National Coral Reef Monitoring Program's Reef fish Visual Census Metadata for the U.S. Caribbean

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SEDAR80-WP-02

21 October 2021

Please cite this document as:

Grove, Laura Jay W., Jeremiah Blondeau, and Jerald S. Ault. 2021. National Coral Reef Monitoring Program's Reef fish Visual Census Metadata for the U.S. Caribbean. SEDAR80-WP-02. SEDAR80, North Charleston, SC. 55 pp.

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10-21-2021

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Table of Contents

NCRMP's Reef Fish Surveys Information

Reef Fish Visual Census Surveys

I. Description

The National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Conservation Program's (CRCP) National Coral Reef Monitoring Program (NCRMP) supports reef fish sampling on hard-bottom (coral) habitats from 0 to 30 m depth. In the U.S. Caribbean, the Reef Fish Visual Census (RVC) survey is coordinated by the NOAA National Ocean Service's (NOS) National Centers for Coastal Ocean Science (NCCOS). The NOAA Fisheries Southeast Fisheries Science Center (SEFSC) is the point of contact for fish data and data management. This collaborative effort relies heavily on the participation of key regional partners for divers, vessels, and supplies (Section VI). The RVC stationary point count (SPC) survey is conducted biennially and is designed to provide status and trends of reef fish populations and communities using standard metrics such as occurrence, richness, density, size-structured abundance, and biomass. These RVC-SPC data inform stock spatial distribution, community composition, effects of exploitation, and fish population changes inside versus outside of management zones (e.g., national and territorial monuments and parks, and marine reserves). Prior to RVC-SPC surveys which began in 2012, NOAA's Center for Coastal Monitoring and Assessment Biogeography Branch conducted regionally focused belt-transect (BT) surveys of reef fish in the U.S. Caribbean annually from 2001 to 2011, and as part of NCRMP, from 2012 to 2015 in collaboration with SEFSC. A calibration study between BT and RVC-SPC method estimates is presently underway.

II. Methodology

Sampling Survey Design

Detailed descriptions of the historical (regional) and current (island-wide) survey sampling designs used in the U.S. Caribbean are provided in "*A Cooperative Multi-Agency Reef Fish Monitoring Protocol for the U.S. Virgin Islands Coral Reef Ecosystem*" (Bryan et al. 2013). The design specifically refers to the U.S. Virgin Islands; however, all survey modifications discussed were also subsequently applied to Puerto Rico.

Briefly, from 2001 to 2011, the historical, regional survey design used stratified random sampling with the primary aim of creating an inventory of reef fish species for status and trend analyses (e.g., Kendall et al. 2003; Monaco et al. 2007). The regional survey included large portions of St. John (specifically, Virgin Islands National Park and Virgin Islands Coral Reef National Monument), eastern St. Croix (specifically, Buck Island Reef National Monument), and southwest Puerto Rico (specifically, La Parguera Natural Reserve; **Appendix 1**). The survey was stratified by benthic habitat types (e.g., hard-bottom and soft-bottom categories), management type, and geographic zones (Menza et al. 2008; Bryan et al. 2013). Survey sites were randomly allocated proportional to available habitat in the survey domain.

In 2012, a new island-wide survey design was implemented with the following aims: (1) identify high priority species for the survey to target (allocation of sampling by species); (2) partition variance of the sampling effort by specific strata (e.g., depth, habitat) to develop an optimal allocation scheme to improve sampling accuracy and precision; and, (3) provide island-wide estimates of size-structured abundance, biomass, and occurrence for use in stock assessment and fisheries management (Bryan et al. 2013). The island-wide survey design was adapted from the long-term two-stage stratified survey design for reef fish developed in South Florida in a collaboration between SEFSC, University of Miami, Florida Fish and Wildlife

Conservation Commission, and the National Park Service (Brandt et al. 2009; Smith et al. 2011). The island-wide design was optimized for selected economically and ecologically important reef fish species that included: blue tang, *Acanthurus coeruleus*; coney, *Cephalopholis fulva*; French grunt, *Haemulon flavolineatum*; foureye butterflyfish, *Chaetodon capistratus*; queen triggerfish, *Balistes vetula*; red hind, *Epinephelus guttatus*; stoplight parrotfish, *Sparisoma viride*; threespot damselfish, *Stegastes planifrons*; and yellowtail snapper, *Ocyurus chrysurus* (Bryan et al. 2013). Threespot damselfish was removed as an allocation species in 2017. While the sample design is optimized for selected species, all fish species of similar trophic groups, life histories, and behaviors are well represented in these data.

The island-wide survey design used 10 "habitat" strata defined by five habitat types and two depth categories (Bryan et al. 2013). A sixth habitat type that includes "unknown" habitat (i.e., hard) was included beginning in 2013 in St. Thomas, in 2016 in St. John, and 2016 in Puerto Rico and St. Croix after it was realized that this category reliably included hard-bottom reef structure (**Table 1**, **Fig. 1**). Since strata variances were known from pilot sampling (i.e., using previous three survey years data), a Neyman optimal allocation scheme (Cochran, 1977) was used to place greater sampling effort in strata with higher variance, as well as weight sampling effort proportional to the stratum area (Smith et al. 2011; Bryan et al. 2013). Greater effort was expended within smaller regional management zones to allow for inside versus outside comparisons. This is because reef fish variance is similar (i.e., inside versus outside by stratum) which mathematically requires an equal amount of effort.

This survey design allows for better precision for selected species, as well as cost savings to NCRMP through more efficient regional sampling (Smith et al. 2011). Ultimately, the final number of survey sites represents a balance between estimator precision (i.e., a CV of 20% or less is targeted for selected species), and the physical (i.e., boats, personnel) and budgetary constraints of NCRMP and its partners. Lastly, the present survey design was modified to incorporate St. Thomas, USVI. Consequently, estimates of size-structured abundance, biomass, and occurrence are now produced for three island-wide sampling domains: St. Croix, St. Thomas/St. John (combined due to close proximity), and Puerto Rico.

Table 1. Description of RVC survey strata (n = 12) used in the U.S. Caribbean's sampling design from 2012 to present. The strata are comprised of six habitat types crossed with the two depth intervals defined as shallow (0 to < 12 m) and deep (12 to 30 m). See Appendix A in Bryan et al. (2013) for a more detailed description and images.

Survey Strata	Abbreviation	Description
Aggregate reef deep	AGRFDEEP	A combination of linear fringing, fore, and shelf edge reefs and spur and groove formations.
Aggregate reef shallow	AGRFSHLW	
Bedrock deep	BDRKDEEP	Geological formation exposed due to erosion, includes colonized and uncolonized bedrock.
Bedrock shallow	BDRKSHLW	
Hard (unknown) deep	HARDDEEP	Areas of hardbottom structure, but unclear on specific type (i.e. aggregate, pavement).
Hard (unknown) shallow	HARDSHLW	
Patch reef deep	PTRFDEEP	Coral formations that are isolated by sand halos or vegetation, includes individual and aggregate patches.
Patch reef shallow	PTRFSHLW	
Pavement deep	PVMTDEEP	Solid carbonate rock, low relief, colonized or uncolonized with and without sand channels.
Pavement shallow	PVMTSHLW	
Scattered coral and rock deep	SCRDEEP	Small, isolated scatter coral and rock in unconsolidated sediment and reef rubble.
Scattered coral and rock shallow	SCRSHLW	

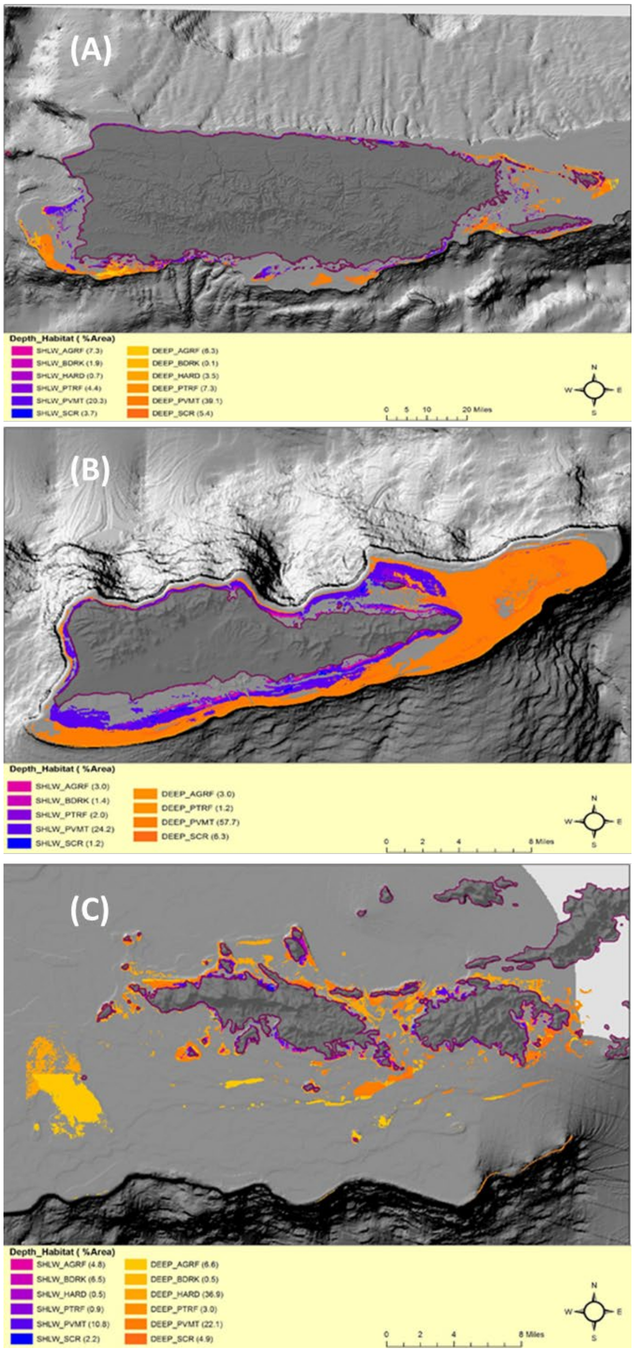

Figure 1. Extent of survey sampling domains used in the U.S. Caribbean from 2012 to present: (A) Puerto Rico; (B) St. Croix; and, (C) St. Thomas/St. John. Percent of total sampling domain is listed for each of the 12 sampling strata.

Belt-Transect Surveys

The historical U.S. Caribbean belt transect (BT) method consisted of a single visual BT of dimensions 25 x 4 m (= 100 m^2) area, adapted from Brock (1954). A single BT diver was partnered with two benthic survey divers for safety purposes, and all divers completed individual surveys along the same transect tape draped along the seafloor. The transect location (i.e., centroid of survey grid cell) and direction (0 – 360°) were randomly pre-determined before the divers entered the water. From 2001 to 2011, divers surveyed at the location they landed (i.e., hard-bottom or soft-bottom habitats, including sand and sea grass). In 2012 to 2015, divers only surveyed hard-bottom habitats (e.g., aggregate reef, patch reef, pavement). To identify and enumerate fishes, the BT diver swam slowly in one direction along the transect recording fish in the water column and under ledges ahead of, or perpendicular to them, but never behind the area already surveyed (i.e. if the diver completed 15 meters, s/he would only record new fishes within the remaining 10 m). The diver had flexibility to move off the transect line as long as they remained within 2 m of the centerline. Fishes were identified to species level and the number of individuals by species were tallied by fork length (FL) into 5 cm size bins up to 35 cm (0–5, 5–10 cm, etc.). Fishes > 35 cm FL were recorded to the nearest cm. This included selected economically and ecologically important species such as groupers, snappers, hogfish, and lionfish.

BT survey time was standardized to 15 minutes, regardless of habitat type. Surveys were terminated if visibility was < 2 m. **Appendix 2** provides the BT field sampling protocols.

RVC Stationary Point Count Surveys

The reef visual census (RVC) stationary point count (SPC) method, adapted from Bohnsack and Bannerot (1986), uses two paired divers each surveying adjacent, nonoverlapping 15 m diameter cylinders (177 m^2 area) in hard-bottom habitats. The two divers simultaneously surveyed reef fish from the sea floor to sea surface while centered within their respective, imaginary cylinders. Divers used an all purpose tool (APT) that consisted of a one meter PVC pipe marked with 10 cm increments and a 30 cm perpendicular attachment at one end with 1 cm marked increments to measure fish. For the first five minutes, divers identified all observed fishes to species level, and in the subsequent five minutes, individuals were enumerated by species and fork length size was recorded to the nearest cm. As additional species were encountered they were similarly counted, measured, and added to the appropriate time period (5–10 minutes or 10–15 minutes). For the selected economically and ecologically important species including groupers, snappers, hogfish, and lionfish, fork length was recorded to the nearest cm for the first 10 individuals and then additional lengths (i.e., 11 or more fishes) were recorded in three categories: minimum, maximum, and mode (most frequent). All other species sizes were recorded to the nearest cm using the three categories. If distinctly different life stages for a species were apparent, then two different entries by species' size groupings were recorded separately.

Total RVC-SPC survey time ranged from 15 to 25 minutes, depending on habitat type and biomass present. The first 10 minutes of each survey are those data included in the analysis-ready dataset for fishery targeted and non-cryptic mobile species that provide a standardized "snapshot" of the reef fish abundance and size structure. Surveys were not conducted if visibility was < 4 m. **Appendix 3** provides a comprehensive description of the RVC field sampling protocol (Reef Visual Census (RVC) Fish Survey Protocol for the Atlantic Region: U.S. Caribbean, Florida and Gulf of Mexico: 2020).

Rationale for Changes in Survey Methods

Both BT and SPC survey methods are widely used to monitor fish populations (Pais and

Cabral, 2017). NCRMP's decision to change the U.S. Caribbean regional survey design to exclusively an SPC methodology was made to harmonize the program's data with other prominent U.S. reef fish surveys in Florida, Gulf of Mexico, and the Pacific (i.e., Hawaii, Samoa, Guam, etc.). Importantly, the change to RVC-SPC surveys produce reliable data on common fisheries target species (i.e., snappers, groupers) that can be used to inform U.S. fisheries management needs.

There is no "perfect" visual survey method that is the 'best fit' for all coral reef fish species. Fish behavior contributes to biases that affect all surveys' accuracy and precision, including response to divers (i.e., attraction or avoidance; Chiappone et al. 2000), shy versus bold behaviors, schooling, mobile versus sedentary, and cryptic versus non-cryptic (Pais and Cabral, 2018). Some bias will always exist due to the non-instantaneous nature of surveys, because the survey sample lasts minutes and during which fish can enter and exit the sample area (Pais and Cabral, 2017). This could lead to an overestimation of more mobile species (Kulbicki et al. 2010; Pais and Cabral, 2018). On the other hand, fish that hide and avoid divers will often be missed leading to an underestimation (Minte-Vera et al. 2008; Pais and Cabral, 2018).

Modeled comparisons of SPC and BT surveys have found biases with both methods: SPC had reportedly higher bias and less precision, while BT surveys were biased for schooling, shy and bold fishes (Pais and Cabral, 2018). However, empirical studies in the Florida Keys that compared BT and SPC methods concluded that SPC counts were more accurate for higher densities of commercially and recreationally targeted fishes (i.e., groupers, snappers, hogfish, triggerfish, etc.) as compared to BT surveys (Colvocoresses and Acosta, 2007). In addition, mobile smaller species (i.e., sizes less than fishery minimum lengths or non-targeted species) after a few minutes tended to acclimate to the SPC diver's presence (Bohnsack and Bannerot, 1986; Colvocoresses and Acosta, 2007). In the Pacific, in-situ BT and SPC methods had comparable density estimates for mobile, more visible/conspicuous fishes (e.g., Scaridae), but SPC samples using a 7 m radius had greater density estimates for sedentary Serranidae (Samoilys and Carlos, 2000). Fish size and area sampled were also important factors correlated with more accurate density estimates for larger species (Minte-Vera et al. 2008).

Thus, for the purposes of abundance estimation and quantification of changes in fishery targeted species in particular, the RVC-SPC method is ideal as a survey method to detect larger, timid, and sedentary fish species for several reasons: (1) it accurately and precisely detects fishery-targeted species (i.e., non-cryptic species); (2) it minimizes fish avoidance and behavioral effects due to divers actively swimming; and, (3) provides a larger area surveyed (177 m^2 for SPC versus 100 m^2 for BT). For ecosystem/community studies, the BT method offers an advantage of better detecting small, cryptic species (e.g., gobies, blennies, etc.) that may also have shy and/or sedentary behaviors. A calibration study is presently underway in the U.S. Caribbean to link historical BT surveys with the more current RVC-SPC sampling so that these datasets can inform multi-decadal evaluations of time series estimates of size-structured abundance of the reef fish community.

Data QA/QC

In the field, the accuracy and completeness of the BT and RVC-SPC diver datasheets were confirmed following each dive. Data were entered into an Excel database for BT surveys and, an online data entry system developed by SEFSC for the RVC-SPC surveys data. Data were first "proofed" by the diver who cross-checked their field datasheet to their database entry. Next, an agency data manager cross-checked entries with the original datasheets and the boat logs (i.e., survey date, time, site number) to ensure all samples were entered into the database, and that latitude/longitude sample location coordinates were correct. All data were then compiled and checked for errors and outliers using common data exploration techniques (i.e., sorting histograms). The underwater site photos, benthic habitat metrics (i.e., rugosity, slope), and survey location identified by GPS (boat or map centroid for BT surveys and hand-held unit attached to the dive buoy for RVC-SPC surveys) were used to confirm sampled strata.

III. Temporal Coverages

Belt-Transect Surveys

BT surveys were conducted annually from 2001–2011 in the U.S. Caribbean (St. Croix, St. John, and Puerto Rico). Surveys were conducted during two-week blitz missions in each of the three regions during summer (June to August) and winter/spring months (January to March). In 2013, St. Thomas was added to the St. John sampling domain, and in 2013 a regional rotation began until 2015. In the regional rotation schedule: St. Croix was sampled in 2012 and 2015; St. Thomas/St. John in 2013 and 2015; and, Puerto Rico in 2012 and 2014 (**Table 2**). Sampling mainly occurred during summer months (May to October). These two-week missions received increased NOAA partner support beginning in 2012 that allowed for more, island-wide samples to be completed in St. Croix, St. Thomas/St. John, and in Puerto Rico over a shorter time period (i.e., 6 weeks total).

RVC Stationary Point Count Surveys

In 2016, U.S. Caribbean RVC-SPC surveys began in Puerto Rico, and in 2017 the SPC surveys were implemented in the U.S. Virgin Islands. To better align sampling efforts and funding support across all U.S. Atlantic jurisdictions, NCRMP changed all U.S. Caribbean to be in the same year. As a result, Puerto Rico, St. Croix, and St. Thomas/St. John were surveyed for a second time using RVC-SPC methods in 2019 (**Table 2**). NCRMP plans to continue sampling the U.S. Caribbean every other year in odd years.

In the U.S. Virgin Islands, bienniel sampling continues to consist of two-week blitz missions to St. Croix and St. Thomas/St. John (i.e., four weeks total). Sampling occurs during the summer months, from June to August with trips scheduled to St. Croix in May/June and St. Thomas/St. John in July/August to reduce potential variations due to seasonality. In Puerto Rico, sampling is contracted to regional experts that survey from June through October.

Table 2. The number of primary sample units (i.e., survey sites) successfully sampled on hardbottom habitats by year and sampling domain. Belt-transect surveys occurred from 2001 to 2015. The historical (regional) sampling design was used from 2001 to 2011 and in 2012 to present surveys began an island-wide sampling design (hashed line). Reef visual census stationary point count (RVC SPC) surveys began in 2016 to present (solid gray line).

Year	**St. Croix (n)**	**St. Thomas/St. John (n)**	**Puerto Rico (n)**
2001	86	25	36
2002	76	72	71
2003	165	109	82
2004	114	128	83
2005	170	128	95
2006	185	127	100
2007	90	129	173
2008	167	134	86
2009	157	132	116
2010	118	134	74
2011	41	133	51
2012	262	-	35
2013	-	275	-
2014	-	-	223
2015	239	255	-
2016	-	-	230
2017	181	237	-
2018	-	-	-
2019	314	322	192

IV. Spatial coverage

Historical Period Survey Design

In the USVI, the local NPS (St. John and St. Croix) and NPS South Florida/Caribbean Inventory and Monitoring Network (SFCN), were the key partners that provided both personnel and field equipment (i.e., boats, dive tanks, etc.) to conduct surveys. As a result, from 2001 to 2011 most of the BT survey sites sampled (n ranged = 150 to 250 annually) occurred within and around the National Parks in St. Croix (Buck Island Reef National Monument) and St. John (Virgin Islands National Park and Virgin Islands Coral Reef National Monument including the mid shelf reef habitat south of St. John; see **Appendix 3**). In Puerto Rico, NOAA-NOS led efforts were focused in La Parguera Natural Reserve, and from 2001 to 2011 sampling obtained approximately 170 sites per year (**Appendix 1**). All regions survey samples were conducted in either hard or soft bottom habitats in < 30 m deep.

Present Period Survey Design

Island-wide stratified random sampling surveys were conducted from 2012 to 2019, during which each USVI region targeted 250 sites and Puerto Rico targeted 300 sites during sampled years. From 2012–2015 BT surveys were used; and, from 2016–2019 RVC-SPC surveys were used. All survey sampling sites sampled are exclusively conducted on hard-bottom habitat in < 30 m deep (**Appendix 1**).

V. Data Source Contacts

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Phone: (305) 361-4479

VI. Analysis-Ready Datasets

Analysis-ready (AR) datasets are publicly available at National Centers for Environmental Information (NCEI) or upon request to NOAA SEFSC's data source contacts. AR datasets are created after a thorough QA/QC process. Both BT and RVC-SPC raw datasets contain numbers at length abundance for all observed species plus pertinent site metadata (i.e., site latitude and longitude, statistical strata, depth, etc.); however, they differ slightly between BT and RVC-SPC collection methods. BT datasets only use one diver to record fish data at each site, and the AR dataset contains the number of fish observed at each size bin (mid-point of 5 cm bins) for every species. In addition, the final AR dataset for BT samples consists of only fish observed at each site (i.e., species not observed are excluded).

On the other hand, RVC-SPC AR datasets differ in two main ways due to how the data are collected. In the field, each species is recorded as the total number seen, followed by what the distribution of those numbers-at-size looked like (i.e., minimum, maximum, and mode). These observations are then distributed using a triangular distribution. Since two divers sample each site in the RVC-SPC method, each species observed could have up to ten (10) individual sizes so that the final AR dataset consists of the average (at each length, post-distribution) numbers of fish observed at each site per diver-pair. Additionally, for convenience, the final AR dataset include zeros (0) for all species that were not observed. Island-wide relative abundance (i.e., density) estimates are at the survey site level, and means and variances are computed (**Appendix 4**) by stratum, and a known stratum weighting factor that is a function of the finite 50 x 50 m grids of the survey domain with hard-bottom habitat grid cells derived from detailed habitat maps ranging from 0 to 30 m deep (Bryan et al. 2013).

VII. Data Limitations

Spatial Limitations

- Regionally focused sampling from 2001 to 2011, and then island-wide sampling from 2012 to present (**Appendix 1**).
- All regional sampling domains have nearly complete island-wide spatial coverage, except for a longitudinal break at the USVI and British Virgin Islands' international border, and at the northern coast of Puerto Rico.

Temporal Limitation

- Annual sampling from 2001 to 2011. Biennial sampling from 2012 to present.

Methodology Limitation

- BT method (2001 to 2015) was changed to RVC-SPC method in 2016.
- BT divers collected fish sizes in 5 cm bins up to 35 cm, then to the nearest cm when > 35 cm.

Depth Limitation

- All surveys are conducted from 0 to 30 m of water depth.

Habitat Limitation

- BT surveys were completed on hard and soft habitats (e.g., sea grasses and sand) from 2001 to 2011. In 2012 to present, BT and RVC-SPC surveys sampled exclusively on hard-bottom habitats.

Ongoing Efforts to Address Data Limitations

- BT and RVC-SPC method calibration surveys are presently ongoing in Puerto Rico, and in the USVI. These are funded by NOAA CRCP and MARFIN grants.
- The Deeper Coral Reef Monitoring Program (DCRMP) in St. Thomas/St. John, USVI is a temporary CRCP funded project (2019 to 2022) to employ RVC-SPC methods for the portion of the reef shelf not covered by NCRMP (30 to 60 m).

VIII. Partnerships (listed in alphabetical order)

Puerto Rico

- Coastal Survey Solutions (CSS)

- HJR Reefscaping (HJR)
- Isla Mar Research Expeditions (IMRE)
- Puerto Rico Department of Natural and Environmental Resources (DNER)
- University of Puerto Rico (UPR)

U.S. Virgin Islands

- National Park Service (NPS), St. John, St. Croix, and SFCN
- USVI Department of Planning and Natural Resources (DPNR), including East End Marine Park (EEMP)
- University of Miami (UM)
- University of the Virgin Islands (UVI)
- The Nature Conservancy (TNC)

IX. Field Descriptions

Sample Maps: Annual Sampling Maps (see **Appendix 1**)
Belt-Transect: Field Protocol (see **Appendix 2**)
RVC Stationary Point Count: Field Protocol (see **Appendix 3**)

X. References

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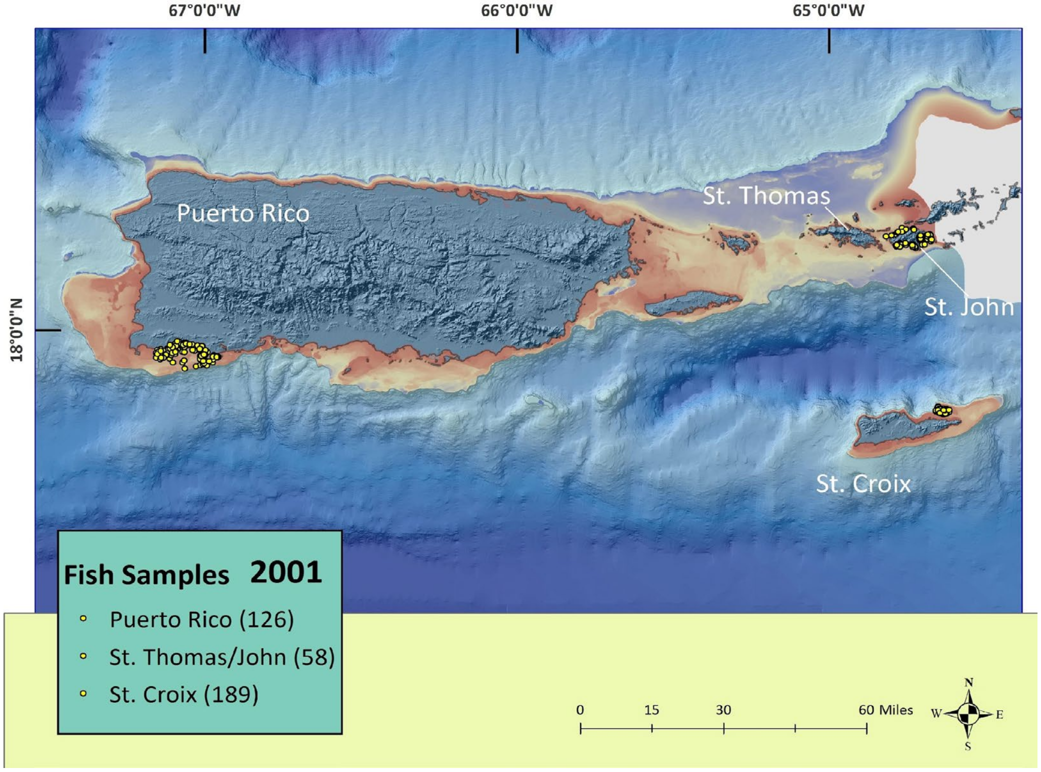
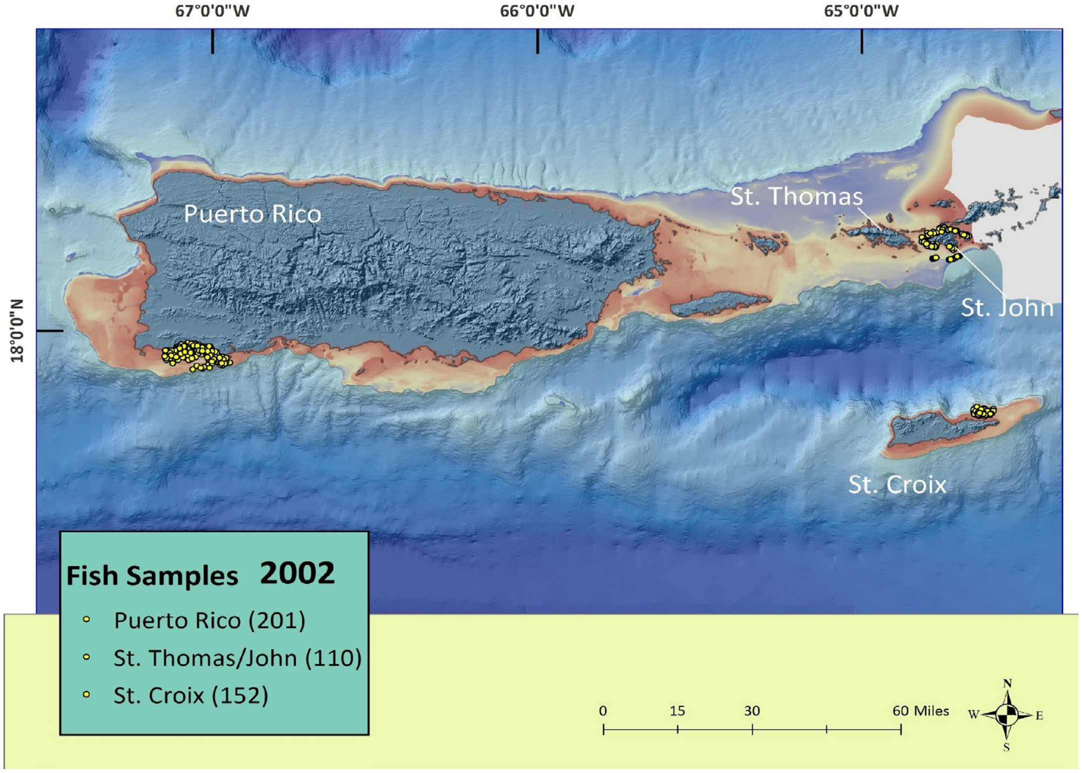
Acknowledgments

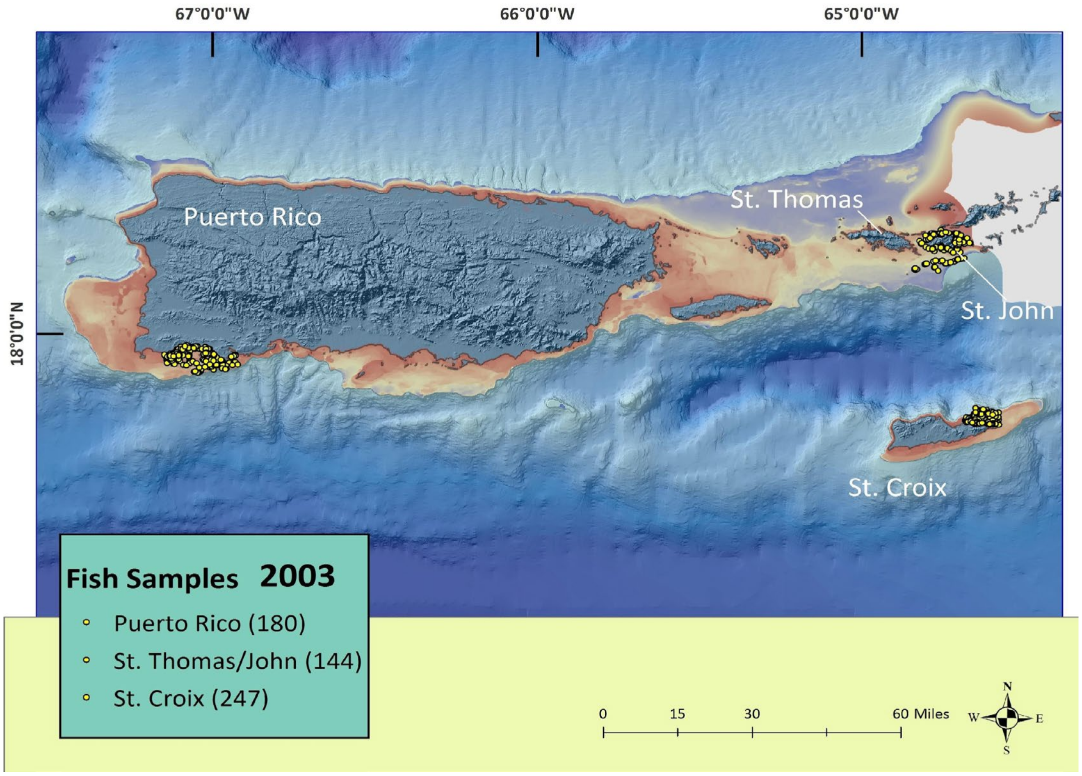
We thank Kimberly Edwards (NCRMP Atlantic benthic lead), Erica Towle (NCRMP National Coordinator), and SEFSC NCRMP Population and Ecosystem Monitoring and Sustainable Fisheries Divisions staff including Caitlin Langwiser, Dione Swanson, Nancie Cummings, and Adyan Rios for their thoughtful and constructive reviews of this working paper. NCRMP is funded by NOAA's Coral Reef Conservation Program (project #743).

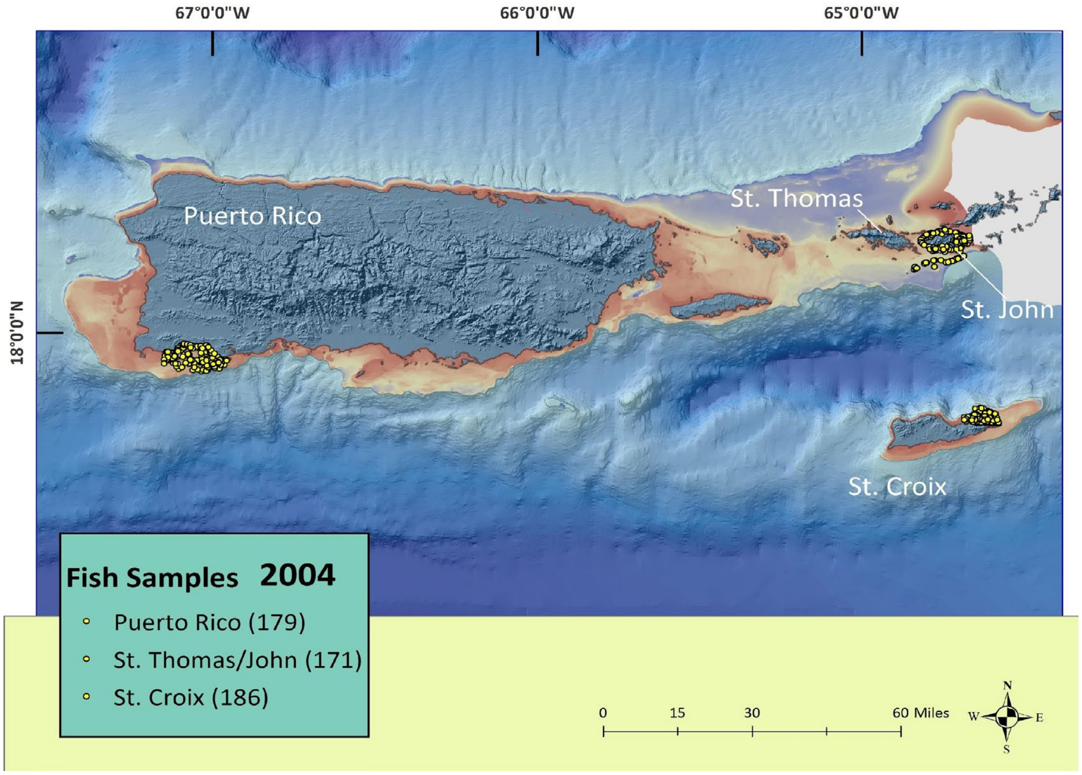
Appendix 1

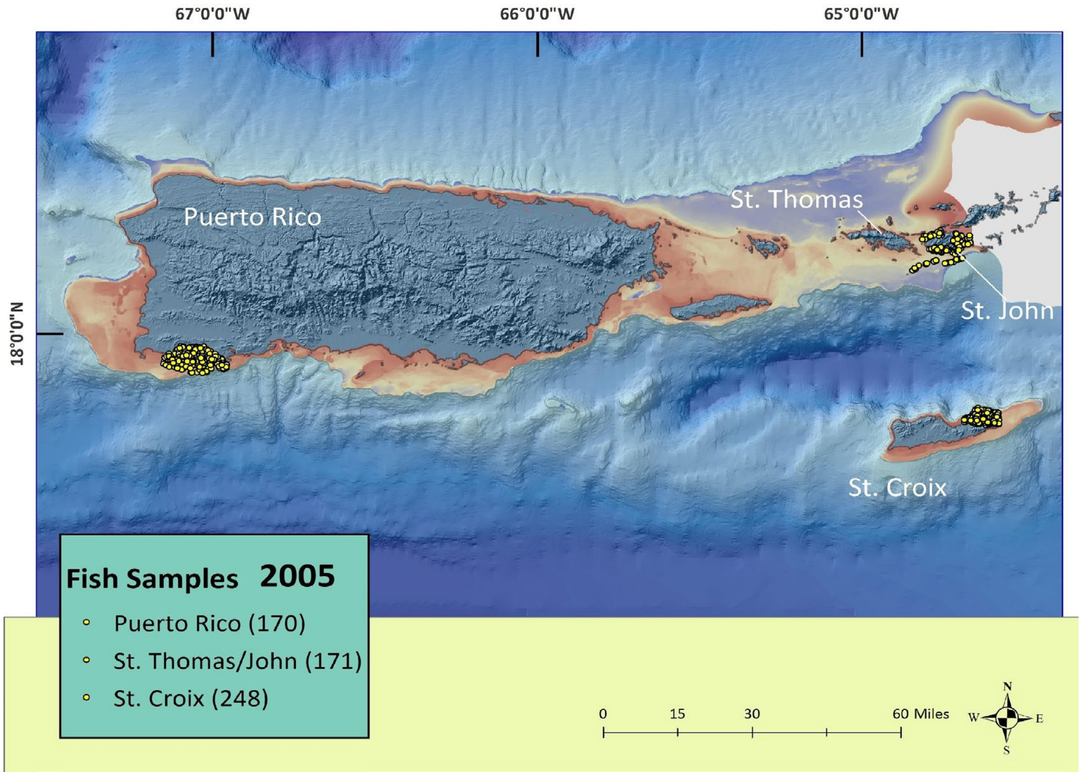
Maps of all survey sites (i.e., soft and hard bottom habitat) completed by year (2001–2019) in the U.S. Caribbean sampling domains (Puerto Rico, St. Croix, and St. Thomas/St. John). Number in parentheses represents the number of sites sampled in a given year in each domain.






67°0'0"W
66°0'0"W
65°0'0"W
18°0'0"N
Puerto Rico
St. Thomas
St. John
St. Croix
Fish Samples 2003
Puerto Rico (180)
St. Thomas/John (144)
St. Croix (247)
0
15
30
60 Miles
N
W
E
S


67°0'0"W
66°0'0"W
65°0'0"W
18°0'0"N
Puerto Rico
St. Thomas
St. John
St. Croix
Fish Samples 2004
Puerto Rico (179)
St. Thomas/John (171)
St. Croix (186)
0
15
30
60 Miles
N
W
E
S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Puerto Rico
St. Thomas
St. John
St. Croix
Fish Samples 2005
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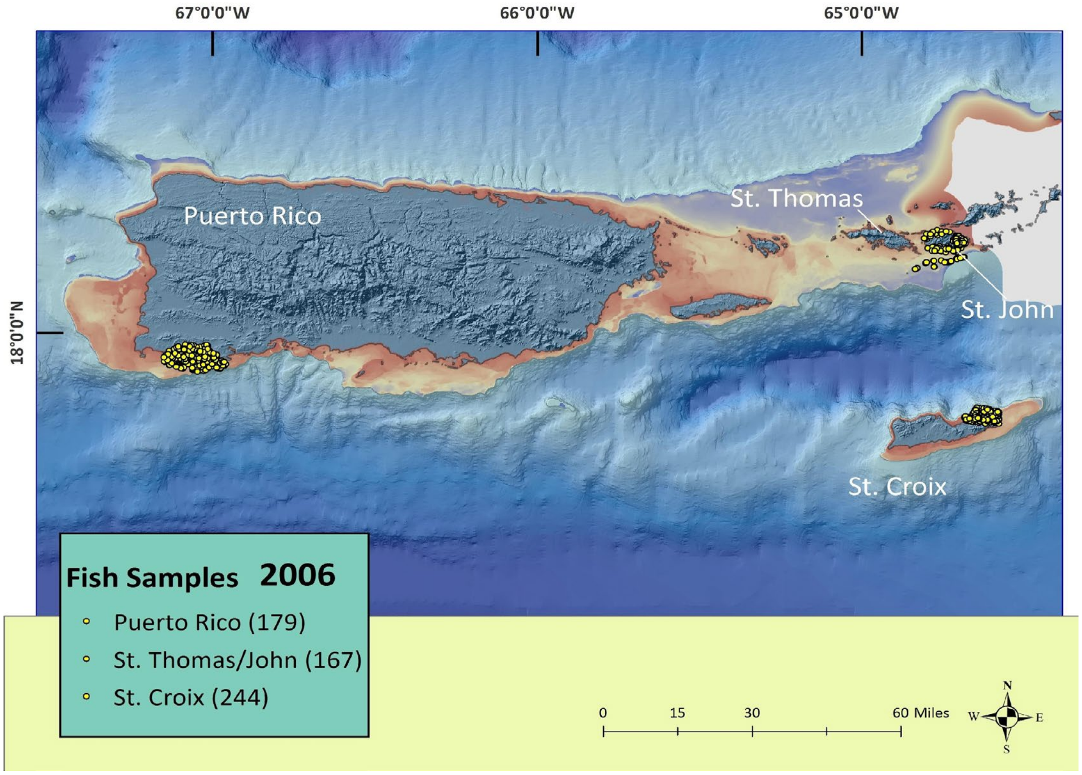
St. Thomas/John (171)
St. Croix (248)
0
15
30
60 Miles
N
W
E
S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St. John
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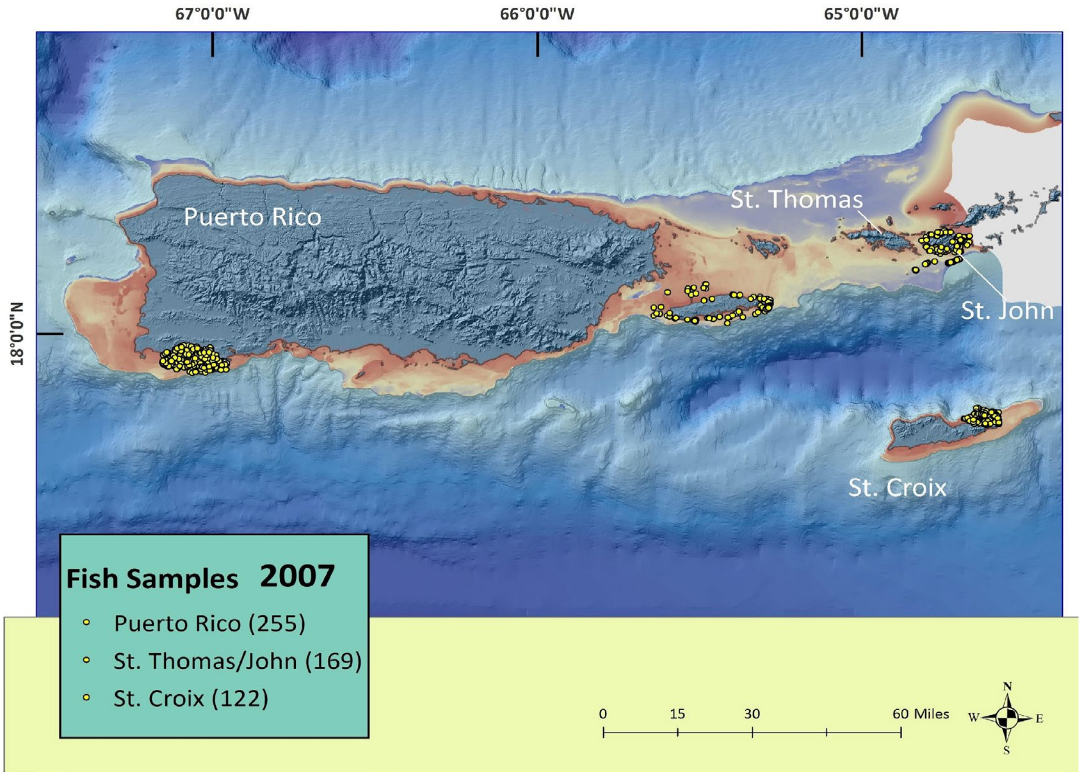
15
30
60 Miles
N
W
E
S



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Fish Samples 2007
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St. Thomas/John (169)
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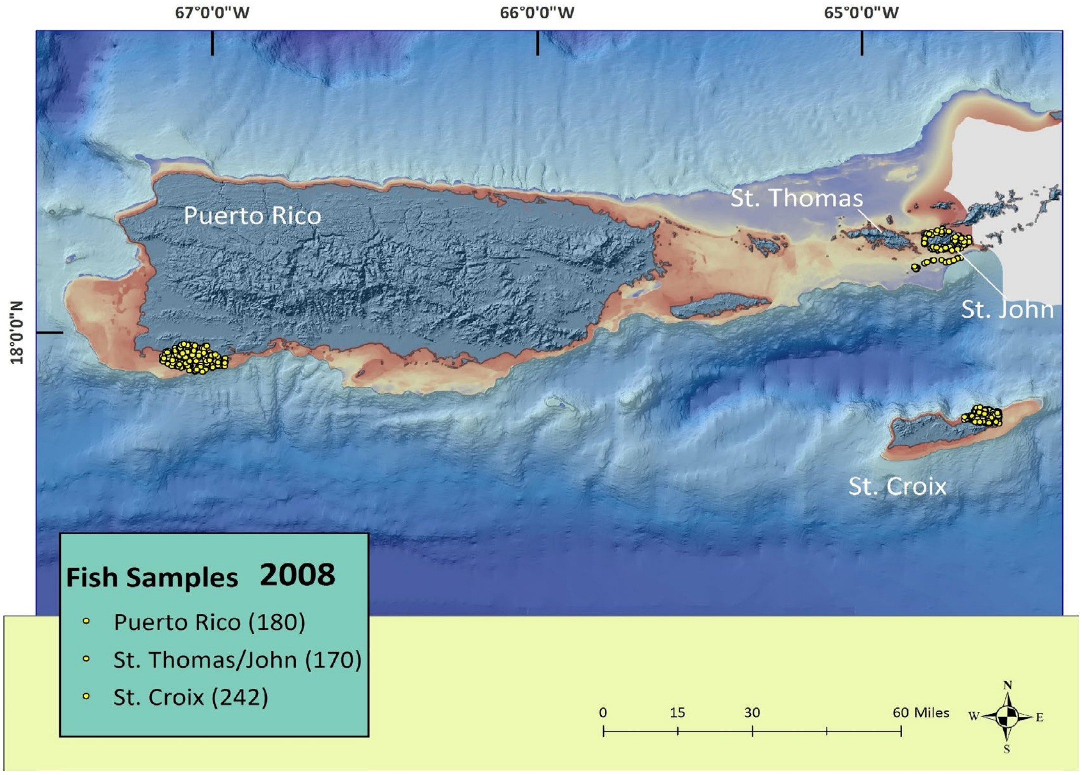
0
15
30
60 Miles
N
W
E
S



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St. John
St. Croix
Fish Samples 2008
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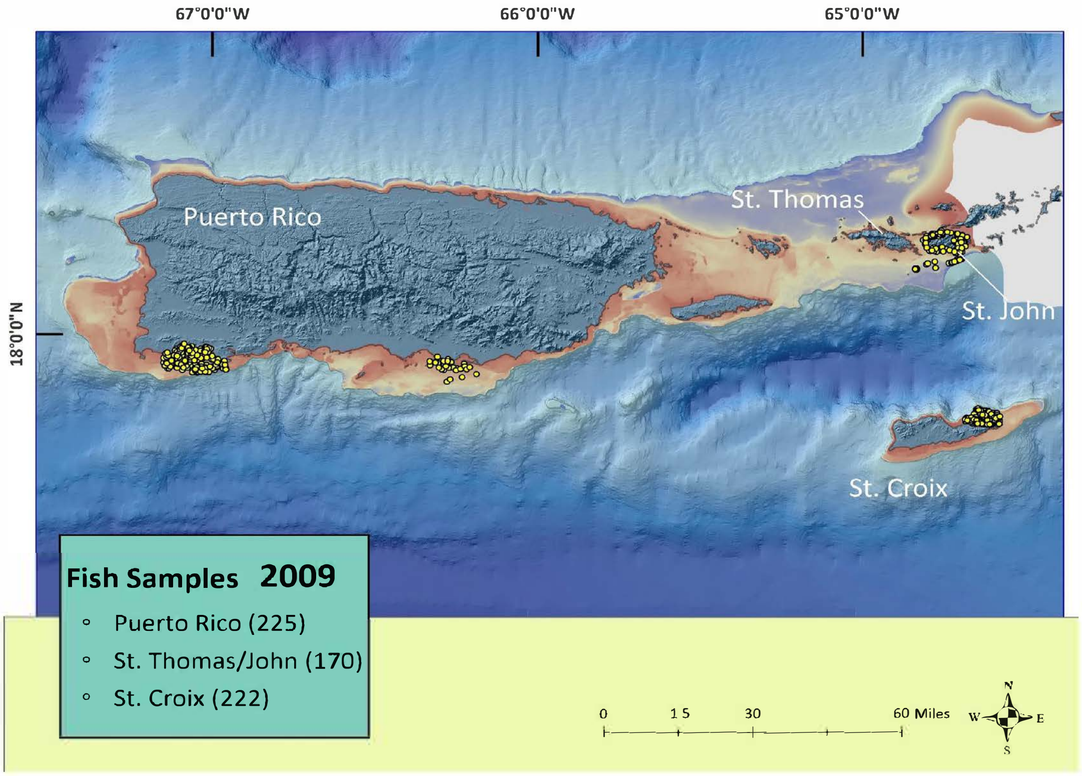
St. Thomas/John (170)
St. Croix (242)
0
15
30
60 Miles
N
W
E
S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St. Thomas
St. John
St. Croix
Fish Samples 2009
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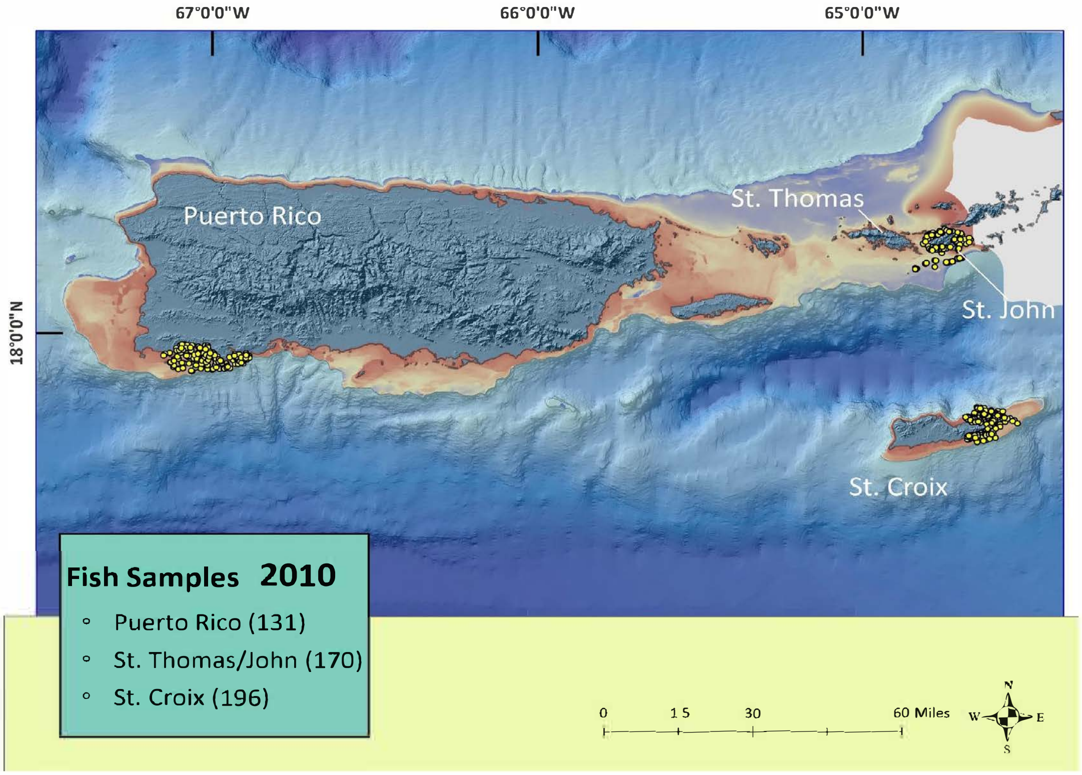
St. Thomas/John (170)
St. Croix (222)
0
15
30
60 Miles
N
W
E
S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St. Thomas
St. John
St. Croix
Fish Samples 2010
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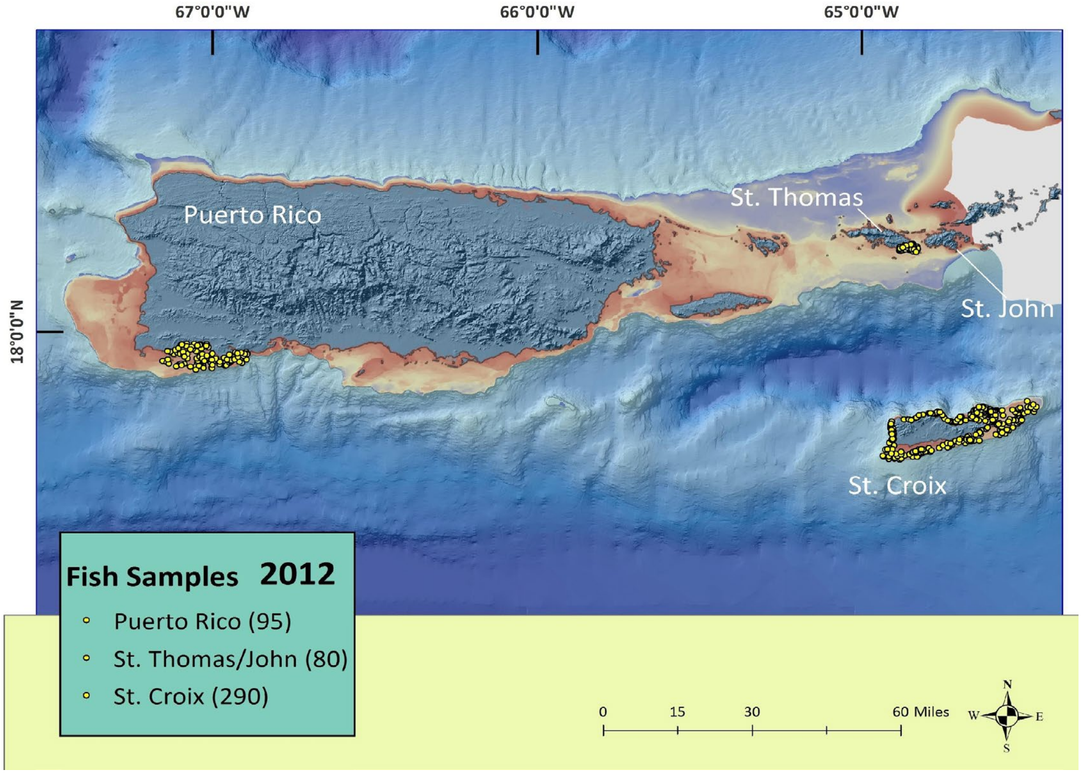
St. Thomas/John (170)
St. Croix (196)
0
15
30
60 Miles
N
W
E
S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St. John
St. Croix
Fish Samples 2012
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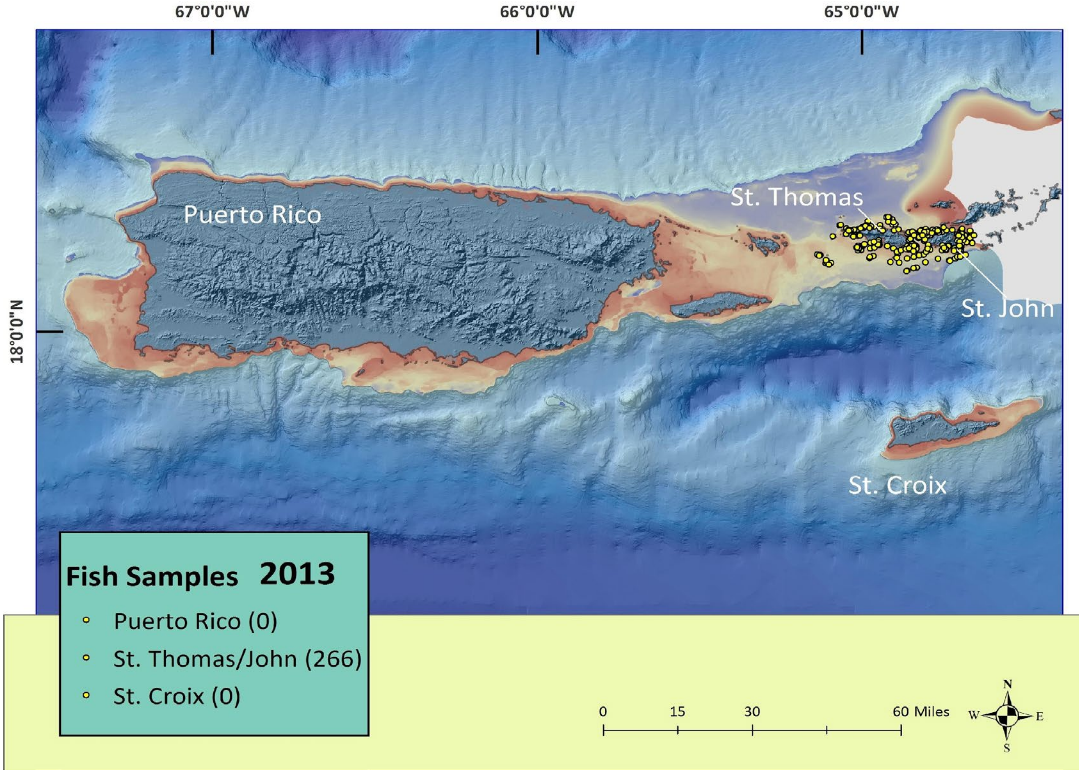
St. Thomas/John (80)
St. Croix (290)
0
15
30
60 Miles
N
W
E
S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St. Thomas
St. John
St. Croix
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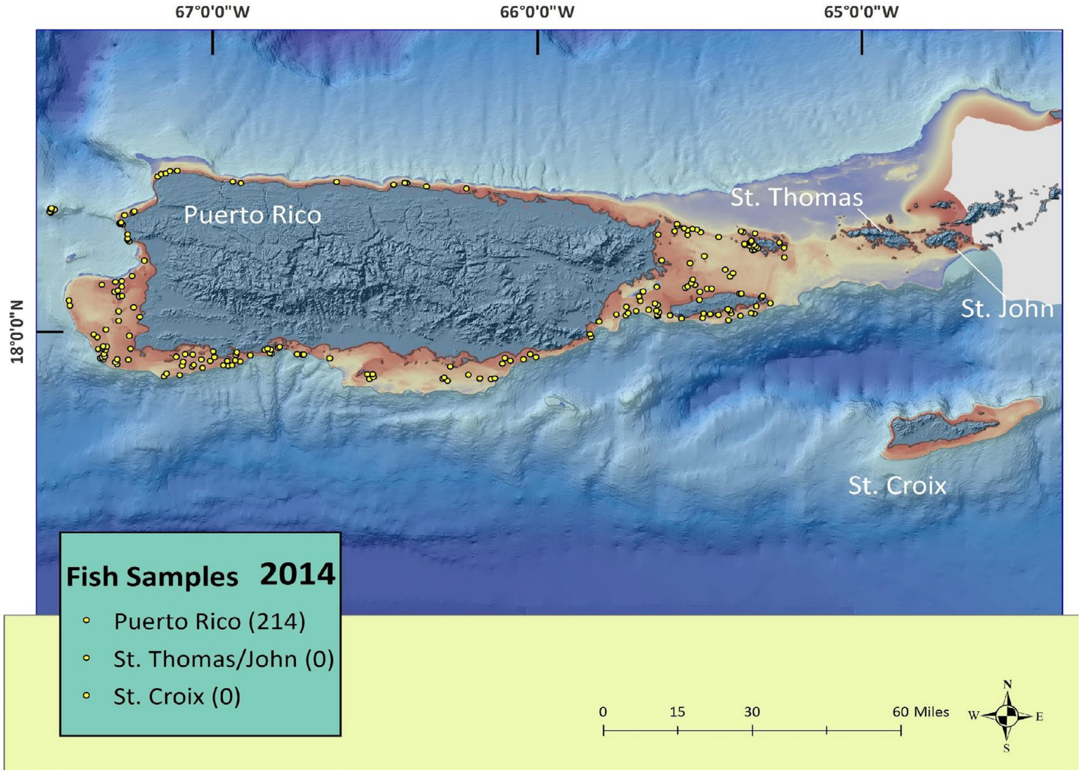
St. Thomas/John (266)
St. Croix (0)
0
15
30
60 Miles
N
W
E
S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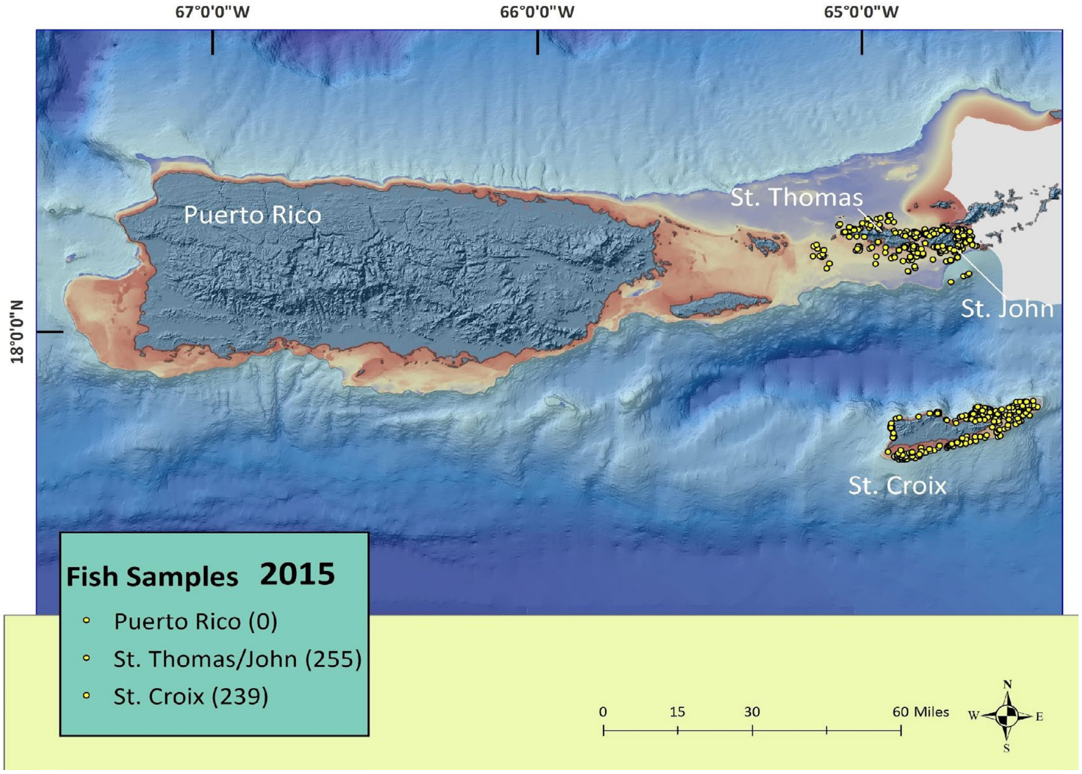
St. Thomas
St. John
St. Croix
Fish Samples 2014
Puerto Rico (214)
St. Thomas/John (0)
St. Croix (0)
0
15
30
60 Miles
N
W
E
S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St. Thomas
St. John
St. Croix
Fish Samples 2015
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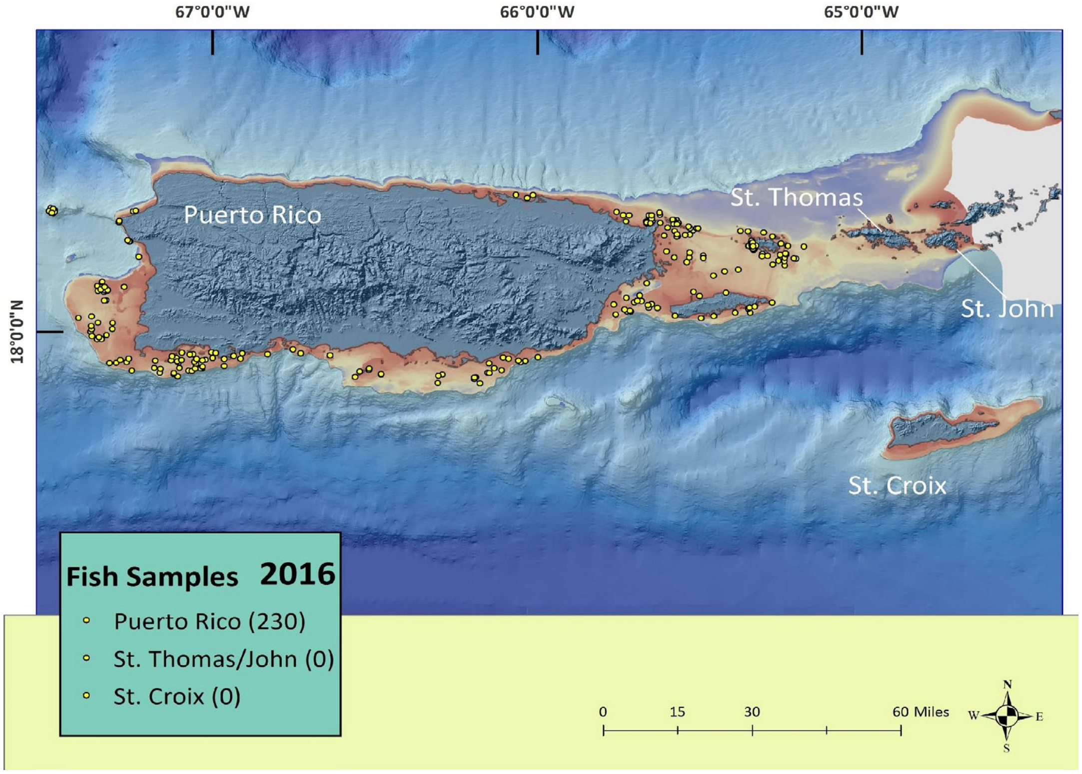
St. Thomas/John (255)
St. Croix (239)
0
15
30
60 Miles
N
W
E
S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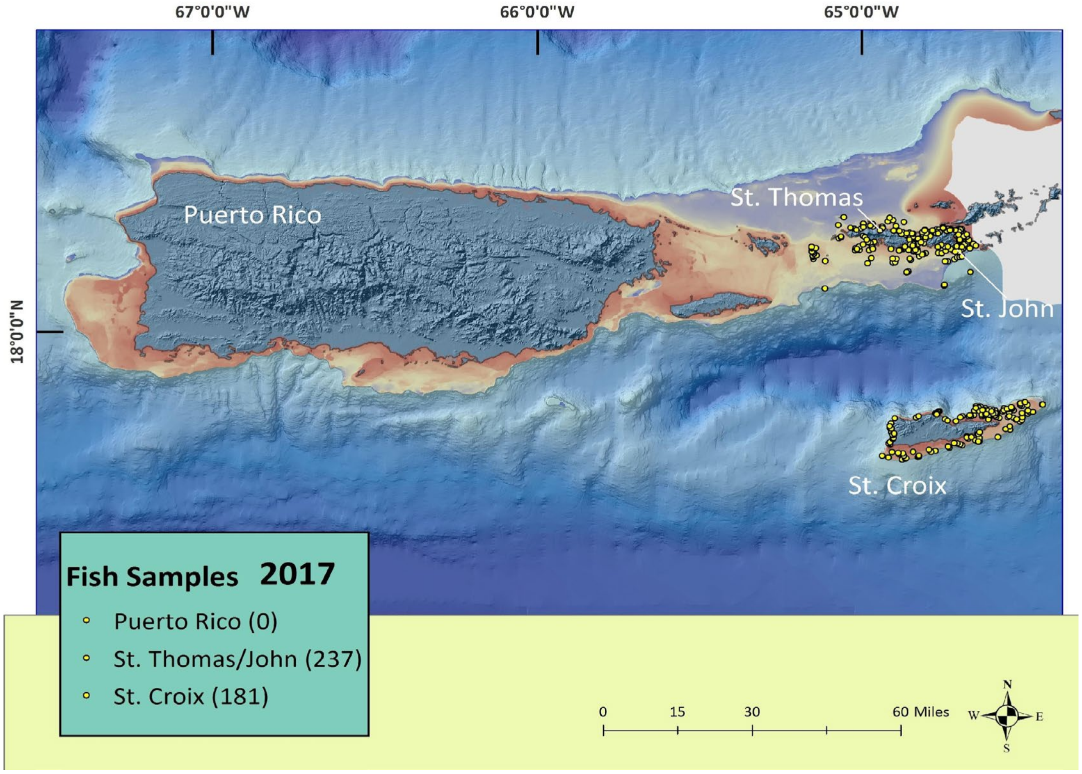
Puerto Rico
St. Thomas
St. John
St. Croix
Fish Samples 2016
Puerto Rico (230)
St. Thomas/John (0)
St. Croix (0)
0
15
30
60 Miles
N
W
E
S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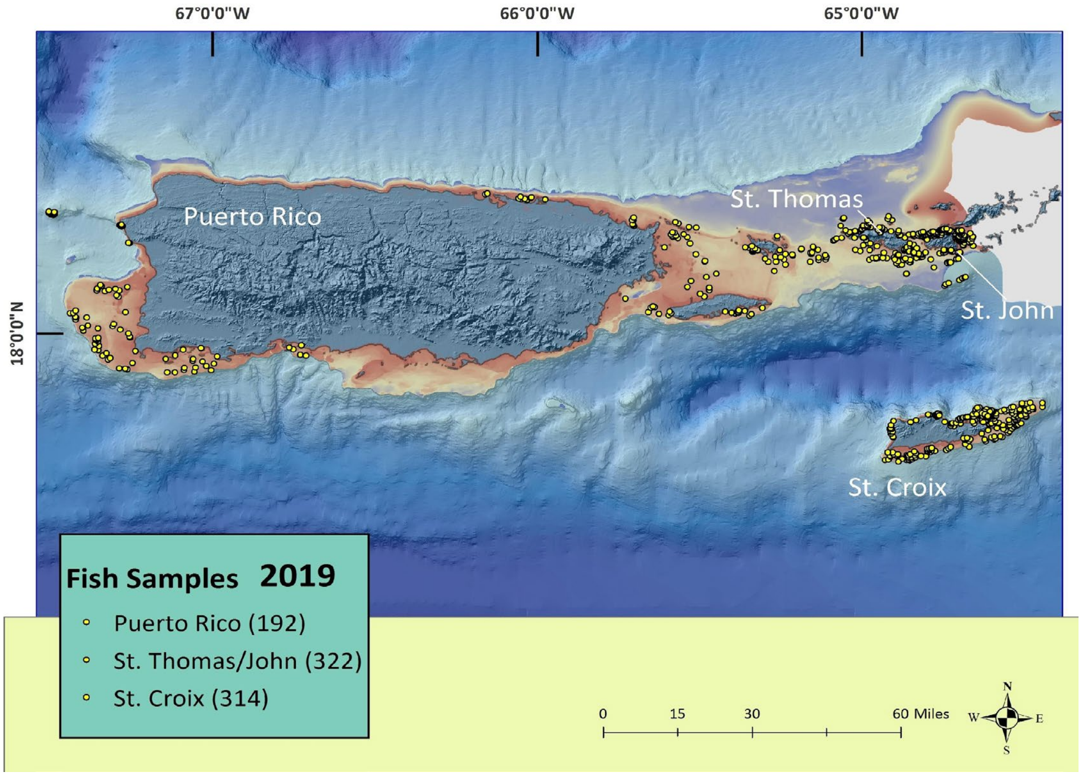
Puerto Rico
St. Thomas
St. John
St. Croix
Fish Samples 2017
Puerto Rico (0)
St. Thomas/John (237)
St. Croix (181)
0
15
30
60 Miles
N
W
E
S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Puerto Rico
St. Thomas
St. John
St. Croix
Fish Samples 2019
Puerto Rico (192)
St. Thomas/John (322)
St. Croix (314)
0
15
30
60 Miles
N
W
E
S

Appendix 2
National Coral Reef Monitoring Program's 2013 Belt Transect Fish Survey Protocol for the U.S. Caribbean

Belt Transect Fish Survey Protocol for U.S. Caribbean

National Coral Reef Monitoring Program
Coral Reef Conservation Program, National Oceanic and Atmospheric Administration
Updated: 26 June 2013, by NOAA NCCOS

Belt Transect Fish Census

Once in the field, the boat captain navigates to previously selected sites using a handheld GPS unit. On-site, divers are deployed and maintain contact with each other throughout the entire census. One diver is responsible for collecting data on the fish communities utilizing the belt-transect visual census technique over an area of $100m^2$ (25m length X 4m width). The belt-transect diver obtains a random compass heading for the transect prior to entering the water and records the compass bearing (0-360°) on the data sheet. Where appropriate, the boat can drop a weighted float that will mark the start of the transect. The boat can drop the divers near the float and the team descends down the float line. Dropping a float in the VINP and VICR is not an option so divers are dropped as close to the GPS position as possible. The divers will descend as rapidly, yet safely, as possible to maintain relative proximity to the centroid position. If it becomes apparent that no hardbottom is in the vision of the dive team (i.e., continuous sand or seagrass or limited visibility), then the dive will be terminated and an alternate selected. If hardbottom is observed in the vicinity of the site, then the dive continues as planned-starting on the centroid, or close approximation, and on the predetermined random bearing. Do not alter the predetermined course if the centroid is not on hardbottom or the bearing does not cover hardbottom.

Visibility at each site must be sufficient to allow for identification of fish at a minimum of 2m away. Once reasonable visibility is ascertained, the diver attaches a tape measure to the substrate and allows it to roll out for 25m while s/he collects data.

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 s/he stays within the 4m transect width and does 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 meter 15, s/he can look 10 meters distant, but if s/he is at meter 23, s/he can only look 2 meters ahead).

On-site, 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 99 ft.

The transect should take 15 minutes regardless of habitat type or number of animals present. This allows more mobile animals the opportunity to swim through the transect and standardizes the samples collected to allow for comparisons.

Data are collected on the following:

1. Logistic information - diver name, dive buddy, station, transect bearing, date, time of survey.

2. Taxa presence - as the tape rolls out at a relatively constant speed, the diver records all fish species to the lowest taxonomic level possible that come within 2m 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. As the fish diver proceeds down the transect, they need to attach an ankle weight to the tape so the tape is relatively immovable for the LPI diver. The tape could also be tied around a hard feature but with minimal tape usage as the LPI diver is making measurements every 20cm.

4. Abundance & size - the number of individuals per species is tallied in 5cm size class increments up to 35cm using visual estimation of **fork length** (Figure 1). If an individual is greater than 35cm, then an estimate of the **actual fork length** is recorded. Actual size (cm FL) is recorded for certain managed species. These include:

Cephalopholis cruentata	graysby
Cephalopholis fulva	coney
Dermatolepis inermis	marbled grouper
Epinephelus adscensionis	rock hind
Epinephelus guttatus	red hind
Epinephelus morio	red grouper
Epinephelus striatus	nassau grouper
Lutjanus analis	mutton snapper
Lutjanus apodus	schoolmaster
Lutjanus buccanella	blackfin snapper
Lutjanus cyanopterus	cubera snapper
Lutjanus griseus	gray snapper
Lutjanus jocu	dog snapper
Lutjanus mahogoni	mahogany snapper
Lutjanus synagris	lane snapper
Mycteroperca bonaci	black grouper
Mycteroperca interstitialis	yellowmouth grouper
Mycteroperca tigris	tiger grouper
Mycteroperca venenosa	yellowfin grouper
Mycteroperca phenax	scamp
Ocyurus chrysurus	yellowtail snapper
Lachnolaimus maximus	hogfish

5. When the Fish diver has completed the fish survey and is at m 25, s/he begins the swim back to m 0 while conducting the Topographic Complexity Survey (Supplemental 1).

6. Photos - individuals too difficult to identify or unique in some manner may be photographed for later clarification.

7. At the end of the survey, when divers are on the boat, the LPI diver reviews the fish datasheet for completeness and legibility. LPI diver checks, at a minimum, the following:
    a. Legibility of all logistic information
    b. Legibility of all species codes, bin size class marks and size numbers
    c. Legibility of all rugosity measure numbers

8. When LPI diver has certified Fish datasheet has met this quick qa/qc check, LPI diver initials sheet in “check by diver” box.

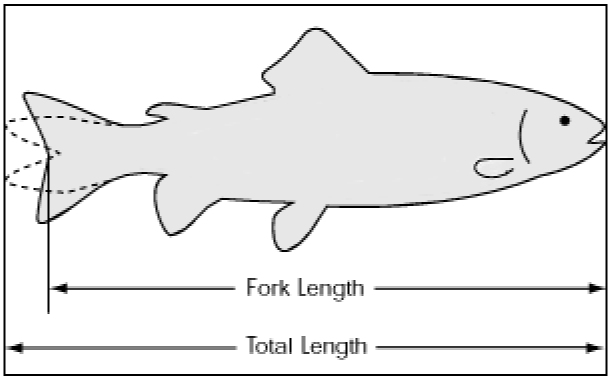


Figure 1: Fork length measurement compared with total length measurement. Fork length is recorded.

Supplemental 1:

Topographic Complexity Survey Protocol for the U.S. Caribbean

Introduction

NCRMP is a broad spatial snapshot for reef condition (*i.e.* fish species composition/density/size, benthic cover, and coral density/size/condition) to provide context for local-scale studies of tropical reef ecosystems. Data collection will occur at stratified random sites where the sampling domain for each region (*e.g.* Puerto Rico and USVI) is partitioned by habitat type and depth, sub-regional location (*e.g.* along-shelf position) and management zone. NCRMP is intended to supplement local monitoring efforts by providing large-scale data on reef fishes and the benthos.

The following protocol pertains to NCRMP topographic complexity surveys conducted in conjunction with reef fish surveys using a 25-m x 4-m belt transects. The purpose of this survey is to provide information on the topographic complexity (substratum rugosity) of survey locations where reef fish surveys and line point-intercept surveys are conducted. The data collection procedure described below captures basic information on the depth range, vertical relief, and surface topography.

Characterization of topographic complexity along a 25-m fish transect consists of three separate elements:

- Minimum and maximum depth along each 25-m transect;
- Amplitude of substratum relief, recorded as the maximum vertical relief in a 25-m x 4-m belt transect; and
- An estimate of the relative proportion of different relief categories for the sample unit (i.e., 100-m^2 belt transect), using six different categories ranging from < 0.2 m to > 2 m.

Minimum/maximum depth and maximum vertical relief measurements are made within the 25-m x 4-m portion of the transect. In the U.S. Caribbean, 24 relief frequency measurements occur along **BOTH** transect sides (starting at meter 24 and 2-m out on each transect side).

Step 1 (slope). **Substratum slope**: using a digital depth gauge, record the maximum and minimum depth encountered within the 25-m x 4-m belt transect. This information provides the depth range of the sample unit, as well as the potential variability of the substratum in certain habitats such as spur and groove.

Step 2 (amplitude). **Maximum vertical relief**: using a digital depth gauge or a 0.5- or 1-m measuring device, record the maximum vertical relief present in the 25-m x 4-m belt transect area. This is accomplished by measuring the height of the most structurally complex feature in the sample unit, whether a coral head, barrel sponge, side of a coralline spur, or other topographic feature. Note that gorgonians, branching sponges, and branching *Millepora alcicornis* colonies are NOT included in this measurement.

Step 3 (frequency). **<u>Surface area topography (relief frequency)</u>**: An estimate of the surface topography of the sample unit (i.e., 25-m x 4-m fish belt transect) can be accomplished in many ways. In the U.S. Caribbean, the entire transect cannot be easily viewed all at once. Therefore, one approach is to subdivide the 100-m^2 area into smaller subplots (e.g. 2-m x 2-m areas, n=24 per sample unit in this example), with each subplot scored for the highest hard-bottom relief feature (Figure 1). Each 2-m x 2-m sub-plot is scored for vertical relief using one of the following six categories: < 0.2 m, 0.2-<0.5 m, 0.5-<1.0 m, 1.0-<1.5 m, 1.5-<2 m and 2+ m. Looking within each individual sub-plot, measure the highest relief feature (not including "soft complexity" features such as branching gorgonians, sponges, and fire corals) and place a mark in the appropriate relief category on the datasheet.

Example data along a 25-m x 4-m belt transect, subdivided into 2-m x 2-m subplots (for ease of sampling):

(24 marks recorded on the underwater datasheet)

Category	Frequency (number of 2-m x 2-m units)
< 0.2 m	5
0.2-<0.5 m	6
0.5-<1.0 m	10
1.0-<1.5 m	2
1.5-<2.0m	2
2 m+	0

In this example, an estimated 20% of the sample unit had < 0.2 m of relief, 24% had 0.2-0.5 m of relief, and so on.

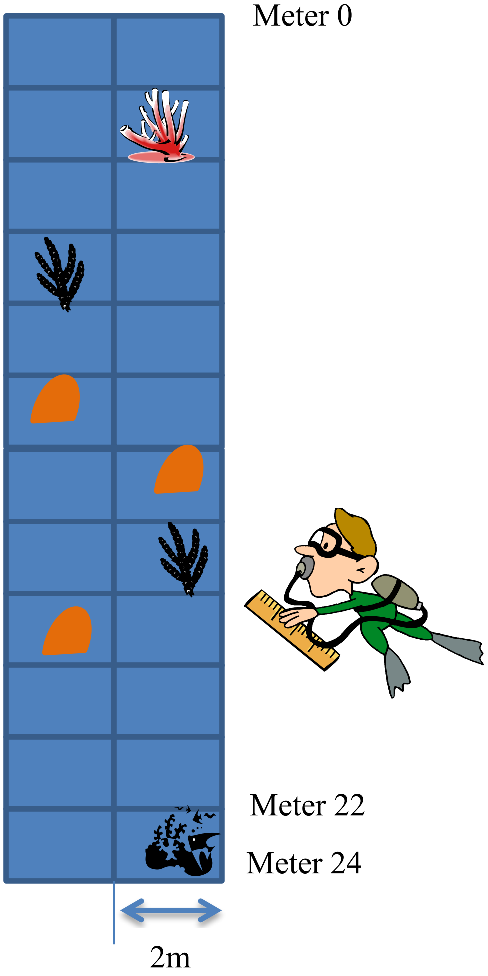


Figure 1. Example of the 2-m x 2-m grids for measuring topographic complexity along a 25-m x 4-m belt transect survey area for reef fishes in the U.S. Virgin Islands and Puerto Rico.

Reef Visual Census (RVC) Fish Survey Protocol for the Atlantic Region: US Caribbean, Florida and the Gulf of Mexico: 2020

National Coral Reef Monitoring Program (NCRMP)
Coral Reef Conservation Program (CRCP), National Oceanic and Atmospheric Administration (NOAA)

Introduction

The National Coral Reef Monitoring Program (NCRMP) is a broad-spatial snapshot for reef condition (*i.e.*, fish species composition/density/size, benthic cover, and coral density/size/condition) to provide context for local-scale studies of tropical reef ecosystems. Data collection will occur at stratified random sites where the sampling domain for each region (*e.g.*, Puerto Rico, U.S. Virgin Islands (USVI), Flower Garden Banks (FGB) and Florida) is partitioned by habitat type and depth, sub-regional location (*e.g.*, along-shelf position) and management zone. NCRMP will provide broader geographic context to supplement local monitoring efforts and studies of tropical reef ecosystems.

NCRMP fish surveys conducted in the Pacific and Florida regions are conducted using the Reef Visual Census (RVC) point count method (Brandt et al., 2009). This protocol will describe fish surveys conducted in the U.S. reefs in the Caribbean, Gulf of Mexico, and Florida.

Goal of Fish Surveys

The goal of the fish community surveys is to collect and report information on species composition, density, size, abundance, and derived metrics (*e.g.*, species richness, diversity) using the RVC method in a stratified random sampling design on hardbottom and coral reef habitats in the U.S. coral reef jurisdictions. While all jurisdictions will use the RVC method, slight adjustments must be made in order to account for regional implementation nuances. This protocol is intended for the Florida and Flower Garden Banks National Marine Sanctuary 2020 sampling season and may be refined in subsequent years.

General Task Description

The Reef fish Visual Census (RVC) method is modified from Bohnsack and Bannerot (1986), and occurs with the diver remaining at a fixed site. Fish are surveyed within an imaginary 15 m diameter cylinder centered on the diver and extending vertically from the substrate to the limits of vertical visibility, sometimes the surface. In Florida, traditionally two individual teams, consisting of two divers per team sampled concurrently, but in 2020 Florida reduced the sample frame grid size to 50x50m and subsequently altered the sampling to a 1-stage design as we have been using the Caribbean. Each diver, in the 2 person team, is conducting a 7.5 m radius stationary point count fish survey. Data collected by each pair is averaged respectively to reduce variability at the site level.

Line Point-Intercept (LPI) and Coral Demographic surveys are not collected at all fish sites. However, sites that require both fish and benthic surveys, a team of two benthic divers can be deployed simultaneously with the fish team (Supplemental I; Figure A), and establish the benthic transect on the appropriate habitat with the least amount of interference with the fish surveys. Refer to *Benthic Assessment Protocols for the Atlantic Region: U.S. Caribbean, Florida and the Gulf of Mexico: 2020* and *Coral Demographics Survey Protocol for the Atlantic Region: U.S. Caribbean, Florida and Gulf of Mexico: 2020*

RVC Diver responsibilities include collecting:

- Fish information
- Benthic cover information
- Coral Disease information
- Overall topographic information
- Site photos

General Site Information

Navigating to site

Once in the field, the boat captain navigates to the selected site using a handheld GPS unit. On-site, divers are deployed and maintain visual contact with each other throughout the entire census.

****Divers should always be aware of dive buddy and make frequent visual contact with dive buddy throughout entire dive (this includes during surveys as well)****

1. Each boat will have up to three **(3)** GPS units:
    a. One **(1)** for navigation to sites, and
    b. Each boat will have one (1) dive flag/float with a GPS unit attached. This setup is unique for each boat and will be used by the diver teams to mark the site for surface support, to mark a starting point for the dive teams and to verify site location with computer generated sites. Record each team's unique GPS # and dive flag numbers on the daily boat log (Figure 1; Supplemental II).
    c. If using a GPS unit other than handheld to navigate to the sites, a handheld GPS is used to collect topside waypoints (see #3 below)
2. Dive teams enter the water at selected GPS coordinates, descend to bottom, affix the surface float line to the bottom, set up survey areas and begin data collection.
    a. If the benthic team is diving with the fish team, **ALL dive teams should enter the water as close to the same time as possible.**
3. As the dive team(s) deploy from the vessel, the boat captain will use the handheld GPS to mark a waypoint of the surface float/flag and record the coordinates on the boat log (Supplemental II).

4. Once all surveys are completed all divers convene at the affixed float line and begin their ascent to the surface together.

****Boat drivers will safely mark waypoint, after divers have descended****

Establishing the cylinders – Evaluating the Site

Upon descent, the team assesses the suitability of the site by ascertaining: (1) presence/absence of hardbottom, (2) observed habitat type, and (3) visibility of the cylinder.

1. As the team descends and assesses the site, the fish team ascertains the presence of hardbottom.
    a. Hardbottom presence/absence
        i. Present – If hardbottom is present, continue habitat type assessment
        ii. Absent – If hardbottom is not **visible** at the the site (no hardbottom at all, *i.e.*, continuous sand or seagrass combined with limited visibility),
            1. Then the dive will be terminated and an alternate site selected,
            2. **Do not swim around searching for hardbottom – this is not reconnaissance**.

2. Observed habitat type – If the team(s) deploy over hardbottom they are to establish cylinders where deployed.
    a. If necessary, during descent, divers will swim to appropriate habitat within visual range
        i. If divers enter the water over sand, they will swim to nearby reef habitat for sampling.
        ii. If divers enter the water over hardbottom different from that expected **and** observe expected habitat type within visible range from where deployed, they will swim to expected habitat for sampling.

    b. If divers enter the water over hardbottom different from that expected and **do not** observe expected habitat type nearby, they will establish cylinders where deployed and indicate the alternate habitat on the datasheet and boat log.

3. When a benthic team deploys with the RVC team, benthics to set up adjacent to the cylinders if possible, using the same anchor point for the belt transect. Benthics can swim to nearby hardbottom if it is patchy where the RVC is established, if they remain in visual context with the RVC divers and the surface float (Supplemental I).

4. Under optimal visibility conditions, the distance between dive buddies should be 15 m (Supplemental I). The surface float can be secured to the bottom and serve as a starting point to measure the radius of the sampling cylinder using the All Purpose Tool (APT; i.e., 7.5 m or 4.0 m depending on visibility) as a:

a. Determine visibility of the cylinder.

   i. If horizontal visibility is greater than or equal to 7.5m, then the radius of the cylinder will be 7.5m.

   ii. If the horizontal visibility is less than 7.5m but greater than 4 m, then the diver will set up in the middle of a 5m cylinder and slightly move from the middle to observe the area needed to fulfill the 7.5 m cylinder. The APT (Figure 1), or some other type of marker, can be used to mark the initial midpoint.

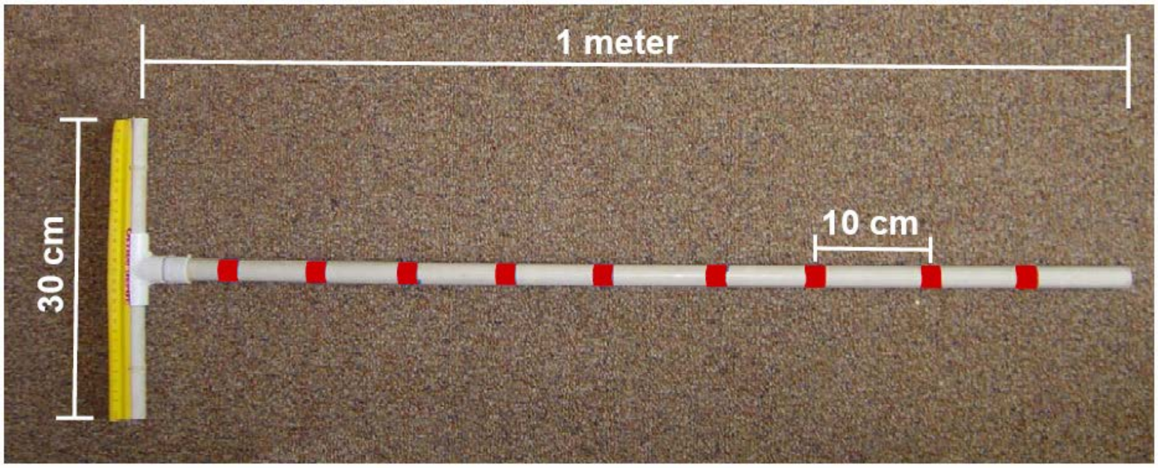


Figure 1. The All Purpose Tool (APT) is used as a tool for measuring benthic relief, estimating fish lengths, and the dimensions of survey cylinder.

Additional APT uses:

- Visual aid to measure visibility and fish sizes
- Point of reference (e.g., edge of cylinder, fish measurement) during data collection
- Point of return for both divers following data collection

5. **Terminating the dive –** Certain environmental conditions are not safe for operations and surveys should be automatically terminated and alternates chosen when:

   a. **Visibility is less than 4 m**

   b. **Bottom currents are strong enough that the divers cannot maintain a stationary position**,

   c. **Depth of the selected site is greater than 99 ft**.

Reasons to terminate a dive:

- Visibility (< 4m)
- Strong currents
- Depth (> 99ft)

** **ALWAYS** Indicate reasons for terminating dives on boat logs**

RVC Sequence of events

RVC data collection occurs in three phases: (1) Predive, (2) fish counting/measuring, (3) and site/benthic/topographic assessment (Figure 2).

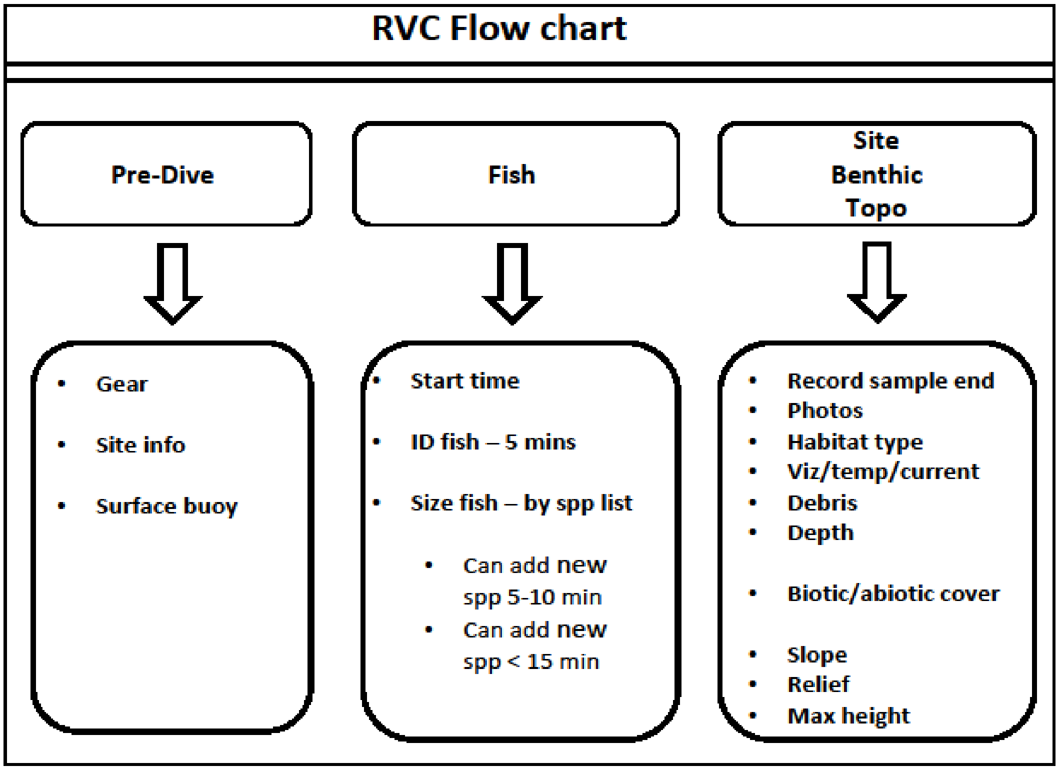


Figure 2. Reef visual census (RVC) sequence of events.

Predive

Station information is to be recorded in two primary locations prior to entering the water: *Boat/Dive log* (Figure 3) and *datasheet* (Figure 4).

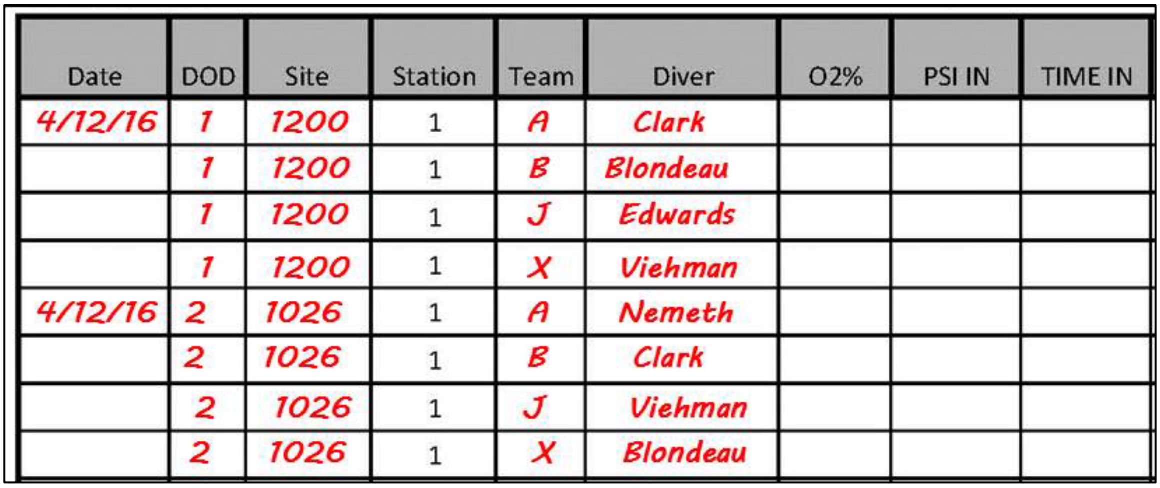
Boat Log

Key fields to record for station information include (Figure 3):

1. *Site* – The 4-digit station number.
2. *Station* – The location of each "team" of replicate fish divers at the station.
    a. All regions are now 1-stage and always '1'
3. *Team (Team member assignment)* – Letter code identifying the type of survey data being collected by the diver within their dive team.
    a. Fish (A/B) – A two-diver fish team consists of a Diver A and Diver B.
    b. Benthic (J/X) – The diver collecting Benthic Assessment data is assigned the code 'J'; the diver collecting Demographic data is assigned 'X'.

** Codes are assigned to diver positions within the team and type of data collected; therefore, diver team codes could change by station as divers potentially rotate**

4. *Comments* – After the survey is complete record coral disease with tissue loss at the site specifically for cases of Stone Coral Tissue Loss Disease..



Date	DOD	Site	Station	Team	Diver	O2%	PSI IN	TIME IN
4/12/16	1	1200	1	A	Clark			
	1	1200	1	B	Blondeau			
	1	1200	1	J	Edwards			
	1	1200	1	X	Viehman			
4/12/16	2	1026	1	A	Nemeth			
	2	1026	1	B	Clark			
	2	1026	1	J	Viehman			
	2	1026	1	X	Blondeau			

Figure 3. Example of boat log with specific station information filled out. DOD = Dive of the day.

<u>Example:</u> Figure 3 provides an example of a boat log and the specific station information to record at the dive site. The first dive of the day consisted of four divers, one fish team and one benthic team. The fish divers are Clark and Blondeau, identified by the A/B codes. For the first dive, Clark is team member A and Blondeau is team member B. For the second dive of the day, Nemeth is team member A and Clark is team member B as the divers rotated.

Datasheet

Divers should pre-populate station information, same as recorded on the boat log, on their datasheet prior to entering the water.

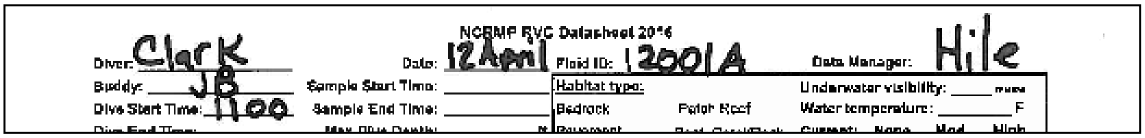
1. *Logistic and station information* – Names of all divers, Field ID, date, time of survey, mission data manager and meters completed (Figure 4; Supplemental III). Fill in all categories legibly.
    a. **Field ID** – The **Field ID** is a unique alpha-numeric number the diver is to record on the datasheet at each station.

FIELD ID = (**SITE #**) + (**STATION #**) + (**TEAM letter**)

<u>Example</u> (Figure 4): Diver Clark recorded the **Field ID** 12001A. According to the boat/dive log (Figure 3), Clark is diver A for site 1200 (and 1 used for all Caribbean fish surveys).

- Dive start time is the time divers leave the boat.

- The diver can enter visibility as they will need to determine visibility as they establish the cylinder.



NCRMP RVC Datasheet 2016

Diver: Clark
Date: 12April
Field ID: 12001A
Data Manager: Hile
Buddy: JB
Sample Start Time: ____________
Habitat type:
Underwater visibility: _____ m
Dive Start Time: 1100
Sample End Time: ____________
Bedrock
Patch Reef
Water temperature: _________ F

Figure 4. Example of pre-dive datasheet station entries prior to entering the water.

Fish counting/measuring

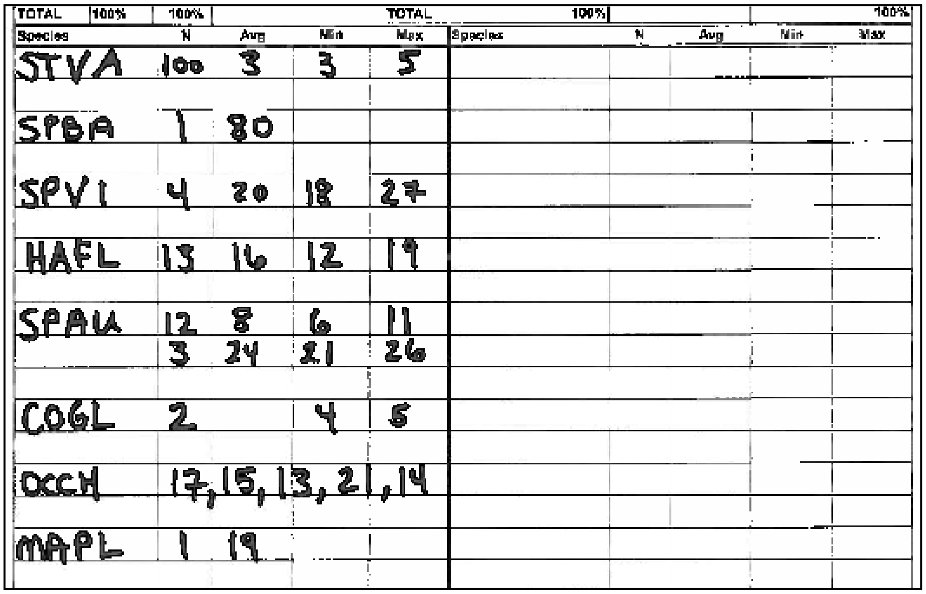
Once the cylinders have been established the team begins to identify fish.

1. Each diver will identify to the species level or lowest possible taxon and record on the datasheet, all fish that enter the cylinder for **5 minutes** (Figure 5). This includes the space above the cylinder (Supplemental I, Figure B).

2. Not all species loiter around the cylinder and let themselves be counted, therefore diver may record numbers and sizes of those fish that are most likely not going to be in the cylinder both during and after the 5 minute identification phase to assure they are recorded. Highly mobile species such as jacks, sharks or skittish species may zoom in and out of the cylinder while a diver is in the identifying phase of the survey.

3. After 5 minutes, the diver begins to work down the list of identified species on the datasheet and begins to estimate fork length size to the nearest 1 cm. For enumeration and size estimation for most species, one 360-degree rotation is typically made for each species (Figure 4).

   For example (Figure 5), fishes are measured by total number (N), average size (AVG), minimum size (Min) and maximum size (Max). For single fish, the number and size are listed. For two fish, the diver can list both sizes, either in the Min and Max columns, or if they are the same size, list the number twice.



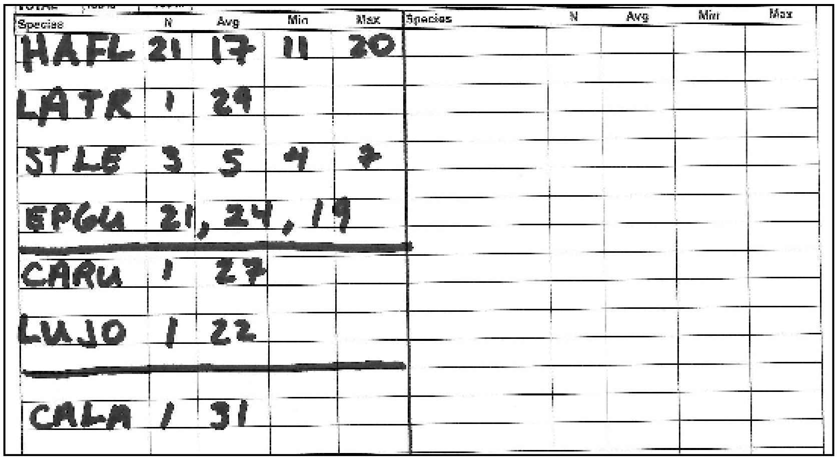
TOTAL 100% 100% TOTAL 100% 100%

Species	N	Avg	Min	Max	Species	N	Avg	Min	Max
STVA	100	3	3	5					
SPBA	1	80							
SPVI	4	20	18	27					
HAFL	13	16	12	19					
SPAU	12	8	6	11					
	3	24	21	26					
COGL	2		4	5					
OCCH	17,	15,	13, 21,	14					
MAPL	1	19							

Figure 5. Example of fish observations during RVC survey.

4. After the 5 minute identification phase, new species may be added as the diver is counting and measuring the species identified in the first 5 minutes.
   a. The diver should draw a line under the initial 5 minute list and add the fish below that line.
   b. The diver can add new species for 5 more minutes and draw another line under the second grouping of species.

c. If the fish survey is continuing into 15 minutes, new species can be added in a third grouping (Figure 6).



Species	N	Avg	Min	Max	Species	N	Avg	Min	Max
HAFL	21	17	11	20					
LATR	1	29							
STLE	3	5	4	7					
EPGU	21, 24, 19								
CARU	1	27							
LUJO	1	22							
CALA	1	31							

Figure 6. Example of adding new fish species after the 5 and 10 minute segments.

5. Some species, parrotfish in particular, have individuals that have bimodal size groups. If the diver is comfortable with estimating both groups individually then it is recommended that they do so.
    a. This provides a greater resolution of the community structure of these species. For example in Figure 5, the species code SPAU (*Sparisoma aurofrenatum*, redband parrotfish) commonly has groups of juveniles and adults intermixed.
    b. If the diver is not experienced or comfortable with this technique then one range of sizes is sufficient.

6. Important commercial and/or recreational species such as groupers and snappers should be individually sized up to a group total of 10 individuals (Table 1). If there are more than 10 in the group, the remainder should be estimated with minimum, maximum, and average sizes individually. These species are:

Table 1. List of commercial and/or recreational species for individual sizing.

Species Name	Common Name	Species Name	Common Name
Cephalopholis cruentata	graysby	*Lutjanus jocu*	dog snapper
Cephalopholis fulva	coney	*Lutjanus mahogoni*	mahogany snapper
Dermatolepis inermis	marbled grouper	*Lutjanus synagris*	lane snapper
Epinephelus adscensionis	rock hind	*Mycteroperca bonaci*	black grouper
Epinephelus guttatus	red hind	*Mycteroperca interstitialis*	yellowmouth grouper
Epinephelus morio	red grouper	*Mycteroperca tigris*	tiger grouper
Epinephelus striatus	Nassau grouper	*Mycteroperca venenosa*	yellowfin grouper
Lutjanus analis	mutton snapper	*Mycteroperca phenax*	scamp
Lutjanus apodus	schoolmaster	*Ocyurus chrysurus*	yellowtail snapper
Lutjanus buccanella	blackfin snapper	*Lachnolaimus maximus*	hogfish
Lutjanus cyanopterus	cubera snapper	*Pterois volitans*	red lionfish
Lutjanus griseus	gray snapper		

****The point count is over when all fish have been identified, counted and sized.****

Site/Benthic/Topographic assessment

Following the fish survey, site information is collected and recorded on the Fish/Habitat data sheet (Figure 7). The following variables are measured and recorded:

1. Habitat type: chosen from the following categories (circle **one** on the Fish/Habitat datasheet). 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. **NOTE: habitat types are different in the U.S. Caribbean, Flower Garden Banks, and Florida (Supplemental IV).**

2. Water temperature and currents: 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 the same position with a gentle kick), High (diver struggles to stay in the same position).

3. 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 (Supplemental V).

4. 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. These values should not be zero.

5. Surface Relief Coverage: for hard vertical relief (e.g., coral structure, coralline spur, rocky outcrop): the estimated percentages of hard/soft relief that fall into the following categories (all values in meters): < 0.2, 0.2-0.5, .05-1.0, 1.0-1.5, and >1.5. These values should sum to 100%.

6. Surface Relief Coverage for soft vertical relief (e.g., octocorals, sponges and algae): the category (< 0.2, 0.2-0.5, .05-1.0, 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.

7. Abiotic Footprint: the percentage of the cylinder comprised of sand, hardbottom and rubble. These percentages should sum to 100%.
    a. 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).
        i. Sand is considered the substratum when sediment depth is usually 2-3 cm in depth or greater.
        ii. It excludes a surface “dusting” of sediment particles overlying a consolidated substratum.
    b. Rubble ranges from coarse gravel (> 5 mm) to unconsolidated and moveable rocks (e.g. dislodged and moveable coral fragments). This category differs from consolidated hardbottom because of its loose and moveable nature.
    c. Consolidated hardbottom 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.

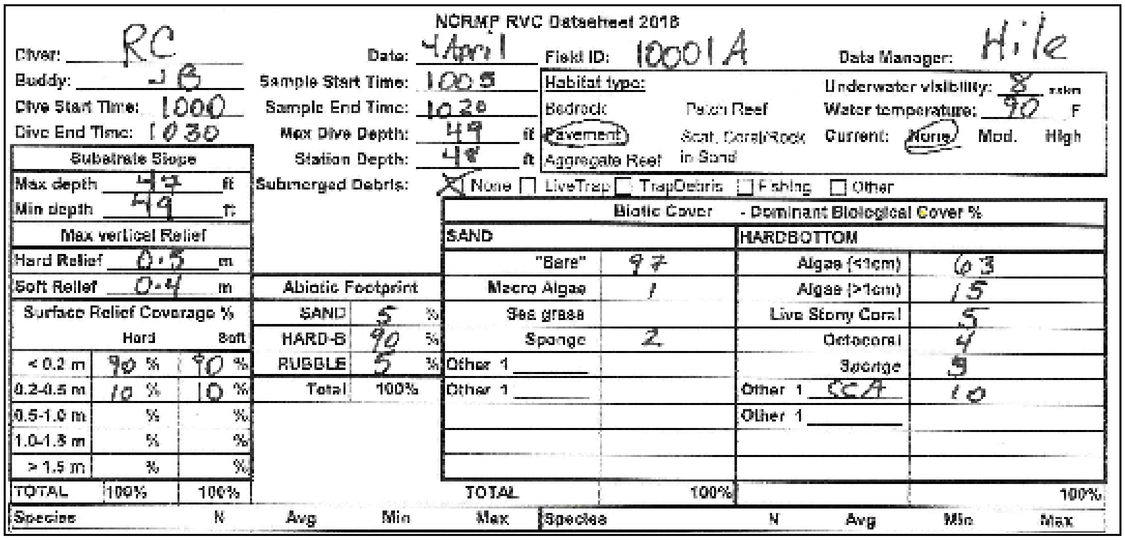
8. Biotic Cover
    a. SAND: the percentage of the sand substrate that corresponds to the following categories: bare, under/supporting growth of macroalgae, under/supporting growth of seagrass, under / supporting growth of sponges, and other. These values should sum to 100%. See preceding section for sand definition.
    b. 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 abundant benthic taxonomic groups. These values should sum to 100%.
9. Submerged Debris: indicate if live fishing traps, trap debris, fishing gear (line, etc) or other man-made debris.
10. Coral disease with Tissue Loss: in light of increasing concern for coral disease in Florida and the Caribbean, a field was added to all dive sheets to track evidence of recent mortality and associated coral tissue loss related to disease at the site level using the following selections in your header information.

Coral Disease with Tissue Loss: ☐ None ☐ Not sampled ☐ Fast (>1 cm) ☐ Slow (<1 cm)

Each diver is to note 1 of the 4 options with an ‘X’ in the appropriate box:

None - no disease with tissue loss is observed at the site
Not Sampled - diver was not able to observe
Fast (>1cm) - tissue loss due to disease is observed on at least 1 coral colony at the site and the maximum width of tissue loss is >1cm in width/diameter, therefore rate of disease spread is fast (acute).

Slow (<1cm) - tissue loss due to disease is observed on at least 1 coral colony at the site and the maximum width of tissue loss is <1cm in width/diameter, therefore rate of disease spread is slow (sub-acute).



NCRMP RVC Datasheet 2018

Diver: RC
Buddy: JB
Dive Start Time: 1000
Dive End Time: 1030
Date: 4 April
Sample Start Time: 1005
Sample End Time: 1020
Max Dive Depth: 49 ft
Station Depth: 48 ft
Field ID: 10001A
Data Manager: Hile

Habitat type: Bedrock [✓ Pavement] Aggregate Reef Patch Reef Scat. Coral/Rock in Sand
Underwater visibility: 8 [illegible]
Water temperature: 90 F
Current: [✓ None] Mod. High

Submerged Debris: ☒ None ☐ LiveTrap ☐ TrapDebris ☐ Fishing ☐ Other

Substrate Slope		
Max depth 47 ft		
Min depth 49 ft		
Max vertical Relief		
Hard Relief 0.5 m		
Soft Relief 0.4 m		
Surface Relief Coverage %	Hard	Soft
< 0.2 m	90 %	90 %
0.2-0.5 m	10 %	10 %
0.5-1.0 m	%	%
1.0-1.5 m	%	%
> 1.5 m	%	%
TOTAL	100%	100%

Abiotic Footprint	
SAND	5 %
HARD-B	90 %
RUBBLE	5 %
Total	100%

Biotic Cover - Dominant Biological Cover %

SAND		HARDBOTTOM	
"Bare"	97	Algae (<1cm)	63
Macro Algae	1	Algae (>1cm)	15
Sea grass		Live Stony Coral	5
Sponge	2	Octocoral	4
Other 1 ______		Sponge	3
Other 1 ______		Other 1 CCA	10
		Other 1 ______	
TOTAL	100%		100%

Species	N	Avg	Min	Max	Species	N	Avg	Min	Max

Figure 7. Example of site information, benthic cover and topographic information gathered during an RVC survey in the U.S. Caribbean (note the habitat types).

Site Photographs

Photos should include RVC survey area for general site characterization. Additional photos may include divers conducting surveys, unique features, and species for ID purposes. In Florida, one diver in each two diver buddy team will take pictures. In the U.S. Caribbean, benthic and fish teams often dive together and the benthic assessment diver will take pictures.

1. Station Documentation: at least five photographs per station
    a. Take one photograph of the station and logistic information at the top of the datasheet prior to taking any photographs of the site. The station name, date, time and heading information should be clear and legible in the photograph.
    b. Take four site photographs at the four cardinal compass headings (i.e. 0°, 90°, 180° and 270°).
    c. Additional photographs may be taken of anything unusual (*e.g.*, rare fish, bleached or rare corals), for species identification purposes, unique site features, and other divers.
2. For the process for downloading and storing site photographs, refer to the *Photo Documentation Manual*.

Field Equipment

- SCUBA gear
- Fish survey datasheet, clipboard, pencil (& backup pencil)
- All Purpose Tool (APT; Figure 1)
- Camera/housing

Data sheet review

At the end of the survey, when divers are on the boat, the dive team exchanges datasheets for review by checking for completeness and legibility. A diver cannot review his/her own datasheet.

1. *RVC fish datasheet* – Review includes, at a minimum, verifying the following:
    a. Completeness and legibility of all site information prior to dive.
    b. Completeness and legibility of all species, counts and size numbers.
    c. Completeness and legibility of Topographic Complexity records
    d. Completeness of submerged debris and coral disease with tissue loss. Record coral disease with tissue loss in the boat log.
    e. Discuss among team members and concur on habitat type
    f. Discuss any strange, unique, weird (first time you have ever seen it) type of species as this can help with species ID errors.

Supplemental I: Illustrations of survey placement and cylinders

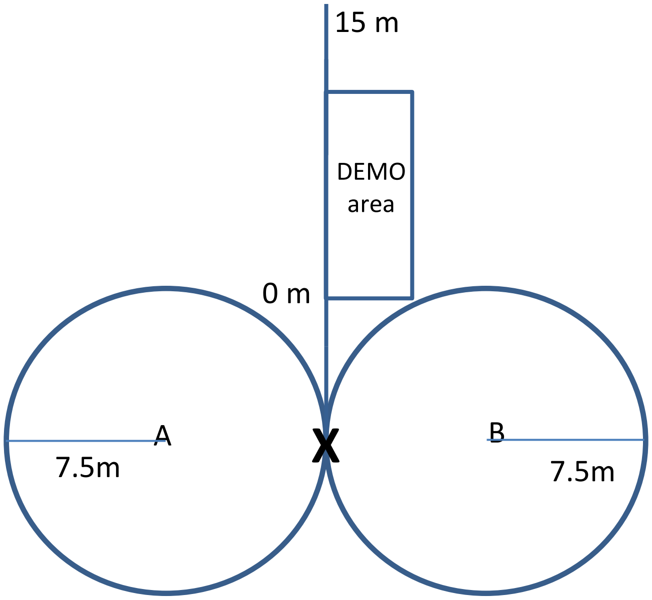


Figure A. Suggested placement of fish and benthic survey areas combined if continuous hardbottom. A and B represent two fish divers.

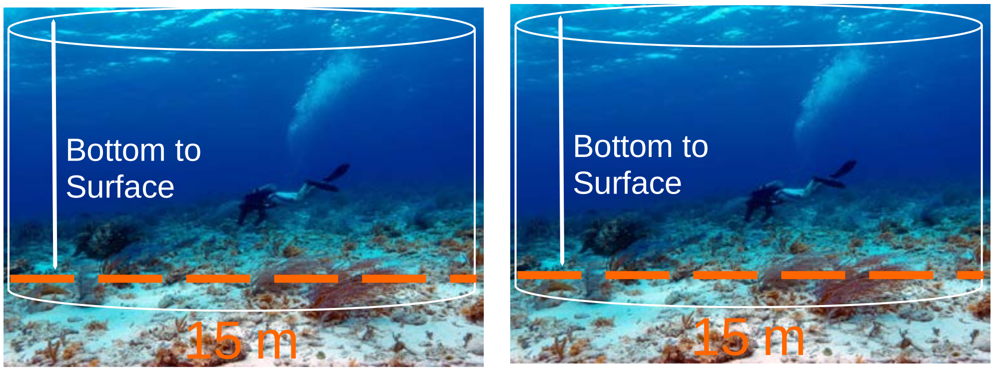


Figure B. Photos indicating optimal cylinder placement. The dive team's surface buoy will be tied to the bottom in between both cylinders. Benthic team may start transect in the vicinity of the fish team's surface buoy.

Supplemental II: Example of Boat Log

Date:

NCRMP

Divemaster:

Supervisor's Dive Log

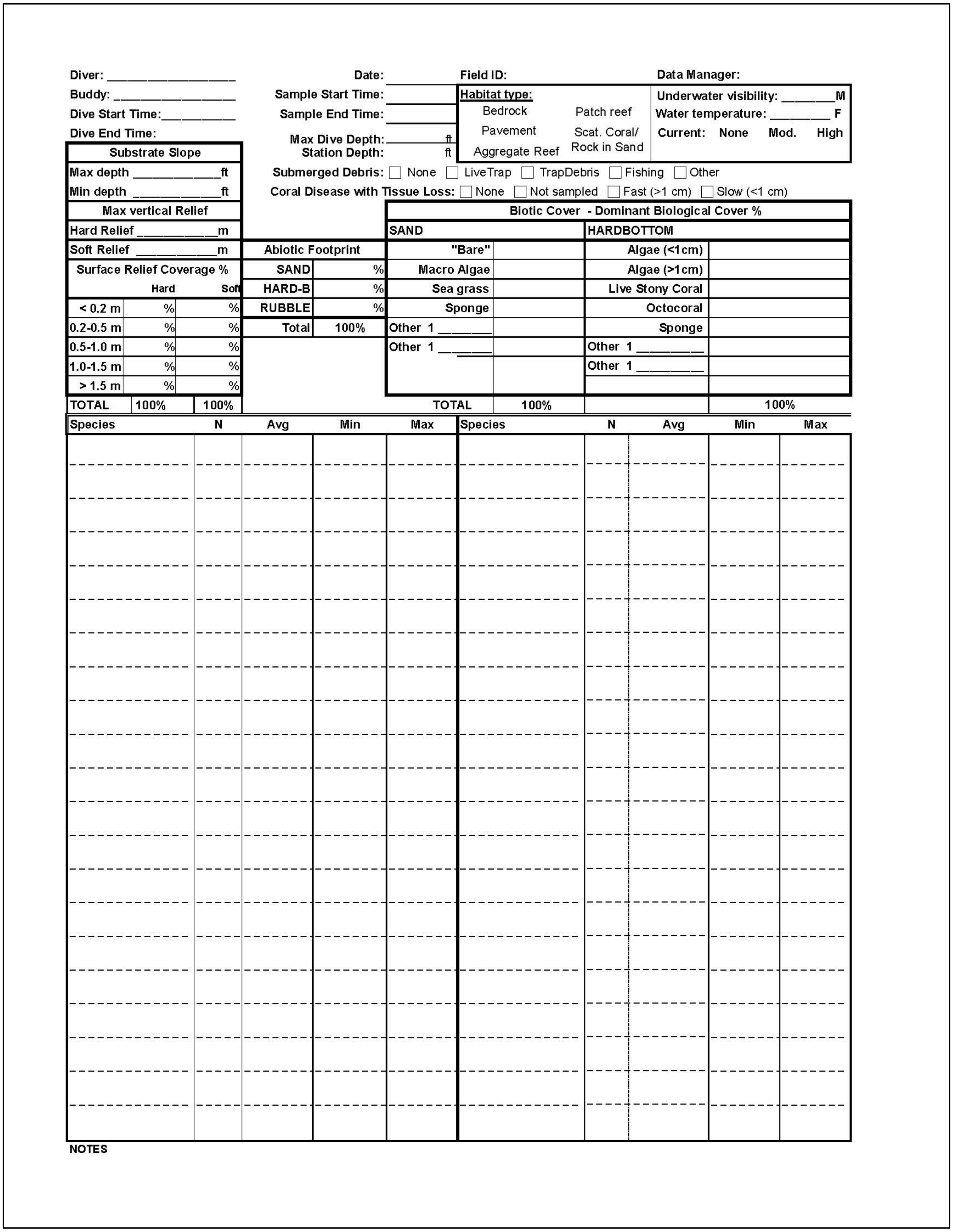
Page ______ of ______

										Actual Dive				
Date	DOD	Field ID	Station	Team	Diver	O2%	PSI IN	TIME IN	Flag #	Depth	BT	TIME OUT	PSI OUT	Comments

DOD= # dive of day

Supplemental III: RVC Datasheets

Example 1: 2020 RVC Datasheet for U.S. Caribbean



Diver: ___________________
Buddy: __________________
Dive Start Time:___________
Dive End Time:

Date:
Sample Start Time:
Sample End Time:
Max Dive Depth:_________ft
Station Depth: ft

Field ID:
Habitat type:
Bedrock
Patch reef
Pavement
Scat. Coral/ Rock in Sand
Aggregate Reef

Data Manager:
Underwater visibility: ________M
Water temperature: _________ F
Current: None Mod. High

Submerged Debris: ☐ None ☐ LiveTrap ☐ TrapDebris ☐ Fishing ☐ Other
Coral Disease with Tissue Loss: ☐ None ☐ Not sampled ☐ Fast (>1 cm) ☐ Slow (<1 cm)

Substrate Slope
Max depth ____________ft
Min depth _____________ft

Max vertical Relief
Hard Relief ____________m
Soft Relief ____________m

Surface Relief Coverage %		
	Hard	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%

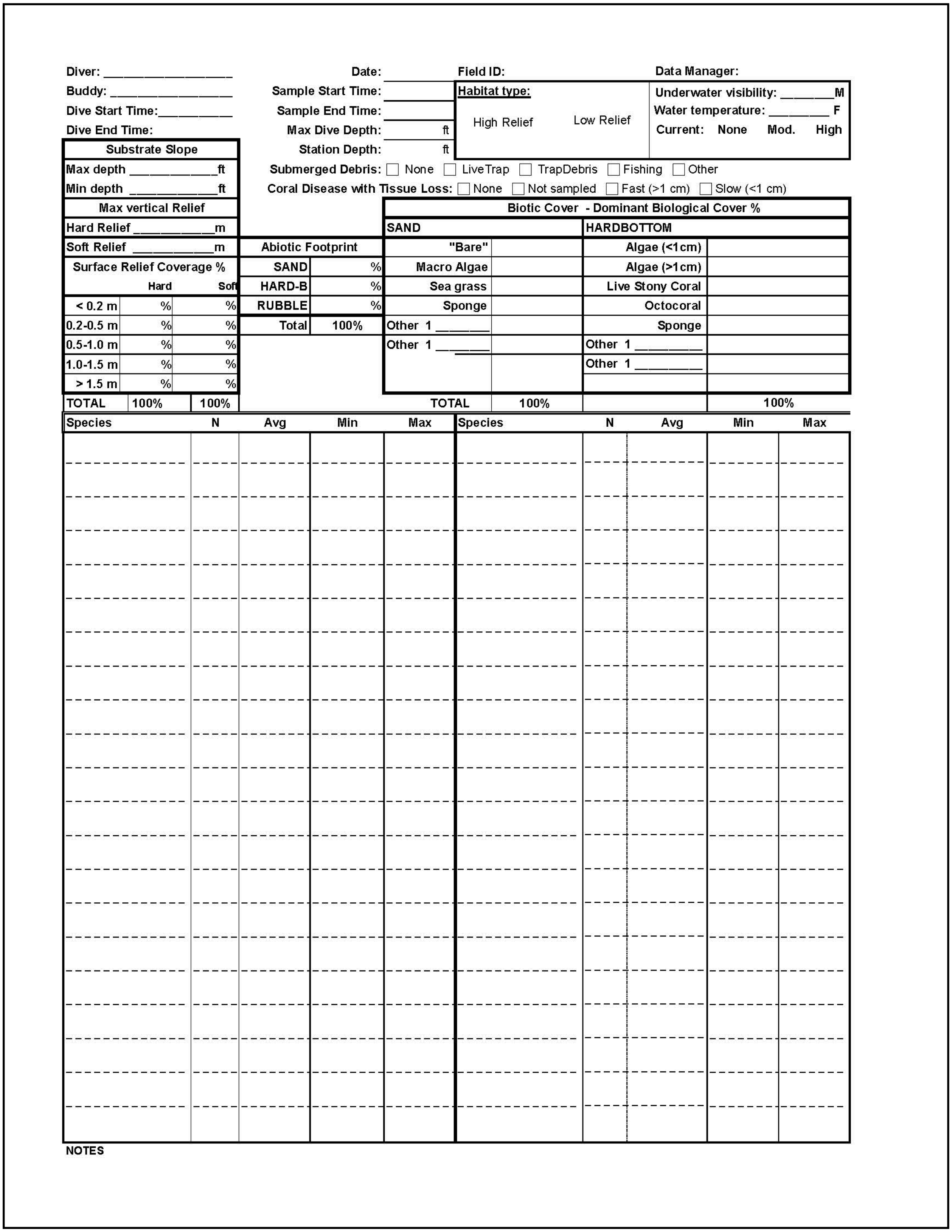
Biotic Cover - Dominant Biological Cover %			
SAND		HARDBOTTOM	
"Bare"		Algae (<1cm)	
Macro Algae		Algae (>1cm)	
Sea grass		Live Stony Coral	
Sponge		Octocoral	
Other 1 _______		Sponge	
Other 1 _______		Other 1 _________	
		Other 1 _________	
TOTAL	100%		100%

Species	N	Avg	Min	Max	Species	N	Avg	Min	Max

NOTES

Supplemental III.

Example 2: 2020 RVC Datasheet for the FGBNMS



Diver: ____________________
Buddy: ____________________
Dive Start Time:___________
Dive End Time:

Date:
Sample Start Time:
Sample End Time:
Max Dive Depth: ft
Station Depth: ft

Field ID:
Habitat type:
High Relief Low Relief

Data Manager:
Underwater visibility: ________M
Water temperature: _________ F
Current: None Mod. High

Submerged Debris: ☐ None ☐ LiveTrap ☐ TrapDebris ☐ Fishing ☐ Other
Coral Disease with Tissue Loss: ☐ None ☐ Not sampled ☐ Fast (>1 cm) ☐ Slow (<1 cm)

Substrate Slope		
Max depth _____________ft		
Min depth _____________ft		
Max vertical Relief		
Hard Relief ____________m		
Soft Relief ____________m		
Surface Relief Coverage %		
	Hard	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%

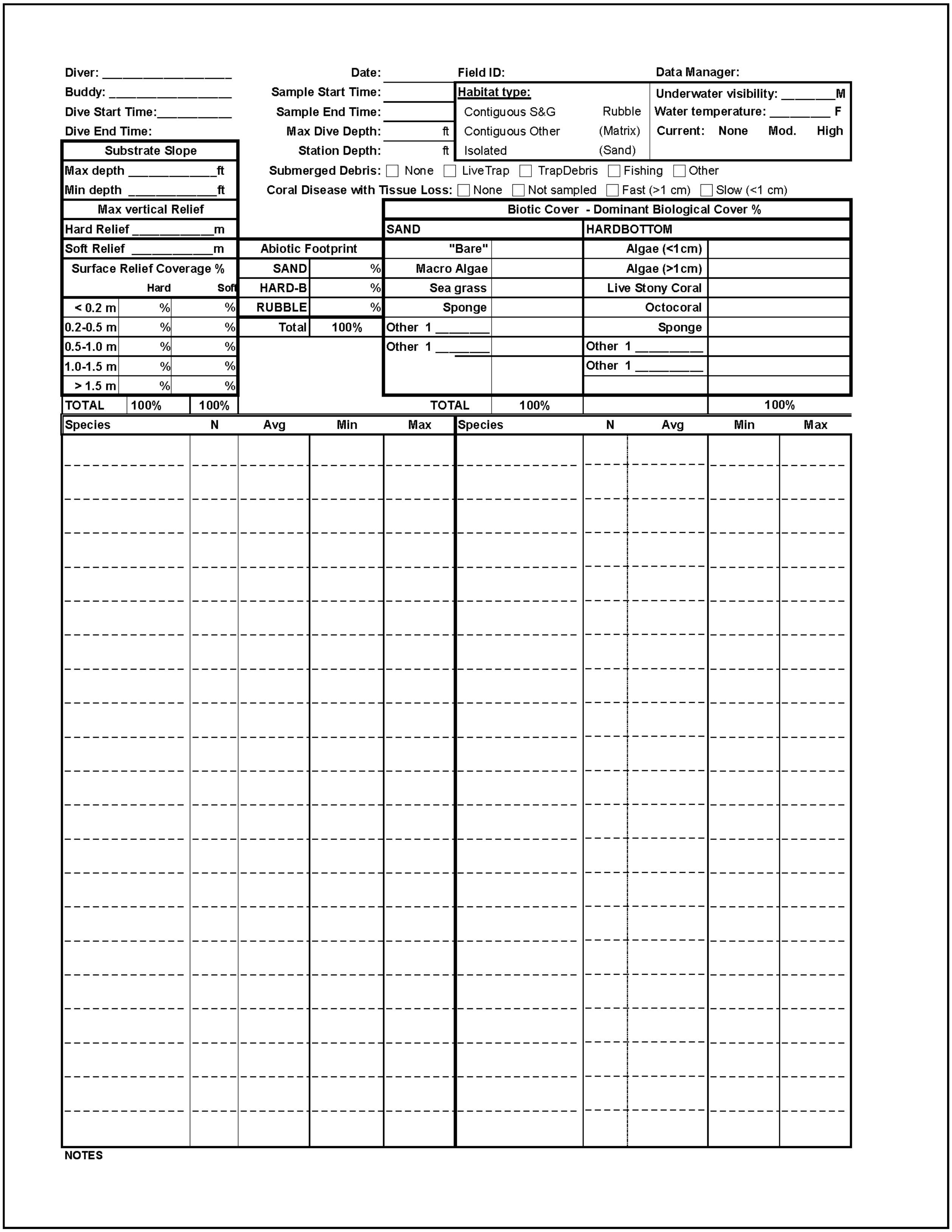
Biotic Cover - Dominant Biological Cover %			
SAND		HARDBOTTOM	
"Bare"		Algae (<1cm)	
Macro Algae		Algae (>1cm)	
Sea grass		Live Stony Coral	
Sponge		Octocoral	
Other 1 _______		Sponge	
Other 1 _______		Other 1 _________	
		Other 1 _________	
TOTAL	100%		100%

Species	N	Avg	Min	Max	Species	N	Avg	Min	Max

NOTES

Supplemental III.

Example 3: 2020 RVC Datasheet for Florida and the Dry Tortugas



Diver: ___________________
Buddy: __________________
Dive Start Time:___________
Dive End Time:

Date:
Sample Start Time:
Sample End Time:
Max Dive Depth: ft
Station Depth: ft

Field ID:

Data Manager:

Habitat type:	
Contiguous S&G	Rubble
Contiguous Other	(Matrix)
Isolated	(Sand)

Underwater visibility: ________M
Water temperature: _________ F
Current: None Mod. High

Submerged Debris: ☐ None ☐ LiveTrap ☐ TrapDebris ☐ Fishing ☐ Other
Coral Disease with Tissue Loss: ☐ None ☐ Not sampled ☐ Fast (>1 cm) ☐ Slow (<1 cm)

Substrate Slope
Max depth _____________ft
Min depth _____________ft
Max vertical Relief
Hard Relief ____________m
Soft Relief ____________m

Surface Relief Coverage %		
	Hard	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"		Algae (<1cm)	
Macro Algae		Algae (>1cm)	
Sea grass		Live Stony Coral	
Sponge		Octocoral	
Other 1 _______		Sponge	
Other 1 _______		Other 1 _________	
		Other 1 _________	
TOTAL	100%		100%

Species	N	Avg	Min	Max	Species	N	Avg	Min	Max

NOTES

Supplemental IV. Habitat Types

U.S. Caribbean habitat types[1]

Aggregate reef: Continuous, high-relief coral formation of variable shapes. Examples of aggregate reefs include fore reef, fringing reef, shelf edge reef, spur and groove reef)

Bedrock: Exposed bedrock contiguous with the shoreline. May be colonized or uncolonized (often covered by a thin sand veneer with sparse coverage of biota).

Patch reef: Coral formations that are isolated from other coral reef formations by sand, seagrass or other habitats. Can be an individual patch reef or aggregate patch reefs.

Pavement: Flat, low-relief, solid carbonate rock. May be colonized or uncolonized (often covered by a thin sand veneer with sparse coverage of biota).

Scattered coral/rock in sand: 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).

Gulf of Mexico (Flower Garden Banks National Marine Sanctuary) habitat types

High relief: The coral reef zone that typically consists of rugose boulder or reef building coral species.

Low relief: The coral reef zone that refers to the deeper (generally between 30-52 m), less rugose and non-reef building species.

Florida and the Dry Tortugas: four main habitat types[2]

Contiguous Spur & Groove: A continuing reef structure with well-defined spur (hardbottom) and groove (sand channel) formations. Can be low or high relief spur and groove.

Contiguous Other: Contiguous low relief hardbottom.

Isolated: Larger reef formations that are isolated by sand, seagrass or other habitats; e.g., patch reefs, rocky outcrops, pinnacles.

Rubble: Scattered rocks and small isolated coral heads in sand or seagrass.

**Matrix and Sand are considered legacy categories and will no longer be used.*

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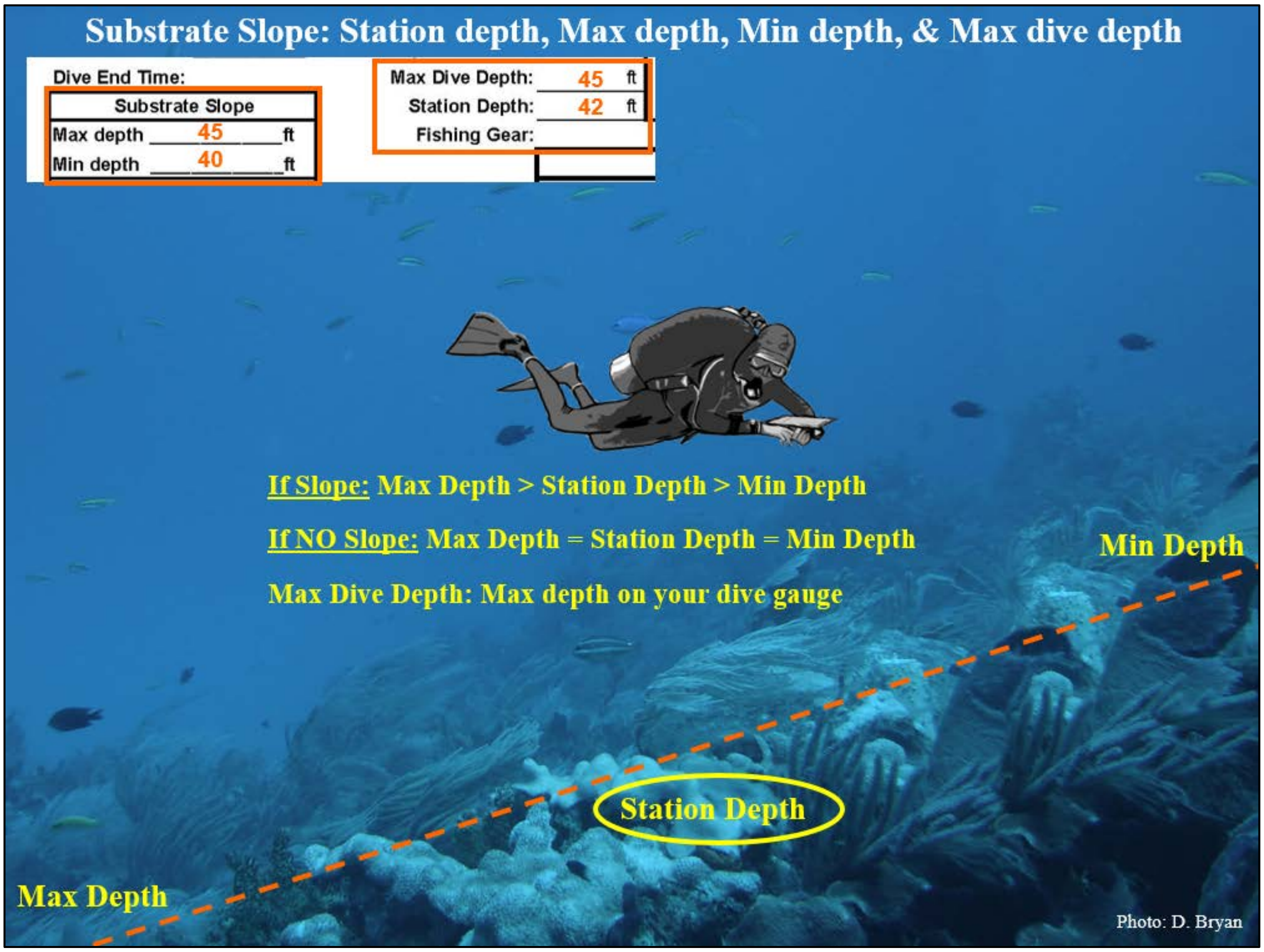
[1] Adapted from:
Kendall, M.S., C.R. Kruer, K.R. Buja, J.D. Christensen, M. Finkbeiner, R.A. Warner, and M.E. Monaco. 2001. Methods Used to Map the Benthic Habitats of Puerto Rico and the U.S. Virgin Islands. NOAA Technical Memorandum NOS NCCOS CCMA 152. Silver Spring, MD. 46 pp.

[2] Adapted from:
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

Supplemental IV. Slope and depth illustrations

Illustration of substrate slope and depth measurements.



Substrate Slope: Station depth, Max depth, Min depth, & Max dive depth

Dive End Time:

Substrate Slope

Max depth 45 ft

Min depth 40 ft

Max Dive Depth: 45 ft

Station Depth: 42 ft

Fishing Gear:

If Slope: Max Depth > Station Depth > Min Depth

If NO Slope: Max Depth = Station Depth = Min Depth

Max Dive Depth: Max depth on your dive gauge

Photo: D. Bryan

Appendix 4

Computational formulae for single-stage stratified random sampling design used for reef-fish visual surveys.

Symbol	Definition	Computational Formula
h	Stratum subscript	
i	Diver sample unit subscript	Grid cell
k	Substratum subscript	
a_{hik}	Area of the *i*th diver unit in substratum k in stratum *h*	Grid cell size = $50\ m\ x\ 50\ m$
a_{hi}	Area of the *i*th diver unit in stratum *h*	
A_{hk}	Area of substratum *k* in stratum *h*	$A_{hk} = \sum_{i=1}^{N_{hk}} a_{hik}$
A_h	Area of stratum *h*	$A_h = \sum_{i=1}^{N_h} a_{hi}$
A	Area of entire survey domain	$A = \sum_h A_h$
n_{hk}	Number of sampled diver units *i* in substratum *k* in stratum *h*	
n_h	Number of sampled diver units *i* in stratum *h*	
N_{hk}	Total possible number of diver units in substratum *k* in stratum *h*	Total number of grid cells
N_h	Total possible number of diver units in stratum *h*	Total number of grid cells
w_{hk}	Substratum *k* weighting factor	$w_{hk} = \frac{N_{hk}}{\sum_{hk} N_{hk}}$
w_h	Stratum *h* weighting factor	$w_h = \frac{N_h}{\sum_h N_h}$
$\bar{D}_{hk}$	Mean density in substratum *k*	$\bar{D}_{hk} = \frac{1}{n_{hk}} \sum_i D_{hik}$

$\overline{D}_h$	Mean density in stratum h	$\overline{D}_h = \frac{1}{n_h}\sum_i D_{hi}$
s_{hk}^2	Sample variance among diver units i in substratum k in stratum h	$s_{hk}^2 = \frac{\sum_i (D_{hik} - \overline{D}_{hk})^{2}}{n_{hk} - 1}$
s_h^2	Sample variance among diver units i in stratum h	$s_h^2 = \frac{\sum_i (D_{hi} - \overline{D}_h)^{2}}{n_h - 1}$
$var[\overline{D}_{hk}]$	Variance of mean density substratum k in stratum h	$var[\overline{D}_{hk}] = \left(1 - \frac{n_{hk}}{N_{hk}}\right)\frac{s_{hk}^2}{n_{hk}}$
$var[\overline{D}_h]$	Variance of mean density in stratum h	$var[\overline{D}_h] = \left(1 - \frac{n_h}{N_h}\right)\frac{s_h^2}{n_h}$
$\overline{D}_{st}$	Domain-wide mean density for a stratified random survey	$\overline{D}_{st} = \sum_h w_h\, \overline{D}_h$
$var[\overline{D}_{st}]$	Variance of domain-wide mean density	$var[\overline{D}_{st}] = \sum_h w_h^2\, var[\overline{D}_h]$
$SE[\overline{D}_{st}]$	Standard error of domain-wide mean density	$SE[\overline{D}_{st}]\sqrt{var[\overline{D}_{st}]}$
$CV[\overline{D}_{st}]$	Coefficient of variation (CV) of domain-side mean density	$CV[\overline{D}_{st}] = \frac{SE[\overline{D}_{st}]}{\overline{D}_{st}}$
n^*	Number of diver unit samples required to achieve a specified variance	$n^* = \frac{(\sum_h w_h s_h)^2}{V(\overline{D}_{st}) + \frac{1}{N}\sum_h w_h s_h^2}$
$V[\overline{D}_{st}]$	Desired variance of domain-wide mean density using a target CV of domain-wide mean density	$V[\overline{D}_{st}] = (CV[\overline{D}_{st}] \cdot \overline{D}_{st})^2$
	Proportional allocation	$n_h = n \cdot w_h$
	Neyman or optimal allocation	$n_h = n\left(\frac{w_h s_h}{\sum_h w_h s_h}\right)$