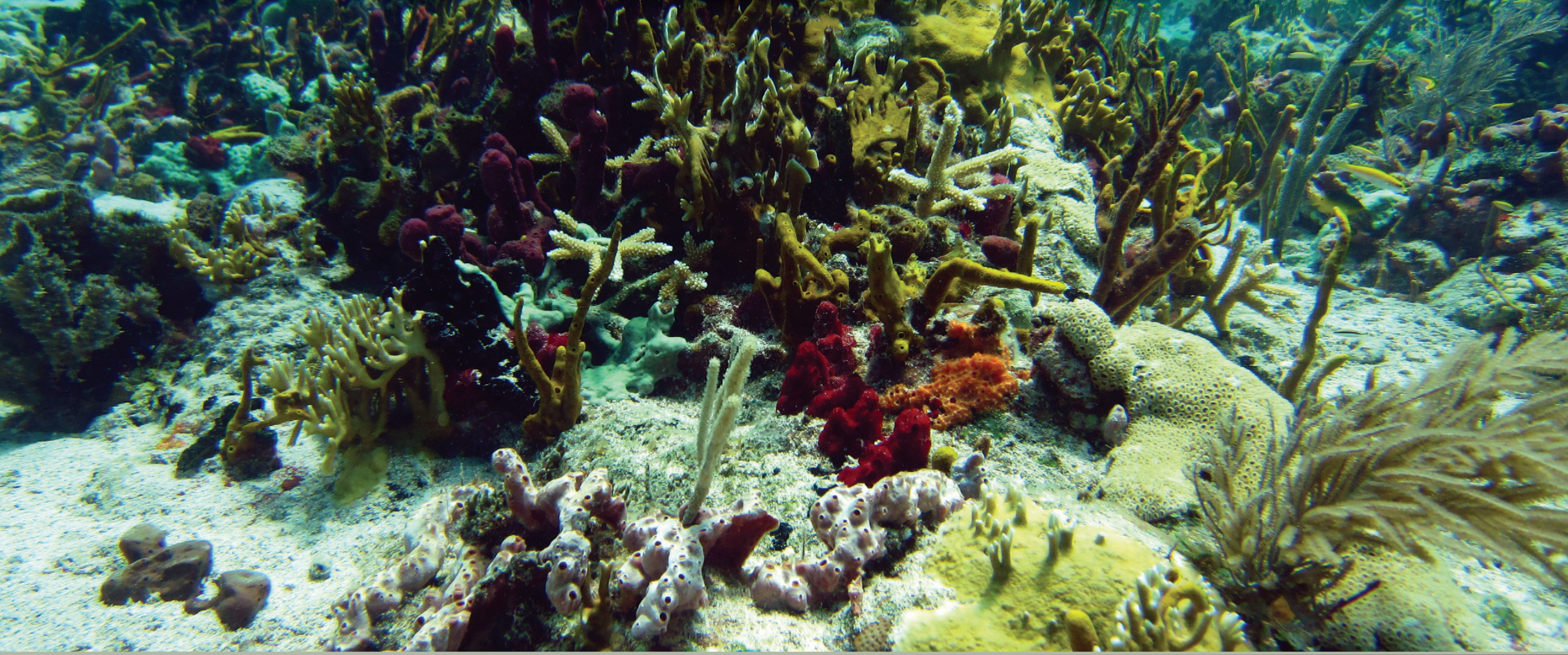
Characterization of Fish Communities and Associated Benthic Habitats in the St. Thomas East End Reserves (STEER)



NOAA National Centers for Coastal Ocean Science

Center for Coastal Monitoring and Assessment

Laurie J. Bauer

Chris F.G. Jeffrey

Chris Caldow

Center for Coastal Fisheries and Habitat Research

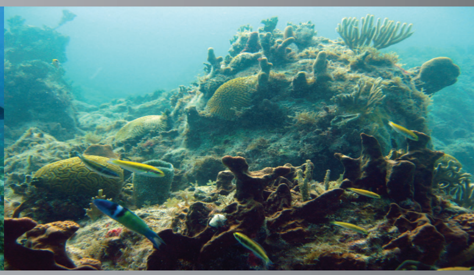
Jenny Vander Pluym

Amy V. Uhrin

The Nature Conservancy

U.S. Virgin Islands and Puerto Rico Program

Anne Marie Hoffman



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Characterization of Fish Communities and Associated Benthic Habitats in the St. Thomas East End Reserves (STEER)

Laurie Bauer[1,2], Jenny Vander Pluym[3], Chris Jeffrey[1,2], Chris Caldow[1],
Anne Marie Hoffman[4], and Amy V. Uhrin[3]

NOAA/NOS/National Centers for Coastal Ocean Science
Biogeographic Assessments Branch (BIOGEO)
Coastal Oceanographic Assessment, Status and Trends Branch (COAST)
1305 East West Highway (SSMC-IV, N/SCI-1)
Silver Spring, MD 20910
USA

September 2014

[1]Center for Coastal Monitoring and Assessment, National Centers for Coastal Ocean Science,
National Ocean Service, National Oceanic and Atmospheric Administration

[2]Consolidated Safety Services, Inc., Fairfax, VA 22030, under NOAA Contract No. DG133C11CQ0019

[3]Center for Coastal Fisheries and Habitat Research, National Centers for Coastal Ocean Science,
National Ocean Service, National Oceanic and Atmospheric Administration

[4]The Nature Conservancy, U.S. Virgin Islands and Puerto Rico Program

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Abstract

Located at the southeastern end of St. Thomas, U.S. Virgin Islands (USVI), the St. Thomas East End Reserves (STEER) is a collection of several existing protected areas, including Cas Cay/Mangrove Lagoon, St. James, and Compass Point Salt Pond Marine Reserves and Wildlife Sanctuaries (MRWS). The marine areas of the STEER include a diverse array of habitats, including coral reefs, lagoons, seagrass beds, and mangrove forests, which support numerous fish and shellfish species. In addition, STEER is an important recreational and commercial resource for the island of St. Thomas. The adjacent watershed is considered highly impacted and urbanized, with numerous sources of point and non-point pollution, leading to concerns about potential contamination and its effects on the marine resources. To fill knowledge gaps and inform management of the STEER, several complimentary projects were developed in coordination with STEER's Core Management Team, including an assessment of biological communities and chemical contamination within the STEER.

In support of this work, field surveys were conducted in June 2012 across coral reef, unconsolidated sediment and mangrove habitats to characterize the fish and benthic communities in the STEER marine ecosystem. Sites were randomly selected within strata to ensure coverage of the entire study region. A total of 80 sites were surveyed during the two-week field mission, including nine in hardbottom areas outside the STEER boundaries that were of interest to natural resource managers. The surveys of benthic habitats, fish communities, marine debris and macroinvertebrates were conducted within 25x4 m transects (100 m^2) along a random heading.

Turf algae dominated the biotic composition of hardbottom sites, followed by macroalgae, hard (scleractinian) corals, sponges, cyanobacteria & filamentous algae, and soft corals (gorgonians). Hard coral cover averaged 5.2%, with the greatest coverage observed in the southern study area, particularly on the southwest reef tract near Long Point. Mustard hill coral (Porites astreoides) was the most abundant species, followed by boulder star coral (Orbicella annularis complex), lesser starlet coral (Siderastrea radians), symmetrical brain coral (Pseudodiploria strigosa), massive starlet coral (Siderastrea siderea), and finger coral (P. porites). Percent cover at mangrove and unconsolidated sediment locations was comprised mostly of seagrass and macroalgae, with smaller amounts of other benthic flora and fauna.

Mangrove sites exhibited the highest mean total fish density, whereas mean levels of biomass were highest on hardbottom. Locations with both high density and biomass included sites on hardbottom adjacent to Cow and Calf Rocks, a patch

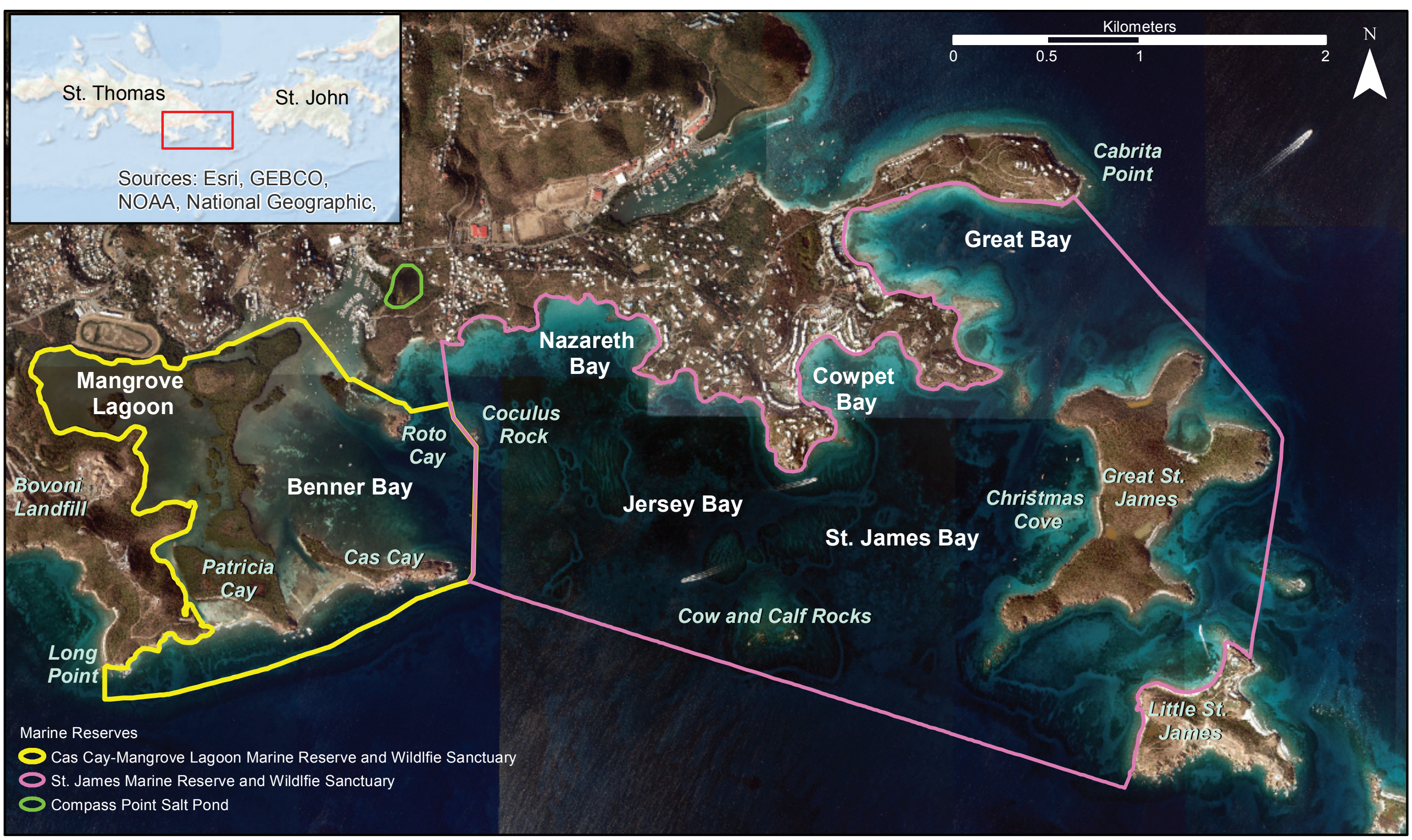


Figure 1. STEER location and management zones (MRWS reserves).

reef southwest of Great St. James Island, a mangrove site near the false entrance to Mangrove Lagoon, and on the southwest reef tract near Long Point, outside the STEER boundary. Species composition varied across benthic habitats within the STEER. Species such as schoolmaster, gray snapper, and herring were most often associated with mangroves, while groupers and surgeonfish were more closely associated with coral reef and hardbottom. Other species, such as yellowtail snapper, were present throughout the STEER, but size-frequency patterns differed across habitat types. In general, both benthic and fish community metrics in the STEER were similar to other U.S. Caribbean monitoring locations sampled with the same methodology.

Introduction

Located at the southeastern end of St. Thomas, U.S. Virgin Islands (USVI), the St. Thomas East End Reserves (STEER) is a marine protected area encompassing 9.6 km^2. STEER is a collection of several existing protected areas, including Cas Cay/Mangrove Lagoon, St. James, and Compass Point Salt Pond Marine Reserves and Wildlife Sanctuaries (MRWS) (Figure 1). The marine areas of the STEER include a diverse array of habitats: coral reefs, lagoons, seagrass beds, and mangrove forests, all of which serve as nursery areas and essential habitat for many fish and shellfish species (STEER 2011). The mangrove forests located along the shores of Benner Bay and Mangrove Lagoon represent the largest remaining mangrove system in the USVI and additionally provide important habitat and roosting areas for a number of sea and shorebird species. Mangrove Lagoon/Benner Bay was previously designated by the territorial government as one of two Areas of Particular Concern (APC) on St. Thomas in recognition of their ecological importance.

The Jersey Bay and a portion of the Red Hook watersheds drain into STEER, and are considered highly impacted and urbanized (Horsley-Witten 2013a). There are numerous point and non-point sources of pollution (DPNR 2003, Horsley-Witten 2013a,b) which include: the unlined Bovoni Landfill adjacent to Mangrove Lagoon, an EPA Superfund site in the Turpentine Run watershed (EPA 2011), unregulated and unmaintained septic and onsite sewage systems, channelized runoff streams containing untreated stormwater, and sediment inputs due to development of steep island slopes. Over one-third of the population of St. Thomas resides in the watershed, and the area experiences many commercial and industrial pressures, including shopping centers, a racetrack, a quarry, and several resorts and condominiums. In addition, numerous marinas and dockyards line the shore, especially along Benner Bay (Figure 2). Turpentine Run, which was channelized during construction of the nearby Clinton Phipps racetrack, drains approximately 60% of the STEER watershed and discharges untreated stormwater and sewage overflows directly into Mangrove Lagoon (Horsley-Witten 2013a). Elevated sedimentation, nutrient and bacteria levels have been detected in the lagoon, particularly following storm events (STEER 2011). Due to both the threats and the ecological value of the wetlands and adjacent marine ecosystems, Jersey Bay and Red Hook Bay watersheds have been designated as “priority watersheds” in St. Thomas (Platenberg 2006). Additionally due to these combined impacts many of the bays in STEER have been declared impaired (DPNR 2010).

Figure 2. Marina in Benner Bay.

A management plan (STEER 2011) was recently developed through collaboration of the Department of Planning and Natural Resources (DPNR), the University of the Virgin Islands (UVI), The Nature Conservancy (TNC), and community groups (e.g., Friends of Christmas Cove). The goal of the STEER Management Plan is to “restore and maintain a functional coastal ecosystem that promotes sustainable recreational opportunities and compatible commercial uses with community engagement through effective management” (STEER 2011). Managers raised concerns on the effects of anthropogenic pressures on the STEER, and identified significant knowledge gaps of the biological communities and of chemical contaminant levels within the STEER, that are necessary to meet the objectives of the plan.

Previous research in STEER has been focused on limited geographic areas. A recent one-year study of fish communities was conducted in Benner Bay/Mangrove Lagoon. Fish traps were used to compare fish diversity and abundance among three geographic strata within the lagoon (Murray 2009; Colletti 2011). This study also produced a benthic habitat map of the lagoon using broad categories (coral reef, mangrove, cyanobacteria, seagrass, macroalgae, and coral rubble) (Colletti 2011). The USVI Territorial Coral Reef Monitoring Program (TCRMP) has been surveying reefs around St. Thomas since 2001 but only has one permanent site within STEER, at Colculus Rock within Benner Bay, and an additional site located just outside STEER near Little St. James (Smith et al. 2012). Benthic cover and coral health have been surveyed annually since 2001, and an annual fish census was added at the Colculus Rock monitoring site in 2009. While the data produced by both of these studies are robust, a STEER-wide assessment characterizing the fish and benthic communities across all habitat types has been lacking.

To fill knowledge gaps and inform management of STEER, several complimentary projects were developed in coordination with STEER's Core Planning Team, with support from NOAA's Coral Reef Conservation Program. These include the Coastal Use Mapping Project (Dillard and D'Iorio 2012), Watershed Management Plan And Condition Report (Horsley-Witten 2013a,b), an updated, fine-scale benthic habitat map (Costa et al. 2013), and an assessment of biological communities and chemical contamination within the STEER. The latter assessment consists of multiple components that will provide baseline information on several research needs, including a bioeffects assessment (chemical contaminants, toxicity, and benthic infauna) in sediments (Pait et al. 2013a), wastewater chemical contaminants as detected by passive water samplers (Pait et al. 2013b), sedimentation rates, nutrient dynamics, and chemical contaminants in coral tissue, conch and fish (Apeti et al. 2014).

The objective of this report is to expand upon previous knowledge to provide a spatially-comprehensive characterization of fish and benthic communities within the STEER. This comprehensive assessment of the fish and benthic communities will be used: (1) as an inventory of the current resources, (2) as a baseline from which to monitor the success rate of any future management actions, and (3) to inform management decisions for the STEER, such as locations for restoration actions. Lastly, we compared results from STEER with other locations in the U.S. Caribbean.

Methods

Site Selection

Field surveys were conducted in June 2012 to characterize the fish communities and associated habitats in the STEER marine ecosystem. Sites were randomly selected within strata to ensure coverage of the entire study region (Figure 3). NOAA's existing benthic habitat map (Kendall et al. 2001) was used as the basis for site stratification. Although a newly updated benthic map was being produced (Costa et al. 2013), it was not yet completed at the time of this study. The strata that were chosen for this study included hardbottom, unconsolidated sediments, and mangrove. The *Hardbottom* strata comprised bedrock, pavement, rubble, and coral reef, while the *Unconsolidated Sediments* stratum comprised submerged aquatic vegetation (i.e., seagrass and macroalgae), as well as uncolonized sand and mud. The

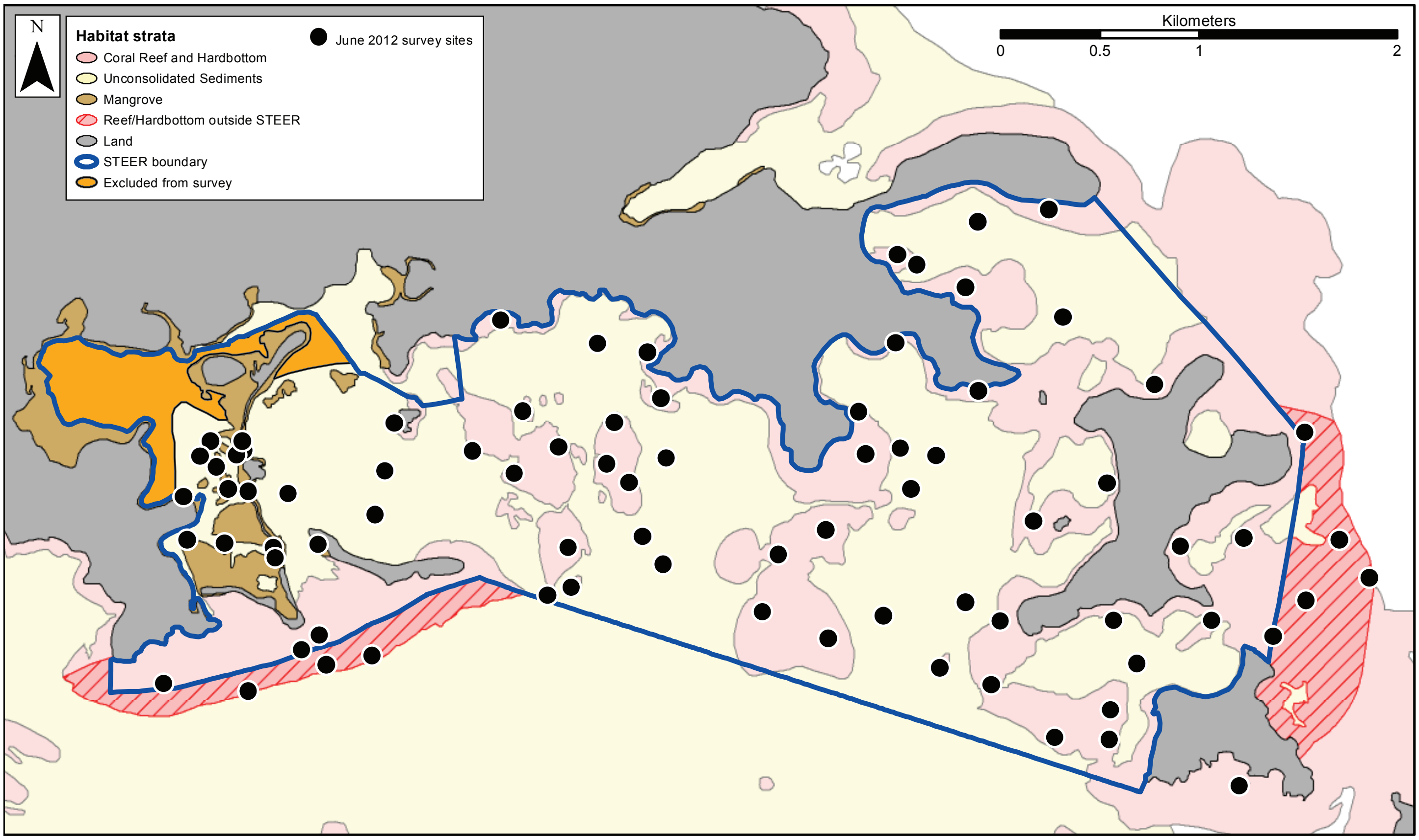


Figure 3. Benthic habitat strata and site locations of the June 2012 survey of benthic habitat composition, fish communities, invertebrates, and marine debris. The boundaries of the St. Thomas East End Reserves (STEER) are shown for reference.

Mangrove stratum comprised the seaward edge of mangrove habitat able to be surveyed with the visual underwater survey methods. In addition, two hardbottom areas outside of STEER that were of interest to STEER's Core Team were included as a separate stratum (9 sites total). These sites were surveyed for exploratory purposes at the request of managers and were not intended to be representative of all hardbottom outside STEER. One of the "outside STEER" sites south of Little St. James was not part of the random selection but a targeted location. The site was chosen with input from TNC due to interest in potential effects of island development on the surrounding marine ecosystem. Unconsolidated sediments and mangroves outside STEER were not surveyed as part of this assessment.

Due to water quality concerns and low visibility, portions of Mangrove Lagoon and Benner Bay were excluded from the study area (Figure 3). In order to effectively survey fish using the underwater visual methods, it is necessary that divers have a minimum of 2 meters visibility. Randomly selected alternate sites were available for each stratum if low visibility prevented a primary site from being surveyed. Surveys for two primary sites (both located south of Benner Bay) could not be completed because they did not meet the visibility requirements. In addition, extra precautions were taken in the area where the inter-island ferries traverse through STEER; while the majority of surveys in this high traffic area were successfully completed, it was necessary to abort one site due to safety concerns. Surveys were completed at alternate sites for all low visibility and high traffic sites that were aborted.

Field Methods

The surveys of benthic habitats, fish communities, marine debris and macroinvertebrates were conducted within 25x4 m transects (100 m^2) along a random heading. Two divers performed the survey at each site (Figure 4a,b). One diver (fish diver) was responsible for visual counts and size estimation of fish species. The second diver (habitat diver) quantified benthic habitat composition, macroinvertebrates and marine debris. These methods have been used to monitor St. John, USVI and other locations within NOAA's Caribbean Coral Reef Ecosystem Monitoring Project (CCREMP) (Pittman et al. 2008; Pittman et al. 2010; Friedlander et al. 2013). The standardized protocols allow for comparisons to be made between different areas. In addition, the protocols include

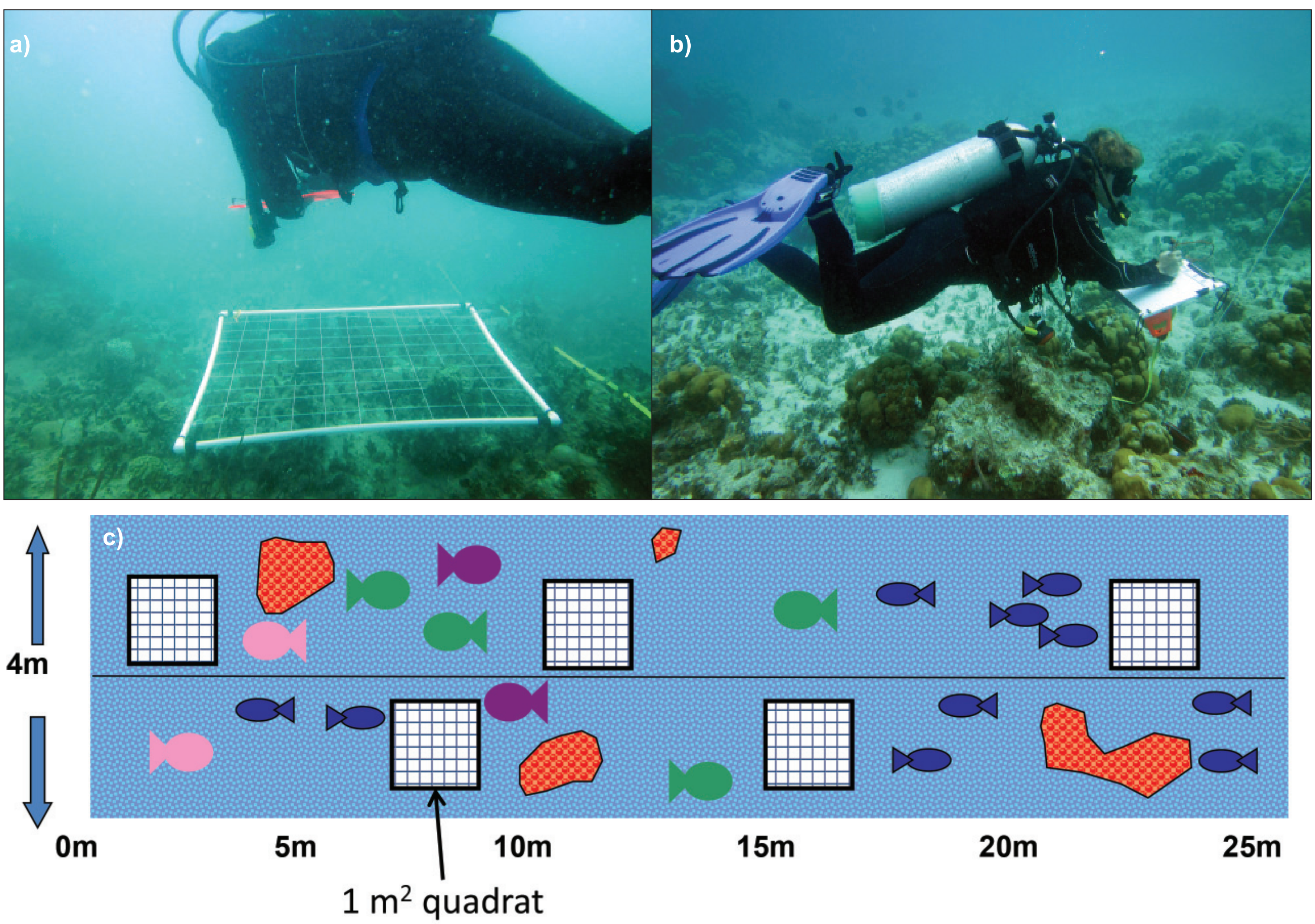


Figure 4. a) Diver collecting data on benthic habitat, b) diver collecting data on fish composition, and c) schematic representation of the placement of the 1m^2 quadrat along a 25 m transect tape during fish and benthic community surveys.

measurement of variables that can be used to monitor and evaluate changes following the reduction in the input of land-based sources of pollution to the marine environment.

Benthic habitat composition

The habitat diver first assigned an overall bottom type (i.e., hardbottom, unconsolidated sediments, or mangrove) to each transect based on *in situ* observation. Data on the percent cover of abiotic and biotic composition at each survey site were recorded within five 1 m^2 quadrats placed randomly along the 25x4 m transect so that one quadrat fell within every 5 m interval along the transect. Positions for quadrat placement and rugosity measurements were selected from a random number chart before each dive. The quadrat was placed at each randomly chosen meter mark and systematically alternated from side to side along the transect tape (Figure 4c). Several variables were measured to characterize benthic composition and structure (Table 1). The quadrat was divided into 100 smaller 10x10 cm squares with string (1 small square = 1% cover) to help the diver with estimation of percent cover. Percent cover was determined by looking at the quadrat from above and visually estimating percent cover in a two dimensional plane. Information was recorded for the following variables:

Table 1. Abiotic and biotic variables measured in five quadrats along fish transects.

Benthic Variables	Measurements		
	Cover (%)	Height (cm)	Abundance (#)
Abiotic			
Hardbottom	X	X	
Sand	X		
Rubble	X		
Fine sediment/silt	X		
Rugosity			
Water depth			
Biotic			
Corals (by species)	X		
Algae			
Macroalgae	X	X	
Turf Algae	X		
Crustose/coralline algae (CCA)	X		
Filamentous algae/cyanobacteria	X	X	
Seagrass (by species)	X	X	
Gorgonians			
Sea rods, whips and plumes	X	X	X
Sea fans	X	X	X
Encrusting form	X		
Sponges			
Barrel, tubes, rope, vase	X	X	X
Encrusting form	X		
Other benthic macrofauna			
Anemonies and hydroids	X		X
Tunicates and zoanthids	X		
Mangroves			
Prop roots			X
Prop roots colonized by algae			X
Prop roots colonized by sponges			X
Prop roots colonized by other biota			X

Abiotic cover - the percent cover (to the nearest 1%) of four abiotic substrate categories (hardbottom, sand, rubble, and fine sediments/silt) were estimated within each 1 m^2 quadrat. The maximum vertical relief of the hardbottom was also measured.

Biotic cover - the percent cover (to the nearest 0.1%) of algae, seagrass, live corals, sponges, gorgonians, and other biota was estimated within each 1 m^2 quadrat. Taxa were identified to the following levels: stony coral (species), seagrass (species), algae (morphological group), sponge (morphological group), and gorgonians (morphological group) (Table 1). Algal groups included macroalgae, turf algae, crustose coralline algae, and filamentous algae/cyanobacteria (e.g., *Schizothrix calcicola*). Turf algae include a mix of short (less than 1cm high) algae that colonize dead coral substrate. For stony and fire corals, the percentage of bleached coral and diseased/dead coral was estimated to the nearest 0.1 %. In addition, the presence of *Acropora palmata* or *A. cervicornis* either within the transect area (100 m^2) or the vicinity of the sample site was also noted by the divers.

Maximum canopy height - the maximum height of sponges, gorgonians, and soft algal groups was recorded to the nearest 1 cm in each quadrat.

Number of individuals - the number of individual upright sponges, gorgonians, non-encrusting anemones, and non-encrusting hydroids was recorded in each quadrat.

Rugosity – for hardbottom sites, rugosity was measured by placing a 6 m chain at two randomly selected positions, ensuring no overlap, along the 25 m belt transect. The chain was positioned along the centerline of the transect such that it followed the substrate's relief. The straight-line horizontal distance covered by the chain was measured. An index of rugosity (R) was calculated as the ratio of contoured surface distance (d) to linear distance (L = 6m) using $R=1-d/L$.

Mangrove habitat data – For surveys conducted in mangrove habitat, all of the habitat variables were collected along with additional data, including: number of prop roots, number of prop roots colonized by algae, number of prop roots colonized by sponges and number of prop roots colonized by other biota (tunicates, anemones, zoanthids, etc).

Macroinvertebrate counts
The habitat diver counted the abundance of spiny lobsters (*Panulirus argus*), long-spined urchins (*Diadema antillarum*), and the abundance and sexual maturity of queen conch (*Strombus gigas*) within the 25x4 m transect at each site. The maturity of each conch was determined by the absence (immature) or presence (mature) of a flared lip.

Marine debris
The number and type of marine debris within the 25x4 m transect were recorded by the habitat diver. Marine debris size and the area of habitat it affected were estimated. Any flora or fauna that were colonizing the debris item were noted.

Fish census
Fish surveys were conducted along the 25x4 m transects (100 m^2) using a fixed survey duration (15 minutes) regardless of habitat type or complexity. Fish were recorded both in the water column and on the substrate, including under ledges and in holes. The number of individuals per species was recorded in 5 cm size class increments up to 35 cm using visual estimation of fork length. If the individual could not be identified to species, they were identified to the extent possible (i.e., genus or family). Individuals greater than 35 cm were recorded as an estimate of the actual fork length to the nearest centimeter. At mangrove sites, the survey was conducted along the edge of the mangrove canopy. The transect was laid out as close to the prop roots and as far into the mangroves as possible, up to 2 m into the prop roots, and then out to the edge of the mangrove overhang such that the total area surveyed was still 100 m^2.

Data Analysis
Benthic habitat
While many benthic variables were measured during the surveys, data analyses for this report focused primarily on describing differences among major habitat types and broad-scale spatial patterns in the percent cover of the sessile biotic components as described in Table 1. Quadrat measurements along each transect were averaged and cumulative coral species richness (the total number of species present), was calculated for each site. Average site values were used to calculate means and standard errors of measured variables for each habitat stratum (mangrove, unconsolidated sediments, hardbottom inside STEER, hardbottom outside STEER). As sites surveyed outside STEER were only selected from limited areas, the data was not sufficient to statistically compare differences in benthic cover on hardbottom inside vs. outside STEER. However, the summary statistics were reported separately and qualitative comparisons were made where appropriate. In addition, data were plotted in a geographic information system (ArcGIS v10.1, ESRI) to examine broad spatial patterns in the benthic cover variables.

Fish
Fish community metrics were summarized by habitat stratum (mangrove, unconsolidated sediments, hardbottom inside STEER, hardbottom outside STEER). As described in the previous section, data collected outside STEER was not sufficient to conduct a robust statistical analysis of differences in fish communities inside and outside STEER, but the summary statistics were reported separately and qualitative contrasts were made where appropriate. Means and standard errors (SE) were estimated for biological community metrics (total density, total biomass, species richness, Shannon diversity, and density and biomass of trophic groups). Means and SE calculations were computed employing methods described by Cochran (1977) in the statistical analysis software, SAS v9.3 (Proc Survey means). Trophic groups surveyed included piscivores, herbivores, invertivores, and zooplanktivores and were defined for each species based on diet information from Randall (1967). It is important to note that these groups are not mutually exclusive because many fish species can be classified into two or more of these groups based on diet. In those circumstances the trophic group was assigned based on the dominant diet component. Biomass was calculated using published length-weight relationships based on the allometric scaling law,

$$W = aL^b$$

where *L* is length in centimeters and *W* is weight in grams, *a* is a condition factor related to body from, and *b* is the scaling exponent indicating either isometric or allometric growth. The midpoint of each size class was used for *L* values up to 35 cm, and the actual length was used for fish >35 cm. For fish in the 0-5 cm size class, 3 cm was used as the mid-point because we do not typically observe fish <1 cm. Values for a and b by species were obtained from FishBase (Froese and Pauly 2008). Biomass for species with no published length-weight relationships was calculated using terms for the closest congener with most similar morphology.

Species diversity was calculated using the Shannon-Weiner Index (H'), a measure that incorporates both richness and evenness (relative abundances):

$$H' = \Sigma_i p_i(\log_e p_i)$$

where p_i is the relative abundance of each species. H' increases as both the richness and evenness of the community increase. Typical values for H' range from 1.5 – 3.5 and rarely exceed 4.

Data were plotted in ArcGIS to examine broad spatial patterns in the fish metrics. In addition, select families and species of commercial and/or ecological interest were selected for further examination. For each selected species/family, a summary of the species distribution, size frequency, and mean density and biomass by habitat strata (*Hardbottom Inside*, *Hardbottom Outside*, *Mangrove*, *Unconsolidated Sediments*) was calculated. Age class (juveniles/sub-adults and adult) was identified based on mean length at maturity as identified by FishBase (Froese and Pauly 2008) and García-Cagide et al. (1994). Where length at maturity was unknown, 1/3 of maximum size was used as a proxy as in Pittman et al. (2008, 2010). In addition, percent occurrence, mean density and biomass (per 100 m^2) and corresponding SE were calculated for all species across all sites within STEER. This information was used to create a summary table of all species observed in this characterization across the STEER sampling domain (Appendix 1). A similar table was generated for the hardbottom sites outside STEER (Appendix 2).

Differences and similarities in species composition were further examined using multivariate statistical techniques (Primer v.6, Clarke and Warwick 2001). Density and biomass data were square-root transformed prior to analysis. Data were arranged in a species density/biomass by site data matrix, which was used to construct a triangular matrix of the percentage similarity in community composition between all pairs of sites using the Bray-Curtis Coefficient. The coefficient is a measure of how similar samples were to each other, ranging from 0% (complete dissimilarity) to 100% (complete similarity). Next, non-metric multidimensional scaling (nMDS) was used to place samples in a two-dimensional configuration such that the rank order of the distances between the samples agreed with the rank-order of the similarities from the Bray-Curtis matrix. Sites were coded by bottom type and management (Inside/Outside STEER) for examination of visual patterns of between site similarity. These factors were also used to test for significant differences in similarity using Analysis of Similarities (ANOSIM), a multivariate, non-parametric version of ANOVA. Outputs of the ANOSIM test include an R statistic and p-value. R is a difference of average rank dissimilarities between and within groups, scaled so that R ranges between 0 (no differences) and 1 (perfect division), while the p-value gives the statistical significance for a test of R = 0. Significant differences in fish community structure were examined with the similarity percentages (SIMPER) routine to identify those species that contributed most to the observed dissimilarity.

To see how fish communities in STEER compare with other parts of the U.S. Caribbean, key fish community metrics (species richness, total biomass, and biomass of groupers, snappers, grunts, and parrotfish) were compared with other locations within NOAA's Caribbean Coral Reef Ecosystem Monitoring Project (http://www8.nos.noaa.gov/biogeo_public/query_main.aspx), including the island of St. John (2011), Eastern St. Croix (2010), which includes the Buck Island Reef National Monument and East End Marine Park, and Southwest Puerto Rico, including La Parguera/Guanica (2012). Mangrove strata comparisons could only be made with SW Puerto Rico. Sites on the mid-shelf reef in St. John were removed from the analysis to allow for a more equitable comparison with STEER. As data were non-normally distributed, nonparametric Wilcoxon tests and the corresponding non-parametric Dunn's multiple comparisons tests (Zar 1999) were used to test for differences among regions (JMP v11.0). Means and standard errors of these metrics were also plotted for visualization.


A school of snapper swim below an undercut mangrove stand near the false entrance to Mangrove Lagoon.

Results

A total of 80 sites were surveyed during the two-week field mission: 26 on unconsolidated sediments, 10 along the mangrove fringes, 35 on hardbottom within STEER, and nine on hardbottom outside STEER boundaries. Two sites within the hardbottom stratum were identified as soft bottom habitat by the survey divers and were subsequently grouped with the unconsolidated sediment surveys for analysis. Conversely, one site within the unconsolidated sediment stratum was reclassified as hardbottom during the survey and subsequently included with the hardbottom surveys for analysis.

Benthic Habitat

Abiotic composition

Not surprisingly, hardbottom substrate dominated sites within the hardbottom strata with minor components of rubble and sand. No fine sediment was observed along transects conducted at these sites (Figure 5a). In contrast, soft bottom sites were primarily composed of sandy bottom with some fine sediment and rubble (Figure 5b). The predominance of sand over fine sediments is likely attributable to the mostly developed coastline within our survey domain and hardbottom habitats bordering the unconsolidated sediments locations. Portions of Benner Bay and Mangrove Lagoon that were excluded from the survey are bordered by vegetated coastline and dominated by fine sediment. Mangrove sites were characterized with fine sediments and sand (Figure 5c).

Biotic composition overview

Turf algae dominated the biotic composition of hardbottom sites with a mean (±SE) percent cover of 51.8 ± 4.5% inside/41.9 ± 10.1% outside, followed by macroalgae (14.9 ± 2.8% inside/14.1 ± 5.3% outside), hard (scleractinian) corals (5.2 ± 0.8% inside/5.2 ± 1.8% outside), sponges (4.8 ± 1.8% inside/4.6 ± 1.1% outside), cyanobacteria & filamentous algae (2.1 ± 0.2% inside/1.8 ± 0.1% outside), and gorgonians (1.3 ± 0.5% inside/2.9 ± 1.3% outside, Figure 6a). Other types of biotic cover were documented in small amounts: fire coral (*Millepora* spp.) (0.6 ± 0.2% inside/0.3 ± 0.1% outside), zoanthids (0.07 ± 0.02% inside/0.1 ± 0.1% outside), seagrass (0.06 ± 0.05% inside/0 outside), and tunicates (0

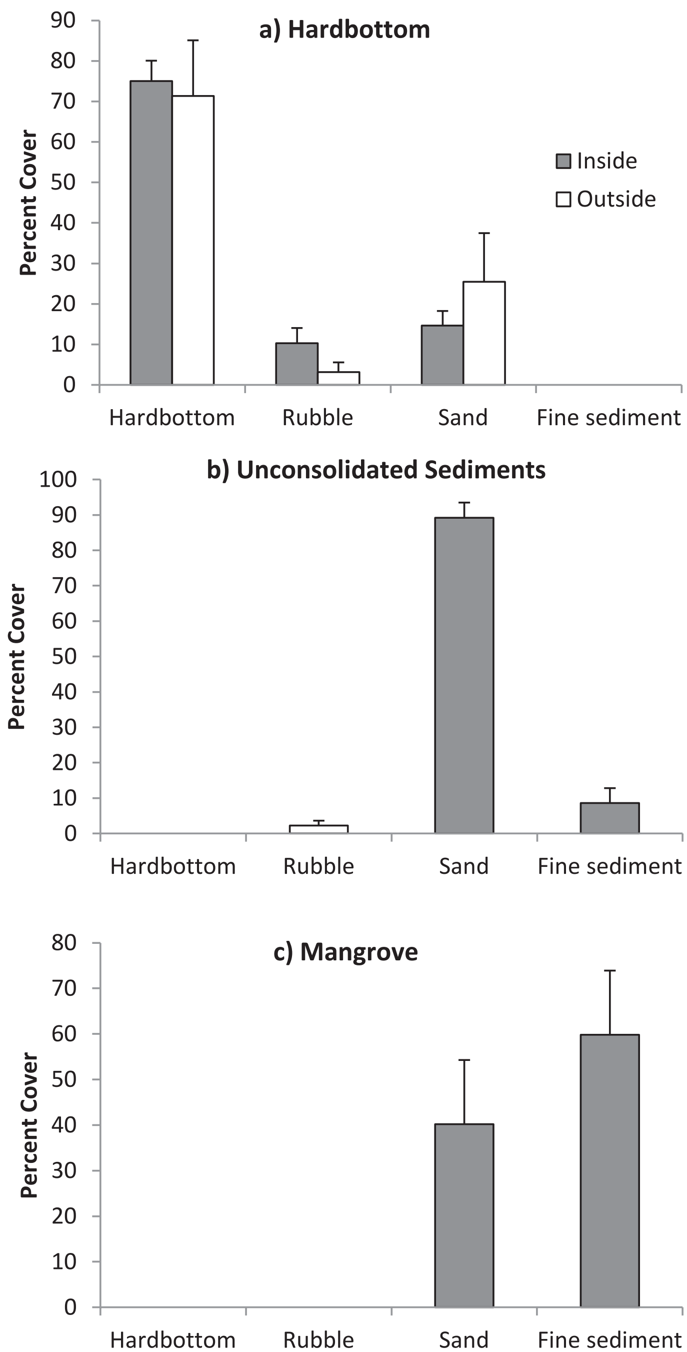


Figure 5. Mean (±SE) percent cover of abiotic substrate by bottom type: a) hardbottom inside (N=35) and outside (N=9) the STEER boundaries, b) softbottom (N=26), and c) mangrove (N=10).

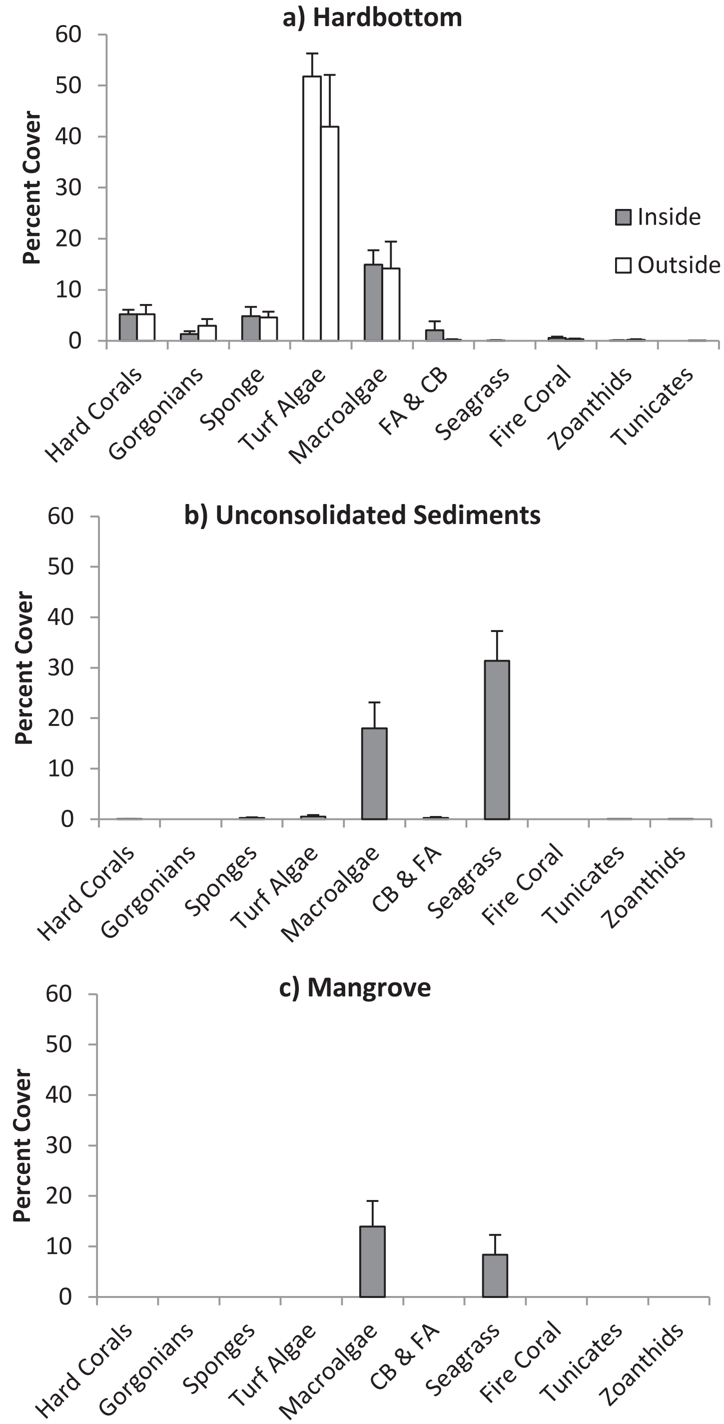


Figure 6. Mean (±SE) percent cover of major cover groups by bottom type: a) hardbottom sites inside (N=35) and outside (N=9) the STEER boundaries, b) softbottom (N=26), and c) mangrove (N=10). FA & CB = filamentous algae and cyanobacteria.

inside/0.008 ± 0.008% outside). Bare, uncolonized substrate averaged 19.1 ± 3.7% inside/30.4 ± 11% outside. Rugosity, which is a measure of the complexity of the habitat, ranged from 0.02 to 0.41 and averaged 0.17 ± 0.04% inside/0.15 ± 0.04% outside (Figure 7). The second highest rugosity (0.37) measurement was recorded at a site in the southwest reef tract near Long Point, outside the STEER boundaries.

Unconsolidated sediment site assemblages in STEER were composed of mostly seagrass (31.4 ± 5.9%) and macroalgae (17.9 ± 5.1%, Figure 6b). Minor components of the benthic community include: turf algae (0.5 ± 0.4%), sponge (0.25 ± 0.11%), cyanobacteria & filamentous algae (0.23 ± 0.23%), hard corals (0.04 ± 0.02%), tunicates (0.009 ± 0.007%), and zoanthids (0.007 ± 0.007%). Bare substrate averaged 49.6 (± 5.9%) which was over twice the mean at hardbottom sites.

Substrate found at mangrove sites was mostly bare, unconsolidated sediment (77.71 ± 6.30 %). The benthic community at these sites was comprised of macroalgae (13.9 ± 5.1%) and seagrass (8.4 ± 3.9%, Figure 6c). Other algae types (turf algae, cyanobacteria and filamentous algae) were largely absent from the benthic substrate in mangrove habitats. Number of prop roots per 1 m^2 ranged from 8-50 roots /m^2 and averaged 20 (±4.0) roots /m^2 across all mangrove sites. Almost 100% of prop roots had algae growing on them (99.9%) with sponges and other invertebrates (tunicates, anemones, and zoanthids) occurring on 28% and 47.4% of the prop roots, respectively (Figure 8).

Figure 8. Mangrove prop roots colonized with algae and benthic fauna.

<u>Hard coral composition</u>

Live scleractinian coral cover ranged from 0% in mangrove and unconsolidated sediments habitats to 0.08-29% cover in hardbottom sites (Figure 9). The greatest coverage of hard corals was found on the southwest reef tract near Long Point located in the southwest corner of the STEER. The STEER boundary passes through the middle of the reef tract so that only half of the ecosystem falls under any management plan. Three of the four sites with the highest coral cover

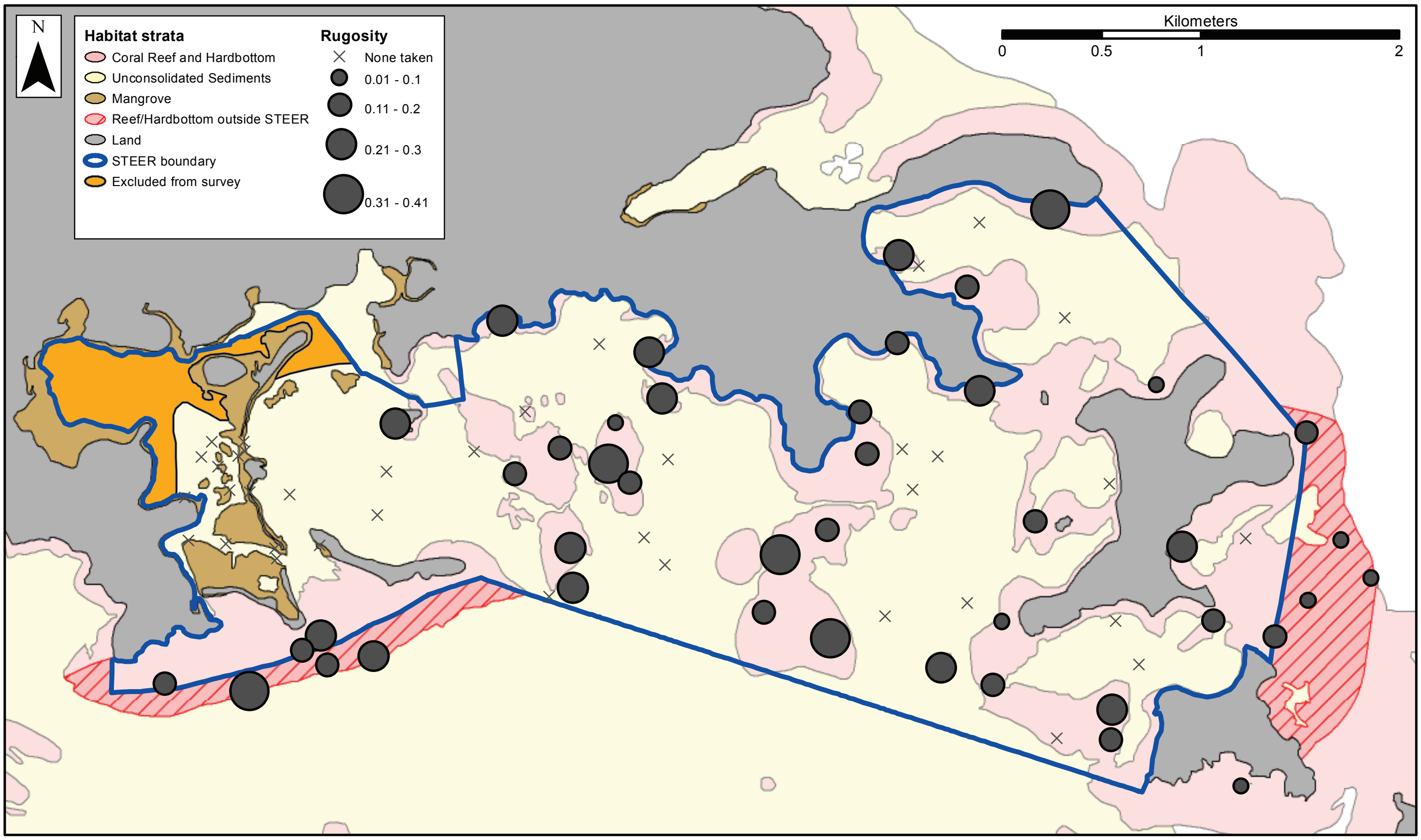


Figure 7. Mean rugosity (hardbottom sites only).

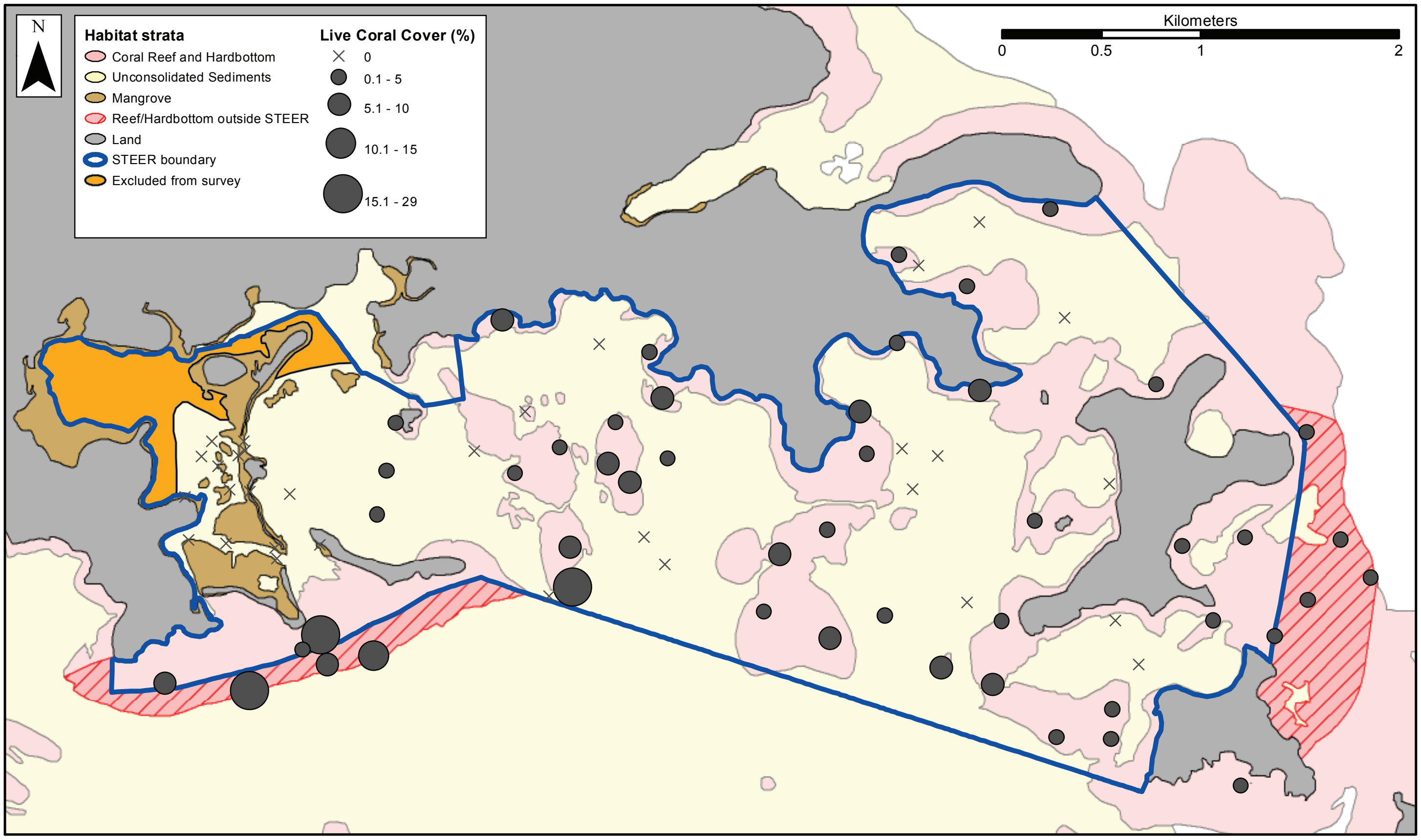


Figure 9. Percent live cover of hard corals.

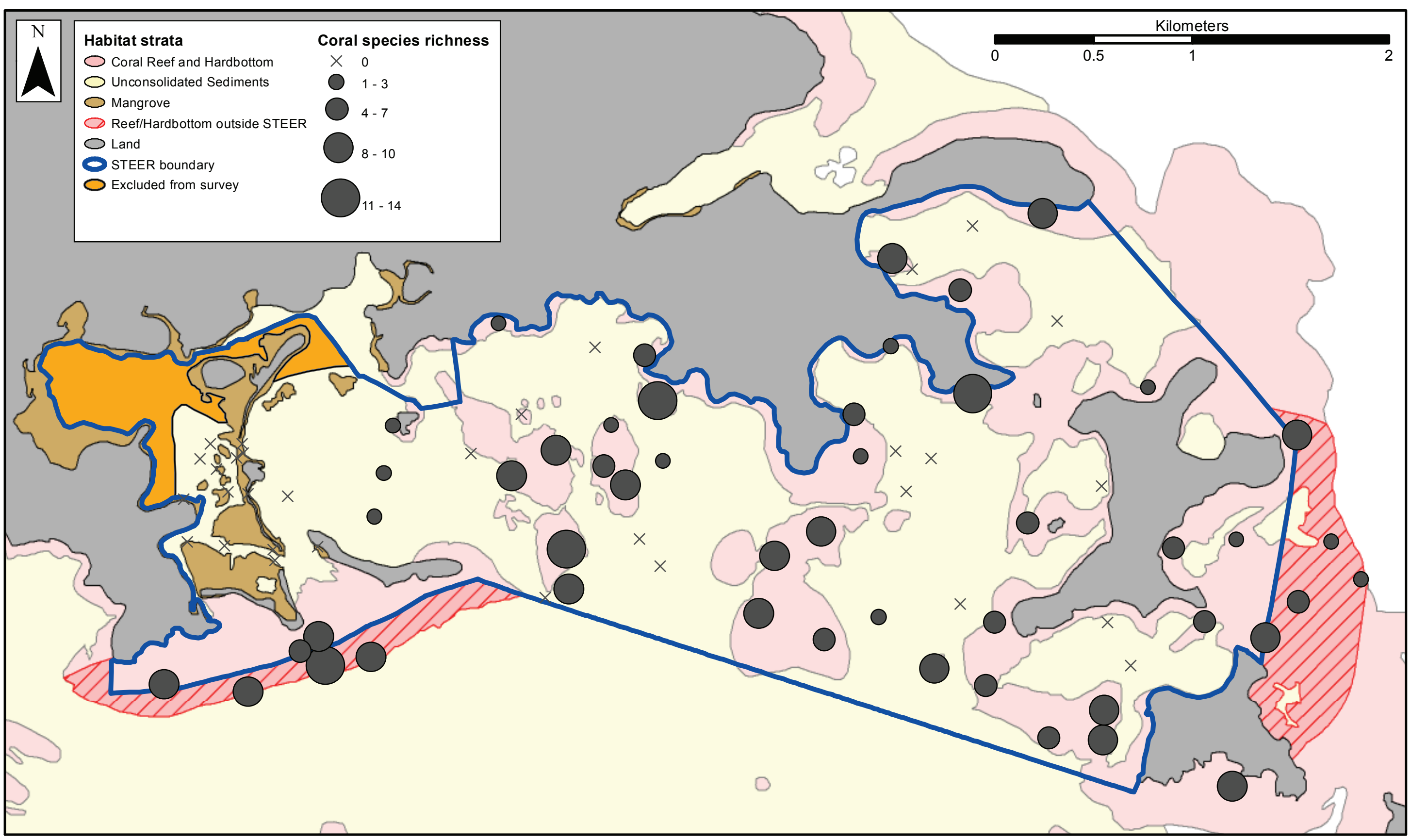


Figure 10. Hard coral species richness.

(11-29%) were in this reef tract with two sites (16.8% and 11%) located outside the STEER boundary. The top six sites for coral cover (7.6-29%) were all located in open water conditions in the southern region of the STEER and further from land features. Overall, coral cover was still low with an average of 5.2 ± 0.8% and 5.2 ± 1.8% on hardbottom habitats inside and outside STEER, respectively.

Hard coral species richness ranged from 0-14 at individual sites with an average of 7.2 ± 0.4 inside and 6.9 ± 1.2% outside (Figure 10). Unlike percent cover, species richness did not reflect any small scale regional patterns, and it does not appear to correlate with percent cover. The five sites with highest richness were evenly distributed throughout hardbottom habitats inside and outside of STEER: two were adjacent to consolidated reef on the shoreline, two were located on offshore, open water hardbottom, and one was outside the STEER boundaries on the southwest reef tract near Long Point.

A total of 26 hard coral species were documented, with 25 of those species recorded at sites inside STEER. *Porites astreoides* (mustard hill coral) was the most abundant species, followed by *Orbicella annularis* complex (boulder star coral), *Siderastrea radians* (lesser starlet coral), *Pseudodiploria strigosa* (symmetrical brain coral), *Siderastrea siderea* (massive starlet coral), and *P. porites* (finger coral) (Figure 11). Outside the STEER boundaries 19 species were recorded with the most abundant species being *O. annularis* complex followed by *P. astreoides*, *S. siderea*, *P. porites*, and *S. radians*.

Acropora cervicornis (staghorn coral), a species listed as threatened under the Endangered Species Act (ESA), was

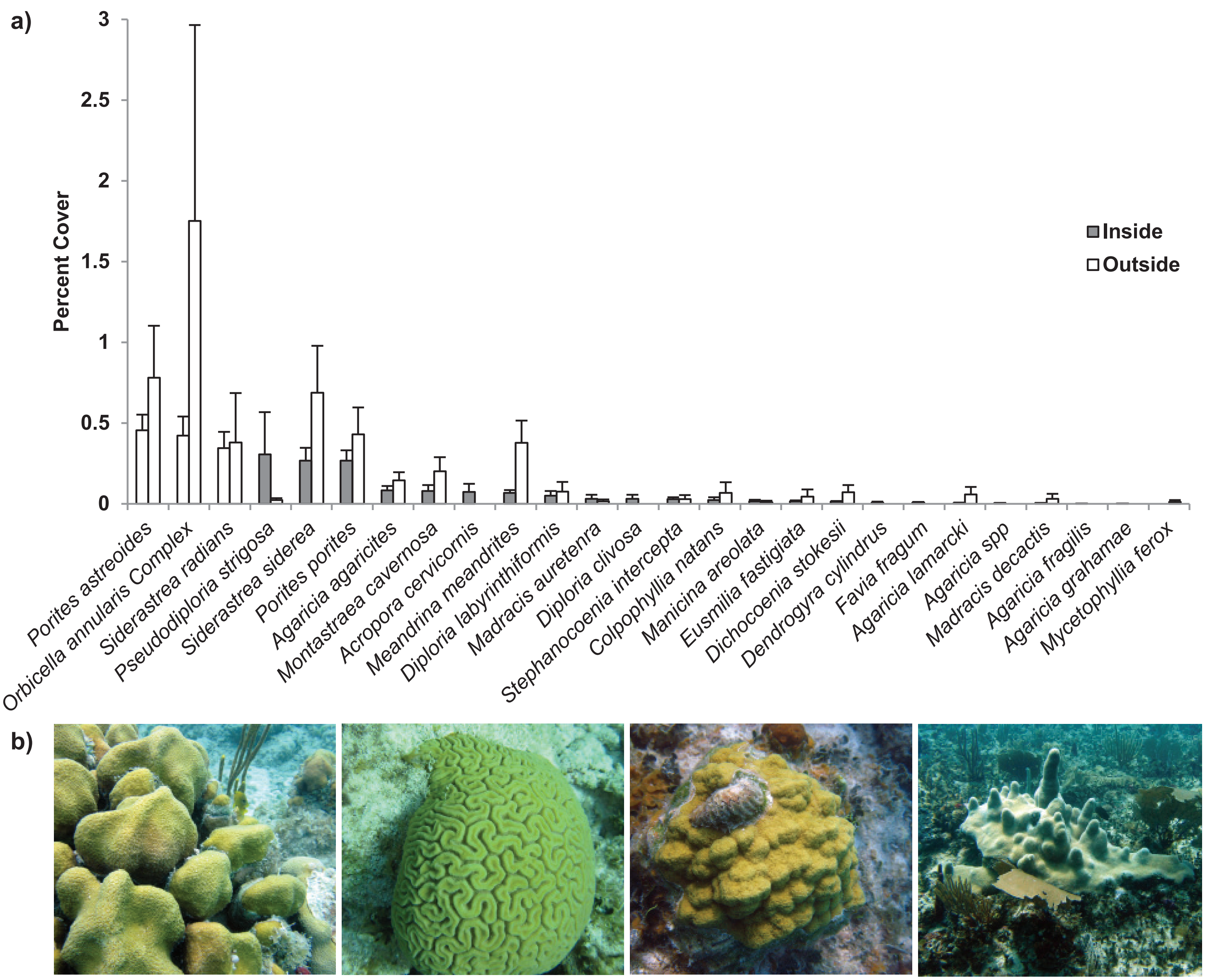


Figure 11. a) Mean (±SE) percent cover of hard corals by species at hardbottom sites (N=44). b) From left to right: common star coral, grooved brain coral, mustard hill coral, and pillar coral.

documented at three sites dispersed around the STEER and *Dendrogyra cylindrus* (pillar coral), a species of concern and proposed for listing under the ESA, was recorded at two locations, both of which were on hardbottom close to the shoreline (Figure 12). One of the sites with *A. cervicornis* was located just inside the reserve on the southwest reef tract near Long Point. This specific reef tract is also home to three sites out of the top four with the greatest overall hard coral cover (Figure 9).

Gorgonian composition

Gorgonian cover ranged from 0-18.4% and primarily occurred on hardbottom habitat (Figure 13). Sites with the highest percent cover (7.44-18.4%) were all exposed to more open ocean conditions. Each of the high cover sites were located in different quadrants of STEER: one is on the southwest reef tract near Long Point, one was located outside the southeast corner of STEER south of Little St. James, and the other was outside the northeast corner of STEER on the eastern shoreline of St. James. This pattern is not surprising as all three of these sites were exposed to high wave action characteristic of open ocean and prevailing on-shore wind patterns, conditions in which gorgonian communities tend to thrive. Average gorgonian cover on hardbottom inside STEER was relatively low (0.9 ± 0.3%) and consisted of sea plumes/rods/whips (0.49 ± 0.14%), sea fans (0.36 ± 0.19%), and encrusting gorgonians (0.05 ± 0.02).

Sponge composition

Sponge cover ranged from 0-64.6% and averaged 2.71 ± 0.84% across all sites (Figure 14). There was no distinctive spatial pattern exhibited by sponge communities—sites with greater than average coverage were distributed on hardbottom habitats throughout STEER and outside the reserves. The site with the highest sponge cover was located in an area of high current velocity between the islands of Little St. James and Great St. James (Figure 14). Inside STEER, mean percent cover differed greatly between hardbottom (4.82 ± 1.8%) and unconsolidated sediments (0.25 ± 0.11%) habitats. Barrel/tube/vase (BTV) sponges accounted for the majority of percent cover overall (3.44 ± 1.48%), while encrusting sponge comprised a smaller portion of the sponge community (1.38 ± 0.36%). On the nine hardbottom sites surveyed outside STEER, mean percent cover was similar to inside: overall sponge (4.59 ± 1.1%), BTV sponges (2.72 ± 0.82%), and encrusting sponge (1.86 ± 0.43%).

Algae and seagrass composition

Macroalgal cover ranged from 0-100% and was found throughout the STEER. Means were similar across bottom types: hardbottom (14.77 ± 2.44%), unconsolidated sediments (17.99 ± 5.14%), and mangrove sites (13.94 ± 5.1%, Figure 15). Percent cover across STEER averaged 15.71 ± 2.21%. The two sites with the highest cover (90-100%) were located in soft bottom habitat in Mangrove Lagoon. Turf algae ranged

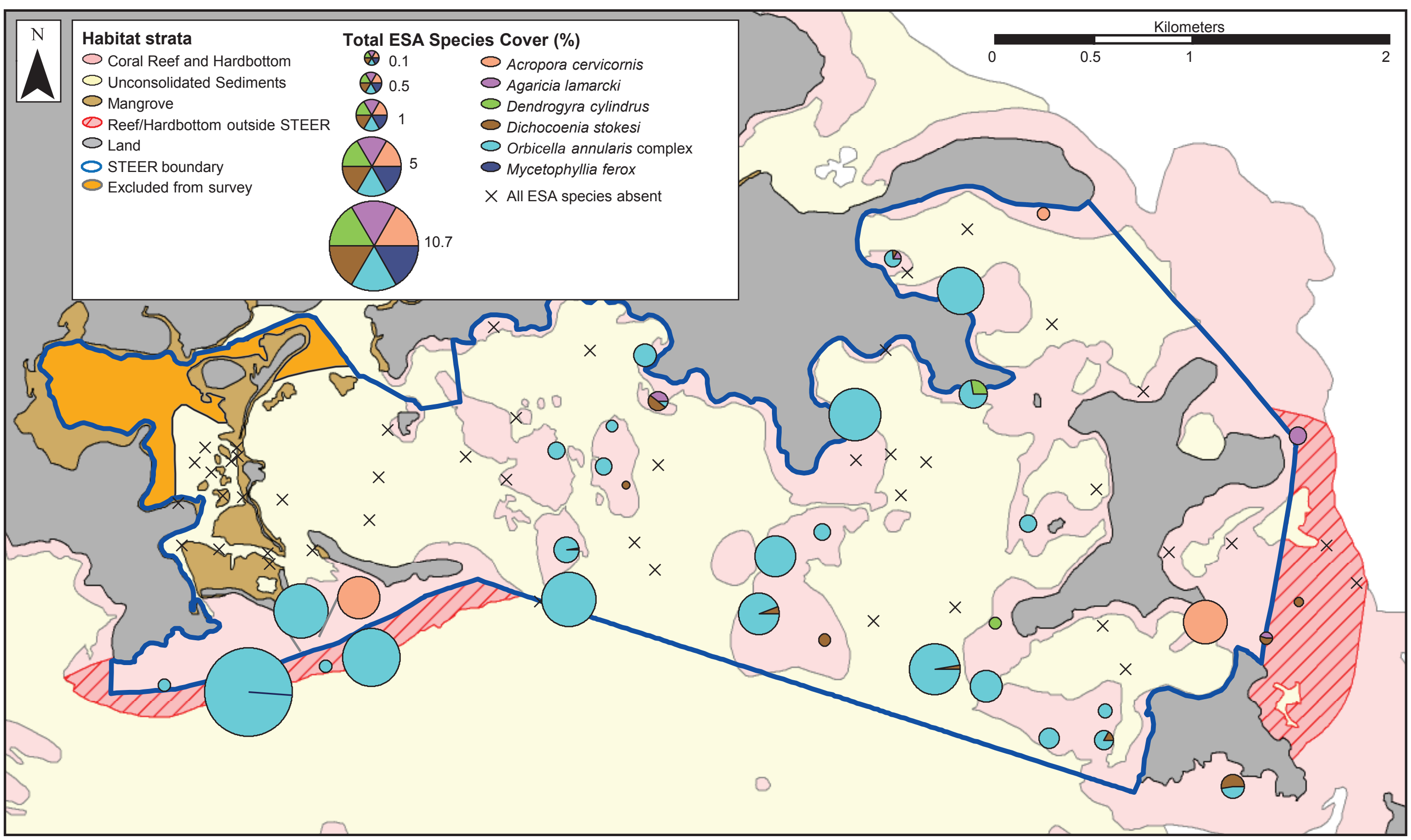


Figure 12. Percent cover of coral species listed as threatened under the Endangered Species Act (ESA) or proposed for future listing. The sizes of the pies are scaled by the total percent cover of the six species at that site.

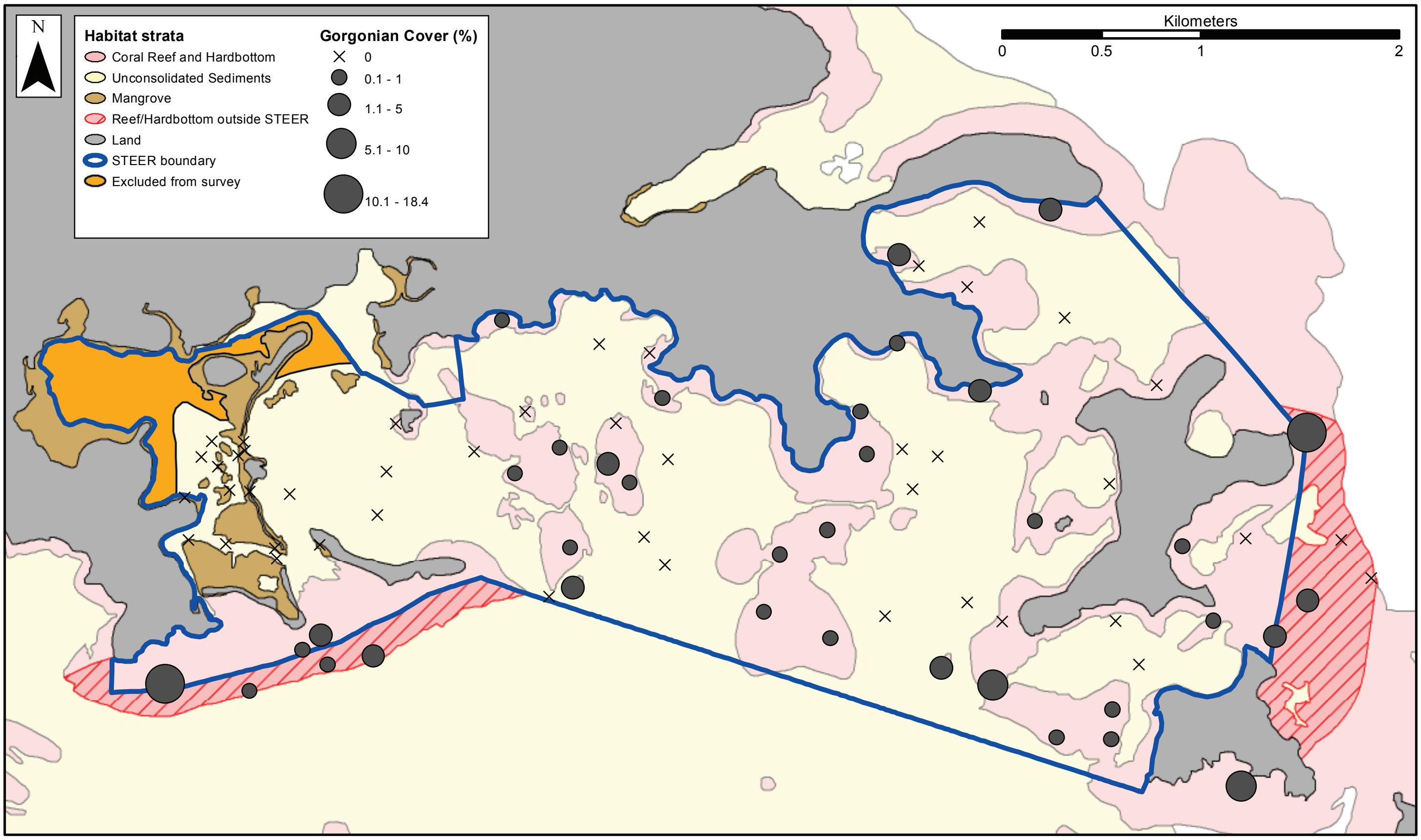


Figure 13. Percent gorgonian cover.

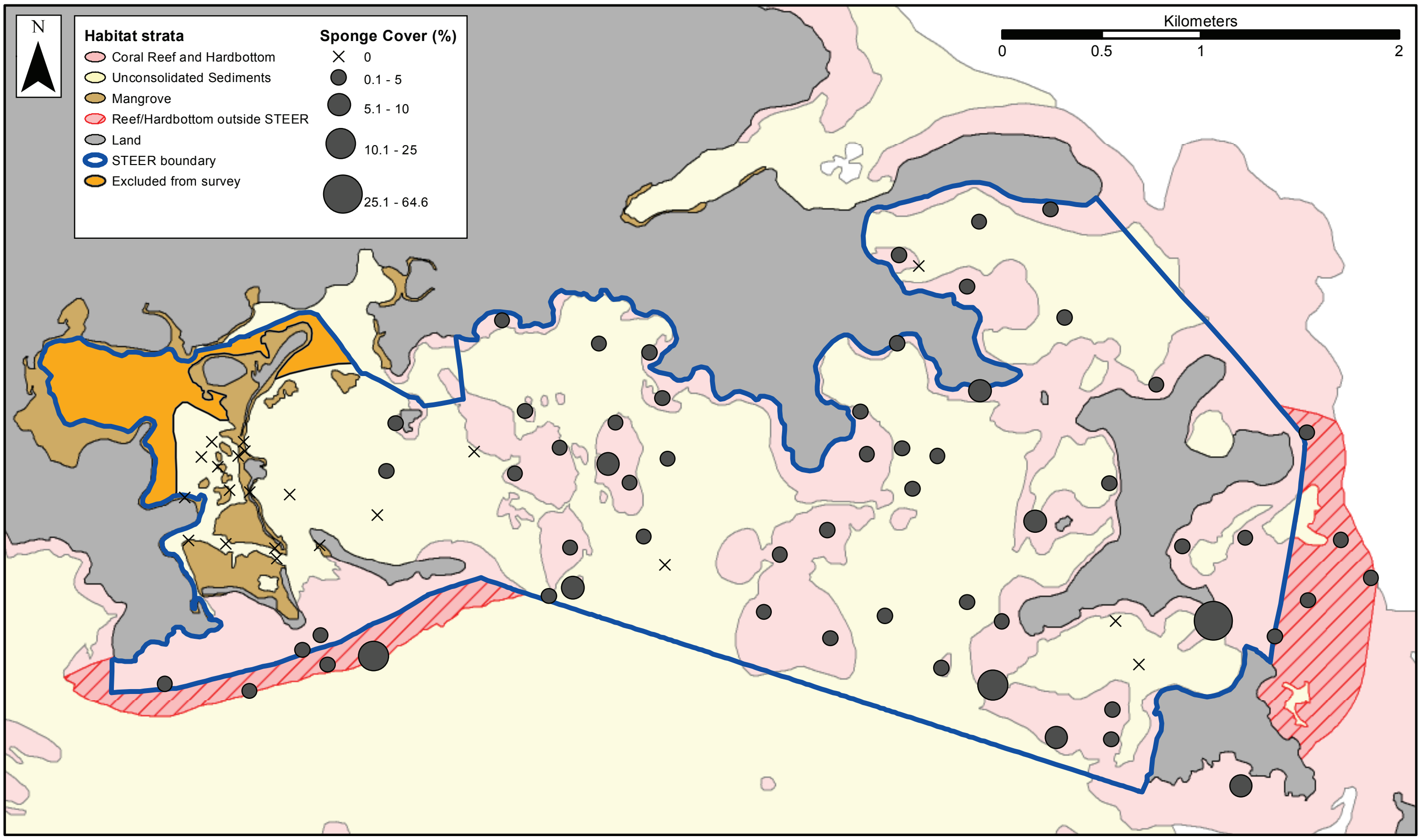


Figure 14. Percent sponge cover.

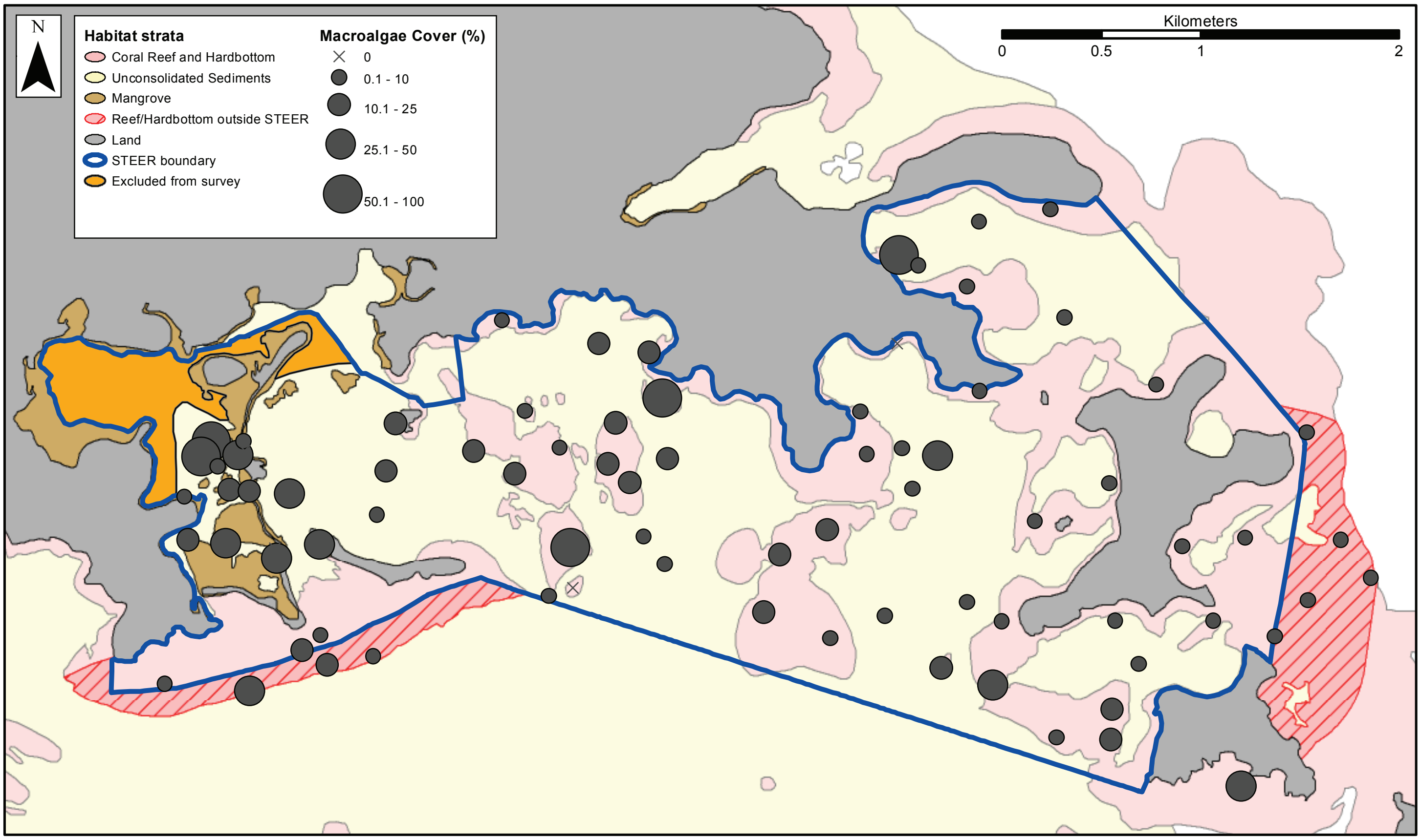


Figure 15. Percent macroalgae cover.

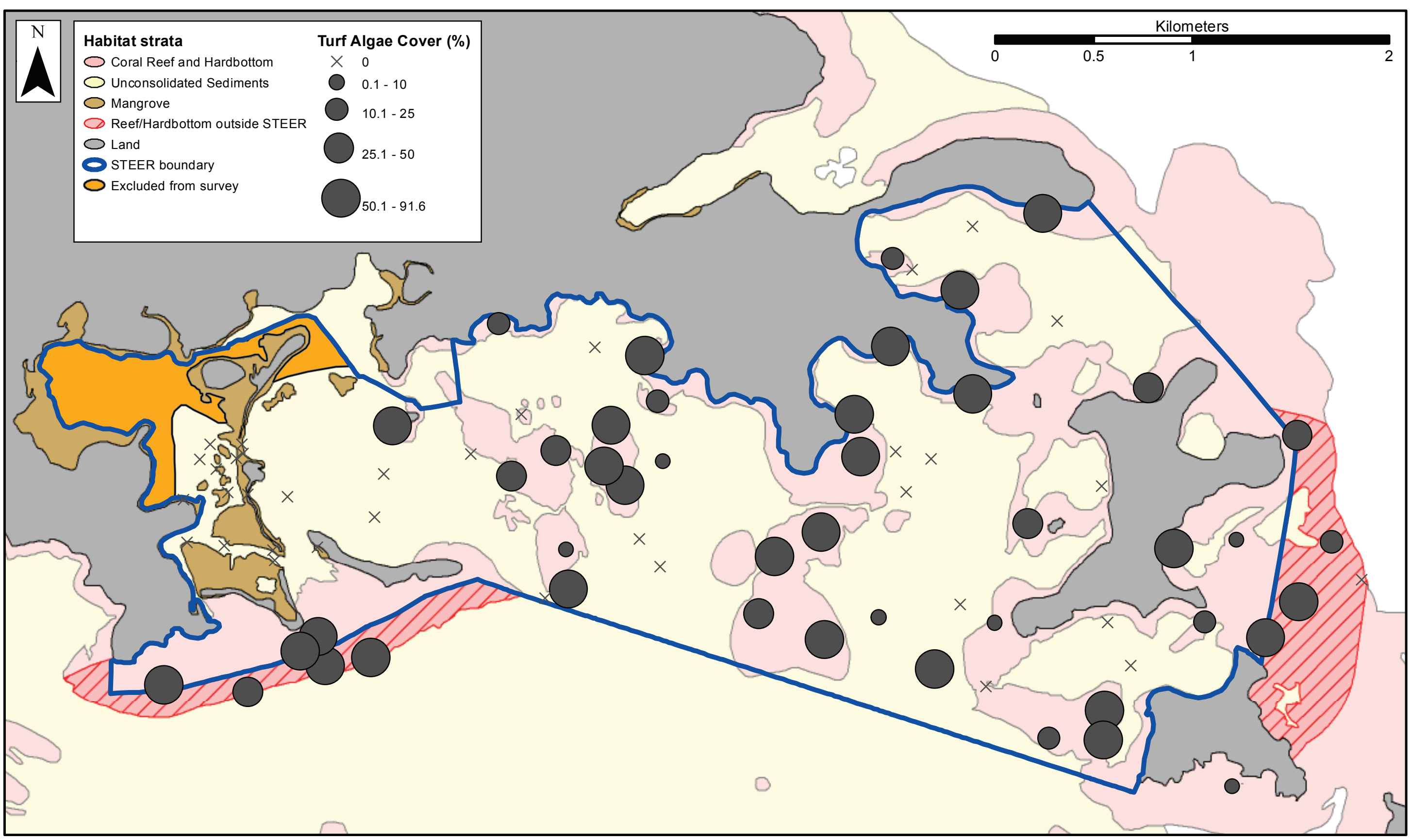


Figure 16. Percent turf algae cover.

widely across STEER (0-91.56%), with an overall average cover of 27.53 ± 3.57%, but were seen almost exclusively on hardbottom habitats (49.78 ± 4.11%, Figure 16). Filamentous algae and cyanobacteria (FA & CB) were documented at only 17 out of the 80 sites surveyed with an overall average of 0.99 ± 0.77%. This algal morphotype was found almost exclusively on hardbottom habitats (Figure 17). The site with the highest observed CB & FA cover was located in the western portion of Nazareth Bay. In general, similar levels of algae were observed at the hardbottom sites outside STEER.

Seagrass was observed on unconsolidated sediments and mangrove areas, as well as some sand gaps interspersed among hardbottom. Percent cover varied from 0-99% (Figure 18). The absence of seagrass at only four of the 26 soft sediment sites is more informative than the pattern of seagrass presence: two sites devoid of seagrass border Mangrove lagoon and the other two sites are located in a channel through mangrove habitat that is near the Bovoni landfill. All four sites are documented as having only macroalgal cover: the two near the lagoon with macroalgal cover of 90% and 100%, the other two near the landfill had 32% and 46%. The majority of seagrass was recorded in unconsolidated sediment habitats: *Syringodium filiforme* (18.14 ± 4.76%) and *Thalassia testudinum* (13.04 ± 3.98%) were the most common species recorded with a very small amount of *Halodule wrightii* (0.21 ± 0.12, Figure 19). All three species were found on unconsolidated sediments, *Halodule* and *Thalassia* were both seen in mangrove habitats, and a minor amount of *Thalassia* was documented in sand patches at a few hardbottom sites. Notably, *Halophila stipulacea*, an introduced species native to the Red Sea (Willette et al. 2014) was not observed in this survey, although it has been previously documented in STEER by other researchers (T. Smith, UVI, personal communication).

Macroinvertebrates

A total of seven spiny lobsters (*Panulirus argus*) were observed at only three sites. Five lobsters were documented in a mangrove fringe near the Mangrove Lagoon, one lobster was spotted outside the STEER along the southwest reef tract near Long Point, and one lobster was seen on hardbottom near Little St. James in the southeast corner of the reserve.

Long-spined urchins (*Diadema antillarum*) were reported at nine sites, all hardbottom substrates, ranging from 2 to an impressive 139 individuals (Figure 20). The top three sites for urchin abundance, which accounted for 86.5% of the urchins documented (16-139 / 100 m^2), were all located close to shore in Cowpet Bay.

Immature queen conch (*Strombus gigas*) were documented at 13 sites (7 unconsolidated sediments, 4 hardbottom, 2 mangrove, Figure 21) throughout the STEER and at one site outside the boundaries. Density ranged from 1-99 individuals / 100 m^2 with the highest densities observed

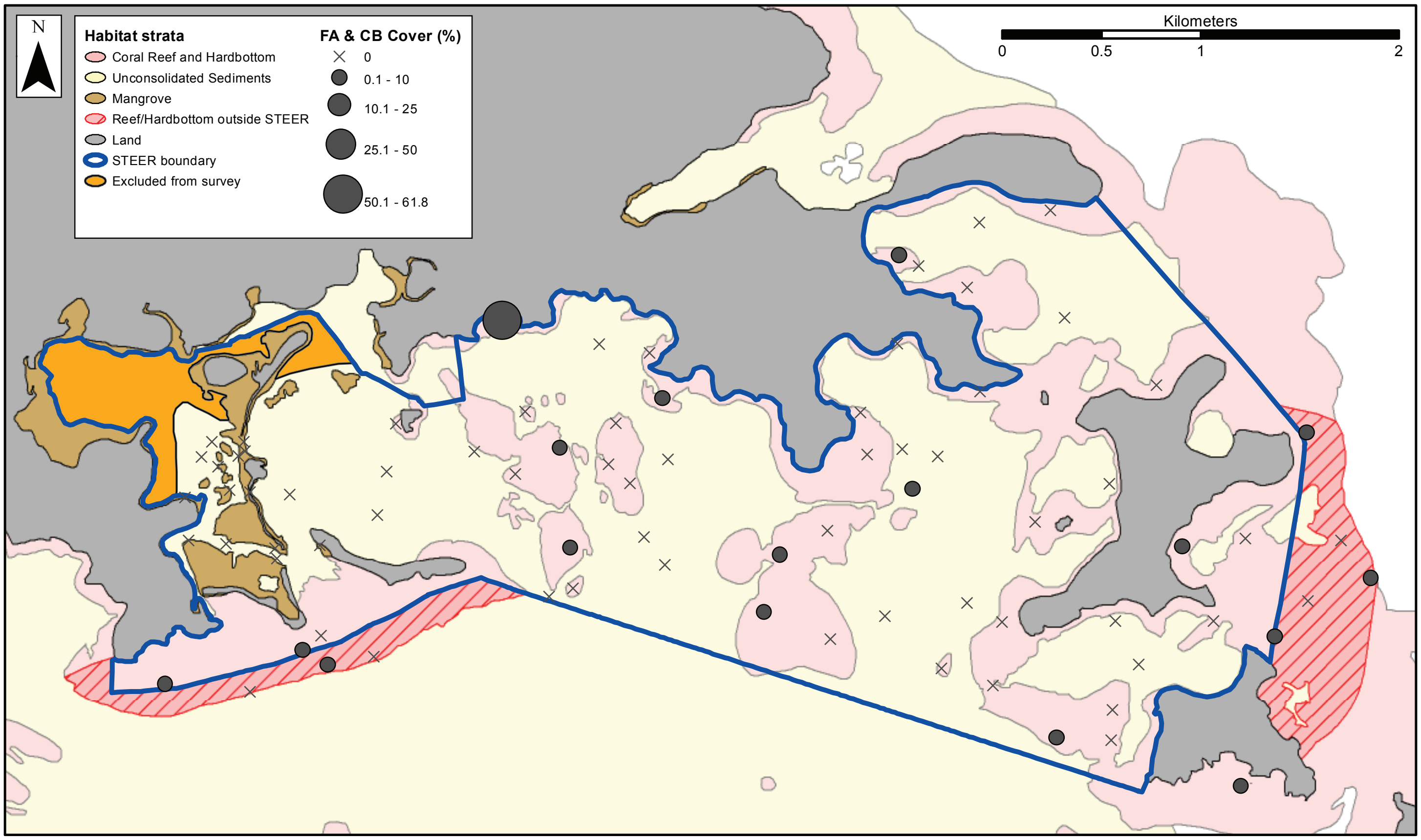


Figure 17. Percent filamentous algae and cyanobacteria (FA & CB) cover.

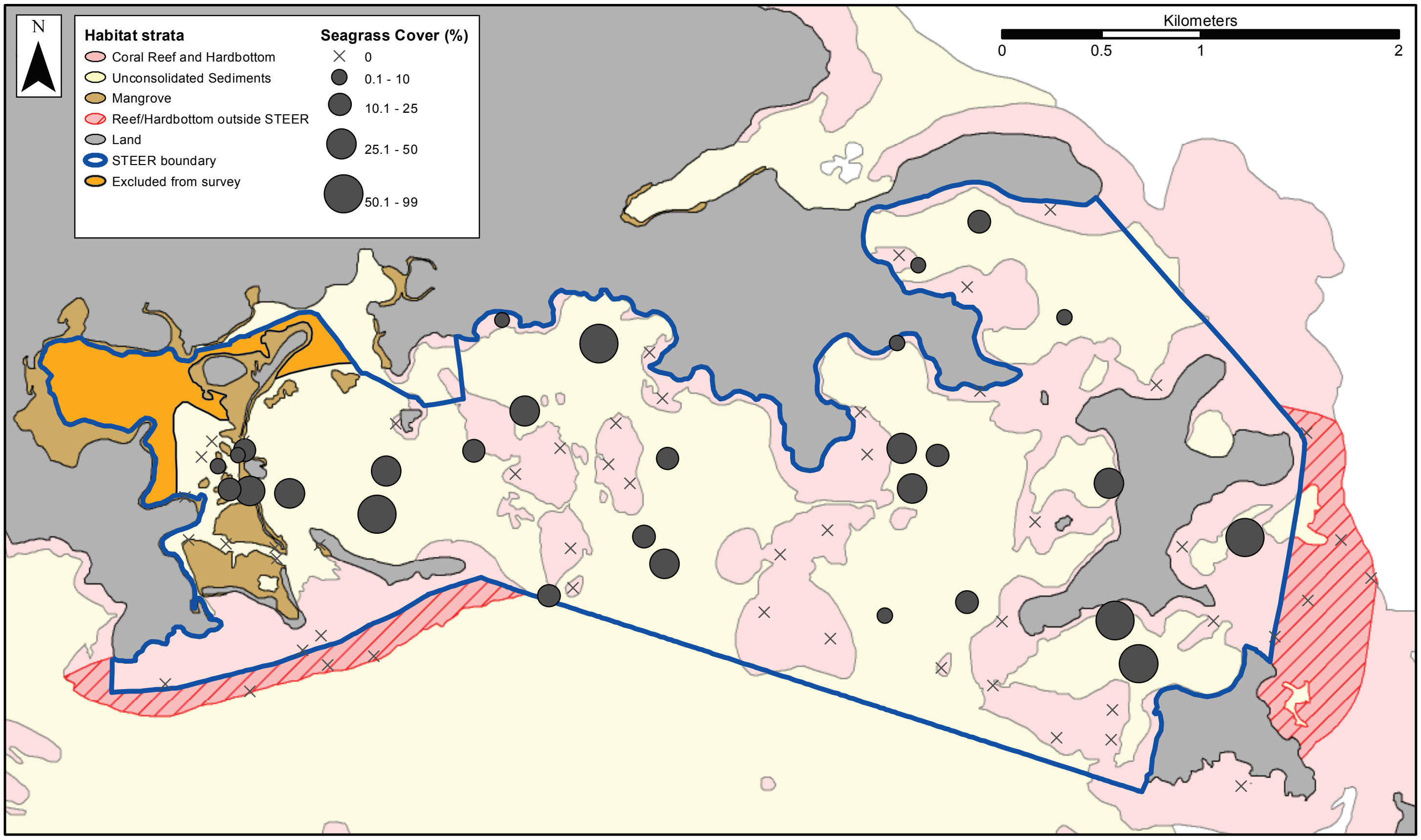


Figure 18. Percent seagrass cover.

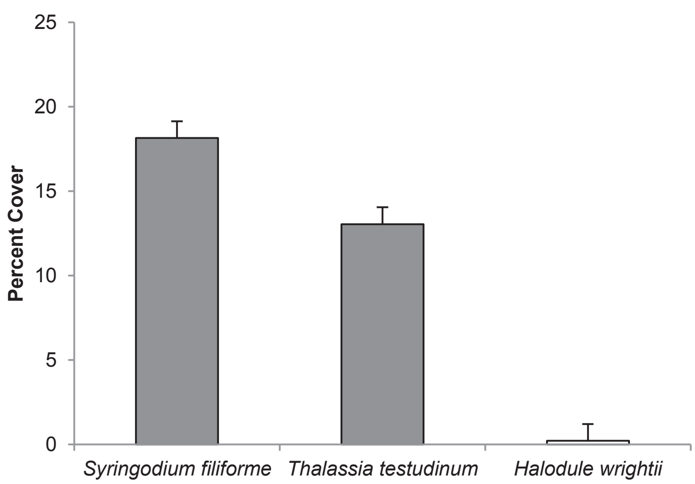


Figure 19. Percent cover of seagrass by species on unconsolidated sediments.

Table 2. Type, number and type of fouling organisms on marine debris items found during STEER transects.

Debris type	Total number	Colonized by
Trap float	1	Uncolonized
Fishing leader	1	Uncolonized
Wood	1	Sponge
Ladder	1	Macroalgae
Chain	1	Macroalgae
Glass bottle	5	Macroalgae, invertebrates
Paper	1	Macroalgae
Plastic bag	2	Uncolonized
Clothing	1	Sponge
Barrel	1	Uncolonized
Sunglasses	1	Uncolonized

at sites in the eastern portion of the study area. Mature queen conch were observed in much lower numbers (0-7 individuals / 100 m^2, Figure 21) at 11 sites (6 soft bottom, 3 hardbottom, 2 mangrove) dispersed inside and outside the reserve. Mature conch were observed primarily at sites where immature conch were also present.

Marine debris

Marine debris was detected at 16 sites in all three bottom types (Table 2). Debris items were found primarily close to shore or in the southern part of Benner Bay (Figure 22). Types of gear varied from fishing leader wire to general trash items such as bottles and plastic bags.

Fish

Community metrics

The fish community observed in the 2012 survey consisted of 36 taxonomic families and 125 species within STEER (Appendix 1). An additional two families, represented by six species, were observed at the sites located in adjacent hardbottom areas outside STEER. Fish species richness

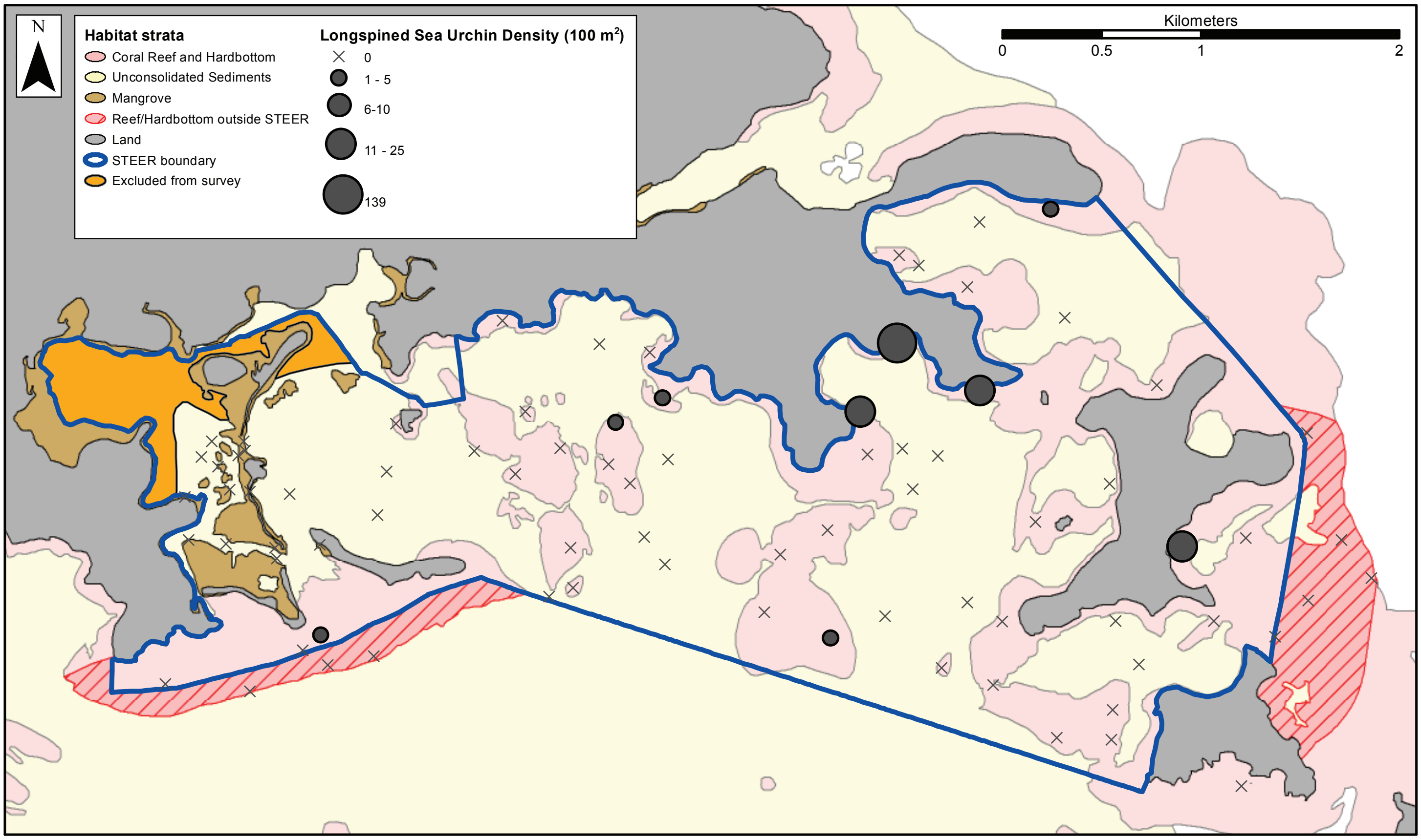


Figure 20. Density of longspined sea urchin (*Diadema antillarum*).

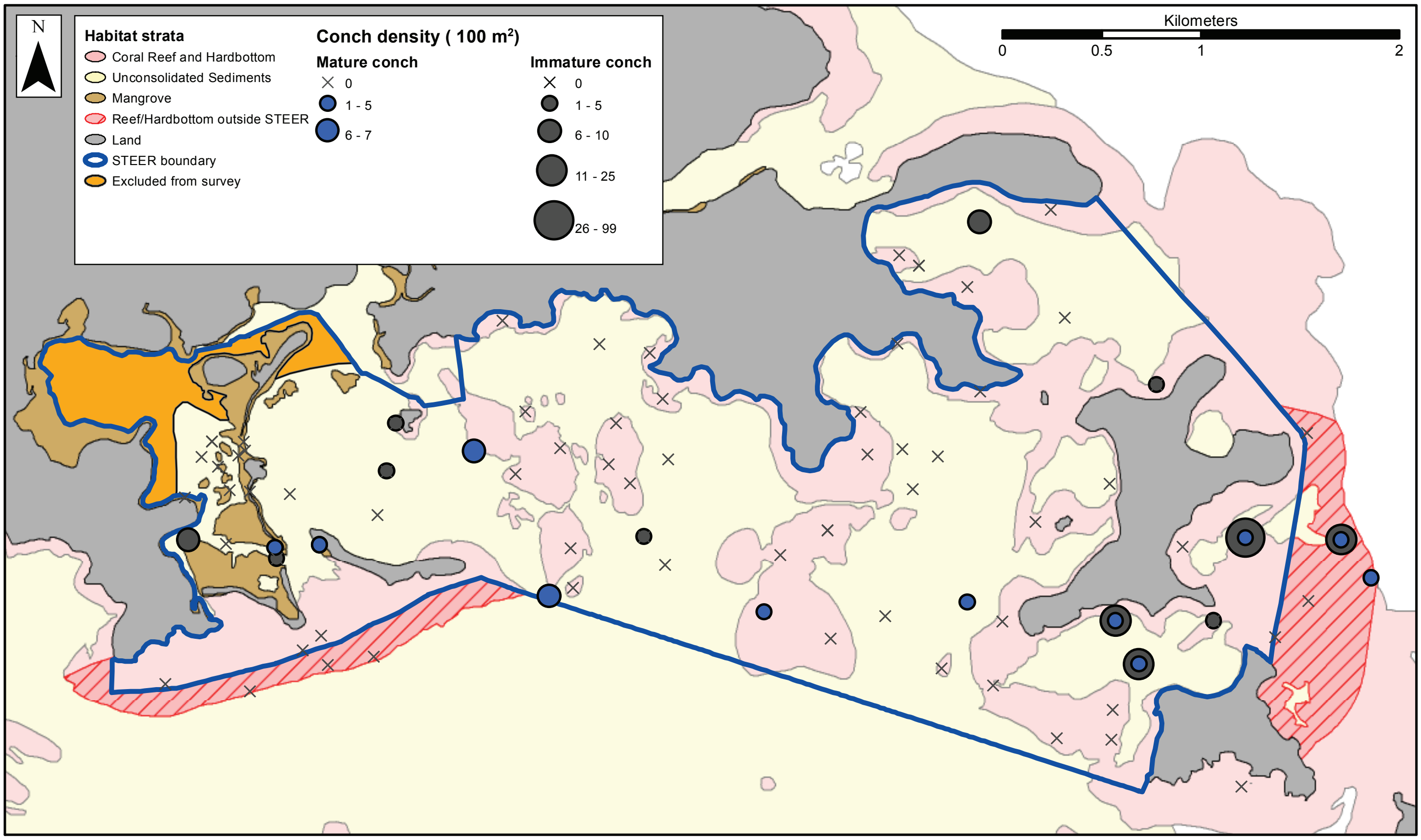


Figure 21. Density of mature and immature Queen conch (*Eustrombus gigas*).

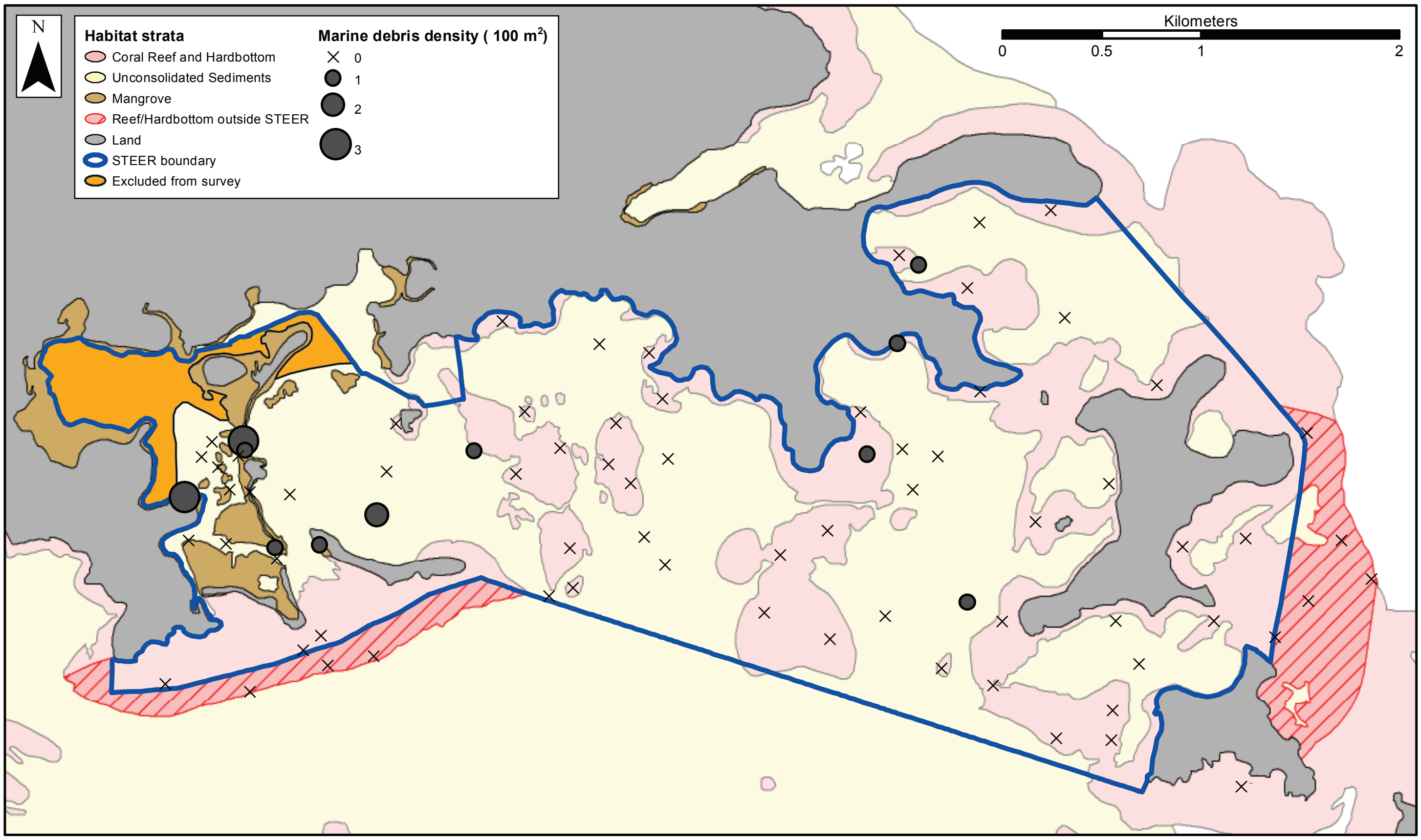


Figure 22. Density of total observed marine debris.

ranged from 1 to 39 species per site (100 m^2). Mean richness was highest on hardbottom, with similar levels inside and outside STEER, followed by mangrove (Figure 23a, Figure 24). The two surveys with 39 observed species were conducted on hardbottom near Cow and Calf Rocks and outside STEER on the southwest reef tract, respectively. Shannon-Weiner diversity, which is a product of richness and evenness, followed similar trends, with highest diversity on hardbottom and intermediate levels in mangrove (Figure 23b, Figure 25). Unconsolidated sediments were typified by lower species richness and diversity.

Mangrove sites exhibited the highest mean total fish density (Figure 23c, Figure 26), whereas mean levels of biomass were highest on hardbottom (Figure 23d, Figure 27). At many mangrove locations, the high density levels were largely due to the presence of schooling silversides and herring (Families Atherinidae and Clupeidae) and small juvenile grunts (Family Haemulidae). The hardbottom site with the highest density, located in Great Bay, was dominated by small gobies. Locations with both high density and biomass included sites on hardbottom adjacent to Cow and Calf Rocks, a patch reef southwest of Great St. James Island, a mangrove site near the false entrance to Mangrove Lagoon, and on the southwest reef tract near Long Point, outside the STEER boundary. The survey with the third greatest biomass level, located on a nearshore reef in Nazareth Bay, was characterized by the presence of several large-bodied parrotfish. Lowest density and biomass was typically observed on unconsolidated sediments, particularly at unvegetated sites.

Biomass and abundance were unevenly distributed among trophic groups (Figure 28). On all habitats, invertivores (e.g., grunts, butterfly fishes) and herbivores (e.g., parrotfish, damselfish) were the most numerically abundant, while piscivores (e.g., snappers, groupers) constituted a smaller percentage. Planktivores (e.g., herring) accounted for over 20% of the abundance in mangroves, but due to their small size only 1% of the biomass. Conversely, piscivores accounted for a higher proportion of the total fish biomass across all habitats, particularly on unconsolidated sediments where the trophic group accounted for three-quarters of the observed biomass, largely due to the presence of several jacks and occasional barracuda.

The highest mean density and biomass of piscivores occurred in mangrove surveys, although biomass was more equitable across bottom types. Piscivores were most frequent in Mangrove Lagoon, on the southwest reef tract near Long Point, east of Cow and Calf Rocks and in the central portion of Jersey Bay. The site east of Cow and Calf Rocks exhibited the highest observed biomass of piscivores. They were notably absent from the western portion of Benner Bay and most hardbottom surveys east of Great St. James, including outside STEER boundaries (Figure 29).

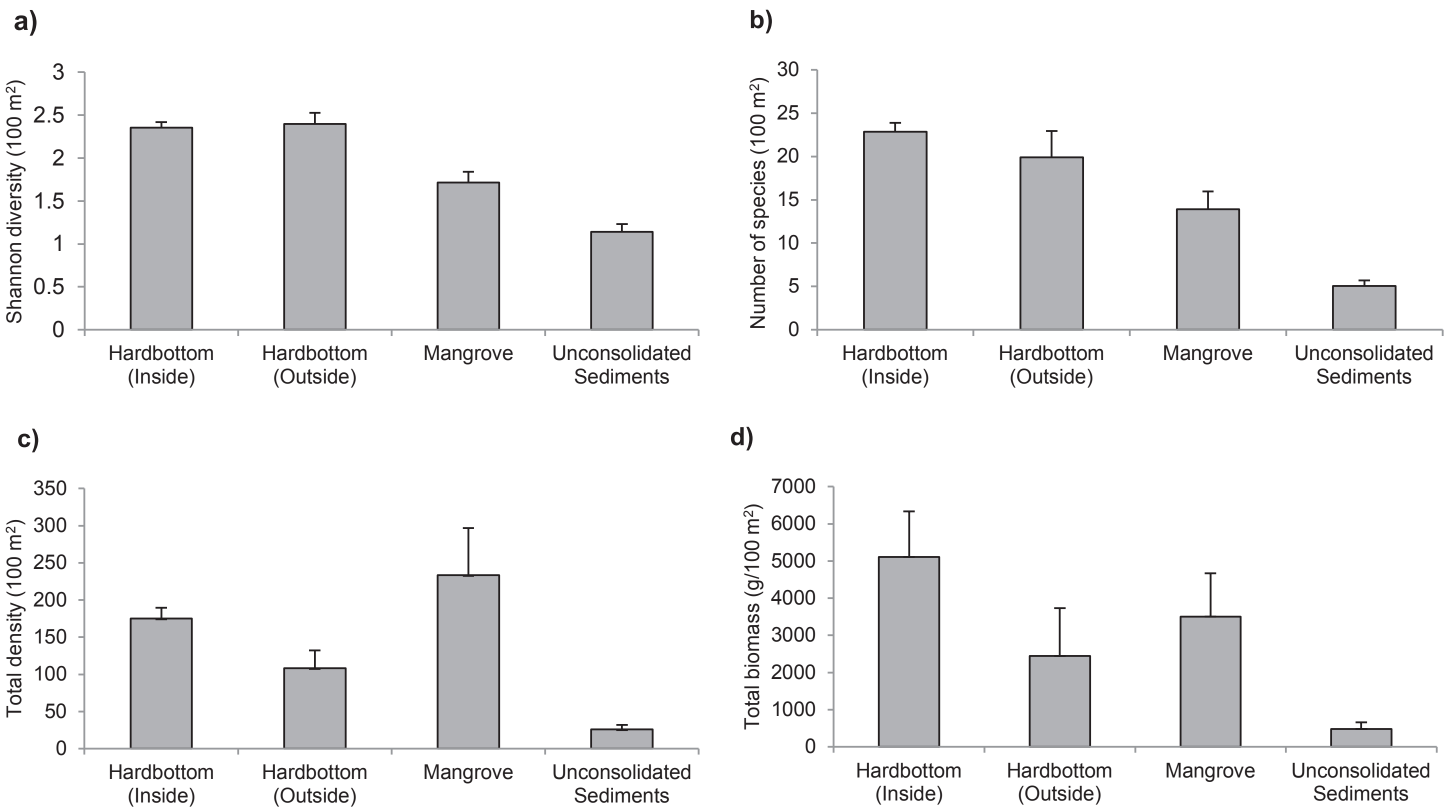


Figure 23. Mean (±SE) fish species a) richness, b) Shannon diversity, c) density, and d) biomass by habitat type.

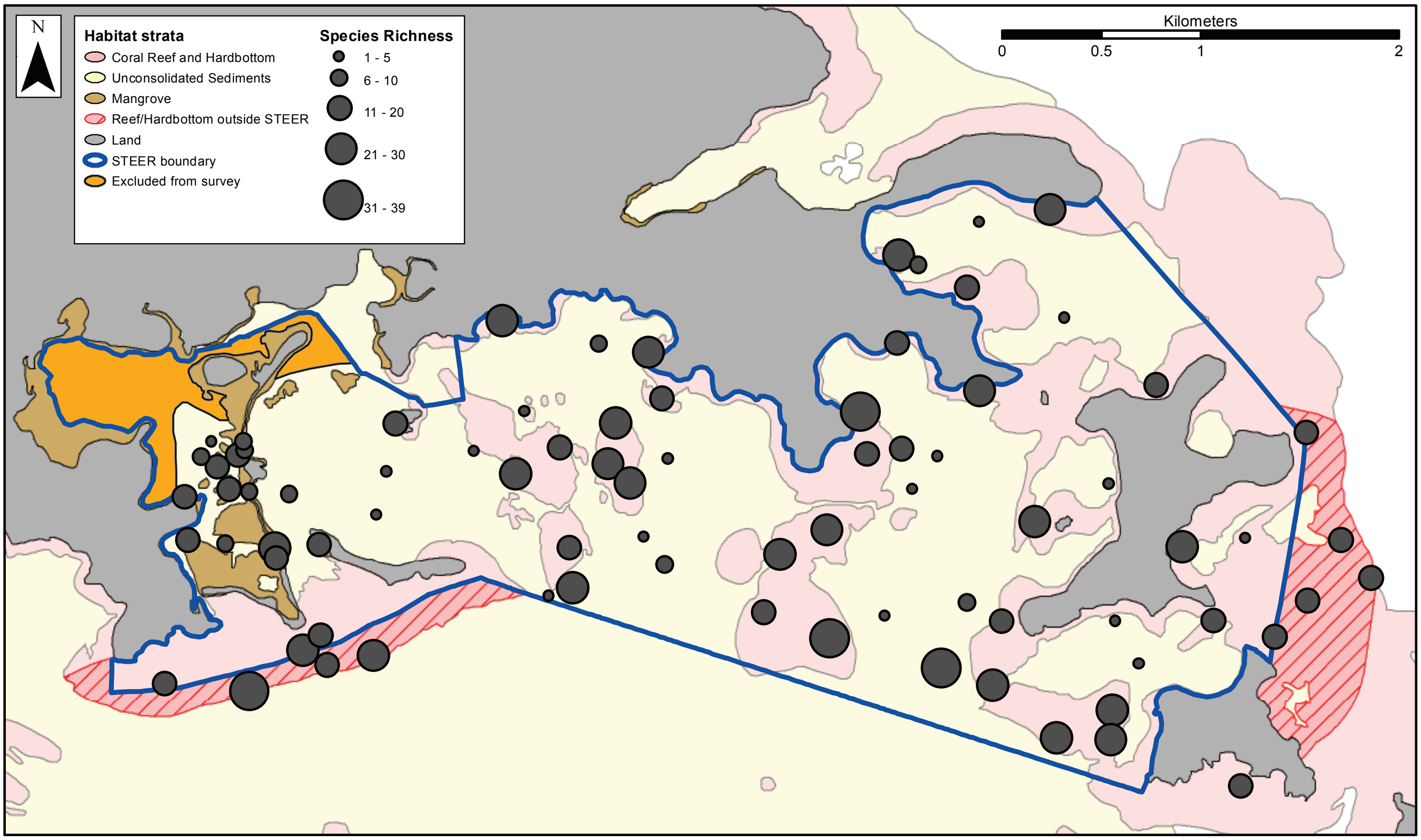


Figure 24. Fish species richness.

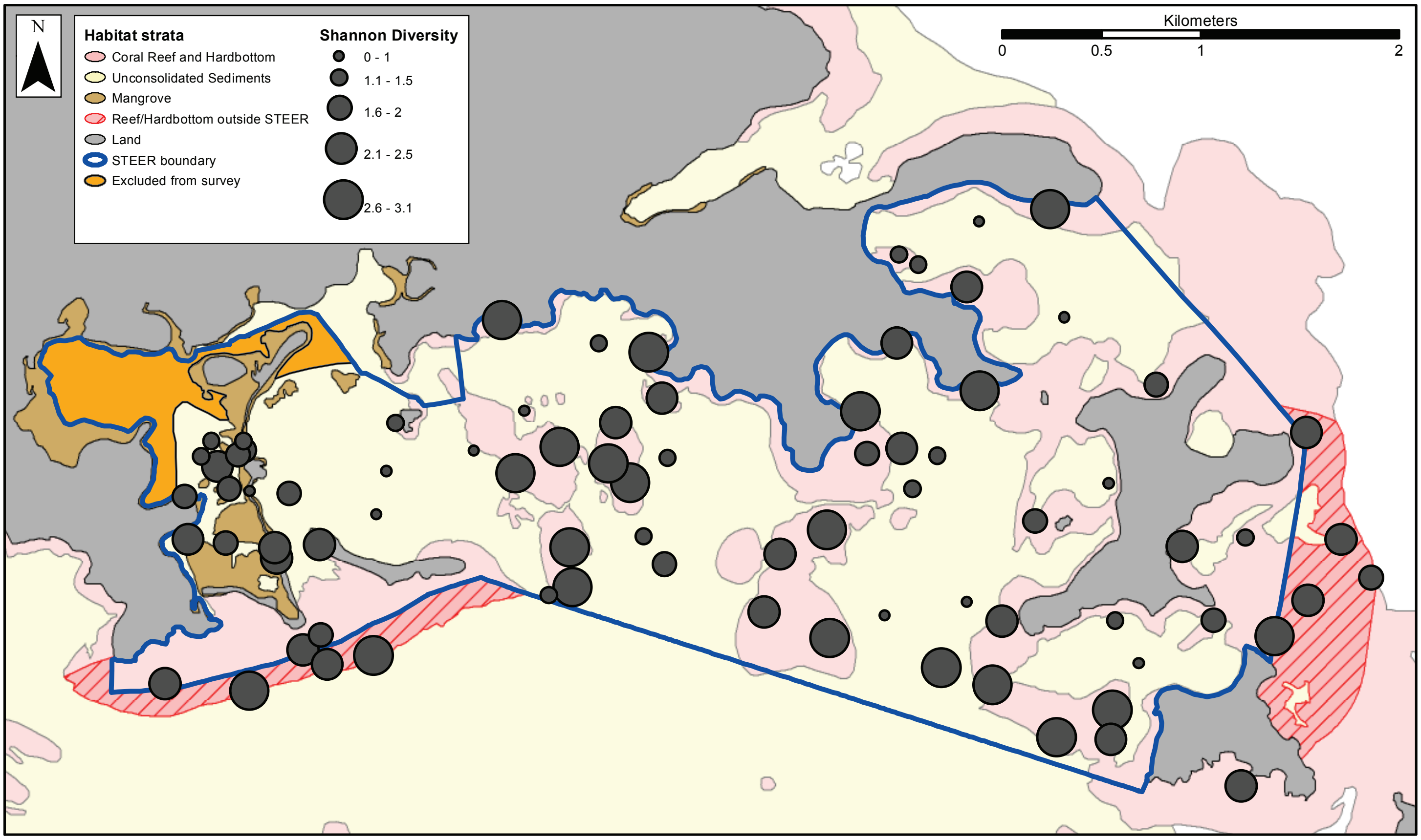


Figure 25. Fish species diversity.

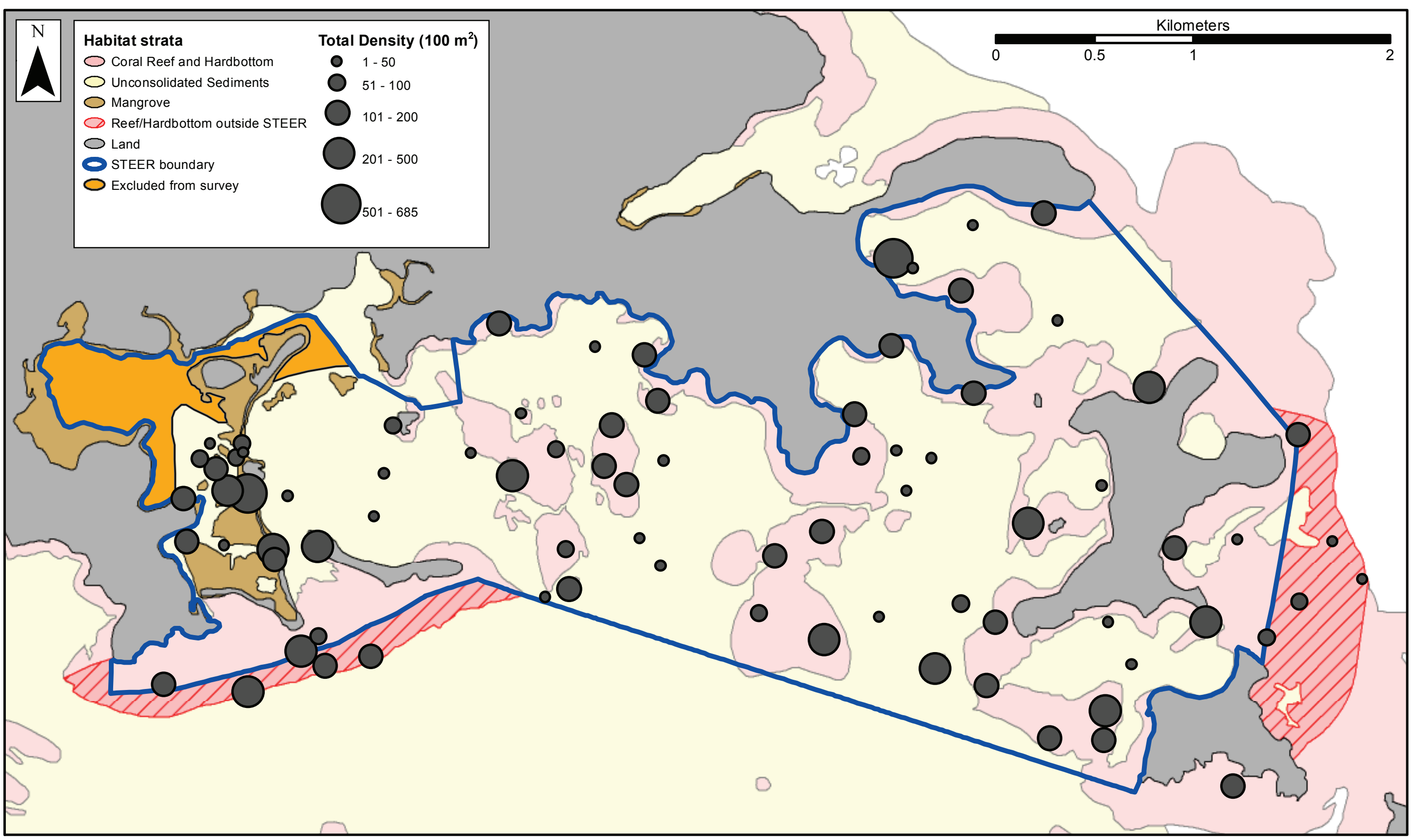


Figure 26. Total fish density.

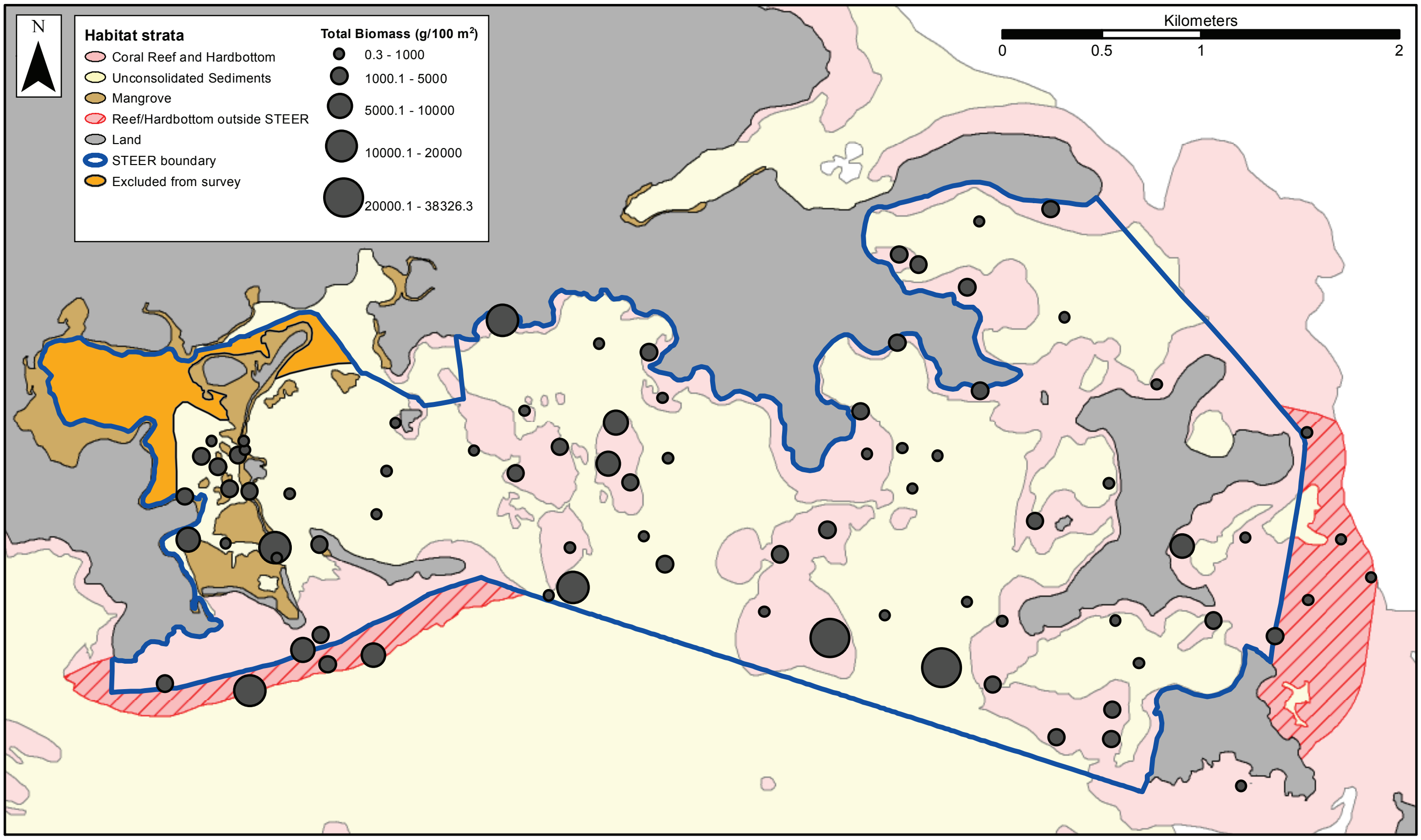


Figure 27. Total fish biomass.

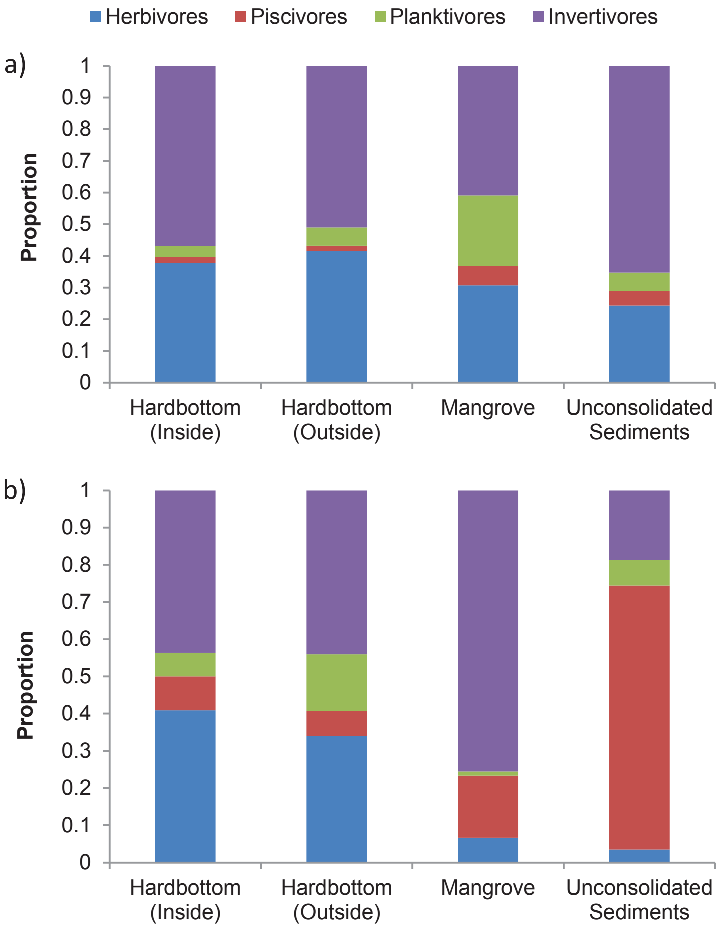


Figure 28. Proportional a) abundance and b) biomass of trophic groups across habitat types.

Family and species composition differed across bottom types (Table 3, Table 4). Fishes of the Family Labridae (wrasses) accounted for over a quarter of the total number of fish on hardbottom, followed by Scaridae (parrotfish), Pomacentridae (Damselfish), Gobiidae (gobies) and Acanthuridae (surgeonfishes). The most abundant species were members of these families (Table 3), with labrid species comprising two of the top five most abundant species on hardbottom both inside and outside STEER (*Thalassoma bifasciatum*, *Halichoeres bivittatus*, *H. garnoti*). Scaridae accounted for the highest proportion of biomass on hardbottom within STEER at 21%, followed by Acanthuridae, Haemulidae (grunts), and Lutjanidae (snappers). Two surgeonfish species, ocean surgeonfish (*Acanthurus bahianus*) and blue tang (*A. coeruleus*), ranked first and third in total biomass on hardbottom within STEER. Two snapper species, gray snapper (*Lutjanus griseus*) and yellowtail snapper (*Ocyurus chrysurus*), were also in the top five. While density proportions were similar in hardbottom surveys outside STEER, proportional biomass differed slightly, with snappers comprising 26% of the observed biomass. Yellowtail snapper accounted for the most biomass on hardbottom outside STEER, with another snapper species, lane snapper (*L. synagris*), also within the top five. The Family Serranidae (seabasses and groupers) comprised a small percent of the biomass on hardbottom both inside and outside STEER (4.4% and 7.6%, respectively). Although the invasive lionfish, *Pterois volitans*, did not occur in any

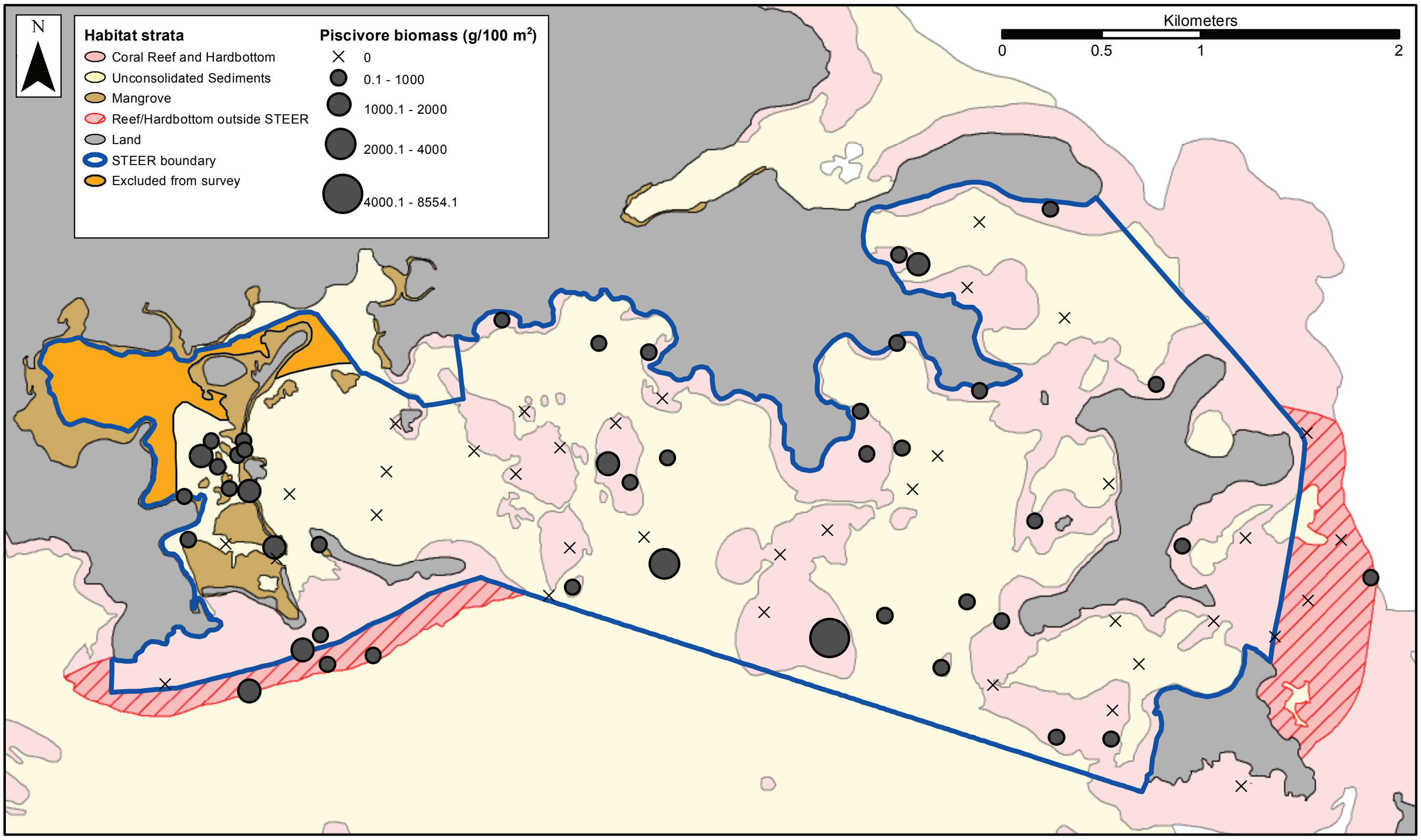


Figure 29. Piscivore biomass.

survey transects, one individual was anecdotally sighted at a site near Christmas Cove.

In mangrove habitat, over 45% of the total density was comprised of small bodied fishes of the families Atherinidae (*Atherinomorus* sp.) and Clupeidae (*Jenkinsia* sp.). The Family Haemulidae was the third most abundant, with juvenile unidentified grunts (*Haemulon* sp.), bluestriped grunt (*H. sciurus*), French grunt (*H. flavolineatum*) accounting for the remaining species within the top five. In contrast, snappers, which were the fifth most abundant family, accounted for over half of the biomass surveyed in mangroves, with gray snapper comprising nearly 40% of the total biomass. Another snapper species, the schoolmaster (*L. apodus*), and two grunt species (*H. sciurus* and *H. flavolineatum*), were in the top five for biomass, as was the nurse shark *Ginglymostoma cirratum*.

On unconsolidated sediments, Labridae accounted for 37.5% of the total density, but only 7% of the biomass. The two most abundant species were the labrids, specifically slippery dick (*Halichoeres bivittatus*) and rosy razorfish (*Xyrichtys martinicensis*). Larger bodied jacks (Family Carangidae) and barracuda (Family Sphyraenidae) accounted for 36.6% and 28.6% of biomass on unconsolidated sediments, respectively. Species within these two families accounted for the top three in proportional biomass.

Six species that were not observed in surveys within STEER were documented at hardbottom sites outside STEER. These included the redspotted hawkfish (*Amblycirrhitus pinos*), trumpetfish (*Aulostomus maculatus*), glasseye snapper (*Heteropriacanthus cruentatus*), hogfish (*Lachnolaimus maximus*), yellowmouth grouper (*Mycteroperca interstitialis*), and longjaw squirrelfish (*Neoniphon marianus*).

The nMDS and ANOSIM analyses further indicate that fish assemblages in STEER differ by bottom type. There was a clear separation of fish communities, based on fish density data, between hardbottom, unconsolidated sediment, and mangrove surveys (Figure 30a). Mangrove and hardbottom sites tended to be highly clustered, indicating a high degree of similarity in species composition among sites within each respective habitat type. In contrast, unconsolidated sediment sites tended to be more dispersed, indicating more dissimilarity among sites within this habitat type. While sites within the unconsolidated sediments bottom type were generally characterized by low overall abundance, they often varied in their species composition. Within coral reef and hardbottom, there was no distinct separation of sites located inside versus outside the STEER. The results of the ANOSIM test also indicate that there was a statistically significant difference in community composition among the three bottom types, and that the groups were well-separated (Global R= 0.757, $p<0.001$). Pairwise comparisons indicated high dissimilarity between hardbottom and unconsolidated sediments and

Table 3. Top five families in abundance and total biomass, shown as percent of total, by habitat strata.

Hardbottom (Inside)			
Family	**Density**	**Family**	**Biomass**
Labridae	27.0%	Scaridae	21.0%
Scaridae	15.8%	Acanthuridae	18.3%
Pomacentridae	15.3%	Haemulidae	18.0%
Gobiidae	13.8%	Lutjanidae	17.7%
Acanthuridae	13.5%	Serranidae	4.4%
Hardbottom (Outside)			
Family	**Density**	**Family**	**Biomass**
Labridae	27.8%	Lutjanidae	26.1%
Scaridae	20.7%	Scaridae	22.8%
Pomacentridae	15.9%	Pomacanthidae	8.6%
Acanthuridae	9.5%	Acanthuridae	8.3%
Gobiidae	9.1%	Serranidae	7.6%
Mangrove			
Family	**Density**	**Family**	**Biomass**
Atherinidae	23.1%	Lutjanidae	51.5%
Haemulidae	22.3%	Haemulidae	21.7%
Clupeidae	21.2%	Ginglymostomatidae	8.2%
Lutjanidae	13.1%	Scaridae	4.4%
Gerreidae	8.2%	Sphyraenidae	3.7%
Unconsolidated Sediments			
Family	**Density**	**Family**	**Biomass**
Labridae	37.5%	Carangidae	36.8%
Scaridae	22.2%	Sphyraenidae	28.6%
Gerreidae	10.3%	Labridae	7.4%
Lutjanidae	7.8%	Echeneidae	6.2%
Haemulidae	7.7%	Scombridae	5.2%

between hardbottom and mangrove (Table 5). The top five species that contributed to dissimilarity between hardbottom and mangrove strata, as determined by the SIMPER analysis, included small herring (*Jenkinsia sp.*), flagfin mojara (*Eucinostomus melanopterus*), and schoolmaster (*Lutjanus apodus*), which were more common in mangroves, and bluehead wrasse (*T. bifasciatum*), and ocean surgeonfish (*A. bahianus*), which were more common on hardbottom. The top five species contributing to the dissimilarity between hardbottom and unconsolidated sediments strata included wrasse, surgeonfish, parrotfish, and damselfish species that were all more abundant on hardbottom than unconsolidated sediments (Table 5). One of the hardbottom surveys outside STEER showed similarity with the surveys on unconsolidated sediments by its location on the nMDS plot. This site, located east of Great St. James Island, was characterized by rubble habitat and low overall abundance. The R statistic for the pair of mangrove and unconsolidated sediments was lower indicating while the two groups were still clearly different, there was some overlap in species composition. The top species contributing to the dissimilarity between the two strata were all more abundant on mangrove and included small herring (*Jenkinsia sp.*), schoolmaster (*L. apodus*), gray snapper (*L. grisius*), bluestriped grunt (*H. sciurus*), and flagfin mojarra (*E. melanopterus*).

Table 4. Top five species in abundance and total biomass, shown as percent of total, by habitat strata

Hardbottom (Inside)			
Species	**Density**	**Species**	**Biomass**
Thalassoma bifasciatum	15.9%	*Acanthurus bahianus*	8.2%
Coryphopterus personatus/hyalinus	12.5%	*Haemulon flavolineatum*	7.6%
Acanthurus bahianus	7.9%	*Acanthurus coeruleus*	6.0%
Halichoeres bivittatus	6.3%	*Lutjanus griseus*	5.9%
Scarus iseri	5.7%	*Ocyurus chrysurus*	5.2%
Hardbottom (Outside)			
Species	**Density**	**Species**	**Biomass**
Thalassoma bifasciatum	13.3%	*Ocyurus chrysurus*	14.0%
Stegastes partitus	9.3%	*Sparisoma viride*	11.7%
Halichoeres garnoti	6.9%	*Lutjanus synagris*	9.2%
Coryphopterus personatus/hyalinus	6.8%	*Pomacanthus arcuatus*	5.9%
Sparisoma aurofrenatum	6.5%	*Mulloidichthys martinicus*	5.4%
Mangrove			
Species	**Density**	**Species**	**Biomass**
Atherinomorus species	23.1%	*Lutjanus griseus*	39.3%
Jenkinsia species	21.2%	*Haemulon sciurus*	13.6%
Haemulon species	8.0%	*Ginglymostoma cirratum*	8.2%
Haemulon sciurus	7.1%	*Lutjanus apodus*	7.5%
Haemulon flavolineatum	6.8%	*Haemulon flavolineatum*	4.3%
Unconsolidated Sediments			
Species	**Density**	**Species**	**Biomass**
Xyrichtys martinicensis	18.1%	*Sphyraena barracuda*	28.6%
Halichoeres bivittatus	16.2%	*Caranx crysos*	24.1%
Gerres cinereus	7.5%	*Carangoides bartholomaei*	10.2%
Sparisoma radians	6.7%	*Echeneis naucrates*	6.2%
Ocyurus chrysurus	4.6%	*Scomberomorus regalis*	5.2%

Using species biomass resulted in a similar MDS configuration (Figure 30b) and ANOSIM results as for species density, albeit with a slightly lower Global R (R =

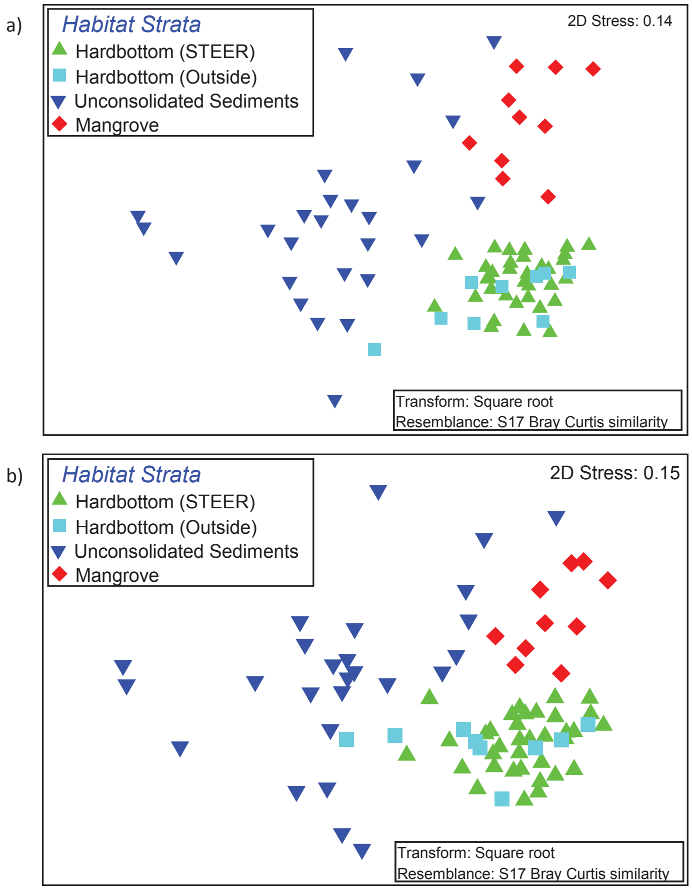


Figure 30. Non-metric multidimensional (nMDS) scaling ordination based on between site similarity composition using species a) density and b) biomass data. Sites are color-coded by habitat type and study area.

0.661, p<0.001). Pairwise comparisons showed hardbottom and unconsolidated sediments were well separated (Table 5). The results of the SIMPER analysis indicated that the top species contributing to the dissimilarity between these two strata included yellowtail snapper and two species of surgeonfish and parrotfish. The R value for the hardbottom-mangrove pairwise comparison was slightly lower than with the abundance data (R = 0.662) indicating a slightly higher degree of similarity but still overall clearly different in terms of species biomass assemblage. Similar to the ANOSIM analysis using density data, mangrove and unconsolidated sediments showed less separation than the other paired habitats.

Select families and species

Groupers (Serranidae)

Groupers (*Cephalopholis*, *Epinephelus*, and *Mycteroperca* spp.) were infrequent, primarily small in size, and were exclusively associated with hardbottom (Figure 31). Most grouper individuals belonged to two species: graysby (*Cephalopholis cruentata*), and red hind (*Epinephelus guttatus*). Notably, only one coney (*Cephalopholis fulva*), typically a common grouper species in the Caribbean, was observed. Species in the larger-bodied genus *Mycteroperca* were largely absent from the survey, with the exception of one yellowmouth grouper (*Mycteroperca interstitialis*) documented at a site outside STEER on the southwest reef complex near Long Point.

Table 5. Pairwise Analysis of Similarities (ANOSIM) comparisons between habitat types based on fish species density and biomass data, and list of top five species contributing to the dissimilarity from the SIMPER analysis. Species are listed in decreasing order of percent contribution to the average dissimilarity. The R statistic ranges between 0 and 1 and represents whether pairs of habitats are well separated (closer to 1) or barely separable (closer to 0). Species are listed in decreasing order of percent contribution to the average dissimilarity.

	Species Density			Species Biomass		
Group	**R**	**p-value**	**Top species (% contribution to dissimilarity)**	**R**	**p-value**	**Top species (% contribution to dissimilarity)**
Hardbottom, Mangrove	0.894	0.001	*Jenkinsia* sp. (6.02%)	0.662	0.001	*Lutjanus griseus* (9.96%)
			Thalassoma bifasciatum (5.44%)			*Haemulon sciurus* (5.89%)
			Eucinostomus melanopterus (4.15%)			*Lutjanus apodus* (5.18%)
			Acanthurus bahianus (3.92%)			*Acanthurus bahianus* (5.03%)
			Lutjanus apodus (3.92%)			*Acanthurus coeruleus* (3.88%)
Hardbottom, Unconsolidated Sediments	0.772	0.001	*Thalassoma bifasciatum* (8.42%)	0.724	0.001	*Acanthurus bahianus* (8.07%)
			Acanthurus bahianus (5.88%)			*Acanthurus coeruleus* (5.73%)
			Halichoeres bivittatus (4.51%)			*Sparisoma aurofrenatum* (4.88%)
			Sparisoma aurofrenatum (4.25%)			*Ocyurus chrysurus* (3.86%)
			Stegastes partitus (4.17%)			*Sparisoma viride* (3.46%)
Unconsolidated Sediments, Mangrove	0.382	0.001	*Jenkinsia* sp. (9.55%)	0.327	0.001	*Lutjanus griseus* (16.93%)
			Lutjanus apodus (7.61%)			*Haemulon sciurus* (10.06%)
			Eucinostomus melanopterus (7.45%)			*Lutjanus apodus* (9.81%)
			Haemulon sciurus (6.57%)			*Sphyraena barracuda* (6.80%)
			Lutjanus griseus (6.25%)			*Haemulon* sp. (4.99%)

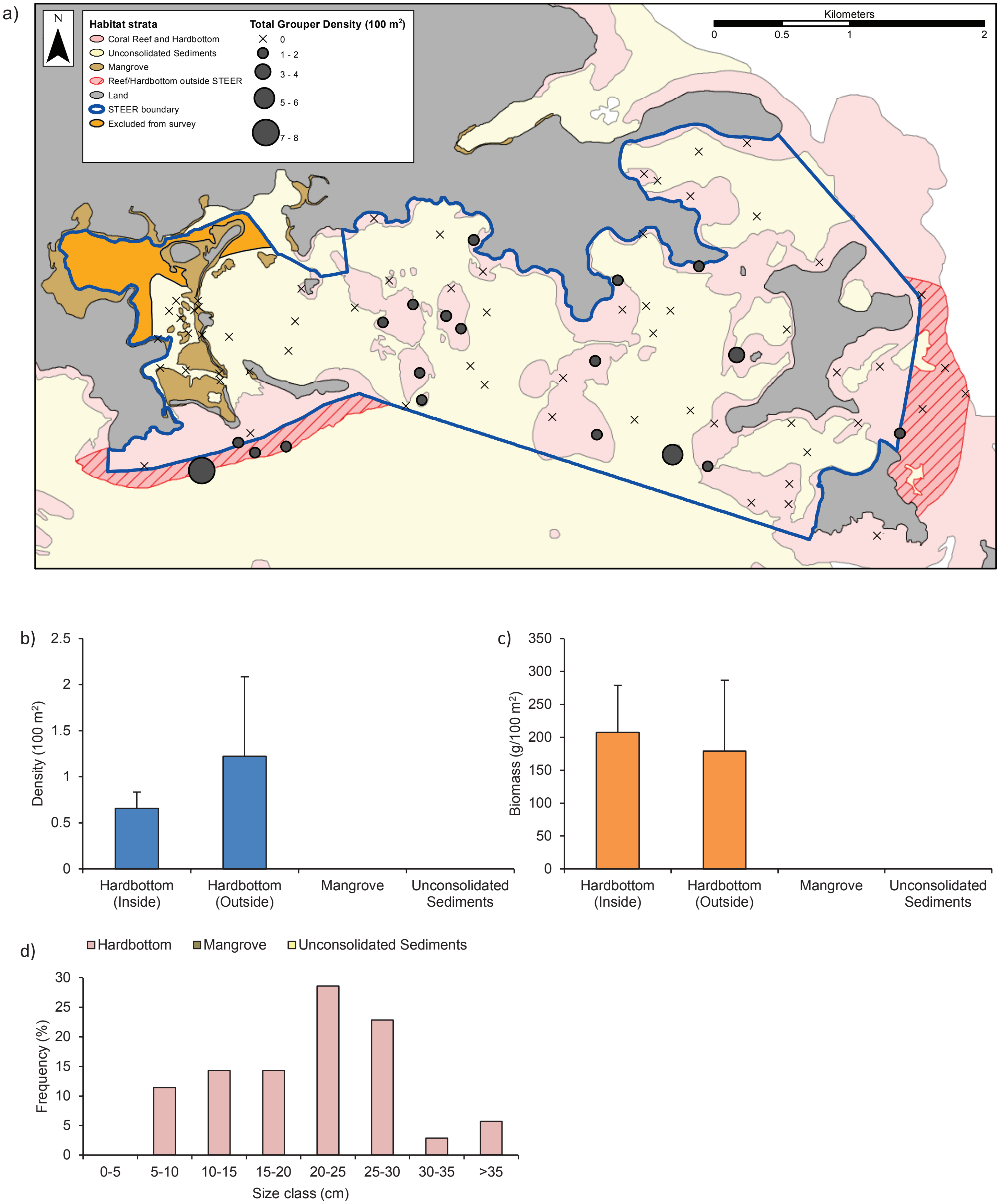


Figure 31. Grouper (Family Serranidae) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

Red hind was the most abundant grouper species observed in the study, occurring in 13% of surveys within STEER. The species was also sighted in three surveys outside of STEER, east of Great St. James and south of Patricia Cay/Mangrove Lagoon (Figure 32). The species was found exclusively on hardbottom, including patch reefs, nearshore rocky areas, and high rugosity aggregate reef. The site with the highest density was a patch reef southwest of Great St. James Island. The majority of observed individuals were small adults, although two 40 cm fish were also seen (Figure 32d).

Graysby showed a similar distribution pattern and habitat affiliation as red hind. The species occurred in 11% of transects within STEER and in two surveys outside STEER. Mean density was higher, but more variable, on hardbottom outside STEER compared to inside, primarily due to the presence of six individuals at one site (Figure 33). The majority of individuals were small adults 15-30 cm in length (Figure 33d).

Snappers (Lutjanidae)

Snappers were detected across STEER in all investigated habitats but were most abundant in mangroves (Figure 34). However, as described below, distribution varied by species and life stage. The lowest mean density and biomass was observed over unconsolidated sediments. A total of seven Lutjanid species were documented, with schoolmaster (*Lutjanus apodus*), yellowtail (*Ocyurus chrysurus*), and gray snappers (*L. griseus*) accounting for the majority of observations. The remaining species, mahogany (*L. mahogoni*), lane (*L. synagris*), dog (*L. jocu*) and mutton (*L. analis*) were less frequently sighted (Appendix 1). Dog snapper were primarily sighted as single individuals, but a higher density (10 individuals / 100 m^2) was observed on nearshore hardbottom at a site in Great Bay. Lutjanidae size frequency was skewed toward smaller size classes (Figure 34d).

Gray snapper were observed in 23% of survey transects within STEER and were almost exclusively associated with mangrove fringes and cays (Figure 35). However, the second highest observed density, and second highest biomass, was observed on a patch reef in St. James Bay. The site with the highest density and biomass was located near the false entrance to Mangrove Lagoon. About 70% of observed individuals were juveniles/subadults, while the remaining were mostly small adults (Figure 35d). Two individuals >35 cm were observed in Mangrove Lagoon.

Schoolmaster were observed at 24% of sites within STEER and also at two additional reef sites outside the reserve. Similar to gray snapper, the species was most abundant in nearshore mangrove fringes and cays (Figure 36). A few individuals were observed on hardbottom habitat across the study area, while none were observed on unconsolidated sediments. The majority of schoolmaster (>90%) were juveniles/subadults (Figure 36d). All of the adult-sized individuals, about 9% of the total, were located on hardbottom.

Yellowtail snapper was the most frequently sighted Lutjanid species, occurring in over 50% of survey transects within STEER. Mean density of yellowtail snapper was similar in both mangrove and hardbottom habitats, with lower levels on unconsolidated sediments (Figure 37). The sites with the highest abundance and biomass were mostly located in the western half of the study area, while the species was less frequently sighted in the east (Figure 37). Highest biomass levels were observed on the southwest reef tract near Long Point. The majority (~70%) of individuals were juveniles/subadults, particularly those associated with unconsolidated sediments and mangrove (Figure 37d). The majority of observed adults were located on hardbottom, leading to higher mean biomass compared to the other bottom types. Smaller sized adults were most common, with no individuals >35 cm length observed.

Mahogany snapper were not commonly observed, occurring at 7% of sites within STEER, but notably sizable densities were present in survey transects at Cow and Calf Rocks (20 individuals / 100 m^2) and a nearby patch reef (10 individuals / 100 m^2) (Figure 38). This species was absent from unconsolidated sediments and from hardbottom surveys outside the reserve boundary. Adult-sized individuals were only observed on hardbottom.

Grunts (Haemulidae)

Fishes in the grunt family were present in all habitat types. Mangrove habitat had the highest mean density, while hardbottom and unconsolidated sediment habitats exhibited similar density levels (Figure 39). Mean biomass was highly variable on hardbottom habitat due to a large concentration of biomass near Cow and Calf Rocks (>23 kg / 100 m^2). The family was represented by nine species (Appendix 1). French grunt (*Haemulon flavolineatum*), bluestriped grunt (*H. sciurus*), white grunt (*H. plumierri*), and tomtates (*H. aurolineatum*) were most frequently sighted and had the highest mean abundance and biomass of the grunt species. Porkfish (*Anisotremus virginicus*), black margate (*A. surinamensis*), and the remaining species were observed less frequently (Appendix 1). Over one-third of observed grunts in mangrove habitat were small juveniles that could not be identified to the species level. These juveniles were also associated with unconsolidated sediments.

French grunt were present within 35% of survey transects in STEER, as well as two hardbottom sites outside the STEER boundary. The species was commonly observed on mangrove and hardbottom habitats across the study area but was absent

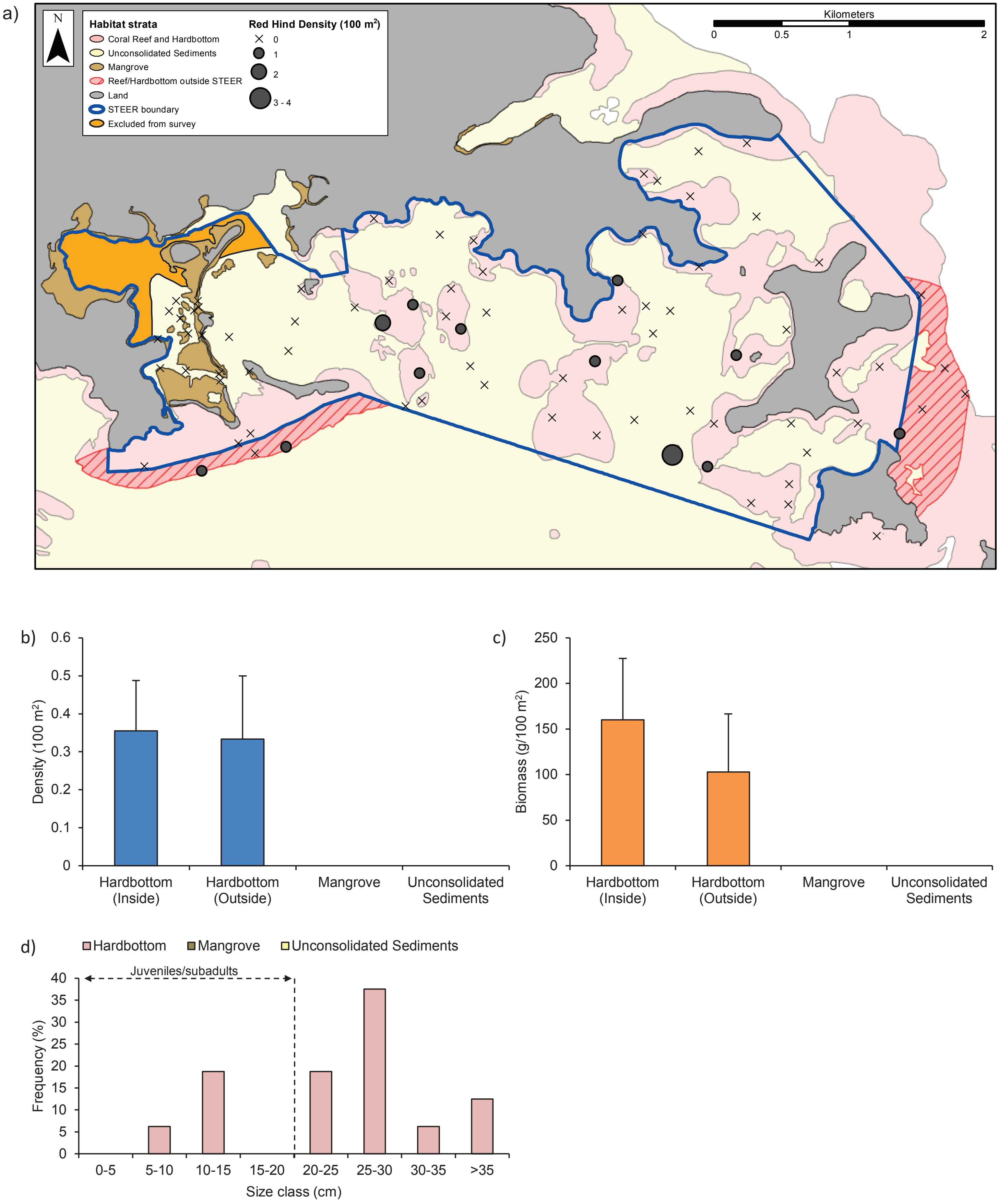
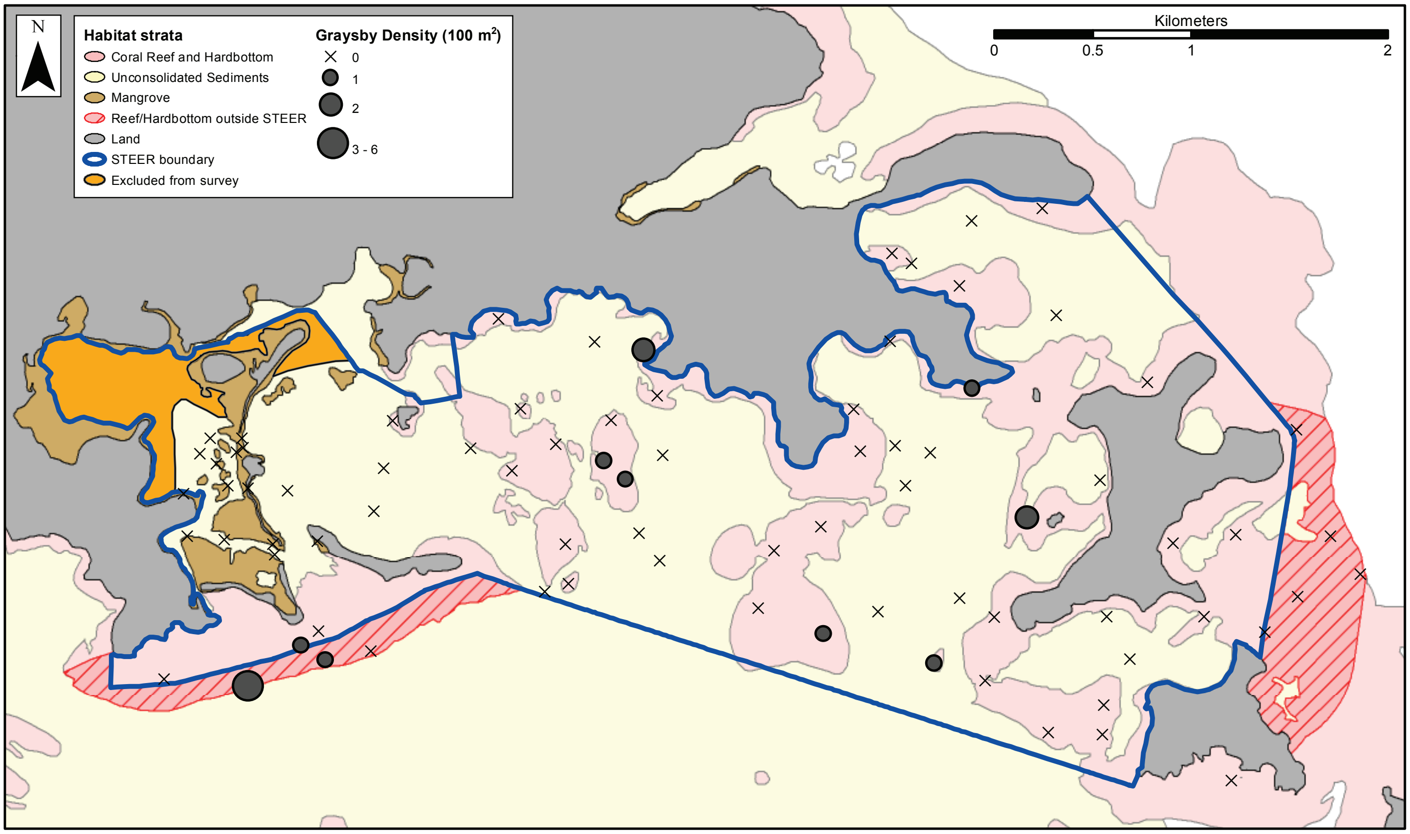
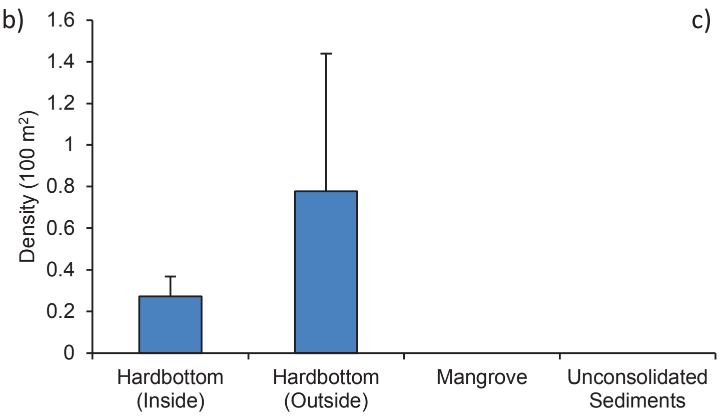


Figure 32. Red hind (*Epinephelus guttatus*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

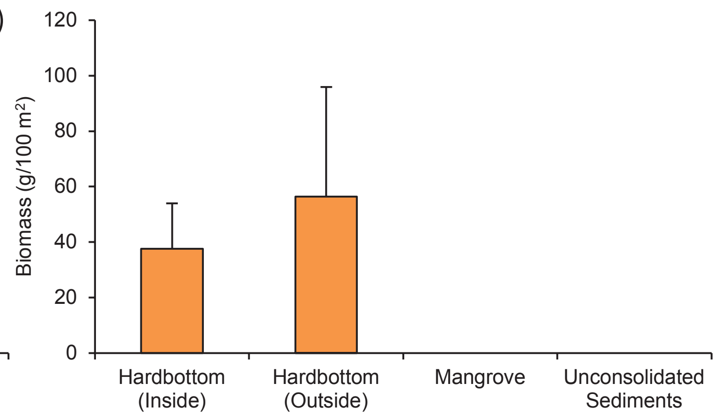
a)



b)



c)



d)

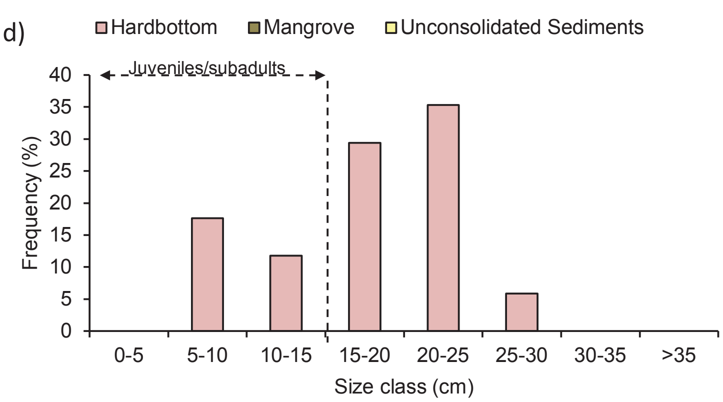


Figure 33. Graysby (*Cephalopholis cruentata*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

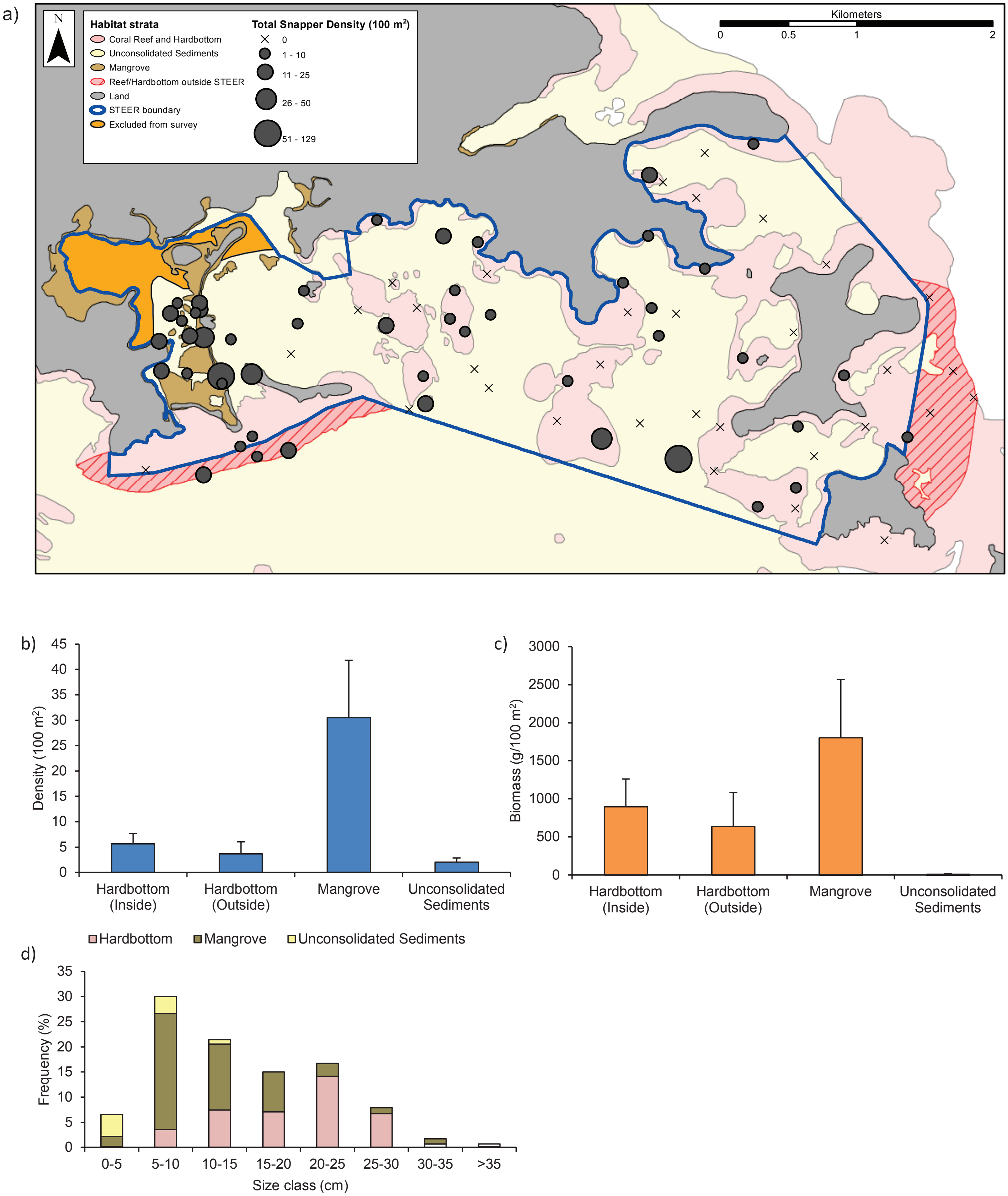


Figure 34. Snapper (Family Lutjanidae a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

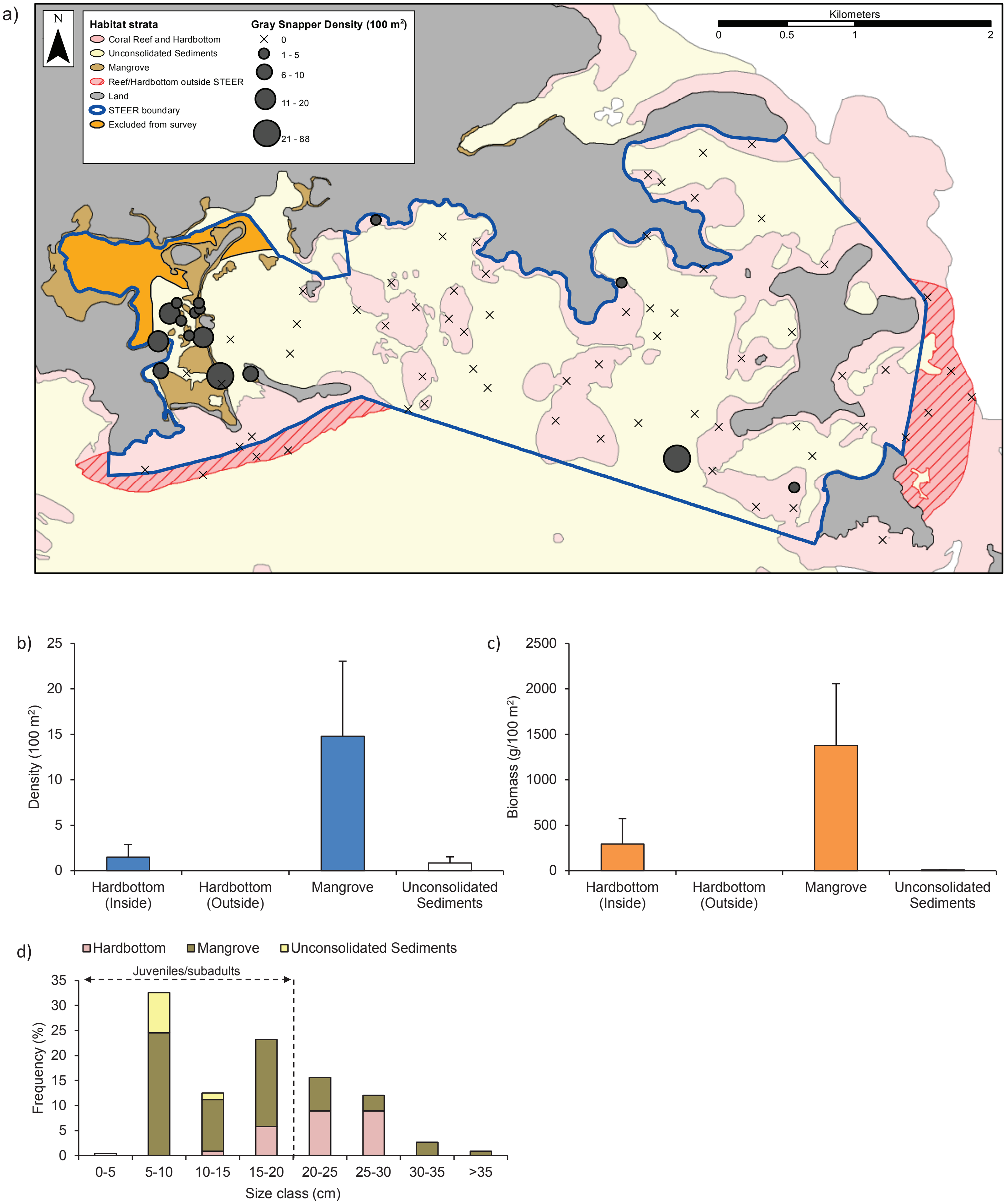


Figure 35. Gray snapper (*Lutjanus griseus*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

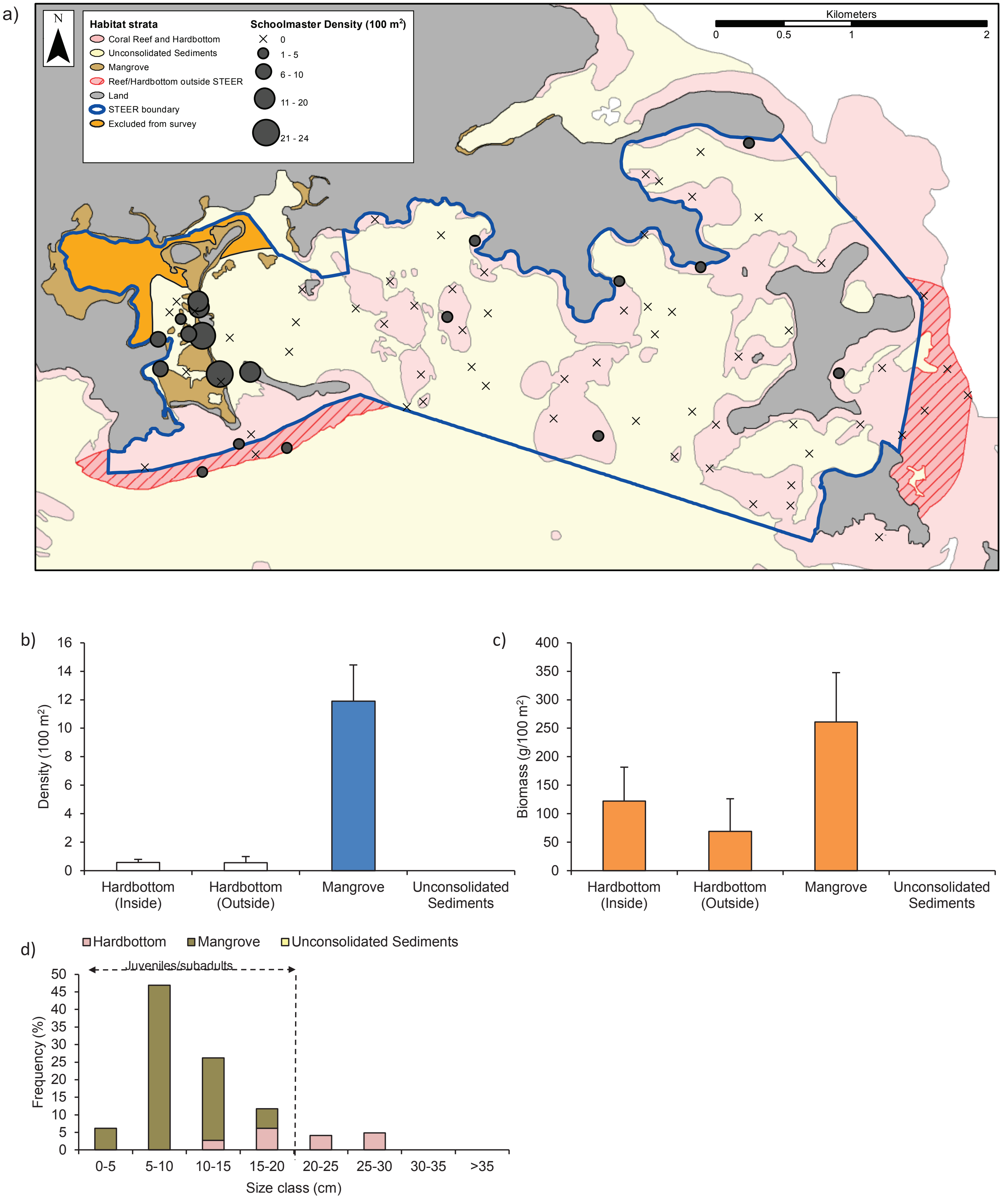


Figure 36. Schoolmaster (*Lutjanus apodus*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

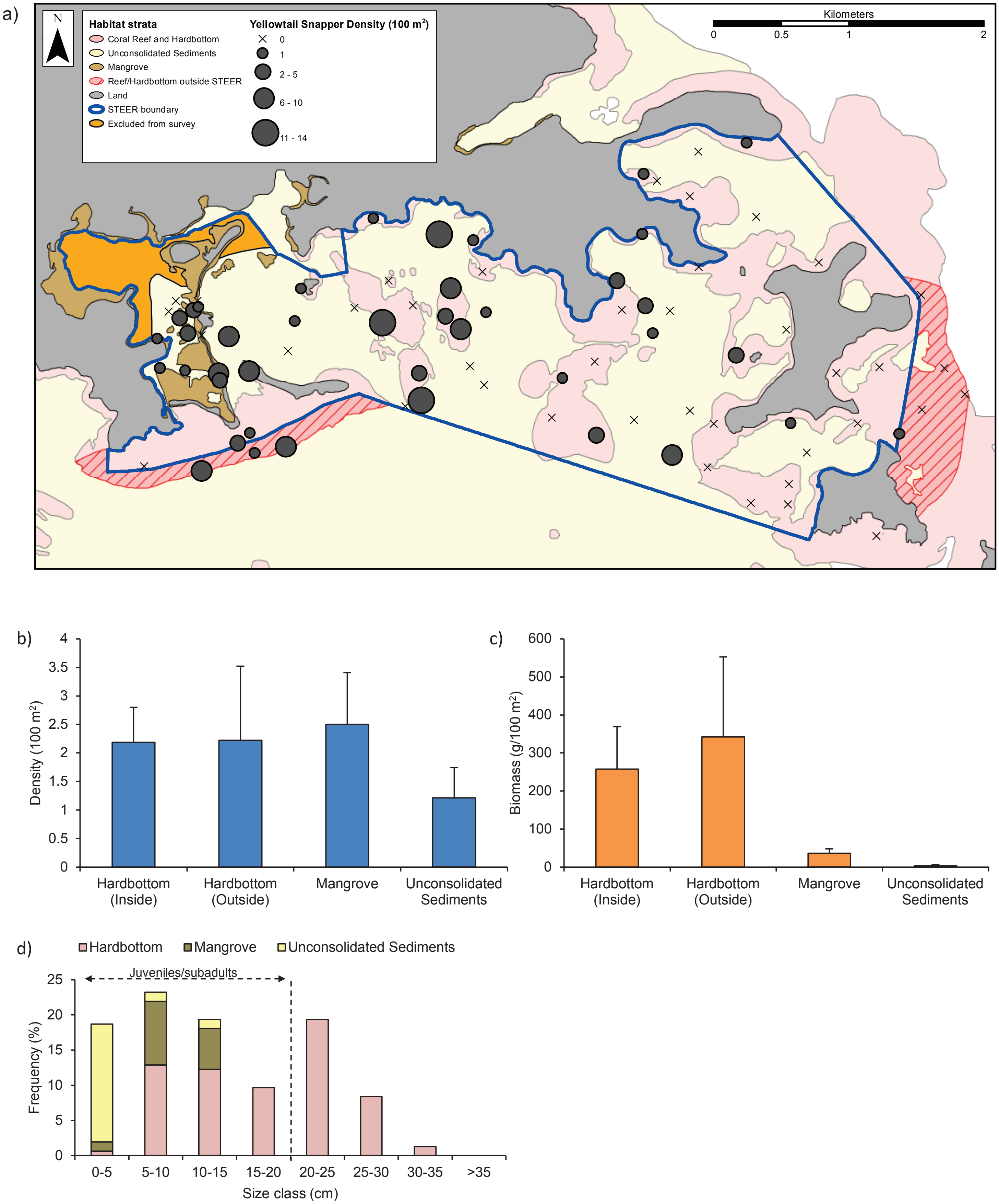


Figure 37. Yellowtail snapper (*Ocyurus chrysurus*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

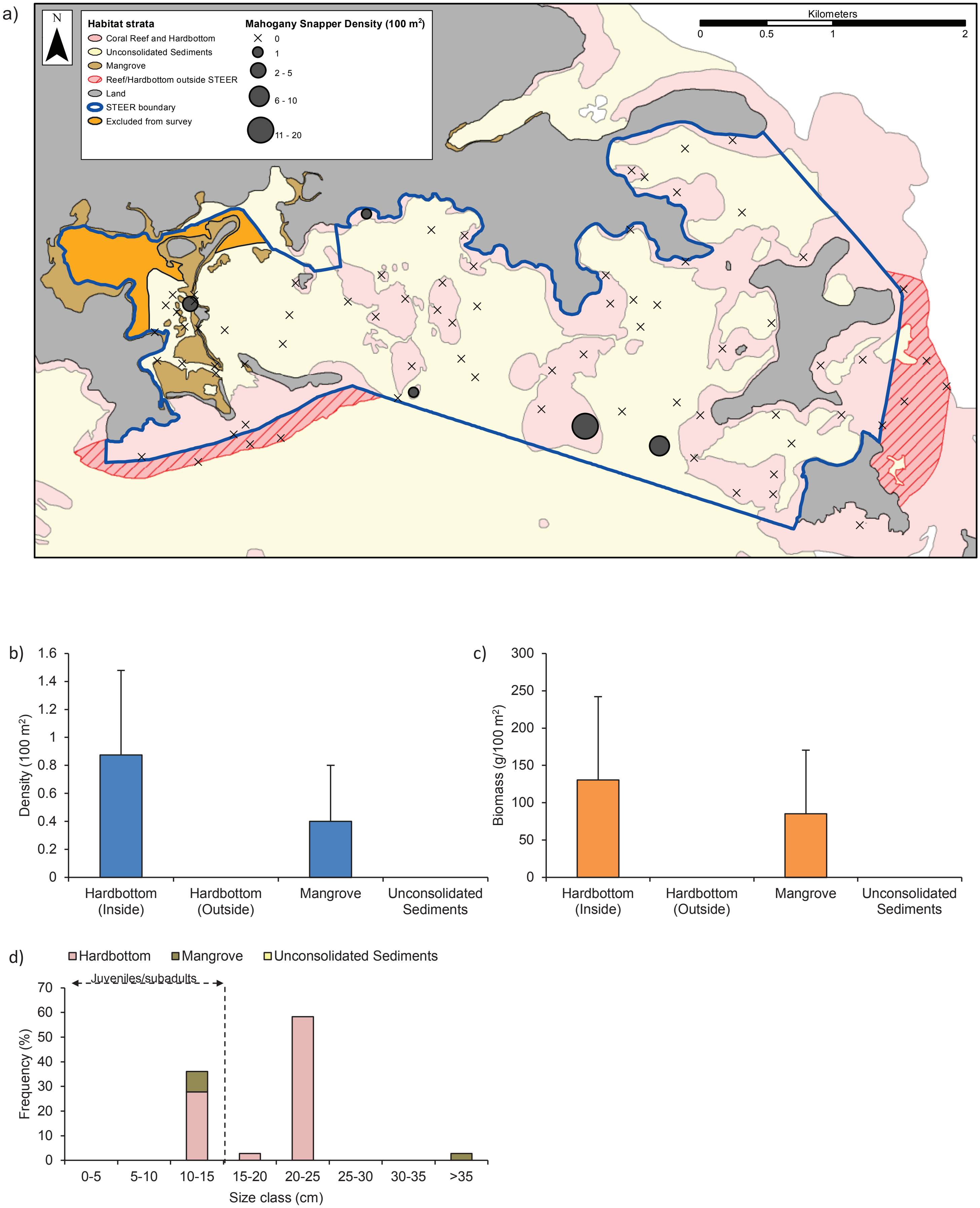


Figure 38. Mahogany snapper (*Lutjanus mahogoni*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

a)

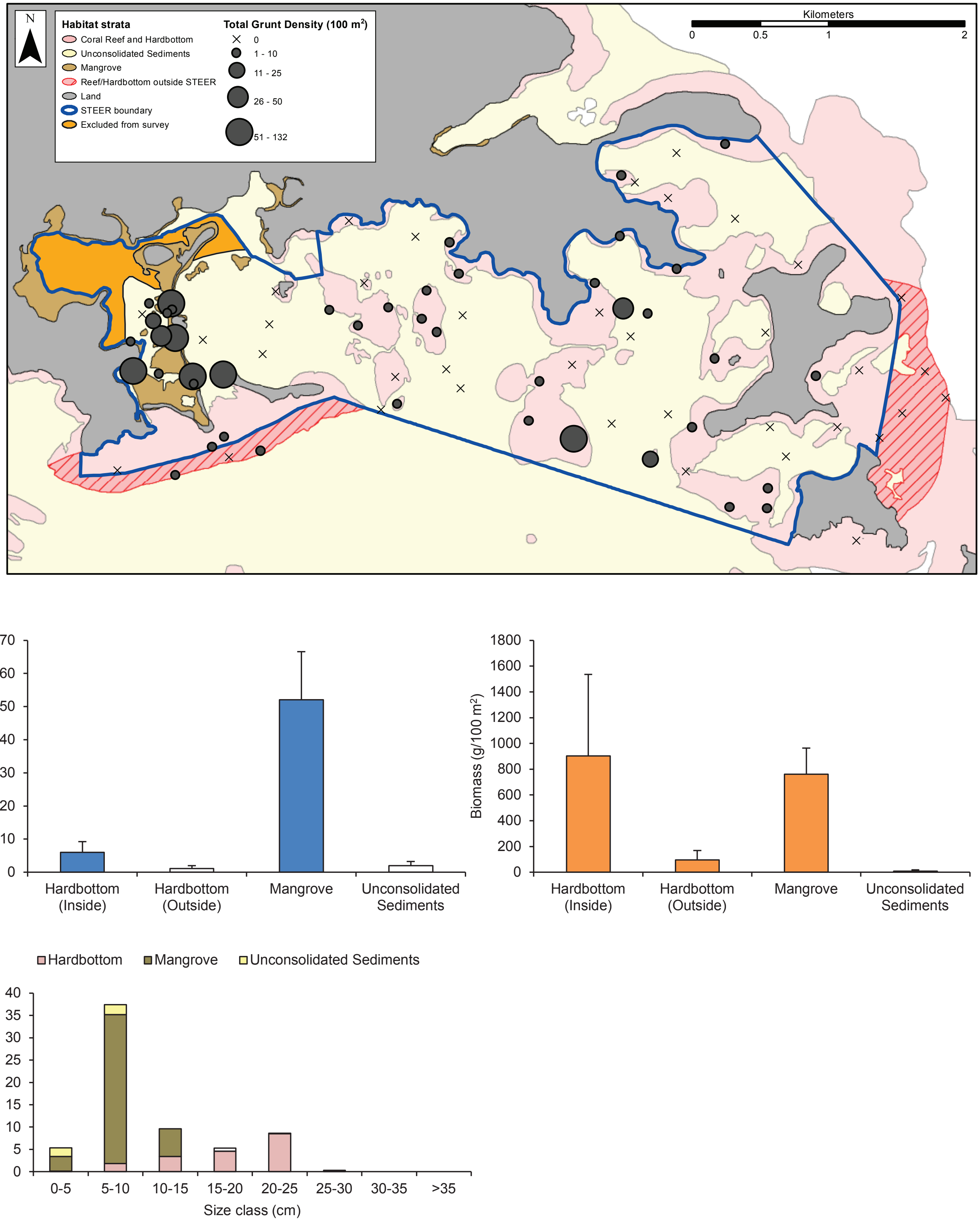


Figure 39. Grunt (Family Haemulidae) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

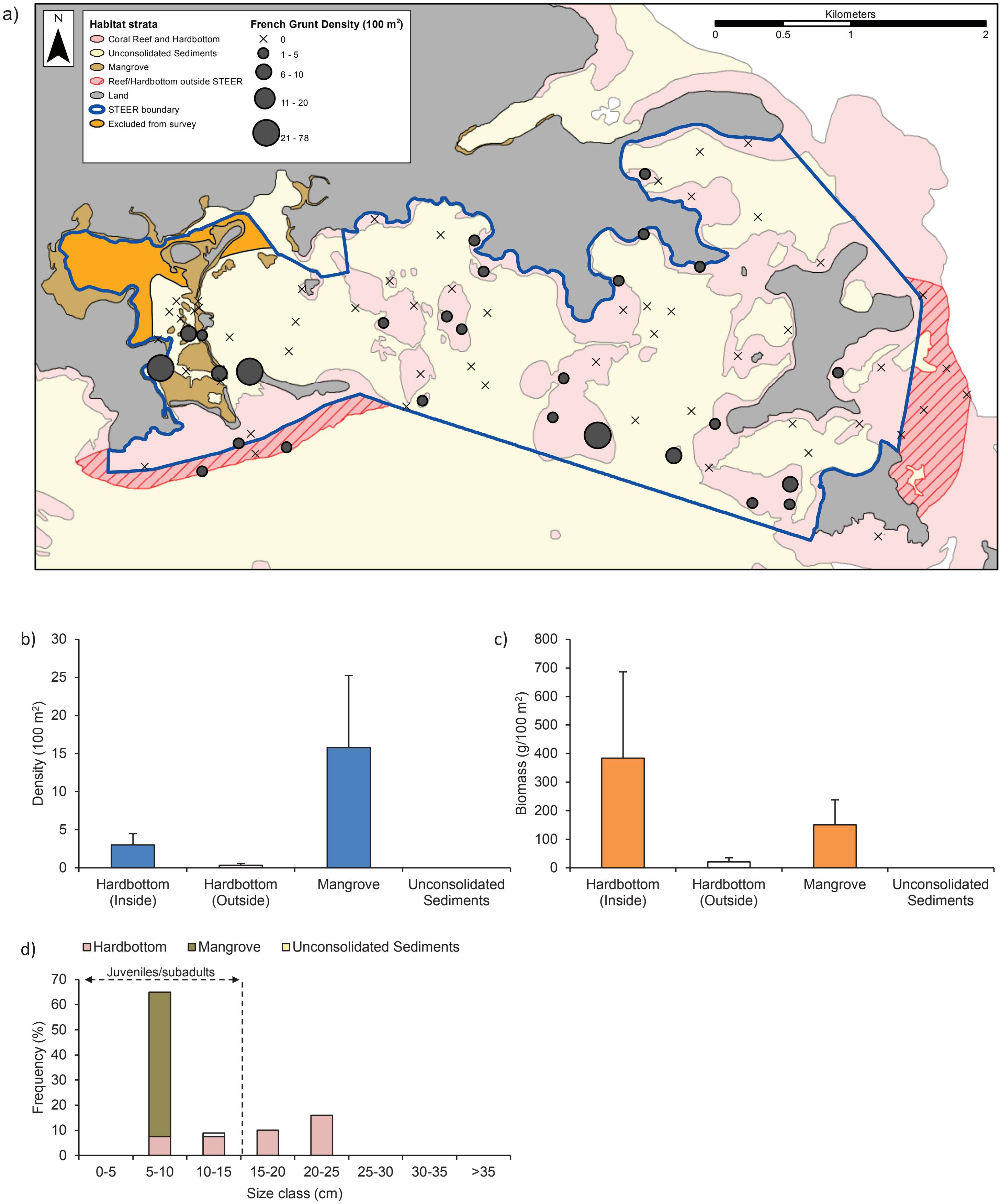


Figure 40. French grunt (*Haemulon flavolineatum*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

from surveys on unconsolidated sediments (Figure 40). While mean density was highest in mangroves, there was high variability and the majority of individuals were small juveniles in the 5-10 cm size class. In contrast, a larger range of sizes was present on hardbottom habitat, although sub-adults and small adults were most common (Figure 40d).

Bluestriped grunt were sighted in 21% of surveys within STEER and one site outside the STEER boundary. The species was most abundant in mangrove habitat, with densities up to 50 individuals / 100 m^2 (Figure 41). Mean biomass was highest on hardbottom but exhibited high spatial variability; when present, the species usually occurred as single individuals but occasional larger aggregations were found. While all size classes were present in mangroves, juveniles/sub-adults were most common (Figure 41d). Hardbottom was typically inhabited by the larger size classes.

Tomtate were found across all habitats but were less frequently sighted than the previously described grunt species, occurring in only 8% of survey transects within STEER. However the species was observed in larger densities (>10 individuals / 100 m^2) at a few locations, including Cow and Calf Rocks and a soft sediment site outside Cowpet Bay (Figure 42). Approximately 60% of observed individuals were juveniles/sub-adults, with the remaining being in the size class just above the average size at maturity (Figure 42d).

Surgeonfish (Acanthuridae)

Acanthurids (surgeonfish) were present in all three bottom types and across all depths throughout the STEER, but the family was most abundant in hardbottom habitats (Figure 43). Fewer sightings were observed in Benner Bay and Mangrove Lagoon, with the exception of the survey near the false entrance. Ocean surgeonfish (*Acanthurus bahianus*) and blue tang (*A. coeruleus*) were the most frequently observed species in both study areas, while doctorfish (*A. chirirgus*) was less common (Appendix 1).

Ocean surgeonfish were observed at multiple sites spanning the shelf and bottom types, including nearshore and lagoon areas (Figure 44). The species was present in over half of the transects within STEER and all but two of the hardbottom sites outside STEER. A cluster of particularly high density sites were located on spur and groove habitat and pavement with sand channels habitat in Jersey Bay. The species was generally observed in lower numbers outside the reserves compared to inside. Size frequencies tended towards the smaller size classes, with >40% of observed individuals under 5 cm in length (Figure 44d).

Blue tang were documented in 42% of survey transects within STEER, primarily on hardbottom. The species was only present at one mangrove location and was absent from unconsolidated sediment surveys (Figure 45). Blue tang were also documented at the majority of hardbottom sites outside the reserve boundary, although mean density and biomass were lower compared to inside STEER. The species occurred across most hardbottom types but the two locations with highest observed densities were located on shallow nearshore rock/boulder habitat in Great Bay. Similar to ocean surgeonfish, smaller size classes were most frequent and all observed individuals were <20 cm (Figure 45d).

Parrotfish (Scaridae)

Parrotfishes (Family Scaridae) were a common component of the STEER fish community. The family was represented by 11 species (Appendix 1). The species with the highest site frequency, density and biomass were striped parrotfish (*Scarus iseri*), redband parrotfish (*Sparisoma aurofrenatum*), princess parrotfish (*Sc. taeniopterus*), and stoplight parrotfish (*Sp. viride*). Most larger-bodied species were absent from the study areas, however rainbow parrotfish (*Sc. guacamaia*) occurred in one survey transect in Nazareth Bay. The site was also characterized by the largest observed parrotfish biomass in STEER and by the presence of several adult-sized yellowtail parrotfish (*Sp. Rubripinne*). A spawning aggregation of yellowtail parrotfish has previously been noted at nearby Coculus Rock (Smith et al. 2012). Overall, the highest levels of density and biomass were observed on hardbottom habitat, with intermediate and lowest levels in mangroves and unconsolidated sediments, respectively (Figure 46). Species composition varied across bottom types. All eleven species were observed on hardbottom, while mangrove was only represented by striped, redband, stoplight, and bucktooth parrotfishes. Unconsolidated sediments were also typified by juveniles of the aforementioned species, as well as the smaller bodied bluelip parrotfish (*Cryptotomus roseus*). Overall, the smallest size classes were most abundant, with >80% of observed individuals at <10 cm (Figure 46d).

Redband parrotfish were sighted in 54% of survey transects within STEER. Mean density was similar on hardbottom inside and outside STEER, with slightly higher mean biomass inside STEER (Figure 47). The species was common across all hardbottom types, including nearshore rock/boulder, patch reefs, and pavement. Lower densities were typically observed over unconsolidated sediments and mangrove, with the notable exception of mangrove sites near the false entrance to Mangrove Lagoon and Cas Cay. The size distribution was skewed towards the smaller size classes (0-10 cm) while ~20% of the observed individuals were above the mean size at maturity (Figure 47d).

Stoplight parrotfish were observed in all three habitats within STEER, but exhibited highest abundance and biomass on hardbottom (Figure 48). The species was present across

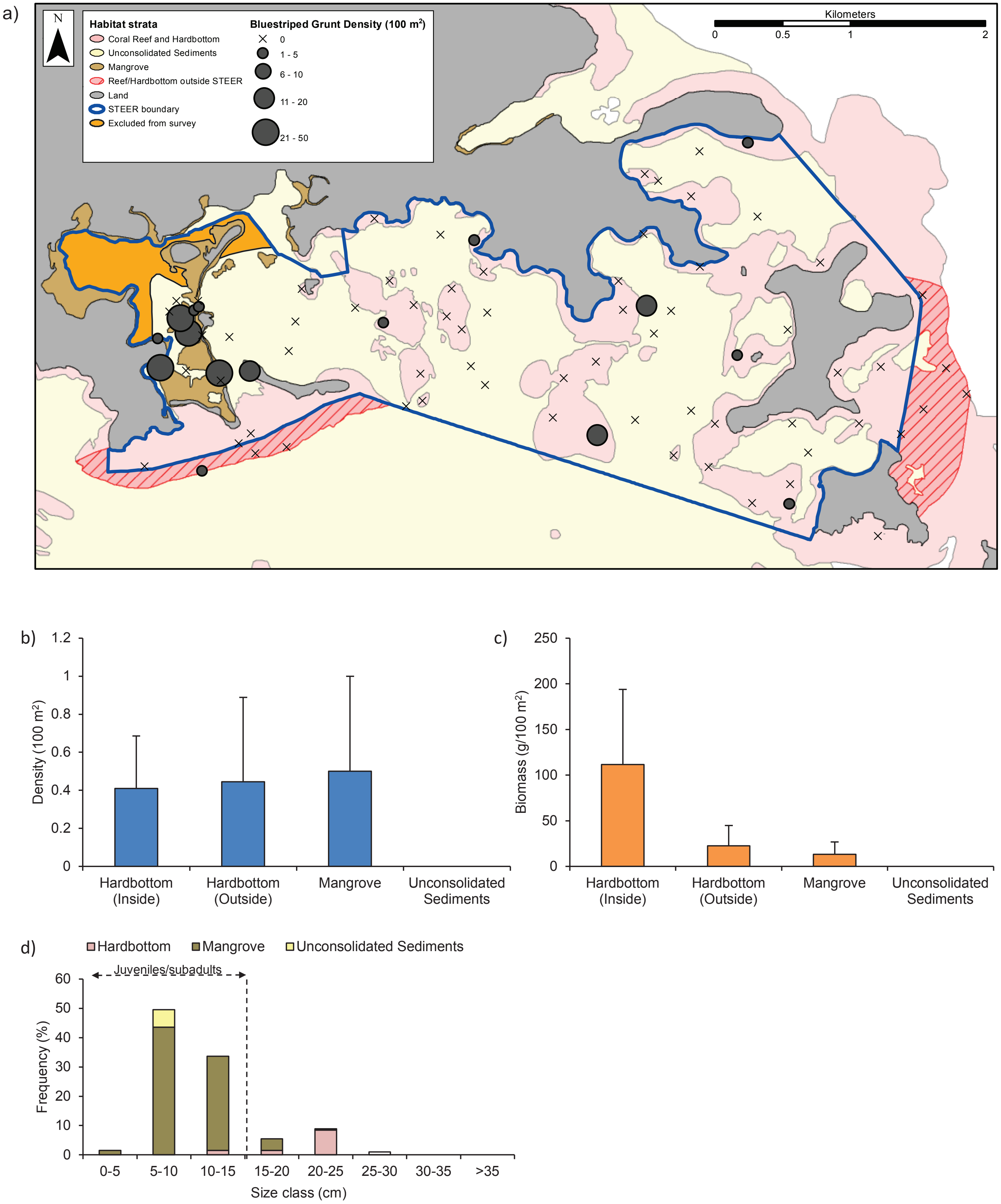
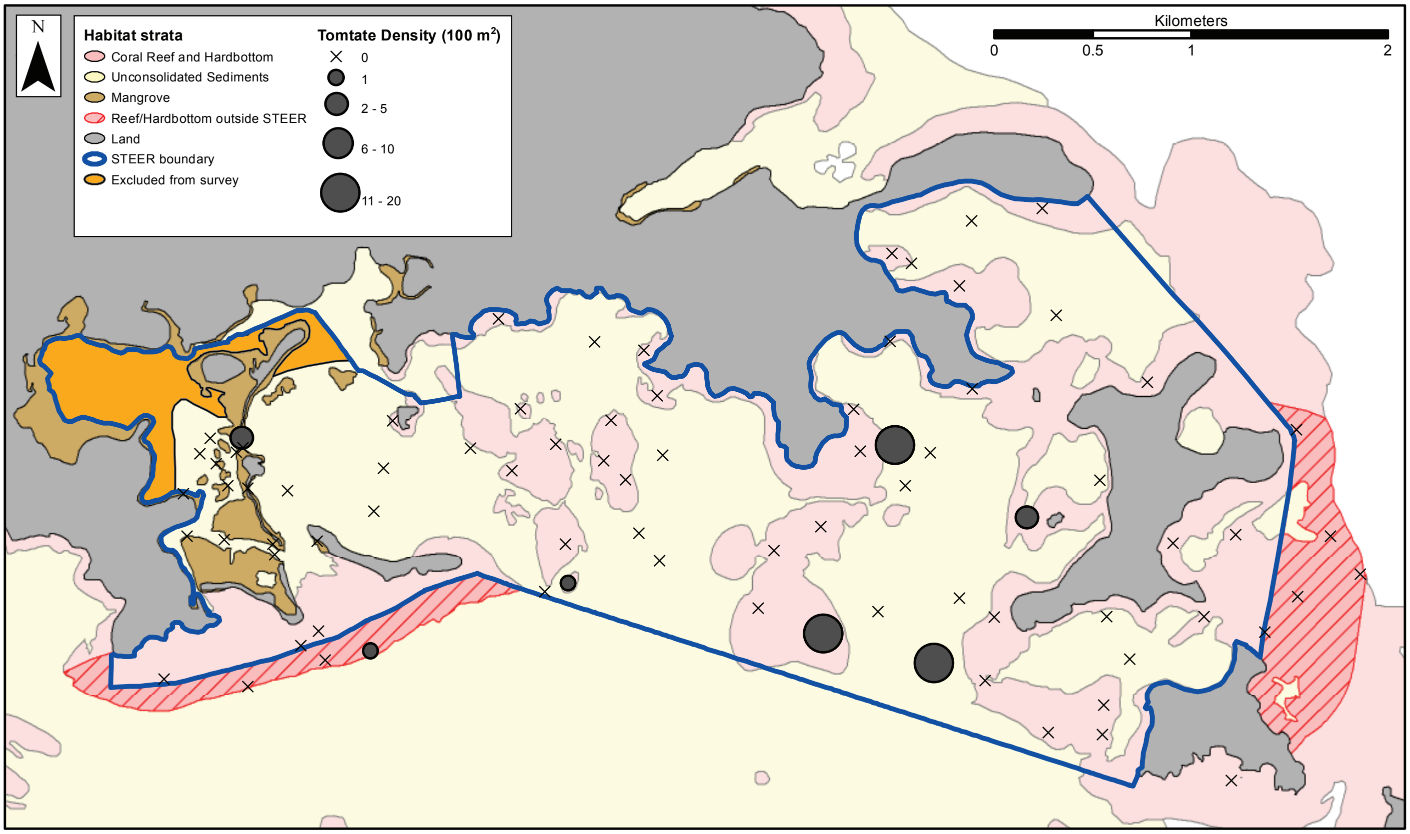
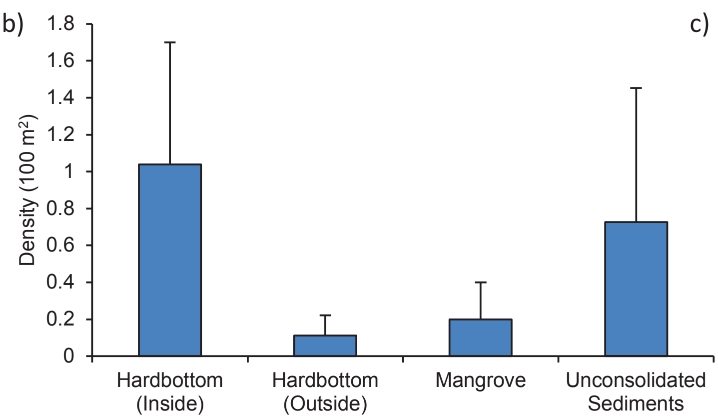


Figure 41. Bluestriped grunt (*Haemulon sciurus*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

a)



b)



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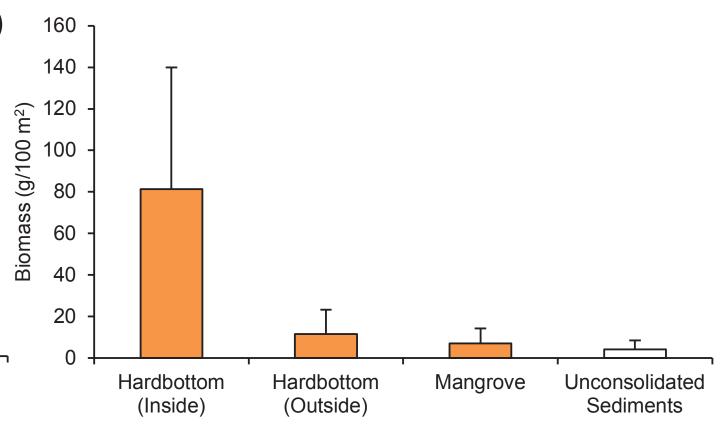


d)

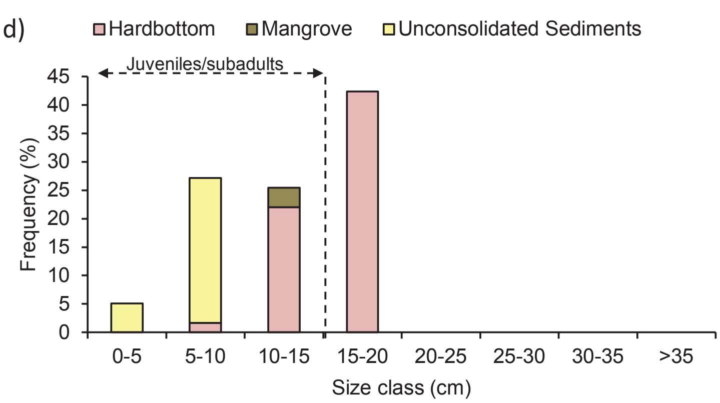


Figure 42. Tomtate (*Haemulon aurolineatum*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

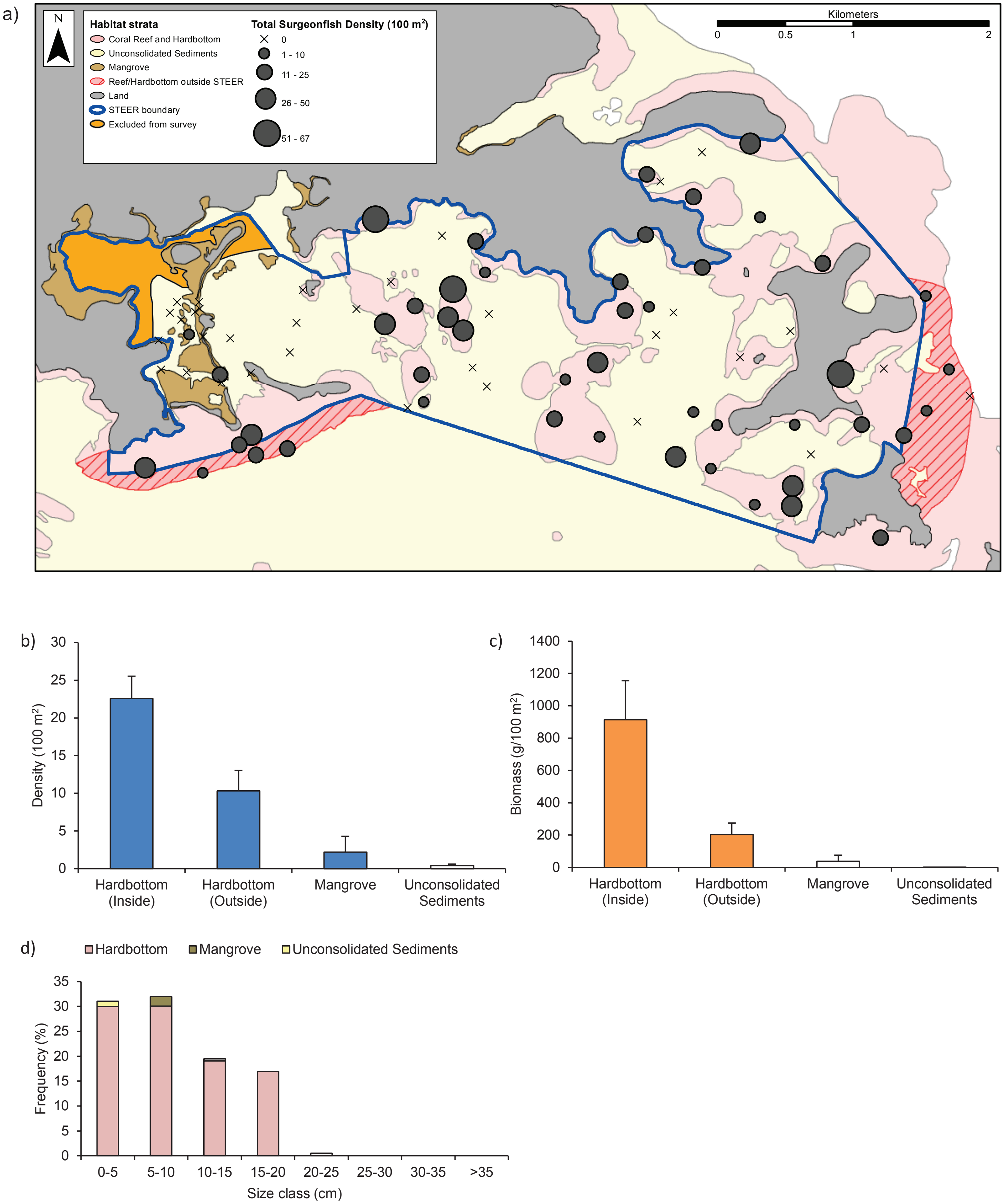


Figure 43. Surgeonfish (Family Acanthuridae) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

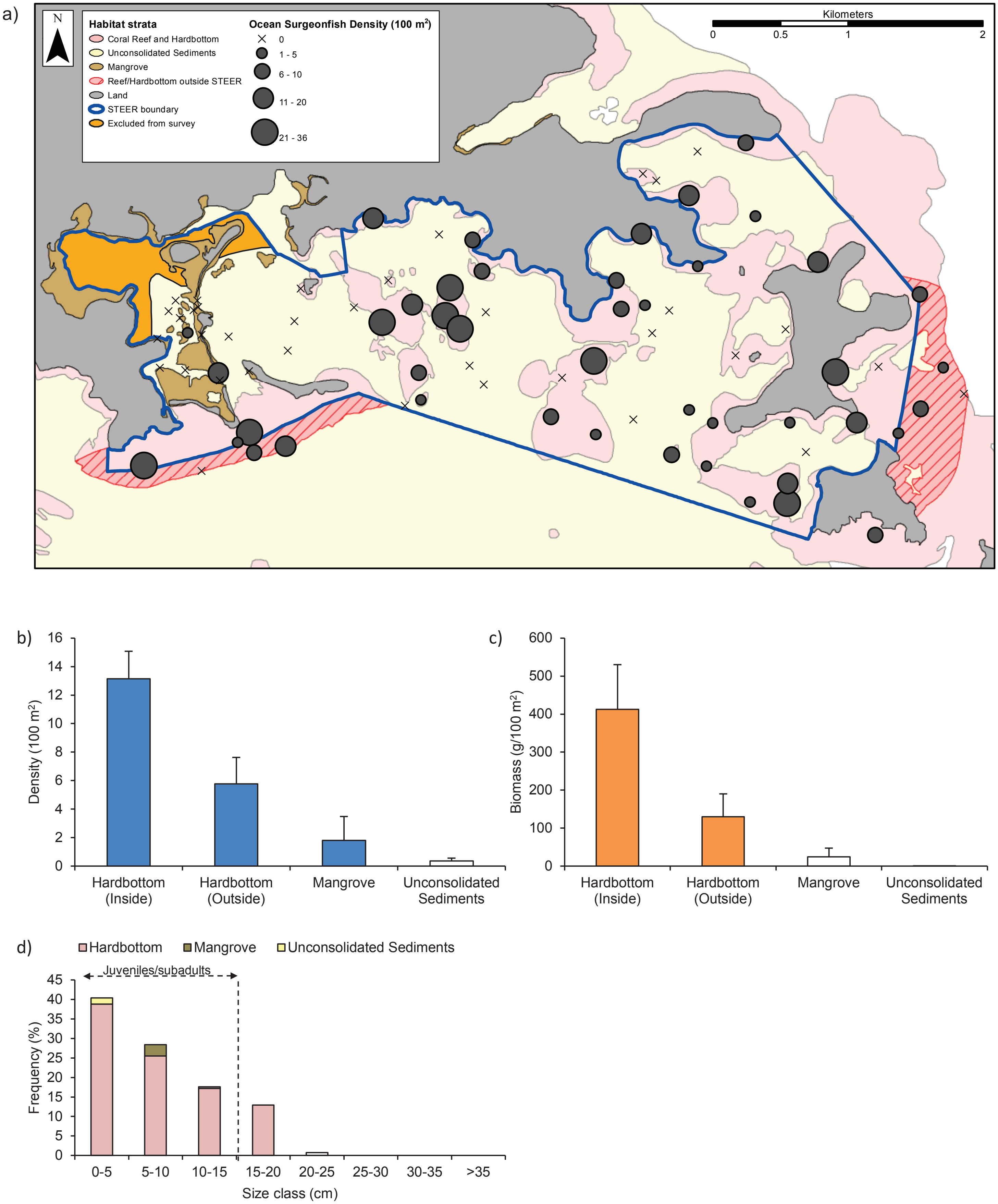


Figure 44. Ocean surgeonfish (*Acanthurus bahianus*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

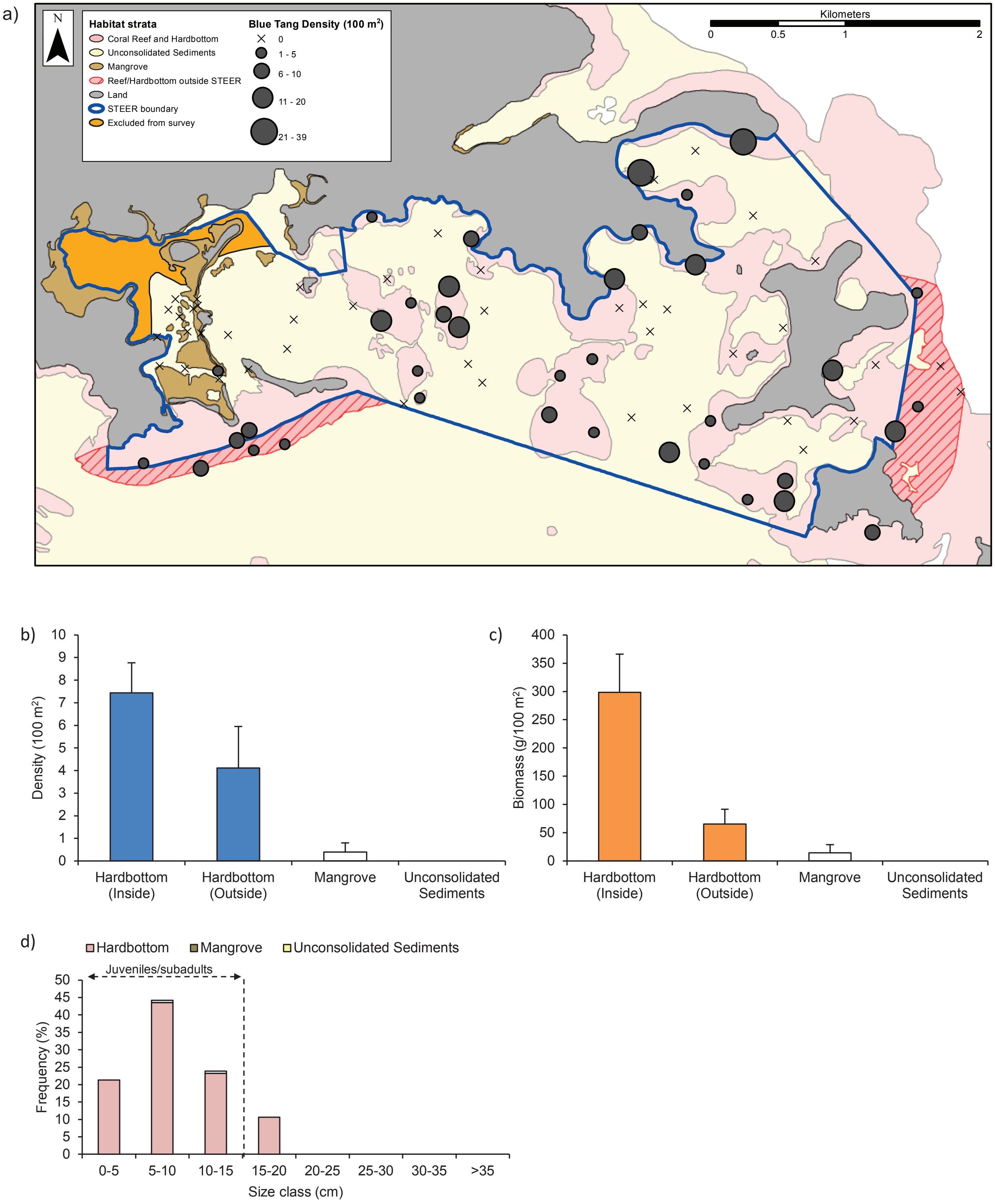


Figure 45. Blue tang (*Acanthurus coeruleus*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

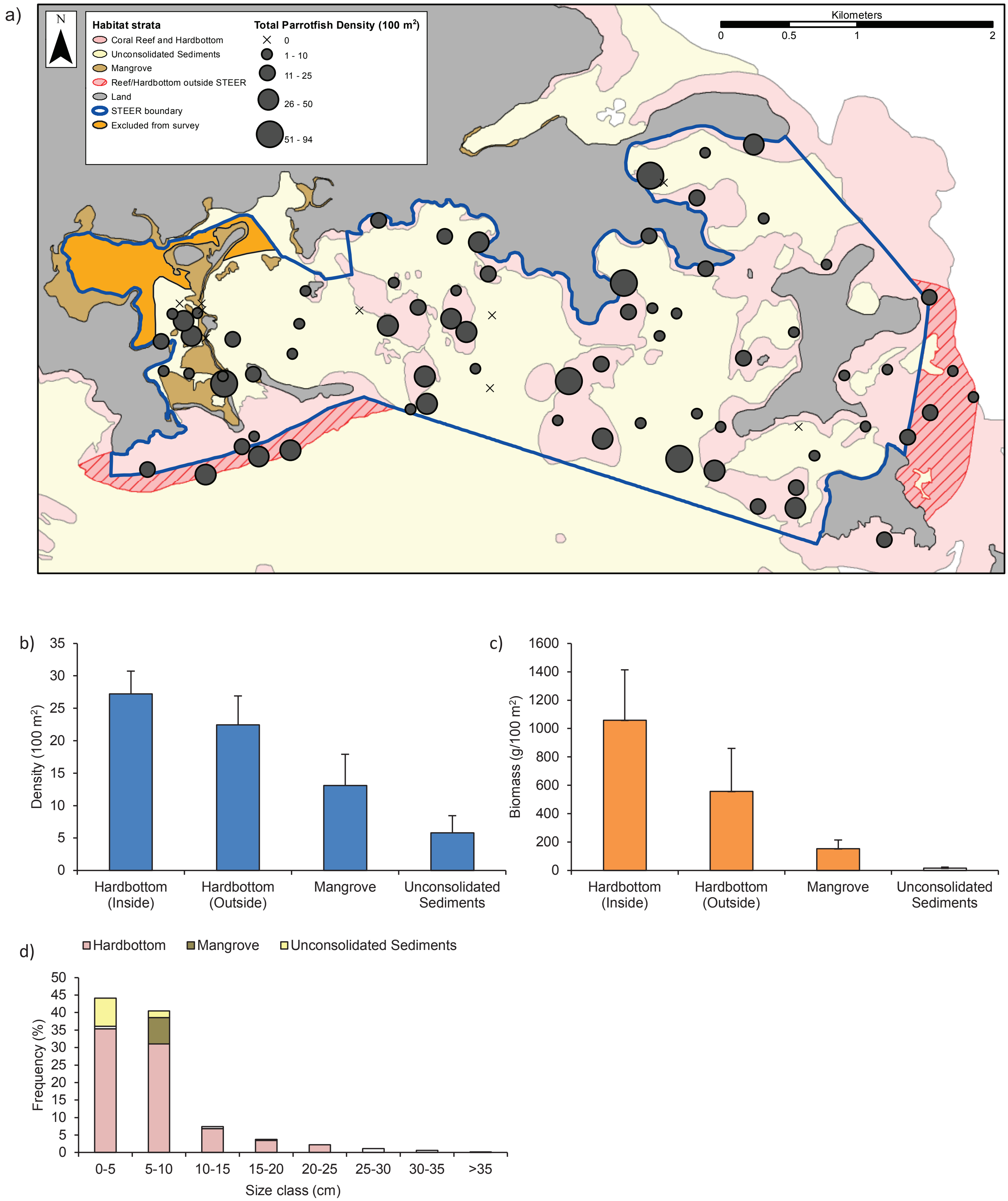


Figure 46. Parrotfish (Family Scaridae) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

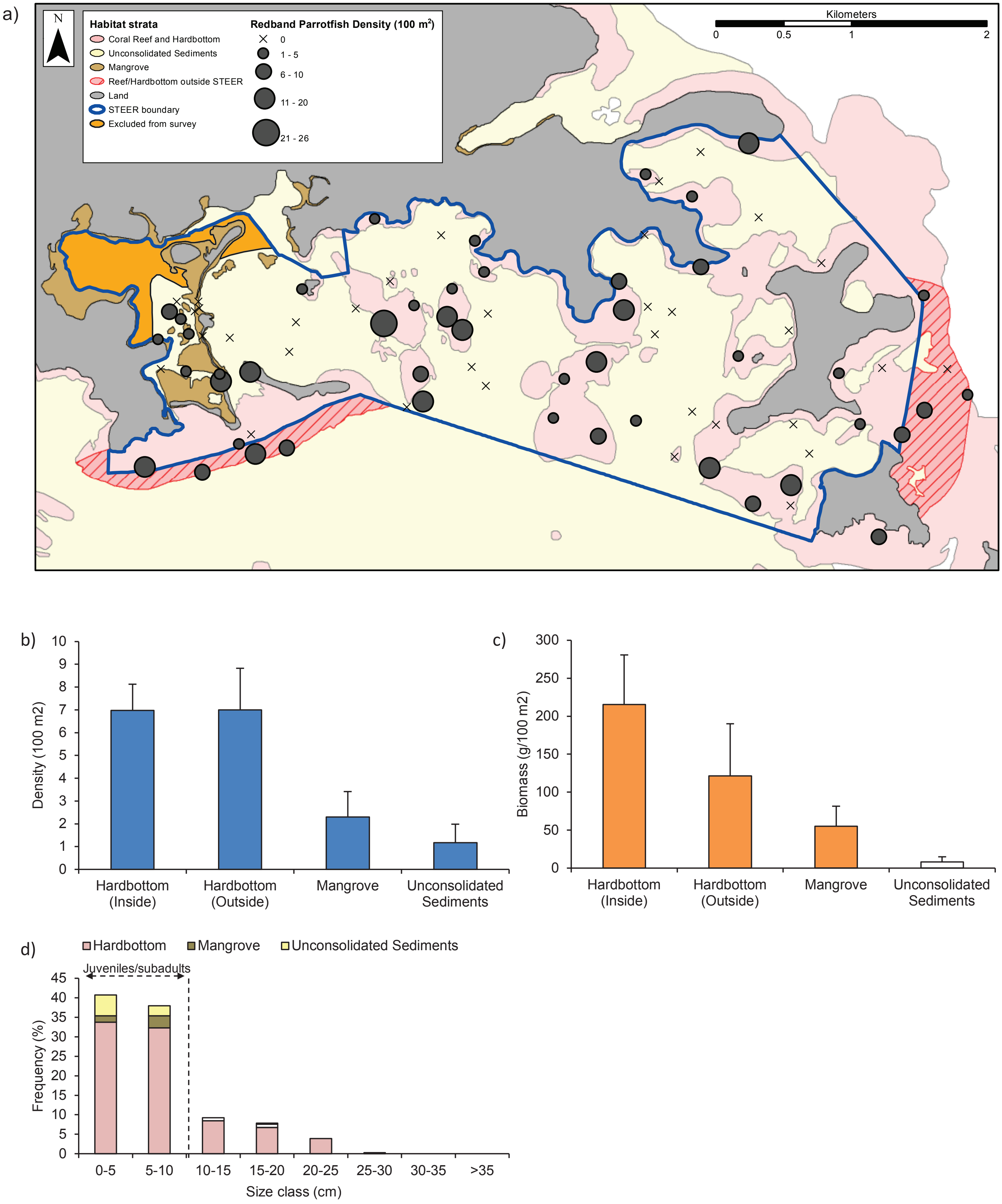


Figure 47. Redband parrotfish (*Sparisoma aurofrenatum*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

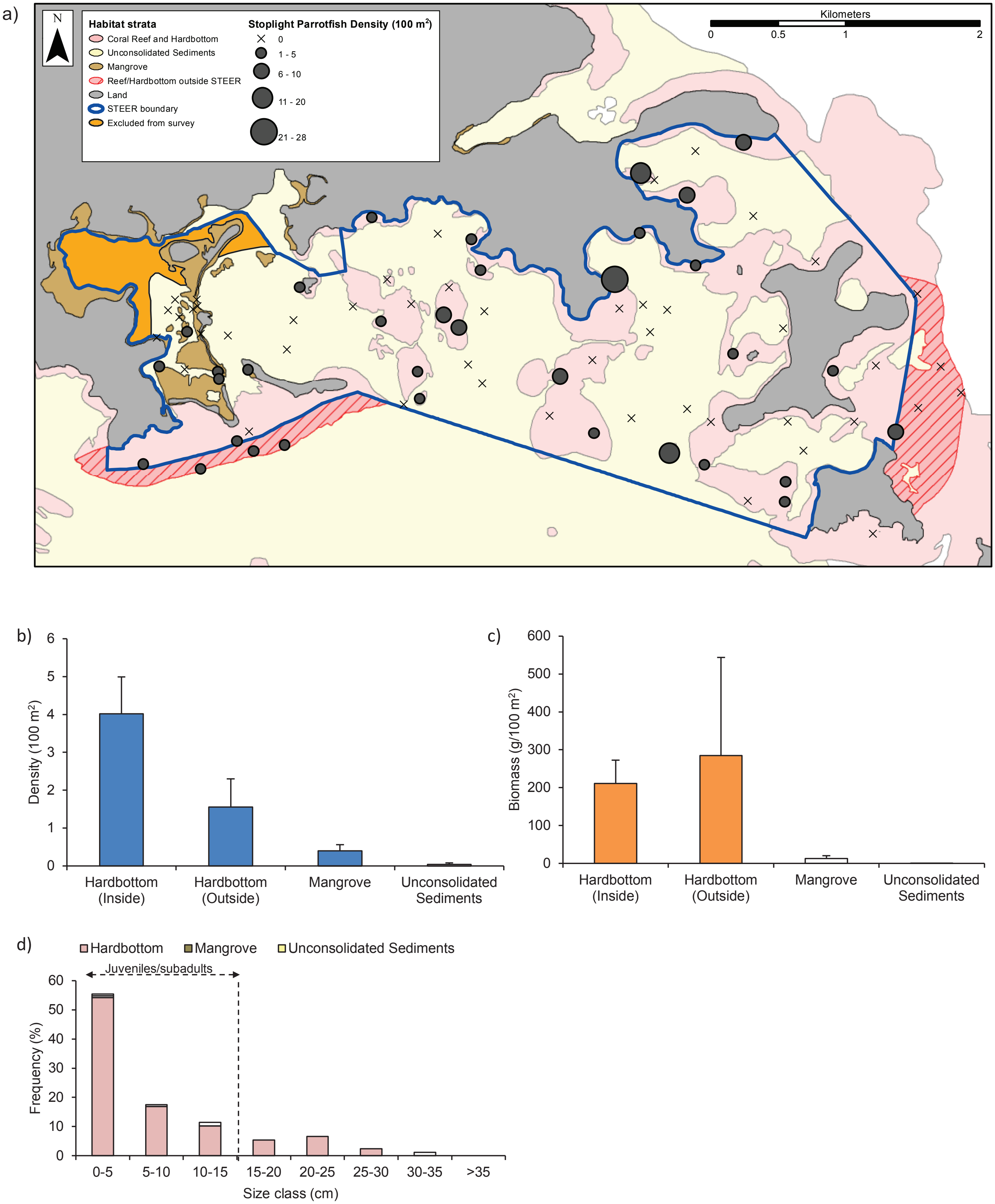


Figure 48. Stoplight parrotfish (*Sparisoma viride*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

all hardbottom types but sites with higher values occurred on nearshore rocky habitat in Cowpet and Great Bays and a patch reef in St. James Bay. Biomass at hardbottom sites outside STEER exhibited a high degree of variability due to the presence of a few larger sized individuals at one location. Over 50% of the observed individuals were in the smallest size class (0-5 cm) while 15% were small adults (Figure 48d).

Striped parrotfish were present in 59% of survey transects within STEER and were common on both hardbottom and in mangroves (Figure 49). The site with the highest observed density, located in Cowpet Bay, was also characterized by the highest density of spotlight parrotfish. The species was less frequently sighted in the eastern portion of the study area and was absent in several of the surveys east of Great St. James Island. Small juveniles were dominant, particularly in mangroves and on soft sediments, and overall only 5% of observed individuals were larger than the mean size at maturity (Figure 49d).

Princess parrotfish occurred in 23% of survey transects within STEER and over half of the hardbottom surveys outside the reserve. Highest mean density and biomass occurred on hardbottom, while the species was absent from surveys in mangroves (Figure 50). The densest aggregation occurred on hardbottom in Great Bay, while the location with the second highest observed density was on unconsolidated sediments near the false entrance to Mangrove Lagoon. The overwhelming majority (95%) of observed individuals were juveniles/subadults (Figure 50d).

<u>Other species</u>

Wrasses (Labridae)

Fishes of the Family Labridae were ubiquitous members of the STEER fish community, occurring in 85% of all surveys within STEER and all but one hardbottom survey. Wrasses were present in all habitats and across the geographic area, but with fewer sighting frequencies in Mangrove Lagoon (Figure 51). Mean density and biomass were highest on hardbottom. The family was represented by 12 species (Appendix 1), with some variation by habitat. Bluehead (*Thalassoma bifasciatum*), slippery dick (*Halichoeres bivittatus*), yellowhead wrasse (*H. garnoti*), and clown wrasse (*H. maculipinna*) were the most frequently encountered species on hardbottom, while razorfish species, particularly rosy razorfish (*Xyrichtys martinicensis*), were more frequent on unconsolidated sediments. Hogfish (*Lachnolaimus maximus*) was absent from surveys within STEER but one individual was sighted within a transect on the southwest reef complex outside of the reserve boundary. The size distribution was skewed towards the smaller size classes (Figure 51d) because small-bodied Labrid species were most abundant.

Goatfishes (Mullidae)

Goatfish were present in 20% of survey transects within STEER, in addition to several of the hardbottom surveys outside STEER. The family was represented by two species, spotted goatfish (*Pseudupeneus maculatus*) and yellow goatfish (*Mulloidichthys martinicus*). Yellow goatfish was observed exclusively on hardbottom while spotted goatfish was documented within two unconsolidated sediment surveys. Goatfishes were typically observed in low densities (1-5 individuals / 100 m^2) but one larger cluster (27 individuals / 100 m^2) was recorded on an area of pavement with sand channels in Jersey Bay (Figure 52).

Damselfishes (Pomacentridae)

Damselfishes were present across all bottom types, occurring in 62% of surveys within STEER and all but one hardbottom site outside the reserve. Highest densities and biomass were observed on hardbottom, with intermediate levels in mangrove habitat and low frequency of occurrence on unconsolidated sediments (Figure 53). Damselfish were prevalent across hardbottom types but highest densities were observed at sites in the southern portion of the study area, including surveys near Cow and Calf Rocks, southeast of Great St. James Island, and outside the STEER boundary south of Patricia Cay. The family was represented by 10 species (Appendix 1). Frequently observed species included the bicolor damselfish (*Stegastes partitus*), cocoa damselfish (*S. variabilis*), longfin damselfish (*S. diencaeus*), and beaugregory (*S. leucostictus*).

Triggerfish (Balistidae)

Queen triggerfish (*Balistes vetula*) was uncommonly encountered in the survey, occurring at only three sites within STEER and none outside (Figure 54). The species was observed exclusively on hardbottom in the central and southeastern areas of STEER and in densities of 1-2 individuals / 100 m^2. Three of the four observed individuals were adult-sized (Figure 54d).

Comparison with Other U.S. Caribbean Monitoring Locations

The benthic community found on hardbottom sites in STEER is similar to that described by long term NOAA monitoring programs using the same methods as this study in Eastern St. Croix, which includes Buck Island Reserve National Monument and the East End Marine Park, around the island of St. John, and Southwest Puerto Rico (SWPR), which includes the areas of La Parguera and Guanica. Overall community structure was similar: hardbottom habitats in all three regions were dominated by turf and macroalgae with low overall coral cover (Figure 55a). However, results of the nonparametric tests indicate that percent hard coral cover was significantly greater on hardbottom within STEER

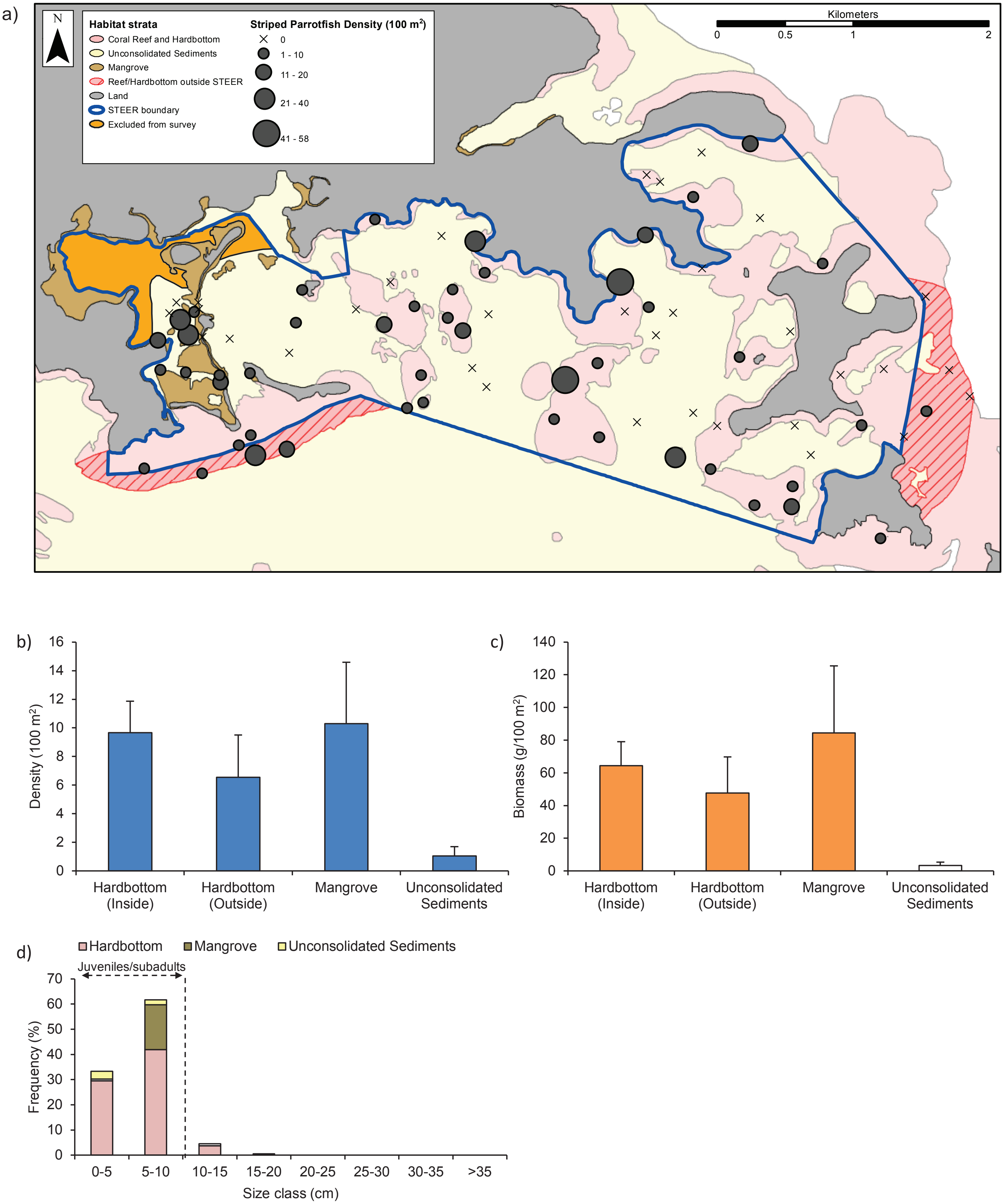


Figure 49. Striped parrotfish (*Scarus iseri*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

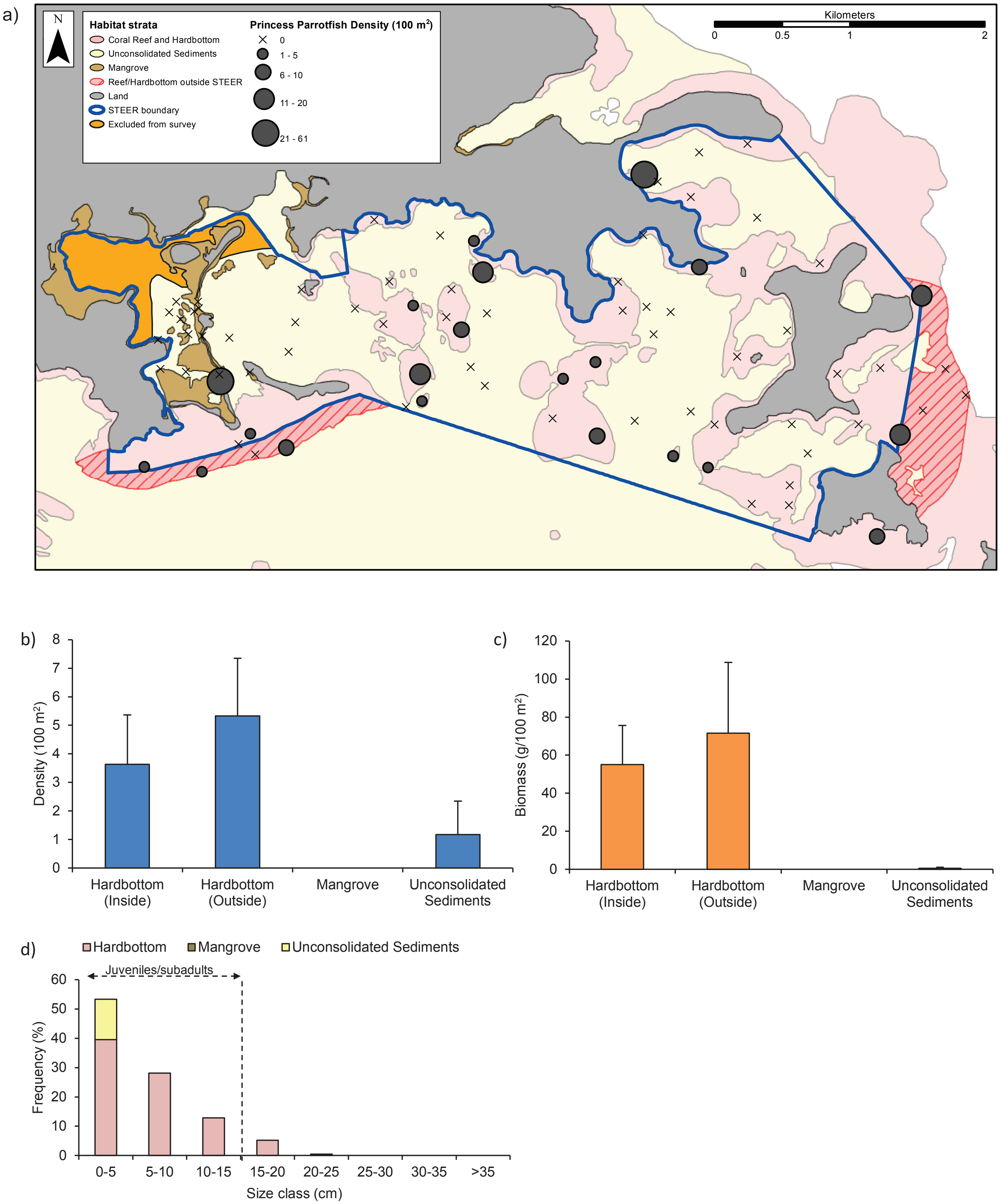


Figure 50. Princess parrotfish (*Scarus taeniopterus*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

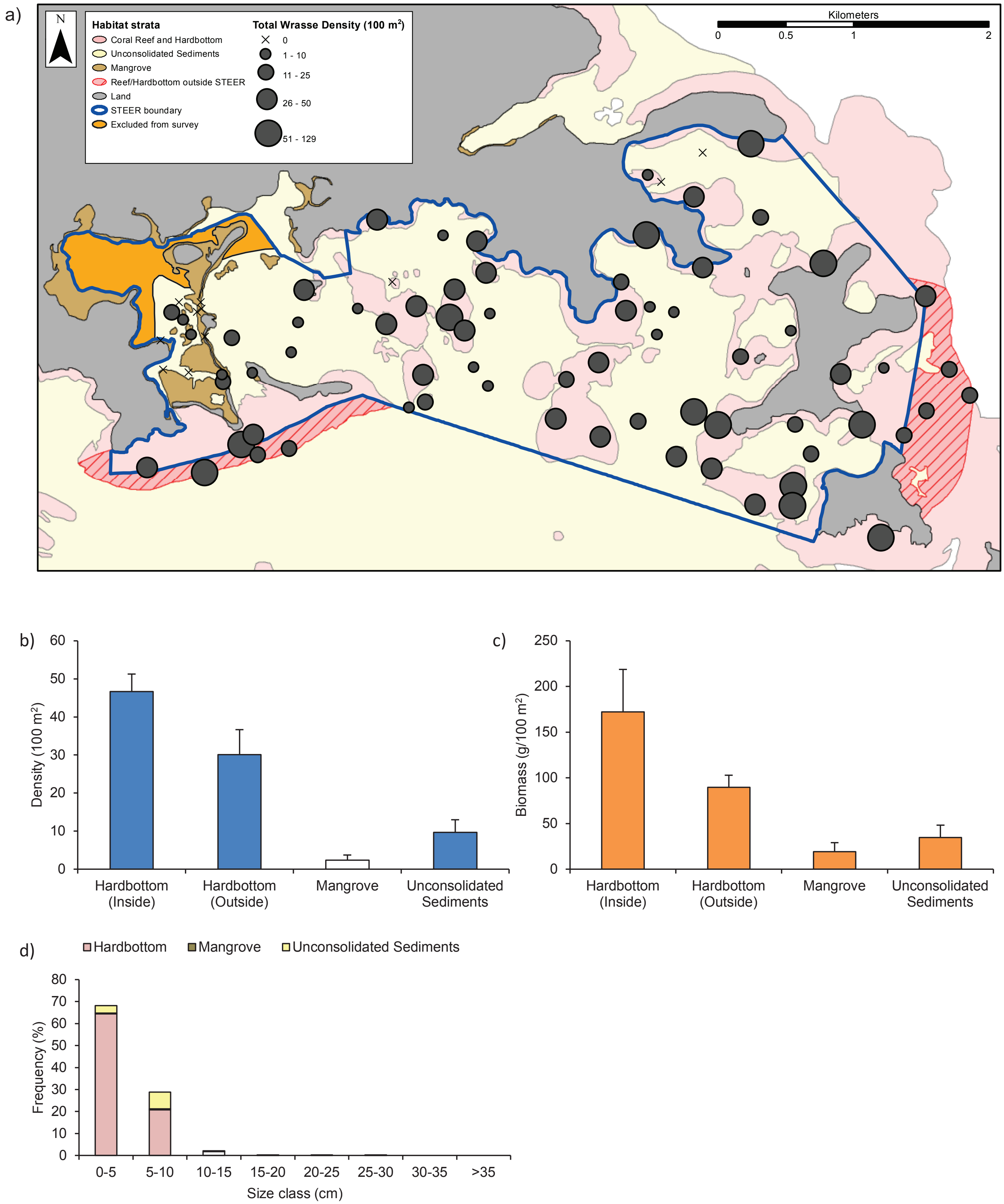


Figure 51. Wrasse (Family Labridae) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

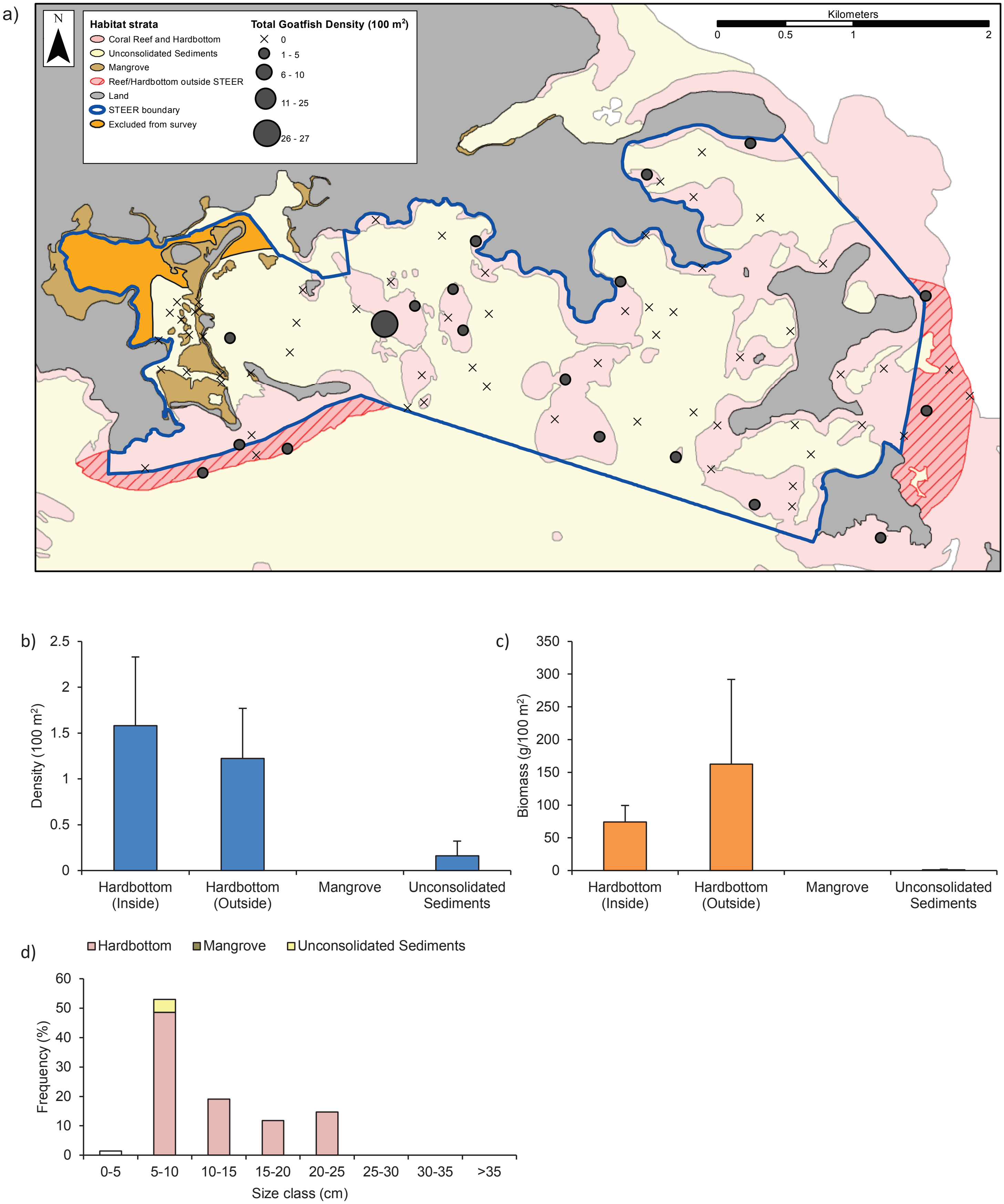


Figure 52. Goatfish (Family Mullidae) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

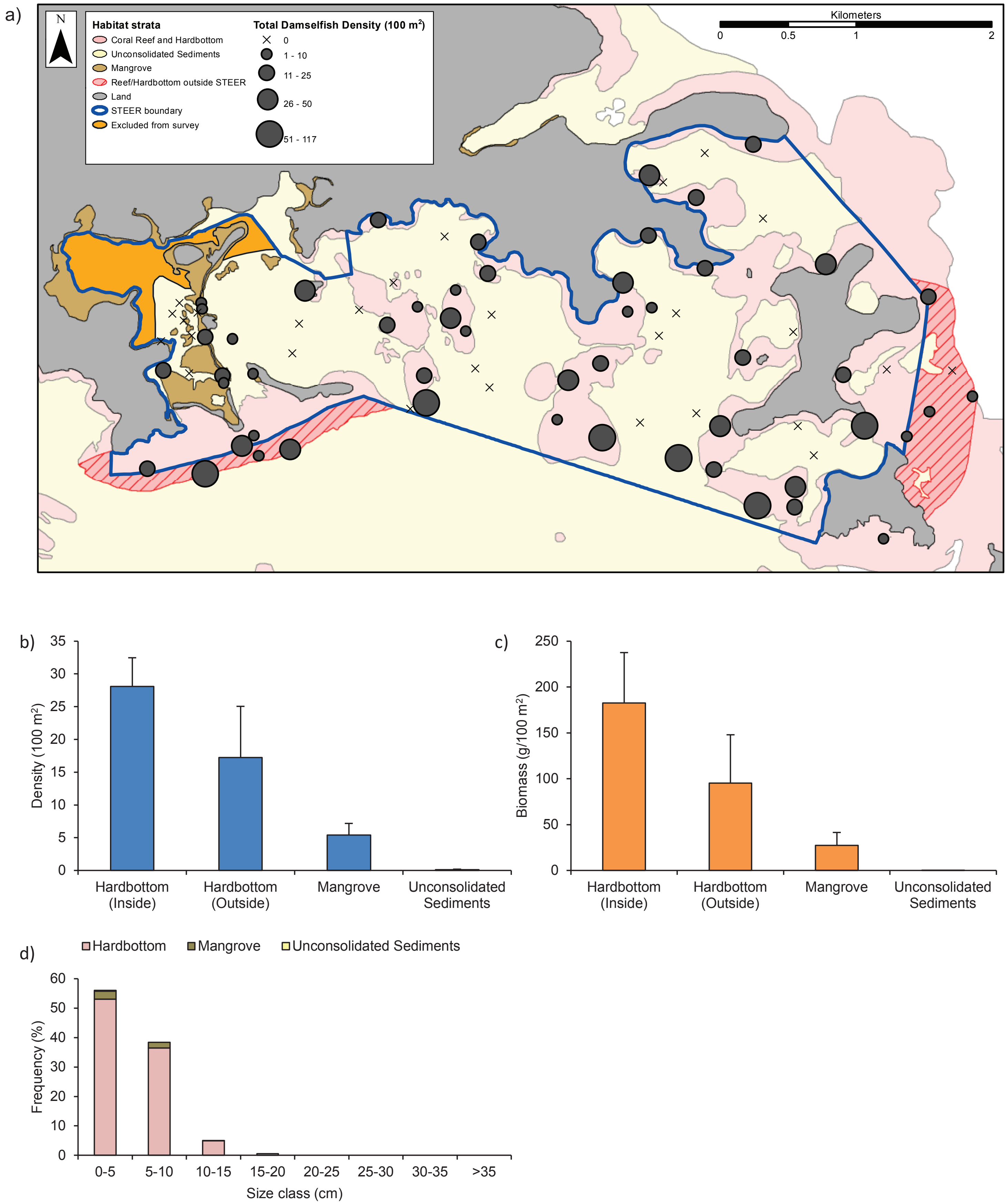


Figure 53. Damselfish (Family Pomacentridae) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

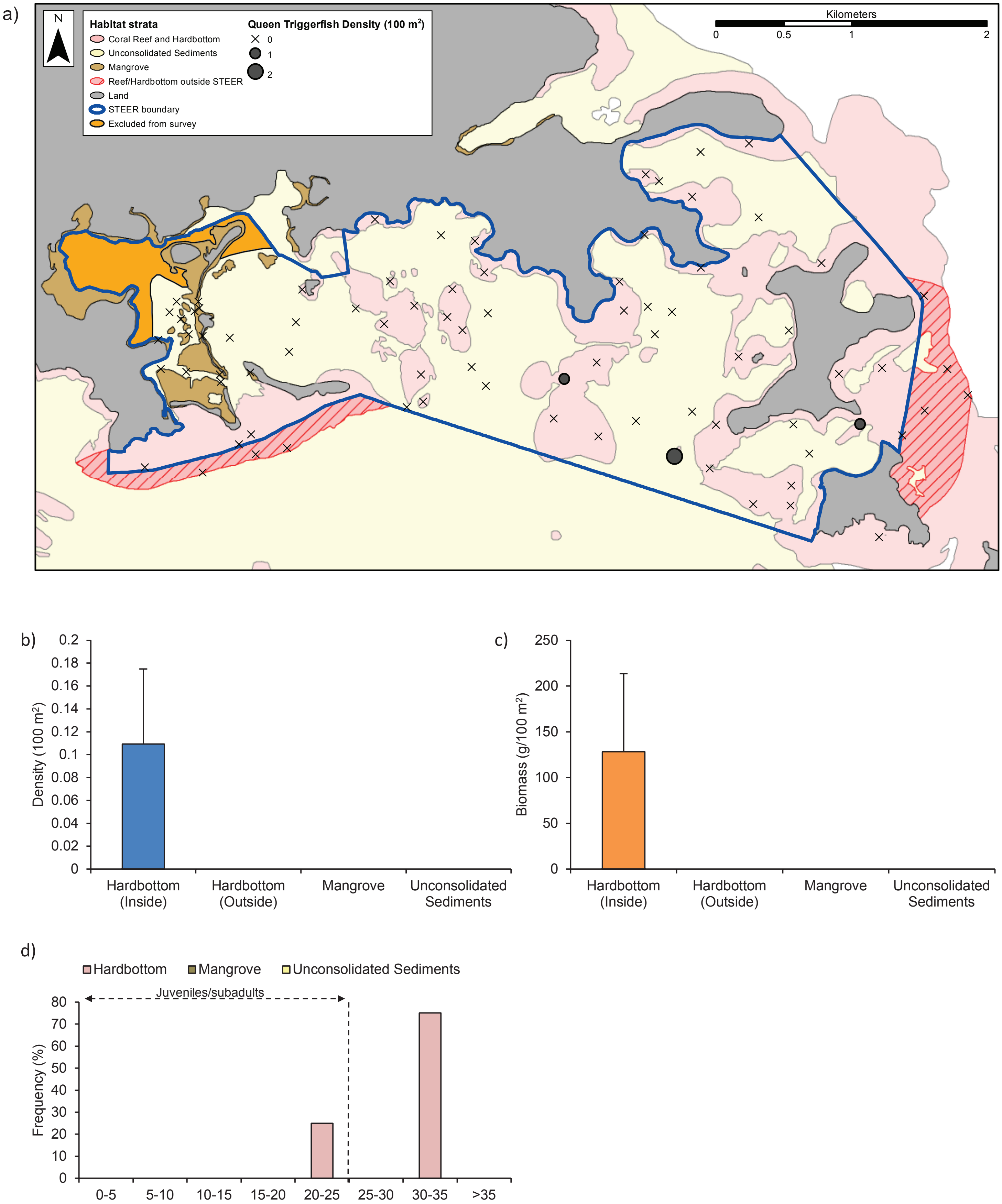


Figure 54. Queen triggerfish (*Balistes vetula*) a) spatial distribution, b) mean density (±SE) by habitat, c) mean biomass (±SE) by habitat, and d) size frequency.

compared to Eastern St. Croix (p = 0.034) and SWPR (p = 0.021), but did not differ from St. John. In contrast, soft coral cover was significantly lower in STEER compared to SWPR (p<0.0001) but was higher than St. John (p = 0.003). Both macroalgae and turf algae were significantly higher in STEER compared to Eastern St. Croix (p = 0.004 and p = 0.001, respectively), but were not statistically different from the other two study locations. Due to the ephemeral nature of turf algae, percent cover values can be influenced by seasonal and interannual variation.

Unconsolidated sediment habitats in all four study regions were dominated by seagrass and macroalgae, with the highest means occurring in STEER (Figure 55b). Results of the nonparametric comparisons indicated that seagrass cover was significantly greater in STEER compared to St. John (p = 0.011) and SWPR (p = 0.001), while the p = value for the pairwise comparison with Eastern St. Croix was marginally significant (p = 0.052). Similarly, percent cover of macroalgae was significantly higher in STEER compared to the other study locations (St. John: p = 0.019, St. Croix: p = 0.004, SWPR: p = 0.036). Seagrass beds in all four study areas were composed of mostly *Syringodium filiforme* and *Thalassia testudinum* in which smaller amounts of sponges, gorgonians, living corals and other benthic invertebrates were also documented. Levels of seagrass and macroalgae cover in mangroves were similar in STEER and SWPR (Figure 55c) and there was no statistical difference between the two study areas.

On hardbottom habitat, fish species richness (Figure 56a) in STEER was similar to St. John and was significantly greater compared to Eastern St. Croix (p=0.001) and SWPR (p<0.001). While the overall test was significant, total biomass (Figure 56b) on hardbottom in STEER did not differ significantly from any of the other study areas. At the family level, biomass levels were not consistent across regions (Figure 56c-f). Grouper biomass did not vary significantly among regions, while grunt biomass was significantly greater on hardbottom in STEER compared to Eastern St. Croix (p=0.009 and p=0.002, respectively). Similarly, snapper biomass was significantly lower in Eastern St. Croix compared to STEER, SWPR, and St. John (p<0.01 for all comparisons). Parrotfish biomass was similar between all four regions with no significant differences detected.

On unconsolidated sediments, total fish biomass was significantly lower in STEER and St. John compared to Eastern St. Croix, due primarily to the occurrence of several southern stingrays in St. Croix in 2010. Grouper biomass did not vary significantly among regions. While grunt biomass was significantly greater in SWPR compared to St. John and Eastern St. Croix, no pairwise comparisons with STEER were significant. Snapper and parrotfish biomass were

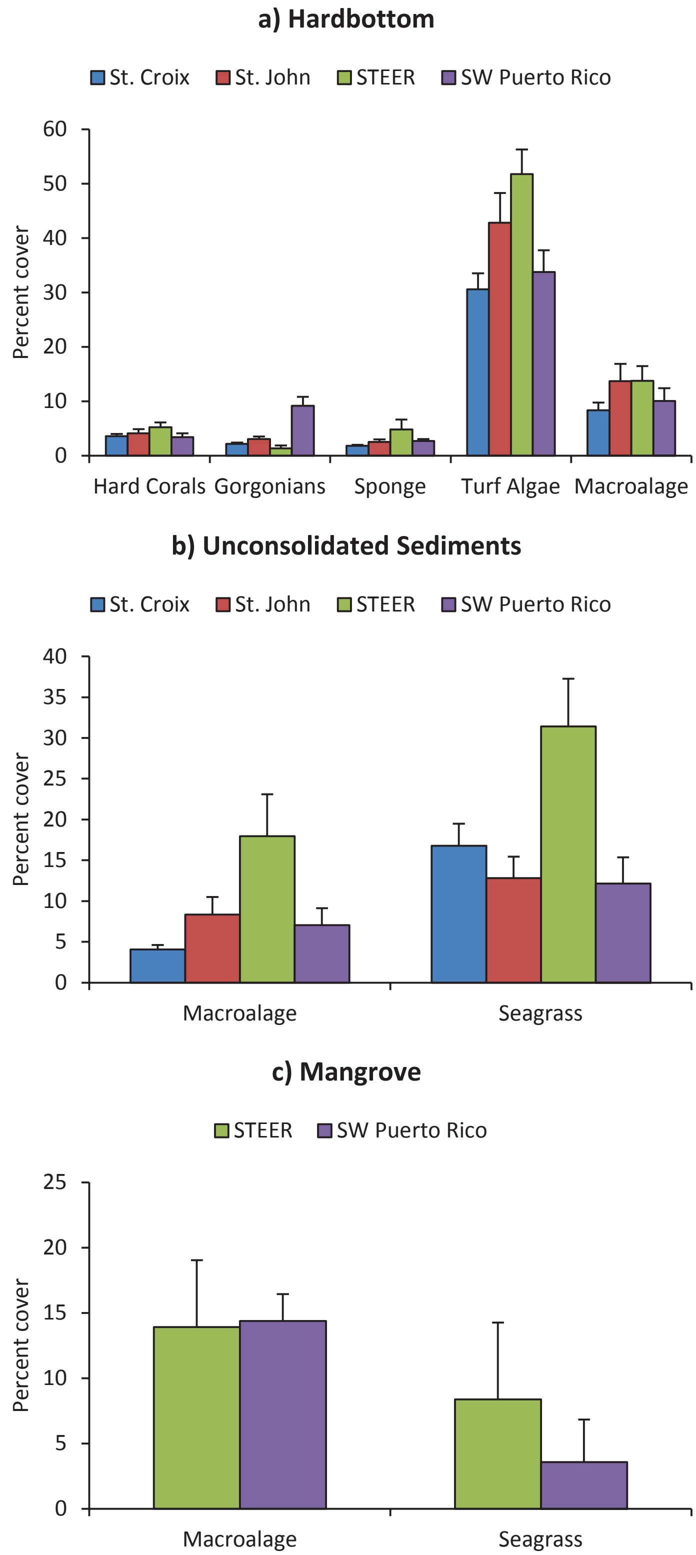


Figure 55. Comparison of benthic cover groups between STEER and other locations within NOAA's Caribbean Coral Reef Ecosystem Monitoring Program. Estimated mean (±SE) percent cover on a) hardbottom, b) unconsolidated sediments, and c) mangrove.

similar across all study areas with no statistical differences detected.

Mangroves in STEER had similar fish community metrics compared to mangroves in SWPR. Although mean total biomass was larger in STEER than SWPR, there was high variance among STEER sites and results of the non-parametric tests indicated no significant difference between the two regions. Species richness and biomass of the other groups also did not vary significantly between STEER and SWPR.

In summary, despite differences in fishing regulations, fish community metrics in STEER were similar to other U.S. Caribbean monitoring locations sampled with the same methodology. With a few exceptions for baitfishing and hook and line with permit, STEER is primarily a no-take reserve. Portions of the St. John (Virgin Islands National Park, Virgin Islands National Reef Monument) and St. Croix (Buck Island

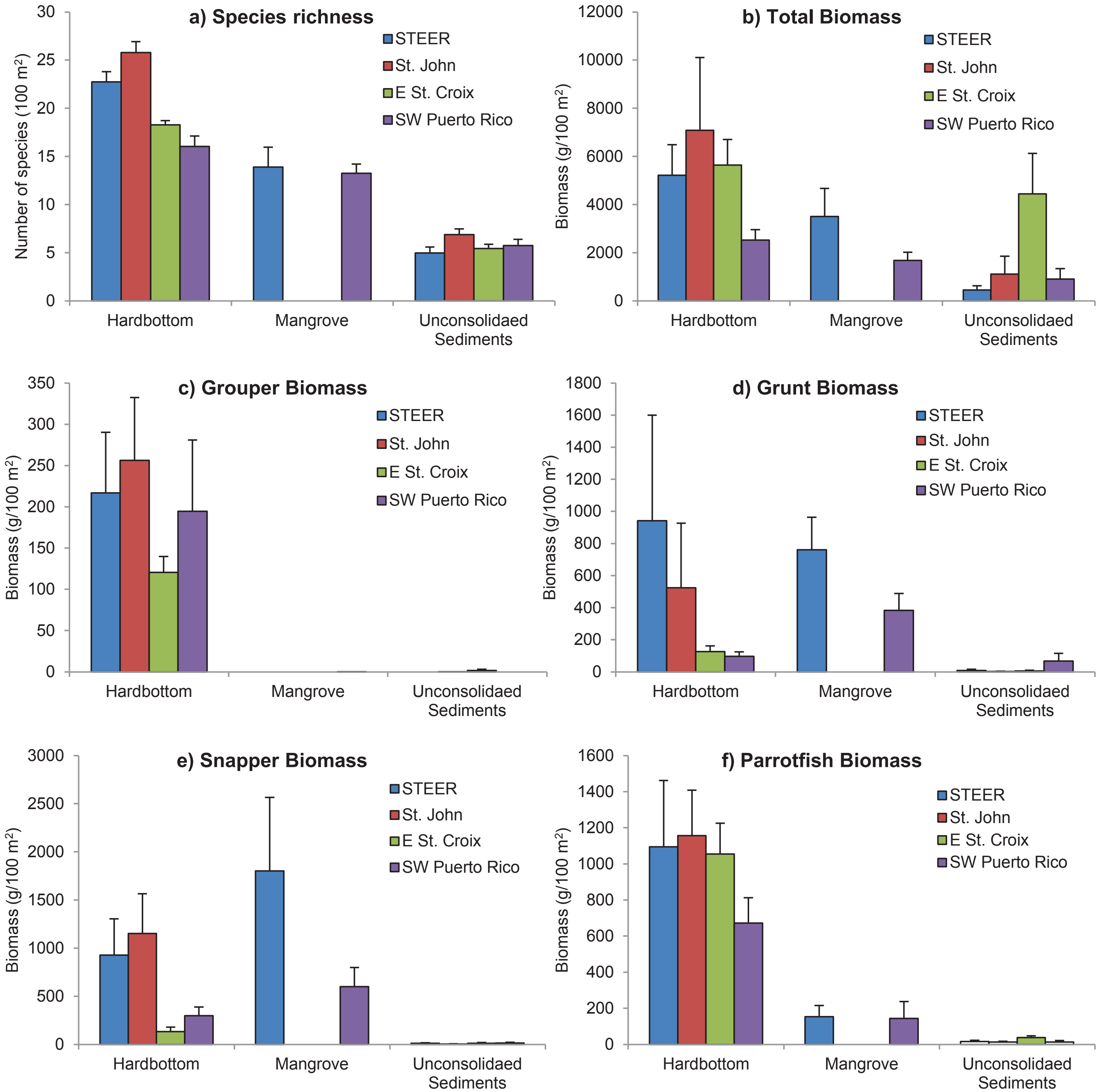


Figure 56. Comparison of community metrics between STEER and other locations within NOAA's Caribbean Coral Reef Ecosystem Monitoring Program. Estimated mean (±SE) a) species richness, b) total biomass, c) grouper biomass, d) grunt biomass, e) snapper biomass, and f) parrotfish biomass.

National Reef Monument, East End Marine Park) study areas are also no-take, while the SWPR study area is open to fishing. On hardbottom habitat, STEER differed only from SWPR (higher species richness) and St. Croix (higher grunt and snapper biomass). The difference from St. Croix may be partially due to differences in habitat as eastern St. Croix lacks the extensive mangroves that in STEER appear to serve as important nursery areas for juvenile fishes in these families. No metrics were significantly different between STEER and nearby St. John. These two islands share many similarities in terms of geographic location, physiographic environment, and distribution of benthic habitats, although St. John is more sparsely populated in comparison. Although this comparison focused on broad community metrics for this assessment, more in-depth analysis could be conducted to look for differences at the species level, or to examine how factors such as fishing pressure and other anthropogenic factors (e.g., depth and habitat complexity) affect community composition across the USVI and Puerto Rico. For instance, although fishing is greatly restricted in STEER, poaching still occurs (Dillard and D'lorio 2012). At the same time, fewer snapper are generally taken on the south shore of St. Thomas and St. John due to concerns about ciguatera poisoning (Smith et al. 2012).

Discussion and Conclusions

This study provides a baseline characterization of the fish and benthic communities of STEER necessary to assess the effectiveness of the comprehensive management plan (STEER 2011) and potential watershed restoration activities (Horsely-Witten Group 2013a). STEER includes an interconnected mosaic of marine habitats, including the largest remaining mangrove system in St. Thomas (IRF/UVI 1993), extensive beds of submerged aquatic vegetation, and coral reef communities. The establishment of STEER enables this complex area to be managed as one comprehensive unit rather than the existing individual reserves and wildlife sanctuaries (STEER 2011).

Gray Angelfish (*Pomacanthus arcuatus*) in STEER.

The low coral cover observed in STEER reflects the record declines of coral reefs in the USVI and the Caribbean as a whole (Wilkinson, 2000; Catanzaro et al., 2002; Jeffrey et al., 2005; Rogers et al., 2008). Rogers et al. (2008) reported that some reefs in the USVI had over 40% coral cover during the 1980s but was subsequently reduced to 25% cover by the 1990s, with hurricane damage and disease cited as the main causative factors. Additional stressors contributing to decline in coral cover include sediment input from increased development (MacDonald et al., 1997; Brooks et al., 2007), associated nutrient enrichment (Fabricius 2005) and land-based sources of pollution (Warne et al., 2005). Additionally, climate change poses a broader regional threat to corals (Donner et al., 2007). The mass bleaching event in 2005 followed by a coral disease outbreak (Bruno et al. 2007) caused a 60% decline in cover of key coral species in the USVI (Miller et al. 2009).

The 2005 bleaching event was captured by multiple monitoring programs around the Caribbean. Each region in the USVI being monitored had low coral cover across reef types and years (Rothenberger et al. 2008), with each island's reefs exhibiting the trend of decline (Rogers et al. 2008). At permanent monitoring sites in St. Croix, weighted mean estimates of live coral decreased from 8.0% in February 2001 to 2.9% in October 2006, similar to reefs in St. John which were 8.4% in 2001 and declined to 4.5% by July of 2006 (Rogers et al. 2008). Friedlander et al. (2013) reported that coral cover has continued to decline in St. John to less than 3% regardless of protective status as of 2009.

The Territorial Coral Reef Monitoring Program (TCRMP), which began in 2001, uses digital video transects to estimate benthic cover of hardbottom habitats at 33 long-term monitoring sites in the USVI, including 16 locations around St. Thomas (Smith et al. 2012). This effort includes nearshore, midshelf, and outershelf reef systems in an effort to capture the diversity of reef types in the USVI. Mean live coral cover for all nearshore reefs in St. Thomas declined from 20.3% in 2002 to 9.3% in 2007 after the bleaching event and subsequent disease outbreak. This is the lowest average cover observed since the monitoring began in 2001 (unplublished data, Smith pers. comm). Since 2007, percent coral cover has increased slightly (Smith et al. 2013).

Percent live coral cover in STEER was similar to that observed in NOAA's long-term monitoring study in nearby St. John (Friedlander et al. 2013), but was much lower than the data reported by TCRMP. For example, the only TCRMP site within STEER, at Colculus Rock, is reported to have over twice the coral cover than two randomly selected sites in the current study that were located within 300 m of the TCRMP site and at similar depths (11.5% TCRMP, 3.88% & 4.6% this study). The differences of overall coral cover between the TCRMP sites and those sampled in this study may be attributed to the focus of this study in the shallow waters of STEER (35% of NOAA sites surveyed during this effort were <5 m; 100% of TCRMP were >5 m), differences in how sites were selected, and the distinct estimation methods. This may also reflect deeper reefs being less susceptible to bleaching (Sheppard 2006; T. Smith, UVI, pers. comm.) and subsequent disease outbreaks and therefore maintain higher coral cover overall. The higher overall values at TCRMP sites do call attention to other reefs around St. Thomas that should be considered for protection (Smith et al. 2012).

Coral community structure inside and around STEER is similar to that of nearshore reefs around St. John (Friedlander et al. 2013), St. Croix (Pittman et al. 2008), and Puerto Rico (Bauer et al. 2013). Our study sites also reflect the species composition documented by TCRMP in STEER and around St. Thomas (Smith et al. 2012). The majority of reefs in the USVI have become dominated by *Orbicella*, *Porites*, *Siderastrea*, and *Diploria/Pseudodiploria* genera (Jeffrey et al. 2005; Herzlieb et al. 2006; Rogers et al. 2008), particularly after the decades long decimation of acroporids due to white band disease, hurricanes (Rogers et al. 1993), and bleaching events (Miller et al., 2006; Rogers et al., 2008). ESA-listed species were infrequently observed in the 2012 field survey. Elkhorn coral (*Acropora cervicornis*) was documented at three sites in STEER during this study and ranged from 0.2-2.6% coverage. Staghorn coral (*A. palmata*) was not recorded in any survey quadrats, but was anecdotally observed at two shallow sites, one east of Great St. James Island and the other on the southwest reef tract south of Patricia Cay.

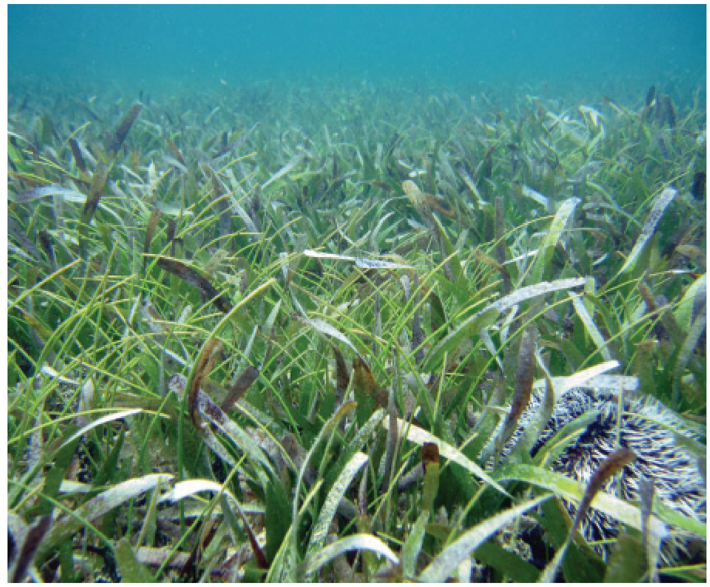
STEER encompasses a unique seascape in the USVI while possibly being one of the most impacted due to the high population density in the watershed. In addition to changes in the coral reefs as previously noted, historical studies also indicate changes in the mangrove and seagrass communities. Grigg et al. (1971) noted an increase in shoreline development and boating activity and associated poor water quality in Benner Bay. The authors also expressed concern about increasing anthropogenic stress on Mangrove Lagoon and the southern reaches of Benner Bay, where turbidity and other water quality parameters varied with fluctuations in storm runoff and tidal cycles. In addition to the increasing development and maritime activities, at that time, a sewage treatment plant also discharged effluent directly into the inner Mangrove Lagoon, which receives little flushing (Grigg et al. 1971). The outfall continued to be operational until wastewater was diverted to the new Mangrove Lagoon Wastewater Treatment Plant (MLWTP) in 2003, which discharges into the ocean at Long Point, outside and down current from STEER (DPNR 2003). There have been notable changes in the seascape of the Mangrove Lagoon complex over time. Whereas seagrass covered much of the seafloor in the lagoon in the 1970s, macroalgae presently dominates the benthos (Colletti 2011).

Elkhorn coral (*Acropora palmata*) and other species colonize a coral reef in STEER.

Species composition varied across benthic habitats within the STEER. Species such as schoolmaster, gray snapper, and herring were most often associated with mangroves, while groupers and surgeonfish were more closely associated with coral reef and hardbottom. Other species, such as redband parrotfish, striped parrotfish, and yellowtail snapper, were present across multiple habitat types. Habitat utilization patterns may be influenced by factors such as lifestage, time of day, and surrounding seascape structure. In addition, Pittman et al. (2011) demonstrated that the scale at which surrounding seascape structure influences fish density varies by species. Species with smaller home ranges and diurnal shifts in feeding and habitat utilization, such as juvenile French grunt, were more responsive to smaller scale habitat patterns than species with broader movement patterns (Pittman et al. 2011).

Many coral reef fish species exhibit ontogenetic shifts in diet and habitat as they transition between post-settlement, juvenile, and adult lifestages (Nagelkerken et al. 2000; Cocheret de la Morinière et al. 2002). Mangroves, seagrass, and shallow nearshore reefs have been shown serve as important "nursery" habitat for the juvenile stages. Colletti (2001) previously suggested that Benner Bay/Mangrove Lagoon functions as nursery habitat for several coral reef species but particularly yellowtail snapper, schoolmaster, and French grunt. The size frequencies observed in this study also infer use of southern Mangrove Lagoon by juvenile individuals of these three species. Schoolmaster juveniles/subadults were predominantly observed in mangrove surveys, both within Mangrove Lagoon and western Benner Bay, while adults were only documented on hardbottom. This is consistent with previous research documenting ontogenetic shift of this species from mangrove to coral reefs as adults although adults will also utilize mangroves (Nagelkeren et al. 2000). While all sizes of yellowtail snapper were observed on coral reef and hardbottom, only individuals of the smallest size classes (<15 cm) were observed in mangrove and unconsolidated sediment habitats, both inside and outside Mangrove Lagoon. The smallest individuals (0-5 cm) were most frequently associated with seagrass beds. Similarly, juvenile French grunts were most frequently associated with mangroves but were occasionally observed on shallow hardbottom or unconsolidated sediments, while adults were exclusively seen on hardbottom. In addition, juvenile grunts in the smallest size class (0-5 cm) that could not be identified to the species level were commonly documented in mangroves and unconsolidated sediments, with the highest densities occurring at mangrove locations in western Benner Bay. This indicates that while Mangrove Lagoon appears to serve as important nursery habitat for yellowtail snapper and grunts, other shallow bays and bottom types within STEER are also utilized by juveniles. Further research is warranted to fully examine the nursery function of Mangrove Lagoon. Adams et al. (2006) recommended an interdisciplinary approach that includes building conceptual models, identifying habitat-specific density patterns, direct study of fish movements through the use of natural and artificial tags, and examination of underlying processes and mechanisms. A broader sampling scope would be required to capture areas of Mangrove Lagoon that cannot be sampled with visual surveys.

In a recent assessment of chemical contaminants in sediments within STEER, higher levels of chemical contaminants were found in Mangrove Lagoon and Benner Bay, as well as significant sediment toxicity (Pait et al. 2013a). The areas where highest contaminant levels were observed were not sampled in this survey due to low visibility and diver safety concerns. However, previous research indicated that the fish community in the inner Mangrove Lagoon differs from the middle and outer portions that were included in this study. In the recent trapping study, researchers from DPNR and UVI found significant differences in species diversity, species composition, and abundance of fishes between the degraded inner lagoon section and the middle/outer lagoon sections (Murray 2009, Colletti 2011). In particular, Colletti (2011) found that mangrove fringes with adjacent dense seagrass/macroalgal cover and in close proximity to coral reefs had significantly higher species richness and total abundance of juvenile fish than the inner bay, which was characterized by high cyanobacterial cover. This pattern was also observed in relation to the density of several individual snapper and grunt species (Colletti 2011). Similar trends of lower fish species richness and density in the inner lagoon in comparison to middle/outer sections were found in a previous trapping study conducted from 1986-1988 (Boulon 1992). Overall, Colletti (2011) found similar patterns in juvenile fish abundance in comparison to Boulon (1992), but fewer species were observed in comparison to the earlier study. The differences in fish community between the different sections of the lagoon may be influenced by additional factors, including contaminated water/sediments and low dissolved oxygen. Murray (2009) observed that occasionally fish caught in the inner lagoon were dead when traps were retrieved after soaking for one day, and it was presumed that these fish died of suffocation due to the extremely low dissolved oxygen present. Insufficient food could also be a factor for species that are primarily benthic feeders (e.g., grunts) as Pait et al. (2013a) observed a severely diminished infaunal community in this area. The outer portion of the lagoon experiences more flushing from the false entrance to Mangrove Lagoon between Patricia and Bovoni Cays. Shoals have built up at the mouths of additional inlets (DPNR 2003). Overall, the DPNR and UVI work and the current assessment demonstrate the importance of Mangrove Lagoon and Benner Bay as habitat for snappers, grunts, parrotfish, and other species, and highlights the need to conserve and restore this ecosystem.



Seagrass bed in STEER, including turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*).

Protected status and water quality improvement are two approaches that may help improve coral, mangrove and seagrass ecosystem health, but cannot mitigate the effects of the greatest global threat to coral reefs: high thermal stress (Hughes et al. 2003; Bruno et al. 2007; Baker et al. 2008). Sustained high water temperatures in the summer often lead to bleaching events that can be followed by disease outbreaks due to the compromised health of bleached corals (Miller et al. 2009). Contributing to the disease outbreaks are warmer winter temperatures that may reduce the mortality rates of coral pathogens and increase the amount of coral disease (Bruno et al. 2007). Adopting a seascape-wide coral reef management approach includes protecting mesophotic and mid-shelf reefs, which are not as susceptible to bleaching or disease and could serve as “reef refuges” to maintain healthy stocks of some benthic and fish communities. These stocks would then in turn provide source populations for nearshore systems like STEER (Smith et al. 2012).

As part of this assessment, we also surveyed several locations just outside of the STEER boundaries that were of interest to managers. While the area to the east of the STEER primarily consisted of pavement/rubble, sites on the southwest reef complex that stretches from Long Point east to Cas Cay ranked high in terms of coral cover, fish species richness, total fish density and total fish biomass. The highest grouper density was also observed in a survey along this reef, including the only sighting of yellowmouth grouper. Factors that may contribute to the biological richness of this area include high structural complexity and proximity to both the mangrove fish nursery to the north and open ocean to the south. Although the shoreward portion of this reef complex is already included within STEER, the southern portion of the reef should also be considered for inclusion in the reserve due to its ecological importance and connectivity to the significant mangrove forest in Mangrove Lagoon. The area receives a considerable amount of boat traffic from ferries traversing to/from Charlotte Amalie, and the recent coastal use assessment indicates that the area is also a hotspot for fishing (Dillard and D’Iorio 2012).

This study provides just one spatially comprehensive snapshot of the current conditions within STEER, so it is important that fish and benthic communities within the reserves continue to be monitored over time to meet management objectives (STEER 2011). In addition to yearly monitoring of TCRMP permanent sites, the coral reef and hardbottom habitats in St. Thomas and STEER will continue to be surveyed every two years through NOAA’s National Coral Reef Monitoring Program (NCRMP). At each survey location, fish belt transects, as used in this study, will be conducted, while line point intersect (LPI) and coral demographics transects will be used to characterize the benthic communities. Mangroves, seagrasses, and other soft sediments will not be included in the NCRMP monitoring; however these habitats provide critical ecosystem services, including nutrient cycling, carbon sequestration, shoreline stabilization, nursery habitat for fish, and protection from wind/waves. Hence, further research and monitoring in these areas are warranted. Due to the limitations in conducting visual surveys in much of Mangrove Lagoon and Benner Bay, a repeat of the trapping study (Murray 2009; Colletti 2011) or alternative methods could be explored to cover areas that cannot be surveyed by visual census. In addition, periodic re-mapping of benthic habitats will capture large-scale changes in the reserve and the habitats that support benthic invertebrate and fish communities.

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Appendix 1. Mean species site frequency, density, and biomass for fish species observed within STEER in the 2012 survey.

Species	Common name	Family	Trophic group	% of Surveys	Mean Density (SE)	Mean Biomass (SE)
Abudefduf saxatilis	Sergeant Major	Pomacentridae	I	18%	0.44 (0.25)	17.12 (11.27)
Acanthurus bahianus	Ocean Surgeonfish	Acanthuridae	H	52%	4.96 (0.67)	148.28 (41.43)
Acanthurus chirurgus	Doctorfish	Acanthuridae	H	14%	0.73 (0.35)	72.65 (40.24)
Acanthurus coeruleus	Blue Tang	Acanthuridae	H	42%	2.67 (0.47)	107.21 (23.71)
Acanthemblemaria maria	Secretary Blenny	Chaenopsidae	PL	1%	0.03 (0.03)	0.01 (0.01)
Anisotremus surinamensis	Black Margate	Haemulidae	I	3%	<0.01 (<0.01)	0.02 (0.01)
Anisotremus virginicus	Porkfish	Haemulidae	I	1%	0.01 (0.01)	5.25 (5.25)
Apogon aurolineatus	Bridle Cardinalfish	Apogonidae	PL	1%	0.08 (0.08)	0.04 (0.04)
Archosargus rhomboidalis	Sea bream	Sparidae	H	3%	<0.01 (<0.01)	0.11 (0.11)
Atherinomorus species	silversides	Atherinidae	H	3%	0.45 (0.41)	0.12 (0.11)
Bathygobious soporator	Frillfin Goby	Gobiidae	I	3%	0.02 (0.01)	0.01 (0.01)
Balistes vetula	Queen Triggerfish	Balistidae	I	4%	0.04 (0.02)	46.04 (30.5)
Bodianus rufus	Spanish Hogfish	Labridae	I	6%	0.05 (0.02)	11.75 (6.11)
Calamus bajonado	Jolthead Porgy	Sparidae	I	1%	0.02 (0.02)	24.33 (24.33)
Carangoides bartholomaei	Yellow Jack	Carangidae	P	1%	0.03 (0.03)	30.82 (30.82)
Calamus calamus	Saucereye Porgy	Sparidae	I	3%	0.36 (0.33)	36.17 (31.46)
Caranx crysos	Blue Runner	Carangidae	P	6%	0.17 (0.11)	80.27 (57.82)
Calamus species	porgies	Sparidae	I	1%	<0.01 (<0.01)	0.05 (0.05)
Caranx lugubris	Black Jack	Carangidae	P	1%	0.01 (0.01)	16.44 (16.44)
Calamus penna	Sheepshead Porgy	Sparidae	I	1%	<0.01 (<0.01)	0.01 (0.01)
Calamus pennatula	Pluma Porgy	Sparidae	I	1%	0.01 (0.01)	2.8 (2.8)
Cantherhines pullus	Orangespotted Filefish	Monacanthidae	I	1%	0.01 (0.01)	1.03 (1.03)
Caranx species	jacks	Carangidae	P	1%	<0.01 (<0.01)	0.89 (0.89)
Canthigaster rostrata	Sharpnose Puffer	Tetraodontidae	I	34%	0.49 (0.09)	1.19 (0.33)
Carangoides ruber	Bar Jack	Carangidae	P	18%	0.64 (0.31)	18.18 (7.19)
Cephalopholis cruentata	Graysby	Serranidae	P	11%	0.1 (0.03)	13.49 (5.8)
Cephalopholis fulva	Coney	Serranidae	I	1%	0.01 (0.01)	3.55 (3.55)
Chaetodon capistratus	Foureye Butterflyfish	Chaetodontidae	I	32%	0.46 (0.12)	5.03 (1.21)
Chromis cyanea	Blue Chromis	Pomacentridae	PL	15%	1.17 (0.54)	6.36 (3.94)
Chromis multilineata	Brown Chromis	Pomacentridae	I	13%	1.55 (0.89)	6.23 (3.8)
Chaetodon striatus	Bande Butterflyfish	Chaetodontidae	I	1%	0.01 (0.01)	0.12 (0.12)
Clepticus parrae	Creole Wrasse	Labridae	PL	1%	0.06 (0.06)	16.14 (16.14)
Coryphopterus glaucofraenum	Bridled Goby	Gobiidae	I	23%	1.01 (0.37)	2.17 (1.02)
Coryphopterus personatus/ hyalinus	Masked/glass Goby	Gobiidae	I	17%	8.29 (3.83)	7.49 (3.28)
Coryphopterus species	goby Coryphopterus	Gobiidae	I	1%	0.01 (0.01)	0.01 (0.01)
Cryptotomus roseus	Bluelip Parrotfish	Scaridae	H	11%	0.34 (0.13)	1.3 (0.8)
Ctenogobius saepepallens	Dash Goby	Gobiidae	I	1%	0.01 (0.01)	0.07 (0.07)
Echeneis naucrates	Sharksucker	Echeneidae	PL	1%	0.03 (0.03)	18.56 (18.56)
Elacatinus species	goby Elacatinus	Gobiidae	I	1%	0.02 (0.02)	0.22 (0.22)
Elacatinus oceanops	Neon Goby	Gobiidae	I	4%	0.05 (0.03)	0.01 (0.01)
Epinephelus guttatus	Red Hind	Serranidae	I	13%	0.13 (0.05)	57.4 (23.91)
Equetus punctatus	Spotted Drum	Sciaenidae	I	1%	0.01 (0.01)	3.68 (3.68)
Eucinostomus melanopterus	Flagfin Mojarra	Gerreidae	I	14%	0.55 (0.35)	1.28 (1.04)

Appendix 1 (cont). Mean species site frequency, density, and biomass for fish species observed within STEER in the 2012 survey.

Species	Common name	Family	Trophic group	% of Surveys	Mean Density (SE)	Mean Biomass (SE)
Gerres cinereus	Yellowfin Mojarra	Gerreidae	I	23%	1.39 (0.7)	13.04 (5.95)
Ginglymostoma cirratum	Nurse Shark	Ginglymostoma-tidae	I	1%	<0.01 (<0.01)	2.38 (2.38)
Gnatholepis thompsoni	Goldspot Goby	Gobiidae	H	14%	0.15 (0.06)	0.03 (0.01)
Gobiidae species	gobies	Gobiidae	I	6%	0.04 (0.02)	0.03 (0.01)
Gramma loreto	Fairy Basslet	Grammatidae	I	3%	0.08 (0.05)	0.03 (0.02)
Haemulon aurolineatum	Tomtate	Haemulidae	I	8%	0.83 (0.52)	31.93 (21.14)
Halichoeres bivittatus	Slippery Dick	Labridae	I	62%	6.45 (1.19)	18.16 (3.97)
Haemulon carbonarium	Caesar Grunt	Haemulidae	I	1%	0.29 (0.29)	60.22 (60.22)
Halichoeres cyanocephalus	Yellowcheek Wrasse	Labridae	P	1%	0.02 (0.02)	0.11 (0.11)
Haemulon species	grunts	Haemulidae	I	13%	0.68 (0.29)	1.07 (0.62)
Haemulon flavolineatum	French Grunt	Haemulidae	I	35%	1.21 (0.55)	139 (108.32)
Halichoeres garnoti	Yellowhead Wrasse	Labridae	I	39%	2.22 (0.85)	10.77 (2.95)
Haemulon melanurum	Cottonwick	Haemulidae	I	1%	0.01 (0.01)	0.42 (0.42)
Halichoeres maculipinna	Clown Wrasse	Labridae	I	32%	0.72 (0.12)	2.04 (0.72)
Haemulon parra	Sailors Choice	Haemulidae	I	1%	<0.01 (<0.01)	0.03 (0.03)
Haemulon plumierii	White Grunt	Haemulidae	I	10%	0.15 (0.1)	40.2 (29.32)
Halichoeres poeyi	Blackear Wrasse	Labridae	I	17%	0.37 (0.12)	0.84 (0.37)
Halichoeres radiatus	Puddingwife	Labridae	I	15%	0.17 (0.05)	0.79 (0.37)
Haemulon sciurus	Bluestriped Grunt	Haemulidae	I	21%	0.67 (0.34)	58.12 (37.96)
Holocentrus adscensionis	Squirrelfish	Holocentridae	I	20%	0.3 (0.09)	12.43 (5.15)
Holacanthus ciliaris	Queen Angelfish	Pomacanthidae	I	8%	0.1 (0.05)	12.84 (7.81)
Holocanthus species	Angelfish species	Pomacanthidae	I	1%	<0.01 (<0.01)	0 (0)
Holocentrus rufus	Longspine Squirrelfish	Holocentridae	I	23%	0.38 (0.12)	24.98 (6.23)
Holacanthus tricolor	Rock Beauty	Pomacanthidae	I	6%	0.07 (0.04)	2.25 (1.15)
Hypoplectrus chlorurus	Yellowtail Hamlet	Serranidae	I	1%	0.01 (0.01)	0.16 (0.16)
Hypoplectrus indigo	Indigo Hamlet	Serranidae	I	1%	0.01 (0.01)	0.53 (0.53)
Hypoplectrus nigricans	Black Hamlet	Serranidae	I	3%	0.03 (0.02)	0.27 (0.2)
Hypoplectrus species	hamlets	Serranidae	I	4%	0.07 (0.05)	0.22 (0.21)
Hypoplectrus puella	Barred Hamlet	Serranidae	I	6%	0.04 (0.02)	0.16 (0.08)
Hypoplectrus unicolor	Butter Hamlet	Serranidae	I	6%	0.1 (0.07)	0.57 (0.33)
Jenkinsia species	herring	Clupeidae	PL	8%	0.41 (0.17)	0.02 (0.01)
Kyphosus sectator	Chub (Bermuda/Yellow)	Kyphosidae	H	3%	0.02 (0.01)	3.64 (2.71)
Lactophrys triqueter	Smooth Trunkfish	Ostraciidae	I	3%	0.04 (0.03)	9.12 (9)
Lutjanus analis	Mutton Snapper	Lutjanidae	I	1%	<0.01 (<0.01)	0.03 (0.03)
Lutjanus apodus	Schoolmaster	Lutjanidae	P	24%	0.3 (0.08)	46.08 (21.08)
Lutjanus griseus	Gray Snapper	Lutjanidae	I	23%	1.2 (0.65)	122.41 (99.96)
Lutjanus jocu	Dog Snapper	Lutjanidae	P	6%	0.13 (0.1)	25.1 (13.56)
Lutjanus mahogoni	Mahogany Snapper	Lutjanidae	P	7%	0.32 (0.22)	47.57 (39.9)
Lutjanus synagris	Lane Snapper	Lutjanidae	I	4%	0.07 (0.05)	8.42 (6.92)
Malacoctenus boehlkei	Diamond Blenny	Labrisomidae	I	1%	0.01 (0.01)	0.04 (0.04)
Malacoctenus macropus	Rosy Blenny	Labrisomidae	I	1%	0.03 (0.03)	0.02 (0.02)
Malacoctenus triangulatus	Saddled Blenny	Labrisomidae	I	20%	0.27 (0.07)	0.22 (0.12)
Microspathodon chrysurus	Yellowtail Damselfish	Pomacentridae	H	11%	0.12 (0.04)	6.93 (4.16)
Monacanthus ciliatus	Fringed Filefish	Monacanthidae	H	1%	0.03 (0.03)	0.01 (0.01)

Appendix 1 (cont). Mean species site frequency, density, and biomass for fish species observed within STEER in the 2012 survey.

Species	Common name	Family	Trophic group	% of Surveys	Mean Density (SE)	Mean Biomass (SE)
Monacanthus tuckeri	Slender Filefish	Monacanthidae	PL	4%	0.04 (0.02)	0.07 (0.06)
Mulloidichthys martinicus	Yellow Goatfish	Mullidae	I	4%	0.08 (0.05)	9.85 (7.21)
Myripristis jacobus	Blackbar Soldierfish	Holocentridae	I	1%	0.03 (0.03)	2.9 (2.9)
Ocyurus chrysurus	Yellowtail Snapper	Lutjanidae	PL	51%	1.57 (0.4)	94.82 (39.83)
Opistognathus aurifrons	Yellowhead Jawfish	Opistognathidae	PL	11%	0.31 (0.12)	0.36 (0.18)
Ophioblennius macclurei	Redlip Blenny	Blenniidae	H	7%	0.18 (0.12)	0.15 (0.07)
Paradiplogrammus bairdi	Lancer Dragonet	Callionymidae	I	1%	0.03 (0.03)	0.02 (0.02)
Pomacanthus arcuatus	Gray Angelfish	Pomacanthidae	I	3%	0.03 (0.02)	8.63 (7.12)
Pomacanthus paru	French Angelfish	Pomacanthidae	I	7%	0.08 (0.03)	11.91 (7.11)
Pseudupeneus maculatus	Spotted Goatfish	Mullidae	I	18%	0.58 (0.29)	17.45 (6.39)
Scarus guacamaia	Rainbow Parrotfish	Scaridae	H	1%	0.03 (0.03)	80.9 (80.9)
Scarus iseri	Striped Parrotfish	Scaridae	H	59%	4.22 (0.91)	25.95 (5.74)
Scomberomorus regalis	Cero	Scombridae	P	1%	0.03 (0.03)	15.8 (15.8)
Scarus taeniopterus	Princess Parrotfish	Scaridae	H	23%	2.04 (0.96)	20.1 (7.32)
Scarus vetula	Queen Parrotfish	Scaridae	H	7%	0.09 (0.04)	24.57 (13.92)
Serranus baldwini	Lantern Bass	Serranidae	P	3%	0.05 (0.04)	0.85 (0.71)
Serranus tabacarius	Tobaccofish	Serranidae	P	3%	0.04 (0.03)	0.42 (0.31)
Serranus tigrinus	Harlequin Bass	Serranidae	I	24%	0.43 (0.14)	2.67 (0.96)
Serranus tortugarum	Chalk Bass	Serranidae	PL	4%	0.09 (0.06)	0.03 (0.02)
Sparisoma atomarium	Greenblotch Parrotfish	Scaridae	H	15%	0.42 (0.19)	0.42 (0.21)
Sparisoma aurofrenatum	Redband Parrotfish	Scaridae	H	54%	3.26 (0.7)	82.81 (24.54)
Sphyraena barracuda	Great Barracuda	Sphyraenidae	P	15%	0.14 (0.08)	87.2 (49.97)
Sparisoma chrysopterum	Redtail Parrotfish	Scaridae	H	6%	0.1 (0.07)	0.97 (0.57)
Sparisoma radians	Bucktooth Parrotfish	Scaridae	H	14%	1.11 (0.51)	1.43 (0.9)
Sparisoma rubripinne	Yellowtail Parrotfish	Scaridae	H	11%	0.47 (0.21)	77.07 (43.74)
Sphoeroides spengleri	Bandtail Puffer	Tetraodontidae	I	1%	<0.01 (<0.01)	0.01 (0.01)
Sparisoma viride	Stoplight Parrotfish	Scaridae	H	42%	1.47 (0.34)	75.86 (21.51)
Stegastes adustus	Dusky Damselfish	Pomacentridae	H	10%	0.33 (0.17)	2.55 (1.86)
Stegastes diencaeus	Longfin Damselfish	Pomacentridae	H	25%	1.19 (0.44)	8.12 (3.39)
Stegastes leucostictus	Beaugregory	Pomacentridae	I	27%	1.05 (0.35)	3.36 (1.17)
Stegastes partitus	Bicolor Damselfish	Pomacentridae	H	35%	2.8 (0.71)	7.87 (4.4)
Stegastes planifrons	Threespot Damselfish	Pomacentridae	I	23%	0.89 (0.32)	4.05 (1.54)
Stegastes variabilis	Cocoa Damselfish	Pomacentridae	H	28%	0.67 (0.18)	3.18 (1.13)
Synodus intermedius	Sand Diver	Synodontidae	P	3%	0.05 (0.03)	0.19 (0.13)
Thalassoma bifasciatum	Bluehead	Labridae	I	51%	9.66 (1.54)	9.68 (1.98)
Xyrichtys martinicensis	Rosy Razorfish	Labridae	I	10%	3.02 (1.98)	12.9 (8.42)
Xyrichtys novacula	Pearly Razorfish	Labridae	I	3%	0.08 (0.06)	0.33 (0.24)
Xyrichtys splendens	Green Razorfish	Labridae	I	4%	0.11 (0.07)	0.35 (0.25)

Appendix 2. Mean species site frequency, density, and biomass for fish species observed in hardbottom surveys outside STEER (n=9) in the 2012 survey.

Species	Common name	Family	Trophic group	% of Surveys	Mean Density (SE)	Mean Biomass (SE)
Acanthurus bahianus	Ocean Surgeonfish	Acanthuridae	H	78%	5.78 (1.85)	129.64 (60.66)
Acanthurus chirurgus	Doctorfish	Acanthuridae	H	11%	0.44 (0.44)	8.05 (8.05)
Acanthurus coeruleus	Blue Tang	Acanthuridae	H	78%	4.11 (1.84)	65.46 (26.32)
Amblycirrhitus pinos	Redspotted Hawkfish	Cirrhitidae	I	22%	0.22 (0.15)	0.3 (0.29)
Aulostomus maculatus	Trumpetfish	Aulostomidae	P	11%	0.11 (0.11)	17.35 (17.35)
Calamus pennatula	Pluma Porgy	Sparidae	I	11%	0.11 (0.11)	31.73 (31.73)
Cantherhines pullus	Orangespotted Filefish	Monacanthidae	I	11%	0.11 (0.11)	4.92 (4.92)
Canthigaster rostrata	Sharpnose Puffer	Tetraodontidae	I	89%	2.33 (0.55)	7.69 (4.15)
Carangoides ruber	Bar Jack	Carangidae	P	11%	0.11 (0.11)	0.75 (0.75)
Cephalopholis cruentata	Graysby	Serranidae	P	22%	0.78 (0.66)	56.44 (39.43)
Chaetodon capistratus	Foureye Butterflyfish	Chaetodontidae	I	22%	0.56 (0.38)	8.31 (5.63)
Chromis cyanea	Blue Chromis	Pomacentridae	PL	44%	2.56 (1.74)	4.02 (2.41)
Chromis multilineata	Brown Chromis	Pomacentridae	I	11%	1.44 (1.44)	6.16 (6.16)
Chaetodon striatus	Banded Butterflyfish	Chaetodontidae	I	11%	0.11 (0.11)	1.38 (1.38)
Coryphopterus glaucofraenum	Bridled Goby	Gobiidae	I	67%	1.33 (0.47)	2.43 (1.03)
Coryphopterus personatus/ hyalinus	Masked/glass Goby	Gobiidae	I	33%	7.33 (4.19)	4.81 (2.74)
Elacatinus species	goby Elacatinus	Gobiidae	I	11%	0.11 (0.11)	0.03 (0.03)
Epinephelus guttatus	Red Hind	Serranidae	I	33%	0.33 (0.17)	102.78 (63.76)
Gnatholepis thompsoni	Goldspot Goby	Gobiidae	H	22%	0.56 (0.38)	0.12 (0.08)
Gobiidae species	gobies	Gobiidae	I	11%	0.56 (0.56)	0.36 (0.36)
Gramma loreto	Fairy Basslet	Grammatidae	I	11%	1.11 (1.11)	4.03 (4.03)
Haemulon aurolineatum	Tomtate	Haemulidae	I	11%	0.11 (0.11)	11.61 (11.61)
Halichoeres bivittatus	Slippery Dick	Labridae	I	56%	5.11 (2.33)	23.32 (15.13)
Haemulon flavolineatum	French Grunt	Haemulidae	I	22%	0.33 (0.24)	21.31 (14.32)
Halichoeres garnoti	Yellowhead Wrasse	Labridae	I	78%	7.44 (2.19)	32.03 (11.6)
Halichoeres maculipinna	Clown Wrasse	Labridae	I	33%	1.44 (1.09)	4.84 (4.78)
Haemulon plumierii	White Grunt	Haemulidae	I	11%	0.44 (0.44)	22.48 (22.48)
Halichoeres poeyi	Blackear Wrasse	Labridae	I	11%	0.11 (0.11)	0.52 (0.52)
Halichoeres radiatus	Puddingwife	Labridae	I	22%	0.22 (0.15)	0.7 (0.66)
Haemulon sciurus	Bluestriped Grunt	Haemulidae	I	11%	0.22 (0.22)	40.57 (40.57)
Heteropriacanthus cruentatus	Glasseye Snapper	Priacanthidae	PL	11%	0.11 (0.11)	23.79 (23.79)
Holocentrus adscensionis	Squirrelfish	Holocentridae	I	33%	1.44 (0.99)	33.91 (23.32)
Holacanthus ciliaris	Queen Angelfish	Pomacanthidae	I	11%	0.11 (0.11)	15.07 (15.07)
Holocentrus rufus	Longspine Squirrelfish	Holocentridae	I	11%	0.22 (0.22)	1.58 (1.58)
Holacanthus tricolor	Rock Beauty	Pomacanthidae	I	11%	0.22 (0.22)	51.79 (51.79)
Hypoplectrus nigricans	Black Hamlet	Serranidae	I	11%	0.11 (0.11)	0.46 (0.46)
Hypoplectrus puella	Barred Hamlet	Serranidae	I	11%	0.44 (0.44)	1.83 (1.83)
Hypoplectrus unicolor	Butter Hamlet	Serranidae	I	22%	0.22 (0.15)	1.49 (0.98)
Lachnolaimus maximus	Hogfish	Labridae	I	11%	0.11 (0.11)	5.27 (5.27)
Lactophrys triqueter	Smooth Trunkfish	Ostraciidae	I	11%	0.22 (0.22)	8.15 (8.15)
Lutjanus apodus	Schoolmaster	Lutjanidae	P	22%	0.56 (0.44)	68.94 (57.37)
Lutjanus synagris	Lane Snapper	Lutjanidae	I	11%	0.89 (0.89)	225.69 (225.69)
Malacoctenus triangulatus	Saddled Blenny	Labrisomidae	I	11%	0.22 (0.22)	0.05 (0.05)
Microspathodon chrysurus	Yellowtail Damselfish	Pomacentridae	H	11%	0.33 (0.33)	3.96 (3.96)

Appendix 2. Mean species site frequency, density, and biomass for fish species observed in hardbottom surveys outside STEER (n=9) in the 2012 survey.

Species	Common name	Family	Trophic group	% of Surveys	Mean Density (SE)	Mean Biomass (SE)
Monacanthus tuckeri	Slender Filefish	Monacanthidae	PL	11%	0.11 (0.11)	0.66 (0.66)
Mulloidichthys martinicus	Yellow Goatfish	Mullidae	I	11%	0.56 (0.56)	130.99 (130.99)
Mycteroperca interstitialis	Yellowmouth Grouper	Serranidae	P	11%	0.11 (0.11)	19.74 (19.74)
Myripristis jacobus	Blackbar Soldierfish	Holocentridae	I	22%	0.33 (0.24)	43.86 (36.38)
Neoniphon marianus	Longjaw Squirrelfish	Holocentridae	I	11%	0.11 (0.11)	7.93 (7.93)
Ocyurus chrysurus	Yellowtail Snapper	Lutjanidae	PL	44%	2.22 (1.3)	342.24 (210.03)
Opistognathus aurifrons	Yellowhead Jawfish	Opistognathidae	PL	11%	0.44 (0.44)	0.11 (0.11)
Ophioblennius macclurei	Redlip Blenny	Blenniidae	H	11%	0.11 (0.11)	0.43 (0.43)
Pomacanthus arcuatus	Gray Angelfish	Pomacanthidae	I	22%	0.22 (0.15)	143.4 (94.85)
Pseudupeneus maculatus	Spotted Goatfish	Mullidae	I	44%	0.67 (0.29)	31.61 (23.69)
Scarus iseri	Striped Parrotfish	Scaridae	H	56%	6.56 (2.95)	47.72 (22.08)
Scarus taeniopterus	Princess Parrotfish	Scaridae	H	56%	5.33 (2.01)	71.6 (37.17)
Scarus vetula	Queen Parrotfish	Scaridae	H	11%	0.22 (0.22)	26.24 (26.24)
Serranus baldwini	Lantern Bass	Serranidae	P	11%	0.11 (0.11)	0.04 (0.04)
Serranus tigrinus	Harlequin Bass	Serranidae	I	33%	0.67 (0.37)	3.09 (2)
Serranus tortugarum	Chalk Bass	Serranidae	PL	11%	0.89 (0.89)	0.32 (0.32)
Sparisoma atomarium	Greenblotch Parrotfish	Scaridae	H	33%	1.44 (0.99)	5.03 (4.86)
Sparisoma aurofrenatum	Redband Parrotfish	Scaridae	H	89%	7 (1.83)	121.45 (68.68)
Sparisoma radians	Bucktooth Parrotfish	Scaridae	H	11%	0.11 (0.11)	0.04 (0.04)
Sparisoma rubripinne	Yellowtail Parrotfish	Scaridae	H	11%	0.22 (0.22)	0.1 (0.1)
Sparisoma viride	Stoplight Parrotfish	Scaridae	H	44%	1.56 (0.75)	284.68 (259.1)
Stegastes adustus	Dusky Damselfish	Pomacentridae	H	11%	0.11 (0.11)	1.33 (1.33)
Stegastes diencaeus	Longfin Damselfish	Pomacentridae	H	22%	0.22 (0.15)	1.43 (1.32)
Stegastes leucostictus	Beaugregory	Pomacentridae	I	44%	0.44 (0.18)	4.52 (1.79)
Stegastes partitus	Bicolor Damselfish	Pomacentridae	H	89%	10.11 (3.54)	60.59 (31.32)
Stegastes planifrons	Threespot Damselfish	Pomacentridae	I	11%	1.22 (1.22)	9.71 (9.71)
Stegastes variabilis	Cocoa Damselfish	Pomacentridae	H	56%	0.78 (0.32)	3.6 (1.57)
Thalassoma bifasciatum	Bluehead	Labridae	I	78%	14.44 (5.23)	20.97 (9.22)
Xyrichtys martinicensis	Rosy Razorfish	Labridae	I	11%	0.78 (0.78)	0.21 (0.21)
Xyrichtys novacula	Pearly Razorfish	Labridae	I	11%	0.33 (0.33)	1.44 (1.44)
Xyrichtys splendens	Green Razorfish	Labridae	I	11%	0.11 (0.11)	0.47 (0.47)

U.S. Department of Commerce
Penny Pritzker, *Secretary*

National Oceanic and Atmospheric Administration
Kathryn Sullivan, *Acting Under Secretary for Oceans and Atmosphere*

National Ocean Service
Holly Bamford, *Assistant Administrator for Ocean Service and Coastal Zone Management*




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