NOAA's New Coral Reef Fish Monitoring Program in the US Caribbean

NOAA's Nuevos Peces de Arrecife de Coral Programa de Monitoreo en el Caribe Estado Unidos

NOAA's Nouveaux Poissons de Récifs Coralliens et Programme de Surveillance dans les Caraïbes de États-Unis

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ABSTRACT

NOAA's Coral Reef Conservation Program has developed a national coral reef fish and coral monitoring program (National Coral Reef Monitoring Program, NCRMP) throughout the US Pacific, Atlantic, and Caribbean. The goal of the program is to use standardized approaches to collect a suite of biological, oceanographic, and socioeconomic information at a national scale to help coastal managers gauge the status, trends, and conditions of US coral reef ecosystems. NCRMP has biological, climate, and socioeconomic monitoring components.

NCRMP's biological monitoring of fish and benthic communities in the Atlantic and Caribbean jurisdictions began in 2013; and will occur biennially in Puerto Rico, US Virgin Islands, Florida, and the Flower Garden Banks National Marine Sanctuary. Biological monitoring occurs through *in-situ* visual scuba surveys based on stratified random sampling designed for hardbottom areas up to depths of 30.5 m.

Reef fish abundance, diversity, and size are being recorded. Benthic metrics include percent cover of dominant benthic communities (corals, sponges, gorgonians, etc) as well as coral abundance, size structure, and condition. Collectively, these data will provide context for existing jurisdictional monitoring and will provide meaningful status and trends information at the jurisdictional scale (and likely island scale as well). Here, we present preliminary information from our maiden USVI surveys (2012-2013) and provide some discussion concerning logistics, coordination, and partnership development. We also discuss the utility of these data to inform coastal managers about the status and condition of coral reef ecosystems within their jurisdictions.

KEY WORDS: Coral reefs, coral, fish, monitoring, climate

INTRODUCTION: NCRMP – NATIONAL PERSPECTIVE

The National Oceanic and Atmospheric Administration (NOAA) Coral Reef Conservation Program (CRCP) recently developed and implemented a national-level coral reef ecosystem monitoring program, the National Coral Reef Monitoring Program (NCRMP), to collect systematic and standardized information across 10 US jurisdictions (NOAA Coral Program 2014). The Program developed a working group of scientists and experts to develop appropriate indicators and a comprehensive monitoring plan to assess status and trends of the nation's reefs over time. The plan includes monitoring of benthic and reef fish communities, socioeconimcs, and climate indicators. Benthic and fish monitoring will be conducted by diver-based visual census, using a stratified random-sampling design throughout shallow water (<30.5m) coral reefs. Carbonate chemistry water sampling will be conducted at a subset of the biological sampling areas, while a smaller number of fixed stations will have an array of instrumentation, including ocean acidification monitoring buoys. Satellite monitoring of regional thermal stress will complement *in situ* measurements of ocean temperature. Socioeconomic monitoring will include human dimension surveys of coastal residents.

Monitoring will focus on broad, synoptic data collection that will contextualize local/regional monitoring being conducted through other programs. NCRMP is distinct and separate from CRCP's territorial grant programs, but it would be valuable for synergies to develop between the two

The working group reached consensus on the key monitoring questions for the NCRMP to support conservation of the nation's coral reef ecosystems:

i) What is the *status* of U.S. coral reef ecosystems?
   - What is the status of coral reef biota?
   - What is the status of human knowledge, attitudes, and perceptions regarding the importance and uses of coral reefs?

ii) What are the *trends* in conditions of U.S. coral reef ecosystems?
   - How is the community structure of coral reef biota changing over time?
   - How are temperature and carbonate chemistry in waters surrounding coral reefs changing over time?
   - How are human uses of, interactions with, and dependence on coral reefs changing over time?

Table 1 displays the monitoring indicators as recommended by the NCRMP working group.

Table 1. NCRMP themes and core indicators.

Monitoring Themes	Indicators
Biological	
*Coral and Benthos	Abundance and size structure
	Condition (bleaching , disease, mortality)
	Percent cover or major taxa
	Key species
	Rugosity
*Reef fish	Abundance and size structure
	Diversity/species richness
	Key species
Climate	
*Thermal Stress	Temperature/thermal stress
	Vertical thermal structure
*Ocean Acidification	Carbonate chemistry
Socioeconomics	
	Knowledge, attitudes, and perceptions of coral reefs and management strategies
	Participation in coral reef activities
	Population changes and distribution
	Economic dependence on coral reefs

Geographic Coverage

The NCRMP is limited to shallow water coral reef ecosystems in the following Coral Program priority geographic areas (Miller et al. 2011):

Pacific:

i) American Sāmoa (AS)
ii) Commonwealth of the Northern Mariana Islands (CNMI)
iii) Guam
iv) Hawai'i (HI), including the Main Hawaiian Islands (MHI) and the Northwestern Hawaiian Islands (NWHI)
v) Pacific Remote Island Areas (PRIA), including Wake, Johnston, Palmyra, and Kingman Atolls and Howland, Baker, and Jarvis Islands

Atlantic:

i) Florida (FL), including Martin County through Dry Tortugas
ii) Flower Garden Banks (FGB)
iii) Puerto Rico (PR)
iv) U.S. Virgin Islands (USVI)

NCRMP monitoring will focus on hard bottom reef habitats < 30.5 meters because of the higher logistical and financial costs associated with monitoring beyond these depths. Similarly, while the impacts of land-based sources of pollution (LBSP) are acknowledged to be significant in certain areas and instances, efforts to monitor water quality indicators would be cost-prohibitive and are deemed outside the scope of the NCRMP. Because of logistical and financial constraints, Pacific jurisdictions will be surveyed triennially while those in the Atlantic and Caribbean will be surveyed biennially.

Goals and Implementation

The goals of NCRMP monitoring (NOAA Coral Program 2014) are to:

i) Develop consistent and comparable methods and standard operating procedures (SOPs), which detail specific field, laboratory, and/or analytical procedures and best practices, for all indicators (with periodic updates to reflect new technologies or logistical considerations)
ii) Develop and maintain strong partnerships with federal, state/territory, and academic partners collect scientifically sound, geographically comprehensive biological, climate, and socioeconomic data in U.S. coral reef areas
iii) Deliver high-quality data, data products, and tools to the coral reef conservation community.
iv) Provide context for interpreting results of localized monitoring
v) Provide periodic assessments of the status and trends of the nation's coral reef ecosystems

The rest of this manuscript describes the activities of the Atlantic and Caribbean Biological Monitoring subgroup of the NCRMP program. This group is responsible for conducting and analyzing the benthic and reef fish surveys in Florida, the USVI, Puerto Rico, and the Flower Garden Banks region.

METHODS
NCRMP U.S. CARIBBEAN

Biological Monitoring

This manuscript will focus on the biological monitoring activities in the Atlantic and Caribbean jurisdictions (Figure 1), and results will be presented for the USVI, which was monitored in 2012/2013. More specific information for the Pacific biological monitoring and other NCRMP themes can be found in the monitoring plan (NOAA Coral Program 2014). In the U.S. Caribbean, NCCOS has been monitoring fish and benthic communities in localized areas within St. Croix (Pittman et al. 2008), Puerto Rico (Pittman et al. 2010) and St. John (Friedlander et al. 2013) using a stratified random design. The protocols for fish monitoring have been slightly modified for NCRMP in the U.S. Caribbean. Benthic percent cover (Line Point Intercept) and coral demographic protocols (Roberson et al. 2014) were developed by a working group of federal, state and academic experts and generally reflect adapted best practices from other benthic programs (e.g. AGGRA) for monitoring benthic communities.

Survey Design

The overall survey design is optimized for the scale of the NCRMP reporting units (typically jurisdiction or island scale), rather than providing comprehensive information at a single site or local spatial scales. The target domain is hard bottom reef habitats shallower than 30.5 m within the NOAA Coral Program geographic priority areas. The

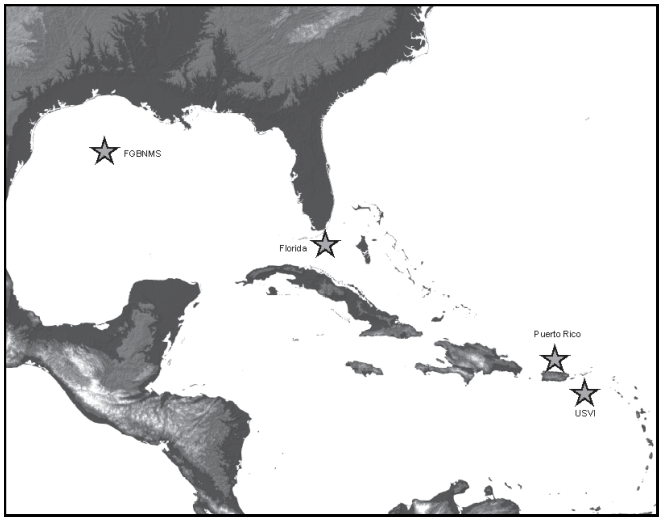

Figure 1. NCRMP jurisdictions in the Atlantic and the Caribbean.

NCRMP working group adopted the general principle of geographically comprehensive monitoring, i.e., that the broad goal is spreading sampling effort widely across reefs within each jurisdiction, rather than focusing effort at *representative* stations, given concerns that identifying such stations is an inherently subjective and unreliable process (Rodgers et al. 2010) and may not allow scaling up to population-level metrics.

The most appropriate means to ensure that biological survey data are representative of the target domain is to randomize site locations within that domain. Data quality will generally be optimized (e.g., variance minimized) by stratification of the target domain. Depending on the quality and extent of available bathymetry and habitat information, the survey design uses a combination of depth (e.g., shallow, deep), habitat type (e.g., spur and groove, colonized pavement), and management zone (e.g., MPA, no-take area, etc.).

Stratification schemes for USVI and Puerto Rico are similar. Specifically, there is a spatial component to the stratification as well to provide geographic coverage of the jurisdiction that also incorporates important managed areas, hard bottom habitat types (colonized pavement, patch reef, bedrock, linear reef, and scattered coral and rock in sand), and two depth zones (deep > 13 m, shallow < 13 m).

A sampling frame that incorporates all levels of stratification is used to structure the stratified random approach (Figure 2). The resolution and quality of the underlying benthic habitat maps are the limiting factor for the size of the sampling frame. In the USVI and Puerto Rico, habitat maps are of good quality and the sampling frame is 50 x 50 m (Kendall et al. 2000). This size is the minimum to encompass the area of the NCRMP fish transect (25 x 4 m) where the survey starts at the center of the grid. All fish and benthic surveys are conducted concurrently, albeit at various scales (Figure 3). Specific details of the fish, line-point-intercept (LPI), and coral demographic protocols can be found here: http://coastalscience.noaa.gov/projects/detail?key=180.

Initially, survey allocation will be developed as an iterative process where surveys will be proportionally distributed by strata area. Within a few years of monitoring, we expect to have sufficient data to allocate surveys amongst the strata with a statistical design that weights each strata based on the variance structure of specific fish and coral indicator species.

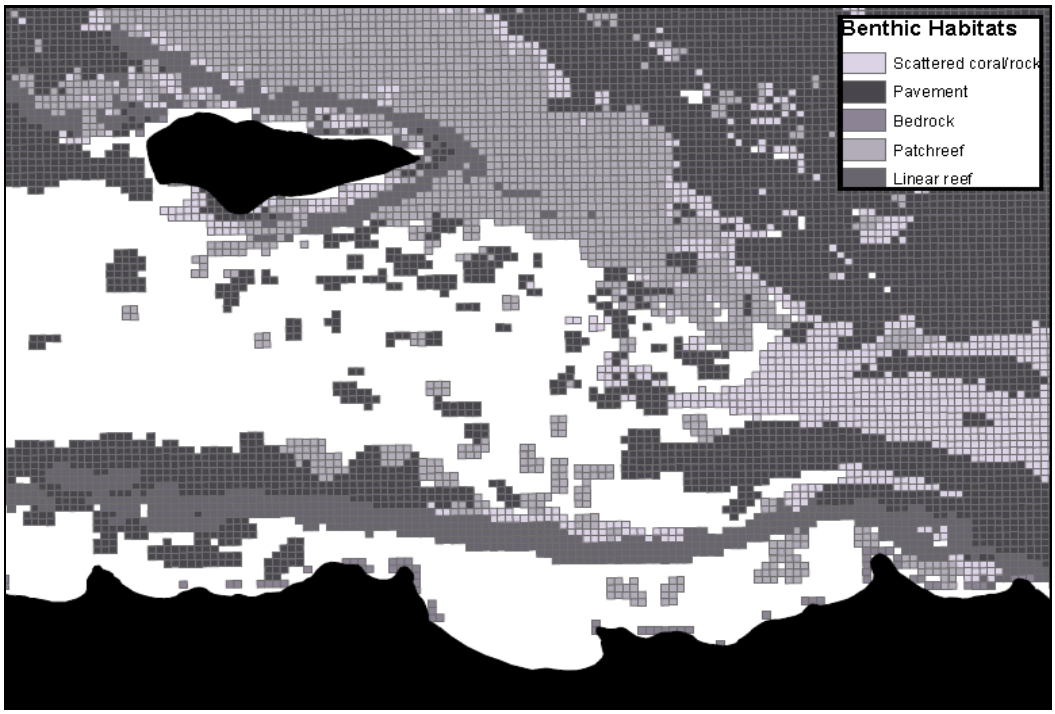

Figure 2. NCRMP 50x50 m sampling frame around Buck Island and northeastern St. Croix.

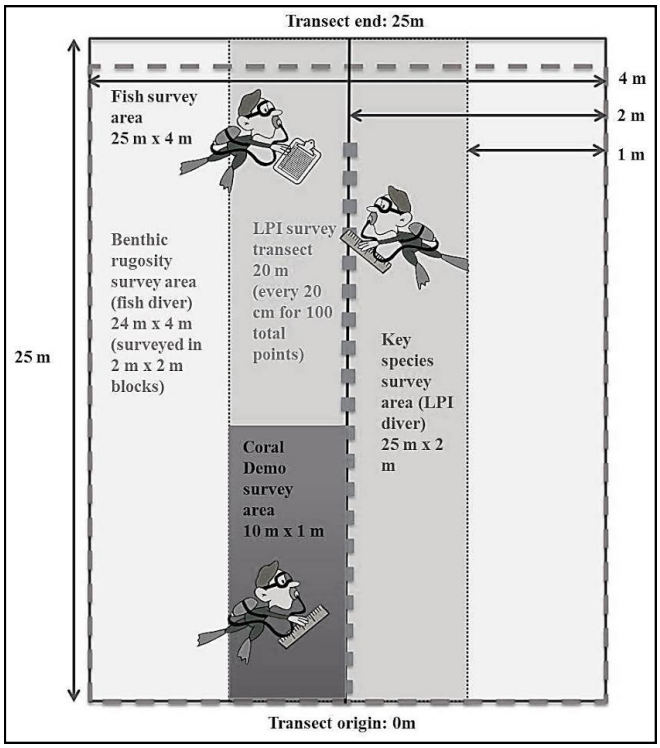

Figure 3. Generalized depiction of NCRMP surveys within a transect.

Reef Fish Monitoring

The reef fish survey takes place on a random bearing within the sampling grid along a 25 x 4 m transect. NCRMP reef fish surveys gather data on species specific fish abundance, size structure, and diversity. This abundance data can be converted to a range of indicators including richness per sample unit, calculated diversity, and evenness measures. Similarly, information on size and numbers allows for the calculation of density, abundance, and biomass per taxon or functional group, with biomass estimated using species-specific length-to-weight conversion parameters. Once the fish survey is completed, the diver collects coarse habitat complexity data.

Reef Benthic Monitoring

In the US Caribbean, a line point intercept (LPI) method will be used to quantify a metric of benthic cover. Typically, the type of substrate (e.g., pavement, dead coral skeletons, rubble, sand) is recorded along with the benthic organism covering this substrate. Many coral reefs have a small percentage of cover by scleractinian corals, so other benthic components are more important to characterizing benthic communities and habitat. Percent cover of non-coral benthos is the focus in this sampling approach, especially different functional groups of algae (including turfs, macroalgae, and crustose coralline algae) and other invertebrates (eg. gorgonians and sponges). Percent cover is calculated by tallying the frequency of each taxa or group and dividing by the total number of observations.

Coral Monitoring

The density and size-frequency distribution of corals provides valuable insights into the demography and space utilization in the context of their geographical and environmental range. Species size-frequency distribution characteristics can be quantified mathematically (skewness, mode, coefficient of variation, etc.), allowing detection of change over time and comparison of different populations, provided sampling effort generates robust distributions.

The working group recommended that coral population structure (size-frequency and colony density) be derived from *in situ* coral demographic surveys along belt transects that systematically assess a predetermined and replicable reef area. In the Atlantic/Caribbean, a 1 x 10 m transect will measure all coral colonies in three dimensions (maximum diameter, perpendicular diameter, and height) and record colony condition (recent mortality, disease, and bleaching). These metrics paint a more complete story of population dynamics of the coral community than percent cover metrics alone.

Data Management

All data management is conducted by NOAA. In the field, fish and benthic data are entered into an offline data entry program. After fieldwork concludes, datafiles from the offline program are integrated into an enterprise-level database at NOAA in Silver Spring, MD and quality controlled. All original datasheets are compared to database output for accuracy. Graphs of frequency are generated to evaluate anomalous abundance or size information for all species observed. The process typically takes four to six months, and once data are deemed clean an *analysis ready data set* is provided to all partners. This data format will be served on an NCCOS website.

RESULTS

St. Croix, USVI - 2012

A preliminary assessment was conducted in 2012 to evaluate survey design and logistics for fish monitoring in St. Croix, USVI. The survey domain was stratified by five habitat types and two depth zones and spatially partitioned geographically (East, West, North, and South) and by no-take protected areas (Buck Island Reef National Monument, Salt River Ecological Reserve, and East End Marine Park; Figure 4a). NCRMP benthic protocols were not developed at this time, so benthic percent cover estimates were generated using a 1 m^2 quadrat at 5 random locations along a reef fish belt transect as per (Pittman et al. 2008). Overall 276 fish and benthic surveys were completed (Figure 4b).

Accomplishments —

i) A team of 35 field participants from five agencies/ academic institutions used seven boats to complete all surveys in 10.5 days of operations.
ii) Most boats averaged six surveys per day.
iii) Multiple dive shops around the island were used.
iv) SCUBA reciprocity was granted between NPS and UVI, increasing staffing flexibility.
v) Data summary report was released in 2014.

St. John/St. Thomas - 2013

The full suite of NCRMP fish and benthic protocols were implemented in St. John and St. Thomas, USVI in July 2013. The survey domain (Figure 5a) was stratified by five habitat types and two depth zones and spatially partitioned by non-managed waters nearshore, non-managed waters offshore, and no-take reserves (Virgin Islands National Park, Virgin Islands Coral Reef Monument, and St. Thomas East End Reserve). A total of 250 primary fish and LPI sites were proportionally allocated by strata, and an additional 100 sites were allocated as alternates. 125 coral demographic survey sites were proportionally allocated by strata across the region. These sites were allocated independently from the reef fish allocation. Overall, 285 sites were surveyed for fish, and LPI and 221 sites were surveyed for coral demographics (Figure 5b).

NCRMP surveys will return to USVI (all three islands) in 2015.

Accomplishments —

i) A team of 37 field participants from six agencies/ academic institutions used six boats to complete all surveys in 10 days of operations.
ii) Most boats averaged six dives per day.
iii) Two dive shops one on St. John and one on St. Thomas were used.
iv) Boats were stationed at Cruz Bay on St. John and Brewers Bay (UVI) and Benner Bay on St. Thomas.
v) Fish and LPI surveys were completed in about 30 mins; surveys that included coral demographics average 45 minutes per survey
vi) Data were quality controlled and checked in nine months. Data delivered to partners in winter of 2014.

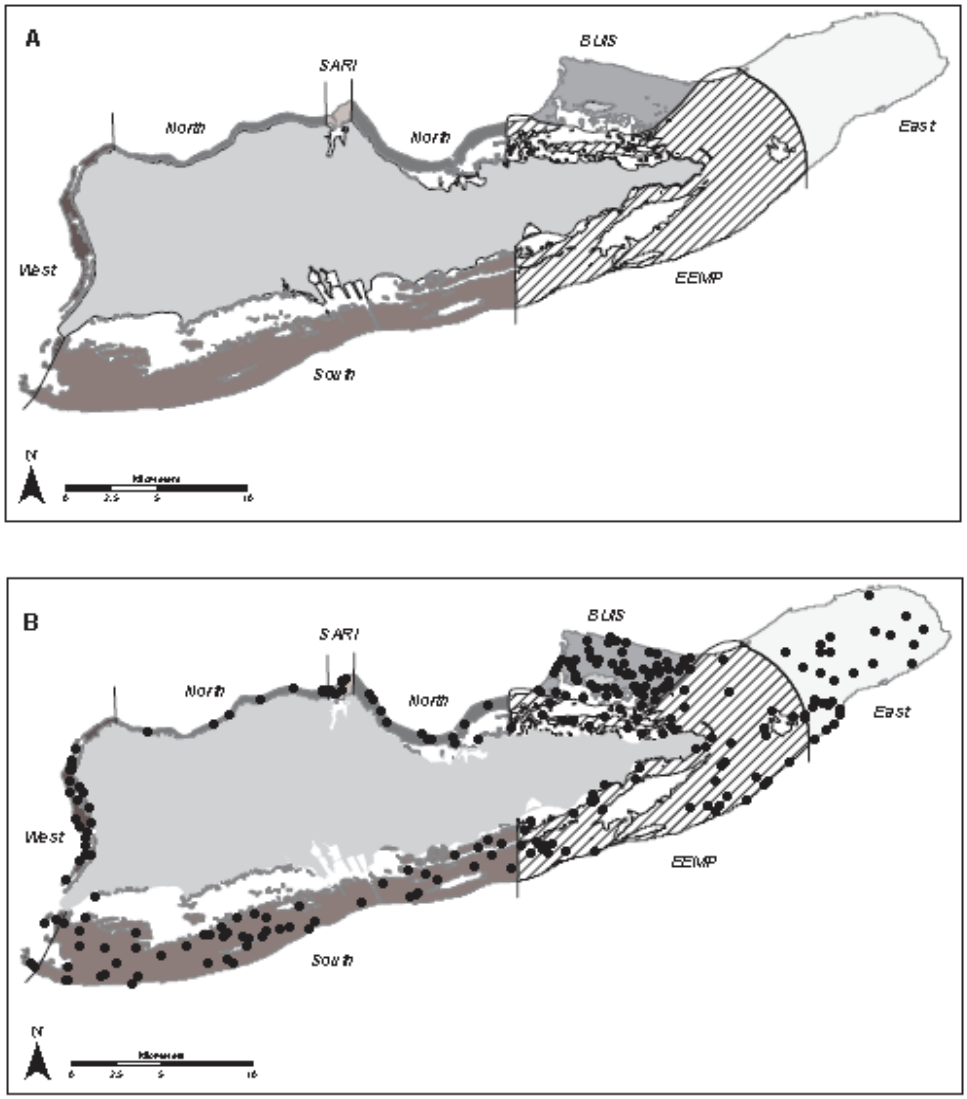

Figure 4. A) Regional strata for pre-NCRMP survey design. B) Location of fish and benthic surveys, 2012. BIRNM=Buck Island Reef National Monument, EEMP=East End Marine Park, SARI=Salt River Ecological Reserve.

DISCUSSION

To date, The NCRMP Atlantic Biological Monitoring Team has completed surveys in all the Atlantic/Caribbean jurisdictions using well over 100 different divers. In order to maintain consistency and high data quality, NCRMP must prioritize training and capacity building in the regions. Prior to each mission, all field personnel will go through taxa identification and protocol training to ensure that all participating divers are calibrated on taxa identification and sizing (for fish). All field personnel need to be aware of the specific protocols and any changes that may have occurred since the last NCRMP mission.

The volume of datasheets and number of divers makes quality control of data a significant task and completion can take six to nine months. Other quality control procedures are being evaluated. Once data quality is assured, all partners are given access to the data: http://www8.nos.noaa.gov/bpdmWeb/queryMain.aspx.

All other NCRMP data (socioeconomic and climate) will be housed in enterprise level NOAA databases and made publically available. Specific data management, quality control, and access protocols are still in development. NCRMP is committed to making data widely available, and providing access and training to researchers and resource managers that can access and analyze data to meet their specific needs – including regional coral reef management.

In conclusion, NCRMP's Atlantic Biological Monitoring program in the U.S. Caribbean is poised to become an influential monitoring program that can help U.S. Caribbean resource managers track the status and trends of important fish and benthic organisms, and contextualize local or regional monitoring efforts. The success of the program relies heavily on local partnership and engagement, and NOAA CRCP is making a long-term commitment to ecosystem monitoring, training, data management, and dissemination. U.S. Caribbean NCRMP documents, trip reports and other related materials can be found on the NCCOS website: http://coastalscience.noaa.gov/projects/detail?key=180.

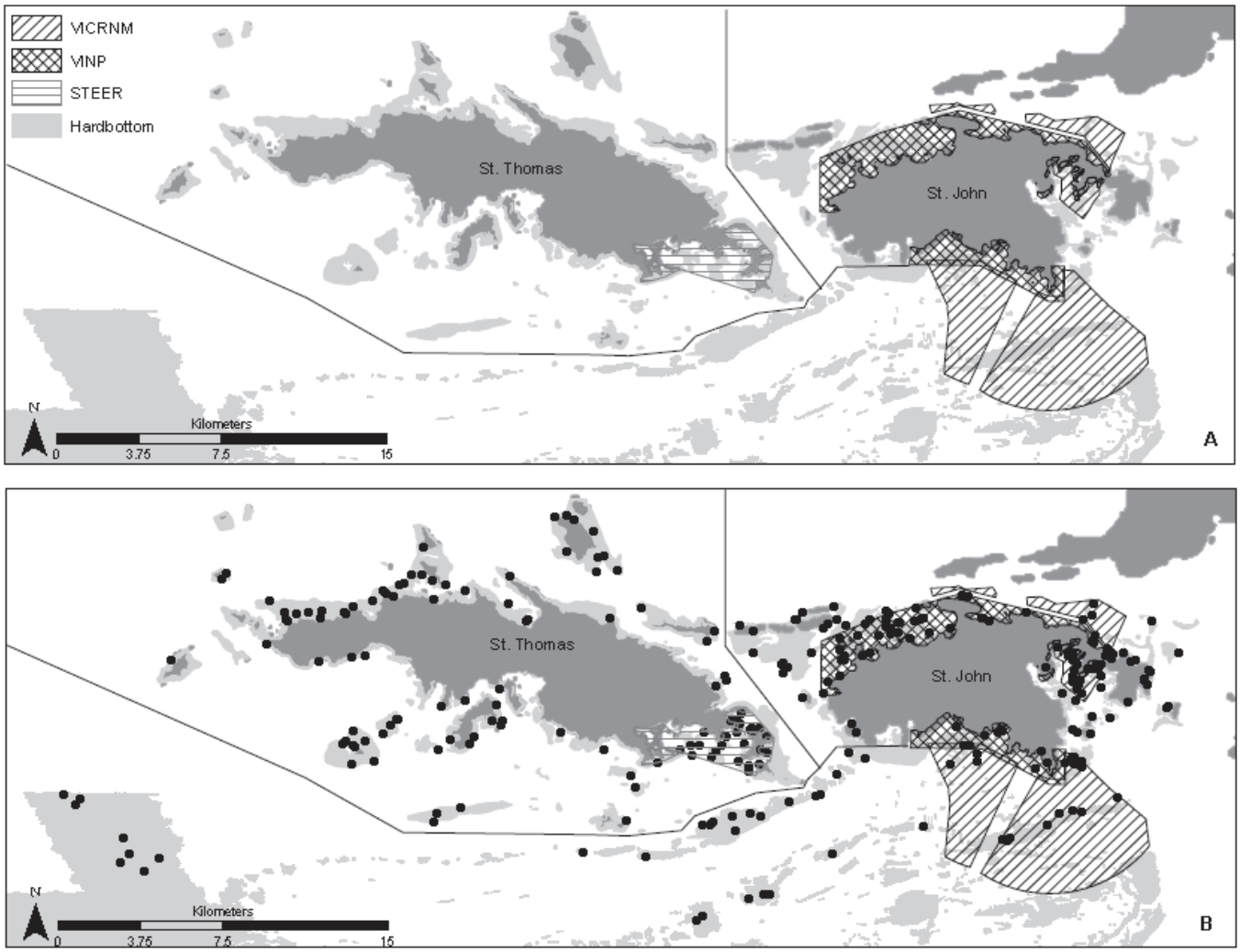

Figure 5. A) Regional strata for St. John and St. Thomas NCRMP survey design. B) Location of fish, benthic and coral surveys, 2013. VICRNM = Virgin Island Coral Reef National Monument; VINP = Virgin Island National Park; STEER = St. Thomas East End Reserve.

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- National Park Service, Virgin Islands National Park and Coral Reef National Monument
- The Nature Conservancy
- USVI Department of Parks and Natural Resources
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