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EXECUTIVE SUMMARY

Currently, US Caribbean stock assessments use data-limited approaches to determine stock status and sustainability benchmarks, and are reliant on fisheries-dependent data sources. Data obtained from fishery-independent surveys are preferable because they provide an unbiased estimate of abundance with which to calibrate stock assessments. Therefore, it is advantageous to develop statistically rigorous fishery-independent surveys to complement, and ultimately reduce dependence on fisheries-dependent data.

An initial step in developing fishery-independent surveys is to better understand the extent of existing programs in the US Caribbean, and their utility for stock assessment. To that end, the group endeavored to: identify existing fishery-independent data sources, fully document each data source and evaluate its utility for stock assessment. The group also made recommendations for improvement.

Following a comprehensive review of the existing fishery-independent survey programs in the US Caribbean and adjacent waters (**Sections 2 and 4**), the group acknowledged the diversity of sampling programs, statistical designs and objectives. The majority of the research presented at this workshop encompassed smaller scale biological/ecological research, which was conducted for a variety of objectives not directly related to stock assessment. Although many studies provided important information about abundance, density, and size structure for particular species in localized areas, they were not generally scalable to the larger population. This limited their utility for stock assessment.

To better support US Caribbean stock assessments, it is essential to improve the data collection activities by developing comprehensive new surveys and/or improving the temporal and spatial scales of existing efforts. To that end, the group evaluated the utility, cost and feasibility of expanding existing sampling efforts in the US Caribbean, and made recommendations for the prioritization of future survey efforts for several managed taxa (**Section 3**). The group also made a number of "Best Practice" recommendations for the development of new surveys and/or adaptation of existing surveys in the US Caribbean. They include:

1. Identify species of interest in the US Caribbean to allow optimization of survey design.
2. Consult experts in survey design, statistics and stock assessment prior to modifications/expansion/development of surveys.
3. Use similar methods across platforms to ensure adequate spatial coverage.
4. When using different gears, overlap spatially and temporally to allow calibration of methods.
5. Use cooperative research programs when feasible (i.e., include fishing community).
6. Develop/Enhance capacity to process and analyze age, reproductive information etc.
7. Conduct a regional workshop to identify gaps in stock demographic data.
8. Focus on filling spatial gaps to achieve a "representative fraction of the populations"
9. Enhance data mining and recovery – scour and capture as much regional data as possible (including spatial data/GIS) to aid in refining survey design and optimization.
10. Expand habitat mapping, including high resolution bathymetry.
11. Collect information to facilitate EBFM and next-generation stock assessment.

Table of Contents

ACRONYMS

ABC: Acceptable Biological Catch
ACL: Annual Catch Limit
ALS: Abrir la Sierra, Puerto Rico
ARBIMON: Automated Remote Biodiversity Monitoring Network
ArcGIS: Geographic Information Software (ESRI ©)
AST: Atlantic Standard Time
BDS: Bajo de Sico, Puerto Rico
CCMA: NOS NCCOS - Center for Coastal Monitoring and Assessment
CCR: Closed Circuit Re-breather
CCRI: University of Puerto Rico - Caribbean Coral Reef Institute
CFMC: Caribbean Fisheries Management Council
CPUE: Catch per Unit Effort
CRCP: NOAA's Coral Reef Conservation Program
CSCOR: NOS Center for Sponsored Coastal Research
CV: Coefficient of Variation
DABSE III PLUS: A Software for Statistics and Data Management
DNER: Puerto Rico Department of Natural and Environmental Resources
EBFM: Ecosystem Based Fishery Management
EEZ: Exclusive Economic Zone
EFH: Essential Fish Habitat
ESA: Endangered Species Act
FGBNMS: Flower Garden Bank National Marine Sanctuary
FRL: Fisheries Research Laboratory
FSA: Fish Spawning Aggregation
GB: Grammanik Bank, St. Thomas, USVI
GDS: Gonadal Development Stages
GLMMIX: Generalized Linear Mixed Model
GPS: Global Positioning System
GSI: Gonadosomatic Index
ID: Generally "Identifier"
L50: Length at 50% Maturity
MARMAP: Marine Resources Monitoring, Assessment, and Prediction
MATLAB: A software package for statistics, mathematics and data visualization.
MCE: Mesophotic Coral Ecosystem
MOCNESS: Multiple Opening-Closing Net Environmental Sensing System
MPA: Marine Protected Area
MSY: Maximum Sustainable Yield
NCCOS: NOS National Centers for Coastal and Ocean Science
NCRMP: CRCP's National Coral Reef Monitoring Program
NMA: Newly Mature Adult
NMFS: NOAA National Marine Fisheries Service
NOAA: National Oceanographic and Atmospheric Administration
NOS: National Ocean Service
NPS: National Park Service

OA: Old Adult
OFL: Overfishing Limit
ONMS: NOS Office of National Marine Sanctuaries
PAM: Passive Acoustic Monitoring
PRDNER: Puerto Rico Department of Natural and Environmental Resources
PSU: Primary Sample Units
PVC: Poly-vinyl Chloride
RVC: Reef Visual Census (stationary point count methodology)
SAS: A Software for Statistics and Data Management
SCUBA: Self-contained Underwater Breathing Apparatus
SDHC: Secure Digital High Capacity
SEAMAP: Southeast Area Monitoring and Assessment Program
SEAMAP-C: Southeast Area Monitoring and Assessment Program – US Caribbean
SEDAR: Southeast Data, Assessment and Review
SEFIS: SouthEast Fishery-Independent Survey
SEFSC: NOAA Fisheries Service Southeast Fisheries Science Center
SERO: NOAA Fisheries Service Southeast Regional Office
SPC: Stationary Point Count
SSB: Spawning Stock Biomass
SSU: Second-Stage Units
TCREMP: Territorial Coral Reef Monitoring Program
TOUR: Tourmaline Reef, USVI
UM-RSMAS: University of Miami Rosenstiel School of Marine Science
UPR: University of Puerto Rico
USVI: United States Virgin Islands
VOA: Very Old Adult

1. WORKSHOP JUSTIFICATION

Currently in the US Caribbean, stock assessments and fisheries management are reliant on data poor methodologies to determine stock status and sustainability benchmarks. The data poor methods that have been used to date (i.e., mean length estimators and the Only Reliable Catch (ORCs) approach) have been reliant on fisheries-dependent data sources. These fishery-dependent data sources include length samples of landed fish and reported landings. The reliability of these data has been questioned during several stock assessments run through the Southeast Data Assessment and Review (SEDAR) process in recent years. The recognized uncertainty in these data has led to initiatives to improve the quality of fishery-dependent data (e.g., US Caribbean Commercial Data Improvement Project and Marine Recreational Information Program). Also recognized through the assessment process is the advantage of developing statistically rigorous fishery-independent surveys to complement and potentially reduce our reliance on fisheries-dependent data, at least for some species.

An initial and important step in developing fishery-independent surveys is to understand the extent of existing programs and their utility to stock assessment and fisheries management. Dr. Ron Hill from the SEFSC's Galveston Laboratory initiated this process and assembled and summarized the available fishery-independent survey data for the US Caribbean from 1950 to the present. The utility of these series for stock assessment has not been formally evaluated. The workshop efforts presented in this report are an extension of the work Dr. Hill et al. (e.g. http://sedarweb.org/docs/sar/CaribData_Final_0.pdf) and have stemmed from the need to obtain a better and more comprehensive understanding of the existing fishery-independent surveys that are being conducted in the US Caribbean. To that end, the objectives of this workshop were as follows:

1) Identify fishery-independent data sources in the US Caribbean;
2) Document the data source (e.g., Point of Contact, purpose of sampling, sampling methodology, species encountered and encounter frequency, relevant metadata);
3) Evaluate utility for stock assessment and make recommendations;
4) Build collaborations.

Data obtained from fishery-independent surveys play an important role in stock assessments when they are available. They are typically used to provide an unbiased estimate of abundance with which to calibrate stock assessments. Information regarding life history and size/age structure may also be collected. Key features of fishery-independent surveys include: 1) fishery-independent surveys do not rely on perceived areas of high density or catch rates, thereby minimizing non-random sampling, 2) ideally fishery-independent surveys are designed to address clearly defined objectives and are based on a random or stratified random experimental design or a model based design, 3) the sampling domain is representative of the population of interest as defined by the stock assessment, and 4) the survey is designed to detect changes over time within a specified margin of error (e.g., designed to ensure the CV meets an *a priori* threshold).

A crucial component of fishery-independent surveys, which differs from smaller scale, fishery-independent biological/ecological research, is that the sampling domain of the survey should be representative of the population being assessed. For example, in the US Caribbean, stock assessments are conducted on an island-platform basis. Therefore, the fishery-independent surveys used in these stock assessments would ideally be island-wide surveys that cover the juvenile, adult, or both components of the population.

The majority of the research presented at this workshop encompassed smaller scale biological/ecological research, which was conducted for a variety of objectives not directly related to stock assessment. Although many studies provided important information about abundance, density, and size structure for particular species in localized areas, they were not generally scalable to the larger population. This limited their utility for stock assessment. One survey, the NCRMP visual survey, had recently initiated island-wide surveys, which will make these data valuable for stock assessments of species primarily found in shallow waters (e.g. < 100 feet). Similar expansion in time and space could enhance the utility of other surveys for stock assessment, particular if clear objectives are defined, and the sampling designs are optimized and evaluated (e.g. power analyses). To facilitate that effort, the working group's conclusions and recommendations can be found in **Section 3** of this report.

2. WORKSHOP PRESENTATIONS AND DISCUSSIONS

2.1 Introductions and terms of reference

The US Caribbean Fishery-Independent Survey Workshop (Funding source MARFIN 2013) was held September 16-18, 2014 at the Southeast Fisheries Science Center (SEFSC) in Miami, Florida. Following a welcome and introduction by Dr. Theo Brainerd, the SEFSC Deputy Director, the workshop co-conveners Shannon Cass-Calay, Bill Arnold, Meaghan Bryan and Jennifer Schull greeted the group, discussed meeting logistics, and provided an overview of the workshop agenda (**Appendix 1**) and objectives.

The list of participants is included as **Appendix 2**. The following individuals shared rapporteur duty during the workshop: Dr. Arnold, Dr. Bryan, Dr. Mandy Karnauskas, Adyan Rios, Jennifer Schull, and Dr. Cass-Calay. Materials from the meeting, including the agenda, participant list, survey summaries and presentations are available here: http://sero.nmfs.noaa.gov/sustainable_fisheries/caribbean/fish_indep_wkshp/index.html.

Dr. Cass-Calay provided a brief introduction to the data requirements of stock assessments, the characteristics of "idealized" fishery-independent data and the relative challenges of fishery-dependent data. An ideal fishery-independent data source is characterized by a long time series covering most or all of a species' range and employing a constant methodology (or at least understanding changes in methodology). Another important aspect of an ideal fishery-independent index is that the data are collected using a statistically robust design. Fishery dependent data is affected by technological advances, regulatory changes, changes in fishing behavior etc.

2.2 Overview of Available Models and Data Requirements

An overview and discussion of model and data requirements for fisheries stock assessment was provided by Dr. Meaghan Bryan. The goal of this presentation was to highlight the differences between data poor and data rich stock assessment. Data poor/data limited models are typified by a lack of sufficient information to use in traditional stock assessment. Data poor stock situations generally lack catch and effort data, indices of abundance, age composition data, and the data often suffer from temporal and spatial constraints. In contrast, data rich models generally rely on various data sources including catch and effort data, length and age composition data, and fishery-independent indices. Data rich assessment models also provide for outcomes (e.g., abundance estimates, stock status determination, and fisheries reference points) within the traditional stock assessment context.

A table of models and their data requirements (**Table 2.2.1**) was the focal point of the presentation and following discussion. All stocks in the US Caribbean are considered data-poor and in US Caribbean waters we presently use a mean length estimation approach because it requires minimal data and is suitable for use even when only fishery-dependent data are available. Outcomes from the mean length estimation approach include advice about overfishing status. However, estimates of management quantities (e.g., Overfishing Limit (OFL), Acceptable Biological Catch (ABC), Annual Catch Limit (ACL), and Maximum Sustainable Yield (MSY)) are not produced, nor is the fishing mortality at MSY generated. The assessment challenges in the US Caribbean were reviewed. These include deficiencies with landings data (e.g., expansion factors), recent changes in US Virgin Islands reporting forms, fisher selectivity (e.g., plate size fish), a reduction in biological sampling, and the lack of well determined life history parameters. To improve the utility of assessments in the US Caribbean, Dr. Bryan suggested that, in the short-term, continued and expanded collection of length frequency data and the collection of life history information are needed. Additional long-term improvements include the movement towards adoption of traditional stock assessment approaches by improving data and validating territorial landings.

Table 2.2.1 Examples of stock assessment models and their data requirements**.**

INCREASING COMPLEXITY AND INFORMATION REQUIREMENTS

MODELS				
Data Requirements	Mean Length Estimator	Depletion Corrected Average Catch (DCAC)	Surplus Production Model	Integrated Stock Assessment Model (Length or Age Based)
Annual Length Data	X			X
Age-Length Relationship	X			X
Natural Mortality	X	X		X
Species Specific Catch		X	X	X
Catch-at-Age				X
Effort			X	X
Depletion		X		
Age/Length Composition				X
Discards			X	X

The discussion following the presentation started off with acknowledging the limitations of the current stock assessment method used in the US Caribbean. Namely, fishers from the USVI have indicated that due to market demands they target and keep plate-sized fish. Discard information is not reported or collected, therefore there is appreciable uncertainty about the selectivity pattern of the USVI reef fish fishery. This anecdotal information also suggests that selectivity is dome-shaped, which violates the assumption of knife-edge selectivity of the mean length estimator. The workshop participants recognized that our understanding of fishery-dependent selectivity patterns is poor in the US Caribbean and that is a limitation to stock assessment.

Given that the workshop's main focus was on fishery-independent surveys the discussion quickly segued into one that broadly considered the selectivity of fishery-independent surveys and how the methods used and experimental design behind a survey can also influence selectivity patterns. In general, it was recognized that although each fishery-independent survey will have a particular selectivity pattern, overlapping and calibrated surveys could be conducted to ensure broad coverage of the full length/age range of a species.

Another important topic during the introductory session focused on how the discussions throughout the workshop should proceed. The workshop participants upon arrival recognized that the presently available fishery-independent data are not adequate for stock assessment. Until this workshop, data gaps have been challenging to quantify and articulate; requests were made for this topic to be discussed throughout the workshop and in the fishery-independent workshop report, as it is essential to provide guidance for obtaining financial resources. To that end, workshop participants wanted to frame the discussions to address the following questions: which sampling efforts are most cost effective in the Caribbean, and what are the most important data gaps to address? The answers are not straightforward given that the main goals of each program may or may not be to address stock assessment issues. NOAA's Coral Reef Conservation Program (CRCP) is willing to move towards collecting data that could be relevant for stock assessment, although it was emphasized that the coral program may not achieve that goal in its entirety since stock assessment is not the CRCP's primary focus or goal, and sampling is limited in both depth and habitat.

2.3 Review of Catalog of Fishery-Independent Surveys in the US Caribbean

An overview of a project cataloging known fishery-independent surveys in the US Caribbean was presented by Dr. Ron Hill from the SEFSC. His presentation provided an historical perspective on work conducted in the region. Dr. Hill provided an overview of fishery-independent sampling activities and research both historic and present in the US Caribbean as well as information presented at a 2009 Southeast Data Assessment and Review (SEDAR) data evaluation workshop. Some of the surveys described included the Southeast Area Monitoring and Assessment Program - Caribbean (SEAMAP-C) from both Puerto Rico and the US Virgin Islands, larval and post-larval surveys, reef fish surveys, benthic surveys, and invertebrate surveys (lobster and conch). These surveys were conducted by a variety of entities including Federal Agencies, NGOs, States and Territories and academic partners.

The presentation led to a discussion about the diversity of different surveys in the region, and how essential it is to have a strong survey design, and good geographic and temporal coverage. Methodologies were discussed that might allow different sources of related data to be "sewn together", but the general feeling was that the utility of the results would be limited. However, having historical data for context for modern surveys would likely be of great utility for resource management and also for refining modern survey design. Thus, obtaining historic data may be a useful activity, assuming it could be acquired.

The workshop organizers reminded the attendees that 19 surveys would be discussed during this workshop, but there were likely surveys or data sources that have been missed. Given time and cost constraints, the conveners had to prioritize. The attendees were encouraged to bring additional fishery-independent data sources to the organizers attention for inclusion.

2.4 Biogeography Diver Based Surveys (historical) & NCRMP Diver Based Surveys

An overview of the Coral Reef Conservation Program's (CRCP) National Coral Reef Monitoring Program (NCRMP) was presented by Mr. Randy Clark. NCRMP is comprised of four, interrelated surveys covering benthos, fish, people, and climate. This presentation covered the benthic and fish surveys, which are led jointly by the NOS Biogeography Program and the NMFS Southeast Fisheries Science Center. The NCRMP is working towards fairly standardized approaches across US coral reef jurisdictions. In the US Caribbean, the plan is to sample every other year, with sampling occurring during even-numbered years in Florida and Puerto Rico and during odd-numbered years in the US Virgin Islands and the Flower Garden Banks (Gulf of Mexico). It is important to note that these surveys are not designed for stock assessment purposes, though data may have utility for that purpose. The NCRMP employs a stratified random design to acquire data on fish abundance and to characterize coral reef habitat. There is a spatial component embedded within a statistically-based sampling design. The method involves surveying a 25mx4m transect during a 15 minute timed swim. Prior to NCRMP, the NOS Biogeography Program conducted a 10+ year survey at a smaller spatial scale (La Parguera, Puerto Rico and protected areas in St. Croix and St. John), but NCRMP requires sampling across the entire domain. The sampling program focuses on hard bottom habitat, stratified by depth, region, habitat type, and protection. Mr. Clark focused his discussion on pilot NCRMP sampling activities that occurred on St. Croix in 2012. As a compromise for length based assessments, fish lengths (total length) for snapper and grouper are collected to the centimeter, while other species are "binned" into 5 cm length increments. The statistical target of this monitoring is a coefficient of variation (CV) of 20% or better, though the metrics have yet to be determined. A power analyses to evaluate sample size has not yet been conducted. The team will use a suite of species to help optimize and drive sample allocation, and these indicator species may differ among the islands.

Separate from the US Caribbean is the Flower Garden Banks survey. This region is in the northernmost part of the Gulf of Mexico but has extensive deep coral reef habitats. Some parallels were drawn between this region and the mesophotic reef habitats sampled by Reni Garcia in Puerto Rico. NCRMP's SCUBA-based survey activity is limited to depths less than 30m, so other technologies must be used below those depths (e.g., Remote Underwater Vehicles (ROVs), Autonomous Underwater Vehicles (AUVs) or camera arrays).

The first topic of discussion centered on whether the transect surveys include all species or select target species. Mr. Clark clarified that the divers count and identify everything they see within the 25 m x 4 m transect. A separate question focused on how the CV is obtained. Mr. Clark responded that the CVs would be calculated by species, or perhaps a subset of species based on ecological or economic value. Binning of length measurements was discussed and while it would be optimal to get individual lengths to the centimeter for each fish, the method is not ideal for this. The conversation then shifted to conducting comparisons between fished vs. unfished sites. For example, have there been comparisons between the relatively unexploited Flower Gardens Bank and the more heavily exploited sites in the US Caribbean? Mr. Clark explained that recreational hook and line fishing is allowed at the Flower Gardens Bank, so it isn't a perfect reference point. He also stated they are not seeing big fish in their US Caribbean surveys.

Comparability to Florida is limited because NCRMP employs a different method there (Stationary Point Counts). The issue of visibility was raised and Mr. Clark replied that it is rarely a problem as long as the diver can see two meters. However, it was noted that fish can be counted along the entire length of the transect, so visibility can impact the counts. On the occasion when visibility conditions are limiting, this needs to be considered and should be noted in the database. Additional questions focused on historical comparisons and sample station distributions between the NCRMP survey and a trap survey study conducted on St. Croix by scientists at the SEFSC (see 7. below). Gear selectivity is an important issue so there would be value in comparing catchability of the two different methods, especially if the trap method might be suitable for depths outside safe diving limits. Mr. Clark discussed changes in trap performance as traps degrade and foul, and how this may affect comparability. Sampling effort was discussed and how effort was distributed across the four Atlantic jurisdictions was described (biennial). Allocation of effort was also discussed with various tradeoffs between adding sites versus adding replication within sites. Mr. Clark responded that it is impossible to do everything with a limited budget, but that effort should be allocated in the way that most increases sampling efficiency.

2.5 Reef Visual Census (RVC) Surveys

Drs. Jerry Ault, Steve Smith, and Jim Bohnsack presented the reef visual census (RVC) program, with a focus on refining the experimental design to improve performance. Dr. Bohnsack is the architect of this visual survey method, initiating the approach in 1979. Dr. Ault led off the presentation by asking "what design is best for cost-effective surveys?" For assessing populations you need to know both what is landed on the dock and what is left in the water. Dr. Ault argues that a new data paradigm is required, focused on looking at all species, all sizes, on appropriate spatial scales (including Marine Protected Areas), within the context of movements and habitats. Information such as this is not provided by fishery-dependent data. He further argues that a valid fishery-independent approach requires that all measures are based on a fixed area search method. Dr. Ault then proceeded to describe the ideal sampling approach, including stratification, optimization, and allocation with an emphasis on the need to allocate the most samples to the most variable areas. An iterative approach is required, to refine the survey year after year, learning from each new data acquisition and adapting accordingly. This approach brings the coefficient of variation (CV) down. Dr. Ault made the claim that in-water and on-dock estimators should be the same. He then discussed applications and the correspondence between fishery-dependent and fishery-independent outcomes, ending with an argument that a more coherent approach will yield better results, as opposed to various groups operating separately.

The discussion opened with a question about Neyman Allocation Curves and how to use them to reduce variability in the data. Beyond increasing effort, the answer is to refine stratification. A follow-up question asked about sample sizes and managed areas, specifically inquiring as to whether CVs are area-specific. Dr. Ault replied that their approach is to partition among management areas, stratify and apply samples within each stratum. Dr. Smith explained the design should obtain stock-wide metrics as well as metrics that pertain to the different strata (including managed areas). It requires taking a compromise approach to achieve the two goals, which results in an increase in sample intensity. Dr. Smith described the "happy medium", which is reflected by a 15-20% CV for most exploited species and an even lower CV for non-target species. With respect to MPA performance, it's more realistic that a 25-30% CV will be achieved.

The next question focused on field methods, specifically the Bohnsack-Bannerot Stationary Point Count (SPC) employed by the RVC program versus various transect sampling approaches. Dr. Ault replied that he prefers the cylinder approach because that approach requires no movement by the diver and the fish are therefore more relaxed. It also tends to be quicker and capture the target habitat better. But does it affect detectability? Either method is acceptable, as long as the method is applied consistently. ***Consistency in the sampling approach is essential, and having an optimized high-quality underlying survey design is essential.*** A question was asked about capturing rare species. Dr. Ault explained this can be addressed by employing an appropriate sample size and applying careful spatial allocation of those samples based on learning. Elements of patchiness and rugosity and the method with which any index of abundance integrates among these habitat characteristics should also be considered.

There was broad agreement that thorough habitat mapping is essential. Quality of available maps is a large driver of survey quality and optimization. In response to a request for information on what the next step is to further reduce CV, two fundamental approaches were described: 1) improve the map itself; 2) conduct additional analyses to identify occupation/density patterns. Either would allow better understanding of how the animals distribute themselves. The discussion ended with a question about reducing zeros. Dr. Ault reiterated the importance of sample allocation with respect to the need to statistically manage zeros, but he acknowledged the baseline is not known. To clarify this point, Dr. Ault provided an analogy with political campaigns, the lesson being to stay away from dead zones. With respect to overfished species, it's important to ensure detection capability as they increase in abundance and reoccupy habitats. To accomplish this, it is necessary to monitor "hot spots." Also, specialized techniques may be required for patchy species such as queen conch. Finally, greater emphasis needs to be placed on analysis. It's common for 95-98% of available research dollars to be spent on field work and only 2-5% to be spent on analysis of the resultant data. Dr. Ault advises a greater emphasis and investment in data analysis.

2.6 St. John Long-term Reference Reef Fish Monitoring

Dr. Jim Beets from the University of Hawai'i Hilo presented a summary of a long-term reef fish monitoring project that has been conducted in St. John. The St. John long-term reference reef fish monitoring project began in 1988 after Hurricane Hugo. The main goal was to monitor biodiversity at "hot spots" in St. John (Haulover, Newfound, Yawzi Point and Tektite). However, changes in methodology were made in 1995 for broader spatial coverage, so most analysis of survey data is from that point forward. The survey consists of the Bohnsack-Bannerot stationary point count surveys at haphazardly chosen stations within strata at depths from 3-20 m during July-August of each year. Actual sizes of reef fish were measured to the centimeter. Monitoring data yields information on assemblage characteristics, biomass, species richness (diversity), and tracks changes in commercial species. Complementary benthic cover data were presented from 1998-2014 from the NPS Inventory and Monitoring Program. An additional trap study on St. John (Yawzi Point) was conducted in 1982/1983 and 1993/1994. While mesh size in the fishery changed in 1982/1983, the survey used the same mesh size consistently. Traps were soaked for 5-7 days.

The discussion focused on addressing questions related to the consistency of survey gear and the species that were observed. Consistent survey methodologies for the stationary point counts (SPC) surveys were adopted in 1995. Trap mesh size was standardized in the survey. Yellowtail snapper and gray snapper appeared to be showing increasing trends through time, driving much of the trend analysis for fished species. The lack of lionfish in the surveys was noted. While lionfish are established on St. John, they were not reported in the survey. It was suggested that this was either because they are more frequently encountered in deeper water on St. John or because spearfishers are allowed to remove them from National Park waters.

2.7 St. Croix Cooperative Fishery-Independent Trap Survey

Assessing fisheries in the US Caribbean through traditional stock assessment methodologies is a challenging undertaking and there is little confidence in fishery-dependent data in the territories. Additionally, most fishery-independent surveys in the US Caribbean are not spatially or temporally consistent. Dr. Todd Gedamke presented a summary of a pilot trap survey, funded by NOAA's Coral Reef Conservation Program. The survey was designed to explore if this approach could be an effective strategy for executing a cooperative fishery-independent survey program in the US Caribbean to obtain mean-length estimations and provide a relative index of abundance for stock assessment. The project worked directly with St. Croix fishers to build, deploy and retrieve standardized fish traps according to a sophisticated experimental survey design. Fishers were paid for their time and effort and were allowed to keep their catch when caught in areas open to fishing. While logistically complex, the pilot survey design and execution were successful. Lessons learned will help refine the design for future surveys if the approach is adopted. For example, there were hurdles with accessing different management jurisdictions (e.g., Buck Island Reef National Monument), trap selectivity/catchability issues need to be resolved, sensitive coral habitats must be avoided (especially Endangered Species Act (ESA) coral critical habitat), and seasonality issues must be addressed. This approach would be directly applicable to other data-poor, island-based fisheries such as those found in the Wider Caribbean and the Wider Pacific basins.

The design, cooperative nature, and potential future directions of this survey were the focus of the discussion. The success of this project as a proof-of-concept in collaborative fishery-independent data collection was discussed. The group agreed that financial incentives and direct experiences by fishers can be used to gain the support of the fishing industry in the US Virgin Islands and that fisher involvement in future surveys can create more effective sampling in the region than could be carried out by staff aboard scientific research vessels. The group acknowledged the difficulty of quantifying the effective area sampled. It was also noted that trap size and configuration, soak times and baiting techniques influence the selectivity and catchability of the trap gear. For example, 24 hours soaks with squid bait were effective for many species, but did not work well for parrotfish. To fully understand selectivity/catchability would require a significant increase in effort and/or a targeted research project. Comparing the results of the trap survey to spatially overlapping commercial or fishery-independent data was suggested. It was noted that comparing the data from the trap survey to commercial data would likely be problematic because of the low geographic resolution of information reported by commercial fishermen. However, overlapping future trap studies with fishery-independent visual surveys would be possible and effective, as visual surveys are depth limited and the trap study would be an excellent way to extend fishery-independent surveys into deeper waters.

Since expanding the current sampling strategy to the entire US Caribbean quickly becomes expensive and logistically difficult, the group discussed how to potentially expand the area sampled without drastically increasing the number of traps. This would require further refining the sample allocation using better fine-scale maps and using a geospatial stratified survey design to optimize sampling. The group acknowledged that there are people and assets in the US Caribbean that could participate in and oversee future collaborative data collection. Once the need for capacity building in geospatial analysis techniques is met and the code is developed, the analyses could be somewhat automatic. It was noted that such a program could also be an effective way to obtain samples (otoliths, spines, and gonads) for use in reproduction, and age and growth studies.

The cooperative nature of the trap project was applauded and suggested as a model for future fishery-independent surveys to ensure fisher confidence in the data collected and to ensure full coverage of the entire survey area. Additionally, working with the fishing community is much more cost effective than using NOAA vessels and personnel from the mainland. Perhaps a cost-sharing arrangement with the fishers could be negotiated. Several comments suggested commercial fishers would be willing to get involved. Cultivating capacity within the University of the Virgin Islands and University of Puerto Rico was also suggested as a way to build the infrastructure needed to execute these trap surveys. With observers on board, the survey would also be effective at estimating discards. The need for building capacity in survey design and modeling in the jurisdictions was suggested as a future need to be factored into future budgets.

2.8 Recent Longline and Other NOAA Surveys & Early US Caribbean Fishery-Independent Information

Dr. Walter Ingram from the SEFSC's Pascagoula Laboratory gave a historical overview of fishery-independent information collected from the US Caribbean dating back to 1959. These surveys were originally designed to explore fishery resources in the US Caribbean. Most of the information is captured in cruise reports. Data are digitally available starting in 1979. The surveys conducted in the US Caribbean were inconsistent, varied temporally and spatially, and used a variety of gears (although there is detailed information about the gear). This information could be used to explore gear biases so that length-frequency data could be extracted.

Background information included a detailed spreadsheet describing each survey's objectives and coverage, and this spreadsheet can be found at the following weblink: (http://sero.nmfs.noaa.gov/sustainable_fisheries/caribbean/fish_indep_wkshp/documents/pdfs/presentations/ingram_early_fi_caribbean_surveys.pdf). Digitizing data before 1979 has not been a priority due to its limited utility. There is likely some interesting information that could be mined from the historical surveys, especially for determining how to optimize a long-term, systemic survey for the future.

2.9 Caribbean Reef Fish Video Survey

The SEFSC has been investing in a Caribbean Reef Fish Survey aboard a NOAA vessel since 2009, principally to provide fishery-independent estimates of reef fish stocks in the US Caribbean and to collect biological samples for age and reproductive information. Dr. Matthew Campbell from the SEFSC's Pascagoula Laboratory presented an overview of this Survey. The survey samples around Puerto Rico, St. Thomas and St. Croix and is intended to be conducted every three years, generally in the late spring/early summer. The presentation focused mainly on the video sampling, but the gears used have included video, stereo-video, chevron traps, vertical line (bandit reels), longline and acoustic biomass estimates. A stratified random design is used, using region and depth as the strata. Data were presented on the gear, locations of sampling, and catches from each gear.

The discussion focused on gear attributes, vessel requirements and future directions so the survey could be used and standardized to provide meaningful estimates of abundance for stock assessment. There was concern about the catchability of traps due to their size, configuration, bait, and soak times (1 hour). The stereo cameras can identify and measure fish up to 10 meters away and can also measure the distance to the fish. However, sampling area is confounded since the cameras are baited. Cameras are also restricted to <150m because of light limitation. It was suggested that the camera gear saturates after about 10-15 minutes so perhaps the soak time for the cameras could be lessened to allow coverage of more stations. Cameras are also hindered by low-light and low visibility environments. Longlines are limited in that they may have hook saturation issues (and are mainly used to get hard parts, not generate indices). Vertical line catches were generally low and it was suggested that deployments could be refined to increase catchability. Gear is weighted to keep it fishing in the appropriate location. The vessels also have excellent positioning power to keep the survey on site. Although certain gears were able to better sample certain species, there are now three years of vertical line data making it possible to compare observations across gears. All the gears have catchability issues and knowing the sampling frame is important for quantitative conclusions.

The site maps presented generated concern about the spatial coverage of the surveys. Site selection and stratification could be improved by incorporating habitat data, especially available structure. Also, the south coast of Puerto Rico had not been sampled adequately. This was an artifact of history and not intentional. Seasonality of surveys was also discussed since some species spawn or migrate during the survey time and this activity may influence distribution and behavior. Age and reproduction samples collected from these surveys have yet to be analyzed.

Considerable discussion ensued about the efficiency of using a NOAA ship to conduct these surveys. The survey is allotted 4 weeks of which 2 weeks is transit. Also, the NOAA ships have deep drafts and typically can't work in less than 15 m depth. It was suggested to swap time on a NMFS ship for the Nancy Foster (an NOS ship) which is typically in the US Caribbean for a longer stretch of time, thereby justifying the transit time costs. The SEFSC should think carefully how to optimize the use of valuable ship time for optimal benefit to the agency (i.e., focusing on deep water surveys and/or use of heavy gear (e.g., camera arrays are heavy (~600lbs) and require a >70' vessel with a pot-hauler). NOAA vessels also conduct multi-beam mapping which is essential for survey optimization. The discussion about future survey approaches focused on the video gear, with the other extractive sampling used more for hard parts than for generating an index of abundance. Folding this survey into a larger, consistent strategy for generating indices of abundance (not just presence/absence) will be important. Pairing gears to explore probability of detection/occupancy might help with this (e.g., traps with cameras on them) or randomizing comparable gears on target habitats and comparing catchability. Refining research on camera techniques to get an index of abundance/density is needed.

2.10 The SouthEast Fishery-Independent Survey (SEFIS)

Dr. Nate Bacheler from the SEFSC's Beaufort Laboratory presented a summary of the SouthEast Fishery-Independent Survey (SEFIS). This is a fairly new fishery-independent survey focused on the snapper grouper complex along the southeastern US Atlantic seaboard. This survey was presented at the workshop as an example of a large-scale hard-bottom focused fishery-independent survey with some facets that may be suitable for adoption in the US Caribbean.

Limited MARMAP fishery-independent sampling has occurred in the region since the 1970s, and SEFIS was created in 2010 to work with MARMAP to increase sampling, expand sampling, and add video gear, especially in the wake of more restrictive red snapper management that hampered fishery-dependent sampling. Surveys go to 100 m depth and are conducted from Cape Hatteras, NC to the St. Lucie Inlet, FL. SEFIS is a stratified random survey focused on hard-bottom; unfortunately, less than 10% of the study area (> 80,000 km^2) has been mapped. Gear includes menhaden-baited chevron traps to retrieve biological samples and an array of camera gear. Site selection is based on existing maps, on-going multi-beam activities, and information shared by the fishing community. The survey is led by the SEFSC with partnership from state agencies and academic institutions. Recently calculated trap- and video-based indices of abundance from this survey have had CVs of approximately 10 – 20%.

The discussion focused on the sampling frame, survey optimization and gear selectivity. Members of the group noted that sampling efficiency could be increased by siting traps in areas of known hard bottom habitat. Dr. Bacheler noted that many commercial fishermen were cooperative in providing extensive information on the location of hard bottom habitats because they want their "hotspots" to be included in the survey, but that the survey was also invested in attempting to map areas of unknown habitat via multi-beam sonar. The group discussed the strength of an adaptive survey design approach, whereby sample values from previous years are used to optimize the survey in future years. For example, the variances from the last several years' estimates of density can be used to determine the number of samples needed in that habitat for the future.

It was noted that the surveys included detailed habitat data collected by cameras. Originally, habitats were grouped into six different types, but statistical modeling indicated that habitat has not been a significant predictor of any stock dynamics, likely due to the highly patchy nature of the habitat, which is an issue for other surveys as well. Patchy habitats are difficult to sample with directional camera gear. Also, cameras measure only what is in the immediate individual area, and bait effects potentially extend much further. Thus, the measures of habitat detected by the camera are not necessarily representative of the sample site. Effective sampling area for each trap is definitely an issue that still needs to be resolved. The group concluded that habitat mapping and the definition of sampling frame were urgent needs that applied not only in this instance but in many other surveys.

Data processing and analysis were discussed. Extracting the data from videos is a time-consuming process, so typically a random sample of snapshots has been used. This has the advantage of being faster, but the disadvantage that rare species were frequently missed. One participant noted that using a qualitative rather than quantitative metric of abundance might speed processing. One value of the camera/trap paired survey is that the camera will indicate when traps do not sit properly on the substrate, and these samples can be thrown out. The appropriate sampling unit to be used was discussed; currently analyses are using the trap as the sampling unit.

From a logistics standpoint, it was noted that these surveys are very complex and expensive to execute. Ship time and video processing drive the high expense of the survey. Sampling frame and mapping seem to be the greatest developmental needs for refining the survey as it moves forward. Another area of research is looking at occupancy and n-mixture models using traps and video together to separate patterns in distribution or abundance from the sampling process itself.

2.11 SEAMAP-C in Puerto Rico

Aida Rosario, emeritus at the Puerto Rico Department of Natural and Environmental Resources (PRDNER), presented an overview of the SEAMAP-C program. A number of agencies participate in SEAMAP-C including Puerto Rico Sea Grant, PRDNER, the Virgin Islands Division of Fish and Wildlife, the Caribbean Fishery Management Council, the US Fish and Wildlife Service, and the National Marine Fisheries Service. Although agencies from the US Virgin Islands are participants, the presentation's focus was on activities in Puerto Rico. Details about the SEAMAP-C projects conducted in the US Virgin Islands were not described.

A variety of projects are funded by SEAMAP-C:
1. Reef fish survey (Puerto Rico and US Virgin Islands);
2. Queen conch survey (Puerto Rico and US Virgin Islands);
3. Lobster survey (Puerto Rico and US Virgin Islands);
4. Parrotfish survey (US Virgin Islands);
5. Yellowtail snapper survey (Puerto Rico and US Virgin Islands);
6. Lane snapper survey (Puerto Rico);
7. Deep water snapper survey (Puerto Rico and US Virgin Islands); and,
8. Hydroacoustic survey (Puerto Rico and US Virgin Islands).

The surveys were described in the following PowerPoint presentation: http://sero.nmfs.noaa.gov/sustainable_fisheries/caribbean/fish_indep_wkshp/documents/pdfs/presentations/rosario_seamap-c_surveys.pdf. The surveys in Puerto Rico are conducted on a 4-year rotating cycle. The main goals of each survey can be found in Section 3.8 - 3.13, but the general intentions of the SEAMAP-C surveys in Puerto Rico are to:

1. Collect, manage, and disseminate fishery-independent data on the species encompassed in the marine waters within the territorial sea and the Exclusive Economic Zone contiguous to Puerto Rico;
2. Enable Puerto Rico to identify, implement and measure the effectiveness of fishery management measures for their territorial waters;
3. Enable Puerto Rico to take full advantage of an integrated, coordinated, and cost effective approach to fishery-independent data collection to fulfill priority data needs;
4. Enhance the usefulness of the data, minimize the costs, and increase the accessibility of information to fishery managers through the Caribbean region;
5. Support plans to conserve and manage the fisheries that are Caribbean in scope;
6. Provide indices of abundance.

The various surveys used a variety of methods. Ms. Rosario provided an overview of the methods and the changes in the methods through time. Including a description of each survey would be too immense for this report. Detailed descriptions of the methods can be found in sections 3.8 - 3.13. In general, the surveys have a limited spatial scale and have been mainly restricted to the west coast of Puerto Rico due to funding and boat limitations. Sampling locations are chosen from a grid of potential sites, where the grid is defined by a series of one-mile by one-mile squares. Fishing can occur anywhere within the grid; exact locations are not generally known due to the lack of GPS. Approximately 15 sites are sampled per sampling cycle.

Much of the discussion after the presentation was focused on potential improvements in the sampling design. Suggestions included using habitat maps to stratify the sampling universe rather than using the current grid system, better defining the goals of the surveys, optimizing sampling for a suite of important species in Puerto Rico, and increasing the spatial coverage of the surveys.

2.12 Fish Spawning Aggregation Surveys in Puerto Rico

Dr. Michelle Schärer described efforts to monitor spawning aggregations in Puerto Rico using acoustic techniques. Dr. Schärer's work focuses on areas of depth discontinuity (e.g. shelf-breaks) off the west coast of Puerto Rico, including the areas known as Abrir la Sierra Bank, Bajo de Sico, and Tourmaline Bank where spawning aggregations for a variety of species have been observed. Along with her general discussion of spawning activities in this area, she described specific work on characterizing a remnant Nassau grouper spawning aggregation and her use of visual survey results to validate acoustic monitoring work.

In response to questions from the audience, a few clarifications were made at the beginning of the discussion. It was noted that detection distance for the acoustic sensors is theoretically about 300 m, but has not been validated empirically. Additionally, there is a sex dichotomy in the production of sound, where it is believed males produce particular sounds during reproductive behaviors. These sounds are species-specific and can be differentiated with training; thus, the acoustic method is useful for multi-species spawning aggregations. Currently, video surveys are used to estimate fish lengths with laser calipers and not to provide counts of densities or abundances; only the underwater visual surveys (SCUBA and closed circuit rebreather) are used for this purpose. It was also noted that the acoustic receivers have been left on some sites throughout the year, so data to determine if secondary spawning events occur are available although they have not been analyzed.

Much of the discussion revolved around whether or not the acoustic work could be used to create an index of abundance. Dr. Schärer noted that a very good correlation between acoustics and underwater visual surveys was found in one year for red hind, but in another year the two were unrelated. There are a number of intricacies that still need to be explored, and factors that need to be considered such as migration between spawning sites, environmental conditions, and the size of fishes, all of which might affect sound levels. Also, the behavior of the fish is sometimes limiting, as individual's movements may affect detectability due to sources of background noise. The group pointed out that in order for any index to be representative of the entire population, a good portion of all active spawning sites would need to be surveyed.

This led again into a discussion parallel with other sections, on the importance of defining the sampling frame. In this case, it is necessary to define all spawning grounds of a given population. This can be done via more broad-scale methodologies such as using many small receivers or conducting over-the-side hydrophone surveys or fisheries acoustic surveys. The latter was considered more feasible. Dr. Schärer stated that such an undertaking can easily get unwieldy through logistic issues at sea and the massive acoustic files that must then be stored and processed. It was suggested that a library of sounds, following the GenBank cataloguing approach used for genetic information, could be used to develop automated sound analyses algorithms and thereby increase analytical efficiencies while reducing costs. The group discussed scalability of the project, and advanced technologies such as AUVs were mentioned as potential methods for larger-scale studies. In general, the workshop participants were excited about the prospects of using acoustic approaches to estimate population abundance but acknowledged the science is still evolving and maturing.

2.13 Mesophotic Surveys

Mesophotic coral ecosystems are defined as those biological communities at depths (typically 30 m to 70 m) where photosynthesis is still important for benthic productivity. Dr. Richard Appeldoorn described the mixed-gas rebreather diving technologies and sampling strategies used to characterize reef fish populations at these depths. A clarification on the method for measuring rugosity was requested, and the presenter noted that multi-beam data are used to create this measure. A short discussion was held on the topic of extending the mesophotic surveys. The group asked whether dives could be extended to even deeper habitats. The presenter noted that extensive training of dive personnel is required for these deep dives, and safety is always a priority. The main obstacle appears to be a lack of funding with which to expand the work. It was noted that these surveys are typically carried out through university partnerships.

2.14 Fishery-Independent Survey of Commercially Exploited Fish and Shellfish Populations from Mesophotic Reefs within the EEZ of Puerto Rico

Dr. Jorge (Reni) Garcia-Sais started the afternoon session with a presentation on mesophotic surveys in Puerto Rico. This survey was a pilot study with the following main objectives: 1) characterize the main species assemblages of commercially important fish and shellfish seen in each of the benthic habitats and depths surveyed (30m-50m) within three study areas (Abrir La Sierra Bank, Bajo de Sico, and Tourmaline Bank), 2) provide inferences of seasonal variations by species at Abrir La Sierra Bank, with particular interest on queen conch, 3) produce rough population size estimates for target species based on field estimated densities and benthic habitat areas at each site, and 4) provide a preliminary analysis of the status of the commercially important fish and shellfish populations within the mesophotic habitats surveyed based on the length frequency data.

This study used a visual census methodology. Two divers using rebreathers surveyed commercially important fishes (groupers, snappers, hogfish, queen triggerfish, large parrotfish, barracuda, sharks, lionfish) and shellfish (queen conch, spiny lobster) along drift transects that were approximately 250 m long. Divers estimated fish and lobster lengths visually, whereas direct length measurements were made for conch.

The questions that followed were about interpretations of stock status from the collected observations. One workshop participant asked whether larger, overfished parrotfish species, such as blue and midnight parrotfish, were observed during the survey. Dr. Garcia indicated that sightings of parrotfish were extremely rare (i.e., two). Rainbow parrotfish were also rarely seen, but were large, ~1 meter in length. Another participant asked whether in general stock size appeared to be increasing. Dr. Garcia responded that based on an analysis in 2002, red hind were thought to be in a highly overfished state, but that he has been seeing higher numbers of larger fish, which is suggestive of an increase in stock size. Dr. Garcia noted, however, that he still views overexploitation as a major problem, particularly because of fishing on the major spawning aggregations and that stock recoveries may be limited to localized regions.

2.15 Larval Surveys in the US Caribbean

This presentation given by Dr. John Lamkin described larval fish surveys conducted aboard NOAA ships from 2008-2010. Nearshore, shelf edge and offshore sampling was conducted using a variety of collection techniques (e.g., Bongo and MOCNESS trawls) to collect settlement-stage larval organisms. Oceanographic information (biological, physical and chemical) was also collected. Cruise dates and locations varied significantly from year to year, making it difficult to construct a meaningful time series especially with little information about the spawning dynamics of many of the reef fish. The survey did not follow a statistically designed protocol for any particular species or for use in stock assessment, as this survey was piggy-backed on another funded cruise activity. The focus of the presentation was on the relative abundance of parrotfish larvae collected through time, but that identifying parrotfish larvae to species is extremely difficult. Genetic methods could be used to identify parrotfish larvae to species but cost ~$10 per sample. Snappers and groupers can be identified to species, but are caught infrequently.

The discussion on this survey was limited, but highlighted concerns about the ability of this survey to provide meaningful indices for stock assessment. Surveys would need to be more frequent to capture more spawning events, and would need to be standardized in time and space. Additionally, these surveys are extremely expensive, with high costs to conduct at sea (especially on NOAA vessels), and to support the personnel to sort and analyze larval fish samples. The presenter noted that many of the samples have not been sorted or identified. Specific applications to stock assessment were discussed. One participant noted that such larval surveys are often used as an indicator of stock abundance, but could potentially be used as an index of recruitment as well. The information could be helpful for generating estimates of spawning stock biomass, but this is a limited use of the data. In addition to linking to spawning stock biomass (SSB) in a stock assessment, the data could provide information on genetic diversity and number of females. Dr. Lamkin noted that one of the most important uses of the survey was to understand larval connectivity and transport processes across the region.

2.16 TCREMP: US Virgin Islands coral reef monitoring program

Mr. Jeremiah Blondeau from the SEFSC in Miami provided an overview of the US Virgin Islands Territorial Coral Reef Monitoring Program organized by Dr. Richard Nemeth and Ms. Elizabeth Kadison of the University of the Virgin Islands. The program was initiated by the Coral Reef Conservation Act of 2000, which mandated all maritime areas and zones subject to the jurisdiction or control of the US monitor coral reef communities. The main objectives of the project are to: 1) monitor the status and trajectories of coral reefs and fish communities across a majority of habitats and threats, including land-based sources of pollution, overfishing and thermal stress, 2) link changes in coral reef health with specific stressors, indicating specific management interventions most effective for preserving reefs and reef fish communities, and 3) integrate assessments of understudied mesophotic coral reef ecosystems and threatened species in the US Virgin Islands.

The first two years of this project (2001 and 2002) concentrated on the fringing reefs surrounding St. Croix. In 2003, monitoring continued on St. Croix reefs and began at reef systems distributed across the insular platform surrounding St. Thomas/St. John. This annual survey uses belt transects and roving diver surveys at fixed sites. A more detailed description of the methods and sites can be found at: https://sites.google.com/site/usvitcrmp/ and http://www.uvi.edu/files/documents/Research_and_Public_Service/CMES/uvi_cmes_tcrmp_description.pdf. All fish are enumerated and lengths are visually estimated and binned into 5 cm or 10 cm increments. Mr. Blondeau mentioned that the majority of sampling was conducted along the "mid-shelf reef". Clarification was requested about the use of the term "mid-shelf reef." Mr. Blondeau noted that he was referring to areas on the platform shelf extension, rather than the true mid-shelf reef. No sampling occurs on these latter areas.

There was extensive discussion about length measurements, in particular whether binning in 5 cm/ 10 cm bins or recording length to the nearest centimeter is more appropriate. It was noted that for highly abundant species it is difficult to measure every fish while doing a transect survey and one participant noted that binning can reduce variability amongst observers. It was also mentioned that typically a binning method is used for transect surveys and the nearest centimeter method is recorded for stationary point count (SPC) surveys. Regardless of the method used, a potentially more important issue is that of diver bias on length estimates. Participants noted that in many cases, extensive training of divers takes place to reduce any biases. For the RVC program that uses SPC methodology, a visual measuring aid is carried by each individual diver to assist in calibrating length measurements. Other participants noted that these biases can be significant and need to be taken into account. The group discussed various ways to improve length estimation, such as lasers mounted on clipboards or stereo cameras. Another significant issue that was brought up was whether these surveys are measuring a representative sample of the total population.

Discussion about site selection and the ramifications of this choice also evolved. Fixed sites were chosen to represent a variety of habitats and were picked before habitat maps were available. Fixed sites were also employed primarily to monitor coral cover through time. One participant indicated that fixed stations can help to distinguish between spatial and temporal variance, whereas, random stratification of survey sites was thought to capture interannual variability more accurately.

It was a general consensus of the workshop participants that it was inappropriate to extrapolate observations from a fixed station survey to population levels estimates for fish species. These data were thought to be most appropriate for making interannual comparisons. ***An important theme that emerged during the workshop was that for any survey it is important to consider the objectives of the work and the target species' spatial scale of movement when determining whether extrapolation to population level estimates is useful.***

2.17 Fishery-Independent Queen Conch Surveys in Northeast St. Croix

Dr. Ron Hill from SEFSC's Galveston Laboratory made the final presentation of the day. Dr. Hill provided a summary of the conch visual surveys that he and Ms. Jennifer Doerr have been conducting in the US Virgin Islands. The main goal of this survey is to better understand the abundance and distribution of queen conch inside and outside the reserves in northeast St. Croix. Additional objectives were to 1) generate fishery-independent density estimates suitable for contributing to stock assessment models, 2) quantify length-based differences (juvenile/adult age classes) in conch densities and distribution by habitat, depth, and management regime (i.e., inside and outside marine protected areas), and 3) compare population density patterns with historical surveys conducted in the area (SEAMAP-C). The surveys were conducted in September, 2010 and September, 2011 for four days. Site selection was based on stratified random sampling. Strata include management zone, depth, and habitat type. It was noted that the survey was initially stratified by many habitat categories, but through time the number of habitat categories was reduced to ensure manageability. Conch were enumerated, size was measured to the nearest centimeter, and life stage was estimated.

The discussion that evolved was diverse. One participant asked about the demographic make-up within Buck Island. Dr. Hill indicated that there were numerous small conch in shallow areas and that larger adults were also observed. He also mentioned that conch can move from deeper habitats into shallow/cleaner water habitats to reproduce. There was some discussion about how life stages were defined. Adult conch were defined as having a 9 inch (22.9 cm) shell or a flared lip with 3/8 inch (0.95 cm) thickness, which is similar to the fishery definition. SEAMAP-C uses a different definition. A recommendation from the workshop participants was to work together to make the definitions similar. One workshop participant was curious about whether egg masses were counted. Dr. Hill indicated that egg masses were counted and ~2.5% of surveyed adults have them. With respect to the survey method, one participant asked if the current method was surveying an adequate number of sites with conch. Dr. Hill noted that the zero count surveys take little time to complete – approximately 12 minutes. Sites with moderate numbers of conch (50-60) take approximately 45 min – 1 hour to survey. Sites with very many conch (hundreds) can take over 2 hours and multiple diver teams to complete. It was noted that SEAMAP-C's conch survey methodologies differed from this survey.

3. RECOMMENDATIONS AND CONCLUSIONS

3.1 Recap and Review of Indices Discussed, including Survey Summaries

Following a comprehensive review of the existing fishery-independent survey programs in the US Caribbean and adjacent waters, the group acknowledged the diversity of sampling programs, statistical designs and objectives. A comprehensive description of each survey, filled out by the point of contact for each survey, is included as **Section 4** of this report. It was generally agreed that while the breadth of existing information is extensive, to date there has been little strategic effort to develop programmatic surveys that can quantify relative abundance of managed species on appropriate temporal and spatial scales.

To facilitate a consideration of future survey efforts in the US Caribbean, Dr. Cass-Calay and Dr. Bryan requested that the group reconsider the various data needs for stock assessment, from data-limited techniques through fully integrated statistical catch-at-age models (**Table 2.2.1**).

3.2 Recommendations for Future Surveys in the US Caribbean

The working group prepared a summary of recommended surveys in the US Caribbean. The list was not initially prioritized, and no consideration was given to cost. Priority and cost were considered in a separate exercise to be described in **Section 3.3**. Of particular interest are the group's general recommendations for any new survey, which could be considered "Best Practices" for the development of new surveys and/or adaptation of existing surveys in the US Caribbean. They include:

12. Identify species of interest in the US Caribbean to allow optimization of survey design.
13. Consult experts in survey design, statistics and stock assessment prior to modifications/expansion/development of surveys.
14. Use similar methods across platforms to ensure adequate spatial coverage.
15. When using different gears, overlap spatially and temporally to allow calibration of methods.
16. Use cooperative research programs when feasible (i.e., include fishing community).
17. Develop/Enhance capacity to process and analyze age, reproductive information etc.
18. Conduct a regional workshop to identify gaps in stock demographic data.
19. Focus on filling spatial gaps to achieve a "representative fraction of the populations"
20. Enhance data mining and recovery – scour and capture as much regional data as possible (including spatial data/GIS) to aid in refining survey design and optimization.
21. Expand habitat mapping, including high resolution bathymetry.
22. Collect information to facilitate EBFM and next-generation stock assessment.

The group also made recommendations for surveys that target shallow-water reef fish, mesophotic species, conch and lobster, larvae/recruits and pelagic species. These are summarized below.

1. Shallow-water reef species and reef communities (e.g. yellowtail snapper, queen triggerfish, lane snapper, red hind, hogfish, blue tang, parrotfish, white grunt, Nassau grouper, jacks).
    a. Visual Surveys
        i. Continue NCRMP with a focus on refining methodology and increasing resolution of fish abundance data
            1. Expand spatially to meet sampling frame necessary to index population dynamics.
            2. Expand or optimize sampling to obtain representative sampling for target species, reduce CV to the extent practicable.
            3. Explore refining length measurements to eliminate size-binning of fish lengths
        ii. Use cameras and other technologies to enhance survey (e.g., go-pro drop cameras, go-pros on divers to validate observations. Laser calipers and stereo cameras to improve size measurements.
        iii. Use cameras to expand visual census to deeper depths.
        iv. Recommend that visual surveys capture, at minimum 0-30m.
        v. Consider the use of AUVs with high-resolution cameras. These are useful in shallow and deeper water, including places where you cannot drop cameras. AUVs could provide habitat mapping and high-resolution images.
        vi. Consider using passive acoustics to provide ancillary information about the abundance of fish.
        vii. Before modifying, expanding or developing surveys, convene a panel of experts (i.e. survey design, statisticians, stock assessment experts) to develop “best practice” guidelines for visual surveys.
    b. Gear-based surveys (e.g., trap, hook and line, longline).
2. Surveys in >30 m depth, including shallow and mesophotic habitats (e.g., large snappers and groupers, parrotfishes, blackfin snapper, queen conch, silk and queen snapper).
    a. Diver Surveys
        i. same recommendations as shallow-water, special considerations for diver safety
    b. Fishing Gear
        i. Highly recommended to use cooperative research with fishermen.
        ii. Consider the target species when developing survey methods and sampling gears (e.g. bait selection, soak time, hook size, mesh and funnel size, trap type).
    c. Drop Camera/Video surveys
    d. Active Acoustic Biomass coupled with other gears/methods.

    e. AUVs and ROVs – gives you other ecosystem information and ground-truthing on habitat mapping.
    f. Passive Acoustics (applicable to shallow as well) – spawning indices
3. Conch
    a. Visual Diver surveys including counts and size/age structured information (difficult/impossible to optimize for both reef fish and conch using same sampling frame).
        i. Circular Plots
        ii. Transects
    b. Video surveys (hard to ID conch on video)
4. Lobster
    a. Visual Diver surveys including counts and size/age structured information (difficult/impossible to optimize for both reef fish and lobster using same sampling frame).
        i. Circular Plots
        ii. Transects
    b. Video surveys (cryptic nature of lobster makes video surveys challenging)
    c. Traps
    d. Larval collectors
    e. Casitas/structure
5. Larval Recruitment Surveys – spawning stock biomass, recruitment, egg production.
    a. MOCNESS, Bongos, Light traps, etc.
6. Pelagic Species – Coastal Pelagics, HMS
    a. Managed by Territorial Gov'ts.
    b. Neonate shark tagging in USVI, PR

3.3 Priority, Cost and Feasibility

The group recognized that to adequately support stock assessment models, it is essential to improve the data collection activities in the US Caribbean by developing comprehensive new surveys and/or improving the temporal and spatial scales of existing efforts. To that end, the group considered the utility, cost and feasibility of expanding existing sampling efforts in the US Caribbean, and made recommendations for the prioritization of future survey efforts for several managed taxa. This was done during a group exercise where individual participants described their recommendations on small pieces of paper and then posted them on wall posters under one of four matrix categories: Low Priority/Low Cost, Low Priority/High Cost, High Priority/Low Cost, and High Priority/High Cost.

The recommendations of the working group are summarized in **Table 3.3.1**. The group made several general recommendations with regard to "over-arching procedural concepts", and generally agreed that these activities would be of relatively low cost. Specifically, the working group strongly supported the identification of a team of experts to coordinate future fishery-independent survey development in the US Caribbean. They recommended that this group include experts in survey design, statistics and stock assessment and be tasked to review methods and revisions, and enhance cooperation and coordination. The group also strongly supported funding data mining and recovery activities and conducting analyses to determine the most influential and efficient surveys, and quantify the cost of expansion. There was general agreement that surveys with limited utility (towards what they were originally designed for) should be redesigned or terminated in order to expand the temporal-spatial coverage of more effective surveys. Similarly, the group recommended reducing the overlap in related surveys to the extent possible through calibration to harmonize methods, combine results, and other collaborations. Finally, the group strongly supported the enhancement and development of research survey programs in cooperation with the local fishing community and territorial partners (e.g. CRP: Cooperative Research Program).

With regard to gear calibration, the group strongly recommended that paired surveys (e.g., trap/camera, diver/camera) be encouraged to improve estimation of selectivity and detectability, and to promote the combination of related surveys when feasible. This was also thought to be relatively inexpensive.

The group made several recommendations regarding visual and camera surveys. Some were expected to be high priority and low cost including: validation of diver estimated lengths, cross-calibration of laser and stereo camera length frequency and the use of cameras on divers to validate count data. Of high priority, but likely higher cost, the group strongly recommended the use of drop cameras paired with visual surveys to improve estimates of selectivity and detectability, the expansion of NCRMP visual surveys (spatially, annual frequency and species observed), and the addition of a mesophotic diving/camera component to capture deep water stocks. Of lower priority, but also low expected cost, the group recommended that visual surveys collect fish lengths with 1 cm resolution for all stocks in a fisheries management plan (or all species) if practicable.

The group also emphasized the need for improved habitat mapping in the US Caribbean. Of high priority and low cost, the group recommended a collaborative effort to better define habitat strata, with the intent to harmonize cooperative data collection activities and facilitate analyses. The group also recommended prioritization of shallow water (<30m) habitat maps from existing data. Also of high priority, but moderate to high cost, the group recommended expanded mapping and high-resolution multi-beam mapping of priority areas. One low-priority but low cost recommendation was made, to revise the Minimum Mapping Unit MMU of habitat maps to increase the resolution of existing data.

To improve surveys conducted on spawning aggregations, the group made two high priority, low cost recommendations, to prioritize the species and sites selected for long-term monitoring and to explore the value of active acoustics to develop relative indices of density or biomass. Of high priority, but higher associated cost, the group recommended the expansion of passive acoustic monitoring sites to survey a representative fraction of spawning aggregations, and coupling visual surveys with hydroacoustic instruments to improve the reliability of relative biomass/density estimates.

The group considered two types of fishing gear based surveys, trap and hook and line. In general there was strong support for trap surveys conducted in cooperation with the fishing industry. The group also recommended placing cameras on traps, or combining efforts with existing diver based surveys to improve estimates of trap selectivity. Hook and line based surveys were also considered high priority, particularly for their utility to survey mesophotic and deeper species that cannot be easily observed by divers and/or cameras. However, it is important to standardize hook and line effort to avoid skill bias. If conducted at appropriate temporal-spatial scales, both types of gear based surveys were expected to be of moderate to high cost.

The group considered the diversity of sampling programs that have been conducted through SEAMAP-C. It was evident that SEAMAP-C has supported an extensive list of projects with a variety of objectives. However, these projects have been conducted on a small to moderate spatial scale (relative to fish populations), and over a short duration which has limited the utility of SEAMAP-C in the context of stock assessment. To improve its utility for stock assessment, the group recommended that the program be thoroughly evaluated in consultation with survey design and population dynamics experts with the intent of refining the sampling programs to augment the spatial-temporal coverage for priority species. The group also recommended that SEAMAP-C conduct gear-based surveys that include deeper waters, but did not specify the recommended gear. Finally, the group also supported continued efforts to assemble all SEAMAP-C in a database(s) to enable attempts to calibrate data collected using older methodologies and newer approaches.

For surveys that target conch and lobster, the group strongly recommended surveys be coupled with expanded tagging studies, and enhanced to improve spatial coverage. They also strongly supported efforts to develop collaborative sampling opportunities with the local fishing community. These efforts were thought to be fairly inexpensive. Of high priority but higher cost, the group recommended evaluating the multiple conch and lobster surveys to develop a single conch and a single lobster survey that could be implemented across St. Thomas/St. John, St. Croix and Puerto Rico. Additionally calibration of historic data could be conducted to facilitate its aggregation over larger spatial scales.

The group recognized that life history information is essential to stock assessment, and that this information must be collected over a representative fraction of the population of a managed species. The group also acknowledged that conducting age and growth studies on tropical reef fish is exceedingly nuanced and tricky and requires a great deal of skill and training to do it correctly with proper age validation techniques. The group recommended enhanced funding to obtain and process age, growth, maturity and other life history information for priority species across appropriate temporal and spatial scales. This activity was thought to be relatively inexpensive and high priority, though skill and training may be a bottleneck.

The group also made a few high priority, low cost recommendations of a general nature. Specifically, the group recommended the development of a strategic plan for future surveys, data collection activities etc., in the US Caribbean be developed in collaboration with federal, council and territorial partners. They also recommended that juvenile surveys be considered, at least for high priority species and that observer programs be considered to obtain information on discards. It was acknowledged that the latter activity was expected to be relatively expensive.

The group also acknowledged that some activities, while of inherent value, were currently of low priority (for stock assessment) and have high expected costs. For those reasons, the group recommended reduced use of NOAA "white-ships" which incur high transit costs in favor of expanded use of smaller regional vessels. The group also concluded that larval surveys, surveys for highly-migratory pelagic species, remote sensing methodologies and the use of ROVs, AUVs and towed sleds were not of sufficient value for stock assessment to justify their high expense. However, it should be noted that as basic stock assessment data (e.g. catch, length frequency, life-history, CPUE) becomes more available, and costs of advanced technologies decline, these recommendations will require additional evaluation.

Table 3.3.1. Cost and priority of data collection and survey activities in the US Caribbean.

Recommendation	High Priority - Low Cost	High Priority - High Cost	Low Priority - Low Cost	Low Priority - High Cost
Overarching procedural concepts				
Provide database design and assistance to ensure timely data entry and standard analysis.	■			
Establish a team of experts in survey design, statistics and assessment to review methods, revisions to methods and enhance cooperation and coordination.	■			
Prioritize access to sampling design expertise, perhaps through "team of experts".	■			
Prioritize target species, develop spatial frame for target species (i.e., maps), decide on suite of gears/methods for sampling the spatial frame, and develop statistical design for the survey.	■			
Coordination of efforts to streamline and reduce overlap of similar surveys. When possible, collaborate to combine similar to efforts to increase coverage (e.g. combine reef fish surveys with conch and lobster).	■			
Determine the cost to expand surveys to improve utility for stock assessment. Coordinate and prioritize surveys, reallocate funds to more effective, efficient surveys.	■			
When possible, maintain sample design over time to facilitate the development of time series.	■			
Integrate across boundaries (political, technical, analytical).	■			
Encourage cooperative sampling efforts (e.g. CRP).	■			
Optimization of design for surveys (i.e., NCRMP).			■	
Data mining				
Enhance funding for data mining and recovery.	■			
Compile data from various methods on a single searchable platform. Identify data gaps.	■			

Table 3.3.1 (continued).

Recommendation	High Priority - Low Cost	High Priority - High Cost	Low Priority - Low Cost	Low Priority - High Cost
Calibration/Validation				
Pair gear types to facilitate estimation of selectivity and detectability.	■			
Robust calibration studies between methods or sampling areas to facilitate combining different studies.	■			
Automate processing of length estimation of stereo video images.	■			
Visual and Camera Surveys				
Validate diver-estimated lengths.	■			
Cross-calibrate lasers and stereo-cameras used to measure length on visual surveys.	■			
Use cameras on divers to validate counts.	■			
Calibrate drop camera survey study with existing trap and/or diver survey to facilitate estimates of selectivity and detectability and to allow monitoring of deep-water species.	■	■		
Expand NCRMP visual surveys; optimize for priority reef fish species. Develop this as partnership: NOS, NMFS, NPS, UPR, UVI, PR DPNR, UVI DNR, UM).	■	■		
Expand NCRMP shallow water reef fish survey to annual sampling.	■	■		
Expand NCRMP to survey fish, conch, and lobsters in shallow and deep water.		■		
Add mesophotic diving component to NCRMP cooperative visual survey program (UVI, UPR, DPNR, USVI DNR, NPS).		■		
Expand use of stereo-video drop cameras for 30-150m reef fish and habitat.		■		
Improve video methods for deep water surveys.		■		
Data mine existing video data.		■		
Do visual surveys to 1 cm length resolution for any FMP species or all species.			■	

Table 3.3.1 (continued).

Recommendation	High Priority - Low Cost	High Priority - High Cost	Low Priority - Low Cost	Low Priority - High Cost
Spawning Aggregations and Hydroacoustics				
Select spawning aggregations (species, sites) for long-term monitoring (relative abundance and size frequency).				
Use active acoustics to create an index of density/biomass.				
Expand passive-acoustic spawning site monitoring program to improve estimates of relative and/or absolute abundance of population or spawning biomass, and monitor closed areas.				
Couple visual surveys with hydroacoustics to improve abundance estimates.				
Fishing gear based surveys (Hook and Line/Trap).				
Design and implement a region-wide hook and line survey for mesophotic and greater depths through cooperative sampling programs (e.g. CRP).				
Develop long-term cooperative trap sampling with emphasis on mesophotic and deep water. Overlap this with visual surveys and put drop cameras on traps.				
SEAMAP				
Evaluate, review and improve survey designs of SEAMAP-C.				
Evaluate SEAMAP-C - consult survey design and population dynamics experts, calibrate older data, and expand spatial coverage of priority surveys.				
Expand SEAMAP-C to additional areas and collect annual data, or carry out gear based SEAMAP survey that includes deep-water.				

Table 3.3.1 (continued).

Recommendation	High Priority - Low Cost	High Priority - High Cost	Low Priority - Low Cost	Low Priority - High Cost
Conch and lobster surveys				
Carry out lobster abundance surveys coupled with expanded tagging studies.	■			
Expand regular surveys (periodic) to greater spatial coverage.	■			
Enhance conch and lobster surveys through collaborations with recreational and commercial divers/fishers.	■			
Conch survey circular plot		■		
Select a single conch survey technique and calibrate old data to increase spatial coverage.		■		
Larval surveys				
Icthyoplankton surveys to estimate annual recruitment.				■
Icthyoplankton surveys to estimate spawning stock biomass, production.				■
Vehicle surveys				
Vehicle based, deep water work (e.g., AUV, ROV, towed sleds).				■
Habitat Mapping				
Better define habitat strata to harmonize cooperative data collection and facilitate analyses.	■			
Prioritize production of shallow (~30m) habitat maps from existing data.	■			
Allocate at least some of NCRMP sampling into areas of hard bottom not yet mapped to close major spatial gaps. Estimates will use post-stratification and can be reanalyzed once maps are available to improve ability to detect trends.	■			
Make a concerted and collaborative effort to determine gaps in habitat mapping and prioritize new surveys.	■	■		
High resolution bathymetry of unexplored coral reef systems (Vieques and St. Thomas).		■		
Benthic habitat mapping of explored reef systems.		■		
Invest in high quality multibeam mapping of priority areas.		■		
Revise MMU of habitat maps (increase resolution of existing info).			■	

Table 3.3.1 (continued).

Recommendation	High Priority - Low Cost	High Priority - High Cost	Low Priority - Low Cost	Low Priority - High Cost
Age and growth				
Enhance efforts (i.e. funding) to obtain and process age, growth, maturity and other life history information across appropriate temporal spatial scales.				
Miscellaneous				
Develop a strategic plan for surveys, data collection etc. Obtain agency approval for survey implementation.				
Develop juvenile surveys in nursery grounds.				
Reduce use of NOAA "White-Ships" to reduce cost of transit times. Use smaller regional or local vessels.				
Observer survey program to obtain discard information from fisheries.				
Workshop to assess data gaps.				
Pelagic surveys.				
Deepwater (white ship) habitat mapping.				
Development of remote monitoring techniques/methodologies.				

4. COMPREHENSIVE DESCRIPTION OF SURVEYS IN THE US CARIBBEAN AND ADJACENT WATERS

The following descriptions were provided by the points of contact for the survey. For each survey, the meeting co-conveners requested information on the funding source, points-of-contact, goals and objectives, intended outcomes, survey design, temporal-spatial coverage and a self-appraisal of pros, cons and utility for stock assessment. The responses were provided by points-of-contact and some were modified to achieve consistent formats. The editors made every effort to preserve information and opinions expressed by the authors. For further information regarding individual surveys, hyperlinks to survey documentation and technical/peer-reviewed publications are listed below.

4.1 National Coral Reef Monitoring Program (NCRMP)

How is it funded, who administers it?

- NOAA Coral Reef Conservation Program (CRCP). Historically CRCP funded NCCOS work in Puerto Rico. CRCP, the National Park Service and CCMA funded work in St John and St. Croix. Flower Garden Banks National Marine Sanctuary monitoring was funded by NOAA's Office of National Marine Sanctuaries and CRCP.

Why was the survey originally designed?

- NCRMP: To standardize reef and coral monitoring across all US coral reef jurisdictions. Prior to NCRMP monitoring in Puerto Rico was established to first characterize the benthic habitats, fish and invertebrate communities in the La Parguera Natural Reserve. Subsequent monitoring was to examine spatial patterns and associated habitat affinities between fish communities, benthic habitats, and benthic communities
- FGBNMS: surveys were designed to provide a spatially comprehensive characterization of fish and invertebrates and generate a baseline of population estimates fish and benthic communities.
- St John surveys were designed to first spatially characterize the coral reef ecosystem, then monitor and assess fish and benthic communities around the island of St. John.
- St. Croix surveys were designed to first, characterize fish and benthic communities, then monitor changes in communities, primarily as it related to inside or outside the Buck Island Reef National Monument.

What are/were the intended outcomes/objectives?

- The NCRMP program is intended to support conservation of the nation's coral reef ecosystems through documenting and understanding the status and trends of core indicators. A comprehensive description of the NCRMP program can be found at: https://nccospublicstor.blob.core.windows.net/projects-attachments/180/2014_GCFI_US_National_Coral_Reef_Monitoring_Program_NCRMP.pdf.
- Puerto Rico and US Virgin Islands data were to be used to help resource managers make management decisions.

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

http://sero.nmfs.noaa.gov/sustainable_fisheries/caribbean/fish_indep_wkshp/surveys/ncrmp/index.html (look for hyperlinks under "geographic coverage"

How often is the survey conducted (annually, biennially, biannually etc.)?

- NCRMP: Biennially (US Virgin Islands & FGBNMS odd years; Florida reef tract & Puerto Rico even years)
- Surveys in Puerto Rico and US Virgin Islands were annual from 2000-2012 (but in smaller areas)
- Surveys in FGBNMS were annual from 2006-2007, 2010-2012

Is it seasonal?

- Surveys conducted in the summer throughout most of the Atlantic/Caribbean
- Puerto Rico-Spring and Fall, St Croix – Spring and Fall, St. John – Summer FGBNMS - Summer

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Stratified random: NCRMP:
- In the US Virgin Islands, Puerto Rico strata are: Zone (geographic regionalization), habitat type (pavement, linear reef, patch reef, bedrock, scattered coral rock and sand), and depth (shallow >12.9 m, deep <12.9 m)
- FGBNMS strata are 2: bank (East and West) and relief type (high relief, low relief).
- Historically, Puerto Rico surveys were stratified by hard, soft, mangrove to depths of 100'. Same for US Virgin Islands to 100'. FGBNMS surveys were stratified by bank and habitat relief (high or low) and at depths between 60-110'

Describe allocation of sites per strata (proportional/weighted?) and number of sites

- NCRMP has started with site allocation based on strata proportional area, with the ultimate goal of having allocation determined by statistical optimal allocation design to maintain precision within 20%
- FGBNMS site allocation also based on proportional area of strata. US Virgin Islands

Describe the methodology and gear

- In-situ scuba surveys (25x4m 15 min swimming transect) from small boat. Numbers and sizes of all fish enumerated, measured in 5cm bins, and to the cm for any fish over 30cm. Transect tapes, quadrats (prior to NCRMP), measuring devices (tapes, PVC, etc.).

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- NCRMP: 2013-US Virgin Islands surveys 282 fish/LPI - variance structure unknown for now
- NCRMP: 2013 FGBNMS surveys 69 fish/LPI - variance structure unknown for now

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?
- Survey design captured all species (except for the ultra cryptics)
- Surveys were conducted during daylight hours, missed the nocturnal species movements
- Pre-NCRMP surveys surveyed non-hardbottom species, especially those in mangroves. Especially important in Puerto Rico.

What are the gear/method biases (catchability, size selectivity)?
- Cryptics can be difficult; fish avoidance to diver can impact catchability

What are the temporal/spatial limitations?
- NCRMP biennial timeframe is necessary based on the resources.
- NCRMP spatial design is limited to 100' or less
- Pre-NCRMP spatial design encompassed all ecosystem components, not just hard bottom
- Spatial design is ideal to examine biological patterns at the scale of an island or jurisdiction. The spread of survey points in a stratified random design can be logistically cumbersome.

Is this survey expected to continue into the future?
- Yes

It is relatively expensive/inexpensive, logistically difficult/easy?
- Economically, it is costing $1.07 Million per year in the Atlantic/Caribbean
- Logistics: US Virgin Islands & FGBNMS relatively easy. Puerto Rico difficult

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage
- Biannual coverage is not preferred
- Spatial coverage is good to assess fish populations throughout a jurisdiction; however depth range is an issue

Data generated: length frequency, spawning stock biomass, mortality etc.
- Biomass
- Length frequency
- Frequency of occurrence
- Population estimates by habitat types
- Species richness
- Diversity indices
- Community structure, trophic groups, etc.

Provide any other information that may be relevant to this discussion
- N/A

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

Methods/protocols

St John

http://www2.coastalscience.noaa.gov/publications/detail.aspx?resource=ZkLaj6QXfndslVpEEeSU9rVY/Opd2Lp8O2PS2+g0cwE=

St. Croix
http://www2.coastalscience.noaa.gov/publications/detail.aspx?resource=ih5GYB5RkXge9lYp5WIffNjrXfy7cB2fVtHC5opbHOE=

Puerto Rico
http://www2.coastalscience.noaa.gov/publications/detail.aspx?resource=TQDDaQTzSHYyvH2qjSIR7Y5BjLQzv+d9cHdIyLvTWpI=
FGBNMS
http://www2.coastalscience.noaa.gov/publications/detail.aspx?resource=noTxWAgvnxDAOstUl9MKTFBTPr5tNWs8bKFqQAGslRU=

Peer-review publications, SEDAR reports
http://www2.coastalscience.noaa.gov/publications/detail.aspx?resource=oFGitUW2uSY9oyXYVCfpC3kmhb/5Xl978jpor3iufBw=

http://www2.coastalscience.noaa.gov/publications/detail.aspx?resource=W1SMQwkf7vd5q/AdmmRXhge+hQFV24V5jiC/fMUbL/w=

http://www2.coastalscience.noaa.gov/publications/detail.aspx?resource=wMcSb3lvoqmKVpv+fBfw82mUZfK61qz6XZTbSdK8TQc=
http://www2.coastalscience.noaa.gov/publications/detail.aspx?resource=7ByQIBbsgtmTyjaGrODvDnh9kcwSqydqb2ryBgohkXk=

http://www2.coastalscience.noaa.gov/publications/detail.aspx?resource=YbA3+aoE2aLjqPb32QypJSn2m9BpUm3yZ/5fQviET14=

http://www2.coastalscience.noaa.gov/publications/detail.aspx?resource=P8MFj8BHUPozDokfHSf9Cml4hxYnvE6LDfNatWkYhcs=

4.2 Southern Florida Reef-fish Visual Survey

How is it funded, who administers it?

- Partnership funded by NOAA CRCP, State of Florida, and National Park Service
- Key scientific partners: NOAA Southeast Fisheries Science Center, University of Miami Rosenstiel School of Marine and Atmospheric Science, FL Fish and Wildlife Conservation Commission, NPS South Florida/Caribbean Network, Dry Tortugas National Park, Nova Southeastern Univ.

Why was the survey originally designed?

- 1979: Evaluate effects of spearfishing zones (open, closed) on reef-fish community
- 1994: Expanded to (1) provide size-structured abundance metrics for stock assessment; (2) to evaluate efficacy/performance of no-take marine reserves; and, (3) to evaluate reef-fish community dynamics (e.g., structure/diversity).

What are/were the intended outcomes/objectives?

- To provide estimates of abundance-at-size for reef-fish species (encompassing both pre-exploited and exploited sizes) in the southern Florida coral reef ecosystem.
    - These in turn are used: (1) to estimate population indicator variables (e.g., average size, relative abundance, biomass, etc.) for determining resource sustainability in stock assessments; (2) to design spatial protection strategies and evaluate their efficacy; and, (3) to analyze species and community dynamics (e.g., community structure and diversity, spatial use of habitats, etc.).

Describe the temporal and spatial coverage of the survey.

Show the geographic coverage (including depth) of the survey (maps are helpful)

- All mapped live coral habitats <33 m in the southern Florida reef tract extending from the Dry Tortugas northeastward through Martin County.
- Three main subregions: Dry Tortugas, Florida Keys (including Biscayne National Park), and Southeast FL (northern Miami-Dade, Broward, Palm Beach, and Martin counties).

How often is the survey conducted (annually, biennially, biannually etc.)?

- Florida Keys: annual, 1979-2012; every other year starting in 2014.
- Dry Tortugas: mostly every other year, 1999-2014.
- Southeast FL: annual, 2012-2014, every other year starting in 2016.

Is it seasonal?

- One principal season, May-Sep

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Stratified-random; strata are combination of cross-shelf position, depth, reef morphology and complexity, and spatial management zones.

Describe allocation of sites per strata (proportional/weighted?) and number of sites

- Optimal (Neyman) allocation strategy, weighted by both stratum size and stratum variance of density for principal exploited species (snappers, groupers, grunts, wrasses).
- Florida Keys and Dry Tortugas: about 800 statistical sample units per survey in each subregion (400 primary sample units (PSU), 2 second-stage units (SSU) per PSU, 2 diver counts per SSU).
- Southeast Florida: 500-600 sample units per survey.

Describe the methodology and gear

- Scuba air/nitrox divers, visual stationary plot (7.5 m radius) method.

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Principal biological data, each sample unit (SSU): numbers-at-length (cm) by fish species.

- Principal environmental data, each SSU: latitude, longitude, min-max-mean depth, reef morphology (patchy, contiguous, spur-groove), substrate composition (soft bottom, hardbottom), substrate vertical relief, biotic cover (corals, octocorals, macroalgae, sponges, etc.).
- Outputs: strata and whole sample frame estimates of proportion occurrence, density-abundance, abundance-at-length, and mean length by species and life stage (juvenile/adult, pre-exploited/exploited); additional derived estimates of biomass by species (using weight-length conversions) and community metrics (species richness, etc.).
- Variance structure: standard error of mean density ranges from 15-20% of the mean value (CV) for principal exploited species within each survey subregion, enabling statistical detection of temporal changes in density of 30-40%; standard errors are generally lower for non-target species (10-15% of mean value).

Self-Evaluation of pros and cons of Survey

What suite of species does this survey target (what are gaps)?

- Reef-associated fishes at depths <33 m; the survey frame includes principal habitats for juvenile/late juvenile and adult life stages for most shallow-water species; does not include early juvenile life stages of some species that occur outside the survey frame (e.g., seagrass beds in coastal bays).

What are the gear/method biases (catchability, size selectivity)?

- Lower size limit for species detection and identification is about 1-2 cm.
- Sightability (i.e., catchability) is low for small cryptic species, and less than 100% for all species.

What are the temporal/spatial limitations?

- Spatial limitations are rooted in the operating maps: (A) The survey frame is restricted at present to depths shallower than 33 m, the safe diving limit for standard open circuit scuba air/nitrox; diving technology and personnel capabilities are available to sample deeper reefs, but participating agencies are risk-averse to diving deeper at present. (B) The spatial survey frame is restricted to areas where coral reef habitats have been mapped; there are still numerous areas in the southern Florida coral reef ecosystem that are not mapped or are mapped poorly, including reef habitats deeper than 25 m, the Marquesas region between Key West and the Dry Tortugas, the area around Riley's Hump in the Tortugas region, etc.
- Temporal limitations: (A) Seasonal restrictions: weather conditions outside the primary May-Sep time frame are less favorable for diving (e.g., grouper spawning seasons in winter). (B) Sampling frequency restrictions: decreases in funding have changed the frequency from annual to every 2 years in most survey subregions.

Is this survey expected to continue into the future?

- Yes, as long as the multiagency partnership and funding stays together.

It is relatively expensive/inexpensive, logistically difficult/easy?

- In the general realm of fishery-independent surveys, moderately inexpensive and logistically straightforward.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- High utility for regional assessments; survey frame encompasses the principal stock area for a number of high-profile exploited reef fish species, and provides updates of key indices every 1-2 years. Survey frame overlaps with commercial and recreational fleets, with two notable exceptions: fishing fleets sample deeper reefs, diver visual survey samples no-take marine reserves.

Data generated: length frequency, spawning stock biomass, mortality etc.

- Survey provides same indices and indicator variables needed for assessment as fishery-dependent catch-sampling programs, but with greater statistical rigor.
- Additionally, survey provides indices for pre-exploited recruits to the fishery and data for the entire reef fish community.

Provide any other information that may be relevant to this discussion

- Statistical principles and framework for probability sampling of southern Florida reef-fish community were the basis for design and implementation of large-scale diver visual surveys in the northwestern Hawaiian Islands, Puerto Rico, and the US Virgin Islands.

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

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

Bohnsack, J.A., McClellan, D.B., Harper, D.E., Davenport, G.S., Konoval, G.J., Eklund, A.M., Contillo, J.P., Bolden, S.K., Fischel, P.C., Sandorf, G.S., Javech, J.C., White, M.W., Pickett, M.H., Hulsbeck, M.W., Tobias, J.L., Ault, J.S., Meester, G.A., Smith, S.G., Luo., J., 1999. Baseline data for evaluating reef fish populations in the Florida Keys. NOAA Tech. Memo. NMFS-SEFSC-427.

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.

Peer Review Publications

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Ault, J.S., Bohnsack, J.A., Meester, G.A., 1998. A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in the Florida Keys. Fish. Bull. (Wash. D.C.) 96, 395-414.

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Meester, G.A., A. Mehrotra, J.S. Ault, and E.K. Baker. 2004. Designing marine reserves for fishery management. Management Science 50(8): 1031-1043.

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Ault, J.S., S.G. Smith, J.A. Bohnsack, J. Luo, D.E. Harper and D.B. McClellan. 2006. Building sustainable fisheries in Florida's coral reef ecosystem: positive signs in the Dry Tortugas. Bulletin of Marine Science 78: 633-654.
Ault, J.S., S.G. Smith, J. Luo, M.E. Monaco and R.S. Appeldoorn. 2008. Length-based assessment of sustainability benchmarks for coral reef fishes in Puerto Rico. Environmental Conservation 35: 221-231.
Bartholomew, A., Bohnsack, J.A., Smith, S.G., Ault, J.S., Harper, D.E., McClellan, D.B. 2008. Influence of marine reserve size and boundary length on the initial response of exploited reef fishes in the Florida Keys National Marine Sanctuary, USA. Landscape Ecology 23(Suppl. 1): 55-65.
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Ruttenberg, B.I., P.J. Schofield, J.L. Akins, A. Acosta, M.W. Feeley, J. Blondeau, S.G. Smith and J.S. Ault. 2012. Rapid invasion of Indo-Pacific lionfishes (*Pterois volitans* and *Pterois miles*) in the Florida Keys, USA: evidence from multiple pre- and post-invasion data sets. Bulletin of Marine Science 88: 1051-1059.
Ault, J.S., S.G. Smith, J.A. Bohnsack, J. Luo, N. Zurcher, D.B. McClellan, T.A. Ziegler, D.E. Hallac, M. Patterson, M.W. Feeley, B.I. Ruttenberg, J. Hunt, D. Kimball and B. Causey. 2013. Assessing coral reef fish population and community changes in response to marine reserves in the Dry Tortugas, Florida, USA. Fisheries Research 144: 28-37.
Ault, J.S., S.G. Smith, J. Browder, W. Nuttle, E.C. Franklin, J. Luo, G.T. DiNardo and J.A. Bohnsack. 2014. Indicators for assessing the ecological dynamics and sustainability of southern Florida's coral reef and coastal fisheries. Ecological Indicators 44: 164-172.

4.3 Virgin Islands National Park Reef Fish Monitoring

How is it funded, who administers it?

- Creatively! Several sources in first 2 decades, NPS, NOAA, Sea Grant. Now NPS I&M Program

Why was the survey originally designed?

- Monitoring of Diversity Hot Spots; 4 Reference Reefs selected around St. John

What are/were the intended outcomes/objectives?

- Monitoring of long-term trends

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- Four Reference Reefs of similar size, structure, and coral cover (10,000+m2)
- Sampling depth 5-20m

How often is the survey conducted (annually, biennially, biannually etc.)?

- Annual sampling (July-August)
-

Is it seasonal?

- No

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Stratified, haphazard sampling; 18 samples on fore reef platform, 18 on fore reef edge

Describe allocation of sites per strata (proportional/weighted?) and number of sites

- Four Reference Reefs in four bays, 2 north side; 2 south side

Describe the methodology and gear

- Unmodified Bohnsack-Bannerot Visual Stationary Point Counts. 2-3 divers in most years.
- 15 m diameter, 5 min species counts; number and sizes added at end of 5 min
- 1989-1994: 15 m Plot counts conducted. Returned to unmodified counts in 1995.

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Regression trends calculated for 1995-2014 data; variance is homoscedastic

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?

- All reef fish species are targeted; large individuals, transient species, and nocturnal species are under-represented.

What are the gear/method biases (catchability, size selectivity)?

- Visual methods are biased to observable, non-cryptic species

What are the temporal/spatial limitations?

- Sampling is limited to Reference Reefs around St. John. Results provide trends for that island and Virgin Islands National Park in their high diversity hot spots. Results should not be extrapolated to other islands or offshore reefs.

Is this survey expected to continue into the future?

- Yes! As a task in the NPS I&M Program.

It is relatively expensive/inexpensive, logistically difficult/easy?

- Inexpensive and relatively easy. Can be conducted by 2 divers over 4 days

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

Data generated: length frequency, spawning stock biomass, mortality etc.

- This Monitoring Project was not designed to provide data for stock assessment.
- It was designed to provide Biodiversity Data Trends on Four Diversity Hot Spots for future resource management assessment by NPS

Provide any other information that may be relevant to this discussion

- High-diversity reefs must be recognized as high-priority strata for monitoring programs. These hotspots are vital for assessment of trends (canaries in the coal mine), important spawning and juvenile nursery sites, and source refugia.

Provide most relevant documentation (w/PDFs or hyperlinks if possible)
Several NPS reports

Friedlander, A. and J. Beets. 2007. Temporal Trends in Reef Fish Assemblages inside Virgin Islands National Park and around St. John, US Virgin Islands, 1988-2006. NOAA. NOAA/NOS/NCCOS/CCMA– Biogeography Branch Technical Report.

NPS report and publication *in prep*.

4.4 St. Croix Cooperative Fishery-Independent Trap Survey

How is it funded, who administers it?

- One time funding through CRCP, administered by SEFSC Sustainable Fisheries Division (Gulf and Caribbean branch)

Why was the survey originally designed?

- A total void of spatially comprehensive fishery-independent data in US Caribbean

What are/were the intended outcomes/objectives?

- Proof of concept that a cooperative fishery-independent program was doable in the US Caribbean
- Spatially comprehensive snapshot of CPUE , species composition, and length data
- Estimation of spatial structure to be able to create maps of relative abundance

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- Entire shelf of St. Croix - 6 feet - ~150 feet. A map of the distribution of sampling sites can be found in Figure 1 on page 3 of Bryan et al. (2013).

How often is the survey conducted (annually, biennially, biannually etc.)? Is it seasonal?

- One time. Surveys were conducted between October 5, 2010 and November 13, 2010.

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Novel mix of stratified random and spatially optimal sampling design to fill in spatial gaps. Key point is that one is design based and the other is model based.
- Four strata for design based were hard bottom, soft bottom, closed areas, open areas.

Describe allocation of sites per strata (proportional/weighted?) and number of sites

- ~600 stations
- Allocation of 400 samples to stratified random was proportional to area of each habitat type
- Allocation of 200 spatial optimal samples was to identify the location that would result in the greatest reduction in spatial variance to fill in spatial gaps.

Describe the methodology and gear

- Chevron fish traps of local design baited with squid for 24 hour soak

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Data collected was number and length by species, number hours fished (protocol was for 24 hours but standardized by actual soak time).
- Variance structure is dependent on sampling method (stratified random or spatially optimal) and on the distribution and abundance of species of interest and can be described as requested

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?

- All shelf species that get caught in traps when baited with squid for a 24 hour soak. Top 10 species were white grunt, queen triggerfish, blue tang, banded butterflyfish, yellowtail snapper, doctorfish, black durgeon, schoolmaster snapper, red hind, and blue runner. Five Nassau grouper were captured.

What are the gear/method biases (catchability, size selectivity)?

- Size selectivity is likely to be dome shaped for species that grow large enough to be excluded by funnel size.
- Catchability was not estimated. Relative catchability for herbivorous species was relatively low as the traps were not fished to capture parrotfishes (see next bullet).
- Fishing methods could be modified for future work to target other species (e.g. unbaited, longer soak times would be expected to serve as habitat attractants for herbivores; bread and short soaks are commonly used for snappers; long soaks and cow hide bait is commonly used for lobsters).

What are the temporal/spatial limitations?

- In study area of St. Croix, limitations were setting traps in extremely deep water, and presence of protected corals preclude setting traps in areas of *Acropora spp*.

Is this survey expected to continue into the future?

- Unknown, no dedicated funding

It is relatively expensive/inexpensive, logistically difficult/easy?

- Per station, the sampling is relatively inexpensive and the fact that it uses gear similar to standard fishing means fishing logistics are relatively easy. However, logistically achieving the sampling design can be difficult.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- Very good to excellent on spatial and weak on temporal.

Data generated: length frequency, spawning stock biomass, mortality etc.

- Length frequency data are most valuable. Mortality rates can be calculated from length frequency. Given temporal weakness and lack of time series, the estimates must be treated with caution.

Provide any other information that may be relevant to this discussion

- N/A

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

Bryan, Meaghan D., Gedamke, T., and Walter, John F. 2013. A pilot, cooperative fishery-independent trap survey of Saint Croix, United States Virgin Islands. NOAA Technical Memorandum NMFS-SEFSC-641, 28pp.

Presentations:

Gedamke, Todd, J Schull, B Kojis. Genesis of a cooperative fishery-independent survey for an island platform in the US Caribbean, Gulf and Caribbean Fisheries Institute. 2010.

Bryan, Meaghan D., T. Gedamke, JF Walter, and J Schull. A pilot, cooperative fishery-independent survey of Saint Croix, US Virgin Islands, American Fisheries Society. 2013

4.5 A Brief Summary of Early Exploratory and Fishery-Independent Caribbean Surveys Conducted by NMFS Pascagoula

How is it funded, who administers it?

- NMFS Pascagoula

Why was the surveys originally designed?

- To explore possible fishery resources in the US Caribbean.

What are/were the intended outcomes/objectives?

- Various. See table in link: http://sero.nmfs.noaa.gov/sustainable_fisheries/caribbean/fish_indep_wkshp/documents/pdfs/presentations/ingram_early_fi_caribbean_surveys.pdf

Describe the temporal and spatial coverage of the survey

Show the geographic coverage of the survey

- See table and **Figure 4.5.1** below

How often is the survey conducted?

- Annually, but not necessarily during the same season each year.

Is it seasonal?

- No

Describe the underlying experimental design
See table in link:
http://sero.nmfs.noaa.gov/sustainable_fisheries/caribbean/fish_indep_wkshp/documents/pdfs/presentations/ingram_early_fi_caribbean_surveys.pdf

- **Describe the methodology and gear**
- See in link above

Describe the outputs of the survey

- The data are digitally available from 1979. Most datasets contain catch and length data with gear type, location, and limited environmental/habitat information.

Self-Evaluation of pros and cons of Survey

What suite of species does this survey target?

- These surveys targeted multiple species. The reef associated surveys have collected red hind, while the deeper surveys collect members of the deep water snapper group.

What are the gear/method biases?

- There are numerous gear and method biases, due to the fact that each survey has its own specific objectives (see table in link above).

What are the temporal/spatial limitations?

- Due to the fact that each survey has its own specific objectives (see table in link above), there is no consistent temporal/spatial sampling over the time series. Also, in all surveys listed below the density of sampling effort is low compared to the area of the US Caribbean.

Is this survey expected to continue into the future?

- No

It is relatively expensive/inexpensive, logistically difficult/easy?

- It is expensive and logistically difficult to conduct NOAA "white boat" surveys.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- These data are of limited utility, due to the lack of consistent temporal/spatial sampling over the time series.

Data generated

- CPUE data are of very limited utility, and length data may be of some utility for certain species.

Provide any other information that may be relevant to this discussion

- N/A

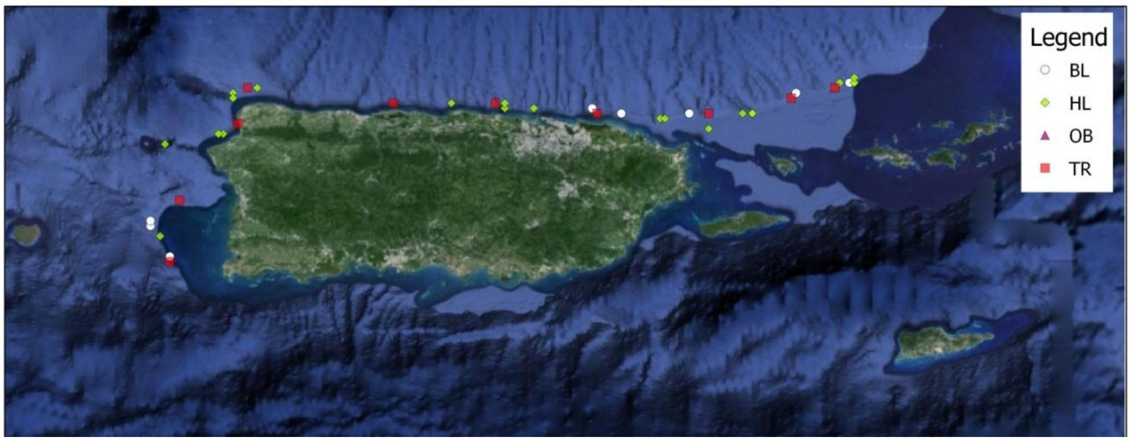
Provide most relevant documentation

- Cruise reports can be found here:

http://sero.nmfs.noaa.gov/sustainable_fisheries/caribbean/fish_indep_wkshp/surveys/early_fi/index.html

Figure 4.5.1 Maps showing sampling distribution of traps, handlines, off-bottom longline, and bottom longline effort from 1979-1985.

1979



1980

1981

Figure 4.5.1 (cont.)

1982

1983

1984

Figure 4.5.1 (cont.)

1985

4.6 Caribbean Reef Fish Video Survey

How is it funded, who administers it?

- SEFSC funded, SEFSC-Pascagoula administers it

Why was the survey originally designed?

- The Caribbean Reef Fish survey is designed to provide much-needed fishery-independent indices of spawning stocks of reef fish in US Caribbean waters using cameras, traps and vertical line catch gear (bandit reels).

What are/were the intended outcomes/objectives?

- Same objective as in above. Additionally we are now coordinating as much as possible with NOS Beaufort on mutual habitat mapping goals.

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- US Caribbean including Puerto Rico, St. Thomas, and St. Croix.

How often is the survey conducted (annually, biennially, biannually etc.)?

- 2009 and 2012. Intended to be every 3 years (word of mouth).

Is it seasonal?

- Conducted in late spring – early summer (May-June).

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)

- Stratified-random based on habitat and depth.

Describe allocation of sites per strata (proportional/weighted?) and number of sites

- Proportional

Describe the methodology and gear

- Primary sampling tool is a stationary baited stereo-camera. Current secondary sampling tool is the vertical line gear. Historically there have also been traps and longlines deployed during the cruise. In 2012 we also collected acoustic biomass information with scientific echosounders (ME70).

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Video drops are read in the exact same way as the SEAMAP reef fish video survey of the Gulf of Mexico. This produces a MinCount (MaxN) value of abundance. Vertical lines are used to collect age, growth and reproductive information. Very little has been done with the data. Two years is certainly not enough to create any indices of abundance. Might be useful for community structure and habitat.

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are the gaps)?

- Caribbean reef fish species living in the mesophotic zone.

What are the gear/method biases (catchability, size selectivity)?

- Bottom placement of camera does not evaluate anything up in the water column well. Cryptic species are difficult to identify. Baited cameras concentrate biomass and make estimation of spatial densities problematic if not impossible. MinCount has been shown to be non-linearly related to true abundance in modeling and tank experiments.

What are the temporal/spatial limitations?

- Ship time and budget constraints seem to preclude this survey actually taking place. Cameras are limited to 150m or shallower. Shallow inshore reef areas are inaccessible aboard NOAA ship Pisces (15m cut off). Previously, poor mapping of the area resulted in poor site selection (advancements in mapping are helping tremendously).

Is this survey expected to continue into the future?

- Yes, budget dependent.

Is it relatively expensive/inexpensive, logistically difficult/easy?

- Difficult for me to assess from the monetary standpoint. Logistically speaking the transit time from the continental US to the sampling location is long. All scientific crew fly into San Juan and board the vessel in Puerto Rico (~12 individuals) which can be costly but isn't logistically difficult. Inport in Frederiksted, St Croix is typically not an issue. Sometimes permitting can be slow.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- Spatial coverage has improved in recent years and will be much improved given the amount of mapping effort NOS Beaufort has put in. Temporal coverage is problematic. Previously site locations were chosen in poor locations, particularly for Puerto Rico.

Data generated: length frequency, spawning stock biomass, mortality etc.

- If this survey is going to be useful the frequency of the survey needs to increase.

Provide any other information that may be relevant to this discussion

- N/A

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

- SEAMAP protocols for all gears.

4.7 SouthEast Fishery-Independent Survey

How is it funded, who administers it?

- Funded by NMFS Expand Annual Stock Assessments, run by NMFS-SEFSC-Beaufort lab

Why was the survey originally designed?

- To expand fishery-independent sampling on the Southeast Atlantic Coast for red snapper and other snapper-grouper species

What are/were the intended outcomes/objectives?

- Expand fishery-independent sampling in the region via multibeam mapping, (2) including underwater video as a survey gear, and (3) provide biological samples and indices of abundance to improve stock assessments for snapper-grouper species.

Describe the temporal and spatial coverage of the survey

- The survey is conducted from east-central Florida to Cape Hatteras, North Carolina (**Figure 4.7.1**).

How often is the survey conducted (annually, biennially, biannually etc.)?

- Annually. Began in 2010.

Is it seasonal?

- Yes, April – October each year.

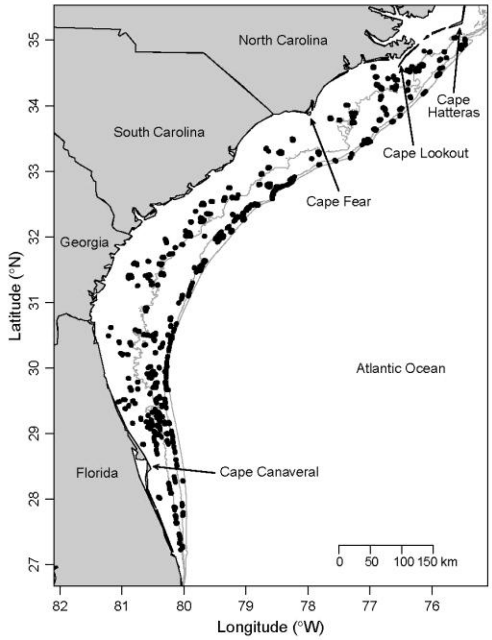


Figure 4.7.1. Spatial distribution of chevron trap sampling by the Southeast Reef Fish Survey between North Carolina and Florida. Each point represents a single station in the sampling frame, and gray lines indicate 30-, 50-, and 100-m isobaths. Note that symbols often overlap.

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Simple random sampling design, but will likely be stratified random in 2015.

Describe allocation of sites per strata (proportional/weighted?) and number of sites.

- Overall, approximately 1,500 stations sampled each year, no allocation.

Describe the methodology and gear.

- Baited chevron fish traps with attached video cameras.

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data.

- Trap and video indices of abundance available for priority fish species. Coefficients of variation were approximately 15-20% (video) and 20-25% (traps) for gray triggerfish and red snapper (SEDAR 41).

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?

- Snapper-grouper species of economic importance. Non-fishery (but common) species such as tomtate or scup are enumerated in traps but not counted on video due to time constraints.

What are the gear/method biases (catchability, size selectivity)?

- Traps tend to have low catchabilities and flat-topped or dome selectivity patterns. Video "catchabilities" are likely higher and video is likely less selective than traps.

What are the temporal/spatial limitations?

- Winter spatial dynamics are unknown since no winter sampling occurs. The survey is spatially comprehensive given the approximately 1500 samples each year.

Is this survey expected to continue into the future?

- Yes.

It is relatively expensive/inexpensive, logistically difficult/easy?

- Relatively expensive due to ship time; logistically difficult.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage.

- Adequate.

Data generated: length frequency, spawning stock biomass, mortality etc.

- Length, weight, age, genetic, and reproductive information for priority species. Trap- and video-based indices of abundance are available for most species.

Provide any other information that may be relevant to this discussion.

- Currently examining ways that trap and video information can be combined using occupancy or N-mixture modeling approaches, so that underlying abundance patterns can be separated from the detection/sampling process.

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

http://sedarweb.org/sedar-41
http://www.sefsc.noaa.gov/FEBpub/bacheler_etal_2013_FB.pdf
http://icesjms.oxfordjournals.org/content/70/4/873.abstract
http://www.sciencedirect.com/science/article/pii/S0165783613000167
http://sedarweb.org/s41rd34-depth-related-distribution-postjuvenile-red-snapper-southeastern-us-atlantic-ocean-waters
http://www.nrcresearchpress.com/doi/abs/10.1139/cjfas-2013-0086#.VAm56fldV8E
http://www.int-res.com/articles/feature/m517p001.pdf

4.8 Reef Fish Monitoring Lane Snapper Survey

How is it funded, who administers it?

- Funded by SEAMAP-C Program and administered by DNER

Why was the survey originally designed?

- The SEAMAP-C decided to implement the recommendations made in SEDAR 8 for the yellowtail snapper in creating a lane snapper survey since the sampling methodology used in the SEAMAP survey did not sample lane snapper effectively as other species.

What are/were the intended outcomes/objectives?

- To collect, manage, and disseminate fishery-independent data on the Lane snapper, *Lutjanus synagris*, encompassed in marine waters within the territorial sea and the Exclusive Economic Zone contiguous to Puerto Rico.

- Enable Puerto Rico to identify, implement and measure the effectiveness of fishery management measures for their territorial waters.
- Enable Puerto Rico to take full advantage of an integrated, coordinated, and cost effective approach to fishery-independent data collection to fulfil priority data needs.
- Enhance the usefulness of the data, minimize the costs, and increase the accessibility of information to fishery managers through the Caribbean region.
- Support plans to conserve and manage the fisheries that are Caribbean scope.
- Establish lane snapper abundance along the west and east platform of Puerto Rico.

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- Maps are included at the end of the document for sampling stations at the east and west coasts (**Figures 4.8.1 -4.8.2**).

How often is the survey conducted (annually, biennially, biannually etc.)?

- Every five years

Is it seasonal?

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

Describe allocation of sites per strata (proportional/weighted?) and number of sites

Describe the methodology and gear

- Interview fishermen to collect information on fishing sites on the east and west coast of the Island.
- Stratify the west, south and east area in fishing sites and non-fishing sites, fishermen input required for this. Select randomly 5 non- aggregation sites and 10 (if available) sites. Quadrants will be located by Global Positioning Systems (GPS). Sample each area four times, one per season.
- Sampling will be conducted between 5:30 and 7:30 in the afternoon.
- For sampling a 300 feet #130 line was deployed. This line was anchored at both ends, with buoys to identify them. The line had 18" of a 20 pound fishing line hanging with a #10 hook at the end, every 36". Squid was used as bait. The line soaked for 45 minutes, after which it was lifted and the fish collected.
- All data were recorded and analyzed.
- For each trip the following data will be recorded was:
    A. Date, time (i.e. time out and time returned to dock).Quadrant code (latitude and longitude).
    C. Fishing time for line to the nearest 15 minutes.
    D. Weather conditions.
    E. Depth.
    F. Total number of hooked fished per vessel.
    G. Number, weight, length, reproductive condition and identification of fish per hook and line as well as by individual fishermen.
- Data were entered in the provided SEAMAP database and analysed using Microsoft Excel and SigmaPlot version 12.0.

Histology Procedure

As a side study to this project the gonads of the fish caught were collected and preserved for histological analysis.

- Pictures of the gonads were taken and identified with the gonad information.
- Upon collection gonads were weighed, fixed in Davidson's fixative, embedded in Paraplast, sectioned and stained with hematoxylin and eosin.
- The slides were examined to determine sex and reproductive stage.
- The same categories used for the visual identification were used for female fishes. It was observed that for males, the reproductive stages were not as discrete as in females, for this reason the categories used were mature or immature. The results were compared with the visual classification recorded when processing the fish.
- The purpose of this was to create a visual aid for the reproductive stage identification of gonads for the different fish species, and use it as a quality control for the visual identification of the fish gonads.
- The annual reproductive cycle was described by the monthly distribution of gonadal development stages (GDS) and by the average gonadosomatic index (GSI=100[ovary weight/ ovary weight + somatic weight]) plotted against month of collection for some species that were under evaluation by the Reproduction Program.
- To determine size at maturity (defined as the smallest size class in which 50% of the individuals are sexually mature, L50) a maturity curve was also developed for those species under consideration by the Reproductive Program.

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Annual and completion reports to SEAMAP Program. Data is used by different user for stock assessment.

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?

- The target species is the lane snapper, although the species composition includes several families of fish.

What are the gear/method biases (catchability, size selectivity)?

What are the temporal/spatial limitations?

- We need additional sampling to evaluate any of these limitations.

Is this survey expected to continue into the future?

- Yes

It is relatively expensive/inexpensive, logistically difficult/easy?

- Relatively expensive and logistically difficult.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- It was not designed to determine seasonality.

Data generated: length frequency, spawning stock biomass, mortality etc.

- Data generated include CPUE/station and per coast, length frequency, species composition per coast, reproduction and spawning season for target species and other individuals with enough samples to determine so.

Provide any other information that may be relevant to this discussion

- N/A

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

- SEAMAP-C Sampling Protocol Manual
- SEDAR 8
- Final report to SEAMAP 2012

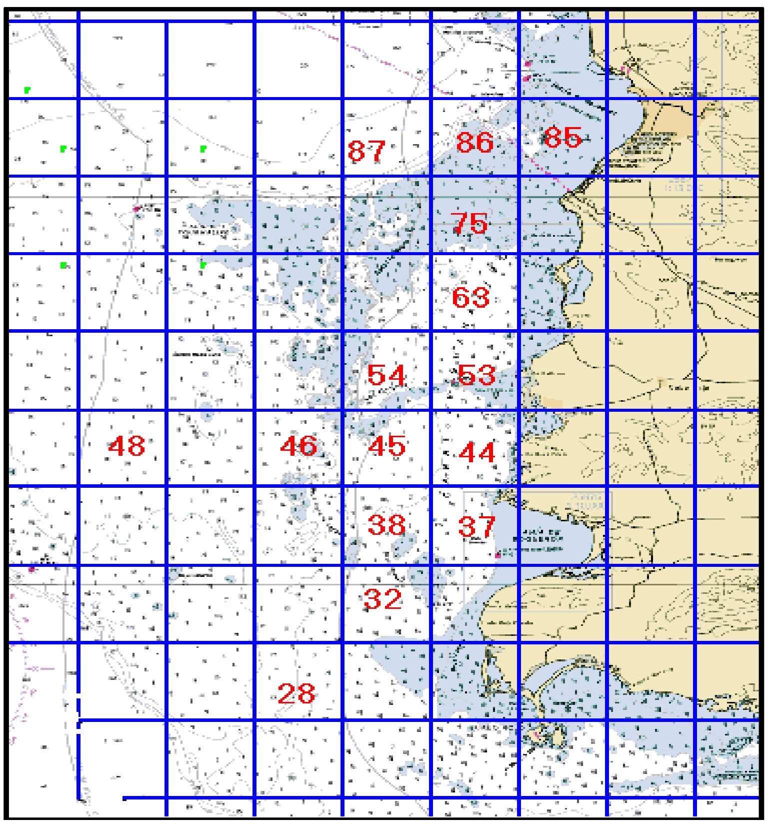


Figure 4.8.1. Sampled stations off the west coast during the lane snapper survey October 2011 to March 2012.

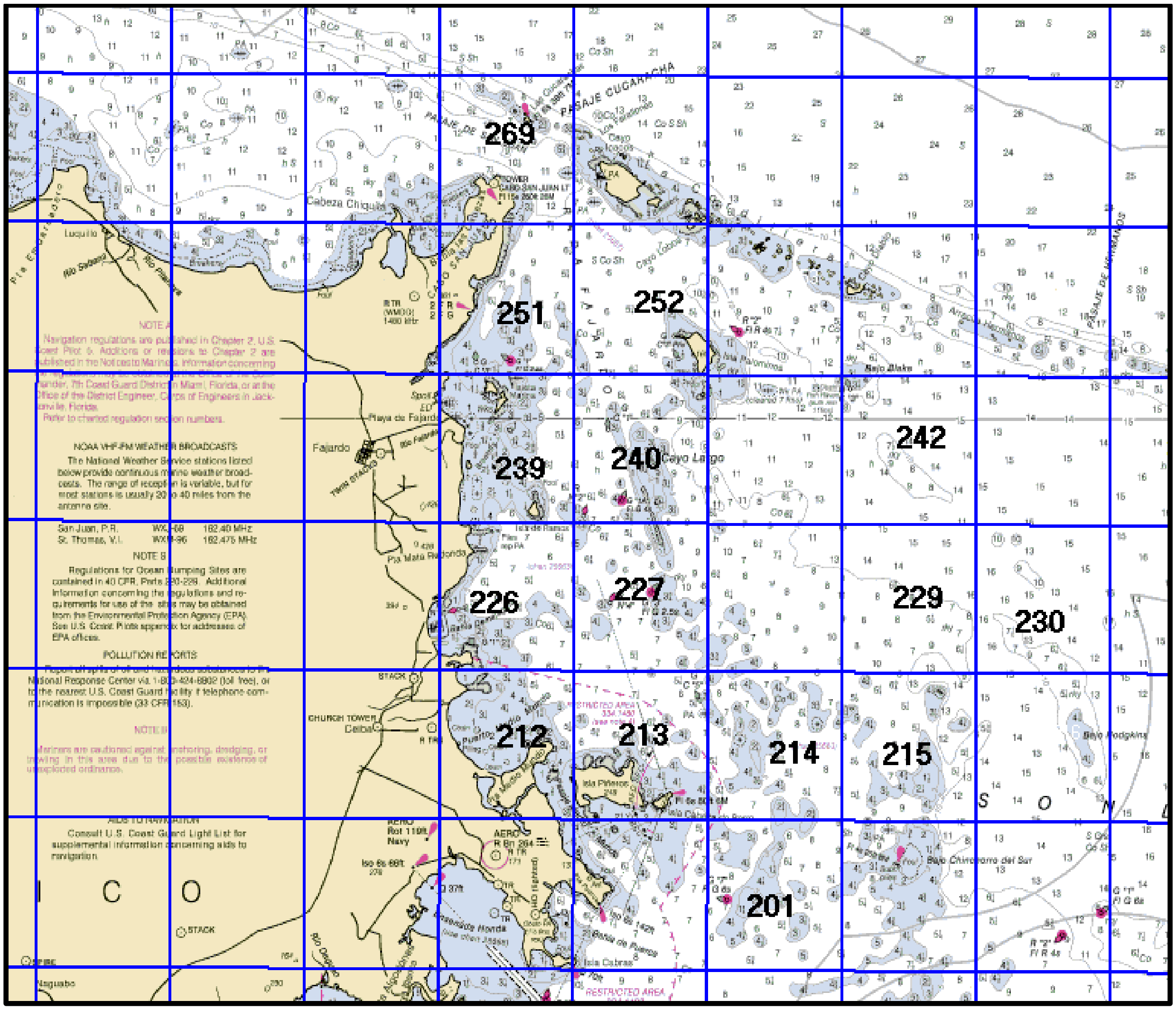


Figure 4.8.2. Sampled stations off the east coast during the lane snapper survey January to September 2012.

4.9 Recruitment of Spiny Lobster, Panulirus argus, off the southwestern Puerto Rico

How is it funded, who administers it?

- SEAMAP Program and administered by Puerto Rico DNER

Why was the survey originally designed?

- The purpose of this survey was to provide spiny lobster recruitment assessment information needed to identify fishery management needs and to implement plans to protect and restore the fishery stocks to support viable productive recreational and commercial fisheries.

What are/were the intended outcomes/objectives?

- The objective of this study was to collect and analyze data on the spiny lobster post larval recruitment and their environment encompassed in the marine waters within the territorial sea of Puerto Rico.
- Provide Puerto Rico with a time series data on pueruli settlement at seven sites off the west coast of Puerto Rico.
- To assess pueruli abundance by depth on the west coast of Puerto Rico.
- Provide information to support the Caribbean Fishery Management Council's effort to implement and monitor the effectiveness of fishery management plans for fisheries in the US EEZ.
- To conduct a population dynamics spiny lobster survey to determine the spatial and temporal variations in larval settlement, distribution and recruitment within the territorial sea of P.R. and the US EEZ, off the west coast of Puerto Rico.

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- See Below

How often is the survey conducted (annually, biennially, biannually etc.)?

- Once every five years

Is it seasonal?

- No

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Fixed site

Describe the methodology and gear

- See Below

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

See Below

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?

- Spiny lobster larval stages

What are the gear/method biases (catchability, size selectivity)?

What are the temporal/spatial limitations?

Is this survey expected to continue into the future?

- Yes*

It is relatively expensive/inexpensive, logistically difficult/easy?

- Relatively inexpensive but logistically difficult

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

Data generated: length frequency, spawning stock biomass, mortality etc.

Provide any other information that may be relevant to this discussion

- See Below

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

APPROACH 1999

Modified Witham collectors were used. As per Bannerot *et al.* (1992), and Butler and Herrnkind (I 992), this collector consisted of a PVC float and substrate, each one holding 6 pages of nylon-webbed unbacked carpet matting (NomadTM, 3M Co. Inc.) 61 x 4.5 x 0.5 cm. The collector was anchored with polypropylene line tied to concrete blocks. A Styrofoam buoy was tied to each corner of the PVC float.

Sampling stations are shown in **Figure 4.9.1**. Each collector was set in, or adjacent to, Joyuda lagoon, Boquerón Bay, Puerto Real Bay, Punta Ostiones, Playa Buyé, and Cayo Fanduca. The collectors were placed no deeper than 3 meters. A station will consist of one collector and placed approximately 3 km apart from one another. Collectors were sampled at least once every 2 weeks. Collectors were lifted from the water in a mesh bag to catch pueruli that washed out of the filter material. All collectors were thoroughly searched on board the boat and pueruli and juvenile counted. Pueruli were staged as follows: stage I - transparent, stage 2 - semi-pigmented, and stage 3 - pigmented. First stage juveniles will be distinguished from pueruli by their rounded carapace and erect supra orbital spines. This stage was considered as a stage 4 in our samples.

For each trip the following data were recorded:

a. Date, time;
b. Latitude and longitude using a GPS (station number);
c. Habitats type under the collector;
d. Weather conditions;
e. Pueruli numbers and stage and/or juvenile numbers and stages;
f. Salinity, turbidity, and temperature at each station.

Each station consisted of two Witham collectors.

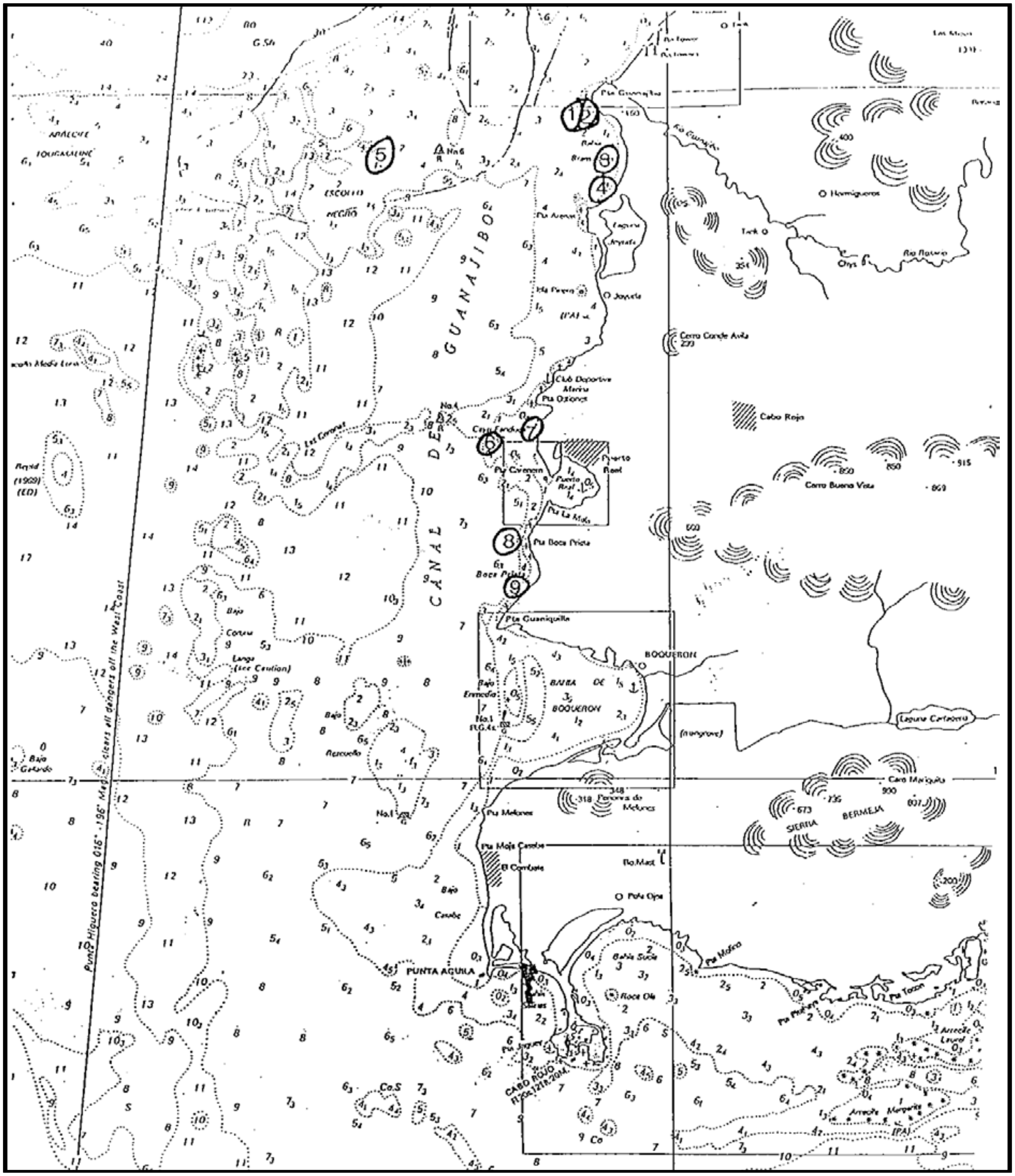


Figure 4.9.1. Sampled stations off the West Coast of Puerto Rico during lobster settlement survey from January 1998 to December 1998. Bold numbers indicate sampled stations.

Station 1 – Punta Guanajibo FRL facilities 18º09.615’N 67º11.026’W. Punta Guanajibo is south of the Guanajibo River, being the river south mouth margin. Therefore, fresh water influence to the stations close to this river is high. Water turbidity is high during the raining season. When the prevailing sea current shifts due south water transparency becomes very low. Bottom substrate consists of fine sediment with fairly well developed turtle grass mats (*Thalassia testudinum*).

Station 2 – Punta Guanajibo FRL facilities 18º09.312’N 67º11.264’W. This station is located due west of the previous one in direction to shore moving into Bahía (Bay) Bramadero. Distance between these two stations is more or less 200 m.

Station 3 – Bahía Bramadero north 18º08.834’N 67º11.162’W. This station is located near a hard bottom, consisting of rocks near shore more or less located at the center of the bay. The coastline used to be a mangrove-lined, at the present time only a small portion of mangrove remains north of the station site. Water turbidity tends to be less, than the two previous stations, although the distance between them is less than one (1) nm. Bottom substrate consists of highly developed turtle grass bed and very fine sediment.

Station 4 – Bahía Bramadero south 18º08.411N 67º11.423’W. This station is located near shore about 500 m south of the previous one. Fresh water runoff is higher in this station due to the fact that drainage from inland is located exactly in front of it. Bottom substrate is highly muddy, with sparse turtle grass mats.

Station 5 – Bahía Bramadero south 18º08.531, N 67º11.003’W. Fresh water runoff is higher in this station due to the fact that drainage from inland is located exactly in front of it. Bottom substrate is highly muddy, with sparse turtle grass mats.

Station 6 – Escollo Negro 18º08.617’N 67º14.713’W, this is an emerging fringing reef located 4-nm southwest from Punta Guanajibo.
Station 7 – Escollo Negro 18º08.628’N 67º15.020’W, this is an emerging fringing reef located 4-nm southwest from Punta Guanajibo.

Station 8 – Cayo El Ron 18º06.361’N 67º15.791’W. The name of this station comes from an emerging fringing reef located about 4½ nm from shoreline, in front of Punta Ostiones. Bottom substrate consists of fine sediment covered with turtle grass, and soft coral.

Station 9 - Cayo El Ron 18º06.231’N 67º15.496’W. The name of this station comes from an emerging fringing reef located about 4½ nm from shoreline, in front of Punta Ostiones

Station 10 – Cayo El Ron 18º06.036’N 67º15.564’W. The name of this station comes from an emerging fringing reef located about 4½ nm from shoreline, in front of Punta Ostiones. This station is located west of the two previous ones.

Artificial Habitats

Twenty modified Witham collectors were deployed at ten stations (two collectors/stations). As per Bannerot *et al*. (1992), Butler and Herrnkind (1992) and Quinn and Kojis (1997), this collector consisted of a PVC float and substrate, each one holding 6 pages of nylon-webbed unbacked carpet matting (Nomad ™, 3M Co. Inc) 61 x 4.5 x 0.5 cm. The collector was anchored with polypropylene line tied to concrete blocks. A Styrofoam buoy was tied to each corner of the PVC float.

Biological growth over the artificial habitats (fouling) was consistent with local flora and fauna. Fouling was permitted to provide a settlement surface similar to surrounding natural environment. Fouling was partially removed when overgrown became too heavy and affect floatation of the artificial habitats.

APPROACH

Each collector was set in, or adjacent to, Bramadero Bay, El Negro Reef, and El Ron Reef. The collectors were placed no deeper than 3 meters. A station will consist of two collectors placed approximately 50 feet apart from one another. Collectors were sampled at least once every 2 weeks. Collectors were lifted from the water in a mesh bag to catch pueruli that washed out of the filter material. All collectors were thoroughly searched on board the boat and pueruli and juvenile counted. Pueruli were staged as follows: stage 1 - transparent, stage 2 - semi-pigmented, and stage 3 - pigmented. First stage juveniles will be distinguished from pueruli by their rounded carapace and erect supra orbital spines. This stage was considered as a stage 4 in our samples.

The study areas were distributed from 18° 09.615'N; 67° 11.026'W to 18° 06.036' N; 67° 15.564' W (**Figure 4.9.2**). Distance from shore varied from approximately 0.5 to 5 nautical miles. The insular platform in this area is from 12-16 km wide; with an average depth of 25 m. Southeast trade winds prevail, resulting in a complex surface water flow dominated by island topography rather than by prevailing wind. In general terms water flow is along the coast from north to south. Emergent coral reefs are more common to the northwest of the study area. They do not comprise more than 10% of the shelf area. The coastline consists of well develop mangrove (*Rhizophora mangle*) forest at discreet locations, entwine with sandy beaches, and rocky coasts.

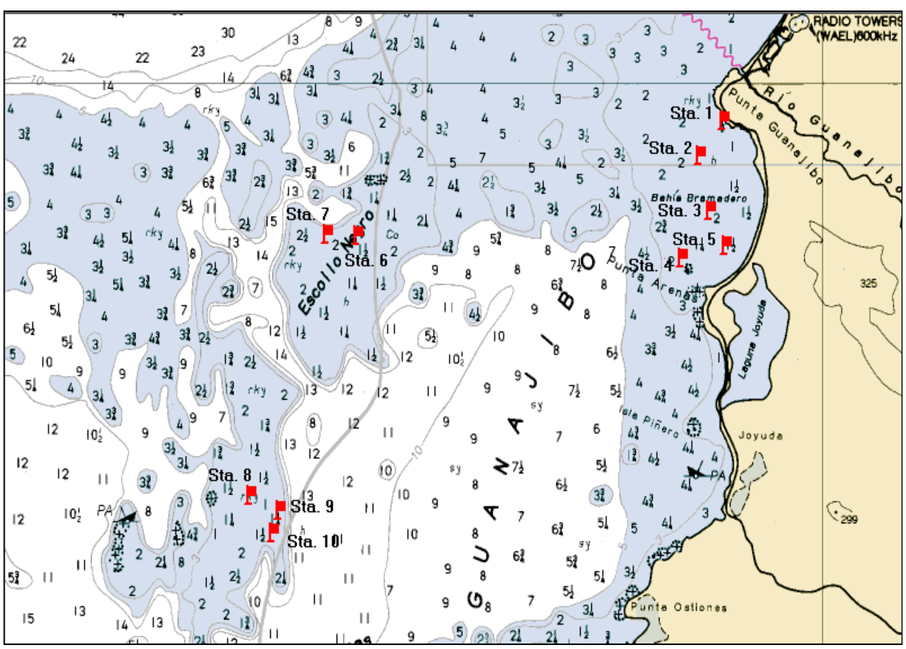


Figure 4.9.2. Spiny lobster post larvae collector stations 2003.

METHODOLOGY 2008
Study 1- Pueruli settlement

1. Seven stations were selected along the west coast platform according to depth and distance from the shoreline (**Table 4.9.1**. **Figure 4.9.3**).

Table 4.9.1. Description of station coordinates, deployment dates and replacements in 2008**.**

Station	Id	Latitude	Longitude	Date deployed
A	A1	18°08.113	67°13.704	3-Mar-08
	A2	18°08.105	67°13.692	3-Mar-08
	A2	18°08.040	67°13.673	5-Aug-08
B	B1	18°05.900	67°14.812	3-Mar-08
	B1	18°05.916	67°14.813	29-Apr-08
	B2	18°05.915	67°14.791	3-Mar-08
C	C1	18°02.291	67°15.240	3-Mar-08
	C2	18°02.231	67°15.260	3-Mar-08
D	D1	18°06.671	67°17.954	3-Mar-08
	D1	18°06.728	67°17.968	29-Apr-08
	D2	18°06.690	67°17.954	3-Mar-08
	D2	18°06.788	67°17.996	29-Apr-08
E	E1	18°07.258	67°18.941	3-Mar-08
	E2	18°07.247	67°18.968	3-Mar-08
F	F1	18°05.068	67°18.053	3-Mar-08
	F2	18°05.051	67°18.069	3-Mar-08
G	G1	18°02.627	67°18.031	3-Mar-08
	G1	18°02.682	67°18.050	19-Aug-08
	G2	18°02.661	67°18.033	3-Mar-08

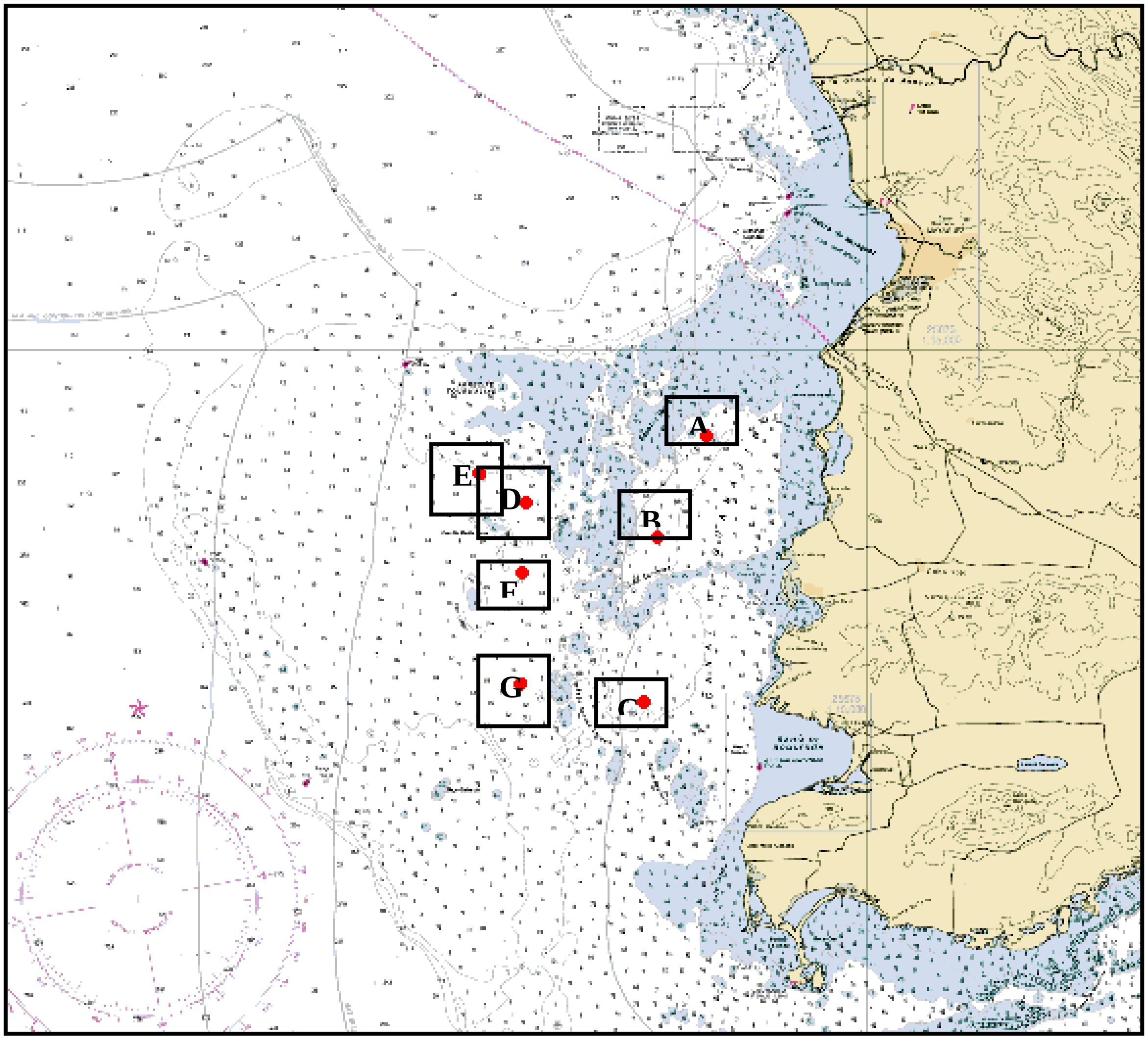


Figure 4.9.3. Location of stations for the spiny lobster pueruli collector's study 2008.

2. Fifty six modified Witham pueruli collectors (Witham et al, 1968; Pillips et al., 2005) were constructed of rectangular PVC frame with 6 sheets of air conditioning filter materials, each measuring 30 x 30 cm. Each sheet was folded around the PVC frame making 12 sheets. A piece of rope was passed inside the PVC frame to keep the frame together in case it broke. The rope went out through two of the corners of the frame. The two ends of the rope were nut tightly and a clip loop in the nut (**Figure 4.9.4**).

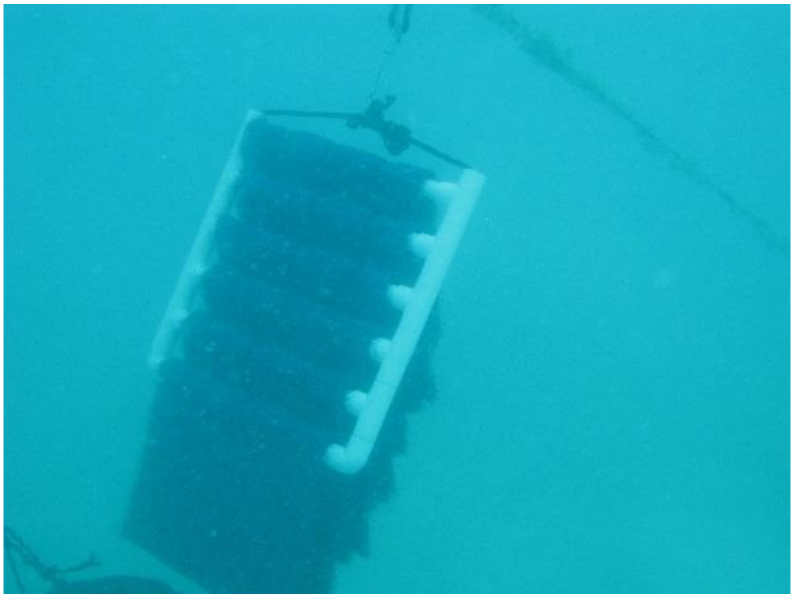


Figure 4.9.4 Spiny Lobster pueruli collector

3. The collectors were attached with the clip directly to a buoyed line anchored to the bottom. The line from the collector to the anchored line, used previously, was modified to prevent incidental entanglements of sea turtles. The anchored line had two buoys, one with the identification number and the other with a DO NOT DISTURB, STUDY ON PROGRESS signed carved on it.

4. Two sets of collectors were deployed at each station, 30 m apart from each other. Each set consisted of two collectors hooked to an anchored line. One of the collectors was hook at a depth range between 30-40 feet and the other at a depth range of 60-80 feet, 2m above the sea floor.

5. Fifty six (56) pueruli collectors were constructed in order to replaced monthly the collectors sampled. This was done to control overgrowth of other organisms in the structures. The collectors sampled were taken back to land and placed on the ground to dry with the sun.

6. Collectors were sampled once a month, between the new and the full moon. For sampling, a diver covered the collector with a fine mesh netting (so the pueruli couldn't escape), unsnap the collector, and clip it to a line with a buoy, while the replacement collector was placed in position. Once both collectors were clipped, they were brought to the boat. The anchored line was clean from organism on each visit.

7. Collectors were search for spiny lobster pueruli. All pueruli found were counted, classified according to developmental stage (transparent, pigmented and juveniles). Juveniles were distinguished from pueruli by their rounded carapace and erect supraorbital spines. The pueruli were kept in a small aquarium and released away from the area of the collectors.

8. Damaged or lost collectors were replaced.

4.10 Queen Conch Survey

How is it funded, who administers it?

- SEAMAP Program, administered by the Puerto Rico Department of Natural and Environmental Resources

Why was the survey originally designed?

- To collect, analyze, manage and disseminate fishery-independent data on the queen conch, *Strombus gigas*, resources and their habitat, encompassed in marine waters within the territorial sea and Exclusive Economic Zone (EEZ) contiguous to Puerto Rico

What are/were the intended outcomes/objectives?

- Enable Puerto Rico to identify, implement and measure the effectiveness of fishery management measures for our Territorial Waters.
- Establish and conduct a fishery-independent survey to obtain CPUE, estimate biological production of the queens' conch, evaluate trends in the fishery, and evaluate the condition of the fishery habitats.

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- The position of the survey is shown in **Figures 4.10.1 and 4.10.2**.

How often is the survey conducted (annually, biennially, biannually etc.)?

- The sampling cycle was designed to conduct the survey every four years.

Is it seasonal?

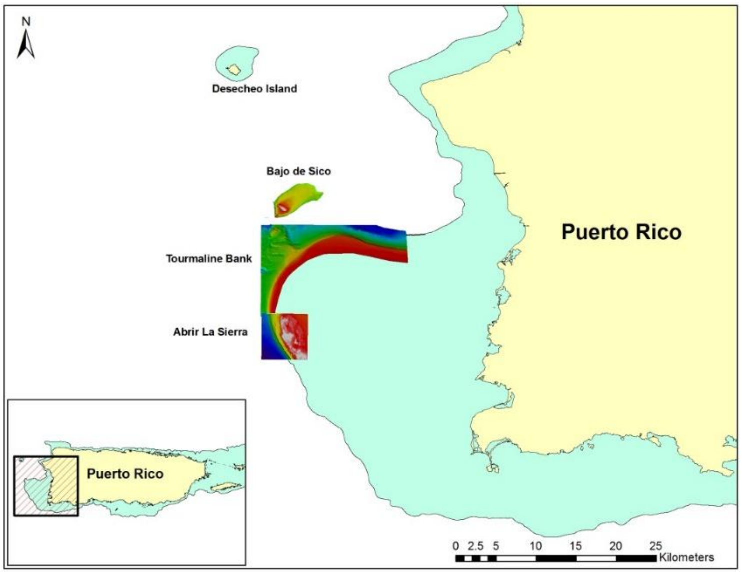


Figure 4.10.1 Position of Abrir La Sierra relative to the western insular shelf of Puerto Rico. (From Garcia-Sais *et al.* 2012).

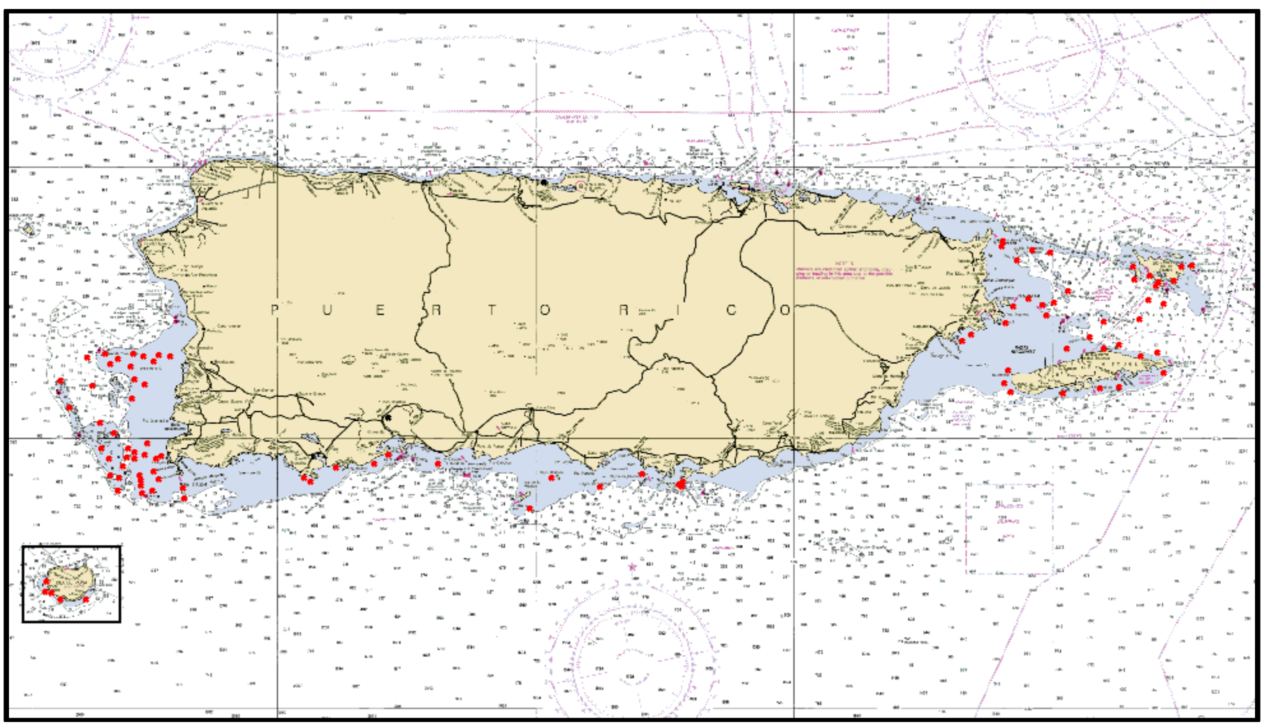


Figure 4.10.2. Nautical chart with plots of the starting point of the queen conch survey transects. 2006.

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Stratified random per identified areas of where the species might be fished currently.

Describe allocation of sites per strata (proportional/weighted?) and number of sites

- Number of total sites is 100 stations.

Describe the methodology and gear

- Visual census using underwater scooters to maximize area coverage (see below)

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Age distribution by depth and habitat stratum. Density by coasts and depths.

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?

- Queen conch and habitat description.

What are the gear/method biases (catchability, size selectivity)?

- Visual census area covered. Diver experience in detecting burrow individuals.

What are the temporal/spatial limitations?

- Depth restriction to less of 100' for diver security. If the survey is not finished during the close season, fishing activity can affect the results.

Is this survey expected to continue into the future?

- Yes

It is relatively expensive/inexpensive, logistically difficult/easy?

- Relatively inexpensive, logistically difficult.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- Provide useful information for stock assessment

Data generated: length frequency, spawning stock biomass, mortality etc.

Provide any other information that may be relevant to this discussion

- N/A

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

- See below

2006 Approach (Procedures):

During this year the Queen's conch, *Strombus gigas*, resources surrounding Puerto Rico will be surveyed. The following methodology will be used:

1. Queen conch fishermen along the west, east and south coast of Puerto Rico will be interviewed about their fishing grounds. Information collected in the interview will include fishing history on the area to separate new fishing grounds from those with a greater fishing

pressure. This information will be compared with the data collected for the queen conch stratification survey done on 1995 (Rosario, 1995). The same questionnaire will be used.

2. Sample stations will be selected in a stratified randomized manner. Stratification will be based on expected abundances as determined by historical fishing patterns. A minimum of 100 stations will be targeted.

3. Prior to the start of the survey divers will be trained on the use of the scooters; to identify and measure live conch; and maintain speed, direction and transect width. They will also be briefed on safety rules.

4. Transects are expected to be conducted during the closure season for the queen conch, from 1 July to 30 September of each year. This will prevent to a certain degree doing transects in places recently fished out. Also we want to avoid spreading the surveys during a whole year given that queen conch grow fast during their first two years (Appeldoorn).

5. Abundance and density of queen conch will be estimated from visual census surveys conducted along transect by Scuba divers using underwater scooters. Maximum survey time will be 45 minutes and will not exceed the no-decompression limits. Differential Global Position Systems will be used to locate the beginning and end of each transect. One of the divers will carry the Scuba safety buoy. The other diver will carry the compass to follow a fixed direction for a set period of time. Depth, habitat type, start and end time, time at each habitat change will be recorded. While conducting transect, the scooter will be kept approximately one meter above the substrate so that path width remained constant at 4 meters within the transect. All conchs will be counted.

6. The length of the individual conch will be measure to the nearest cm; and adult age will be estimated to one of the four relative age classes (newly mature, adult, old adult, and very old adult). Record will be kept of time when each individual is found and time when the survey is resumed. Habitat types will be the following: sand, coral, hard ground, gorgonians, sea grass and algal plains.

7. Length of transect will be obtained by calculating the distance between the beginning and end points of each transect. Using this information, speed will be calculated in meters/minute. Total area will be calculated by multiplying the distance of each transect by the transect width (4 meters). Densities will be calculated by summing the number of an adult conch observed per transect divided by the total area of each transect. Densities for each habitat will be derived by dividing the number of conch per habitat type by the total area of that habitat type per transect. Densities based on depth will be calculated by determining the number of conch in each depth range divided by the time and speed over that depth range. Overall abundance will be estimated. Length (juvenile, adult) and age (adult) frequencies will be determined. Differences in density or abundance by habitat, depth, or location will be statistically tested.

8. Length frequency distribution for adults and juveniles respectively are created. Juvenile length frequency distribution was analysed using the Bhattacharhya's method of the FISATII program.

Approach 1995

Stratification was based on expected abundance as determined by historical fishing patterns. In each area sampled (West and East coasts) two strata were defined. One consisted of the area identified to be areas of current or former fishing activity or areas known to have juveniles or other adults but not fished. The second stratum was all areas not identified as having or had conch. Within each stratum, stations were selected randomly from a grid set at 0.1-min latitude b 0.1-min longitude. One hundred stations were targeted. Areal emphasis for the survey was the southwest insular shelf of Puerto Rico, but some sampling was reserved for the east coast shelf. Estimates of abundance and density of queen conch were made from via\Sal surveys along strip-transects. Surveys were conducted by divers using underwater scooters. Transect width was four meters. Transect length was variable based on depth, but maximum survey time was set at 45 minutes, and no dives exceeded the no-decompression limits for diving safely. At each station, parallel transects were made (one/diver).

Global Positioning System was used to locate the beginning and the end of each transect. A buoy was dropped at the starting point of each transect, from which divers followed a fixed compass heading for a set period of time, the latter determined by depth. Prior to conducting a transect, a four-meter long marker was placed on the bottom to calibrate transect width.

For each transect, depth and strata time was recorded. While conducting a transect, the scooter was kept approximately one meter above the substrate so path width remained constant at 4 meters. All conch were counted. The length of all individuals were estimated to the nearest 1 cm, and if an adult its age was estimated to one of four relative age classes based on the degree of shell erosion: newly mature, adult, old adult, and very old adult. Records were kept of habitat type, depth, time over each habitat type and depth, and time of appearance of each conch observed. Habitats types were recorded using classes based on sediment characteristics or dominant biota: Sand, Gorgonian, Thalassia, Halimeda, Halophila, Mud, Coral, Hard Bottom, and Rubble. Combinations of these were used to classify areas of mixed habitat. For analysis habitats were grouped into six categories: sand, mud, coral reef, coral rubble, sea grass and algal plain.

Transect length was obtained by calculating the distance between the beginning and end points of each transect. Total area was calculated by multiplying the distance of each transect by the transect width. Area for each habitat was calculated by multiplying the total area by the percentage of time spent over each habitat. Densities for each habitat were derived by dividing the number of conch per habitat type by the total area of that habitat type per transect. Overall abundance was estimated from the data on density/station. Length (juvenile, adult) and age (adult) frequency distributions were determined, differences in density by habitat were tested using the Kruskal-Wallis non-parametric analysis.

Prior to the start of the actual survey, divers were trained to identify live conch, maintain speed and transect width, and to estimate length and adult age-classes. A reference collection of adult conch for each age group was maintained.

2013 Approach

Visual Surveys

In 2006, interviews with fisherman identified areas of past conch fishing grounds, present conch fishing grounds and areas known to have juveniles on the west, east and south coasts. The west coast is the primary fishing grounds for queen conch in Puerto Rico. These maps were digitized into a GIS database using ArcMap and used as boundaries to create 46 random survey sites off the west coast, within the 90-ft contour, using the “create random points” tool (**Figure 4.10.3**). The 90-ft boundary was chosen for diver safety. All categories (past, present and juvenile) were given the same weight during the site selection, though many of the polygons overlapped.

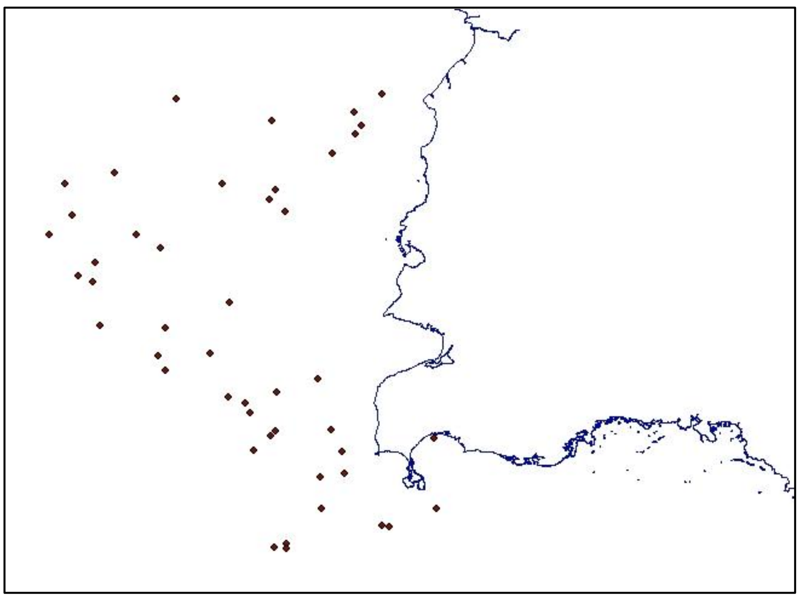


Figure 4.10.3 Location of random sample sites for the 2013 conch visual surveys relative to the mainland of Puerto Rico.

Methods for this survey were kept identical with previous years’ surveys to facilitate comparison of results between surveys. All divers participating were trained in the following: identification of Strombus gigas, use of the underwater scooters including maintaining constant direction and speed as well as safety protocol, estimating lengths and identifying age classes using an established reference collection, completing practice transects and recording all applicable data.

At each of the sites, paired visual surveys were done on SCUBA with the help of underwater scooters to maximize distance travelled. Each diver surveyed a 4m wide transect of variable length depending on depth and available dive time, but for a maximum of 45 minutes. One diver carried a safety buoy which helped identify the transect end point and allowed the surface support vessel to track the divers; the other diver carried a compass set to a fixed random heading so the dive pair could follow a straight line. During the survey, habitat, depth, age class and estimated length were recorded for each conch, as well as observations of copulation or egg laying. Classifications of habitat included sand, gorgonians, Thalassia, Syringodium, Halimedia, algae, reef, hard bottom or any combination of these. Age classes were juvenile (J), newly mature adult (NMA), adult (A), old adult (OA) and very old adult (VOA). Transect distance was calculated in ArcMap by measuring the straight line distance connecting the start and end positions.

Data Analysis

Total area surveyed was calculated by multiplying the transect length by 4m width and then doubling the area (two transects per site) and finally summing over all 46 sites (92 transects). Densities were calculated by dividing number of conch observed at each site by the area surveyed. Comparisons of densities of both adults and juveniles between years (1997, 2001, 2006 and 2013) were made by modeling densities as a function of management regime (territorial or federal), depth, habitat and year using a log transformed negative binomial distribution. Analyses were conducted using the generalized linear model function (GLIMMIX) of SAS. This distribution was chosen over a Poisson because it is better equipped to handle high variability. No spatial correlation term was included in the model because the inclusion of the depth and habitat terms explained most of the variability. Including the management regime in the model helped to elucidate the effectiveness of a more than 10 year closure of the fishing grounds in the federal area. Trends regarding age structure and size frequency were also described. The spawning stock for the west coast was calculated using only the older age classes (adult, old adult and very old adult) densities multiplied by estimates of suitable habitat area on the western platform based on the previously digitized strata. This spawning stock was then compared to the mesophotic population estimate at Abrir La Sierra (Garcia Sais et al. 2012) to get an idea of the potential contribution of the mesophotic population relative to the shallow water stock.

4.11 Shallow Water Reef Fish Survey

How is it funded, who administers it?

- SEAMAP Program, administered by the Puerto Rico Department of Natural and Environmental Resources. Some leverage funding from Fish and Wildlife Sport Fish Restoration Program to increase the number of stations and samples for reproduction information.

Why was the survey originally designed?

- This survey was designed to provide fisheries-independent data on shallow water reef fish resources essential to effective management of those resources.

What are/were the intended outcomes/objectives?

OBJECTIVES Reef fish 88-2002

- The aims of the survey were to collect, manage, and disseminate fisheries-independent data collection of shallow-water reef fish, queen conch and spiny lobster resources and their environment. These data were used to obtain catch per unit effort estimates, to determine species composition and to evaluate annual trends in the fishery. The data are also available for comparison with fisheries-dependent data collected under other statistics projects of Puerto Rico and the US Virgin Islands.

OBJECTIVES Reef fish 2003-13

- Collect and disseminate fisheries-independent data on shallow water reef fish resources.
- Obtain catch per unit effort estimates, to determine species composition and to evaluate annual trends in the fishery.
- Enable Puerto Rico to identify, implement and measure the effectiveness of fishery management measures for their Territorial Waters.
- Enable Puerto Rico to take full advantage of an integrated, coordinated, and cost effective approach to fishery-independent data collection to fulfill priority data needs.
- Provide information to support the Caribbean Fishery Management Council's effort to implement and monitor the effectiveness of fishery management plans for fisheries in the US Economic Exclusive Zone.
- Enhance the usefulness of the data, minimize the costs, and increase the accessibility of information to fishery managers through the Caribbean region.
- Serve as information and coordination effort to support plans to conserve and manage the fisheries that are Caribbean scope.

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- Figure 4.11.1-4.11.4

How often is the survey conducted (annually, biennially, biannually etc.)?

- Two to three consecutive years every five years.

Is it seasonal?

- No

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Stratified random samples

Describe allocation of sites per strata (proportional/weighted?) and number of sites

- 60 stations per coast randomly selected by depths

Describe the methodology and gear

- Hook and line at present time, details include below.

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Annual and final reports to SEAMAP

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?

- Shallow water reef fish species, including deep water snappers (silk, blackfin and vermillion snappers caught in water less than 50 ft.).

What are the gear/method biases (catchability, size selectivity)?

- Catchability of some species and size selectivity of most species.

What are the temporal/spatial limitations?

- Most of the temporal and spatial limitations are related to collecting spawning information.

Is this survey expected to continue into the future?

- Yes

It is relatively expensive/inexpensive, logistically difficult/easy?

- Expensive and logistically difficult.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

Data generated: **length frequency, spawning stock biomass, mortality etc.**

- Data produced included CPUE/coast and station, reproduction information, spawning, length frequency.

Provide any other information that may be relevant to this discussion

- N/A

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

- SEAMAP-C Sampling Protocol Manual
- SEDAR 8, Final report to SEAMAP 2012

1989 Pilot study used to adopt SEAMAP Methodology
Methods and Materials:

The coastline and shallow water platform area of Puerto Rico west of the 67th parallel was divided into 2 x 2 mile square quadrats and each numbered. (There are approximately 120 such quadrats including areas surrounding the islands of Mona, Monito and Desecheo).

Of the 120 quadrats, 53 were selected using random number tables. This covered 44% of the entire area.

Over a period of 15 months, each of the 53 quadrats was sampled by trap and hook and line fishing (the predominant methods used by fishermen in these areas) at least two times, giving a minimum of 143 trips in the year. These trips were carried out by two Fisheries Research Laboratory vessels each making a minimum of two trips a week for 40 weeks. Additional trips were made to a randomly selected sub-sample of the 53 originally selected quadrats.

For each trip the following data were recorded:
a. fishing method (hook and line/fish traps)
b. date, time spent fishing
c. weather
d. quadrat code
e. physical coordinates and depth
f. gear effort (i.e., number of traps and duration of set, number of hooks, number of fishing lines)
g. total weight of the entire catch by gear type

For each catch (by hook and/or trap) the following data were obtained:
a. species composition of entire catch
b. individual size (i.e. fork length (FL) and/or weight, in grams) for each species
c. for certain species otoliths were extracted
d. sex and gonadal state of maturation

In order to more closely mimic local fisheries it was decided to used three different sizes of hooks per line (Mustad Sea Kirby Hooks No. 5, 6, and 7). Each line had one of each of the three different hooks approximately one foot apart. Two different kinds of traps were used depending on the depth at which they were set. For depths up to 50 fathom traps dimensions were 4' x 4' x 2', while for depths over 50 fathoms trap dimensions were 6' x 5' x 2'. This decision was taken for practical reasons, since smaller traps are easily carried or moved by strong currents at greater depths. Mesh size of both trap type was 1 1/4". Bait used for hooks was squid and for fish traps tuna gonads were used with which many fishermen bait their traps in the sampled area. To reduce gear loss, traps were set for an average of 6 daylight hours during each trip, while hook fishing was carried out.

Data obtained from the fisheries-independent survey was entered into a micro-computer using DBASE III PLUS and Lotus 1-2-3 to facilitate the preparation of periodic summaries.

Quarterly and annual summaries of monitoring results were made available to NMFS, local fishermen, management agencies, and other interested parties.

Length frequency analyses for those species that comprised the major catch were produced, as well length weight regressions. Outliers and extreme values were removed from length weight regression, visually taking those that were on/or over approximately two standard deviations off the best fitted line.

Reef fish 2003-06
Methods:

Location
Following the methodology established previously for similar studies (Rosario, 2004), the western platform area of Puerto Rico, up to the 50 fathoms contour, was divided into two squared nautical miles sampling stations. Mona Island and Desecheo Island were included and their surrounding platform was divided in stations as well. Each sampling station was defined by four GPS coordinates and identified with a number. Each station was classified according to the following depth ranges:
• Shallow- 1 to 10 fathoms
• Medium- 11 to 20 fathoms
• Deep- 21 to 50 fathoms

According to the station bathymetry it could have been classified under the three categories. Five stations from each category were randomly chosen. Some stations were added to cover off-shore marine protected areas on the west that has been traditionally monitored (Bajo de Cico, Tourmaline, Abrir la Sierra and Mona Island). This decision was made after the sampling was begun, reason for which the amount of sampled stations is greater than 15.

Sampling

The aim of the study was to sample each station ten times. The sampled area within a station was only that within the depth range for which the station was chosen. Sampling order was randomly chosen. Weather conditions, vessel condition and gear and personnel availability determined the sampling dates.

Two methods were used to sample the shallow-water reef fish at the stations, fish traps and hook and line. Fish traps were made of 1½" mesh size, with two doors, one of which was tied with a special rope that will deteriorate fast and allow fish to escape in case that the trap gets lost. Heavier steel rods were used for the trap bottom frame to assure the trap will place itself on the ground with the opening facing up. A total of fifteen traps were deployed during the sampling. The traps were divided in five sets of three. Each trap was identified, at the float, according to their respective set (e.g. 1-1, 1-2, 1-3, 2-1…). A small cage holding the bait (sardines) was placed at the same side of the trap opening to forbid fish access to the bait without entering the trap. At each station fish traps were deployed in sets, but individually, at least 150m apart. Soak time of the fish trap was five hours, from the time when the first fish trap was deployed to the time when the first fish trap was recovered.

Hook and line fishing was performed during fish traps soaking period for four hours. The vessel was kept adrift, moving it only when the vessel reached the station's boundaries or areas exceeding the depth range for which the station was chosen. The vessel was usually turned off while adrift. The area sampled was determined by recording the coordinates at the beginning and end of the fishing period. A minimum of three fisher, each using a line with three hooks (size #06 and #04), and using squid as bait.

Fish collected were placed in bags identified with the date, station number and origin (fish trap ID or fishermen ID). The fish were taken to the Fisheries Research Laboratory (FRL) facility where they were placed on a freezer until processed. When processing the fish, it was weighted, measured (total and fork length), sexed and its reproductive stage determined by visual inspection. Five categories were used for the reproductive stage: undetermined (1), resting (2), enlarging (3), ripe (4) and spent (5).

SEAMAP standard data sheets for every fish trap and fishers were completed. The data were entered and stored on SEAMAP software 3.0.

Histology

As a side study to this project the gonads from a sub-sample of fish caught were collected and preserved for histological analysis. Pictures of the gonads were taken and identified with the gonad information. The slides were examined to determine sex and reproductive stage. The same categories used for the visual identification were used for female fishes. It was observed that for males, the reproductive stage were not as discrete as in females, for this reason the categories used were mature (M) or immature (I). The results were compared with the visual classification recorded when processing the fish. The purpose of this was to create a visual aid for the reproductive stage identification of gonads for the different fish species, and use it as a quality control for the visual identification of the fish gonads. A total of 84 gonads were collected. From the collected tissues, 61 were fixed adequately and gave good information. A selection was made of gonads pictures with their respective histology reading and presented in figure 20.

2010 Reef fish east and west coasts of Puerto Rico

OBJECTIVE:
The aim of the present survey was to collect, manage, and disseminate fisheries-independent data collection of shallow water reef fish resources and their environment. These data were used to obtain catch per unit effort estimates, to determine species composition and to evaluate annual trends in the fishery. The data are also available for comparison with fisheries-dependent data collected under other statistics projects of Puerto Rico and the US Virgin Islands.

APPROACH:
Assess the survey design and standardize sampling methodologies identified in the Statistical Survey Design Analysis. Establish and conduct fishery-independent surveys to obtain CPUE (biomass per unit gear), determine species composition, evaluate trends in the fishery, and characterize the fishery habitats. Data obtained from the Pilot Study were also analyzed in order to establish the optimal design for the long term Reef Resources Survey.

Project Objective:

- Enable Puerto Rico to identify, implement and measure the effectiveness of fishery management measures for their Territorial Waters.
- Enable Puerto Rico to take full advantage of an integrated, coordinated, and cost effective approach to fishery-independent data collection to fulfil priority data needs.
- Provide information to support the Caribbean Fishery Management Council's effort to implement and monitor the effectiveness of fishery management plans for fisheries in the US EEZ.
- Enhance the usefulness of the data, minimize the costs, and increase the accessibility of information to fishery managers through the Caribbean region.
- Serve as an information and coordination effort to support plans to conserve and manage the fisheries that are Caribbean scope.
- Establish reef fish abundance, according to depth, along the south, west and east platform of Puerto Rico.
- Improve the gonads maturity stage identification chart for different fish species.
- Provide data on species of interest for management to improve their stock assessment.

Procedure

1.Previous 2 x 2 nautical miles quadrants used for the western platform were used. The east and south coast were divided as well in 2 x 2 nautical miles quadrants. Some details concerning sampling are subject to minor modifications depending on logistics and prevailing conditions of weather and vessels.

2.Thirty quadrants were randomly chosen for the east and west, and ten for the south. Quadrants were located by Global Positioning Systems (GPS). Each quadrant was sampled twice. Sampling station and date were random selected and varied according to weather and sampling logistics.

3.At each quadrant fishing was done using hook and line with fish hooks #06, sinker units (weights) and squid as bait. Three lines (equal to three fishers) were used for sampling, each with three hooks. Quadrants were sampled for 4 hours during each trip.

4.For each trip the following data were recorded:

A. Date, time (i.e. time out and time returned to dock)Quadrant code (latitude and longitude).
C. Fishing time for line to the nearest 15 minutes.
D. Weather conditions.
E. Depth.
F. Total number of hooked fished per vessel.
G. Number, weight, length, reproductive condition and identification of fish per hook and line as well as by individual fishermen.
H. Substrate type was characterized whenever possible.

5. Catches by individual fisherman were kept separated for each fishing trip. The data were entered with an identification code for each fisher so that it could be analyzed for each fishing member. These data could provide an estimate of fisherman productivity and also an indication of the variability of individual fisherman performance.

6. Data were entered, edited, and stored on microcomputer on Access standardized format. Semi-annual summaries performance and annual reports including data summaries were completed using Excel and Word. Data were also entered and stored on SEAMAP software and sent to the SEAMAP Database Manager in Pascagoula, MS. Statistical analysis was performed using SigmaPlot 12. The Kolmogorov-Smirnov two-sample test and the t-test were used to compare size frequency distributions and mean size. Sex ratios were tested statistically for significant deviations from the expected 1:1 with a chi-square test (α=0.05) (Sokal and Rolhf, 1981).

7. A statistical analysis of data, including recommendations on sampling design will follow completion of the study.

8. Classification of species composition by first, second, third, and trash fish is the general market value presented by Matos and Sadovy (1990) for P.R. Some modifications have arisen to this classification, as certain species that formerly did not have commercial values are now being reported in landings, with commercial value (Matos, 1993). This classification varies markedly from coast to coast, but in general, reflects the classification used by the majority of fishermen in P.R. The two categories that tend to vary most in terms of how species are classified according to their market value are third and “trash” (“brosa”) fish. The major difference concerns the classification of squirrelfishes. In certain areas, such as the west coast, this group is considered to have no market value (trash fish); while, in others such as the south coast, it is classified as third class.

9. Species with a minimum sample size of one hundred individuals for the entire year are taken into consideration for the analysis of length-frequency data. A 10 mm size class interval is considered the most appropriate for collected groupers, sand tilefish and squirrelfishes.

Histology Procedure:

1. All fish captured was visually sexed as follows:
   I. Unripe individuals are designated as F1 and M1.
   II. Sub-ripe individuals are classified as F2 and M2.
   III. Ripe individuals are designated F3. (Females with ovaries usually transparent and colourless; enlarge gonad with large, well developed eggs); and M3 (males with testes with loose or running milt).
   IV. Spent gonads F4 and M4; individuals with enlarged and flaccid gonads.

2. Two principal gonad stages were used for each sex to establish the spawning period of selected species: ripe and spent gonads.

3. All gonads were collected and preserved for histological analysis. Pictures of the fish and the gonads were taken and identified with the gonad tag information. The slides were examined to determine sex and reproductive stage.

4. The same categories used for the visual identification were used for female fishes. It was observed that for males, the reproductive stage were not as discrete as in females, for this reason the categories used were mature (M) or immature (I). The results were compared with the visual classification recorded when processing the fish. The purpose of this was to create a visual aid for the reproductive stage identification of gonads for the different fish species, and use it as a quality control for the visual identification of the fish gonads.

5. Spawning season and size of maturity was calculated for all species with enough data.

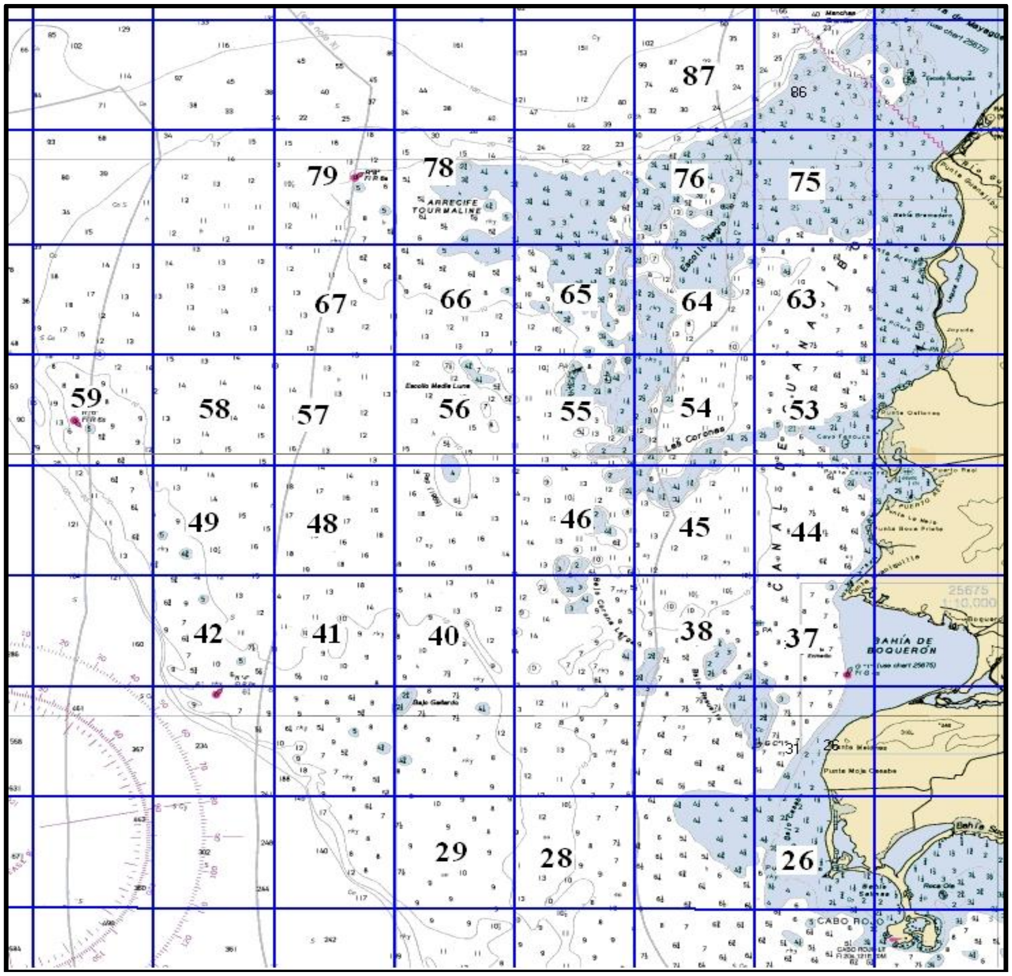
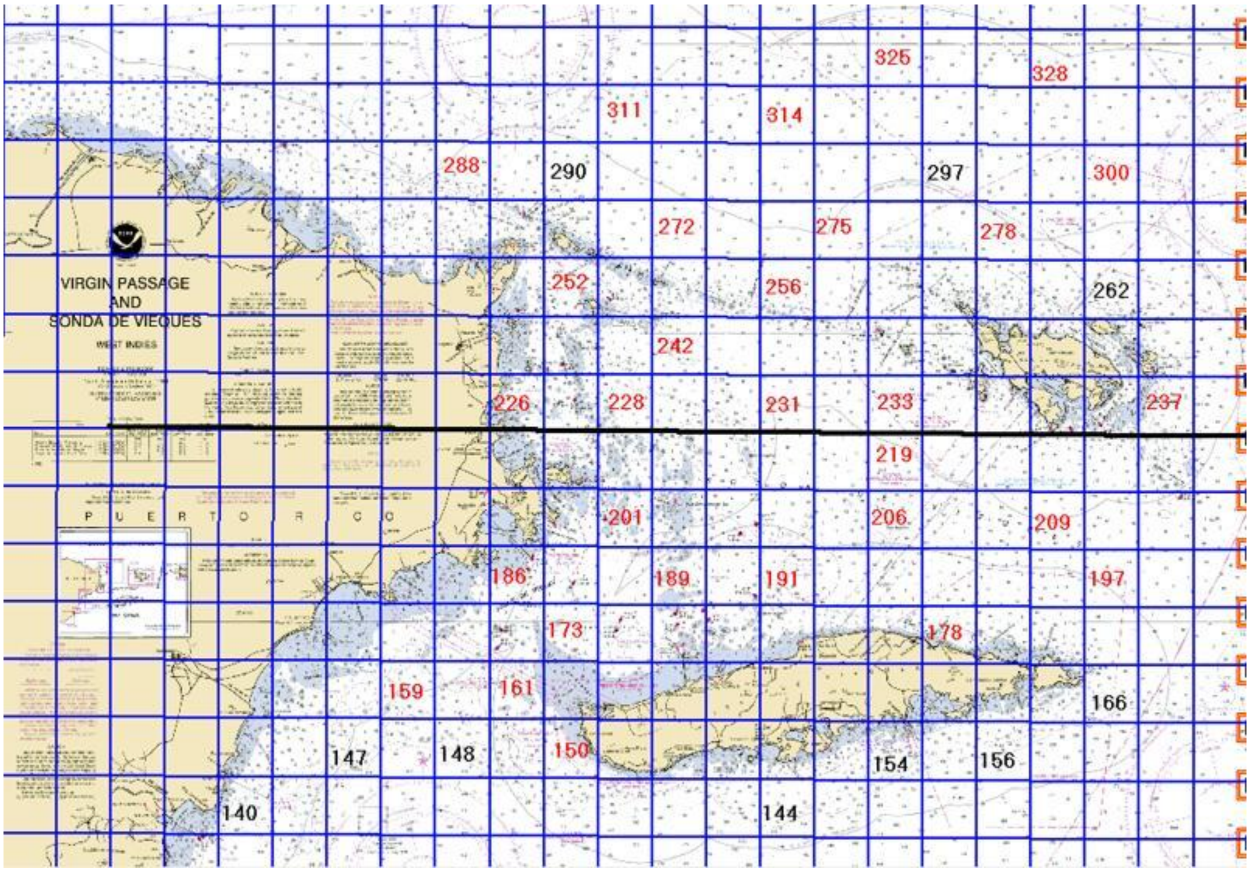


Figure 4.11.1. Sampled stations off west coast reef fish survey.


VIRGIN PASSAGE
AND
SONDA DE VIEQUES
WEST INDIES
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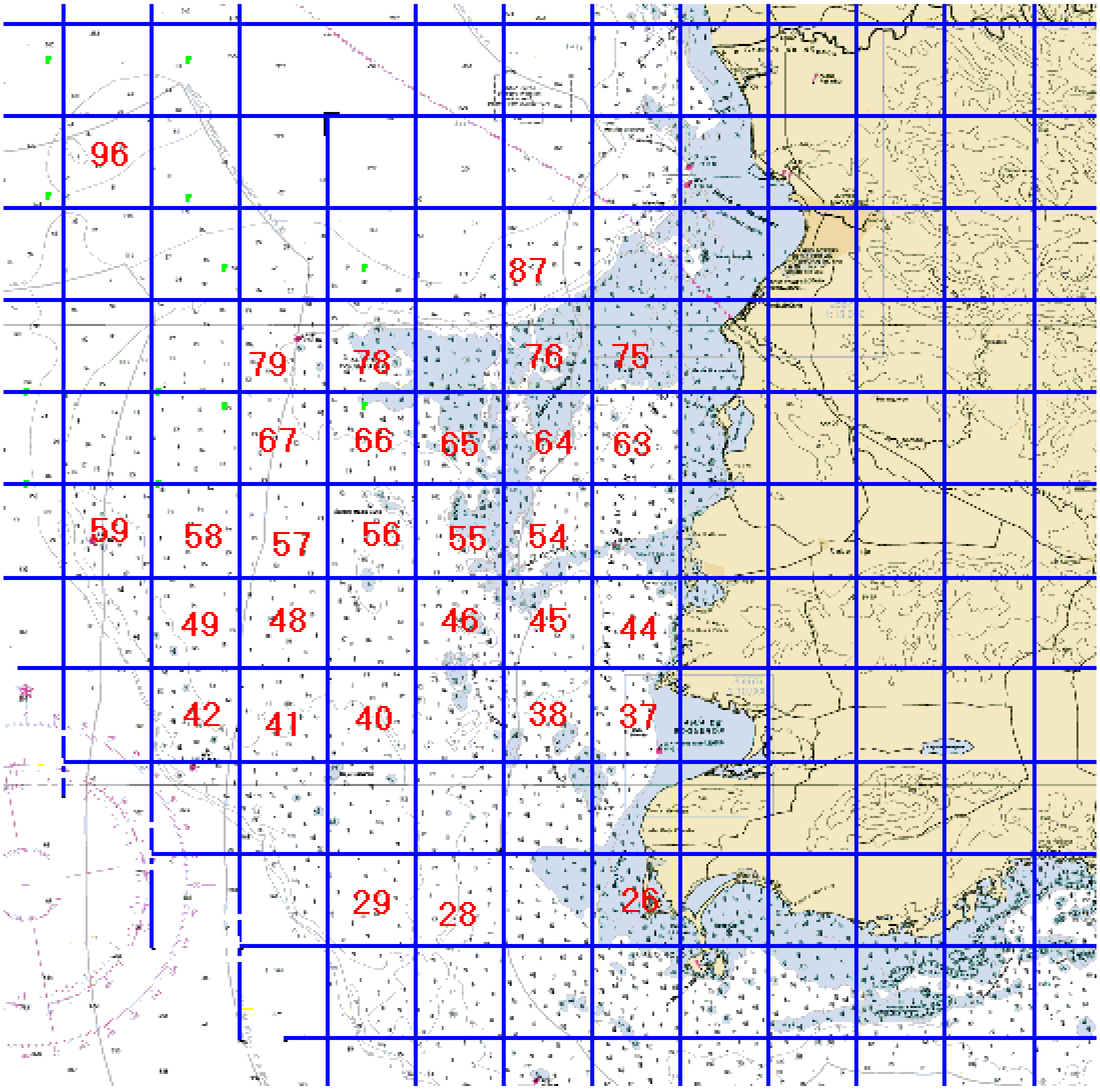

Figure 4.11.3. Sampled stations off the west coast of Puerto Rico during 2013.

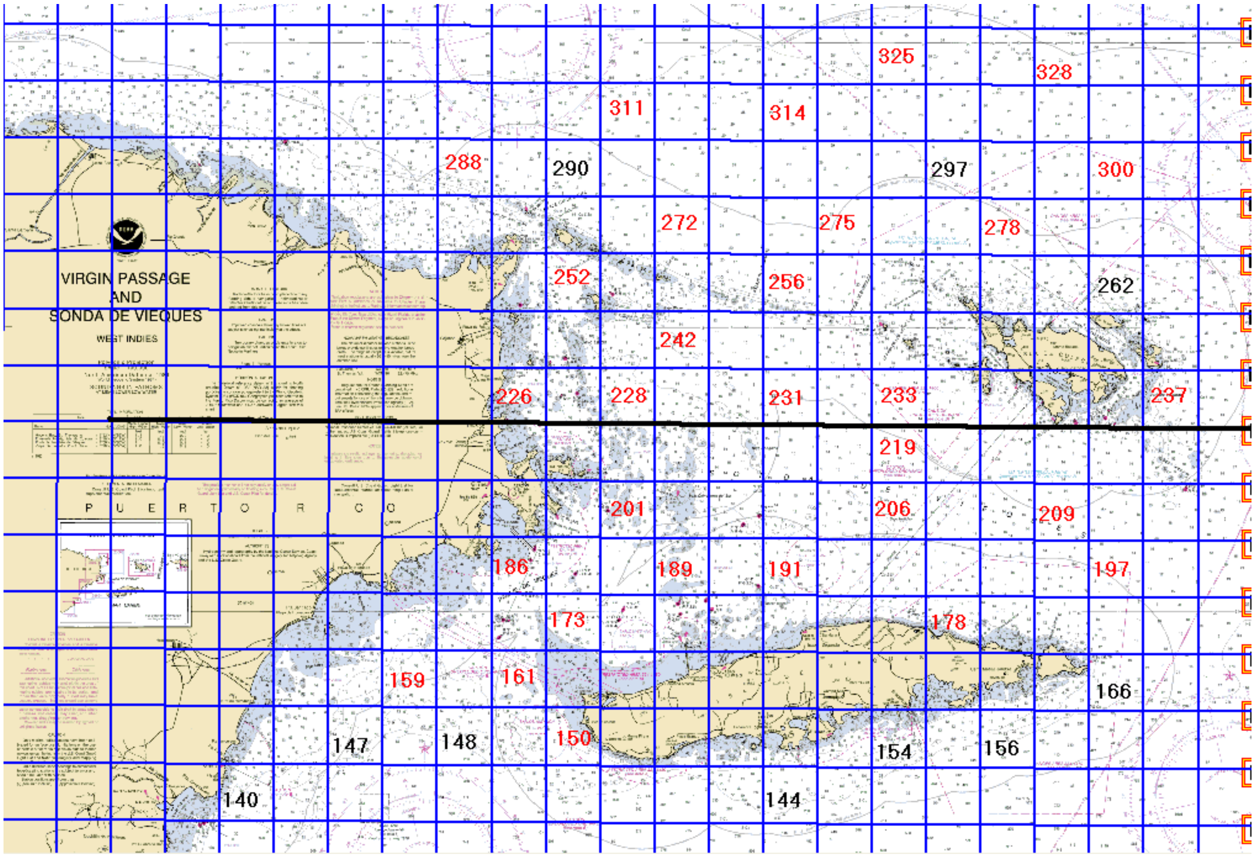

Figure 4.11.4. Stations sampled during the reef fish survey off the east coast 2013.

4.12 Study on the juvenile recruitments of the spiny lobster (Panulirus argus)

How is it funded, who administers it?

- SEAMAP Program and administered by DNER

Why was the survey originally designed?

- The purpose of this survey was to provide spiny lobster recruitment assessment information needed to identify fishery management needs and to implement plans to protect and restore the fishery stocks to support viable

What are/were the intended outcomes/objectives?

- The purpose of this study is to estimate, spatially and temporally, the settlement and recruitment of juvenile stages of the spiny lobster (*Panulirus argus*).
- Provide Puerto Rico with a time series data on pueruli settlement at seven sites off the west coast of Puerto Rico.
- To assess pueruli abundance by depth on the west coast of Puerto Rico.
- Provide information to support the Caribbean Fishery Management Council's effort to implement and monitor the effectiveness of fishery management plans for fisheries in the US EEZ.
- To conduct a population dynamics spiny lobster survey to determine the spatial and temporal variations in larval settlement, distribution and recruitment within the territorial sea of P.R. and the US EEZ, off the west coast of Puerto Rico.

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

How often is the survey conducted (annually, biennially, biannually etc.)?

- Every five years Every five years

Is it seasonal?

- No

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Fixed sites

Describe allocation of sites per strata (proportional/weighted?) and number of sites

Describe the methodology and gear

- Divers visual census, see below

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- See Below

Self-Evaluation of pros and cons of Survey

What suite of species does this survey target (what are gaps)?

- Many gaps

What are the gear/method biases (catchability, size selectivity)?
What are the temporal/spatial limitations?
Is this survey expected to continue into the future?
It is relatively expensive/inexpensive, logistically difficult/easy?

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- Temporal coverage

Data generated: length frequency, spawning stock biomass, mortality etc.

- Size information

Provide any other information that may be relevant to this discussion

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

SEAMAP-C Sampling Protocol Manual
SEDAR 8, Final report to SEAMAP 2012

Methodology

On each station a lobster artificial shelter was constructed. The shelter was built using 16 cement blocks. Eight of the blocks were placed on the seafloor forming a square shape two cement blocks per side. The other eight blocks were placed in top of the first layer of blocks. The blocks were tied to each other with nylon rope. Identification numbers were assigned to each shelter. Numbers 1 to 10 were assigned to the shelters in the first set. Numbers 11 to 20 were assigned to the shelters in the second set. Acrylic identification tags were attached to each shelter with their ID number engraved on it. In every other station the shelter was covered with a black canvas Stations with covered artificial shelters were: 2, 4, 6, 8, 10, 11, 13, 15, 17 and 19. The canvas was hold in place by tying it with steel wire to four steel rods that were nailed to the sea floor, one on each corner of the square. A cable was tied from shelter to shelter to ease the location of the stations under water.

Starting on March 2003 the stations (**Figure 4.12.1**) were visited once a month to collect data on juvenile lobster recruits present on the shelters. Covered shelters were opened to observe presence of recruits on the inside of the shelter. Recruits quantity and size information was collected. The sizes here reported are from the cephalothorax, measuring from the spines to the end of the thorax. Size classification was: less or equal to 1”, from 1.1” to 2”, from 2.1” to 3”, from 3.1” to 4”, from 4.1” to 5”, and greater than 5.1”. On our last visit, 23 February 2004, the canvases were removed to avoid damage to the adjacent areas by the eventual displacement of these.

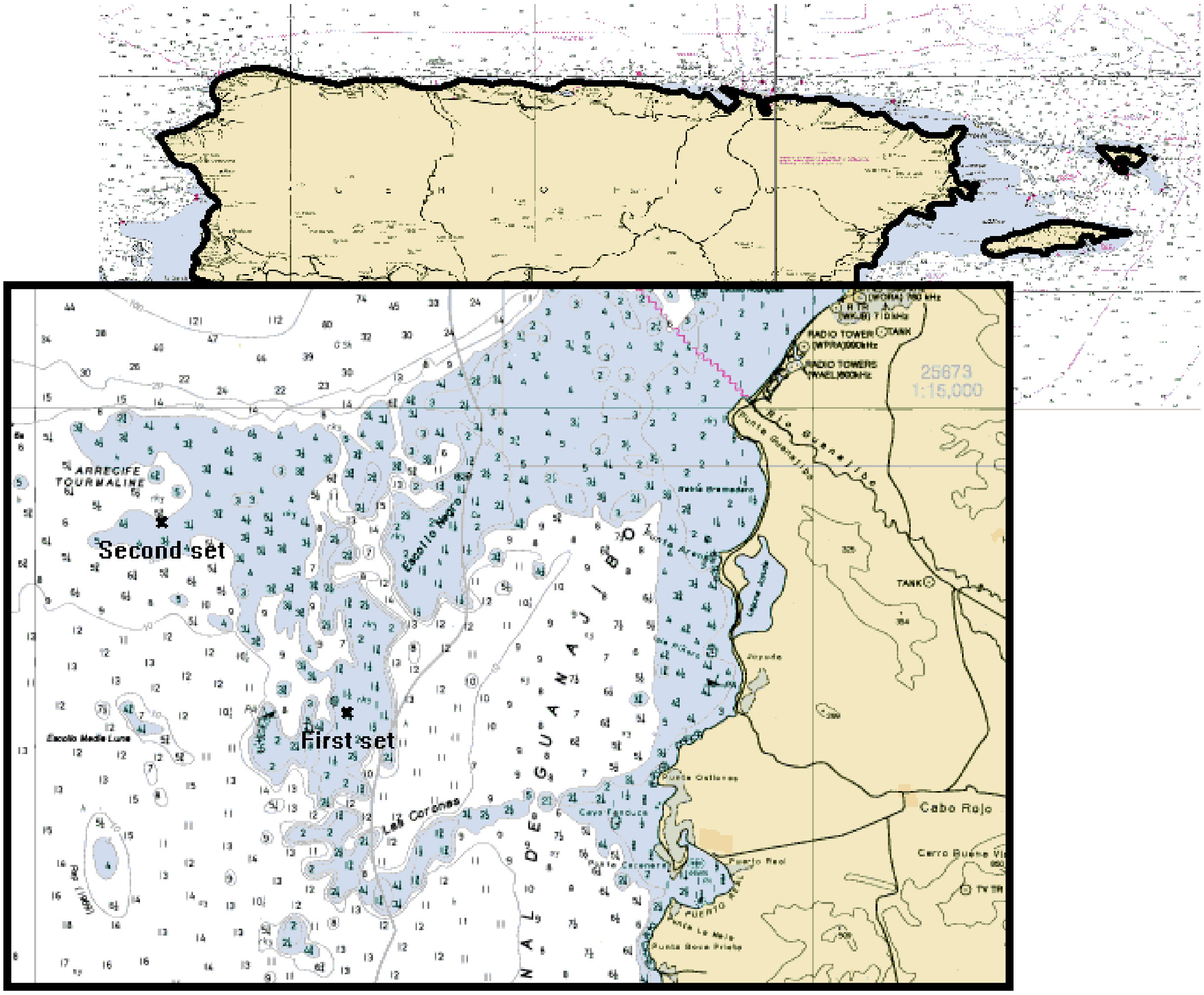

Figure 4.12.1. Location of the artificial shelter sets 2003.

Study 2- Artificial shelters for juvenile lobsters 2008

1. Six sets of ten juvenile lobster artificial shelters were constructed at various sites on the west coast platform. The six areas were selected based on depth, bottom type and proximity to a reef (**Figure 4.12.2**). **Table 4.12.1** summarizes the coordinates for every artificial shelter within each station. Each shelter was at least 30 m apart from each other.

Table 4.12.1 Coordinates of the spiny lobster artificial shelters**.**

ID	Latitude	Longitude
Bramadero	18°08.331	67°11.136
El Negro	18°08.795	67°14.208
Fanduco	18°05.002	67°12.435
El Ron	18°06.344	67° 16.046
Combate	17°59.266	67°13.113
Pta. Aguila	17°56.724	67°12.260

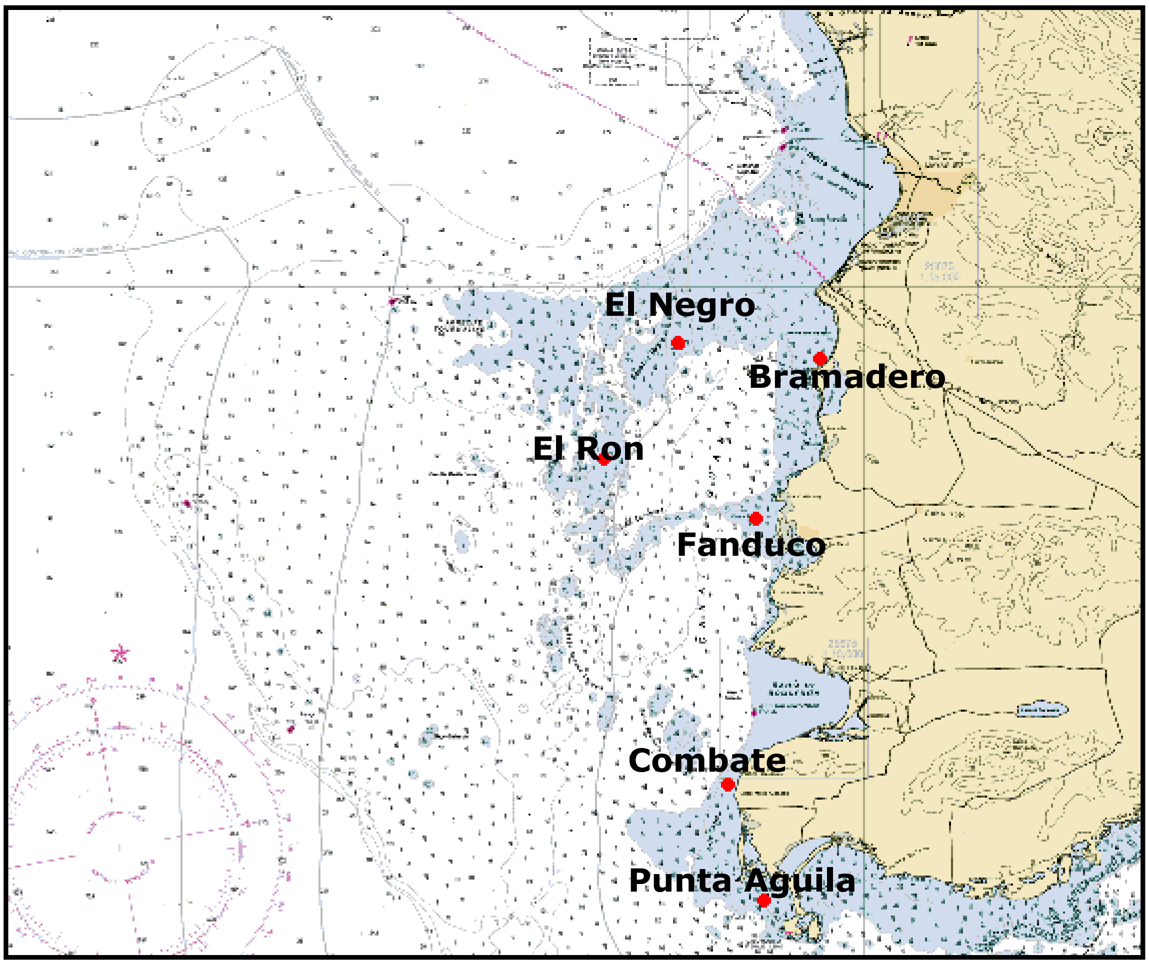

Figure 4.12.2 Spiny lobster artificial shelter stations 2007-08.

2. Each artificial shelter was built using 16 cement blocks. Eight of the blocks were placed on the seafloor forming a square shape, two cement blocks per side. The other eight blocks were placed in top of the first layer of blocks. The blocks were tied to each other with nylon rope (**Figure 4.12.3**).

Figure 4.12.3 Spiny Lobster artificial shelter

3. Sampling was done monthly between the full and the new moon.
4. For sampling, divers inspected each shelter once a month and count the number of juvenile lobsters in the shelter. Lobsters were measured using a measuring stick.
5. Lobsters found on the shelters were left in place.
6. Surveys were clean during each visit and octopuses were removed as possible.

4.13 Reef Fish Monitoring Yellowtail Snapper Survey

How is it funded, who administers it?

- Funded by SEAMAP-C Program and administered by DNER

Why was the survey originally designed?

- SEDAR (8) was charged with the assessment of the Caribbean yellowtail snapper and spiny lobster in 2005. In the analysis of the available fisheries-independent surveys conducted by SEAMAP it was found out extremely low numbers of captured yellowtail snappers in relation to CPUE. Due to the small sampled and to the fact that the sampling methodology used in the SEAMAP survey for the data set analyzed do not sample yellowtail snapper effectively as other species, not much contribution was made to the stock assessment. As a result several recommendations were made in regard to the sampling of yellowtail snapper by

SEAMAP. SEDAR preliminary analysis of the Puerto Rico SEAMAP data survey suggested that the methodology of sampling is was not equal for all the species in our fisheries, and it was needed to address this issue in relation to the overall objectives of the program. Another finding was related to the fact that all surveys only covered west coast of Puerto Rico, due to constrains in the funding allocated to the program.

Among the major recommendations made by the participants of SEDAR workshop are the followings:

- Work toward developing a species specific commercial landings sales ticket in the US Virgin Islands commercial fisheries.
- Implement hard part biological sampling in US Virgin Islands and Puerto Rico.
- Work towards identifying the primary information needs regarding improving the ongoing fishery-independent sampling initiatives for yellowtail snapper populations in the Caribbean.
- The SEAMAP-Caribbean working group took these recommendations and evaluated an appropriate sampling protocol to address the yellowtail snapper fisheries in the Caribbean. With this survey it was intended to collect hard parts as well as to improve the collection of yellowtail snappers. Increase funding not only allowed to undertake a yellowtail snapper survey in the west coast, but also the east coast.

What are/were the intended outcomes/objectives?

- The aim of the present survey was to collect, manage, and disseminate fisheries-independent data collection of shallow water reef fish resources and their environment. These data were used to obtain catch per unit effort estimates, to determine species composition and to evaluate annual trends in the fishery. The data are also available for comparison with fisheries-dependent data collected under other statistics projects of Puerto Rico and the US Virgin Islands.
- Enable Puerto Rico to identify, implement and measure the effectiveness of fishery management measures for their territorial waters.
- Enable Puerto Rico to take full advantage of an integrated, coordinated, and cost effective approach to fishery-independent data collection to fulfil priority data needs.
- Enhance the usefulness of the data, minimize the costs, and increase the accessibility of information to fishery managers through the Caribbean region.
- Support plans to conserve and manage the fisheries that are Caribbean scope.
- Establish yellowtail snapper abundance along the west and east platform of Puerto Rico.

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- Includes stations at the east and west coasts of Puerto Rico (**Figures 4.13.1 and 4.13.2**)

How often is the survey conducted (annually, biennially, biannually etc.)?

- At the present time is scheduled to be conducted every four years.

Is it seasonal?

- The survey design seeks to detect if there is any seasonality in the yellowtail snapper fishery by carrying out 15 trips per season. The results from the west coast yielded statistically significant results by season. The season in which the higher numbers of individuals were recorded was winter, followed by fall, spring and summer. East coast results do not provide evidence to corroborate these results, since the sampling did not included the fall season. Besides the season in which the higher number of individuals was recorded corresponded to the spring, followed by winter and summer, and the results were not statistically significant. Comparison of recorded total number per season by coasts yielded significant results. The next sampling period will follow the previous survey methodology to determine seasonality.

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Stratify the west and east area in fishing and non-fishing sites.

Describe allocation of sites per strata (proportional/weighted?)

- Select randomly 5 non-fishing sites and 10 (if available) fishing sites.

Describe the methodology and gear

- Sampling will be conducted at night for two hours using hook and line and sardine as bait. Three lines, each with three hooks, will be used during the sampling.

Procedures

Yellowtail snapper survey:

Stratify the west and east area in fishing sites and non-fishing sites. Select randomly 5 non-fishing sites and 10 (if available) fishing sites.

Sample each area four times, one per season.

Sampling will be conducted at night for two hours using hook and line and sardine as bait.

Three lines, each with three hooks, will be used during the sampling.

For each trip the following data will be recorded:

- Date, time (i.e. time out and time returned to dock)
- Quadrant code (latitude and longitude).
- Fishing time for line to the nearest 15 minutes
- Weather conditions
- Depth
- Total number of hooked fished per vessel.
- Number, weight, length, reproductive condition and identification of fish per hook and line as well as by individual fishermen.
- Data were entered in the provided SEAMAP database and analysed using Microsoft Excel and SigmaPlot version 12.0.

Histology Procedure

As a side study to this project the gonads of the fish caught were collected and preserved for histological analysis. Pictures of the gonads were taken and identified with the gonad information. Upon collection gonads will be weighed, fixed in Davidson's fixative, embedded in Paraplast, sectioned and stained with hematoxylin and eosin. The slides were examined to determine sex and reproductive stage. The same categories used for the visual identification were used for female fishes. It was observed that for males, the reproductive stage were not as discrete as in females, for this reason the categories used were mature (M) or immature (I). The results were compared with the visual classification recorded when processing the fish. The purpose of this was to create a visual aid for the reproductive stage identification of gonads for the different fish species, and use it as a quality control for the visual identification of the fish gonads.

The annual reproductive cycle will be described by the monthly distribution of gonadal development stages (GDS**)** and by the average gonadosomatic index (GSI=100[ovary weight/ ovary weight + somatic weight]) plotted against month of collection for some species that are under evaluation by the Reproduction Program of the FRL. To determine size at maturity (defined as the smallest size class in which 50% of the individuals are sexually mature, L_{50}) a maturity curve will also be developed for those species under consideration by the Reproductive Program.

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?

- Specifically the yellowtail snappers, nonetheless several species of snappers made the bulk of the catch.

What are the gear/method biases (catchability, size selectivity)?

- There might be potential size selectivity whereas individuals smaller than 150 mm of length are not represented.

What are the temporal/spatial limitations?

- We need more than one year of sampling to detect these limitations.

Is this survey expected to continue into the future?

- Yes

It is relatively expensive/inexpensive, logistically difficult/easy?

- Relatively expensive and logistically difficult.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- Produce both coverage

Data generated: length frequency, spawning stock biomass, and mortality etc.

- data produced include CPUE/coast and station, reproduction information, spawning, length frequency.

Provide any other information that may be relevant to this discussion

N/A

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

SEAMAP-C Sampling Protocol Manual
SEDAR 8, Final report to SEAMAP 2012

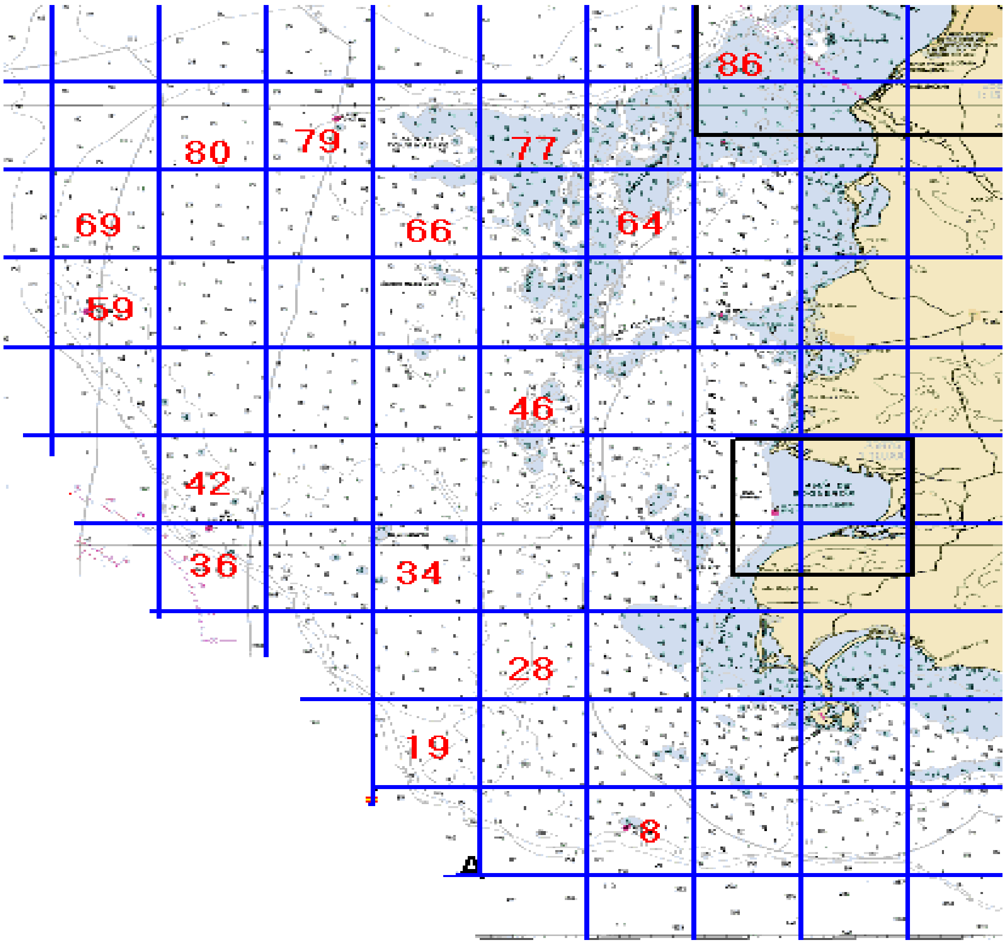

Figure 4.13.1. Sampled stations for yellowtail snapper survey off the west coast of Puerto Rico during 2010-11.

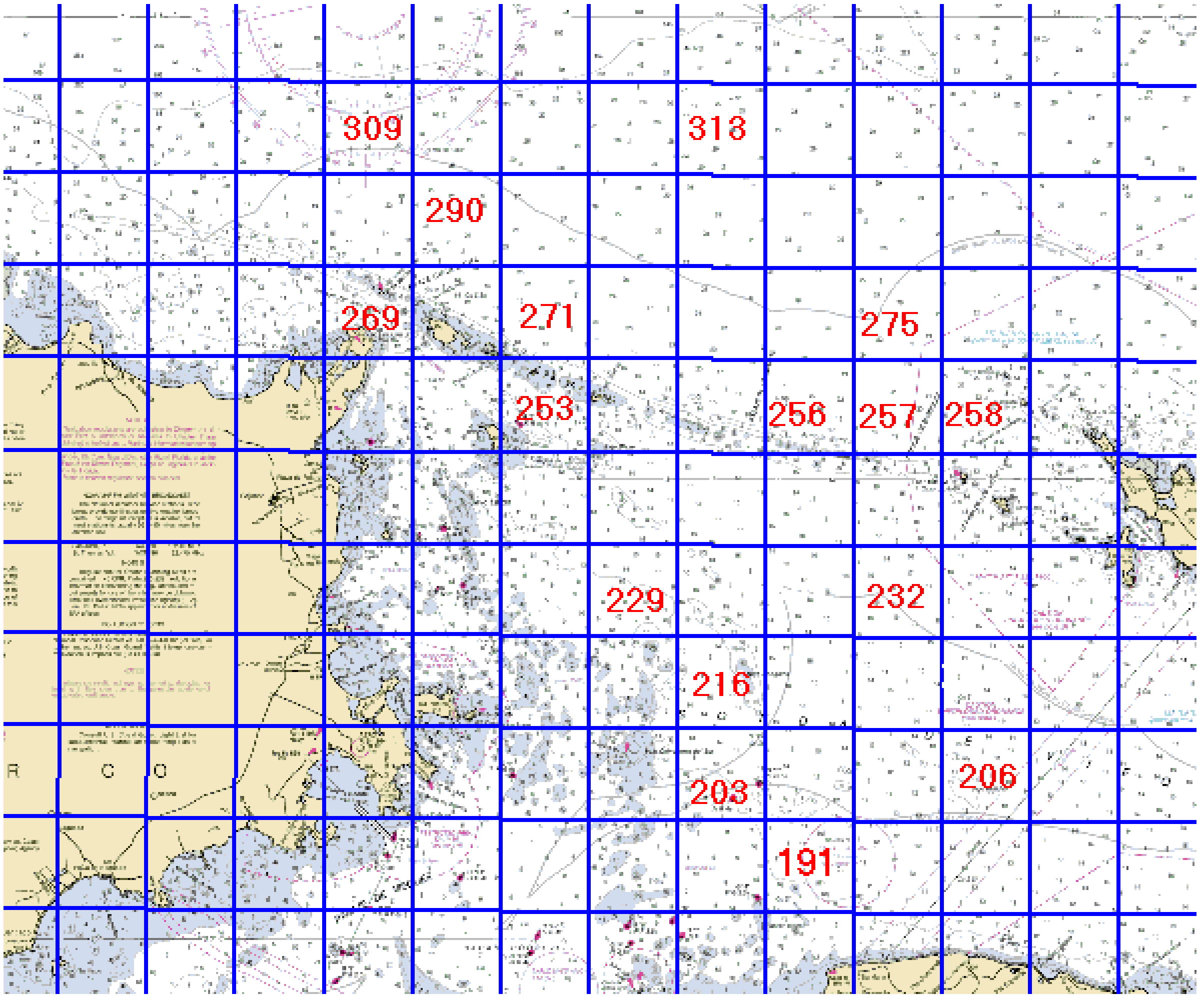

Figure 4.13.2. Selected stations off the east coast of Puerto Rico for yellowtail snapper survey.

4.14 Fish spawning aggregation (FSA) and passive acoustic monitoring (PAM) research for Nassau grouper (Epinephelus striatus)

How is it funded, who administers it?

- CFMC, CCRI

Why was the survey originally designed?

- To characterize Nassau grouper fish spawning aggregations (FSA) and determine the feasibility of passive acoustic monitoring (PAM) for assessment

What are/were the intended outcomes/objectives?

- Quantify the abundance of Nassau grouper
- Estimate the size structure of Nassau grouper
- Determine the timing and spatial variability of reproductive activity
- Determine the presence of other species at the FSA

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

The spatial coverage is summarized in **Figures 4.14.1** and **4.14.2**.

- Bajo de Sico (depths 25-70m), Puerto Rico
- Grammanik Bank (40-70m), St. Thomas, US Virgin Islands

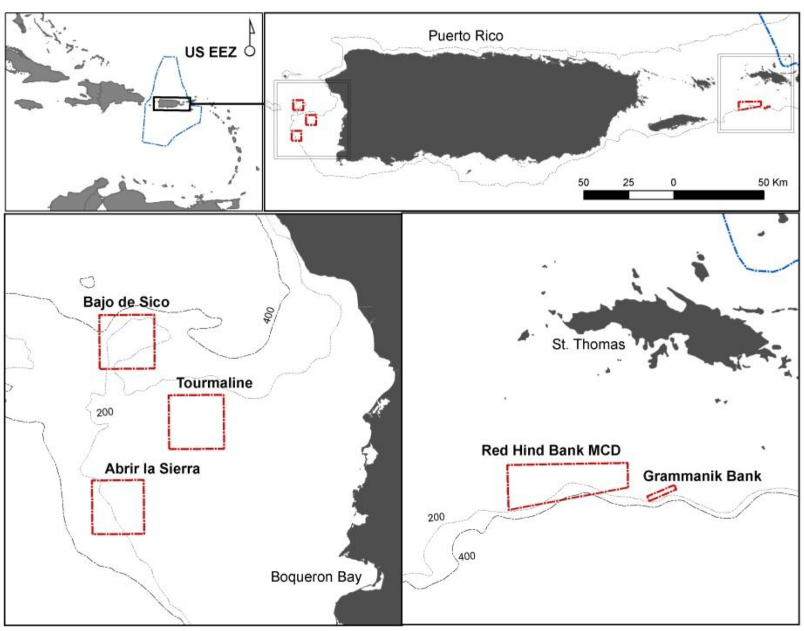

Figure 4.14.1. Sampling locations for fish spawning aggregation and passive acoustic monitoring.

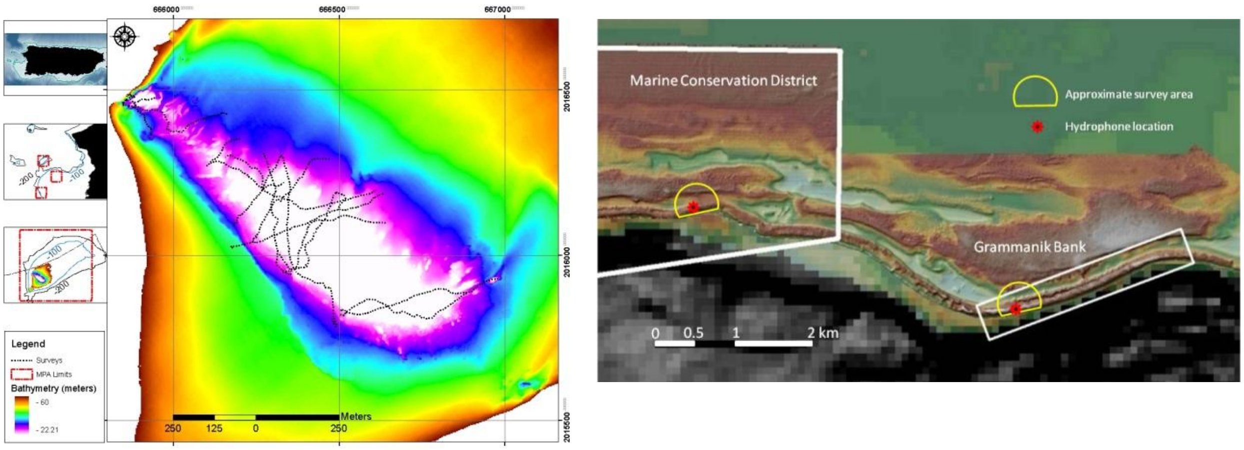

Figure 4.14.2. Bajo de Sico, Puerto Rico at left, Red Hind Bank MCD & Grammanik Bank, St. Thomas at right.

How often is the survey conducted (annually, biennially, biannually etc.)?

- Yearly

Is it seasonal?

- Surveys are conducted from December to May (June in US Virgin Islands)
- PAM is recording from November to June

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Fixed site at two Nassau grouper FSA in the US Caribbean (known FSA sites)
- Acoustic recorders (DSG) at various sites throughout BDS, one site at Grammanik Bank (GB) and one at a historic Nassau grouper spawning site in the Red Hind Bank Marine Conservation District

Describe allocation of sites per strata (proportional/weighted?) and number of sites.

- Repeated surveys over time at the same sites to capture short-term variations in abundance, size and condition during the spawning aggregation.

Describe the methodology and gear

Maximum abundance estimates

- Surveys to document groupers are conducted throughout the reproductive season on days when aggregation is expected (based on PAM). The maximum abundance of groupers by species is quantified on drifts or roving surveys conducted along the structure of the reef or depth contour in one continuous direction determined by the current at the time of the dive. Each grouper is tallied during the survey. On peak spawning days a slightly modified methodology was used to quantify the color-phases of Nassau grouper during the same drift along the reef.

- Surveys are conducted with closed circuit rebreather (CCR) due to the depths at which grouper aggregate (100' to 170') and last 15 to 20 minutes.
- At the Grammanik Bank additional visual survey methods were employed to quantify groupers. Fixed belt transects consisted of twelve 30 m segments that were marked with a polystyrene float tied 3 m above the bottom within the western portion of the Grammanik Bank. The last segment ended at the FSA site and the first segment was 360 m to the east. During transect surveys each diver would swim and count all *E. striatus* up to 20 m to the south or north of the line of floats (i.e., 30 m x 20 m belt transects).

- Roving dives were used to count target species in areas outside the belt transects usually to the north and west of the DSG. Unrestricted point counts were used to collect data on fish behavior, color phases and abundance at a specific site, usually at the DSG location. Divers conducting unrestricted point counts would remain in a specific location and estimate total abundance of aggregating species within a 360 degree area defined by the limits of underwater visibility (Samoilys and Carlos 2000).

Size estimates with video and laser caliper

- Surveys with video (GoPro camera) and laser caliper are conducted as divers drift in one direction through the aggregation site (**Figure 4.14.3**). Each grouper encountered during the dive is recorded with video and the two red lasers are pointed and held on the side of the fish at a perpendicular angle. Still images are extracted from the video, processed and analyzed with Adobe Photoshop measurement tool to estimate the size of each individual. With this data length frequency distributions are generated.

Figure 4.14.3. Materials used for rigging the video camera and underwater lasers for calibration of images

- PAM is conducted at the main spawning site at 55 m depth and in addition three sites at distances of 250 to 1500m, at similar depths have DSGs. Each DSG is programmed to record continuously during at least six months with a sampling schedule of 20 seconds every 5 minutes onto 32-gigabyte removable secure digital high capacity (SDHC) flash memory cards. Files are digitized at a sample rate of 10 KHz, and units are powered by an array of 24 D-cell batteries for the duration of the deployment. DSG recorders are attached weighted bases near the seafloor. After deployment the DSGs are inspected for proper functioning at times when surveys were conducted at each site, then dsg files are converted to .wav files and examined manually.

- Vocalizations of Nassau grouper with high signal to noise ratios are identified visually and audibly for each file with the aid of spectrograms generated in Ishmael 2.0 (Cooperative Institute for Marine Resource Studies Bioacoustics Lab). Manually counted vocalizations of each species are summed per day resulting in an estimate of total vocalizations per day at each site. For Nassau grouper courtship associated calls are counted throughout the day.

- Time-series of total vocalizations per day are created in MATLAB (Mathworks) to determine temporal patterns of peak and elevated vocalization levels during each lunar cycle (full moon to full moon). Periods of elevated vocalizations are defined as days when vocalization totals were greater than or equal to half the maximum vocalizations for each lunar cycle.

- The data worksheets used to characterize the color phase of Nassau Grouper are shown in **Figure 4.14.4**.

DATE		SITE	OBS	DATE		SITE	OBS	DATE		SITE	OBS
START		CUR		START		CUR		START		CUR	
END		DPTH		END		DPTH		END		DPTH	
BARRED				BARRED				BARRED			
BICOLOR				BICOLOR				BICOLOR			
WHITE-BELLY				WHITE-BELLY				WHITE-BELLY			
DARK				DARK				DARK			
OTHER SPP				OTHER SPP				OTHER SPP			

D=distended; F=following; C=circling

Figure 4.14.4. Datasheet used to quantify the color phases of Nassau grouper during FSA surveys.

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Maximum number of Nassau grouper and color phase per day (density from the stationary surveys at the Grammanik Bank)
- Length frequency distribution per day
- Courtship associated sound record per hour, day, lunar or monthly cycle

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?

- Focused on Nassau grouper and other groupers are detected sporadically
- PAM records all species that have sounds described for
- Non-destructive sampling

What are the gear/method biases (catchability, size selectivity)?

- Limited to depth range 30 to 70m (CCR) and approachable individuals/species
- Limited to species that are known to produce sounds associated with reproduction, more research needed for other species and the behavioral context of variability in sound production still needs work.

What are the temporal/spatial limitations?

- Only one site is measured at a specific time, unknowns for other sites or times of the year. However the abundances are expected to decline the rest of the year
- DSG location must be within 100-300 m of the known courtship/spawning arena in order to consistently collect sounds during reproductive displays. This area may change over time and needs to be verified by *in situ* surveys during the peak of the aggregation.

Is this survey expected to continue into the future?

- Unknown at this time.

It is relatively expensive/inexpensive, logistically difficult/easy?

- Technical diving training, DSG and video laser equipment (CCR) costly
- Getting to and surveying sites can be challenging due to currents or weather conditions since they have to be done at specific times of the month/day.
- PAM can be labor intensive because sounds are currently quantified manually, however there are recent developments of computer assisted sound recognition modeling techniques (Automated Remote Biodiversity Monitoring Network (ARBIMON) that may provide more efficient data acquisition and analysis of these time series (see Aide et al. 2013).

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- High-resolution temporal coverage of few sites
- Surveys need to be consistently done in order to provide sufficient data to be useful to compare over time.

Data generated: length frequency, spawning stock biomass, mortality etc.

- Length frequency and spawning stock biomass
- Reproductive sound signal series

Provide any other information that may be relevant to this discussion

- The natural behavior of certain species during spawning aggregations provides an opportunity focus surveys and attain large amount of data in a relatively short time period. This is essential for species that have low probability of occurrence and are rarely detected in non-targeted surveys.
- Repeated surveys over long time frames are essential to generate a sufficiently robust data set to be able to generate trends in abundance or size structure. This methodology doesn't cause any mortality.

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

Schärer M, Nemeth R, Tuohy E, Clouse K, Nemeth M and R Appeldoorn (2014) Nassau grouper *Epinephelus striatus* Fish Spawning Aggregations in the US Caribbean. Proceedings of the Gulf and Caribbean Fisheries Institute 66: in press.

Schärer M, Rowell T, Nemeth M and R Appeldoorn (2013) The Courtship Associated Sounds of Nassau Grouper, *Epinephelus striatus* (Pisces: Epinephelidae) during Spawning Aggregations. Proceedings of the Gulf and Caribbean Fisheries Institute 65:302-304.

Aide TM, Corrada-Bravo C, Campos-Cerqueira M, Milan C, Vega G, Alvarez R. (2013) Real-time bioacoustics monitoring and automated species identification. *PeerJ* 1:e103 http://dx.doi.org/10.7717/peerj.103

Schärer MT, Rowell TJ, Nemeth MI and RS Appeldoorn (2012) Sound production associated with reproductive behavior of Nassau grouper *Epinephelus striatus* at spawning aggregations. Endangered Species Research 2012:29–38.

4.15 Fish spawning aggregation (FSA) and passive acoustic monitoring (PAM) research for red hind (Epinephelus guttatus) and other groupers at multi-species sites

How is it funded, who administers it?

- CCRI, SEAMAP-C

Why was the survey originally designed?

- To characterize red hind FSA and later on to determine the applicability of sound signal processing techniques for assessments

What are/were the intended outcomes/objectives?

- Test the feasibility of using PAM for routine assessments (see Rowell et al. 2012)
- Quantify the abundance of red hind and other grouper species
- Estimate the size structure of red hind and other grouper species
- Determine the timing of reproductive activity at a site
- Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- At this time PAM is being conducted at four locations mainly for red hind (Mona Island, Abrir la Sierra, Tourmaline and El Seco) in Puerto Rico and two locations (Red Hind Bank in St. Thomas and Lang Bank, St. Croix) in the US Virgin Islands (**Figure 4.15.1**). Abrir la Sierra (depths 20-40m) has been surveyed most consistently, however the same methodology was used to gather data at Mona Island, Buoy 4, Bajo de Sico and other sites on the western insular platform of Puerto Rico.

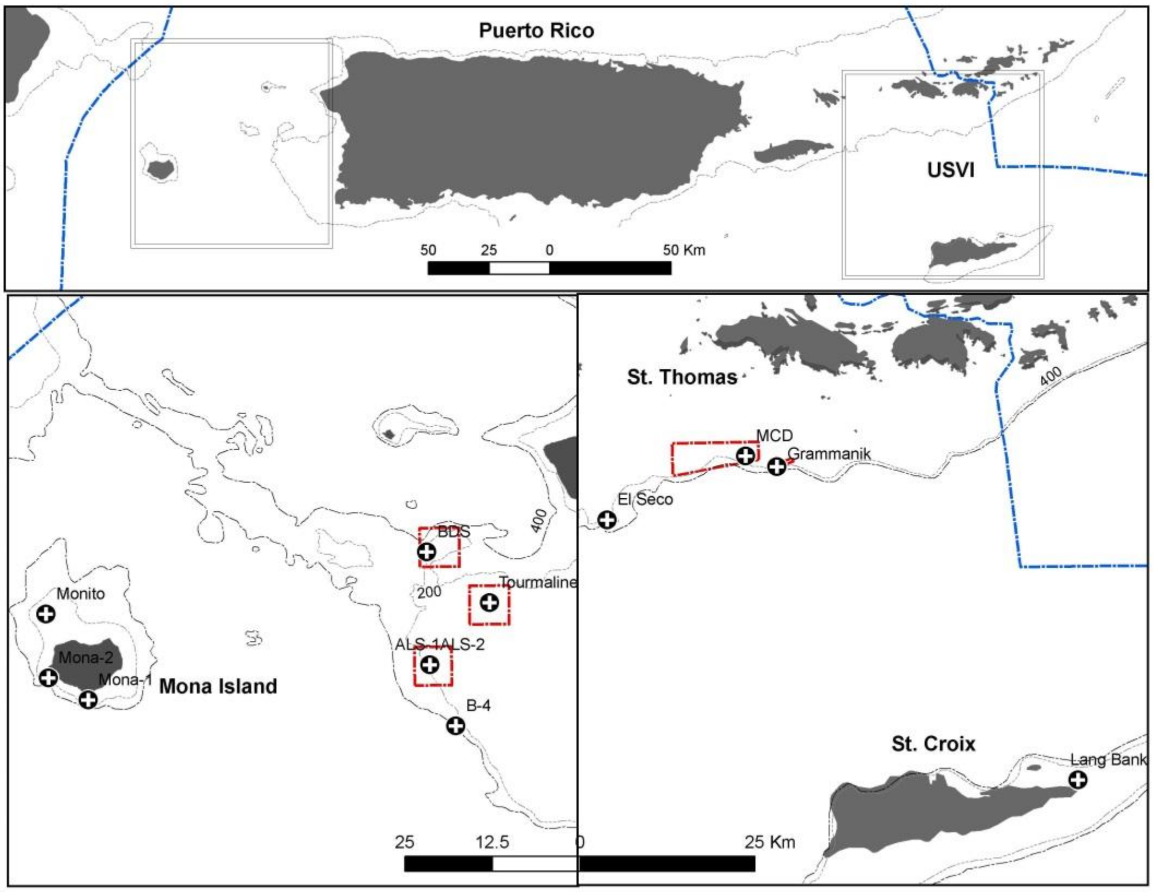

Figure 4.15.1. Sites where PAM recorders have been deployed in the US Caribbean.

How often is the survey conducted (annually, biennially, biannually etc.)?

- Yearly at some sites, but not consistently

Is it seasonal?

- Surveys are conducted during reproductive season (December to May)
- PAM recorders are deployed during six to seven months (November to June) depending on the target species of the particular site

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Fixed site at red hind FSA

Describe allocation of sites per strata (proportional/weighted?) and number of sites.

- Repeated surveys over time at the same site to capture short-term variations in abundance, size and condition during the spawning aggregation.
- PAM provides a high-resolution (every 5 minutes) temporal record of the reproductive activity that can be used to calibrate the survey data over the spawning peak.

Describe the methodology and gear

Abundance and size estimates

- Surveys to document groupers are conducted throughout the reproductive season on days when aggregation is expected to form (based on PAM). The maximum abundance, density and size of groupers by species is quantified on GPS-tracked drift or roving surveys conducted along the depth contour in one continuous direction determined by the current at the time.

- The diver tows a hand-held GPS unit on the surface buoy while collecting data underwater after synchronizing the divers watch and the GPS clock. Each red hind (or group) and a visual estimate of size are noted along with the time to the nearest 30-second interval. Only red hind within a 4-m wide belt are counted in order to continue in the predetermined direction.

- Surveys are conducted at 16:00 with open circuit diving with time durations between 20 to 40 minutes. Surveys are conducted in the late afternoon in order to maximize the chances of observing most of the red hind that engage in reproductive displays in the latter part of the day (See Mann et al. 2010). Two pairs of divers survey along the same area in parallel without crossing each other's path simultaneously.

- After the dive the GPS track is downloaded and based on the time started and ended a length is calculated by converting the points from the track into lines and measuring in Arc GIS software. Transect length is multiplied by 4m (width) to estimate the area surveyed and determine density.

- In the US Virgin Islands R. Nemeth has employed belt transects to quantify red hind at the Red Hind Bank and the latter of these data could be compared to the PAM record as well. (See SEDAR Red Hind).

Passive acoustic record

- Each DSG is programmed to record continuously during at least six months with a sampling schedule of 20 seconds every 5 minutes onto 32-gigabyte removable secure digital high capacity (SDHC) flash memory cards. Files are digitized at a sample rate of 10 KHz, and units are powered by an array of 24 D-cell batteries for the duration of the deployment. DSG recorders are attached with hose clamps to rebar located within 100m of the aggregation sites or on weighted bases near the seafloor. After deployment the DSGs are inspected for proper functioning at times when surveys were conducted at each site, then dsg files are converted to .wav files and examined manually.

- Vocalizations of red hind or other grouper with high signal to noise ratios are identified visually and audibly for each file with the aid of spectrograms generated in Ishmael 2.0 (Cooperative Institute for Marine Resource Studies Bioacoustics Lab). Manually counted vocalizations of each species are summed per day resulting in an estimate of total vocalizations per day at each site. For red hind courtship associated calls are counted for the 18:00-19:00 AST hour period as this is the most consistent time of the day with sound production (see Mann et al. 2010).

- Time-series of total vocalizations per day are created in MATLAB (Mathworks) to determine temporal patterns of peak and elevated vocalization levels during each lunar cycle (full moon to full moon). Periods of elevated vocalizations are defined as days when vocalization totals were greater than or equal to half the maximum vocalizations for each lunar cycle.

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Maximum number and density (after calculation of area surveyed) or red hind
- Length frequency distribution per day
- Continuous passive acoustic record from which the courtship associated sounds can be quantified on a daily, monthly or lunar basis to compare over time.

Self-Evaluation of pros and cons of Survey

What suite of species does this survey target (what are gaps)?

- Focused on red hind, other groupers are counted but surveys need to be focused to capture other species due to temporal and site variability
- PAM records all species that have sounds described for
- Non-destructive sampling

What are the gear/method biases (catchability, size selectivity)?

- Limited to depth range of safe diving with open circuit and approachable individuals/species, water visibility and time of day may affect results or comparisons over time.

- Limited to groupers that are known to produce sounds associated with reproduction, more research needed for other species and the behavioral context of variability in sound production still needs work.

What are the temporal/spatial limitations?

- Only one site is measured at a specific time, unknowns for other sites or times of the year. However the abundances are expected to decline the rest of the year.

- DSG location must be within 100-300 m of the known courtship/spawning arena in order to consistently collect sounds during reproductive displays. This area may change over time and needs to be verified by *in situ* surveys during the peak of the aggregation.

Is this survey expected to continue into the future?

- Unknown at this time

It is relatively expensive/inexpensive, logistically difficult/easy?

- Dive training and equipment required especially for visual size-estimation of individuals

- Getting to and surveying sites can be challenging due to currents or weather conditions, since they have to be done at specific times of the month/day.

- PAM can be labor intensive because sounds are currently quantified manually, however there are recent developments of computer assisted sound recognition modeling techniques (Automated Remote Biodiversity Monitoring Network (ARBIMON) that may provide more efficient data acquisition and analysis of these time series (see Aide et al. 2013).

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- High-resolution temporal coverage of few sites with PAM equipment
- Surveys need to be consistently done in order to provide sufficient data to be useful to compare over time

Data generated: length frequency, spawning stock biomass, mortality etc.

- Length frequency and spawning stock biomass
- Reproductive sound signal series

Provide any other information that may be relevant to this discussion

- The natural behavior of certain species during spawning aggregations provides an opportunity focus surveys and PAM to attain large amount of data in a relatively short time period. This is essential for species that have low probability of occurrence and are rarely detected in non-targeted surveys.

- Repeated surveys over long time frames are essential to generate a sufficiently robust data set to be able to generate trends in abundance or size structure. This methodology doesn't cause any mortality.

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

Rowell T, Appeldoorn R and M Schärer (2013) Passive Acoustics Record Grouper Spawning Activity at Multi-species Aggregations. *Proceedings of the Gulf and Caribbean Fisheries Institute* 65:281-283

Appeldoorn R, Schärer M, Rowell T, and M Nemeth (2013) Measuring Relative Density of Spawning Red Hind (*Epinephelus guttatus*) from Sound Production: Consistency Within and Among Sites. *Proceedings of the Gulf and Caribbean Fisheries Institute* 65:284-286

Aide TM, Corrada-Bravo C, Campos-Cerqueira M, Milan C, Vega G, Alvarez R. (2013) Real-time bioacoustics monitoring and automated species identification. *PeerJ* 1:e103 http://dx.doi.org/10.7717/peerj.103

Rowell TJ, Schärer MT, Mann DA, Nemeth MI, Rivera JA and Appeldoorn RS (2012) Sound production as an indicator of red hind density at a spawning aggregation. Marine Ecology Progress Series 462:241-250

Schärer MT, Nemeth MI, Mann DA, Locascio JV, Appeldoorn RS and TJ Rowell (2012) Sound production and reproductive behavior of Yellowfin grouper, *Mycteroperca venenosa* (Serranidae) at a spawning aggregation. *Copeia* 2012:135-144

Rivera JA, Kellison T, Appeldoorn RS, Schärer MT, Nemeth MI, Rowell T, Mateos D, and P Nealson (2011) Detection of Mona Island and Abrir La Sierra, Puerto Rico Red Hind (*Epinephelus guttatus*) 1 m off the Bottom with Hydroacoustic Techniques. *Proceedings of the Gulf and Caribbean Fisheries Institute* 63: 143−148

Rowell TJ, Appeldoorn RS, Rivera JA, Mann DA, Kellison T, Nemeth M and MT Schärer-Umpierre (2011) Use of passive acoustics to map grouper spawning aggregations, with emphasis on red hind, *Epinephelus guttatus*, off western Puerto Rico. *Proceedings of the Gulf and Caribbean Fisheries Institute* 63: 139−142

Mann D, Locascio J, Schärer MT**,** Nemeth MI and RS Appeldoorn (2010) Sound production by red hind *Epinephelus guttatus* in spatially segregated spawning aggregation sites. *Aquatic Biology* 10:149-154

4.16 Mesophotic Surveys

How is it funded, who administers it?
- Funded by a grant from NOS/CSCOR to UPR/CCRI

Why was the survey originally designed?
- Fish work was part of a broader effort on corals, algae, inverts and fishes
- To characterize mesophotic coral ecosystem (MCE) fish communities > 50 m in Southeast Puerto Rico
- To assess connectivity between shallow and MCE fish communities
- To relate diversity and abundance to habitat features

What are/were the intended outcomes/objectives?
- To characterize MCE fish communities > 50 m across the US Caribbean
- To assess connectivity between shallow and MCE fish communities
- To relate diversity and abundance to habitat features
- Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

Figure 4.16.1. Locations (arrows) of diver surveys of MCE fishes > 50 m within the US Caribbean. Solid lines indicate that multiple sites were surveyed along the indicated range**.**

How often is the survey conducted (annually, biennially, biannually etc.)?

- Most sites were surveyed only once
- Replicate samples were taken at sites off La Parguera, Puerto Rico

Is it seasonal?

- Two sites of La Parguera were sampled seasonally for 1 year

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- No statistical allocation used; surveys were exploratory
- Target depths were 50 and 70 m at each site
- Sites were chosen to provide a range of geomorphologies based on slope, orientation relative to prevailing swell and included main Puerto Rico-Virgin Islands Shelf, small islands and isolated banks. Some sites chosen to provide lee conditions for diver safety
- At La Parguera, fixed/repeated sites were selected to represent two types of habitat – one being more rugose with steeper slope and higher coral cover, and one being less rugose with shallower slope and lower coral cover.

Describe allocation of sites per strata (proportional/weighted?) and number of sites

- On a large scale, 25 sites were sampled. In two areas, La Parguera Puerto Rico and Cane Bay, St. Croix multiple subsites were sampled

Describe the methodology and gear

- Visual census using trimix rebreathers
- 15 minute, 10 x 3m belt transects
- First evasive species were recorded, followed by sedentary species
- Roving surveys made to quantify fishery target species outside belt transects
- 2 sets of surveys/dive when possible

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Per transect or roving survey, data were number and sizes of individuals of each species
- Transect data are standardized to estimate density
- Roving surveys emphasize frequency of occurrence

Self-Evaluation of pros and cons of Survey

What suite of species does this survey target (what are gaps)?

- Mesophotic fishes > 50 m depth (50 & 70 m target depths)

What are the gear/method biases (catchability, size selectivity)?

- Limited to non-cryptic diurnal fishes
- Diver avoidance bias, but much less than open-circuit diving
- Density estimates not possible for large species
- Limited bottom time (20 min)
- Limited dives/day (~3)

What are the temporal/spatial limitations?

- Limited only by diver safety issues: e.g. wave, currents

Is this survey expected to continue into the future?

- Funding dependent

It is relatively expensive/inexpensive, logistically difficult/easy?

- Gear is expensive and training takes a full year
- Can be done off small or large vessels, but must have access to gases.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- Coverage is potentially high if have access to trimix

Data generated: length frequency, spawning stock biomass, mortality etc.

- Length/biomass structure and derived parameters is N is large
- Info on what shallow visual census potentially misses

Provide any other information that may be relevant to this discussion

- N/A

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

Ivonne Bejarano Rodríguez. 2013. Deep reef fishes off La Parguera insular slope, Puerto Rico, and their connectivity with shallow reefs. Ph.D. Dissertation, UPR-Mayagüez

Peer-review publications, SEDAR reports

Bejarano, I., R.S. Appeldoorn, M. Nemeth. 2014. Fishes associated to mesophotic coral ecosystems in La Parguera, Puerto Rico. Coral Reefs. 33: 313-328.

Sherman, C., R. Appeldoorn, M. Carlo, M. Nemeth, H. Ruíz, I. Bejarano. 2009. Use of technical diving to study deep reef environments in Puerto Rico. Pp 58-65. *In*: Pollock NW, ed. Diving for Science 2009. Proceedings of the American Academy of Underwater Sciences 28th Symposium, Dauphin Island, AL

Sherman, C., R. Appeldoorn, D. Ballantine, I. Bejarano, M. Carlo, D. Kesling, M. Nemeth, F. Pagan, H. Ruiz, N. Schizas, E. Weil. Exploring the mesophotic zone: Diving operations and scientific highlights of three research cruises (2010-2012) across Puerto Rico and US Virgin Islands. Proceedings of the American Academy of Underwater Sciences, Curacao 2013. In press.

4.17 Fishery-Independent survey of commercially exploited fish and shellfish populations from mesophotic reefs within the Puertorrican EEZ

How is it funded, who administers it?

- NOAA – CFMC

Why was the survey originally designed?

- As part of the characterization of federally managed Essential Fish Habitats (EFH) seasonally closed to fishing, Abrir la Sierra (ALS), Bajo de Sico (BDS) and Tourmaline (TOUR) Reefs

What are/were the intended outcomes/objectives?

- Characterize the main species assemblages of commercially important fish and shellfish populations present from each of the benthic habitats and depths surveyed. Analyze variations of the species assemblages between sites
- Provide inferences of seasonal variations by species at ALS, with particular interest on queen conch
- Produce rough estimates of population sizes for target species based on field estimated densities and benthic habitat areas at each site
- Conduct a preliminary analysis of the status of the commercially important fish and shellfish populations within the mesophotic habitats surveyed based on the length frequency data

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- Mesophotic depths from 30 – 50 m

How often is the survey conducted (annually, biennially, biannually etc.)

- One time survey at each site, increased sampling at ALS

Is it seasonal?

- It had a seasonal component at ALS

Describe the underlying experimental design

Fixed site or stratified-random (if stratified-random, describe the strata)

- stratified by habitat, with roughly proportional geographic coverage

Describe allocation of sites per strata (proportional/weighted?) and number of sites

- 8 transects per each of the 3 main habitats at TOUR and BDS; 24 at each of the 3 main habitats at ALS

Describe the methodology and gear

- Visual census by two rebreather divers surveying commercially important fishes (groupers, snappers, hogfish, queen trigger, large parrots, barracuda, sharks, lionfish) and shellfish (queen conch, spiny lobster) along drift transects approx. 250 m long. Visual length estimates for fish and lobster. Length measurements for conch

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Species composition, density estimates per habitat, per site and per season (ALS) for each species. Length frequency distributions per habitat and site for each species; rough estimates of population sizes per habitat and site

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are the gaps)?

- See above with emphasis on queen conch

What are the gear/method biases (catchability, size selectivity)

- cryptic behavior (lobster, conch, groupers)

What are the temporal/spatial limitations?

- less than 5 % of total area sampled, surveyed few dates at BDS and Tour

Is this survey expected to continue into the future?

- TBD – CFMC may have input

Is it relatively expensive/inexpensive, logistically difficult/easy?

- $165K for the 3 sites; 120 transects. All sites deep, >100' (technical diving required); 4 divers/navigators minimum staff; far from shore 10 – 20 miles offshore

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal Coverage

Data generated: length frequency, spawning stock biomass, mortality etc.

- This was a pilot study characterizing commercially important spp assemblages from mesophotic habitats in Puerto Rico. The work produced a unique data set that achieved in good part the main goal objectives (see IV) with many relevant and novel ecological insights and fishery management implications considering the limited effort engaged.
- Comparative analyses are constrained by small sample sizes for many of the species of interest.
- Variance structure is very strongly impacted by the large amount of 0's resulting in replicate transects per habitat and per site for many of the species of interest, rendering high uncertainty for comparative analyses between habitats and sites. Still, important trends that suggest real temporal and spatial patterns are exposed that deserve further consideration and sampling effort.

Provide any other information that may be relevant to this discussion

- García-Sais, Jorge R Ph.D., Jorge Sabater-Clavell, Rene Esteves, Milton Carlo, Fishery independent survey of commercially exploited fish and shellfish populations from mesophotic reefs within the Puertorrican EEZ.
-

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

- See above

4.18 The United States Virgin Islands Territorial Coral Reef Monitoring Program

How is it funded, who administers it?

- Funded by NOAA's Coral Reef Conservation Program, Administered by The Division of Coastal Zone Management, US Virgin Islands Department of Planning and Natural Resources Administration

Why was the survey originally designed?

- The program was initiated by the Coral Reef Conservation Act of 2000, which mandated all maritime areas and zones subject to the jurisdiction or control of the US monitor coral reef communities. The first two years of this project (2001 and 2002) concentrated on the fringing reefs surrounding St. Croix. In 2003, monitoring continued on St. Croix reefs and began at reef systems distributed across the insular platform surrounding St. Thomas/St. John.

What are/were the intended outcomes/objectives?

- Objectives included monitoring the status and trajectories of coral reefs and fish communities across a majority of habitats and threats, including land-based sources of pollution, overfishing and thermal stress.
- Also to link changes in coral reef health with specific stressors, indicating specific management interventions most effective for preserving reefs and reef fish communities.
- A third objective is to integrate assessments of understudied mesophotic coral reef ecosystems and threatened species in the US Virgin Islands.

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- The TCRMP includes the three major islands of the US Virgin Islands: St. Thomas, St. John and St. Croix. Sites are shown below.

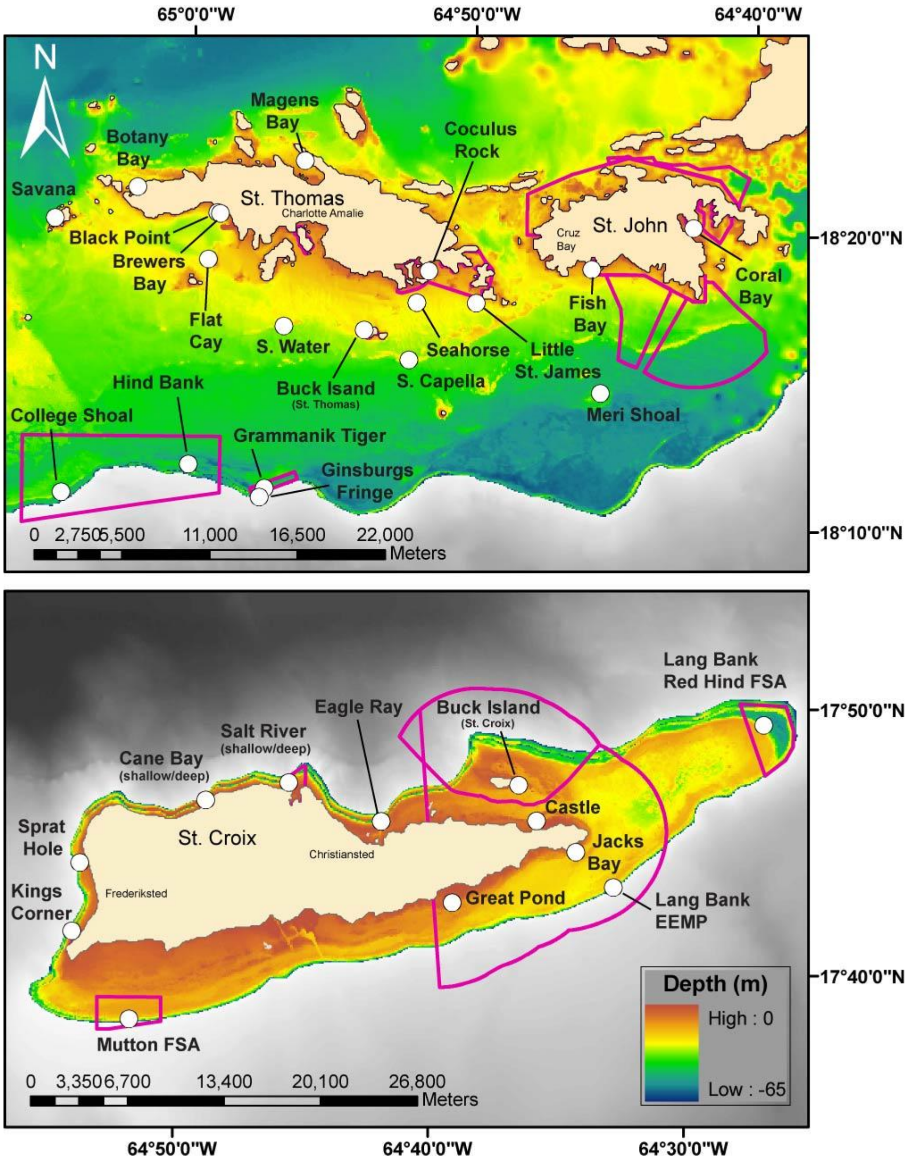

Figure 4.18.1. Station locations for the Territorial Coral Reed Monitoring Program (TCRMP).

How often is the survey conducted (annually, biennially, biannually etc.)?

- Survey is conducted annually.

Is it seasonal?

- Typically the surveys are conducted during the Summer and Autumn months (July-November)

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Fixed site

Describe allocation of sites per strata (proportional/weighted?) and number of sites

- The Territorial Coral Reef Monitoring Program (TCRMP) began in 2003 with 15 fixed sites: 7 in the northern US Virgin Islands and 8 surrounding St. Croix. In 2008 the number of fixed sites expanded to 11 in the northern US Virgin Islands and 14 on St. Croix and in 2012, an additional 4 sites were added to St. Thomas/St. John bringing the total in the northern US Virgin Islands to 15.
- All sites are in scleractinian coral reef communities (>5% coral cover prior to mass bleaching and mortality in 2005) and were selected as representative coral reef habitats spaced across the insular shelves of the US Virgin Islands in a total of four habitat strata based on proximity to shore and water depth.
- These strata included nearshore (5-20 m), offshore shallow (7-20 m), offshore deep (24-30 m) and shelf edge deep (24-40 m). Sites within each habitat type exhibit similar characteristics of structure and benthic cover.
- Sites were included on fish spawning aggregation areas (FSAs) in both the northern US Virgin Islands (Grammanik Bank and Red Hind Marine Conservation District, MCD) and St. Croix (Lang Bank FSA and Mutton Snapper FSA), however data collection is conducted outside of the spawning season for all of the grouper species.

Describe the methodology and gear

- Visual fish census methodology at fixed sites consists of single divers performing 10 timed 30x 2m (2003-2008) or 10 timed 25x4m (2009-2013) belt transects to assess fish abundance and size.
- To perform a belt transect, a diver attaches the end of a 25m transect line to the substrate at a random point and swam in a predetermined random direction, identifying fishes to the lowest taxa and counting all fish within 1 or 2m (depending on year) of either side of the transect line, including up the water column to the surface.
- Fish counts were placed in size bins based on total length: 1-5cm, 6-10cm, 11-20cm, 21-30cm, 31-40cm, 41-50cm, 51-60cm, 61-70cm, 71-80cm and >80cm. Approximate time for each transect is 15 minutes.
- In addition to transects, three replicate roving dives are conducted at each site. Roving dives are 15 min (sites > 25m depth) or 30 min (sites < 25m depth) in duration. Divers swim a haphazard pattern recording all species and their relative encounter rate: one, 2-10, 11-100, 101-1000 or over 1000. Groupers, large snappers, and hogfish are recorded by exact number.

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Currently data output is limited to descriptive statistics of the coral reef fish community.

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?

- The survey targets coral reef species. Most of the sites are in water less than 40m. Deeper water species are not seen, nor fish normally not associated with coral reef.

What are the gear/method biases (catchability, size selectivity)?

- Method biases: visual surveys are on SCUBA and underestimate fish abundance and biomass.

What are the temporal/spatial limitations?

- Temporal limitations: survey is conducted only once annually so seasonal biases may be included in the data.
- Spatial limitations: Limited number of sites. More sites could be added to decrease spatial limitations but this would add to expense. Other habitats could be added however the program is centered on coral reefs and a large part of it involves monitoring coral coverage and health.

Is this survey expected to continue into the future?

- yes

It is relatively expensive/inexpensive, logistically difficult/easy?

- Moderately expensive. Fairly labor-intensive and transportation costs are high. Survey team travels annually to St. Croix for 5-10 day missions.
- Logistically it is not difficult as all sites are relatively near land (within 10 miles) and conditions are generally good to fair. Survey techniques are easy to learn and follow, and little gear except SCUBA equipment is needed.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- Both spatial and temporal coverage is fairly good. Spatially the program covers St. Thomas, St. John and St. Croix, both inshore and out. Temporally the program has spanned 10 years.

Data generated: length frequency, spawning stock biomass, mortality etc.

- Length frequencies and spawning stock biomass data is limited on most fisheries species because they are infrequently encountered and surveyed in our program.

Provide any other information that may be relevant to this discussion

N/A

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

https://www.researchgate.net/publication/259005675_The_United_States_Virgin_Islands_Territorial_Coral_Reef_Monitoring_Program._2011_Annual_Report?ev=prf_pub

4.19 Fishery-Independent Queen Conch Surveys in Northeast St. Croix

How is it funded, who administers it?

- Internal MARFIN funding to SEFSC-Galveston (J. Doerr/R. Hill)

Why was the survey originally designed?

- To understand the abundance and distribution of queen conch inside/outside reserves in northeast St. Croix

What are/were the intended outcomes/objectives?

- To generate fishery-independent density estimates suitable for contributing to stock assessment models
- To quantify length-based differences (juvenile/adult age classes) in conch densities and distribution by habitat, depth, and management regime (i.e. inside and outside marine protected areas)
- To compare population density patterns with historical surveys conducted in the area (SEAMAP-C).

Describe the temporal and spatial coverage of the survey

Show the geographic coverage (including depth) of the survey (maps are helpful)

- Northeast Shelf of St. Croix, US Virgin Islands, see **Figure 4.19.1.**

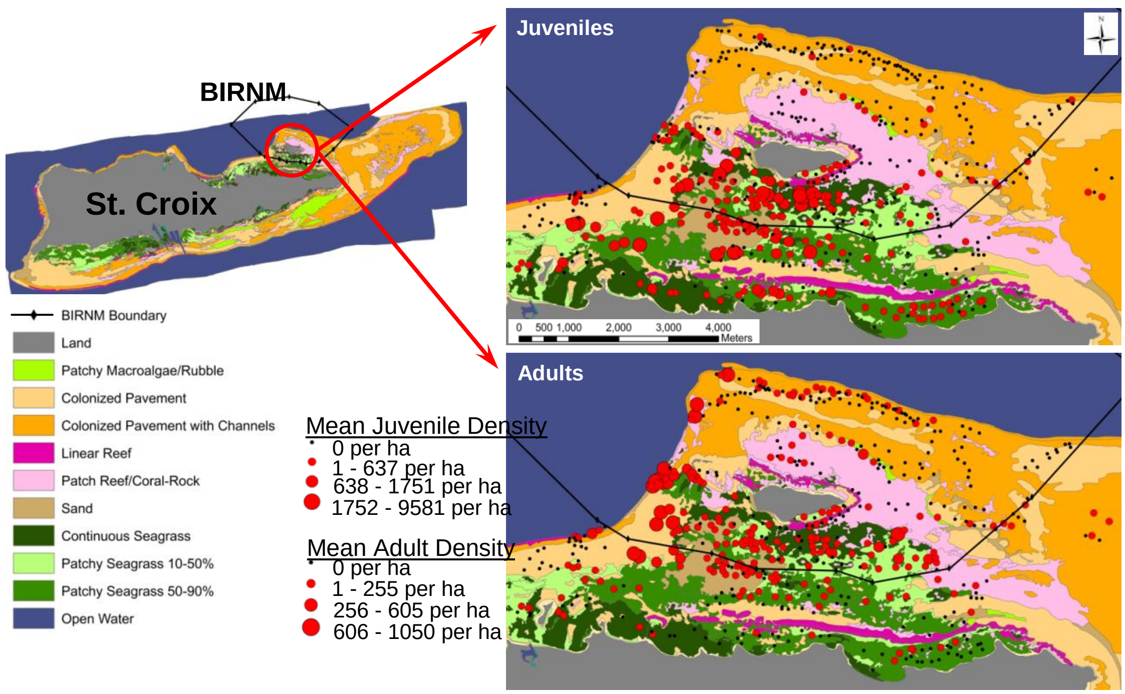

Figure 4.19.1. (From Doerr and Hill, ms in prep). Map of St. Croix, US Virgin Islands, showing the spatial coverage and arrangement of benthic habitat types, the administrative boundary of Buck Island Reef National Monument, and radial survey locations.

How often is the survey conducted (annually, biennially, biannually etc.)?

- Surveys were conducted during four dates from Sept 2010-Sept 2011

Is it seasonal?

- Intention was to survey early spring and late summer however delayed funding forced a modification of sampling schedule

Describe the underlying experimental design

Fixed site or stratified-random (If stratified-random, describe the strata)?

- Design was stratified-random, with management zones, depths and habitat types as strata.

Describe allocation of sites per strata (proportional/weighted?) and number of sites

- As a first attempt to apply this method, we tried to ensure adequate distribution across the area spatially and some proportional weighting for depth zones and habitat types based on available habitat maps. Diver-observed habitats were used in analysis causing some modification to distributions.

Describe the methodology and gear

- At each sample site we dropped a weighted line attached to a buoy and recorded the location using a hand-held GPS receiver. Divers descended to the bottom where they clipped a 10-meter survey line above the weight, and recorded water depth. The divers swam the end of the survey line in a circle and searched the entire area (314 m2) for conch; one diver swam at the end of the line and one swam at the mid-point of the line. Shell length (tip of the spire to end of the siphonal groove) and lip thickness (area of greatest thickness along the flared lip approximately 3 cm in from the edge of the shell) of each conch encountered were measured *in situ* and recorded, and any mating activity and the presence of egg masses was noted. Benthic habitat type was visually characterized by both divers and assigned to a habitat type following NOAA benthic habitat map categories (Kendall et al. 2001). If no conch were observed in the first pass around the circle, the divers reversed direction and resurveyed the area.

Describe the outputs of the survey

Describe the data outputs & include a discussion of the variance structure of the data

- Data outputs are number of conch by size (nearest cm) and estimated (fishery) life stage per 10m-radius circle (314 m^2) and each circle/conch is associated with actual depth, actual habitat and mapped habitat, management zone, and geomorphic zone, as well as date and time.

Self-Evaluation of pros and cons of survey

What suite of species does this survey target (what are gaps)?

- Targets queen conch only

What are the gear/method biases (catchability, size selectivity)?

- Boundaries of surveyed area are well defined, as are depth, zone, and habitat type. All sizes are included. Catchability should be high but can be affected by conch's burying behavior or poor visibility. Our method calls each diver to be responsible for inner and outer bands with some overlap. Divers flag conch as they are spotted for later measurement, if they are few, but collect them to the center of the circle if there are many. This ensures divers move around inside their circle and increase the chance of encounter. The repeated survey, in the event of zero conch, ensures a better chance to see any missed the first time.

What are the temporal/spatial limitations?

- Diving technologies may limit depth of sampling or require specially trained divers for deeper than 100-140 ft.

Is this survey expected to continue into the future?

- We have proposed conducting surveys in St. Thomas and St. John and would like to rotate surveys between areas every 3-5 yrs.

It is relatively expensive/inexpensive, logistically difficult/easy?

- The surveys are relatively inexpensive, however they do require a number of divers. We used six (3 pairs) and dove two nearby sites at a time from a single small boat. Travel expenses were the major expense. Limitations from weather, dive logistics, and NOAA dive regulations could be logistical constraints.

Self-Evaluation of utility of survey for generating information for stock assessment

Spatial/Temporal coverage

- Good coverage for the area surveyed; likely this is the minimum number of samples needed to characterize the standing stock.

Data generated

- Abundance, distributions, and length frequency by life stage x habitat, depth, and management zone. Primary purpose would be change over time and spawning stock extrapolations.

Provide any other information that may be relevant to this discussion

N/A

Provide most relevant documentation (w/PDFs or hyperlinks if possible)

5. ACKNOWLEDGMENTS

The funding for this workshop was provided by an internal MARFIN award. The authors would like to thank the rapporteurs, Adyan Rios and Mandy Karnauskas as well Aida Rosario, Michelle Scharer Umpierre, David Bryan, Nathan Bacheler and Richard Appeldoorn for reviewing an early draft of this manuscript. This report would not have been possible without the support of the Southeast Fisheries Science Center, the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS), The Cooperative Institute of Marine and Atmospheric Studies, the scientific community of the US Caribbean and the Caribbean Fisheries Management Council.

APPENDIX 1. AGENDA

US Caribbean Fishery-Independent Survey Workshop
September 16-18, 2014
Miami Florida
AGENDA

Workshop Terms of Reference:
1) Identify fishery-independent data sources in the US Caribbean.
2) Document the data source (e.g. POC, purpose of sampling, sampling methodology, species encountered and encounter frequency, relevant metadata).
3) Evaluate utility for stock assessment and make recommendations.
4) Build collaborations.

Day 1 - Tuesday - 9/16/14		
8:30 - 9:00	Coffee	
9:00 - 9:10	Welcome to SEFSC	Theo Brainerd
9:10 - 9:40	Introductions and Terms of Reference	Shannon Calay
9:40 - 10:10	Overview of Available Models and Data Requirements	Meaghan Bryan
10:10-10:40	Discussion	
10:40-10:50	BREAK	
10:50 - 11:30	Biogeography Diver Based Surveys (historical) & NCRMP Diver Based Surveys	Randy Clark
11:30 - 12:10	Reef Visual Census (RVC) Surveys	Jerry Ault/Steve Smith
12:10 - 1:30	LUNCH	
1:30 - 2:10	St. John Long-term Reference Reef Fish Monitoring	James Beets
2:10 - 2:50	St. Croix Cooperative Fishery-Independent Trap Survey	Todd Gedamke
2:50 - 3:30	Recent Longline and Other NOAA surveys & Early US Caribbean Fishery-Independent Information	Walt Ingram
3:30 - 3:40	BREAK	
3:40 - 4:20	Caribbean Reef Fish Video Survey	Matthew Campbell
4:20 - 5:00	Discussion/Wrap Up	
5:30	Happy Hour - TBD	

Day 2 - Wednesday - 9/17/14		
9:00 - 9:30	Coffee and Welcome	
9:30 - 10:10	The SouthEast Fishery-Independent Survey (SEFIS)	Nathan Bacheler

10:10-10:50	SEAMAP-C in Puerto Rico	Aida Rosario
10:50 - 11:00	BREAK	
11:00 - 11:40	Fish Spawning Aggregation Surveys in Puerto Rico	Michelle Schärer
11:40 - 12:20	Mesophotic Surveys	Rich Appeldoorn
12:20 - 1:40	LUNCH	
1:40 - 2:20	Fishery-Independent survey of commercially exploited fish and shellfish populations from mesophotic reefs within the Puertorrican EEZ	Reni Garcia
2:20 - 3:00	TCREMP	Jeremiah Blondeau
3:00 - 3:10	BREAK	
3:10 - 3:50	Fishery-Independent Queen Conch Surveys in NE St. Croix	Ron Hill
3:50 - 5:00	Wrap up and Discussion	

Day 3 - Thursday - 9/18/14		
9:00 - 9:30	Coffee	
9:30 - 10:30	Recap and Review of Indices Discussed, include Survey Summaries	
10:30 - 10:40	BREAK	
10:40 - 11:30	Generate Matrix of Priority, Cost and Feasibility	
11:30 - 12:30	Identify Best Practices and Recommendations/Modification for US Caribbean	
12:30 - 2:00	LUNCH	
2:00 - 4:00	Review, Discuss and Modify Draft Report Content	
4:00 - 4:10	BREAK	
4:10 - 5:00	Next Steps, Wrap Up and Adjourn	

APPENDIX 2. LIST OF PARTICIPANTS

Last Name	First Name	Affiliation
Appeldoorn	Rich	University of Puerto Rico
Arnold	Bill	SERO - Caribbean Branch
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Berkson	Jim	SEFSC - RTR Program
Blondeau	Jeremiah	SEFSC - Protected Resources and Biodiversity
Bohnsack	Jim	SEFSC - Protected Resources and Biodiversity
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Calay	Shannon	SEFSC - Sustainable Fisheries
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Die	David	UM RSMAS
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