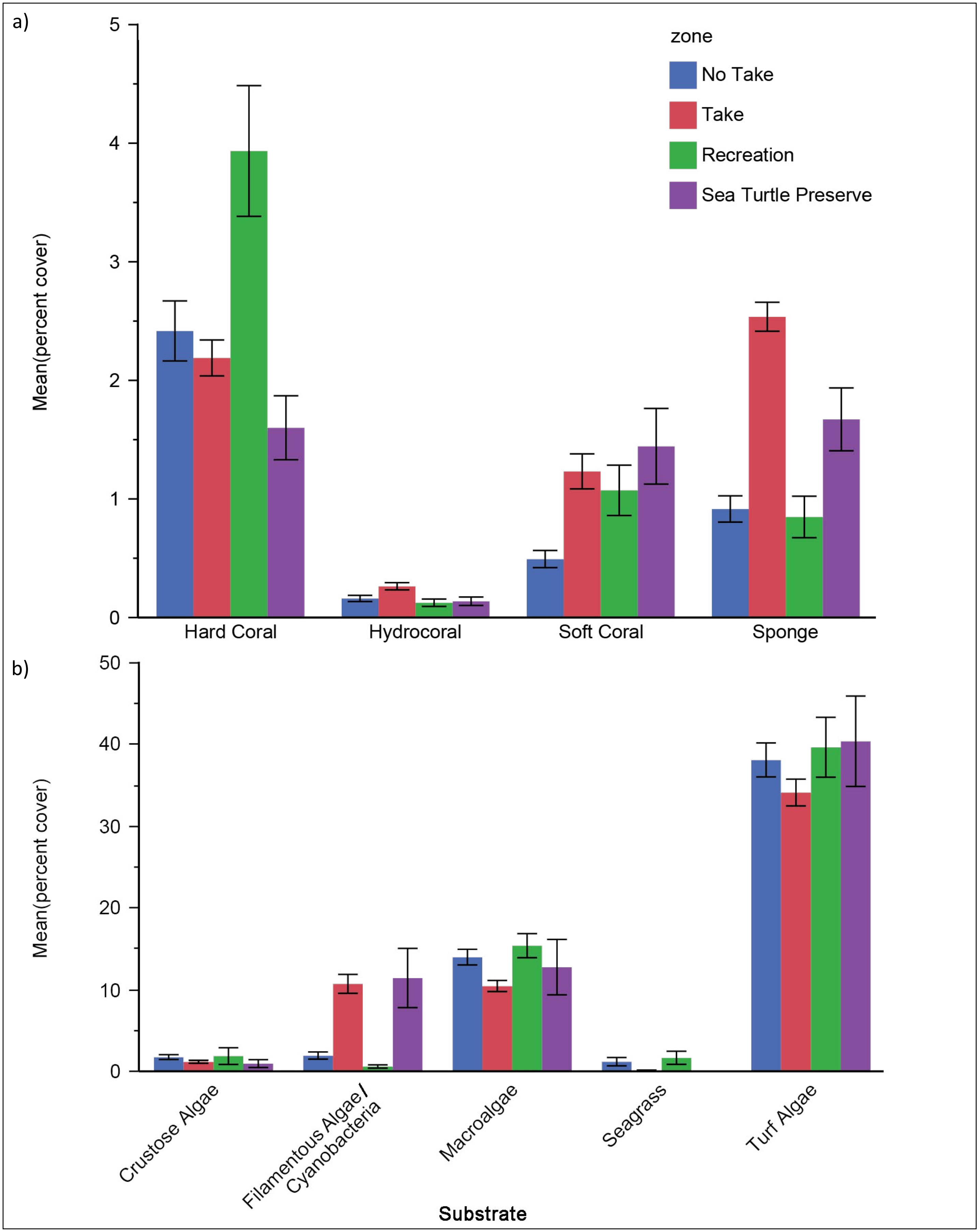


Figure 3.31. Percent cover for (a) coral and sponge groups and (b) submerged aquatic vegetation (SAV) groups within hard substrate by park zone.

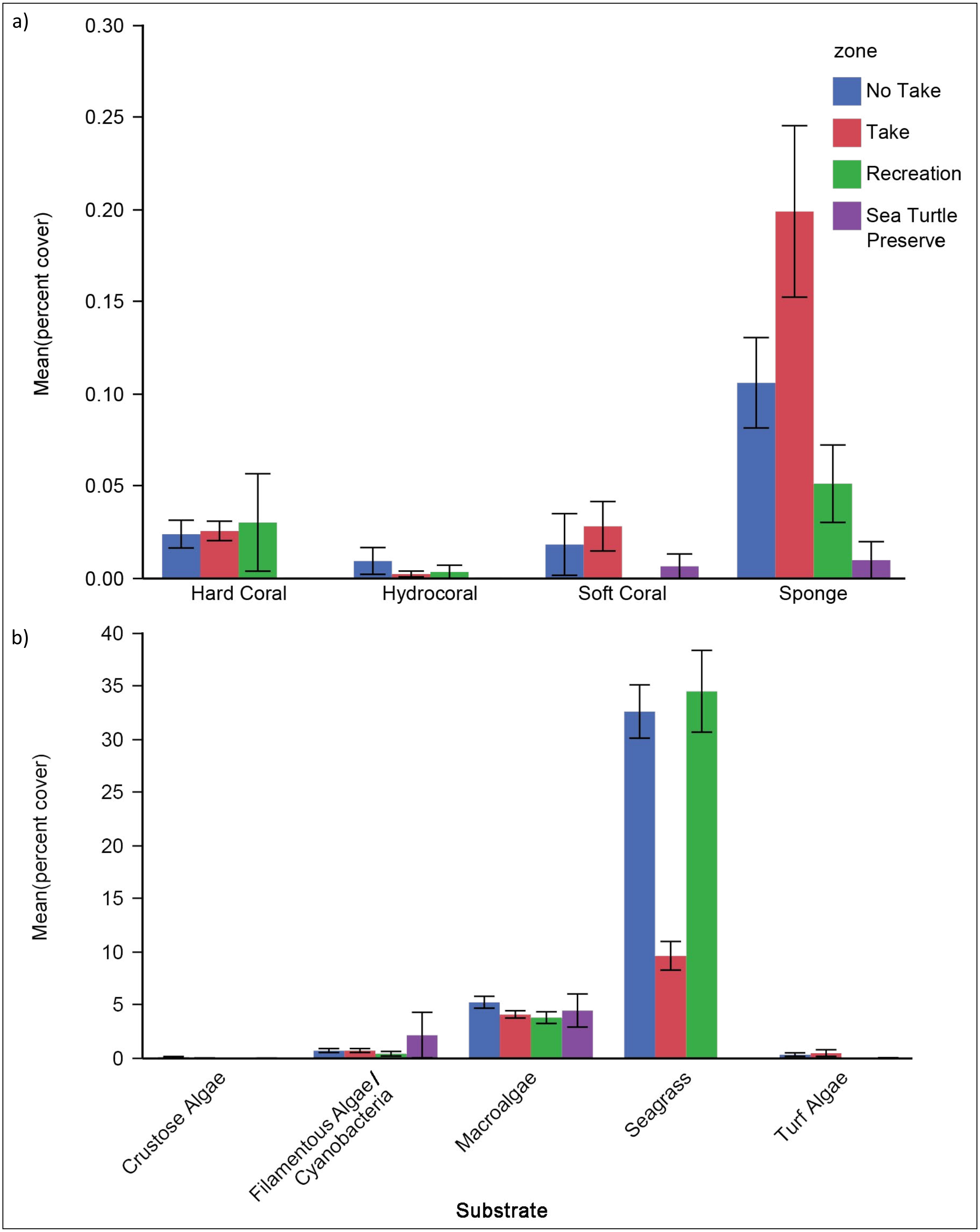


Figure 3.32. (a) Percent cover of (a) dominant benthic coral and sponge groups and (b) SAV groups on soft substrate within park zones.

Marine Fish and Benthic Communities

3.3.2.2. Fish Assemblages and Trophic Groups

The most abundant five species were listed for each individual zone showing that wrasse (Labridae) are the most abundant and widespread fish family found in all park zones (Figure 3.33). The small-bodied species of wrasse dominate the communities in all zones and are considered of low vulnerability to fishing (www.fishbase.org). Four species of parrotfish use the shallow water shoreline zone where fishing is allowed, although these will likely be juveniles. Juvenile grunts (*Haemulon* spp.) are an abundant component of the fish community in the no-take zones.

Average fish biomass for fish assemblages was highest in the “Take Zone”, where commercial and recreational fishing is allowed (Figure 3.34). Comparatively low biomass was recorded in the “No Take” zones, reflecting a larger proportion of juveniles and small-bodied fishes in the assemblage. This is typical of fish assemblages in nearshore lagoonal environments.

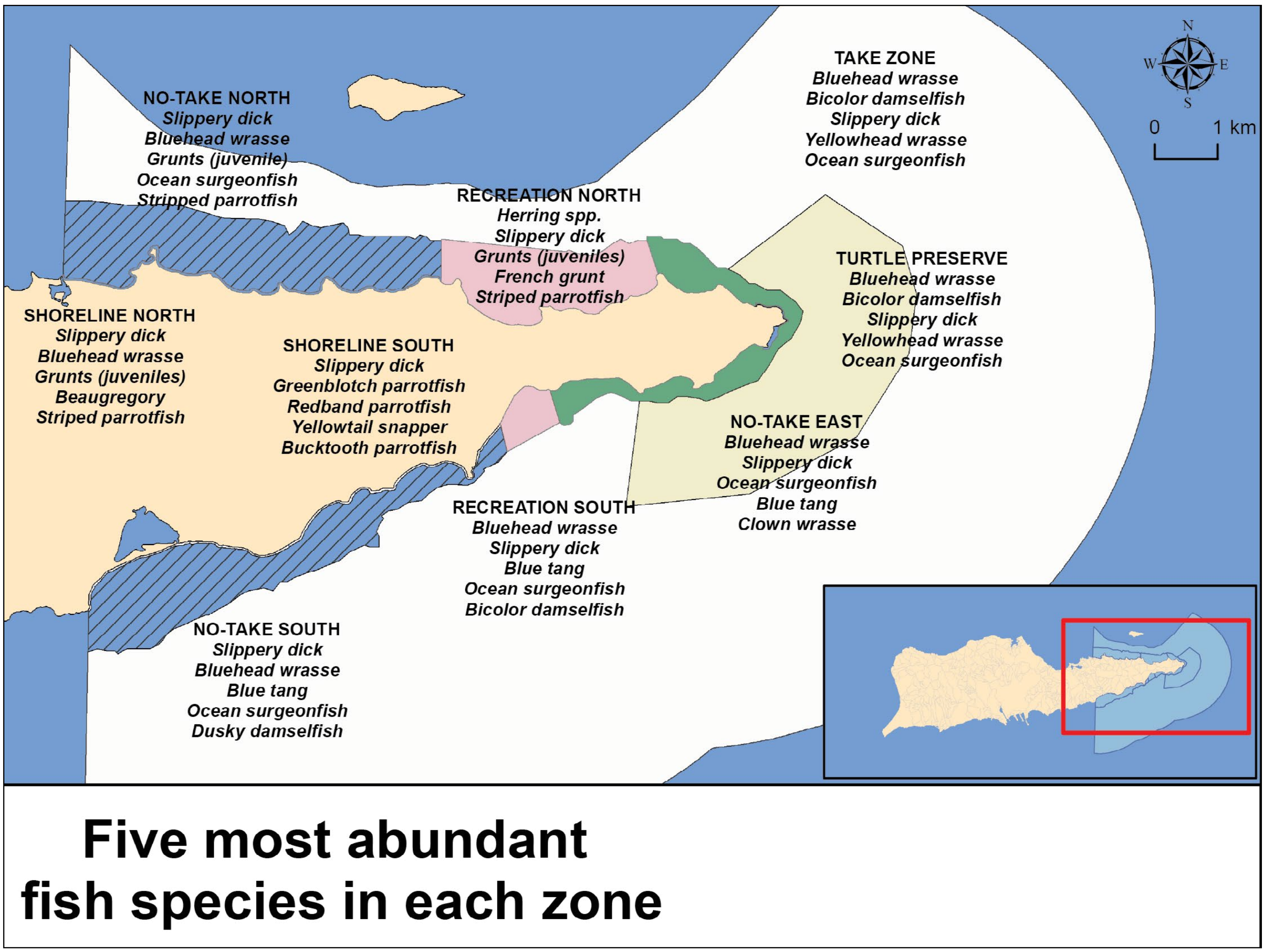
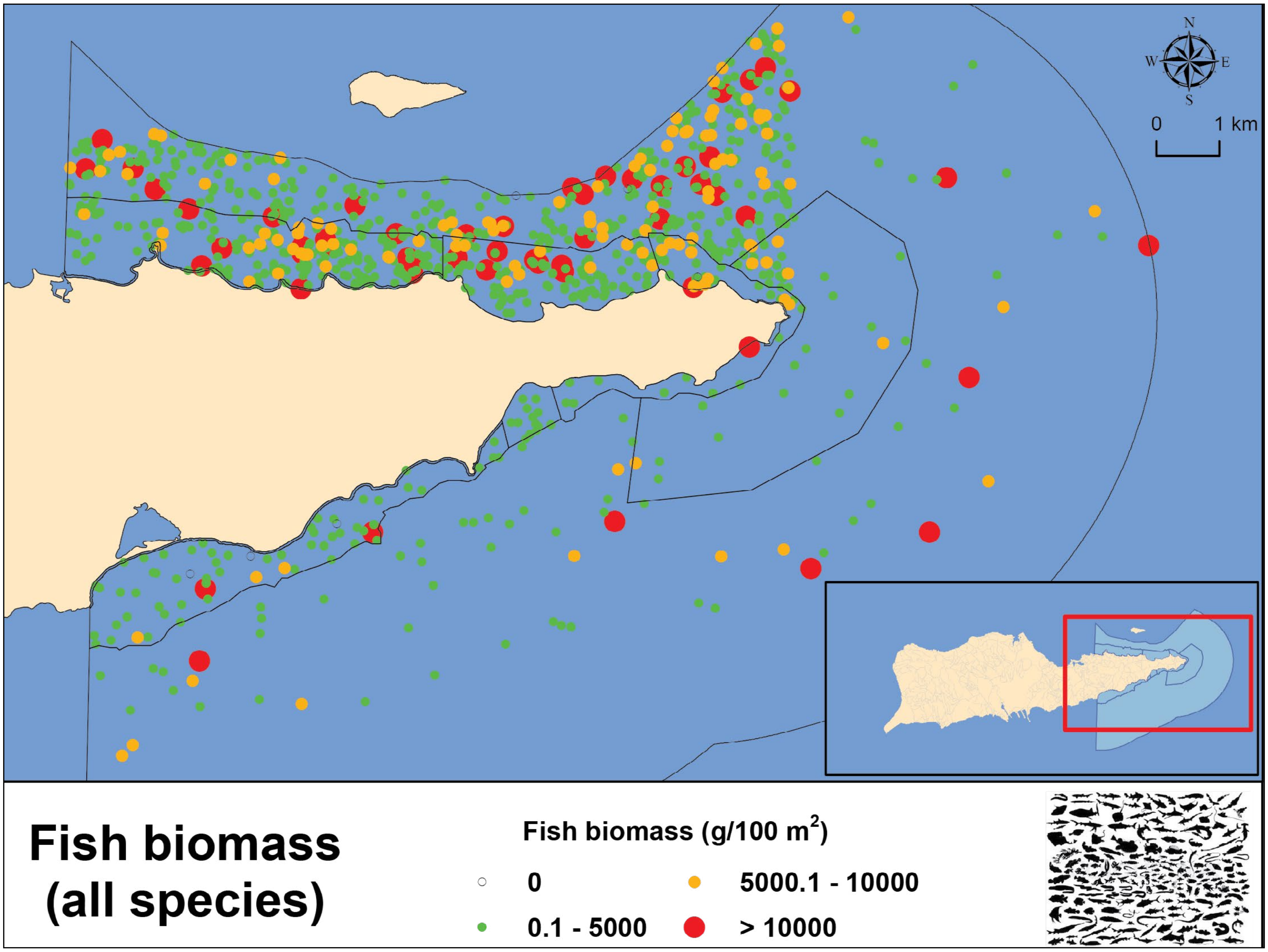


Figure 3.33. List of top five abundant fish species by zone in STXEEMP.



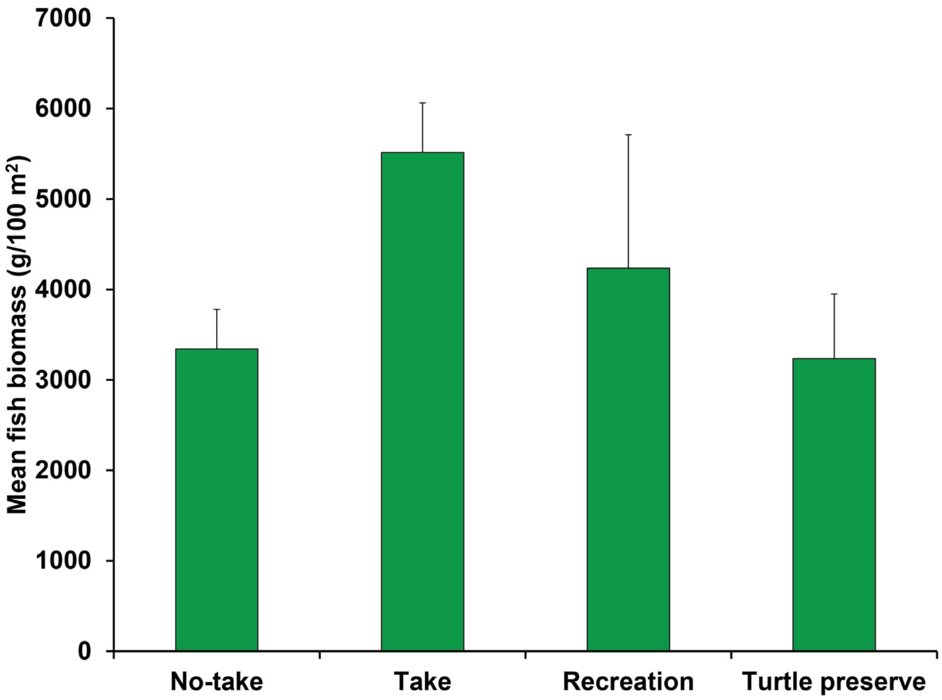


Figure 3.34. Distribution of fish biomass (g/100m²) of all species surveyed within STXEEMP (top); and graph of mean (+SE) fish biomass by major zone type (bottom).

Marine Fish and Benthic Communities

Hotspots for Fish Species Richness

Average number of fish species within survey sites was highest in the Turtle Preserve, but the individual sites with highest species richness (39 and 34 species / 100m^2) were located on offshore reefs between Point Udall and Lang Bank (Figures 3.35 and 3.36). Species richness was highest close to the boundary of the nearshore zones, reflecting the placement of some boundaries following fringing reef features, but with lowest richness closest to shore. Fish assemblages were more diverse in the Take zone than either the No Take or Recreation zones. On the northern coast, the fringing reef inside No Take and Recreation zones from Teague Bay to Cockley Bay supported high species richness and so did the offshore habitats north of Cottongarden Point (Figures 3.35 and 3.36). On the south coast, a cluster of high species richness assemblages existed in the Take zone south of Great Pond Bay. This may reflect complex reef structure in close proximity to mangrove and seagrasses that together offer a synergistic function to support a diverse fish community.

Hotspots of herbivore biomass existed in the Take zone north of Cottongarden Point (Figure 3.37). Although herbivore biomass appeared well-distributed throughout STXEEMP, adult herbivores were absent from 50 % of the sites surveyed with highest adult density occurring in the Take zone exposed to fishing (Figure 3.38). Piscivorous fish (i.e., those carnivorous fish that include fish in their diet) are far more sparsely distributed throughout STXEEMP, but with a biomass hotspot in the recreation zone on the northern coast that was due to large stingrays foraging in seagrass beds (Figure 3.39).

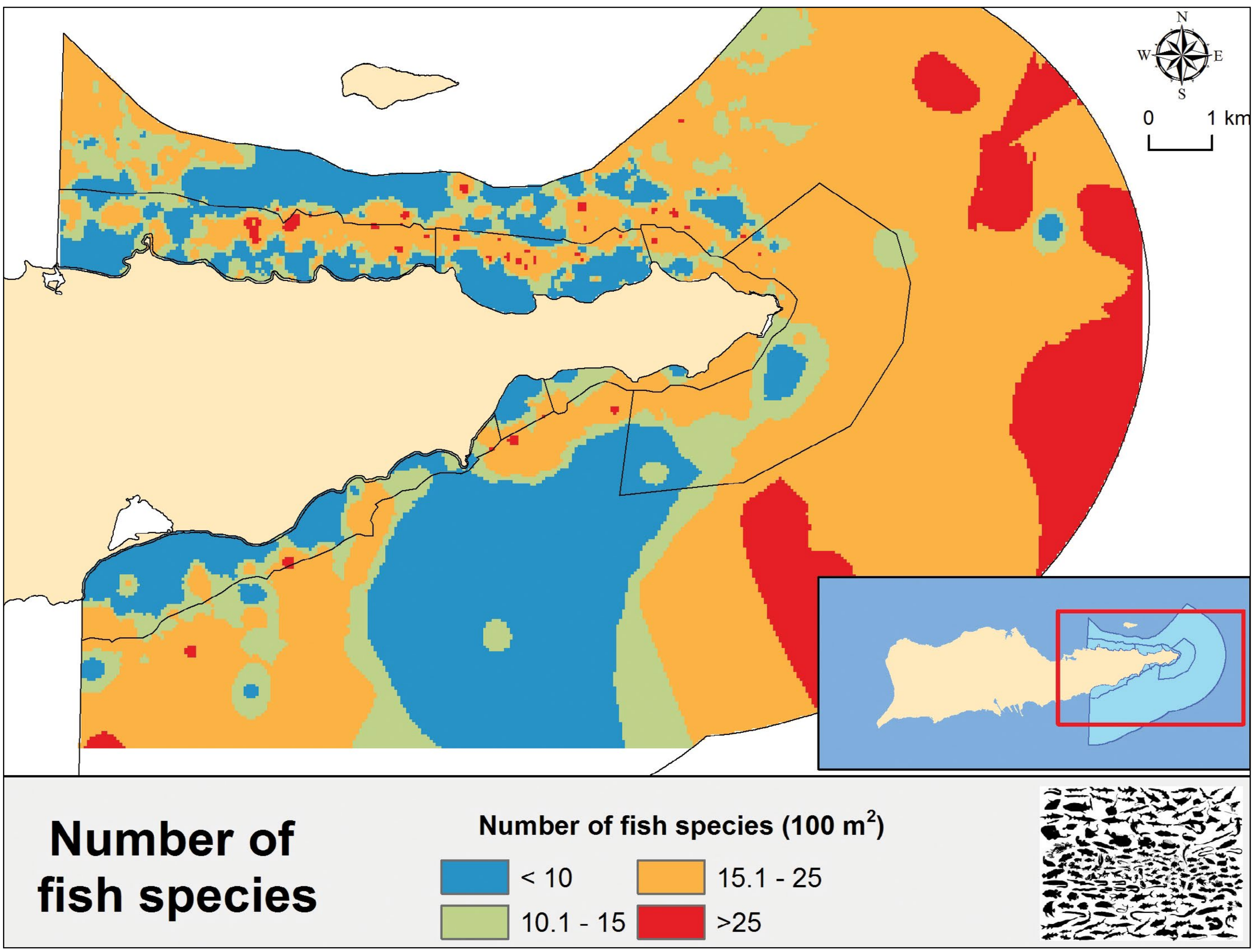


Figure 3.35. Interpolation of fish richness data at each survey location using the Inverse Distance Weighting (IDW) function. IDW applies a greater weighting to the points closer to the prediction location compared with those farther away.

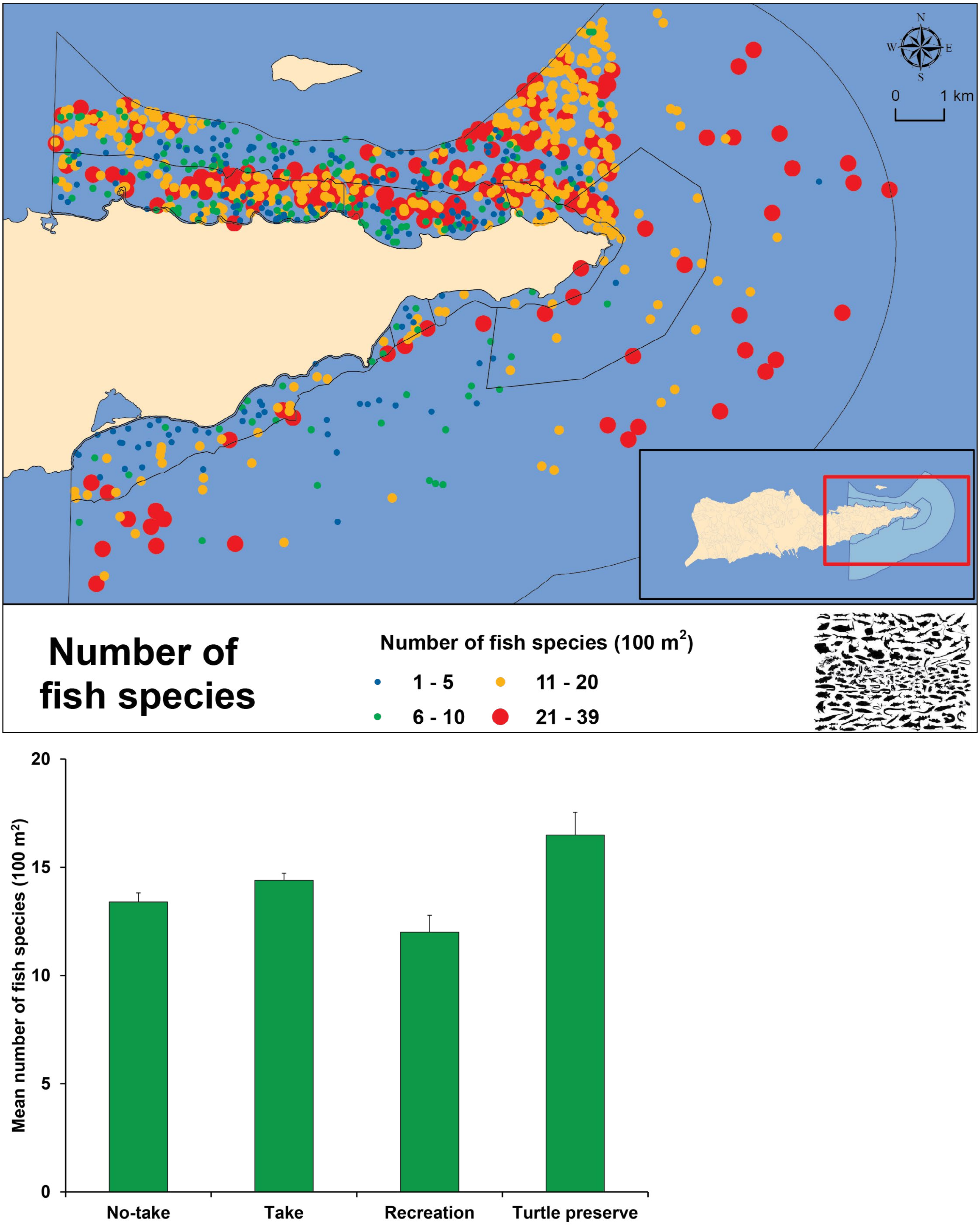
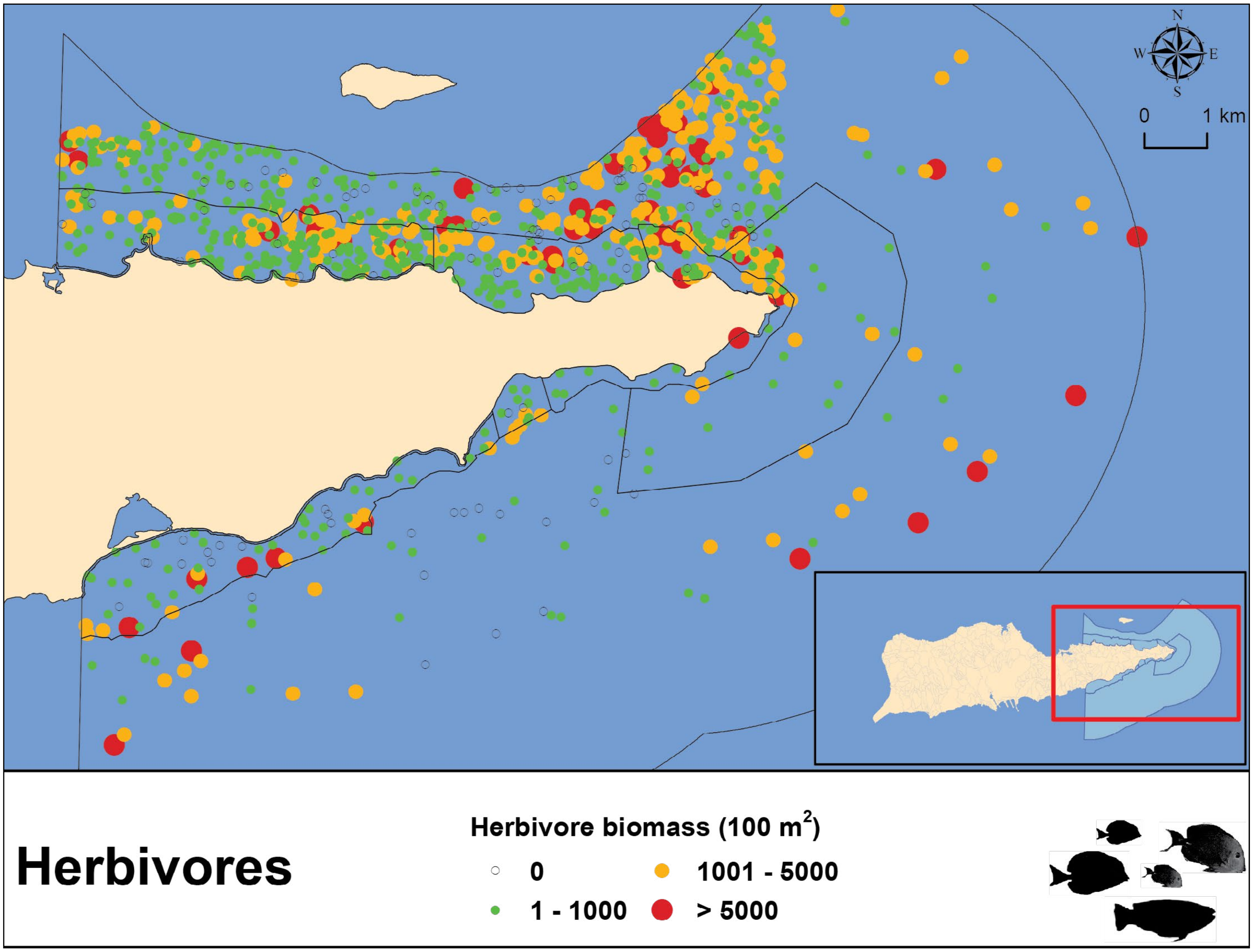


Figure 3.36. Distribution of species richness (100m^2) within STXEEMP (top); and graph of mean (+SE) species richness by major zone type (bottom).



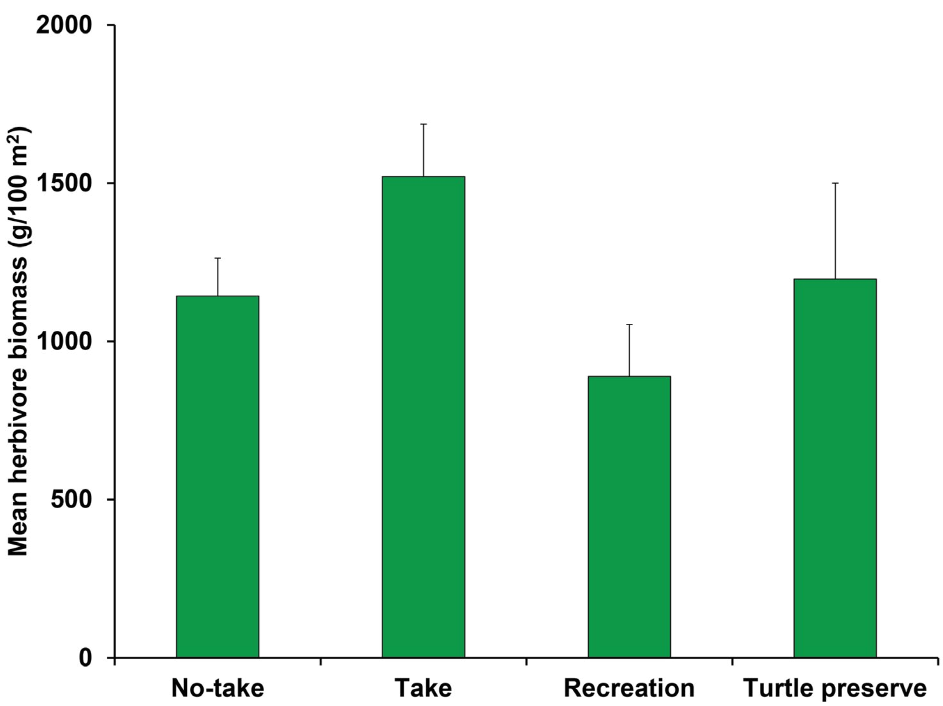
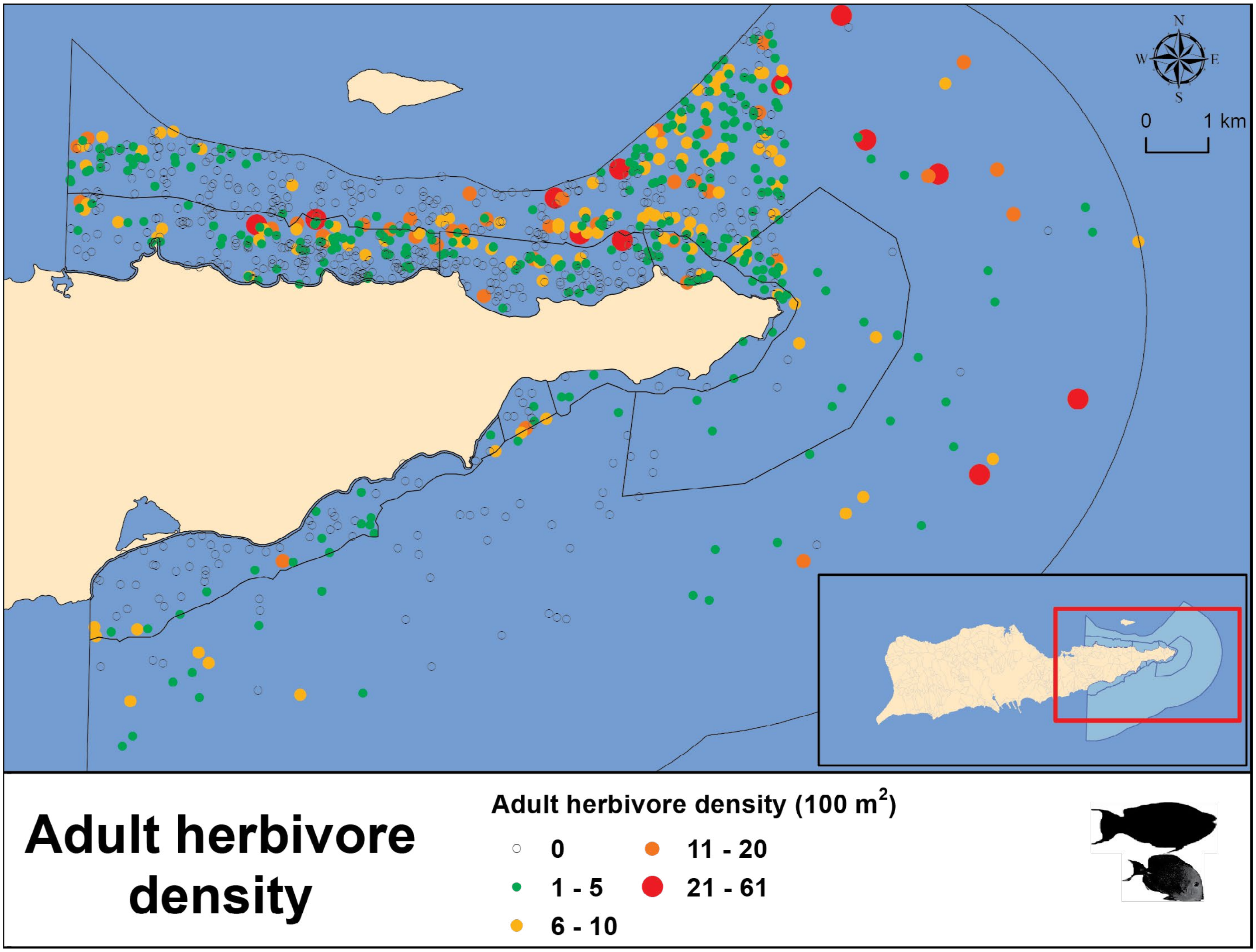


Figure 3.37. Distribution of herbivore biomass (g/100m²) within STXEEMP (top); and graph of mean (+SE) herbivore biomass by major zone type (bottom).



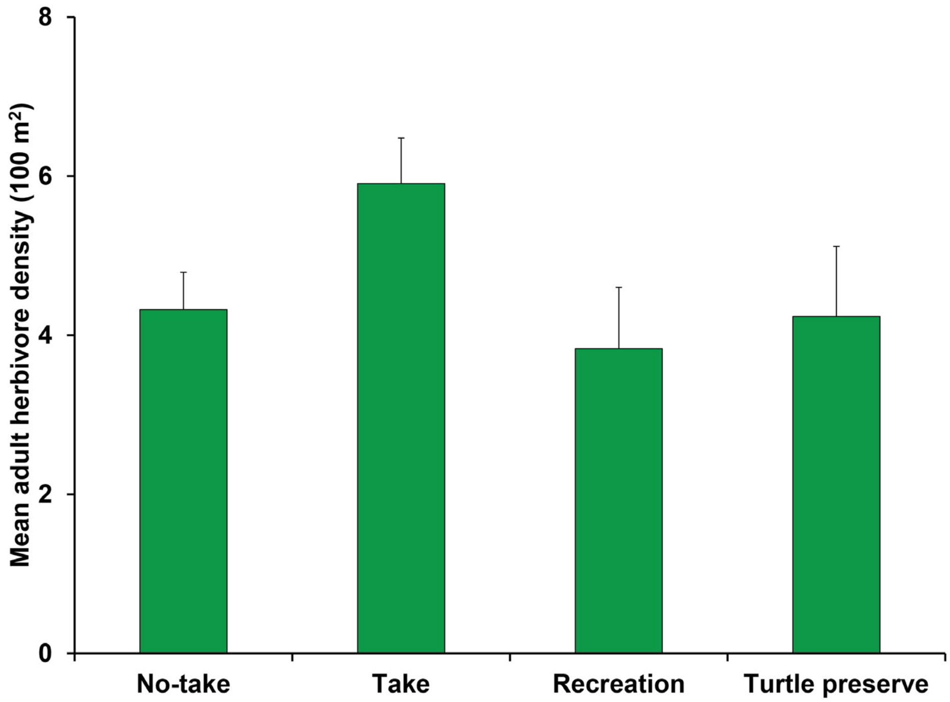
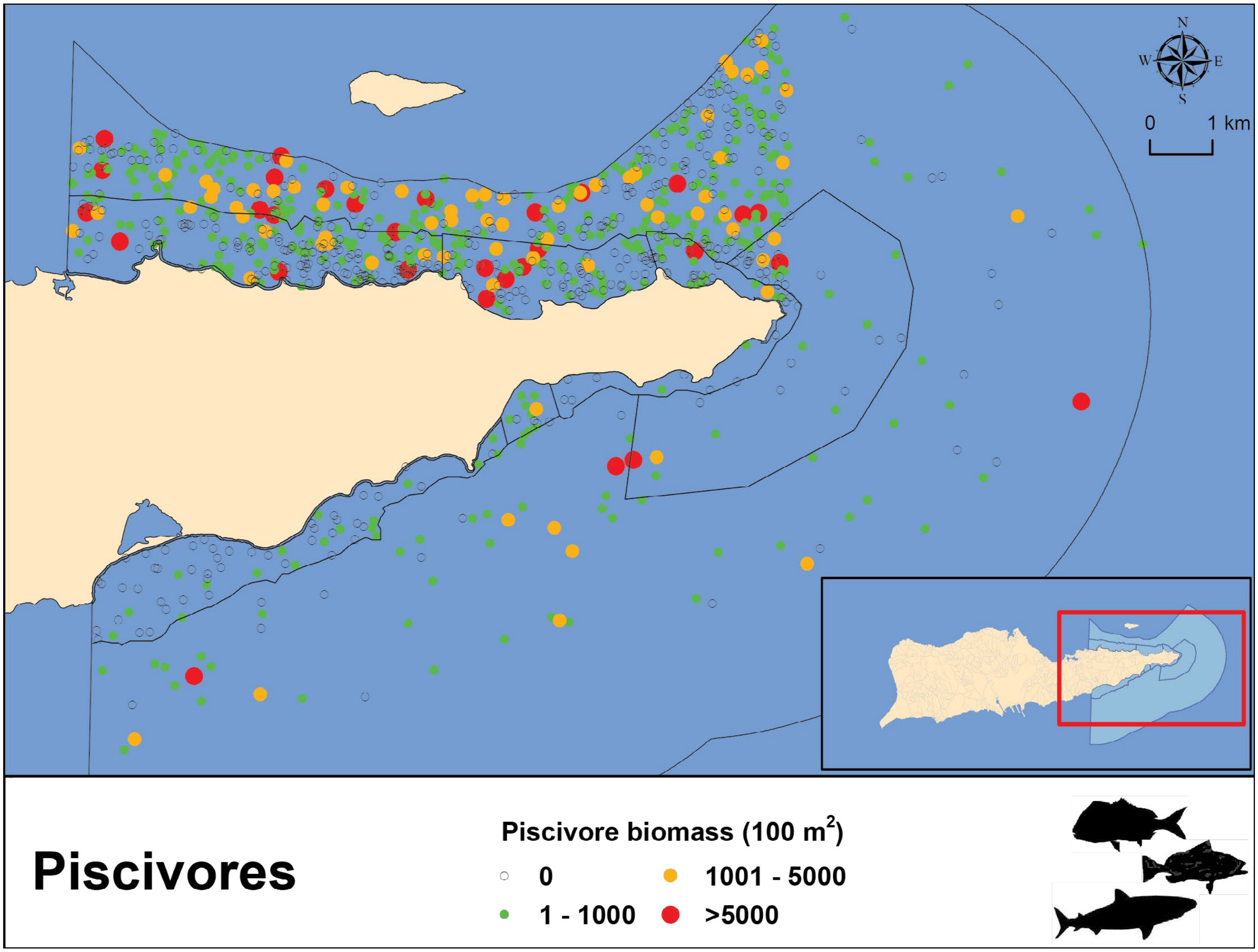


Figure 3.38. Distribution of herbivore density (100m²) within STXEEMP (top); and graph of mean (+SE) herbivore density by major zone type (bottom).



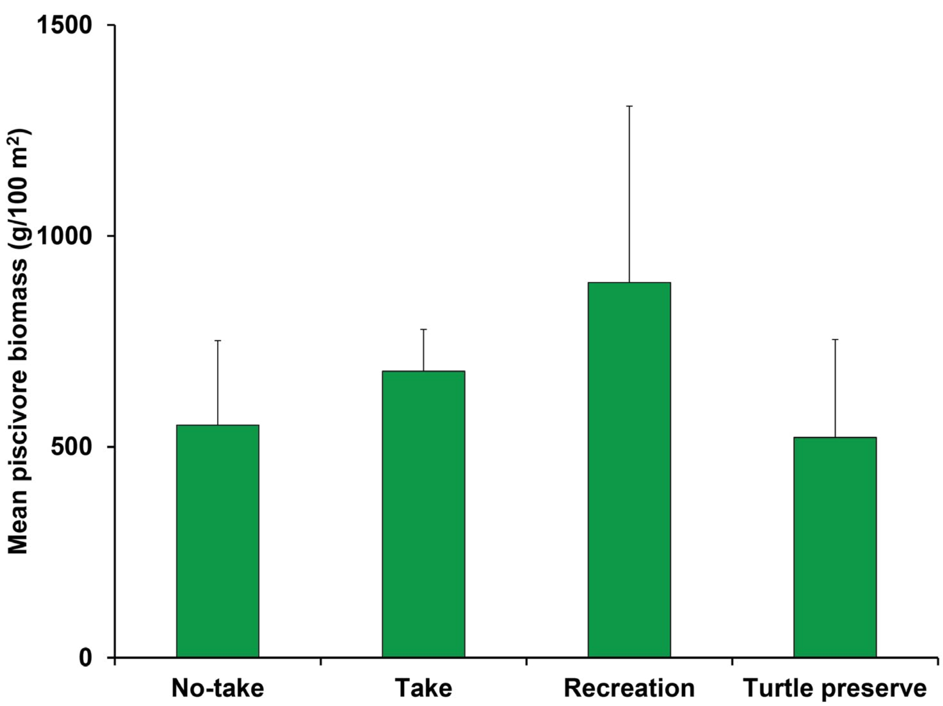


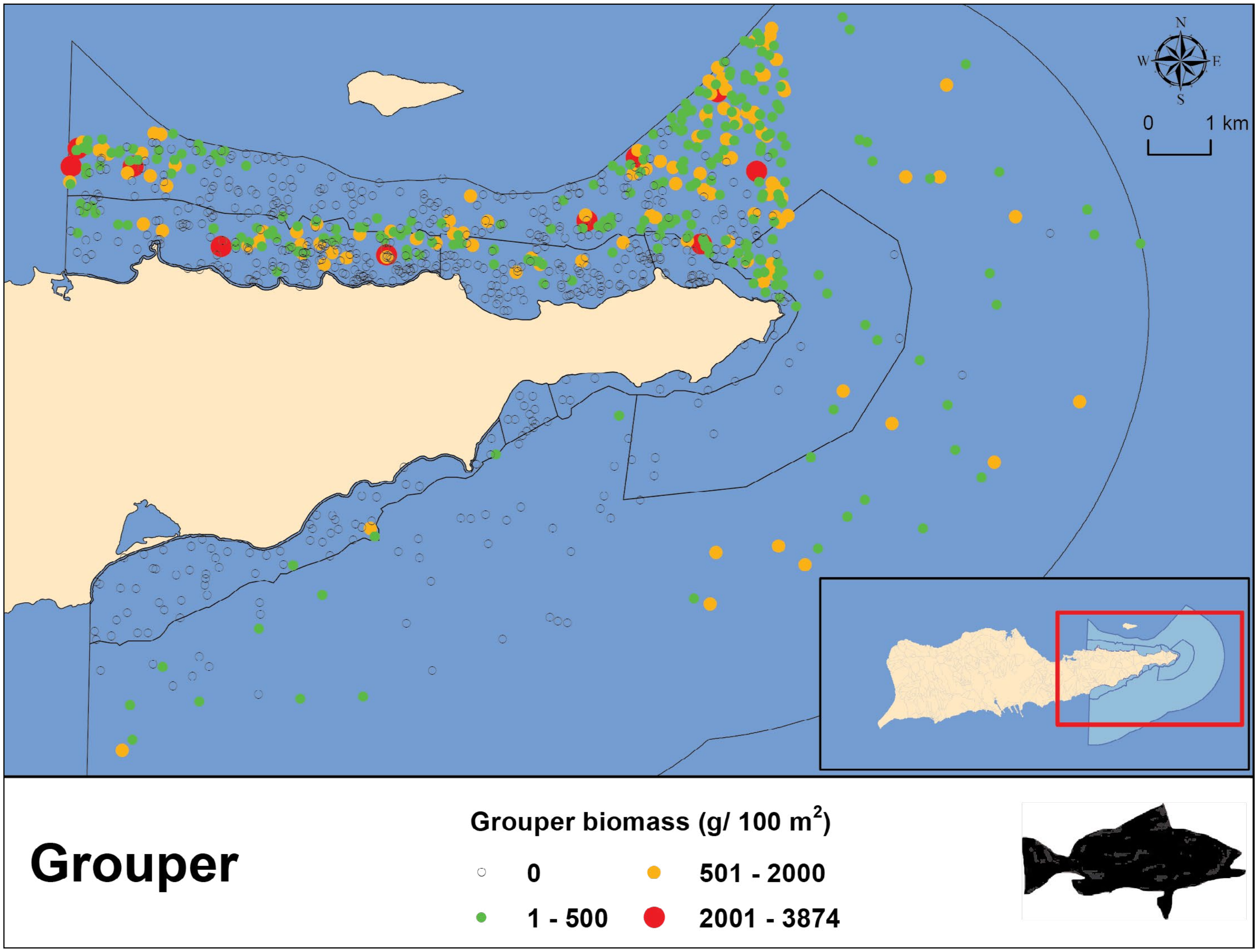
Figure 3.39. Distribution of piscivore biomass (g/100m²) within STXEEMP (top); and graph of mean (+SE) piscivore biomass by major zone type (bottom).

3.3.2.3. Fish Families and Species

Grouper (Sub-family Epinephelinae)

*Figure 3.40. Photo of red hind (*Epinephelus guttatus*) in STXEEMP. Source: NOAA/NOS/NCCOS/CCMA/Biogeography Branch.*

Grouper (Figure 3.40) appeared less abundant on the south shore than the north of STXEEMP. Highest biomass was recorded in the Take zone and Turtle Preserve where fishing is allowed, with lowest biomass in the No Take and Recreation zones (Figure 3.41). Adult groupers were absent from 72 % of survey sites (Figure 3.42). Tiger grouper (*Mycteroperca tigris*) and other species of the genus *Mycteroperca,* such as yellowfin and yellowmouth grouper (*Mycteroperca venenosa* and *Mycteroperca interstitialis*), that are known to exist in the U.S. Caribbean region, were absent from the surveys (Figure 3.43). Historical comparison by Pittman et al. (2008) showed that tiger grouper were once found in the waters of NE St. Croix, albeit at low densities, based on underwater scientific surveys in 1979. Nassau grouper was the only large-bodied, late maturing grouper species sighted and only at three locations with STXEEMP (0.3% of survey sites; 3 of 984 sites). However, an adult grouper hotspot did exist for smaller-bodied grouper species (red hind [*Epinephelus gutattus*], coney [*Cephalopholis fulva*], graysby [*Epinephelus cruentata*], and rock hind [*Epinephelus adscensionis*]), with 11, 10 and 8 adults close to the western edge of the park boundary within the Take zone north of Green Cay. Few adult grouper were sighted in No Take (17% of sites) and Recreation zones (10% of sites) suggesting that even if groupers remained during these protected zones these areas will be unlikely to offer a substantial replenishment function for groupers. Average biomass was higher in the Take zone than No Take zone, but high biomass was evident within the No Take zone along the fringing reef on the north coast (Figure 3.44). red hind were found in very low abundance on the south coast (Figure 3.45). This could indicate a habitat preference related to the differences in seascape structure and wave exposure. Overall, density and occurrence of red hind was low in the STXEEMP (present at 27% of sites; 273 of 984), and observed at 16% (53 of 320) of sites in the No Take zone.



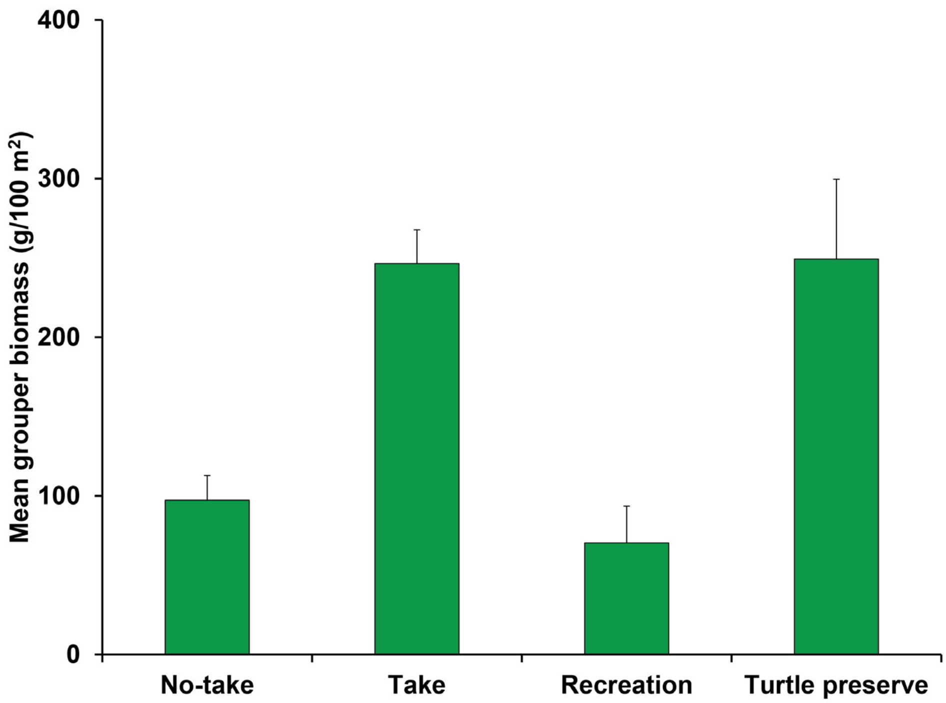
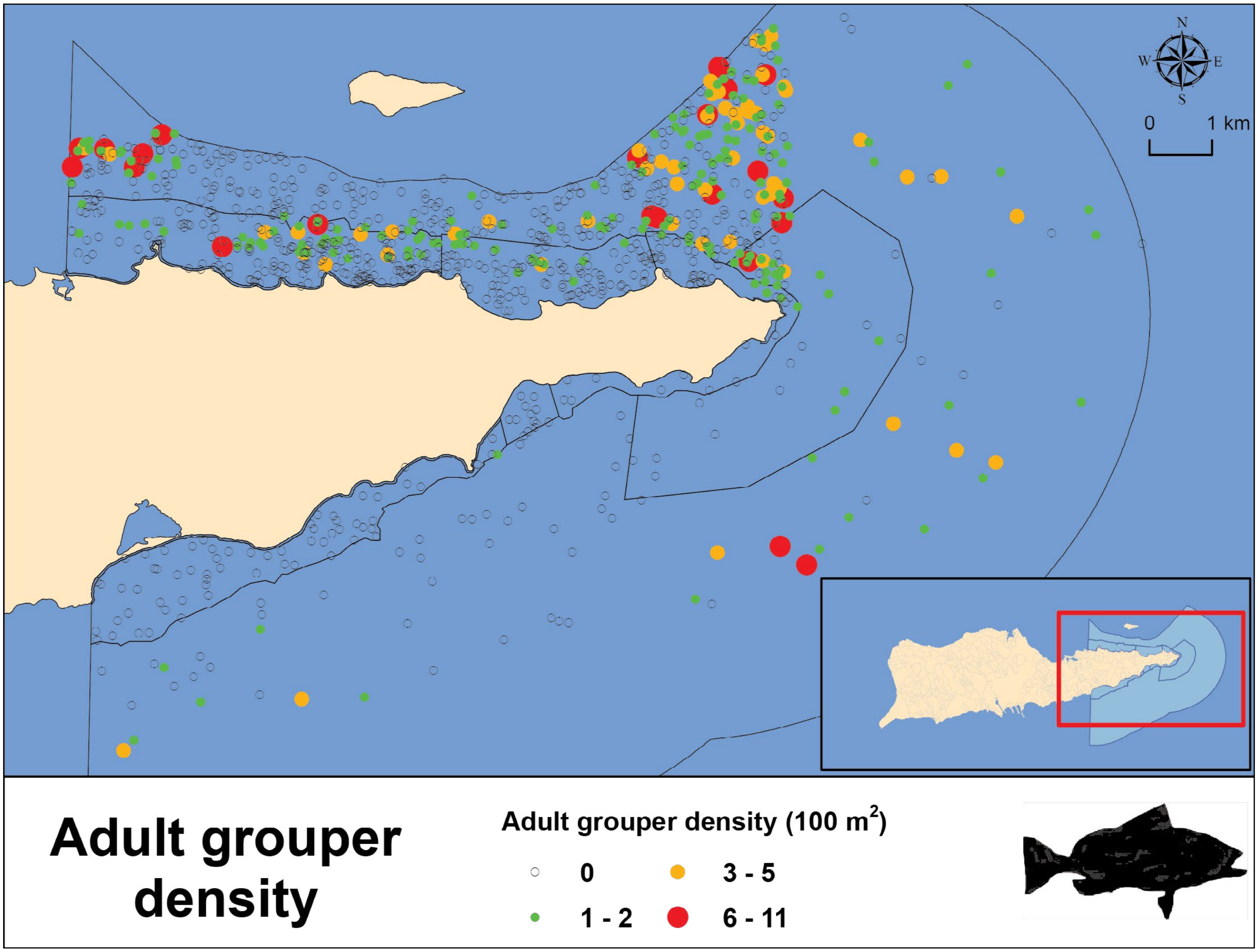


Figure 3.41. Distribution of grouper biomass (g/100m^2) within STXEEMP (top); and graph of mean (+SE) grouper biomass by major zone type (bottom).



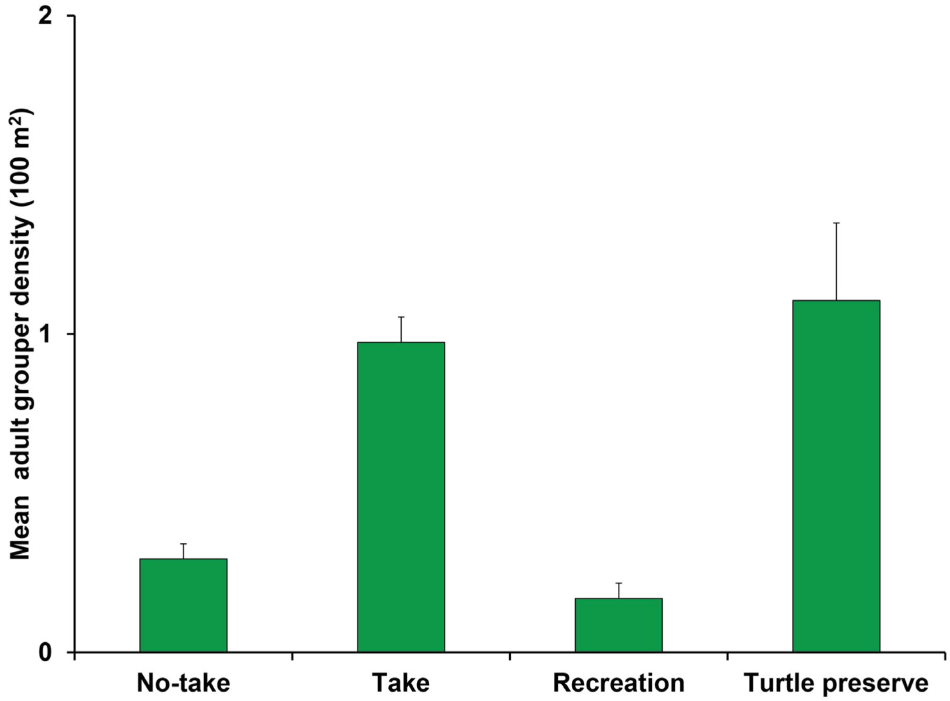


Figure 3.42. Distribution of adult grouper density (100m^2) within STXEEMP (top); and graph of mean (+SE) adult grouper density by major zone type (bottom).

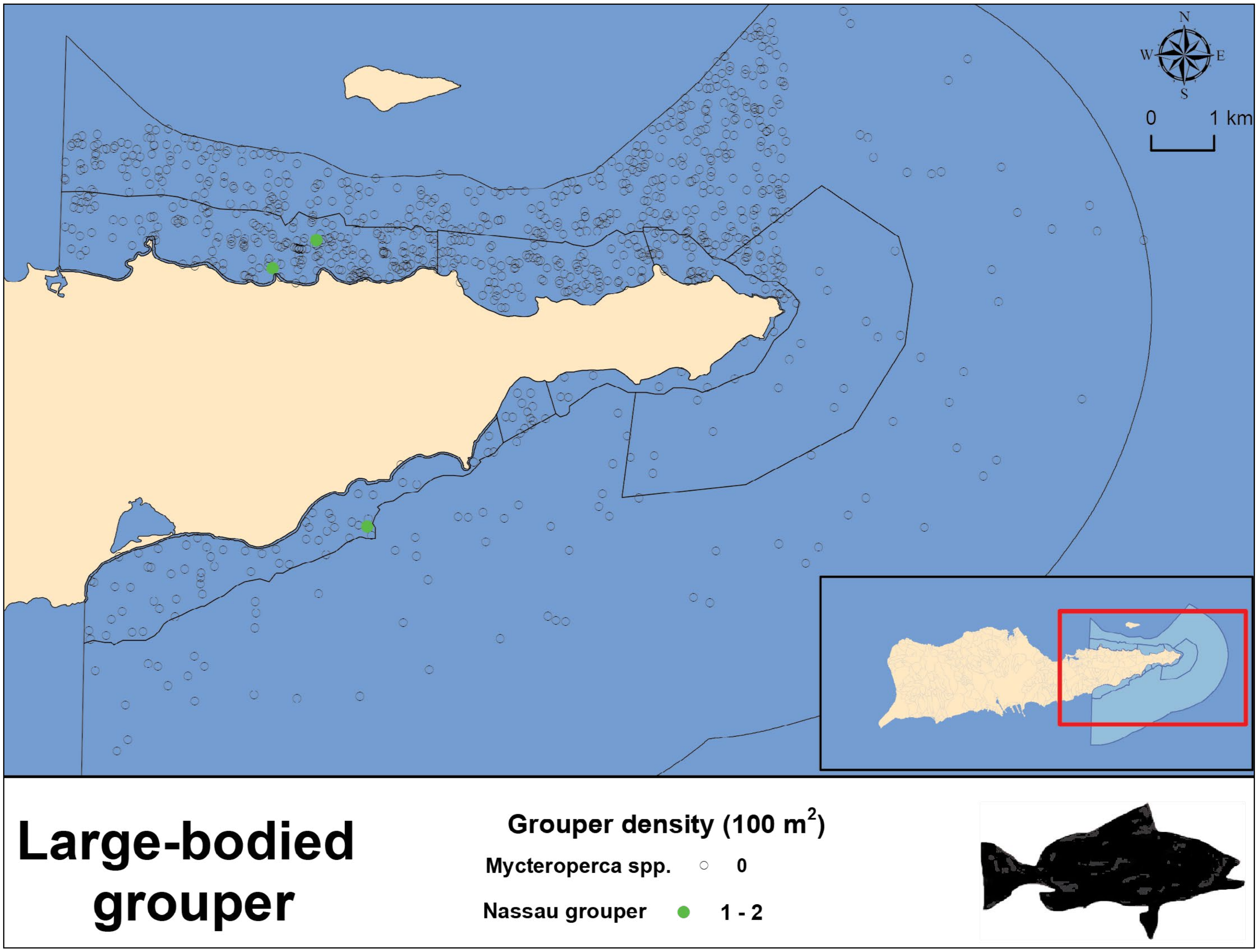


*Figure 3.43. Distribution of adult large-bodied groupers (Nassau grouper [*Epinephelus striatus*] and* Mycteroperca *species) density (100m²) within STXEEMP.*

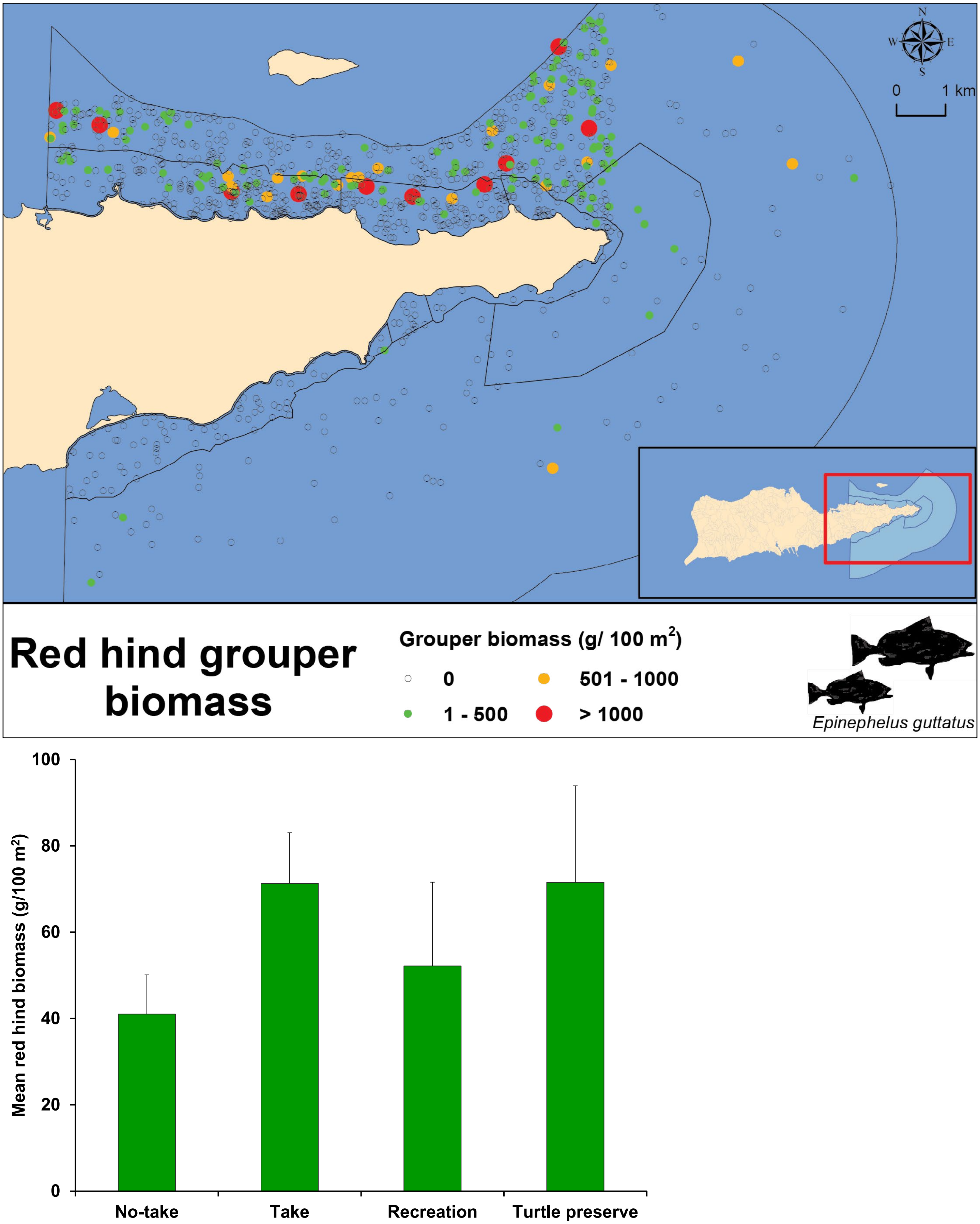
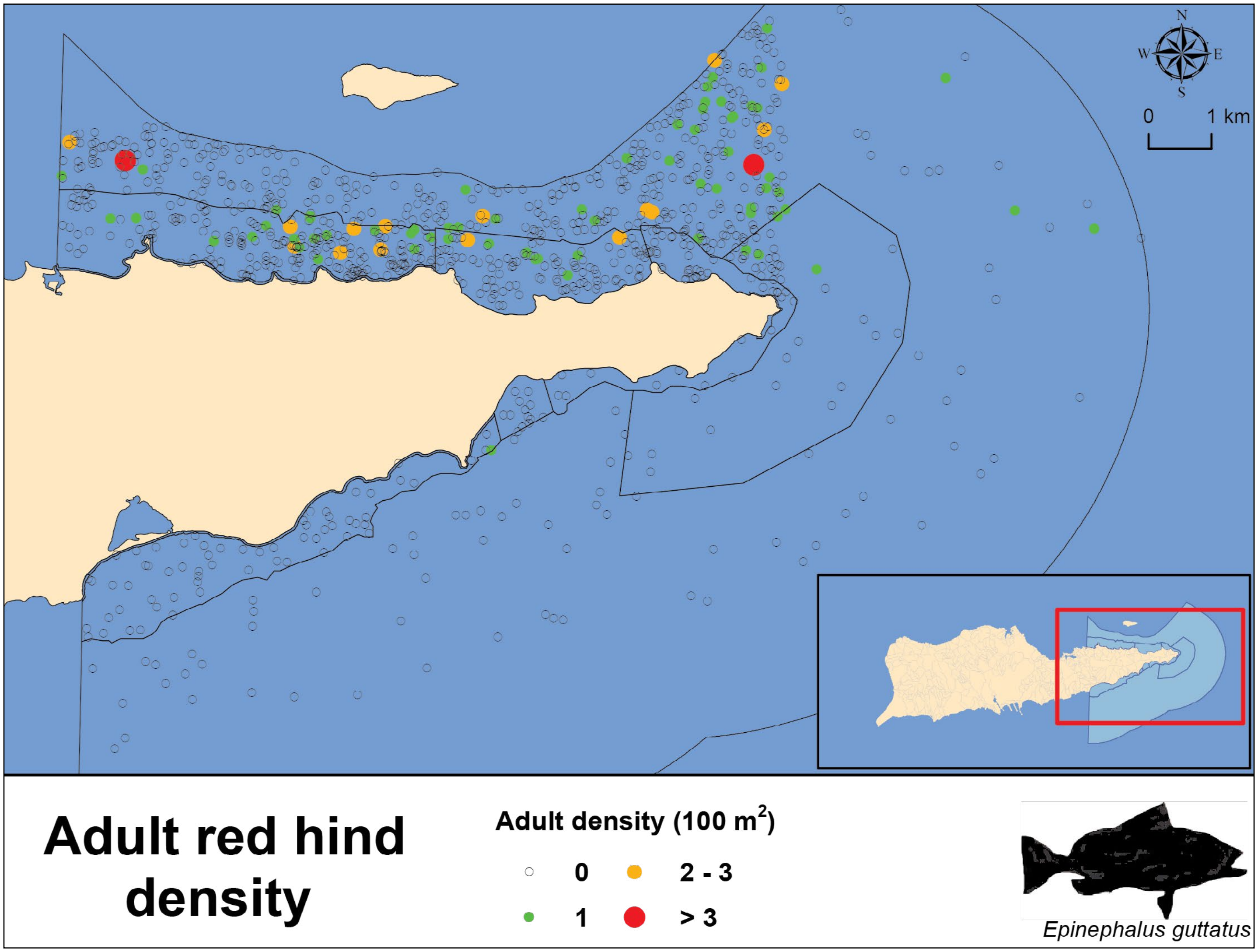


*Figure 3.44. Distribution of red hind (*Epinephelus guttatus*) biomass (g/100m²) within STXEEMP (top); and graph of mean (+SE) red hind biomass by major zone type (bottom).*



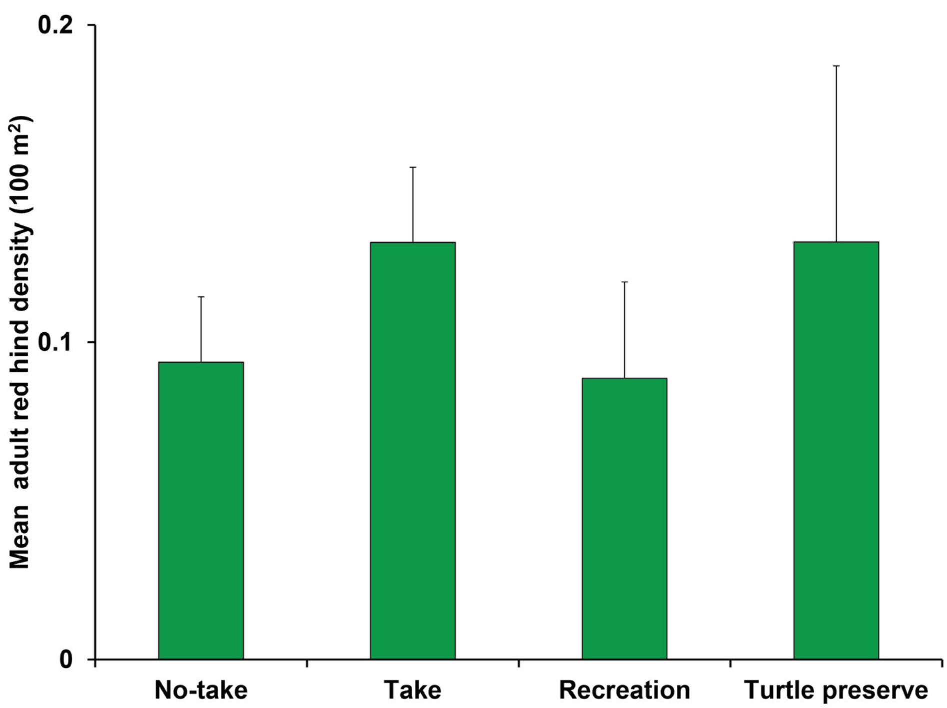
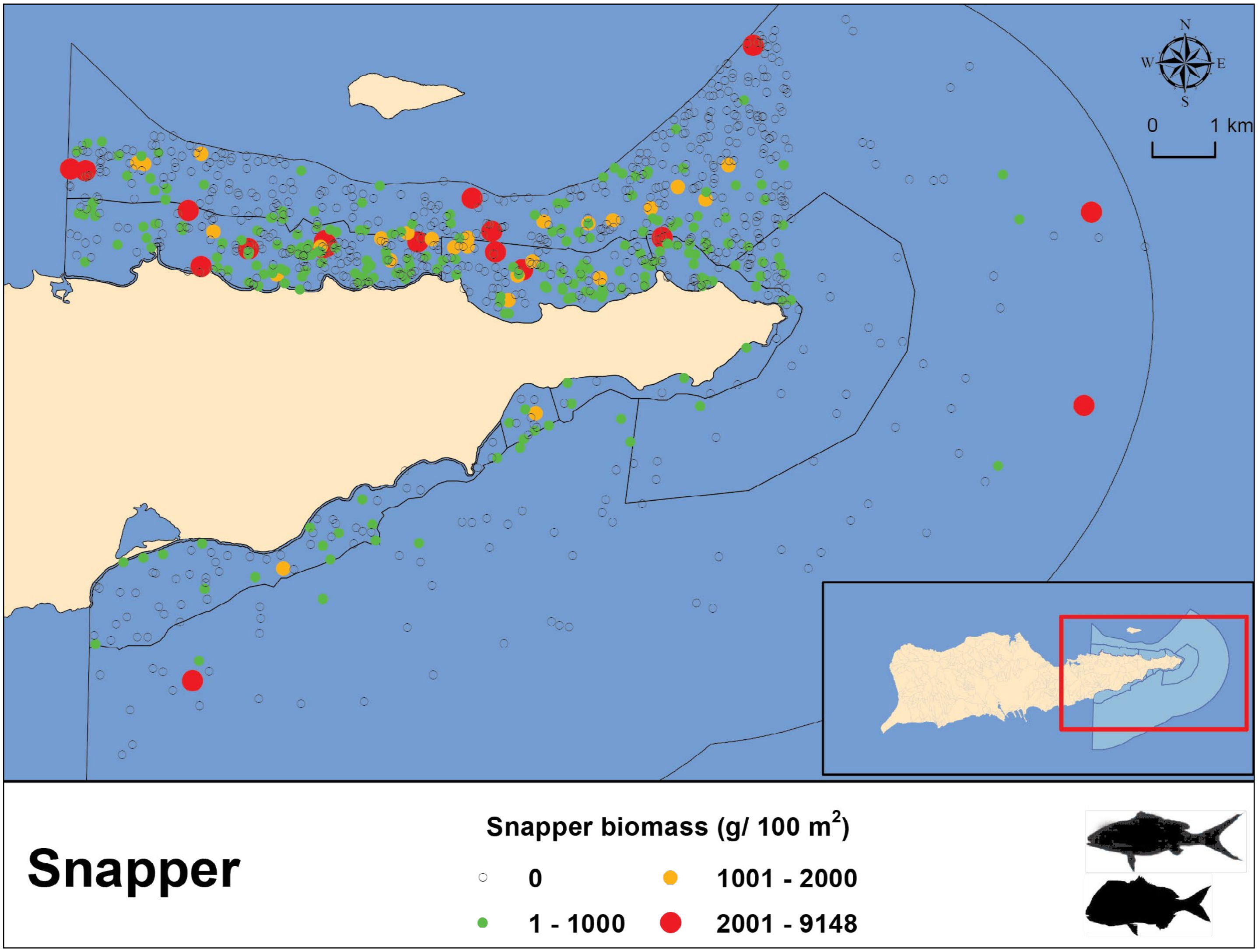


Figure 3.45. Distribution of adult red hind density (100m²) within STXEEMP (top); and graph of mean (+SE) adult red hind density by major zone type (bottom).

Snapper (Lujanidae)

Figure 3.46. Group of juvenile snapper schooling around derelict trap in STXEEMP. Source: NOAA/NOS/NCCOS/CCMA/Biogeography Branch.

Snapper (Figure 3.46) biomass was highest in the No Take and Recreation zones, particularly on the north coast along the fringing reef of Teague Bay that runs east-west close to the boundary with the Take zone (Figure 3.47). Much of the biomass is distributed as juvenile snapper since adult snapper were absent from 89% (110 of 984) of surveyed sites. Adult snapper were sighted in only 13% (53 of 320) of sites in No Take zones (Figure 3.48), and where present were primarily represented by yellowtail snapper (*Ocyurus chrysurus*). In total, 1,397 yellowtail snapper were counted of which 72% were juveniles. yellowtail snapper biomass was widely distributed with higher biomass on the north coast compared with the south (Figure 3.49). High biomass of yellowtail snapper in the No Take zone may be related to close proximity of coral reefs and seagrasses that combined support higher abundance than coral reef distant from seagrasses (Pittman et al. 2007). Adult density of yellowtail snapper was low throughout the STXEEMP, with adults sighted at only 4.5% of sites (44 of 984), but with slightly higher average density (5 % of sites; 17 of 320) inside nearshore No Take and Recreation zones on the north coast compared with the Take zone (Figure 3.50). Other abundant snapper included mahogany snapper (*Lutjanus mahogoni*; 214 observed of which 108 were adults), schoolmaster snapper (*Lutjanus apodus*; 175 observed of which 127 were adults) and mutton snapper (*Lutjanus analis*; 95 observed of which 72 were adults). With the exception of the habitat generalist species, adult yellowtail snapper, formed a larger proportion of the observed population in STXEEMP than did juveniles. This could mean that either juveniles have very specific habitat that were not well represented in the surveys or that the majority of habitat types within STXEEMP do not support a high abundance of juveniles for common snapper species.



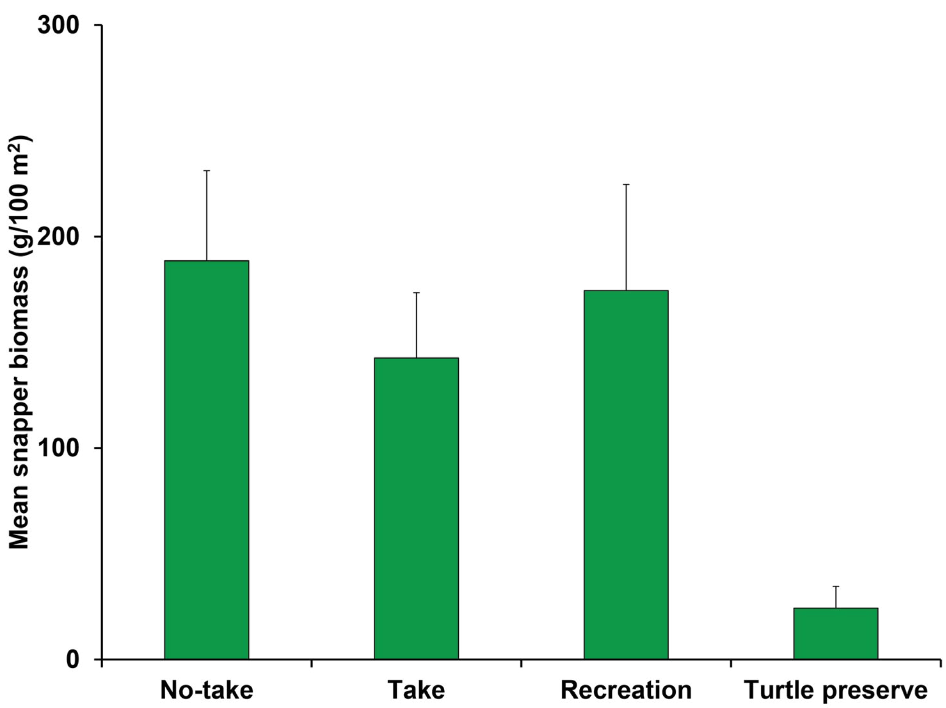
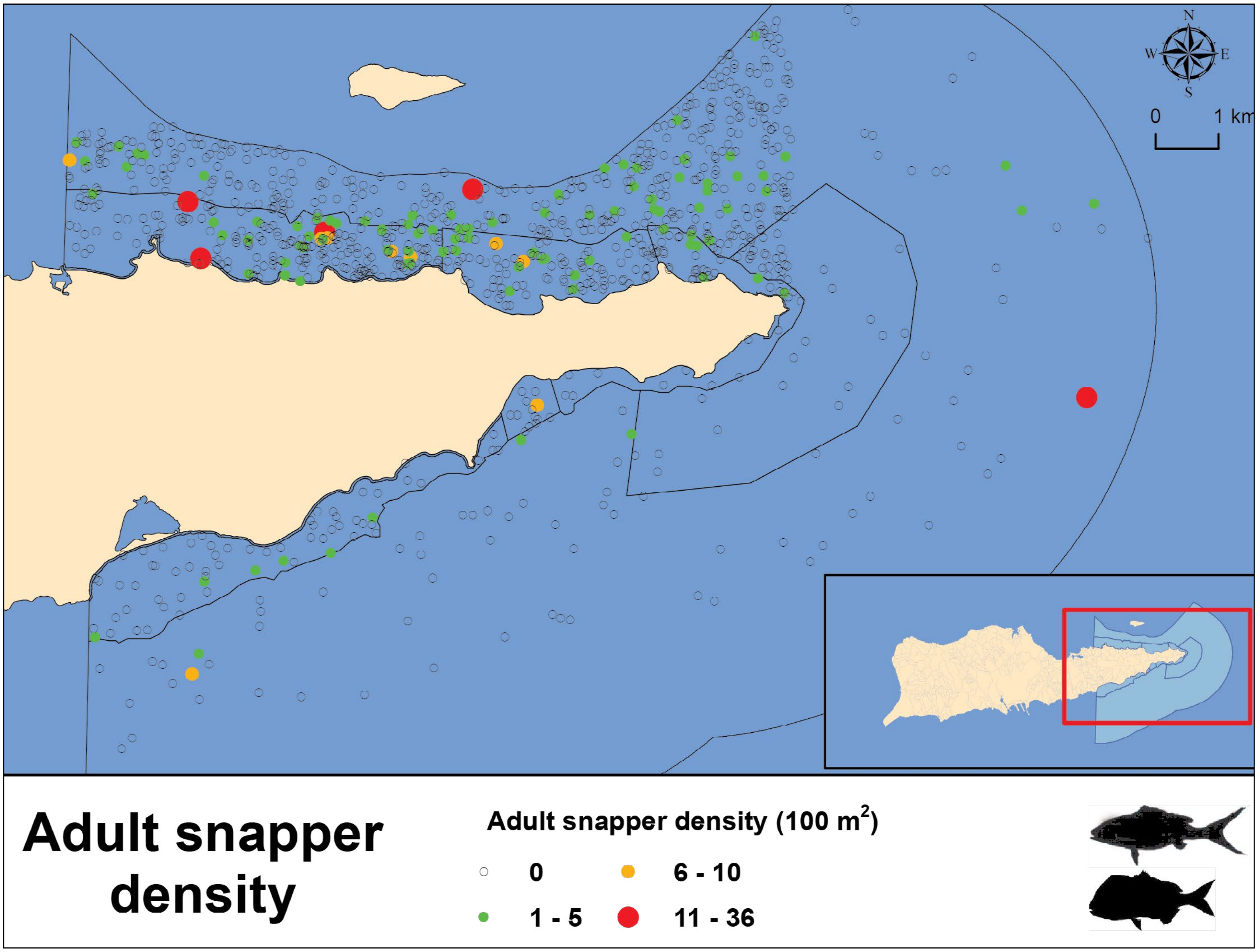


Figure 3.47. Distribution of snapper biomass (g/100m²) within STXEEMP (top); and graph of mean (+SE) snapper biomass by major zone type (bottom).



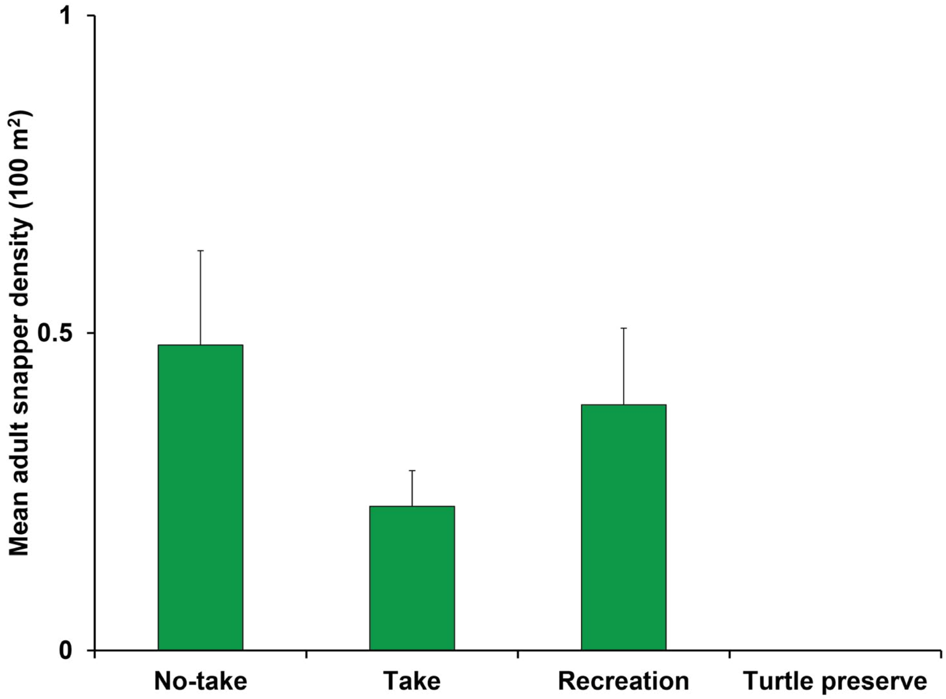


Figure 3.48. Distribution of adult snapper density (100m^2) within STXEEMP (top); and graph of mean (+SE) adult snapper density by major zone type (bottom).

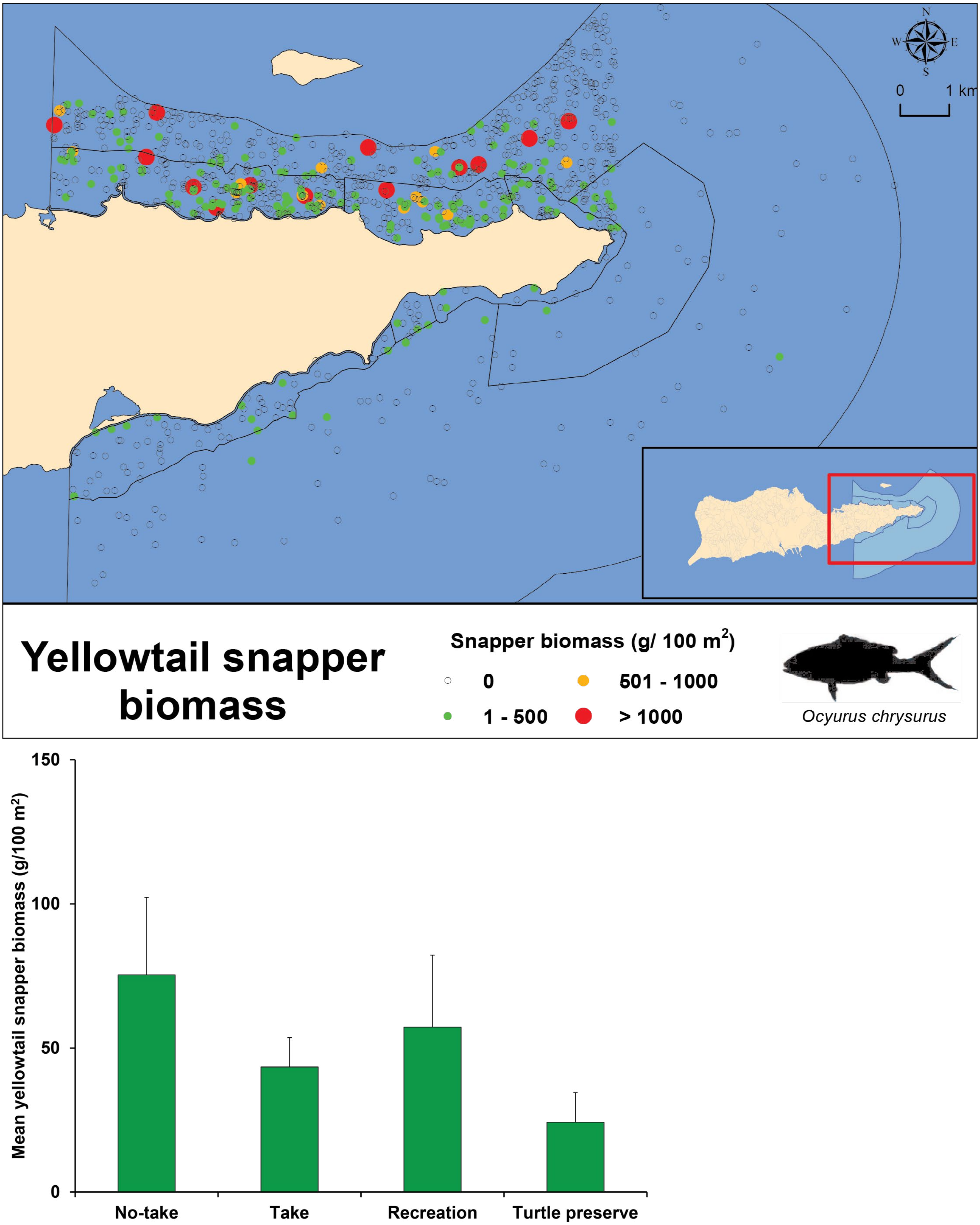
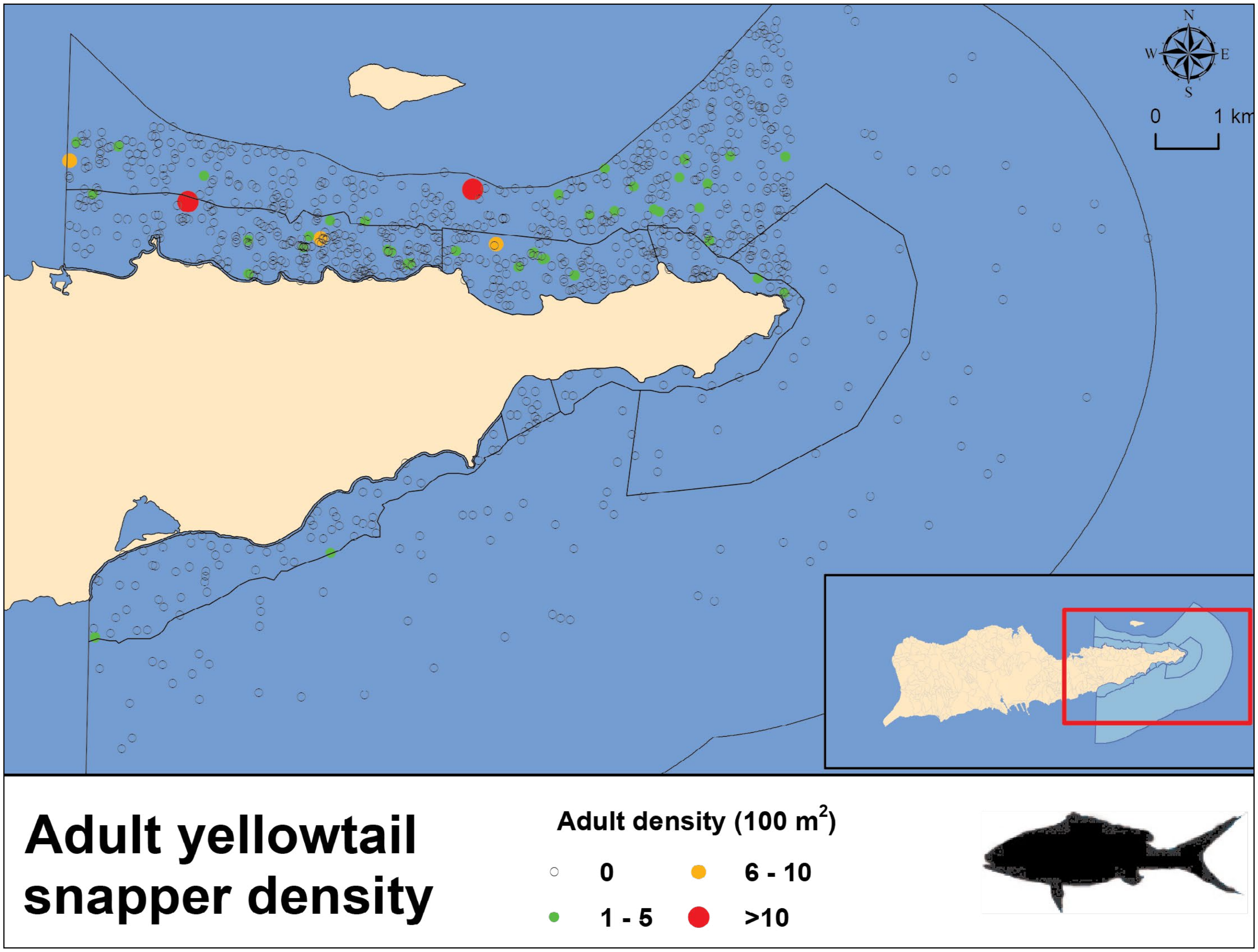


*Figure 3.49. Distribution of yellowtail snapper (*Ocyurus chrysurus*) biomass (g/100m^2) within STXEEMP (top); and graph of mean (+SE) yellowtail snapper biomass by major zone type (bottom).*



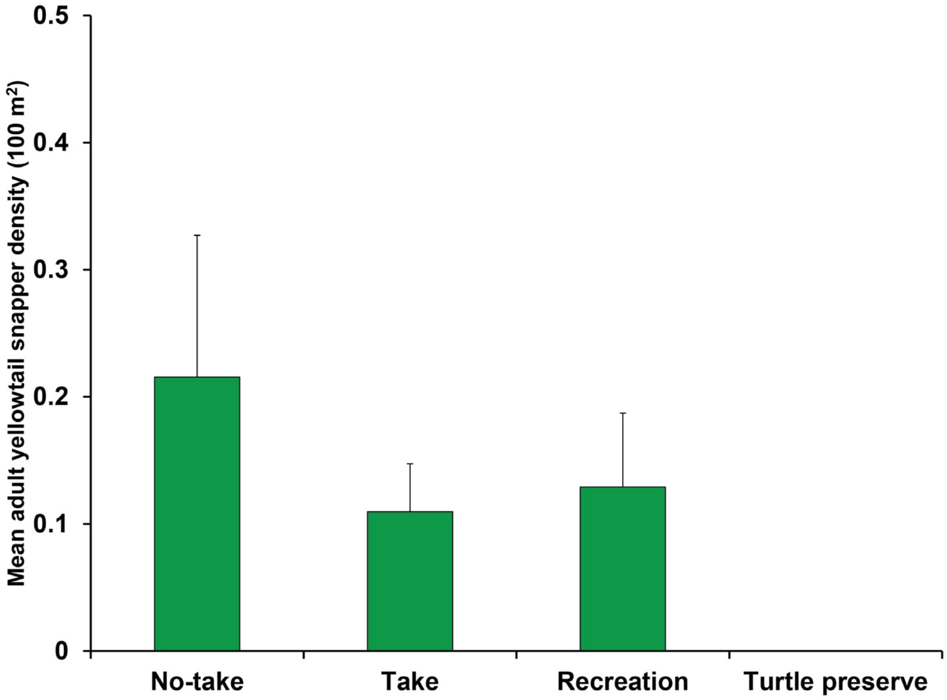


Figure 3.50. Distribution of adult yellowtail snapper density (100m²) within STXEEMP (top); and graph of mean (+SE) adult yellowtail snapper density by major zone type (bottom).

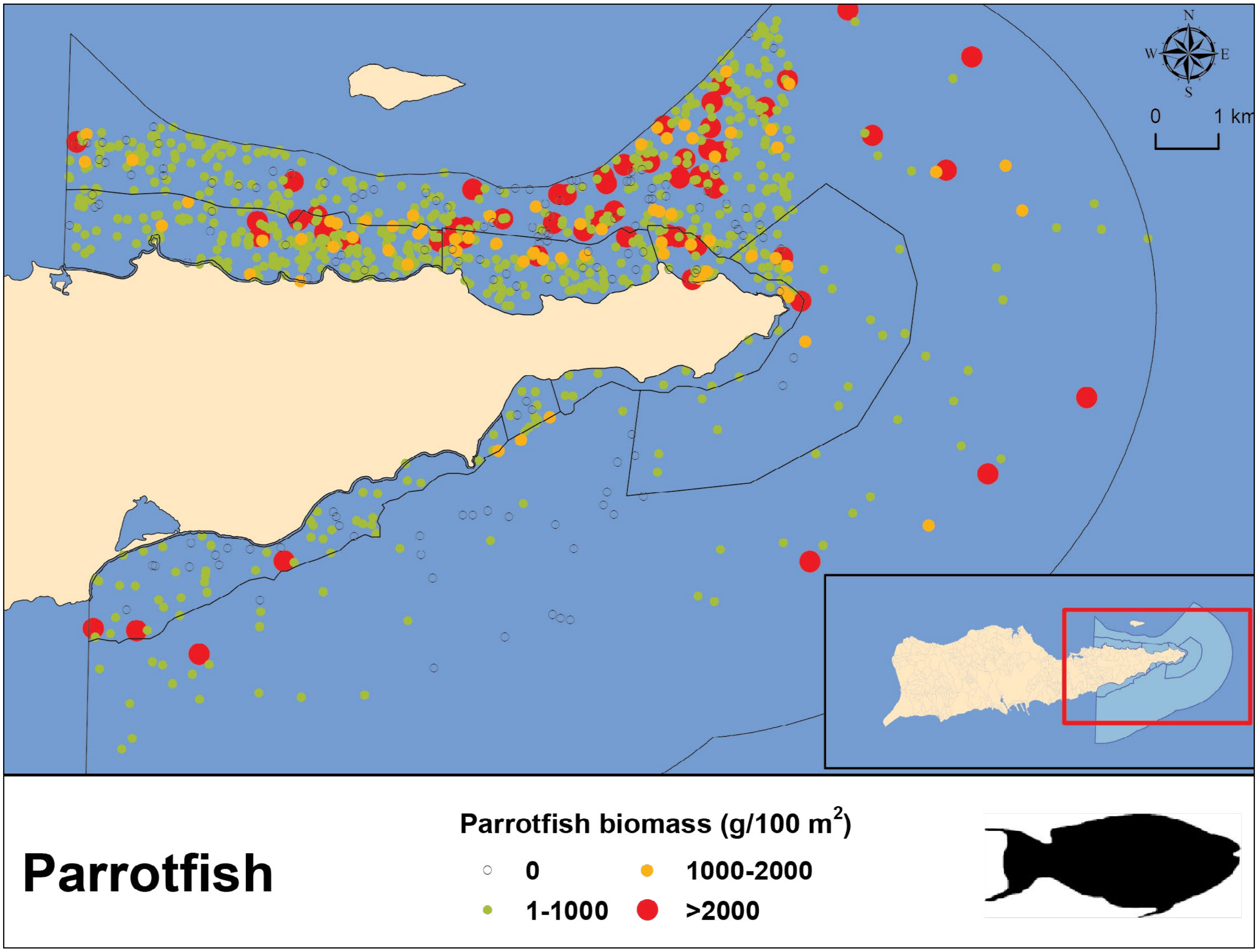
Marine Fish and Benthic Communities

Parrotfish (Scaridae)

Thirteen species of parrotfish were identified within STXEEMP (Figure 3.51). The three most abundance species were redband parrotfish (*Sparisoma aurofrenatum*; 60% juvenile / 40% adult), striped parrotfish (*Scarus iserti*; 93% juvenile / 7% adult), and stoplight parrotfish (*Sparisoma viride*; 70% juvenile / 30% adult). Other abundant species included the bucktooth parrotfish (*Sparisoma radians*) and greenblotch parrotfish (*Sparisoma atomarium*), typically associated with seagrass beds and rarely seen over coral reefs, followed by princess parrotfish (Scarus taeniopterus; 25% juvenile / 75% adult) and queen parrotfish (*Scarus vetula*; 50% juvenile / 50% adult).

*Figure 3.51. Group of juvenile/initial phase striped (*Scarus iseri*) and princess (*Scarus taeniopterus*) parrotfish and terminal phase greenblotch parrotfish (*Sparisoma atomarium*) in St. Croix. Source: NOAA/NOS/NCCOS/CCMA/Biogeography Branch.*

Parrotfish biomass is widely distributed across all zones of STXEEMP, with highest biomass in the north-east region of the Take zone offshore of Cottongarden Point and also in No Take and Recreation zones along the fringing reef of Teague and Cockley Bays (Figure 3.52). The Take zone had higher average density of adults (52% of sites; 261 of 502) than the No Take zone (41 %; 133 of 320; Figure 3.53). Striped parrotfish was one of the most widely distributed parrotfish on the north coast, with highest average biomass in the Take zone (Figure 3.54). These zones were dominated by juvenile fish. Analysis of adult density distributions revealed that sightings occurred at only 5 % of sites throughout STXEEMP and only 4 % of sites in the No Take zone (Figure 3.55). Average biomass of Redband Parrotfish was also higher in the Take zone than No Take. Hotspots of biomass occurred along the fringing reef between Teague and Cockley Bays, in the Take zone north of Cottongarden Point, and north of Green Cay (Figure 3.56). Average adult redband parrotfish density was highest in the Take zone (Figure 3.57). Similar patterns in biomass were observed for stoplight parrotfish, but with lower average density of adults in the Take zone (Figures 3.58 and 4.59). Juveniles were widespread in the nearshore areas and these areas may offer an important nursery habitat, although for many of the parrotfish species adults and juveniles co-occur across a wide range of habitat types (Pittman et al., 2008).



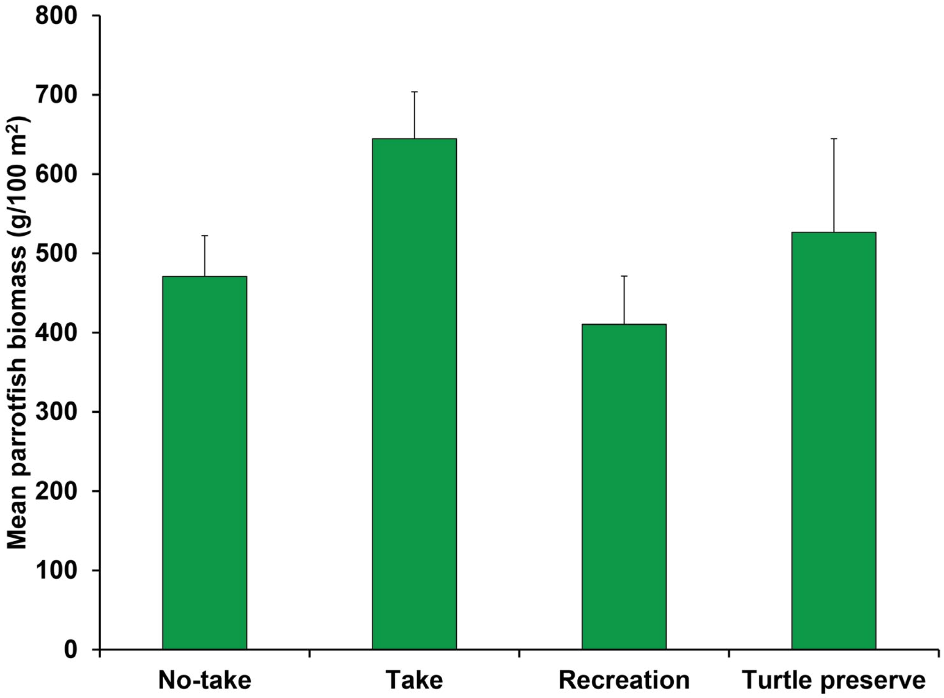
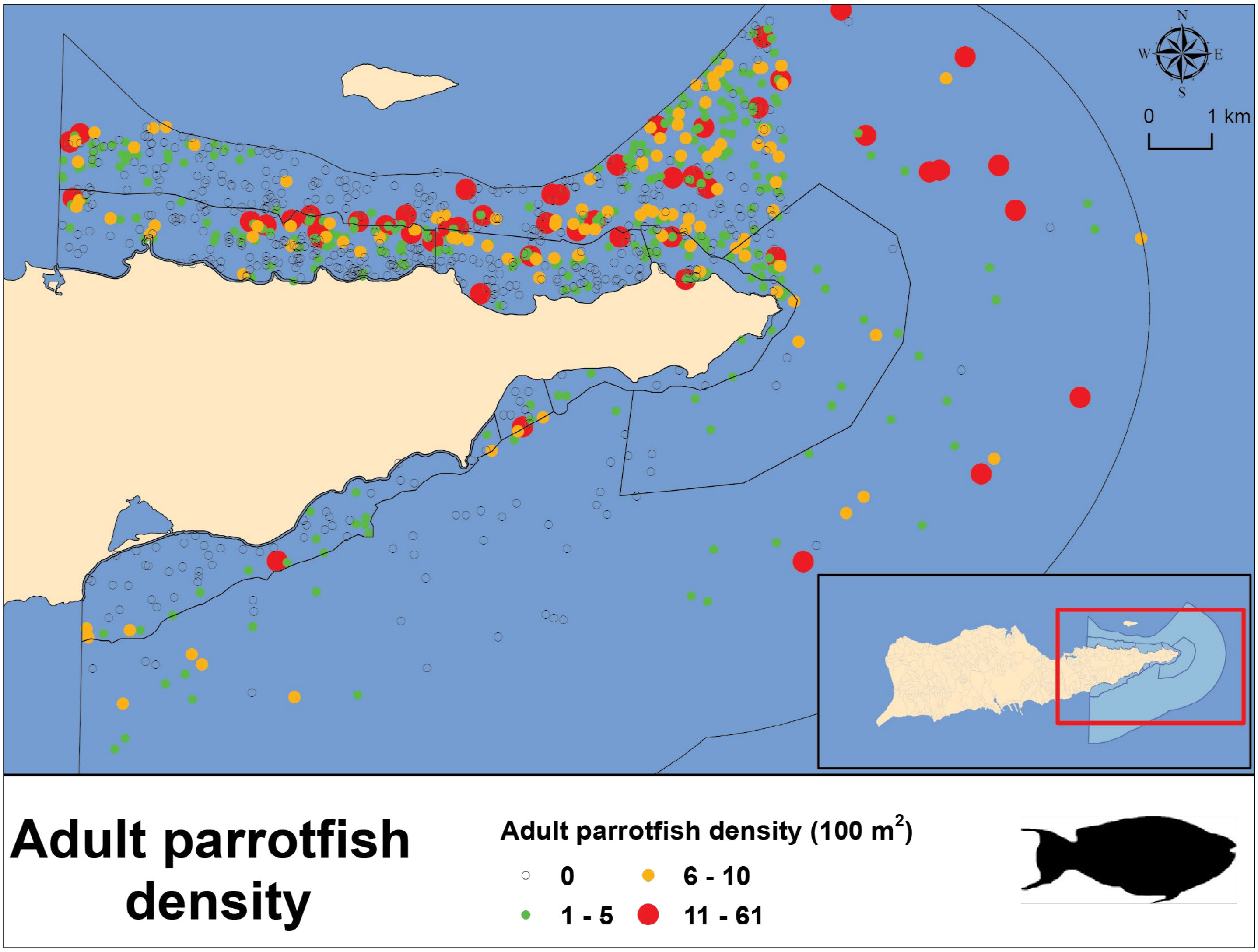


Figure 3.52. Distribution of adult parrotfish biomass (g/100m²) within STXEEMP (top); and graph of mean (+SE) adult parrotfish biomass by major zone type (bottom).



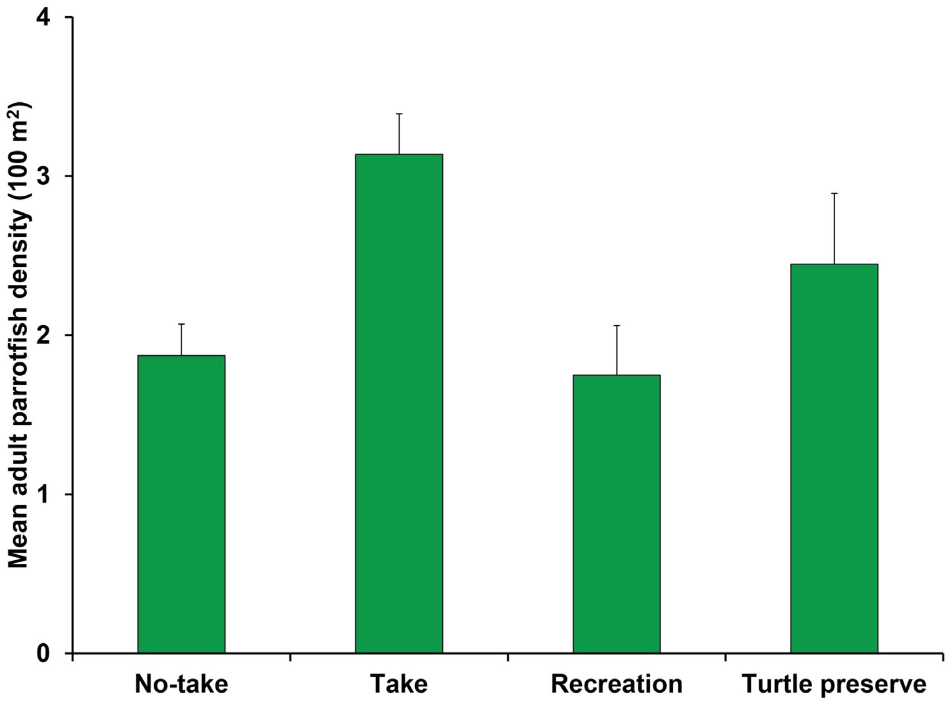


Figure 3.53. Distribution of adult parrotfish density (100m²) within STXEEMP (top); and graph of mean (+SE) adult parrotfish density by major zone type (bottom).

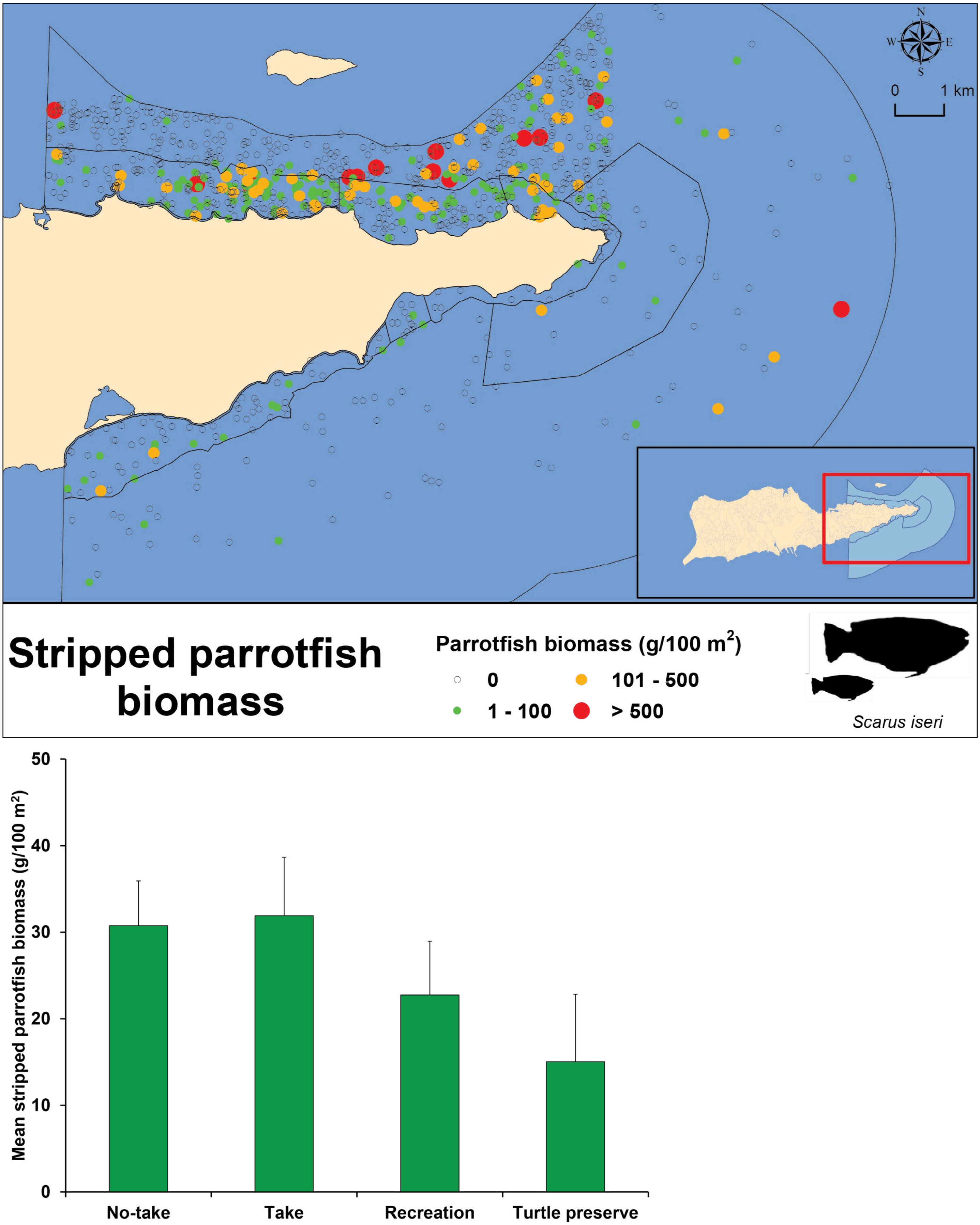


*Figure 3.54. Distribution of striped parrotfish (*Scarus iseri*) biomass (g/100m²) within STXEEMP (top); and graph of mean (+SE) striped parrotfish biomass by major zone type (bottom).*

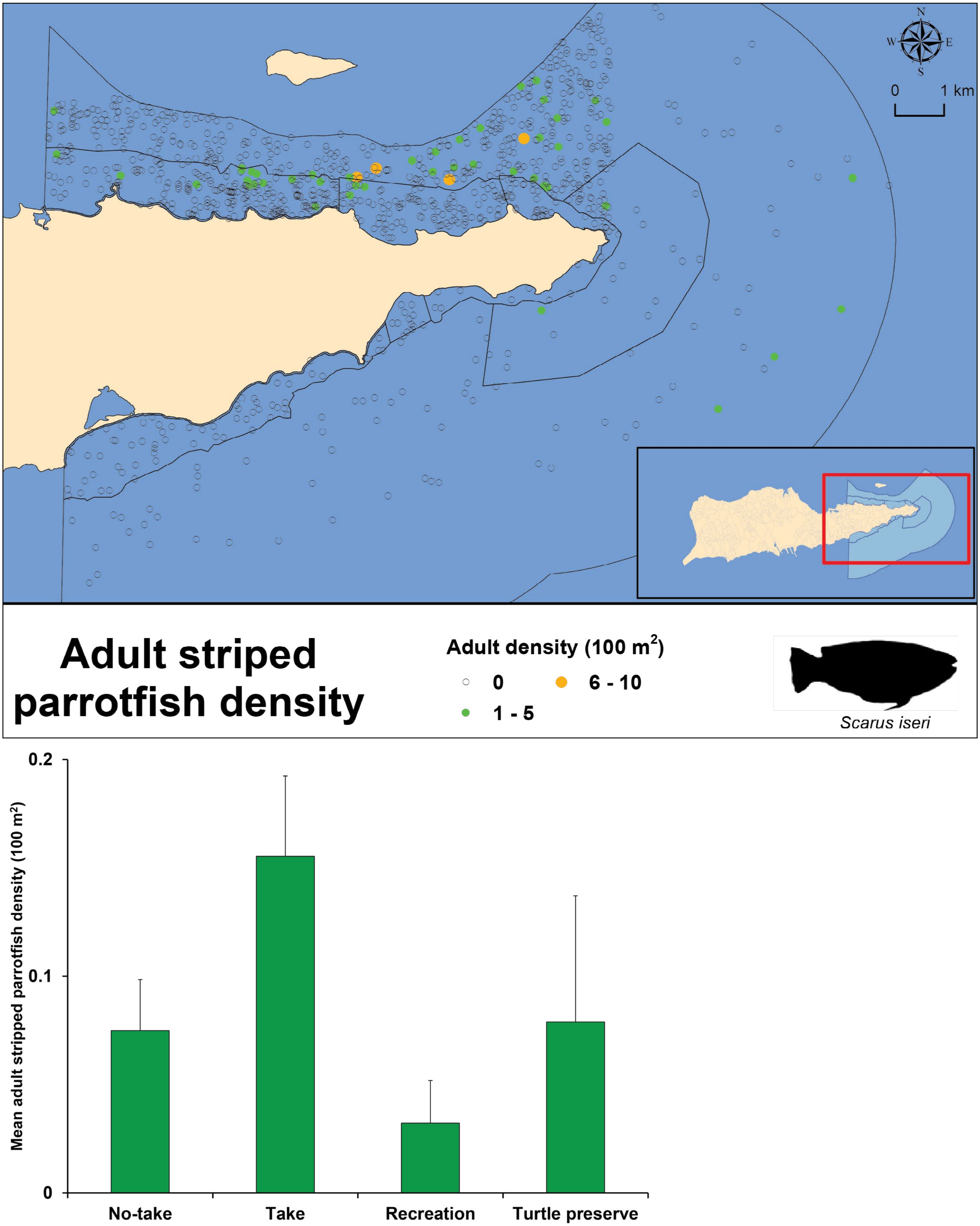
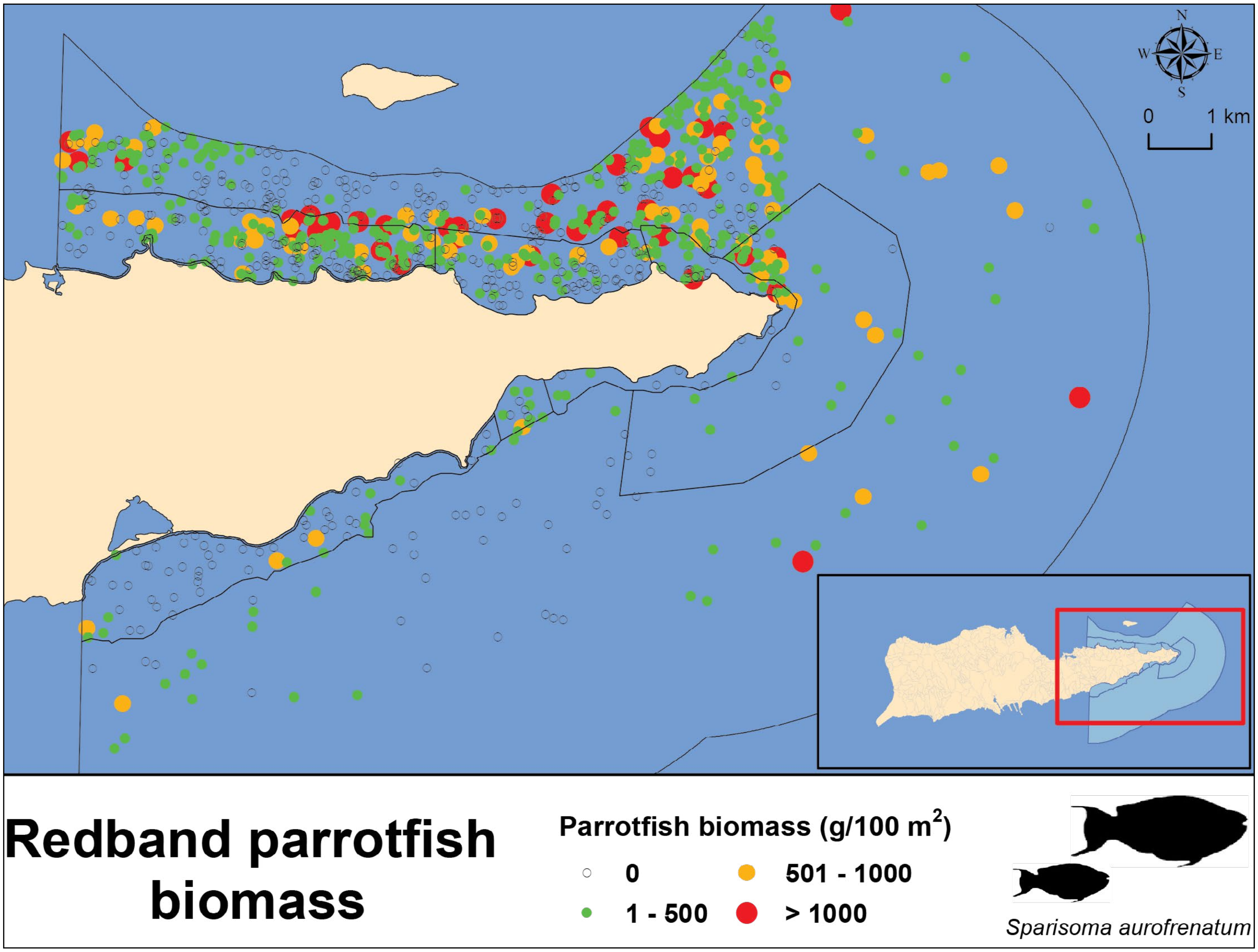


Figure 3.55. Distribution of adult striped parrotfish density (100m²) within STXEEMP (top); and graph of mean (+SE) adult striped parrotfish density by major zone type (bottom).



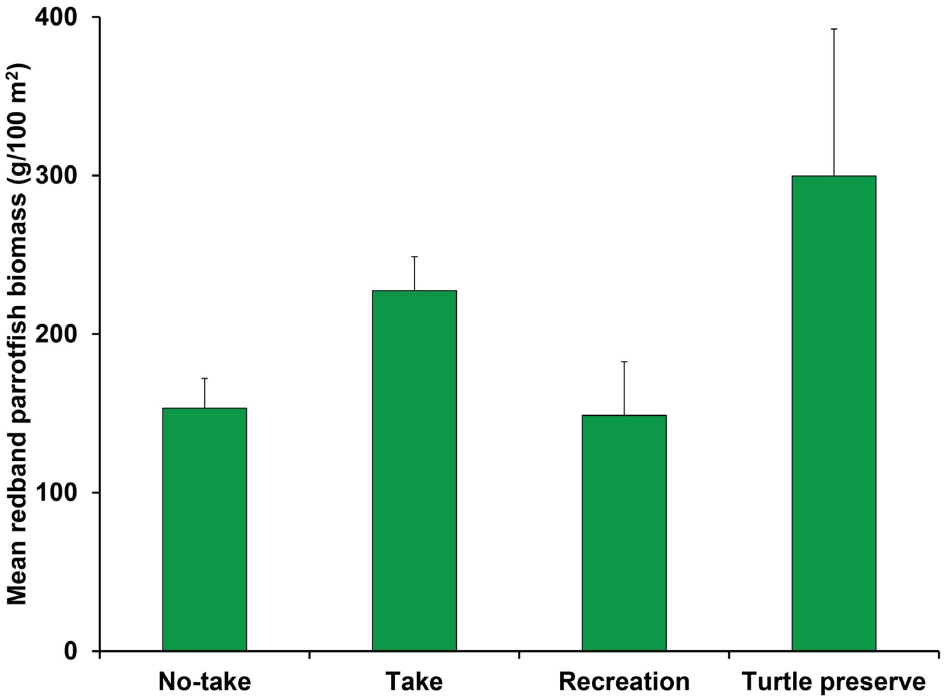
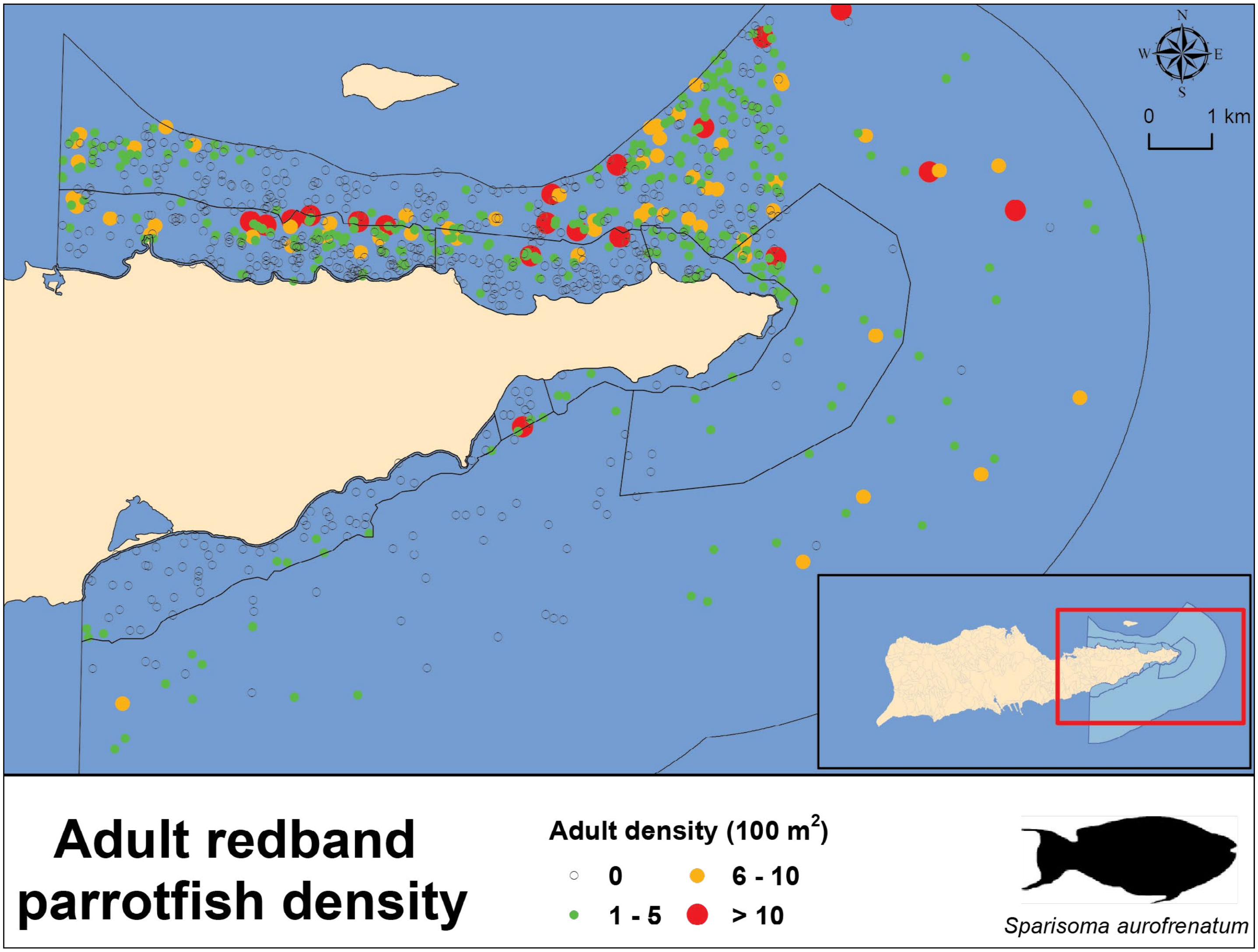


*Figure 3.56. Distribution of redband parrotfish (*Sparisoma aurofrenatum*) biomass (g/100m^2) within STXEEMP (top); and graph of mean (+SE) redband parrotfish biomass by major zone type (bottom).*



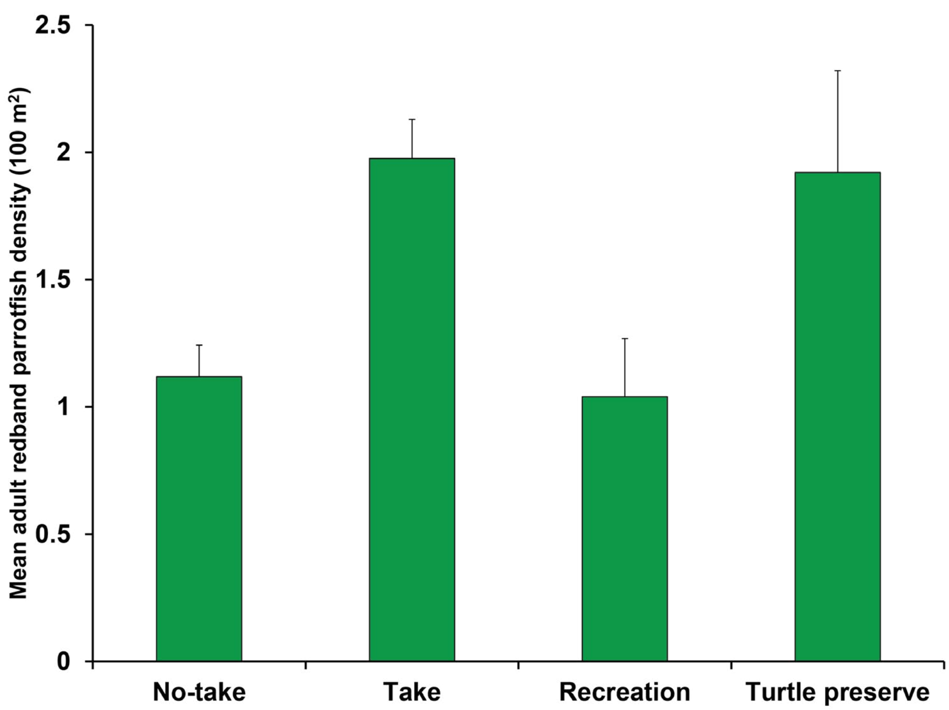
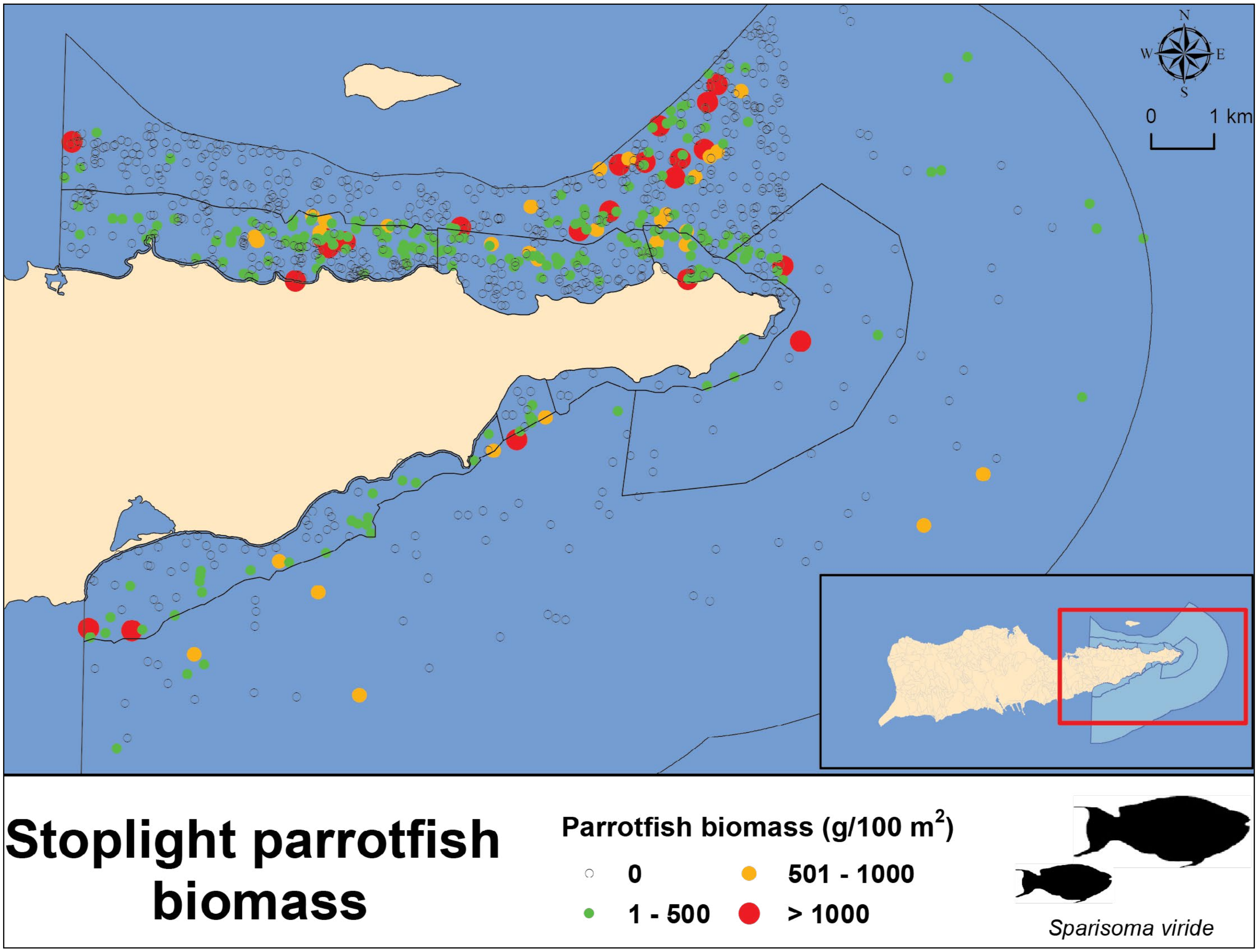


Figure 3.57. Distribution of adult redband parrotfish density (100m²) within STXEEMP (top); and graph of mean (+SE) adult redband parrotfish density by major zone type (bottom).



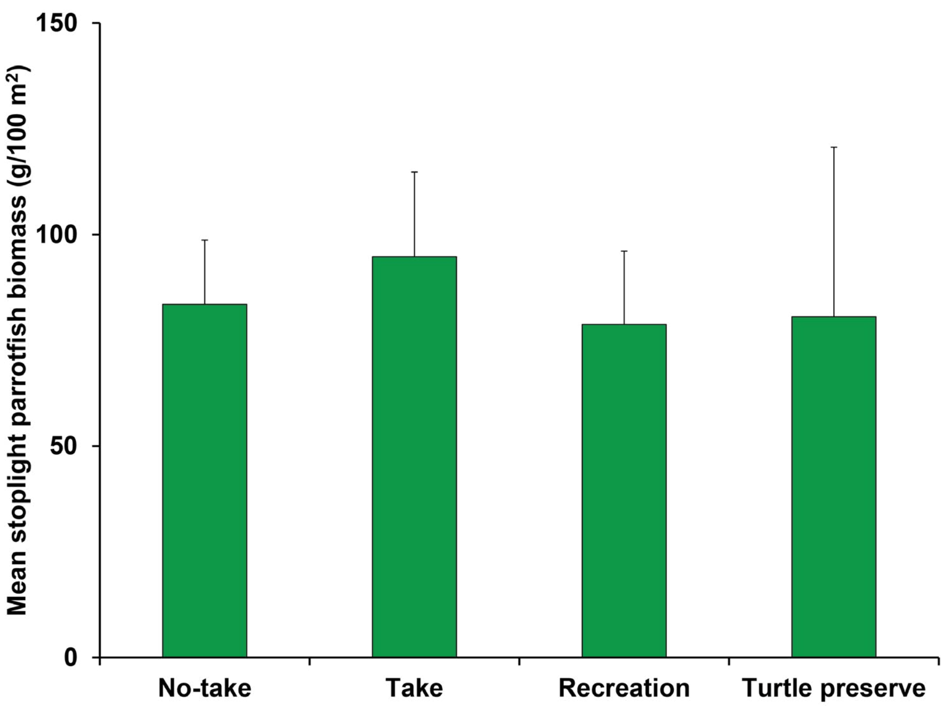


*Figure 3.58. Distribution of stoplight parrotfish (*Sparisoma viride*) biomass (g/100m²) within STXEEMP (top); and graph of mean (+SE) stoplight parrotfish biomass by major zone type (bottom).*

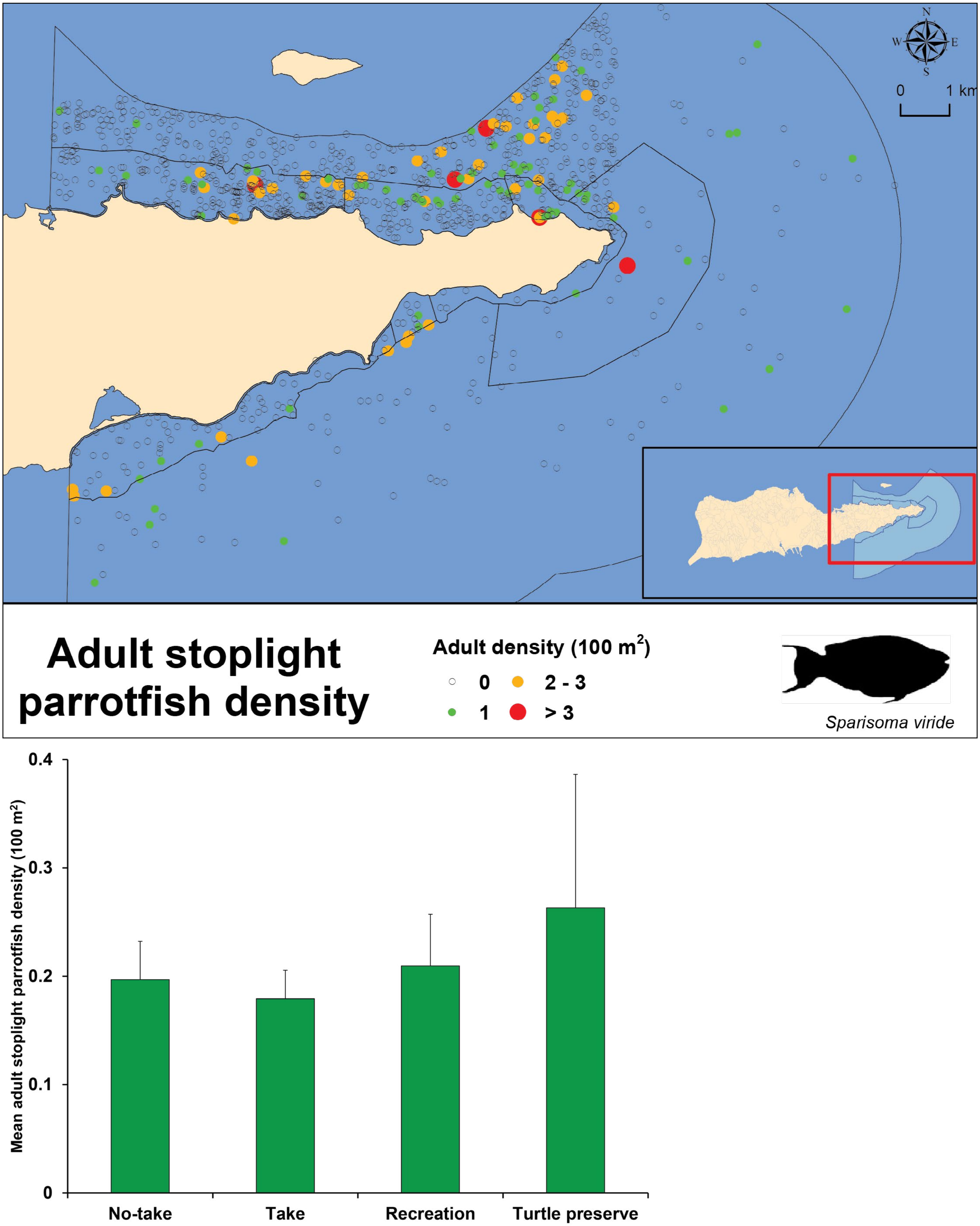
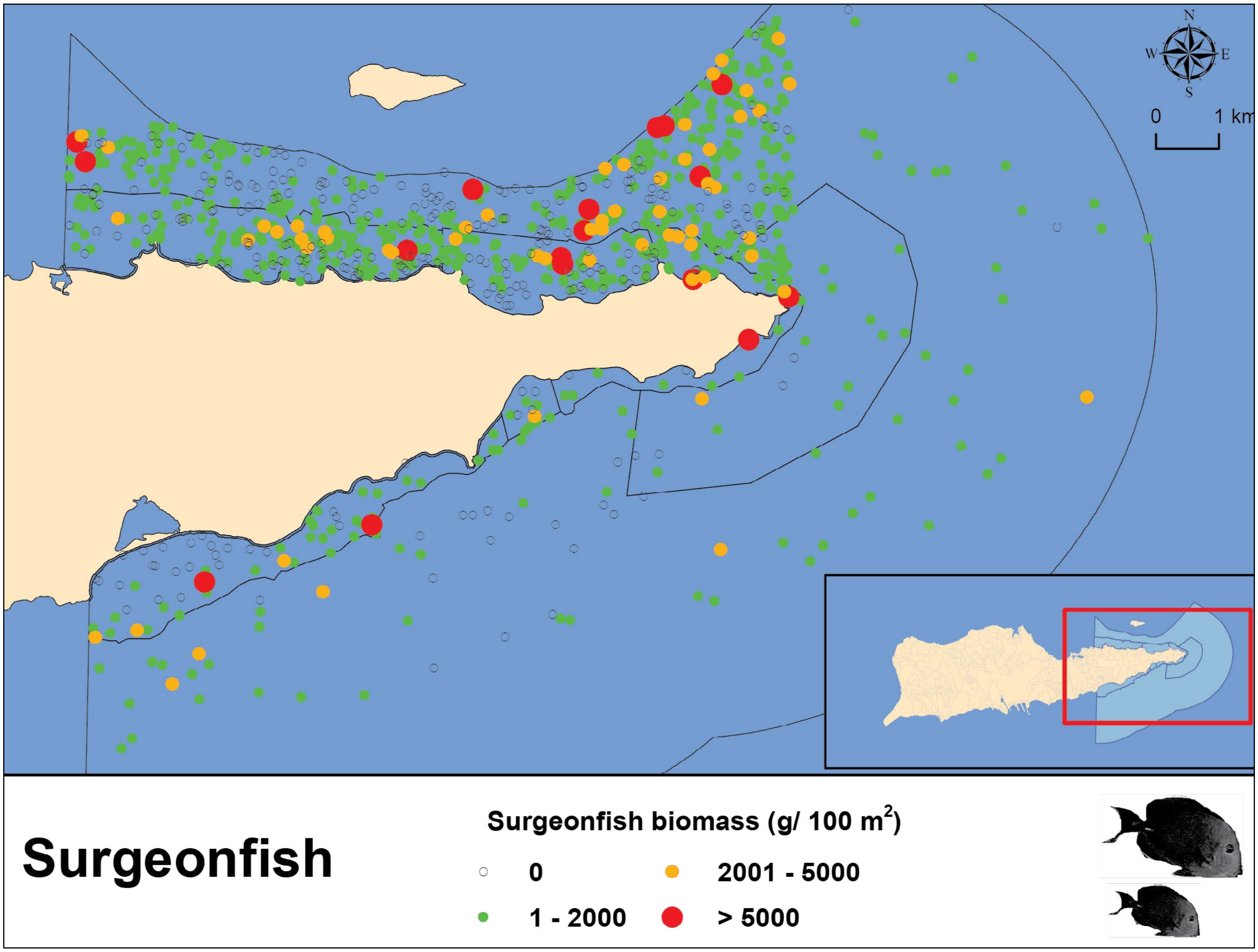


Figure 3.59. Distribution of adult stoplight parrotfish density (100m²) within STXEEMP (top); and graph of mean (+SE) adult stoplight parrotfish density by major zone type (bottom).

Surgeonfish (Acanthuridae)

Surgeonfish (Figure 3.60) biomass was widely distributed across all STXEEMP zones, with highest average biomass recorded for the Take zone and the northern No Take zone (Figure 3.61). Adult surgeonfish, however, were more abundant in the Take zone, particularly on the north coast offshore from Cottongarden Point (Figure 3.62). Adults were sighted at 29% of sites (93 of 320) in the No Take zone. Ocean surgeonfish (*Acanthurus bahianus*), the most abundant surgeonfish species, was widely distributed in STXEEMP, sighted at 64 % of sites with highest average biomass in the Take zone (Figure 3.63). Adult fish, however, were sighted at 23 % of sites, with the highest adult density in the Take zone, with an adult density hotspot evident north of Cottongarden Point (Figure 3.64). Overall, the highest abundance and biomass were associated with coral reefs. More information on habitat-associations and juvenile abundance patterns are available in Pittman et al. (2008).

Figure 3.60. School of surgeonfish in STXEEMP. Source: NOAA/NOS/NCCOS/CCMA/ Biogeography Branch.



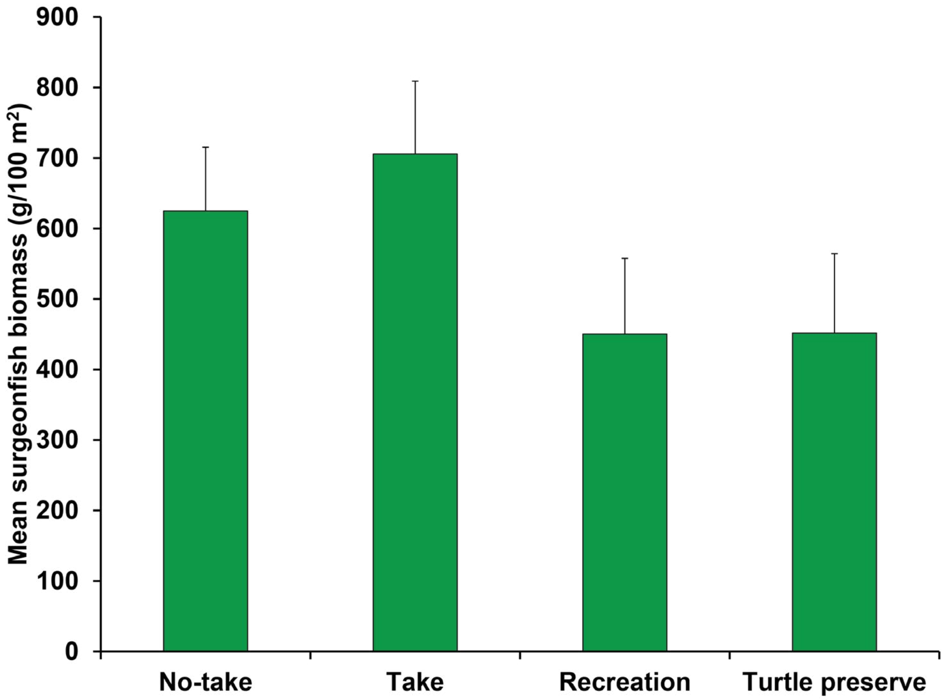


Figure 3.61. Distribution of surgeonfish biomass (g/100m^2) within STXEEMP (top); and graph of mean (+SE) surgeonfish biomass by major zone type (bottom).

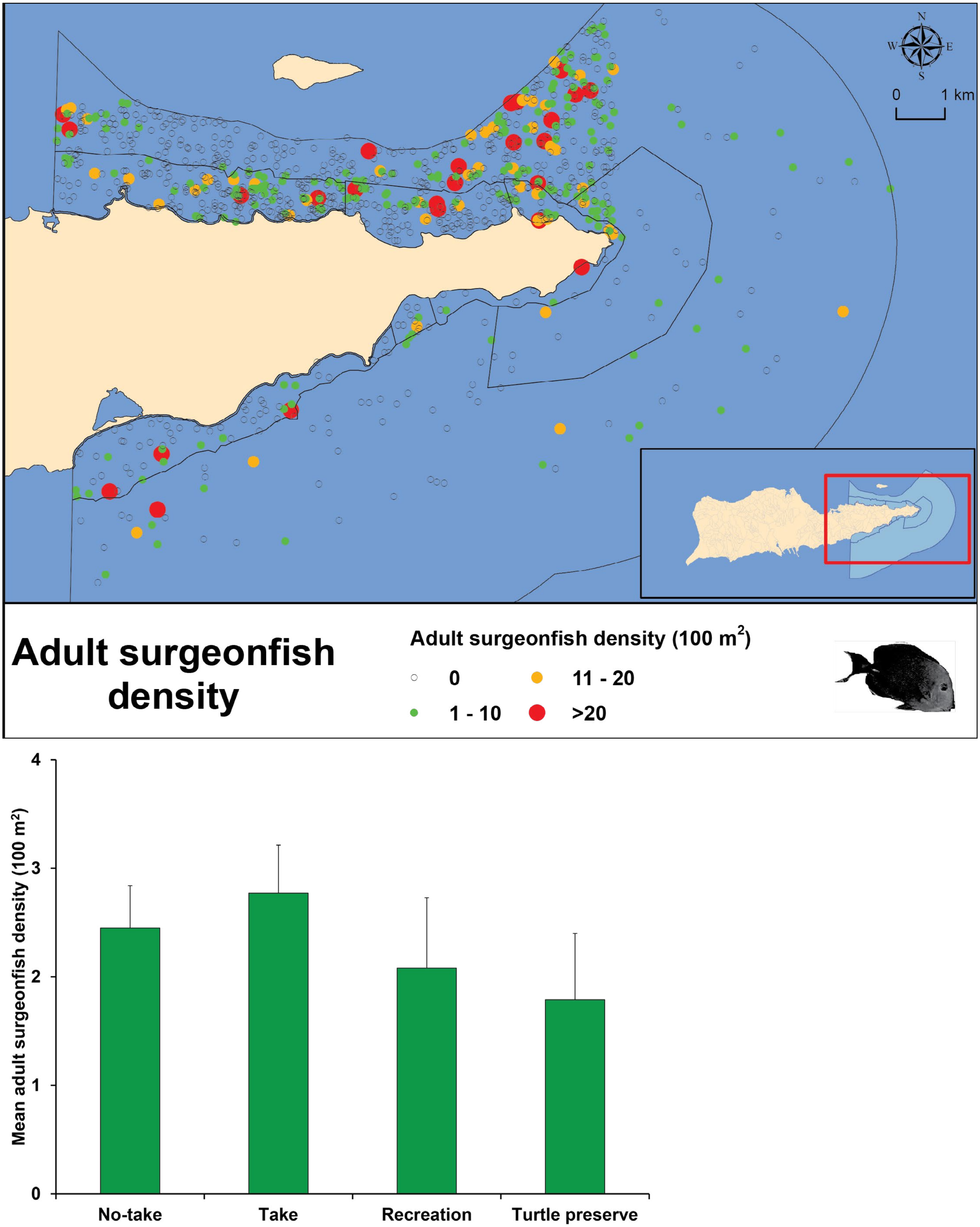


Figure 3.62. Distribution of adult surgeonfish density (100m²) within STXEEMP (top); and graph of mean (+SE) adult surgeonfish density by major zone type (bottom).

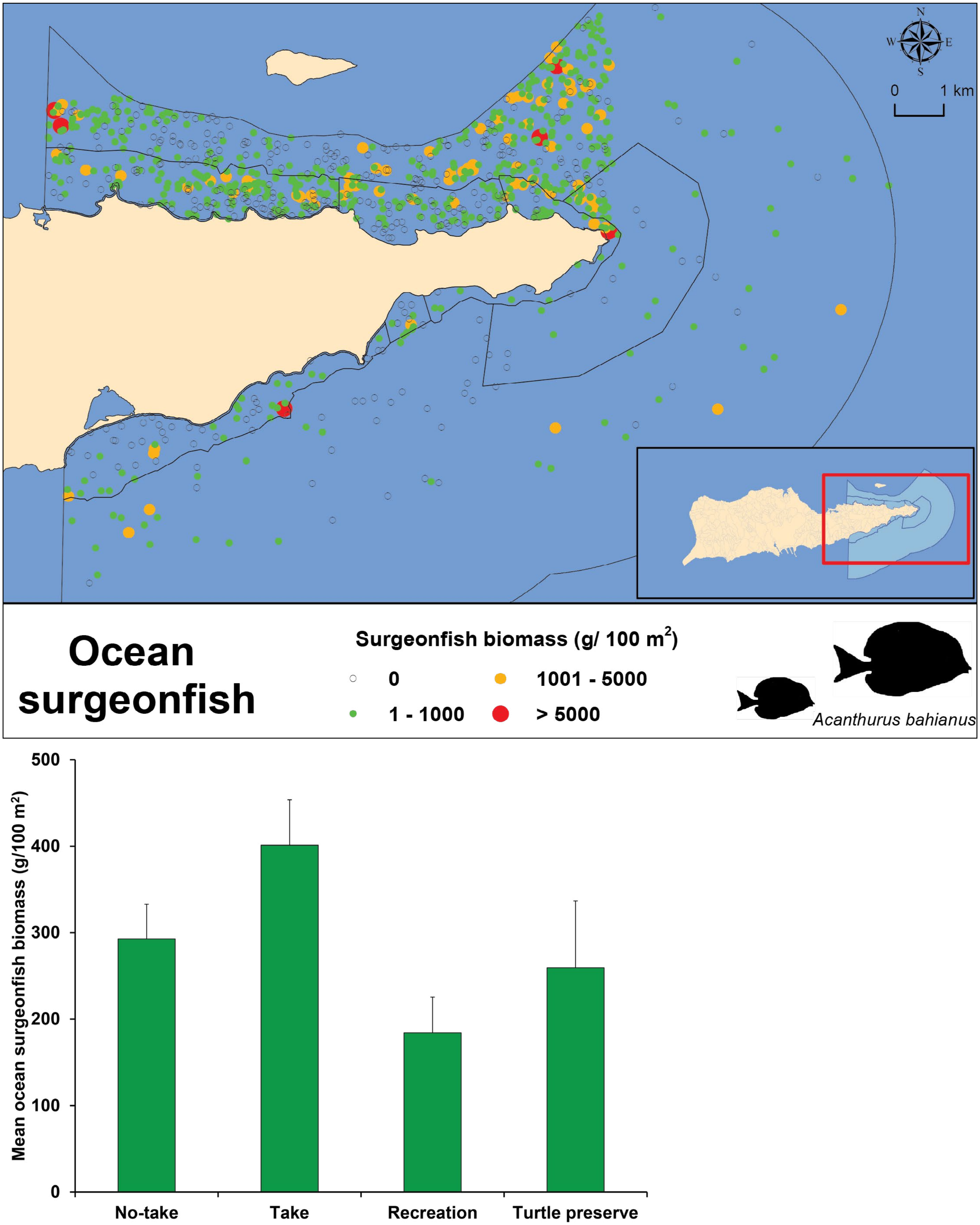
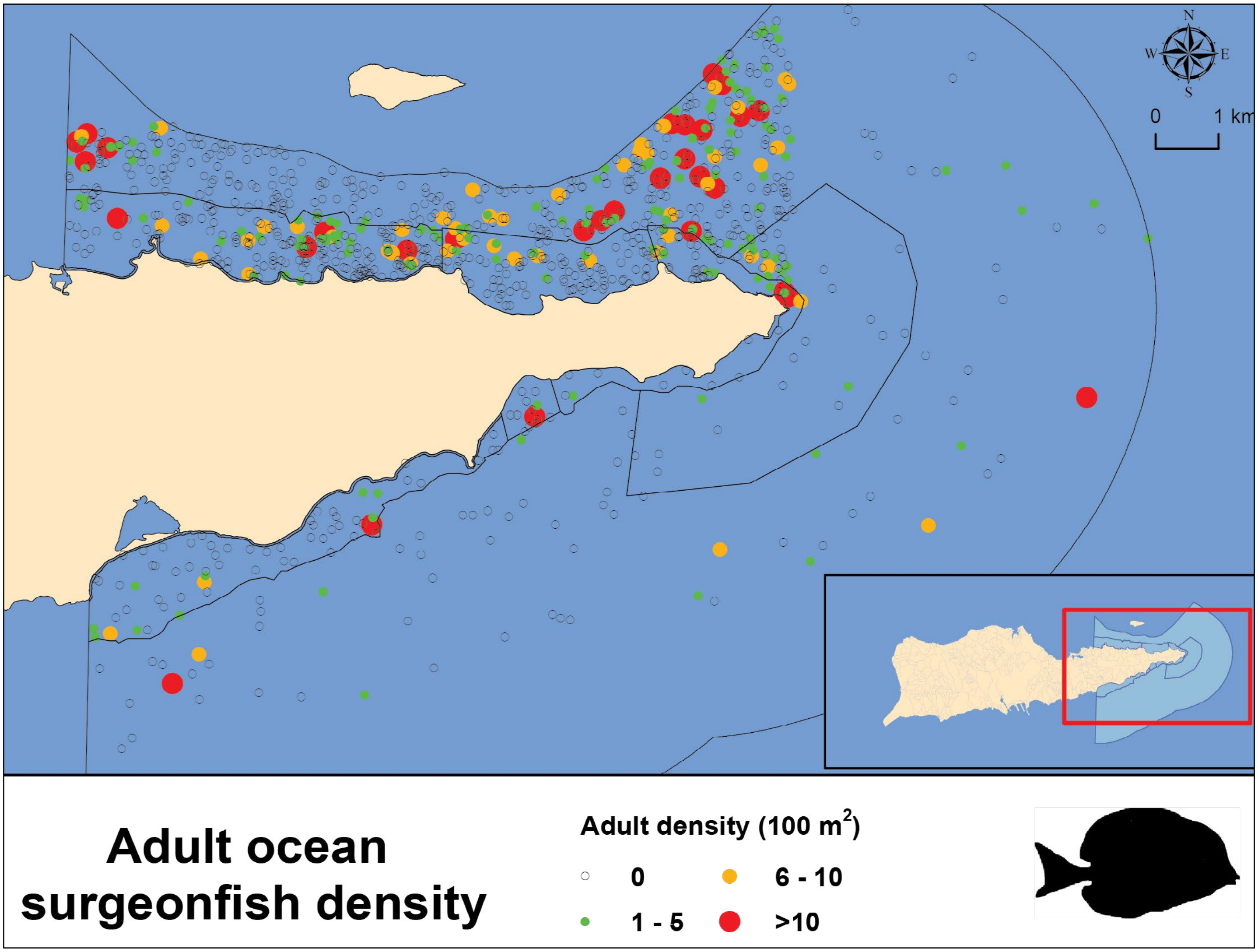


*Figure 3.63. Distribution of ocean surgeonfish (*Acanthurus bahianus*) biomass (g/100m²) within STXEEMP (top); and graph of mean (+SE) ocean surgeonfish biomass by major zone type (bottom).*



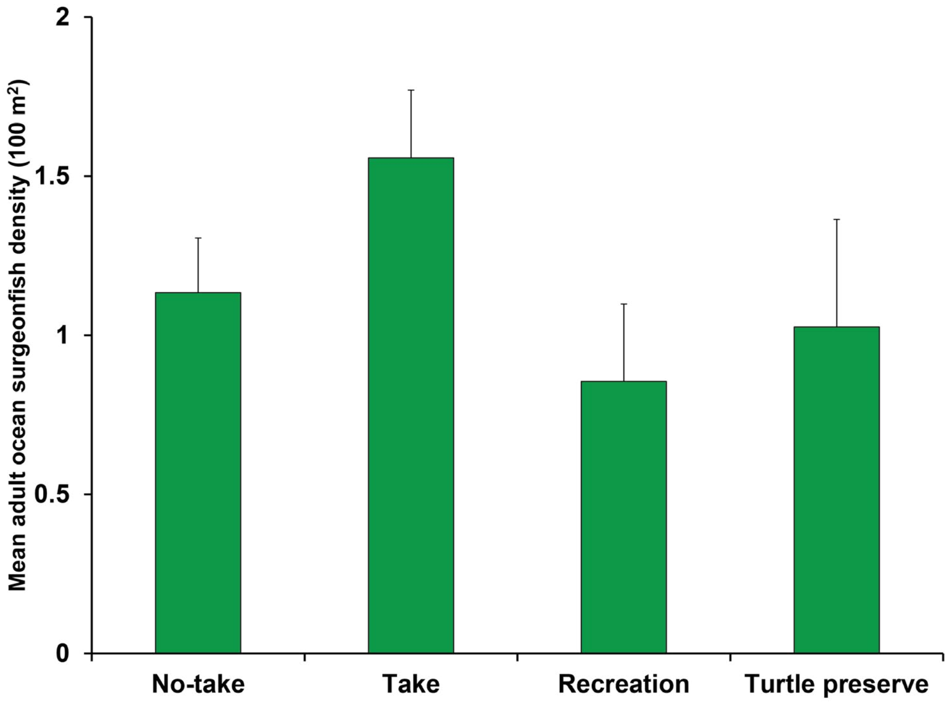
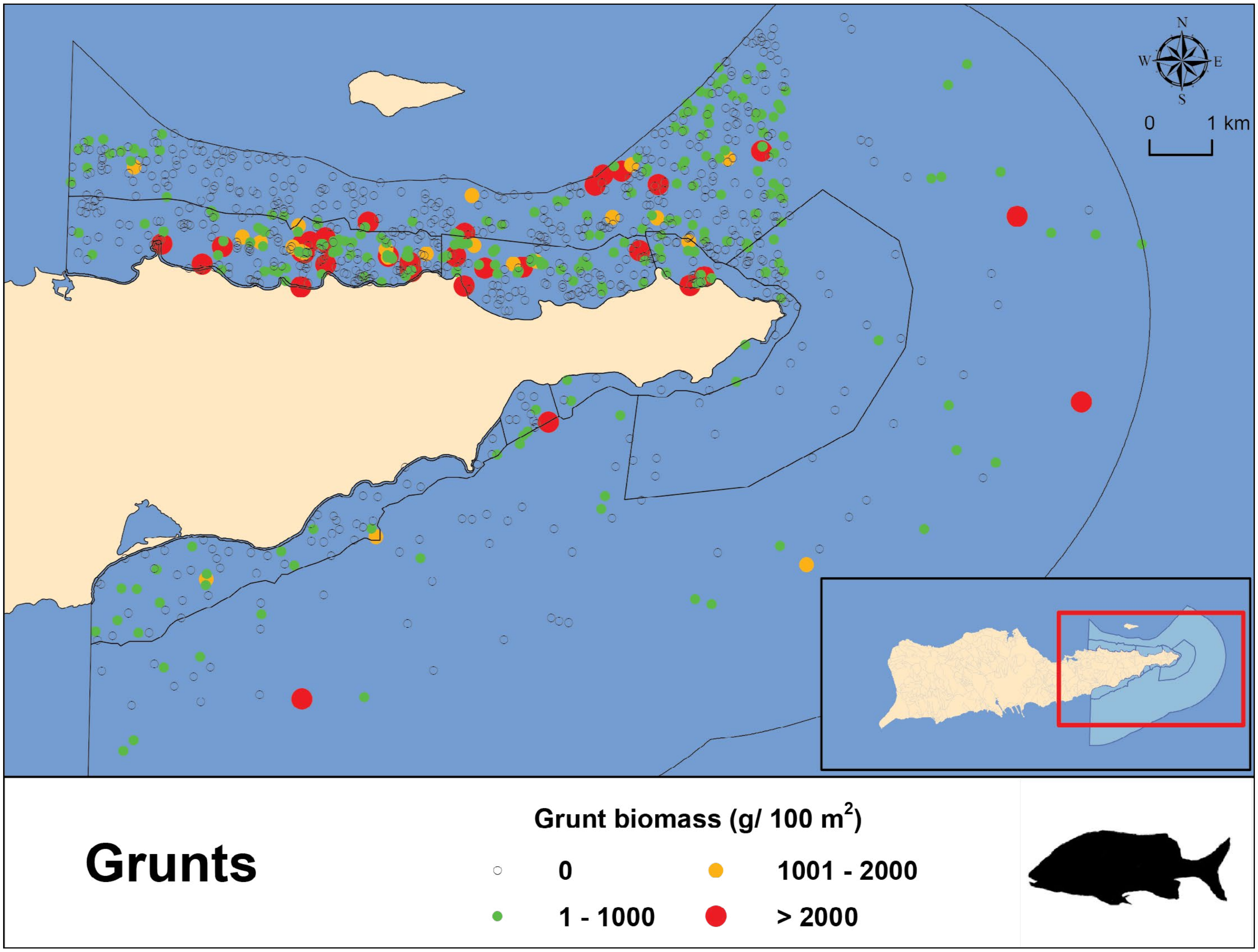


Figure 3.64. Distribution of adult ocean surgeonfish density (100m²) within STXEEMP (top); and graph of mean (+SE) adult ocean surgeonfish density by major zone type (bottom).

Grunts (Haemulidae)

Thirteen species of grunt were identified within STXEEMP (Figure 3.65). Adult grunts represented 18% of all grunts recorded in STXEEMP. Within the No Take zone, adult grunt were observed at 20% of sites (65 of 320) mostly on the northshore (Figures 3.66 and 3.67). The most abundant grunt species was the French grunt (*Haemulon flavolineatum*), followed by white grunt (*Haemulon plumerii*) and bluestriped grunt (*Haemulon sciurus*). At the species level, it was not possible to calculate the proportion of the population that were juveniles versus adults since many small juveniles were not identified to species level. The rarest species of Haemulids were white margate (*H. album*; 1 adult individual), black margate (*Anisotremus surinamensis*; 1 adult) and porkfish (*Anisotremus virginicus*; 2 adults). Grunt biomass and adult grunt density were highest in the No Take and Recreation zones reflecting known grunt preference for nearshore coral reefs in close proximity to seagrasses (Figures 3.66, 4.68 and 3.70). It is likely that the mix of shallow-water structured seascapes (reef, seagrasses, sand) within the No Take and Recreation zones of STXEEMP provide an important nursery habitat function for several of the grunt species. This is particularly evident on the northshore. Average density of adult French grunt and white grunt are higher in the No Take areas than Take areas (Figures 3.69 and 3.71). Adults and juveniles show co-occurrence in their spatial distribution, therefore nearshore zones will offer some protection for multiple life stages.

*Figure 3.65. Group of French grunts (*Haemulon flavolineatum*) in St. Croix. Source: NOAA/NOS/NCCOS/CCMA/Biogeography Branch.*



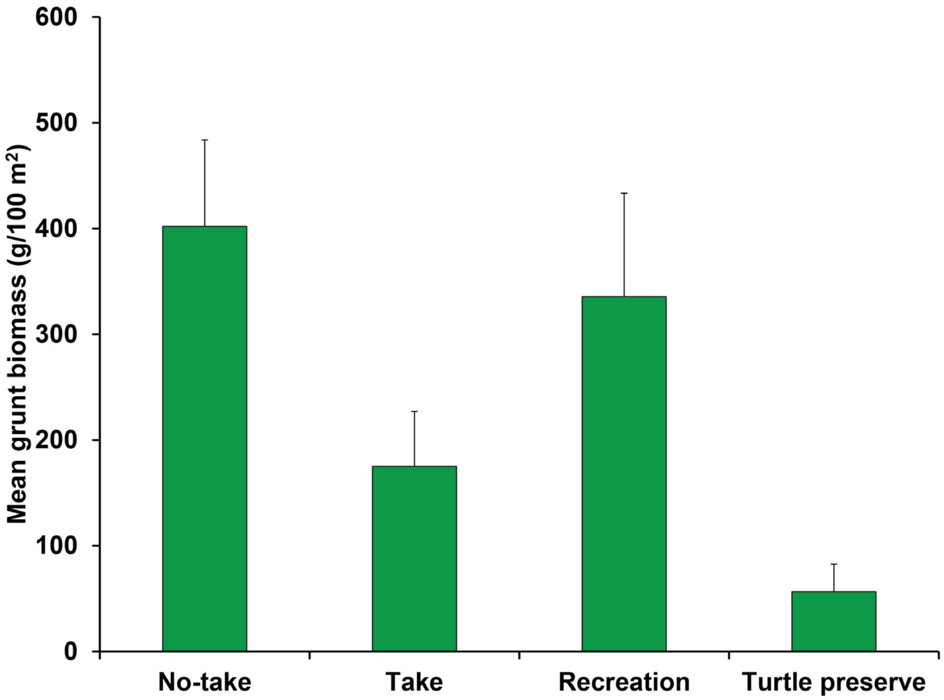
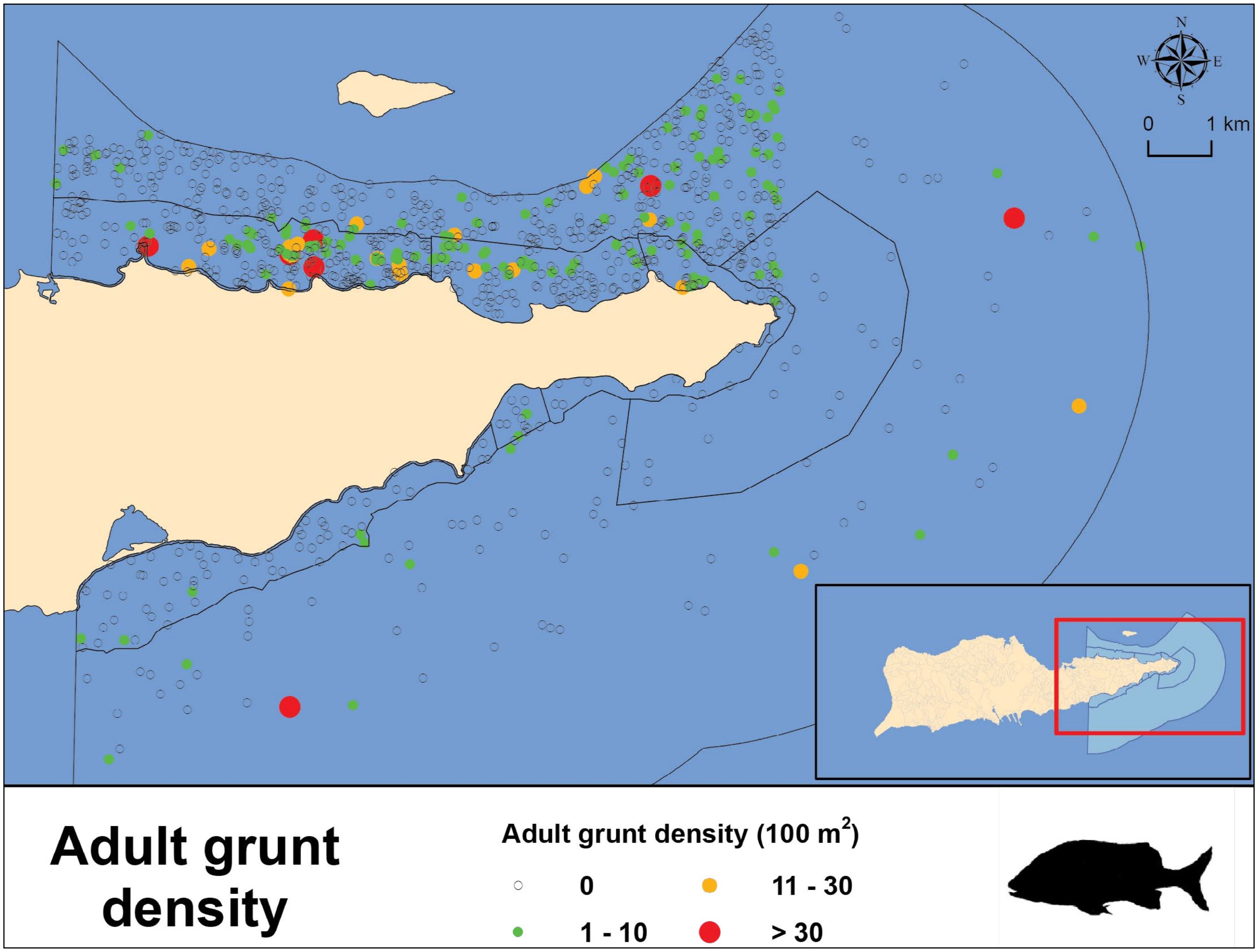


Figure 3.66. Distribution of grunt biomass (g/100m²) within STXEEMP (top); and graph of mean (+SE) grunt biomass by major zone type (bottom).



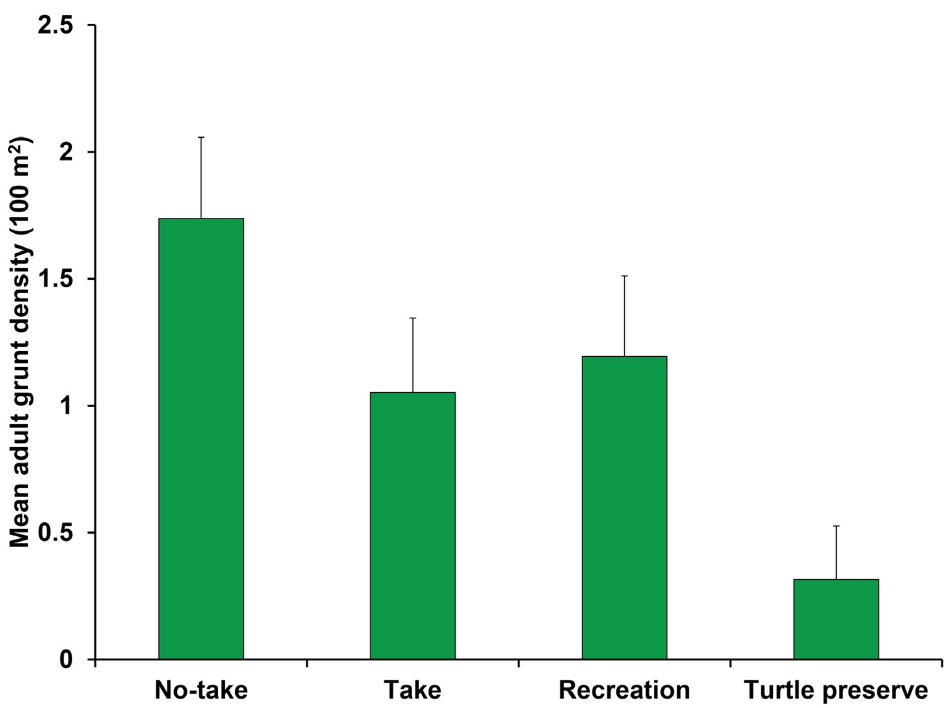


Figure 3.67. Distribution of adult grunt density (100m²) within STXEEMP (top); and graph of mean (+SE) adult surgeonfish density by major zone type (bottom).

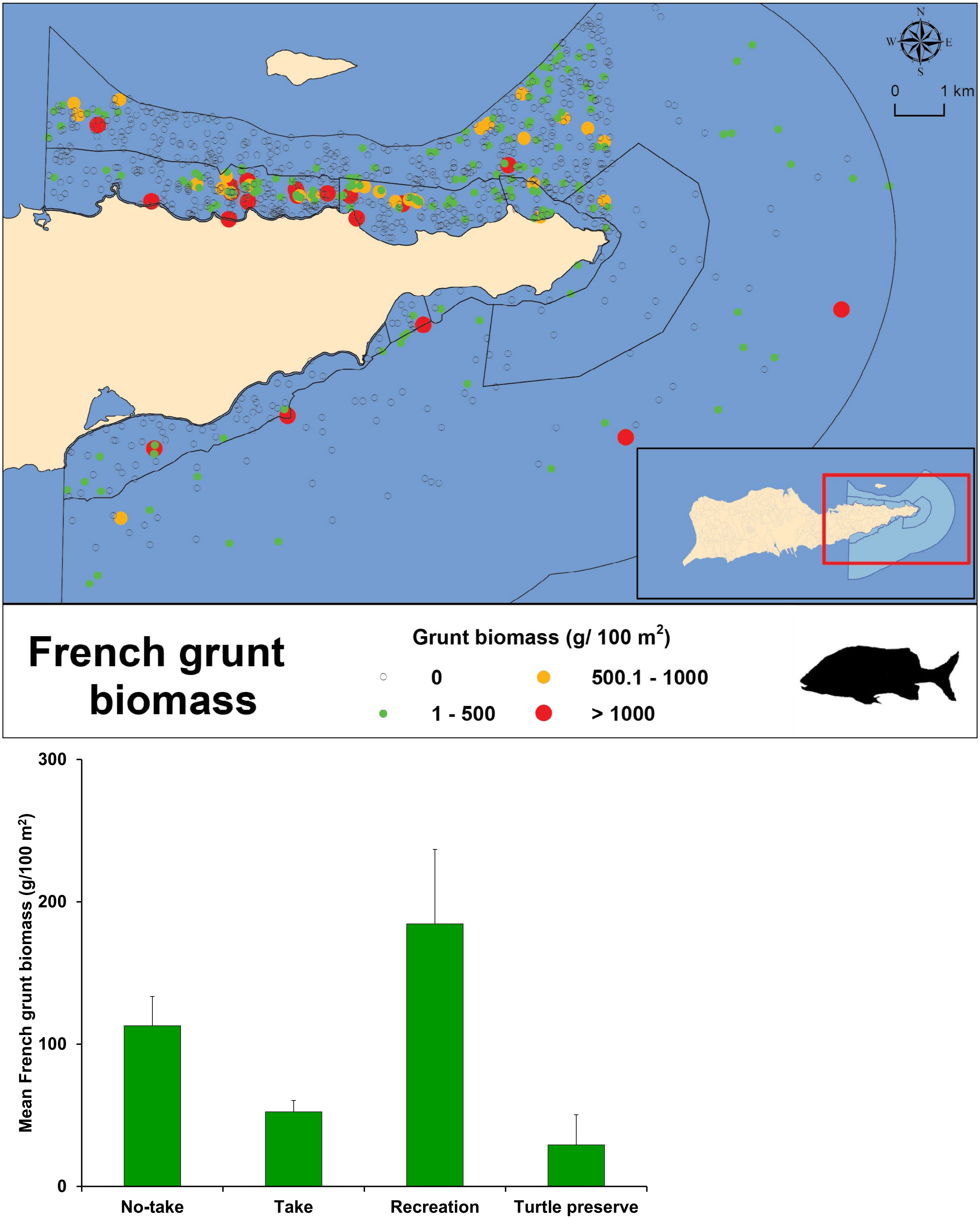
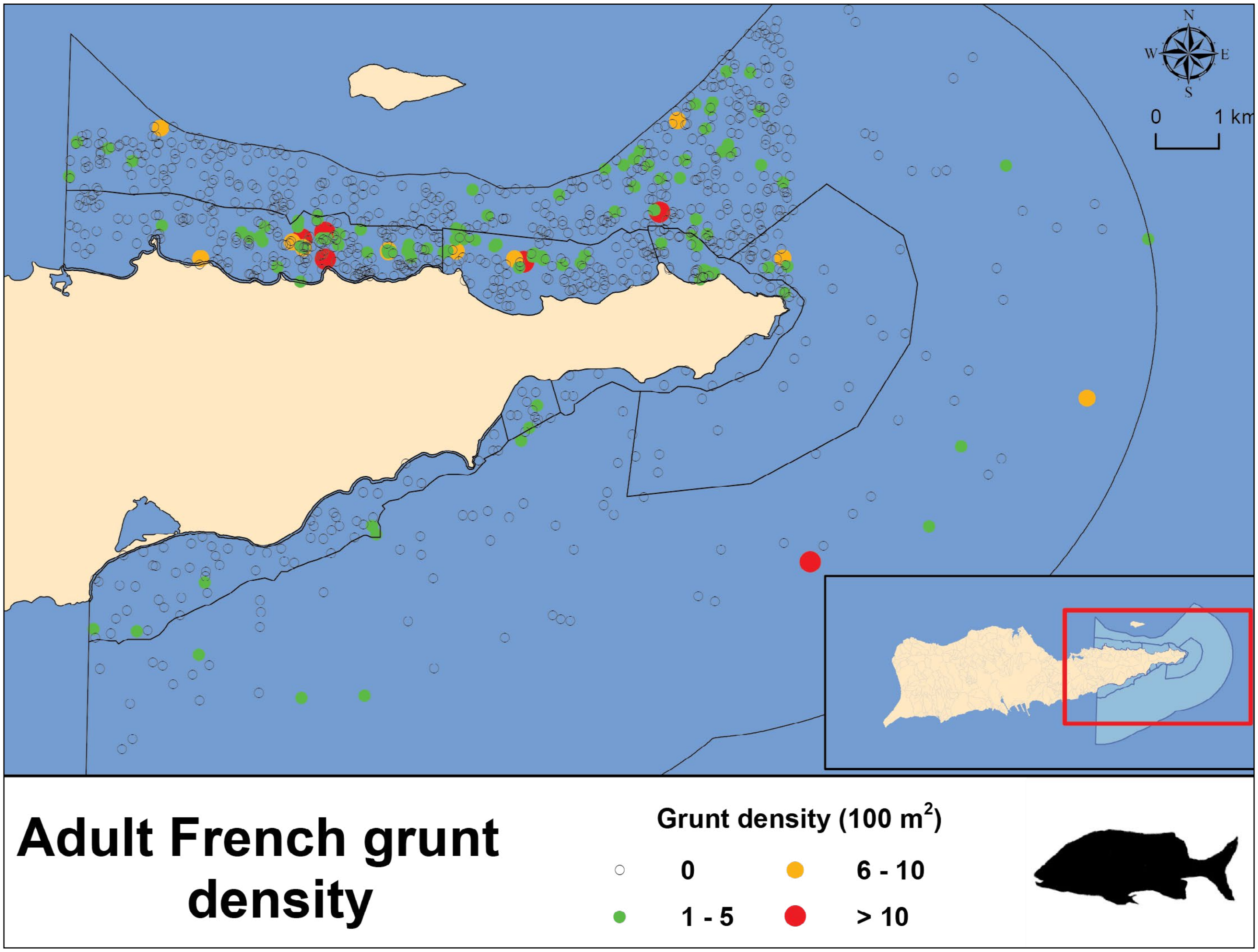


*Figure 3.68. Distribution of French grunt (*Haemulon flavolineatum*) biomass (g/100m²) within STXEEMP (top); and graph of mean (+SE) French grunt biomass by major zone type (bottom).*



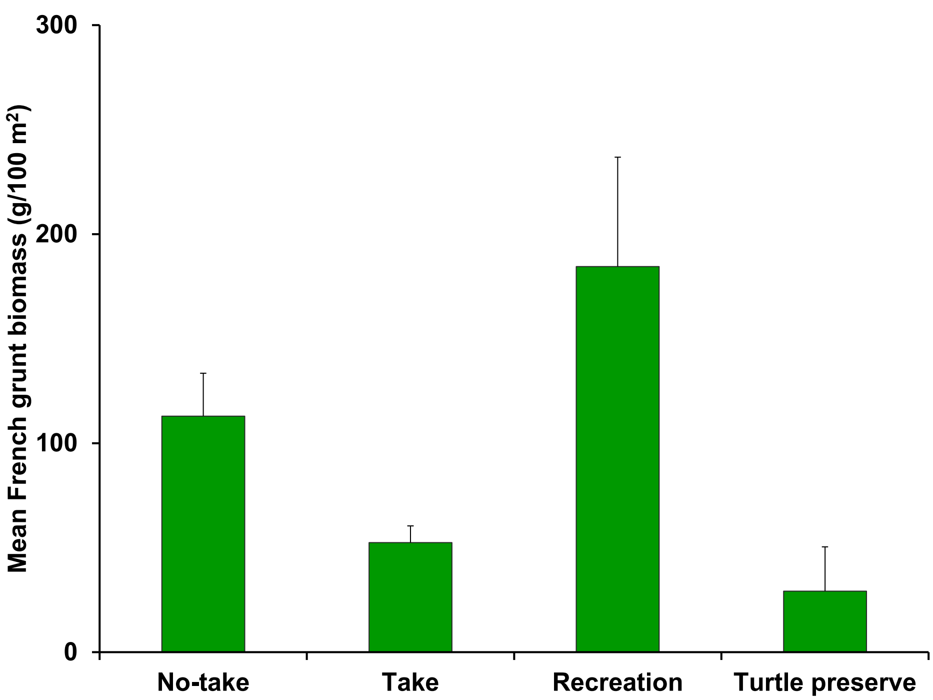
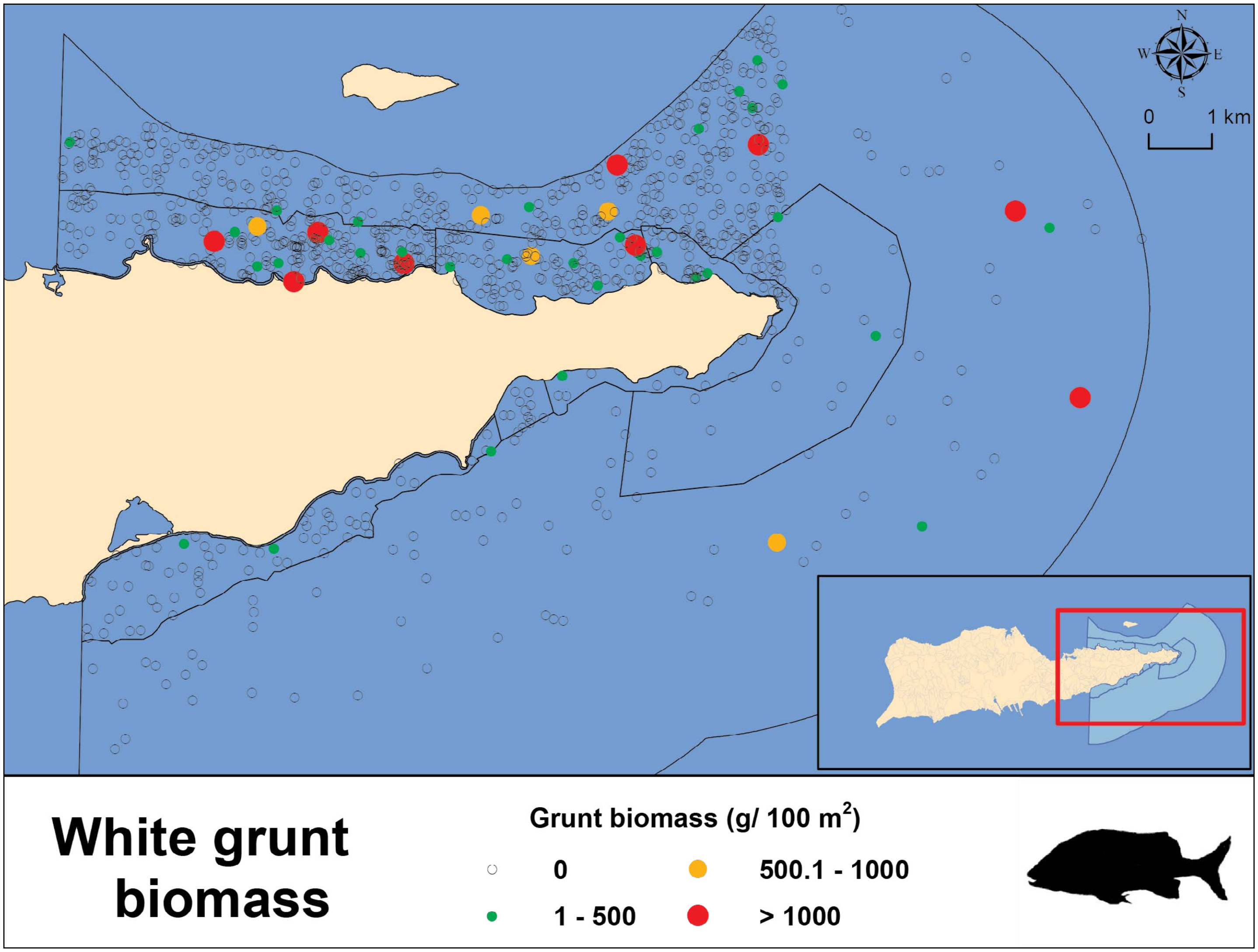


Figure 3.69. Distribution of adult French grunt density (100m2) within STXEEMP (top); and graph of mean (+SE) adult French grunt density by major zone type (bottom).



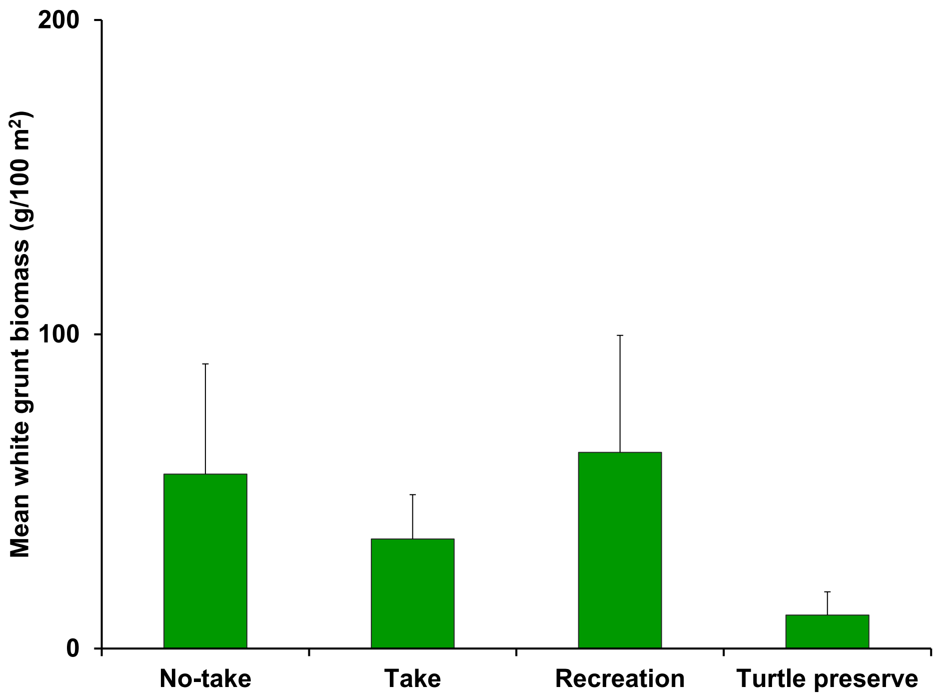
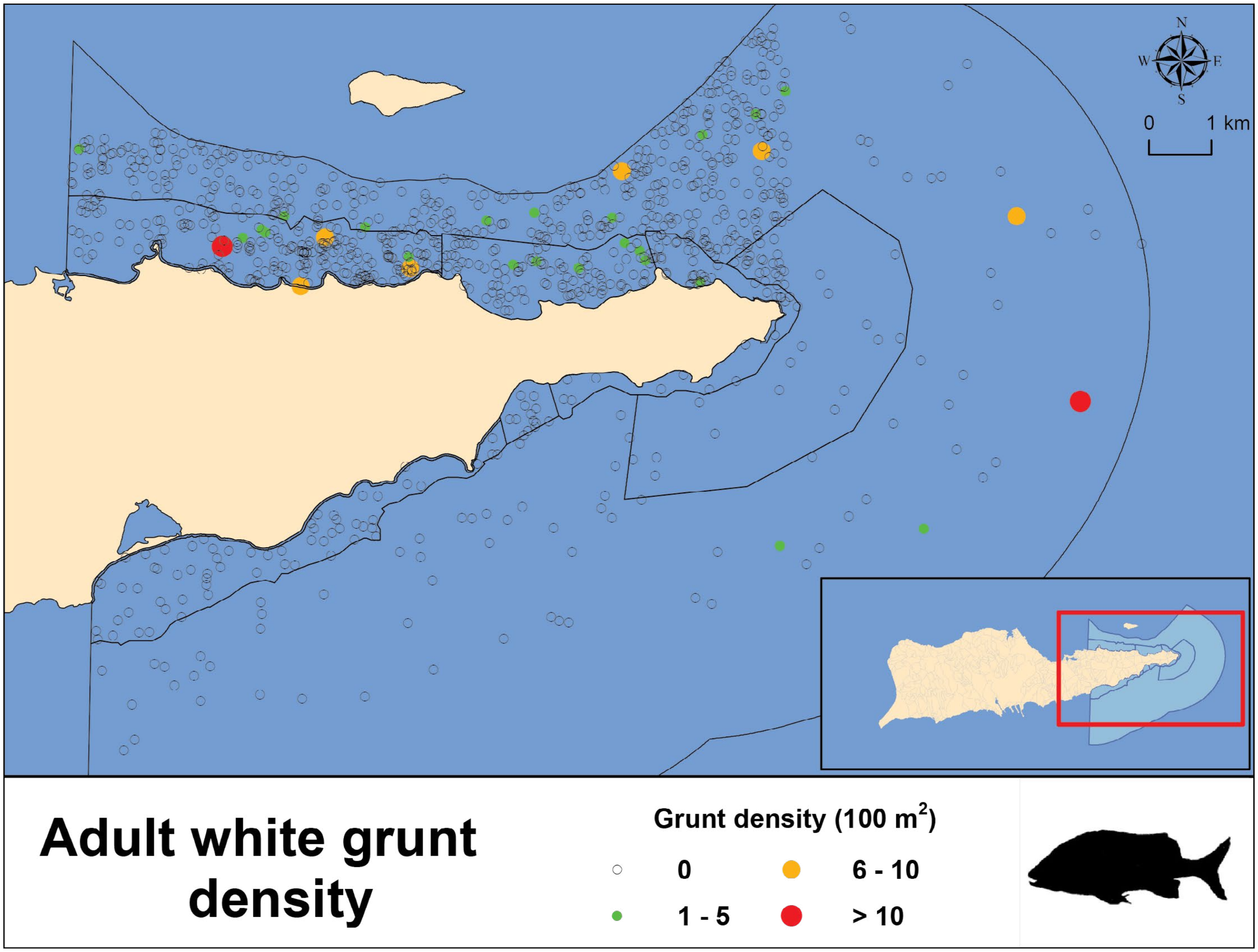


*Figure 3.70. Distribution of white grunt (*Haemulon plumierii*) biomass (g/100m^2) within STXEEMP (top); and graph of mean (+SE) white grunt biomass by major zone type (bottom).*



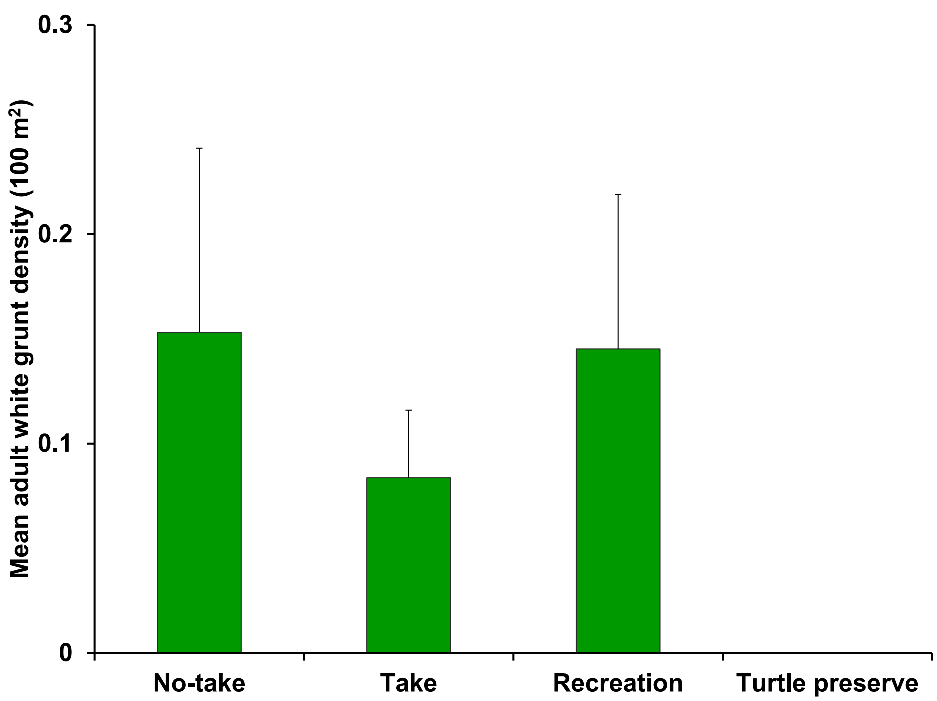


Figure 3.71. Distribution of adult white grunt density (100m²) within STXEEMP (top); and graph of mean (+SE) adult white grunt density by major zone type (bottom).

Goatfish (Mullidae)

Goatfish (Figure 3.72) biomass was highest in the No Take and Recreation zone on the north coast, primarily along the fringing reef between Teague Bay and Coakley Bay (Figure 3.73). Adults, however, were sparsely distributed with no obvious hotspot areas. Adults were observed at 16% of sites (53 of 320) in the No Take zone (Figure 3.74).

*Figure 3.72. Yellowtail goatfish (*Mulloidichthys maritinicus*) in STXEEMP. Source: NOAA/NOS/NCCOS/CCMA/Biogeography Branch.*

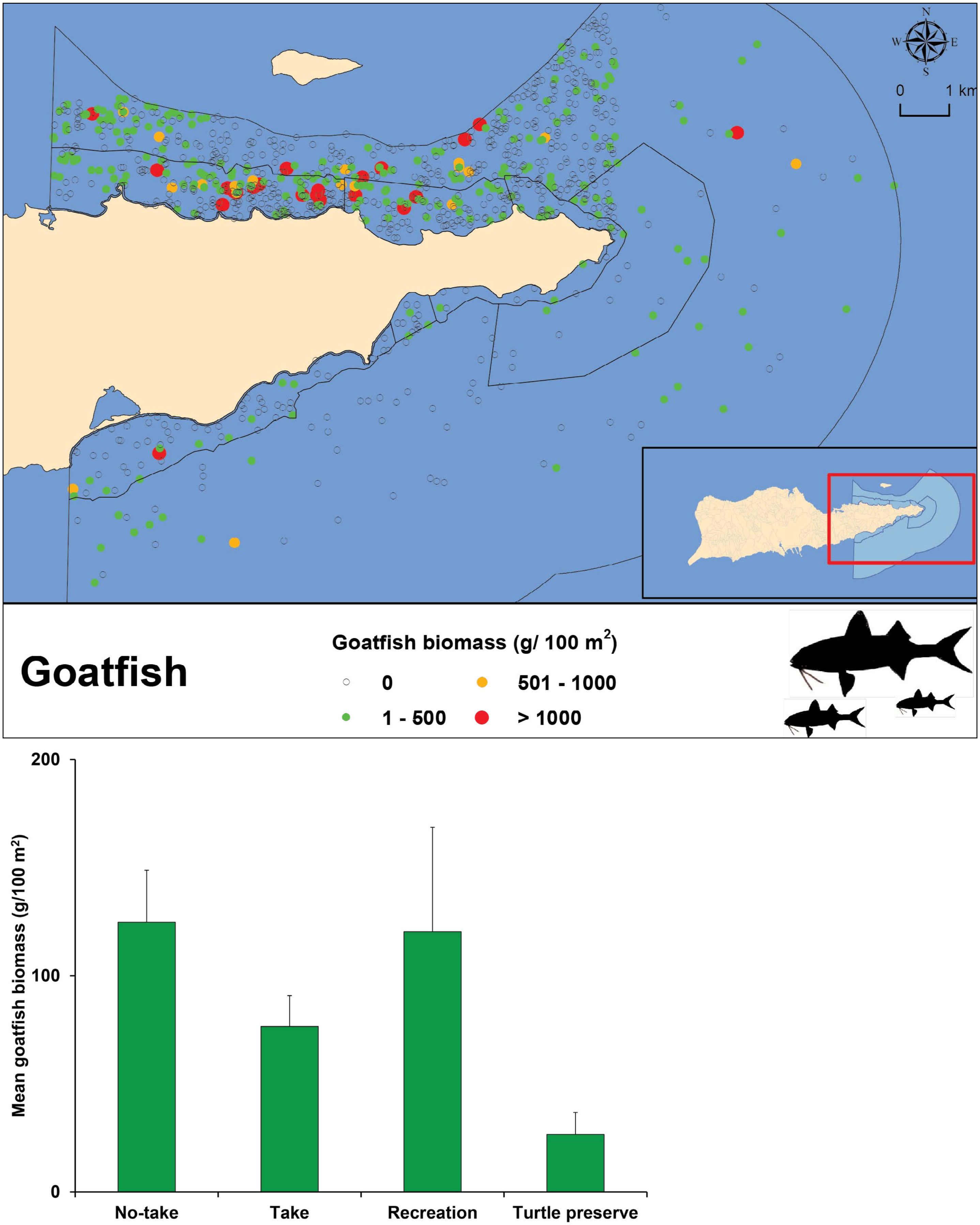
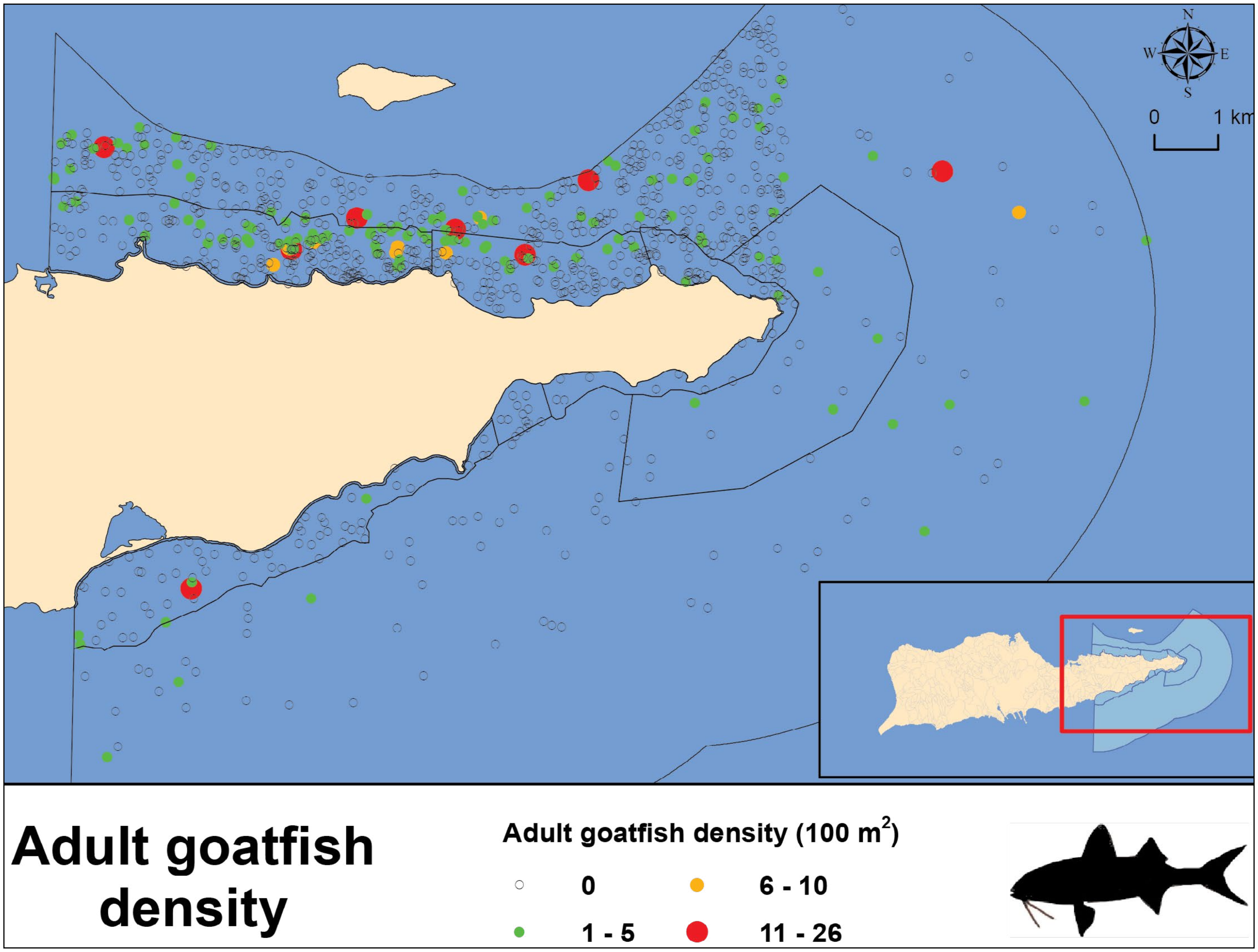


Figure 3.73. Distribution of goatfish biomass (g/100m^2) within STXEEMP (top); and graph of mean (+SE) goatfish biomass by major zone type (bottom).



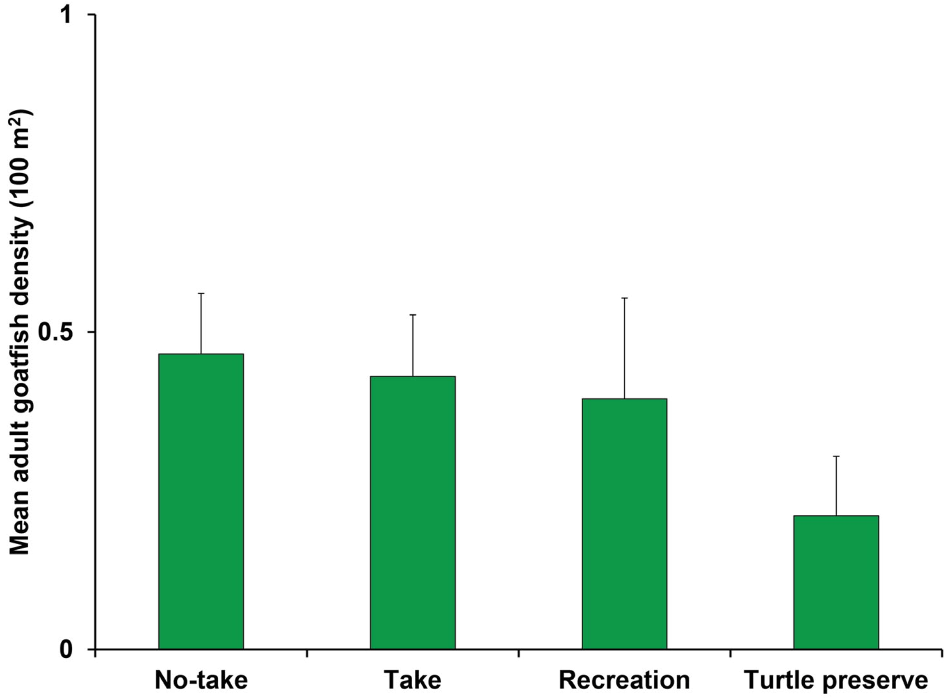


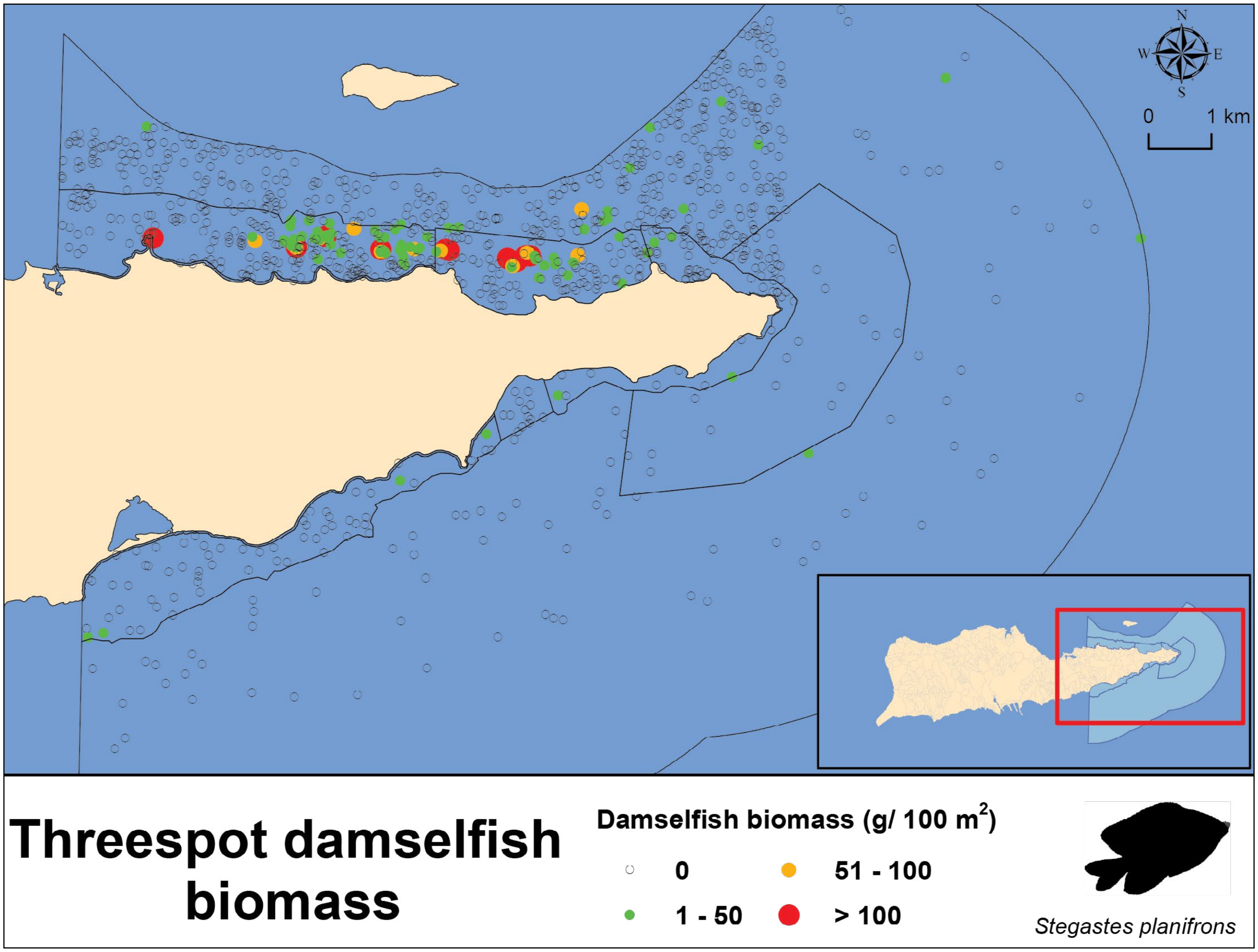
Figure 3.74. Distribution of adult goatfish density (100m²) within STXEEMP (top); and graph of mean (+SE) adult goatfish density by major zone type (bottom).

Marine Fish and Benthic Communities

Threespot damselfish (*Stegastes planifrons*)

Threespot damselfish density was included in this analysis because it was considered to be a reliable indicator of the presence of live coral and topographically complex substrate in shallow water areas (Figure 3.75). In STXEEMP, Threespot Damselfish were almost exclusively observed along the fringing reef within the northern No Take and Recreation zones (Figure 3.76) further highlighting the potential importance of this linear reef feature that spans multiple management units and exists close to the border with a Take zone.

*Figure 3.75. Threespot damselfish (*Stegastes planifrons*) in St. Croix. Source: NOAA/NOS/NCCOS/CCMA/Biogeography Branch.*



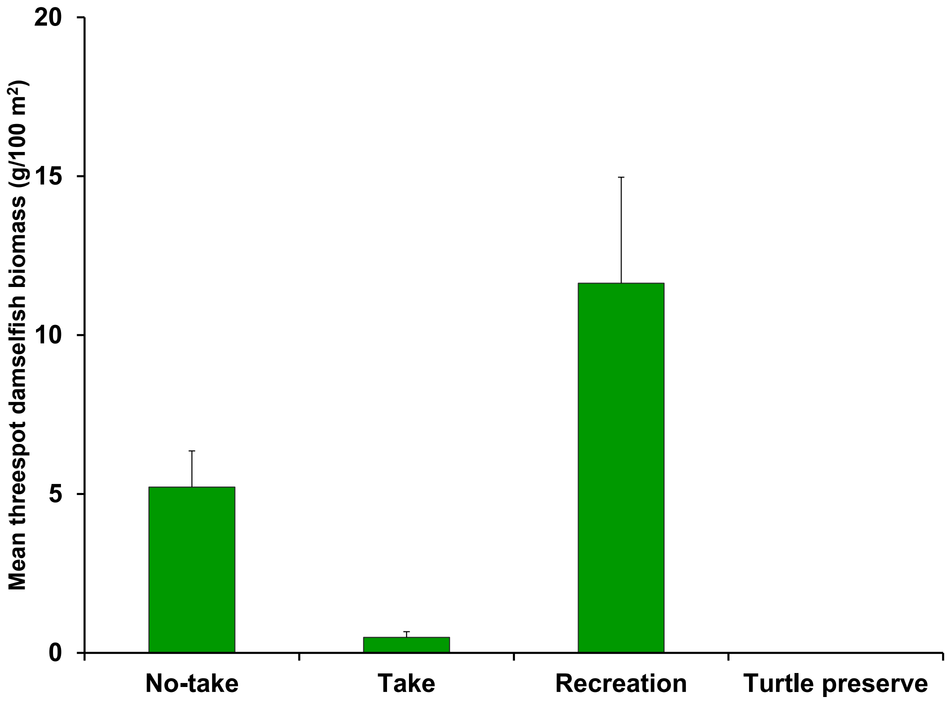


*Figure 3.76. Distribution of threespot damselfish (*Stegastes planifrons*) biomass (g/100m²) within STXEEMP (top); and graph of mean (+SE) threespot damselfish biomass by major zone type (bottom).*

Key Findings and Recommendations

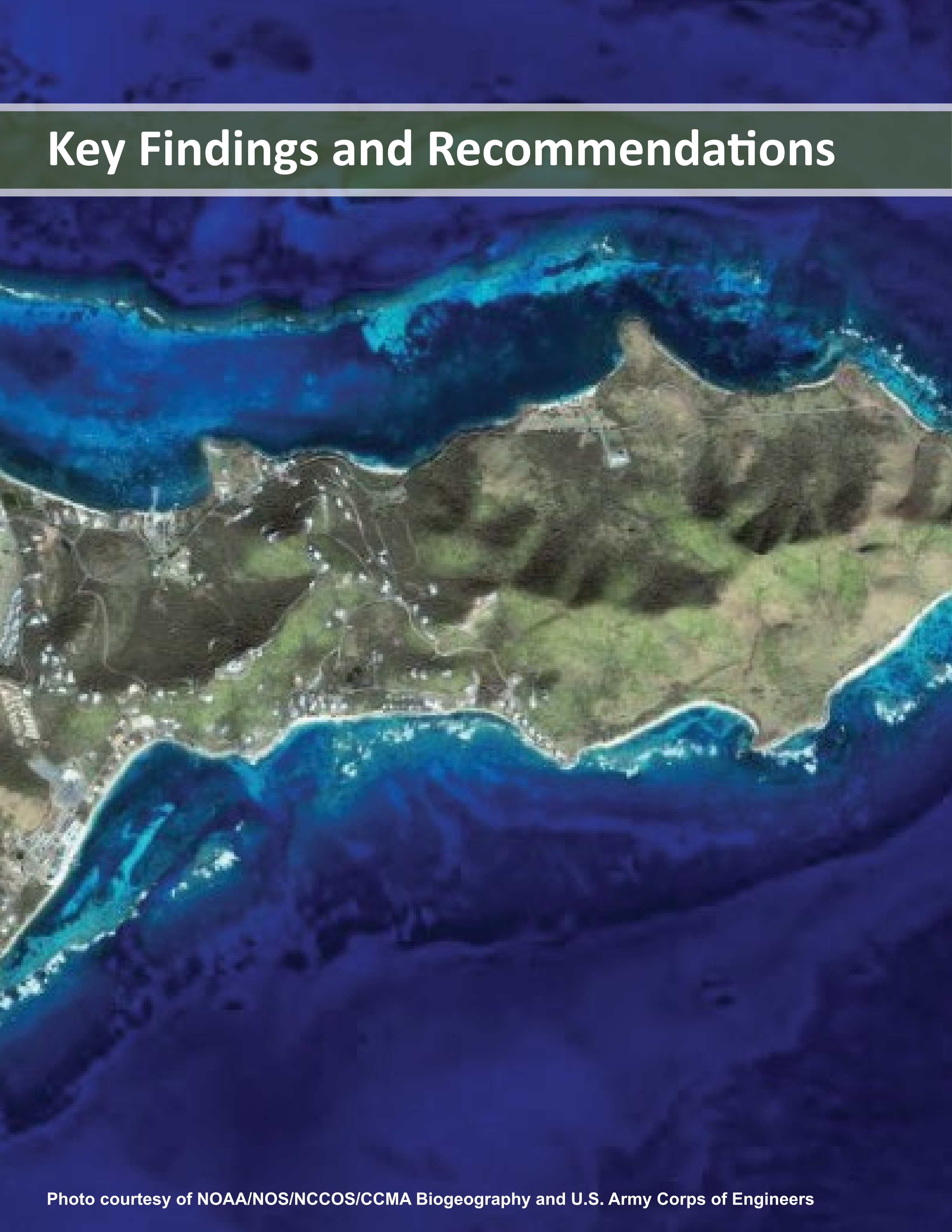


Photo courtesy of NOAA/NOS/NCCOS/CCMA Biogeography and U.S. Army Corps of Engineers

Key Findings and Recommendations

LANDSCAPE-SEASCAPE LINKAGES

- Develop a management prioritization strategy using information from this report to begin identifying direct causes of poor water quality in areas with priority marine communities, i.e., ESA-listed Acroporid corals, diverse coral reef, areas with high potential to recover to diverse coral reefs.
- The areas identified as having a high density of dirt roads should be managed specifically to limit and reduce sediment run-off as it negatively impacts corals and seagrass communities and negatively impacts the goals of the STXEEMP.
- The areas identified as having high LDI should be managed to limit the further development of impervious surfaces as high levels of impervious surfaces will lead to increases in LBSP.
- The areas up-slope of the watershed impact zones which are identified as containing sensitive species should be managed to insure that conditions in these environments are sustainable for sensitive species.
- Regular monitoring of benthic habitats and critical species should be implemented in order to create an adaptive management process relative to the goals and targets of the management plan. Permanent monitoring sites should be established at coral hotspot areas, such as the fringing reef along the north shore, to monitor the impact of water quality on coral health, abundance and community composition.
- Benthic monitoring should include the areas of the watershed impact zones in order to determine if LBSP are negatively impacting the natural resources of the STXEEMP.

STXEEMP ZONATION, BIOTIC PATTERNS AND EXPECTATIONS OF MPA PERFORMANCE

Is the placement and size of No Take zones sufficient for replenishment of fished populations?

- The placement of No Take zones only in nearshore areas will offer protection for fish assemblages that are dominated by small-bodied and juvenile fishes that are not primary target species of the fishery. Highest densities of adult fish vulnerable to fishing exist in the Take zone. In contrast, comparatively few adults of fishery target species exist in the No Take zone. This finding indicates that the current zoning design of STXEEMP will play only a minor role in replenishment of fished populations or, at worst, may fail to fulfill the objective of population replenishment as stated in the management plan. This report should be used to inform future design and to adjust down expectations of STXEEMP performance in the role of replenishment for species vulnerable to fishing.
- Very few adult grouper exist in No Take and Recreation zones and therefore these zones provide no real potential for replenishment of grouper populations
- Two hotspots for fish biomass and adult density of fished species currently exist in the Take zone adjacent to No Take zones.
- Of the harvested families of fish, the STXEEMP will likely offer partial protection for grunts based on the higher densities of adult grunts in No Take and Recreation zones. However, several species of grunt are known to forage widely and undertake ontogenetic shifts across the shelf to deeper water reefs preferred as adult habitat For example, tagged bluestriped grunts in the U.S. Virgin Islands had mean home ranges of 14,087 m^2 and a maximum of 29,944 m^2 (Hitt et al., 2011), and while a single white grunt traversed a distance of 6.2 km in a year (Pittman et al., submitted PloSONE; Friedlander et al., 2013).
- No-take areas are too small to offer adequate protection for mobile animals during their life history movements. Recent data from acoustic tracking of fish in MPAs of the Virgin Islands indicate that 62% of 162 tagged fish from 18 species were capable of travelling more than 1 km and provide some evidence that many

species are capable of travelling beyond the borders of smaller MPAs (Pittman et al., in review PLoSOne). This has potentially serious implications for the effectiveness of the STXEEMP No Take zones in achieving their intended purpose. Many coral reef-associated species traverse the shelf through daily movements, ontogenetic habitat shifts and spawning migrations, yet the No Take areas encompass only shallow nearshore areas offering only partial protection for most mobile animals. Fish associated with the important fringing reef on the north coast may not receive adequate protection during their routine movements because the reef feature exists close to the boundary with the Take zone where fish could be harvested. In the northern region, if connectivity exists between STXEEMP No Take areas and the adjacent No Take MPA of Buck Island Reef National Monument, then the combined areas may function synergistically to offer greater protection for fish. The existence of ecological connectivity between the two MPAs is currently unknown.

- The existing placement of No Take zones only in nearshore lagoonal areas in close proximity to land may impact ecological performance. Further research is needed to establish the potential threat from runoff and water quality on fish populations, fish assemblage structure, other fauna and flora, and general habitat quality.

- Data in this report should be used during the management plan review process to critically examine zone locations, size, and boundary placement with regard to their ability to perform adequately to meet management objectives. If boundaries remain fixed then we recommend a process to redefine objectives to achieve more realistic expectations relative to goals of replenishment and biodiversity protection and setting of achievable targets for ecological performance. If an information-based review of boundaries takes place, then we recommend the development of boundary alternatives to offer a range of options or scenarios each of which should offer the potential for higher ecological performance.

- Many of the survey sites in the Take zone between Point Udall and Lang Bank supported high fish species richness. This offshore area has received little survey effort beyond the sampling conducted through this project and could justify special focus in future survey and monitoring.

- Although not examined in this study, the interdependence of highly vulnerable, large-bodied fish populations (i.e., tiger grouper [*Lutjanus tigris*], Nassau grouper, dog snapper [*Lutjanus jocu*], cubera snapper [*Lutjanus cyanopterus*]) within STXEEMP on the nearest multi-species fish spawning aggregation at Lang Bank requires urgent investigation. The spawning aggregation is vulnerable to fishing and harvesting populations of snapper, grouper and other species that aggregate could rapidly deplete island-wide populations, thus impacting the replenishment potential of STXEEMP.

- Special research and management attention should be given to productive, topographically complex coral reefs that exist in close proximity to seagrasses and mangroves. An example is the coral reefs in the Take zone offshore from the Great Pond area on the south shore, and the coral reefs offshore of Green Cay. Mangrove-seagrass-coral reef seascapes, when connected by close proximity, can maintain enhanced productivity, diversity and resilience, but will need to be managed as a connected system of habitats rather than a single habitat approach.

- Some bias in the depiction of fish population distributions between north and south shore exists in this report due to uneven sampling. We have sought to address this by additional surveys in the southern STXEEMP carried out as part of this project. To supplement the quantitative scientific surveying, we recommend gathering, documenting and mapping local knowledge to help to fill some gaps and guide future more detailed in-water surveys.

- Deeper water areas of the STXEEMP could not be surveyed by conventional SCUBA diving techniques. We recommend requesting a NOAA ship-based effort to characterize the seafloor and biological communities in the deep waters. Potential remote sensing technologies available include splitbeam acoustic echosounder for mapping fish size and distribution; multibeam echosounder for high resolution seafloor mapping; and deployment of remotely operated vehicles (ROVs) to capture video and photography of biological communities. Similar efforts have been conducted around St. Thomas, St. John and Puerto Rico to support management decision making.

- Our first survey mission to the south shore of STXEEMP added four new species to our species list after 10 years of surveys in St. Croix. The fish were sargassum triggerfish (*Xanthichthys ringens*), bridal cardinalfish (*Apogon aurolineatus*) and cherubfish (*Centropyge argi*), and a long-spined sea biscuit (*Plagiobrissus grandis*) was observed for the first time.
- Benthic surveys of the STXEEMP are incomplete, particularly on the south shore. Additional surveys are needed to effectively characterize the distribution of species and habitats within the STXEEMP.
- Approximately 30% of the STXEEMP (deeper >35 m waters) remains unclassified seafloor. The Park management should request that the NOAA seafloor mapping team create a benthic habitat map for these areas.
- Distributions and abundance of spiny lobster (*Panulirus argus*), long-spine sea urchins (*Diadema antillarum*) and queen conch (*Strombus gigas*) should be assessed.
- Shallow water powered visual surveys (e.g., using manta tow and scooters) of listed coral species should be conducted to determine the locations that may require priority action with regard to in-water human activities and activities that influence water quality through changing watershed condition.
- The Turtle Preserve zone requires more survey effort to determine its conservation value. This zone currently has few restrictions on fishing. The biological resources and vulnerability to fishing should be ascertained as a priority to inform the review of zone regulations. Information on the distribution of fishing effort would be valuable.
- In this project we have demonstrated that a data-driven approach to optimizing and evaluating zoning design is possible. We recommend that the principal of representation and replication of habitats be examined as a technique to evaluate STXEEMP design. Specifically, efforts should be made to consider design scenarios that include a more complete range of species and habitat types, particularly within no-take zones. These elements should be represented across their range of depth and geographic distribution.

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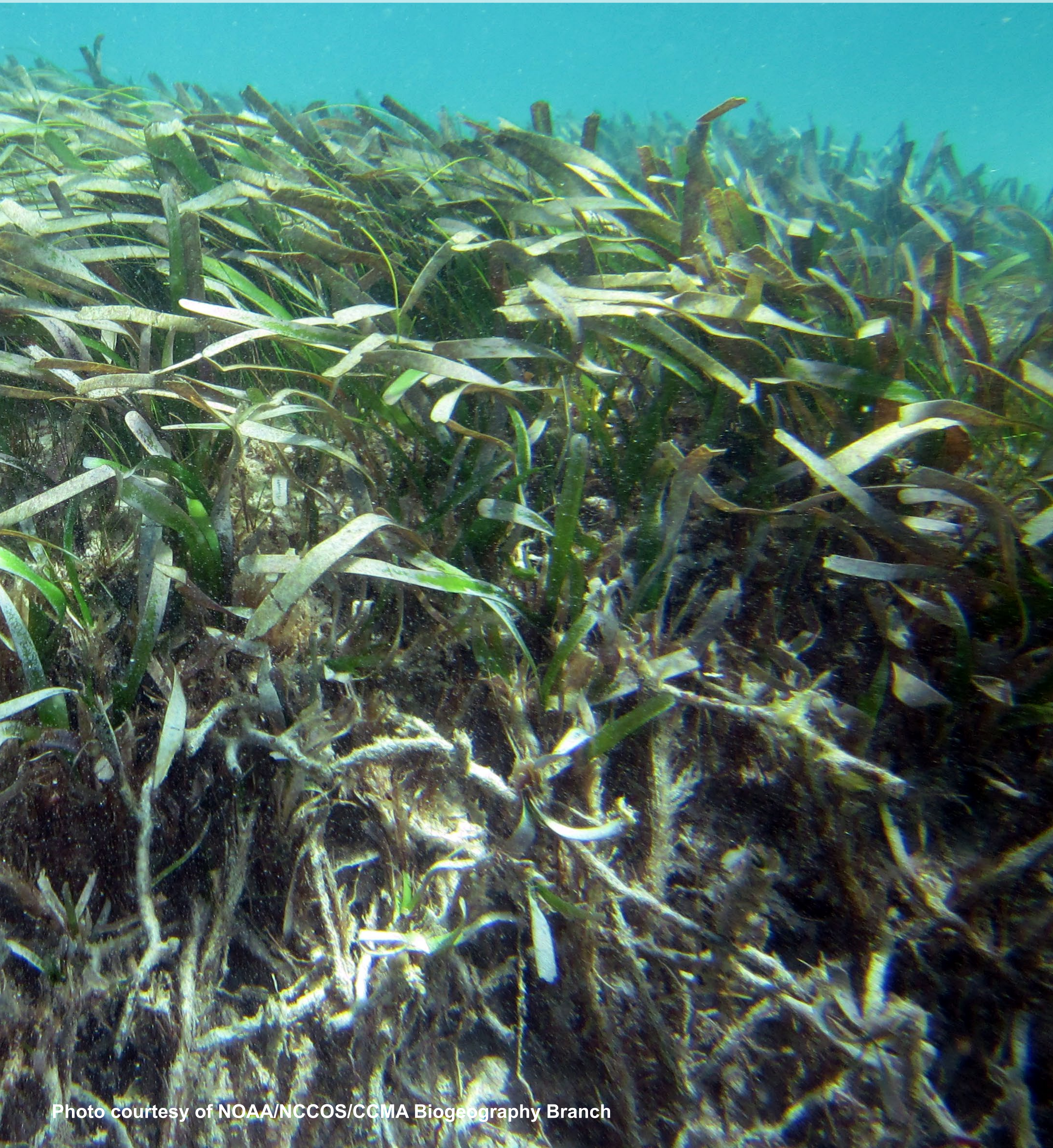

Photo courtesy of NOAA/NCCOS/CCMA Biogeography Branch

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Appendices

Photo courtesy of USVI DPNR

APPENDIX A: FIELD SURVEY SAMPLING METHODOLOGY

To assist in monitoring coral reef ecosystem resources and to achieve a better understanding of fish-habitat relationships in the U.S. Caribbean, NOAA National Centers for Coastal Science (NCCOS) Center for Coastal Monitoring and Assessment's Biogeography Branch (CCMA-BB) developed a fish and macro-invertebrate monitoring protocol to provide precise, fishery-independent and size-structured survey data, needed to comprehensively assess faunal populations and communities (Menza et al., 2006). In addition, a complementary benthic composition survey was also developed to support studies of fish-habitat relationships. These data collection activities and analytical products are core components of NOAA's Coral Reef Conservation Program (CRCP) implemented through CCMA-BB's Caribbean Coral Reef Ecosystem Monitoring (CREM) project. CREM protocols were created primarily to quantify long-term changes in fish species and assemblage diversity, abundance, biomass and size structure and to compare these metrics between areas inside and outside of Marine Protected Areas (MPAs). A stratified random sampling design was used to optimize the allocation of samples and allow rigorous inferences to the entire study area. Three strata were selected based upon: 1) the study objectives; 2) parsimony in the approach; and 3) results from statistical analyses of variance (Menza et al., 2006). The "hard" stratum is comprised of bedrock, pavement, rubble and coral reefs, and the "soft" stratum is comprised of sand, seagrasses and macroalgal beds.

This report uses underwater census data collected in St. Croix, USVI. There were two complementary components to the biological field methods: (1) fish surveys and (2) benthic habitat composition surveys.

FISH SURVEYS

Fish were surveyed with consistent visual census protocol for 15 minutes along a 25 m long by 4 m wide belt transect (100 m2; Figure E.1). The fixed duration of 15 minutes standardizes the samples collected to facilitate between-site comparisons. The number of individuals per species is recorded in 5 cm size class increments up to 35 cm using the visual estimation of fork length. Individuals greater than 35 cm are recorded as an estimate of the actual fork length to the nearest centimeter. To decrease the total time spent writing, four letter codes are used that consist of the first two letters of the genus name followed by the first two letters of the species name. In the rare case that two species have the same four-letter code, the first letter of the species name where a difference occurs is used as the last letter of the code. If the fish can only be identified to the family or genus level then this is all that is recorded. If the fish cannot be identified to the family level then no entry is necessary.

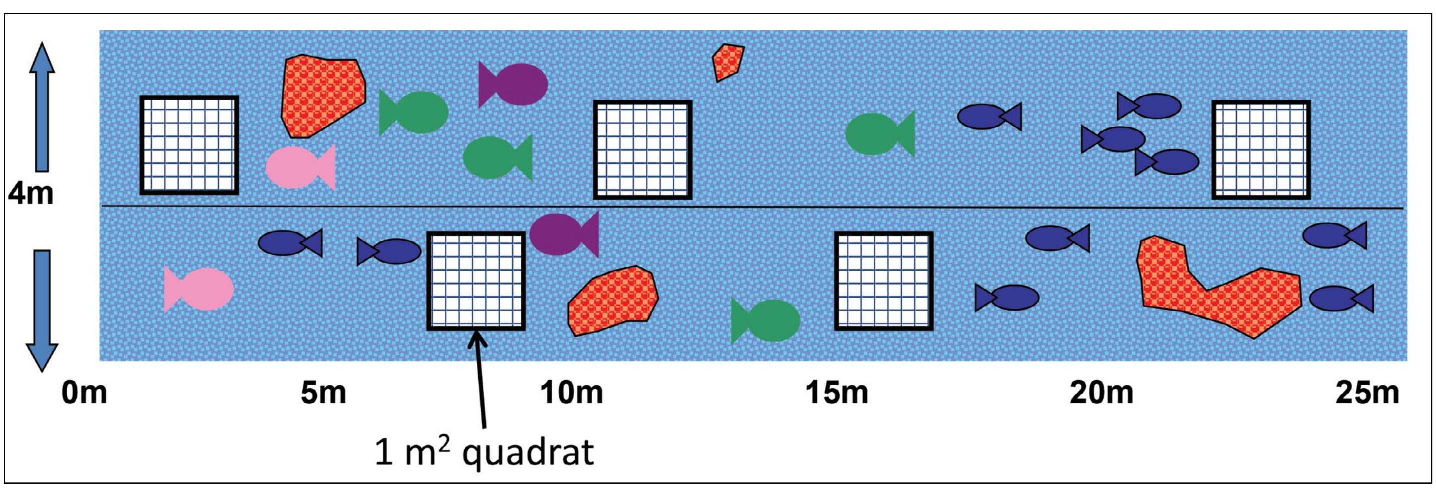

Figure A.1. Schematic of fish transect with random habitat quadrat.

Appendices

BENTHIC HABITAT COMPOSITION SURVEYS

The method presented in this report for benthic habitat composition data collection is the full-scale habitat composition census.

Full-scale Habitat Composition Census

To conduct benthic habitat surveys, an observer places a 1 m2 quadrat divided into 100 (10 x 10 cm) smaller squares (1 square = 1% cover) at five randomly pre-selected locations along the transect, such that a quadrat is placed once somewhere within every 5 m interval along the transect (Figure A.1). Percent cover is estimated within the quadrat in a two-dimensional plane perpendicular to the observer's line of vision (Figure A.1).

Information recorded includes:

Habitat structure (e.g., colonized hardbottom, spur and groove, patch reef, pavement) - was based on the habitat types used in the benthic habitat maps (Kendall et al., 2002), until 2004, after which habitat structure was classified only to hard, soft and mangrove.

Abiotic footprint - defined as the percent cover (to the nearest 1%) of sand, rubble, hardbottom, fine sediments and other non-living bottom types within a 1 m2 quadrat.

Biotic footprint - defined as the percent cover to the nearest 1% of algae, seagrass, upright sponges, gorgonians and other biota and to the nearest 0.1% for live, bleached and recently dead/diseased coral within a 1 m2 quadrat.

Transect depth profile - the depth at each quadrat position. Depth is measured with a digital depth gauge and rounded up or down to the nearest foot.

Maximum canopy height - for each biota type, height of soft structure (e.g., gorgonians, upright sponges, seagrass, algae) is recorded to the nearest 1 cm.

Hardbottom rugosity - measured by placing a 6-m chain at two randomly selected start positions ensuring no overlap along 25-m belt transect. The chain is placed such that it follows the relief along centerline of the belt transect. Two divers measure the straight-line horizontal distance covered by the chain.

Proximity of structure - on seagrass and sand sites, the habitat diver records the absence or presence of reef or hard structure within 3 m of the belt transect.

Queen conch

The abundance of immature and mature queen conch (Strombus gigas) was assessed and quantified within the 25 x 4 m belt transects used for fish surveys. The maturity of each conch was determined by the presence (mature) or absence (immature) of a flared lip. Conch were included in the survey protocol from August 2004 onward.

Caribbean spiny lobster

Abundance of Caribbean spiny lobsters (Panulirus argus) was reported for the period 2005-2007. Lobster sightings were recorded during fish and benthic composition surveys (i.e., within the 100 m2 survey unit area). Lobsters were recorded if seen, but without active searches of holes or crevices.

Long-spined sea urchins

Long-spined sea urchins (Diadema antillarum) were counted within the 25 x 4 m belt transect during 2006 and

2007. No measurements of size or estimates of maturity were collected.

Marine debris data
Type of marine debris within 25 x 4 m belt transect was noted. The size of the marine debris and the area of affected habitat is also recorded along with a note identifying any flora or fauna that colonized the debris. Marine debris data collection began in 2007.

Photography
The point count or habitat diver will take at least two photos in different directions at each site to maintain an anecdotal and permanent visual description of the sites that were sampled. Proper care and maintenance is necessary for all camera and camera housings. It is important to maintain the cameras and housings before, after, and in between dives.

Data management
All fish and benthic habitat survey data were quality assessed before storage on an online relational database. All survey data were stored with a unique identification number and a geographical coordinate to facilitate spatial analyses. The database (including metadata) that provides detailed field methods are available online: http://ccmaserver.nos.noaa.gov/ecosystems/coralreef/reef_fish/protocols.html.

Although the 1-m2 quadrat remained the basic method of choice for habitat data collection, overtime, changes in data collection methods were made for some habitat variables and several additional variables were added. These changes were deemed necessary to capture more precise information and as many variables as possible to explain better the observed variability in reef fish assemblage metrics.

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Appendices

APPENDIX B: FIELD MISSION REPORTS

St. Croix, USVI Mission Report

NOAA/NOS/NCCOS/CCMA/Biogeography Branch

October 18 – October 29, 2010

A cooperative investigation between NOAA's National Ocean Service and National Marine Fisheries Service-Southeast Fisheries Science Center (NMFS SEFSC), the National Park Service, the Virgin Islands Department of Planning and Natural Resources and East End Marine Park, and The Nature Conservancy

NOAA
National Ocean Service
National Centers for Coastal Ocean Science
Center for Coastal Monitoring and Assessment
Biogeography Branch
Silver Spring, MD 20910

January 2010

Funding provided by NOAA's CRCP and CCMA, and the National Park Service

St. Croix, USVI Mission Report

A cooperative investigation between NOAA's National Ocean Service and National Marine Fisheries Service-Southeast Fisheries Science Center (NMFS SEFSC), the National Park Service, the Virgin Islands Department of Planning and Natural Resources and East End Marine Park, and The Nature Conservancy

October 18 – October 29, 2010

During this mission data was collected for both the Caribbean Coral Reef Ecosystem Monitoring (CREM) project and a land-sea characterization of the East End Marine Park (EEMP) to determine Marine Protected Area (MPA) efficacy.

Mission Purpose:
The intent of this field mission was twofold. First, to continue ongoing efforts of the CREM project: (1) to spatially characterize the distribution, abundance and size of both reef fishes and conch, benthic habitat composition, and abundance of *Diadema* and Caribbean spiny lobster within and around the waters of Buck Island Reef National Monument (BUIS) and the EEMP of St. Croix; (2) to correlate this information to *in-situ* data collected on associated habitat parameters; and (3) to use this information to establish the knowledge base necessary for enacting management decisions in a spatial setting and to establish the efficacy of those management decisions.

Second, the regular St. Croix survey area was extended eastward and southward to encompass a more extensive area of the EEMP. The surveys were conducted in partnership with EEMP (VIDPNR), The Nature Conservancy (TNC), and NOAA's National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC). The purpose of this modification was to collect information on the distribution and diversity of marine communities across the zones in the southern half of EEMP where presently very little information is available. The survey techniques used are compatible with those used for the northern portion of EEMP and neighboring BUIS to facilitate comparative analyses. In water surveys collected data on federally listed *Acropora* species, Nassau grouper (*Epinephelus striatus*) and other fauna of special concern (i.e., conch, sea urchins, lobster and the invasive lionfish).

Information collected thus far for the on-going CREM project is being extensively utilized by NOAA, NPS, DPNR and others. Examples include NPS' use of NOAA-produced habitat maps in monitoring efforts; The Ocean Conservancy's use of maps and fish data in efforts to assist EEMP with zonation designations within the Park; and USGS/University of Miami's and NOVA Southeastern University's use of habitat maps for cryptic fish inventories. Information is also used to develop protocols for NPS, detailing how, where, and when to monitor nearshore fish assemblages, and by NOAA Coral Reef Watch to characterize and monitor the spatial extent of coral bleaching and recovery within U.S. Caribbean coral reef ecosystems. The data collected will aid NPS managers in understanding and making informed decisions regarding the resources of the South Florida / Caribbean Network. The data are also available to the public online and have been used by academia, other institutions and various individuals.

The data in this report are separated into two groups within each section. They are labeled "BUIS" for the annual on-going St. Croix mission (Figure 1) and "South" for the additional data collected on the southward and eastward area of the EEMP (Figure 2).

Operational Accomplishments:

- NPS and Dive Experience air and Nitrox (32%) tanks were used during this mission. All tanks were filled at Dive Experience.

BUIS:

- A total of 122 sites were surveyed within the study area (Figure 1), and information on fish distribution, abundance and size (Table 1); benthic habitat composition (Table 3); bleaching; conch, lobster and *Diadema* abundance and distribution (Table 5); and marine debris (Table 7) was collected. The project team consisted of one NPS and six NOAA (four CCMA, two SEFSC) scientific divers. NPS and NOAA dive logs were maintained.

- Two NPS boats were used for the duration of the mission. The NPS policy of live-boating was implemented to avoid any potential damage to resources from anchor drops and allowed divers to work more efficiently.

- The boat captains for BUIS sampling were: Eric Cotto (NPS/BUIS), Karen Maloof (NPS/BUIS) and Hank Tonnemacher (NPS Contractor)

South:

- A total of 74 sites were surveyed within the study area (Figure 2), and information on fish distribution, abundance and size (Table 2); benthic habitat composition (Table 4); bleaching; conch, lobster and *Diadema* abundance and distribution (Table 6); and marine debris (Table 8) was collected. The project team consisted of six NOAA (three CCMA, three SEFSC), two University of Miami-RSMAS and two TNC scientific divers. NPS and NOAA dive logs were maintained.

- One TNC and one VIDPNR boat were used for the duration of the mission. The NPS policy of live-boating was implemented to avoid any potential damage to resources from anchor drops and allowed divers to work more efficiently.

- The boat captains for the EEMP south side sampling were: Jose Sanchez (VIDPNR) and Kemit-Amon Lewis (TNC),

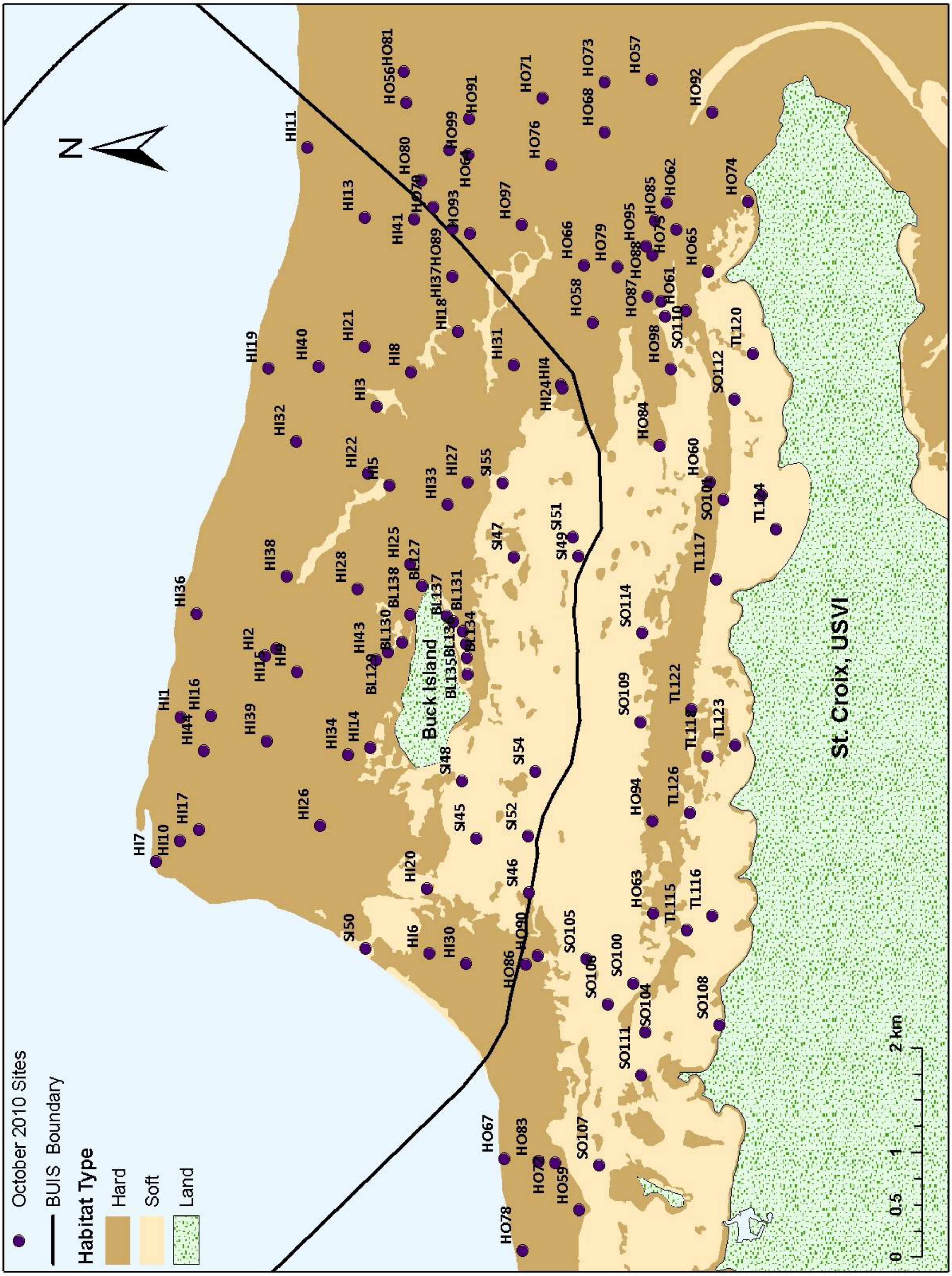


Figure 1. Map of Buck Island Reef National Monument detailing the benthic composition and selected survey points sampled during the October 2010 mission.

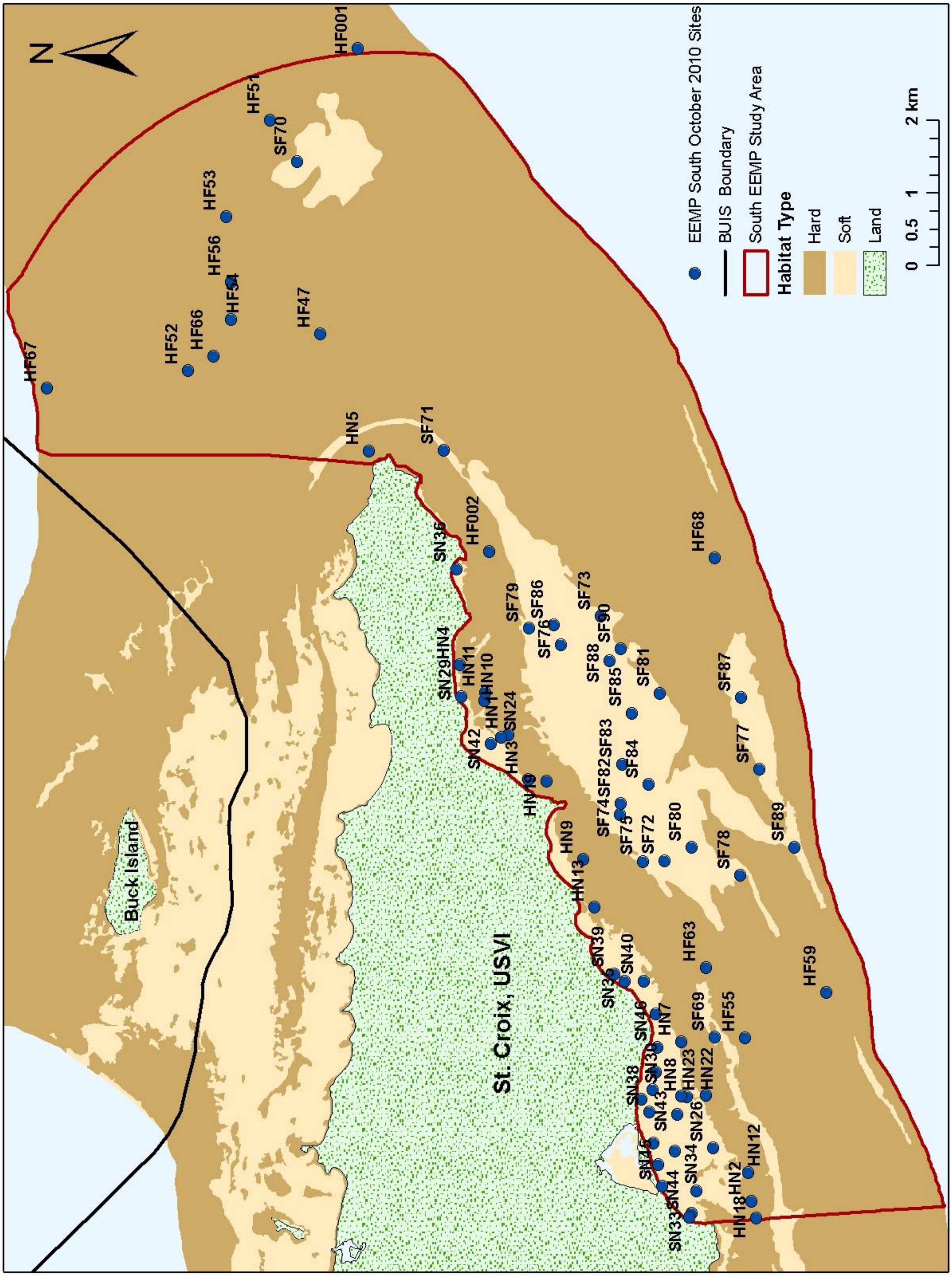


Figure 2. Map of the South side of the East End Marine Park detailing the benthic composition and selected survey points sampled during the October 2010 mission.

Summary of Surveys:

Fish

- Fish species abundance, size and distribution were characterized using the belt transect survey method (http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish/protocols.html) at all sites. The data are weighted based on area sampled and are summarized in Tables 1 and 2. See Appendix A for data calculations.

Table 1. Fish abundance, richness and biomass (all per 100m^2). Data are from the October 2010 St.Croix-BUIS mission.

Location	Habitat Type	# of Surveys	# indiv / 100m^2		Biomass (g) / 100m^2		# species /100m^2		Mean Diversity*	
			Mean	(± SE)	Mean	(± SE)	Mean	(± SE)	Mean	(± SE)
Inside	Hard	42	222.4	20.4	7564.52	1831.48	18.6	0.7	2.09	0.06
	Soft	17	35.1	10.2	11007.43	6468.02	5.6	1.2	1.11	0.16
	OVERALL	**59**	**179.2**	**12.6**	**8358.06**	**1428.12**	**15.6**	**0.49**	**1.86**	**0.04**
Outside	Hard	39	221.5	15.8	5114.57	2310.89	18.8	0.7	2.04	0.06
	Soft	24	42.2	10.9	5424.00	3416.41	6.6	1.0	1.18	0.12
	OVERALL	**63**	**137.1**	**9.9**	**5260.16**	**1549.89**	**13.1**	**0.47**	**1.64**	**0.04**
Both	Hard	81	222.0	9.5	6502.44	1022.03	18.7	0.37	2.07	0.06
	Soft	41	40.0	6.2	7131.25	2251.28	6.3	0.59	1.16	0.13
	OVERALL	**122**	**157.1**	**4.0**	**6726.85**	**822.53**	**14.3**	**0.25**	**1.74**	**0.03**

*Shannon Diversity Index

Table 2. Fish abundance, richness and biomass (all per 100m^2). Data are from the October 2010 St. Croix-South mission.

Location	Habitat Type	# of Surveys	# indiv / 100m^2		Biomass (g) / 100m^2		# species /100m^2		Mean Diversity*	
			Mean	(± SE)	Mean	(± SE)	Mean	(± SE)	Mean	(± SE)
Nearshore	Hard	16	189.5	20.9	2919.05	736.17	15.9	0.8	2.18	0.07
	Soft	22	31.5	7.1	130.46	34.41	4.4	0.5	1.02	0.11
	OVERALL	**38**	**112.2**	**7.1**	**1555.26**	**200.41**	**10.3**	**0.34**	**1.61**	**0.04**
Offshore	Hard	16	215.7	32.6	4963.53	1000.77	18.5	1.6	2.02	0.14
	Soft	20	25.6	4.3	2293.52	643.88	4.9	0.6	1.09	0.13
	OVERALL	**36**	**187.6**	**9.5**	**4568.64**	**415.26**	**16.5**	**0.55**	**1.88**	**0.07**
Both	Hard	32	214.3	29.2	4851.73	896.52	18.4	1.39	2.02	0.14
	Soft	42	27.0	2.9	1770.39	372.11	4.8	0.37	1.07	0.12
	OVERALL	**74**	**180.9**	**20.1**	**4303.52**	**619.16**	**15.9**	**0.96**	**1.86**	**0.09**

*Shannon Diversity Index

L-R: Group of sergeant majors (*Myripristis jacobus*), yellow goatfish (*Mulloidichthys marinticus*) and juvenile snapper (*Lutjanus* spp.); highhat (*Pareques acuminatus*); pikeblenny (*Chenopsis* sp.); and a group of princecss parrotfish (*Scarus taeniopterus*), squirrelfish (*Holocentrus adscensionis*), white grunts (*Haemulon plumierii*), and a rock beauty (*Holocanthus tricolor*)

Habitat

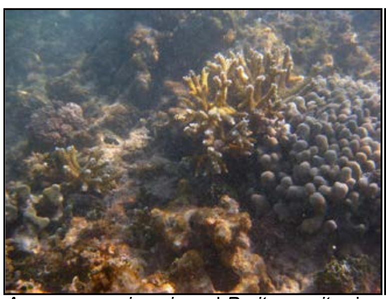
- Benthic composition data were collected at all sites during the October 2010 mission. Hardbottom data are weighted based on area sampled and are summarized in Tables 3 and 4. Detailed methodology can be found at http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish/protocols.html. See Appendix A for data calculations.

Table 3. Average percent cover of habitat types for 81 hardbottom sites for October 2010 St. Croix-BUIS mission.

Strata Type	# of Surveys	% Coral		% Hydrocorals		% Algae/ Seagrass		% Turf/ Crustose		% Gorgonian		% Sponge	
		Mean	(+SE)	Mean	(+SE)	Mean	(+SE)	Mean	(+SE)	Mean	(+SE)	Mean	(+SE)
Inside	42	4.84	0.70	0.50	0.18	30.26	4.59	39.96	5.02	3.41	0.55	1.91	0.36
Outside	39	3.14	0.62	0.25	0.04	48.86	5.02	17.78	4.29	2.12	0.33	2.22	0.35
Both	**81**	**4.10**	**0.34**	**0.39**	**0.06**	**38.32**	**2.42**	**30.35**	**2.42**	**2.85**	**0.24**	**2.04**	**0.18**

Table 4. Average percent cover of habitat types for 32 hardbottom sites for October 2010 St. Croix-South mission.

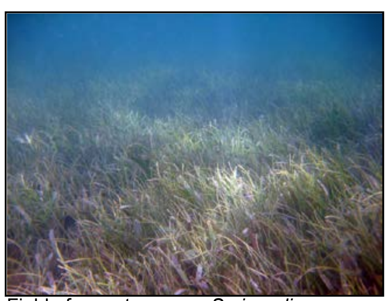
Strata Type	# of Surveys	% Coral		% Hydrocorals		% Algae/ Seagrass		% Turf/ Crustose		% Gorgonian		% Sponge	
		Mean	(+SE)	Mean	(+SE)	Mean	(+SE)	Mean	(+SE)	Mean	(+SE)	Mean	(+SE)
Nearshore	16	1.82	0.83	0.23	0.17	23.28	6.01	60.81	6.62	0.24	0.15	0.18	0.09
Offshore	16	3.07	0.92	0.18	0.06	36.42	7.75	21.09	6.31	0.81	0.27	2.15	0.36
Both	**32**	**3.01**	**0.83**	**0.18**	**0.06**	**35.70**	**6.95**	**23.26**	**5.66**	**0.78**	**0.24**	**2.04**	**0.32**



Acropora cervicornis and *Porites porites* in BUIS.

Outcrop of *Montastraea annularis* mounds in BUIS.

Live *Acropora palmate* in *Acropora* rubble in BUIS.



Field of manatee grass *Syringodium filiforme* on the south side of the EEMP.

Macroinvertebrates

Conch

BUIS

- The number of queen conch (*Strombas gigas*) observed within 36 of the 122 transects surveyed is summarized by location and benthic composition type in Table 5.

Table 5. Conch abundance surveyed during the St. Croix - BUIS October 2010 mission.

Location	Habitat	# surveys	Immature	Mature	Total
Inside	Hard	6	13	15	28
	Soft	13	58	50	108
	Both	**19**	**71**	**65**	**136**
Outside	Hard	2	1	9	10
	Soft	15	99	29	128
	Both	**17**	**100**	**38**	**138**
Both	Hard	8	14	24	38
	Soft	28	157	79	236
	Both	**36**	**171**	**103**	**274**

South

- The number of queen conch (*Strombas gigas*) observed within 14 of the 74 transects surveyed is summarized by location and benthic composition type in Table 6.

Table 6. Conch abundance surveyed during the St. Croix - South October 2010 mission.

Location	Habitat	# surveys	Immature	Mature	Total
Inshore	Hard	1	1	0	1
	Soft	6	14	0	14
	Both	**7**	**15**	**0**	**15**
Offshore	Hard	1	0	1	1
	Soft	6	2	17	19
	Both	**7**	**2**	**18**	**20**
Both	Hard	2	1	1	2
	Soft	12	16	17	33
	Both	**14**	**17**	**18**	**35**

Lobster

BUIS

- Three Caribbean spiny lobster, *Panulirus argus*, were recorded on three of the 122 transects surveyed. The lobsters were observed on hardbottom sites, one site within BUIS and two within the EEMP.

South

- There were no Caribbean spiny lobster, *Panulirus argus*, recorded on the 74 transects surveyed.

Sea urchins

BUIS

- A total of 38 long-spined sea urchins, *Diadema antillarum*, were recorded at 5 of the 122 transects. The urchins were recorded on hardbottom sites, one within BUIS and 37 within the EEMP.

South

- Only four long-spined sea urchins, *Diadema antillarum*, were recorded at two of the 74 transects. The urchins were recorded on nearshore hardbottom sites.

Marine Debris

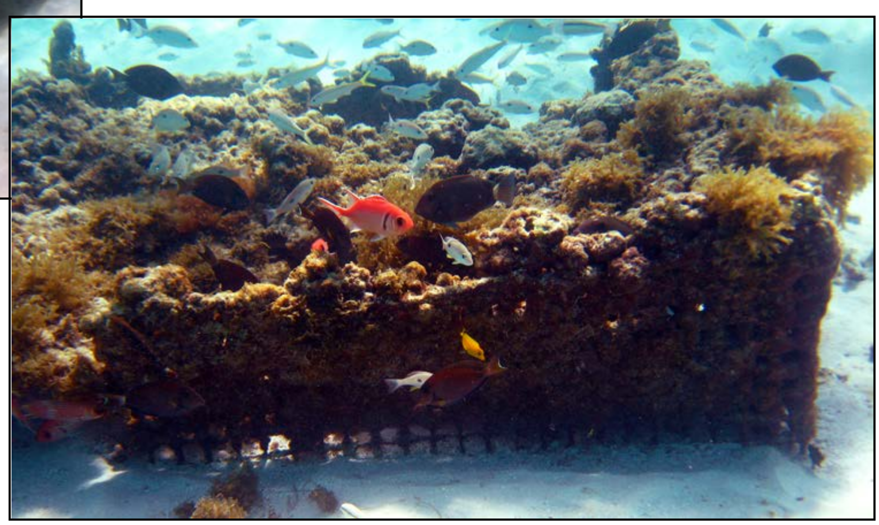
♦ Marine debris data have been recorded during missions in St. Croix since 2007. The marine debris observed within transects during this mission are summarized in Tables 7 and 8.

Table 7. The type and size of debris, area affected, and what the debris was colonized by during this St. Croix-BUIS mission.

Station	Habitat Type	Debris Type	Debris Area (cm^3)	Area Affected (cm^3)	Colonized By
HI17	Hard	rope	3	100	nothing
SI47	Soft	glass bottle	15	15	nothing
HO71	Hard	derelict fish pot	75	750	MILLSPP, sponge, cyano,
BL135	Soft	plastic	10	10	crustose coralline algae

Table 8. The type and size of debris, area affected, and what the debris was colonized by during this St. Croix-South mission.

Station	Habitat Type	Debris Type	Debris Area (cm^3)	Area Affected (cm^3)	Colonized By
SN34	Soft	metal rebar	32	32	turf algae, crustose coralline algae, macro algae, snails



Derelict fish pot, turned artificial habitat, located on the south side of St. Croix in the EEMP.

Events of Note:

- There were three fish recorded for the first time in St. Croix region, all St. Croix-South, during this mission:
    - Sargassum triggerfish (*Xanthichthys ringens*)
    - Bridal cardinalfish (*Apogon aurolineatus*)
    - Cherubfish (*Centropyge argi*)

- Bleaching was observed but not nearly as severe or widespread as October 2005.

Top row L-R: *Diploria strigosa*, *Agaracia* species, *Porites porites*, *Montastraea annularis* complex;
Bottom row L-R: *Colpophyllia natans*, *Diploria labrynthiformis*, *Montastraea* species, *Montastraea annularis* complex

- A few weeks before the mission, St. Croix received unprecedented rainfall amounts. The effects were evident at some sites in the northern study area in terms of cyanobacteria/filamentous algae carpets.

Sediment in Teague Bay reef (Photo: Zandy Hillis-Starr)

- A long-spined sea biscuit (*Plagiobrissus grandis*) was observed for the first time during the more than10 years of monitoring in this area. South side (EEMP), seen and recorded by Marc Nadon and Nathan Vaughn on 22 Oct 2010. They said the thing was "bounding" across the sand and then stopped and buried itself.

- A dolphin and her calf were observed during two dives on different days; other divers saw dolphins during other surveys as well.

Logistics of Note:

- Divers surveying the BUIS study region collected video on each of the transects to use in CCMA-BB's re-mapping efforts.
- Divers noted colder water temperatures with readings from 83-85°F
- We continued to implement the NPS policy of live-boating during our dive operations.
- Commute times for the EEMP South side teams on the EEMP and TNC boats ranged from 45 minutes (calm days) to one and quarter hour (rough days).
- Weather (wind and 4-6+ ft seas) prevented surveys on three days for the southern EEMP sites and one day for the BUIS/Northern EEMP sties.
- SEFSC divers were an integral part of the success of this mission. Few dives were needed for methodology training.
- TNC divers Sarah Bergeron and Jacob Metzger participated in habitat training the first week and then collected data during the second week.
- We coordinated with Todd Gedamke (SEFSC) to place two fish traps on sites in northern study area as a pilot to see if traps could be placed in highly rugose areas without damage to reefs. Todd also plans to look at trap data versus visual census data.
- During the first week, divers on TNC boat assisted with *Acropora palmata* nursery maintenance.

Mission Participants:

Laurie Bauer (NOAA/CCMA BB)
Sara Bergeron (TNC)
Jeremiah Blondeau (NOAA/NMFS SEFSC)
Eric Cotto (NPS/BUIS – Boat Captain)
Bryan Costa (NOAA/CCMA BB)
Kimberly Edwards (NOAA/CCMA BB)
Dav Grenda (NOAA/NMFS SEFSC)
Matt Kendall (NOAA/CCMA BB)
Kemit-Amon Lewis (TNC – Boat Captain)
Ian Lundgren (NPS/BUIS)
Karen Maloof (NPS/BUIS – Boat Captain)
Dave McClellan (NOAA/ NMFSC SEFSC)
Jacob Metzger (TNC)
Mark Monaco (NCCOS/CCMA BB)
Marc Nadon (UM-RSMAS)
Simon Pittman (NOAA/CCMA BB)
Kimberly Roberson-UDS (NOAA/CCMA BB)
Ben Ruttenburg (NOAA/NMFS SEFSC)
Jose Sanchez (VIDPNR/EEMP –Boat Captain)
Hank Tonnemacher (NPS Contractor – Boat Captain)
Nathan Vaughan (UM-RSMAS)

Appendices

St. Croix, USVI East End Marine Park Mission Report

NOAA/NOS/NCCOS/CCMA/Biogeography Branch

October 31 – November 10, 2011

A cooperative investigation between NOAA's National Ocean Service, the Virgin Islands Department of Planning and Natural Resources and East End Marine Park, and The Nature Conservancy

NOAA
National Ocean Service
National Centers for Coastal Ocean Science
Center for Coastal Monitoring and Assessment
Biogeography Branch
Silver Spring, MD 20910

December 2011

Funding provided by NOAA's CRCP and CCMA, USVI DPNR and TNC

St. Croix, USVI Mission Report

A cooperative investigation between NOAA's National Ocean Service, the Virgin Islands Department of Planning and Natural Resources and East End Marine Park, and The Nature Conservancy

October 31 – November 10, 2011

During this mission data was collected for both the Caribbean Coral Reef Ecosystem Monitoring (CREM) project and a land-sea characterization of the East End Marine Park (EEMP) to determine Marine Protected Area (MPA) efficacy.

Mission Purpose:
The intent of this field mission was twofold. First, to continue ongoing efforts of the CREM project: (1) to spatially characterize the distribution, abundance and size of both reef fishes and conch, benthic habitat composition, and abundance of *Diadema* and Caribbean spiny lobster within and around the waters of the EEMP of St. Croix; (2) to correlate this information to *in-situ* data collected on associated habitat parameters; and (3) to use this information to establish the knowledge base necessary for enacting management decisions in a spatial setting and to establish the efficacy of those management decisions.

Second, the sampling region was extended eastward and southward to encompass a more extensive area of the EEMP. The surveys were conducted in partnership with NOAA's Center for Coastal Fisheries Habitat Research (CCFHR), EEMP (VIDPNR) and The Nature Conservancy (TNC). The purpose of this modification was to collect information on the distribution and diversity of marine communities across the zones in the southern half of EEMP where presently very little information is available. The survey techniques used are compatible with those used for the northern portion of EEMP and neighboring BUIS to facilitate comparative analyses. In water surveys collected data on federally listed *Acropora* species, Nassau grouper (*Epinephelus striatus*) and other fauna of special concern (i.e., conch, sea urchins, lobster and the invasive lionfish).

Information collected thus far for the on-going CREM project is being extensively utilized by NOAA, NPS, DPNR and others. Examples include NPS' use of NOAA-produced habitat maps in monitoring efforts; The Ocean Conservancy's use of maps and fish data in efforts to assist EEMP with zonation designations within the Park; and USGS/University of Miami's and NOVA Southeastern University's use of habitat maps for cryptic fish inventories. Information is also used to develop protocols for NPS, detailing how, where, and when to monitor nearshore fish assemblages, and by NOAA Coral Reef Watch to characterize and monitor the spatial extent of coral bleaching and recovery within U.S. Caribbean coral reef ecosystems. The data collected will aid NPS managers in understanding and making informed decisions regarding the resources of the South Florida / Caribbean Network. The data are also available to the public online and have been used by academia, other institutions and various individuals.

Operational Accomplishments:

- A total of 66 sites were surveyed within the study area (Figure 1), and information on fish distribution, abundance and size (Table 1); benthic habitat composition (Table 2); bleaching; conch, lobster and *Diadema* abundance and distribution (Table 3); and marine debris (Table 4) was collected. The project team consisted of eight NOAA (seven CCMA, one CCFHR) and 2 TNC scientific divers. NOAA dive logs were maintained.

- One TNC and one VIDPNR boat were used for the duration of the mission. The NPS policy of live-boating was implemented to avoid any potential damage to resources from anchor drops and allowed divers to work more efficiently.

- The boat captains for the EEMP south side sampling were: Jose Sanchez (VIDPNR), Stopher Slade (TNC) and Chris Biggs (TNC).

- TNC and Dive Experience air and Nitrox (32%) tanks were used during this mission. All tanks were filled at Dive Experience.

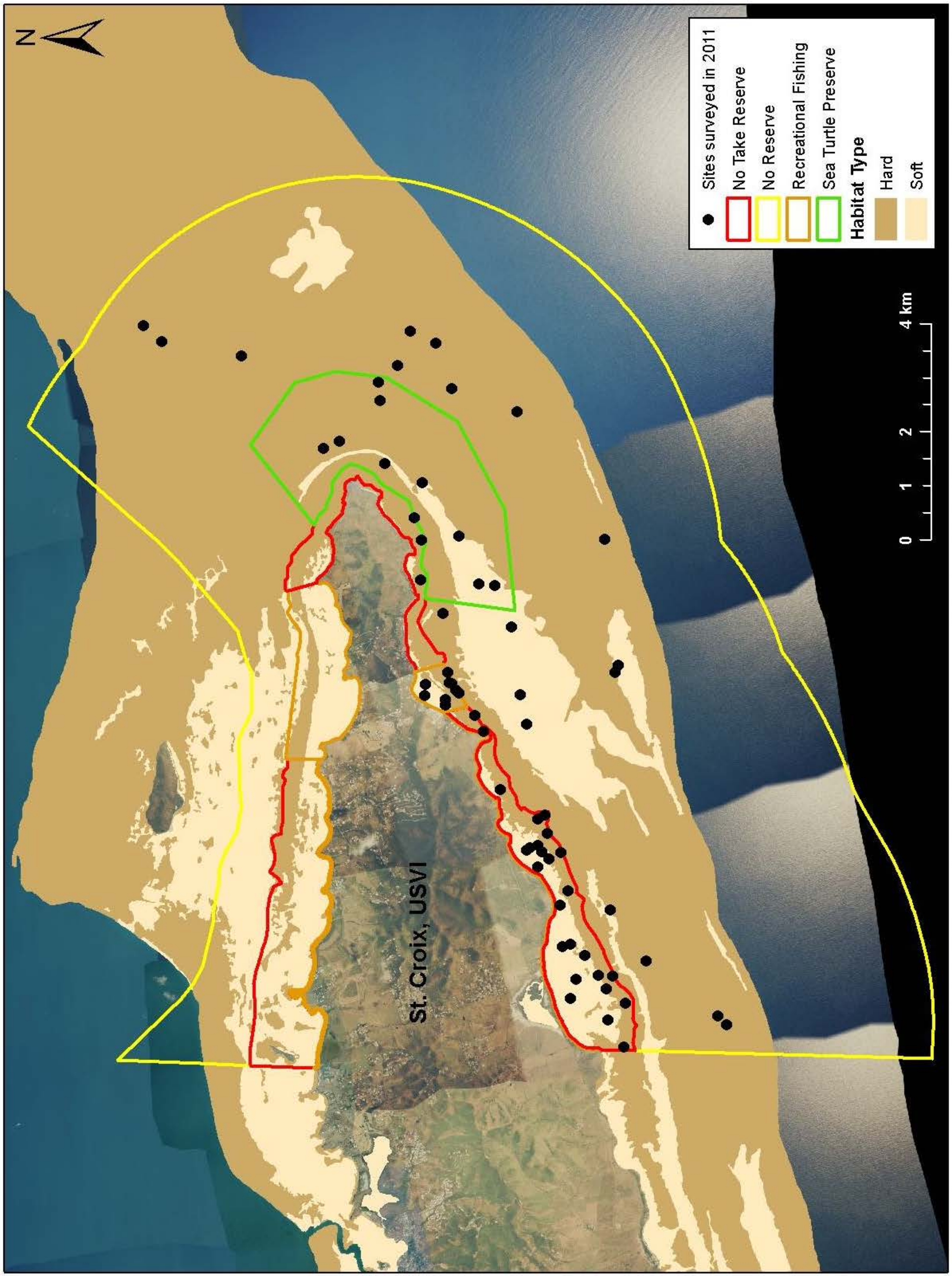


Figure 1. Map of St. Croix's East End Marine Park detailing the park zonation, benthic composition and selected survey points sampled during the October 2011 mission.

Summary of Surveys:

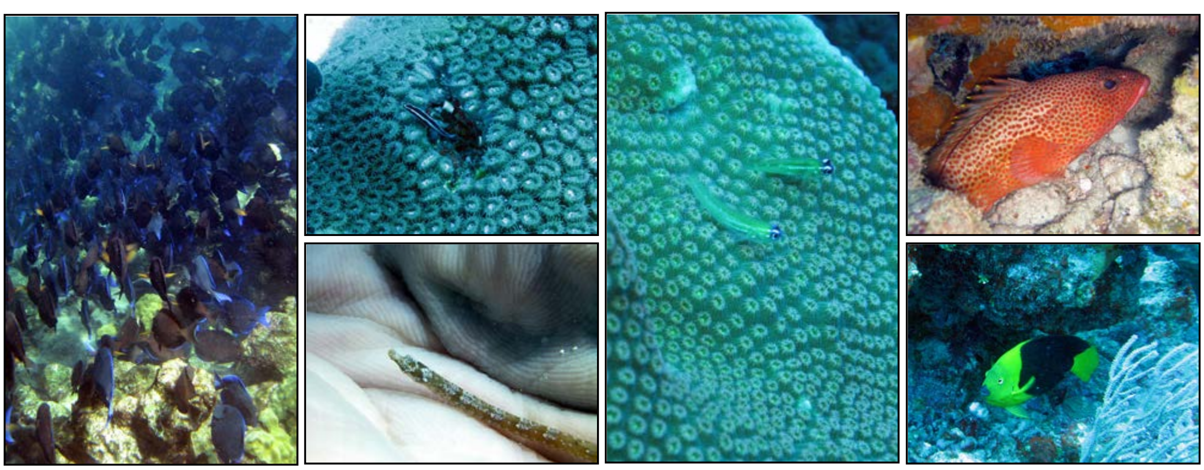
Fish

- Fish species abundance, size and distribution were characterized using the belt transect survey method (http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish/protocols.html) at all sites. The data are weighted based on area sampled and are summarized in Tables 1. See Appendix A for data calculations.

Table 1. Fish abundance, richness and biomass (all per 100m^2). Data are from the October 2011 St. Croix EEMP mission.

Habitat Location	Habitat Strata	Number of Surveys	# indiv / 100m^2		biomass (g) /100m^2		# species / 100m^2		Mean Diversity*	
			Mean	(± SE)	Mean	(± SE)	Mean	(± SE)	Mean	(± SE)
No-Take	Hard	15	147.8	13.6	4031.03	1287.98	16.8	1.3	2.08	0.10
	Soft	14	15.9	4.7	160.66	76.63	3.3	0.7	0.70	0.16
	OVERALL	**29**	**84.0**	**4.7**	**2157.3**	**360.7**	**10.3**	**0.5**	**1.41**	**0.06**
Fish-Rec	Hard	5	320.4	201.2	2084.47	627.20	17.2	2.6	1.86	0.38
	Soft	4	24.8	10.8	235.63	89.05	4.8	1.5	0.94	0.33
	OVERALL	**9**	**147.3**	**38.3**	**1001.9**	**138.3**	**9.9**	**1.0**	**1.32**	**0.18**
Turtle	Hard	5	130.0	6.1	3470.12	1641.67	19.4	0.9	2.20	0.06
	Soft	4	89.5	25.4	1349.36	782.92	10.0	1.6	1.58	0.29
	OVERALL	**9**	**123.6**	**5.0**	**3132.5**	**1180.5**	**17.9**	**0.7**	**2.10**	**0.05**
None	Hard	14	166.3	16.9	4477.10	789.99	21.8	1.4	2.37	0.07
	Soft	5	22.4	6.1	1278.47	784.15	5.4	1.2	1.16	0.30
	OVERALL	**19**	**145.2**	**12.4**	**4008.2**	**592.2**	**19.4**	**1.0**	**2.19**	**0.05**
All Zones	Hard	39	161.6	11.5	4316.2	560.6	21.2	0.9	2.33	0.05
	Soft	27	28.5	3.1	1016.9	341.4	5.4	0.5	1.10	0.14
	OVERALL	**66**	**137.8**	**7.8**	**3726.4**	**389.0**	**18.4**	**0.7**	**2.11**	**0.03**

*Shannon Diversity Index



L-R(T-B): School of Blue Tangs (*Acanthurus coeruleus*) and Ocean Surgeonfish (*Acanthurus bahianus*); Broadstripe Goby (*Elacatinus prochilos*) on *Montastraea cavernosa* polyps; *Sygnathus dawsoni* pipefish; Peppermint Gobies (*Coryphopterus lipernes*) on *Montastraea annularis* complex; Red Hind (*Epinephelus guttatus*); and Rock Beauty (*Holacanthus tricolor*).

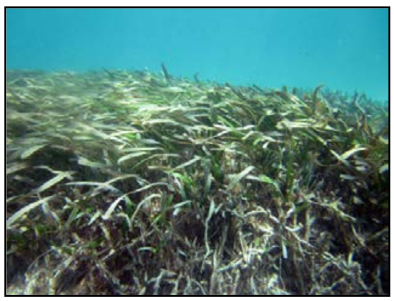
Habitat

- Benthic composition data were collected at all sites during the October 2011 mission. Hardbottom data are weighted based on area sampled and are summarized in Tables 2. Detailed methodology can be found at http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish/protocols.html. See Appendix A for data calculations.

Table 2. Average percent cover of habitat types for 66 hardbottom sites for October 2011 St. Croix EEMP mission.

Strata Type	# of Surveys	% Coral		% Hydrocorals		% Algae/ Seagrass		% Turf/ Crustose		% Gorgonian		% Sponge	
		Mean	(+SE)	Mean	(+SE)	Mean	(+SE)	Mean	(+SE)	Mean	(+SE)	Mean	(+SE)
No-Take	15	2.39	0.96	0.08	0.04	16.64	2.71	50.08	6.70	0.17	0.10	0.18	0.07
Fish-Rec	5	3.68	1.00	0.04	0.03	20.78	5.72	63.00	8.76	4.12	1.16	0.10	0.04
Turtle	5	1.36	0.46	0.10	0.06	28.46	4.36	57.09	5.58	1.38	0.73	2.12	0.11
None	14	3.35	1.25	0.14	0.02	29.16	4.82	35.71	5.94	1.30	0.42	2.34	0.33
All zones	**39**	**3.06**	**2.28**	**0.13**	**0.10**	**28.42**	**20.11**	**39.24**	**25.05**	**1.27**	**0.90**	**2.19**	**1.61**


Elkhorn coral (*Acropora palmata*)


Turtle grass (*Thalassia testudinum*)


Finger coral (*Porites porites*)

Macroinvertebrates

Macroinvertebrate data was collected at all 66 sites during the October 2011 St. Croix EEMP mission.

Conch

♦ The number of queen conch (Eu*strombas gigas*) observed within 16 of the 66 transects surveyed is summarized by location and benthic composition type in Table 3.

Table 3. Conch abundance surveyed during the St. Croix -EEMP October 2011 mission.

Location	Habitat	# surveys	Immature	Mature	Total
No-take	Hard	0	0	0	0
	Soft	5	5	2	7
	OVERALL	**5**	**5**	**2**	**7**
Fish-Rec	Hard	0	0	0	0
	Soft	2	4	2	6
	OVERALL	**2**	**4**	**2**	**6**
Turtle	Hard	0	0	0	0
	Soft	2	0	2	2
	OVERALL	**2**	**0**	**2**	**2**
None (Open)	Hard	4	3	7	10
	Soft	3	0	2	3
	OVERALL	**7**	**3**	**9**	**13**
All zones	Hard	4	3	7	10
	Soft	12	9	8	18
	OVERALL	**16**	**12**	**15**	**28**

Lobster

♦ There were 15 Caribbean spiny lobsters, *Panulirus argus*, recorded on 5 of the 66 transects surveyed during this mission. All of the individuals were recorded on hardbottom habitats within the No-take zone of the EEMP.

Sea urchins

♦ There were 13 long-spined sea urchins, *Diadema antillarum*, recorded on 5 of the 66 transects surveyed during this mission, all in hardbottom habitats. Eleven individuals were recorded at two stations within the No-take zone, three urchins at two stations within the No Restriction zone and one urchin was recorded at one station within the Fishing-Recreation zone of the EEMP.

Marine Debris

♦ The marine debris observed within transects during this mission are summarized in Table 4. Both pieces of debris were recorded within the No-take zone of EEMP.

Table 4. The type and size of debris, area affected, and what the debris was colonized by during this 2011 St. Croix EEMP mission.

Station	Habitat Type	Debris Type	Debris Area (cm^3)	Area Affected (cm^3)	Colonized By
HR43	Hard	rope	40	20	turf, macroalgae, millepora spp.
HR46	Hard	glass bottle	120	120	crustose algae, bryozoans

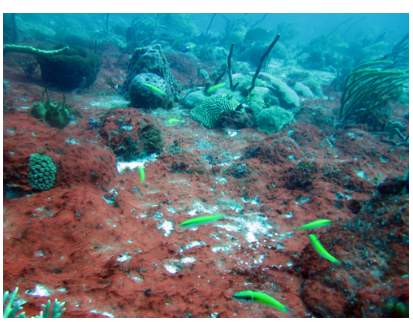
Events of Note:

♦ Very little debris were recorded or observed during this mission.

♦ A shark was seen at one sampling station

♦ Dolphins were seen on occasion, primarily at the surface

♦ A large cyanobacterial mat was seen at one site covering the marjority of the benthic fauna within the affected area.



Logistics of Note:

- Thunderstorms and rough seas forced the two dive teams in early one day.
- We continued to implement the NPS policy of live-boating during our dive operations.
- Commute times for the EEMP South side teams on the EEMP and TNC boats ranged from 45 minutes (calm days) to one and quarter hour (rough days).
- TNC divers Stopher Slade and Chris Biggs dove as observational divers as time and conditions permitted.
- Overall, seas were calm with water temperatures reported from 82°-85° at depth

Mission Participants:

Laurie Bauer (NOAA/CCMA BB)
Bryan Costa (NOAA/CCMA BB)
Kimberly Edwards (NOAA/CCMA BB)
Matt Kendall (NOAA/CCMA BB)
Kemit-Amon Lewis (TNC)
Stopher Slade (TNC-Boat Captain)
Jenny Vanderpluym (NCCOS/CCFHR)
Randy Clark (NCCOS/CCMA BB)
Chris Biggs (TNC-Boat Captain)
Mark Monaco (NCCOS/CCMA BB)
Kimberly Roberson-UDS (NOAA/CCMA BB)
Jose Sanchez (VIDPNR/EEMP –Boat Captain)
Roger Mays-UDS (NOAA/CCFHR)

Appendix – Equations

- Overall habitat and fish mean values for each stratum (locations and substrate type) and combined strata were calculated using the following equations (Menza et al., 2006):

Mean density for the stratified survey domain is obtained by summing the weighted averages of sample strata means,

$$\bar{y}_{st} = \sum_{h=1}^{L} W_h \bar{y}_h$$

where L is the number of strata, and strata weighting factors (W_h) are given by

$$W_h = \frac{N_h}{\sum_{h=1}^{L} N_h} = \frac{N_h}{N}$$

where N is the total number of possible sample units in all strata. The weighting factor W_h represents the proportion of the overall survey domain (or sampling frame) contained within stratum *h*.

Two examples of calculations are provided below:

- For one stratum type (e.g. BUIS strata),

$$y_{BIRNM} = \left(\text{mean \# indiv inside BUIS} \times \frac{\text{area inside BUIS}}{\text{total area strata}} \right) + \left(\text{mean \# indiv outside BUIS} \times \frac{\text{area outside BUIS}}{\text{total strata area}} \right)$$

- The overall and combined standard error values for fish and habitat data were calculated using the estimated variance of the mean (Menza et al., 2006). The variance of $\bar{y}_{st}$ is estimated as

$$\mathrm{var}\left[\bar{y}_{st}\right] = \sum_{h=1}^{L} W_h^2 \,\mathrm{var}\left[\bar{y}_h\right]$$

For benthic composition calculations, W_h = 1 because only mean estimates were derived for the hardbottom area stratum.

References:

Menza, C., J. Ault, J. Beets, J. Bohnsack, C. Caldow, J. Christensen, A. Friedlander, C. Jeffrey, M. Kendall, J. Luo, M. Monaco, S. Smith and K. Woody. 2006. A Guide to Monitoring Reef Fish in the National Park Service's South Florida / Caribbean Network. NOAA Technical Memorandum NOS NCCOS 39. 166 pp.

Appendices

APPENDIX C: DATA SOURCE TABLE

Table C.1. List of source files used for data analyses and illustration.

Description	Layer Name	Source	Year
Land			
Land Cover (NOAA-CCAP)	USVI_STX_Landcover_CCAP_2007	NOAA Coastal Service Center, Coastal Change Analysis Program	2007
NHD Hydrologic Units	STX_NHD_catchment_areas	US Geological Survey, National Hydrography Dataset	unknown
Watersheds	STX_watersheds	World Resources Institute, Reefs at Risk	unknown
Watershed Analysis Units	Watershed_Analysis_Units	NOAA NCCOS Biogeography Branch	2013
Shoreline	STX_shoreline	unknown	unknown
Buck Island Shoreline	BUIS_shoreline	unknown	unknown
Shoreline Characterization	USVI_shoreline_characterization_ESI	NOAA Environmental Sensitivity Index	
East End Marine Park Manmade Shoreline	EEMP_shoreline_man_made	NOAA Environmental Sensitivity Index	
Roads	STX_East_End_Roads	Horsley Witten Group	2011
Landscape Development Index	Landscape_Development_Index	NOAA NCCOS Biogeography Branch	2013
Landcover (UVI)	STX_landcover_UVI	University of the Virgin Islands	1998
Soils	STX_Soils	unknown	unknown
Coastal Zone Management Teir 1	STX_CZM_tier_1	Virgin Islands Division of Coastal Zone Management	unknown
Rivers	STX_rivers	unknown	unknown
Wetlands	STX_wetlands	unknown	unknown
Marine			
Sensitive Corals (CREM)	STX_sensitive_species_CREM	NOAA NCCOS Biogeography Branch	2002-2012
Sensitive Corals (NCRMP)	STX_sensitive_species_NCRMP	NOAA NCCOS Biogeography Branch	2012
Sensitive Corals (EEMP)	STX_sensitive_species_EEMP	NOAA NCCOS Biogeography Branch	2010-2011
Sensitive Corals Combined	STX_sensitive_species_BB	NOAA NCCOS Biogeography Branch	2002-2012
Acropora (FWC)	STX_Acropora_FWC	Florida Fish and Wildlife Conservation Commission	2002-2012
Areas of Particular Concern	STX_areas_of_particular_concern	Virgin Islands Division of Coastal Zone Management	2002-2012
Habitat Surveys (CREM)	STX_benthic_habitat_surveys_CREM	NOAA NCCOS Biogeography Branch	2002-2012
Habitat Surveys (NCRMP)	STX_benthic_habitat_surveys_NCRMP	NOAA NCCOS Biogeography Branch	2012
Habitat Surveys (EEMP)	STX_benthic_habitat_surveys_EEMP	NOAA NCCOS Biogeography Branch	2010-2011
Habitat Surveys Combined	STX_benthic_habitat_surveys_BB	NOAA NCCOS Biogeography Branch	2002-2012
Benthic Habitat Map	STX_Benthic_Habitat_BB	NOAA NCCOS Biogeography Branch	2001
Buck Island Fine Scale Map	Buck_Island_Benthic_Habitat_BB	NOAA NCCOS Biogeography Branch	2007
Buck Island Deep Benthic Map	BUIS_benthic_habitat_Deep_BB	NOAA NCCOS Biogeography Branch	unknown
Buck Island Moderate Depth Benthic Map	BUIS_benthic_habitat_moderate_depth_BB	NOAA NCCOS Biogeography Branch	unknown
East End Marine Park	East_End_Marine_Park	unknown	unknown
Benthic Habitat (w/i marine analysis units)	EEMP_Benthic_Habitat_MAU	NOAA NCCOS Biogeography Branch	2013
Benthic Survey Locations	EEMP_Survey_Effort	NOAA NCCOS Biogeography Branch	2013

Table C.1. Continued... List of source files used for data analyses and illustration.

Description	Layer Name	Source	Year
Marine Analysis Units	Marine_Analysis_Units	NOAA NCCOS Biogeography Branch	2013
Marine Protected Areas	USVI_MPA_Inventory	NOAA Marine Protected Areas Center	unknown
Sensitive Coral Species (within marine analysis units)	Sensitive_Species_MAU	NOAA NCCOS Biogeography Branch	2013
Benthic Habitats Mapped within Park Zones	Benthic_Habitat_Zones	NOAA NCCOS Biogeography Branch	2013
Benthic Habitats Surveyed within Park Zones	Benthic_Survey_Zones	NOAA NCCOS Biogeography Branch	2013
Species Richness for Fish within Marine Analysis Units	Fish_Richness	NOAA NCCOS Biogeography Branch	2013
Mean Species Richness for Fish within Marine Analysis Units	Fish_Richness_Mean	NOAA NCCOS Biogeography Branch	2013
Fish			
Fish Biomass	allFish_Biomass	NOAA NCCOS Biogeography Branch	2002-2012
Goatfish	goatfish	NOAA NCCOS Biogeography Branch	2002-2012
Grouper (Epinephelidae)	grouper	NOAA NCCOS Biogeography Branch	2002-2012
Grunts (Haemulidae)	grunts	NOAA NCCOS Biogeography Branch	2002-2012
Herbivore Adult Density	Herbivore__AdultDensity	NOAA NCCOS Biogeography Branch	2002-2012
Parrotfish Adult Density	Parrotfish_AdultDensity	NOAA NCCOS Biogeography Branch	2002-2012
Parrotfish Biomass (Scaridae)	Parrotfish_biomass	NOAA NCCOS Biogeography Branch	2002-2012
Snapper observations	snapper	NOAA NCCOS Biogeography Branch	2002-2012
Goatfish Adult Density	adultgoatfish	NOAA NCCOS Biogeography Branch	2002-2012
Threespot damselfish (Stegastes planifrons)	STPL	NOAA NCCOS Biogeography Branch	2002-2012
Surgeon (Acanthuridae)	surgeon	NOAA NCCOS Biogeography Branch	2002-2012
Trophic groups	trophicgroups	NOAA NCCOS Biogeography Branch	2002-2012
Grids			
Buck Island Bathymetry 2006	BuckIsland_bathy_2006	NOAA NCCOS Biogeography Branch	2006
Buck Island Bathymetry 2011	BuckIsland_bathy_2011	unknown	unknown
Lang Bank Bathymetry	LangBank_bath	unknown	unknown
Bathymetry North of St Croix	STX_bath_north_BB	NOAA NCCOS Biogeography Branch	2006
GEODAS Caribbean Bathymetry	US_Carib_GEODAS_bathy	unknown	unknown
US Virgin Islands Nautical Chart	USVI_chart	NOAA NOS Coastal Survey	2004
St Croix Landcover	USVI_STX_Landcover_CCAP_2007	NOAA Coastal Change Analysis Program	2011

APPENDIX D: GEODATABASE

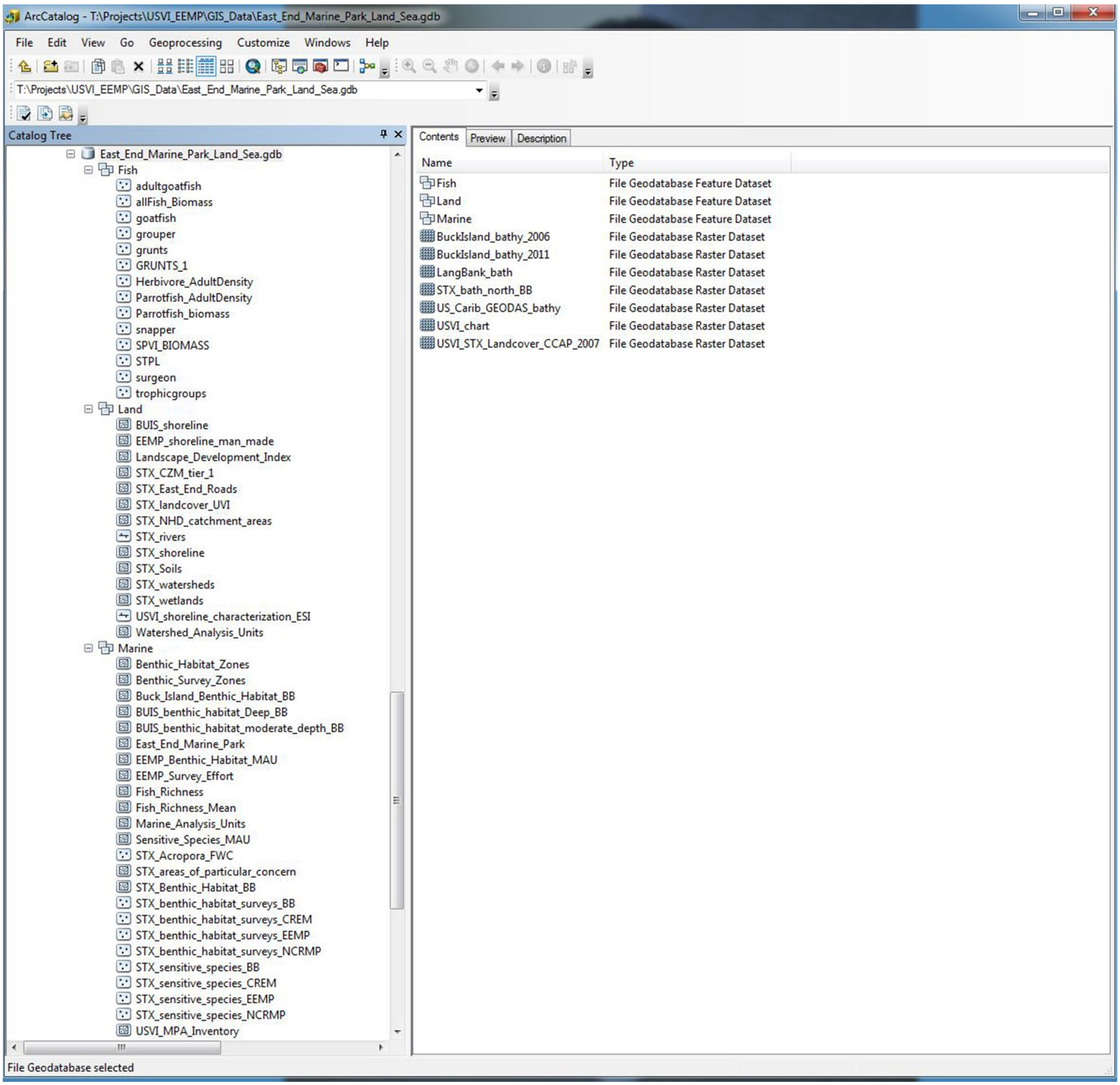


Figure D.1. Example of compiled files in geodatabase.

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