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A Cooperative Multiagency Reef Fish Monitoring Protocol for the U.S. Virgin Islands Coral Reef Ecosystem, v. 1.00

Natural Resource Report NPS/SFCN/NRR—2013/672

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

ON THE COVER
Clockwise from the top left; bluestripped grunt (*Haemulon sciurus*), bluehead wrasse (*Thalassoma bifasciatum*), bar jack (*Caranx ruber*), schoolmaster snapper (*Lutjanus apodus*), school of bluestriped grunts, gray anglefish (*Pomacanthus arcuatus*) and in the center yellowtail snapper (*Ocyurus chrysurus*).

Photographs by: Evan D'Alessandro and Kirk Kilfoyle

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Natural Resource Report NPS/SFCN/NRR—2013/672

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Summary

Reef fish populations are an essential component of the United States Virgin Islands (USVI) coral reef ecosystem and are of great economic, ecological and cultural importance to the region. Yet, striking population and community level declines have been observed over the past several decades due to intensive exploitation and systemic degradation of essential habitats.

This protocol entitled "*Cooperative Multiagency Reef Fish Monitoring Protocol for the U.S. Virgin Islands Coral Reef Ecosystem"* provides the necessary technical background and detailed description of key methods for monitoring and assessment of reef fish populations throughout the USVI. The objective of this protocol is to determine the status, trends, and variability of reef fish species populations and communities within hard-bottom habitats at dive-able depths within the U.S. Virgin Islands and Puerto Rico regions, specific sub-regions (e.g., St. Croix, St. John/Thomas), and inside vs. outside different management zones (e.g., national and territorial parks, monuments, and reserves) using measures including abundance, density, occupancy, spatial distribution, size structure, species richness, and community composition. Special attention is paid to specific exploited and ecologically important reef fish species.

A probabilistic stratified random sampling design is used as the central statistical method for collecting size-structured abundance data for USVI reef fishes from a finite sample frame of grid cells classified by habitat and depth. Field methods consist of a 25m x 4m linear belt reef fish visual survey in which reef fish species are counted and measured. The resulting quantitative metrics (e.g., density, abundance, occupancy) allow multispecies assessments in a large-scale geographic or ecosystem context as well as within managed areas.

These fishery independent surveys are the framework necessary for understanding how natural and anthropogenic stressors contribute to change in reef fish populations and communities and provide information essential to the sustainable management of these resources. Resource assessment metrics allow managers to evaluate ecosystem risk and the efficacy of management actions, such as traditional fishery actions (e.g., size limits, bag limits) or spatial protection (i.e., marine protected areas) that may quantify the role of national parks within the broader ecosystem dynamics. The approach also provides the opportunity to expand the survey to include the Puerto Rico shelf. Finally, this protocol manual, including 9 standard operating procedures (SOPs), provides the requisite information to implement the first ecosystem-wide U. S. Caribbean reef fish visual survey that meets the needs of the national parks and other participating scientific and management organizations.

Implementation of this protocol is expected to be a collaborative effort amongst federal, territorial, academic, and non-governmental organization partners including but not limited to the National Oceanic and Atmospheric Administration (NOAA) Center for Coastal Monitoring and Assessment Biogeography Branch (BB), NOAA Southeast Fisheries Science Center Division of Protected Resources and Biodiversity (SEFSC), National Park Service (NPS) South Florida/Caribbean Network (SFCN), Virgin Islands National Park (VIIS), Buck Island Reef National Monument (BUIS), Virgin Islands Department of Planning and Natural Resources (DPNR), the University of Miami's Rosenstiel School of Marine and Atmospheric Science (UM), University of Virgin Islands (UVI), and The Nature Conservancy (TNC). The regional scale of this effort to monitor reef fish across all territorial waters warrants BB be the lead

agency as it is beyond the scope of the National Park Service. SFCN will represent the NPS to ensure data collected within park boundaries are robust enough to evaluate effectiveness of management actions, e.g., no-fishing within MPAs.

This document benefits greatly from the published developments in statistical survey design and multispecies stock assessment of reef fishes in the southern Florida coral reef ecosystem and builds directly upon over 10 years of reef fish monitoring within and near USVI national parks. Publication of this protocol manual was made possible through a research funding agreement between the National Park Service (NPS) South Florida/Caribbean Network (SFCN) and the University of Miami's Rosenstiel School of Marine and Atmospheric Science (UM). Its development benefitted greatly from partnership collaborations with the National Oceanic and Atmospheric Administration (NOAA) Southeast Fisheries Science Center (SEFSC), Division of Protected Resources and Biodiversity, and NOAA Center for Coastal Monitoring and Assessment, Biogeography Branch (BB).

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This document draws strongly upon sections of the sister document entitled *A Cooperative Multi-agency Reef Fish Monitoring Protocol for the Florida Keys Coral Reef Ecosystem* by Brandt et al. (2009) in which Natalia Zurcher (UM) was heavily involved and she is gratefully acknowledged for her work on that document as well as her constructive comments towards this protocol. Jeremiah Blondeau (SEFSC) provided local knowledge of the USVI ecosystem and GIS mapping expertise. Comments from two reviewers, Alex Chester and Jim Tilmant, greatly improved this document and we are appreciative of their time and knowledge. This research was sponsored by the NPS's Cooperative Ecosystems Study Unit Agreement No. H5000060104 provided by the NPS SFCN.

Acronyms

ACL	Annual catch limit
APT	RVC All-Purpose Tool
BB	NOAA Center for Coastal Monitoring and Assessment Biogeography Branch
BPDM	Biogeography Program Database Management
BUIS	Buck Island Reef National Monument
CREAM	NOAA Coral Reef Ecosystem Assessment and Monitoring Database
CREMP	NOAA Coral Reef Ecosystem Monitoring Program
CV	Coefficient of variation (standard deviation of the mean / mean)
EEMP	St. Croix East End Marine Park
GIS	Geographic Information System
NMFS	NOAA National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
QA/QC	Quality Assurance / Quality Control
RVC	Reef-fish Visual Census
SARI	Salt River Bay National Historical Park and Ecological Preserve
SEFSC	NOAA National Marine Fisheries Service Southeast Fisheries Science Center
SFCN	NPS South Florida / Caribbean Network
SOP	Standard Operating Procedure
UM	University of Miami, Rosenstiel School of Marine and Atmospheric Science
USVI	United States Virgin Islands
VICR	Virgin Islands Coral Reef National Monument
VIIS	Virgin Islands National Park

1.0 Introduction

1.1 Rationale for Selecting this Resource to Monitor

The sustainability of multispecies coral reef fisheries is a key conservation concern given their economic and ecological importance, the dependence of subsistence and artisanal fishers on reef fisheries for their livelihoods, and the considerable threats to coral reef habitats (i.e., coral bleaching and disease, pollution and climate change) (Ault et al. 1998, 2005a, 2008). Sustainability refers to the ability of an exploited fish stock to produce economically viable yields at suitable levels in the short term, while maintaining sufficient reproductive capacity to continue providing these yields into the indefinite future. Reef fish communities are a vital component of coral reef ecosystems throughout the world and intensive exploitation and overfishing is perhaps the major threat to these ecosystems (Ault et al. 2005a, 2008). The status of reef fish communities is of primary importance to the national parks in South Florida and the U.S. Virgin Islands as well as managers of other natural areas. Over 100 area scientists, government staff, and non-government organizations ranked monitoring of "marine fish communities" 2nd in priority out of 44 "vital signs" (indicators of park natural resource health) for the parks in the National Park Service South Florida / Caribbean Network (Patterson et al. 2008).

Several western Atlantic reef fish populations have declined precipitously over the past several decades due to a combination of direct and indirect anthropogenic stressors, including overfishing (Ault et al. 1998, 2005b, 2008, Mora 2008, Stallings 2009). These declines have also been recorded in the USVI and once historically productive reef fish are now relatively rare (Rogers and Beets 2001). Declines in reef fish can affect the coral reef ecosystem as well as the people who depend on fishery resources to support themselves (Done 1992, Hughes 1994, Moberg and Folke 1999). The complex life history strategies of many reef fish species can span multiple habitats and can include a large-scale dispersal phase (Lindeman et al. 2000). Fish assemblages can therefore be characteristic of specific habitats and the transport mechanisms among habitats and regions (Kimmel 1985, Chittaro et al. 2005). While changes in reef fish abundances and structure may indicate direct effects from overfishing, they can also be indicators of the status and trends of the system as a whole, and may be a reflection of one or a combination of changes in habitat quality, connectivity, fishing pressure, biological factors such as productivity, competition, and predation patterns, and long-term ecosystem resilience.

Successful management strategies require robust data to guide decisions as well as subsequent information to evaluate actions. A large scale monitoring program is needed to provide reef fish population level metrics for the USVI as well as inside the national parks. The ability to place national park reef fish resources in a regional ecosystem context not only allows for the evaluation of management actions but it also provides the ability to determine the ecological role of a park in the greater ecosystem. This document details the steps involved in carrying out a multiagency monitoring program of USVI reef fish populations and provides a blueprint for an efficient, high-precision statistical survey design tailored to collect population level data. The protocol conforms to the Oakley et al. (2003) formatting guidelines for NPS long-term monitoring protocols and is partially based on previously published guides for reef fish monitoring (Menza et al. 2006, Brandt et al. 2009).

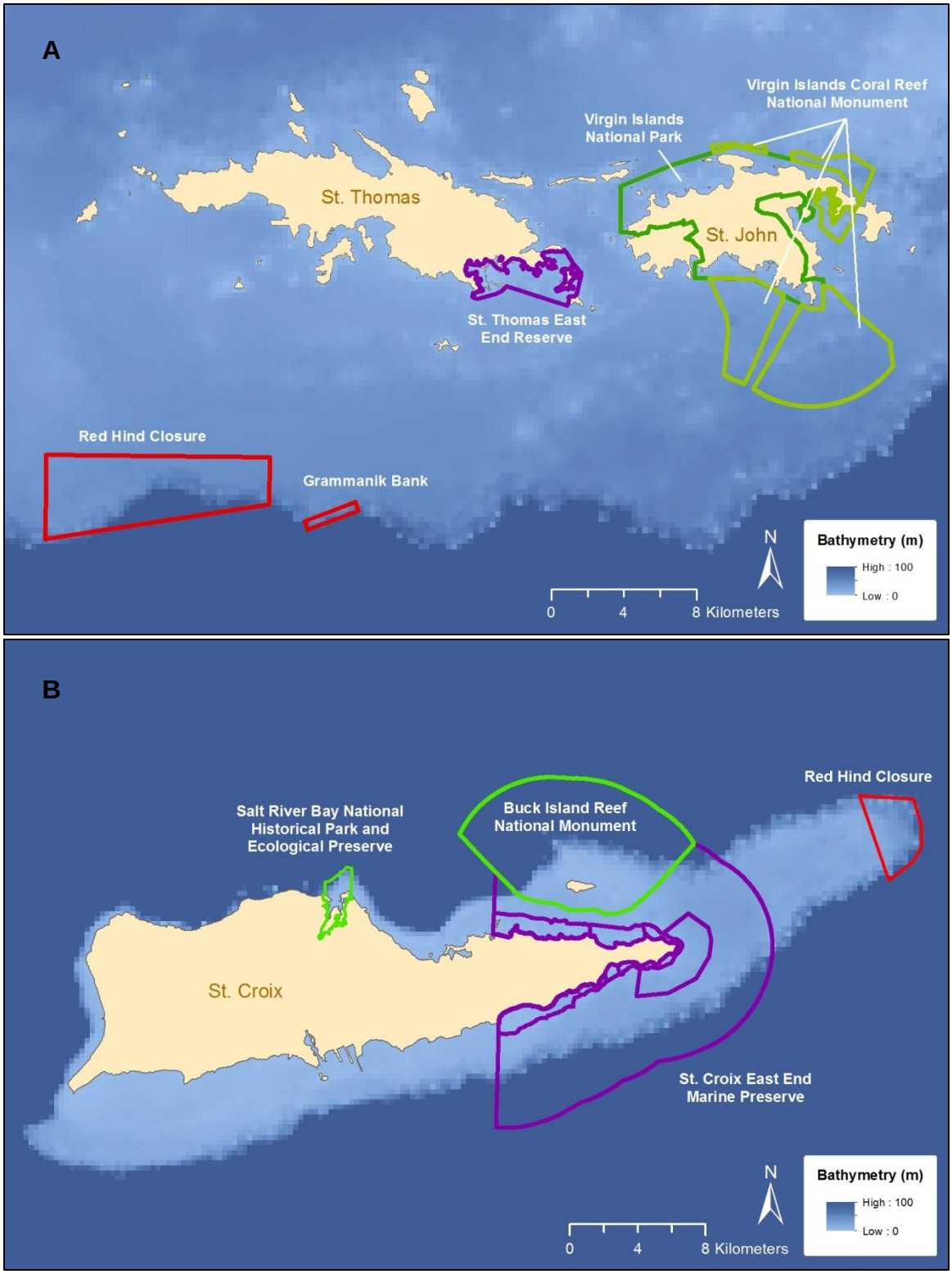

Figure 1. (A) Map of St. Thomas and St. John showing different management zones including Virgin Islands National Park (VIIS), Virgin Islands Coral Reef National Monument (VICR), St. Thomas East End Reserve (STEER), Red Hind Closure, and Grammanik Bank. (B) Map of St. Croix showing Buck Island Reef National Monument (BUIS), Salt River Bay National Historical Park and Ecological Preserve (SARI), St. Croix East End Marine Preserve (EEMP) and Red Hind Closure.

1.2 Background

The USVI are located in the northern Caribbean Sea on the western edge of the lesser Antilles, about 62 km east of Puerto Rico. The archipelago consists of three main volcanic islands: (1) St. Thomas (2) St. John and (3) St. Croix (Figure 1). St. Thomas and St. John are located on the Puerto Rico shelf with the British Virgin Islands. St. Croix, the largest island in the USVI, is about 60 km south of St. John and is separated by the 4,000 m deep Virgin Island trough. Each of these islands is surrounded by a diverse inter-connected coral reef ecosystem that has long provided sustenance and tourism for the inhabitants. Declines in natural resources and the desire to protect the ecosystem for current and future generations led to the creation of several national parks in the archipelago.

Four units of the U.S. National Park Service with significant marine resources fall within this region (Figure 1). The Virgin Islands National Park (VIIS) was created in 1956 in St. John and has since undergone several expansions and now encompasses 5,944 ha. Buck Island Reef National Monument (BUIS) was established in 1961 as a protected area of 356 ha; in 2001 it was expanded to its current size of 7,695 ha. Salt River Bay National Historical Park and Ecological Preserve (SARI) was created in 1992 (410 ha) and the Virgin Islands Coral Reef National Monument (VICR) was established in 2001 (5,100 ha). BUIS and VICR do not allow fishing. VIIS allows fishing (except spearfishing) with some restrictions on trap size. In addition to the national parks, the territorial St. Croix East End Marine Park (EEMP) was established in 2003 (15,540 ha) and includes about 1,300 ha closed to fishing.

The reef fish assemblages found in the parks and surrounding waters of the USVI are associated with the broader coral reef ecosystem of the Lesser and Greater Antilles which include Puerto Rico and the British Virgin Islands (Roberts 1997). Over the past 50 years, anthropogenic and environmental stressors throughout the region have affected coral reef fishes inside and outside of national parks. An ecosystem approach to monitoring and assessment of reef fishes is needed to fully understand resource risks and management impacts.

1.2.1 Fishing and Ecosystem Stressors

The USVI benthic communities have not escaped the Caribbean-wide coral decline that has occurred over the last few decades (Gardener et al. 2003, Rogers and Miller 2006). Bleaching, disease, sedimentation, physical destruction (hurricanes) and anthropogenic stresses have all negatively impacted USVI coral reefs. Changes in habitat structure and quality are known to have quantifiable repercussions to associated reef fish abundances and diversity (McClanahan 1994, Wilson et al. 2006). In addition to habitat degradation, artisanal, commercial and recreational fishing have long taken place in the USVI, and the decline of large predators and extirpation of spawning aggregations (e.g., Nassau grouper, *Epinephelus striatus*) have been documented (Olsen and LaPlace 1978, Beets and Friedlander 1992, Beets and Rogers 2002).

Through fishing pressure and perhaps changes in habitat, the USVI reef fish assemblage appears to have changed. Phase shifts, during which a community of organisms move from one stable state to another, have occurred on coral reef ecosystems elsewhere (Done 1992, Hughes 1994) and for benthic ‘reef’ communities in the USVI (Rogers and Miller 2006). A stock assessment for shallow water reef fish in 1992 described the decline in average length for a majority of commercially harvested species (Appeldorn et al. 1992) and the reef fish community in the USVI has remained depauperate despite the creation of various marine protected areas (MPAs) (Rogers

and Beets 2001, Beets and Rogers 2002, Monaco et al. 2007, Monaco et al. 2009). Although no-take marine reserves have been shown to increase average size and species abundances within their boundaries (Polunin and Roberts 1993), this has not occured within USVI national parks (Rogers and Beets 2001, Monaco et al. 2007, Monaco et al. 2009), although the Red Hind Conservation District closure (Beets and Friedlander 1998, Nemeth 2005) and Grammanik Bank closure (Kadison et al. 2010) have been effective at increasing sizes and abundance of fish within the reserves and associated with increases in sizes of fish caught in neighboring areas (Nemeth 2005). The underlying reason for the lack of marine reserve efficacy in USVI national parks is unclear, but it may be attributed to a combination of general coral reef community decline and continued fishing pressure made possible by inadequate enforcement of fishing regulations.

1.2.2 Fisheries Management

Fishery management regulations in the U.S. Virgin Island territorial waters (0-3 miles) are administered by the USVI Division of Fish and Wildlife and in Federal waters (3-200 miles) by the Caribbean Fishery Management Council. Several protected areas and season closures account for the bulk of management tools being used in the USVI in conjunction with gear restrictions (minimum opening sizes for traps and banned gillnets) and a 12 inch total length minimum size limit on yellowtail snapper. Twenty four territorial marine parks and 7 federal marine parks have been created, of which several include no-fishing zones (NOAA NOS 2009). Although these regulations have not stopped the local decline of reef fish (Beets and Rogers 2002), new annual total catch limits (ACLs) (required by law under the 2006 re-authorization of the Magnuson-Stevens Act) are currently being designed which may represent the first attempt to directly control fishing efforts.

Precise and accurate population estimates are required to set ACLs. These estimates can be obtained through the collection of fishery-dependent data (commercial catch and effort) or through strategically designed fishery-independent surveys. Fishery-dependent information is typically the principal data source supporting stock assessments yet there are risks in basing assessments entirely upon data from fishing operations (Walters and Martell 2004). Fishery-dependent data in USVI is collected through a Commercial Catch Reporting program and the trip intercept program. Data collection issues such as the lumping of species into groups and non-random spatially biased port sampling has limited the use of these data for stock assessments (SEDAR 2007 and SEDAR 2011). In lieu of fishery-dependent data, independent surveys can instead provide scientists and managers with the data needed to oversee a sustainable fishery (Ault et al. 1998, 2005a, 2008). A survey designed to capture population-level abundance at length estimates can be used to employ length-based assessment methods that were developed for tropical marine fishes (Ault et al. 1998, 2005a, 2008).

1.2.3 Historical Reef Fish Research and Monitoring

There is a rich history of coral reef and reef fish research in the USVI starting with early observations from Dr. Jack Randall in the late 1950's and early 1960's in St. John. Since then, numerous scientists from around the globe have conducted research in these waters furthering our understanding of coral reef ecosystems and the organisms which inhabit them. Rothenberger et al. (2008) in "*The State of Coral Reef Ecosystems of the US Virgin Islands*" provides a good source for the bulk of this research.

Despite extensive studies in the region, long term efforts directed at understanding trends in reef fish assemblages have been limited to the monitoring of several sites around St. John beginning in 1988 (Friedlander and Beets 2008). The number of sites has changed with time, but surveys have continued on an annual basis providing a historic perspective on the fish assemblages at these reefs. Currently four sites are annually surveyed; Yawzi Reef, Tektite, Haulover Bay West and Newfound Bay West (Figure 2). Additional reef fish surveys have been conducted on fixed sites in St. Thomas and St. Croix by the University of the Virgin Islands (Nemeth et al. 2005).

Larger-scale characterization of fish populations using fishery-independent visual fish censuses were conducted in VIIS and BUIS from 2001-2011 by the NOAA Center for Coastal Monitoring and Assessment Biogeography Branch (BB) in collaboration with NPS.. Even though the survey design has changed over time to meet management objectives, on average 160 and 200 sites were surveyed each year in St. John and adjacent to BUIS, VIIS and VICR including the mid shelf reef habitat south of St. John (Figure 3). The primary method was a visual linear belt transect (25 m x 4 m) adapted from Brock (1954) to assess fish abundance, composition, and size distributions (Menza et al. 2006). Data collected during this survey have been used to define habitat influences on fish community metrics (Kendall et al. 2004, Pittman el al. 2007 and Kendall and Miller 2010), habitat influences on

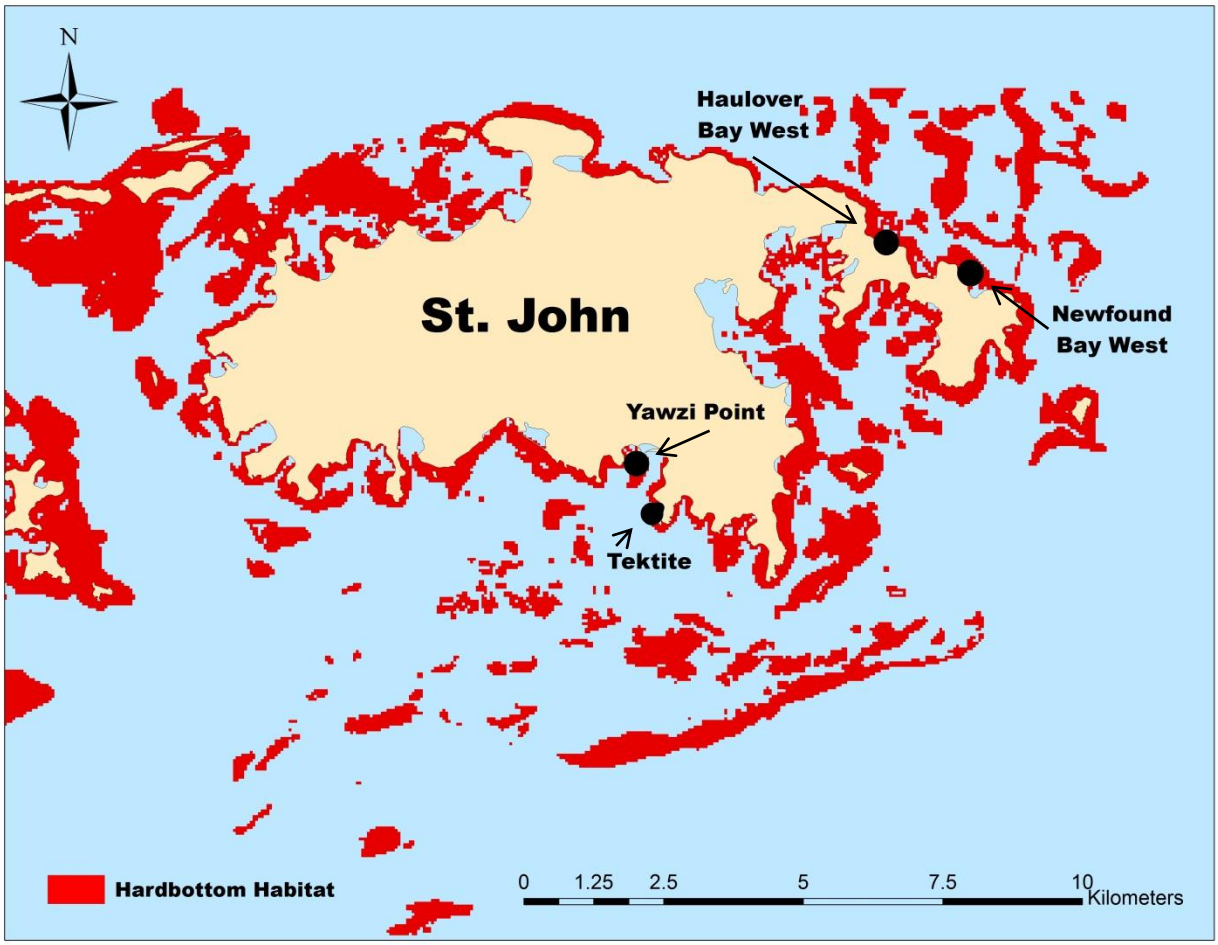

Figure 2. Location of four long-term fish monitoring sites around St. John, USVI.

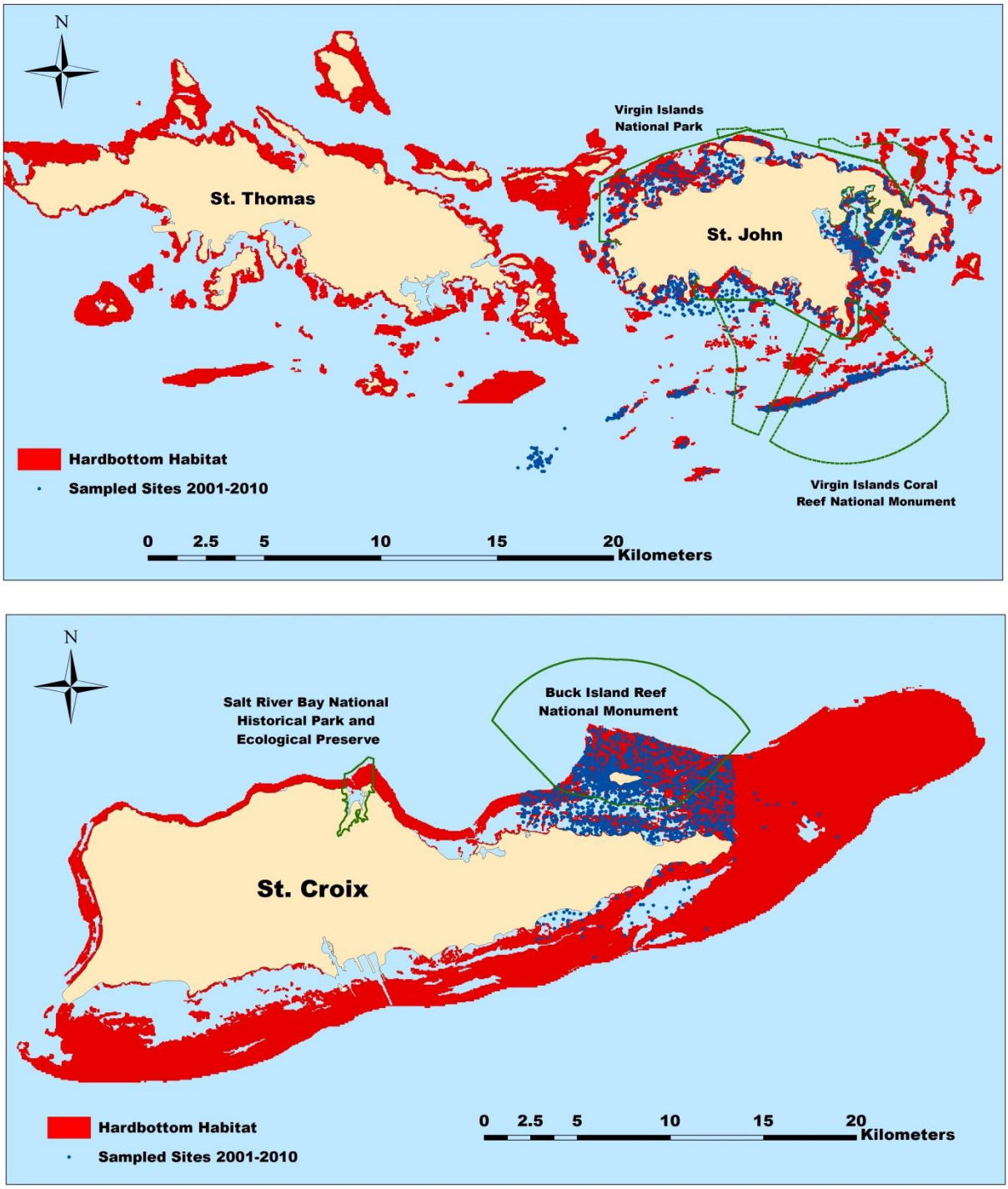

Figure 3. Coral Reef Ecosystem Monitoring Program sampling effort from 2001-2010 around St. John and St. Croix, USVI.

individual species (Kendall et al. 2003) as well as differences in fish assemblages inside and out of national parks (Monaco et al. 2007, 2009). Additionally, reef fish distributions within and around BUIS have also been described (Pittman et al. 2008).

Despite a rich history of reef fish research in the USVI, no program has attempted to monitor ecosystem-wide populations and community status until now. Sampling around St. Thomas has

been minimal and only a small section of St. Croix has been surveyed. Population-level estimates are fundamental components of ecosystem management (Levin et al. 2009), and the lack thereof can hinder the implementation and evaluation of proper management actions. This protocol outlines refinement of the historical efforts described aboveto expand spatial coverage to provide USVI-wide population estimates of coral reef fish as well as park-level estimates and to improve the power to detect species level changes spatially and temporally.

1.2.4 Reef Visual Census Survey Method used in South Florida

Stationary point count surveys have been used for several decades to collect information on reef fish (Brock 1954, Bohnsack and Bannerot 1986). Three partners in this USVI collaborative effort (NPS, SEFSC and UM) use the stationary point count method for visual surveys in south Florida (Brandt et al. 2009) and NOAA's Pacific Islands Fisheries Science Center has transitioned from transects to stationary point counts throughout the Pacific. The reef visual census (RVC) stationary point count method used in south Florida consists of a diver surveying fish from a fixed point in the center of an imaginary cylinder of radius 7.5m (Brandt et al. 2009).

Although belt transects have historically been used in the USVI and are presented in this protocol as the current method, a growing interest in standardizing methods within the NPS and NOAA National Marine Fisheries Service strongly recommends that a calibration study comparing the two methods is warranted to allow comparison of results among regions and compare the strengths and weakenesses in both approaches in the USVI.

1.3 Measurable Objectives of Monitoring

The objective of this protocol is to determine the status, trends, and variability of reef fish species populations and communities within hard-bottom habitats at dive-able depths within the U.S. Virgin Islands and Puerto Rico regions, specific sub-regions (e.g., St. Croix, St. John/Thomas), and inside vs. outside different management zones (e.g., national and territorial parks, monuments, and reserves) using measures abundance, density, occupancy, spatial distribution, size structure, species richness, and community composition. Special attention is paid to specific exploited and ecologically important reef fish species.

The sampling design is optimized with respect to focal species which are economically and/or ecologically important that represent various trophic groups, territories and life history characteristics. For the USVI these include coney (*Cephalopholis fulva*), red hind (*Epinephelus guttatus*), yellowtail snapper (*Ocyurus chrysurus*), French grunt (*Haemulon flavolineatum*), foureye butterflyfish (*Chaetodon capistratus*), threespot damselfish (*Stegastes planifrons*), stoplight parrotfish (*Sparisoma viride*), blue tang (*Acanthurus coeruleus*), and queen triggerfish (*Balistes vetula*). Although the sample design is optimized with respect to these species, all fish species are recorded. Dive-able depths for SCUBA are currently limited to approximately 30m but could be expanded in the future with closed-circuit rebreather technologies.

1.4 Overview of Monitoring Program

This protocol describes a probabilistic sampling approach that provides population and community metrics for resource management in the USVI. The monitoring program is based on an iterative approach which progresses from sample design to analysis and reporting (Figure 4). The survey design was developed on the same principles as the reef fish visual survey program in south Florida (Brandt et al. 2009, Smith et al. 2011a). Field methodologies and data assimilation include a refinement of BB's CREMP program (Menza et al. 2006). Data collected will be used towards periodic improvements in the survey design, analysis and annual reports.

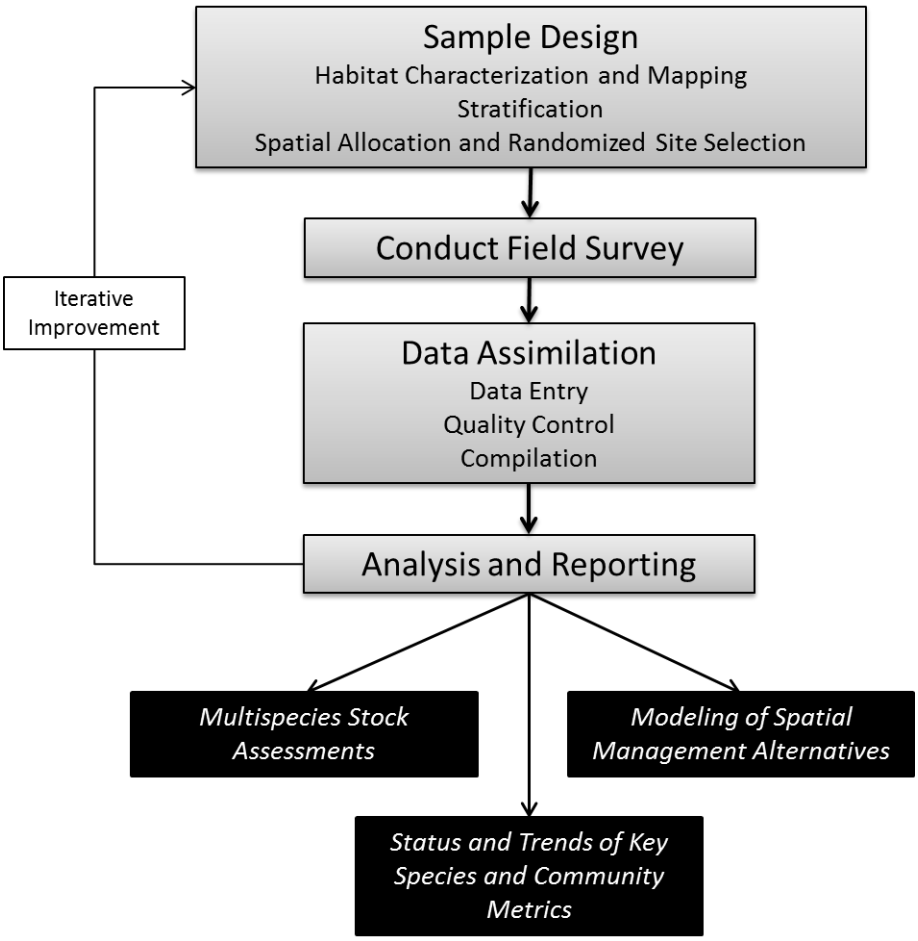

Figure 4. Monitoring program flow chart (redrawn from Smith et al. 2011a).

1.5 Link to Management Decision-Making

This protocol does not define thresholds or triggers for management decision-making as this is premature at this stage of the program. However, NOAA and territorial governments can use the data to conduct multi-species stock assessments; support changes to annual total catch limits (ACLs), bag limits, size limits, closures, and gear changes; and evaluate the effectiveness of the size and location of marine protected areas and determine if and where changes are needed.

Overall there is an expectation that the parks closed to fishing (BUIS, VICR) should see increases in numbers and size of exploited species over time compared with open-use areas

outside those parks and a return to a healthier ecological balance with increases in the higher trophic levels. Subsequent to increases within these parks, areas adjacent to the parks are expected to see increases as well (i.e. “spillover”). Failure to detect such trends could cause the parks to consider changes in enforcement levels, increases in public education efforts, and targeted studies into the lack of response, e.g., determining whether critical spawning aggregation sites and/or juvenile habitats are outside park boundaries, or investigating the effects of a new invasive species (e.g., lionfish).

Finally the data can be used in public outreach communications to educate the public and park visitors about the status of reef fish, the rationale for the various fishing restrictions, and whether the combination of management actions are having the desired effect.

2.0 Sample Design

2.1 Historic Survey Background

The stratified random sampling design historically used by BB and NPS in St. Croix and St. John originated from a desire to "collect reef fish data in an unbiased manner with minimal logistic requirements and few decision rules" (Menza et al. 2008). This design has been applied from the year 2001 to 2011 with the objective of creating an inventory of reef fish species and provides an initial assessment of USVI reef fishes status and trends (Kendall et al. 2003, 2004, Monaco et al. 2007, Pittman et al. 2007, 2008). The survey domain included the majority of St. John and the eastern end of St. Croix (Figure 3). This domain was stratified by benthic habitat, management zone and geographic zone. Habitat strata were divided into hard-bottom and soft-bottom categories. Management zones were divided into inside and outside BUIS, VICR and VIIS. Additional geographic zoning was used for St. John and included the mid-shelf reef and Coral Bay.

2.2 Rationale for Modifying Design

The monitoring protocol presented in this document modifies the historical sampling design with an enhanced stratification of habitat for partitioning of random sampling and an optimal sample allocation scheme to improve sampling efficiency.

Survey design is a long-standing, theoretically and methodologically advanced field of statistics developed for the specific purpose of estimating abundance metrics (means, proportions, totals) for a population within a finite spatial domain (Hansen et al. 1953, Cochran 1977, Särndal et al. 1992, Lohr 1999). Probabilistic survey design principles have been successfully applied for decades and these techniques have the advantage of generating population level metrics, as well as optimizing sampling efficiency to obtain high precision estimates at low sample sizes. One of the first steps in designing a survey is to generate a sampling frame from which random samples can be chosen. Currently the sampling frame is loosely defined. A geo-spatially referenced grid, of which grid size is a balance of map resolution and species range, has been shown to work for other tropical marine surveys (Ault et al. 1999, Smith et al. 2011a, 2011b). The adoption of a gridded approach to survey design allows for statistical and ecological improvements (SOP 1 – "Sample Frame and Habitat Classification").

Reef fish are distributed heterogeneously and a stratified random sampling technique can increase survey efficiency by dividing the sample universe into smaller units with homogenous variance. The historical survey had two habitat strata, hard and soft bottom, but through improvements in benthic habitat maps as well as a better understanding of reef fish distribution, additional strata can be created (SOP 2 – "Stratification"). For this survey 10 strata are defined (5 habitat types each with two depth categories) which effectively partition variance by strata throughout the USVI region.

In conjunction with an enhanced stratified random sampling design, an optimal sample allocation scheme can also improve sampling efficiency. If strata variances are known, optimal allocation will reduce sampling effort for a target precision in comparison to a random and proportional allocation (Cochran, 1977). A Neyman optimal allocation directs a greater amount of effort towards strata with higher variance but also weights that amount of effort by proportional area of each strata (SOP 3 – "Sample Allocation"). In addition, by better estimating the variance per

strata for each species, the precision of individual species estimates generally improves even if the sample allocation isn't absolutely optimal for that species.

2.3 Target Population and Sample Frame

A primary consideration of a monitoring program is to delineate the target population which will be monitored and define a sample frame from which samples will be drawn. Reef fish are the targeted population for this survey and the sampling frame contains all mapped hardbottom habitat found in less than 30 m depth throughout the USVI.

The Puerto Rico shelf including the waters of the USVI at depths less than 200 m includes a wide range of habitat types (Kendall et al. 2001). Reef fish utilize a variety of these habitats throughout their life history (Christensen et al. 2003, Grober-Dunsmore et al. 2007). Mangroves, seagrasses and unconsolidated vegetated and non-vegetated habits are all important areas for juvenile reef fish but adult abundances are often low (Parrish 1989). Population metrics of juvenile fish are difficult to estimate due to large variable recruitment events as well as difficulty in accurately surveying them due to their small sizes and typically cryptic nature (Shulman 1985, Willis 2001, Bozec et al. 2011). Hence, given limited resources for sampling, effort towards population estimates is more efficient when targeting adult populations. The adult reef fish population of species of interest can primarily be observed on hardbottom habitat throughout the USVI, thus, the sampling frame is restricted to hardbottom.

A 50 x 50 m grid was merged with habitat and depth information to create the sampling frame. A single habitat classification was determined for each cell along with an average depth (for details see SOP 1 – "Sample Frame and Habitat Classification"). This frame established a discrete list of sites (or cells) from which to draw a random sample. The sampling frame was divided into two regions: 1) St. Thomas and St. John and 2) St. Croix to aide in population level comparisons in reef fish metrics inside and outside of three management zones (VIIS, VICR, and BUIS). The St. Croix East End Marine Park (EEMP) is also a management zone of interest but it was not included in this analysis.

2.4 Stratification

Sampling efficiency can be improved with a stratified random sample design that properly partitions variance among strata. A group of nine economically and ecologically important species in the USVI were used to help define a stratification scheme as well as optimally allocate samples. The species used for optimization include: blue tang (*Acanthurus coeruleus*), queen triggerfish (*Balistes vetula*), coney (*Cephalopholis fulva*), red hind (*Epinephelus guttatus*), foureye butterflyfish (*Chaetodon capistratus*), French grunt (*Haemulon flavolineatum*), yellowtail snapper (*Ocyurus chrysurus*), stoplight parrotfish (*Sparisoma viride*) and threespot damselfish (*Stegastes planifrons*). These species were chosen to include a broad range of life history traits as well as a variety of habitat utilization patterns. Stratification and allocation was optimized with respect to these species, but since all fish species are recorded, monitoring efforts also obtain important information about many non-targeted species, the overall trophic structure, and form the scientific basis for effective management actions.

Sampling frame grids were stratified into 5 habitat categories (scattered coral/ rock, pavement, bedrock, patch reef and linear reef) (Appendix A) each with two depth classifications (shallow (0-11.9 m) and deep (12- 30m)) (for details see SOP 2 – "Stratification"). Instead of creating

separate regional and management strata, each region is divided into inside and outside management zone areas which are each treated as a separate sampling domain. Although this increases survey sites required region-wide, it allows for population comparisons inside and outside of management zones. Additionally, agency decisions on sampling effort and scale are more transparent but still allow for synergistic sampling where target populations overlap. For example, the region-wide sampling effort will by default consist of multiple sites located within each national park but not enough to reach an acceptable level of precision for those populations. Managers and scientists can then determine whether and by how much to augment the overall survey to meet their precision needs for detecting change.

2.5 Allocation and Site Selection

Monitoring funding varies among collaborating agencies and can fluctuate annually. This survey protocol is designed to enable adjustment of survey effort depending on available budgets. Under optimal funding levels, a region wide sampling effort is encouraged for every other year with a proportionally greater amount of effort within VIIS, VICR and BUIS to allow for inside and outside comparisons. A proportionally greater amount of effort is required within management zones because although they are smaller in comparison to the area outside of them, reef fish variance is similar which requires an equal amount of effort. SARI is a smaller management zone and would require a dramatic proportional over-allocation to obtain a similar level of precision as BUIS. Instead, sampling effort inside of SARI should be enough to insure at least 2 samples within each strata present to allow for the calculation of variance. Table 1 depicts an example of how samples could be allocated among management zones under historic funding levels. The associated coefficient of variation (CV) values for optimization species by management zone and region can be found in SOP 3 – "Sample Allocation". Sampling effort should take place during the same season every year. May through October has been the primary sampling season to date.

Table 1. Sample allocation among management zones using the current funding level. Although national parks represent a smaller proportion of area within a region, an increased level of sampling is required to allow for population level comparisons inside and outside of these management zones.

Region	St. Croix			St. Thomas & St. John			
Management Zone	BUIS	Outside	Region	VIIS	VICR	Outside	Region
# Samples	80	120	200	50	50	60	160

The number and location of sample sites are determined prior to each sampling season using a stratified random sample design with a Neyman optimal allocation scheme (SOP 3 – "Sample Allocation"). Digital layers for habitat, depth, region and management zone are contained within a geographic information system (GIS) and are used to delineate the survey domain, strata and sample units. In order to control for spatial variation in population metrics a single-stage sampling design following Cochran (1977) is used where 50 x 50 m grid cells (2500 m^2) serve as primary sample units with a single sample starting at the center of each cell with a random directional heading. The number of sites to be sampled within each region, management zone and strata is based on the proportional area of the stratum and the variance structure of fish density among strata. This analysis is performed using previous year's data and under different levels of precision for the nine optimization species. The final target number of primary sample units represents a balance between achieving an acceptable precision level in estimating

abundance for each species within each management zone as well as the funding capacities of partners.

2.6 Frequency and Timing

Under optimal funding levels, a USVI- wide sampling effort is encouraged for at least every other year with a proportionally greater amount of effort within VIIS, VICR and BUIS to allow for inside and outside comparisons. Sampling in the USVI can be alternated with a multi-agency sampling effort in Puerto Rico and south Florida. Sampling can occur May-October. However the preferred timing for sampling St. Croix is May and for St. John is July to reduce any variation due to seasonality, although this is generally assumed to be minor. The initial extra effort for shelf-wide surveys using the revised stratification procedures led to the decision of only St. Croix being sampled in 2012, only St. John in 2013, followed by Puerto Rico in 2014. Subsequently St. Croix and St. John can be sampled during the same year (Table 4).

2.7 Change Detectable

Tradeoffs between sampling effort and the resulting Coefficient of Variation (CV) are presented in SOP 2 – "Stratification" and SOP 3 – "Sample Allocation". The change detectable is approximately twice the CV and varies among the selected focal species and regions. For average fish density, change detectable estimates range from a low for Coney (19-28%) to a high for Threespot Damselfish (26-104%) depending on the species and management zone (see Table SOP 3.2 on page SOP 3-7). Although not presented in the SOPs, the level of change detectable in community metrics such as species richness, trophic groups (e.g., piscivores), and taxonomic groupings (e.g., snappers) is likely to be at least the same and most likely smaller than those of individual species metrics as variance of community metrics tends to be smaller.

3.0 Field Methods

3.1 Requisites of a Data Collection Program

A successful survey requires a well-designed method for collecting data. A few major methodology requisites for a reef fish data collection program include: 1) the ability to collect fundamental information for species of interest including fish identification to species level, abundance and size estimate for each individual; 2) a consistent repeatable area component and; 3) accurate representation of fish assemblage within the sampling unit.

An effective sampling methodology should also minimize measurement bias, which is the possibility of certain individuals in a population having a lesser chance of being selected than others. The concept of taking several samples to accurately estimate characteristics of a population requires that each sample is devoid of bias. Since sample area is typically extremely small in comparison to the actual population area, a small bias can have dramatic effects on population estimates. Some factors that can influence sample bias in visual surveys include: diver behavior, underwater currents, visibility, species detectability, species behavior, observer experience/training and fish density.

In addition to data collected on fish, it is imperative that habitat information is collected to aide in analysis and that can be assimilated into future survey designs. These data include: depth, habitat type (as according to stratification scheme), benthic floral and faunal composition, rugosity and relief.

The methods and training described in this protocol are designed to meet these criteria.

3.2 Survey Method

The belt transect method is a method for non-destructive reef fish visual surveys that meets the above requirements. Using this method also allows comparison with data collected by BB and NPS using the belt transect survey method in the USVI (Menza et al. 2006) from the year 2001 to 2012.

The survey method used in this protocol consists of a single 4 m x 25 m belt transect survey (fish and habitat) at each site starting at the center of a randomly selected primary unit (50 x 50 m grid cell) with a randomly chosen direction of travel for the transect. Divers are deployed by live boating (dropping off divers without anchoring). Buddy teams are equipped with their sampling gear and a reel attached to a float to indicate their position. For each site, three types of data are taken: 1) Field/Boat Log form data, which records where, when and by whom sites were sampled along with surface conditions; 2) fish data and; 3) habitat data.

The belt transect is similar to a line transect in that organisms are surveyed along a discrete pathway. The belt transect used in the USVI and recommended in this protocol is 25 m long and fish that are observed within 2 m on either side of the transect are recorded. The speed at which the divers conducts their survey is standardized to 15 minutes per 25 m transect. All fish observed in front of the fish diver within the 4 m width of the belt transect are recorded but no fish are recorded from behind the diver and no fish are recorded beyond the end of the transect. Abundances for all individuals observed are recorded by species into 5 cm length bins as the diver swims along the transect (actual lengths are recorded for fish >35 cm). After the fish diver

has moved 5 m down the transect line the habitat diver begins his/her survey. One gridded 1 x1 m quadrat is placed at pre-determined random locations within each 5 m portion of the transect with the total number of placements equaling five. Corals are identified to species and percent coverage for all benthic organisms are recorded.

A detailed description of the belt transect survey method can be found in SOP 4 – "Field Data Collection: Belt Transect Method" and field data forms are in Appendix B.

3.3 Calibration Study with Reef Visual Census Sampling Methods

A calibration study is necessary to compare data from the USVI to data that is being collected in south Florida which uses a different sampling method: the Reef Visual Census (RVC) approach (see Section 1.2.4 above). The study will be designed with two goals: 1) provide adequate data for a calibration between the two methods, and 2) to evaluate strengths and weaknesses of both techniques for USVI visual surveys. It is included here as both methods (belt transect and RVC point count) would need to be implemented at the same sites for 1-2 years. This would be most effectively accomplished if it occurred during the regular field data collection and involved participants by all partners. The study is further detailed in SOP 5 – "Inter-calibration Study" and SOP 6 – "Inter-calibration Study Additional Field Data Collection: Point Count Method" provides the Reef Visual Census method to be used in the comparison. Smith et al. (in prep) have developed a statistical model to standardize catch and effort indices among fishery-independent survey data. Marc Nadon (pers comm.) has created a tool built on this model to generate conversion coefficients for two different underwater visual survey techniques in the United States Pacific Islands. A similar study is recommended for the USVI and the basic approach is outlined in SOP 5.

3.4 Field Season Preparations and Equipment Setup

In preparation for each field season, the lead agency will call a meeting for collaborating agencies to determine the abilities and needs of each group for participation in field sampling. At this time, a schedule will be determined for all training activities (SOP 7 – "Participant Training") that must take place prior to the start of sampling. All participants are personally responsible for ensuring their compliance with diving authorization requirements. Each agency will be responsible for verifying that their participants conform to the requirements and that they are equipped with all necessary sampling gear for that season (See Chapter 6 – "Participant Roles, Requirements, and Training". Sample numbers, locations, alternative sites and the agency/group responsible for each sample will be determined prior to the start of the field season by the lead agency. Joint sampling efforts among agencies should be discussed and scheduled.

Permits are required from the U.S. Virgin Islands Department of Planning and Natural Resources (DPNR) for conducting fish surveys in the Virgin Islands and park permits from park Resource Management are required for working in BUIS, SARI, VIIS, and VICR. NPS boats driven by NPS staff can work in the national parks without a separate permit but the overarching NOAA-BB effort still needs the appropriate permits. Anchoring is not permitted in VICR and most of VIIS without special permission from NPS Resource Management office and notification of NPS law enforcement personnel.

3.5 Sequence of Events During Field Season

At the start of the field season, the lead agency will provide each partner with a list of sites which they will be responsible for sampling to the best of their abilities. Sampling schedules may vary by agency due to considerations of weather and equipment but a concerted single sampling pulse is recommended. A list of alternate sites will also be provided that can be used in cases where sites are not accessible, habitat classification is incorrect or if an agency has completed their assigned sites and is capable of additional sampling. As many sites as reasonably possible should be surveyed during a day; this goal can be maximized by assigning sampling teams surveys sites that are in the same vicinity.

Data that are collected are the responsibility of the participants and their respective agencies, should be entered into BB's Coral Reef Ecosystem Assessment and Monitoring database (CREAM), and catalogued by the end of the field season following the methods detailed in SOP 8 – "Data entry, Proofing and Management". Preferably, data are entered immediately upon returning from the field (or within 1 day), as this tends to reduce error in data entry. However, all data must be entered at least by the end of the mission. Once all data are catalogued, each agency will follow proofing steps before submission for final verification and entry into the central database (SOP 8 – "Data Entry, Proofing, and Management"). Table 2 provides an outline of the tasks that need to be accomplished each year and approximate target dates for getting this work completed.

Table 2. Tasks that need to be accomplished annually and approximate target dates for getting this work completed.

Annual Tasks	Timeline for Completion
Determine number of samples	Feb-Mar
Sample allocation among strata and sample point selection	Mar- Apr
Assign sample points to agencies/groups Field logistics planning	Apr
Field data collection	May-Sept
Initial data entry & proofing at agency level QA/QC of data at regional level	May-Oct
Data analysis and reporting	Oct-Dec
Archival	Dec - Jan

3.6 Post-mission equipment maintenance and storage

Datasheets are rinsed in freshwater and transferred to BB Data Manager. All field equipment must be rinsed off in freshwater after the sampling trip. Broken equipment must be repaired or replaced as necessary and all equipment returned to its assigned location. Care and maintenance procedures for boats are in their boat SOPs (separate from this document).

4.0 Data Assimilation

4.1 Post-collection Data Handling

Initial quality assurance / quality control (QA/QC) should include discussions among dive buddies immediately after each dive to ensure agreement on main variables (e.g., habitat characteristics, visibility, current) and a review of underwater data sheets to make sure all entries are legible. Data sheets should be maintained securely while on board, and once on land, scanned copies of data sheets should be made and then re-distributed to each individual that collected the data for subsequent data entry into the CREAM database (Figure 5).

4.2 Data Entry

It is the responsibility of each individual participant in the survey to enter and proof their data following data collection (Figure 6). Each diver will enter their data into BB's CREAM database. Data entry into the CREAM database can occur either through the offline Biogeography Program Database Management (BPDM) data entry program or online at: https://www8.nos.noaa.gov/biogeo_public/staff_login.aspx. At the beginning of each field season, BB will provide each participating agency with a copy of the offline database. Divers are responsible for accurately entering their data and to check their entry prior to submitting. Species codes for fish and benthos are found in Appendices C and D respectively.

Each participating agency will assign a data manager who is responsible for ensuring all data is collated (i.e., data sheets, photos, GPS files); all divers have entered and proofed their data; and if data are entered into the offline database, the divers and data manager from each agency need to ensure that all xml files are sent to BB to upload into the CREAM database. The BB data manager will check to make sure each sample has been entered and will contact a partner's data manager if any data are missing.

Entry and subsequent data proofing are expected to occur within two months of each survey. Early entry and proofing is recommended because it is easier to remember dives and to catch mistakes. SOP 8 – "Data Entry, Proofing, and Management" covers data entry steps, proofing, quality assurance/quality control, and database management. All datasheets are scanned and copies can be stored by their respective agencies.

4.3 Data Management

Each partner agency's Data Manager is responsible for submitting the following to BB:

1) Original data sheets
2) Final xml files from offline database after proofing
3) Copies of all photos identifiable at least by date and site
4) Copies of GPS files

The regional database (CREAM) is managed by BB. Once the data have been uploaded, the BB data manager will perform all QA/QC and maintain the location for data download. Photos should be managed by each respective partner with copies sent to BB. At a minimum, photos should be stored in a manner that retains sample date and site number.

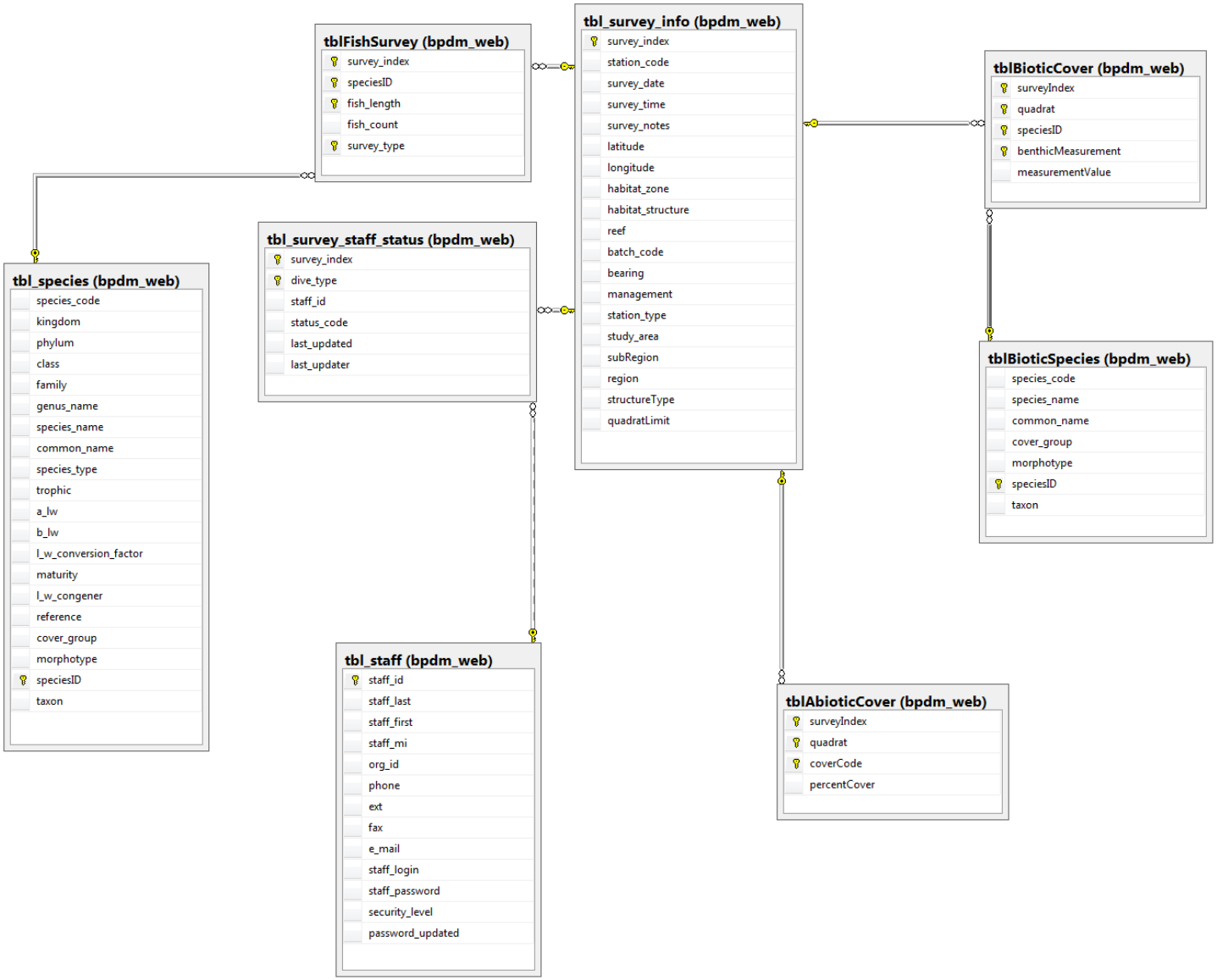

Figure 5. NOAA-BB CREAM database core tables and relationships.

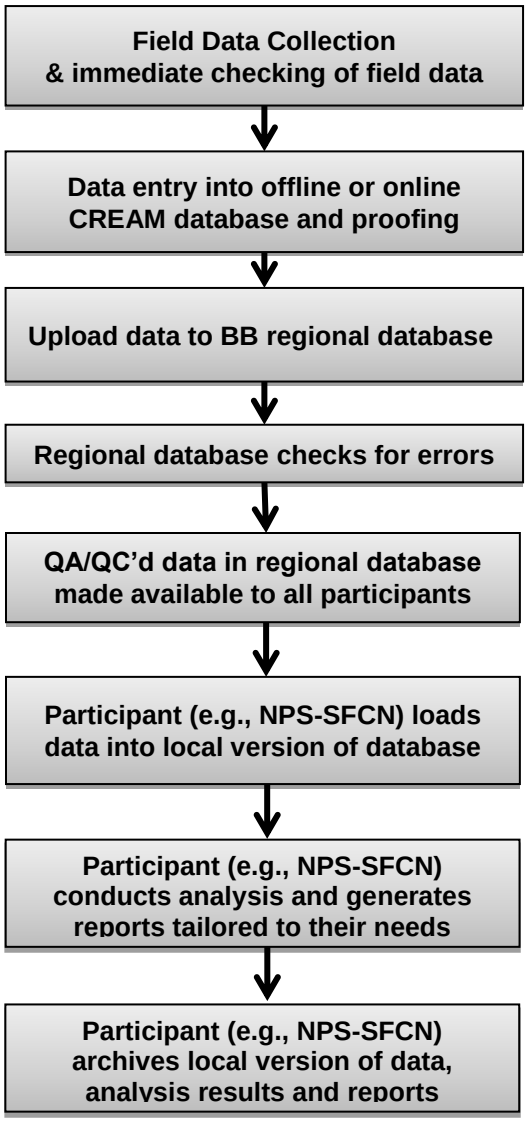

Figure 6. Outline of data flow pathway.

4.4 Overview of Regional Database Design

The BB regional database (CREAM) is located at http://www8.nos.noaa.gov/biogeo_public/query_main.aspx. Each participating agency can download the proofed data from the CREAM website. Fish data are found under the heading Fish Queries and habitat data are under Habitat Queries. Metadata are available by region and type. In the query view, fish data can be accessed by region, year, month, structure, survey type, management zone, trophic level, family and species. Habitat data can be queried by the same factors except instead of trophic level and family, cover type is included. Full data downloads are available under both query locations.

4.5 Metadata and Archiving

BB is responsible for archiving a complete set of the data each year and maintaining metadata associated with the regional database in accordance with NOAA standards and procedures.

4.6 Sensitive Data

The only sensitive data of concern in this protocol are locations of black coral (*Antipathes* spp.). As black coral is a poachable species for jewelry, locations of black coral should not be released to the public either as data or as report maps. To date black coral has not been recorded in the habitat data. Although suggestions have been made to record presence of black coral at the site on the data sheet to assist with creating an inventory of these species, this suggestion has not been implemented at this time. Elkhorn coral (*Acropora palmatta*) and staghorn coral (*Acropora cervicornis*) are federally listed species but generally do not have poaching problems.

4.7 NPS-SFCN Specific Details

The NPS-SFCN specific details are provided in Appendix I to meet the protocol requirements of the NPS-SFCN program.

5.0 Analysis and Reporting

5.1 Recommendations for Routine Data Summaries and Statistical Analyses

The range and types of statistical analyses that can be performed to assess the status and dynamics of reef fish populations and communities depends on the specific research and management questions and resource goals to be addressed. These questions and goals may change through time or vary by agency, but there are some fundamental metrics that should be generated after each sampling season that are outlined in SOP 9- "Data Analysis and Reporting". Table 3 provides a list of metrics whose calculations are described.

Table 3. Example metrics for summary report that can be calculated from data.

Metric	Example	Individual Species	Trophic Guilds[1]	Taxa Groups[2]	Non-fish Taxa[3]
Species Richness	Average # species /site	X			
	New species detected	X			
Occupancy & Spatial Distribution	Total, Adult, Juvenile, Exploited	X	X	X	X
Density	Total, Adult, Juvenile, Exploited	X	X	X	
Abundance	Total, Adult, Juvenile, Exploited	X	X	X	
Coefficient of Variation (CV)	Exploited, Adult or Total Density	X			
Size Structure	Max Length, Average Length, Average Adult Length, Average Exploited Length Length Frequency Distribution (Number of fish in 5 cm length bins)	X			
Biomass[4]	Total Biomass	X	X	X	

[1]Trophic guilds= piscivores, herbivores, invertivores, planktivores, etc.
[2]Taxa groups= groupers, snappers, grunts, parrotfishes, etc.
[3]Non-fish taxa= elkhorn coral, lobsters, long-spined sea urchins, etc.
[4]Biomass is calculated from length x weight relationships.

These analyses utilize a range of survey data types (abundance, occupancy, size, taxonomic identification), and allow for the assessment of the status and trends of reef fish communities and populations over time. SOP 9- "Data Analysis and Reporting" focuses on the specific reporting needs of SFCN, but can be adapted to meet the needs of other groups as well.

To use the NPS-SFCN data analysis and graphing tools described in this document requires MSAccess, MSExcel, ArcGIS, and the freeware statistical program R. The tools will be made available to all partners who can modify them to meet their respective needs.

Starting in 2013 SFCN plans to publish basic summary reports in the Natural Resource Data Summary series (NRDS) following each mission as described in "Appendix I - NPS- SFCN Specific Requirements, Safety, Data Management, and Reporting Standard Operating Procedures". SOP 9 also briefly discusses simple types of trend analysis and multiple mean comparisons that can be conducted with this data.

5.2 Iterative Approach to Survey Design

Monitoring programs comprise an iterative process of sample design and allocation, data collection, data assimilation, and analysis that can be used to improve the sample design and allocation for future surveys (Figure 4). The initial survey design described here for the USVI, including the stratification scheme, is based on previously collected reef fish data as well as existing benthic maps. As the program is implemented, data from previous years can be used to refine the stratification scheme with the objective of further reducing sampling variance and improving the ability to detect change. Therefore it is important that the survey design is revisited and updated every few surveys or when significant changes have been made to benthic maps (SOP 1 – "Sample Frame and Habitat Classification" and SOP 2 – "Stratification").

Sample allocation is determined by calculating population level variance estimates of density per strata but the amount of sampling effort reflects management needs and funding availability. Data collected during each survey season is incorporated into the sample allocation for subsequent surveys. Since the initial data used to estimate variance among strata was spatially limited, it is imperative that future sampling allocation includes the most recent data (SOP 3 – "Sample Allocation").

The existing sampling grid is updated preferably after each survey season based upon field data as appropriate, e.g., linear reef is found to be pavement in a grid cell during a field visit, however if there is concern over diver assessment and ability to classify the entire cell based upon their limited field of vision, the map may be updated after several years based upon the field data with a single person or team providing a consistent reclassification approach. The current grid is assumed to be the most appropriate for conducting analyses with both current and historical data as these geological formation based habitats do not change through time and the discrepancies are assumed to be errors in the original grid.

6.0 Participant Roles, Requirements and Training

6.1 Roles and Responsibilities

Implementation of this protocol is expected to be a collaborative effort amongst federal, territorial, academic, and NGO partners. The regional scale of this effort to monitor reef fish across all territorial waters warrants BB be the lead agency as it is beyond the scope of the National Park Service. SFCN will represent the NPS to ensure data collected within park boundaries are robust enough to evaluate effectiveness of management actions, e.g., no-fishing within MPAs.

At the start of each field season, responsibilities for sampling will be delegated among the participating agencies/organizations. Each agency/organization will provide participants, equipment and facilities to the best of their ability depending on their budget constraints and responsibilities to other projects for that year. All agencies/organizations will designate a data manager, a chain of command, and points of contact for dealing with scheduling and logistical considerations, as well as for questions regarding procedures and policies. Points of contact should be clarified so that all participants, regardless of agency, are aware of who should be contacted in the event of a question or issue. Points of contact and estimates of personnel, equipment, and facility commitments need to be provided two months prior to the start of the sampling season to allow planning to proceed in a timely fashion. Each participating agency/organization is responsible for ensuring adequate training of their personnel as described below before start of sampling.

BB will maintain copies of the sampling grid, be responsible for updating the grid at the conclusion of each sampling season, and annually providing the grid to all parties so each can proceed with sampling analysis to meet their respective reporting needs.

Each agency will have their divers enter their data into the BB CREAM database either through the online entry program or offline into the BPDM program and then send the xml files to the BB data manager. BB is responsible for maintaining the regional database and conducting basic QA/QC checks that are best performed at the regional level. Future discussions can hopefully lead to a shared approach to QA/QC to ease the workload on BB.

BB is responsible for conducting the post-stratification analysis and for developing a new sampling allocation each year. However, sampling allocation should attempt to meet the needs of all partners in order to maintain a multi-agency cooperative approach.

Reciprocity agreements to allow divers on other agency boats may need to be established before beginning of sampling and are the responsibility of the affected agencies/organizations unit dive safety officer(s).

<u>NPS-SFCN Specific Details</u>

SFCN's Marine Ecology Team (Marine Ecologist, Fisheries Biologist, 3 Marine Biological Technicians, any Marine interns) anticipate participating in the sampling of the St. Croix and St. Thomas/St. John regions, but not Puerto Rico. Details of participation will be made yearly based upon number of participating agencies involved, staff workload and availability, and sample design targets. All members of the marine team are trained in field identification of fish species

and benthic fauna, data entry, and proofing and can be assigned to this project as needed. The Marine Ecologist will in addition be responsible for logistics coordination and generating the SFCN data summary report but can delegate the task as necessary. The SFCN Data Manager and SFCN Quantitative Ecologist will be responsible for maintaining and updating the SFCN analysis and reporting tools, database, and templates, and additional data management and QA/QC tasks if BB chooses to delegate more to participating agencies.

6.2 Qualifications

All participants must be trained in reef fish identification as well as in the ability to make the necessary observations (training requirements are covered in the subsequent section). All participants must also be certified to scuba dive in open water by a recognized and licensed organization (e.g., NAUI, PADI) and must possess a certification to use enriched-oxygen (NITROX). Participants must be in compliance with their agency's dive safety regulations. Depending on the agency in charge of the diving operations a letter of reciprocity may need to be exchanged. It is the responsibility of the agency in charge to confirm prior to operations that participating divers are cleared to dive.

NPS-SFCN specific qualifications and training requirements are specified in Appendix I.

6.3 Training

Training is a critical component of the reef fish monitoring program and should incorporate both initial and annual refresher training components. Participants should be capable of accurately identifying and estimating sizes of reef fish that are encountered in the USVI. Participants should be familiar with habitat assessment techniques and benthic categories that are included in the method and detailed in SOP 4 – "Field Data Collection: Belt Transect Method" (and SOP 6 – "Field Data Collection – Point Count Method" if participating in the Calibration Study). Annual out-of-water training meetings and in-water training activities will be held each year before sampling commences as detailed in SOP 7 – "Participant Training". Out-of-water meetings will be held either jointly or independently depending on the needs of each agency and will consist of overviews of sampling design, logistics, field methods, habitat characteristics and data entry and proofing. In-water training will be organized and executed by each agency independently, although personnel exchange among agencies is encouraged.

6.4 Annual Workload and Schedule

The regions of St. Croix (STX) and St. John/St. Thomas (STJ) are expected to alternate years

Table 4. Initial sampling schedule.

Sampling Year	Region
2012	St. Croix
2013	St. John/St. Thomas
2014	Puerto Rico (does not include NPS staff)
2015	St. Croix & St. John/St. Thomas
2016	Puerto Rico (does not include NPS staff)
2017	St. Croix & St. John/St. Thomas

This program is designed to allow some flexibility given the changing budgets and available personnel of the agencies involved. However, to give an example of the overall workload required, sampling around the entire St. Croix island in 2012 involved the collection of 290 data points over 10.5 days of operations in 7 boats using 35 field personnel from BB, SEFSC, BUIS, SFCN, UM-RSMAS, University of Virgin Islands, The Nature Conservancy, and Virgin Islands Department of Planning and Natural Resources (not all personnel were present for full 10 days). Boats typically averaged 6 sites per day (NOAA 2012). Data entry and proofing took approximately 1-2 hours for every day of field work for field personnel. In addition time was required for initial logistics and planning, sample site selection, QA/QC checks at the regional database level, trend analysis, reporting, and post-stratification analysis (approximately 6-8 weeks).

Specific details for NPS-SFCN participation including workload, schedule and budget are provided in Appendix I.

6.5 Safety

All personnel are responsible for following the safety rules, regulations, requirements, policies, and procedures of their respective agency or organization as well as of the parks or protected areas they are working within. In general an attitude of a "culture of safety" and "operational leadership" should prevail in which problems are considered proactively and each person must feel empowered to think about potential problems and speak up early about safety concerns regardless of their position and those concerns must be addressed seriously and respectively by the rest of the team.

Additional NPS-SFCN safety requirements are specified in Appendix I.

6.6 Equipment

Equipment needed is detailed in "SOP 4 – Field Data Collection: Belt Transect Method" and in respective agency dive training and boat SOPs. A more generic list of equipment is as follows:

- Standard dive equipment and accessories
- Boat with dive and boating safety equipment.
- Navigation equipment and accessories (e.g., GPS, maps, charts)
- Belt Transect:
    - Each diver: underwater data sheet, underwater slate, pencil(s), dive watch
    - Each team: reel and line attached to surface buoy/dive flag equipped with handheld GPS in waterproof bag; 25 m tape measure, 1 x 1 m quadrat, 6 m rugosity chain, underwater camera.

6.7 Boat Docks and Dive Shops

Appendix G provides maps and information about boat docks and dive shops that will likely be used by the multi-agency teams for overnight docking, filling of tanks, etc. This list is not meant to endorse any specific dive shop, dock, or operation but instead to list those limited number of facilities on the islands already known to potentially have docking space, ability to fill tanks, and locations/access which provide efficient/cost-effective support for multi-agency teams to accomplish their objectives.

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Standard Operating Procedure 1 – Sample Frame and Habitat Classification

Version 1.0

Purpose

Describes the background and development of the sample frame and habitat classification scheme used for sample allocation within this protocol and how the grid will be updated in the future.

Introduction

Survey design is a long-standing, theoretically and methodologically advanced field of statistics developed for the specific purpose of estimating abundance metrics (means, proportions, totals) for a population within a finite spatial domain (Hansen et al. 1953, Cochran 1977, Särndal et al. 1992, Lohr 1999). A critical component of a survey design is the creation of a sampling frame which includes a complete, explicit list of all possible sampling units. It is a necessity to know the probability (P) of selecting a single sample (($P = \frac{1}{N}$) where N is the total number sample units) as well as have the ability to account for all the area in each survey stratum. A geo-spatially referenced grid, where grid size is a balance of map resolution and species range, has been shown to work for other tropical marine surveys (Ault et al. 1999, Smith et al. 2011a, 2011b). Each grid is used as an independent sample unit from which a random sample can be selected.

When constructing a sample frame it is important that each independent unit represents the overall habitat contained in that unit. Since multiple habitat types may be present in any given sample unit, decision rules need to be applied that appropriately define the habitat. This SOP outlines the decision making process for determining sample unit size and habitat classification

Sample Frame

Grid Size

The grid cell size selected for the sampling frame should reflect map accuracy as well as the distance that habitat influences the density of interested species. In the Florida Keys and Dry Tortugas, the reef tract was divided into 200 x 200 m square girds (Smith et al. 2011a). The decision for grid size was based on map accuracy and required secondary sampling within each primary unit to lower density variance. Habitat maps from the United States Virgin Islands (USVI) provide higher resolution, hence a 50 x 50 m square grid was chosen. A single random sample is collected within each grid cell that represents the cell's density. This sample starts at the center of the grid cell and includes a 25 x 4 m transect with a randomly chosen direction that ends inside the respective grid cell. The total area of each sample (100 m^2) is therefore $1/25^{th}$ of the grid. A single transect should be effective in characterizing the fish assemblage in each grid as the smaller grid size helps capture the sphere of habitat influence yet is large enough to minimize the chance of counting fish from an adjacent sampling unit. Reef fish have various home ranges and species that may be closely associated with a linear reef may also be found on adjacent low relief hardbottom. A randomly chosen transect in a grid with linear reef would

likely capture the associated fish assemblage even if part of the transect was on low relief hardbottom.

Creation of the Grid

The 50 x 50 m UTM grid layer used for the USVI sample frame was created by NOAA's National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment, Biogeography Branch (BB). The grid was created by starting at the extent of the GIS shapefile (northwest of Puerto Rico) and rounding to 100 m. The grid was merged with existing benthic habitat maps to create a database file with the amount of each habitat type present per cell. The composite grid cell classification scheme calculations as described above were run using this database file to generate a single habitat classification for each grid cell. BB then merged existing bathymetric layers to calculate an average depth for each cell and added this layer to the habitat information to create the sampling grid. A grid cell is classified as marine if any portion of the grid cell is below water. Grid cells are assigned a management zone classification if any portion of a boundary is within a grid cell.

Habitat Classification

Habitat and Bathymetric Maps

Benthic habitat maps for the USVI were originally delineated from aerial surveys into 21 distinct habitat types (Kendall et al. 2001). Multibeam data collected annually from 2004 until 2010 was incorporated into existing benthic habitat maps. These combined data sources were used to provide depth information and assign five separate hardbottom habitat classifications for the USVI: 1) linear reef, 2) patch reef, 3) bedrock, 4) pavement, and 5) scattered coral/rock. A detailed description of these habitat types can be found in Kendall et al. (2001) and in Appendix A. Habitat types are represented on the map with polygons so that within each 50 x 50 m grid, multiple habitat types may be present (Figure SOP 1.1). In these cases, a decision rule was applied to assign a single habitat classification to each grid.

Applying Habitat Classification to Grid

In order to determine the most appropriate way to convert a benthic map habitat classification scheme to grid cells, three different decision rule methods were investigated (Table SOP 1.1). The simplest approach is to apply a "Majority Rule" that assigns the majority habitat category to the cell. However, habitats with higher complexity typically have greater diversity and reef fish abundance (Friedlander and Parrish, 1998) hence their presence in a sampling unit should be accorded more weight than a lower complexity habitat. The hierarchal classification of grid cells is based on complexity. The composite method attempts to combine the majority and hierarchical approaches. All three approaches were applied to the grid and the results of each habitat scheme were compared by region; St. John and St. Croix (Table SOP 1.2). For both St. Croix and St. John there was a 20% difference in the number of units classified as linear reef between the hierarchical and majority schemes with more units being classified as linear reef in the hierarchical scheme. The composite scheme split the difference between the two in both regions. The 5% minimum area value used for the hierarchical scheme likely overestimates the amount of higher priority habitat and may not be ideal for partitioning variance. Likewise, the majority area scheme likely underestimates high priority habitat while overestimating the amount of low complexity habitat. We felt the composite rule method best fit our understanding of the spatial distribution of habitat types and reef fish ecology. Therefore, habitat maps created with the

composite classification scheme were subsequently used for stratification calculations, post stratification analysis and optimal allocation.

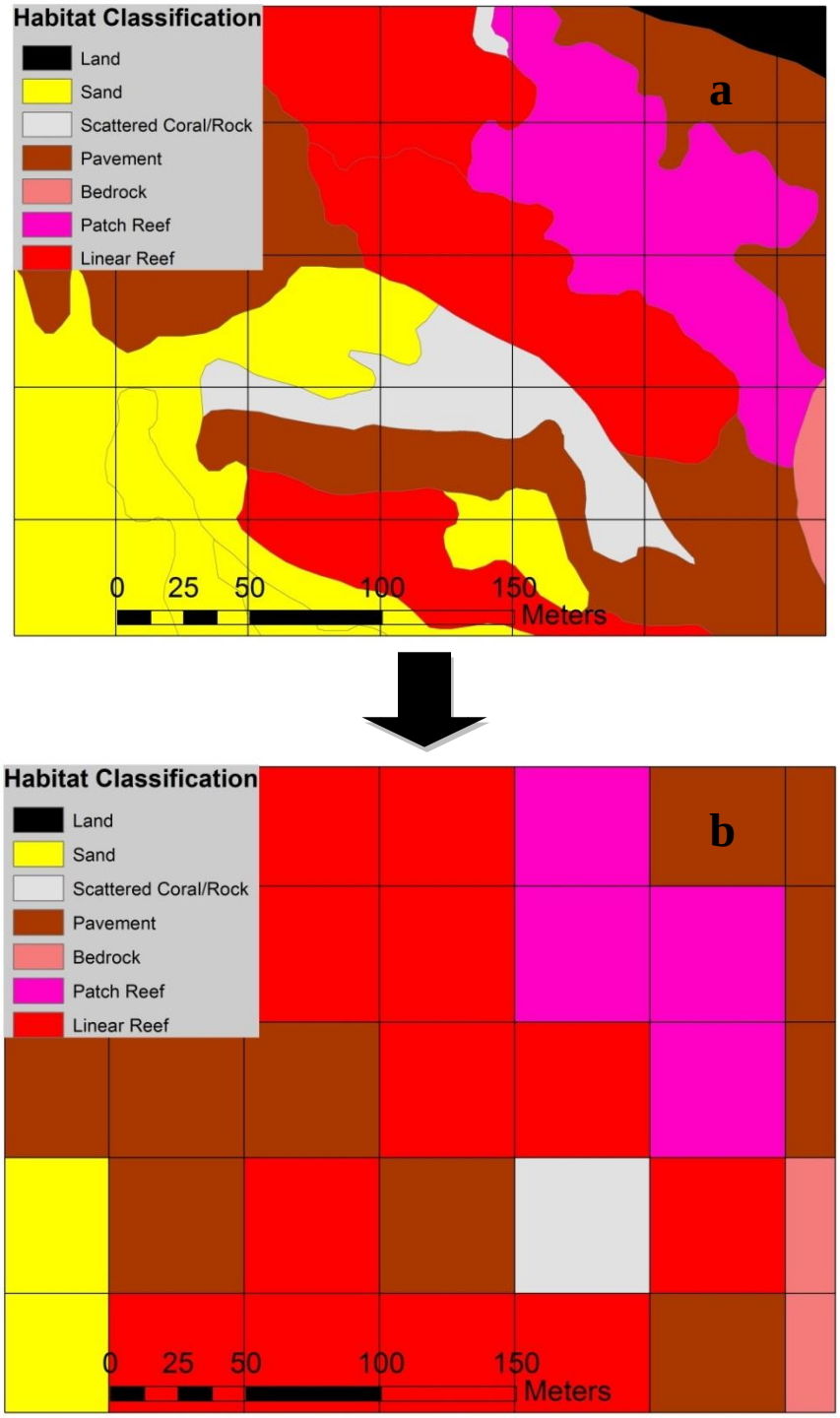

Figure SOP 1.1. A 6.25 ha section of habitat on the south side of St. John with multiple habitat types present. The top figure (a) is the benthic habitat map and the bottom figure (b) is the resulting habitat classification using the composite scheme.

Table SOP 1.1. Three habitat classification decision rules used to classify primary sampling units (grid cells).

Scheme	Description
Hierarchical	Grid cell classification was prioritized by ascending habitat type: 1) linear reef, 2) patch reef, 3) bedrock, 4) pavement, and 5) scattered coral/rock. If a cell contains multiple habitat types, the grid cell was assigned the highest priority habitat that made up a minimum of 5% of the area of the cell
Majority Area	Each grid cell was assigned the majority habitat class within the cell.
Composite	Grid cells were grouped into more complex classes (1-3) and less complex (4-5). If a combined 20% of the habitat in a cell was in the more complex classes, the majority area was used to assign the habitat class from one of those classes. If cells had less than 20% of high complexity habitat, majority area was used.

Table SOP 1.2. Number of 50 x 50 m grids for each habitat type by classification scheme. (*St. John data does not include mid-shelf reef habitat)

	St. Croix			St. John		
Habitat Type	Hierarchical	Majority Area	Composite	Hierarchical	Majority Area	Composite
Linear Reef	6179	5025	5641	3544	2792	3137
Patch Reef	3548	3114	3378	965	946	961
Bedrock	3007	2663	2869	2540	2354	2586
Pavement	78701	77885	77029	4571	5304	4790
Scattered Coral / Rock	5311	8059	7829	332	556	478

Modifying and Maintaining the Grid Cell Layer

In addition to statistical and ecological benefits, a sample frame composed of independent grids is also advantageous through its flexibility in adapting to changes and upgrades in benthic data. This habitat classification scheme represents an initial approach to a hopefully evolving process. There are three opportunities to improve habitat classification. 1) Improvements in habitat maps should be incorporated into classified grids and the current classification scheme should be re-run when new information is available. 2) Habitat maps are not 100% accurate. If divers find a grid that has been incorrectly classified, they should record their GPS coordinates, grid ID and the habitat type that they found. Individual grids can then be updated with diver information. 3) Research towards understanding relationships between reef fish and habitat is dynamic. Grid classification should reflect prevailing knowledge.

The grid layer, bathymetric layers and benthic habitat maps should all be maintained by a single agency but available to all partners. The SFCN and all other partners should receive copy of the

most recent sampling grid each survey season from which to run analyses. After each survey year (or before the next), discrepancies between grid classification and diver habitat type are investigated and where necessary, the grid updated. Updates in cell information, changes in bathymetric layers and changes in habitat maps should be made in consultation with all partners to insure a standard sampling grid is maintained. If additional areas are added to the grid in the future, the procedures described above under "Creation" should be followed for the new areas.

Revision History Log

Version #	Date	Revised by	Changes	Justification

Literature cited

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Standard Operating Procedure 2 – Stratification

Version 1.0

Purpose

Describes the stratification scheme and post stratification analysis used for this protocol and outlines the steps for future survey design refinement.

Introduction

The goal of this monitoring program is to provide estimates of reef fish population level metrics both on a community and species specific scale for the United States Virgin Islands (USVI) along with the ability to distinguish trends and differences inside and outside of several management zones. The goal of the survey design presented in this protocol is to increase the precision of these estimates at the lowest possible cost. To do so, a stratification scheme is required.

Reef fish have patchy distributions that are influenced by physical and biological habitat attributes (Williams 1991). In a stratified random sample design this heterogeneous distribution throughout the sample population is divided into smaller, more homogenous strata. If the variance structure is correctly accounted for in the stratification scheme, survey precision can be increased while maintaining comparable costs. Strata can include geographic regions, management zones, depth, benthic habitats, along with a number of other physical and biological characteristics. A successful stratification scheme uses these characteristics to capture and partition areas of high and low sample variance.

In the USVI, benthic habitat maps and bathymetry are available throughout most of the region occupied by our target population. This SOP outlines how these two characteristics were used to stratify the sampling effort. The stratification schemes chosen in this protocol can and should be improved with additional information. In this SOP, data collected from a relatively small area in the USVI from 2001-2010 are used to guide stratification decisions. Stratification should be revisited when additional spatial and temporal data become available. The same procedures that are described for this initial stratification can be used for subsequent iterations.

Species for Optimization

Although there are hundreds (400-600*)* of reef fish species found in the greater Caribbean coral reef ecosystem, a large number of these species are cryptic or extremely rare and are not normally observed during underwater visual surveys (Böhlke and Chapman 1968, Stark 1968, Smith et al. 2003 and Smith-Vaniz et al. 2006). Of the 246 species of fish observed during ten years of reef surveys (n=1853) on hardbottom habitat in St. Croix and St. John, 149 species were observed at least 1% of the time, 78 at least 5% and only 55 during 10% or more of the surveys (NOAA's National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment, Biogeography Branch (BB) unpub. data). Ideally a survey would be optimized to detect a change in all these species to a given level of precision. However, species with a low frequency of occurrence (<10%) would require a significantly greater sampling effort to detect a change in their population. Instead of trying to optimize a survey for a large number a species, a select few can be chosen.

In the Florida Keys, a group of 8 economically important species were chosen for optimization (white grunt, bluestriped grunt, hogfish, mutton snapper, gray snapper, yellowtail snapper, red grouper and black grouper) (Brandt et al. 2009). In the Northwest Hawaiian Islands, a group of 7 economically and ecologically important species were chosen that represented various trophic groups, territories and life history characteristics.

In the USVI, park managers and science partners composed a list of 9 economically and ecologically important species that represent various trophic groups, territories and life history characteristics (Table SOP 2.1). These species were used to help determine an appropriate stratification scheme and to optimally allocate sampling effort among strata. The use of a select group of species does not connote that others will not benefit from the stratified sample design. Previous work in the Florida Keys has shown that if commercially important species are used for survey optimization, precision levels for other species are often comparable (Smith et al. 2011). In addition, other metrics used to measure ecosystem health such as species richness and diversity typically have low variances and if sample effort is optimized towards individual species, the precision to detect change for these metrics is usually very high. This also pertains to functional groupings.

Table SOP 2.1. Species list used for optimizing survey design. Trophic groups include generalized carnivore (GC), planktivore (PL), benthic carnivore (BC), omnivore (O) and herbivore (H). Average frequency of occurrence on hardbottom habitat from 2001-10 are shown for St. John and St. Croix.

Family	Scientific Name	Common name	Trophic	St. John	St. Croix
Serranidae	*Cephalopholis fulva*	Coney	GC	34.6%	52.5%
Serranidae	*Epinephelus guttatus*	Red hind	GC	39.2%	24.9%
Lutjanidae	*Ocyurus chrysurus*	Yellowtail snapper	PL	40.9%	21.80%
Haemulidae	*Haemulon flavolineatum*	French grunt	BC	42.5%	41.4%
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	BC	55.5%	22.7%
Pomacentridae	*Stegastes planifrons*	Threespot damselfish	O	36.6%	21.8%
Scaridae	*Sparisoma viride*	Stoplight parrotfish	H	61.6%	54.7%
Acanthuridae	*Acanthurus coeruleus*	Blue tang	H	85.4%	71.8%
Balistidae	*Balistes vetula*	Queen Triggerfish	BC	18.4%	15.8%

Initial Stratification

A simple random survey design is often the best choice when a population has a homogenous distribution (no spatial structure in variance). However, reef fish are heterogeneously distributed and there is the potential to increase survey precision by stratifying the sample domain. Smaller homogenous strata with similar variance structure can be used to select sample units more efficiently. Through the relationship between reef fish and multiple stratification covariates (such as depth, habitat type, region), an appropriate stratification scheme can be selected and the survey precision improved.

Reef fish variance is positively related to their density which can be related to a number of covariates such as depth and habitat type (Figure SOP 2.1). To determine an appropriate

stratification scheme for this survey design, the standard deviation of mean abundance was calculated by species for a suite of stratification schemes. The USVI sample domain was divided into two regions: St. John and St. Croix (see Figure 3 in Section 1 of the Protocol). The St. John region encompasses all territorial waters surrounding St. John and St. Thomas out to 30 m depth including portions of the mid-shelf reef. The St. Croix region encompasses all territorial water surrounding St. Croix out to 30 m depth. Benthic habitat was divided into 5 types described in SOP 1 – "Sample Frame and Habitat Classification" (Linear Reef, Patch Reef, Bedrock, Pavement, Scattered Coral/Rock). When developing a stratification scheme, it is important that there has been enough sampling effort in each of the stratum to insure an accurate estimate of variance. The numbers of samples previously taken within each of the proposed stratum are listed in Table SOP 2.2. Depth was also investigated as a possible stratum and to determine the appropriate depth categories, variance was calculated in 3 m depth intervals within each habitat type. Data collected by BB and NPS from 2001-2010 was used to calculate mean abundance and standard deviation by region and strata for the optimization species (Table SOP 2.1). Mean standard deviation of abundance was graphed against potential strata to help visualize any patterns (Figure SOP 2.2).

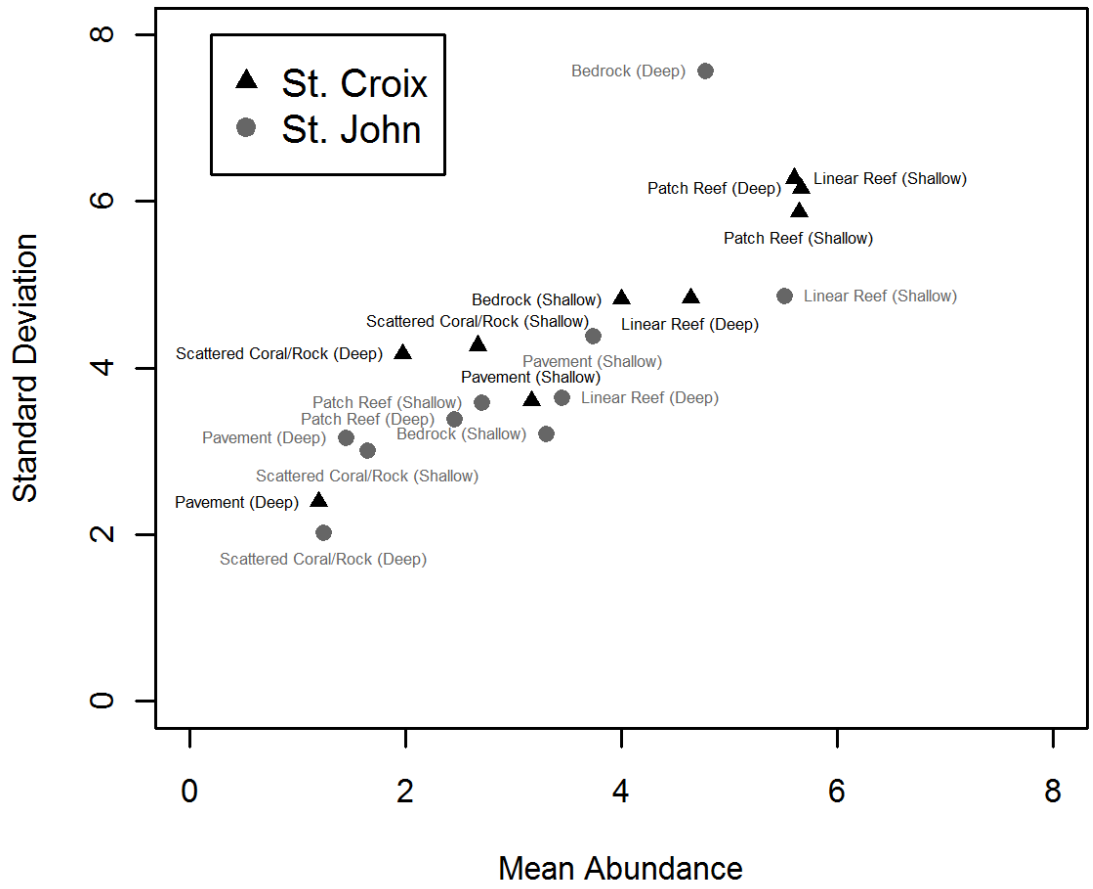

Figure SOP 2.1. Mean abundance and standard deviation of stoplight parrotfish in St. Croix and St. John, USVI (2001-2010) by habitat and depth strata.

Table SOP 2.2. Number of samples by habitat type, as defined by the composite habitat classification scheme (SOP 1), for St. Croix and St. John surveys from 2001-2010.

Habitat Type	St. Croix	St. John
Scattered Coral / Rock	186	79
Pavement	849	411
Bedrock	14	42
Patch Reef	259	109
Linear Reef	180	306

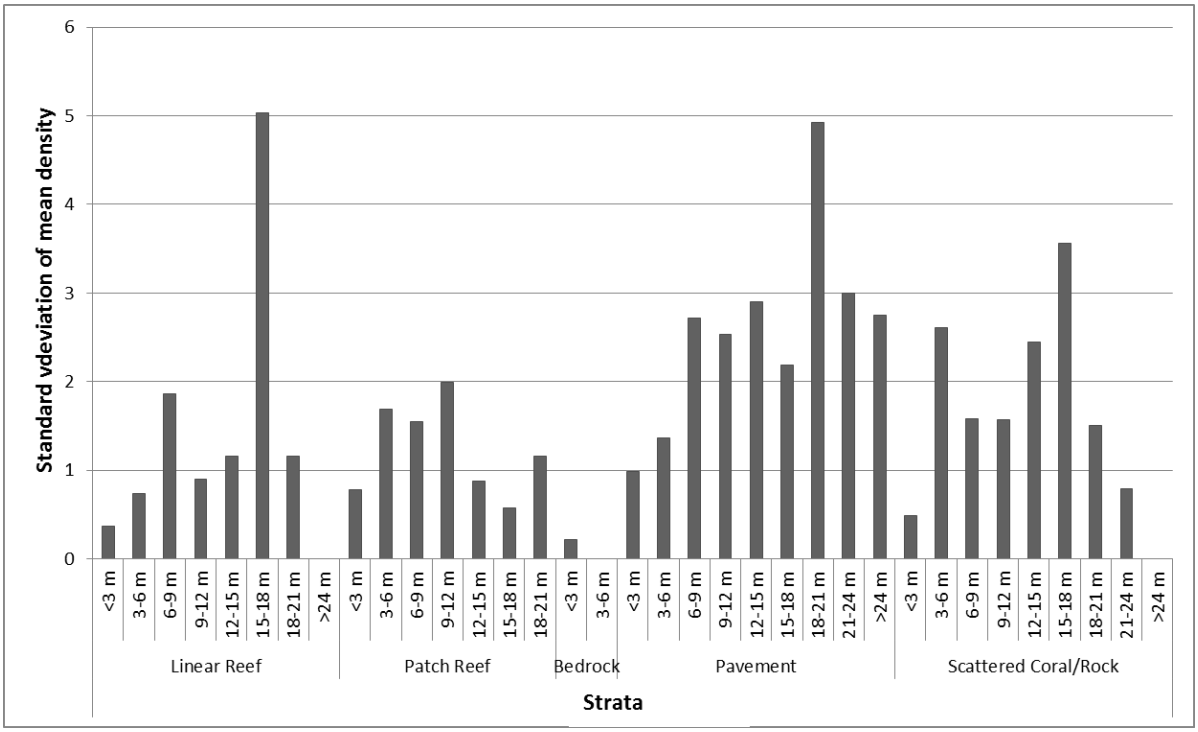

Figure SOP 2.2. The standard deviation of the mean abundance of Coney in St. Croix by habitat class and depth. Depth categories represent 3 m depth intervals starting with < 3 m.

Trends in standard deviation for optimization species by region were investigated and an overall habitat and depth classification scheme was chosen that was a compromise among species and regions. The stratification scheme included the 5 hard bottom classifications with two depth categories per habitat type, 0-11.9 m and 12- 30 m depth for a total of 10 combinations:

- Scattered Coral / Rock, Shallow
- Scattered Coral / Rock, Deep
- Pavement, Shallow
- Pavement, Deep
- Bedrock, Shallow
- Bedrock, Deep
- Patch Reef, Shallow
- Patch Reef, Deep

- Linear Reef, Shallow
- Linear Reef, Deep

This stratification scheme effectively partitions variance (see below) but it should be considered as the first attempt in an iterative process. Forthcoming stratification analysis should follow the steps as described below:

1) Create a list of species to use for survey optimization.

2) Select ecologically significant factors that are likely to divide variance of these species into homogeneous strata.

3) Use GIS, the master grid list and list of previous sampling locations to insure sufficient sampling has occurred in each stratum to calculate density and variance.

4) Calculate density and standard deviation for each proposed stratum to see if variance is partitioned more homogeneously than for the sample grid as a whole.

5) If new strata appear to improve the partitioning of variance for selected species, conduct a post stratification analysis as described in the next section.

Post stratification analysis

Explanation

It is important to compare stratification schemes to determine which choice would yield the most efficient survey design. A technique for making these comparisons is called a post stratification analysis. Data that was collected from previous surveys was used to estimate what variance might be given a certain stratification scheme. A particularly useful calculation in a post stratification analysis is the number of sample units (n*) (under an optimal allocation scheme) that are required to obtain a predetermine variance. The equations for calculating n* are as follows:

*Calculations for n**

$$n^* = \frac{\left(\sum_h w_h s_h\right)^2}{V\left(\overline{D}_{st}\right) + \frac{1}{N}\sum_h w_h s_h^2} \qquad \text{(SOP 2.1)}$$

To calculate n* the sample mean($\overline{D}_{st}$), sample variance of density in stratum h (s_h^2) and the standard deviation (s_h) need to be calculated for each strata (h) by species. n_h is the number of samples taken in each stratum (h).

$$\overline{D}_h = \frac{1}{n_h}\sum_j D_{hj} \qquad \text{(SOP 2. 2)}$$

$$s_h^2 = \frac{1}{n_h - 1}\sum_{j=1}^{n_h}\left(D_{hj} - \overline{D_h}\right)^2 \qquad \text{(SOP 2.3)}$$

$$s_h = \sqrt{s_h^2} \qquad \text{(SOP 2.4)}$$

The total survey mean$\left(\overline{D}_{st}\right)$ for each species can then be calculated using a stratum weighting factor (w_h). The total possible number of primary units in a stratum, N_h, is dependent on stratum area, so values for N_h are derived directly from GIS habitat maps.

$$w_h = \frac{N_h}{\sum_h N_h} \qquad \text{(SOP 2.5)}$$

And

$$\overline{D}_{st} = \sum_h \left(w_h \overline{D_h}\right) \qquad \text{(SOP 2.6)}$$

Domain wide estimates of the variance for density ($\mathrm{var}\left[\overline{D}_{st}\right]$) can also be calculated. Variance of mean density ($\mathrm{var}\left[\overline{D}_h\right]$) is first calculated.

$$\mathrm{var}\left[\overline{D}_h\right] = \left(1 - \frac{n_h}{N_h}\right)\frac{s_h^2}{n_h} \qquad \text{(SOP 2.7)}$$

Then

$$\mathrm{var}\left[\overline{D}_{st}\right] = \sum_h w_h^2\, \mathrm{var}\left[\overline{D}_h\right] \qquad \text{(SOP 2.8)}$$

The standard error for this estimate ($SE\left[\overline{D}_{st}\right]$) can be calculated.

$$SE\left[\overline{D}_{st}\right] = \sqrt{\mathrm{var}\left[\overline{D}_{st}\right]} \qquad \text{(SOP 2.9)}$$

The desired variance (*V*) for domain-wide density can be calculated with mean fish density under a stratified design $\left(\overline{D}_{st}\right)$ and a targeted *CV* value.

$$V = \left(CV\left[\overline{D}_{st}\right] \bullet \overline{D}_{st}\right)^2 \qquad \text{(SOP 2.10)}$$

The *CV* is the standard error (*SE*) as expressed as a proportion of the mean ($\overline{D}_{st}$):

$$CV\left[\overline{D}_{st}\right] = \frac{SE\left[\overline{D}_{st}\right]}{\overline{D}_{st}} \qquad \text{(SOP 2.11)}$$

Initial Comparisons Between Stratification Schemes

To evaluate stratification schemes, n* values for CVs of 15% and 20% were calculated for four different stratification schemes for each optimization species: 1) simple random; 2) depth only stratification (0-6 m, 6- 18m, and 18m +); 3) habitat only (5 hardbottom classifications) and; 4) a habitat and depth combination (as described above). Data from 2007-2010 surveys was used for this analysis and the sample population was defined by the current sampling universes (St. Croix and St. John). These results were used to compare the various stratification schemes (Tables SOP 2.3 and SOP 2.4).

The 95% confidence interval for a population metric is approximately two standard errors above and below the mean. Therefore, the ability to detect a significant difference (95% confidence) translates to approximately ±2 times the CV. If mean fish density in a sub-region has a CV of 20%, then a 40% change in density can be detected. CV values of 15% and 20% were used for the comparison but target CV values will vary depending on management needs and available funding.

Juvenile French grunt (< 10cm) are found in clumped aggregations associated with micro habitat that is likely not picked up in our habitat classification scheme (Shulman 1985). Since the variance structure of these individuals is likely different than adults, French grunts were analyzed as a combined, juvenile (<10 cm) and adult (≥ 10 cm) populations.

Stratification schemes were evaluated by comparing n* values for each species over a range of CVs. The goal was to find a stratification that generally reduces n* for multiple species compared to a random survey and provides the lowest CV compared to other stratification schemes.

The combined "habitat and depth" stratification scheme successfully partitioned variance for optimization species and is an improvement over a simple random design as well as a depth or habitat only stratification. However, improvements varied by species. Foureye butterflyfish appear to be uniformly distributed across depths and habitats so there is little benefit with stratification. Threespot damselfish variance in St. Croix is extremely high and it is unlikely that sampling at realistic levels would allow for precise population metrics to be determined. Juvenile French grunt variance is extremely high and it will be difficult to measure changes in population metrics with expected levels of survey effort.

Future post-stratification analysis

A large assumption in this stratification scheme is that the variance structure calculated from a relatively small area of St. Croix and St. John represents the entire USVI. There is an abundance of literature documenting effects of habitat and depth on reef fish distribution and this relationship should remain significant throughout the region (Luckhurst and Luckhurst 1978, Friedlander and Parrish 1998, Chapman and Kramer 1999). However, it is recommended that the stratification scheme be re-evaluated with new data collected from a larger area. In addition to the collection of new fish data, it is important to re-evaluate stratification as improvements in habitat maps are made. Complexity has been shown to directly affect fish abundance and the current classification scheme may not properly capture that characteristic. After stratification has been reviewed with updated data, a post stratification analysis should be conducted to determine the most appropriate stratification scheme for survey efficiency.

Table SOP 2.3. Number of samples (n*) for a given CV value for optimization species by region and stratification scheme. Average density as calculated by a given stratification scheme is provided.

Species	Region	Stratification	Avg Density	n* 15	n* 20
Blue tang	St. Croix	Habitat & Depth	4.63	126	71
Blue tang	St. Croix	Habitat	6.30	179	101
Blue tang	St. Croix	Depth	3.88	199	112
Blue tang	St. Croix	Random	5.60	237	133
Blue tang	St. John	Habitat & Depth	4.13	77	43
Blue tang	St. John	Habitat	1.79	100	56
Blue tang	St. John	Depth	4.06	86	48
Blue tang	St. John	Random	4.88	162	91
Queen triggerfish	St. Croix	Habitat & Depth	0.69	112	63
Queen triggerfish	St. Croix	Habitat	0.42	212	119
Queen triggerfish	St. Croix	Depth	0.54	120	67
Queen triggerfish	St. Croix	Random	0.28	351	197
Queen triggerfish	St. John	Habitat & Depth	0.32	93	52
Queen triggerfish	St. John	Habitat	0.13	168	95
Queen triggerfish	St. John	Depth	0.41	133	75
Queen triggerfish	St. John	Random	0.28	304	171
Coney	St. Croix	Habitat & Depth	2.13	51	29
Coney	St. Croix	Habitat	1.89	62	35
Coney	St. Croix	Depth	1.54	90	50
Coney	St. Croix	Random	1.22	130	73
Coney	St. John	Habitat & Depth	1.04	53	30
Coney	St. John	Habitat	0.41	115	65
Coney	St. John	Depth	1.25	46	26
Coney	St. John	Random	0.98	179	101
Foureye buterflyfish	St. Croix	Habitat & Depth	0.52	185	104
Foureye buterflyfish	St. Croix	Habitat	0.45	219	123
Foureye buterflyfish	St. Croix	Depth	0.37	277	156
Foureye buterflyfish	St. Croix	Random	0.41	252	142
Foureye buterflyfish	St. John	Habitat & Depth	1.18	97	55
Foureye buterflyfish	St. John	Habitat	0.50	89	50
Foureye buterflyfish	St. John	Depth	1.47	77	43
Foureye buterflyfish	St. John	Random	1.25	94	53
Red hind	St. Croix	Habitat & Depth	0.34	203	114
Red hind	St. Croix	Habitat	0.30	214	121
Red hind	St. Croix	Depth	0.32	223	126
Red hind	St. Croix	Random	0.22	316	178
Red hind	St. John	Habitat & Depth	0.58	106	60
Red hind	St. John	Habitat	0.22	134	75
Red hind	St. John	Depth	0.71	112	63
Red hind	St. John	Random	0.54	149	84

Table SOP 2.3. con't.

Species	Region	Stratification	Avg Density	n* 15	n* 20
Stoplight parrotfish	St. Croix	Habitat & Depth	1.19	110	62
Stoplight parrotfish	St. Croix	Habitat	1.73	147	83
Stoplight parrotfish	St. Croix	Depth	1.03	195	110
Stoplight parrotfish	St. Croix	Random	1.70	223	126
Stoplight parrotfish	St. John	Habitat & Depth	2.15	86	48
Stoplight parrotfish	St. John	Habitat	0.97	99	55
Stoplight parrotfish	St. John	Depth	2.04	113	64
Stoplight parrotfish	St. John	Random	2.74	92	52
Threespot damselfish	St. Croix	Habitat & Depth	0.67	1289	726
Threespot damselfish	St. Croix	Habitat	0.56	1668	939
Threespot damselfish	St. Croix	Depth	0.48	1376	774
Threespot damselfish	St. Croix	Random	0.56	1382	778
Threespot damselfish	St. John	Habitat & Depth	2.53	81	46
Threespot damselfish	St. John	Habitat	0.88	219	123
Threespot damselfish	St. John	Depth	2.28	189	106
Threespot damselfish	St. John	Random	2.49	268	151
Yellowtail snapper	StCroix	Habitat & Depth	0.48	425	239
Yellowtail snapper	StCroix	Habitat	0.49	459	258
Yellowtail snapper	StCroix	Depth	0.38	533	300
Yellowtail snapper	StCroix	Random	0.52	404	227
Yellowtail snapper	StJohn	Habitat & Depth	0.94	181	102
Yellowtail snapper	StJohn	Habitat	0.41	154	87
Yellowtail snapper	StJohn	Depth	1.01	258	145
Yellowtail snapper	StJohn	Random	1.18	191	107

Table SOP 2.4. Number of samples (n*) for a given CV value for French grunt by region and stratification scheme. Values were calculated for all French grunt combined, juveniles only (<10 cm length) and adults (>10 cm). Average density as calculated by a given stratification scheme is provided.

Species	Region	Stratification	Avg Density	n* 15	n* 20
French grunt	St. Croix	Habitat & Depth	1.78	482	272
French grunt	St. Croix	Habitat	1.69	538	304
French grunt	St. Croix	Depth	1.62	1192	672
French grunt	St. Croix	Random	2.57	4255	2397
French grunt	St. John	Habitat & Depth	1.17	228	128
French grunt	St. John	Habitat	0.52	339	191
French grunt	St. John	Depth	1.17	382	215
French grunt	St. John	Random	1.45	561	316
French gunt (juvenile)	St. Croix	Habitat & Depth	0.74	1653	945
French gunt (juvenile)	St. Croix	Habitat	0.76	1655	946
French gunt (juvenile)	St. Croix	Depth	0.91	2852	1614
French gunt (juvenile)	St. Croix	Random	1.71	9430	5321
French gunt (juvenile)	St. John	Habitat & Depth	0.30	628	355
French gunt (juvenile)	St. John	Habitat	0.16	1096	620
French gunt (juvenile)	St. John	Depth	0.21	2286	1299
French gunt (juvenile)	St. John	Random	0.47	4333	2443
French grunt (adult)	St. Croix	Habitat & Depth	1.04	229	129
French grunt (adult)	St. Croix	Habitat	0.94	247	139
French grunt (adult)	St. Croix	Depth	0.71	310	175
French grunt (adult)	St. Croix	Random	0.85	353	199
French grunt (adult)	St. John	Habitat & Depth	0.86	199	112
French grunt (adult)	St. John	Habitat	0.36	247	139
French grunt (adult)	St. John	Depth	0.96	263	148
French grunt (adult)	St. John	Random	0.98	248	139

Revision History Log

Version #	Date	Revised by	Changes	Justification

Literature Cited

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Standard Operating Procedure 3 – Sample Allocation

Version 1.0

Purpose

Describes background and rationale for using a stratified random approach based upon data collected previously within the United States Virgin Islands (USVI) and describes procedures for optimal sample allocation.

Introduction

This SOP outlines a single-stage stratified random sampling allocation scheme designed to collect reef fish data on a scale that supports population level estimates for the entire USVI but also allows for rigorous comparisons inside and outside of management zones. The single-stage stratified random design increases the efficiency of sampling by effectively stratifying the survey domain based on variables that influence the variability of fish population densities. This sampling scheme in our case includes the establishment of two broad regions with independent management zones within each and then stratifying the sample domain within each region and management zone based on habitat and depth, as described in SOP 2. A Neyman (or optimal) allocation is then followed, in which the number of units to be sampled are allocated according to stratum size and stratum standard deviation of specific fish species densities to achieve the greatest overall precision possible. This scheme increases the efficiency of sampling by allocating greater sampling effort to those strata that are larger and more variable while smaller, less variable strata receive less effort.

Sample Regions

The two regions and their independent management zones used in this protocol are: 1) St. John and St. Thomas and 2) St. Croix. Within the St. John and St. Thomas region, all hardbottom habitats within Virgin Islands National Park (VIIS), Virgin Islands Coral Reef National Monument (VICR) and all hardbottom habitats outside of these management zones are targeted for sampling (Figure SOP 3.1). In the St. Croix region, targeted sampling zones include hardbottom habitats within Buck Island Reef National Monument (BUIS), Salt River Historic Park and Ecological Reserve (SARI) and hardbottom habitat outside these management zones (Figure SOP 3.1). The amount and type of hardbottom habitat in each region and management zone as calculated from the habitat classification scheme described in SOP 1 for each stratum is shown in Table SOP 3.1. The East End Marine Park (EEMP) is also a management zone of concern but was not included in this analysis.

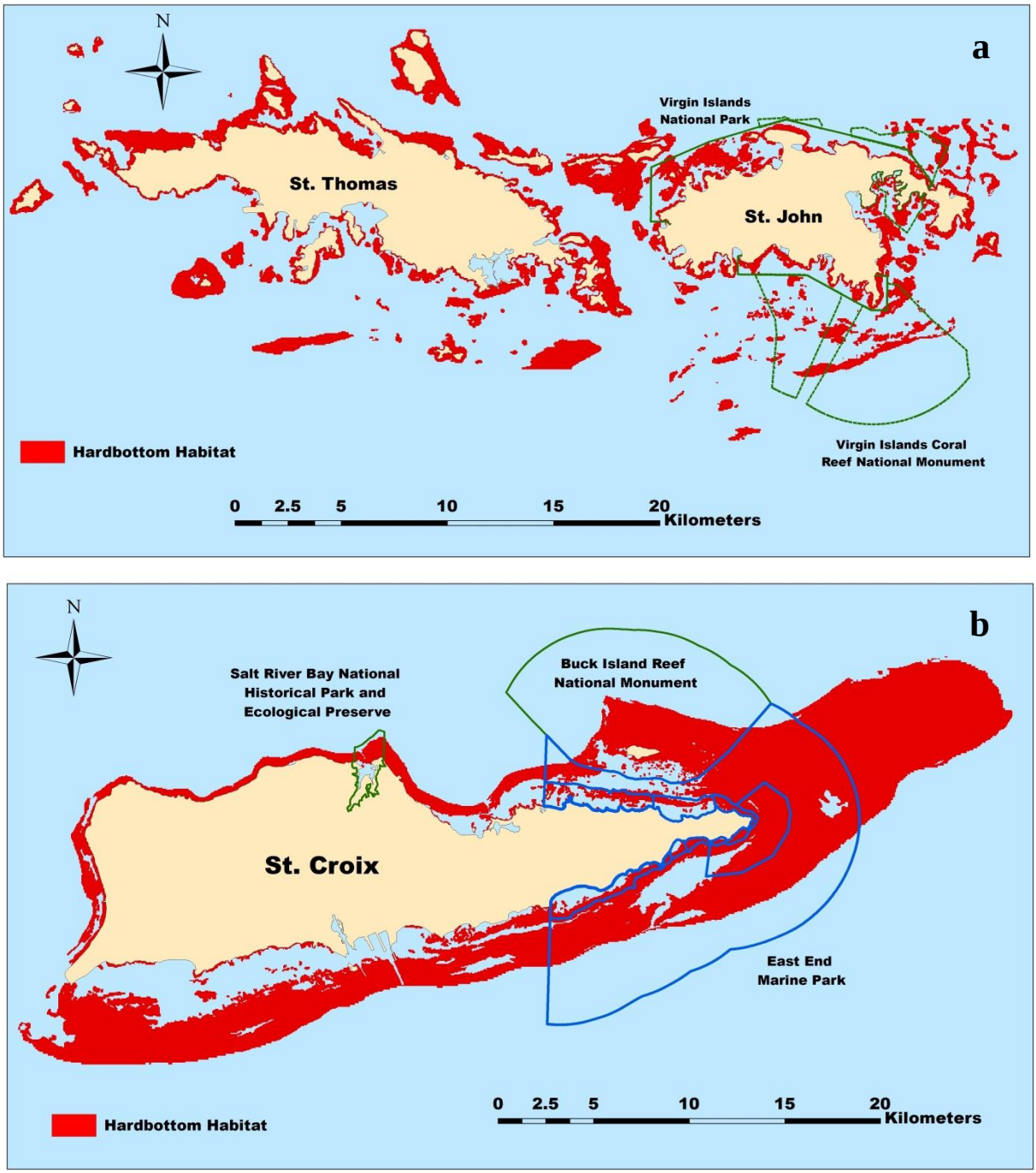


Figure SOP 3.1 USVI sampling regions (St. Thomas and St. John (a) and St. Croix (b)) and management zones (VICR, VIIS, BUIS, SARI and EEMP). Red fill indicates mapped hardbottom habitat.

Table SOP 3.1. Stratum area (km^2) and total number of grids within each region and management zone.

Stratum Classification	BUIS	SARI	St. Croix	VIIS	VICR	St. Thomas & St. John
Deep, Scattered coral/ rock	0.55	0.01	15.96	0.05	1.14	5.93
Deep, Pavement	4.87	0.08	142.18	2.23	2.45	25.58
Deep, Bedrock	0.00	0.00	0.00	0.14	0.01	2.35
Deep, Patch reef	1.68	0.00	3.29	0.46	1.43	4.99
Deep, Linear reef	0.37	0.04	4.15	0.80	0.54	11.20
Shallow, Scattered coral/ rock	0.93	0.01	3.69	0.66	0.27	3.50
Shallow, Pavement	8.01	0.94	48.63	2.58	1.07	17.20
Shallow, Bedrock	0.02	0.07	2.57	0.49	0.07	5.48
Shallow, Patch reef	3.06	0.01	5.50	0.44	0.19	1.68
Shallow, Linear reef	0.59	0.22	10.17	1.78	0.68	7.92
Total Area (km^2)	**20.06**	**1.38**	**236.13**	**9.61**	**7.84**	**85.81**
Total # of Hard bottom Grids	**8024**	**552**	**94452**	**3843**	**3136**	**34324**

Stratified Design

To verify that the stratified random sample designed established within this protocol will result in improved population estimates, the precision of estimates were compared under simple random and stratified random designs. A useful way to evaluate the effects of sampling effort on the precision of estimates obtained is to construct separate n* curves for each sampling zone. The formulas for calculating n* are found in SOP 2. Estimates of n* for each national park (BUIS, VIIS and VICR) were calculated for four species with a simple random sample design and the stratified random design described in SOP 2 (Figures SOP 3.2 & 3.3). Data to construct these figures came from sampling effort within each zone from 2007 to 2010. CV values from previous surveys (2002-2010) are included as a reference. The benefits gained from the stratified sample design are clear in these figures as are the various levels of sampling required to reach a target level of precision within each management zone.

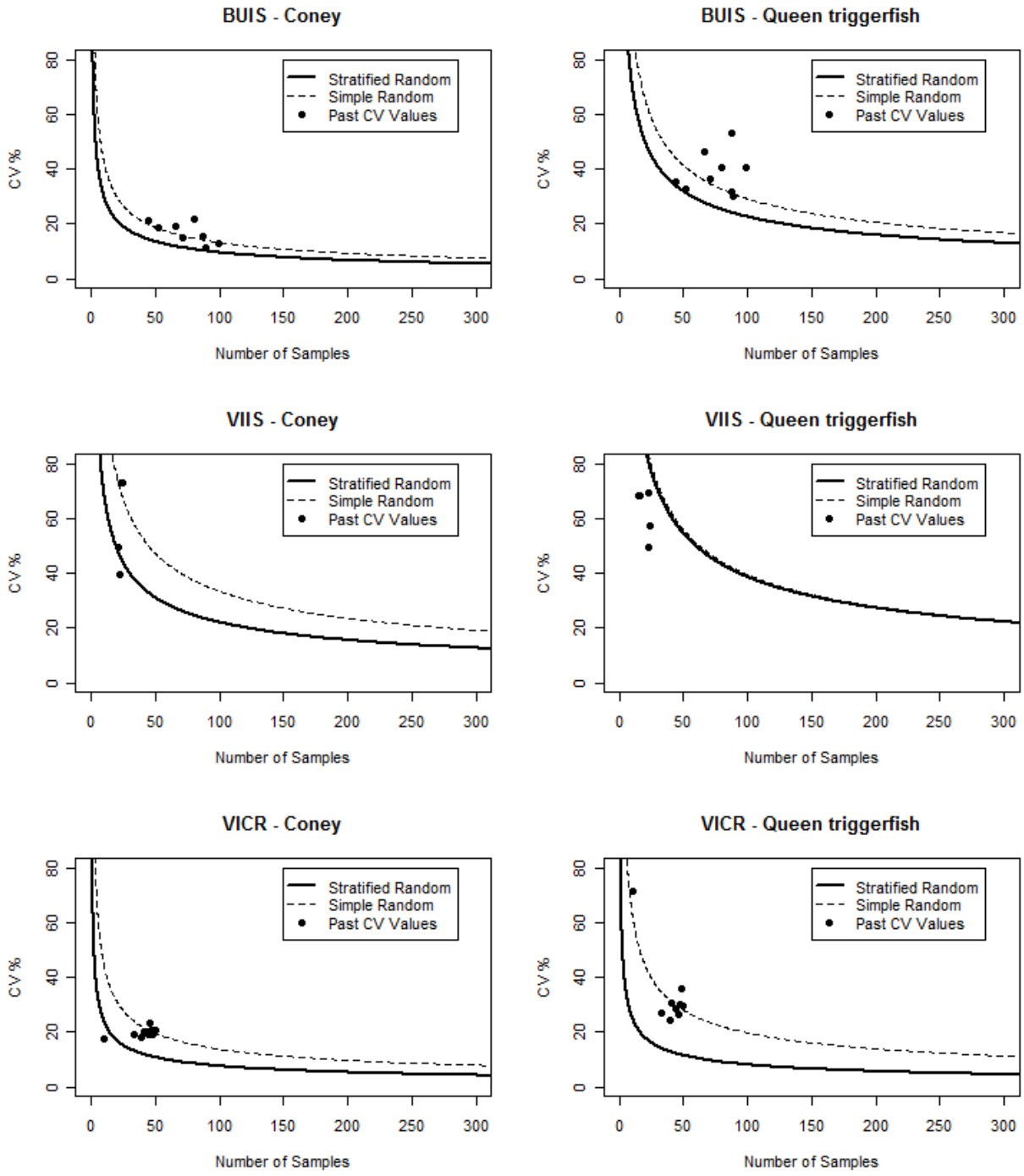


Figure SOP 3.2. Coney and queen triggerfish n* curves for BUIS, VIIS and VICR. Stratified and simple random survey designs are shown along with CV values from surveys from 2002-2010.

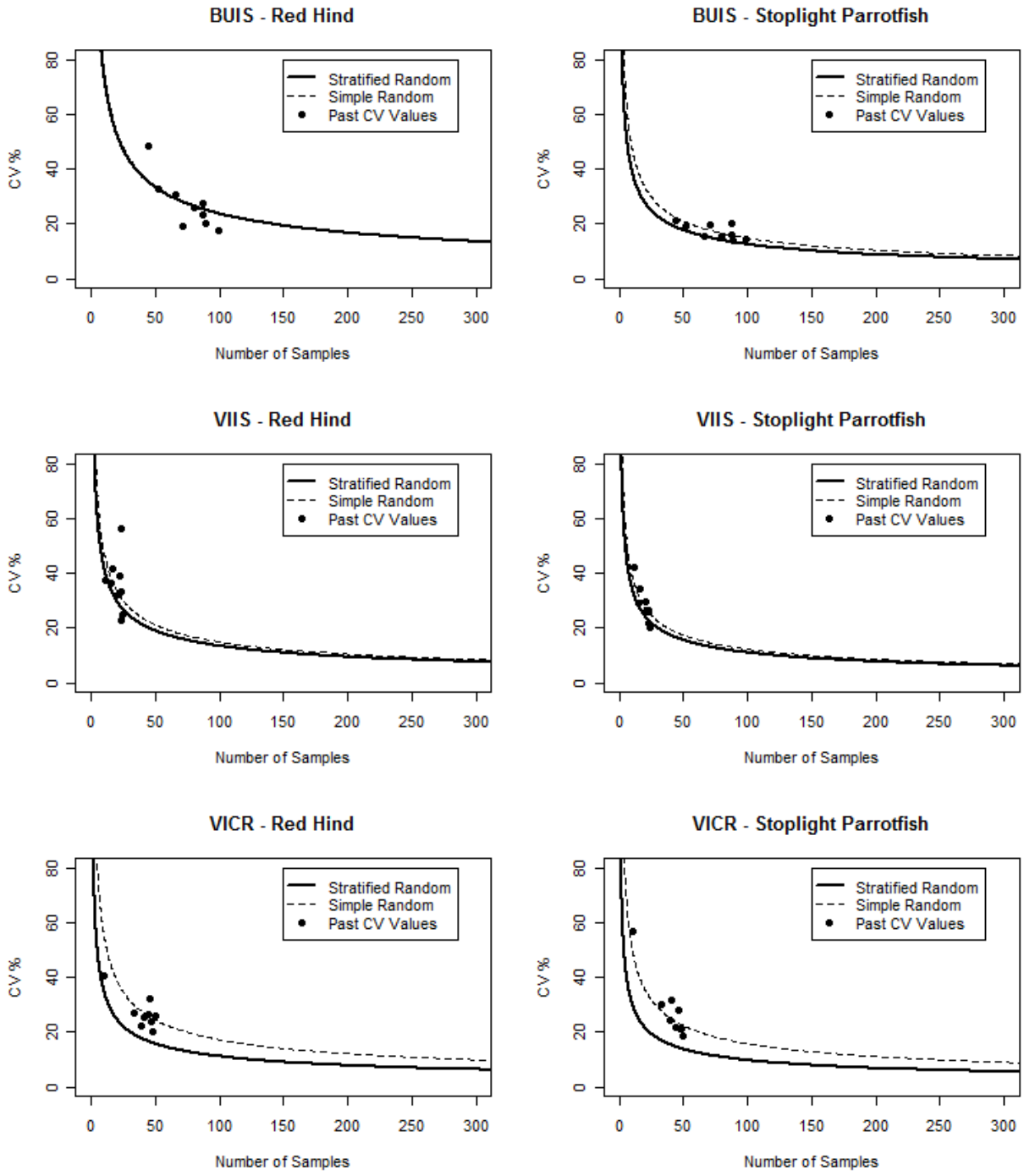


Figure SOP 3.3. Red hind and stoplight parrotfish n* curves for BUIS, VIIS and VICR. Stratified and simple random survey designs are shown along with CV values from surveys from 2002-2010.

Prior to each survey season, the best distribution of sampling effort must be recalculated separately for each region as well as for inside and outside of each management zone using updated data on CV's within each habitat stratum and management zone as well as the overall amount of participating agency effort available for that year. A disadvantage in having multiple sample zones within a survey domain is the increase in sampling effort required to reach a target level of precision for each region or management zone of interest. The benefits include a clear understanding of effort required to meet management needs at different spatial scales, a design that can easily be scaled up or down with available funding, and the ability to make statistically robust comparisons among regions and zones. The overall level of effort (total number of sites sampled) will likely be determined by budgetary restraints but it is important to investigate the level of precision achieved under a range of sampling efforts prior to sample allocation.

Sample Allocation

Sample allocation for the USVI region wide survey under this design requires two steps. The first step is deciding on the number of samples required for each region and management zone to reach a desired precisions and the second step is determining the optimal allocation of sampling among stratum.

Decisions on regional levels of effort (total number of samples) may be pre- determined by budget and personnel constraints but the best distribution of that effort inside and outside of management zones can be established by analysis. A hypothetical sampling allocation among regions and management zones is used here as an example. Average annual sampling effort from the last ten years and fish data from 2007-2010 was used to determine expected CV levels by management zone and region. The equation for calculating expected CV values for each species was:

$$CV\left[\overline{D}_{st}\right] = \frac{SE\left[\overline{D}_{st}\right]}{\overline{D}_{st}} \qquad \text{(SOP 2.11)}$$

The variable names used for this equation can be found in Appendix E. CV values were estimated based on an optimal allocation of sampling effort among stratum within each region. A Neyman allocation scheme was used in which allocation is based on the proportional area each stratum and the variance structure of fish density within that stratum. Average annual effort from the last ten years was divided among management areas with the hope of gaining equal precision both inside and outside of management zones.

The results based on average annual sample effort with the stratified random sampling design and optimal allocation suggests that CV values for most species used for optimization could be between 10 and 30 percent for every management zone (Table 3.2). Regional CV values could be even lower with most between 10 and 20 percent. The allocation of sample units among regions and management zones is flexible and should be reevaluated prior to each survey season. Given a total number of primary units within each region and management zone to be sampled, the allocation among stratum can be made. The following formula is used to determine the optimal number of primary units to sample within each stratum (variable names in Appendix E).

$$n^*_h = n^* \bullet \left(\frac{w_h s_h}{\sum_h w_h s_h} \right) \qquad \text{(SOP 3.2)}$$

These calculations are made for multiple levels of desired variance for each species. They are then compared among species and also with the total capacity of the agencies cooperating to conduct sampling. A final target n* is chosen that will accomplish the best possible balance between achievable precision for the most number of exploited species and agency capabilities. It is possible that strata with low proportions of total habitat and/or low variance may have no samples allocated by the optimal distribution formula under a given effort. ***In these circumstances it is important that a minimum of three samples are allocated to that stratum to allow for variance calculations.***

Site Selection

Once the total number of samples to be collected within each region, management zone and stratum classification are determined, individual sites are selected. The grid cells (i) to be sampled per stratum are randomly selected from the complete list of (N_h) cells within a stratum using a discrete uniform probability distribution, which assigns equal selection probability to each grid cell (Law 2007). The GPS coordinates for the center of each grid cell to be sampled are then generated. Currently, a single 100 m^2 fish transect comprises the sample unit but in the future it may be beneficial to have replicate transects within each grid cell sampled. A random directional heading is chosen for each sample transect. Field methods are further described in SOP 4 – "Field Data Collection: Belt Transect Method".

Table SOP 3.2. Predicted CV values for optimization species by management zone and region using past level of survey effort with new stratified random sampling effort.

	St. Croix			St. Thomas & St. John			
	BUIS	Outside	Region Wide	VIIS	VICR	Outside	Region Wide
Blue tang	12.9	15.8	12.1	19.2	16.8	15.8	9.8
Queen triggerfish	25.3	14.4	11.3	21.7	19.1	18.5	11.3
Coney	10.7	9.6	7.5	15.9	14.8	13.6	8.4
Foureye butterflyfish	18.1	18.9	14.6	20.8	22.0	17.9	11.2
Redhind	26.5	19.5	15.2	22.1	20.6	20.5	12.4
French grunt (>10cm)	20.5	21.3	16.3	29.8	32.3	29.8	18.0
Yellowtail snapper	31.3	28.3	21.8	29.3	31.5	31.7	18.8
Stoplight parrotfish	14.0	15.3	11.5	18.8	21.6	20.0	12.0
Threespot damselfish	44.7	51.8	39.2	24.7	13.1	22.7	12.9
# Samples	80	120	200	50	50	60	160

Determining Sample Allocation for Each Survey

Prior to each survey, the chief analyst needs to meet with representatives from each collaborating agency to determine the number of grid cells that will be sampled. To aide in this discussion, the analyst should provide n* values for CV's of 15% and 20% based on the current stratification

scheme and data on optimization species from the latest 4 surveys. Graphs depicting CV values over a range of sampling effort (n* curves) (e.g., SOP 3.2-5) can also be useful in aiding with decisions on effort for each region and management zone. Budget and needs for target levels of precision can be used to determine appropriate sampling effort and the overall number of grid cells to be sampled. It is important to note that the estimated number of sites necessary to achieve a desired level of precision can fluctuate between surveys and that allocation should be revisited prior to each survey. A balance of the CV values for each species inside and outside management zones should be strived for during allocation since comparison are made at the lowest level of precision between the two zones. Since SARI is so small, instead of having an independent allocation determined by CV levels, a minimum of 2 surveys per stratum (16 total) should be forced into the park out of the overall allocation.

Once a total number of samples for the survey have been decided, the next step is to determine how those samples will be allocated among stratum. Equation SOP 3.2 should be used to optimally allocate sampling among strata. To determine the proportion of the total number of samples that will be conducted in each stratum, the weighted standard deviation for that stratum is divided by the sum of all weighted standard deviations and then multiplied by the total number of samples to be collected. This procedure is done for all species used for optimization. Since each species has a different variance structure as it relates to strata, the allocation will be different among species. A table including optimal allocation values for all species by stratum can be constructed to aide in the decision process by the chief analyst. Table SOP 3.3 is an example for VIIS using data from 2007-2010. Effort is shown as a percentage of total effort for that management zone. The percentage of each stratum in the management zone is also shown as a reference. A proportional allocation of effort would follow these values and comparing individual optimal allocation to proportional allows the analyst to see which strata require over- or under-sampling. A decision on allocation between strata has to be a compromise between the optimal allocation for each species and an overall allocation.

A table with the number of sites allocated to each strata by zone (management or outside) is then created. NOAA's National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment, Biogeography Branch's ArcGIS site selection tool can then be used to randomly select the grid cells to be sampled. The chief analyst should produce and distribute the list of randomly chosen survey sites for within and outside of each management zone for each region two weeks prior to the survey using the optimal allocation method. Each collaborating agency will then indicate which sites they will be responsible for surveying.

Revision History Log

Version #	Date	Revised by	Changes	Justification

Literature Cited

Law, A. M. 2007. Simulation Modeling and Analysis. 4th edition McGraw-Hill, New York.

Table SOP 3.3. Optimal allocation of sampling effort among strata as a percentage of total samples in VIIS for optimization species.

Stratum	Number of Grids	% of Habitat	Blue tang	Queen triggerfish	Coney	Foureye butterflyfish	Red hind	French grunt (>10cm)	Yellowtail snapper	Stoplight parrotfish	Threespot damselfish
Pavement, Deep	891	23.6%	22.2%	57.4%	20.1%	25.8%	36.8%	50.0%	15.6%	22.7%	10.7%
Patch reef, Deep	185	4.9%	0.9%	2.5%	4.1%	4.2%	2.0%	2.5%	3.2%	4.4%	2.2%
Linear reef, Deep	318	8.4%	1.6%	4.3%	7.0%	7.3%	3.4%	4.7%	31.0%	7.6%	3.8%
Scattered Coral/ Rock, Shallow	264	7.0%	1.3%	3.5%	5.8%	6.0%	2.8%	3.5%	4.6%	6.3%	3.2%
Pavement, Shallow	1030	27.3%	21.8%	15.4%	22.5%	29.8%	40.3%	13.8%	18.0%	33.2%	23.0%
Bedrock, Shallow	197	5.2%	4.8%	5.1%	21.1%	6.5%	2.1%	5.0%	4.2%	4.7%	8.8%
Patch reef, Shallow	175	4.6%	0.9%	2.3%	3.8%	4.0%	1.9%	2.3%	3.1%	4.2%	2.1%
Linear reef, Shallow	711	18.9%	46.7%	9.5%	15.6%	16.3%	10.8%	18.2%	20.3%	17.0%	46.3%

Standard Operating Procedure 4 – Field Data Collection: Belt Transect Method

Version 1.0

Purpose
Describe the steps for using the belt transect method for collecting fish and habitat data.

Equipment
The sampling team will consist of two divers. Each diver will be equipped with a data sheet and underwater slate, pencil(s) and dive watch. The dive team will also be equipped with a reel and line which is attached to a surface buoy/dive flag equipped with a GPS unit. The diver who will be making fish observations (designated the "fish diver") will take a 25 m tape measure and the benthic habitat diver will take a 1x1 m quadrat, 6 m rugosity chain and underwater camera.

Sequence of Events in the Field
Each day, sampling teams should attempt to visit sites within the same vicinity to maximize sampling efficiency. Teams should strive to sample sites across multiple habitat types each day to avoid temporal biases in fish-habitat characterizations that could arise by sampling multiple sites within 1-2 habitat types on a given day. The number of dives per day can be increased by scheduling deeper sites first and then moving to shallower water.

If several boats are deployed, it is important to have a brief meeting in the morning to ensure that no site overlap occurs and that each group knows where the other team or teams will be operating. Once in the field, the boat captain navigates to the previously selected sites to be sampled using a boat or handheld GPS unit.

Details of Observations Made in the Field

Field/ Boat Log
Field personnel not diving at a site should fill out the field/boat log (Appendix B).

1) Dive of day – Cumulative site number (e.g., 1, 2, 3…). This number will be the same for the fish and habitat data recorded at each site.

2) Site ID – This is a code listed on the sample site list.

3) Estimated time – Estimated time of beginning of dive.

4) Diver team – Divers' initials.

5) Latitude and longitude in degrees and minutes – Position of surface vessel when divers enter the water (dd° mm.mmm').

6) GPS unit – GPS Unit ID used by the team.

7) Habitat type – The diver's consensus of the habitat type that was sampled; habitat types are defined in Appendix A.

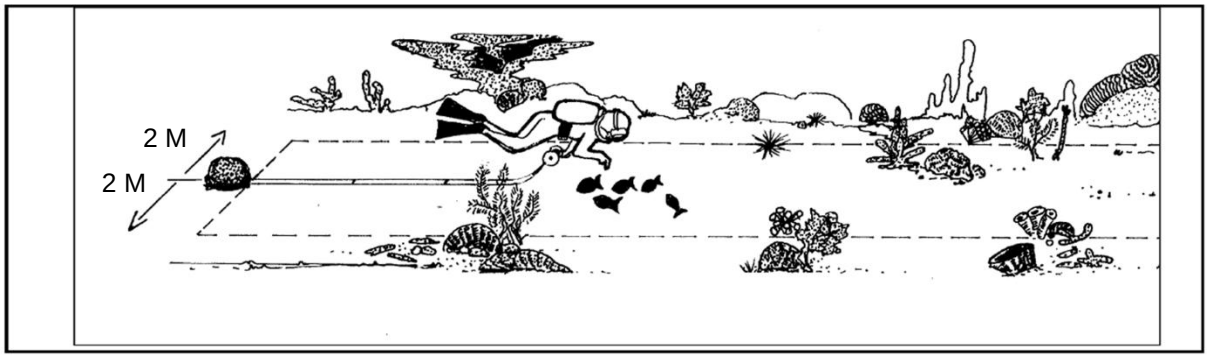
8) Comments – Any additional information judged to be important by the surface data collector (e.g., notation of a specific camera used by a diver).

Fish Diver

On-site, divers are deployed at the center coordinates of each grid cell and maintain contact with each other throughout the entire census. One diver (the designated fish diver) is responsible for collecting data on the fish communities utilizing the belt-transect visual census technique over an area of 100 m^2 (25 m length x 4 m width). The fish diver obtains a compass heading for the transect prior to entering the water from a pre-printed random number sheet with values from 0 to 360 and records the compass bearing (0-360°) on the data sheet. Visibility at each site must be sufficient to allow for identification of fish at a minimum of 2 m away. During descent both divers should scan the bottom habitat to determine if the site has been correctly characterized. If no hardbottom habitat is observed, then divers should return to the boat and move to an alternative site. If the hardbottom present is not the same as on the maps, the survey should continue but a note should be made of the differences on the datasheet. In a situation where the randomly chosen heading takes the diver directly away from hardbottom habitat the diver should adjust their heading clockwise until the transect covers appropriate habitat. Once reasonable visibility is ascertained as well as direction of travel, the fish diver attaches a tape measure to the substrate and allows it to roll out for 25 m while collecting fish data (Figure SOP 4.1).

The transect should take 15 minutes regardless of habitat type or number of fish present. This allows more mobile species the opportunity to swim through the transect, and standardizes the samples collected to allow for comparisons. No attempt to avoid structural features within a habitat such as a sand patch or an anchor should be made as these features affect fish communities and are "real" features of the habitats. The only instance where the transect should deviate from the designated path is to stay above the 30 m maximum depth limit.

Although the habitat should not be altered in any manner by lifting or moving structure, the observer should record fish seen in holes, under ledges and in the water column. To identify, enumerate, or locate new individuals, divers may move off the centerline of the transect as long as they stay within the 4 m transect width and do not look back along area already covered. The diver is allowed to look forward toward the end of the transect for the distance remaining (i.e., if the diver is at 15 m, they can look 10 m distant, but if they are at 23 m, they can only look 2 m ahead to record fish).



Belt Transect Census

Figure SOP 4.1. Conceptual diagram of belt transect survey (from Rogers et al. 1994).

The following data is collected (Field Forms found in Appendix B):

1) Logistic information – Diver name, dive buddy, date, time of survey, site code, transect bearing.

2) Taxa presence – As the tape roles out at a relatively constant speed, the diver records all fish species to the lowest taxonomic level possible that come within 2 m of either side of the transect. To decrease the total time spent writing, four letter codes are used that consist of the first two letters of the genus name followed by the first two letters of the species name. In the rare case that two species have the same four-letter code, letters are added to the species name until a difference occurs. If the fish can only be identified to the family or genus level then this is all that is recorded. If the fish cannot be identified to the family level then no entry is necessary.

3) Abundance and length – Abundance and length data are collected individually for all species observed. For fish less than 35 cm in fork length, abundance values are recorded in pre-established 5 cm length class segments. Individual fork length measurements to the nearest cm are made for all fish greater than 35 cm.

4) Photos – Individuals too difficult to identify or unique in some manner may be photographed for later clarification.

Habitat Diver

The habitat diver follows the fish diver along the belt transect and records data on small-scale benthic habitat composition and structure. The habitat diver places a 1 m^2 quadrat divided into 100 (10 x 10 cm) smaller squares (1 square equals 1 percent cover) at 5 separate positions. Each position is selected from a random number table before entering the water such that there is one random point within every 5 m interval along the transect. Percent cover is obtained as if looking at the quadrat in a two dimensional plane (i.e., a photograph) vs. three dimensions where percent cover could add up to greater than 100%.

The following data is collected (Field Forms found in Appendix B):

1) Logistic information – Diver name, dive buddy, date, time of survey, site code and location(m) at which each quadrat is placed.

2) Habitat classification – A general habitat classification of the site is recorded as either linear reef, patch reef, colonized pavement, colonized bedrock or scattered coral rock and sand. These are the habitat types used for stratification and a description of these classifications is found in Appendix A. The habitat diver records this information but he/she should consult with the fish diver.

3) Transect depth profile – The depth at each quadrat position. Depth is measured with a digital depth gauge to the nearest 1 ft.

4) Abiotic footprint – Defined as the percent cover (to the nearest 1 percent) of sand, rubble, hard bottom, and fine sediments within a 1 m^2 quadrat. Rubble refers to rocks and coral fragments that are moveable; immovable rocks are considered hard bottom. The percent cover given as a part of the abiotic footprint should total 100 percent. In a seagrass area for example, despite the fact that seagrass may provide 50 percent cover the underlying substrate

is 100 percent sand so this is what is recorded. To estimate percent cover, the habitat diver first positions the quadrat at the chosen meter mark along the transect tape. If the meter mark is an odd number, then the quadrat is placed on left side of the tape; if even, it is placed on the right. Next, the habitat diver lays the quadrat along the substrate (regardless of the slope) and estimates percent cover based on a two-dimensional (planar) view (e.g., if bottom is sloping, the quadrat is not held horizontally). Also, the diver should try to use the same planar view for all estimates of percent cover. The habitat diver then estimates, for each quadrat, the height (in centimeters) of the hardbottom from the substrate to get a sense of bottom relief. Note: Height is collected for all hardbottom substrates, excluding rubble; height is not collected for softbottom substrate.

5) Biotic footprint – Defined as the percent cover (to the nearest 0.1 percent) of algae, seagrass, live corals, sponges, gorgonians, and other biota (tunicates, anemones, zooanthids, and hydroids) within a 1 m^2 quadrat. The remaining cover is recorded as bare substrate to bring the total to 100 percent. Again, the diver must use a planar view to estimate percent cover of the biota. Seagrasses and gorgonians should not be stacked upright. For example, e.g., if a single seagrass blade crosses 10 squares, then total seagrass coverage should be the sum of the area taken up by that blade in all 10 squares instead of the area covered if the blade was held upright. Species covering less than 0.1 percent of the area are not recorded. Taxa are identified to the following levels: stony coral-species, algae-morphological group (macro, turf, crustose, rhodolith, filamentous, cyanobacteria), sponge-morphological group, and gorgonians-morphological group. When estimating percent cover, it is important to realize there is a balance between precision and time. For stony corals, the approximate area covered by living coral tissue is recorded. Coral skeleton (without living tissue) is usually categorized as turf algae or uncolonized substrate. Data on the condition of coral colonies are also recorded. When coral is noticeably bleached, the percentage of bleached coral is estimated to the nearest 0.1 percent. Diseased/dead coral refers to coral skeleton that has recently lost living tissue because of disease or damage that is still visible, and has not yet been colonized by turf algae (See Habitat Data Sheet in Appendix B). Turf algae include a mix of short (less than 1cm high) algae that colonize dead coral substrate.

6) Maximum canopy height – For each soft biota type (e.g., gorgonians, seagrass, algae), structure is recorded to the nearest 10 cm.

7) Number of individuals – For sponges, gorgonians and "other" biota type (non-encrusting anemones and non-encrusting hydroids), the number of individuals at the quadrat level is recorded.

8) Rugosity – This measurement is obtained by placing a 6-m chain at two randomly selected positions along the 25 m belt transect. The chain is placed such that it follows the substrate's relief along the centerline of the belt transect. The straight-line horizontal distance covered by the chain is recorded. The chain is placed on top of any hard substrate encountered, but not on top of soft corals or sponges since we are measuring hard bottom rugosity. Rugosity measurements typically are made by the fish diver while awaiting the completion of benthic habitat measurements by the habitat diver. Upon completion of the dive, the rugosity data are transferred from the fish data sheet to the habitat data sheet by the habitat diver.

9) Abundance and maturity of queen conchs (*Strombus gigas*) – A count of the total number of conch encountered within the 25 m x 4 m belt transect are enumerated. The maturity of each conch is determined by the presence or absence of a flared lip and labeled mature or immature, respectively. If conch abundance is counted by a fish diver, the data are then reported to habitat diver. The decision of who will collect conch data should be made prior to entering the water.

10) Abundance of spiny lobsters (*Panilaurus argus*) – A count of the total number of lobsters encountered within the 25 m x 4 m belt transect. No measurements are taken. If lobster abundance is counted by a fish diver, the data are then reported to habitat diver. The decision of who will collect lobster data should be made prior to entering the water

11) Abundance of long-spined urchin (*Diadema antillarium*) – A count of the total number of urchins encountered within the 25 m x 4 m belt transect. No measurements are taken. If urchin abundance is counted by a fish diver, the data are then reported to habitat diver. The decision of who will collect urchin data should be made prior to entering the water.

12) Marine debris – Type of marine debris within the transect is noted. The size of the marine debris and the area of habitat that it is affecting is also recorded along with a note identifying any flora or fauna that has colonized it.

13) Presence of *Acropora* – The presence of *Acropora palmata* and *A. cervicornis* on the transect and at the site are recorded separately.

NOTE: If rugosity data are collected by a fish diver after their count, data must be transferred to the habitat data sheet. The habitat diver is responsible for transferring the data to their data sheet; however, the fish diver should assist the habitat diver with this task by reporting the data once the dive concludes.

Revision History Log

Version #	Date	Revised by	Changes	Justification

Literature Cited

Rogers, C., G. Garrison, R. Grober, Z. Hillis-Starr, and R. E. M. Franke. 1994. Coral reef monitoring manual for the Caribbean and western Atlantic. Virgin Islands National Park. 114 p.

Standard Operating Procedure 5 – Inter-calibration Study

Version 1.0

Purpose

To provide conversion coefficients between belt transect and point count surveys for Caribbean reef fish.

Background

There are several non-destructive visual methods available for surveying reef fish but in the United States Virgin Islands (USVI), a belt transect (SOP 4) has been used by the National Park Service (NPS) and NOAA's National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment, Biogeography Branch (BB) since 2001 to survey reef fish in St. John and St. Croix. NOAA National Marine Fisheries Service (NMFS) is a new partner in Caribbean visual surveys and in south Florida both NPS and NMFS use the point count method to survey reef fish (Brandt 2009). In order to compare fish abundance data collected under two different survey methods, an inter-calibration study is required.

Inter-calibration studies for trawl gear and acoustic fisheries research are not uncommon (Pelletier 1998 and Lewy et al. 2004). However, despite several studies comparing underwater visual surveys (Samoilys and Carlos 2000 and Colvocoresses and Acosta 2007), calibration studies are rare. Smith et al. (*In prep.*) have developed a statistical model to standardize catch and effort indices among fishery-independent survey data. Marc Nadon (pers comm.) has created a tool built on this model to generate conversion coefficients for two different underwater visual survey techniques in the United States Pacific Islands. A similar study is recommended for the USVI and the basic approach is outlined in this SOP.

Data Collection

USVI belt transects (SOP 4) and RVC point count surveys (SOP 6) should be conducted in the same region during the same time period. Paired surveys in which each method is conducted side by side are preferable but if a good stratification scheme is available, it may not be required.

From 2001 until 2009 NPS and BB conducted paired transect and point count surveys in St. John, but unfortunately the point count methodology that was used differs from that used in south Florida and there was a bias towards less experienced divers conducting the point counts. Although these data may not be used for generating precise conversion coefficients, they can be used to estimate the sampling effort needed for a future inter-calibration study. A total of 578 paired surveys were conducted over 10 years in St. John during which 198 species were encountered out of 246 observed on visual surveys in the region. Of these 198 species there was enough data available to generate conversion coefficients for 69 species using Nadon's (unpublished) standardization tool. A more detailed analysis of this data set and a list of species that require a calibration coefficient could lead to a more precise estimate of samples needed. In addition, it is important to determine if different life stages for individual species should be calibrated separately.

Initially it is recommended that paired transect and point count surveys are collected for at least an entire survey season in each of the two regions in the USVI. It is likely that a second survey

season of paired counts would also be required to allow for the comparison of infrequent species. Both surveys should be conducing following the protocols in SOPs 4 and 6. For paired surveys, divers should conduct their surveys on the same habitat type. Divers should rotate between methods to ensure no diver bias in calibration study.

Analysis

Abundance (or density) values of individual species can be inter-calibrated between belt transect and point count surveys with Nadon's (unpublished) automated program. A csv file with data under the following headings needs to be created: Site, Strata, Year, Method, Species and Abundance. If different life stages are required for individual species they should be given different names under the species column. The program analyzes the abundance distribution of each species for normality and performs a transformation if needed. A generalized linear model (with site, year and strata as covariates) is then separately run for each species and method to estimate percent prevalence and abundance when present. These values are then multiplied together for each method to obtain an estimated abundance obtained with that method. The ratio of those values is the conversion coefficient.

Acknowledgements

Marc Naddon (personal communication, February 2012, mnadon@rsmas.miami.edu)

Revision History Log

Version #	Date	Revised by	Changes	Justification

Literature Cited

Brandt, M. E., N. Zurcher, A. Acosta, J. S. Ault, J. A. Bohnsack, M. W. Feeley, D. E. Harper, J. H. Hunt, T. Kellison, D. B. McClellan, M. E. Patterson, and S. G. Smith. 2009. A cooperative multi-agency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resource Report NPS/SFCN/NRR—2009/150. National Park Service, Fort Collins, Colorado.

Colvocoresses, J. and A. Acosta. 2007. A large-scale field comparison of strip transect and stationary point count methods for conducting length-based underwater visual surveys of reef fish populations. *Fisheries Research* 85: 130-141.

Lewy, P., J. R. Nielsen and H. Hovgård. 2004. Survey gear calibration independent of spatial fish distribution. *Canadian Journal of Fisheries and Aquatic Sciences* 61: 636-647.

Pelletier, D. 1998. Intercalibration of research survey vessels in fisheries: a review and an application. *Canadian Journal of Fisheries and Aquatic Sciences* 55: 2672-2690.

Samoilys, M. A. and G. Carlos. 2000. Determining methods of underwater visual census for estimating the abundance of coral reef fishes. *Environmental Biology of Fishes* 57: 289-304.

Smith, S.G., J. S. Ault, M. Nadon, R. Michael and P. Rubec. *In prep*. Standardization of catch-effort indices among gears for fishery-independent data: case studies in Florida and Hawaii.

Standard Operating Procedure 6 – Inter-calibration Study Additional Field Data Collection: Point Count Method

Version 1.0

Purpose
Describes the steps for conducting reef fish sampling using the point count method.

Equipment
Each diver will be equipped with a data sheet and underwater slate, pencil(s), dive watch, and reference measuring tool (a marked PVC "t-stick" consisting of a 1m shaft marked at 10cm intervals and 30cm cross-piece marked at 1cm intervals – Figure SOP 6.1). The reference tool/t-stick is hereafter referred to as an All-Purpose Tool or APT. In addition to the APT, divers may use tools such as a ruler affixed to a clipboard or slate, measuring tape, or gradations marked directly on a clipboard or slate. Preferably, divers will also be equipped with a digital camera for habitat documentation and to record images for subsequent verification or identification of fish or invertebrates, as necessary. Each dive team will be equipped with a reel and line attached to a surface buoy/dive flag with a handheld GPS in a water proof bag.

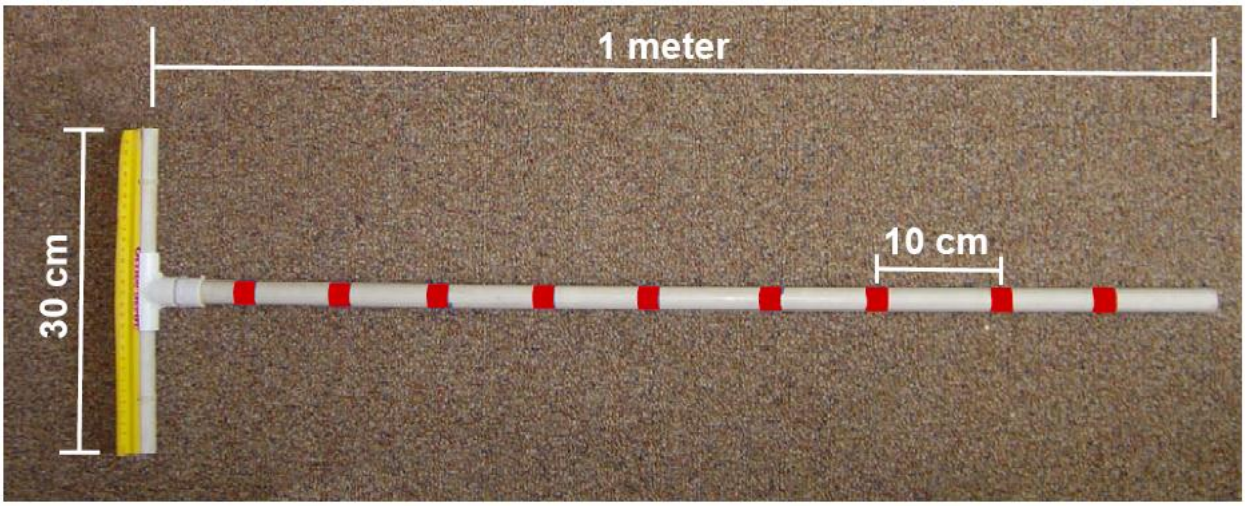


Figure SOP 6.1. The RVC All Purpose Tool (APT) used as a reference device for measuring habitat vertical relief, estimating fish lengths and the location of the center and outer edge of the sample cylinder.

Sequence of Events in the Field
Each day, sampling teams should attempt to visit sites within the same vicinity to maximize sampling efficiency. Teams should strive to sample sites across multiple habitat types each day to avoid temporal biases in fish-habitat characterizations that could arise by sampling multiple sites within 1-2 habitat types on a given day. The number of dives per day can be increased by scheduling deeper sites first and then moving to shallower water.

If several boats are deployed, it is important to have a brief meeting in the morning to ensure that no site overlap occurs and that each group knows where the other team or teams will be

operating. Once in the field, the boat captain navigates to previously selected sites using a boat or handheld GPS unit.

Locating and Assessing the Sample Site (Primary Unit)

Sample sites are located using a vessel-mounted or hand-held GPS unit. Upon arrival at the sample site, divers should attempt to determine (e.g., via interpretation of depth finder display, battiscope, or snorkeling) whether the benthic habitat at the survey location is hardbottom habitat. If the pre-assigned habitat type cannot be located, the sampling should proceed at the initial site coordinates, with divers recording the new habitat type on the Field/Boat Log. If the benthic habitat is not hardbottom habitat, the divers should note this on the Field/Boat Log. They should then prepare to dive the next site for that habitat on a list of alternate sites provided at the start of the field season. The alternate site does not need to be surveyed in the same day as the original site.

Diver Deployment, Descent, and Location of Survey Sites

The GPS unit used for vessel navigation should have waypoints stored for each site listed in the annual plan. Vessel distance from a given stored waypoint can be used to determine that the sampling occurs within the targeted primary unit. All diver deployment should be through a live boat technique in which divers are dropped off from a boat that is not anchored. Preferably, the live boating approach is utilized with at least 4 divers aboard the research vessel. This allows for the rotation of diver teams at every other site and provides at least two scientists on the surface to pilot the research vessel, record surface data, keep track of and retrieve divers.

The field workers / captain piloting the vessel will deploy two divers. If necessary, during descent, divers will swim to appropriate habitat (e.g., if divers enter the water over sand, they will swim to nearby reef habitat for sampling). On reef habitat, each diver haphazardly chooses a sampling location such that each diver is within the distance of accepted "dive buddy" separation standards of his/her buddy. As described, each dive team will be equipped with a reel with line attached to a surface buoy. The reel can be secured to the bottom and serve as a starting point to measure the radius of the sampling cylinder using the APT (i.e., 7.5 m or 5.0 m depending on visibility), as a visual aid to measure visibility, as a point of reference (e.g., edge of cylinder) during data collection and as a point of return for both divers following data collection.

Details of Observations Made in the Field

Data will be recorded on two data forms: (1) the Field/Boat Log and (2) the Fish/Habitat data sheet. Data for form (1) is recorded at the surface and data for form (2) is collected and recorded underwater at the sample site by divers.

Field Forms (printable form in Appendix B)

<u>Field/Boat Log</u>

This form serves as a record of where, when and by whom sites were sampled each day. The following information is recorded on the form:

1) <u>Dive of day</u> – Cumulative site number (e.g., 1, 2, 3…). This number will be the same for each of the two lines of data recorded at each site.

2) <u>Site ID</u> – This is a code listed on the sample site list.

3) Estimated time – Estimated time of beginning of dive. For divers using the anchoring method, the estimated time for the second set of paired surveys will be the time immediately preceding those surveys.

4) Diver team – Divers' initials.

5) Latitude and longitude in degrees and minutes – Position of surface vessel when divers enter the water (dd° mm.mmm').

6) Habitat type – The diver's consensus of the habitat type that was sampled; habitat types are defined in Appendix A.

7) Comments – Any additional information judged to be important by the surface data collector (e.g., notation of a specific camera used by a diver).

Fish/Habitat Data Sheet

Fish and habitat data are entered on the Fish/Habitat Data Sheet (Figure SOP 6.2). Prior to each dive, divers should enter their name (name of observer / diver), name of dive buddy, and date on the data sheet. After entering the water, choosing a specific survey site, and recording dive and sample start times (time of beginning of dive and time of beginning of data collection, respectively; Figure SOP 6.2), each diver begins collection of fish, habitat, and sample-specific data as described in the following section.

Diver: _____	Date:	Field Number:	
Buddy: _____	Sample Start Time:	Habitat type:	Underwater vis. : _____ ft m
Dive Start Time:_____	Sample End Time:	1. Scat. Coral/ Rock 4. Patch Reef	Water temperature: _____
Dive End Time:	Max Dive Depth: ft	2. Pavement 5. Linear Reef	Radius of cylinder: 7.5m 5.0m
Substrate Slope	Station Depth: ft	3. Bedrock 0. (Sand)	Current: None Mod. High
Max depth _____ft	Fishing Gear:		
Min depth _____ft			

Max vertical Relief	
Hard Relief _____m	
Soft Relief _____m	

Surface Relief Coverage %	Hard	Avg. of Sof
< 0.2 m	%	%
0.2-0.5 m	%	%
0.5-1.0 m	%	%
1.0-1.5 m	%	%
> 1.5 m	%	%
TOTAL	100%	100%

Abiotic Footprint	
SAND	%
HARD-B	%
RUBBLE	%
Total	100%

Biotic Co\ - Dominant Biological Cover %			
SAND		HARDBOTTOM	
"Bare"		~~Crustose Algae~~	
~~Algal Turf (<1cm)~~		Algae (<1cm)	
Macro Algae		Algae (>1cm)	
Sea grass		Live Stony Coral	
Sponge		Octocoral	
_____ Other 1		Sponge	
_____ Other 2		_____ Other 1	
		_____ Other 2	
TOTAL	100%		100%

Species	N	Avg	Min	Max	Species	N	Avg	Min	Max
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Comments:

Presence of: *A. palmata* *A. cervicornis* *Dendrogyra cylindrus*

Black Coral Spiny Lobster # Conch # Diadema #

Figure SOP 6.2. Fish/Habitat Data Sheet.

Collecting Fish Data

The Reef fish Visual Census (RVC) methodology is modified from Bohnsack and Bannerot (1986), and occurs with the diver remaining at a fixed site. Fish are surveyed within an imaginary cylinder centered on the diver and extending from the reef substrate to the limits of vertical visibility, usually the surface (Figure SOP 6.3). If horizontal visibility is greater than or equal to 7.5 m, then the radius of the cylinder will be 7.5 m. If the horizontal visibility is less than 7.5 m but greater than 5 m, then the radius of the cylinder will be 5 m. If the horizontal visibility is less than 5 m, then further data collection will not occur.

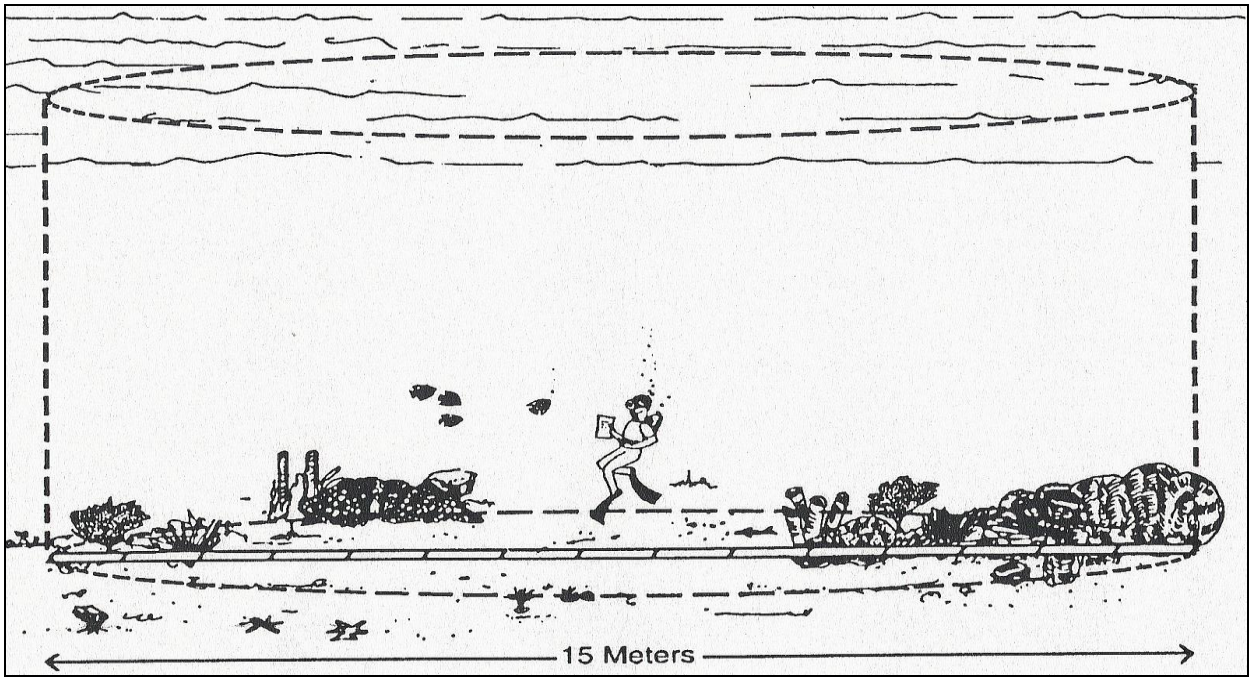

Figure SOP 6.3. Conceptual diagram of RVC diver within 7.5m-radius survey cylinder (from Rogers et al. 1994).

Once horizontal visibility has been measured and the appropriate cylinder radius has been established, the RVC survey begins. Divers establish an imaginary fixed point on the bottom to serve as the center of the sample cylinder, and hover above the point (maintaining neutral buoyancy) to avoid damaging the benthic habitat. Divers record the sample start time on the Fish/Habitat Data Sheet and begin a timed count, using the stopwatch function on the diver's watch to keep track of time. For a five-minute period, divers record all fish species observed. During this period, divers should rotate their position (while remaining above the imaginary fixed point) to ensure that all portions of the cylinder are surveyed. The diver should treat the survey as if they are taking a snapshot in time of all species and their associated densities and size distribution that they observe in the cylinder.

After five minutes have elapsed, data are collected by each diver on the abundance ("N" column in Figure SOP 6.2) and sizes for each species. Individual fork lengths are recorded for all species greater than 35 cm. For all other species, abundance ("N" column) and mean, minimum and maximum fork lengths ("Avg", "Min" and "Max") are recorded.

For species with few individuals (e.g., angelfish, barracuda, hogfish) or for highly mobile species (e.g., sharks and Carangids), individuals are enumerated and their sizes are estimated when first observed. For enumeration and size estimation of other species (e.g., damselfish, wrasses, grunts, etc.), one 360-degree rotation is typically made for each species.

Concurrent with the species enumeration and length estimation described above, new species that are observed after the initial five-minute observation period and until completion of all data collection are also recorded, as are estimates of their abundance and minimum, mean, and maximum lengths. These species are noted on the Fish/Habitat Data Sheet as having been observed "Between 5 and 10 minutes" or "After 10 minutes", depending on the time elapsed at time of observation. If an individual or individuals of a species observed in the initial five-minute observation period is observed after data on the abundance, mean, minimum and maximum fork lengths for that species have been recorded, the diver should exclude these individuals from the count and continue recording only new species data.

During the survey, the reference measurement tool (APT) is used to aid in measuring habitat vertical relief, estimation of fish lengths and the location of the center and outer edge of the sample cylinder. To the extent that conditions (e.g., current) permit, the diver should remain at the center of the survey cylinder for the entirety of the fish data collection portion of the survey.

Sample-Specific Data
Following fish data collection, the following sample-specific data are recorded on the Fish/Habitat data sheet: water temperature, current speed (None, Mod, or High), maximum dive depth, and station depth (bottom depth at the diver's survey location). The horizontal visibility will have been measured and recorded prior to the RVC survey.

Habitat Data
Following the sample-specific data collection, habitat data are collected and recorded on the Fish/Habitat data sheet. The following variables are measured and recorded:

1) Habitat type – Chosen from the following categories (circle one on the Fish/Habitat data sheet). At the surface, the diver should discuss with their buddy and other team members and try to come to a consensus. If a consensus is not achieved, divers should note that in the Field/Boat Log.

2) Target habitats (see Appendix A for descriptions):
   - Scattered coral/ rock
   - Pavement
   - Bedrock
   - Patch Reef – includes solitary and aggregate patch reefs
   - Linear Reef

3) Water temperature, Visibility and Current – Temperature and visibility at the bottom; water current estimated by divers for each paired survey; categories as follows: None (none), Mod. (diver is able to stay in same position with a gentle kick), High (diver struggles to stay in same position).

4) Non-target habitats – if after diving for 5 minutes divers fail to find any of the target habitat types, divers should conduct a count in one of the non-target habitats noting the habitat type on the Field/Boat Log.
   - Sand-seagrass-hard-bottom matrix: mostly soft bottom, non-reef habitat
   - Macroalgae including rhodoliths

5) Substrate Slope – the maximum and minimum depths within the sample cylinder. These values refer to the maximum and minimum depths on the imaginary plane underlying the sample cylinder. If there is a slope these depths will be different (Figure SOP 6.5).

6) Max Vertical Relief – the maximum vertical relief within the sample cylinder of both hard (e.g., coral structure, coralline spur, rocky outcrop) and soft (e.g., octocorals, sponges and macroalgae) substrate (Figure SOP 6.5). These values should not be zero.

7) Surface Relief Coverage for Hard Vertical Relief (e.g., coral structure, coralline spur, rocky outcrop and sand) – the estimated percentages of hard relief that fall into the following categories (all values in meters): < 0.2, 0.2-0.5, 0.5-1.0, 1.0-1.5, and >1.5. These values should sum to 100% (Figure SOP 6.5).

8) Surface Relief Coverage for Soft Vertical Relief (e.g., octocorals, sponges and algae) – the category (< 0.2, 0.2-0.5, 0.5-1.0, 1.0-1.5, and >1.5m) representing the average vertical relief of all soft relief should be indicated by writing "100%" by that category (Figure SOP 6.5).

9) Abiotic Footprint – the percentage of the cylinder comprised of sand, hardbottom and rubble. These percentages should sum to 100%. Sand is defined as coarse biogenic or oolitic sand (grain sizes typically between 0.5-2 mm) and finer silt sized particles (< 0.2 mm). Sand is considered the substratum when sediment depth is usually 2-3 cm in depth or greater. It excludes a surface "dusting" of sediment particles overlying a consolidated substratum. Rubble ranges from coarse gravel (> 5 mm) to unconsolidated and moveable rocks (e.g., dislodged and moveable coral fragments). This category differs from consolidated hard-bottom because of its loose and moveable nature. Consolidated hard-bottom includes solid, consolidated lithogenic or biogenic substratum, including living and dead coral, and non-coral hard-bottom. Areas covered by seagrass should be coded as sand, since the biotic "grass" is growing in the abiotic sand substrate.

10) Biotic Cover - SAND – the percentage of the sand substrate that corresponds to the following categories: bare, under / supporting growth of macroalgae, under / supporting growth of seagrass, under / supporting growth of sponges, and other (e.g., Sargassum; see Appendix F for more examples). These values should sum to 100%. See preceding section for sand definition.

11) Biotic Cover – HARDBOTTOM – While looking at an aerial, canopy view of the cylinder, the percentage of the hardbottom substrate covered with algae < 1 cm height (e.g., turf algae, *Lobophora*), macroalgae > 1 cm height (e.g., *Halimeda*, *Dictyota*), live coral, octocoral, sponge, and other (e.g., *Palythoa*, *Cliona*; see Appendix F for more examples). These values should sum to 100%.

12) Comments – Under the "comments" section, divers should record information such as economically important species observed before or after the RVC survey (e.g., while descending or ascending). If present, divers should also record the type and amount of fishing gear or debris (e.g., monofilament line, traps or trap debris including buoy line, etc.) within the cylinder in the "Fishing gear" section of the Fish/Habitat Data Sheet (see Figure SOP 6.2). Additionally, any comments relative to the sampling or conditions encountered should be recorded in the "Comments" section of the data sheet as well as a camera number if used.

13) Presence – The presence of several economically and ecologically important invertebrates is recorded at the end of the dive. Corals including *Acropora palmata, Acropora cervicornis, Dendrogyra cylindrus,* and black coral. The number of Spiny Lobster, Conch and *Diadema antillarum* are recorded.

Following fish and habitat data collection, sample end time is recorded and divers ensure that all sections on the Reef / Habitat data sheet are completed. Dive end time is recorded after all data have been collected and immediately prior to dive ascent.

Post-Collection Data Sheet and Logs Processing

Once all data collection has been completed underwater, divers deployed from an anchored vessel then return to the research vessel, while divers deployed from a live boating vessel ascend to the surface immediately adjacent to their surface dive flag and wait for the research vessel to approach. Immediately upon returning from a dive, initial QA/QC should include discussions between buddy teams to ensure agreement on variables such as habitat type, bottom current, and other variables of interest. Data sheets are maintained in a secure area aboard the research vessel. Once on land, data sheets are redistributed to data collectors for data entry. Copies (electronic or paper) of all data sheets should be made before redistribution to data collectors in case of loss of original data sheets. These copies should be maintained in a single storage location.

Information recorded at-sea on the Boat/Field logs should be entered into spreadsheet files customized for this data. Latitude-Longitude positions are entered into the Boat/Field log. It is suggested that Latitude-Longitude positions be recorded in the form of degrees and minutes to three decimal places (dd° mm.mmm').

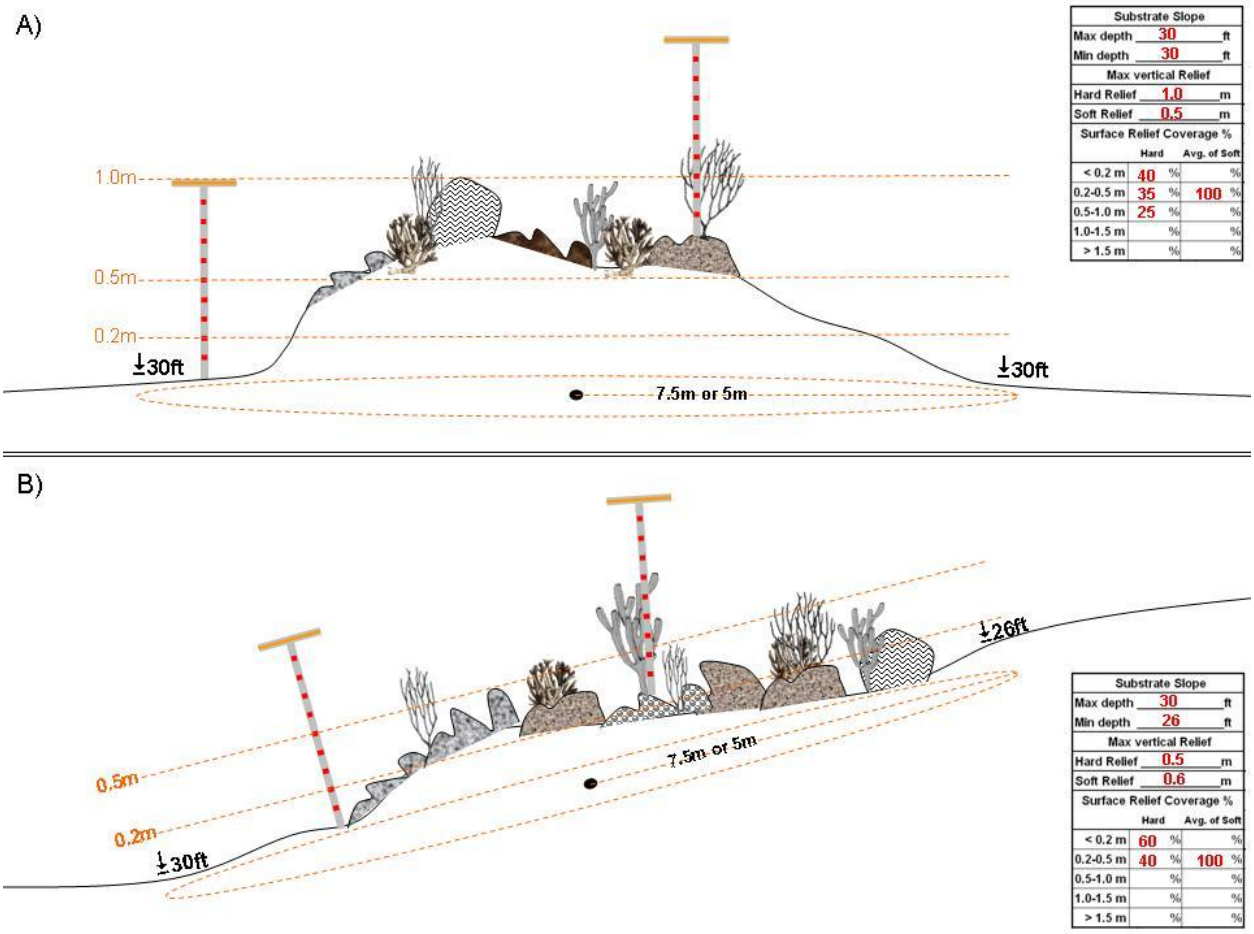

Figure SOP 6.4. Diagram showing how to measure substrate slope, max vertical relief and surface relief coverage. If there is NO slope then Max Depth = Min Depth (A). If there is a slope, then Max Depth > Min Depth (B). Soft Relief is measured from base of attachment to maximum height. Surface relief coverage (%) for the hard substrate components (e.g., coral structure, coralline spur, rocky outcrop and sand) is estimated by determining the percentages of the cylinder area that occupy the following vertical height categories (all values in meters): <0.2, 0.2-0.5, 0.5-1.0, 1.0-1.5, and >1.5. Average surface relief coverage (%) for soft substrate components (e.g., octocorals, sponges and algae) is estimated as the vertical height category within the cylinder representing the average vertical relief of all soft substrate components in the cylinder (including macroalgae). This should be indicated by writing “100%” in that vertical relief category.

Revision History Log

Version #	Date	Revised by	Changes	Justification

Literature Cited

Bohnsack, J. A. and S. P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Tech. Report NMFS 41. 15 p.

Rogers, C., G. Garrison, R. Grober, Z. Hillis-Starr, and R. E. M. Franke. 1994. Coral reef monitoring manual for the Caribbean and western Atlantic. Virgin Islands National Park. 114 p.

Standard Operating Procedure 7 – Participant Training

Version 1.0

Purpose

Describes training for initial participants as well as annual refresher training regarding species identification, habitat characterization, in-water training, and data entry and proofing.

Initial Participant Training

Species identification

Participants conducting fish observations should be competent in the identification of reef fish to the species level before conducting in-water training. Participants should utilize resources including, but not limited to, the most recent edition of Humann and Deloach (2002b), the Reef Fish ID: Florida, Caribbean, Bahamas – Interactive Edition CD/DVD field guide and the Reef Environmental Education Foundation on-line fish identification quizzes.

Participants conducting habitat observations should be competent in the identification of corals to the species level before conducting in-water training. Coral Reef Identification (Humann and Deloach 2002a) is a standard guide that should be used to help train divers.

It is the responsibility of the program leaders for the National Park Service (NPS), NOAA's National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment, Biogeography Branch (BB), NOAA's National Marine Fisheries Southeast Fisheries Science Center (SEFSC) to ensure that all participants from each respective agency or institution possess the necessary identification skills.

Habitat characterization

All participants should be familiar with the habitat classification scheme used in the stratified survey design (SOP 1 - " Sample Frame and Habitat Classification"). They should be capable of distinguishing habitat types and classifying the different abiotic characteristics of the habitat that are measured. Participants should understand the metrics and terms used to assess major benthic groups and show familiarity with their identification. Guides for identification of major benthic groups and commonly misidentified organisms can be found in Appendix F. It is suggested that these guides be printed and laminated and brought into the field as a reference.

In-water training

In-water training is intended to assess the accuracy of a diver's estimates of fish size and distance from diver, identification and estimates of corals and measure the ability of the diver to collect habitat data. There are two methods for in-water training: model training and comparison.

<u>Model Training</u>

1) Models of fish that are typically observed during visual surveys (optimally, both fishery-targeted and non-targeted species) are prepared for deployment in the field.

2) A suitable test area is located (reef habitat, relatively shallow depth). Visibility must exceed 10 meters and the current should be minimal.

3) A measuring tape transect (30 m or longer) is extended in a straight line within the test area. Fish models (~20-30) are placed at varying distances (within the limits of visibility and at 0.5-m intervals) from the transect tape at predetermined and marked distances along the tape.

4) For each fish model, a test administrator measures and records the (1) fish species, (2) model size (fork length to nearest cm) and (3) distance from the mark on the transect tape to the fish model (to nearest 0.5 m) for each model and (4) habitat data.

5) Trainees enter the water with SCUBA gear, a reference measuring tool and clipboard. The reference measuring tool will be a marked t-stick/APT (See SOP 6 for description). For each fish model, trainees estimate and record the (1) fork length (to nearest cm) and (2) distance from the center point (to nearest 0.5 m) and (3) complete the habitat data section of the fish/habitat data sheet.

6) The estimated total length and distance from the transect tape for each model and habitat data are entered by each trainee into electronic format and compared with actual values to assess examinee-specific errors or consistent biases. This assessment may range from (1) an instructor or instructors assessing each trainee's results, with subsequent reporting of results to, and discussion with, each trainee to (2) self-assessment by trainees, with subsequent group discussion of each trainee's results.

7) In all cases, additional training should be provided for examinees that exhibit consistent and considerable (> 20%) error, on average, in size or distance estimation, until error rates are less than 20%. Additional training should also be provided until the examinee has attained 100% accuracy in fish identifications. Habitat data should be examined by an instructor or instructors and determined if examinee needs more training.

A new diver's first visual count dives should occur with an experienced fish counter. The experienced fish counter should provide guidance, answer questions, and help the new diver with any fish identification skills. The new diver should also be calibrating their size estimates by comparing their size estimates to non-mobile reef components that can be measured exactly. Data taken during these first few dives and until the diver demonstrates competency with all necessary data recording skills should be marked as "Training – Observer" dives by selecting this from the "Sample Type" drop down list on the Sample Data screen upon entry into the RVC data entry program.

<u>Comparison training</u>

Divers which have displayed a proficiency in species identification can train in water with veteran divers. Divers in training first conduct multiple divers observing the 'work' flow underwater and practice identifying fish and estimating lengths. Once they are comfortable with the work that is conducted, they shadow an experienced diver and collect all the data as if it was a true survey. After each survey the divers compare species identifications and estimated lengths. Divers are also encouraged to discuss any species that might have not been within boundaries of visual survey and estimated lengths of such species. After several of these dives have been conducted and the veteran diver is confident that the new diver can accurately identify fish, the roles are reversed and the new diver collects the data for the site and the veteran diver follows and collects separate data to validate the new diver. Both types of training dives should occur

over a variety of habitat strata as fish assemblages are likely to differ. This may take several days of conducting paired counts until both the veteran and novice divers are confident that the data collected meets high standards.

Annual Refresher Training for Previous Participants

Each year, prior to the start of annual surveys, all survey divers, including those who have previously participated in surveys, should attend out-of-water training meetings that can be held either jointly or independently depending on the needs and abilities of the agencies. These out-of-water training meetings should cover the sampling design, survey logistics, survey methods, habitat characteristics, and data entry and proofing methods so that participants are familiar with all steps of the monitoring program. Presentations given at these training meetings will be posted online so that they are accessible to all participants throughout the field season.

In-water training should be organized collaboratively when possible or if not, by each agency independently and focus on method execution, proper equipment handling, species identification and size estimation, and proper habitat characterization. Participants are also encouraged to independently use computer programs and field guides to practice species identification.

Data Entry and Proofing Training

Prior to surveying, all participants should be proficient in the use of the data entry program. Designated data managers from each agency should also be familiar with the steps involved in collating the data and producing proofing reports for individual divers to check their data and for submitting final data files for data verification. When a new data manager is appointed, an experienced data manager from one of the agencies should be assigned to train the new data manager in the steps involved.

Diver Training Log

A record of diver training should be maintained in both the local and regional database. This will assist evaluation of unusual data in the QA/QC step.

Diver Name	Agency	Initial Participant Training (date)	Refresher Training (date)	Data Entry and Proofing Training/ Review (date)

Revision History Log

Version #	Date	Revised by	Changes	Justification

Literature Cited

Humann, P. and N. DeLoach. 2002a. Reef Coral Identification: Florida, Caribbean, Bahamas, 3rd Edition. New World Publications, Jacksonville, FL.

Humann, P. and N. DeLoach. 2002b. Reef Fish Identification: Florida, Caribbean, Bahamas, 3rd Edition. New World Publications, Jacksonville, FL.

Standard Operating Procedure 8 – Data Entry, Proofing and Management

Version 1.0

Purpose

Describes data entry, proofing and management procedures for individual divers and agency data base managers.

Introduction

Data management is an important multilevel process that involves multiple participants and agencies. Steps that should be taken to manage collected data include data entry, proofing and storage. This SOP describes those steps for the visual surveys in the United States Virgin Islands (Table SOP 8.1).

Table SOP 8.1. Data entry and proofing steps, responsible person and forms and programs used.

Steps	Responsible Person	Forms/ Program Used
1. Field data collection	Diver	1. Fish data sheet 2. Habitat data sheet 3. Boat log
2. Enter data and proof against data sheets	Diver	1. Online: Coral Reef Ecosystem Database (CREAM) 2. Offline: Biogeography Program Database Management (BPDM)
3. Check that all data has been entered and send to regional database	Agency data manager	
4. Check to make sure all data is accounted for	Regional data manager	CREAM
5. Automated QA/QC program check and manual verification and proof	Regional data manager	CREAM
6. Data storage	Regional data manager and Agency data manager	CREAM local database

Data Entry

Divers enter their data from their data sheets into an electronic database within two weeks of collection. Each collaborating agency should have a copy of NOAA's National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment, Biogeography Branch's (BB) offline database (Biogeography Program Database Management (BPDM)) to enter data. Once this data has been entered, checked and proofed as described below, offline data files are provided to the BB database manager for upload into Coral Reef Ecosystem Database (CREAM). Additionally, if an internet connection is available, data entry can be made directly on-line to the database at: https://www8.nos.noaa.gov/bpdm_web/staff_login.aspx.

Belt Transect – Data Entry into Offline Database

Steps below describe steps for entering data into the CREAM offline BPDM database.

1) Open the offline_BPDM.exe file to get the first screen (Figure SOP 8.1.). This program should be loaded onto each computer that will be used for data entry during a field season.

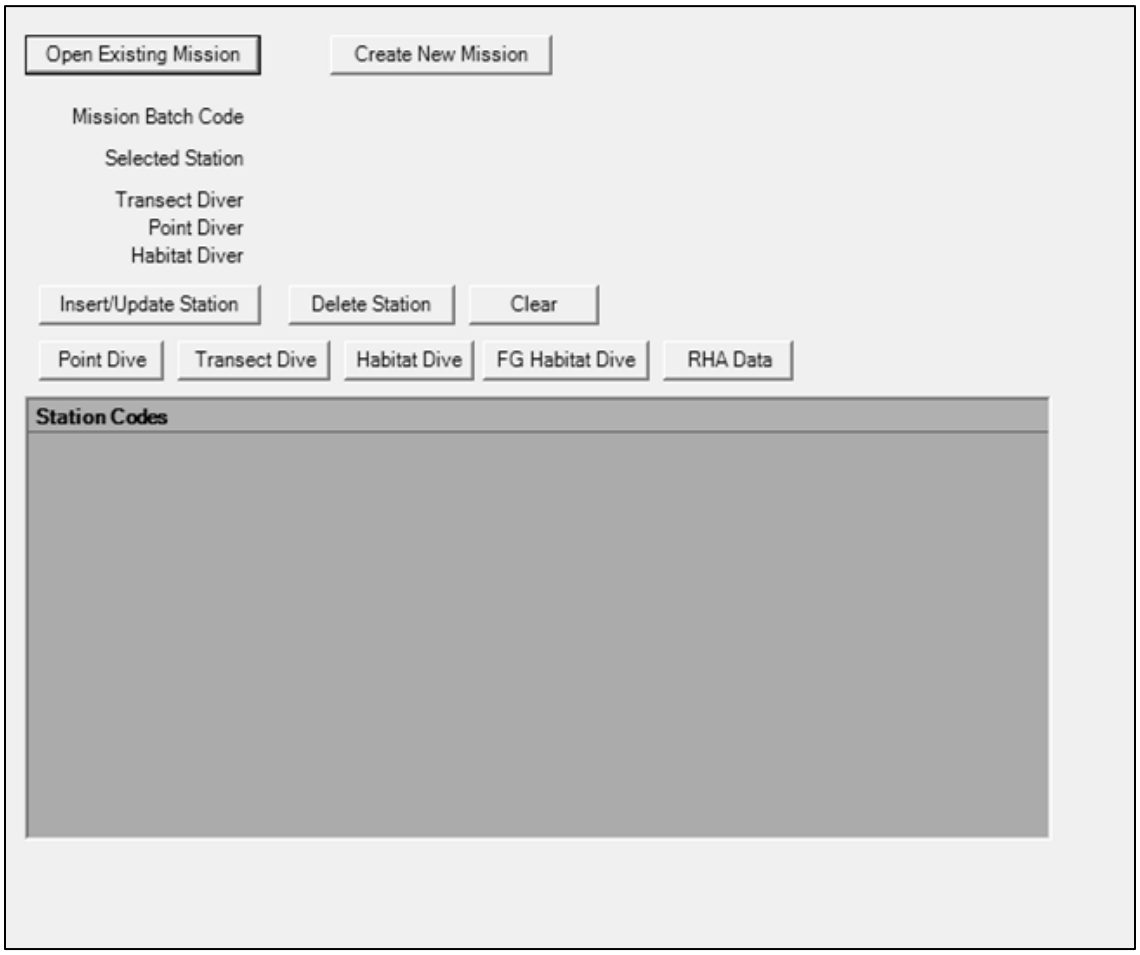

Figure SOP 8.1. Initial view of BPDM database.

2) If it is the first mission entered on computer click on the Create New Mission box. Use the drop down tabs to select the Batch Code (Figure SOP 8.2). Select region, site, month and year that the sample was collected and click on Create Batch File.

Figure SOP 8.2. Creating a batch file.

3) Once a Batch File has been created, a station (or site) data can then be entered. Click on Insert/Update Station and enter the Station Code, the transect diver's first and last name separated by a "." and the habitat diver's first and last name (Figure SOP 8.3). Then click on Add Station.

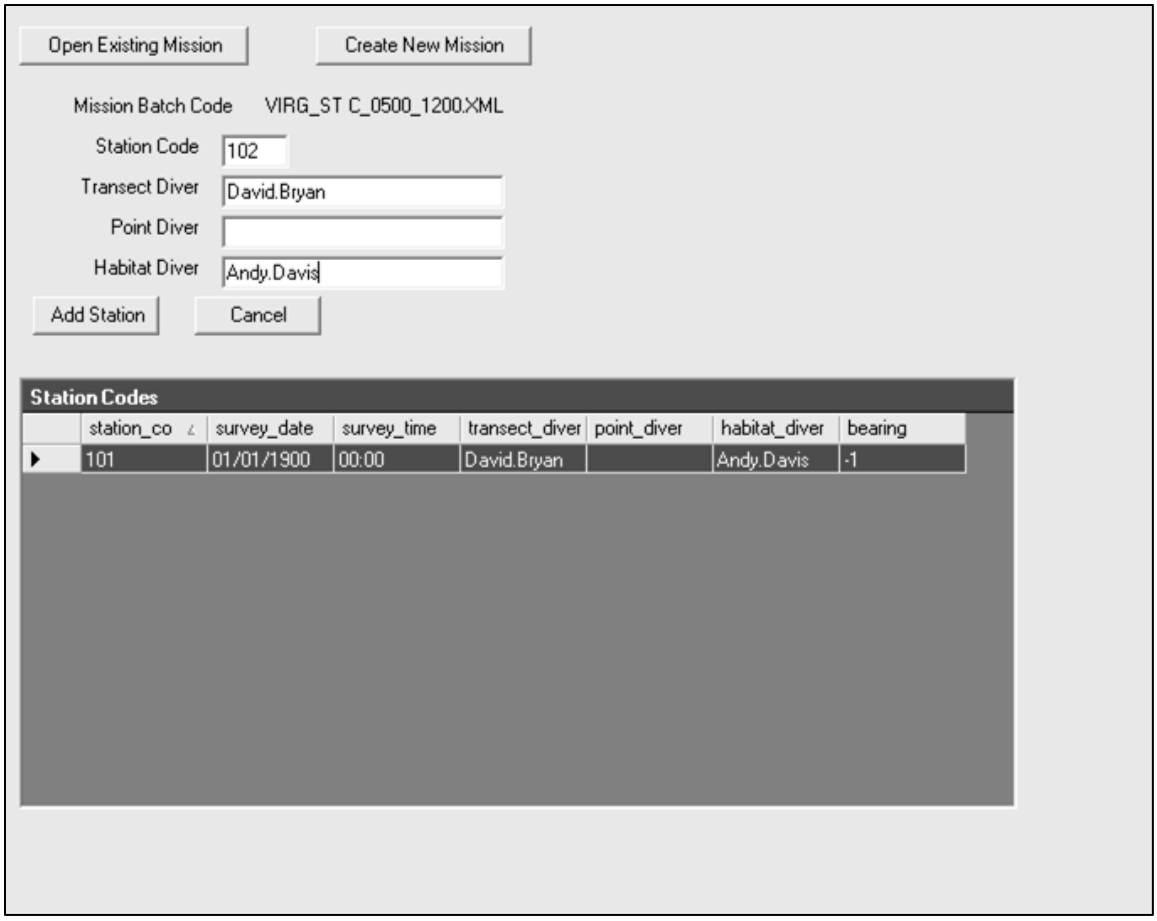

Figure SOP 8.3. Entering station code and diver's names.

4) To begin entering data, select the station that you want to enter data for and click on the data type (Point Count, Transect, Habitat or RHA) that you have for that station (Figure SOP 8.2). This will pop-up a new screen with the form selected.

5) Fish Transect Data (Figure SOP 8.4) – The first step is to update the bearing in which the transect was run. Date and time should be entered and the update bearing button selected. Then use the drop down box under species code to select the species to enter length data and then type in the abundance of that species in each size category. If fish over 35 cm were observed click on the > 35 box and enter the count and size of fish in the pop-up box and click on insert. After all lengths for a species have been entered, click on insert and move to next species. Once all species for a station have been entered click on close fish survey.

Figure SOP 8.4. Entry form for fish data.

6) <u>Habitat Transect Data (Figures SOP 8.5 and SOP 8.6)</u> – There are two tabs for the Habitat data. First, click on the Char/Abio tab, select Hard Structure and begin entering data. When finished click on Update. Next click on Biotic Cover tab to enter the rest of the benthic transect data. Individual corals in each quadrat are entered on the top of the form. A drop down menu is available to select coral species by code. The percent cover (to the nearest 0.1 %) and relief information for each quadrat are entered here. For benthic species other than scleractinian corals (algae, seagrasses, gorgonians, sponges and other invertebrates), fill in the bottom section of the sheet. Total percent coverage must add up to 100% . The Calculate Uncolonized Substrate button can be used to automatically estimate uncolonized substrate percent based on a 100% total. The number of all macro-invertebrates observed (queen conch, *Diadema*, lobster) and information on marine debris are also recorded. Once all the information on the screen has been entered, click on Update.

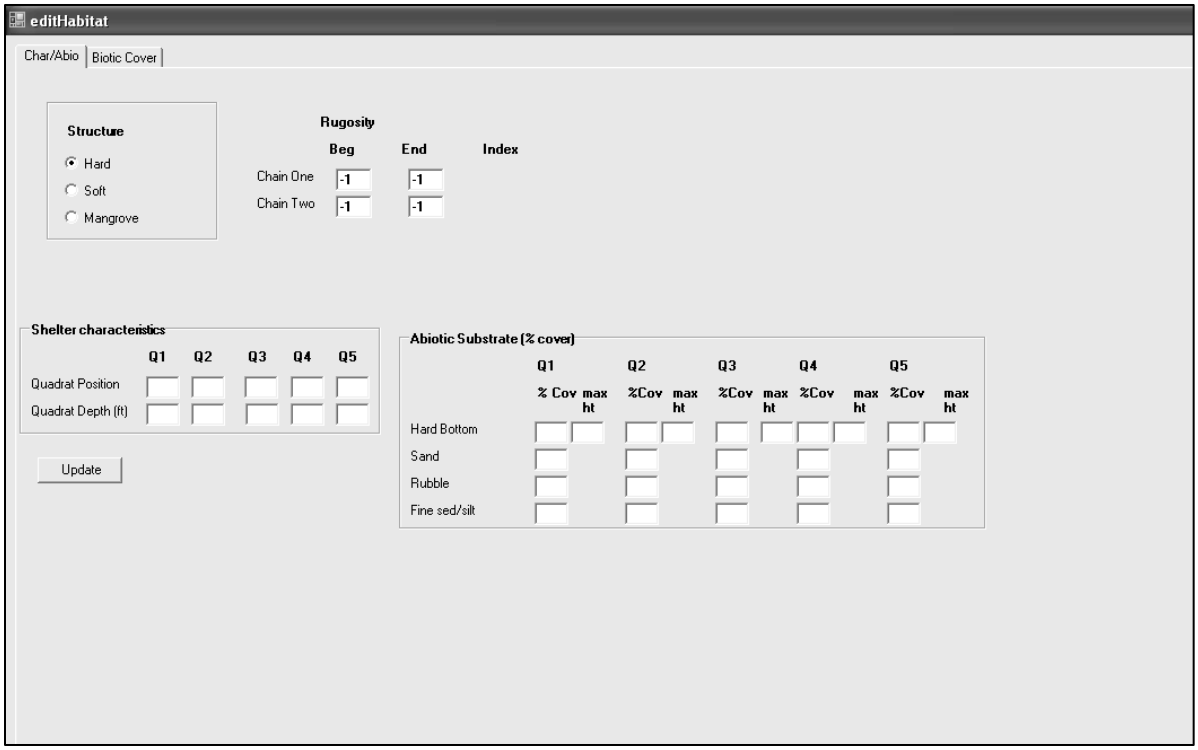

Figure SOP 8.5. Habitat data form I.

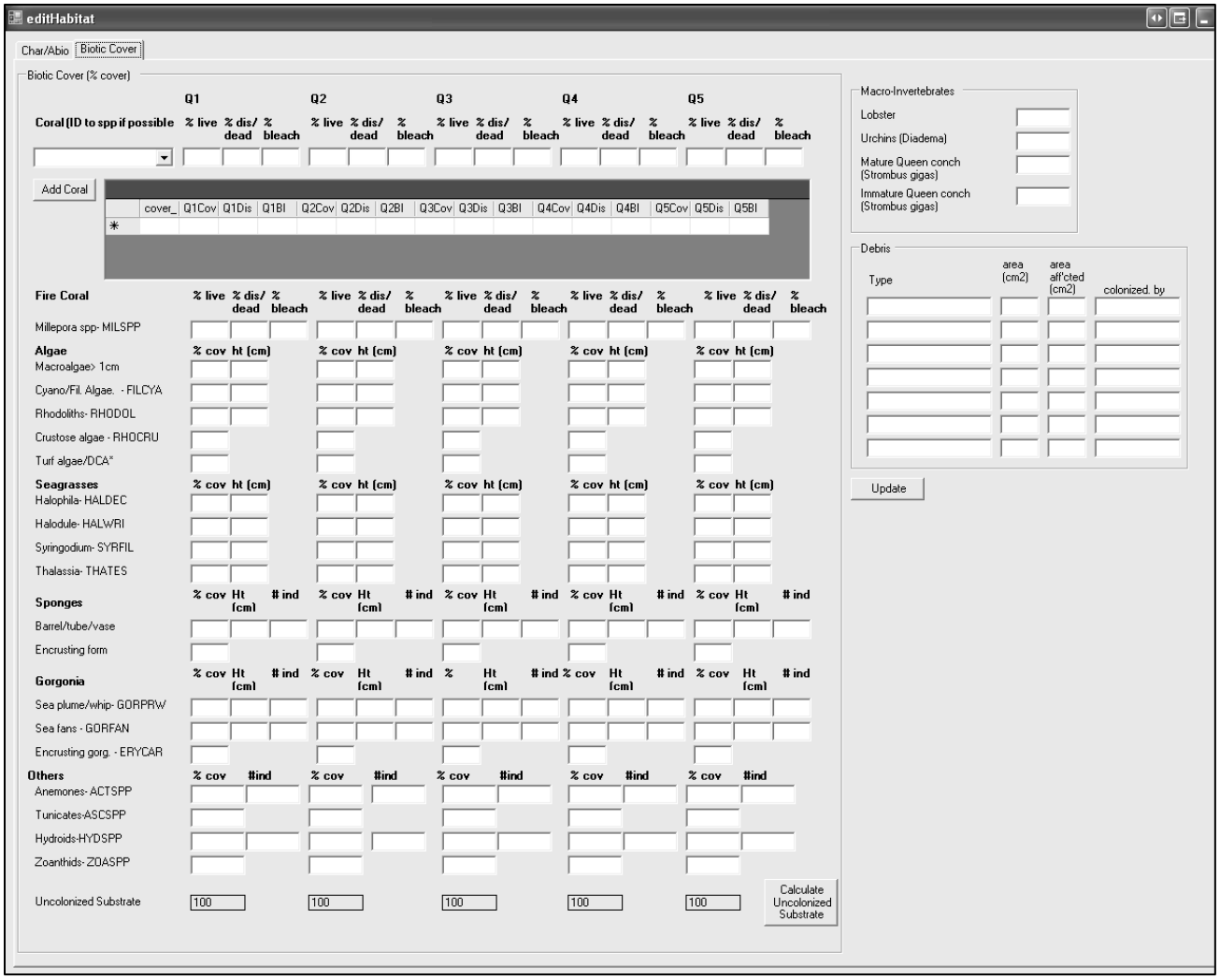

Figure SOP 8.6. Habitat data form II.

Belt Transect – Data Entry Online

Online entry of data is available on BB's website: https://www8.nos.noaa.gov/biogeo_public/staff_login.aspx.

Photo Storage and Management

Photos for each site are stored in a directory structure with that site name. A copy of all photos should be sent to BB with special photos (e.g., previously unseen species) highlighted.

Data Check and Proofing

Each diver should conduct a 100% verification (i.e., data check or proofing) of their data before submitting their xml files. In the case of NPS, a 10% check should be conducted by a second person as part of an agency requirement. Once each diver from a participating agency has entered all their data, each agency database manager checks to make sure that all surveys sites are accounted for and that fish, habitat and boat log data match. In the case of NPS and SEFSC, GPS logs are checked against site coordinates. The xml files created from the offline database are then sent to the BB data manager for a final check to insure that all data have been entered.

QA/QC and Verification

Once all the data have been entered, checked and proofed, the lead database manager/ statistician runs a series of automated and manual QA/QC programs and verifies that the data are ready for the creation of the final database. These checks include but are not limited to:

- Check that all assigned points were completed and data (Field/boat log, fish, and habitat) have been entered, and proofed
- Checks that each point has a field log, fish and habitat data entry completed.
- Check whether divers recorded strata habitat classification matches expected and see if discrepancies are explainable. (Requires ability to overlay habitat map on top of grid).
- Check GPS track logs versus assigned coordinates to make sure sampling occurred in right grid cell.
- Check for new previously unrecorded species codes and consult with fish biologists whether they are reasonable or a likely error.
- Check for logical checks on all numbers, where habitat estimates should total to 100%.
- Check that all required fields are filled out.
- Check for size lengths out of range for species.
- Check for missing data, e.g., species records without lengths.
- Resolve problems where possible and make a determination whether to declare a point invalid if unresolvable errors are involved that will affect the statistics.
- Compare highest fish counts, unusual fish species, % coral cover among divers for any unusual data (e.g., stony coral cover consistently higher than other divers, one diver always sees a particular fish that isn't recorded by anyone else
- After multiple years, or sufficient data collection, check whether average lengths differ for same species among divers (e.g., consistent diver bias).

Data Storage

Regional data for the belt transects are stored in the relational database managed by BB and data are made available through the web page from which all partners have access (http://www8.nos.noaa.gov/biogeo_public/query_main.aspx).

NPS-SFCN specific details of the NPS-SFCN data storage and reporting database are provided in Appendix I.

Archiving and Metadata

BB is responsible for archiving a complete set of the regional data each survey year together with appropriate metadata.

NPS-SFCN specific archiving is specified in Appendix I.

Revision History Log

Version #	Date	Revised by	Changes	Justification

Standard Operating Procedure 9 – Data Analysis and Reporting

Version 1.0

Purpose

Describes basic data analysis and reporting that is recommended following each survey season. Suggested tables and equations for calculating variables are included.

Introduction

Data analyses and reporting will be specific to management questions and resource goals that are being addressed, however, some suggested analyses should be applied to the data after each survey. This includes data for reports as well as information for the iterative approach to sample design. Data that is housed by NOAA's National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment, Biogeography Branch (BB) should be accessible to all partners after QA/QC. A standard format will be provided that will allow for a variety of population level analyses. This SOP includes a description of these analyses.

Creating an Initial Analysis-Ready Dataset

Generating Fish Analysis Data

Data housed by BB will be available for download for each collaborator after final QA/QC. A standardized format will be utilized to enable basic analyses. Table SOP 9.1 lists the fields for the analysis ready data set from which subsequent calculations described in this SOP can be made. In addition to this data set, which includes fish and habitat data, a list of all possible strata for each region and management zone should be created along with a list of surveyed sites.

Table SOP 9.1. Data fields for an analysis ready data set.

Field	Description
survey_index	discrete site number
sub-region	St. John/St. Thomas or St. Croix
management_cd	four letter code of management region, if outside management (None)
Year	
quad_depth	average depth from divers
hab_c	habitat classification
Strat	stratification
species_cd	four letter species code (see Appendix C), for each survey_index #, all species in database are included with zeros for those not observed at that site
Len	length for each species (cm), for binned data the mid-point is used (0-5=3, 5-10=7.5, 10-15=12.5, 15-20=17.5, 20-25=22.5, 25-30=37.5, 30-35=32.5, >35=actual length
Num	number of fish at each length

Documenting Summary Statistics for Strata

Optimal sampling effort for each survey requires an adjustment to the allocation of sites sampled among strata and management zone. A list including the number of sites selected within each strata and management zone, the actual number of sites surveyed and the total number of girds is imperative for population estimates and should be included with each report. The strata classifications from the survey data sheet (diver team classification, not the grid map) are used for all subsequent calculations. Tables SOP 9.2 and 9.3 are based on the current stratification scheme but should be updated with changes to strata.

Table SOP 9.2 Summary statistics for strata in St. Croix.

Zone	Strata	Total # Grid Cells	# Grid Cells Selected	# Grid Cells Surveyed
BUIS	Deep, Scattered coral/ rock			
BUIS	Deep, Pavement			
BUIS	Deep, Bedrock			
BUIS	Deep, Patch reef			
BUIS	Deep, Linear reef			
BUIS	Shallow, Scattered coral/ rock			
BUIS	Shallow, Pavement			
BUIS	Shallow, Bedrock			
BUIS	Shallow, Patch reef			
BUIS	Shallow, Linear reef			
SARI	Deep, Scattered coral/ rock			
SARI	Deep, Pavement			
SARI	Deep, Bedrock			
SARI	Deep, Patch reef			
SARI	Deep, Linear reef			
SARI	Shallow, Scattered coral/ rock			
SARI	Shallow, Pavement			
SARI	Shallow, Bedrock			
SARI	Shallow, Patch reef			
SARI	Shallow, Linear reef			
OUMG	Deep, Scattered coral/ rock			
OUMG	Deep, Pavement			
OUMG	Deep, Bedrock			
OUMG	Deep, Patch reef			
OUMG	Deep, Linear reef			
OUMG	Shallow, Scattered coral/ rock			
OUMG	Shallow, Pavement			
OUMG	Shallow, Bedrock			
OUMG	Shallow, Patch reef			
OUMG	Shallow, Linear reef			

Table SOP 9.3 Summary statistics for strata in St. John.

Zone	Strata	Total # Grid Cells	# Grid Cells Selected	# Grid Cells Surveyed
VIIS	Deep, Scattered coral/ rock			
VIIS	Deep, Pavement			
VIIS	Deep, Bedrock			
VIIS	Deep, Patch reef			
VIIS	Deep, Linear reef			
VIIS	Shallow, Scattered coral/ rock			
VIIS	Shallow, Pavement			
VIIS	Shallow, Bedrock			
VIIS	Shallow, Patch reef			
VIIS	Shallow, Linear reef			
VICR	Deep, Scattered coral/ rock			
VICR	Deep, Pavement			
VICR	Deep, Bedrock			
VICR	Deep, Patch reef			
VICR	Deep, Linear reef			
VICR	Shallow, Scattered coral/ rock			
VICR	Shallow, Pavement			
VICR	Shallow, Bedrock			
VICR	Shallow, Patch reef			
VICR	Shallow, Linear reef			
OUMG	Deep, Scattered coral/ rock			
OUMG	Deep, Pavement			
OUMG	Deep, Bedrock			
OUMG	Deep, Patch reef			
OUMG	Deep, Linear reef			
OUMG	Shallow, Scattered coral/ rock			
OUMG	Shallow, Pavement			
OUMG	Shallow, Bedrock			
OUMG	Shallow, Patch reef			
OUMG	Shallow, Linear reef			

Statistical Background

All subsequent calculations remain the same whether the transect or point count field method is used to collect data. The only difference is the calculation of N_h (the total number of possible is samples in stratum h) where A_h is the stratum area.

$N_h = \frac{A_h}{100\ \mathrm{m}^2}$ Belt Transect SOP 9.1

$N_h = \frac{A_h}{177\ \mathrm{m}^2}$ Point Count

Proportion Occurrence

An inventory of fish species observed and their frequency of occurrence should be generated by sub-region and park.

Proportion occurrence for each species is calculated first by strata ($\bar{P}_h$), then multiplied by a weighting factor (W_h) and summed to provide a management zone estimate ($\bar{P}_{st}$).

$$\bar{P}_h = \frac{1}{n_h}\sum_j P_{hj} \qquad \text{SOP 9.2}$$

W_h is the stratum weighting factor. This weighting factor is calculated for each stratum as:

$$w_h = \frac{N_h}{\sum_h N_h} \qquad \text{SOP 2.5}$$

The total number of primary units (grid cells) in a stratum, N_h, is dependent on stratum area, so values for N_h are derived directly from GIS habitat maps.

$$\bar{P}_{st} = \sum_h w_h \bar{p}_h \qquad \text{SOP 9.3}$$

Variance and standard error are also calculated for proportion occurrence each year. Variance is first calculated for each strata ($\mathrm{var}\left[\bar{P}_h\right]$). ($n_h$) is the total number of sites visited in each strata.

$$var[\bar{P}_h] = \left(1 - \frac{n_h}{N_h}\right) \times \frac{\left(\frac{n_h}{(n_h-1)}\right)\times \bar{p}_h \times (1-\bar{p}_h)}{n_h} \qquad \text{SOP 9.4}$$

Total management zone variance ($\mathrm{var}\left[\bar{P}_{st}\right]$) is calculated by summing all strata variance values that have been multiplied by the squared stratum weighting factor.

$$\mathrm{var}[\bar{P}_{st}] = \sum_h var[\bar{P}_h]\, W_h^2 \qquad \text{SOP 9.5}$$

Standard error for proportion occurrence can also be calculated:

$$SE\left[\bar{P}_{st}\right] = \sqrt{var[\bar{P}_{st}]} \qquad \text{SOP 9.6}$$

Species Richness

In addition to proportion occurrence for all species, a total count of species observed throughout all surveys as well as mean species richness (defined here as average number of species observed per 100 m^2) can be calculated.

The mean species richness ($\overline{Sp}_h$) for each stratum (h) within the entire domain or specified region of interest is first calculated. Where n_h is the number of primary units sampled in stratum h.

$$\overline{Sp}_h = \frac{1}{n_h}\sum_h sp_{hj}$$

SOP 9.7

To calculate the overall stratified mean species richness for the domain ($\overline{Sp}_{st}$) stratum densities and a weighting factor are used:

$$\overline{Sp}_{st} = \sum_h w_h \overline{Sp}_h$$

SOP 9.8

The sample variance of species richness in stratum *h* ($\overline{Sp}_h^2$), variance by strata (*var*[$\overline{Sp}_h$]) and variance of domain species richness (*var*[$\overline{Sp}_{st}$]) can be calculated.

$$\overline{Sp}_h^2 = \frac{1}{n_h - 1}\sum_i \left(\overline{Sp}_{hi} - \overline{Sp}_h\right)^2$$

SOP 9.9

$$\mathrm{var}\left[\overline{Sp}_h\right] = \left(1 - \frac{n_h}{N_h}\right)\frac{\overline{Sp}_h^2}{n_h}$$

SOP 9.10

$$\mathrm{var}\left[\overline{Sp}_{st}\right] = \sum_h \frac{w_h^2\,\mathrm{var}\left[\overline{Sp}_h\right]^2}{n_h} - \sum_h \frac{w_h\,\mathrm{var}\left[\overline{Sp}_h\right]^2}{N}$$

SOP 9.11

Density and Abundance

<u>Mean Density</u>
A primary motivation of monitoring reef fish is to evaluate changes in population structure of economically important fish species whose populations fluctuate in response to environment changes and/or fishing pressure. A key component of annual data analysis should consist of calculating population measures for these species and comparing metrics among management zones and relative to previous sampling.

Robust estimators of population "health" for focal species include average density of species at different lifestages and average length of exploited phase individuals (Ault et al. 2001; Ault et al. 2005. These two biological indicators should be calculated annually and compared to previous years, and between management zones with consideration to habitat. Mean density of lifestages and should also be considered spatially across the domain.

Mean fish density can be estimated for the entire domain (i.e., USVI) or for a specified region of interest (i.e., habitat class, management zone, geographic sub-region). Fish density, D, is the number of individuals observed per diver station (i.e., individuals observed/100m^2). The mean density ($\overline{D}_h$) for each stratum (*h*) within the entire domain or specified region of interest is first calculated. Where n_h is the number of primary units sampled in stratum h.

$$\overline{D}_h = \frac{1}{n_h} \sum_j D_{hj}$$

SOP 2.2

To calculate the overall stratified mean density for the domain ($\overline{D}_{st}$), stratum densities and a weighting factor are used:

$$\overline{D}_{st} = \sum_h \left(w_h \overline{D_h} \right)$$

SOP 2.6

W_h is the stratum weighting factor (SOP 2.4).

Overall stratified mean density and mean density for each stratum can be calculated separately for different life stages of species of concern. Mean densities calculations should then be compared with consideration to changes through time and potential patterns in space.

Sample variance of density in stratum *h* is first calculated among primary units in each stratum:

$$s_h^2 = \frac{1}{n_h - 1} \sum_{j=1}^{n_h} \left(D_{hj} - \overline{D_h} \right)^2$$

SOP 2.3

Then the variance of the mean density for each stratum is calculated.

$$\mathrm{var}\left[\overline{D}_h\right] = \left(1 - \frac{n_h}{N_h}\right) \frac{s_h^2}{n_h}$$

And finally, the variance for the survey mean density $var\left[\overline{D}_{st}\right]$ is calculated using the weighting factors for each stratum.

$$\mathrm{var}\left[\overline{D}_{st}\right] = \sum_h w_h^2 \, \mathrm{var}\left[\overline{D}_h\right]$$

SOP 2.8

Abundance

Survey wide total abundance values ($\hat{Y}_{st}$) for each species (i.e., estimated total number of fish in an area) can be estimated by sub-region and management zone after stratum densities are calculated. First abundance values for each stratum are calculated:

$$\hat{Y}_{h=(\bar{D}_h)(N_h)}$$

SOP 9.12

N_h values can be for management zones or sub-regions. Then abundances are summed for all strata to get a total abundance.

$$\hat{Y}_{st} = \sum_h \hat{Y}_h$$

SOP 9.13

Survey wide variance for abundance ($var\left[\hat{Y}_{st}\right]$) can be calculated as follows:

First strata variance is calculated:

$$\mathrm{var}\left[\hat{Y}_h\right] = \mathrm{var}\left[\bar{D}_h\right](N_h)^2$$

SOP 9.14

The survey wide variance is then calculated by summing up the variances of each strata.

$$\mathrm{var}\left[\hat{Y}_{st}\right] = \sum_h \mathrm{var}\left[\hat{Y}_h\right]$$

SOP 9.15

The standard error and CV of this estimated are calculated as follows:

$$SE\left[\hat{Y}_{st}\right] = \sqrt{\mathrm{var}\left[\hat{Y}_{st}\right]}$$

SOP 9.16

And

$$CV[\bar{\hat{Y}}_{st}] = \frac{SE[\bar{\hat{Y}}_{st}]}{\bar{\hat{Y}}_{st}}$$

SOP 9.17

Length Based Measurements

Average Size in the Exploited Phase ($\bar{L}$)

Average length at exploited phase for selected species should be calculated at the end of each survey season. Currently the only species of reef fish with a size limit in the USVI is yellowtail snapper and subsequent analysis of commercial catch data is required to determine the length at

exploitation for all other species. This metric is calculated by averaging the length of all fish of a given species that are already greater than or equal to the exploited phase size limit. At this time, lengths are not weighted by strata.

The average size of an animal (length or weight) in the exploited phase of the stock (Beverton and Holt 1957) is a physiologically-based indicator that is sensitive to direct and indirect stress on marine ecosystems (Ault et al. 2005). It is highly correlated with average population size, and reflects fishing mortality rate. As fishing mortality rate increases, ($\overline{L}$) decreases at a rate proportional to the population-dynamic tolerance of a stock (Ault et al. 2005). $\overline{L}$ will decrease until it is nearly equal to the minimum size of first capture regulated by fishery management. By its definition, there also exists a value of $\overline{L}$ corresponding to a population size that produces maximum sustainable yields on a continuing basis.

$\overline{L}$ at time t is defined as:

$$\overline{L}(t) = \frac{F(t)\int_{a_c}^{a_\alpha} N(a,t)L(a,t)da}{F(t)\int_{a_c}^{a_\alpha} N(a,t)da}$$

where a_c is the minimum age at first capture, a_λ is the oldest age in the stock, *N(a,t)* is the abundance for age class *a*, *L(a,t)* is the length-at-age, and *F(t)* is the instantaneous fishing mortality rate at time *t*.

<u>Average Length of Adult Fish</u>
Since most fish in the USVI do not have size limits and the minimum length of the exploited phase is typically unknown, the average length of adult fish can be calculated instead if an accurate estimate of length at maturity (L_m) is available. Fish length data is collected in 5 cm bins so a midpoint is used to determine if a fish is an adult or juvenile and for calculating averages. In addition to average length of adult fish, frequency occurrence graphs of numbers at lengths are useful for evaluating the health of a population.

Assessing Changes to Reef Fish Metrics
An advantageous property of statistical sampling theory is that survey design estimates, such as stratum density and the variance of stratum density, do not require knowledge of the underlying probability distribution (e.g., normal, gamma, etc.) of the respective population metric, (e.g., observations of stratum animal density, y_{hi}) (Cochran 1977). A second property, based on large sample theory, is that survey design estimates (e.g., population means and totals) are normally distributed due to the central limit theorem if sample size is large. These properties facilitate the analysis of survey design estimates among times or areas (e.g., monitoring density over time, assessing MPA effectiveness).

A simple, straightforward approach to performing statistical tests for differences among survey estimates for a particular time or area is via inspection of confidence intervals (*CI*). If the sample

is relatively large (n > 100) and has a normal distribution, the survey mean ($\bar{y}_{st}$) will lie within a *CI* bounded by:

$$\bar{y}_{st} \pm t_{\alpha/k,df} SE[\bar{y}_{st}]$$

with a probability of α, the Type I error rate, and where t is the critical value of Student's t-distribution, and degrees of freedom $d.f. = n_{h-1}$. Most commonly used reef metrics do not possess a normal distribution which means the Type I error rate will not equal α. Cochran (1977) states α will be very close to what is expected if:

$$n > 25\ G_1^2$$

where G_1^2 is a Fisher's measure of skewness. If a sample is too small and the population is heavily skewed, transforming the data (e.g., log[y_{st} + 1], [y_{st}]2) may help. With the cooperative effort of this program, this is typically not an issue.

*CI*s can be used to test the hypothesis that samples were drawn from the same population, as is done to assess temporal change or determine MPA effectiveness. Cochran (1977), Sokal and Rohlf (2001), and Zar (1996) describe methods using *CI*s to test for differences among means. A comparison of multiple *CI*s (e.g., a time series) requires a Bonferoni adjustment to α. The Bonferoni adjustment is necessary because the true Type I error rate of simultaneous multiple tests is not α, as it should be for a single test. As the number of means (e.g., years) increases, however, a different adjustment may be more appropriate, for instance Tukey's or SNK (Sokal and Rohlf 2001).

A useful relationship is that the 95% CI for a population metric is approximately twice the *CV*, because the value of t for α = 0.05 and *d.f.* > 20 is approximately 2. Thus, for example, a stratified random sampling survey that provides a domain-wide estimate of abundance with a *CV* of 15% would be able to statistically detect a minimum change of 30% in population abundance between survey time periods (with a Type I error rate = 0.05).

Multi-Species Fishery Stock Assessments

Periodically, it is important to quantitatively assess stocks of the exploited reef species across the sampling domain and evaluate their status relative to established Federal and International benchmarks for sustainable management of fishery resources. Calculation of mean fish density by lifestage and $\bar{L}$ for each of the focal species is described above. Population dynamic parameters such as natural mortality rate, fishing mortality rate, spawning stock biomass, and spawning potential ratio may also be derived from the data set annually or when needed. Methodologies for computing these parameters from the data can be found in the scientific literature; for example, in Ault and Ehrhardt (1991), Ehrhardt and Ault (1992), and Ault and Olson (1996).

Summary Reporting

At the end of each survey season, NPS will prepare a report containing analyses described in the section above. This report will provide managers and interested parties a single document from

which to evaluate spatial and temporal trends of population level metrics. Specifics of this report are described below.

To generate this report some supplemental fields will need to be added to the analysis ready data set in Table SOP 9.1 based upon a compiled lookup table containing the relevant information (Table SOP 9.4). This lookup table (tlu_Species in NPS-SFCN database) requires an initial investment of effort to research L_m (length at maturity), L_E (length of exploited phase), whether a species is considered a reef fish for purpose of reef fish species richness calculation, and what trophic level it belongs to. Much of this information is available from Fishbase.org or from the research literature. However differences in these values can cause differences in reports across agencies (presumably minor) so there is benefit to inter-agency sharing and comparing of these lookup tables and links to source references should be maintained.

Table SOP 9.4 Additional fields for analysis ready data set.

Field	Description
Maturity	"Adult" or "Juv" based upon *len* compared with length at maturity.
Exploited	"Yes/No" column based upon *len* compared with minimum length of exploited phase.
Reef Fish	"Yes/No" based upon whether species is to be included in the Reef Fish Species Richness calculation (i.e., does not include cryptic, pelagic, or nocturnal species)
Trophic	Trophic category (P – Main diet consists of fish (piscivorous); H – Main diet consists of algae, seagrasses, organic detritus, etc.; SI – Main diet consists of sessile invertebrates; MI – Main diet consists of mobile invertebrates; Z – Main diet consists of plankton such as phytoplankton and/or zooplankton)
NPSReportZone	BUIS, SARI, OutBUIS, OutNPS
Family name	Scientific family name
Genus name	Scientific genus name

Individual Fish Species

A basic summary report will be created for all species using the metrics described in Table SOP 9.5. Individual 2 page summaries will be created for 24 focal species listed in Table SOP 9.6. An example of these two page summaries is provided in Figures SOP 9.1 and 9.2 below.

Separating Adults from Juveniles

Length at maturity (L_m) for individual species is determined from published literature or Fishbase.org. A lookup table (tlu_Species) of these values will be maintained by NPS including references. If a fish length is $\geq L_m$, it is classified as an adult, otherwise it is classified as juvenile. In the case where lengths have been binned, the mid-point is used as the default length for all fish in that bin.

Exploited Species Metrics

The only species with a size limit restriction in the USVI is yellowtail snapper. Thus this is the only species recorded under the exploited density metric.

NPS Reporting Zones

Data reports include several metrics that are broken down by reporting zone. In some cases these are the same as management zone and in other cases multiple management zones may be lumped into a single reporting zone (e.g., OutNPS). A description is included below:

St. Croix

BUIS = Buck Island Reef National Monument
SARI = Salt River Bay National Historical Park and Ecological Preserve
OutBUIS = Initial area south of BUIS monitored from 2003-2010
OutNPS = All areas outside BUIS and SARI including EEMP

St. John

VIIS = Virgin Islands National Park
VICR = Virgin Islands Coral Reef National Monument
InitOutNPS = Initial areas outside VIIS and VICR using sampling frame from 2003-2010.
OutNPS = Outside NPS parks including all of St. Thomas

Table SOP 9.5. Individual species metrics for summary report.

Occupancy	Adult (SE) Juvenile (SE) Total (SE)
Density	Adult (Mean, SE) Juvenile (Mean, SE) Total (Mean, SE) Exploited Phase (Mean, SE)
Coefficient of Variation (CV)	Adult Density
Abundance	Adult (Mean, SE) Juvenile (Mean, SE)
Fish Length	Max Length (cm) Average Adult Length (cm) Average Exploited Length (cm)
Length Frequency	Number of fish in 5 cm length bins

Table SOP 9.6. Focal species list for reporting.

	Common Name	Scientific Name	Optimization Species
Grouper	Graysby	*Cephalopholis cruentatus*	
	Coney	*Cephalopholis fulva*	X
	Red Hind	*Epinephelus guttatus*	X
	Yellowfin Grouper	*Mycteroperca venenosa*	
Snapper /Grunt	French Grunt	*Haemulon flavolineatum*	X
	Bluestripe Grunt	*Haemulon sciurus*	
	Mutton Snapper	*Lutjanus analis*	
	Schoolmaster	*Lutjanus apodus*	
	Gray Snapper	*Lutjanus griseus*	
	Mahogany Snapper	*Lutjanus mahogoni*	
	Lane Snapper	*Lutjanus synagris*	
	Yellowtail snapper	*Ocyurus chrysurus*	X
Other Focal Species	Ocean Surgeonfish	*Acanthurus bahianus*	
	Blue tang	*Acanthurus coeruleus*	X
	Queen triggerfish	*Balistes vetula*	X
	Ocean Triggerfish	*Canthidermis sufflamen*	
	Blue Runner	*Caranx crysos*	
	Foureye Butterflyfish	*Chaetodon capistratus*	X
	Hogfish	*Lachnolaimus maximus*	
	Striped Parrotfish	*Scarus iserti*	
	Redband Parrotfish	*Sparisoma aurofrenatum*	
	Stoplight Parrotfish	*Sparisoma viride*	X
	Threespot Damselfish	*Stegastes planifrons*	X
Exotic	Lionfish	*Pterois volitans*	

Makebelieve Snapper (*scientific name*)

Adult Density (#fish/100m² site)

Zone	Variable	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2014	2016
BUIS	Avg	0.83	0.90	0.93	0.89	1.50	1.30	1.60	1.90	1.70	2.10	1.90	2.20
	SE	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.25	0.25	0.25
SARI	Avg										0.98	0.69	1.18
	SE										0.80	0.80	0.80
OutNPS	Avg										0.76	0.83	0.79
	SE										0.15	0.15	0.15
OutBUIS	Avg		0.81	0.76	0.74	0.79	0.83	0.90	0.85	0.81			
	SE		0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50			

Adult Abundance (Total # adults in each zone expressed in 1000's)

Zone	Variable	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2014	2016
BUIS	Avg	166.5	180.5	186.6	178.5	300.9	260.8	321.0	381.1	341.0	421.3	381.1	441.3
	SE	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0	2.0	2.0
SARI	Avg										13.5	9.5	16.2
	SE										0.4	0.4	0.4
OutNPS	Avg										1632	1782	1696
	SE										12.9	12.9	12.9
OutBUIS	Avg		162.5	152.5	148.4	158.5	166.5	180.5	170.5	162.5			
	SE		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0			

Total Occupancy (Percent of 100m² sites occupied by adults and juveniles)

Zone	Variable	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2014	2016
BUIS	Avg	15	13	19	15	16	18	20	23	25	23	26	24
	SE	5	5	5	5	5	5	5	5	5	5	5	5
SARI	Avg										19	14	16
	SE										15	15	15
OutNPS	Avg										19	16	17
	SE										3	3	3
OutBUIS	Avg		13	18	16	18	21	19	15	12			
	SE		4	4	4	4	4	4	4	4			

Adult Average length (cm)

Zone	Variable	2002	2003	2004	2005	2006	2007	2008	2009	2010	2012	2014	2016
BUIS	Avg		32.5		32.5		32.5	34.3	36.8	35.7	37.1	38.0	38.8
	SE		2.5		2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5
SARI	Avg										32.5	32.5	32.5
	SE										2.5	2.5	2.5
OutNPS	Avg										32.5	32.5	32.5
	SE										2.5	2.5	2.5
OutBUIS	Avg		32.5		32.5	32.5		32.5	32.5				
	SE		2.5		2.5	2.5		2.5	2.5				

Size Class Distribution (Current Year, Last 3 years including current year, First 3 years (2002-2004))

Year	Zone	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	>100
Current	BUIS	0%	0%	21%	15%	11%	16%	14%	9%	8%	2%	3%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	SARI	0%	0%	26%	23%	26%	23%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	OutNPS	0%	0%	25%	20%	30%	23%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Last 3	BUIS	0%	0%	19%	18%	18%	19%	11%	6%	5%	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2002-04	BUIS	0%	0%	14%	28%	30%	27%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Figure SOP 9.1 Excel spreadsheet illustrating page 1 of a hypothetical individual species data summary for St. Croix.

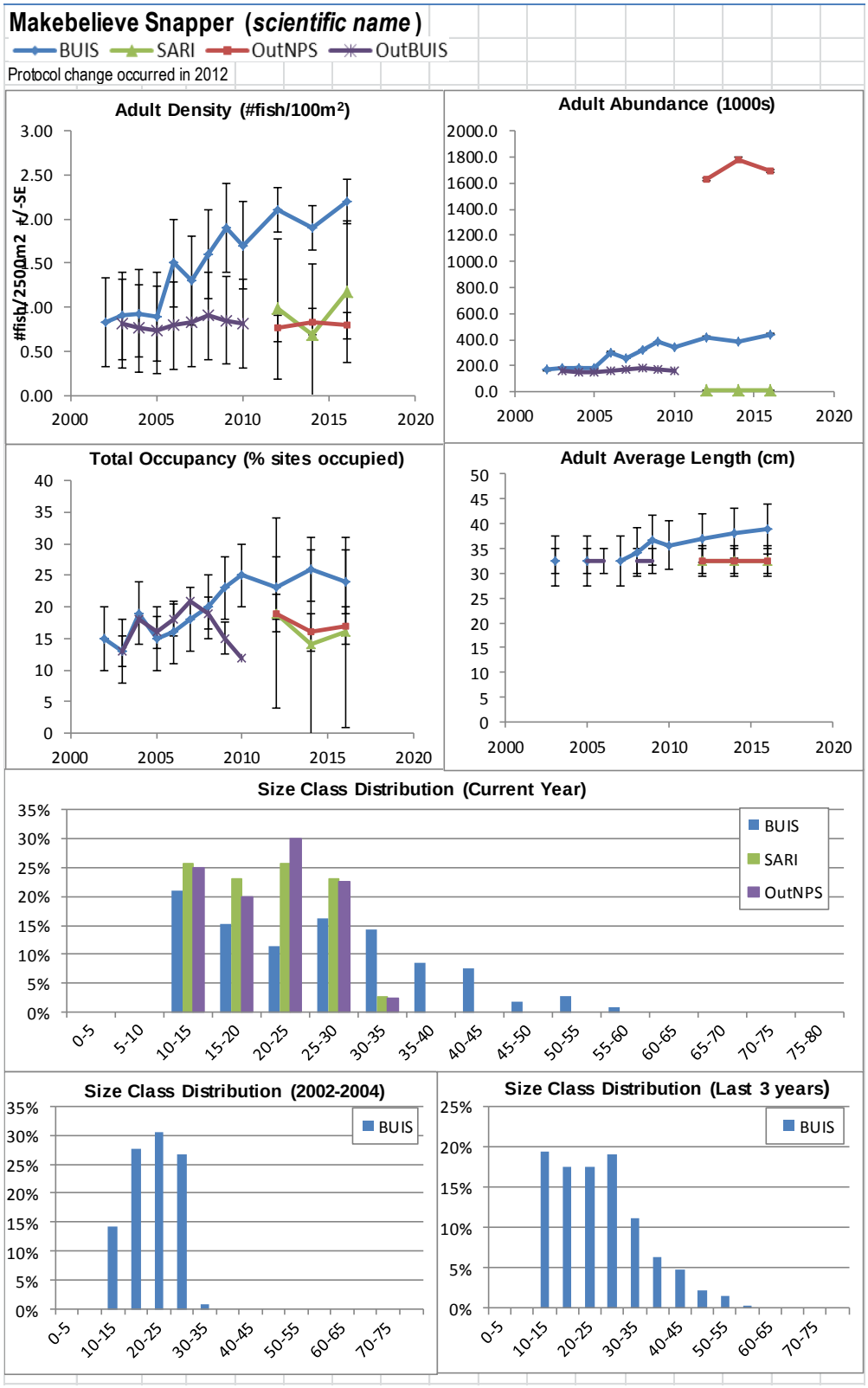

Figure SOP 9.2. Excel spreadsheet illustrating page 2 of a hypothetical individual species summary figures for St. Croix

Species Counts and Species Richness Summary

In addition to individual species reports a few community metrics should be reported. A running list of total number of species and new species observed by management zone should be reported in Table SOP 9.7. Mean species richness of reef fish by management zone over time should also be reported (Table SOP 9.8).

Table SOP 9.7 Summary of species counts for current sampling period

Zone	Total Species	Total New Species
BUIS		
SARI		
OutNPS		

Table SOP 9.8 Reef fish species richness (average # detected per 100m^2) for St. Croix.

Zone	Variable	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
BUIS	Avg											
	SE											
SARI	Avg											
	SE											
OutBUIS	Avg											
	SE											
OutNPS	Avg											
	SE											

Community-level Reporting

Loss of trophic guilds (e.g., loss of large piscivores) can impact reef fish communities as a whole and have cascading effects on the rest of the ecosystem (corals, algae, etc.).Trophic level reporting will be calculated as density using the following categories:

P – Main diet consists of fish (piscivorous)
H– Main diet consists of algae, seagrasses, organic detritus, etc.
I – Main diet consists of invertebrates
Z – Main diet consists of plankton such as phytoplankton and/or zooplankton)

If a species can be counted in more than one category, it will be included in both categories' summary statistics. Reporting will follow the format of Table SOP 9.8.

Average density of total groupers, total snappers, total grunts and total parrotfishes will be also collectively calculated. Reporting will follow the format of Table SOP 9.8.

Non-fish Species

Within the National Parks, non-fish species occurrence should also be included in reports. In the case of *Acropora palmatta*, *Acropora cervicornis*, and Black Coral, the coordinates of these species should be provided to the associated park Resource Management Chief to assist with their ESA species reporting and rare species tracking, but should not be shared with the public to avoid poaching problems, especially in the case of black coral.

Table SOP 9.9 Additional invertebrate species recorded (St. Croix).

	BUIS		SARI	
Species	# Sites Present	% Occurrence	# Sites Present	% Occurrence
Acropora palmatta (elkhorn coral)				
Acropora cervicornis (staghorn coral)				
Lobster				
Diadema				
Queen Conch				

Incorporating Pre-2012 Data into Tables and Graphs

Summary reports created by NPS will include data collected prior to protocol changes that took place in 2012. Appendix H has more details of the history of the legacy data collection.
The incorporation of this data into the desired tables and graphs requires several decisions which are highlighted below:

- Grid and survey design statistics described in this SOP are used for the analysis
- Only hardbottom sites are included in analysis.
- Pre-2012 St. Croix data will be analyzed as a complete random design with the following 2 analysis zones
    - BUIS, 2003-2010
    - OutBUIS, 2003-2010
- Pre-2012 St. John data will be analyzed as a Stratified Random Design with the following 3 analysis zones
    - VIIS, 2003-2011, Midshelf reef as strata (In,out)
    - VICR, 2003-2011, Midshelf reef as strata (In,out)
    - InitOutNPS, 2003-2001, Midshelf reef as strata (In,out),
- Total number of grids (Ntot) is calculated for OutBUIS and InitOutNPS by using BB's sampling universe for these areas from 2003-2010. Ntots for BUIS, VIIS and VICR are calculated using current mapped park boundaries (this is different from the 2012 and later analysis in which any 50m x 50m grid cell which touches a boundary is considered "in" the park. Thus total abundance calculations will be based upon different areas and will automatically differ in the pre-2012 calculations).
- During post survey analysis, if two transects happen to have been surveyed within the same grid cell, the results of these two transects are averaged.

NPS-SFCN Data Summary Report procedures

The technical software specific step-by-step details of creating an NPS-SFCN Data Summary Report using the NPS-SFCN database and associated R Code are in Appendix I.

Design Performance Analysis

An analysis of sampling allocation performance should be completed after each season. This analysis aids in determining sampling allocation for the subsequent year as described in SOP 3. Sampling design performance is ultimately the result of trade-offs between surveying cost (usually measured by the number of samples) and population estimate precision. A performance measure that is typically used is the *CV* of density, which is defined and discussed in detail in

SOP 3. Additional data helps define the variance structure for each stratum which can change the allocation of sampling effort.

Revision History Log

Version #	Date	Revised by	Changes	Justification

Literature Cited

Ault, J. S., J. A. Bohnsack, S. G. Smith, and J. G. Luo. 2005. Towards sustainable multispecies fisheries in the Florida, USA, coral reef ecosystem. *Bulletin of Marine Science* 76:595-622.

Ault, J. S. and N. M. Ehrhardt. 1991. Correction to the Beverton and Hold Z-estimator for truncated catch length-frequency distributions. *ICLARM Fishbyte* 9:37-39.

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Ault, J. S., S. G. Smith, G. A. Meester, J. Luo and J. A. Bohnsack. 2001. Site characterization for Biscayne National Park: assessment of fisheries resources and habitats. NOAA Technical Memorandum NMFS-SEFSC-468. 185 p.

Beverton, R. J. H. and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fishery Investigation Series II, Ministry of Agriculture Fisheries and Food, London XIX:1-533.

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Sokal, R. R. and F. J. Rohlf. 2001. Biometry; the principles and practice of statistics in biological research. 3rd edition. W.H. Freeman and Company, New York.

Zar, J. H. 1996. Biostatistical Analysis. 3rd edition. Simon & Schuster, Upper Saddle River, NJ.

Standard Operating Procedure 10 – Revising the Protocol

Version 1.0

Purpose
Define how changes in the protocol will occur and how they will be tracked.

When used
Changes can be suggested at any time following the procedures outline below.

Procedures
Once published in the Natural Resource Report Series, the protocol "A Cooperative Multiagency Reef Fish Monitoring Protocol for the U.S. Virgin Islands Coral Reef Ecosystem" can only be modified through the use of a versioning system. The South Florida / Caribbean Network will take charge of editing changes to the protocol and will follow the following guidance:

1) Changes to the protocol that affect multiple agencies, i.e., sampling, field data forms, stratification, quality assurance/quality control, data management, and/or analysis theory and equations, require concurrence of NOAA, University of Miami-RSMAS, and the National Park Service South Florida / Caribbean Network preferably by the authors themselves or their replacements within the respective agencies. If modifications are major, outside review may be needed.

2) Minor editorial changes and formatting can proceed provided they do not affect the content and substance of the protocol and are communicated to all parties. Such changes will only require in-house review by network staff. Suggestions can be made at any time, but SFCN may choose to compile them over the course of a year before releasing a new version,

3) Changes in details of respective agency analysis and reporting procedures do not need review as they are not included here with the exception of SFCN. Changes in the details of SFCN's reporting procedures which are described under this protocol can occur and are dealt with similarly to 2) above but should stay under the umbrella of the descriptions in this protocol. However NPS-SFCN will inform other agencies of updates to their analysis and reporting procedures as other groups may wish to use the same database analysis and graphing tools.

4) Protocols edits and versioning are tracked in the Revision History Log attached to the entire protocol and each individual SOP. Major changes results in an update by whole numbers (i.e,. version 1.0, version 2.0, etc.) and minor changes by hundredths (e.g., version 1.01, version 1.02, etc.) Record the new version number, date of revision, author of the revision, describe the change, and provide a rationale for the change.

5) *IMPORTANT:* Any changes to an individual SOP must also be tracked in the protocol's Revision History Log and the version number of the protocol MUST be updated, even if the change is editorial and only to one SOP.

6) A digital version of the new protocol will be distributed to all agencies, organizations, and persons involved in implementing the protocol including parks and other areas the

monitoring is being implemented within. The protocol will also be made available on the SFCN website and at http://irma.nps.gov.

7) Each agency/organization is responsible for informing their respective data manager about the changes to the protocol, so the new version number can be incorporated in the project metadata, reports, etc.

Revision History Log

Version #	Date	Revised by	Changes	Justification

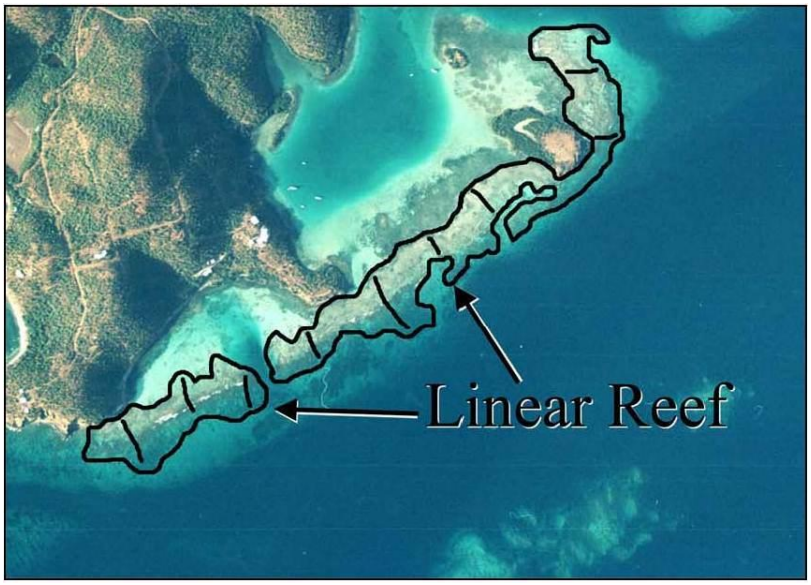
Appendix A. Description of Habitat Classifications.

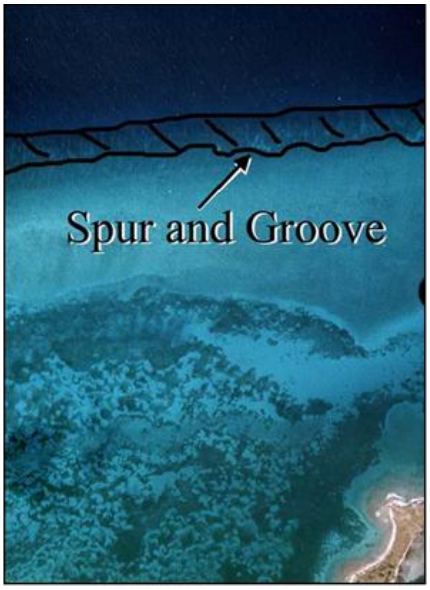
A detailed description of the five hardbottom habitats (linear reef, patch reef, bedrock, pavement and scattered coral/rock) types used for this protocol can be found in Kendall et al. 2001. An excerpt from that document is included in this appendix.

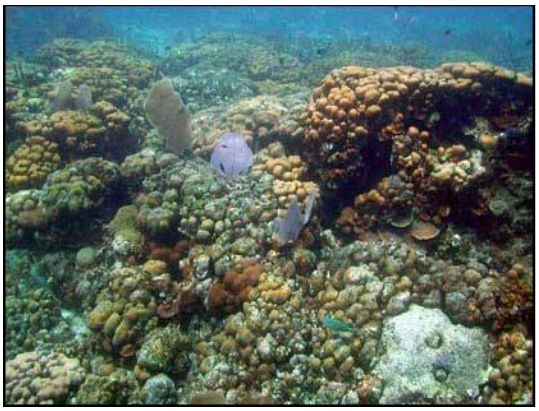
Linear Reef: A combination of linear reefs and spur and groove formations.

Linear Reef: Linear coral formations that are oriented parallel to shore or the shelf edge. These features follow the contours of the shore/shelf edge. This category is used for such commonly used terms as fore reef, fringing reef, and shelf edge reef.

Spur and Groove: Habitat having alternating sand and coral formations that are oriented perpendicular to the shore or bank/shelf escarpment. The coral formations (spurs) of this feature typically have a high vertical relief compared to pavement with sand channels and are separated from each other by 1-5 meters of sand or bare hardbottom (grooves), although the height and width of these elements may vary considerably. This habitat type typically occurs in the fore reef or bank/shelf escarpment zone.







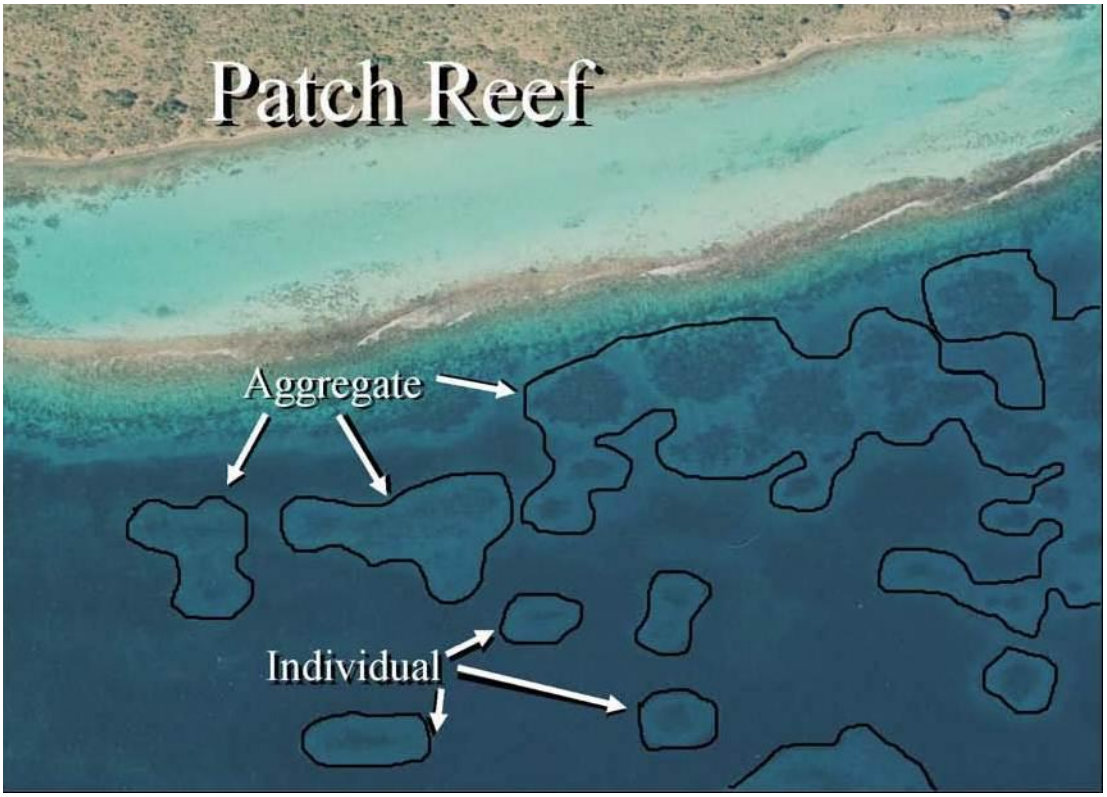
Linear Reef

Spur and Groove

Patch Reef(s): Coral formations that are isolated from other coral reef formations by sand, seagrass, or other habitats and that have no organized structural axis relative to the contours of the shore or shelf edge. A surrounding halo of sand is often a distinguishing feature of this habitat type when it occurs adjacent to submerged vegetation. Two types of patch reefs were combined.

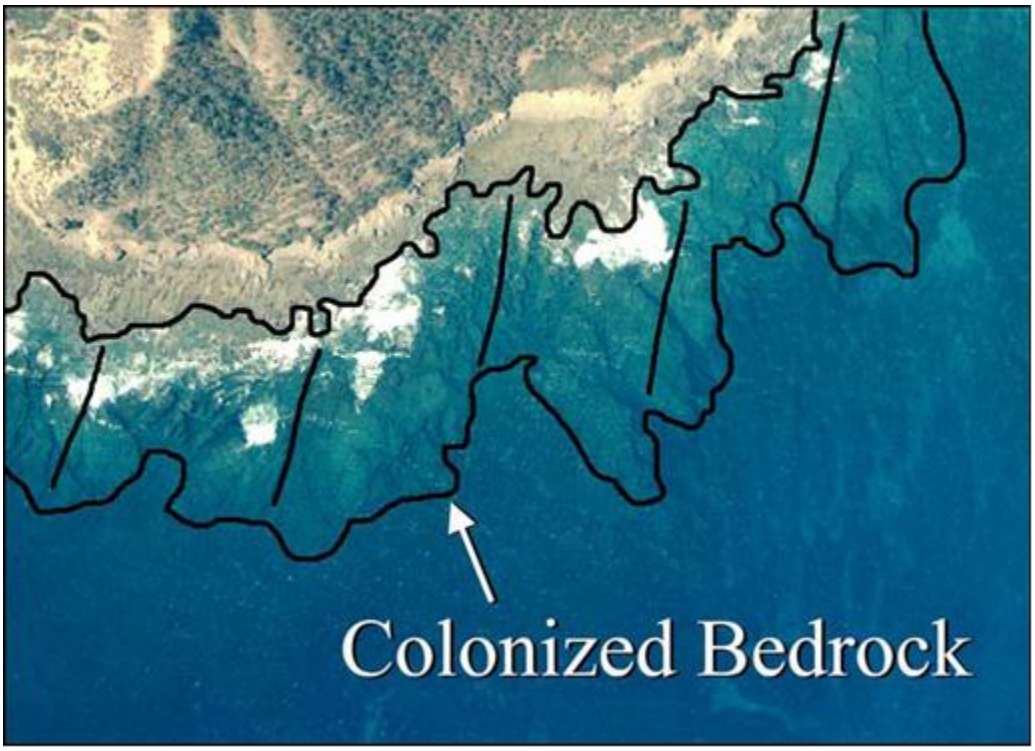
Individual patch reef: Distinctive single patch reefs that are equal to or larger than the minimum mapping unit. When patch reefs occur in submerged vegetation and a halo is present, the halo is included with the patch reef polygon.

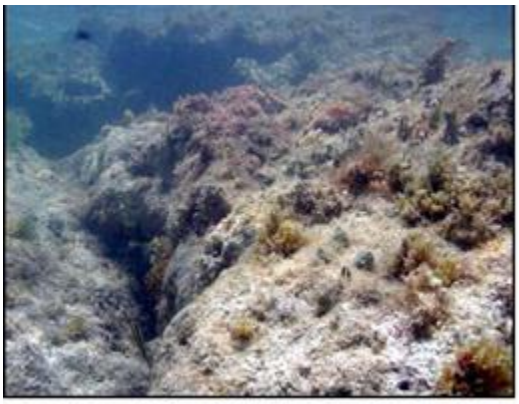
Aggregate patch reefs: Clustered patch reefs that individually are too small (smaller than the MMU) or are too close together to map separately. Where aggregate patch reefs share halos, the halo is included in the polygon.



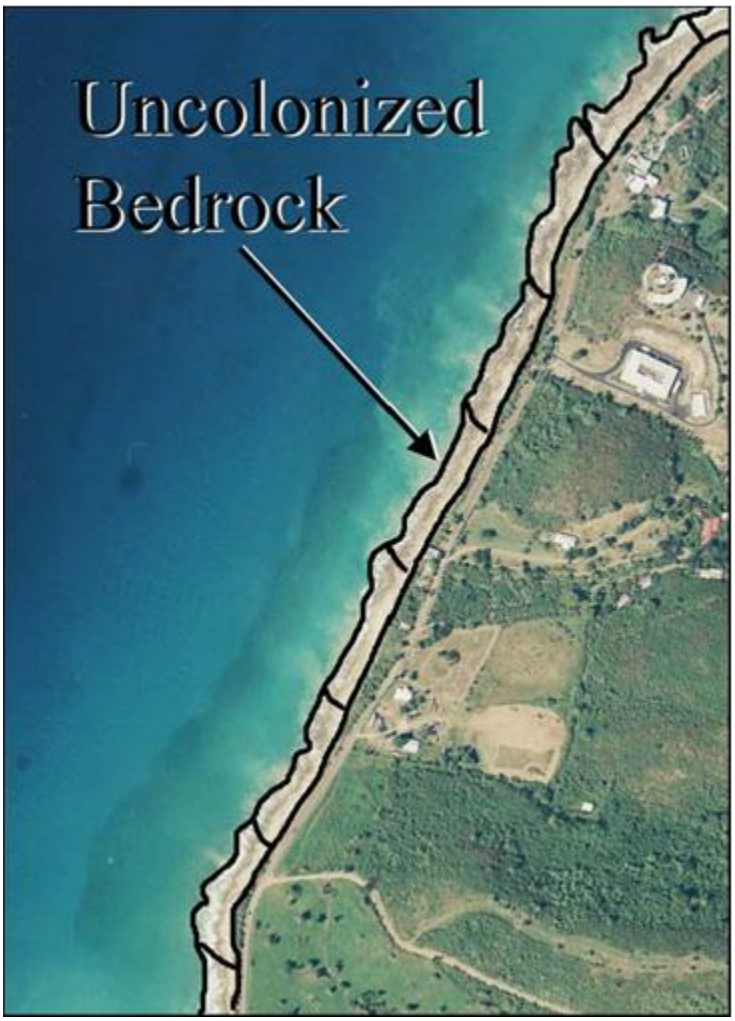
Bedrock: The geological formation and subsequent erosion has resulted in the exposure of bedrock in the USVI. Colonized and uncolonized bedrock were combined into a single bedrock category.

Colonized Bedrock: Exposed bedrock contiguous with the shoreline that has coverage of macroalgae, hard coral, gorgonians, and other sessile invertebrates that partially obscures the underlying rock.





Uncolonized Bedrock: Exposed bedrock contiguous with the shoreline that has sparse coverage of macroalgae, hard coral, gorgonians and other sessile invertebrates that does not obscure the underlying rock.

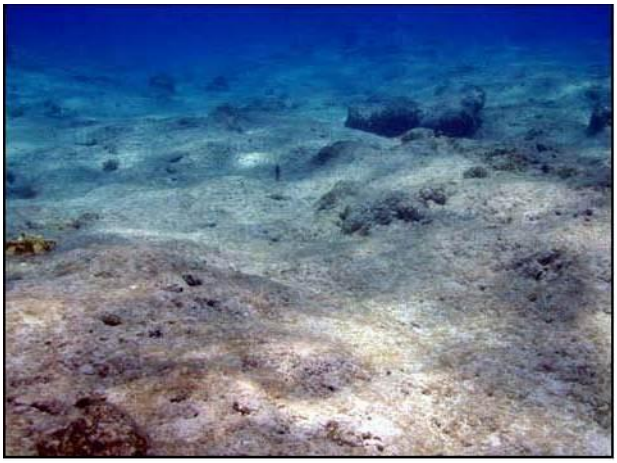


Pavement: Solid carbonate rock that constitutes the majority of hardbottom habitat on USVI shelf was classified as a general pavement category. The pavement category is a combination of; colonized pavement, colonized pavement with sand channels, uncolonized pavement and uncolonized pavement with sand channels.

Colonized Pavement: Flat, low-relief, solid carbonate rock with coverage of macroalgae, hard coral, gorgonians, and other sessile invertebrates that are dense enough to partially obscure the underlying carbonate rock.

Colonized Pavement with Sand Channels: Habitat having alternating sand and colonized pavement formations that are oriented perpendicular to the shore or bank/shelf escarpment. The sand channels of this feature have low vertical relief compared to spur and groove formations. This habitat type occurs in areas exposed to moderate wave surge such as that found in the bank/shelf zone.

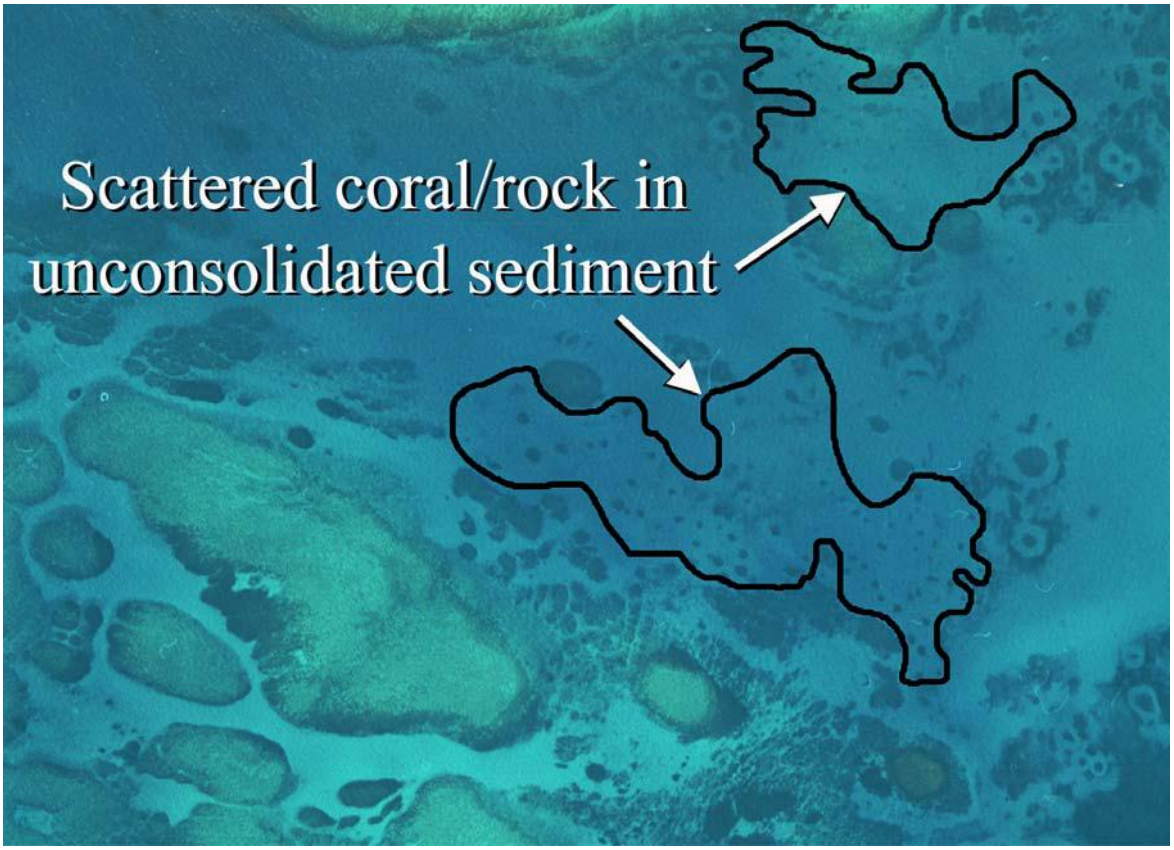
Uncolonized Pavement: Flat, low relief, solid carbonate rock that is often covered by a thin sand veneer. The pavement's surface often has sparse coverage of macroalgae, hard coral, gorgonians, and other sessile invertebrates that does not obscure the underlying carbonate rock



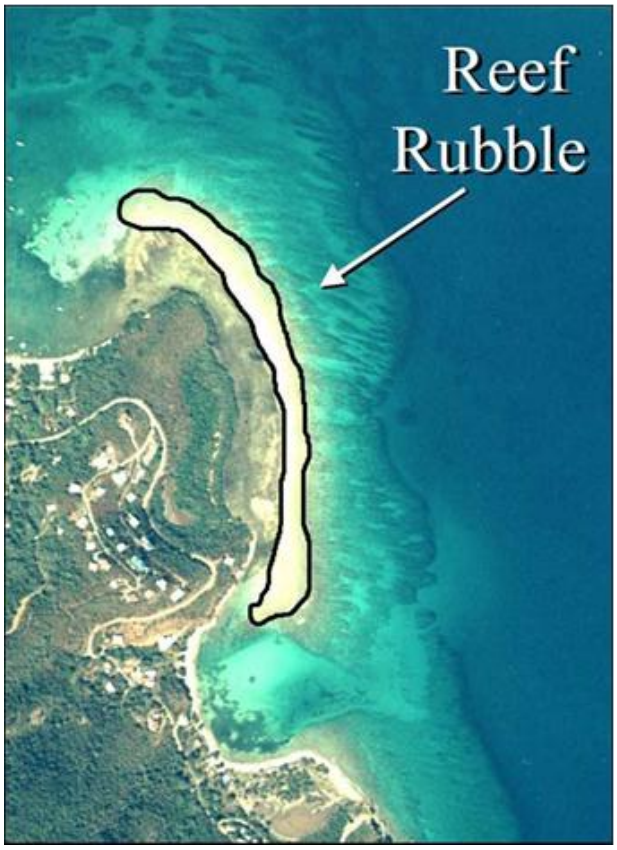
Uncolonized Pavement with Sand Channels: Habitat having alternating sand and uncolonized pavement formations that are oriented perpendicular to the shore or bank/shelf escarpment. The sand channels of this feature have low vertical relief compared to spur and groove formations.

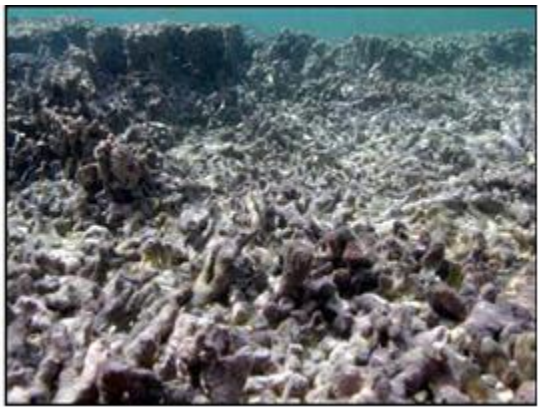
Scattered Coral/Rock: This category is a combination of scattered coral/rock in unconsolidated sediment and reef rubble.

Scattered Coral/Rock in Unconsolidated Sediment: Primarily sand or seagrass bottom with scattered rocks or small, isolated coral heads that are too small to be delineated individually (i.e., smaller than individual patch reef).



Reef Rubble: Dead, unstable coral rubble often colonized with filamentous or other macroalgae. This habitat often occurs landward of well-developed reef formations in the reef crest or back reef zone.





Literature Cited

Kendall, M.S., C.R. Kruer, K.R. Buja, J.D. Christensen, M. Finkbeiner, R.A. Warner and M.E. Monaco 2001. Methods used to map the benthic habitats of Puerto Rico and the U.S. Virgin Islands NOAA Technical Memorandum, vol. 152, Silver Spring, Maryland.

Appendix B. Printable Field Forms

The following pages are data sheets formatted so that they can be printed directly onto sheets of underwater paper for use in the field. For this reason, no page numbers or headings are included.

1st page: Boat/ Field log

2ndpage: Transect fish data sheet

3rd page: Transect habitat data sheet

4th page: RVC fish and habitat data sheet

Field / Boat Log **DATE** _____

Page _____ of _____

Dive of Day	Site ID	Est. Time	Fish Diver	Habitat Diver	Latitude	Longitude	Habitat Type	GPS Unit	Comments

SAND / SAV ONLY (Reef w/i 3m of P diver)
0 < 4 m^2 > 4 m^2

Name:		Station:		Method:	P T
Buddy:		Date:		Chain 1: *	-
Bearing:		Time		Chain 2: *	-

* Transfer chains to Habitat Data Sheet *

	fish ID	<5	5-10	10-15	15-20	20-25	25-30	30-35	>35
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
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26									
27									
28									
29									
30									
31									
32									
33									
34									
35									

Biogeography Program Benthic Composition Data Sheet

Fish transect diver	
Habitat diver	

Station	
Date	
Time	

STRUCTURE (Circle)					
Hard (select)	Patch Reef	Col. Pavement	Linear Reef	Scattered Coral/Rock	Col. Bedrock
Soft					

Soft sites only: (REEF w/i 3 m of diver)		
none	< 4m^2	> 4m^2

Rugosity (REEF only)	Begin	End
Chain 1		
Chain 2		

Transfer chains from fish sheet

Shelter Characteristics	Q1	Q2	Q3	Q4	Q5
Quadrat Position					
Quadrat Depth (ft)					

Abiotic Substrate (% cover)	Q1		Q2		Q3		Q4		Q5	
	% cov	max ht	% cov	max ht	% cov	max ht	% cov	max ht	% cov	max ht
Hard Bottom										
Sand										
Rubble										
Fine sed /silt										

Biotic Cover (% cover)	Q1			Q2			Q3			Q4			Q5		
BARE SUBSTRATE															
Hard Coral (ID to spp if possible)	% live	% dis / dead	% bleach	% live	% dis / dead	% bleach	% live	% dis / dead	% bleach	% live	% dis / dead	% bleach	% live	% dis / dead	% bleach
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
Fire Coral	%	% dis	% blch	%	% dis	% blch	%	% dis	% blch	%	% dis	% blch	%	% dis	% blch
Millepora spp- MILSPP															
Algae	% cov	Ht (cm)		% cov	Ht (cm)		% cov	Ht (cm)		% cov	Ht (cm)		% cov	Ht (cm)	
Macroalgae >1cm - MACROA															
Cyano / Fil. Algae - FILCYA															
Rhodoliths - RHODOL															
Crustose algae - RHOCRU															
Turf algae/DCA* - TURALG															
Seagrasses	% cov	Ht (cm)		% cov	Ht (cm)		% cov	Ht (cm)		% cov	Ht (cm)		% cov	Ht (cm)	
Halophila - HALDEC															
Halodule - HALBEA															
Syringodium - SYRFIL															
Thalassia - THATES															
Sponges	%	Ht (cm)	# ind	%	Ht (cm)	# ind	%	Ht (cm)	# ind	%	Ht (cm)	# ind	%	Ht (cm)	# ind
Barrel/tube/vase - PORBTV															
Encrusting form - PORENC															
Gorgonia (%, ht (cm), # ind)	%	Ht (cm)	# ind	%	Ht (cm)	# ind	%	Ht (cm)	# ind	%	Ht (cm)	# ind	%	Ht (cm)	# ind
Sea plume/rod/whip - GORPRW															
Sea fans - GORFAN															
Encrusting gorg. - ERYCAR															
Other	%	# ind		%	# ind		%	# ind		%	# ind		%	# ind	
Anemones (non-encrust)- ACTSPP															
Tunicates - ASCSPP															
Hydroids (non-encrust) - HYDSPP															
Zoanthids - ZOASPP															

Macro-invertebrates	
Queen Conch (*E. gigas*)	
MATURE Flared Lip Present (# per transect)	IMMATURE No Flared Lip (# per transect)
LOBSTER (*P. argus*) (# per transect)	DIADEMA (*D. antillarum*) (# per transect)

Acropora presence (check if YES)			
A. palmata		*A. cervicornis*	
Transect	Site	Transect	Site

Notes

Marine Debris			
Debris Type	area (cm^2)	area aff'ctd (cm^2)	Colonized by

* DCA- dead coral algae = turf algae

Diver: _____ Date: _____ Field Number:

Buddy: _____ Sample Start Time: _____

Dive Start Time: _____ Sample End Time: _____

Dive End Time: Max Dive Depth: _____ ft

Station Depth: _____ ft

Fishing Gear:

Habitat type:	
1. Contiguous S&G	4. Rubble
2. Cont. Not S&G	5. (Matrix)
3. Isolated	0. (Sand)

Underwater visibility: _____ ft m

Water temperature: _____ F

Radius of cylinder: 7.5m 5.0m

Current: None Mod. High

Substrate Slope		
Max depth _____ft		
Min depth _____ft		
Max vertical Relief		
Hard Relief _____m		
Soft Relief _____m		
Surface Relief Coverage %		
	Hard	Avg. of Soft
< 0.2 m	%	%
0.2-0.5 m	%	%
0.5-1.0 m	%	%
1.0-1.5 m	%	%
> 1.5 m	%	%
TOTAL	100%	100%

Abiotic Footprint	
SAND	%
HARD-B	%
RUBBLE	%
Total	100%

Biotic Cover - Dominant Biological Cover %			
SAND		HARDBOTTOM	
"Bare"		~~Crustose Algae~~	
~~Algal Turf (<1cm)~~		Algae (<1cm)	
Macro Algae		Algae (>1cm)	
Sea grass		Live Stony Coral	
Sponge		Octocoral	
_____ Other 1		Sponge	
_____ Other 2		_____ Other 1	
		_____ Other 2	
TOTAL	100%		100%

Species	N	Avg	Min	Max

Species	N	Avg	Min	Max

Comments:

Presence of: *A. palmata* *A. cervicornis* *Dendrogyra cylindrus*

Montastraea complex (*M. annularis* *M. faviolata* *M. franksi* [if known])

Mycetophyllia ferox *Dichocoenia stokesii*

Black Coral Spiny Lobster # Conch # Diadema #

Appendix C. Species Codes for Reef Fish

Species Code	Common Name	Scientific Name
ABHI	Flat needlefish	*Ablennes hians*
ABSA	Sergeant major	*Abudefduf saxatilis*
ABTA	Night sergeant	*Abudefduf taurus*
ACBL	TUBE BLENNY sp	*Acanthemblemaria UNK*
ACUK	SURGEONFISH sp	*Acanthurus UNK*
ACAS	Roughhead blenny	*Acanthemblemaria aspera*
ACBA	Ocean surgeonfish	*Acanthurus bahianus*
ACCH	Doctorfish	*Acanthurus chirurgus*
ACCO	Blue tang	*Acanthurus coeruleus*
ACDE	Pipehorse	*Acentronura dendritica*
ACMA	Secretary blenny	*Acanthemblemaria maria*
ACPO	Honeycomb cowfish	*Acanthostracion polygonius*
ACQU	Scrawled cowfish	*Acanthostracion quadricornis*
ACSP	Spinyhead blenny	*Acanthemblemaria spinosa*
AENA	Spotted eagle ray	*Aetobatus narinari*
ALAF	Mutton hamlet	*Alphestes afer*
ALSC	Scrawled filefish	*Aluterus scriptus*
ALVU	Bonefish	*Albula vulpes*
AMPI	Redspotted hawkfish	*Amblycirrhitus pinos*
ANSU	Black margate	*Anisotremus surinamensis*
ANVI	Porkfish	*Anisotremus virginicus*
APAU	Bridle cardinalfish	*Apogon aurolineatus*
APBI	Barred cardinalfish	*Apogon binotatus*
APLA	Whitestar cardinalfish	*Apogon lachneri*
APMA	Flamefish	*Apogon maculatus*
APUK	CARDINALFISH sp	*Apogon UNK*
APPS	Twospot cardinalfish	*Apogon pseudomaculatus*
APQU	Sawcheek cardinalfish	*Apogon quadrisquamatus*
APTO	Belted cardinalfish	*Apogon townsendi*
ARRH	Sea bream	*Archosargus rhomboidalis*
ASPU	Blackfin cardinalfish	*Astrapogon puncticulatus*
ASST	Conchfish	*Astrapogon stellatus*
ATUK	SILVERSIDE sp	*Atherinomorus UNK*
AUMA	Trumpetfish	*Aulostomus maculatus*
BASO	Frillfin goby	*Bathygobious soporator*
BAVE	Queen triggerfish	*Balistes vetula*
BEUK	NEEDLEFISH Family sp	*Belonidae UNK*
BOBO	White-eye goby	*Bollmannia boqueronensis*
BOLU	Peacock flounder	*Bothus lunatus*
BOOC	Eyed flounder	*Bothus ocellatus*

Species Code	**Common Name**	***Scientific Name***
BORU	Spanish hogfish	*Bodianus rufus*
BOUK	LEFTEYE FLOUNDER sp	*Bothus UNK*
CABJ	Jolthead porgy	*Calamus bajonado*
CABR	Yellow jack	*Carangoides bartholomaei*
CACA	Saucereye porgy	*Calamus calamus*
CACR	Blue runner	*Caranx crysos*
CAHI	Crevalle jack	*Caranx hippos*
CALA	Horse-eye jack	*Caranx latus*
CAUK	PORGY sp	*Calamus UNK*
CALU	Black jack	*Caranx lugubris*
CAMA	American whitespotted filefish	*Cantherhines macrocerus*
CNUK	PUFFER sp	*Canthigaster UNK*
CAPA	Sheepshead porgy	*Calamus penna*
CAPT	Pluma	*Calamus pennatula*
CAPU	Orangespotted filefish	*Cantherhines pullus*
CXUK	JACK sp	*Caranx UNK*
CARO	Sharpnose puffer	*Canthigaster rostrata*
CARU	Bar jack	*Carangoides ruber*
CASU	Ocean triggerfish	*Canthidermis sufflamen*
CEAR	Cherubfish	*Centropyge argi*
CECR	Graysby	*Cephalopholis cruentata*
CEFU	Coney	*Cephalopholis fulva*
CEUN	Common snook	*Centropomus undecimalis*
CHUK	PIKEBLENNY sp	*Chaenopsis UNK*
CHAN	Bridled burrfish	*Chilomycterus antennatus*
CHCA	Foureye butterflyfish	*Chaetodon capistratus*
CHCY	Blue chromis	*Chromis cyanea*
CHFA	Atlantic spadefish	*Chaetodipterus faber*
CHLI	Yellowface pikeblenny	*Chaenopsis limbaughi*
CHMU	Brown chromis	*Chromis multilineata*
CHOA	Bluethroat pikeblenny	*Chaenopsis ocellata*
CHOU	Spotfin butterflyfish	*Chaetodon ocellatus*
CHSE	Reef butterflyfish	*Chaetodon sedentarius*
CHST	Banded butterflyfish	*Chaetodon striatus*
CLPA	Creole wrasse	*Clepticus parrae*
CLUK	HERRING Family sp	*Clupeidae UNK*
CODI	Colon goby	*Coryphopterus dicrus*
COEI	Pallid goby	*Coryphopterus eidolon*
COEL	Shortfin pipefish	*Cosmocampus elucens*
COGL	Bridled goby	*Coryphopterus glaucofraenum*
COLI	Peppermint goby	*Coryphopterus lipernes*

Species Code	Common Name	*Scientific Name*
COPE	Masked/Glass goby	*Coryphopterus personatus/hyalinus*
CYUK	GOBY sp	*Coryphopterus UNK*
COTR	Manytooth conger	*Conger triporiceps*
CRRO	Bluelip parrotfish	*Cryptotomus roseus*
CTSA	Dash goby	*Ctenogobius saepepallens*
CTST	Marked goby	*Ctenogobius stigmaticus*
DAAM	Southern stingray	*Dasyatis americana*
DAVO	Flying gurnard	*Dactylopterus volitans*
DEUK	SCAD sp	*Decapterus UNK*
DEMA	Mackerel scad	*Decapterus macarellus*
DIAR	Silver porgy	*Diplodus argenteus caudimacula*
DIBI	Dwarf sand perch	*Diplectrum bivittatum*
DIFO	Sand perch	*Diplectrum formosum*
DIHB	Spottail pinfish	*Diplodus holbrooki*
DIHO	Balloonfish	*Diodon holocanthus*
DIHY	Porcupinefish	*Diodon hystrix*
DOME	Dwarf wrasse	*Doratonotus megalepis*
ECCA	Chain moray	*Echidna catenata*
ECNA	Sharksucker	*Echeneis naucrates*
ECNE	Whitefin sharksucker	*Echeneis neucratoides*
ELUK	GOBY sp	*Elacatinus UNK*
ELCH	Shortstripe goby	*Elacatinus chancei*
ELDI	Orangesided goby	*Elacatinus dilepis*
ELEV	Sharknose goby	*Elacatinus evelynae*
ELLO	Spotlight goby	*Elacatinus louisae*
ELMU	Greenbanded goby	*Elacatinus multifasciatus*
ELOC	Neon goby	*Elacatinus oceanops*
ELPR	Broadstripe goby	*Elacatinus prochilos*
ELSA	Leopard goby	*Elacatinus saucrus*
EMUK	TUBE BLENNY sp	*Emblemariopsis UNK*
EMPA	Sailfin blenny	*Emblemaria pandionis*
ENUK	ANCHOVIES Family sp	*Engraulidae UNK*
EEUK	TRIPLEFIN sp	*Enneanectes UNK*
ENNI	Viper moray	*Enchelycore nigricans*
EPAD	Rock hind	*Epinephelus adscensionis*
EPGU	Red hind	*Epinephelus guttatus*
EPMO	Red grouper	*Epinephelus morio*
EPST	Nassau grouper	*Epinephelus striatus*
EQLA	Jackknife fish	*Equetus lanceolatus*
EQPU	Spotted drum	*Equetus punctatus*
EUAL	Little tunny	*Euthynnus alletteratus*

Species Code	Common Name	*Scientific Name*
EUUK	MOJARRA sp	*Eucinostomus UNK*
EUGU	Silver jenny	*Eucinostomus gula*
EUJO	Slender mojarra	*Eucinostomus jonesii*
EUME	Flagfin mojarra	*Eucinostomus melanopterus*
GACU	Tiger shark	*Galeocerdo cuvier*
GECI	Yellowfin mojarra	*Gerres cinereus*
GICI	Nurse shark	*Ginglymostoma cirratum*
GNTH	Goldspot goby	*Gnatholepis thompsoni*
GBUK	GOBY Family sp	*Gobiidae UNK*
GBUK	Rockcut goby	*Gobiosoma grosvenori*
GRLO	Fairy basslet	*Gramma loreto*
GYFU	Green moray	*Gymnothorax funebris*
GYMI	Goldentail moray	*Gymnothorax miliaris*
GYUK	MORAY EEL sp	*Gymnothorax UNK*
GYMO	Spotted moray	*Gymnothorax moringa*
GYVI	Purplemouth moray	*Gymnothorax vicinus*
HAAL	Margate (White)	*Haemulon album*
HAAU	Tomtate	*Haemulon aurolineatum*
HABI	Slippery dick	*Halichoeres bivittatus*
HACH	Smallmouth grunt	*Haemulon chrysargyreum*
HACR	Caesar grunt	*Haemulon carbonarium*
HACU	Painted wrasse	*Halichoeres caudalis*
HACY	Yellowcheek wrasse	*Halichoeres cyanocephalus*
HAUK	GRUNT sp	*Haemulon UNK*
HAFL	French grunt	*Haemulon flavolineatum*
HAGA	Yellowhead wrasse	*Halichoeres garnoti*
HLUK	WRASSE sp	*Halichoeres UNK*
HAME	Cottonwick	*Haemulon melanurum*
HAMR	Spanish grunt	*Haemulon macrostomum*
HAMU	Clown wrasse	*Halichoeres maculipinna*
HAPA	Sailors choice	*Haemulon parra*
HAPI	Rainbow wrasse	*Halichoeres pictus*
HAPL	White grunt	*Haemulon plumierii*
HAPO	Blackear wrasse	*Halichoeres poeyi*
HARA	Puddingwife	*Halichoeres radiatus*
HASC	Bluestriped grunt	*Haemulon sciurus*
HAST	Striped grunt	*Haemulon striatum*
HECR	Glasseye snapper	*Heteropriacanthus cruentatus*
HELO	Brown garden eel	*Heteroconger longissimus*
HIUK	PIPEFISH sp	*Hippocampus UNK*
HIRE	Longsnout seahorse	*Hippocampus reidi*
HOAD	Squirrelfish	*Holocentrus adscensionis*

Species Code	Common Name	*Scientific Name*
HOCI	Queen angelfish	*Holacanthus ciliaris*
HOUK	ANGELFISH SP	*Holocanthus UNK*
HORU	Longspine squirrelfish	*Holocentrus rufus*
HOTR	Rock beauty	*Holacanthus tricolor*
HYAB	Yellowbelly hamlet	*Hypoplectrus aberrans*
HYCH	Yellowtail hamlet	*Hypoplectrus chlorurus*
HYGU	Shy hamlet	*Hypoplectrus guttavarius*
HYIN	Indigo hamlet	*Hypoplectrus indigo*
HYNI	Black hamlet	*Hypoplectrus nigricans*
HYUK	HAMLET sp	*Hypoplectrus UNK*
HYPU	Barred hamlet	*Hypoplectrus puella*
HYUN	Butter hamlet	*Hypoplectrus unicolor*
INVI	Boga	*Inermia vittata*
JEUK	HERRING sp	*Jenkinsia UNK*
KYSE	Chub (Bermuda/Yellow)	*Kyphosus sectator*
LABI	Spotted trunkfish	*Lactophrys bicaudalis*
LAUK	TRUNKFISH sp	*Lactophrys UNK*
LAMA	Hogfish	*Lachnolaimus maximus*
LANU	Hairy blenny	*Labrisomus nuchipinnis*
LATG	Trunkfish	*Lactophrys trigonus*
LATQ	Smooth trunkfish	*Lactophrys triqueter*
LIRU	Peppermint basslet	*Liopropoma rubre*
LOCY	Crested goby	*Lophogobius cyprinoides*
LOMI	Swordtail jawfish	*Lonchopisthus micrognathus*
LUAN	Mutton snapper	*Lutjanus analis*
LUAP	Schoolmaster	*Lutjanus apodus*
LUBU	Blackfin snapper	*Lutjanus buccanella*
LUCY	Cubera snapper	*Lutjanus cyanopterus*
LUGR	Gray snapper	*Lutjanus griseus*
LUJO	Dog snapper	*Lutjanus jocu*
LUMA	Mahogany snapper	*Lutjanus mahogoni*
LUSY	Lane snapper	*Lutjanus synagris*
LUUK	SNAPPER sp	*Lutjanus UNK*
MAAU	Goldline blenny	*Malacoctenus aurolineatus*
MABO	Diamond blenny	*Malacoctenus boehlkei*
MAGI	Dusky blenny	*Malacoctenus gilli*
MAUK	SCALY BLENNY sp	*Malacoctenus UNK*
MAMA	Rosy blenny	*Malacoctenus macropus*
MAPL	Sand tilefish	*Malacanthus plumieri*
MATR	Saddled blenny	*Malacoctenus triangulatus*
MAVE	Barfin blenny	*Malacoctenus versicolor*
MEAT	Tarpon	*Megalops atlanticus*

Species Code	Common Name	*Scientific Name*
MENI	Black durgon	*Melichthys niger*
MICA	Seminole goby	*Microgobius carri*
MICH	Yellowtail damselfish	*Microspathodon chrysurus*
MIUK	GOBY sp	*Microgobius UNK*
MISI	Microgobius signatus	*Microgobius signatus*
MOCI	Fringed filefish	*Monacanthus ciliatus*
MOUK	FILEFISH sp	*Monacanthus UNK*
MOTU	Slender filefish	*Monacanthus tuckeri*
MUCE	Striped mullet	*Mugil cephalus*
MUMA	Yellow goatfish	*Mulloidichthys martinicus*
MUUK	MORAY EEL Family sp	*Muraenidae UNK*
MYBO	Black grouper	*Mycteroperca bonaci*
MYBR	Sharptail eel	*Myrichthys breviceps*
MYUK	GROUPER sp	*Mycteroperca UNK*
MYIN	Yellowmouth grouper	*Mycteroperca interstitialis*
MYJA	Blackbar soldierfish	*Myripristis jacobus*
MYOC	Goldspotted eel	*Myrichthys ocellatus*
MRUK	SNAKE EEL sp	*Myrichthys UNK*
MYTI	Tiger grouper	*Mycteroperca tigris*
MYVE	Yellowfin grouper	*Mycteroperca venenosa*
NELO	Orangespotted goby	*Nes longus*
NEMA	Longjaw squirrelfish	*Neoniphon marianus*
NONE	No fish	*No fish*
OCCH	Yellowtail snapper	*Ocyurus chrysurus*
ODDE	Reef croaker	*Odontoscion dentex*
OGNA	Shortnose batfish	*Ogcocephalus nasutus*
OPAU	Yellowhead jawfish	*Opistognathus aurifrons*
OPUK	SNAKE EEL Family sp	*Ophichthidae UNK*
OIUK	JAWFISH sp	*Opistognathus UNK*
OPMC	Redlip blenny	*Ophioblennius macclurei*
OPMR	Banded jawfish	*Opistognathus macrognathus*
OPOP	Spotted snake eel	*Ophichthus ophis*
OPWH	Dusky jawfish	*Opistognathus whitehursti*
OXST	Spotfin goby	*Oxyurichthys stigmalophius*
PAAC	Highhat	*Pareques acuminatus*
PABA	Lancer dragonet	*Paradiplogrammus bairdi*
PAFU	Atlantic creolefish	*Paranthias furcifer*
PAMA	Seaweed blenny	*Parablennius marmoreus*
PESC	Glassy sweeper	*Pempheris schomburgkii*
POAR	Gray angelfish	*Pomacanthus arcuatus*
POPA	French angelfish	*Pomacanthus paru*
PRAC	Longsnout butterflyfish	*Prognathodes aculeatus*

Species Code	Common Name	*Scientific Name*
PRAR	Bigeye	*Priacanthus arenatus*
PRHI	Rusty goby	*Priolepis hipoliti*
PSMA	Spotted goatfish	*Pseudupeneus maculatus*
PTHE	Hovering goby	*Ptereleotris helenae*
PTVO	Red Lionfish	*Pterois volitans*
RERE	Common remora	*Remora remora*
RYBI	Freckled soapfish	*Rypticus bistrispinus*
RYSA	Greater soapfish	*Rypticus saponaceus*
SACO	Reef squirrelfish	*Sargocentron coruscum*
SAVE	Dusky squirrelfish	*Sargocentron vexillarium*
SCUK	PARROTFISH sp	*Scarus UNK*
SCCE	Midnight Parrotfish	*Scarus coelestinus*
SCCR	Molly miller	*Scartella cristata*
SCCU	Blue parrotfish	*Scarus coeruleus*
SCGU	Rainbow parrotfish	*Scarus guacamaia*
SCIS	Striped parrotfish	*Scarus iseri*
SOUK	SCORPIONFISH sp	*Scorpaena UNK*
SCPL	Spotted scorpionfish	*Scorpaena plumieri*
SCRE	Cero	*Scomberomorus regalis*
SCTA	Princess parrotfish	*Scarus taeniopterus*
SCVE	Queen parrotfish	*Scarus vetula*
SEBA	Lantern bass	*Serranus baldwini*
SECR	Bigeye scad	*Selar crumenophthalmus*
SEDU	Greater amberjack	*Seriola dumerili*
SEFL	Twinspot bass	*Serranus flaviventris*
SEPU	Pygmy sea bass	*Serraniculus pumilio*
SEUK	SEABASS sp	*Serranus UNK*
SETA	Tobaccofish	*Serranus tabacarius*
SETI	Harlequin bass	*Serranus tigrinus*
SETO	Chalk bass	*Serranus tortugarum*
SPUK	PARROTFISH sp	*Sparisoma UNK*
SPAT	Greenblotch parrotfish	*Sparisoma atomarium*
SPAU	Redband parrotfish	*Sparisoma aurofrenatum*
SPBA	Great barracuda	*Sphyraena barracuda*
SPCH	Redtail parrotfish	*Sparisoma chrysopterum*
SPPI	Southern sennet	*Sphyraena picudilla*
SPRA	Bucktooth parrotfish	*Sparisoma radians*
SPRU	Yellowtail parrotfish	*Sparisoma rubripinne*
SPSP	Bandtail puffer	*Sphoeroides spengleri*
SPTE	Checkered puffer	*Sphoeroides testudineus*
SPVI	Stoplight parrotfish	*Sparisoma viride*
STAD	Dusky damselfish	*Stegastes adustus*

Species Code	**Common Name**	***Scientific Name***
STDI	Longfin damselfish	*Stegastes diencaeus*
STLE	Beaugregory	*Stegastes leucostictus*
STPA	Bicolor damselfish	*Stegastes partitus*
STPL	Threespot damselfish	*Stegastes planifrons*
STUK	BUTTERFISH Family sp	*Stromateidae UNK*
STVA	Cocoa damselfish	*Stegastes variabilis*
SYUK	SAND FLOUNDER sp	*Syacium UNK*
SYDA	Sygnathus dawsoni	*Sygnathus dawsoni*
SYFO	Inshore lizardfish	*Synodus foetens*
SYIN	Sand diver	*Synodus intermedius*
SYSA	Bluestriped lizardfish	*Synodus saurus*
THBI	Bluehead	*Thalassoma bifasciatum*
TRFA	Permit	*Trachinotus falcatus*
TRGO	Palometa	*Trachinotus goodei*
TRUK	Searobin Family	*Triglidae UNK*
TYCR	Houndfish	*Tylosurus crocodilis crocodilis*
XARI	sargassum triggerfish	*Xanthichthy ringens*
XYMA	Rosy razorfish	*Xyrichtys martinicensis*
XYNO	Pearly razorFish	*Xyrichtys novacula*
XYUK	RAZORFISH sp	*Xyrichtys UNK*
XYSP	Green razorfish	*Xyrichtys splendens*

Appendix D. Benthic Codes

Species Code	Taxon or Common Name	Scientific Name
ACRCER	Branching/pillar coral	*Acropora cervicornis*
ACRPAL	Branching/pillar coral	*Acropora palmata*
ACTSPP	Anemones	*All anemone species*
AGAAGA	Leaf/plate/sheet coral	*Agaricia agaricites*
AGAFRA	Leaf/plate/sheet coral	*Agaricia fragilis*
AGAGRA	Leaf/plate/sheet coral	*Agaricia grahamae*
AGAHUM	Leaf/plate/sheet coral	*Agaricia humilis*
AGALAM	Leaf/plate/sheet coral	*Agaricia lamarcki*
AGASPP	Leaf/plate/sheet coral	*Agaricia spp*
ASCSPP	Tunicates	*All tunicate species*
CANSPP	Flower/cup coral	*Caryophyllia n. spp*
CIRLEU	Black coral	*Cirrhipathes (Stichopathes) leutkeni*
CLAARB	Branching/pillar coral	*Cladocora abruscula*
COLNAT	Brain coral	*Colpophyllia natans*
DENCYL	Branching/pillar coral	*Dendrogyra cylindrus*
DIAANT	Sea urchins	*Diadema antillarum*
DICSTO	Encrusting/mound/boulder coral	*Dichocoenia stokesii*
DIPCLI	Brain coral	*Diploria clivosa*
DIPLAB	Brain coral	*Diploria labyrinthiformis*
DIPSPP	Brain coral	*Diploria spp*
DIPSTR	Brain coral	*Diploria strigosa*
ERYCAR	Gorgonians	*Encrusting gorgonians*
EUSFAS	Flower/cup coral	*Eusmilia fastigiata*
EUSGIG	Gastropods	*Eustrombus gigas*
FAVFRA	Encrusting/mound/boulder coral	*Favia fragum*
FILCYA	Filamentous algae/cyanobacteria	*All filamentous algae/cyanobacteria sp.*
GORFAN	Gorgonians	*Sea fans*
GORPRW	Gorgonians	*Branching gorgonians*
HALBEA	Seagrasses	*Halodule beaudettei*
HALDEC	Seagrasses	*Halophila decipiens*
HELCUC	Leaf/plate/sheet coral	*Helioceris cucullata*
HYDSPP	Hydroids	*All hydroid species*
ISORIG	Fleshy coral	*Isophyllastrea rigida*
ISOSIN	Fleshy coral	*Isophyllia sinuosa*
MACROA	Macroalgae	*All macroalgae species*
MADDEC	Encrusting/mound/boulder coral	*Madracis decactis*
MADMIR	Branching/pillar coral	*Madracis mirabilis*
MADPHA	Encrusting/mound/boulder coral	*Madracis pharensis*
MADSPP	Branching/pillar coral	*Madracis spp*
MANARE	Brain coral	*Manicina areolata*
MEAMEA	Brain coral	*Meandrina meandrites*
MILSPP	Fire coral	*All Millepora species*
MONANN	Encrusting/mound/boulder coral	*Montastraea annularis*
MONANX	Encrusting/mound/boulder coral	*Montastraea annularis complex*
MONCAV	Encrusting/mound/boulder coral	*Montastraea cavernosa*
MONFAV	Encrusting/mound/boulder coral	*Montastraea faveolata*
MONFRA	Encrusting/mound/boulder coral	*Montastraea franksi*

Species Code	Taxon or Common Name	Scientific Name
MONSPP	Encrusting/mound/boulder coral	*Montastraea spp*
MUSANG	Fleshy coral	*Mussa angulosa*
MYCALI	Fleshy coral	*Mycetophyllia aliciae*
MYCDAN	Fleshy coral	*Mycetophyllia danaana*
MYCFER	Fleshy coral	*Mycetophyllia ferox*
MYCLAM	Fleshy coral	*Mycetophyllia lamarckiana*
MYCREE	Fleshy coral	*Mycetophyllia reesi*
MYCSPP	Fleshy coral	*Mycetophyllia spp*
OCUDIF	Branching/pillar coral	*Oculina diffusa*
OCUROB	Branching/pillar coral	*Oculina robusta*
PANARG	Lobsters	*Panulirus argus*
PORAST	Encrusting/mound/boulder coral	*Porites astreoides*
PORBRA	Branching/pillar coral	*Porites branneri*
PORBTV	Upright sponges	*All upright sponge species*
PORCOL	Leaf/plate/sheet coral	*Porites colonensis*
PORDIV	Branching/pillar coral	*Porites divaricata*
PORENC	Encrusting sponges	*All encrusting sponge species*
PORPOR	Branching/pillar coral	*Porites porites*
PORSPP	Branching/pillar coral	*Porites spp*
RHOCRU	Crustose algae	*All crustose algae species*
RHODOL	Rhodolith algae	*All macroalgae species*
SCLSPP	Stony coral	*Scleractinia spp*
SCOCUB	Fleshy coral	*Scolymia cubensis*
SCOSPP	Fleshy coral	*Scolymia spp*
SIDRAD	Encrusting/mound/boulder coral	*Siderastrea radians*
SIDSID	Encrusting/mound/boulder coral	*Siderastrea siderea*
SIDSPP	Encrusting/mound/boulder coral	*Siderastrea spp*
SOLBOU	Encrusting/mound/boulder coral	*Solenastrea bournoni*
SOLSPP	Encrusting/mound/boulder coral	*Solenastrea spp*
STEINT	Encrusting/mound/boulder coral	*Stephanocoenia intercepta*
SYRFIL	Seagrasses	*Syringodium filiforme*
THATES	Seagrasses	*Thalassia testudinum*
TUBCOC	Flower/cup coral	*Tubastraea coccinea*
TURALG	Turf algae	*All macroalgae species*
ZOASPP	Zoanthids	*All zoanthid species*

Appendix E. Glossary of Statistical Symbols and Computational Formulas Used in the Coral Reef Fish Sampling Survey.

Symbol	Definition	Computational Formula	Equation Number
Mean Density, Variance and Allocation			
h	Stratum subscript		
j	Sample unit subscript		
D_j	Density in sample unit *j*		
A_h	Stratum area	Total units in stratum *h* $\bullet$ 2500 m^2	
n_h	Number of units sampled in stratum *h*		
N_h	Total possible number of sample units in stratum *h*	$N_h = \frac{A_h}{100\ \mathrm{m}^2}$ Belt Transect $N_h = \frac{A_h}{177\ \mathrm{m}^2}$ Point Count	SOP 9.1
$\overline{D}_h$	Mean density in stratum *h*	$\overline{D}_h = \frac{1}{n_h}\sum_j D_{hj}$	SOP 2.2
s_h^2	Sample variance of density in stratum *h*	$s_h^2 = \frac{1}{n_h - 1}\sum_{j=1}^{n_h}\left(D_{hj} - \overline{D}_h\right)^2$	SOP 2.3
s_h	Standard deviation in stratum *h*	$s_h = \sqrt{s_h^2}$	SOP 2.4
w_h	Stratum *h* weighting factor	$w_h = \frac{N_h}{\sum_h N_h}$	SOP 2.5
$\overline{D}_{st}$	Domain-wide mean density for a stratified random survey	$\overline{D}_{st} = \sum_h \left(w_h \overline{D}_h\right)$	SOP 2.6
$\mathrm{var}\left[\overline{D}_h\right]$	Variance of mean density	$\mathrm{var}\left[\overline{D}_h\right] = \left(1 - \frac{n_h}{N_h}\right)\frac{s_h^2}{n_h}$	SOP 2.7
$\mathrm{var}\left[\overline{D}_{st}\right]$	Variance of domain-wide mean density	$\mathrm{var}\left[\overline{D}_{st}\right] = \sum_h w_h^2\ \mathrm{var}\left[\overline{D}_h\right]$	SOP 2.8
$SE\left[\overline{D}_{st}\right]$	Standard error	$SE\left[\overline{D}_{st}\right] = \sqrt{\mathrm{var}\left[\overline{D}_{st}\right]}$	SOP 2.9
$V\left[\overline{D}_{st}\right]$	Target variance for domain-wide mean density	$V\left[\overline{D}_{st}\right] = \left(CV\left[\overline{D}_{st}\right] \cdot \overline{D}_{st}\right)^2$	SOP 2.10
$CV\left[\overline{D}_{st}\right]$	Coefficient of variation	$CV\left[\overline{D}_{st}\right] = \frac{SE\left[\overline{D}_{st}\right]}{\overline{D}_{st}}$	SOP 2.11

n^*	Number of primary unit samples required to achieve a specified variance	$n^* = \dfrac{\left(\sum_h w_h s_h\right)^2}{V\left(\overline{D}_{st}\right) + \dfrac{1}{N}\sum_h w_h s_h^2}$	SOP 2.1
n^*_h	Optimal allocation of primary units among strata	$n^*_h = n^* \bullet \left(\dfrac{w_h s_h}{\sum_h w_h s_h}\right)$	SOP 3.1
Abundance			
$\hat{Y}_h$	Stratum abundance	$\hat{Y}_{h=(\overline{D}_h)(N_h)}$	SOP 9.12
$\hat{Y}_{st}$	Survey wide total abundance	$\hat{Y}_{st} = \sum_h \hat{Y}_h$	SOP 9.13
$\mathrm{var}\left[\hat{Y}_h\right]$	Abundance variance in stratum *h*	$\mathrm{var}\left[\hat{Y}_h\right] = \mathrm{var}\left[\overline{D}_h\right](N_h)^2$	SOP 9.14
$\mathrm{var}\left[\hat{Y}_{st}\right]$	Sample variance of abundance	$\mathrm{var}\left[\hat{Y}_{st}\right] = \sum_h \mathrm{var}\left[\hat{Y}_h\right]$	SOP 9.15
$SE\left[\hat{Y}_{st}\right]$	Standard error of abundance	$SE\left[\hat{Y}_{st}\right] = \sqrt{\mathrm{var}\left[\hat{Y}_{st}\right]}$	SOP 9.16
$CV[\overline{\hat{Y}}_{st}]$	Coefficient of variation of abundance	$CV[\overline{\hat{Y}}_{st}] = \dfrac{SE[\overline{\hat{Y}}_{st}]}{\overline{\hat{Y}}_{st}}$	SOP 9.17
Proportion of Occurrence			
P_j	Occurrence in sample unit *j*		
$\bar{P}_h$	Proportion occurrence by strata	$\bar{P}_h = \dfrac{1}{n_h}\sum_j P_{hj}$	SOP 9.2
$\bar{P}_{st}$	Domain-wide proportion occurrence	$\bar{P}_{st} = \sum_h w_h \bar{p}_h$	SOP 9.3
$\mathrm{var}\left[\overline{P}_h\right]$	Strata variance for proportion occurrence	$var[\bar{P}_h] = \left(1 - \dfrac{n_h}{N_h}\right) \times \dfrac{\left(\dfrac{n_h}{(n_h - 1)}\right) \times \bar{p}_h \times (1 - \bar{p}_h)}{n_h}$	SOP 9.4
$\mathrm{var}\left[\overline{P}_{st}\right]$	Domain-wide proportion occurrence variance	$\mathrm{var}[\bar{P}_{st}] = \sum_h var[\bar{P}_h]\, w_h^2$	SOP 9.5
$SE\left[\overline{P}_{st}\right]$	Standard error for domain-wide proportion occurrence	$SE\left[\overline{P}_{st}\right] = \sqrt{var[\bar{P}_{st}]}$	SOP 9.6
Species Richness			

Sp_j	Species richness per site *j*		
$\overline{Sp}_h$	Mean strata species richness	$\overline{Sp}_h = \frac{1}{n_h}\sum_h sp_{hj}$	SOP 9.7
$\overline{Sp}_{st}$	Mean domain wide species richness	$\overline{Sp}_{st} = \sum_h w_h \overline{Sp}_h$	SOP 9.8
$\overline{Sp}_h^2$	Sample variance of species richness in stratum *h*	$\overline{Sp}_h^2 = \frac{1}{n_h - 1}\sum_i \left(\overline{Sp}_{hi} - \overline{Sp}_h\right)^2$	SOP 9.9
$\mathrm{var}\left[\overline{Sp}_h\right]$	Variance of mean species richness	$\mathrm{var}\left[\overline{Sp}_h\right] = \left(1 - \frac{n_h}{N_h}\right)\frac{\overline{Sp}_h^2}{n_h}$	SOP 9.10
$\mathrm{var}\left[\overline{Sp}_{st}\right]$	Survey wide variance of species richness	$\mathrm{var}\left[\overline{Sp}_{st}\right] = \sum w_h^2 \,\mathrm{var}\left[\overline{Sp}_h\right]$	SOP 9.11

Appendix F. Habitat Information Sheets

The following pages are habitat information sheets formatted so that they can be printed directly onto sheets of underwater paper for use in the field. For this reason, no page numbers or headings are included.

1st page: Stony Corals

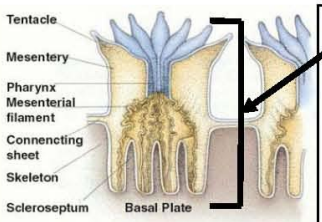
2nd page: Octocorals and Sponges

3rd page: Macroalgae, Seagrass and Other

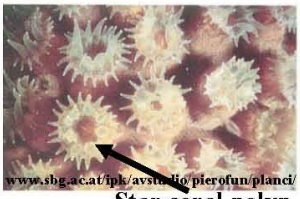
4th page: Other (zooanthids), special interest organisms, and living vs. bleached vs. recently dead coral identification.

STONY CORALS

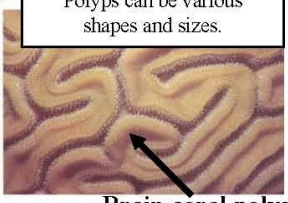
General coral anatomy:



Coral Polyp: A coral colony is made up of genetically identical polyps that are connected. Each polyp is an individual which is essentially a mouth surrounded by tentacles. Polyps can be various shapes and sizes.



Star coral polyp



Brain coral polyp

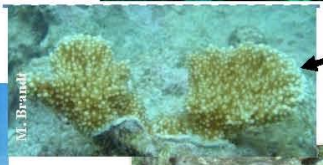
Stony coral morphotypes:

Massive:

All stony corals are rigid and leave behind reef framework when they die. Polyps vary in size and shape and tentacles are typically retracted during the day (exception is pillar coral – bottom right photo – which feeds during the day)

Branching:

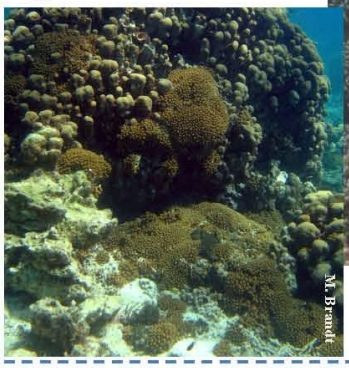
The presence/absence of either species should be noted at the bottom of the data sheet



Small encrusting colonies of *A. palmata.* Note the white growing edges and prominent corallites

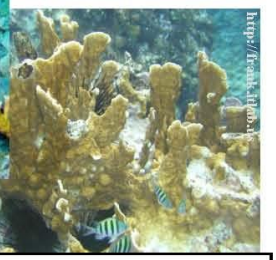
Leafy, platey:

Finger:



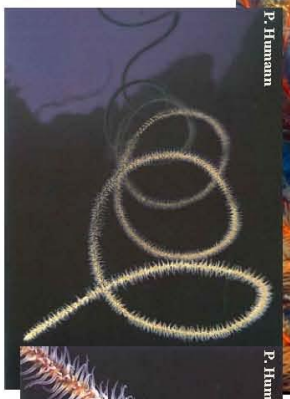
Other stony coral types:

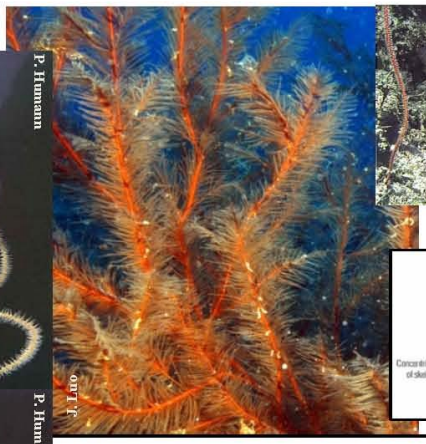
Fire corals

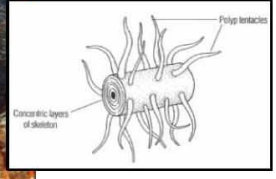


Tend to be orange/tan in appearance with white tips/edges. Stinging polyps look like sharp spines.

Black corals





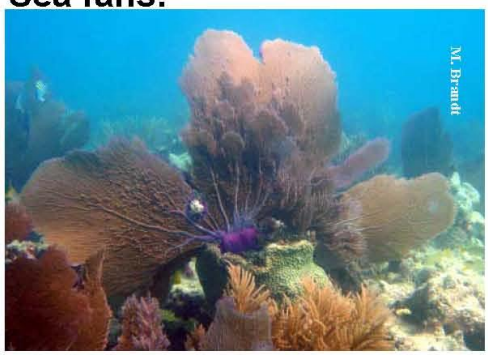


Unlike gorgonians, only tentacles come off of the branches (left close-up and diagram above), giving colonies a pine tree-like appearance. **Note the presence of black coral at bottom of data sheet!**

OCTOCORALS

Octocoral morphotypes:

Sea fans:



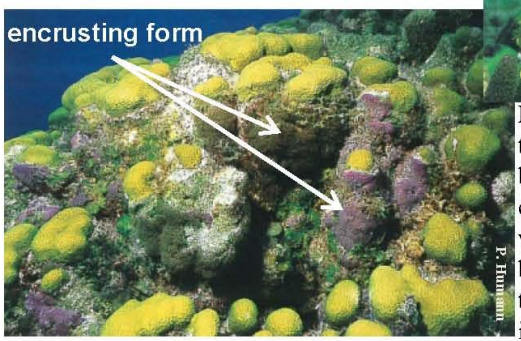
Sea rods and plumes:

Encrusting octocorals:

Erythropodium caribaeorum

Encrusting gorgonians often look like macroalgae. The two most common species of encrusting gorgonians are *Erythropodium caribaeorum* (left) and *Briareum asbestinum* (below). *Erythropodium* has brown tissue and long tentacles that make it look "hairy". *Briareum* has purple tissue with brown tentacles that also make it look hairy or furry. When the tentacles are retracted the ployps will often be apparent.

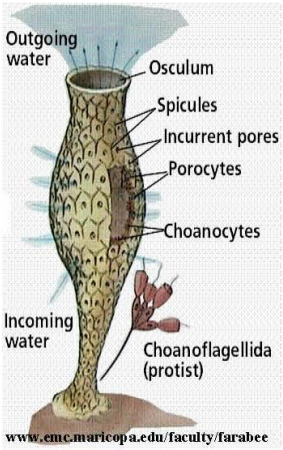
Briareum asbestinum

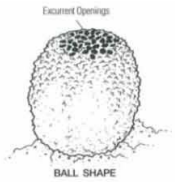


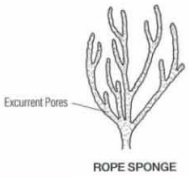
Left photo: Encrusting form is the purple and brown at the bases of the coral colony columns. Top arrow indicates where tentacles are extended, bottom arrow indicates where tentacles are retracted. Yellow is live stony coral.

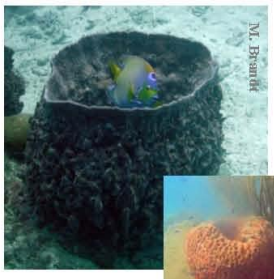
SPONGES

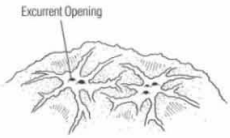
General sponge anatomy:



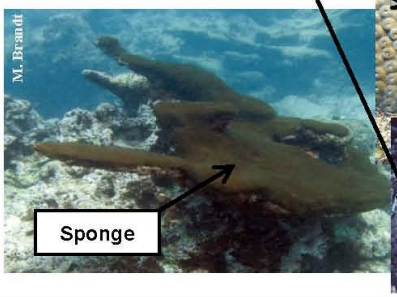


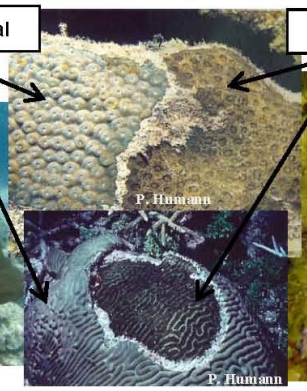


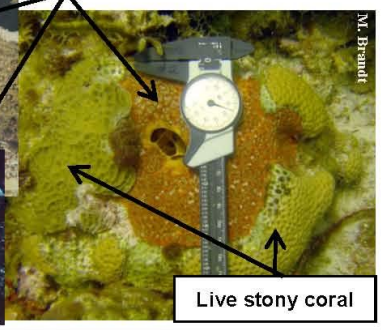




Common encrusting sponges include two species of boring sponges, *Cliona langue* (left) and *C. delitrix* (right). *C. langue* is brown and appears smooth while *C. delitrix* is typically bright red with conspicuous pores and osculums.



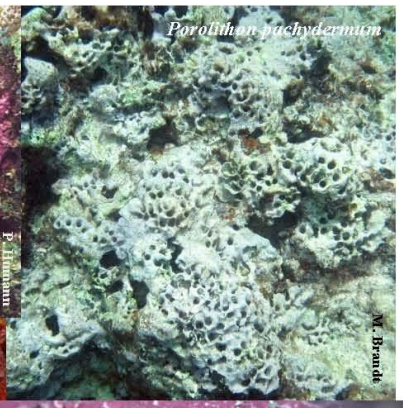




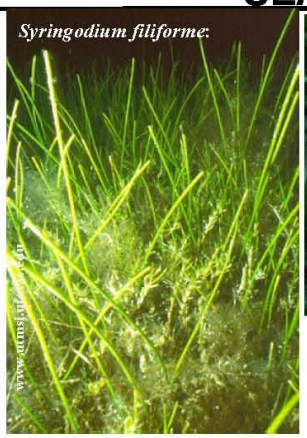
MACROALGAE

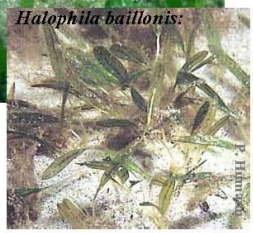
Macroalgae commonly found on hardbottom substrates:

Crustose coralline algae ("algae <1cm" on data sheets) is only found on hard substrates and is usually red or purple in color:

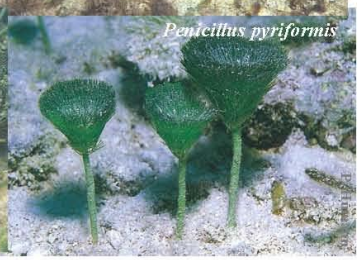


SEAGRASSES





Macroalgae commonly found on sand substrates:



"OTHER": Anemones, Tunicates

Anemones:

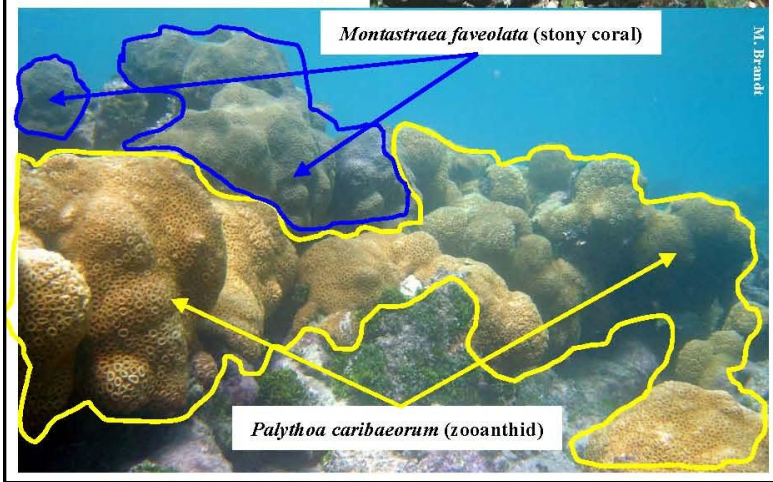
Stichodactyla helianthus can occur in dense clusters and may look like stony coral. Look for flimsy edges of individuals.

Mat tunicate:

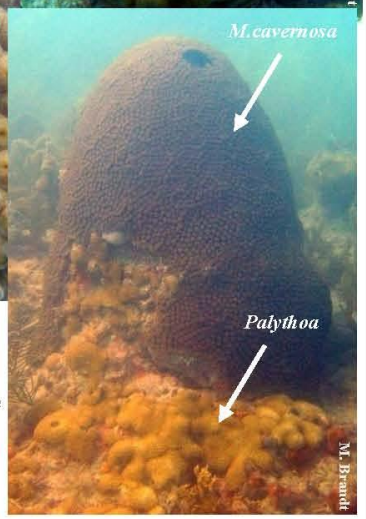
Left photo – *T. solidum* can look like an encrusting sponge, but it is a tunicate! It appears as a green mat with slits.

"OTHER": Zooanthids (*Palythoa*)

Palythoa caribaeorum **(Order: Zooanthid):**



The polyps of the stony coral *Montastraea cavernosa* (below and right) and the zooanthid *Palythoa caribaeorum* (left) look very similar.



***M. cavernosa*: usually dark in color (unless bleaching). When polyps are open, the mouths are a light color. When touched, the colony feels hard and slimy.**

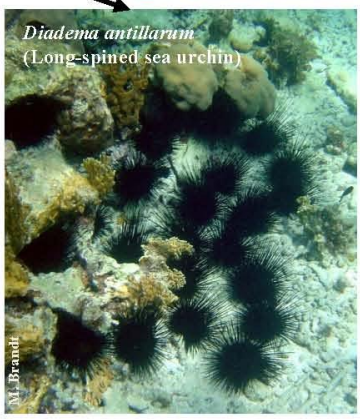
***Palythoa*: pale in color. When polyps are open, the mouths are hollow and deep. When touched, the colony feels soft and rubbery.**

Bottom of the data sheet

Comments:

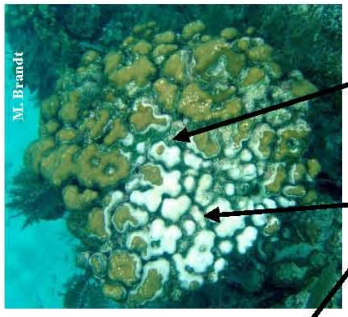
Presence of: *A. palmata* *A. cervicornis* Black Coral

Spiny Lobster # Conch # Diadema #



Living vs. bleached vs. recently dead stony coral:

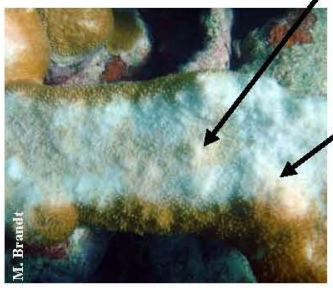
Living tissue: Corallites (polyp structure) are well defined, tentacles can sometimes be observed, no sediment on tissue.
Bleached coral: Tissue still present, algal symbionts absent or degraded giving colony a pale or whitish appearance.
Recently dead coral: Tissue absent. Sediment can settle and some algal colonization may have begun <1 day after death.
Old dead coral: Tissue absent, skeleton degraded, heavy sediment and algal colonization. Dead coral can appear alive if corallite structure is not degraded (e.g., brain corals and *Montastraea cavernosa* often retain their corallite structure long after death).

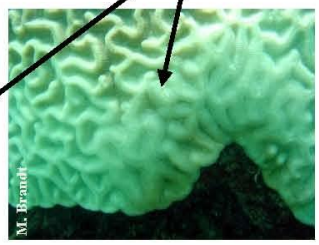


Normal living tissue

Recently dead

Bleached tissue





For questions or comments about these cards, please contact Marilyn Brandt at mbrandt@rsmas.miami.edu or 305-421-4736.

Appendix G. Boat Docks and Dive Shops

Below are contact information and maps to boat docks and dive shops. This list is not meant to endorse any specific dive shop, dock, or operation but to provide a list of known vendors.

St. Croix

Anchor Dive Center
Address: Salt River National Park
St. Croix, VI 00823
Phone: (340) 778-1522
Web: http://www.anchordivestcroix.com/
Open Daily: 8:00 am - 3:00 pm

Dive Experience
Address: 111 Strand Street
Christiansted, VI 00820
Phone: (340) 773-3307
Web: http://www.divexp.com/
Open Daily: 8:00 am - 5:00 pm
(4:00 pm on Sundays)

Green Cay Marina
Address: 500 Southgate
Christiansted, VI 00820
Phone: (340) 718-1453
Web:http://www.tamarindreefresort.com/index.php/marina/welcome
Open Daily: 8:00 am - 5:00 pm
(4:00 pm Sat, Sun and Holidays)

Salt River Marina
Address: Route 801, Salt River
St. Croix, VI 00823
Phone: (340) 778-9650

St. Croix Marine
Address: Gallows Bay
St. Croix, VI 00824
Phone: (340) 773-0289
Web: http://www.stcroixmarine.com/
Store open: Mon. – Sat., 8 am – 5 pm
Yard open: Mon. – Fri., 7:30 am - 4:30 pm

St. Croix Ultimate Bluewater Adventures (SCUBA)
Address: 81 Queen Cross Street
Christiansted, VI 00820
Phone: (340) 773-5994
Web: http://www.stcroixscuba.com/
Open Daily: 7:30 am - 6:00 pm

St. John

Cruz Bay Watersports
Address: Cruz Bay
St. John, VI 00831
Phone: (340) 776-6234
Open daily: 8:00 am - 6:00 pm

Low Key Watersports
Address: One Bay Street, Cruz Bay
St. John, VI 00831
Phone: (340) 693-8999
Web: http://www.divelowkey.com/
Open Daily: 8:30 am - 6:00 pm

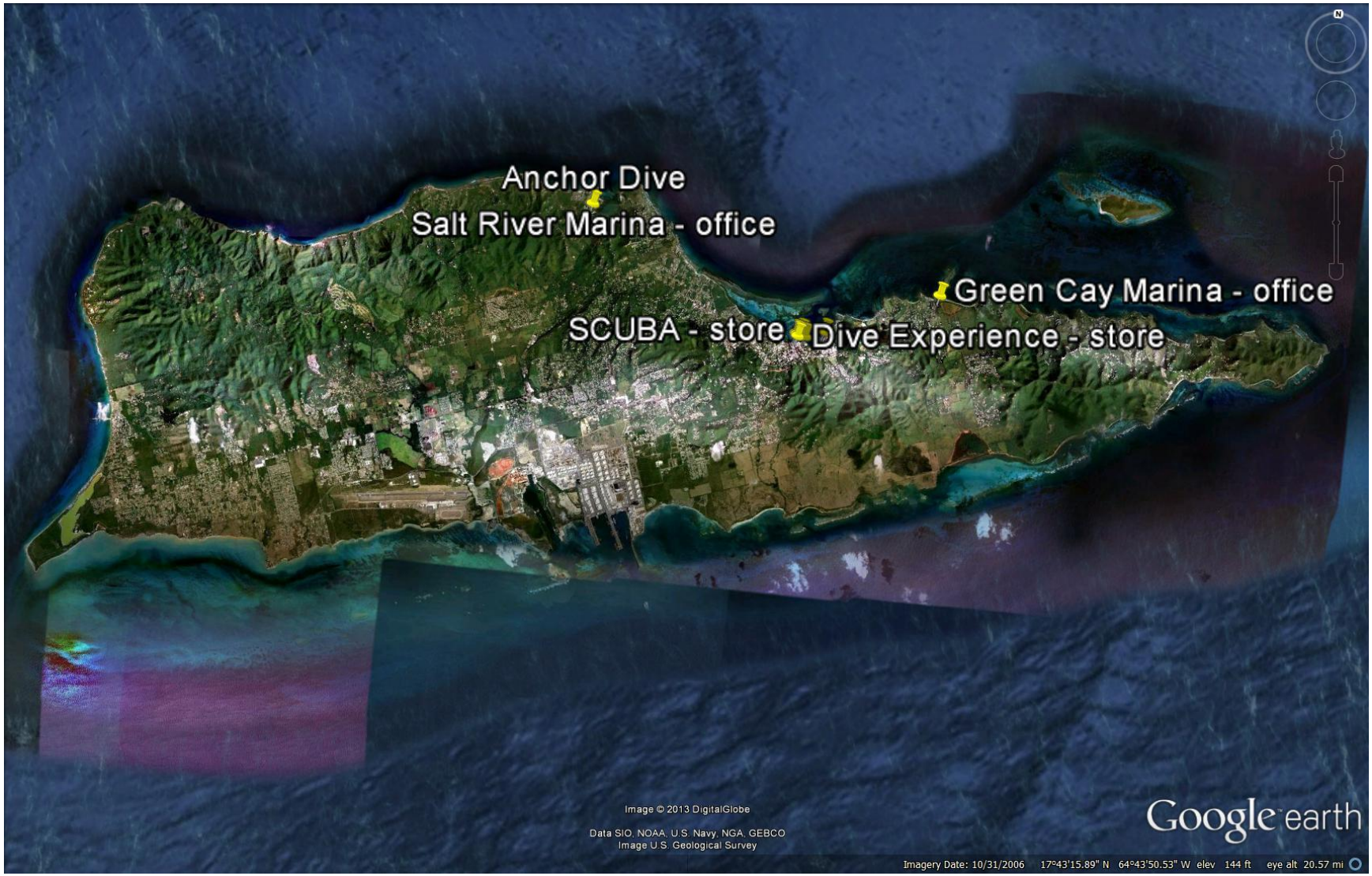
St. Thomas

American Yacht Harbor
Address: 6100 Red Hook Quarters #2
St. Thomas, VI 00802
Phone: (340) 775-6454
Web: http://www.igy-americanyachtharbor.com/
Open Daily: 7:30 am - 5:00 pm

Hi-Tech Water Sports
Address: 17 Crown Bay
Charlotte Amalie
St. Thomas, VI 00804
Phone: (340) 774-5650
Open Daily: 9:00 am - 4:30 pm

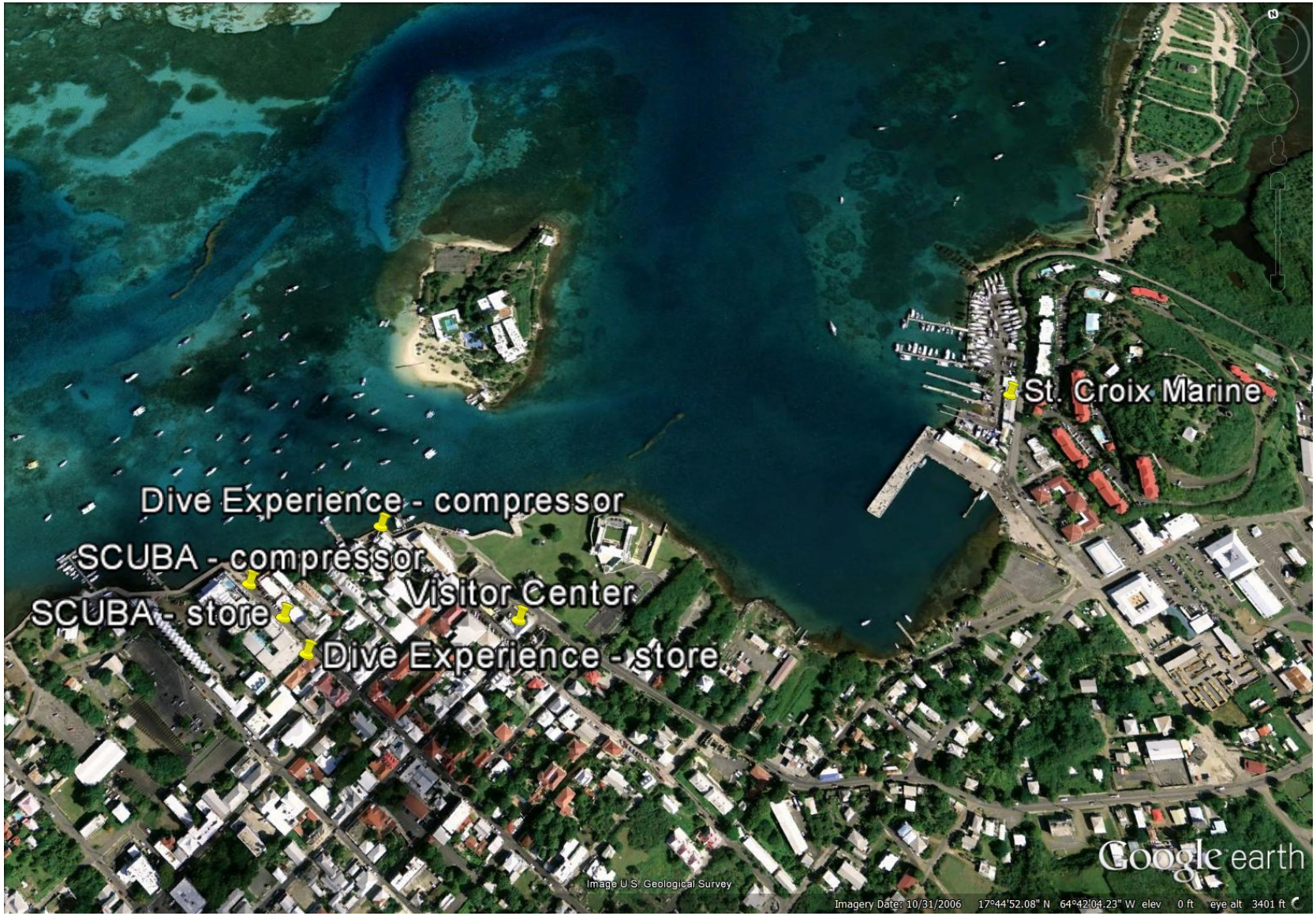
Red Hook Dive Center
Address: 6100 Red Hook Quarters E1-1
St. Thomas, VI 00802
Phone: (340) 777-3483
Web: http://redhookdivecenter.com/
Open Daily: 8:00 am - 5:00 pm

St. Croix


Anchor Dive
Salt River Marina - office
Green Cay Marina - office
SCUBA - store
Dive Experience - store
Image © 2013 DigitalGlobe
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image U.S. Geological Survey
Google earth
Imagery Date: 10/31/2006 17°43'15.89" N 64°43'50.53" W elev 144 ft eye alt 20.57 mi

St. Croix / Salt River

St. Croix / Christiansted



St. John

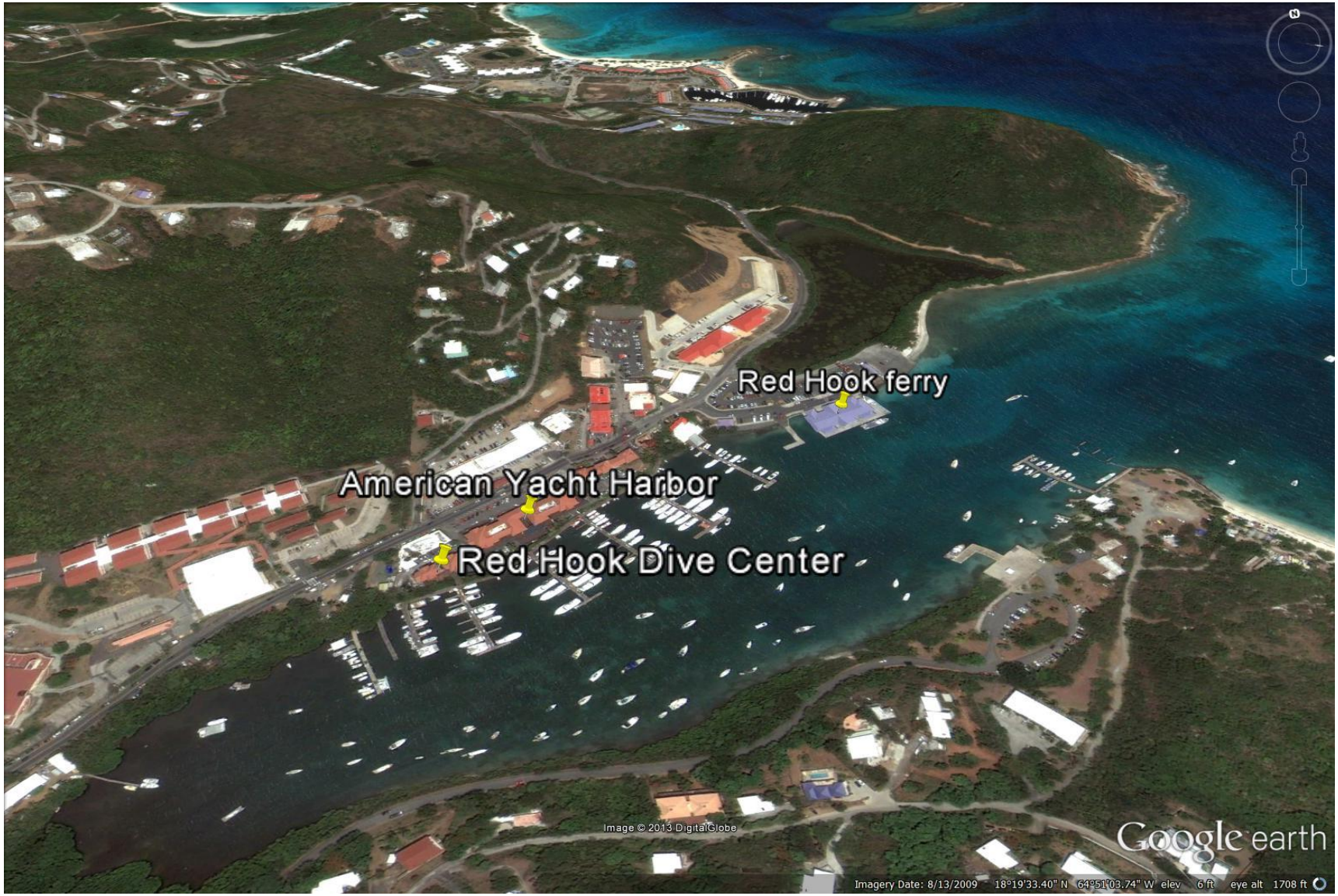
Low Key Watersports
Cruz Bay Watersports
9028 ft
Image © 2013 DigitalGlobe
Google earth
Imagery Date: 1/3/2012 18°20'02.46" N 64°43'47.27" W elev 1143 ft eye alt 41483 ft

St. John / Cruz Bay

St. Thomas

UVI Marine Science Center
Hi-Tech Water Sports
Red Hook Dive Center
American Yacht Harbor
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2013 DigitalGlobe
Image U.S. Geological Survey
Google earth
Imagery Date: 8/13/2009 18°19'48.04" N 64°56'07.26" W elev 24 ft eye alt 14.21 mi

St. Thomas / Red Hook



Appendix H. Legacy Data Collection History

Table Appendix H-1.Sampling history for NOAA BB led belt-transect St. Croix fish monitoring. This table was compiled from summaries of the data sets, “Data Caveats” provided in BB’s metadata, and BB’s trip reports. Note: Details of benthic data collection have changed over time but are not fully documented below. See the NOAA BB website at http://www.ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish/.

	BUIS		EEMP		No Mgmt		SARI		
Sampling Dates	**# Hard Sites**	**# Soft Sites**	**# Hard Sites**	**# Soft Sites**	**# Hard Sites**	**# Soft Sites**	**# Hard Sites**	**# Soft Sites**	**Changes/Data Caveats**
2/6 - 2/15/2001	50	69							Geographic scope: old BUIS monument boundaries +0.5 km; Strata: Seagrass, Sand, Hard; Lengths of some fish with forklengths greater than 35 cm had length recorded as 0. A small subset of sites were resampled during each mission through June 2002 in Puerto Rico and October 2002 in St. Croix. These station names contain the letter 'P' indicating they are permanent stations.
8/13 - 9/21/2001	29	41							
1/21 - 1/31/2002	38	44							Fish lengths for all fish >35 cm are recorded.
10/21 - 10/25/2002	34	36							Seagrass and Sand combined into Softbottom strata. Expansion to new BUIS monument boundaries;
3/24 - 4/3/2003	42	33	41	1	1				Added EEMP area south of park as separate management zone; Benthic map used for stratification updated.Resampling of permanent sites stops.
10/20 - 10/30/2003	37	27	37	28					
2/21 - 2/21/2004	7	2							Only sampling period using RHA protocol at BUIS
3/22 - 4/2/2004	18	10	16	12					
10/18 - 10/28/2004	38	27	36	26	1	2			Immature & mature conch first appear in dataset
3/20 - 3/31/2005	38	24	36	28		1			
10/17 - 10/27/2005	48	11	45	12	1	4			Sea urchins and lobster first appear in dataset
4/10 - 4/21/2006	48	10	37	21	4				
10/30 - 11/10/2006	51	10	41	21	1				
10/8 - 10/18/2007	50	13	39	19	1				Marine Debris recorded for first time. Algae data collection changed from identification of each alga to the genus level to grouping algae into six morphological groups: macro, turf, crustose, filamentous, rhodolith, and cyanobacteria for more efficient data collection.
3/10 - 3/19/2008	42	17	38	23	1	1			
10/20 – 10/29/2008	44	15	37	23	1				
3/2 – 3/13/2009	43	9	25	21	1	1			
10/26 – 11/6/2009	47	12	39	23	1				
10/18 – 10/29/2010	42	15	38	26	1				
10/18 - 10/29/2010			32	42					Sampled areas east & south of St. Croix in EEMP
10/31 – 11/10/2011			39	27					Sampling is outside national parks & expands to east &south EEMP
5/8 – 5/18/2012	68		62		145		15		Geographic scope expanded to all of St. Croix. Large Multi-agency effort. Hardbottom only. Stratified into 5 HB strata. 2-stage design with 50m x 50m grid cell as primary unit & 25m x 4m belt transect as secondary unit.

Table Appendix. H-2. Sampling history for NOAA BB led belt-transect St. John fish monitoring. This table was compiled from summaries for the data sets and "Data Caveats" provided in BB's metadata. Details of benthic data collection have changed over time but are not fully documented below. See the NOAA BB website at http://www.ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish/.

	VIIS		VICR		No Mgmt		
Sampling Dates	**# Hard Sites**	**# Soft Sites**	**# Hard Sites**	**# Soft Sites**	**# Hard Sites**	**# Soft Sites**	**Changes/Data Caveats**
7/25 - 8/1/2001	12	12	3		10	21	Geographic scope: VIIS with some areas outside but still nearshore St. John Strata: Seagrass, Sand, Hard; Lengths of some fish with forklengths greater than 35 cm had length recorded as 0. During the first mission to St. John samples were also stratified by depth (less than or equal to 40 ft or greater than 40 ft).
7/15 - 7/29/2002	25	20	10		35	20	Fish lengths for all fish >35 cm are recorded. Seagrass and Sand combined into Softbottom strata. Expanded into mid-shelf reef both inside & outside VICR. Begin using RHA benthic protocol for deep or difficult sites to reduce bottom time.
7/14 - 7/25/2003	22	28	37		47	10	Further expanded scope of mid-shelf reef surveys into new areas and expanded into Coral Bay. RHA used in Coral Bay.
2/24 – 2/29-2004			12		16		
7/19 – 7/29/2004	27	27	40	5	59	13	Immature & mature conch first appear in dataset
7/10 – 7/21/2005	19	26	51	7	51	17	
7/10 – 7/27/2006	18	23	49	4	49	24	Sea urchins and lobster first appear in dataset
6/24 – 9/19/2007	15	22	52	4	53	23	Marine Debris recorded for first time. Bohnsack-Bannerot point count conducted at 90 RHA sites. Algae data collection changed from identification of each alga to the genus level to grouping algae into six morphological groups: macro, turf, crustose, filamentous, rhodolith, and cyanobacteria for more efficient data collection.
4/28 – 7/30/2008	11	23	51	4	60	21	Bohnsack-Bannerot point count conducted at 75 RHA sites.
4/13 – 7/16/2009	22	28	51	2	48	19	
7/5 – 7/15/2010	15	26	50	1	55	23	RHA methodology changed to create a habitat visual estimate along each 5m of transect rather than 1 for point count cylinder
7/16 – 7/28/2011	9	12	52	1	58	40	The habitat_structure for 90 sites is blank (49 in VICR, 41 in No Mgmt). However these are presumed to be hardbottom along the mid-shelf reef.

Appendix I. NPS- SFCN Specific Requirements, Safety, Data Management, and Reporting Standard Operating Procedures

Version 1.00

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NPS-SFCN Annual Workload and Budget

As a participating but not lead agency, SFCN personnel that participated in field sampling in 2012 included the Marine Ecologist, 3 Marine Biological Technicians, and an intern. The SFCN data summary report is anticipated to take approximately a week. All sample design selection and data management tasks were handled by BB and UM in 2012. However in the future, some more tasks may be delegated to individual agency Data Managers. This anticipated workload of data entry, QA/QC, data management, analysis, and reporting within SFCN is approximately 20-25% of funds allocated to the project and with regional data management conducted by BB, the NPS Inventory and Monitoring program target of allocating approximately 30% of the project budget for data management has been met.

Table Appendix I-1. SFCN Budget.

Category	Expense	Amount
SFCN St. Croix Budget	Travel (except housing)	$7,490
	Housing (if can't get park housing)	$9,450
	Fuel ($400/week)	$800
	St. Croix Dockspace ($25/day*11 days=$275)	$275
	Nitrox Airfills ($20/tank * 10 tanks * 11 days= $2200)	$2,200
	Dive salary incl. hazard pay	$15,855
	Data entry/proofing, management, analysis, reporting, archiving	$9,911
SFCN St. John Budget	Travel (except housing) – South Florida staff	$4,914
	Housing (if can't get park housing)	$5,670
	Fuel ($400/week)	$800
	Nitrox Airfills ($20/tank * 10 tanks * 11 days= $2200)	$2,200
	Salary incl. hazard pay	$15,855
	Data entry/proofing, management, analysis, reporting, archiving	$9,911
Equipment	Dive equipment ($200/diver/year)	$1,200
	Survey equipment ($500/season)	$500
SFCN Periodic costs	Dive training (8 annual and 40 hours every three years)	
	Computers, GPS devices, software, etc.	
	Salary for updating database analysis and graphing tools with major software changes	
	Boat and vehicle maintenance	

Although these are estimated costs associated with this protocol, park/partner support has helped reduce costs (e.g., housing, vehicles, boats, equipment). SFCN data management, logistic support, etc. workload estimates may go up depending on the degree of delegation of tasks to individual agencies BB choses in the future.

NPS-SFCN Additional Qualifications and Training

Additional NPS Qualifications for operations by NPS staff on NPS boats:

- NPS Blue Card Diver (Ref NPS RM4, 485 DM 27)
- MOCC (ref 36 CFR part 3, 485 DM 22) (necessary if driving an NPS boat)

Tasks may be performed by personnel in training status under the supervision of properly qualified persons. Specific guidelines and applicable regulations shall be strictly adhered to at all

times. This list is not meant to be all inclusive and may be supplemented by individual agency and/or park regulations and qualification requirements.

NPS-SFCN Additional Safety Requirements

NPS-SFCN personnel must also review the respective SOP associated with operation of each SFCN vessel, Float Plan Safety Sheet, and any other SOPs associated with this protocol and must review and sign all Job Hazard Analyses associated with this protocol. These SOPs and JHAs are located in the SFCN Safety SOP & JHA Binder. Electronic versions are available at Z:\Safety\ with filenames given by protocol in SFCN_Safety_SOP_and_JHA_Binder.pdf. NPS-SFCN personnel must follow all rules, regulations, requirements, policies, and procedures from the NPS Dive Program, any park specific requirements, and any other requirements of the National Park Service not otherwise specified herein.

All NPS-SFCN personnel will follow the Safe Pratices Manual and Emergency Operations Plan specific to the respective park they are operating within. Interagency dive operation protocols and diver reciprocity agreements will be exchanged and approved prior to the mission. Dive team roles and responsibilities as predicated in NPS Resource Manual 4 (Diving Management Reference Manual) will be reviewed in a safety briefing before each dive trip

Completion of the Department of Interior's Motorboat Operator Certification Course (MOCC) is required for the solo operation of an NPS vessel. Non-certified MOCC personnel may drive a park boat under the supervision of someone whom is MOCC certified. All SFCN vessels operate using state-of-the-art GPS chart plotters to ensure safe and efficient navigation.

NPS-SFCN Data Management

SFCN will download data from the BB public webpage and append tables in a local version of the database to aid in automating queries and analyses for generating NPS focused data summary reports.

NPS-SFCN File Storage

Storage locations for NPS data, analysis exports, maps and reports are given in Table

NPS-SFCN Post-collection Data Handling

Datasheets are collected by BB, scanned, and returned to individual participants for data entry and QA/QC. SFCN will store these documents in folder *Z:\SFCN\Vital_Signs\Marine_fish_communities\data\NOAA_USVI_data\Scanned_DataSheets* with name *YYYY_Region_PersonName.pdf.*

NPS-SFCN Data Entry

SFCN data entry will proceed as described in SOP 8 – "Data Entry, Proofing, and Management". BB offline database is located in *Z:\SFCN\Vital_Signs\Marine_fish_communities\data\NOAA_USVI_data* with *YYYYMMDD_* added to the database name.

NPS-SFCN Database

The SFCN database is located in *Z:\SFCN\Vital_Signs\Marine_fish_communities\data\NOAA_USVI_data\SFCN_USVI_fish.mdb.*

The database design uses the Natural Resource Database Template (NRDT) format in MSAccess. Figure I-1 shows the diagram of database relationships.

Table Appendix I-2. Storage locations for SFCN data, exports, maps, and reports.

File type	Folder	Filename
Datasheets	\Marine_fish_communities\data\NOAA_USVI_data\Scanned_DataSheets\	YYYY_Region_Divername.pdf
BB offline data entry tool	\Marine_fish_communities\data\NOAA_USVI_data\	YYYYMMDD_filename
Database	\Marine_fish_communities\data\NOAA_USVI_data\	SFCN_USVI_Fish.mdb
Data downloads	\Marine_fish_communities\data\NOAA_USVI_data\Downloads\	DownloadDate*(YYYYMMDD)*_Filename
R code	\Marine_fish_communities\data\NOAA_USVI_data	ConvertFishDownload.R Report_Generation.R Report_Template.Rmd
Exports	\Marine_fish_communities\data\NOAA_USVI_data\Exports\	YYYY_Region_Sampling_Effort_Statistics.xlsx YYYY_Region_Sample_Locations.xlsx YYYY_Region_FishSummary.pdf SpeciesCode.html & .png
Graphing Templates	\Marine_fish_communities\data\NOAA_USVI_data\Graphs\	STX_Graphing_Template STJ_Graphing_Template
Map Templates	\Marine_fish_communities\spatial_info\Map_Template\	STX_Map_Template STJ_Map_Template
Report Maps	\Marine_fish_communities\spatial_info\Report_Maps\	YYYY_Region_map.mxd,.dbf, …
Data Summary Report Template	\Marine_fish_communities\documents\summaries_reports\templates\	STX_Fish_NRDS_Template.docx STJ_Fish_NRDS_Template.docx
Data Summary Reports	\Marine_fish_communities\documents\summaries_reports\STX\ \Marine_fish_communities\documents\summaries_reports\STJ\	YYYYMMDD_STX_NRDS_YYYY.docx YYYYMMDD_STJ_NRDS_YYYY.docx
Backup Templates	\Marine_fish_communities\documents\protocol\templates\	
Protocol	\Marine_fish_communities\documents\protocol\	YYYYMMDD_USVI_Fish_Protocol.pdf
Archives	Z:\SFCN_Archive\Vital_Signs\Marine_Fish_Communities\USVI\Data	Database, protocol, reports

NPS-SFCN Database Relationships

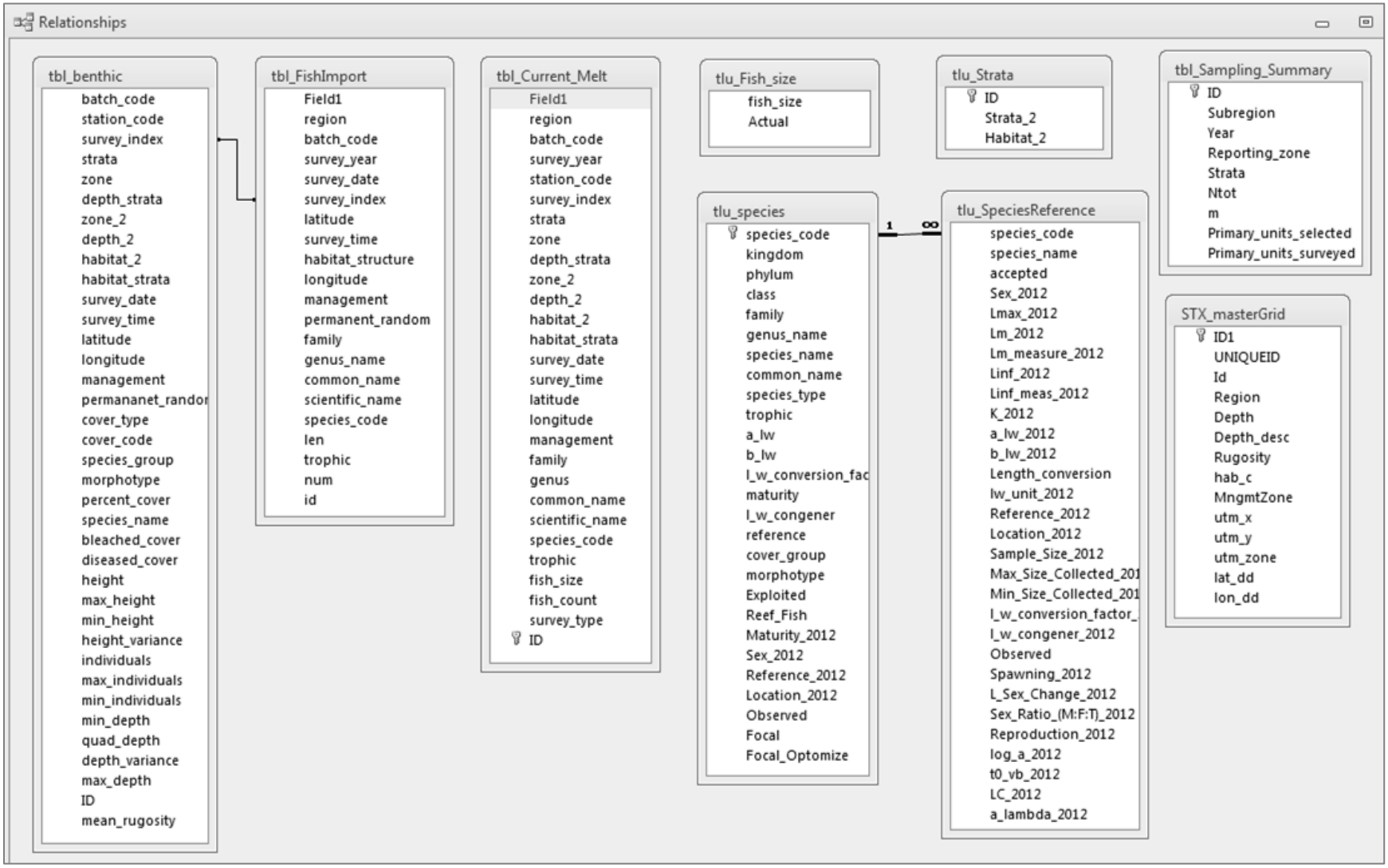

Figure Appendix I-1. SFCN database relationships diagram.

SFCN Database Tables Description

Table: STX_MasterGrid
Description: St. Croix master grid of 50m x 50m grid cells.

Field Name	Type	Size	Description
ID1	Number	4	Automatically generated unique number generated as grid is loaded into database
UNIQUEID	Text	255	Unique identification number for each grid cell
Id	Number	8	Numeric code for sub-region, e.g., 0=West, 1=East, 2=North, 3=South
Region	Text	255	Sub-region, e.g. North, South, East, West area around St. Croix
Depth	Number	8	Average grid cell depth in meters
Depth_desc	Text	255	Grid cell depth strata name= Shallow: 0 to <12 m and Deep: 12+ m
Rugosity	Number	8	Average grid cell rugosity calculated from bathymetry.
hab_c	Number	8	Number representing habitat assigned to grid cell: 0=Land & Unknown, 1=Sand, 2=Mud, 3=Macroalgae, 4=Seagrass, 5=Scattered Coral/Rock, 6=Pavement, 7=Bedrock, 8=Patch reef, 9=Linear, otherwise unknown
MngmtZone	Number	8	Numeric code identifying a management zone: 0=Unmanaged, 1=SARI, 2=BUIS, 3=EEMP
utm_x	Number	8	UTM Easting coordinate of grid cell center point
utm_y	Number	8	UTM Northing coordinate of grid cell center point
utm_zone	Number	8	UTM zone UTM_X and UTM_Y are located within
lat_dd	Number	8	Latiitude of a grid cell center point in decimal degrees. Precise to 7 decimal places.
lon_dd	Number	8	Longitude of a grid cell center point in decimal degrees. Precise to 7 decimal places.

Table: tbl_Benthic
Description: Data collected at a specific field location concerning benthic.

Field Name	Type	Size	Description
batch_code	Text	255	An alphanumeric code that identifies the region, month and year of each mission: mm00-yy00 Example: October 2007 = 1000-0700
station_code	Text	255	an alphanumeric code describing each specific station done within a mission
survey_index	Number	4	A numerical index that uniquely identifies each specific station done within a mission
strata	Text	255	3-letter sampling design strata code combining zone, depth_strata, and habitat_strata
zone	Text	255	One letter abbreviation on Zone_2, e.g., B=Buck, E=East, U=EEMP, N=North, R=SARI, S=South, W=West
depth_strata	Text	255	One letter depth strata code= S: 0-11.9 m and D: 12+ m
zone_2	Text	255	Based on jurisdiction at locations sites were sampled and type of benthic habitat composition information collected.
depth_2	Text	255	Depth strata name= Shallow: 0-11.9m and Deep: 12+ m
habitat_2	Text	255	Habitat strata name assigned to grid cell, i.e. SCR, Pavement, Bedrock, Patchreef, Reef.
habitat_strata	Text	255	Habitat Code assigned to grid cell, i.e., S=SCR, V=Pavement, B=Bedrock, P=Pavement, R=Reef
survey_date	Date/Time	8	The date in which a specific survey is done formatted as mm/dd/yyyy

Field Name	Type	Size	Description
survey_time	Date/Time	8	The specific time of a dive formatted in military time
latitude	Number	8	The latitude of a station recorded in decimal degrees. Precise to 5 decimal places.
longitude	Number	8	The longitude of a station recorded in decimal degrees. Precise to 5 decimal places.
management	Text	255	Based on jurisdiction at locations sites were sampled and type of benthic habitat composition information collected.
permananet_random	Text	255	A label each site is assigned based on how the site was selected and sampled.
cover_type	Text	255	Type of substrate cover: abiotic or biotic
cover_code	Text	255	For cover_type=Abiotic: Hard, Rubble, Sand, Fine sediment. For Biotic: Six letter codes --for coral first 3 letters of genus name + first 3 letters of species name; for other taxa a code to type is used (Appendix D)
species_group	Text	255	The hierarchical grouping of species in the same class or order
morphotype	Text	255	Grouping of like forms within each cover_group
percent_cover	Number	8	As the percent cover (to the nearest 0.1 percent) of living algae, seagrass, live corals, sponges, gorgonians, and other biota (tunicates, anemones, zooanthids and hydroids) within a 1m2 quadrat
species_name	Text	255	Taxonomic species name of fish created from the genus and species of fish
bleached_cover	Number	8	The percentage of bleached coral estimated to the nearest 0.1 percent
diseased_cover	Number	8	Refers to coral skeleton that has recently lost living tissue because of disease or damage that is still visible, and has not yet been colonized by turf algae. Recorded to the nearest 0.1 percent
height	Number	4	A measurement (recorded in cm) of the height of the hardbottom from the substrate to get a sense of bottom relief
max_height	Number	4	Maximum canopy height recorded out of 5 quadrat measurements at site
min_height	Number	4	Minimum canopy height recorded out of 5 quadrat measurements at site
height_variance	Number	4	Hardbottom height value reported as an average of 5 quadrat measurements
individuals	Number	4	For sponges, gorgonians and "other" biota type (non-encrusting anemones and non-encrusting hydroids) the number of individuals at the quadrat level is recorded
max_individuals	Number	4	Maximum number of individuals recorded out of 5 quadrat measurements at site
min_individuals	Number	4	Minimum number of individuals recorded out of 5 quadrat measurements at site
min_depth	Number	4	Minimum depth recorded out of 5 quadrat measurements at site
quad_depth	Number	8	The depth at each quadrat position. Depth is measured to the nearest 1ft
depth_variance	Number	8	Depth value reported as an average of 5 quadrat measurements
max_depth	Number	4	The maximum depth at that site
ID	Number	4	
mean_rugosity	Number	8	A mean of two rugosity values measured by placing a 6-m chain at two randomly selected positions along the 25m belt transect. The chain is placed such that it follows the substrate's relief along the centerline of the belt transect.

Table: tbl_Current_Melt
Description: Fish data that has transposed using the melt command in R.

Field Name	Type	Size	Description
Field1	Text	255	
region	Text	255	Location of mission
batch_code	Text	255	An alphanumeric code that identifies the region, month and year of each mission: mm00-yy00 Example: October 2007 = 1000-0700
survey_year	Number	4	The year in which a specific survey is done formatted as yyyy
station_code	Text	255	An alphanumeric code describing each specific station done within a mission. May contain strata code.
survey_index	Number	4	A numerical index that uniquely identifies each specific station done within a mission
strata	Text	255	Strata code combining zone, depth_strata, and habitat_strata
zone	Text	255	One letter abbreviation of zone_2
depth_strata	Text	255	One letter depth_strata code= S: 0-11.9 m and D: 12+ m
zone_2	Text	255	Name of area where points are independently selected within incl. both management (BUIS, SARI, EEMP) and general area (North, South, West)
depth_2	Text	255	Depth strata name= Shallow: 0-11.9m and Deep: 12+ m
habitat_2	Text	255	Habitat name assigned to grid cell (SCR, Pavement, Bedrock, Patchreef, Reef).
habitat_strata	Text	255	Habitat code assigned to grid cell (S=SCR, V=Pavement, B=Bedrock, P=Patchreef, R=Reef).
survey_date	Date/Time	8	The date in which a specific survey is done formatted as mm/dd/yyyy
survey_time	Date/Time	8	The specific time of a dive formatted in military time
latitude	Number	8	The latitude of a station recorded in decimal degrees. Precise to 5 decimal places.
longitude	Number	8	The longitude of a station recorded in decimal degrees. Precise to 5 decimal places.
management	Text	255	Based on jurisdiction at locations sites were sampled and type of benthic habitat composition information collected.
family	Text	255	Taxonomic family of fish species
genus	Text	255	Taxonomic genus of fish species
common_name	Text	255	Common name of fish species
scientific_name	Text	255	Taxonomic species name of fish created from the genus and species of fish
species_code	Text	255	Four letter codes are used that consist of the first two letters of the genus name followed by the first two letters of the species name.
trophic	Text	255	Trophic group of fish derived from http://www.fishbase.org and/or Randall (1965) and indicated by trophic codes based on majority in species diet.
fish_size	Text	255	Length of fish in cm
fish_count	Number	4	Number of individual fish
survey_type	Text	255	Type of survey: t=transect; p=point
ID	Number	4	

Table: tbl_FishData
Description: Fish data for the selected year for analysis.

Field Name	Type	Size	Description
Field1	Number	4	
region	Text	255	Location of mission
batch_code	Text	255	An alphanumeric code that identifies the region, month and year of each mission: mm00-yy00 Example: October 2007 = 1000-0700
survey_year	Number	4	The year in which a specific survey is done formatted as yyyy
survey_date	Date/Time	8	The date in which a specific survey is done formatted as mm/dd/yyyy
survey_index	Number	4	A numerical index that uniquely identifies each specific station done within a mission
latitude	Number	8	The latitude of a station recorded in decimal degrees. Precise to 5 decimal places.
survey_time	Date/Time	8	The specific time of a dive formatted in military time
habitat_structure	Text	255	The structure of a specific station: hard, soft or mangrove
longitude	Number	8	The longitude of a station recorded in decimal degrees. Precise to 5 decimal places.
management	Text	255	Based on jurisdiction at locations sites were sampled and type of benthic habitat composition information collected.
permanent_random	Text	255	A label each site is assigned based on how the site was selected and sampled.
family	Text	255	Taxonomic family of fish species
genus_name	Text	255	Taxonomic genus of fish species
common_name	Text	255	Common name of fish species
scientific_name	Text	255	Taxonomic species name of fish created from the genus and species of fish
species_code	Text	255	Four letter codes are used that consist of the first two letters of the genus name followed by the first two letters of the species name.
length	Number	8	Length of fish in cm averaged from either Bin class or actual value if greater than 35 cm. Greater than 100 entered as 101
trophic	Text	255	Trophic group of fish derived from http://www.fishbase.org and/or Randall (1965) and indicated by trophic codes based on majority in species diet.
num	Number	4	Number of individuals
Len	Number	4	Length of fish in cm averaged from either Bin class or actual value if greater than 35 cm. Greater than 100 entered as 101
id	Text	255	

Table: tbl_FishImport
Description: Fish data for all years that have been imported from tbl_Current_Melt.

Field Name	Type	Size	Description
Field1	Text	255	
region	Text	255	Location of mission
batch_code	Text	255	An alphanumeric code that identifies the region, month and year of each mission: mm00-yy00 Example: October 2007 = 1000-0700
survey_year	Number	4	The year in which a specific survey is done formatted as yyyy
station_code	Text	255	An alphanumeric code describing each specific station done within a mission. May contain strata code.
survey_index	Number	4	A numerical index that uniquely identifies each specific station done within a mission
strata	Text	255	Strata code combining zone, depth_strata, and habitat_strata
zone	Text	255	One letter abbreviation of zone_2
depth_strata	Text	255	One letter depth_strata code= S: 0-11.9 m and D: 12+ m
zone_2	Text	255	Name of area where points are independently selected within incl. both management (BUIS, SARI, EEMP) and general area (North, South, West)
depth_2	Text	255	Depth strata name= Shallow: 0-11.9m and Deep: 12+ m
habitat_2	Text	255	Habitat name assigned to grid cell (SCR, Pavement, Bedrock, Patchreef, Reef).
habitat_strata	Text	255	Habitat code assigned to grid cell (S=SCR, V=Pavement, B=Bedrock, P=Patchreef, R=Reef).
survey_date	Date/Time	8	The date in which a specific survey is done formatted as mm/dd/yyyy
survey_time	Date/Time	8	The specific time of a dive formatted in military time
latitude	Number	8	The latitude of a station recorded in decimal degrees. Precise to 5 decimal places.
longitude	Number	8	The longitude of a station recorded in decimal degrees. Precise to 5 decimal places.
management	Text	255	Based on jurisdiction at locations sites were sampled and type of benthic habitat composition information collected.
family	Text	255	Taxonomic family of fish species
genus	Text	255	Taxonomic genus of fish species
common_name	Text	255	Common name of fish species
scientific_name	Text	255	Taxonomic species name of fish created from the genus and species of fish
species_code	Text	255	Four letter codes are used that consist of the first two letters of the genus name followed by the first two letters of the species name.
trophic	Text	255	Trophic group of fish derived from http://www.fishbase.org and/or Randall (1965) and indicated by trophic codes based on majority in species diet.
fish_size	Text	255	Length of fish in cm
fish_count	Number	4	Number of individual fish
survey_type	Text	255	Type of survey: t=transect; p=point
ID	Number	4	

Table: tbl_FishMetric

Description: Temporary table generated during analysis to speed up the query. Field descriptions are deleted each time the table is recreated.

Field Name	Type	Size	Description
Survey_Year	Number	2	The year in which a specific survey is done formatted as yyyy
management	Text	255	Based on jurisdiction at locations sites were sampled and type of benthic habitat composition information collected.
Habitat_Structure	Text	255	The structure of a specific station: hard, soft or mangrove
species_code	Text	255	Four letter codes are used that consist of the first two letters of the genus name followed by the first two letters of the species name.
Ntot	Number	4	Total number of primary units
CountOfsurvey_index	Number	4	Number of primary units surveyed in the field based upon field data
m	Number	4	Number of secondary units per primary unit
AvgOfSumOfFish	Number	8	Average density
VarOfSumOfFish	Number	8	Variance of AvgOfSumOfFish
f	Number	8	Percentage of survey sites containing fish
var_D	Number	8	Variance of mean density
SE_D	Number	8	standard error of mean density
CV_D	Number	8	Coefficient of variation
ytot	Number	8	Average density time Ntot
var_ytot	Number	8	Variance of ytot
se_ytot	Number	8	Standard error of ytot

Table: tbl_Sampling_Summary

Description: Summary data concerning number of sites and habitat types sampled each year.

Field Name	Type	Size	Description
ID	Number	4	
Subregion	Text	255	Location of mission
Year	Number	4	The year in which a specific survey is done formatted as yyyy
Reporting_zone	Text	255	Based on jurisdiction at locations sites were sampled and type of benthic habitat composition information collected.
Strata	Text	255	The structure of a sp ecific station: hard, soft or mangrove
Ntot	Number	4	Total number of primary units
m	Number	4	Number of secondary units per primary unit
Primary_units_selected	Number	4	Number of primary units selected initially for sampling based upon map
Primary_units_surveyed	Number	4	Number of primary units surveyed in the field based upon field data

Table: tlu_Fish_Size
Description: Length values used to convert fish bin lengths to average sizes.

Field Name	Type	Size	Description
fish_size	Text	255	Fish size bin
Actual	Number	4	Average size of bin

Table: tlu_Species
Description: Species list lookup table.

Field Name	Type	Size	Description
species_code	Text	50	Four letter codes are used that consist of the first two letters of the genus name followed by the first two letters of the species name.
kingdom	Text	50	Taxonomic kingdom of fish species
phylum	Text	50	Taxonomic phylum of fish species
class	Text	50	Taxonomic class of fish species
family	Text	50	Taxonomic family of fish species
genus_name	Text	50	Taxonomic genus of fish species
species_name	Text	50	Taxonomic species name of fish created from the genus and species of fish
common_name	Text	50	Common name of fish species
species_type	Text	1	Indicates whether fish or habitat data
trophic	Text	10	Trophic group of fish derived from http://www.fishbase.org and/or Randall (1965) and indicated by trophic codes based on majority in species diet.
a_lw	Number	8	Intercept for length weight relationship: Value of constant "a" in length/weight relationship W=aL^b
b_lw	Number	8	slope for length weight relationship: Value of constant "b" in length/weight relationship W=aL^b
l_w_conversion_factor	Number	8	Conversion factor
maturity	Number	8	Length of sexual maturity
l_w_congener	Text	50	Congener (closest similar fish) to use for length weight relationship if a_lw and b_lw are missing
reference	memo	0	Reference document
cover_group	Text	100	Type of substrate cover: abiotic or biotic
morphotype	Text	100	Grouping of like forms within each cover_group
Exploited	Number	8	Legal size for harvest
Reef_Fish	Yes/No	1	Is this considered a reef fish
Maturity_2012	Number	4	2012 update based on Fish Base
Sex_2012	Text	10	Male, female, unknown; m,f,u
Reference_2012	Text	255	2012 update based on Fish Base
Location_2012	Text	255	Region where study was conducted
Observed	Yes/No	1	Observed in the field
Focal	Yes/No	1	Species for which individual species reports are generated
Focal_Optomize	Yes/No	1	Species that are used to optimize the sampling design for the following year

Definition of Queries in SFCN USVI Fish Database

Query: qry_Data_Append
Purpose: Imports data from tbl_Current_Melt to tbl_FishImport. This query filters out sites that are 100% sand.
Code: INSERT INTO tbl_FishImport (region, batch_code, survey_year, survey_index, management, habitat_structure, survey_date, latitude, survey_time, longitude, family, genus_name, common_name, scientific_name, species_code, len, trophic, num, ID)
SELECT tbl_Current_Melt.region, tbl_Current_Melt.batch_code, tbl_Current_Melt.survey_year, tbl_Current_Melt.survey_index, tbl_Current_Melt.zone_2 AS management, qry_Sitelist.strata, tbl_Current_Melt.survey_date, tbl_Current_Melt.latitude, tbl_Current_Melt.survey_time, tbl_Current_Melt.longitude, tbl_Current_Melt.family, tbl_Current_Melt.genus AS genus_name, tbl_Current_Melt.common_name, tbl_Current_Melt.scientific_name, tbl_Current_Melt.species_code, IIf([tlu_Fish_size]![fish_size] Is Null,[tbl_Current_Melt]![fish_size],[tlu_Fish_size]![Actual]) AS len, tbl_Current_Melt.trophic, tbl_Current_Melt.fish_count AS num, tbl_Current_Melt.ID
FROM tlu_Fish_size RIGHT JOIN ((tbl_Current_Melt INNER JOIN qry_Sitelist ON tbl_Current_Melt.survey_index = qry_Sitelist.survey_index) INNER JOIN qry_Site_No_Sand ON qry_Sitelist.survey_index = qry_Site_No_Sand.survey_index) ON tlu_Fish_size.fish_size = tbl_Current_Melt.fish_size
ORDER BY tbl_Current_Melt.zone_2, qry_Sitelist.strata, IIf([tlu_Fish_size]![fish_size] Is Null,[tbl_Current_Melt]![fish_size],[tlu_Fish_size]![Actual]);

Query: qry_FishCountSite
Purpose: This query calculates the number of fish per species, per survey index site.
Code: SELECT tbl_fishdata.survey_index, tbl_fishdata.species_code, Sum(tbl_fishdata.num) AS SumOfnum, tbl_fishdata.survey_year, IIf([tbl_fishdata]![management]="BUCK","BUCK",IIf([tbl_fishdata]![management]="SARI","SARI","Outside")) AS management, tbl_fishdata.habitat_structure
FROM tbl_fishdata
GROUP BY tbl_fishdata.survey_index, tbl_fishdata.species_code, tbl_fishdata.survey_year, IIf([tbl_fishdata]![management]="BUCK","BUCK",IIf([tbl_fishdata]![management]="SARI","SARI","Outside")), tbl_fishdata.habitat_structure;

Query: qry_FishAllSpeciesSite
Purpose: This query provides the distinct fish species per survey index site.
Code: SELECT DISTINCT qry_FishCountSite.survey_index, qry_FishCountSite.survey_year, qry_FishCountSite.management, qry_FishCountSite.habitat_structure, tbl_FishData.species_code
FROM qry_FishCountSite, tbl_FishData;

Query: qry_FishNullPop
Purpose: This query essentially populates fish species not seen at a specific survey index site with a value of “0” so that statistical calculations (e.g. variance) can be performed.

Code: SELECT qry_FishAllSpeciesSite.survey_index, qry_FishAllSpeciesSite.survey_year, qry_FishAllSpeciesSite.management, qry_FishAllSpeciesSite.habitat_structure, qry_FishAllSpeciesSite.species_code, IIf([SumOfnum] Is Null,0,[SumofNum]) AS SumOfFish
FROM qry_FishAllSpeciesSite LEFT JOIN qry_FishCountSite ON
(qry_FishAllSpeciesSite.survey_index = qry_FishCountSite.survey_index) AND
(qry_FishAllSpeciesSite.survey_year = qry_FishCountSite.survey_year) AND
(qry_FishAllSpeciesSite.management = qry_FishCountSite.management) AND
(qry_FishAllSpeciesSite.habitat_structure = qry_FishCountSite.habitat_structure) AND
(qry_FishAllSpeciesSite.species_code = qry_FishCountSite.species_code);

Query: qry_FishAvgSite
Purpose: This query calculates the average number of fish per management unit. The query is based off another query, qry_FishNullPop.
Converts all non BUIS and SARI management sites to "Outside"
Code: SELECT qry_FishNullPop.species_code, Avg(qry_FishNullPop.SumOfFish) AS AvgOfSumOfFish, Var(qry_FishNullPop.SumOfFish) AS VarOfSumOfFish, qry_FishNullPop.survey_year,
IIf([qry_FishNullPop]![management]="BUCK","BUCK",IIf([qry_FishNullPop]![management]="SARI","SARI","Outside")) AS management, qry_FishNullPop.habitat_structure
FROM qry_FishNullPop
GROUP BY qry_FishNullPop.species_code, qry_FishNullPop.survey_year,
IIf([qry_FishNullPop]![management]="BUCK","BUCK",IIf([qry_FishNullPop]![management]="SARI","SARI","Outside")), qry_FishNullPop.habitat_structure
HAVING
(((IIf([qry_FishNullPop]![management]="BUCK","BUCK",IIf([qry_FishNullPop]![management]="SARI","SARI","Outside")))<>"none"))
ORDER BY qry_FishNullPop.species_code;

Query: qry_FishMetric_1
Purpose: Preps data for qry_FishMetric. If avD is null value is replaced with value from qry_Fish_Var. For SE_D if var_D is null then SE_D is set to null. For CV_D if AvgOfSumOffish is null then CV_D is set to null. For se_ytot if var_ytot is set null then se_ytot is set to null.
Code: SELECT qry_FishAvgSite.survey_year, qry_FishAvgSite.management, tbl_Sampling_Summary.Strata AS Habitat_Structure, qry_FishAvgSite.species_code, tbl_Sampling_Summary.Ntot, qry_SiteList_StrataCount.CountOfStrata AS CountOfsurvey_index, tbl_Sampling_Summary.m, qry_FishAvgSite.AvgOfSumOfFish, qry_FishAvgSite.VarOfSumOfFish, [CountOfsurvey_index]/[Ntot] AS f, (1-[f])*([VarOfSumOffish]/[CountOfsurvey_index]) AS var_D, Sqr([var_D]) AS SE_D, ([SE_D]/[AvgOfSumOffish])*100 AS CV_D, [Ntot]*[AvgOfSumOffish] AS ytot, ([Ntot]*[Ntot])*[var_D] AS var_ytot, Sqr([var_ytot]) AS se_ytot
FROM qry_SiteList_StrataCount INNER JOIN (qry_FishAvgSite INNER JOIN tbl_Sampling_Summary ON (qry_FishAvgSite.habitat_structure = tbl_Sampling_Summary.Strata) AND (qry_FishAvgSite.management = tbl_Sampling_Summary.Reporting_zone) AND (qry_FishAvgSite.survey_year = tbl_Sampling_Summary.Year)) ON (qry_SiteList_StrataCount.Year =

qry_FishAvgSite.survey_year) AND (qry_SiteList_StrataCount.strata = qry_FishAvgSite.habitat_structure) AND (qry_SiteList_StrataCount.Zone1 = qry_FishAvgSite.management);

Query: qry_Sitelist
Purpose: Preps data for qry_Site_No_Sand
Code: SELECT qry_BenthicData.batch_code, qry_BenthicData.station_code, qry_BenthicData.survey_index, qry_BenthicData.strata, qry_BenthicData.zone, qry_BenthicData.depth_strata, qry_BenthicData.Zone_2 AS Zone1, qry_BenthicData.depth_2, qry_BenthicData.[tbl_benthic.Habitat_2] AS Expr1, qry_BenthicData.habitat_strata, qry_BenthicData.survey_date, qry_BenthicData.Year, qry_BenthicData.latitude, qry_BenthicData.longitude
FROM qry_BenthicData
GROUP BY qry_BenthicData.batch_code, qry_BenthicData.station_code, qry_BenthicData.survey_index, qry_BenthicData.strata, qry_BenthicData.zone, qry_BenthicData.depth_strata, qry_BenthicData.Zone_2, qry_BenthicData.depth_2, qry_BenthicData.[tbl_benthic.Habitat_2], qry_BenthicData.habitat_strata, qry_BenthicData.survey_date, qry_BenthicData.Year, qry_BenthicData.latitude, qry_BenthicData.longitude;

Query: qry_BenthicData
Purpose: Preps data for qry_SiteSand
Code: SELECT tbl_benthic.batch_code, Year([survey_date]) AS [Year], tbl_benthic.station_code, tbl_benthic.survey_index, IIf([tbl_benthic]![quad_depth]>39.37,"Deep","Shallow") & ", " & [tlu_Strata]![Strata_2] AS strata, tbl_benthic.zone, tbl_benthic.depth_strata, tbl_benthic.zone_2, tbl_benthic.depth_2, tbl_benthic.habitat_2, tbl_benthic.habitat_strata, tbl_benthic.survey_date, tbl_benthic.latitude, tbl_benthic.survey_time, tbl_benthic.longitude, tbl_benthic.management, tbl_benthic.permananet_random, tbl_benthic.cover_type, tbl_benthic.cover_code, tbl_benthic.species_group, tbl_benthic.morphotype, tbl_benthic.percent_cover, tbl_benthic.species_name, tbl_benthic.bleached_cover, tbl_benthic.diseased_cover, tbl_benthic.height, tbl_benthic.max_height, tbl_benthic.min_height, tbl_benthic.height_variance, tbl_benthic.individuals, tbl_benthic.max_individuals, tbl_benthic.min_individuals, tbl_benthic.min_depth, tbl_benthic.quad_depth, tbl_benthic.depth_variance, tbl_benthic.max_depth, tbl_benthic.ID, tbl_benthic.mean_rugosity, tlu_Strata.Habitat_2
FROM tbl_benthic LEFT JOIN tlu_Strata ON tbl_benthic.habitat_2 = tlu_Strata.Habitat_2;

Query: qry_SiteSand
Purpose: Preps data for qry_Site_No_Sand
Code: SELECT qry_BenthicData.batch_code, qry_BenthicData.station_code, qry_BenthicData.survey_index, qry_BenthicData.strata, qry_BenthicData.zone, qry_BenthicData.depth_strata, qry_BenthicData.zone_2, qry_BenthicData.depth_2, qry_BenthicData.[tbl_benthic.Habitat_2] AS Expr1, qry_BenthicData.habitat_strata, qry_BenthicData.survey_date, qry_BenthicData.latitude, qry_BenthicData.survey_time, qry_BenthicData.longitude, qry_BenthicData.management, qry_BenthicData.permananet_random, qry_BenthicData.cover_type,

qry_BenthicData.cover_code, qry_BenthicData.species_group, qry_BenthicData.morphotype, qry_BenthicData.percent_cover, qry_BenthicData.species_name, qry_BenthicData.bleached_cover, qry_BenthicData.diseased_cover, qry_BenthicData.height, qry_BenthicData.max_height, qry_BenthicData.min_height, qry_BenthicData.height_variance, qry_BenthicData.individuals, qry_BenthicData.max_individuals, qry_BenthicData.min_individuals, qry_BenthicData.min_depth, qry_BenthicData.quad_depth, qry_BenthicData.depth_variance, qry_BenthicData.max_depth, qry_BenthicData.ID, qry_BenthicData.mean_rugosity
FROM qry_BenthicData
WHERE (((qry_BenthicData.cover_code)="sand") AND
((qry_BenthicData.percent_cover)=100) AND
(([qry_BenthicData].[tbl_benthic.Habitat_2])<>"scr"));

Query: qry_Site_No_Sand
Purpose: Preps data for qry_Sitelist_StrataCount
Code: SELECT qry_Sitelist.Year, qry_Sitelist.Zone1, qry_Sitelist.strata, qry_Sitelist.survey_index, qry_Sitelist.latitude, qry_Sitelist.longitude
FROM qry_Sitelist LEFT JOIN qry_SiteSand ON qry_Sitelist.survey_index = qry_SiteSand.survey_index
WHERE (((qry_SiteSand.survey_index) Is Null))
ORDER BY qry_Sitelist.Year, qry_Sitelist.Zone1, qry_Sitelist.strata, qry_Sitelist.survey_index;

Query: qry_Sitelist_StrataCount
Purpose: Preps data for qry_FishMetric
Code: SELECT qry_Sitelist.Year,
IIf([qry_Sitelist]![Zone1]="BUCK","BUCK",IIf([qry_Sitelist]![Zone1]="SARI","SARI","Outside")) AS Zone1, qry_Sitelist.strata, Count(qry_Sitelist.strata) AS CountOfstrata
FROM qry_Site_No_Sand INNER JOIN qry_Sitelist ON qry_Site_No_Sand.qry_Sitelist.survey_index = qry_Sitelist.survey_index
GROUP BY qry_Sitelist.Year,
IIf([qry_Sitelist]![Zone1]="BUCK","BUCK",IIf([qry_Sitelist]![Zone1]="SARI","SARI","Outside")), qry_Sitelist.strata
ORDER BY qry_Sitelist.Year,
IIf([qry_Sitelist]![Zone1]="BUCK","BUCK",IIf([qry_Sitelist]![Zone1]="SARI","SARI","Outside")), qry_Sitelist.strata;

Query: qry_FishMetric_
Purpose: Preps data for qry_FishMetric
*Code:*_ SELECT qry_SiteList_StrataCount.Year AS Survey_Year, qry_SiteList_StrataCount.zone1 AS management, qry_SiteList_StrataCount.Strata AS Habitat_Structure, qry_FishMetric_1.species_code, qry_FishMetric_1.Ntot, qry_SiteList_StrataCount.CountOfstrata AS CountOfsurvey_index, qry_FishMetric_1.m, qry_FishMetric_1.avD, qry_FishMetric_1.s2, qry_FishMetric_1.f, qry_FishMetric_1.var_D, qry_FishMetric_1.SE_D, qry_FishMetric_1.CV_D, qry_FishMetric_1.ytot, qry_FishMetric_1.var_ytot, qry_FishMetric_1.se_ytot INTO tbl_FishMetric

FROM qry_FishMetric_1 RIGHT JOIN qry_SiteList_StrataCount ON
(qry_FishMetric_1.survey_year = qry_SiteList_StrataCount.Year) AND
(qry_FishMetric_1.Habitat_Structure = qry_SiteList_StrataCount.strata) AND
(qry_FishMetric_1.management = qry_SiteList_StrataCount.Zone1)
WHERE (((qry_FishMetric_1.avD) Is Not Null));

Query: qry_FishMetric
Purpose: This query calculates density and abundance statistics (e.g. variance, standard deviation) per fish species code, per habitat structure
Code: SELECT qry_FishAvgSite.survey_year, qry_FishAvgSite.management,
tbl_Sampling_Summary.Strata AS Habitat_Structure, qry_FishAvgSite.species_code,
tbl_Sampling_Summary.Ntot, qry_SiteList_StrataCount.CountOfStrata AS
CountOfsurvey_index, tbl_Sampling_Summary.m, qry_FishAvgSite.SumOfSumOfFish,
qry_FishAvgSite.VarOfSumOfFish AS Expr1, [CountOfsurvey_index]/[Ntot] AS f, IIf((1-
[f])*([VarOfSumOffish]/[CountOfsurvey_index])>0,(1-
[f])*([VarOfSumOffish]/[CountOfsurvey_index]),[qry_Fish_Var]![var_d_1]) AS var_D,
IIf([var_D]>0,Sqr([var_D]),Null) AS SE_D,
IIf([SumOfSumOfFish]>0,([SE_D]/[SumOfSumOfFish])*100,Null) AS CV_D,
[Ntot]*[SumOfSumOfFish] AS ytot, ([Ntot]*[Ntot])*[var_D] AS var_ytot,
IIf([var_ytot]>0,Sqr([var_ytot]),Null) AS se_ytot
FROM (qry_SiteList_StrataCount INNER JOIN (qry_FishAvgSite INNER JOIN
tbl_Sampling_Summary ON (qry_FishAvgSite.survey_year = tbl_Sampling_Summary.Year)
AND (qry_FishAvgSite.management = tbl_Sampling_Summary.Reporting_zone) AND
(qry_FishAvgSite.habitat_structure = tbl_Sampling_Summary.Strata)) ON
(qry_SiteList_StrataCount.Zone1 = qry_FishAvgSite.management) AND
(qry_SiteList_StrataCount.strata = qry_FishAvgSite.habitat_structure) AND
(qry_SiteList_StrataCount.Year = qry_FishAvgSite.survey_year)) LEFT JOIN qry_Fish_Var
ON (qry_FishAvgSite.survey_year = qry_Fish_Var.survey_year) AND
(qry_FishAvgSite.habitat_structure = qry_Fish_Var.habitat_structure) AND
(qry_FishAvgSite.species_code = qry_Fish_Var.species_code);

Query: qry_FishOccData
Purpose: This query provides a count of the sum of fish found for a specific fish species in a specific habitat strata
Code: SELECT qry_FishCountSite.species_code, qry_FishCountSite.habitat_structure,
qry_FishCountSite.survey_year, qry_FishCountSite.management,
Count(qry_FishCountSite.SumOfFirstOfnum) AS CountOfSumOfnum
FROM qry_FishCountSite
WHERE (((qry_FishCountSite.SumOfFirstOfnum)>0))
GROUP BY qry_FishCountSite.species_code, qry_FishCountSite.habitat_structure,
qry_FishCountSite.survey_year, qry_FishCountSite.management;

Query: Qry_SamplingNtot
Purpose: Preps data for qry_Fish_Var_1
Code: SELECT tbl_Sampling_Summary.Year, tbl_Sampling_Summary.Reporting_zone,
Sum(tbl_Sampling_Summary.Ntot) AS SumOfNtot

FROM tbl_Sampling_Summary
GROUP BY tbl_Sampling_Summary.Year, tbl_Sampling_Summary.Reporting_zone;

Query: qry_Fish_Var_1
Purpose: Preps data for qry_Fish_Var
Code: SELECT qry_FishMet.survey_year, qry_FishMet.management, qry_FishMet.habitat_structure, qry_FishMet.species_code, qry_FishMet.Ntot, qry_FishMet.CountOfsurvey_index AS nh, qry_FishMet.m, qry_FishMet.avD, qry_FishMet.s2, qry_FishMet.f, qry_FishMet.var_D, qry_FishMet.SE_D, qry_FishMet.CV_D, qry_FishMet.ytot, qry_FishMet.var_ytot, qry_FishMet.se_ytot, [Countofsumofnum]/[CountOfsurvey_index] AS Occupancy, (1-[f])*((([nh]/([nh]-1))*[Occupancy]*(1-[Occupancy]))/[nh]) AS var_P, [ntot]/[sumofntot] AS wh, [wh]*[Occupancy] AS wh_P, (([wh]*[wh])*[var_p]) AS wh_2_var_P, [avD]*[wh] AS wh_avD, ([wh]^2)*[var_D] AS wh_2_var_D
FROM qry_SamplingNtot RIGHT JOIN (qry_FishMet LEFT JOIN qry_FishOccData ON (qry_FishMet.species_code = qry_FishOccData.species_code) AND (qry_FishMet.habitat_structure = qry_FishOccData.habitat_structure) AND (qry_FishMet.management = qry_FishOccData.management) AND (qry_FishMet.survey_year = qry_FishOccData.survey_year)) ON (qry_SamplingNtot.Year = qry_FishMet.survey_year) AND (qry_SamplingNtot.Reporting_zone = qry_FishMet.management)
WHERE (((qry_FishMet.CountOfsurvey_index)>1));

Query: qry_Fish_Var_2
Purpose: Preps data for qry_Fish_Var_3
Code: SELECT qry_Fish_Var_1.survey_year, qry_Fish_Var_1.habitat_structure, qry_Fish_Var_1.species_code, Max(qry_Fish_Var_1.nh) AS MaxOfnh
FROM qry_Fish_Var_1
GROUP BY qry_Fish_Var_1.survey_year, qry_Fish_Var_1.habitat_structure, qry_Fish_Var_1.species_code
ORDER BY qry_Fish_Var_1.survey_year, qry_Fish_Var_1.habitat_structure, Max(qry_Fish_Var_1.nh) DESC;

Query: qry_Fish_Var_3
Purpose: Preps data for qry_Fish_Var
Code: SELECT qry_Fish_Var_2.survey_year, qry_Fish_Var_2.habitat_structure, qry_Fish_Var_2.species_code, qry_Fish_Var_2.MaxOfnh, Min(qry_Fish_Var_1.var_P) AS MinOfvar_P
FROM qry_Fish_Var_2 INNER JOIN qry_Fish_Var_1 ON (qry_Fish_Var_2.MaxOfnh = qry_Fish_Var_1.nh) AND (qry_Fish_Var_2.species_code = qry_Fish_Var_1.species_code) AND (qry_Fish_Var_2.habitat_structure = qry_Fish_Var_1.habitat_structure) AND (qry_Fish_Var_2.survey_year = qry_Fish_Var_1.survey_year)
GROUP BY qry_Fish_Var_2.survey_year, qry_Fish_Var_2.habitat_structure, qry_Fish_Var_2.species_code, qry_Fish_Var_2.MaxOfnh
ORDER BY qry_Fish_Var_2.habitat_structure;

Query: qry_Fish_Var
Purpose: Provides a substitute variance for habitat zones with a single sampling location

Code: SELECT qry_Fish_Var_1.survey_year, qry_Fish_Var_3.habitat_structure, qry_Fish_Var_1.species_code, qry_Fish_Var_1.nh, qry_Fish_Var_1.var_P, qry_Fish_Var_1.wh_2_var_D, qry_Fish_Var_1.avd AS avD_1, qry_Fish_Var_1.s2 AS s2_1, qry_Fish_Var_1.var_d AS var_D_1, qry_Fish_Var_1.SE_D, qry_Fish_Var_1.CV_D, qry_Fish_Var_1.ytot, qry_Fish_Var_1.se_ytot, qry_Fish_Var_1.Occupancy, qry_Fish_Var_1.wh_P, qry_Fish_Var_1.wh_avD, qry_Fish_Var_1.wh_2_var_P
FROM qry_Fish_Var_1 INNER JOIN qry_Fish_Var_3 ON (qry_Fish_Var_1.survey_year = qry_Fish_Var_3.survey_year) AND (qry_Fish_Var_1.habitat_structure = qry_Fish_Var_3.habitat_structure) AND (qry_Fish_Var_1.species_code = qry_Fish_Var_3.species_code) AND (qry_Fish_Var_1.nh = qry_Fish_Var_3.MaxOfnh) AND (qry_Fish_Var_1.var_P = qry_Fish_Var_3.MinOfvar_P)
ORDER BY qry_Fish_Var_1.survey_year, qry_Fish_Var_3.habitat_structure, qry_Fish_Var_1.nh DESC;

<u>Query: qry_FishOccupancy</u>
Purpose: This query allows for the occupancy statistics to be calculated from the data available. Weighted density for occupancy is also calculated within the query
Code: SELECT tbl_FishMetric.survey_year, tbl_FishMetric.management, tbl_FishMetric.habitat_structure, tbl_FishMetric.species_code, tbl_FishMetric.Ntot, [tbl_FishMetric]!CountOfsurvey_index AS nh, tbl_FishMetric.m, tbl_FishMetric.avD, IIf([s2]>0,[s2],[s2_1]) AS s2_, tbl_FishMetric.f, ((1-[f])*([s2_]/[nh])) AS var_D, IIf([var_D]>0,Sqr([var_D]),Null) AS SE_D, IIf([avD]>0,([SE_D]/[avD])*100,Null) AS CV_D, tbl_FishMetric.ytot, IIf([avD]>0,[var_ytot],[ntot]*[ntot]*[var_D]) AS var_ytot_, IIf([var_ytot]>0,Sqr([var_ytot]),Sqr([var_ytot_])) AS se_ytot, IIf([Countofsumofnum]/[CountOfsurvey_index]>0,[Countofsumofnum]/[CountOfsurvey_index],0) AS Occupancy, IIf([nH]>1,(1-[f])*((([nh]/([nh]-1))*[Occupancy]*(1-[Occupancy]))/[nh]),IIf([qry_fish_var]![var_P]>0,[qry_fish_var]![var_P],0)) AS var_P, [ntot]/[sumofntot] AS wh, [wh]*[Occupancy] AS wh_P, (([wh]*[wh])*[var_p]) AS wh_2_var_P, [tbl_FishMetric]![avD]*[wh] AS wh_avD, ([wh]^2)*[var_D] AS wh_2_var_D, qry_Fish_Var.s2_1, qry_SamplingNtot.SumOfNtot
FROM qry_Fish_Var RIGHT JOIN (qry_SamplingNtot RIGHT JOIN (tbl_FishMetric LEFT JOIN qry_FishOccData ON (tbl_FishMetric.survey_year = qry_FishOccData.survey_year) AND (tbl_FishMetric.management = qry_FishOccData.management) AND (tbl_FishMetric.habitat_structure = qry_FishOccData.habitat_structure) AND (tbl_FishMetric.species_code = qry_FishOccData.species_code)) ON (qry_SamplingNtot.Reporting_zone = tbl_FishMetric.management) AND (qry_SamplingNtot.Year = tbl_FishMetric.survey_year)) ON (qry_Fish_Var.species_code = tbl_FishMetric.species_code) AND (qry_Fish_Var.habitat_structure = tbl_FishMetric.Habitat_Structure) AND (qry_Fish_Var.survey_year = tbl_FishMetric.Survey_Year)
WHERE (((tbl_FishMetric.species_code) Is Not Null))
ORDER BY tbl_FishMetric.survey_year, tbl_FishMetric.management, tbl_FishMetric.habitat_structure, tbl_FishMetric.species_code;

Query: qry_FishWeightedVariance
Purpose: This query calculates summary statistics for abundance, density, and occupancy. However, the density and occupancy calculated are weighted. This query is based off the query qry_FishOccupancy
Code: SELECT qry_FishOccupancy.survey_year, qry_FishOccupancy.management, qry_FishOccupancy.tbl_FishMetric.species_code AS Species_Code, Sum(qry_FishOccupancy.wh) AS SumOfwh, Sum(qry_FishOccupancy.wh_P) AS SumOfwh_P, Sum(qry_FishOccupancy.wh_2_var_P) AS SumOfwh_2_var_P, Sqr([SumOfwh_2_var_P]) AS SE_P, Sum(qry_FishOccupancy.wh_avD) AS Dbar, Sum(qry_FishOccupancy.wh_2_var_D) AS Vbar_D, Sqr([Vbar_D]) AS SE_D_, Sum(qry_FishOccupancy.ytot) AS SumOfytot, Sum(qry_FishOccupancy.var_ytot_) AS SumOfvar_ytot, Sqr([sumofvar_ytot]) AS se_ytot_, [se_ytot_]/[sumofytot] AS CV
FROM qry_FishOccupancy
GROUP BY qry_FishOccupancy.survey_year, qry_FishOccupancy.management, qry_FishOccupancy.tbl_FishMetric.species_code;

Qry_FishLength:
Purpose: This query preps data for qry_FishLengthBin.
Code: SELECT tbl_FishData.Field1, tbl_FishData.region, tbl_FishData.batch_code, tbl_FishData.survey_year, tbl_FishData.survey_date, tbl_FishData.survey_index, tbl_FishData.latitude, tbl_FishData.survey_time, tbl_FishData.habitat_structure, tbl_FishData.longitude, IIf([tbl_fishdata]![management]="BUCK","BUCK",IIf([tbl_fishdata]![management]="SARI","SARI","Outside")) AS management, tbl_FishData.permanent_random, tbl_FishData.family, tbl_FishData.genus_name, tbl_FishData.common_name, tbl_FishData.scientific_name, tbl_FishData.species_code, IIf([Len]>100,101,IIf([len]>=96,97.5,IIf([len]>=91,92.5,IIf([len]>=86,87.5,IIf([len]>=81,82.5,IIf([len]>=76,77.5,IIf([len]>=71,72.5,IIf([len]>=66,67.5,IIf([len]>=61,62.5,IIf([len]>=56,57.5,IIf([len]>=51,52.5,IIf([len]>=46,47.5,IIf([len]>=41,42.5,IIf([len]>=36,37.5,[len])))))))))))))) AS length, tbl_FishData.trophic, tbl_FishData.ID, tbl_FishData.num, tbl_FishData.Len
FROM tbl_FishData
ORDER BY tbl_FishData.species_code, IIf([Len]>100,101,IIf([len]>=96,97.5,IIf([len]>=91,92.5,IIf([len]>=86,87.5,IIf([len]>=81,82.5,IIf([len]>=76,77.5,IIf([len]>=71,72.5,IIf([len]>=66,67.5,IIf([len]>=61,62.5,IIf([len]>=56,57.5,IIf([len]>=51,52.5,IIf([len]>=46,47.5,IIf([len]>=41,42.5,IIf([len]>=36,37.5,[len])))))))))))));

Query: qry_FishLengthBin
Purpose: This query converts values greater than 35cm into 5cm increment bins (i.e. 37.5 42.5, 47.5) for use in qry_FishLengthTotal
Code: SELECT qry_FishLength.Field1, qry_FishLength.region, qry_FishLength.batch_code, qry_FishLength.survey_year, qry_FishLength.survey_date, qry_FishLength.survey_index, qry_FishLength.latitude, qry_FishLength.survey_time, qry_FishLength.habitat_structure, qry_FishLength.longitude, qry_FishLength.management, qry_FishLength.permanent_random, qry_FishLength.family, qry_FishLength.genus_name, qry_FishLength.common_name, qry_FishLength.scientific_name, qry_FishLength.species_code, qry_FishLength.length,

qry_FishLength.trophic, qry_FishLength.ID, qry_FishLength.Len, qry_FishLength.length AS Actual, qry_FishLength.num
FROM qry_FishLength;

Query: qry_FishLengthTotal:
Purpose: This query allows to transpose the fish length values found in the query qry_FishLengthBin. The fish length values become headings and the field is populated by the counts existing for the newly created fields/headings. This was done via crosstab query function
Code: TRANSFORM Sum(qry_FishLengthBin.num) AS SumOfnum
SELECT qry_FishLengthBin.species_code, qry_FishLengthBin.survey_year, qry_FishLengthBin.management
FROM qry_FishLengthBin
GROUP BY qry_FishLengthBin.species_code, qry_FishLengthBin.survey_year, qry_FishLengthBin.management
PIVOT qry_FishLengthBin.Actual;

Query: qry_Fish_MaxLength
Purpose: This query determines the maximum length of a fish species for a specific year and management unit
Code: SELECT tbl_FishData.survey_year, IIf([tbl_Fishdata]![management]="BUCK","BUCK",IIf([tbl_Fishdata]![management]="SARI"," SARI","Outside")) AS management, tbl_FishData.common_name, tbl_FishData.scientific_name, tbl_FishData.species_code, Max(tbl_FishData.Len) AS length
FROM tbl_FishData
GROUP BY tbl_FishData.survey_year, IIf([tbl_Fishdata]![management]="BUCK","BUCK",IIf([tbl_Fishdata]![management]="SARI"," SARI","Outside")), tbl_FishData.common_name, tbl_FishData.scientific_name, tbl_FishData.species_code
ORDER BY tbl_FishData.species_code;

Query: qry_Fish_Avg01
Purpose: This query calculates the sum of the lengths per fish species per survey year and management unit by multiplying the lengths of the fish by the count of those observed lengths.
Code: SELECT tbl_FishData.survey_year, IIf([tbl_Fishdata]![management]="BUCK","BUCK",IIf([tbl_Fishdata]![management]="SARI"," SARI","Outside")) AS management, tbl_FishData.common_name, tbl_FishData.scientific_name, tbl_FishData.species_code, tbl_FishData.Len AS length, tbl_FishData.trophic, Sum(tbl_FishData.num) AS SumOfnum, [length]*[SumOfnum] AS Expr1
FROM tbl_FishData
GROUP BY tbl_FishData.survey_year, IIf([tbl_Fishdata]![management]="BUCK","BUCK",IIf([tbl_Fishdata]![management]="SARI"," SARI","Outside")), tbl_FishData.common_name, tbl_FishData.scientific_name, tbl_FishData.species_code, tbl_FishData.Len, tbl_FishData.trophic
HAVING (((Sum(tbl_FishData.num))>0));

Query: qry_Fish_Avg02

Purpose: This query basically gathers the sums of the sum of lengths per species from qry_FishAvg01 and divides them by the sum of the count of observed lengths from the same query. This allows the query to calculate for "average fish length."

Code: SELECT qry_Fish_Avg01.survey_year, qry_Fish_Avg01.management, qry_Fish_Avg01.common_name, qry_Fish_Avg01.scientific_name, qry_Fish_Avg01.species_code, Sum(qry_Fish_Avg01.SumOfnum) AS SumOfSumOfnum, Sum(qry_Fish_Avg01.Expr1) AS SumOfExpr1, [SumOfExpr1]/[SumOfSumOfnum] AS Average_
FROM qry_Fish_Avg01
GROUP BY qry_Fish_Avg01.survey_year, qry_Fish_Avg01.management, qry_Fish_Avg01.common_name, qry_Fish_Avg01.scientific_name, qry_Fish_Avg01.species_code;

Query: qry_FishReporting

Purpose: This query mimics the reporting format to be displayed in the protocol. It queries out data from qry_FishWeightedVariance and qry_FishLengthTotal.

Code: INSERT INTO tbl_FishReporting ([Year], [Zone], SpeciesCode, CommonName, ScientificName, CVAdultDensity, TotalDensityAvg, TotalDensitySE, AdultDensity, AdultDensitySE, JuvDensity, JuvDensitySE, ExploitedDensity, ExploitedDensitySE, TotalAbundanceAvg, TotalAbundanceSE, AdultAbundance, AdultAbundanceSE, JuvAbundance, JuvAbundanceSE, TotalOccupancy, TotalOccupancySE, AdultOccupancy, AdultOccupancySE, JuvOccupancy, JuvOccupancySE, Exploited_Percent, AvgLenAdult, AvgLenAdultSE, AvgLenExploited, AvgLenExploitedSE, MaxLengthcm, AverageLength, Focalsp)
SELECT qry_FishWeightedVariance.survey_year AS [Year], qry_FishWeightedVariance.management AS [Zone], qry_FishWeightedVariance.Species_Code AS SpeciesCode, tlu_Species.common_name AS CommonName, tlu_Species.species_name AS ScientificName, "" AS CVAdultDensity, qry_FishWeightedVariance.Dbar AS TotalDensityAvg, qry_FishWeightedVariance.SE_D_ AS TotalDensitySE, "" AS AdultDensity, "" AS AdultDensitySE, "" AS JuvDensity, "" AS JuvDensitySE, "" AS ExploitedDensity, "" AS ExploitedDensitySE, qry_FishWeightedVariance.SumOfytot AS TotalAbundanceAvg, qry_FishWeightedVariance.se_ytot_ AS TotalAbundanceSE, "" AS AdultAbundance, "" AS AdultAbundanceSE, "" AS JuvAbundance, "" AS JuvAbundanceSE, qry_FishWeightedVariance.SumOfwh_P AS TotalOccupancy, qry_FishWeightedVariance.SE_P AS TotalOccupancySE, "" AS AdultOccupancy, "" AS AdultOccupancySE, "" AS JuvOccupancy, "" AS JuvOccupancySE, "" AS Exploited, "" AS AvgLenAdult, "" AS AvgLenAdultSE, "" AS AvgLenExploited, "" AS AvgLenExploitedSE, qry_Fish_MaxLength.length AS MaxLengthcm, qry_Fish_Avg02.Average_ AS AverageLength, qry_FishLengthTotal.*, tlu_Species.Focalsp
FROM (((qry_FishWeightedVariance INNER JOIN qry_FishLengthTotal ON (qry_FishWeightedVariance.survey_year = qry_FishLengthTotal.survey_year) AND (qry_FishWeightedVariance.species_code = qry_FishLengthTotal.species_code) AND (qry_FishWeightedVariance.management = qry_FishLengthTotal.management)) INNER JOIN qry_Fish_MaxLength ON (qry_FishLengthTotal.species_code = qry_Fish_MaxLength.species_code) AND (qry_FishLengthTotal.survey_year =

qry_Fish_MaxLength.survey_year) AND (qry_FishLengthTotal.management = qry_Fish_MaxLength.management)) INNER JOIN qry_Fish_Avg02 ON (qry_Fish_MaxLength.survey_year = qry_Fish_Avg02.survey_year) AND (qry_Fish_MaxLength.management = qry_Fish_Avg02.management) AND (qry_Fish_MaxLength.species_code = qry_Fish_Avg02.species_code)) INNER JOIN tlu_Species ON qry_FishWeightedVariance.Species_Code = tlu_Species.species_code
ORDER BY qry_FishWeightedVariance.survey_year, qry_FishWeightedVariance.management;

Query: qry_FishGroups
Purpose: This query brings in data for Gorupers, Grunts, Snappers, Parrotfishes
*Code:*_ INSERT INTO tbl_FishData (Field1, region, batch_code, survey_year, survey_date, survey_index, latitude, survey_time, habitat_structure, longitude, management, permanent_random, species_code, length, trophic, num, Len, id, scientific_name, common_name)
SELECT tbl_FishImport.Field1, tbl_FishImport.region, tbl_FishImport.batch_code, tbl_FishImport.survey_year, tbl_FishImport.survey_date, tbl_FishImport.survey_index, tbl_FishImport.latitude, tbl_FishImport.survey_time, tbl_FishImport.habitat_structure, tbl_FishImport.longitude, tbl_FishImport.management, tbl_FishImport.permanent_random, tlu_Species.Group, IIf([Len]>100,101,[len]) AS length, tbl_FishImport.trophic, tbl_FishImport.num, tbl_FishImport.Len, tbl_FishImport.id, tlu_Species.Group, tlu_Species.Group
FROM tbl_FishImport INNER JOIN tlu_Species ON tbl_FishImport.species_code = tlu_Species.species_code
WHERE (((tbl_FishImport.survey_year)=[Forms]![frm_FishReporting]![cmbYear]) AND ((tlu_Species.Group) Is Not Null));

Query: qry_FishTrophicP
Purpose: This query brings in data for Piscivores.
*Code:*_ INSERT INTO tbl_FishData (Field1, region, batch_code, survey_year, survey_date, survey_index, latitude, survey_time, habitat_structure, longitude, management, permanent_random, length, num, Len, id, family, genus_name, common_name, scientific_name, species_code, trophic)
SELECT tbl_FishImport.Field1, tbl_FishImport.region, tbl_FishImport.batch_code, tbl_FishImport.survey_year, tbl_FishImport.survey_date, tbl_FishImport.survey_index, tbl_FishImport.latitude, tbl_FishImport.survey_time, tbl_FishImport.habitat_structure, tbl_FishImport.longitude, tbl_FishImport.management, tbl_FishImport.permanent_random, IIf([Len]>100,101,[len]) AS length, tbl_FishImport.num, tbl_FishImport.Len, tbl_FishImport.id, tbl_FishImport.family, tbl_FishImport.genus_name, "Piscivores" AS common_name, "Piscivores " AS scientific_name, "Piscivores " AS species_code, tlu_Species.trophic
FROM tbl_FishImport INNER JOIN tlu_Species ON tbl_FishImport.species_code = tlu_Species.species_code
WHERE (((tbl_FishImport.survey_year)=[Forms]![frm_FishReporting]![cmbYear]) AND ((tlu_Species.trophic) Like "*p*"));

Query: qry_FishTrophicH
Purpose: This query brings in data for Herbivores.

*Code:*_ INSERT INTO tbl_FishData (Field1, region, batch_code, survey_year, survey_date, survey_index, latitude, survey_time, habitat_structure, longitude, management, permanent_random, length, num, Len, id, family, genus_name, common_name, scientific_name, species_code, trophic)
SELECT tbl_FishImport.Field1, tbl_FishImport.region, tbl_FishImport.batch_code, tbl_FishImport.survey_year, tbl_FishImport.survey_date, tbl_FishImport.survey_index, tbl_FishImport.latitude, tbl_FishImport.survey_time, tbl_FishImport.habitat_structure, tbl_FishImport.longitude, tbl_FishImport.management, tbl_FishImport.permanent_random, IIf([Len]>100,101,[len]) AS length, tbl_FishImport.num, tbl_FishImport.Len, tbl_FishImport.id, tbl_FishImport.family, tbl_FishImport.genus_name, "Herbivores" AS common_name, "Herbivores " AS scientific_name, "Herbivores " AS species_code, tlu_Species.trophic
FROM tbl_FishImport INNER JOIN tlu_Species ON tbl_FishImport.species_code = tlu_Species.species_code
WHERE (((tbl_FishImport.survey_year)=[Forms]![frm_FishReporting]![cmbYear]) AND ((tlu_Species.trophic) Like "*h*"));

Query: qry_FishTrophicI
Purpose: This query brings in data for Herbivores.
*Code:*_ INSERT INTO tbl_FishData (Field1, region, batch_code, survey_year, survey_date, survey_index, latitude, survey_time, habitat_structure, longitude, management, permanent_random, length, num, Len, id, family, genus_name, common_name, scientific_name, species_code, trophic)
SELECT tbl_FishImport.Field1, tbl_FishImport.region, tbl_FishImport.batch_code, tbl_FishImport.survey_year, tbl_FishImport.survey_date, tbl_FishImport.survey_index, tbl_FishImport.latitude, tbl_FishImport.survey_time, tbl_FishImport.habitat_structure, tbl_FishImport.longitude, tbl_FishImport.management, tbl_FishImport.permanent_random, IIf([Len]>100,101,[len]) AS length, tbl_FishImport.num, tbl_FishImport.Len, tbl_FishImport.id, tbl_FishImport.family, tbl_FishImport.genus_name, "Invertivores" AS common_name, "Invertivores " AS scientific_name, "Invertivores " AS species_code, tlu_Species.trophic
FROM tbl_FishImport INNER JOIN tlu_Species ON tbl_FishImport.species_code = tlu_Species.species_code
WHERE (((tbl_FishImport.survey_year)=[Forms]![frm_FishReporting]![cmbYear]) AND ((tlu_Species.trophic) Like "*I*"));

Query: qry_FishTrophicZ
Purpose: This query brings in data for Planktivores.
*Code:*_ INSERT INTO tbl_FishData (Field1, region, batch_code, survey_year, survey_date, survey_index, latitude, survey_time, habitat_structure, longitude, management, permanent_random, length, num, Len, id, family, genus_name, common_name, scientific_name, species_code, trophic)
SELECT tbl_FishImport.Field1, tbl_FishImport.region, tbl_FishImport.batch_code, tbl_FishImport.survey_year, tbl_FishImport.survey_date, tbl_FishImport.survey_index, tbl_FishImport.latitude, tbl_FishImport.survey_time, tbl_FishImport.habitat_structure, tbl_FishImport.longitude, tbl_FishImport.management, tbl_FishImport.permanent_random, IIf([Len]>100,101,[len]) AS length, tbl_FishImport.num, tbl_FishImport.Len, tbl_FishImport.id,

tbl_FishImport.family, tbl_FishImport.genus_name, "Planktivores" AS common_name, "Planktivores " AS scientific_name, "Planktivores " AS species_code, tlu_Species.trophic
FROM tbl_FishImport INNER JOIN tlu_Species ON tbl_FishImport.species_code = tlu_Species.species_code
WHERE (((tbl_FishImport.survey_year)=[Forms]![frm_FishReporting]![cmbYear]) AND ((tlu_Species.trophic) Like "*Z*"));

Query: qry_FishLengthSums
Purpose: This query preps data for average length of all fish.
*Code:*_ SELECT [SumOfLengthCombo]/[sumofNum] AS LengthAvg, IIf([SumofNum]<2,Null,([SumofLength_SE1]-(([SumofLength_SE2])^2/[sumofNum]))/([SumofNum]-1)) AS LengthAvgSE, Sum(qry_FishLengthCombo.LengthCombo) AS SumOfLengthCombo, Sum(qry_FishLengthCombo.num) AS SumOfnum, Sum(qry_FishLengthCombo.Length_SE1) AS SumOfLength_SE1, Sum(qry_FishLengthCombo.Length_SE2) AS SumOfLength_SE2, qry_FishLengthCombo.survey_year, qry_FishLengthCombo.management, qry_FishLengthCombo.species_code INTO tbl_FishLengthSums
FROM qry_FishLengthCombo
GROUP BY qry_FishLengthCombo.survey_year, qry_FishLengthCombo.management, qry_FishLengthCombo.species_code;

Query: qry_FishLengthUpdate
Purpose: This query updates data for average length of all fish.
*Code:*_ UPDATE tbl_FishReporting INNER JOIN tbl_FishLengthSums ON (tbl_FishReporting.SpeciesCode = tbl_FishLengthSums.species_code) AND (tbl_FishReporting.Zone = tbl_FishLengthSums.management) AND (tbl_FishReporting.Year = tbl_FishLengthSums.survey_year) SET tbl_FishReporting.AverageLength = [tbl_FishLengthSums]![LengthAvg], tbl_FishReporting.AverageLengthSE = [tbl_FishLengthSums]![LengthAvgSE];

Query: qry_FishDataJuvenile
Purpose: This query brings in data for juvenile fish.
*Code:*_ SELECT tbl_FishImport.Field1, tbl_FishImport.region, tbl_FishImport.batch_code, tbl_FishImport.survey_year, tbl_FishImport.survey_date, tbl_FishImport.survey_index, tbl_FishImport.latitude, tbl_FishImport.survey_time, tbl_FishImport.habitat_structure, tbl_FishImport.longitude, tbl_FishImport.management, tbl_FishImport.permanent_random, IIf([Len]>100,101,[len]) AS length, tbl_FishImport.trophic, tbl_FishImport.num, tbl_FishImport.Len, tbl_FishImport.id, tbl_FishImport.family, tbl_FishImport.genus_name, tbl_FishImport.common_name, tbl_FishImport.scientific_name, tbl_FishImport.species_code, tlu_Species.maturity, tlu_Species.Focalsp INTO tbl_FishData
FROM tbl_FishImport INNER JOIN tlu_Species ON tbl_FishImport.species_code = tlu_Species.species_code
WHERE (((tbl_FishImport.survey_year)=[Forms]![frm_FishReporting]![cmbYear]) AND ((IIf([Len]>100,101,[len]))<[tlu_Species]![maturity]) AND ((tlu_Species.Focalsp) Is Not Null));

Query: qry_FishDataJuvenile
Purpose: This query preps values for juvenile fish.
*Code:*_ SELECT qry_FishWeightedVariance.survey_year, qry_FishWeightedVariance.management, qry_FishWeightedVariance.Species_Code, qry_FishWeightedVariance.Dbar AS TotalDensityAvg, qry_FishWeightedVariance.SE_D_ AS TotalDensitySE, qry_FishWeightedVariance.SumOfytot AS TotalAbundanceAvg, qry_FishWeightedVariance.se_ytot_ AS TotalAbundanceSE, qry_FishWeightedVariance.SumOfwh_P AS TotalOccupancy, qry_FishWeightedVariance.SE_P AS TotalOccupancySE, qry_Fish_Avg02.Average_ AS AverageLength, qry_FishLengthTotal.* INTO tbl_FishReportingJuvenile
FROM ((qry_FishWeightedVariance INNER JOIN qry_FishLengthTotal ON (qry_FishWeightedVariance.management = qry_FishLengthTotal.management) AND (qry_FishWeightedVariance.species_code = qry_FishLengthTotal.species_code) AND (qry_FishWeightedVariance.survey_year = qry_FishLengthTotal.survey_year)) INNER JOIN qry_Fish_MaxLength ON (qry_FishLengthTotal.management = qry_Fish_MaxLength.management) AND (qry_FishLengthTotal.survey_year = qry_Fish_MaxLength.survey_year) AND (qry_FishLengthTotal.species_code = qry_Fish_MaxLength.species_code)) INNER JOIN qry_Fish_Avg02 ON (qry_Fish_MaxLength.species_code = qry_Fish_Avg02.species_code) AND (qry_Fish_MaxLength.management = qry_Fish_Avg02.management) AND (qry_Fish_MaxLength.survey_year = qry_Fish_Avg02.survey_year);

Query: qry_FishDataJuvenile
Purpose: This query updates values for juvenile fish.
*Code:*_ UPDATE tbl_FishReportingJuvenile INNER JOIN tbl_FishReporting ON (tbl_FishReportingJuvenile.qry_FishWeightedVariance_survey_year = tbl_FishReporting.Year) AND (tbl_FishReportingJuvenile.qry_FishWeightedVariance_management = tbl_FishReporting.Zone) AND (tbl_FishReportingJuvenile.qry_FishWeightedVariance_species_code = tbl_FishReporting.SpeciesCode) SET tbl_FishReporting.JuvDensity = [tbl_FishReportingJuvenile]![TotalDensityAvg], tbl_FishReporting.JuvDensitySE = [tbl_FishReportingJuvenile]![TotalDensitySE], tbl_FishReporting.JuvAbundance = [tbl_FishReportingJuvenile]![TotalAbundanceAvg], tbl_FishReporting.JuvAbundanceSE = [tbl_FishReportingJuvenile]![TotalAbundanceSE], tbl_FishReporting.JuvOccupancy = [tbl_FishReportingJuvenile]![TotalOccupancy], tbl_FishReporting.JuvOccupancySE = [tbl_FishReportingJuvenile]![TotalOccupancySE];

Query: qry_FishDataAdult
Purpose: This query brings in data for adult fish.
*Code:*_ SELECT tbl_FishImport.Field1, tbl_FishImport.region, tbl_FishImport.batch_code, tbl_FishImport.survey_year, tbl_FishImport.survey_date, tbl_FishImport.survey_index, tbl_FishImport.latitude, tbl_FishImport.survey_time, tbl_FishImport.habitat_structure, tbl_FishImport.longitude, tbl_FishImport.management, tbl_FishImport.permanent_random, IIf([Len]>100,101,[len]) AS length, tbl_FishImport.trophic, tbl_FishImport.num, tbl_FishImport.Len, tbl_FishImport.id, tbl_FishImport.family, tbl_FishImport.genus_name,

tbl_FishImport.common_name, tbl_FishImport.scientific_name, tbl_FishImport.species_code, tlu_Species.maturity, tlu_Species.Focalsp INTO tbl_FishData
FROM tbl_FishImport INNER JOIN tlu_Species ON tbl_FishImport.species_code = tlu_Species.species_code
WHERE (((tbl_FishImport.survey_year)=Forms!frm_FishReporting!cmbYear) And ((IIf([Len]>100,101,[len]))>=tlu_Species!maturity) And ((tlu_Species.Focalsp) Is Not Null));

Query: qry_FishReportingAdult
Purpose: This query preps data for adult fish.
*Code:*_ SELECT qry_FishWeightedVariance.survey_year, qry_FishWeightedVariance.management, qry_FishWeightedVariance.Species_Code, qry_FishWeightedVariance.Dbar AS TotalDensityAvg, qry_FishWeightedVariance.SE_D_ AS TotalDensitySE, qry_FishWeightedVariance.SumOfytot AS TotalAbundanceAvg, qry_FishWeightedVariance.se_ytot_ AS TotalAbundanceSE, qry_FishWeightedVariance.SumOfwh_P AS TotalOccupancy, qry_FishWeightedVariance.SE_P AS TotalOccupancySE, qry_Fish_Avg02.Average_ AS AverageLength, qry_FishLengthTotal.* INTO tbl_FishReportingAdult
FROM ((qry_FishWeightedVariance INNER JOIN qry_FishLengthTotal ON (qry_FishWeightedVariance.survey_year = qry_FishLengthTotal.survey_year) AND (qry_FishWeightedVariance.species_code = qry_FishLengthTotal.species_code) AND (qry_FishWeightedVariance.management = qry_FishLengthTotal.management)) INNER JOIN qry_Fish_MaxLength ON (qry_FishLengthTotal.species_code = qry_Fish_MaxLength.species_code) AND (qry_FishLengthTotal.survey_year = qry_Fish_MaxLength.survey_year) AND (qry_FishLengthTotal.management = qry_Fish_MaxLength.management)) INNER JOIN qry_Fish_Avg02 ON (qry_Fish_MaxLength.survey_year = qry_Fish_Avg02.survey_year) AND (qry_Fish_MaxLength.management = qry_Fish_Avg02.management) AND (qry_Fish_MaxLength.species_code = qry_Fish_Avg02.species_code);

Query: qry_FishReportingAdultUpdate
Purpose: This query updates data for adult fish.
*Code:*_ UPDATE tbl_FishReportingAdult INNER JOIN tbl_FishReporting ON (tbl_FishReportingAdult.qry_FishWeightedVariance_species_code = tbl_FishReporting.SpeciesCode) AND (tbl_FishReportingAdult.qry_FishWeightedVariance_management = tbl_FishReporting.Zone) AND (tbl_FishReportingAdult.qry_FishWeightedVariance_survey_year = tbl_FishReporting.Year) SET tbl_FishReporting.AdultDensity = [tbl_FishReportingAdult]![TotalDensityAvg], tbl_FishReporting.AdultDensitySE = [tbl_FishReportingAdult]![TotalDensitySE], tbl_FishReporting.AdultAbundance = [tbl_FishReportingAdult]![TotalAbundanceAvg], tbl_FishReporting.AdultAbundanceSE = [tbl_FishReportingAdult]![TotalAbundanceSE], tbl_FishReporting.AdultOccupancy = [tbl_FishReportingAdult]![TotalOccupancy], tbl_FishReporting.AdultOccupancySE = [tbl_FishReportingAdult]![TotalOccupancySE];

Query: qry_FishLengthSumsAdult
Purpose: This query preps data for adult fish length.

*Code:*_ SELECT [SumOfLengthCombo]/[sumofNum] AS LengthAvg, IIf([SumofNum]<2,Null,([SumofLength_SE1]-(([SumofLength_SE2])^2/[sumofNum]))/([SumofNum]-1)) AS LengthAvgSE, Sum(qry_FishLengthCombo.LengthCombo) AS SumOfLengthCombo, Sum(qry_FishLengthCombo.num) AS SumOfnum, Sum(qry_FishLengthCombo.Length_SE1) AS SumOfLength_SE1, Sum(qry_FishLengthCombo.Length_SE2) AS SumOfLength_SE2, qry_FishLengthCombo.survey_year, qry_FishLengthCombo.management, qry_FishLengthCombo.species_code INTO tbl_FishLengthSumsAdult
FROM qry_FishLengthCombo
GROUP BY qry_FishLengthCombo.survey_year, qry_FishLengthCombo.management, qry_FishLengthCombo.species_code;

<u>Query: qry_FishLengthUpdateAdult</u>
Purpose: This query updates values for adult fish length.
*Code:*_ UPDATE tbl_FishLengthSumsAdult INNER JOIN tbl_FishReporting ON (tbl_FishLengthSumsAdult.species_code = tbl_FishReporting.SpeciesCode) AND (tbl_FishLengthSumsAdult.management = tbl_FishReporting.Zone) AND (tbl_FishLengthSumsAdult.survey_year = tbl_FishReporting.Year) SET tbl_FishReporting.AvgLenAdult = [tbl_FishLengthSumsAdult]![LengthAvg], tbl_FishReporting.AvgLenAdultSE = [tbl_FishLengthSumsAdult]![LengthAvgSE];

<u>Query: qry_FishDataExploited</u>
Purpose: This query brings in data for exploited fish.
*Code:*_ SELECT tbl_FishImport.Field1, tbl_FishImport.region, tbl_FishImport.batch_code, tbl_FishImport.survey_year, tbl_FishImport.survey_date, tbl_FishImport.survey_index, tbl_FishImport.latitude, tbl_FishImport.survey_time, tbl_FishImport.habitat_structure, tbl_FishImport.longitude, tbl_FishImport.management, tbl_FishImport.permanent_random, IIf([Len]>100,101,[len]) AS length, tbl_FishImport.trophic, tbl_FishImport.num, tbl_FishImport.Len, tbl_FishImport.id, tbl_FishImport.family, tbl_FishImport.genus_name, tbl_FishImport.common_name, tbl_FishImport.scientific_name, tbl_FishImport.species_code, tlu_Species.maturity, tlu_Species.Focalsp INTO tbl_FishData
FROM tbl_FishImport INNER JOIN tlu_Species ON tbl_FishImport.species_code = tlu_Species.species_code
WHERE (((tbl_FishImport.survey_year)=[Forms]![frm_FishReporting]![cmbYear]) AND ((IIf([Len]>100,101,[len]))>=[tlu_Species]![Exploited]) AND ((tlu_Species.Focalsp) Is Not Null));

<u>Query: qry_FishReportingExploited</u>
Purpose: This query preps data for exploited fish.
*Code:*_ SELECT qry_FishWeightedVariance.survey_year, qry_FishWeightedVariance.management, qry_FishWeightedVariance.Species_Code, qry_FishWeightedVariance.Dbar AS TotalDensityAvg, qry_FishWeightedVariance.SE_D_ AS TotalDensitySE, qry_FishWeightedVariance.SumOfytot AS TotalAbundanceAvg, qry_FishWeightedVariance.se_ytot_ AS TotalAbundanceSE, qry_FishWeightedVariance.SumOfwh_P AS TotalOccupancy, qry_FishWeightedVariance.SE_P

AS TotalOccupancySE, qry_Fish_Avg02.Average_ AS AverageLength, qry_FishLengthTotal.*
INTO tbl_FishReportingExploited
FROM ((qry_FishWeightedVariance INNER JOIN qry_FishLengthTotal ON
(qry_FishWeightedVariance.survey_year = qry_FishLengthTotal.survey_year) AND
(qry_FishWeightedVariance.species_code = qry_FishLengthTotal.species_code) AND
(qry_FishWeightedVariance.management = qry_FishLengthTotal.management)) INNER JOIN
qry_Fish_MaxLength ON (qry_FishLengthTotal.species_code =
qry_Fish_MaxLength.species_code) AND (qry_FishLengthTotal.survey_year =
qry_Fish_MaxLength.survey_year) AND (qry_FishLengthTotal.management =
qry_Fish_MaxLength.management)) INNER JOIN qry_Fish_Avg02 ON
(qry_Fish_MaxLength.survey_year = qry_Fish_Avg02.survey_year) AND
(qry_Fish_MaxLength.management = qry_Fish_Avg02.management) AND
(qry_Fish_MaxLength.species_code = qry_Fish_Avg02.species_code);

<u>Query: qry_FishReportingExploitedUpdate</u>
Purpose: This query updates data for exploited fish.
*Code:*_ UPDATE tbl_FishReportingExploited INNER JOIN tbl_FishReporting ON
(tbl_FishReportingExploited.qry_FishWeightedVariance_survey_year =
tbl_FishReporting.Year) AND
(tbl_FishReportingExploited.qry_FishWeightedVariance_management =
tbl_FishReporting.Zone) AND
(tbl_FishReportingExploited.qry_FishWeightedVariance_species_code =
tbl_FishReporting.SpeciesCode) SET tbl_FishReporting.ExploitedDensity =
[tbl_FishReportingExploited]![TotalDensityAvg], tbl_FishReporting.ExploitedDensitySE =
[tbl_FishReportingExploited]![TotalDensitySE], tbl_FishReporting.ExploitedAbundance =
[tbl_FishReportingExploited]![TotalAbundanceAvg], tbl_FishReporting.ExploitedAbundanceSE
= [tbl_FishReportingExploited]![TotalAbundanceSE], tbl_FishReporting.ExploitedOccupancy =
[tbl_FishReportingExploited]![TotalOccupancy], tbl_FishReporting.ExploitedOccupancySE =
[tbl_FishReportingExploited]![TotalOccupancySE];

<u>Query: qry_FishLengthSumsExploited</u>
Purpose: This query preps data for exploited fish length.
*Code:*_ INSERT INTO tbl_FishLengthSumsExploited (LengthAvg, LengthAvgSE,
SumOfLengthCombo, SumOfLength_SE1, SumOfLength_SE2, SumOfnum, survey_year,
Management, species_code)
SELECT qry_FishLengthSumsExploit.LengthAvg, qry_FishLengthSumsExploit.LengthAvgSE,
qry_FishLengthSumsExploit.SumOfLengthCombo,
qry_FishLengthSumsExploit.SumOfLength_SE1,
qry_FishLengthSumsExploit.SumOfLength_SE2, qry_FishLengthSumsExploit.SumOfnum,
[Forms]![frm_FishReporting]![cmbYear].[Text] AS survey_year,
qry_FishLengthSumsExploit.Management, qry_FishLengthSumsExploit.species_code
FROM qry_FishLengthSumsExploit;

<u>Query: qry_FishLengthUpdateExploited</u>
Purpose: This query updates values for exploited fish length.

*Code:*_ UPDATE tbl_FishLengthSumsExploited INNER JOIN tbl_FishReporting ON (tbl_FishLengthSumsExploited.species_code = tbl_FishReporting.SpeciesCode) AND (tbl_FishLengthSumsExploited.management = tbl_FishReporting.Zone) AND (tbl_FishLengthSumsExploited.survey_year = tbl_FishReporting.Year) SET tbl_FishReporting.AvgLenExploited = [tbl_FishLengthSumsExploited]![LengthAvg], tbl_FishReporting.AvgLenExploitedSE = [tbl_FishLengthSumsExploited]![LengthAvgSE];

Imported Data Files Column Names and Definitions

The following was adapted from the BB file "Reef_Fish_Data_Dictionay.doc" downloadable from the CREAM database web page (http://www8.nos.noaa.gov/biogeo_public/query_main.aspx) plus additions and changes that occurred in 2012.

<u>Fish query column names from email request to BB for 2012+ data</u>

Region
Survey_year
Batch_code
Survey_index
Station_code
Strata
Zone
Zone_2
Depth_strata
Depth_2
Habitat_strata
Habitat_2
Survey_date
Survey_time
Latitude
Longitude
Management
Family
Genus
Scientific_name
Common_name
Species_code
Trophic
Fish_size
Fish_count
Survey_type

<u>Fish query column names from online download particularly for pre-2012 data</u>

Region
Survey_year
Batch_code
Survey_index
Survey_date
Survey_time
Latitude
Longitude
Habitat_structure
Permanent_random
Management
Family
Genus_name
Scientific_name
Common_name
Species_code
Trophic
(size ranges (cm))
- 0-5
- 5-10
- 10-15
- 15-20
- 20-25
- 25-30
- 30-35
- 36
- 37
- 38
- 39
- 40
- … additional lengths added when fish are recorded at those lengths

Habitat data file column names by email request to BB for 2012+ data

Batch_code
Survey_index
Station_code
Strata
Zone
Zone_2
Depth_strata
Depth_2
Habitat_strata
Habitat_2
Survey_date
Survey_time
Latitude
Longitude
Permanent_random
Management
Cover_type
Species_group
Cover_code
Morphotype
Species_name
Percent_cover
Diseased_cover
Bleached_cover
Height
Min_height
Max_height
Height_variance
Individuals
Min_individuals
Max_individuals
Quad_depth
Min_depth
Max_depth
Depth_variance
Mean_rugosity

Habitat data file column names from online "Full Data Download" and particularly for pre-2012 data

Batch_code
Survey_index
Station_code
Survey_date
Survey_time
Latitude
Longitude
Habitat_structure
Permanent_random
Management
Reef
Cover_type
Species_group
Cover_code
Morphotype
Species_name
Percent_cover
Diseased_cover
Bleached_cover
Height
Min_height
Max_height
Height_variance
Individuals
Min_individuals
Max_individuals
Sm_holes
Lg_holes
Quad_depth
Min_depth
Max_depth
Depth_variance
Mean_rugosity

Mastergrid file (STX)
UniqueID
ID
Region
Depth
Rugosity
Hab_c
MngmtZone
Utm_x
Utm_y
Utm_zone
Lat_dd
Lon_dd
Depth_Desc

Habitat data file column names from online "RHA Download" under Habitat Queries particularly for pre-2012 data
region
batch_code
survey_index
Habitat_structure
permanent_random
management
survey_date
survey_time
latitude
longitude
maxDepth
minDepth
rugosity
hard
sand
rubble
coral
gorgonians
sponges
algae

Macroinvertebrate data file column names from online "Marcroinvertebrate download" under Habitat Queries
Region
Survey_year
batch_code
survey_index
latitude
longitude
survey_date
survey_time
Habitat_structure
permanent_random
management
Immature Conch
Mature Conch
Sea Urchin
Spiny Lobster
Total counts

Definition of Imported Data Column Headings

Abundance – BB web download: a sum of the total count of fish for a given species at a given site regardless of size; the abundance value is a single value grouped by species, site and batch code. *NOTE: In SFCN reports abundance is the estimated total number of fish in a reporting zone (e.g. BUIS, SARI, outside NPS).*

Algae – A visual estimate of percent of algae cover of the area in and around the belt transect during Rapid Habitat Assessment (RHA) benthic methodology.

Batch_code – An alphanumeric code that identifies the region, month and year of each mission: mm00-yy00. *Example*: October 2007 = 1000-0700.

Biomass – Optional download field for BB web page. Biomass values are grouped by site, species and size and then summed. Thus, each individual fish size column will have a separate biomass value for each species seen, and sum column giving the total biomass for that species at that site.

- Biomass is calculated using the following formula: ∑(a_lw * average fish_size ^ b_lw). The constants a_lw and b_lw are taken from http://www.fishbase.org
- In the biomass query, the average size of animals within a size range is the midpoint of that interval. For example, animals within the 5-10 cm range have an average size of 7.5 cm, while animals within the 10-15 cm range average 12.5 cm. There are two exceptions to the aforementioned methodology. First, because animals <1 cm are typically not observed, the average size of the 0-5 cm range is designated as 3 cm, or
- The midpoint of 1-5 cm. Secondly, when an animal >35 cm is recorded, no size. approximations are made. Rather, the singular recorded size value is incorporated into the biomass calculation.
- A size column of zero is in place to account for surveys in which no fish were seen and therefore the average size for the species is used for the biomass calculation.

Bleached_cover – The percentage of bleached coral estimated to the nearest 0.1 percent .

Common_name – Common name of fish species.

Coral – A visual estimate of percent of coral cover of the area in and around the belt transect during Rapid Habitat Assessment (RHA) benthic survey methodology.

Cover_code –

- For *Abiotic* data the cover code is the type of substrate:
  - Hard
  - Rubble
  - Sand
  - Fine sediment
- For *Biotic* data the cover code is a 6 letter code consisting of the first 3 letters of the genus and first 3 letters of the species for corals and to type for other taxa. See Appendix D – Benthic Codes.

Cover_type – Type of substrate cover: abiotic or biotic:

- *abiotic* – sand, rubble, hard bottom, and fine sediments. Rubble refers to rocks and coral fragments that are moveable; immovable rocks are considered hard bottom.
- *biotic* – algae, seagrass, live corals, sponges, gorgonians, and other biota (tunicates, anemones, zooanthids, and hydroids).

Depth – Average grid cell depth in meters.

Depth_2 – Depth strata name= Shallow: 0-11.9m and Deep: 12+ m.

Depth_desc – Grid cell depth strata name= Shallow: 0 to <12 m and Deep: 12+ m.

Depth_strata – One letter depth strata code= S: 0-11.9 m and D: 12+ m.

Depth_variance – depth value reported as an average of 5 quadrat measurements.

Diseased_cover – Refers to coral skeleton that has recently lost living tissue because of disease or damage that is still visible, and has not yet been colonized by turf algae. Recorded to the nearest 0.1 percent.

Diversity – Optional download field for BB web page. Value reported is Shannon Diversity, calculated using the following formula: $r = \sum(pi * \log pi)$. pi is the total number of fish of a given species in a site divided by the total number of fish in that same site; the diversity value is a single value grouped by site and batch code.

Family – Taxonomic family of fish species.

Fish_count – Number of individual fish at a given size.

Fish_size – Length of fish in cm. Fish that were binned are given the following lengths:

Bin	Length assigned
0-5 cm	3 cm
5-10 cm	7.5 cm
10-15 cm	12.5 cm
15-20 cm	17.5 cm
20-25 cm	22.5 cm
25-30 cm	27.5 cm
30-35 cm	32.5 cm
35+ cm actual length	

Genus – Taxonomic genus of fish species.

Genus_name – Taxonomic genus of fish species.

Gorgonians – A visual estimate of percent of gorgonian cover of the area in and around the belt transect during Rapid Habitat Assessment (RHA) benthic survey methodology.

Hab_c – Number representing habitat assigned to grid cell

Numeric Habitat code	Grid Habitat	Fish/Benthic Habitat Name	Fish/Benthic Code
-3	Unknown		
-2	Unknown		
-1	Unknown		
0	Land and unknown		
1	Sand		
2	Mud		
3	Macroaglae		
4	Seagrass		
5	Scattered Coral / Rock	SCR	S
6	Pavement	Pavement	V
7	Bedrock	Bedrock	B
8	Patch Reef	Patchreef	P
9	Linear	Reef	R

Habitat_2 – Fish/Benthic Habitat strata name assigned to grid cell (see Hab_c), i.e. SCR, Pavement, Bedrock, Patchreef, Reef.

Habitat_strata – Fish/Benthic Habitat Code assigned to grid cell (see Hab_c), i.e., S, V, B, P, R..

Habitat_structure – The structure of a specific station: hard, soft or mangrove.

Hard– A visual estimate of percent of hardbottom substrate cover of the area in and around the belt transect during Rapid Habitat Assessment (RHA) benthic survey methodology. This includes area under living benthic cover i.e., algae, seagrass, etc. Rubble+Sand+Hard should sum to 100% in RHA data.

Height – A measurement (recorded in cm) of the height of the hardbottom from the substrate to get a sense of bottom relief.

Height_variance – Hardbottom height value reported as an average of 5 quadrat measurements.

ID – Numeric code for sub-region, e.g., 0=West, 1=East, 2=North, 3=South.

Immature conch- Count of the total number of immature conch encountered within the 25 m x 4 m belt transect. The maturity of each conch is determined by the presence or absence of a flared lip and labeled mature or immature, respectively.

Individuals – For sponges, gorgonians and "other" biota type (non-encrusting anemones and non-encrusting hydroids) the number of individuals at the quadrat level is recorded.

Lat_dd – The latitude of a grid cell center point in decimal degrees. Precise to 7 decimal places.

Latitude – The latitude of a station recorded in decimal degrees. Precise to 5 decimal places.

Lg_holes – The number of holes greater than 15cm in the largest dimension. Hole-width or length is visually estimated. The number of large holes are reported as an average of 5 quadrat

measurements.

Lon_dd – The longitude of a grid cell center point in decimal degrees. Precise to 7 decimal places.

Longitude – The longitude of a station recorded in decimal degrees. Precise to 5 decimal places.

Management – *NOTE: Definition depends on data table*

- Fish / habitat data pre-2012. Based on jurisdiction at locations sites were sampled and type of benthic habitat composition information collected. Acronyms consisting of CBI/CBO or MSRI/MSRO indicate these sites were surveyed specifically to evaluate the differences between inside and outside the monument
    - Puerto Rico:
        - PR OTHER – sites do not fall within fishery management zones
    - St. Croix:
        - BUIS – sites sampled fall under the jurisdiction of Buck Island Reef National Monument
        - EEMP – sites sampled fall under the jurisdiction of the East End Marine Park
        - STC OTHER – sites do not fall within fishery management zones
    - St. John:
        - STJ OTHER – sites do not fall within fishery management zones
        - VICR – sites sampled fall under the jurisdiction of the Virgin Island Coral Reef National Monument where full- scale habitat data was collected.
        - VICR CBI – sites sampled fall under the jurisdiction of the Virgin Island Coral Reef National Monument inside Coral Bay where Rapid Habitat Assessment data was collected. These sites were surveyed specifically to evaluate the differences between inside and outside the monument.
        - VICR CBI–STJ OTHER – sites sampled fall under the jurisdiction of the Virgin Island Coral Reef National Monument inside Coral Bay where Rapid Habitat Assessment **AND** full-scale data were collected
        - VICR CBO – sites located outside of the Virgin Island Coral Reef Monument jurisdiction but inside Coral Bay where Rapid Habitat Assessment data was collected. These sites were surveyed specifically to evaluate the differences between inside and outside the monument.
        - VICR CBO–STJ OTHER – sites sampled fall under the jurisdiction of the Virgin Island Coral Reef National Monument along the Mid-Shelf Reef where Rapid Habitat Assessment data **AND** full-scale data were collected. VICR MSRI – sites sampled fall under the jurisdiction of the Virgin Island Coral Reef National Monument along the Mid-Shelf Reef where Rapid Habitat Assessment data was collected. These sites were surveyed specifically to evaluate the differences between inside and outside the monument.
        - VICR MSRO – sites located outside of the Virgin Island Coral Reef Monument jurisdiction but along the Mid-Shelf Reef where Rapid Habitat Assessment data was collected. These sites were surveyed specifically to evaluate the differences between inside and outside the monument.
        - VIIS – sites sampled fall under the jurisdiction of Virgin Island National Park

- Fish/Habitat Data – 2012+ this column is set to Null.
- SFCN database – equals "management" above for pre-2012 data and equals Zone_2 for 2012+ data.

Mature_conch – Count of the total number of mature conch encountered within the 25 m x 4 m belt transect. The maturity of each conch is determined by the presence or absence of a flared lip and labeled mature or immature, respectively.

Max_depth – Maximum depth recorded out of 5 quadrat measurements at site.

Max_height – Maximum canopy height recorded out of 5 quadrat measurements at site.

Max_individuals – Minimum number of individuals recorded out of 5 quadrat measurements at site.

MaxDepth – Maximum depth at that site (RHA sites only).

Mean_rugosity – A mean of two rugosity values measured by placing a 6-m chain at two randomly selected positions along the 25m belt transect. The chain is placed such that it follows the substrate's relief along the centerline of the belt transect.

Min_depth – Minimum depth recorded out of 5 quadrat measurements at site.

Min_height – Minimum canopy height recorded out of 5 quadrat measurements at site.

Min_individuals – Minimum number of individuals recorded out of 5 quadrat measurements at site.

MinDepth – Minimum depth at that site (RHA sites only).

MngmtZone – Numeric code identifying a management zone in mastergrid.
0 – Unmanaged
1 – SARI
2 – BUIS
3 – EEMP

Morphotype – Grouping of like forms within each *cover_group*
- algae – red, brown, green
- cyanobacteria – filamentous/cyanobacteria
- hard corals – brain, branching/pillar, encrusting/mound/boulder, fleshy, flower/cup, leaf/plate/sheet hydroids – fire coral, hydroids
- mangroves – flowering plant
- other invertebrates – sea anemone, tunicate, sea urchin, lobster, snail/nudibranch, zooanthids seagrasses – flowering plant
- soft corals – black coral, encrusting gorgonian, sea fan, sea plume/rod/whip/etc. sponges – barrel/tube/vase/etc., encrusting

Percent_cover – As the percent cover (to the nearest 0.1 percent) of living algae, seagrass, live corals, sponges, gorgonians, and other biota (tunicates, anemones, zooanthids and hydroids) within a $1m^2$ quadrat.

Permanent_random – A label each site is assigned based on how the site was selected and sampled. A small subset of sites were resampled during some of the missions through June 2002 in Puerto Rico and October 2002 in St. Croix. These stations were randomly selected then resampled at later dates.

- random – a randomly selected site
- permanent – a site that was previously sampled (pre-existing survey site – resampled)
- random-permanent – the first time a site was sampled that later became a permanent site was given this label

Quad_depth – The depth at each quadrat position. Depth is measured to the nearest 1ft.

Reef – On seagrass and sand sites, the habitat diver records the absence or presence of reef or hard structure within 3m of the belt transect. A score of zero (0) indicates that no reef or other hard structure is present; one (1) indicates that a reef or hard structure smaller than $4m^2$ is present; and (2) indicates that a reef or hard structure larger than $4m^2$ is present within 3m of the diver.

Region – *NOTE: Definition depends on data table*

- Fish & Benthic data files= Location of mission
  - GULF_FGBT - Flower Garden Banks National Marine Sanctuary (2012)
  - PUER-JOBO – Puerto Rico Jobos Bay (2009)
  - PUER-PARG – La Parguera region, southwest Puerto Rico (2000-2009)
  - PUER-PAGU – Puerto Rico Parguera (2010-2012)
  - PUER-VIEQ – Vieques, Puerto Rico (2007)
  - VIRG-ST C – Buck Island and East End Marine Park region of St. Croix (2001-2010)
  - VIRG-ST J – Mid-shelf reef and entire area around St. John, USVI (2001-2011)
  - VIRG-STCA – Virgin Islands St. Croix All (2012)
  - VIRG-STCS – Virgin Islands St. Croix South (2010, 2011)
  - VIRG-ST T – Virgin Islands St. Thomas (2012)
- Mastergrid file = sub-region, e.g. North, South, East, West area around St. Croix

RHA – Rapid Habitat Assessment; type of habitat survey modified from a detailed (microscale) habitat assessment used to characterize nearshore habitats. The RHA survey has the advantage of reducing bottom time at greater depths (i.e., sites below 80 ft) and provides a general habitat assessment of the survey site. Used in deeper areas around St. John. Visual estimates are made of the area in and around the belt transect types of substrate (hard, sand, rubble) that should total to 100% and of benthic cover (algae, coral gorgonians, sponges). 1 m^2 quadrats are not used. However in 2010, 5 esimates for each 5mx4m of the transect were substituted for the previous single estimate. Data are collected on the following:

- Dive logistics – name of the diver, station ID, date, and the start time of the survey.

- Habitat structure – the dive site is categorized based on the hierarchical classification used to produce the benthic habitat maps.
- Depth – minimum and maximum depth of the survey area, to provide an estimate of bottom slope.
- Rugosity (low, medium, or high) - based on the height of the tallest hardbottom structure.
- Abiotic footprint – an estimate of % cover (within 5%) of hardbottom, sand, and rubble in the 15-m cylinder. The sum of % cover in the abiotic footprint must total 100%.
- Biotic footprint – an estimate of the % cover (within 5%) of live coral, gorgonians, sponges, macro algae, and uncolonized substrate in the 15-m cylinder. The sum of % cover (including uncolonized substrate) in the biotic footprint must total 100%.
- Photography - photos to maintain an anecdotal and permanent visual description of the sites that were sampled.

Richness – Optional download field for BB web page. A count of the total number of unique species in a given site; the richness value is a single value grouped by site and batch code.
Rubble – A visual estimate of percent of rubble substrate cover of the area in and around the belt transect during Rapid Habitat Assessment (RHA) benthic survey methodology. This includes area under living benthic cover i.e., algae, coral, gorgonians, sponges. Rubble+Sand+Hard should sum to 100% in RHA data.

Rugosity – *NOTE: Definition depends on data table*
- In Mastergrid, rugosity is average grid cell rugosity calculated from bathymetry.
- At RHA sites, a visual estimate of rugosity based on the height of the tallest hardbottom structure: low (1), medium (2), high (3).

Sand– A visual estimate of percent of sand substrate cover of the area in and around the belt transect during Rapid Habitat Assessment (RHA) benthic survey methodology. This includes area under living benthic cover i.e., algae, seagrass, etc. Rubble+Sand+Hard should sum to 100% in RHA data.

Scientific_name – Taxonomic species name of fish created from the genus and species of fish.

Sea urchin – Count of the total number of sea urchins (*Diadema antillarium)* encountered within the 25 m x 4 m belt transect.

Size ranges – The number of individuals per species is tallied in 5cm size class increments up to 35cm using visual estimation of fork length. If an individual is greater than 35cm, then an estimate of the actual fork length is recorded. All fish sizes less than 35cm are displayed as ranges. Hence, a fish that is approximately 18 cm in length will be counted as 15–20cm. All ranges increase in increments of 5cm. Prior to 2002, divers were instructed to exclusively record count for fish greater than 35cm. Therefore, the sizes of fish observed over this duration have been input as 0. However, a small proportion of entries prior to 2002 include size values concurrently with fish counts. Beginning in 2002, divers were directed to record both size and count for fish greater than 35cm. However, a few select instances exist after 2002 where only fish count was recorded. Thus, in accordance with the pre-2002 methodology, a size

value of 0 has been entered for these cases.

Sm_holes – The number of holes smaller than 15cm in the largest dimension. Hole-width or length is visually estimated. The number of small holes are reported as an average of 5 quadrat measurements.

Species_code – Four letter codes are used that consist of the first two letters of the genus name followed by the first two letters of the species name. In the rare case that two species have the same four-letter code, a fifth letter is added to the code. This will be the first letter that differs between the organisms' species names. If the fish can only be identified to the family or genus level then this is all that is recorded. If the fish cannot be identified to the family level then no entry is necessary. See "Appendix C – Species Codes for Reef Fish" for specific codes.

Species_group – The hierarchical grouping of species in the same class or order:

- algae – includes macroalgae, crustose algae, filamentous and turf algae
- cyanobacteria – includes blue-green algae
- hard corals – all scleractinian corals hydroids – includes hydroids and fire coral
- mangroves – includes mangrove prop roots and leaves
- other invertebrates – includes anemones, tunicates, zooanthids seagrasses – includes aquatic/marine flowering plants
- soft corals – encrusting and upright/erect forms (i.e. sea fans/plumes/rods/whips)
- sponges – includes encrusting and upright/erect forms (i.e. barrel/tube/rope/vase)

Species_name – Taxonomic species name of fish created from the genus and species of fish.

Spiny lobster – Count of the total number of spiny lobster (*Panilaurus argus)* encountered within the 25 m x 4 m belt transect.

Sponges – A visual estimate of percent of gorgonian cover of the area in and around the belt transect during Rapid Habitat Assessment (RHA) benthic survey methodology.

Station_code – An alphanumeric code describing each specific station done within a mission. Certain stations containing the prefixes MSR or CB have different types of habitat data associated with them. Station_code may contain 3-letter strata code.

Strata – 3-letter sampling design strata code combining zone, depth_strata, and habitat_strata.

Survey_date – The date in which a specific survey is done formatted as mm/dd/yyyy.

Survey_index – A numerical index that uniquely identifies each specific station done within a mission.

Survey_time – The specific time of a dive formatted in military time.

Survey_type – T=Transect; P=Point.

Survey_year – The year in which a specific survey is done formatted as yyyy.

Total_biomass – Optional download field for BB web page. The sum of all the columns of biomass values for each species.

Total_counts – Sum of # sea urchins, conch, and lobster seen on 4m x 25m belt transect.

Trophic – Trophic group of fish derived from http://www.fishbase.org and/or Randall (1965) and indicated by trophic codes based on majority in species diet. If more than one food type accounts for majority of diet then multiple codes are used.

- P – Main diet consists of fish (piscivorous)
- H – Main diet consists of algae, seagrasses, organic detritus, etc. SI – Main diet consists of sessile invertebrates
- MI – Main diet consists of mobile invertebrates
- Z – Main diet consists of plankton such as phytoplankton and/or zooplankton

UTM_X – UTM Easting coordinate of grid cell center point.

UTM_Y– UTM Northing coordinate of grid cell center point.

UTM_zone – UTM zone UTM_X and UTM_Y are located within.

Zone – One letter abbreviation of zone_2. For St. Croix:

- B – Buck
- E – East (unmanaged)
- U – EEMP
- N – North (unmanaged)
- R – SARI
- S – South (unmanaged)
- W – West (unmanaged)

Zone_2 – Name of area where points are independently selected within including both management (BUIS, SARI, EEMP) or sub-region (North, South, West).

Creating a NPS-SFCN Data Summary Report

The NPS-SFCN specific details are provided to meet the protocol requirements of the NPS-SFCN program. Table SOP 9.10 provides a quick look guide for file storage locations on the NPS-SFCN server.

Downloading from NOAA Coral Reef Ecosystem Assessment and Monitoring Database Report Module

1) Go to the NOAA-BB Coral Reef Ecosystem Assessment and Monitoring Database web page http://www8.nos.noaa.gov/biogeo_public/query_main.aspx
   This page has links to query different types of data plus associated metadata.

2) In the top banner click on "Fish Queries". This will take you to http://www8.nos.noaa.gov/biogeo_public/query_fish.aspx

3) Previous sampling year data should already be in the database. To download the most recent sampling year data", set
   a. Region="Virgin Islands St. Croix All"
   b. Year=<current sampling year>
   c. Months="All Months"
   d. Structure="Hard"
   e. Permanent/Random= "All Types"
   f. Management= "All Management"
   g. Trophic Level= "All Tropic"
   h. Family = "All Family"
   i. Species = "All Species"

4) Under "Query Selection" select "Full Data Download"

5) Under "Requester Information" give Name/Title, Organization, E-Mail Address, and a short sentence describing how data will be used, e.g., "Creation of national park data summary reports and graphs".

6) Click "Save as Text".

7) Put resulting .zip file into *Z:\SFCN\Vital_Signs\Marine_fish_communities\data\NOAA_USVI_data\Downloads*

8) Open the *.zip file and copy and paste the *.txt file to the root of *\Downloads*

9) Add "DownloadDate_STX_" or "DownloadDate_STJ_" to the front of the name depending on the region. DownloadDate is in format of *YYYYMMDD*.

Preparing and uploading fish data into NPS-SFCN MSAccess database

1) Open up the statistical program R (Downloadable from http://cran.r-project.org/ ; see http://science.nature.nps.gov/im/datamgmt/statistics/r/install/index.cfm for additional guidance on installation. To run the scripts below, the following "packages" must be installed:
    a. plyr
    b. reshape
    c. ggplot2
    d. scales
    e. grid
    f. xtable
    g. knitr
    h. markdown

    Within R select "Packages" menu then "Install Packages" then a download site (e.g., USA (CA1)) then each name and click "OK" and answer "Yes" to a personal database).

2) In R, open the script *ConvertFishDownload.R* which is saved in *Z:\SFCN\Vital_Signs\Marine_fish_communities\data\NOAA_USVI_data*
    This script takes the file downloaded from the web site and puts each fish species, length, and count on a separate line for easier analysis. Note: It does not add zeros for sites where a species was not seen at any length.

    The script will prompt for the appropriate text file name.

3) Once the script has run (it may take a minute), it produces a .csv file *revfish.csv* in *Z:\SFCN\Vital_Signs\Marine_fish_communities\data\NOAA_USVI_data*

4) Open the MS Access database in *Z:\SFCN\Vital_Signs\Marine_fish_communities\data\NOAA_USVI_data\ SFCN_USVI_Fish.mdb*

5) A "Dashboard" form automatically opens which provides easy access links to the major tasks (Figure Appendix I-1). Click "Upload Fish Data".

6) Enter year (YYYY) and region (STX or STJ). A question will pop up if the database already contains data from that year and region.

7) Navigate to and select the file to upload (revfish.csv).

8) Click "Import Data".

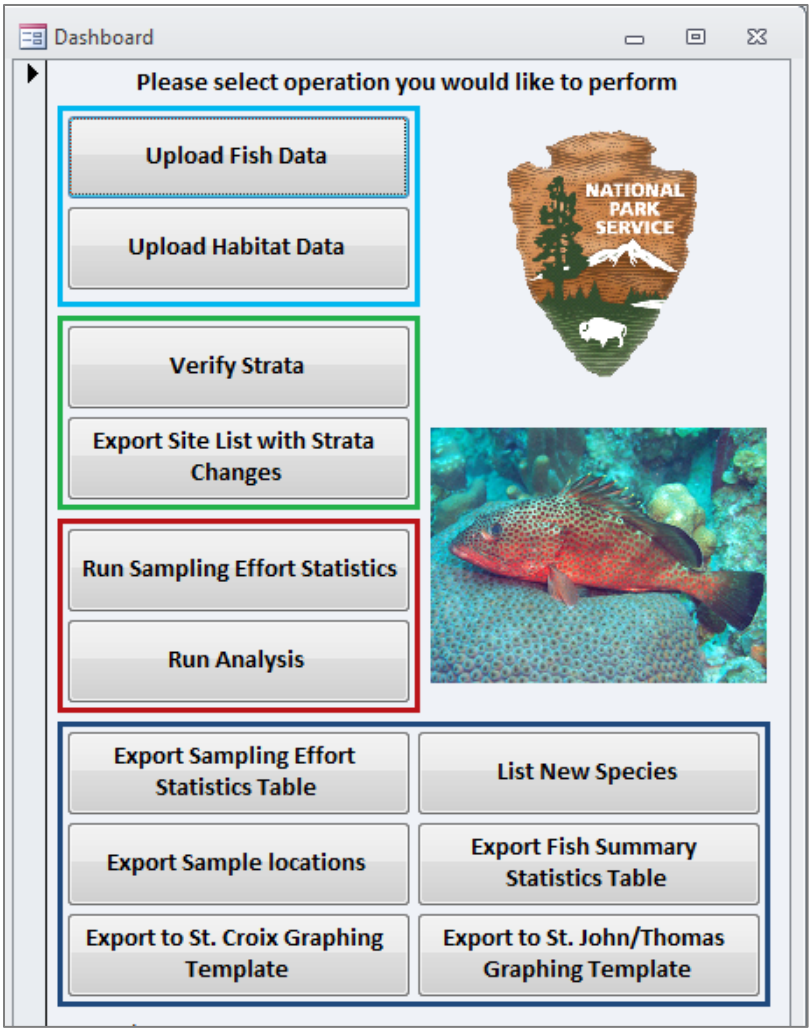

Figure Appendix I-2. SFCN database "Dashboard" form provides easy links to major tasks.

Uploading habitat data into NPS-SFCN MS Access database

1) Go to the NOAA-BB Coral Reef Ecosystem Assessment and Monitoring Database web page "Habitat Queries"
   http://www8.nos.noaa.gov/biogeo_public/query_habitat.aspx

   Follow the procedures for downloading data described above for fish.

2) On the "Dashboard" form in the database , click "Upload Habitat Data".

3) Enter the year and region (STX or STJ)

4) Navigate to and select the habitat *.txt file (e.g., *20130305_STX_habitat_full_dload_3_5_2013_9_42_37.txt*)

5) Click "Import Data".

Pre-analysis stratification corrections

The stratification of each fish survey point is re-evaluated before analysis as follows and a revised stratification column is created for use in the final analyses.

1) On the "Dashboard" form in the local MS Access database, click "Verify Strata".
   a. The assigned depth strata is automatically re-assigned based upon diver depth (Shallow: 0-11.9 m and Deep: 12+ m) when "Run Analysis" is clicked later.

   b. The database will select sites that are all of the following:
      i. Are 100% sand
      ii. Are not classified as SCR (Scattered Coral/Rock)
      iii. Contain only sand, seagrass, macro-algae and do not contain any of coral, soft coral, hydrocoral or sponges

      And then open ArcMap and select those sites that:

      iv. Are >10m from a mapped hard-bottom polygon.

      After reviewing the sites and the ArcMap results, the analyst then returns to the list of sites in MSAccess and verifies (clicks yes) those sites which are to be eliminated from the analysis.

   In the future the database may also check for sites whose grid habitat classification does not match the field habitat classification. This may require the analyst to make a point by point decision. *However, in general the analyst should be reluctant to update the habitat stratification unless the discrepancy is blatant, e.g., the field classification was scattered coral/rock when the classification is Linear Reef.*

2) On the Dashboard form click "Export Site List with Strata Changes". Send an email to NOAA-BB providing a summary of the points whose strata category has been changed based upon the diver data.

Analysis, Reporting, and Graphing Template

1) On Dashboard click "Run Sampling Effort Statistics" and the enter year and region.

2) The database will ask if a new grid must be uploaded, i.e., changes were made to the grid since the previous year's analysis. If so, follow the instructions for uploading the new grid.

3) The database will query for the # grid cells initially planned by strata. Enter this information. If previously entered, the numbers will come up. If unknown, just enter 0's. This will not impact the analysis, but provides a useful comparison of the initial plan versus final implementation and will be part of the printout for the report.

4) Click "Run".

5) Examine the resulting table to check if results (total number of grid cells and number of grid cells sampled) are consistent with expectations. The file *YYYY_Region_Sampling_Effort_Statistics.xlsx* will be automatically saved and then opened for you in *Z:\SFCN\Vital_Signs\Marine_fish_communities\data\NOAA_USVI_data\Exports*

6) "Run Analysis". This operation may take some time. The database proceeds to:
   a. Perform all calculations on the current year data for density, abundance, occupancy, length, and species richness.
   b. Append calculations to the multi-year dataset.

   This may take some time.

7) When the operation is complete a message box will appear on screen saying "Done". Click Ok.

8) Open up the statistical program R.

9) In R, open and run the script *Report_Generation.R* that is in: *Z:\SFCN\Vital_Signs\Marine_fish_communities\data\NOAA_USVI_data*

   The results from "Run Analysis" are placed into the subfolder Z:\SFCN\Vital_Signs\Marine_fish_communities\data\NOAA_USVI_data\Exports and include:

   *.csv file from database output containing
      Individual Fish Species Summary Statistics table
      Trophic Level Summary Statistics table
      Taxonomic Groupings Summary Statistics table
      Species Richness Summary Statistics table

   *.html files (with associated *.png files) from R output of
      Each species tables and graphs
      Trophic tables and graphs (piscivores, herbivores, inverivores, planktivores)
      Taxonomic groupings (groupers, snappers, grunts, parrotfishes)
      Species Richness (Total # species, Species Richness/transect)

10) Review the tables and graphs for species and metrics going into the NRDS report and look for data that appears odd, i.e., unusually large spikes or drops or missing data that could indicate a problem with either the data analysis, QA/QC or the species itself. All data should have been QA/QC'd, but sometimes problems slip through and this is the last opportunity to catch them by looking at the data in the context of previous years.

11) Click "Export Sample Locations" and the file *YYYY_Region_Sample_Locations.xlsx* will be saved to the same *\Exports* folder as above. Use the resulting locations to generate a map for use in the data summary report using the appropriate region (STX or STJ) map template in *Z:\SFCN\Vital_Signs\Marine_fish_communities\spatial_info\Map_Template*

12) Click "Export Fish Summary Statistics Table" as *YYYY_Region_FishSummary.pdf*. Select the current year so the resulting file can be appended into the Data Summary Report.

13) Click "List New Species". A report will be generated listing the species detected for the first time that year. Check this list and make sure it makes sense. Hopefully any typing errors will have been caught long before this stage, but it's possible some errors may show up here and indicate additional QA/QC is needed. Also if a new species identification is suspect (e.g., observed by a newer technician with no picture taken), this can be mentioned in the report.

Click "Export" to export the list *NewSpecies.xlsx* to the same *\Exports* folder as above. This will be included in Appendix B of the report.

Creating the non-fish species summary table

This option is not currently available with the current data export available on the NOAA-BB Coral Reef Ecosystem Assessment and Monitoring Database web page. However if and when this feature becomes available, the MS Access database will be modified such that the steps will be:

1) Click "Upload Non-fish Species Data" button on the Dashboard form to upload the data.

2) Click "Non-fish Species Summary" button on Dashboard form to export table.

3) Select where to save the file, i.e., *Z:\SFCN\Vital_Signs\Marine_fish_communities\documents\Summaries_reports\STX*

Creating the NRDS report

1) Open the Reef Fish NRDS reporting template in *Z:\SFCN\Vital_Signs\Marine_fish_communities\documents\Summaries_Reports\templates*

   Templates are labeled by region, i.e., *STJ_Fish_NRDS_Template.docx* or *STX_Fish_NRDS_Template.docx*

2) Save immediately to a new name in *Z:\SFCN\Vital_Signs\Marine_fish_communities\documents\Summaries_reports\STX*

   with file format *YYYYMMDD_STX_NRDS_YYYY.docx* where *YYYYMMDD* is the date of the working copy and *_YYYY* is the sampling year of the report.

3) Update report. Areas highlighted in yellow will likely need to be updated each sampling session.

4) Update Table 1 from the Sampling Effort Statistics Table exported above: *YYYY_Region_Sampling_Effort_Statistics.xlsx* (cut and paste from MS Excel).

5) Insert the map created above in Figure 1.

6) Under Table 2, add the Status/Trend symbol for each species and a rationale. In general thresholds have not been established so all that can be done at this time is provide a trend arrow without a circle (i.e., the status is not determined). The exception is lionfish which can generally be colored red as lionfish presence is considered a problem.

7) A simple test can be done without statistical software: Metrics are considered statistically different if the 95% confidence interval of the mean does not contain the other mean being compared. Generally one calculates t-value*SE for each mean, then determines if the difference between two means is larger than each confidence interval distance. The number 2 instead of a t-value can be used if the total number of samples is greater than 50 (it should be with the exception of SARI) to provide a test with a 5% alpha level. Look for an overall multi-year trend rather than a single pair of years difference which could be due to annual

variation or a Type 1 error. A Bonferonni adjustment may be necessary if you want to make a point about a single mean being significantly different while making multiple comparisons (the new threshold for significance becomes 0.05/number of comparisons). If making many comparisons, a Tukey or SNK mean separation test may be more appropriate. Generally it's better to compare exploited phase or adult phase rather than using metrics that include juveniles. Provide a rationale for the Status/Trend symbol determination. If thresholds or baselines have been established, include this under reference condition, e.g., "range of years 2003-2007 average density = 0.5 - 4.3 fish/100m" (these are the first 5 years of sampling with a consistent methodology).

8) In Appendix A add the focal species in the order in the Appendix A table of contents by clicking at the beginning of page A-3, then

   Click "Insert" tab, then "Object" -> "Text from File" and navigate to the files to import, e.g.,

   01_CECR.html
   02_CEFU.html
   03_EPGU.html
   04_MYVE.html
   05_LUAN.html
   06_LUAP.html
   …
   22_PTVO.html

   The 4 letter code is the species code. If the "Ctrl" key is held down, multiple files can be selected at once for insertion as a group. The 22 focal species are numbered so they will insert correctly (MS Word inserts in alphabetical order). However additional species of interest can be added as desired after the initial 22 species as all species are exported. This list can be adjusted to better meet management needs or highlight additional species of interest.

   Select everything that was just inserted.

   Click "Page Layout" tab, then under "Spacing", enter 0 for "Before" and "After". This will reduce the spaces between lines so all the tables should fit onto a single page.

   If necessary, go through the Appendix and add page breaks (Ctrl-Enter) and resize pictures to tidy up the presentation.

   Update the Appendix A table of contents page numbers.

9) In Appendix B, click on page Appendix B-3. Add the following files as described above:

   23_SpeciesCounts.html
   24_SpeciesRichness.html
   25_Piscivores.html
   26_Herbivores.html
   27_Invertivores.html

28_Planktivores.html
29_Groupers.html
30_Snappers.html
31_Grunts.html
32_Parrotfishes.html

Open the file *NewSpecies.xlsx* created above and copy and paste the table after "SpeciesCounts.html". This table should have been reviewed for correctness above.

Update the Appendix B table of contents page numbers.

10) Add photos to Appendix D of anything noteworthy, e.g., new species seen in park, storm damage, coral disease outbreaks, etc. Appendix D can be deleted if no pictures are needed.

11) When the report is complete except for Appendix C, select "File" → "Save As". Under "Save as type" select *.PDF. Save file to *Z:\SFCN\Vital_Signs\Marine_fish_communities\documents\Summaries_reports\STX*

12) In Adobe, navigate to Appendix C page and select "Document" → "Insert Pages" → "From File" and navigate to file *YYYY_Region_FishSummary.PDF* exported above. Insert after the Appendix C page and save the file.

Update park species list

Provide the new species records within NPS parks to the SFCN Data Manager to update the park species list in NPSpecies: https://irma.nps.gov/APP/Species/Welcome.

Modifyable graphs for presentations and other reports

A graphing template is provided to allow modifications to graphs for other presentations, or reports. However for the NRDS report, it is recommended to follow the steps above to use the automatically generated R tables and graphs. However the results should be the same, and the graphs below can be substituted if there is a need.

1) Click "Export to St. Croix Graphing Template" button or "Export to St. John/St. Thomas Graphing Template" button as appropriate. This exports the data into the appropriate graphing template and opens it in *\Marine_fish_communities\data\NOAA_USVI_data\Graphs*

2) The graphing template should automatically update for most of the tables. However there are a few exceptions: "Size Class Distribution (Current Year)" and "Size Class Distribution (4 years)" for each species page need to have the years updated individually.

3) (Optional) There is an optional "OptSpecies" worksheet in which any species monitored can be selected and graphed. This is useful for graphing species which do not have a worksheet already developed.

4) If any of the above is not working, copy a backup version of the Graphing Template from \Marine_fish_communities\documents\protocol\Graphs\Backup_Templates\

to
\Marine_fish_communities\data\NOAA_USVI_data\Graphs\

And Click "Export to St. Croix Graphing Template" button or "Export to St. John/St. Thomas Graphing Template" button as appropriate. Occasionally the graphing template gets corrupted, but copying in a backup file usually fixes the problem. If a problem still occurs, see the SFCN Quantitative Ecologist.

Backup templates

Backups of all templates are located in
Z:\SFCN\Vital_Signs\Marine_fish_communities\documents\protocol\templates

NPS-SFCN Metadata and Archiving

SFCN will archive the dataset it uses for its survey year reports by updating metadata associated with the database and storing a copy of the SFCN database, associated metadata, and associated data summary reports in folder *Z:\SFCN_Archive\Vital_Signs\Marine_Fish_Communities\USVI\Data* and then uploading copies of the same to http://irma.nps.gov. The target date for archiving all SFCN data associated with a survey year will be January of the subsequent year. Metadata requirements are further discussed in section 8.3 of the SFCN data management plan (Witcher, 2008).

Revision History Log

Version #	Date	Revised by	Changes	Justification

Literature Cited

Randall, J.E., 1967. Food habits of reef fishes of the West Indies. Stud. Trop. Oceanogr. Miami 5: 665-847.

Froese, R. and D. Pauly. Editors. 2007.FishBase. World Wide Web electronic publication. www.fishbase.org, version (12/2007).

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

NPS 141/121295, 161/121295, 163/121295, 663/121295, June 2013

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