CARIBBEAN PILOT PORT SAMPLING AND CATCH VERIFICATION PROJECT

Final report for the U.S. Virgin Islands and Puerto Rico

(Submitted to the National Marine Fisheries Service Southeast Fisheries Science Center and Atlantic Coastal Cooperative Statistics Program)

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EXECUTIVE SUMMARY

A pilot port sampling program was conducted in the U.S. Caribbean from late September of 2015 to early May of 2016. The sampling program was implemented in two phases—the first in the U.S. Virgin Islands (USVI), and the second in Puerto Rico.

The first phase of the pilot port sampling program was conducted in St. Thomas and St. Croix, USVI, from late September to early November of 2015. Two strata on each island region were defined: St. Thomas high use sites (m = 4 sites), St. Thomas low use sites (m = 6), St. Croix high use sites (m = 4) and St. Croix low use sites (m = 5). The second phase of the pilot port sampling program was conducted in Puerto Rico, from April to early May of 2016 with the four coasts being defined as separate regions: North (Low strata = 11 sites; High strata = 6 sites), South (Low strata = 9 sites; High strata = 6 sites), East (Low strata = 6 sites; High strata = 5 sites) and West (Low strata = 7 sites; High strata = 7 sites).

The sampling methodology was the same for both phases and regions. Within a stratum, the primary sampling unit was the day (N = 30 days, excluding Sundays which were not included in the survey) and all days were sampled. On each sampling day, two sites were selected randomly for sampling and samplers were present from 9 am to 5 pm. The variable of interest was the total number of pounds of fish of a given species that was landed during the day at the site being sampled.

Logistically, the survey implementation went smoothly in all six regions surveyed (i.e. St. Thomas, St. Croix, and four regions in Puerto Rico). In St. Thomas and all the regions sampled in Puerto Rico, the pilot study was received with high degree of cooperation from the commercial fishers. The situation in St. Croix was more challenging as fishing behavior was driven by market demands and fishers would immediately rush off to sell their catch. Thus, St. Croix fishers had less patience for sampling activities and a number of trips could not be sampled or could not be sampled completely. In these cases, ad hoc adjustments had to be made to account for unsampled or partially sampled trips where weights and/or species specific weights could not be collected. This was made by assuming unsampled trips were similar in nature to sampled trips and species recorded only to family group (e.g., parrotfish unknown) were similar to species composition of landings where all fish were identified to species. Additionally, logistics and financial considerations precluded sampling of two offshore islands in Puerto Rico (Culebra and Vieques) and one in St. Thomas (St. John) where landings are known to occur.

In the USVI, the sampling program was successful in that it provided proof of concept and indicated the need for some adjustments for St. Croix. In both USVI regions, it achieved high

precision of the estimates, with proportional standard errors (standard errors expressed as a percentage of the estimate) being 20% for the total catch on St. Thomas and 10% on St. Croix. Proportional standard errors ranged from 16 to 26% for 5 of the top 6 species landed on St. Thomas, from 9 to 19% for St. Croix. In Puerto Rico, the sampling program was successful in that it showed the importance of redefining the strata to be more homogeneous yet still achieved good precision overall. In the four regions of Puerto Rico, it achieved proportional standard errors for the total catch of 18% in the North, 5% in the East, 6% in the South, and 7% in the West. Proportional standard errors for 5 of the top 6 species landed in the North, East, South and West ranged from 15 – 75%, 9 – 25%, 13 – 15%, and 11 – 27%, respectively.

In all regions sampled, results of the pilot survey indicated a wider variety of species being landed than appears in the commercial catch records, and provided estimates of the among day and among sites components of variability, information which is needed to evaluate and optimize a long-term sampling design. This is important for constructing strata, evaluating the timing of landings over the course of the day, allocating sampling effort to high and low use strata, and determining the number of days of sampling needed to achieve a given precision.

In terms of practical logistics for a long term survey we make the following recommendations:

Governance - The first consideration in designing and implementing a long term survey design should be to align the efforts of both federal and territorial efforts. A formalized agreement between the territorial fisheries agencies (DPNR and DRNA) and NOAA should be developed and, if possible, compliance with sampling efforts be mandated. Combining commercial landings enumeration efforts with the existing biostatistical sampling program (i.e. TIP; fishers required to be sampled 4 times a year in the USVI) and/or recreational sampling would minimize the amount of times fishers interact with samplers, reduce the number of scientific personnel and result in greater efficiency of these programs and overall compliance.

Sampling efficiency – In the USVI, market differences between the two regions resulted in different challenges in sampling; however on both islands two recommendations are common: ice must be available for every fisher sampled and a strategy for more rapid sampling should be developed.

In St. Croix, fishers may need to be sampled in two steps: 1) record trip information as the fishers unload to get a complete count of commercial trips, and 2) follow fishers to market to get an enumeration of the catch composition. Alternatively, additional work could be done to explore if sampling could be done very rapidly (i.e. < 10 min) at the landing site through the use of fixed or mobile sorting stations and camera documentation of the catch. Improvements in sampling strategy could be used on both islands to minimize the time necessary for sampling to be conducted. In addition, and to assist in night fishing sampling in particular, an individual based sampling scheme could be explored.

In Puerto Rico, the necessity for ice and rapid sampling was not as obvious as in the USVI due primarily to smaller average landings per trip. Certain locations, with higher usage and/or those sites with a few larger scale fishers would obviously benefit from both but the need is not island wide. While our ability to sample catch compositions was not greatly impacted, improvements in sampling efficiency will be recognized and appreciated by fishers, and result in increased cooperation and a reduction in the number of refused interviews and the amount of fish in lumped categories such as "parrotfish" or "snappers".

In terms of statistical design and efficiency for scaling the current survey up to a year-long survey, we make the following recommendations:

Restratification - Based on usage observed in the pilot study, we recommend that stratum definitions be redefined for all regions that were sampled. In the USVI, and based on our analysis of the pilot survey data, improvements in the standard error around 16% were indicated in St. Thomas. However, the benefits in St. Croix were not as clear. Similarly, in Puerto Rico, there were obvious benefits to restratification on the North Coast, but in other regions restratification indicated improvements for some species and not others. It's important to note that the calculations surrounding restratification are based on the assumption that the observed usage of the sites represents real differences among sites rather than measurement error. Therefore benefits of restratification should be revisited after the first year of an annual survey when more information is available.

Number of samplers per stratum per day - In the pilot study, we surveyed two sites each day in each stratum (m=2). This enabled us to determine the within day (i.e., among site) and the between day components of variance.

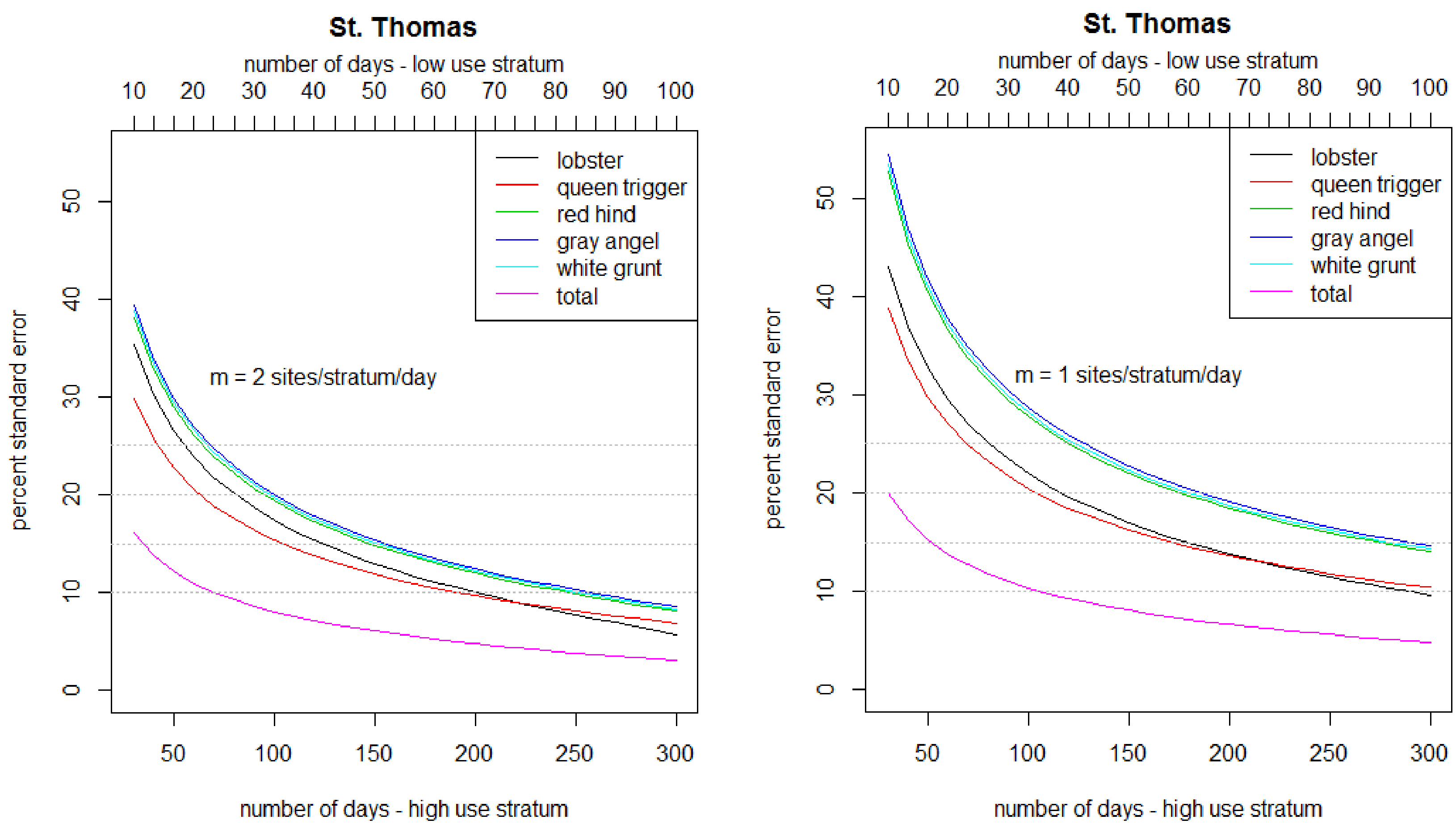
Our analysis shows that choosing m=1 site per day per stratum would be sufficient in most cases (assuming the cost savings would allow for more total days to be sampled). We note that the analysis is contingent on a very simple cost model which does not consider the cost and logistics of hiring additional people. (Four people sampling for 90 days is treated as the same cost as 1 person sampling for 360 days, i.e., 360 person-days in both cases.) It is reasonable to assume that hiring more people is costly and this argues then that the value of m should be as low as possible, i.e., m = 1. However, with m=1 it is not possible to obtain unbiased estimates of the variance of the landings; existing methods would provide overestimates of the variance for this case. So, the survey may be precise but the indication would be that it is less precise. Also, with m=1, one loses the ability to refine the estimates of the variance components and the ability to rank sites is impaired. Thus, the patterns observed during the pilot survey are assumed to hold for all time and we do not have the ability to refine the design as further sampling experience accrues. If cost considerations dictate m=1, we recommend some resources be devoted to having two sites be visited per stratum on some days. Some work is needed to determine the proper analytical methods for the case where the number of samplers per day is variable. It may also be the case that having one port sampler devoted to each stratum is not affordable. In this case, a lattice design may be attractive in that one port sampler can sample the two group of sites (corresponding to the original strata, but the term "stratum" is no longer appropriate because the two groups are not sampled independently). Again, this design should be evaluated in light of the pilot study results and the results of a full year of sampling.

We think it is extremely important to include some means of measuring the among-site component of variance at least in the first full year of a continuing (multi-year) survey because the efficiency of the sampling can undoubtedly be improved with additional information.

Allocation of effort to high versus low use strata - For St. Thomas, more effort should be devoted to the high use strata than the low use. We recommend a ratio of 3:1 for high use days versus low use days. According to our calculations, a more extreme allocation might provide better precision but this is not prudent, in our opinion, because the allocation decision is based on preliminary data from a limited period of the year. For St. Croix, the results are variable across species so a compromise needs to be made since what is best for one species may not be good for another. We recommend that the high use and low use strata be sampled at a ratio of 1:1.

For Puerto Rico, we recommend a ratio of 3:1 for days allocated to high use sites versus low use sites for the East and West; for the South, we recommend a ratio of 1:1. The preliminary indications are that a ratio of 1:3 might be best for the North however this finding is suspect because variance is generally higher when the mean is higher so, even allowing for the difference in size of the high and low strata, we wouldn't expect the optimum allocation to give such weight to the low use stratum. These calculations were done with the original stratification scheme which did not work well in the North; therefore, we recommend that additional calculations be done based on the proposed restratification scheme after a full year of sampling at a ratio of 1:1.

Total number of days - The effects of changing the number of days devoted to sampling was evaluated based on the new allocations to high and low use strata and with the number of port samplers per stratum per day fixed at either m=2 or m=1. The graph and table below illustrate the results for St. Thomas. From these (and the complete results in Section 4.3.3.6 and Section 4.3.4.6) the number of days of sampling can be selected to achieve the desired precision (from the graph), and the results can be converted into person-days of effort (in Table below).



Standard error of estimated St. Thomas landings expressed as a percentage of the landings for a fixed ratio (3:1) of sampling effort in the high use and low use strata for 2 (left) or 1 (right) port sampling agents per stratum per day.

Summary of options for a year-long port sampling survey (*St. Thomas as an example)* - In the table below, the maximum width of the confidence interval is calculated for the top 5 species and for the total catch. In this table we assume a 95% confidence interval is approximately the estimate ± 2 standard errors. Thus, the width of the confidence interval (as a percentage of the estimate) is found by doubling the relative standard error. This table was derived from the figure above by looking for the minimum number of days at which twice the proportional standard error for every species is below the desired level of precision. The --- symbol indicates the desired precision can't be obtained under the constraints imposed with this design. The ratio of sampling effort for the high use and low use strata is fixed at 3:1.

Region	Maximum width of CI	m	Estimated # of days for High use	Estimated # of days for Low use	Number of people days
St. Thomas	40%	2	101	34	270
St. Thomas	30%	2	157	52	418
St. Thomas	20%	2	261	87	696
St. Thomas	40%	1	187	62	249
St. Thomas	30%	1	283	94	377
St. Thomas	20%	1	---	---	---

Further analysis was conducted to evaluate the optimal number of sites to visit in a day (i.e. m = 1 or m = 2) and the results indicate that the minimum number of sites should be visited per day. This would be one site per day. However, with m = 1 it is not possible to obtain an unbiased estimate of the variance. It may be that 1 site could be visited on most days and 2 sites could be visited on some days in order to estimate the variance. However, determining the details of this design would be better informed by an entire year of sampling.

Although the pilot study was successful in obtaining estimates for the 30 day period at the selected sites, the allocation of future effort should include a continuous evaluation of both sites (and usage) and temporal patterns. Sites that were not included in the pilot study (i.e., St. John and Vieques) should be evaluated through at least spot checks and a year-long survey should be designed to provide information to make sure patterns of usage observed in the 30 day pilot survey hold over the whole year.

Logistical constraints- A key issue is the unit of labor available to do survey work. All the above calculations were done under the assumption that fractional person-years could be devoted to sampling which implies part-time employees. However, this work requires substantial training and skill so that the recruitment, training and retention of part-time employees is a limiting factor. We recommend that full-time employees be used for any ongoing survey to insure success of the program.

Final Recommendation for Port Sampling in the US Caribbean

We recommend utilizing the results of this pilot study to implement a full year sampling program with multiple objectives. The primary objective would be to estimate annual landings and investigate temporal variability. The pilot program was conducted during the off season in the USVI and in a relatively high season in Puerto Rico. Differences in effort and landings at other times of the year may have a substantial impact on the variability of estimates. We recommend initiating the program utilizing the same basic survey design as in the pilot study with the sites restratified as indicated in this report.

Although the basic survey design is sound and effective, some improvements might be made. The first is to post-stratify the observations within a stratum by the gear sector (e.g., trap fishermen, divers, mixed gear) or by individual landings history (e.g., known top performers versus everyone else) or some combination of sector and landings history. The second improvement that might be made is to initiate a complementary individuals-based survey. For example, on St. Thomas, much of the landings is accounted for by a handful of top performers. These fishers could be contacted according to a randomized schedule to obtain an estimate of total landings for this group. The group would have to be excluded from the main, site-based survey. But, since the number of top performing fishers is small, it is an easy matter to make sure they are not double counted by the site-based survey.

The amount of sampling effort is going to depend on funding availability. Ideally, four full time samplers would be available in each region but reasonable estimates can be obtained with less effort at the expense of gathering information that can be used to improve the efficiency of the survey. Two full time samplers (e.g. ~500 – 600 people sampling days) could be used per region (m = 1), but the addition of one half time person would allow information to be collected to improve the design as well as allowing additional studies to be conducted to improve efficiency such as by incorporating an individual-based survey into the overall sampling design. Alternatively, if budget constraints dictate less sampling effort, one full time and one half time sampler could be used.

Secondary objectives of a full year program would be to further evaluate refinements or modifications to the overall survey design and to the sampling protocols and procedures. Specifically, two options are being proposed: 1) work with DPNR, DRNA and the fishing community to develop individual based sampling methods and 2) to develop more rapid sampling techniques (e.g. sorting/sampling stations with cameras). The development of individual based sampling methods can improve the efficiency of the basic survey design. But, additionally, it can address the need for information on night fishing (e.g. yellowtail snapper) through a comprehensive list of active fishers and development of an interview or reporting program.

1 INTRODUCTION

1.1 Statement of Need

Excerpt from the RFP announcement:

Since the 2007 reauthorization of the Magnuson Stevens Act (MSA), shortcomings in U.S. Caribbean stock assessments have become apparent. This region has more managed species than continental U.S. fisheries, and insufficient support for monitoring has led to very high uncertainty about landings. Biological information and fishery-independent data for these stocks are lacking, which limits accurate and timely resource management decisions, threatens the economic and cultural vitality of these communities, and compromises the sustainability of the territorial fisheries. If these stocks are to be managed with confidence, as mandated by MSA, NOAA must make this focused investment in territorial fisheries science.

Without this investment, NOAA will continue to lack the scientific information needed to meet its regulatory mandates under MSA and Endangered Species Act (ESA), which will diminish its reputation among stakeholders and its ability to manage stocks, as well as perpetuate uncertainty and unnecessary economic burdens on territorial communities. The stock status of many territorial fisheries populations will remain unknown, potentially leading to overfishing and closures, as well as possible ESA petitions and listings. Implementation of annual catch limits (ACLs) will continue to be hindered by a lack of adequate catch monitoring and biological information in these small-scale, multi-species, multi-gear fisheries, which will in turn then require complex methods and indices to assess. Territorial communities, particularly those dependent on subsistence fishing, may experience the loss of vital near shore resources with severe economic and cultural consequences.

1.2 Goals and Objectives

The primary goal of the Caribbean Fishery Catch Validation Pilot Study (hereafter referred to as "the pilot study") is to gather information necessary to design and implement a long-term catch and effort sampling program for the U.S. Caribbean. A well designed port sampling program should provide critical data for NOAA to manage territorial fisheries and act as a means to evaluate the self-reported landings data obtained from commercial catch records (CCR) in the U.S. Caribbean.

The pilot study has the following objectives:

- Develop and implement a sampling design to estimate commercial landings in each island group (St. Croix and St. Thomas/St. John) in the U.S. Virgin Islands (USVI) and for the four regions in Puerto Rico. Sampling will be of short duration and high intensity so that the variability in landings among days and among landing sites can be estimated.

- Analyze resulting commercial fisheries landing data with respect to mean and variance of landings by site and day, and make recommendations for optimizing the design of a long-term statistical survey for the U.S. Caribbean.
- Analyze additional resulting information (e.g., logistics, partnerships, capacity needs) and make recommendations for successfully carrying out a long-term sampling program for the U.S. Caribbean.
- Evaluate the ability to collect additional information (e.g., biological specimens) during port sampling activities.

1.3 Rationale for Pilot Study

In 2014, a study was conducted to evaluate existing data and make recommendations for a port sampling program in the U.S. Caribbean (MER, 2014). The primary finding of the 2014 study (hereafter referred to as the "MER Estimation Report (2014)") was that only limited information was available on the relative usage of different landing sites and on the variability of landings. A short, high intensity pilot survey was recommended to better characterize variability within and among sites in each region so that future sampling effort could be efficiently allocated.

1.4 Practical Considerations

Immediately following the proposal award, MER Consultants announced the project at the spring 2015 Caribbean Fisheries Management Council (CFMC) meeting and initiated discussions with those involved in the U.S. Caribbean fisheries (e.g. territorial fisheries staff, fishers, CFMC members and staff, and enforcement). The goals of these meetings were to begin socializing the upcoming study, to begin defining relationships and roles, and to discuss logistics. As with any complex field project, a few of the final decisions on project implementation were subject to logistical constraints. These constraints, presented below, should be considered when interpreting results of the pilot study, as well as the recommendations for development of a long term sampling program.

1.4.1 Timing of pilot project

The project was awarded in late March 2015 and contracts were finalized by the end of April 2015. The final decision on implementation dates was based on three primary factors: 1) the amount of time required for project planning and development, 2) hurricane season, and 3) the need to have results for either Puerto Rico or the USVI by the end of 2015. The final decision was to start sampling at the tail end of the hurricane season (i.e., September and October) to minimize the risk of a storm impacting the implementation, while providing enough time for results to be generated. The trade-off in this strategy, however, was that tourism in the USVI is extremely low in September and October. An expected result of this seasonal change in visitation was that fishers reported that demand for fish was also low, and that in response they adjusted their fishing effort down by as much as half of normal during the rest of the year. There was no indication, however, that fishers changed their manner of fishing (i.e. different targeting or gear usage) during this period of lower effort.

In Puerto Rico, a spring sampling period was suggested by both territorial fisheries agents and commercial fishers. The decision was made to start the project following holy week ending on Good Friday (*Semana Santa*), which is a traditional week-long celebration where higher than normal fish consumption occurs and could have affected the 'normal' fishing patterns.

It is important to consider the potential for other temporal differences outside of our sampling period in interpreting and generalizing the results of the pilot study. While high intensity sampling produces more reliable estimates during the sampling period, observed patterns may not persist throughout the year.

1.4.2 Governance and anonymity of individual fishers

This pilot study was conducted with the cooperation and support, but ultimately independent of, the Divisions of Fish and Wildlife (DFW) of the USVI Department of Planning and Natural Resources (DPNR) and Puerto Rico Department of Natural and Environmental Resources (DRNA; Departamento de Recursos Naturales y Ambientales). With few exceptions,[1] all of the port sampling personnel involved in this project were independent contractors with no direct affiliation to either territorial agency. As such, or without additional regulations which were not feasible, fishers had no requirements or incentives to be sampled or to comply with the sampling procedures. To maximize cooperation and participation in the project, and at the recommendation of territorial fisheries staff and fishers in both jurisdictions, data collection procedures were developed that did not include personally identifiable information (e.g. fisher name or boat registration numbers). The analysis proposed in the MER Estimation Report (2014) does not require individual fisher identification, so the primary goal of the project was not impacted and the potential for fishers perceiving the project as a threat was minimized. This was a reasonable trade-off to foster cooperation, but it highlights the complex interplay between roles, regulations, objectives, and the success of a long term port sampling program. The full support of DPNR and DRNA is mandatory for any form of success and a formal framework for

[1] DRNA port agents were presented and/or collected data in collaboration with samplers on 26 occasions and were essential to data collection at one location in Puerto Rico (Pescadería Soltero, Puerto Real). Also, DRNA employees occasionally assisted in data collection during periods of low activity (i.e., weekends and nights). See Section 4.4.1 for a description of Sunday/night fishing.

the relationship between contractors and the departments should carefully be considered to maximize the potential benefits of the sampling program.

1.5 Report Content and Organization

This report presents the planning, design, implementation, and statistical analysis of the pilot study. It also presents recommendations for design and implementation of a long term port sampling program in the U.S. Caribbean. 2, “Project Planning and Development” (p. 13), presents efforts carried out in preparation for implementation, including coordination and outreach, materials development, personnel hiring and training, and the final sampling design. Section 3, “Project Implementation” (p. 29), presents on-the-ground efforts to carry out the pilot study, including sampler assignment and oversight, data collection, and data quality control. Section 4, “Results” (p. 33) presents an evaluation of implementation methods, a statistical description of landings data, a statistical analysis of the sampling design with consideration for study constraints, and a summary of efforts to estimate fishing effort outside the sampling period (i.e. Sundays and nights). Section 5, “Recommendations” (p. 125) presents guidance on development of a long term sampling program in the U.S. Caribbean, including recommended logistics, equipment, sampling methods, and sampling design. Section 6 (p. 135) presents literature cited, and Section 7 (p. 136) presents acknowledgements. Appendices are found in Section 8 (p. 137).

2 PROJECT PLANNING AND DEVELOPMENT

2.1 Coordination and Outreach

A number of planning meetings and outreach activities were carried out in the four months prior to implementation of the pilot study. In the USVI and Puerto Rico, planning meetings with DPNR and DRNA staff and fishers were used to gather input on survey design, sites selected, and overall logistics. In Puerto Rico, HJR Reefscaping, a local contractor led by Dr. Héctor Ruiz and Dr. Michelle Schärer and with offices in Cabo Rojo, was the main partner in coordination, outreach, translation of materials into Spanish, and implementation of the pilot project. Outreach activities in both regions were used to inform stakeholders about the upcoming study. Fishers were targeted so that goals and objectives could be carefully explained, and to generally socialize the project so that members of the fishing community were not surprised when samplers arrived at landing locations.

2.1.1 Territorial natural resource agencies

In the USVI, Dr. Gedamke met with the former and current Directors of the Division of Fish and Wildlife (DFW) of the USVI DPNR, Dr. Roy Pemberton and Ms. Ruth Gomez, respectively, on multiple occasions. The first step was to insure that the project had the full support of DPNR and then to determine sampling dates and locations. DPNR staff, including the former chief of fisheries, Tom Dolan, reviewed the proposal and were asked to provide specific input on the overall sampling design and, most importantly, the relative usage of different landing sites so that a stratification scheme could be approved. The final list and site stratifications were approved by Director Gomez, who took over for former Director Pemberton just before the project started. Due to a variety of factors, Director Gomez was unable to provide any staff to conduct sampling but she was able to approve 'partnership' language for MER Consultants to use in outreach materials (see Appendix 1).

In Puerto Rico, Dr. Gedamke met with the Director of the Research and Commercial Fisheries Management Division and of the Auxiliary Secretary of Management and Conservation of Habitats and Biodiversity Secretariat of the Puerto Rico DRNA, Dr. Ricardo López and Dr. Miguel García, respectively. Subsequent meetings were held with the chief of the Commercial Fisheries Statistics Program of DRNA, Daniel Matos-Caraballo in order to gather specific information and make key decisions regarding the pilot project. The first step was to insure that the project had the full support of DRNA and then to determine sampling dates and locations. DRNA staff, led by Mr. Matos-Caraballo, reviewed the proposal and were asked to provide specific input on the overall sampling design and, most importantly, the relative usage of different landing sites so that a stratification scheme could be approved. The outreach materials, project logo, project title and the final list of sites with site stratifications were approved by Mr. Matos-Caraballo. Mr. Matos-Caraballo approved partnership language and translations for MER

Consultants to use in letters and outreach materials (see Appendix 1). The staff of the DRNA that currently conducts port sampling for the Fisheries Research Laboratory cooperated in planning, coordination and data collection of this project when they had availability and schedules that coincided with their work plans. At many sites during the sampling period, the DRNA staff were present and collected data simultaneously with personnel contracted for this project.

2.1.2 Universities

In the USVI, faculty members at the University of the Virgin Islands (UVI) were contacted immediately following the contract award. Meetings were held with Dr. Tyler Smith (UVI Faculty; CFMC Member), Dr. Richard Nemeth (UVI Faculty), and Dr. Paul Jobsis (Director Center for Marine and Environmental Studies, UVI) to discuss a potential partnership and the direct integration of UVI students into the program. There was considerable interest in a cooperative program which would provide the student body with hands-on experience and a source for research topics, but the time was too short to formalize a relationship for the upcoming fall semester. Drs. Smith and Nemeth were instrumental in distributing outreach and recruiting materials prior to the project and organizing a seminar room for the classroom portion of the training program.

In Puerto Rico, faculty members at the University of Puerto Rico (UPR) were contacted immediately following contract award. Meetings were held with Dr. Richard Appeldoorn (UPR Faculty at Mayagüez; SSC Chair of the CFMC; Caribbean Coral Reef Institute (CCRI)) and with Dr. Deborah Parrilla (UPR Faculty at Humacao) to discuss a potential partnership and the direct integration of UPR students into the program. There was considerable interest in a cooperative program which would provide the student body with hands-on experience and a source for research topics, but the time was too short to formalize a relationship for the upcoming fall semester. Drs. Appeldoorn of the and Dr. Ernesto Otero (Director of the Department of Marine Sciences, UPR at Mayagüez) were instrumental in distributing outreach and recruiting materials prior to the project and organizing a seminar room for the classroom portion of the training program.

2.1.3 Commercial fishers

In the USVI, members of the commercial fishing community have been consulted on the development of a port sampling program since the creation of the MER Estimation Report (2014). Winston Ledee (STT), Tony Blanchard (STT; CFMC member), Julian Magras (STT), Edward Schuster (STX), Gerson Martinez (STX), Carlos Farchette (STX; CFMC Chair), Tom Daly (STX) and others provided practical evaluation of our site usage evaluations and resulting stratification. This exchange of information provided the opportunity to explain the goals of the project to a handful of USVI fishers through one-on-one contact. After explaining the objectives of the project, three fishers on each island allowed us to use a statement of support and their picture on announcement flyers (see Appendix 1). Announcement flyers were distributed to every commercial fisher as part of their annual Commercial Vessel Registration Workshop during the first two weeks of July. Dr. Gedamke attended the St. Thomas workshop and was given the opportunity to introduce the project personally to almost all of the St. Thomas commercial fishers. Flyers were also posted at various locations (e.g., marine outfitters, stores, restaurants, fish markets, etc.) on St. Thomas and St. Croix to reach fishers and helpers who may not have been at the workshop. See Appendix 1 for flyer copies.

In Puerto Rico, members of the commercial fishing community were also consulted on development of a port sampling program as specifics of the logistics were being developed. Conversations with commercial fishers provided practical evaluation of our site usage evaluations and resulting stratification. This exchange of information provided the opportunity to explain the goals of the project to a handful of Puerto Rico fishers individually. After explaining the objectives of the project, a few of them were willing to participate in training and field practice for samplers. Announcement flyers were distributed to commercial fishers and stakeholders during the Caribbean Fishery Management Council April meeting. Dr. Gedamke attended the Council meeting was given the opportunity to introduce the project personally to many commercial fishers. Announcement flyers were posted at various locations (e.g., marine outfitters, stores, restaurants, fish markets, etc.) in Puerto Rico to reach fishers and helpers who were not present at the Council meeting.

2.1.4 Community

In the USVI and Puerto Rico, the fishing community extends beyond just commercial fishers, and garnering full community support for the project was important. A concerted effort was undertaken to contact individuals, organizations, and businesses through targeted distribution of announcement and sponsorship flyers at various locations (e.g., restaurants, stores, boat ramps, post office, etc.). See Appendix 1 for the flyers distributed on in all study regions.

Local businesses were contacted as potential co-sponsors providing in-kind support to the pilot study. The most valuable form of in-kind support from the community was the provision of ice to fishers being sampled, which was expected to minimize the impact of sampling activities and ease the relationship between fishers and samplers. Providing ice was not logistically or fiscally feasible for this pilot study. In St. Thomas, many businesses, from restaurants with relationships with fishers to ice distribution companies, offered to provide ice. The readiness with which businesses supported the pilot project is encouraging for long-term sponsorship and community acceptance of the port sampling project. While the public was receptive in St. Croix, only one business was able to provide a limited amount of ice for the project. In Puerto Rico, the presence of fish processing facilities (i.e. pescaderias) and infrastructure made the provision of ice less valuable to fishers.

2.2 Materials Development

2.2.1 Species identification guide

MER Consultants developed a *Sampler's Reference Guide for the Fishes & Invertebrates of the U.S. Virgin Islands and Puerto Rico* for training and use by samplers in the field. Common and Latin names conformed to the nomenclature in the CCR database for ease of incorporating and/or comparing landings. Personal and copyrighted images were graciously provided by several individuals with the express permission for their use as educational material for the pilot program only. Additional images are covered by a Creative Commons license. The guide covers:

- External anatomy terms and diagrams
- Top 20 species landed in St. Thomas, St. Croix, and Puerto Rico
- Key traits of fish and invertebrates groups (i.e. families)
- Detailed species descriptions organized by group, including common and Latin name, key characteristics, size and representative image.
- Glossary and additional resources

2.2.2 Training and reference manual

MER Consultants developed a *Training and Reference Manual* for training and use by samplers in the field. HJR Reefscaping translated a portion of the *Training and Reference Manual* to Spanish for training and use by samplers. The manual includes:

- Reference guide (sampling checklist, project announcement flyers for displaying to fishers and the public, equipment list, site list, ways to answer common questions, and a contact list)
- Introductory material (background and purpose of the port sampling program, how to collect scientific data in the field, and responsibilities and priorities)
- Preparation (equipment list and instructions for use, data recording protocols, sampling and subsampling techniques)
- Field protocols (site preparation, sampling protocols, leaving a site, reporting data and other information after sampling)
- Standards of behavior (conduct and decorum, dealing with conflict)

- Technical manuals (scales, tablets)
- Glossary

2.2.3 Paper data forms

Three data forms were developed and printed on Rite in the Rain™ paper for use by samplers in the field. HJR Reefscaping translated each data form into Spanish for training and use by samplers in Puerto Rico. See Appendix 2 for copies of the site assignment forms in English and Spanish Forms included:

1. *Site assignment form* – Filled out upon arrival and throughout the day. One form filled per sampler per day. Includes a summary of weather conditions at the site, level of cooperation from fishers, time on and off site, and any comments or notes.
2. *Trip landing form* – Filled out for each trip sampled. Number filled matches number of trips sampled in a day. Includes details on species landed, recorded and estimated weights, amount fully or subsampled, gear, and survey history. In collaboration with local fisheries supervisors, it was decided that personally identifiable information (e.g., fisher name, permit number, vessel registration number, etc.) be excluded from collection.
3. *Sunday/night fishing form* – Filled out if possible, but not mandatory. Form includes interview questions on activity outside of sampling frame in order to characterize effort not captured during regular sampling.

2.2.4 Electronic data platforms

MER Consultants developed two platforms for electronic data entry and management. The first platform is a mobile data entry application installed on the Samsung Galaxy Tab4™ tablets that samplers took into the field. The second is an online data management system hosted on MER Consultants website for supervisors and managers to access and edit electronic data.

2.2.4.1 Mobile data entry application

The mobile data entry application includes digital versions of the three paper data forms described in Section 2.2.3. See Appendix 3 for screenshots of the data entry application. The application also includes additional functionality that improved the ability of samplers to gather thorough data, as well as the ability of supervisors to manage data and monitor samplers.

Additional functions include:

- Access to the tablet camera for photographing every species sampled in a trip and recorded in the trip landing form.

- Continuous marking of GPS locations and timestamps for oversight purposes. (See Section 3.1.2 for a discussion of oversight, and Figure 1 for a screenshot of the KMZ file extracted from one sampler day at Saga Haven in St. Thomas; and Figure 2 for an image of sampling location intensities for all of Puerto Rico.)
- Marking of GPS locations and timestamps when certain data fields are filled (e.g., site arrival) for oversight and validation purposes.
- Access to a non-editable, digital file of the *Sampler's Reference Guide for the Fishes & Invertebrates of the U.S. Virgin Islands and Puerto Rico*.

2.2.4.2 Online data management system

The online data management system hosts, compiles, and provides access to data uploaded by samplers from their data entry applications. The system is designed to allow island managers and the species identification expert to review and follow up on landings data and pictures in a timely manner (ideally shortly after a sampling assignment), as well as quickly run quality control checks and make any necessary corrections. See Appendix 3 for images of the online data management system.

The system includes two databases: an administrative database, and a supervisor database. The administrative database compiles uploaded data and makes it available for download, review, and analysis. See Section 3.3 for a description of the administrative data review process. The supervisor database organizes and displays uploaded pictures of sampled fish and invertebrates, along with the species assignment made by the sampler, for review and correction. The online data management system also includes a link to download the mobile data entry application and KMZ files of St. Croix and Puerto Rico watch points.

2.3 Personnel and Training

2.3.1 Island managers

In the USVI, one supervisor for each island was contracted to carry out the following duties: hiring of the sampling team, manage and supervise on-the-ground sampling, review and QA/QC data collection through the online data management system, and provide written status updates as necessary. The St. Thomas Supervisor was Mr. Peter Freeman, an independent environmental consultant. The St. Croix Supervisor was Mr. Henry Tonnemacher, the sole proprietor of Seven Seas Ltd.

In Puerto Rico, HJR Reefscaping was contracted to handle the supervision of all on the ground logistics. Lead by Dr. Michelle Schärer, the HJR team developed project flyers and announcements to both socialize the project and to recruit and hire the sampling personnel. HJR Reefscaping also retained the services of Ms. Katie Flynn, an independent environmental consultant with experience in sampling commercial fisheries in Puerto Rico, for support on all aspects of the project.

2.3.2 Sampling team

The sampling teams in the USVI and Puerto Rico were recruited through job announcements in various media. In the USVI, job flyers were first distributed at various locations on each island. See Appendix 1 for the job flyers in St. Croix and St. Thomas, respectively. Second, flyers were sent along with vacancy announcements through listservers (e.g., UVI, CFMC), social media (Facebook), and job sites (e.g., Craigslist). Third, a short job announcement was printed in the classifieds section of the Virgin Islands Daily News over a three-week period. In St. Thomas, eight individuals were hired on the sampling team. In St. Croix, eight individuals were initially hired, and two additional team members were hired later on. See Appendix 1 for job announcement flyers in St. Thomas and St. Croix.

In Puerto Rico, an email communication was first broadcast to UPR students and staff by Dr. Richard Appeldoorn announcing the opportunity for student samplers. Second, a flyer was sent along with vacancy announcements through known contacts in Puerto Rico. Third, a flyer and vacancy announcements were posted on social media (Facebook and local fisheries pages). In total 23 samplers were hired from different regions throughout the island of Puerto Rico. See Appendix 1 for job announcement flyers in Puerto Rico in English and Spanish.

2.3.3 Species identification expert

A species identification expert was hired to regularly review species assignments made by samplers. The species identification expert was Mr. Colin Howe, a master's student in the Center for Marine and Environmental Studies at the University of the Virgin Islands. Mr. Howe has had extensive fish identification training through the Reef Environmental Education Foundation (REEF) program and has taught fish identification courses at the John C. Pennekamp Coral Reef State Park in Key Largo, Florida. Mr. Howe reviewed pictures taken by samplers and corresponding species assignments on the online data management system, and corrected assignments as necessary. See Section 2.2.4.2 for a discussion of the online data management system, and Appendix 3 for a screenshot of the page used by the species identification expert. Species identifications were also reviewed by Dr. Joy Young and a team of scientists at HJR Reefscaping with extensive experience in local fisheries.

2.3.4 Training

All hired samplers were trained in catch sampling protocols, which define procedures for sampler when on site. Training utilized the *Training and Reference Manual* developed by MER Consultants, which accompanied each sampler in the field as required equipment. Catch sampling protocols were taught in English and Spanish (Puerto Rico only) to all participants, and include:

- Hours of each day to be sampled.
- Data to be collected from each vessel landing (e.g. gear, time fishing, # of people fishing, weight of each species landed).
- How to sample landings in the most expedient way possible, and also contingency procedures for when large landings are encountered (e.g. how to subsample catch) or when multiple vessels arrive at the same time (e.g. record volumetric estimates by species rather than weigh each).
- How to complete data forms and quality control measures to be implemented once data forms are completed (e.g. all data forms and daily photographs of species to be sent to regional supervisor for review following each sampling day).

All hired samplers were also trained in fish and invertebrate identification, including information on local common names specific to each island and region within each island as needed. Training utilized the *Sampler's Reference Guide for the Fishes & Invertebrates of the U.S. Virgin Islands and Puerto Rico* developed by MER Consultants, which each sampler took with them in the field.

In St. Thomas, training occurred over a two-day period. Day one involved an introductory classroom presentation at UVI, during which Dr. Gedamke provided background on the USVI fisheries, the basics of the sampling project, and fundamentals of fish identification. Mr. Freeman invited a short-list of candidates to the training, and the communications (i.e. level of questions and discussions) served as an effective platform to select final candidates. Dr. Gedamke met with Director Gomez to approve the final selections. Those selected individuals were invited to continue training the following day (market day) in Frenchtown. Day two involved a live demonstration of catch sampling protocol on the Frenchtown site docks, discussion with fishers at Gustave Quetel market, a review of catch sampling protocols, fish identification training (conducted by Dr. Joy Young), and instruction on use of the tablet and MER Consultants data entry application.

In St. Croix, training was planned to occur over a two day period with the classroom component conducted at the Christiansted Customs House provided by the Buck Island National Wildlife Refuge. Mr. Tonnemacher also pre-screened candidates and invited the short-list to attend the first day. As in St. Thomas, this first day was used both as an opportunity to provide background and basic training to the short-list candidates, but also to allow additional screening and the selection of candidates to participate in the hands-on component of the training. On day two, potential samplers met at the LaReine fish market to mimic the same training that was conducted in St. Thomas. Initially, the individuals selling fish allowed Dr. Young to take some photographs of their catch to use in fish identification training. When potential samplers began to look in coolers, however, the fishers became agitated and very vocal in telling us to leave. At this point, two of the potential samplers resigned on the spot and the start of sampling was postponed by three days to allow for additional recruitment and training. To insure that samplers had enough hands on training, arrangements were made to meet a local fisher (Bobbie Thomas) at the Altona Lagoon ramp a couple days later, where Dr. Gedamke demonstrated a complete sampling event on his catch.

In Puerto Rico, training occurred over a two-day period. Day one involved an introductory classroom presentation at the CCRI seminar room on Magueyes Island where the Department of Marine Sciences of the UPR is located. During the training Dr. Gedamke provided background on the USVI fisheries, the basics of the sampling project, and fundamentals of fish identification. Dr. Ruiz provided simultaneous English to Spanish translation during the training,, Dr. Schärer provided administrative support and facilitated training and participation. Additional training included the techniques and expectations of sampling catches in the field with commercial fishers (conducted by Ms. Lindsey Harris; full time port sampler for Florida Fish and Wildlife Conservation Commission).

Day two of training in Puerto Rico involved practical (i.e. hands-on) training with equipment and materials as well as a live demonstration of catch sampling protocol. Equipment and materials were signed out to samplers at the headquarters of HJR Reefscaping in Cabo Rojo for practice and demonstration at a nearby landing site. To insure that samplers had enough hands on training, arrangements were made to meet a local fisher (A. Maldonado) at El Faro in Cabo Rojo the same day, where Dr. Gedamke, with the assistance of Dr. Ruiz and HJR Reefscaping staff, demonstrated a complete sampling event on his catch. Voucher specimens of fish from a recently landed catch were secured by HJR Reefscaping staff and used for fish identification.

2.4 Final Sampling Design

Sampling was conducted according to a design-based schedule described in MER Estimation Report (2014). Per the definition of strata, each stratum was sampled independently of the other strata. The MER Estimation design involved two-stage cluster sampling. At the first stage, the particular days to be sampled were randomly selected. Then, within a day, two sites were selected randomly for sampling. A port sampler was assigned to each of the two sites and the sampler remained there all day (9 am – 5 pm). The variable of interest was the total number of pounds of fish of a given species that was landed during the day at the site being sampled. There were over 50 species of interest (99 species occur in the data) and separate observations were made for each species, i.e., multiple attributes were recorded. This whole procedure was done for each of the strata separately.

Under this design, there are two explicit sources of variability – that associated with the choice of days, and that associated with the choice of sites within the day. It is possible to estimate these two components of variability (s_1^2, the first stage (among day) variability, and s_2^2, the second stage (within day or among site) variability). This information allows for evaluation of the sampling design and optimization of sampling in future surveys.

In implementing the design proposed in MER Estimation Report (2014), it was decided to sample every fishing day in the study period. No commercial fishing activity is believed to take place on Sundays so Sundays were ignored. In this case, the two-stage cluster sampling design with two observations per cluster (day) reduces to stratified random sampling with two observations taken per stratum (day) (see Cochran 1977). Thus, there is no uncertainty associated with the choice of days since every day was selected for sampling. The uncertainty arises from the choice of sites to visit on a day. It is, of course, still possible to estimate the within-day and among-day components of variance which allows for possible modification of the sampling design in the future (e.g., to reduce, possibly, the number of days sampled and increase the number of sites that are sampled on those days that are sampled).

2.4.1 USVI sampling

The MER Estimation Report (2014) originally identified 26 sampling sites in the USVI and the sampling design created four sampling strata: high use sites on St. Thomas, low use sites on St. Thomas, high use sites on St. Croix, and low use sites on St. Croix. Prior to initiating sampling, each site was visited and discussed with local fishers and territorial officials and as a result, the number of sites and stratum designations changed slightly. Assessments of relative usage of locations by fisheries personnel in the months prior to sampling resulted in 11 total sites selected in St. Thomas and 10 total sites selected in St. Croix. In the USVI, four sites on each island were assigned to the high use sampling stratum, and the remaining were assigned to the low use sampling stratum. Logistical considerations were incorporated into the decisions of the final list of sampling sites, and some changes were made prior to implementation. In St. Thomas, Water Bay was excluded due to a lack of activity. In St. Croix, Richmond Hill was excluded due to logistical considerations. The modifications to the original numbers of sites in each stratum are presented in Table 1. The final site locations and corresponding strata for St. Thomas and St. Croix are presented in Tables 2 and 3, respectively. Detailed USVI site descriptions are provided in a separate document.

Table 1. Revisions to original strata in USVI regions.

Stratum	Original number of sites	Final number of sites
St. Thomas, high	7	4
St. Thomas, low	9	6
St. Croix, high	3	4
St. Croix, low	7	5

Table 2. Final St. Thomas site selection and strata assignments.

Site Name	Site Code	Stratum
Saga Haven	SAG	High use
Frenchtown	FRE	High use
Hull Bay	HUL	High use
Mandahl	MAN	High use
Coki Point / Water Bay	COK	Low use
Sapphire	SAP	Low use
Magens Bay	MAB	Low use
Krum Bay	KRB	Low use
Crown Bay	CRB	Low use
Marine Science Center	MSC	Low use

Table 3. Final St. Croix site selection and strata assignments.

Site Name	Site Code	Stratum
Altoona Lagoon	ALT	High use
Gallows Bay	GAL	High use
Frederiksted Fish Market	FFM	High use
Molasses Dock	MOL	High use
Estate Castle Nugent	ECN	Low use
Christiansted Harbor	CHR	Low use
Turner Hole	TUR	Low use
Salt River	SLT	Low use
Teague Bay	TEA	Low use

2.4.2 Puerto Rico sampling

The MER Estimation Report (2014) originally identified 76 sampling sites in Puerto Rico and the sampling design created eight sampling strata, with two (High and Low) for each of four regions of Puerto Rico (East, North, West and South). In preparation for the pilot port sampling implementation these sites were reevaluated in the fall of 2015 and spring of 2016. First, the most recent 3-4 years of self reported catch data provided by NOAA were evaluated and sites ranked by relative landings. This information was evaluated by DRNA experts, including Mr. Daniel Matos-Caraballo, regarding historical landing site locations that are currently part of the

Commercial Fisheries Statistics Program of the DRNA. A questionnaire was then provided to DRNA supervisors and port sampling staff which allowed those most familiar with landing sites to provide comments and relative rankings of usage for each location. Decisions on the final site selections and stratification were made by DRNA just prior to implementation.

A geographically referenced layer was created for display in Google Earth of the sampling locations as part of the implementation and oversight requirements of the project. The commercial fisheries landings data collected by the DRNA staff is an area based strategy (generally an area of coastline) and not a single specific site or point, which was necessary for the implementation of the pilot study. That entailed choosing specific points at each landing site with geographical coordinates where the samplers should remain to intercept fishers landing with catch.

A few sites were excluded from sampling prior to implementation due to logistical constraints, expert opinion of low to no recent landings, safety concerns or changes in the coastline that prevent landing of fishing vessels. Other sites that have been added, but were not in the historical sites database, include newly constructed ramp facilities that are public, but known to be frequented by some fishers with trailers. A few of these sites include ramp and parking facilities constructed with Sport Fish Restoration funds such as: Guayanilla, La Parguera, El Combate and Arecibo. The modifications to the original numbers of sites in each stratum are presented in Table 4. The final site locations and corresponding strata for each Puerto Rico region are presented in Table 5. Detailed Puerto Rico site descriptions are provided in a separate document.

Table 4. Revisions to original strata in Puerto Rico.

Stratum	Original number of sites	Final number of sites
Puerto Rico North, high	4	6
Puerto Rico North, low	13	11
Puerto Rico South, high	8	6
Puerto Rico South, low	12	9
Puerto Rico East, high	8	5
Puerto Rico East, low	9	6
Puerto Rico West, high	11	7
Puerto Rico West, low	11	7

Table 5. Final Puerto Rico site selection with region and strata assignment.

PR Region	Name	Code	Stratum
North	Barrio Bajura	BAJ	High use
North	Jarealito	JAR	High use
North	Puerto Nuevo	PNU	High use
North	La Puntilla	PUN	High use
North	La Princesa	PRI	High use
North	La Coal	COA	High use
North	Punta Peñon	PEN	Low use
North	Arecibo Rampa	ARE	Low use
North	Palmas Altas	PAL	Low use
North	Cerro Gordo	GOR	Low use
North	Mameyal	MAM	Low use
North	Vietnam	VIE	Low use
North	Calle Hoare	HOA	Low use
North	Torrecilla	TOR	Low use
North	Parcelas Vieques	VEQ	Low use
North	Puerto Mosquito	MOS	Low use
North	Fortuna	FOR	Low use
East	Maternillo	MAT	High use
East	Marina Puerto Del Rey	PDR	High use
East	Barrio Los Machos	BLM	High use
East	Hucares	HUC	High use
East	Maunabo	MAU	High use
East	Las Croabas	CRO	Low use
East	Barrio Sardinera	SAR	Low use
East	Punta Santiago	PSA	Low use
East	Punta Candelero	PCA	Low use
East	Playa De Guayanes	PDG	Low use
East	Puerto Yabucoa	PYA	Low use
South	Playa De Salinas	PDS	High use
South	Pastillo	PAS	High use
South	Playa De Ponce	PDP	High use
South	Tallaboa	TAL	High use

Table 5. (Continued) Final Puerto Rico site selection with region and strata assignment.

PR Region	Name	Code	Stratum
South	Bahia De Guanica	BDG	High use
South	Salinas Providencia	SAL	High use
South	Bajo De Patillas	BDP	Low use
South	Playa Las Palmas	PLP	Low use
South	Jobos	JOB	Low use
South	Punta Pozuelo	PPO	Low use
South	Playa De Santa Isabel	SIS	Low use
South	Bahia De Guayanilla	BGU	Low use
South	La Parguera	LPG	Low use
South	La Parguera Rampa	LPR	Low use
South	Punta Papayo	PAP	Low use
West	El Faro Cabo Rojo	FAR	High use
West	El Combate	COM	High use
West	Puerto Real	PRE	High use
West	Soltero Puerto Real	SOL	High use
West	El Seco Rampa	SEC	High use
West	Rincon	RIN	High use
West	Playuela	PLA	High use
West	Boqueron Rampa	BOQ	Low use
West	Tres Hermanos	THE	Low use
West	Barrio Barrero	BAR	Low use
West	Barrio Espinal	BES	Low use
West	Guaniquilla Barrio	GUB	Low use
West	Higuey	HIG	Low use
West	Barrio Tamarindo	BTA	Low use

2.5 Analytical and Estimation Approach

The overall basis for the analytic procedure is described in detail in the MER Estimation Report (2014). For illustrative purposes, consider the procedure for one stratum. On each day selected, two locations will be selected for sampling. One port sampler will go to each of the two sites and remain there the whole time that fish may be landed. As an example, we will assume 50 out of 60 days in the survey period will be sampled and there are 15 sites from which 2 will be selected each sampling day. Let:

N = number of primary sampling units (PSU, days) = 60

n = number of primary sampling units sampled = 50

M = number of secondary sampling units (SSU, locations) = 15

m = number of secondary sampling units sampled from each PSU = 2.

The variable recorded, y_{ij}, is the total weight of fish (of the species of interest) landed on day i in the secondary sampling unit j (defined by location). Then, the mean of the two observations on day i is

$$\bar{y}_i = \sum_{j=1}^{m} \frac{y_{ij}}{m} = \sum_{j=1}^{2} \frac{y_{ij}}{2}, \tag{1}$$

and the mean of all the observations is

$$\bar{\bar{y}} = \sum_{i=1}^{n} \frac{\bar{y}_i}{n} = \sum_{i=1}^{50} \frac{\bar{y}_i}{50}. \tag{2}$$

We note that $\bar{\bar{y}}$ is an unbiased estimate of the population mean over all days and locations. We want an estimate of the total landings, and an unbiased estimate of this would be $NM\bar{\bar{y}} = 60(15)\bar{\bar{y}} = 900\bar{\bar{y}}$.

To estimate the variance of $\bar{\bar{y}}$, we define:

$f_1 = n/N$ = fraction of PSUs (days) sampled = 50/60 = 0.833, (3)

$f_2 = m/M$ = fraction of SSUs (locations) sampled in a day = 2/15 = 0.133, (4)

$s_1^2 = \frac{\sum_{i=1}^{n}(\bar{y}_i - \bar{\bar{y}})^2}{n-1}$ = sample variance among daily means, (5)

$s_2^2 = \frac{\sum_{i=1}^{n}\sum_{m=1}^{m}(y_{ij} - \bar{y}_i)^2}{n(m-1)}$ = sample variance among SSUs (locations) within PSUs (days). (6)

An unbiased estimate of the variance of $\bar{\bar{y}}$ can be obtained as

$$v(\bar{\bar{y}}) = \frac{1-f_1}{n} s_1^2 + \frac{f_1(1-f_2)}{mn} s_2^2 = \frac{1-.833}{50} s_1^2 + \frac{.833(1-.133)}{2*50} s_2^2 = .00334 s_1^2 + .00722 s_2^2. \tag{7}$$

Here, $1 - f_1$ and $1 - f_2$ are the finite population corrections (fpc) that reflect the fact that as you approach 100% sampling at a stage the variance for that stage has to approach 0.

We desire an estimate of the total landings over all locations and all days. As indicated above, this can be obtained as $\hat{Y}_{tot} = NM\,\bar{\bar{y}} = 60(15)\,\bar{\bar{y}} = 900\,\bar{\bar{y}}$. The estimated variance of this is equal to the variance in (7) multiplied by $M^2N^2 = 15^2(60^2) = 810{,}000$. (The result may seem very large but, ultimately, it is the standard error of the estimate, not the variance, which we use to judge precision.)

The true variance of the estimated grand mean is given by (Cochran 1977 eq. 10.8):

$$V(\bar{\bar{y}}) = \left(\frac{N-n}{N}\right)\frac{S_1^2}{n} + \left(\frac{M-m}{M}\right)\frac{S_2^2}{mn}. \quad (8)$$

Note that S_1^2 and S_2^2 are the true variances at the first and second stages, not estimates.

The region-wide estimate of the total catch for a species is simply the sum of the estimates for the low use and the high use strata. The estimated variance of the region-wide total is the sum of the estimated variances for the two strata.

2.6 Sunday and Night Fishing

This section presents the efforts to estimate commercial fishing activity outside of the sampling frame (i.e., Monday through Saturday, 9 am to 5 pm) proposed in the original study design.

A Sunday and night interview processed was developed early in the development of sampling protocols (see Appendix 2 for the Sunday/night interview forms). In the first week of implementation in the USVI, samplers reported difficulty in getting reliable answers and potential analyses were complicated by an inability to identify individual fishers and repeat responses. MER Consultants partnered with staff at DPNR to estimate commercial fishing activity at night and on Sundays on St. Thomas using a variant of the same intercept method employed for the rest of the pilot study.

On St. Thomas, ten nights were randomly selected for sampling at three of the high-strata sites on St. Thomas (Frenchtown, Hull Bay, and Saga Haven) over the period of the pilot study. Mr. Gerard Greaux ("Chub") of DPNR sampled from 6 pm to 12 am at these sites using the same intercept protocol as daytime sampling and used the same materials. On St. Croix, comprehensive Sunday and night sampling was not conducted beyond spot checking, however it was impossible to distinguish between commercial and recreational activity.

In Puerto Rico, a qualitative description of the after hours, night and Sunday fishing was made based on the responses from the Sunday/Night interview questions and an end of season questionnaire developed to elucidate samplers experience at each site. An 'exit' survey was prepared for samplers to gather additional information regarding their impression of sites they sampled most frequently and felt confident in characterizing further. Application of this information is presented in Section 4.4.4.

3 PROJECT IMPLEMENTATION

3.1 Site Selection, Sampler Assignments, and Oversight

3.1.1 Site selection and sampler assignments

Site selection was generated before sampling began by a program written in R (R Core Team, 2012), named 'ThePlan,' and described in the MER Estimation Report (2014). (See Appendix 4 for site selections in all regions). Island managers assigned individual samplers to sites on a weekly basis. Both logistical and personal considerations were taken into account when matching individuals to sites. Over time, managers also tried to maintain a level of consistency in site assignments so that samplers could become accustomed to a site and its regular fishers, and vice versa. The benefits of consistency, however, were weighed against the potential for sampler bias. The result of this tradeoff was that most individual samplers were assigned across two to four regular sites.

3.1.2 Sampler oversight and management

Island managers oversaw and managed sampling efforts by maintaining communication with samplers throughout the day and spot checking sites to confirm samplers were on-site and following protocol.

Island managers were also able to review a suite of electronic data generated throughout the day by the data entry application developed by MER Consultants. This data was uploaded to the electronic data management system when samplers synched their tablets (ideally at the end of the day). The first type of data was from fields in the electronic forms (e.g., arrival time, departure time, site breaks) completed by samplers. The second type of data was from the passive system in the app, which created timestamps and took GPS points at regular intervals. See Figure 1 for a screenshot of GPS points marked for one sampling day on St. Thomas and a summary of all GPS data points in Puerto Rico in Figure 2. Note that in Figure 2 a number of points are presented that are obviously not at assigned landings locations. For example, the locations detected in/around Caguas (inland east) alerted supervisors to an individual who required additional attention and spot – checks.

GPS points were also marked to correspond with the filling of certain fields in the electronic form. For example, when a sampler would enter her start time, the app would create a timestamp and mark the GPS location of the tablet, so that the manager could then download verify the data were created correctly and in good faith.

Figure 1. Screenshot of example GPS points recorded for one sampler day (September 25, 2015, at Saga Haven on St. Thomas).

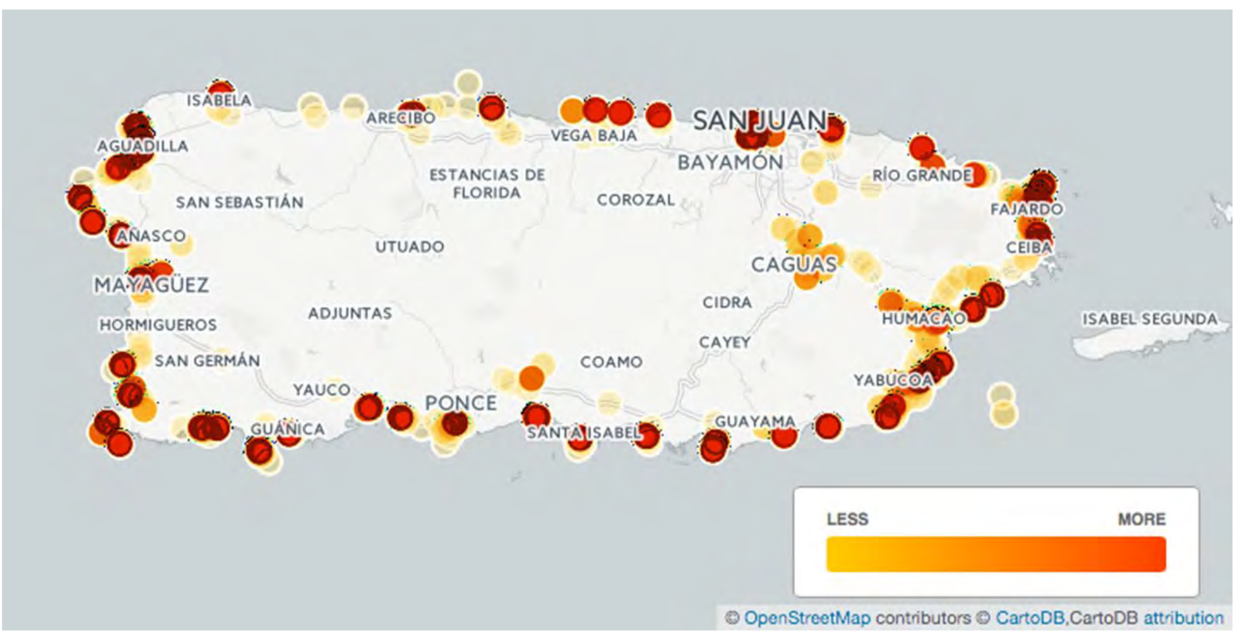


Figure 2. Intensity of all GPS locations recorded for the Pilot Study in Puerto Rico. Note that the locations detected in/around Caguas (inland east) allowed supervisors to pay particular attention to an individual sampler who arrived on station late.

3.2 Data Collection

3.2.1 Electronic and paper forms

Samplers were required to record data using both electronic and paper forms, and to submit both types of forms. Electronic forms were automatically submitted to the online data management system by synching the data entry application. Paper forms were submitted in-person to island managers, usually before scheduled payment. Using both types of forms had a number of benefits. First, it gave samplers the option of using pencil and paper while sorting and weighing, rather than navigating a tablet screen in gloves. Second, it provided a means of quality assurance on the data, because samplers had to review their data in one mode in order to enter it in the other. Third, the paper forms provided a record for island managers to use for quality control.

3.2.2 Pictures for species identification

Samplers were also required (when possible) to take at least one picture of one or more individuals of each species identified in a sample using the data entry application. Pictures were then uploaded with the electronic forms to the online database management system, where they could be accessed by managers and the species identification expert for quality control purposes. While samplers were able to get clear pictures the vast majority of the time, it was not uncommon for circumstances to impede the effort. For example, the lighting may have been poor where sampling needed to take place. Or a rushed situation forced the sampler to forego pictures in the interest of recording weights as quickly as possible. Or as was frequently the case on St. Croix, samplers were only allowed to take a picture of the top of a fisher's cooler, rather than of each species.

In Puerto Rico, samplers were urged to take pictures of any coolers for which they thought they might not have enough time to fully enumerate catch composition by species. This guidance was a direct result from the sampling challenges in St. Croix and proved very useful. In many cases, these 'mixed catch' photographs were used to both verify a sampler's identification of a particular species but more often was used to verify landings weights and species composition of the catch.

3.3 Quality Control

3.3.1 Review of electronic form data

In the USVI, St. Thomas island manager, Mr. Peter Freeman, regularly downloaded and reviewed raw electronic form data submitted by samplers via the data entry application. In Puerto Rico, the island managers Dr. Schärer and Ms. Flynn and quality control supervisor Mr. Freeman regularly downloaded and reviewed raw electronic form data submitted by samplers via the data entry application. The password protected administrative database, part of the online data management system, was continuously updated and available in comma separated value (csv) format. If upon initial review data did not appear complete or accurate, Mr. Freeman inquired directly with samplers, and made any necessary corrections to sampling protocol. Data were then corrected in a master database maintained by Mr. Freeman and eventually used for analysis.

3.3.2 Species verification

During the sampling period, the species identification expert, Mr. Colin Howe, regularly accessed pictures and associated species assignments made by samplers in their electronic forms. These data were accessible through the supervisor database in the online data management system. Mr. Howe reviewed each species assignment and made any necessary corrections directly in the database. Mr. Howe kept record of each change made, as well as any issues (e.g., missing data, unclear pictures) that impeded positive species identification. These records were then passed to Dr. Gedamke, Dr. Schärer, Dr. Young and Mr. Freeman for review.

Early during the sampling period, scores were given to each sampler as to the reliability of their identifications. This allowed supervisors to pay particular attention to specific samplers and provide additional training as necessary. During the final quality control phase of the project, the pictures were re-evaluated in their entirety by Dr. Young and particularly challenging, or rare species were sent out to additional experts for verification.

4 RESULTS

4.1 Project Planning and Implementation

This section presents the results of on-the-ground planning and implementation of the pilot study in both the USVI and Puerto Rico jurisdictions. Results are based on information obtained during the pilot study, including feedback from samplers and fishers, observations about the functionality of materials and technology, logistics issues, and the quality of data gathered through direct sampling.

4.1.1 Coordination and outreach

In the USVI, the overall coordination and outreach activities were successful and sufficient to meet the goals for the pilot study, though a long-term study would benefit from a proportional increase in the outreach efforts in particular. The majority of sampled fishers had been informed of the study ahead of time, which increased their receptiveness to samplers. In particular, commercial fishers quickly recalled being informed of the study from Dr. Gedamke's presentation and distribution of flyers at the Commercial Vessel Registration Workshop on St. Thomas. Accordingly, samplers were instructed to use the phrase, "this is the study you heard about at the vessel registration workshop," as part of their introduction when approaching fishers. In St. Thomas a majority of fishers were also receptive to, if not supportive of, the study—if not initially, after discussing it further with the sampling team. In St. Thomas, efforts to recruit co-sponsors to donate ice were also successful, and relatively easy given the existing relationships between local businesses and the fishing community. These relationships will be easy to re-establish and build upon in the future. In St. Croix, Mr. Tonnemacher was only able to obtain one source for a limited amount of ice and more efforts to reach out to the community are recommended as part of a long term plan.

In Puerto Rico, the overall coordination and outreach activities were successful and sufficient to meet the goals for the pilot study, though a long-term study would benefit from a significant increase in the outreach efforts in particular. Few of the sampled fishers had been informed of the study ahead of time, which did not directly impact their receptiveness to samplers. In Puerto Rico few of the fishers were receptive to, if not supportive of, the study—if not initially, after discussing it further with the sampling team. Due to the number of sites per coast in Puerto Rico and the low probability of randomly sampling the same sites equally the samplers had to invest time and extra effort in explaining to fishers the purpose and scope of the project. Some sites that were sampled more often had the opportunity to develop relationships with samplers. These relationships will be easy to re-establish and build upon in the future.

4.1.2 Governance

Going into the pilot study, an important political consideration was the optimal degree and type of explicit support from DPNR and DRNA to exercise during sampling. The language generated by Dr. Gedamke, Director Gomez in the USVI, and Mr. Matos-Carballo in Puerto Rico (i.e., "the study is being conducted with the support of DPNR" and "in cooperation with DRNA") positioned samplers so that they could at once maintain both independence and authority. The fact that samplers were contractors provided an additionally useful level of separation from a regulatory body.

This balanced position facilitated buy-in and participation from fishers, perhaps because samplers were neither able nor at liberty to respond to complaints or frustrations. This arrangement worked well for the length of the pilot study, during which both fishers and samplers were being introduced to purpose of the study and the protocols involved. In the USVI and as time went on, however, some fishers demonstrated a bit of frustration over the sampling routine. Without a mechanism to require fishers to comply with sampling activities, individual engagement and additional outreach activites would have to be expanded if sampling were to continue much longer. In the USVI, this frustration was much greater in St. Croix than it was in St. Thomas.

In Puerto Rico, frustration was generally minor and related to specific sites and not generalized throughout the island. The collaboration of samplers with DRNA port agents occurred in 26 of 480 samplings and in those cases it appears that this collaboration increased the fishers' cooperation to provide information on their catch. In fact, at one specific location the owners of the pescaderia, which owns the dock where fishers land, would only allow DRNA staff on site to sample. Without their assistance we would have been unable to get any data from this location. At other fish houses, buyers and associations did not present any difficulties in allowing samplers to observe the sorting, weighing, and purchasing of fish, as long as it was previously agreed as to not interfere and reduce the time of the purchase or trailering process. In other cases, samplers were welcomed into fish houses and made part of the local activities by fishers themselves. Some samplers reported that much time was spent in conversations listening to the claims and concerns of fishers.

4.1.3 Materials

Overall, the materials provided samplers in the field functioned well and were adequate for the pilot study. In the USVI, the logistics of acquiring, storing, and providing ice to fishers in a way that met on-site demand and was not overly burdensome on samplers was complicated and challenging at the beginning of the study. In St. Thomas, this was overcome by reaching out to local businesses after sampling began, and became easier during the project. Ice machines dedicated to sampling efforts would benefit the sampling efforts and overall relationships. In Puerto Rico, providing ice was not as important to fishers. However, moving forward consideration should be given to the improving sampling by providing additional support materials like ice, moving buckets, scales, etc., at a few locations with relatively large landing areas (e.g. beaches, multiple marinas).

4.1.4 Personnel and training

Efforts to recruit a sampling team were successful and sufficient for the pilot study. In St. Thomas, eight samplers ended up being hired, six of whom provided the majority of full-time coverage throughout the sampling period. In St. Croix, ten people initially attended the training session, however during the second day of practical training at the La Reine fish market a few fishers expressed their opinion of Science and two potential samplers decided this was not the work for them. As sampling progressed in St. Croix, two additional samplers were utilized to address particularly challenging sampling locations.

In Puerto Rico, 22 samplers were hired to provide 16 samplers per day. A combination of full and part- time samplers were hired due to logistic considerations; 17 were full time and sampled 4-6 days per week, while five samplers were available part time and 1-2 days per week. Due to the large geographical area to be sampled, recruiting was targeted across the island so that 4 and 7 samplers could cover each coast without significant additional travel costs. On some occasions there was a need for a sampler to be assigned in a geographical area other than their local area. This was successfully done due to early notification of scheduling conflicts and also to very efficient personnel management and flexibility of both samplers and managers. All contracting was done locally by HJR Reefscaping in accordance with Puerto Rico legal requirements.

Samplers had diverse backgrounds, which was important considering the idiosyncrasies of different sites. For example, some fishers trusted some samplers more because they had grown up with them, while other fishers appreciated samplers who may have been relatively removed from local affairs. The application criteria and hiring process allowed Dr. Gedamke and the island managers to select individuals who took well to training in fieldwork, fish identification, and data reporting. Within a reasonable time from starting, the sampling teams understood sampling protocols and were able to accurately identify common fish and invertebrate species.

Island managers in the USVI and Puerto Rico successfully fulfilled their contractual duties. The species identification expert hired, Mr. Colin Howe, was also able to efficiently and accurately complete his tasks. The quality control supervisor Mr. Peter Freeman completed his tasks effectively and in a timely fashion.

4.1.5 Oversight and quality control

Overall, the protocols for oversight and quality control were successful and sufficient for the pilot study. While some samplers had occasional issues with sampling protocol and data reporting, they were easily identified by island managers using the online data management system, and easily addressed using direct communication and on-site supervision. Island managers supervised sampling activities through daily communication with samplers, site visits to confirm coverage and verify sampling protocols, and through continuous review of data and pictures submitted to the online data management systems via the data entry application.

The St. Thomas island manager and Puerto Rico quality control manager, Mr. Peter Freeman, provided data quality control by downloading, consolidating, and reviewing data submitted electronically from samplers on both islands to the online data management system. Mr. Freeman followed up with samplers, either directly or indirectly via island managers, with any questions about the completeness or perceived accuracy of the data, and any necessary changes were made directly to a master database, which was later used for analysis.

4.2 Descriptive Statistics

4.2.1 Overview of sampling - USVI

In the USVI, sampling was conducted for a total of 5 weeks (30 sampling days) on each region. On St. Thomas, sampling ran from September 21 to October 24, 2015. On St. Croix, sampling ran from September 30 to November 3, 2015. Over the 60 combined sampling days, 322 trips were sampled and 26,577 pounds of fish and invertebrates were sorted and weighed. Table 6 presents a site-level summary of effort and landings on each region. More than twice as high many trips were sampled in St. Croix than St. Thomas, but the total observed landings were about equal due to a corresponding difference in average pounds per trip. In St. Croix, the number of unsampled trips as a proportion of sampled trips was three times higher than St. Thomas, due to relatively low cooperation from fishers and on-site logistics.

The vast majority of landings and trips sampled in all regions were commercial, rather than recreational or charter, as presented in Figures 3 and 4, respectively. The species that accounted for the most sampled weight on both regions was Caribbean spiny lobster—about a third of total weight sampled on St. Thomas, and a little over a fifth on St. Croix. Tables 7 and 8 present a complete lists of species sampled on St. Thomas and St. Croix, respectively, as well as the weight and percent total weight sampled by species.

It is important to note that these tables include landings of “unknown” species. Indeed, “unknown” accounts for the second highest sampled weight on St. Croix—almost as much as Caribbean spiny lobster. Trap fishing accounts for the vast majority of commercial trips and landings sampled on St. Thomas, while diving accounts for the majority on St. Croix. See Figures 5 and 6 for a detailed breakdown of commercial landings and effort, respectively, by equipment types on both regions. Figures 7 through 9 present the distribution of total commercial effort and landings across strata for both regions.

Table 6. Site-level summary of effort and landings for both USVI regions.

St. Thomas	Strata	# Sampled Trips	# Unsampled Trips	Total Observed Landings (lbs.)	Avg lbs/trip
Coki Point	LOW	5	0	360	72.0
Crown Bay	LOW	0	0	0	0.0
Frenchtown	HIGH	13	5	1742	134.0
Hull Bay	HIGH	13	2	633	48.7
Krum Bay	LOW	8	0	427	53.4
Magens Bay	LOW	1	2	8	8.0
Mandahl	HIGH	8	1	550	68.8
Marine Science Center	LOW	1	0	116	116.0
Saga Haven	HIGH	41	3	8611	210.0
Sapphire	LOW	5	0	218	43.6
	STT Total:	95	13	12665	133.3

St. Croix	Strata	# Sampled Trips	# Unsampled Trips	Total Observed Landings (lbs.)	Avg lbs/trip
Altoona Lagoon	HIGH	71	34	5596	78.8
Christiansted Harbor	LOW	21	12	1716	81.7
Estate Castle Nugent	LOW	18	5	788	43.8
Frederiksted Fish Market	HIGH	32	13	1709	53.4
Gallows Bay	HIGH	29	1	1316	45.4
Molasses Dock	HIGH	46	25	2102	45.7
Salt River	LOW	5	1	112	22.4
Teague Bay	LOW	5	1	573	114.6
Turner Hole	LOW	0	0	0	0.0
	STX Total:	227	92	13912	61.3

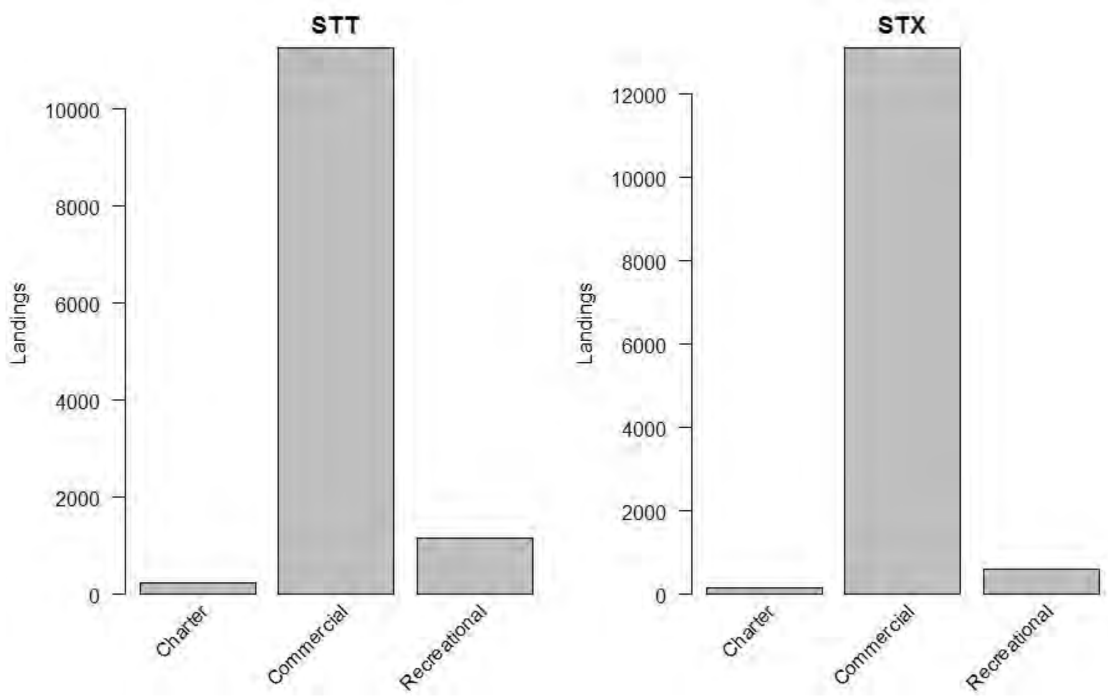


Figure 3. Total landings observed by trip type in both USVI regions.

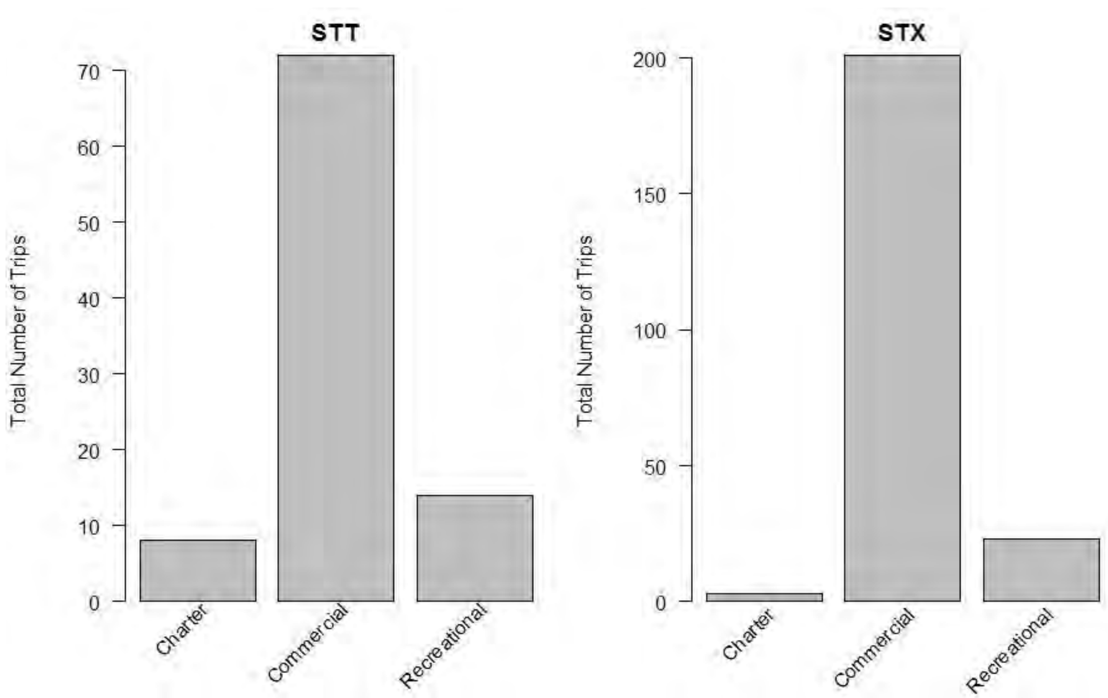


Figure 4. Total number of trips sampled by trip type in both USVI regions.

Table 7. Species composition of all observed trips in St. Thomas.

STT Total Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
lobster_caribbean_spiny	4243	33.5
topsnail_west_indian	1452	45.0
triggerfish_queen	1223	54.6
hind_red	1153	63.7
angelfish_gray	518	67.8
wahoo	241	69.7
grunt_white	204	71.3
jack_bar	195	72.9
snapper_mutton	194	74.4
groupers_unknown	193	75.9
coney	186	77.4
squirrelfish	160	78.7
cowfish_honeycombed	153	79.9
dolphin	144	81.0
grunt_bluestriped	135	82.1
snapper_yellowtail	133	83.1
filefish_whitespotted	121	84.1
tang_blue	119	85.0
angelfish_french	106	85.9
hogfish	102	86.7
grouper_yellowfin	98	87.4
doctorfish	94	88.2
porgy_jolthead	93	88.9
parrotfish_redtail	86	89.6
lionfish	85	90.3
parrotfish_stoplight	84	90.9
angelfish_queen	73	91.5
porgy_saucereye	73	92.1
ballyhoo	71	92.6
runner_blue	65	93.1
barracuda_great	48	93.5
snapper_lane	48	93.9
surgeon_ocean	48	94.3
jacks_scads_unknown	40	94.6
porgies_unknown	40	94.9
hind_rock	38	95.2
grouper_red	36	95.5

Table 7. (Continued) Species composition of all observed trips in St. Thomas.

STT Total Observed Weight by Species		
Species	**Landings (lbs.)**	**Cumulative % of Total**
Species	Species	Species
trunkfish_spotted	34	95.8
conch_queen	33	96.0
lobster_spanish_slipper	33	96.3
porgy_pluma	33	96.5
tunny_little	33	96.8
schoolmaster	28	97.0
mackerel_king	27	97.2
triggerfish_ocean	25	97.4
crustaceans_unknown	23	97.6
triggerfishes_filefishes_unknown	21	97.8
grunts_unknown	19	97.9
crab_speckled_swimming	17	98.1
shark_nurse	16	98.2
surgeonfishes_unknown	16	98.3
margate	14	98.4
runner_rainbow	14	98.5
grunt_caesar	12	98.6
trunkfish_smooth	11	98.7
unknown	11	98.8
grouper_yellowmouth	10	98.9
crab_channel_clinging	8	99.0
jack_cottonmouth	8	99.0
shark_reef	8	99.1
squirrelfish_longspine	8	99.1
trunkfish	8	99.2
cowfish_scrawled	7	99.3
graysby	7	99.3
grunt_french	7	99.4
lobster_ridged_slipper	7	99.4
porkfish	6	99.5
snapper_caribbean_red	6	99.5
angelfishes_unknown	4	99.6
cottonwick	4	99.6
grunt_spanish	4	99.6
herrings_unknown	4	99.7
jack_almaco	4	99.7

Table 7. (Continued) Species composition of all observed trips in St. Thomas.

STT Total Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
parrotfish_princess	4	99.7
porgy_unknown	4	99.7
snapper_gray	4	99.8
snappers_unknown	4	99.8
triggerfish_gray	4	99.8
snapper_queen	3	99.9
tuna_blackfin	3	99.9
filefish_scrawled	2	99.9
octopus_unknown	2	99.9
parrotfish_redband	2	99.9
parrotfishes_unknown	2	100.0
snapper_vermilion	2	100.0
pompano_african	1	100.0
snapper_mahogany	1	100.0
tomtate	1	100.0
trunkfishes_unknown	1	100.0

Table 8. Species and total weights sampled on St. Croix. Note that the high percentage of 'unknown' resulted primarily from situations when a total weight was provided by the fisher (or observed), but additional sampling was refused.

STX Total Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
lobster_caribbean_spiny	3117	22.4
unknown	2987	43.9
dolphin	1821	57.0
wahoo	1213	65.7
parrotfish_stoplight	565	69.7
parrotfish_redtail	403	72.6
schoolmaster	362	75.2
hind_red	264	77.1
barracuda_great	256	79.0
conch_queen	233	80.7
triggerfish_queen	198	82.1
ballyhoo	175	83.3
parrotfishes_unknown	104	84.1
hind_rock	103	84.8
coney	97	85.5
cowfish_honeycombed	97	86.2
snapper_yellowtail	94	86.9
tang_blue	92	87.6
doctorfish	89	88.2
squirrelfish	69	88.7
snapper_blackfin	65	89.2
scad_round	60	89.6
shark_nurse	55	90.0
angelfish_french	54	90.4
parrotfish_princess	54	90.8
grunt_bluestriped	53	91.1
grunt_french	51	91.5
octopus_unknown	46	91.8
margate_black	45	92.2
snapper_mutton	45	92.5
mackerel_king	44	92.8
snapper_silk	44	93.1
grunt_white	43	93.4
lionfish	42	93.7
surgeon_ocean	41	94.0
mixed	40	94.3

Table 8. (Continued) Species and total weights sampled on St. Croix. Note that the high percentage of 'unknown' resulted primarily from situations when a total weight was provided by the fisher (or observed), but additional sampling was refused.

STX Total Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
tuna_skipjack	40	94.6
angelfish_gray	36	94.9
jack_yellow	36	95.1
jack_bar	33	95.4
parrotfish_redband	33	95.6
cero	29	95.8
snapper_dog	26	96.0
snapper_lane	26	96.2
angelfishes_unknown	25	96.4
hogfish	25	96.5
runner_blue	25	96.7
jack_black	24	96.9
lobster_spotted_spiny	24	97.1
angelfish_queen	23	97.2
permit	23	97.4
triggerfishes_filefishes_unknown	23	97.6
barracudas_unknown	21	97.7
octopus_common	20	97.9
tunny_little	20	98.0
crustaceans_unknown	15	98.1
sardine_redear	15	98.2
snapper_caribbean_red	15	98.3
snapper_mahogany	15	98.4
snappers_unknown	15	98.5
choice_sailors	14	98.6
goatfish_yellow	13	98.7
jack_crevalle	13	98.8
snapper_cubera	13	98.9
jacks_scads_unknown	12	99.0
parrotfish_blue	11	99.1
filefish_whitespotted	10	99.2
runner_rainbow	10	99.2
graysby	9	99.3
goatfish_unknown	7	99.3
parrotfish_redfin	6	99.4

Table 8. (Continued) Species and total weights sampled on St. Croix. Note that the high percentage of 'unknown' resulted primarily from situations when a total weight was provided by the fisher (or observed), but additional sampling was refused.

STX Total Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
sharks_rays_unknown	6	99.4
triggerfish_gray	6	99.5
groupers_unknown	5	99.5
porkfish	5	99.5
filefish_scrawled	4	99.6
grunt_caesar	4	99.6
parrotfish_queen	4	99.6
snapper_queen	4	99.7
triggerfish_ocean	4	99.7
bigeye	3	99.7
crab_channel_clinging	3	99.7
margate	3	99.7
trunkfish_spotted	3	99.8
amberjack_greater	2	99.8
goatfish_red	2	99.8
grunts_unknown	2	99.8
hogfish_spanish	2	99.8
lionfishes_unknown	2	99.8
lobster_ridged_slipper	2	99.9
lobster_spanish_slipper	2	99.9
porgy_jolthead	2	99.9
snapper_black	2	99.9
snapper_gray	2	99.9
tilefish_blackline	2	99.9
trunkfish_smooth	2	99.9
tuna_blackfin	2	100.0
cottonwick	1	100.0
grouper_nassau	1	100.0
porgy_pluma	1	100.0
sardine_scaled	1	100.0
tomtate	1	100.0
tripletails_unknown	1	100.0

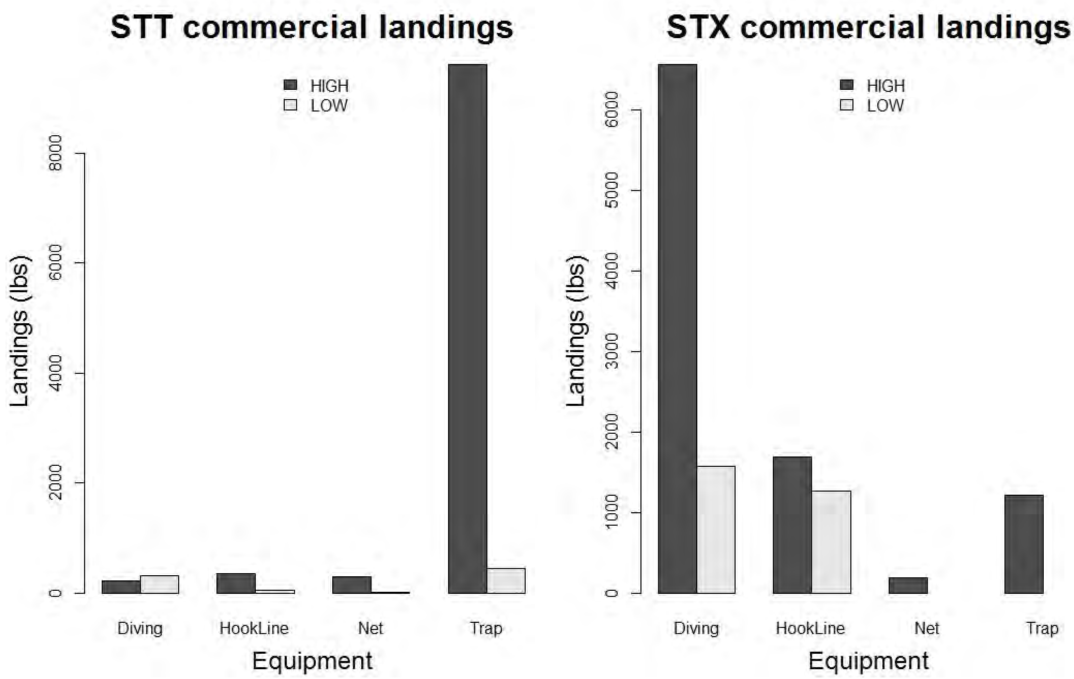


Figure 5. Total commercial landings sampled by equipment type on both USVI regions.

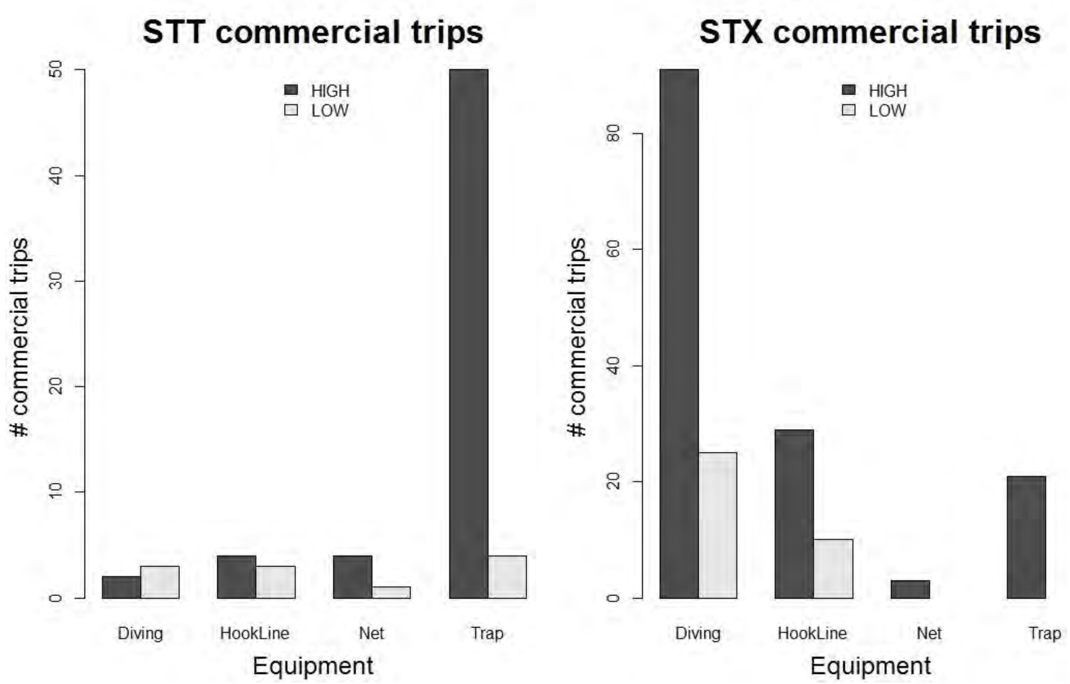


Figure 6. Total commercial trips sampled by equipment type on both USVI regions.

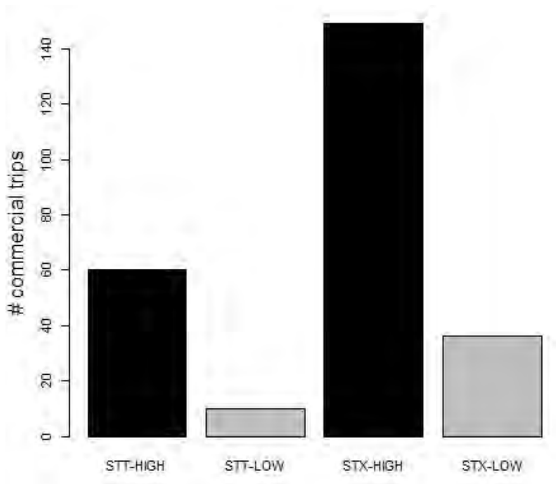


Figure 7. Total commercial trips across strata in both USVI regions.

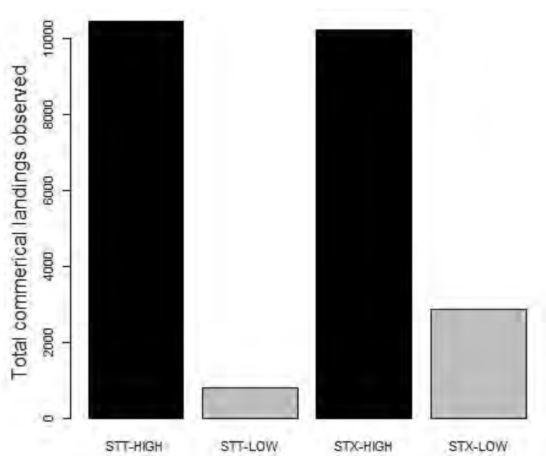


Figure 8. Total landings across strata in both USVI regions.

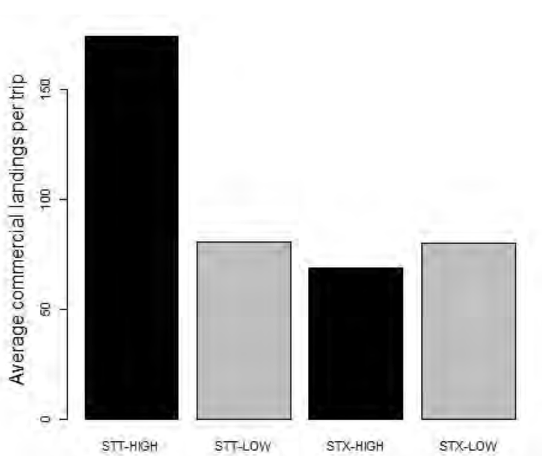


Figure 9. Average commercial landings/trip across strata in both USVI regions.

4.2.1.1 Accounting for Unsampled Trips and Unknown Species in USVI

As seen in Table 8, in St. Croix there were a considerable number of trips where only a total weight was recorded and species composition was unknown. A sample marked as "unknown" could have occurred as a result of two circumstances. First, the sampler was not able to determine the species group or species, and the species identification expert did not have enough information to make the determination. For example, sometimes samplers forgot to take a picture of their catch, or their picture came out blurry. Second, samplers used "unknown" as a blanket term to refer to a mixed catch for which they got a weight or captain's estimate. On St. Croix in particular, it was common for a fisher to only allow samplers to take a picture of the top of their cooler. This second circumstance was rare in St. Thomas, but accounts for the vast majority of "unknown" species assignments in St. Croix.

In some cases trips had to be recorded as 'unsampled' when a sampler was too busy working up another catch or when fishers refused to allow sampler to even look at the catch and estimate weight. It could not be determined if the unsampled trips represented commercial or recreational fishing. The number of unsampled trips was relatively small in St. Thomas (12 %) but was 29 % in St. Croix (Figure 10). In the completed interviews data, the percentage of trips that were commercial (as opposed to recreational) was 77 % in St. Thomas and 89 % in St. Croix. Consequently, the estimated commercial landings in St. Thomas and St. Croix, estimated from observed trips, were adjusted upwards by 100 x .12 x .77 = 9 % and 100 x .29 x .89 = 26 %, respectively, to account for unsampled trips on the assumption that ratio of commercial to recreational trips were the same as sampled trips.

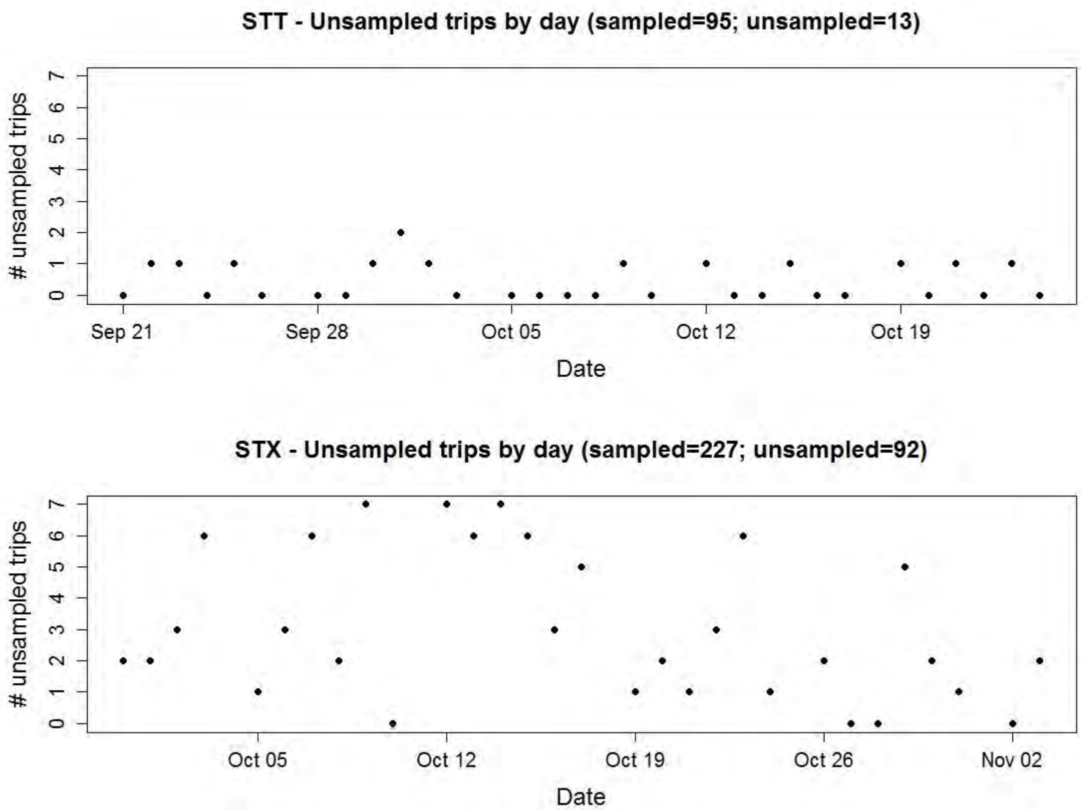


Figure 10. Number of unsampled trips versus day for St. Thomas (top) and St. Croix (bottom). There does not appear to be a trend in the rate of cooperation over time suggesting that fishers did not tire of the sampling program over the 30 day period of operation.

For the St. Croix high use stratum, there were a number of records from divers where the catch weight was estimated but species composition was unknown. To apportion unidentified catch in trips for which only the total pounds landed was recorded, we developed a "profile" of expected species composition from those trips in the stratum that were sampled at least 80%. Thus, for a trip with 40 pounds of unidentified catch, the catch of each species is estimated as the product of 40 pounds x proportion of the catch in a typical trip that is comprised of the species. A similar procedure was used for all strata and gear types when the catch was only identified to family group. For example, if 20 pounds of "parrotfish" (mixed species) was landed, the 20 pounds would be apportioned to species according to the profile for a typical trip. To determine the profile for a typical trip, we aggregated – separately by equipment type, region and stratum – all trips that had 100% of all fish identified. If species-specific information was unavailable for the most specific combination of factors, the profile for a typical trip was obtained by aggregating all trips that had 100% of the catch identified by region and stratum (or by region only if species-specific data was still unavailable in the region-stratum combination).

As a check on the reliability of this procedure, we examined the number of species reported in dive trips in the St. Croix high use stratum that had 100% of the catch identified and found a range from 1 to 20 species (Figure 11). To verify that such low diversity of species was present in some of the landings, and to evaluate potential sampler bias, we subsetted the data by individual port sampler and found that the results did not vary appreciably by port agent. Follow-up interviews with some port samplers indicated that, indeed, there was a great variability in the number of species landed in a trip.

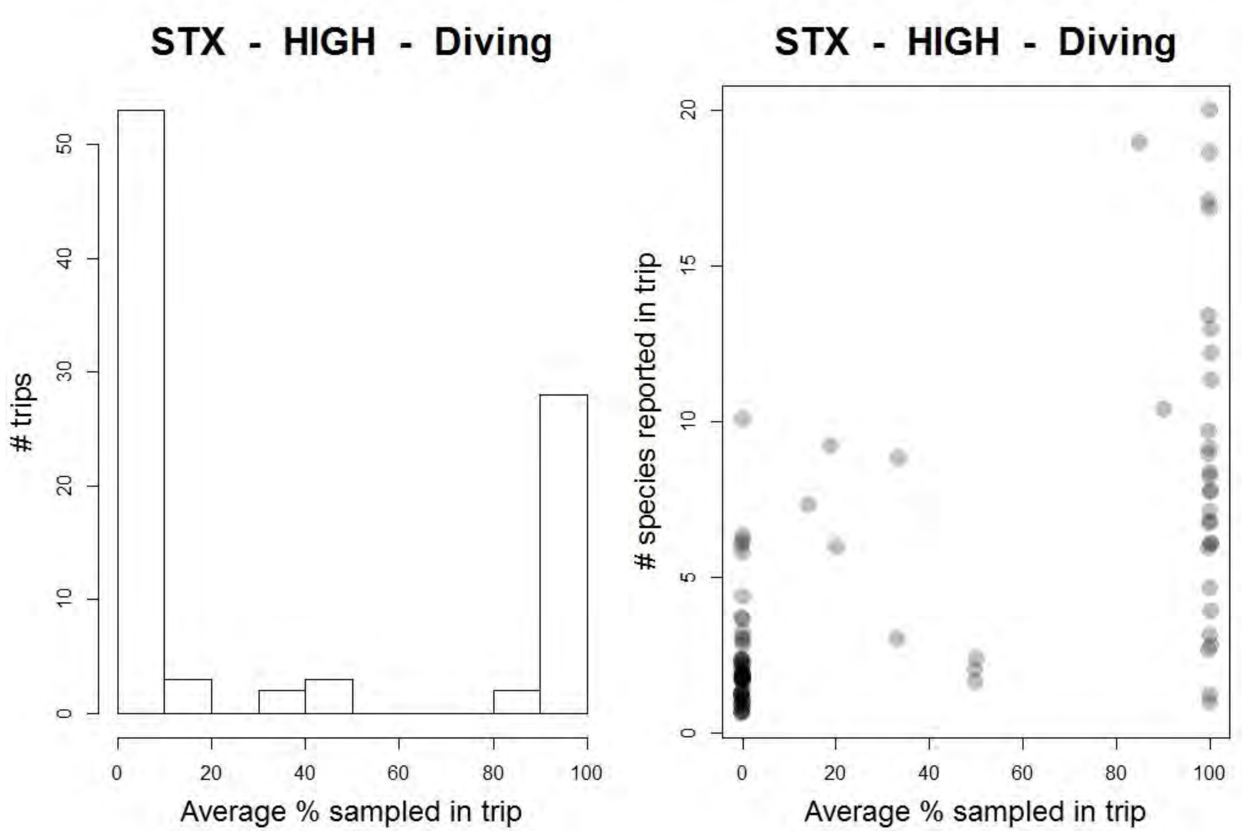


Figure 11. Frequency distribution for trips by amount of the catch that was sampled in STX. Most trips had all or none of the catch fully enumerated. Right: Number of species reported in a trip versus the amount of the catch actually weighed from the trip. Each dot represents a trip; dots are translucent so overlapping dots appear darker. Note that, for trips completely sampled, the number of species examined ranged from 1 to 20 and for those trips where 0% was weighed the number of species represents captains estimates or samplers evaluation of the top of a cooler.

4.2.2 Overview of sampling – Puerto Rico

In Puerto Rico, sampling was conducted from April 13 and May 18, 2016, a total of 5 weeks (30 sampling days). A total of 57 sites in Puerto Rico were sampled between April 13th and May 18th, with four samplers assigned per day, per region. Thus, in Puerto Rico, sixteen samplers were deployed every day for the 30 day sampling period for a total of 480 sampled landing site days. The fishing community was generally very cooperative and allowed samplers to document 992 trips, over 130 species and approximately 37,000 lbs. of landings.

The East coast had the highest observed landings with over 13,000 lbs, and the North coast saw the lowest use with just over 3,000 lbs. being documented. Observed landings on the West and South coasts were similar at just over 9,900 lbs (Figure 12). As in the USVI, the vast majority of landings and trips sampled in all regions were commercial, rather than recreational or charter, as presented in Figure 13 and Figure 14. Queen conch and Caribbean spiny lobster were the first and second highest observed landed species, respectively. Combined these two species comprised over 50% of the catch. Table 9 presents summaries by site for types of effort and landings observed during the project. Tables 10 through 14 present complete lists of species sampled in all of Puerto Rico and on all four coasts, as well as the weight and percent total weight sampled by species.

Although samplers in Puerto Rico were able to sample the complete catch composition by species more commonly than in the USVI, just over 880 lbs. were recorded as 'unknown' or 'mixed catch' species. In most cases, these resulted from situations where the sampler was able to estimate the weight of the total catch, but were unable to sort, identify, and weigh each species individually due to time constraints. Diving accounted for most fishing activities on the West, South, and East coast, while hook and line fishing accounted for most trips on the North coast (Figures 15 -16).

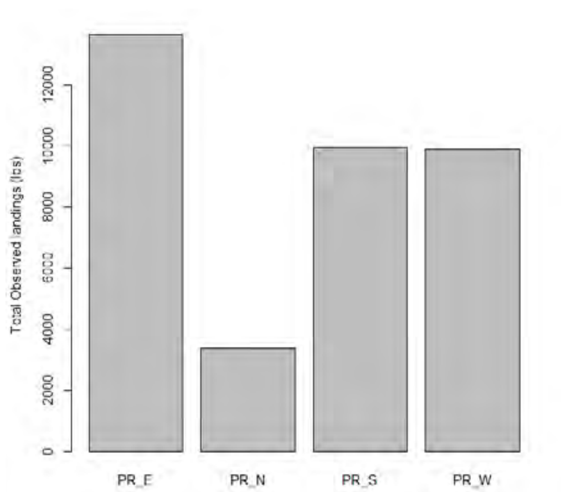


Figure 12. Total Observed Landings by Region in Puerto Rico.

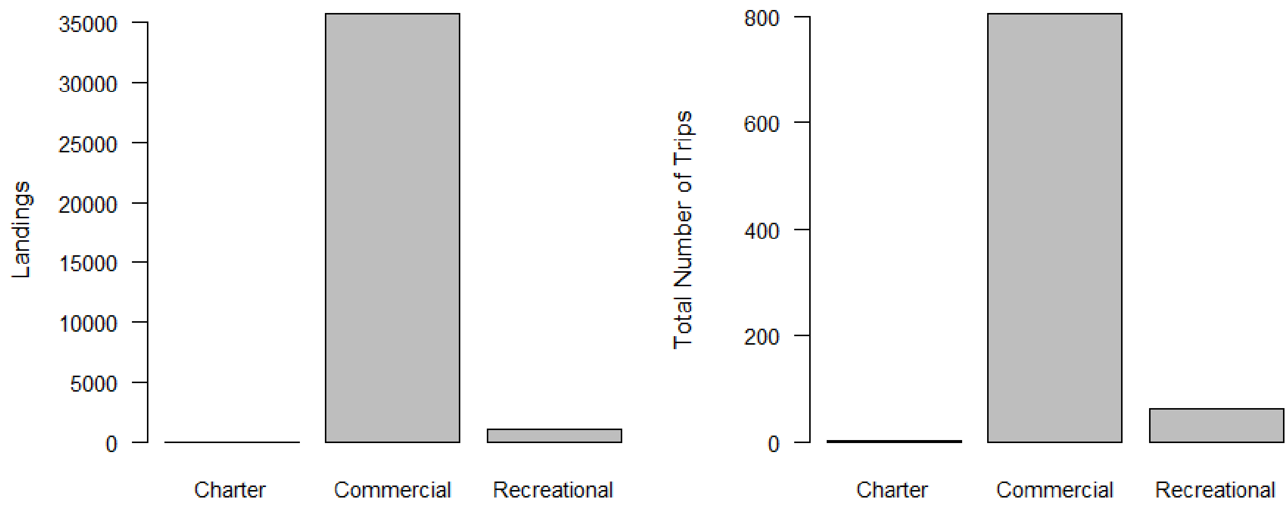


Figure 13. Total landings and trips observed by trip type in Puerto Rico.

Table 9. Site-level summary of effort and landings for Puerto Rico

Puerto Rico- North	Strata	# Sampled Trips	# Unsampled Trips	# Refused Trips	Total Observed Landings (lbs.)	Average lbs/trip
Arecibo Rampa	LOW	4	4	1	38	9.5
Barrio Bajura	HIGH	14	0	0	439	31.4
La Coal	HIGH	4	2	1	132	33.0
Fortuna	LOW	1	1	0	1	1.0
Cerro Gordo	LOW	0	0	0	0	-
Calle Hoare	LOW	1	0	0	5	5.0
Jarealito	HIGH	28	3	1	548	19.6
Mameyal	LOW	6	1	1	91	15.2
Puerto Mosquito	LOW	9	0	4	312	34.7
Palmas Altas	LOW	13	3	0	296	22.8
Punta Peñon	LOW	7	0	1	169	24.1
Puerto Nuevo	HIGH	1	0	0	27	27.0
La Princesa	HIGH	17	2	4	431	25.4
La Puntilla	HIGH	4	2	0	40	10.0
Torrecilla	LOW	9	0	1	311	34.6
Parcelas Vieques	LOW	0	0	0	0	0.0
Vietnam	LOW	9	0	0	551	61.2
	PR-N Total:	127	18	14	3391	26.7

Puerto Rico- East	Strata	# Sampled Trips	# Unsampled Trips	# Refused Trips	Total Observed Landings (lbs.)	Average lbs/trip
Barrio Los Machos	HIGH	15	3	1	1035	69.0
Las Croabas	LOW	4	3	0	161	40.3
Hucares	HIGH	66	14	2	4592	69.6
Maternillo	HIGH	15	1	0	1662	110.8
Maunabo	HIGH	4	2	0	51	12.8
Punta Candelero	LOW	17	3	0	455	26.8
Playa De Guayanes	LOW	11	1	0	219	19.9
Marina Puerto Del Rey	HIGH	43	4	3	3708	86.2
Punta Santiago	LOW	11	4	4	357	32.5
Puerto Yabucoa	LOW	40	9	6	1092	27.3
Barrio Sardinera	LOW	11	0	0	309	28.1
	PR-E Total:	237	44	16	13641	57.6

Puerto Rico- South	Strata	# Sampled Trips	# Unsampled Trips	# Refused Trips	Total Observed Landings (lbs.)	Average lbs/trip
Bahia De Guanica	HIGH	23	0	0	1066	46.3
Bajo De Patillas	LOW	8	3	0	422	52.8
Bahia De Guayanilla	LOW	12	5	0	181	15.1
Jobos	LOW	0	0	0	0	-
La Parguera	LOW	26	7	6	1120	43.1
La Parguera Rampa	LOW	7	2	0	268	38.3
Punta Papayo	LOW	15	0	0	458	30.5
Pastillo	HIGH	30	2	0	1748	58.3
Playa De Ponce	HIGH	27	6	0	1026	38.0
Playa De Salinas	HIGH	2	11	0	126	63.0
Playa Las Palmas	LOW	7	3	0	222	31.7
Punta Pozuelo	LOW	2	0	1	93	46.5
Salinas Providencia	HIGH	37	1	0	1341	36.2
Playa De Santa Isabel	LOW	5	4	1	94	18.8
Tallaboa	HIGH	56	3	0	1784	31.9
	PR-S Total:	257	47	8	9949	38.7

Puerto Rico- West	Strata	# Sampled Trips	# Unsampled Trips	# Refused Trips	Total Observed Landings (lbs.)	Average lbs/trip
Barrio Barrero	LOW	1	0	0	45	45.0
Barrio Espinal	LOW	0	0	0	0	-
Boqueron Rampa	LOW	6	4	2	204	34.0
Barrio Tamarindo	LOW	14	3	3	368	26.3
El Combate	HIGH	29	1	3	1113	38.4
El Faro Cabo Rojo	HIGH	21	1	0	799	38.0
Guaniquilla Barrio	LOW	2	0	0	22	11.0
Higuey	LOW	7	2	3	180	25.7
Playuela	HIGH	35	3	4	1373	39.2
Puerto Real	HIGH	35	11	0	1965	56.1
Rincon Rampa	HIGH	17	7	10	965	56.8
El Seco Rampa	HIGH	25	4	4	554	22.2
Soltero Puerto Real	HIGH	58	3	4	2258	38.9
Tres Hermanos	LOW	5	1	0	59	11.8
	PR-W Total:	255	40	33	9905	38.8

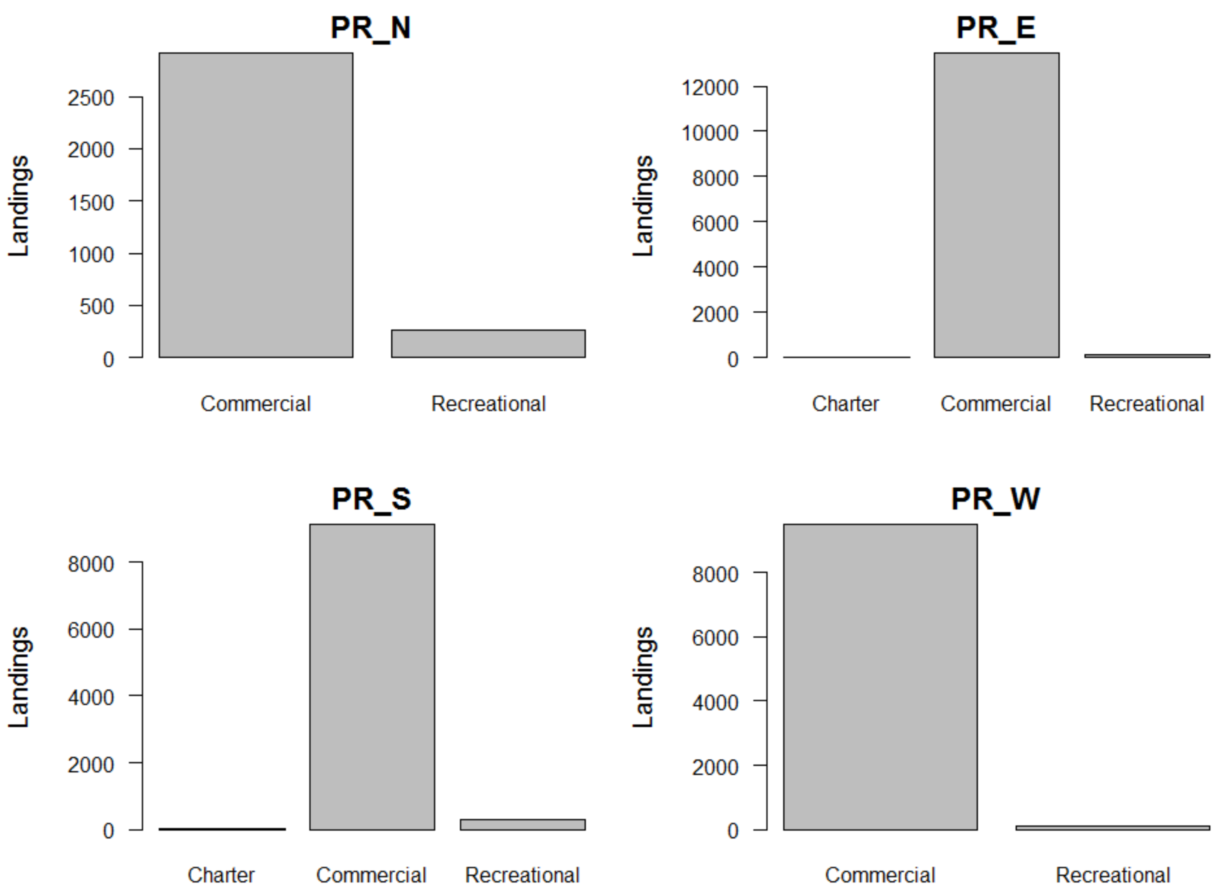


Figure 14. Total landings observed by trip type in Puerto Rico regions

Table 10. Species composition and total weights sampled in Puerto Rico (all).

All Puerto Rico - Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
conch_queen	12373	34.5
lobster_caribbean_spiny	6865	53.7
snapper_silk	1336	57.4
hogfish	1179	60.7
hind_red	1119	63.8
dolphin	922	66.4
triggerfish_queen	892	68.9
unknown	883	71.4
tuna_blackfin	785	73.5
mackerel_king	771	75.7
snapper_lane	672	77.6
snapper_queen	616	79.3
snapper_yellowtail	572	80.9
cero	472	82.2
parrotfish_stoplight	455	83.5
snapper_blackfin	352	84.5
octopus_unknown	312	85.3
snapper_dog	276	86.1
parrotfish_redtail	302	86.9
ballyhoo	257	87.7
barracuda_great	217	88.3
schoolmaster	203	88.8
runner_blue	199	89.4
grunt_white	180	89.9
snappers_unknown	171	90.4
lobster_spanish_slipper	155	90.8
crab_batwing_coral	153	91.2
herring_atlantic_thread	151	91.6
snapper_gray	138	92.0
porgy_pluma	119	92.4
cowfish_scrawled	108	92.7
sardines_unknown	108	93.0
jack_crevalle	97	93.2
grunt_bluestriped	92	93.5
cowfish_honeycombed	90	93.7
snook_common	87	94.0
trunkfish	85	94.2

Table 10. (Continued) Species composition and total weights sampled in Puerto Rico (all).

All Puerto Rico - Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
jenny_silver	81	94.4
lionfish	77	94.7
trunkfish_spotted	76	94.9
tuna_skipjack	69	95.1
snapper_mutton	66	95.2
boxfish_unknown	64	95.4
wahoo	59	95.6
jack_bar	57	95.8
rays_unknown	57	95.9
tunny_little	52	96.1
snapper_vermilion	51	96.2
parrotfish_queen	48	96.3
choice_sailors	43	96.5
harengula_unknown	43	96.6
porkfish	40	96.7
snapper_black	40	96.8
amberjack_greater	39	96.9
sardine_scaled	39	97.0
snapper_cubera	39	97.1
sardine_redear	38	97.2
snapper_wenchman	37	97.3
topsnail_west_indian	36	97.4
groupers_unknown	34	97.5
jack_almaco	32	97.6
pompano_african	32	97.7
coney	31	97.8
trunkfish_smooth	31	97.9
tunas_mackerals_unknown	30	98.0
graysby	26	98.0
margate	26	98.1
tuna_yellowfin	26	98.2
jack_horse_eye	25	98.2
lobster_spotted_spiny	25	98.3
porgies_unknown	25	98.4
dolphin_pompano	24	98.5
porgy_jolthead	24	98.5
sharks_unknown	24	98.6

Table 10. (Continued) Species composition and total weights sampled in Puerto Rico (all).

All Puerto Rico - Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
angelfish_gray	23	98.7
stingray_southern	23	98.7
filefish_whitespotted	22	98.8
parrotfishes_unknown	21	98.8
albacore	20	98.9
parrotfish_princess	18	98.9
tuna_unknown	17	99.0
drummer_whitemouthed	16	99.0
squirrelfish	16	99.1
filefishes_unknown	15	99.1
snapper_cardinal	15	99.2
triggerfishes_unknown	15	99.2
jack_yellow	14	99.2
jacks_unknown	14	99.3
mullet_white	12	99.3
crab_channel_clinging	11	99.3
shark_reef	11	99.4
grouper_misty	10	99.4
herring_unknown	10	99.4
lobster_ridged_slipper	10	99.5
mackerel_unknown	10	99.5
shark_sharpnose	10	99.5
angelfish_french	9	99.5
barracudas_unknown	9	99.6
parrotfish_rainbow	9	99.6
grouper_red	8	99.6
grunt_spanish	8	99.6
grunt_unknown	8	99.7
grouper_yellowedge	7	99.7
porgy_saucereye	7	99.7
goatfish_spotted	6	99.7
mojarra_striped	5	99.7
filefish_scrawled	5	99.7
goatfish_yellow	5	99.8
parrotfish_redfin	5	99.8
snook_fat	5	99.8
amberjack_lesser	4	99.8

Table 10. (Continued) Species composition and total weights sampled in Puerto Rico (all).

All Puerto Rico - Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
bream_sea	4	99.8
crustaceans_unknown	4	99.8
pilchard_false	4	99.8
tilapia_blue	4	99.8
beardfish	3	99.9
hamlet_mutton	3	99.9
jack_black	3	99.9
snapper_mahogany	3	99.9
tilefish_blackline	3	99.9
triggerfish_gray	3	99.9
crab_blue	2	99.9
diapterus_unknown	2	99.9
durgon_black	2	99.9
grouper_yellowfin	2	99.9
mackerel_spanish	2	99.9
scad_round	2	99.9
sennet_southern	2	99.9
surgeonfish_ocean	2	99.9
tilefish_sand	2	99.9
tomtate	2	99.9
cottonwick	1	100.0
crab_blotched_swimming	1	100.0
grunt_caesar	1	100.0
guaguanche	1	100.0
leatherjacket	1	100.0
lookdown	1	100.0
margate_black	1	100.0
mojarra_rhomboid	1	100.0
moray_green	1	100.0
moray_spotted	1	100.0
puddingwife	1	100.0
shellfish_unknown	1	100.0
soldierfish_blackbar	1	100.0
surgeon_ocean	1	100.0
tang_blue	1	100.0
beauty_rock	1	100.0
basslet_fairy	1	100.0
chromis_blue	1	100.0

Table 11. Species composition and total weights sampled in Puerto Rico East.

Puerto Rico East- Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
conch_queen	7275	53.5
lobster_caribbean_spiny	2374	71.0
unknown	547	75.0
hogfish	521	78.9
cero	344	81.4
triggerfish_queen	240	83.2
hind_red	235	84.9
snapper_lane	175	86.2
mackerel_king	169	87.4
grunt_white	135	88.4
snapper_yellowtail	123	89.3
parrotfish_redtail	119	90.2
parrotfish_stoplight	111	91.0
porgy_pluma	99	91.7
snapper_gray	94	92.4
grunt_bluestriped	68	92.9
snapper_queen	59	93.4
snapper_dog	58	93.8
snappers_unknown	55	94.2
crab_batwing_coral	51	94.6
tuna_blackfin	40	94.9
barracuda_great	37	95.1
topsnail_west_indian	36	95.4
runner_blue	34	95.6
trunkfish_spotted	30	95.9
margate	26	96.1
trunkfish_smooth	26	96.3
cowfish_scrawled	25	96.4
lobster_spanish_slipper	24	96.6
porkfish	24	96.8
tunny_little	24	97.0
angelfish_gray	23	97.1
jack_crevalle	23	97.3
trunkfish	19	97.4
snapper_silk	18	97.6
parrotfishes_unknown	17	97.7
pompano_african	17	97.8

Table 11. (Continued) Species composition and total weights sampled in Puerto Rico East.

Puerto Rico East- Observed Weight by Species		
Species	Landings (lbs.)	Cumulative % of Total
jack_bar	15	97.9
graysby	13	98.0
porgy_jolthead	13	98.1
cowfish_honeycombed	12	98.2
snapper_blackfin	12	98.3
coney	11	98.4
groupers_unknown	11	98.5
choice_sailors	10	98.5
crab_channel_clinging	10	98.6
filefishes_unknown	10	98.7
mackerel_unknown	10	98.8
schoolmaster	10	98.8
snapper_cubera	10	98.9
snapper_mutton	10	99.0
angelfish_french	9	99.0
jack_yellow	9	99.1
squirrelfish	9	99.2
grouper_red	8	99.2
grunt_spanish	8	99.3
lobster_ridged_slipper	8	99.4
grunt_unknown	7	99.4
lionfish	6	99.5
goatfish_yellow	5	99.5
herring_atlantic_thread	5	99.5
porgy_saucereye	5	99.6
filefish_scrawled	4	99.6
goatfish_spotted	4	99.6
jacks_unknown	4	99.7
beardfish	3	99.7
dolphin	3	99.7
jack_horse_eye	3	99.7
parrotfish_redfin	3	99.7
porgies_unknown	3	99.8
rays_unknown	3	99.8
filefish_whitespotted	2	99.8
parrotfish_princess	2	99.8
sennet_southern	2	99.8

Table 11. (Continued) Species composition and total weights sampled in Puerto Rico East.

Puerto Rico East- Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
snapper_mahogany	2	99.8
snapper_vermilion	2	99.9
surgeonfish_ocean	2	99.9
tomtate	2	99.9
triggerfishes_unknown	2	99.9
mojarra_striped	1	99.9
boxfish_unknown	1	99.9
cottonwick	1	99.9
crustaceans_unknown	1	99.9
hamlet_mutton	1	99.9
lookdown	1	99.9
margate_black	1	100.0
moray_spotted	1	100.0
octopus_unknown	1	100.0
puddingwife	1	100.0
shellfish_unknown	1	100.0
surgeon_ocean	1	100.0
tang_blue	1	100.0

Table 12. Species composition and total weights sampled in Puerto Rico North.

Puerto Rico North- Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
snapper_silk	548	17.2
lobster_caribbean_spiny	515	33.3
conch_queen	204	39.7
snapper_yellowtail	168	45.0
snapper_queen	159	50.0
herring_atlantic_thread	146	54.6
snapper_blackfin	138	58.9
sardines_unknown	108	62.3
unknown	108	65.7
runner_blue	105	69.0
jenny_silver	81	71.5
cero	72	73.8
snapper_dog	71	76.0
mackerel_king	58	77.8
snapper_lane	51	79.4

Table 12. (Continued) Species composition and total weights sampled in Puerto Rico North.

Puerto Rico North- Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
parrotfish_redtail	50	81.0
snapper_black	40	82.2
sardine_scaled	39	83.4
hind_red	33	84.5
barracuda_great	29	85.4
snapper_vermilion	29	86.3
amberjack_greater	28	87.2
snapper_mutton	24	87.9
tunny_little	23	88.6
filefish_whitespotted	20	89.3
snappers_unknown	20	89.9
tuna_blackfin	19	90.5
choice_sailors	18	91.1
snapper_wenchman	17	91.6
triggerfish_queen	17	92.1
drummer_whitemouthed	15	92.6
jack_horse_eye	15	93.1
pompano_african	15	93.5
snapper_cardinal	15	94.0
snapper_cubera	14	94.4
jack_almaco	12	94.8
parrotfish_stoplight	12	95.2
hogfish	11	95.5
shark_reef	11	95.9
shark_sharpnose	10	96.2
mullet_white	9	96.5
snapper_gray	9	96.8
sardine_redear	8	97.0
schoolmaster	8	97.3
coney	7	97.5
dolphin	7	97.7
jack_crevalle	6	97.9
lionfish	6	98.1
jacks_unknown	5	98.2
snook_fat	5	98.4
bream_sea	4	98.5
pilchard_false	4	98.7
tilapia_blue	4	98.8
graysby	3	98.9

Table 12. (Continued) Species composition and total weights sampled in Puerto Rico North.

Puerto Rico North- Observed Weight by Species		
Species	Landings (lbs.)	Cumulative % of Total
harengula_unknown	3	99.0
jack_bar	3	99.1
mojarra_striped	3	99.2
parrotfishes_unknown	3	99.2
porkfish	3	99.3
cowfish_honeycombed	2	99.4
diapterus_unknown	2	99.5
durgon_black	2	99.5
porgy_pluma	2	99.6
scad_round	2	99.7
tilefish_blackline	2	99.7
trunkfish_smooth	2	99.8
filefish_scrawled	1	99.8
grunt_bluestriped	1	99.8
grunt_caesar	1	99.9
grunt_white	1	99.9
guaguanche	1	99.9
leatherjacket	1	100.0
squirrelfish	1	100.0

Table 13. Species composition and total weights sampled in Puerto Rico South.

Puerto Rico South- Observed Weight by Species		
Species	Landings (lbs.)	Cumulative % of Total
conch_queen	2128	22.5
lobster_caribbean_spiny	2019	43.9
dolphin	524	49.4
mackerel_king	499	54.7
hogfish	487	59.8
snapper_lane	445	64.5
triggerfish_queen	367	68.4
parrotfish_stoplight	324	71.8
octopus_unknown	266	74.7
snapper_yellowtail	216	76.9
hind_red	187	78.9
schoolmaster	146	80.5
parrotfish_redtail	130	87.6
barracuda_great	115	81.7
snapper_dog	115	82.9

Table 13. (Continued) Species composition and total weights sampled in Puerto Rico South.

Puerto Rico South- Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
unknown	108	84.0
ballyhoo	107	85.2
lobster_spanish_slipper	98	86.2
snappers_unknown	89	88.5
snook_common	87	89.4
crab_batwing_coral	70	90.2
jack_crevalle	68	90.9
runner_blue	52	91.5
snapper_silk	49	92.0
parrotfish_queen	48	92.5
rays_unknown	48	93.0
wahoo	47	93.5
grunt_white	43	93.9
cero	40	94.4
harengula_unknown	40	94.8
snapper_blackfin	39	95.2
jack_bar	38	95.6
snapper_gray	32	95.9
snapper_mutton	32	96.3
sardine_redear	30	96.6
grunt_bluestriped	23	96.8
stingray_southern	23	97.1
porgies_unknown	22	97.3
trunkfish_spotted	20	97.5
porgy_pluma	18	97.7
parrotfish_princess	16	97.9
trunkfish	16	98.1
choice_sailors	15	98.2
porkfish	13	98.4
amberjack_greater	11	98.5
groupers_unknown	11	98.6
herring_unknown	10	98.7
graysby	9	98.8
parrotfish_rainbow	9	98.9
lionfish	8	99.0
snapper_vermilion	8	99.0
tuna_skipjack	7	99.1
coney	6	99.2
snapper_queen	6	99.2

Table 13. (Continued) Species composition and total weights sampled in Puerto Rico South.

Puerto Rico South- Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
snapper_wenchman	6	99.3
cowfish_scrawled	5	99.4
jack_yellow	5	99.4
boxfish_unknown	4	99.5
cowfish_honeycombed	4	99.5
dolphin_pompano	4	99.5
jack_horse_eye	4	99.6
porgy_jolthead	4	99.6
mullet_white	3	99.7
snapper_cubera	3	99.7
triggerfish_gray	3	99.7
crab_blue	2	99.7
goatfish_spotted	2	99.8
hamlet_mutton	2	99.8
lobster_ridged_slipper	2	99.8
mackerel_spanish	2	99.8
parrotfish_redfin	2	99.9
porgy_saucereye	2	99.9
trunkfish_smooth	2	99.9
crab_blotched_swimming	1	99.9
crab_channel_clinging	1	99.9
drummer_whitemouthed	1	99.9
mojarra_rhomboid	1	99.9
mojarra_striped	1	99.9
parrotfishes_unknown	1	100.0
snapper_mahogany	1	100.0
squirrelfish	1	100.0
tilefish_blackline	1	100.0
triggerfishes_unknown	1	100.0

Table 14. Species composition and total weights sampled in Puerto Rico West.

Puerto Rico West- Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
conch_queen	2766	28.8
lobster_caribbean_spiny	1957	49.2
tuna_blackfin	726	56.8
snapper_silk	721	64.3
hind_red	664	71.2
snapper_queen	392	75.3
dolphin	388	79.3
triggerfish_queen	268	82.1
snapper_blackfin	163	83.8
hogfish	160	85.5
ballyhoo	150	87.0
unknown	120	88.3
cowfish_scrawled	78	89.1
cowfish_honeycombed	72	89.8
snapper_yellowtail	65	90.5
tuna_skipjack	62	91.2
boxfish_unknown	59	91.8
lionfish	57	92.4
trunkfish	50	92.9
mackerel_king	45	93.4
octopus_unknown	45	93.8
schoolmaster	39	94.2
barracuda_great	36	94.6
lobster_spanish_slipper	33	94.9
crab_batwing_coral	32	95.3
snapper_dog	32	95.6
tunas_mackerals_unknown	30	95.9
trunkfish_spotted	26	96.2
tuna_yellowfin	26	96.5
lobster_spotted_spiny	25	96.7
sharks_unknown	24	97.0
albacore	20	97.2
dolphin_pompano	20	97.4
jack_almaco	20	97.6
tuna_unknown	17	97.8
cero	16	97.9
snapper_wenchman	14	98.1
groupers_unknown	12	98.2
snapper_cubera	12	98.3

Table 14. (Continued) Species composition and total weights sampled in Puerto Rico West.

Puerto Rico West- Observed Weight by Species

Species	Landings (lbs.)	Cumulative % of Total
snapper_vermilion	12	98.5
triggerfishes_unknown	12	98.6
wahoo	12	98.7
grouper_misty	10	98.8
barracudas_unknown	9	98.9
parrotfish_stoplight	8	99.0
runner_blue	8	99.1
coney	7	99.2
grouper_yellowedge	7	99.2
porgy_jolthead	7	99.3
snappers_unknown	7	99.4
rays_unknown	6	99.4
filefishes_unknown	5	99.5
jacks_unknown	5	99.5
squirrelfish	5	99.6
tunny_little	5	99.6
amberjack_lesser	4	99.7
crustaceans_unknown	3	99.7
jack_black	3	99.8
jack_horse_eye	3	99.8
parrotfish_redtail	3	99.8
snapper_gray	3	99.8
grouper_yellowfin	2	99.9
tilefish_sand	2	99.9
graysby	1	99.9
grunt_unknown	1	99.9
grunt_white	1	99.9
jack_bar	1	99.9
moray_green	1	99.9
snapper_lane	1	99.9
soldierfish_blackbar	1	100.0
trunkfish_smooth	1	100.0
beauty_rock	1	100.0
basslet_fairy	1	100.0
chromis_blue	1	100.0

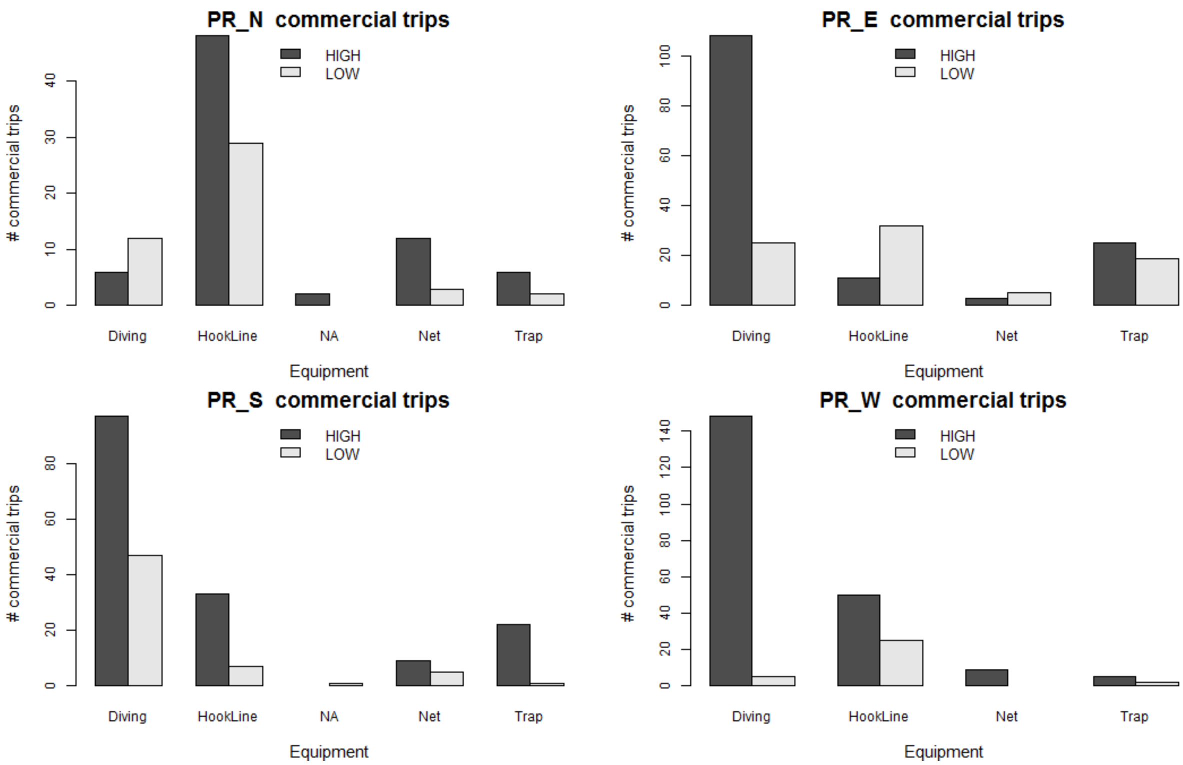


Figure 15. Total commercial trips sampled by equipment type in Puerto Rico (by region).

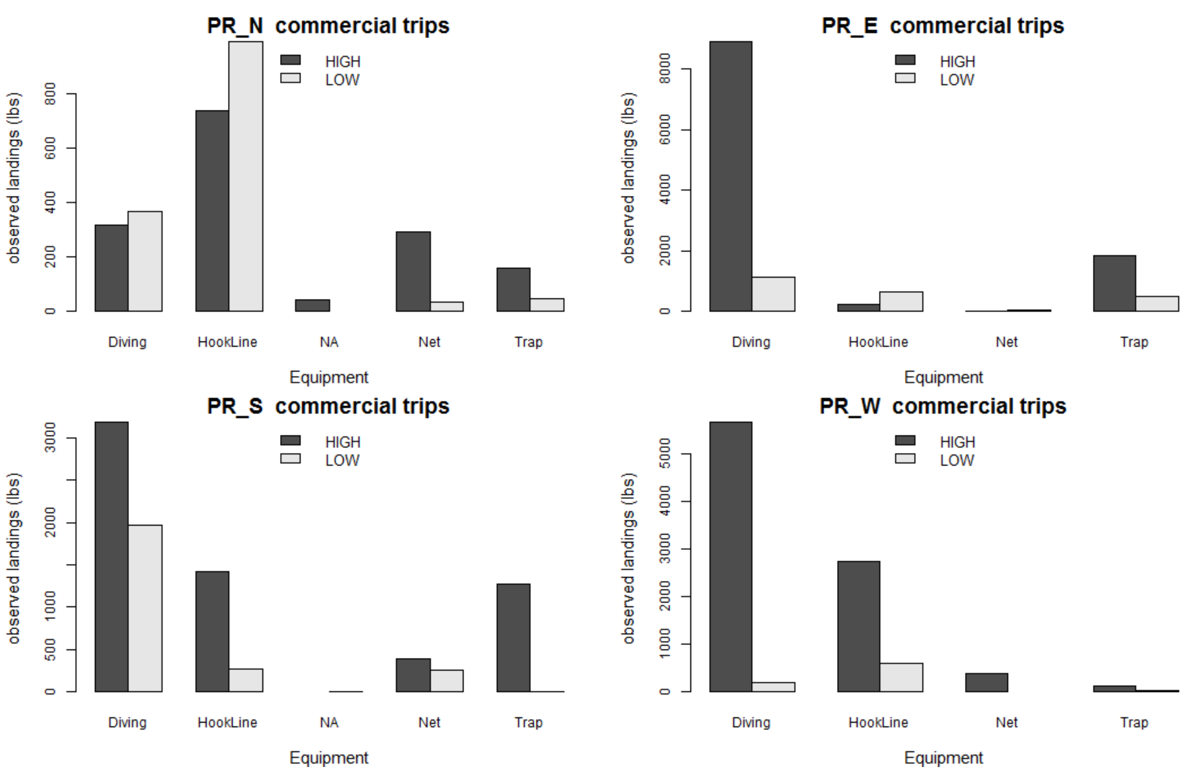


Figure 16. Total commercial landings sampled by equipment type in Puerto Rico (by region).

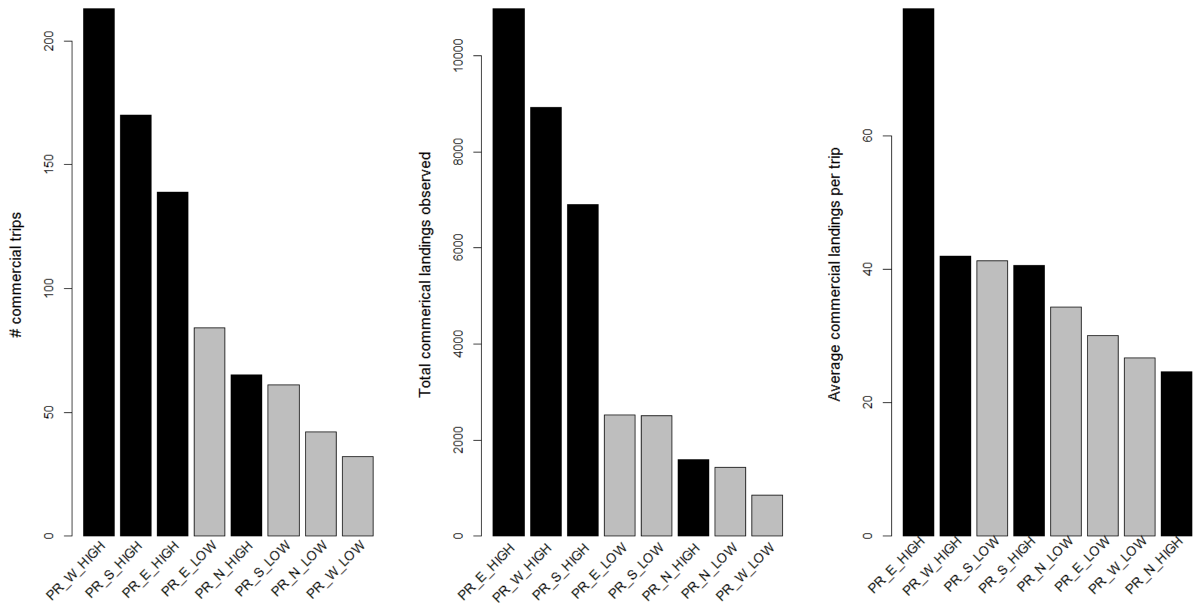


Figure 17. Number of trips, landings, and average landings/trip for commercial trips only in Puerto Rico (all).

4.2.2.1 Accounting for Unsampled Trips and Unknown Species in Puerto Rico

The methods used to account for unsampled trips was similar to USVI methods except an additional category was marked by samplers to designate if the fisherman refused to be interviewed and allow the sampler to estimate the catch. The number of daily refusals did not appear to exhibit any pattern (Figure 18). The 'unsampled' category for the Puerto Rico data refers to when a sampler was too busy to work up that trip. These two categories, 'refusals' and 'unsampled' trips, were summed to one category of 'total unsampled trips'. Similar to USVI methods, the catch in each of the regions of Puerto Rico were adjusted upwards by an expansion factor to account for the landings from the total unsampled trips. The expansion factors were as follows: North = 0.17, East = 0.19, South = 0.16, West = 0.21 (see Section 4.2.2.1).

Compared to USVI, most catch compositions were able to be determined either by the samplers or the the photograph verification after the culmination of the sampling period. The same procedure as in USVI methods of using a 'profile' of expected species composition in the region and stratum was applied to the Puerto Rico unidentified catch.

For the region, stratum, equipment type combination (e.g., PR_E high use stratum for diving) with the unknown catch accounting for more than 5% of the total catch, the method explained above was used. The unidentified catch was only greater than 5% in the north coast, high use stratum for diving.

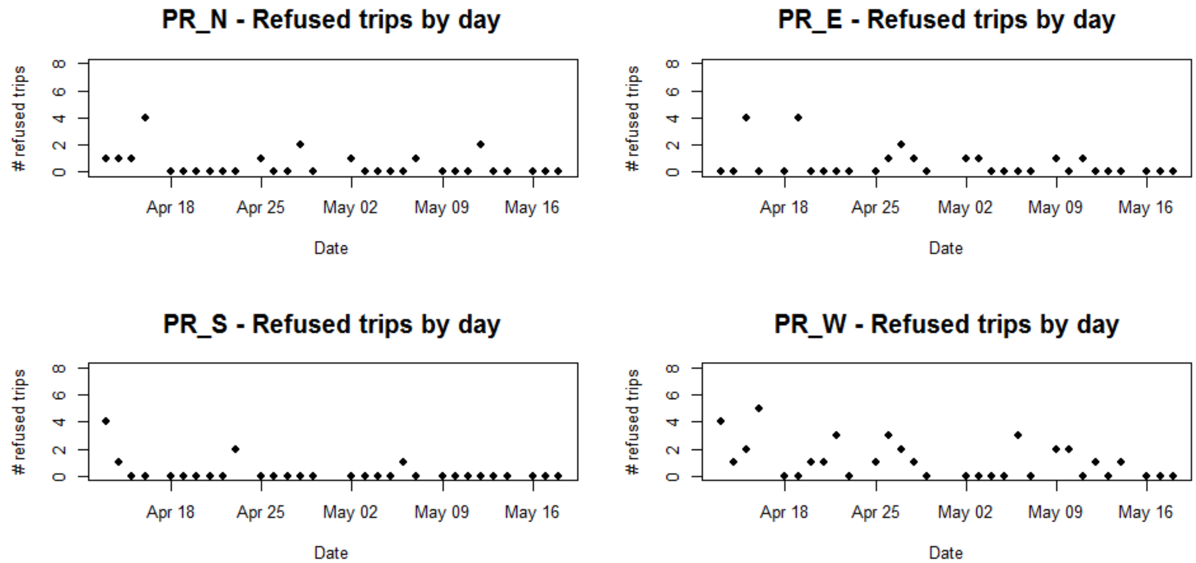


Figure 18. Number of refused trips versus day for four regions in Puerto Rico

4.2.3 Historical vs. observed species composition in the U.S. Caribbean

This section presents a comparison of species composition of landings from self-reported commercial catch records (CCR) to results from the 2015-2016 Pilot Port Sampling program.

The species composition of the landings during the pilot project was compared to the self-reported commercial catch records (CCR) and some differences were noted. Data from the 2012-2015 catch records were used to compare recently reported species and most landed species and data from 1983-2015 catch records were used to determine if species had ever been reported in the U.S. Caribbean. (See Appendix 7 for a detailed comparison.) We note the following differences:

- 145 species of fish and invertebrates were observed by port samplers in the pilot sampling program. CCR data from 2012-2015 documented 113 species. Not all species in the CCR data were observed during the pilot sampling program.
- 55 species of fish and invertebrates were observed during the pilot port sampling program but were not present in CCR data from 2012-2015 (See Table 7a in Appendix 7).
- The lower number of species recorded on the CCR forms may be due to multiple species reported as a single species (i.e. misidentification), reporting of multiple species as a single group, or landings that were not reported (i.e. not present on CCR forms and not written in by fisher).
- Species of note:

- Whitespotted Filefish was the 17th most landed species in St. Thomas, but there are no prior records of landings in the U.S. Caribbean in the data provided for comparison.
- Rock Hind was the 14th most landed species in St. Croix (also observed on St. Thomas), but was last reported in the CCR data from Puerto Rico in 2004.
- Dog Snapper was the 18th most landed species in Puerto Rico (also observed in St Croix), but was last reported in the CCR data from Puerto Rico in 2010.

4.3 Analysis

4.3.1 Calculation of region-specific landings per day by species – USVI

Estimated total landings for each of the four strata are given in Appendix 5. Overall (region wide) USVI landings are given for St. Thomas and St. Croix in Tables 19 and 20, respectively. The numbers were adjusted upward by 9% for St. Thomas and by 26% for St. Croix to account for unsampled trips. For St. Thomas, the estimated average landings per day were 849.8 pounds per day in the high use stratum (4 sites combined) and 86.9 pounds per day in the low use stratum (6 sites combined). Thus, 91 % of the landings on St. Thomas occur in the high use stratum. For St. Croix, the estimated average landings per day were 1126.6 pounds per day in the high use stratum (4 sites combined) and 383.8 pounds per day in the low use stratum (5 sites combined). Thus, 75 % of the landings on St. Croix occurred in the high use stratum. This suggests that precision of the survey could be improved if some sampling effort is shifted from the low use strata to the high use strata.

For St. Thomas, the rank of the species in terms of pounds landed is:

Low use stratum	High use stratum
1 West Indian topsnail	1 Caribbean spiny lobster
2 Caribbean spiny lobster	2 queen triggerfish
3 queen triggerfish	3 red hind
4 redtail parrotfish	4 gray angelfish
5 queen conch	5 white grunt
6 ocean surgeonfish	6 yellowfin grouper
7 dolphin	7 West Indian topsnail
8 gray angelfish	8 mutton snapper
9 red hind	9 bar jack
10 yellowtail snapper	10 coney

Five species are commonly caught in both strata. We note that a reallocation of sampling effort from the low use to the high use stratum might reduce the ability to quantify landings of redtail parrotfish and queen conch because these species were not seen in the high use stratum at this time of year. It should be noted here that Conch season opened on November 1, so in St. Croix only, sampling overlapped with the opening of the season. The West Indian topsnail season also opened during our sampling and as one St. Thomas fishers stated "you'll never see another whelk day like that all year."

For St. Croix, the rank of the species in terms of pounds landed is:

Low use stratum	High use stratum
1 Caribbean spiny lobster	1 Caribbean spiny lobster
2 dolphin	2 dolphin
3 wahoo	3 stoplight parrotfish
4 unknown	4 redtail parrotfish
5 stoplight parrotfish	5 wahoo
6 queen conch	6 schoolmaster
7 red band parrotfish	7 unknown
8 rock Hind	8 queen triggerfish
9 redtail parrotfish	9 red hind
10 gray angelfish	10 great barracuda

Five species were in the list of top ten species for both of the strata. Reduction of sampling effort in the low use stratum might affect the ability to assess the 6th through 8th and the 10th ranked species since these species were not in the top 10 ranked species for the high use stratum.

The results for each USVI region (low + high use strata combined) are given in Appendix 5.

In the USVI, results for the top 6 species, and all species combined, are given below for the four strata (Table 15 through 18) For St. Thomas high use stratum (Table 15), the standard errors for the top 6 species ranged from 15.8 to 46.7 % of the estimate (last column), with an overall standard error (all species combined) of 8.45 %. For the top 5 species, the standard errors were all less than 30% of the estimate. For the St. Thomas low use stratum (Table 16), the standard errors were larger, ranging from 50.78 to 83.05 % of the estimate, with an overall standard error (all species combined) of 25.6 %. The smaller variances for the high use stratum reflect the higher fraction of sites sampled – 50 % of the sites/day for the high use stratum versus one third of the sites/day for the low use stratum. This affects the variance through the introduction of the finite population correction (1 – m/M, see MER Estimation Report, 2014).

For St. Croix high use stratum (Table 17), the standard errors for the top 6 species ranged from 2.39 to 21.25 % of the estimate (last column), with an overall standard error (all species combined) of 4.14 %. For the St. Croix low use stratum (Table 18), the standard errors were larger, ranging from 12.38 to 86.41 % of the estimate, with an overall standard error (all species combined) of 15.27 %. For the top 5 species, the standard errors were all less than 46.18% of the estimate.

The region-wide results (high and low use strata combined) are given in Tables 19 and 20 for the top 6 species and the total catch. For St. Thomas, the standard errors expressed as a percentage of the estimated landings ranged from 15.78 % to 47.01 %. The standard error for the total landings on St. Thomas was 19.56 % of the estimated total. For St. Croix, the standard errors expressed as a percentage of the estimated landings, for the six species with the largest landings, ranged from 8.23 % to 36.15 %. The standard error for the total landings on St. Croix was 9.81 % of the estimated total. Although it appears that the estimates for St. Croix are more precise than those for St. Thomas, it should be remembered that the variance calculations do not include any uncertainty associated with the ad hoc adjustments that had to be made to account for unsampled trips on St. Croix.

Table 15. Results of sampling the St. Thomas high use stratum, for the top 6 species landed and for all species combined. In the notation of Cochran (1977) and MER Estimation Report (2014): avg landings (in pounds) per site per day = $\bar{\bar{y}}$, avg landings per day (entire stratum) = $M\bar{\bar{y}}$, total landings in 30 day survey period = $30M\bar{\bar{y}}$, sample variance among daily means = s_1^2, sample variance among sites within days = s_2^2, std error of avg landings per site per day = $\sqrt{V[\bar{\bar{y}}]}$, std error of avg landings per day = $M\sqrt{V[\bar{\bar{y}}]}$, and std error of avg landings per day as percentage of avg landings per day = $100 * {M\sqrt{V[\bar{\bar{y}}]}}/{M\bar{\bar{y}}}$.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * {M\sqrt{V[\bar{\bar{y}}]}}/{M\bar{\bar{y}}}$
lobster_caribbean_spiny	86.55	346.18	10385.52	25392.33	28562.62	15.43	61.71	17.83
triggerfish_queen	22.53	90.13	2704.03	752.66	1521.39	3.56	14.24	15.8
hind_red	20.71	82.84	2485.2	1170.4	3515.5	5.41	21.65	26.14
angelfish_gray	9.41	37.64	1129.34	263.05	805.28	2.59	10.36	27.53
grunt_white	4.21	16.83	505	50.69	149.71	1.12	4.47	26.54
grouper_yellowfin	4.09	16.34	490.27	138.83	437.13	1.91	7.63	46.72
TOTAL	**212.44**	**849.78**	**25493.33**	**29268.28**	**38635.53**	**17.94**	**71.77**	**8.45**

Table 16. Results of sampling the St. Thomas low use stratum, for the top 6 species landed and for all species combined.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * M\sqrt{V[\bar{\bar{y}}]} / M\bar{\bar{y}}$
topsnail_west_indian	4.94	29.65	889.44	358.87	768.25	2.92	17.53	59.13
lobster_caribbean_spiny	3.45	20.71	621.3	125.92	276.5	1.75	10.52	50.78
triggerfish_queen	1.65	9.92	297.57	55.07	115.8	1.13	6.81	68.61
parrotfish_redtail	0.64	3.82	114.45	6.72	14.28	0.4	2.39	62.64
conch_queen	0.6	3.6	107.91	10.78	22.31	0.5	2.99	83.05
surgeon_ocean	0.49	2.94	88.29	7.22	14.93	0.41	2.44	83.05
TOTAL	**14.48**	**86.87**	**2606.19**	**576.28**	**1236.55**	**3.71**	**22.24**	**25.6**

Table 17. Results of sampling the St. Croix high use stratum, for the top 6 species landed and for all species combined.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * M\sqrt{V[\bar{\bar{y}}]} / M\bar{\bar{y}}$
lobster_caribbean_spiny	64.3	257.19	7715.7	3180.22	6145.6	7.16	28.63	11.13
Dolphin	29.61	118.44	3553.2	2770.45	4753.08	6.29	25.17	21.25
parrotfish_stoplight	28.15	112.59	3377.62	952.67	714.68	2.44	9.76	8.67
parrotfish_redtail	19.74	78.98	2369.35	429.65	552.75	2.15	8.58	10.87
Wahoo	18.02	72.07	2162.16	3350.1	22.33	0.43	1.73	2.39
schoolmaster	13	52.01	1560.42	218.79	612.78	2.26	9.04	17.38
TOTAL	**281.66**	**1126.63**	**33798.76**	**13624.12**	**16131.17**	**11.59**	**46.38**	**4.12**

Table 18. Results of sampling the St. Croix low use stratum, for the top 6 species landed and for all species combined.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * M\sqrt{V[\bar{\bar{y}}]} / M\bar{\bar{y}}$
lobster_caribbean_spiny	25.44	127.19	3815.84	1877.38	1352.45	3.68	18.39	14.46
Dolphin	19.66	98.3	2949.05	3783.35	592.64	2.43	12.17	12.38
Wahoo	14.36	71.78	2153.25	4188.13	10804.48	10.39	51.97	72.41
unknown	5.49	27.45	823.5	255.45	642.75	2.54	12.68	46.18
parrotfish_stoplight	2.49	12.47	374.23	69.4	42.83	0.65	3.27	26.23
conch_queen	1.19	5.96	178.88	39.82	106.18	1.03	5.15	86.41
TOTAL	**76.75**	**383.76**	**11512.82**	**10281.86**	**13677.62**	**11.7**	**58.48**	**15.24**

Table 19. Results of region wide sampling of St. Thomas, for the top 6 species landed and for all species combined. The first numeric column gives the estimated average landings per day (region-wide) in pounds; the second numeric column gives the standard error of the estimate and the last column gives the standard error as a percentage of the estimate.

Species	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
lobster_caribbean_spiny	366.89	62.6	17.06
triggerfish_queen	100.05	15.79	15.78
hind_red	84.47	21.67	25.66
angelfish_gray	39.61	10.43	26.33
topsnail_west_indian	45.96	21.61	47.01
grunt_white	17.33	4.48	25.87
TOTAL	**936.65**	**183.22**	**19.56**

Table 20. Results of region-wide sampling of St. Croix, for the top 6 species landed and for all species combined.

Species	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
lobster_caribbean_spiny	384.38	34.02	8.85
dolphin	216.74	27.96	12.9
Wahoo	143.85	52	36.15
parrotfish_stoplight	125.06	10.3	8.23
parrotfish_redtail	83.49	8.8	10.54
unknown	69.38	12.97	18.7
TOTAL	**1510.39**	**148.21**	**9.81**

We plotted landings versus day of the survey to look for trends and periodicities in the data which might affect the performance of the survey (Figure 20 below). None were found.

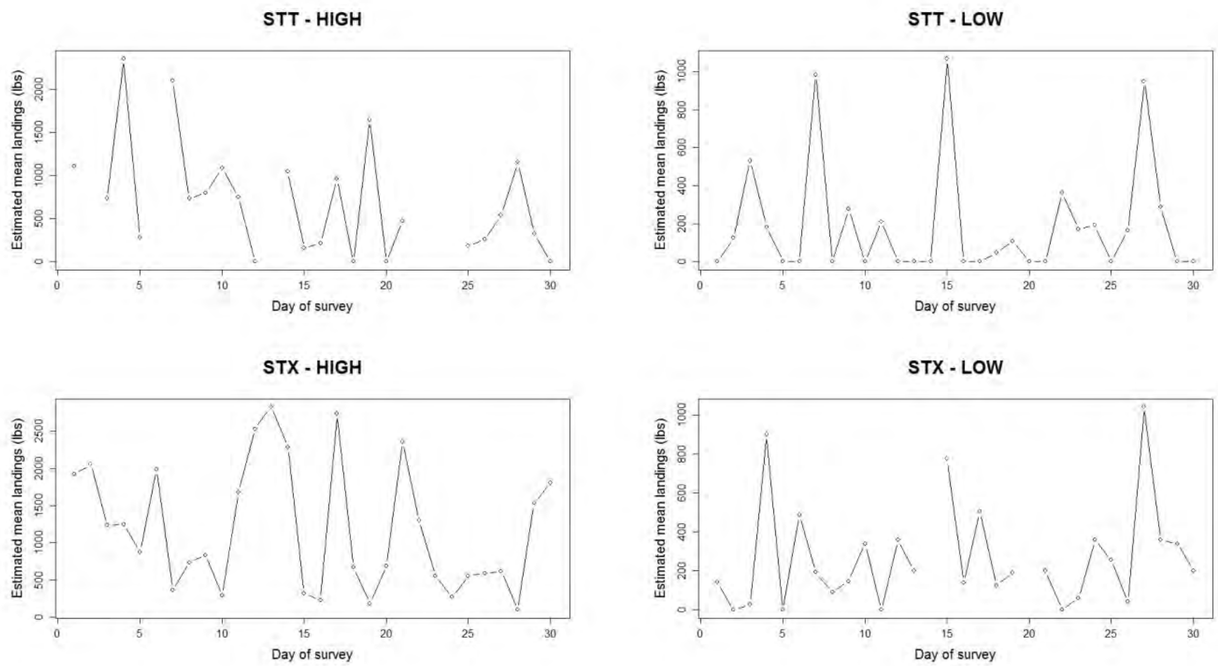


Figure 19. Estimated USVI mean landings in a stratum versus day of the survey to look for trends and periodicities over time.

4.3.2 Calculation of region-specific landings per day by species – Puerto Rico

Estimated total landings for the top 6 species in each of the eight strata are given in Tables 22 through 29; overall (region wide) landings are given in Appendix 6. The results for all species are given in Appendix 5 for each of the eight strata (low + high use strata combined).

The average landings (lbs) per day in each of the regions is summarized below. The north region has half the landings of (each of) the other regions. In general, the vast majority of the landings in a region occur in the high use stratum with the north region being the exception.

Results for the top 6 species, and all species combined, are given below for the eight strata (Tables 22 - 29). The standard errors for the total landings ranged from 6% to 10% of the estimated landings in the high use strata. In the low use strata, the standard errors ranged from 10% to 15% for three of the regions and was 24% for the north region.

Precision of the estimates for individual species was not as good as for total landings. Some species were estimated with standard errors under 15% of the estimated landings but others had very high standard errors. The north region generally had higher standard errors than the other regions.

Table 21. Range of standard errors (as a percentage of the estimated landings) for the top 6 species landed in a stratum and for 5 of the top six species (highest standard error not considered).

Region	Stratum	Top 6	Top 5
North	High	22% - 77%	22% - 64%
North	Low	16% - 83%	16% - 82%
East	High	10% - 51%	10% - 33%
East	Low	20% - 41%	20% - 30%
South	High	13% - 58%	13% - 44%
South	Low	17% - 112%	17% - 41%
West	High	11% - 43%	11% - 33%
West	Low	12% - 86%	12% - 45%

Table 22. Results of sampling the Puerto Rico North high use stratum, for the top 6 species landed and for all species combined. In the notation of Cochran (1977) and MER Estimation Report (2014): avg landings (in pounds) per site per day = $\bar{\bar{y}}$, avg landings per day (entire stratum) = $M\bar{\bar{y}}$, total landings in 30 day survey period = $30M\bar{\bar{y}}$, sample variance among daily means = s_1^2, sample variance among sites within days = s_2^2, std error of avg landings per site per day = $\sqrt{V[\bar{\bar{y}}]}$, std error of avg landings per day = $M\sqrt{V[\bar{\bar{y}}]}$, and std error of avg landings per day as percentage of avg landings per day = $100 * M\sqrt{V[\bar{\bar{y}}]}/M\bar{\bar{y}}$.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * M\sqrt{V[\bar{\bar{y}}]}/M\bar{\bar{y}}$
snapper_silk	6.5	39.03	1170.8	86.26	211.64	1.54	9.23	23.66
lobster_caribbean_spiny	5.51	33.05	991.47	94.68	294.24	1.81	10.84	32.81
herring_atlantic_thread	4.37	26.22	786.48	300.71	59.26	0.98	5.88	22.43
snapper_dog	1.47	8.82	264.52	43.4	115.07	1.13	6.8	77.11
conch_queen	1.22	7.35	220.41	23.55	61.12	0.83	4.96	67.47
snapper_queen	1.18	7.09	212.57	16.33	42.87	0.69	4.15	58.58
TOTAL	**32.02**	**192.15**	**5764.36**	**640.72**	**912.68**	**3.24**	**19.44**	**10.12**

Table 23. Results of sampling the Puerto Rico North low use stratum, for the top 6 species landed and for all species combined.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * M\sqrt{V[\bar{\bar{y}}]}/M\bar{\bar{y}}$
snapper_silk	17.71	194.8	5844.08	3413.5	8232.73	10.6	116.58	59.84
snapper_queen	6.09	66.99	2009.7	613.84	1891.41	5.06	55.68	83.11
conch_queen	4.35	47.85	1435.5	151.49	60.07	0.98	10.75	22.47
lobster_caribbean_spiny	4.23	46.57	1397.22	76.84	138.32	1.38	15.19	32.62
snapper_blackfin	4.18	45.94	1378.08	406.52	0	0.66	7.27	15.83
snapper_yellowtail	3.09	34.03	1020.8	155.1	478.36	2.55	28	82.29
TOTAL	**52.7**	**579.73**	**17391.88**	**5155.42**	**11563.01**	**12.58**	**138.33**	**23.86**

Table 24. Results of sampling the Puerto Rico East high use stratum, for the top 6 species landed and for all species combined.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * M\sqrt{V[\bar{\bar{y}}]}/M\bar{\bar{y}}$
conch_queen	141.65	708.25	21247.45	12572.96	18748.1	13.96	69.81	9.86
lobster_caribbean_spiny	48.5	242.51	7275.41	5750.82	4138.81	6.8	34	14.02
Hogfish	10.61	53.04	1591.11	219.78	400.91	2.03	10.14	19.13
unknown	8.16	40.8	1224	545.4	1759.5	4.2	20.98	51.43
hind_red	5.68	28.42	852.49	168	340.47	1.86	9.32	32.8
triggerfish_queen	4.76	23.8	714	45.37	139.32	1.18	5.91	24.83
TOTAL	**256.85**	**1284.27**	**38527.98**	**19765.67**	**25959.41**	**16.51**	**82.53**	**6.43**

Table 25. Results of sampling the PR-East low use stratum, for the top 6 species landed and for all species combined.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * \frac{M\sqrt{V[\bar{\bar{y}}]}}{M\bar{\bar{y}}}$
conch_queen	20.41	122.49	3674.64	668.93	1745.18	4.41	26.48	21.62
lobster_caribbean_spiny	9.4	56.41	1692.18	131.9	303.44	1.85	11.07	19.63
Unknown	4.99	29.91	897.42	145.67	369.19	2.03	12.19	40.74
Cero	4.3	25.82	774.69	42.89	153.8	1.3	7.82	30.29
mackerel_king	3	17.97	539.19	48.69	70.91	0.9	5.42	30.14
snapper_lane	2.21	13.29	398.68	14.11	34.48	0.62	3.73	28.05
TOTAL	**58.83**	**352.95**	**10588.62**	**1172.42**	**2800.05**	**5.6**	**33.6**	**9.52**

Table 26. Results of sampling the PR-South high use stratum, for the top 6 species landed and for all species combined.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * \frac{M\sqrt{V[\bar{\bar{y}}]}}{M\bar{\bar{y}}}$
lobster_caribbean_spiny	32.38	194.3	5829	2228.25	1326.6	4.08	24.49	12.6
conch_queen	31.65	189.89	5696.76	705.92	2448.77	5.2	31.23	16.45
snapper_lane	12.5	75	2250.13	1061.12	146.11	1.65	9.88	13.17
triggerfish_queen	9.66	57.96	1738.8	531.64	573.07	2.59	15.57	26.86
mackerel_king	8.51	51.08	1532.44	389.43	1240.41	3.71	22.25	43.57
Dolphin	8.41	50.46	1513.8	766.35	2099.78	4.84	29.03	57.52
TOTAL	**157.53**	**945.17**	**28355.11**	**6697.47**	**8959.31**	**10.18**	**61.05**	**6.46**

Table 27. Results of sampling the PR-South low use stratum, for the top 6 species landed and for all species combined.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * \frac{M\sqrt{V[\bar{\bar{y}}]}}{M\bar{\bar{y}}}$
conch_queen	17.61	158.51	4755.42	784.77	1234.68	4.04	36.37	22.95
lobster_caribbean_spiny	14.46	130.14	3904.2	276.21	1068.37	3.7	33.31	25.6
Hogfish	5.26	47.34	1420.2	61.03	106.19	1.18	10.64	22.48
Dolphin	2.59	23.3	699.11	187.72	657.03	2.91	26.15	112.23
parrotfish_stoplight	2.17	19.49	584.73	27.21	61.98	0.9	8.08	41.48
ray_unknown	1.99	17.9	536.91	110.72	0	0.35	3.11	17.35
TOTAL	**58.26**	**524.33**	**15729.79**	**1647.57**	**3710.9**	**6.95**	**62.56**	**11.93**

Table 28. Results of sampling the PR-West high use stratum, for the top 6 species landed and for all species combined.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * {M\sqrt{V[\bar{\bar{y}}]}}/{M\bar{\bar{y}}}$
conch_queen	66.38	464.68	13940.45	4018.56	4103.64	7.18	50.28	10.82
lobster_caribbean_spiny	44.56	311.93	9357.89	2434.36	8529.59	10.04	70.31	22.54
hind_red	16.56	115.95	3478.54	940.17	612.36	2.84	19.88	17.15
tuna_blackfin	16.04	112.31	3369.37	555.23	2325.43	5.23	36.63	32.62
snapper_silk	15.4	107.81	3234.17	586.91	1433.36	4.14	28.98	26.89
Dolphin	12.7	88.94	2668.05	969.42	2445.11	5.4	37.83	42.54
TOTAL	**231.03**	**1617.21**	**48516.32**	**11620.07**	**23048.27**	**16.67**	**116.72**	**7.22**

Table 29. Results of sampling the PR-West low use stratum, for the top 6 species landed and for all species combined.

Species	$\bar{\bar{y}}$	$M\bar{\bar{y}}$	$30M\bar{\bar{y}}$	s_1^2	s_2^2	$\sqrt{V[\bar{\bar{y}}]}$	$M\sqrt{V[\bar{\bar{y}}]}$	$100 * {M\sqrt{V[\bar{\bar{y}}]}}/{M\bar{\bar{y}}}$
tuna_blackfin	5.04	35.29	1058.75	128.65	427.94	2.25	15.76	44.65
snapper_silk	3.81	26.68	800.41	60.26	13.21	0.47	3.26	12.22
lobster_caribbean_spiny	3.65	25.55	766.53	121.89	54.13	0.87	6.08	23.8
conch_queen	1.9	13.27	398.09	70.45	226.4	1.64	11.47	86.42
mackerel_king	1.35	9.46	283.75	31.5	5.9	0.32	2.23	23.61
hind_red	1.07	7.48	224.46	11.7	17.15	0.46	3.21	42.89
TOTAL	**21.44**	**150.06**	**4501.81**	**478.29**	**785.12**	**3.09**	**21.64**	**14.42**

For Puerto Rico North, South and West regions, six species appear in the list of top 10 species landed for both the high and the low use strata. For the East region, only four species appear in the lists for both strata. These results suggest that reducing the effort in one stratum and increasing it in the other will increase the efficiency for some species at the expense of other species.

Table 30. Rank of species in terms of estimated pounds landed by strata for Puerto Rico - North

Rank	Low use stratum	High use stratum
1	snapper_silk	snapper_silk
2	snapper_queen	lobster_caribbean_spiny
3	conch_queen	herring_atlantic_thread
4	lobster_caribbean_spiny	snapper_dog
5	snapper_blackfin	conch_queen
6	snapper_yellowtail	snapper_queen
7	jenny_silver	Cero
8	snapper_black	sardine_scaled
9	dolphin	snapper_blackfin
10	runner_blue	runner_blue

Table 31. Rank of species in terms estimated pounds landed by strata for Puerto Rico - East

Rank	Low use stratum	High use stratum
1	conch_queen	conch_queen
2	lobster_caribbean_spiny	lobster_caribbean_spiny
3	Unknown	Hogfish
4	Cero	Unknown
5	mackerel_king	hind_red
6	snapper_lane	triggerfish_queen
7	Hogfish	snapper_gray
8	snapper_yellowtail	parrotfish_stoplight
9	tuna_blackfin	parrotfish_redtail
10	barracuda_great	grunt_white

Table 32. Rank of species in terms of estimated pounds landed by strata for Puerto Rico - South

Rank	Low use stratum	High use stratum
1	conch_queen	lobster_caribbean_spiny
2	lobster_caribbean_spiny	conch_queen
3	hogfish	snapper_lane
4	dolphin	triggerfish_queen
5	parrotfish_stoplight	mackerel_king
6	ray_unknown	Dolphin
7	barracuda_great	snapper_yellowtail
8	ballyhoo	Hogfish
9	hind_red	octopus_common
10	octopus_common	hind_red

Table 33. Rank of species in terms of estimated pounds landed by strata for Puerto Rico - West

Rank	Low use stratum	High use stratum
1	tuna_blackfin	conch_queen
2	snapper_silk	lobster_caribbean_spiny
3	lobster_caribbean_spiny	hind_red
4	conch_queen	tuna_blackfin
5	mackerel_king	snapper_silk
6	hind_red	Dolphin
7	snapper_blackfin	snapper_queen
8	grouper_misty	triggerfish_queen
9	snapper_queen	Unknown
10	tuna_yellowfin	Ballyhoo

The estimates by region (both strata considered) for the 6 most important species and the total landings are given in Tables 34 - 37 below.

Table 34. Results of sampling Puerto Rico - North, for the top 6 species landed and for all species combined. In the notation of Cochran (1977) and MER Estimation Report (2014): avg landings (in pounds) per site per day = $\bar{\bar{y}}$, avg landings per day (entire stratum) = $M\bar{\bar{y}}$, total landings in 30 day survey period = $30M\bar{\bar{y}}$, sample variance among daily means = s_1^2, sample variance among sites within days = s_2^2, std error of avg landings per site per day = $\sqrt{V[\bar{\bar{y}}]}$, std error of avg landings per day = $M\sqrt{V[\bar{\bar{y}}]}$, and std error of avg landings per day as percentage of avg landings per day = $100 * {M\sqrt{V[\bar{\bar{y}}]}}/{M\bar{\bar{y}}}$.

Species	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
TOTAL	**771.88**	**139.69**	**18.10**
snapper_silk	233.83	116.94	50.01
lobster_caribbean_spiny	79.62	18.66	23.44
snapper_queen	74.08	55.83	75.37
conch_queen	55.20	11.84	21.45
snapper_blackfin	49.97	7.38	14.77
snapper_yellowtail	37.35	28.07	75.15

Table 35. Results of sampling Puerto Rico - East, for the top 6 species landed and for all species combined.

Species	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
TOTAL	**1637.22**	**89.11**	**5.44**
conch_queen	830.74	74.66	8.99
lobster_caribbean_spiny	298.92	35.76	11.96
unknown	70.71	24.26	34.32
Hogfish	65.84	10.59	16.09
Cero	32.00	8.10	25.30
triggerfish_queen	29.16	6.31	21.64

Table 36. Results of Sampling Puerto Rico - South, for the top 6 species landed and for all species combined.

Species	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
TOTAL	**1469.50**	**87.41**	**5.95**
conch_queen	348.40	47.94	13.76
lobster_caribbean_spiny	324.44	41.34	12.74
snapper_lane	79.66	10.76	13.51
Hogfish	77.94	12.41	15.92
Dolphin	73.76	39.07	52.97
triggerfish_queen	63.55	16.07	25.28

Table 37. Results of sampling Puerto Rico - West, for the top 6 species landed and for all species combined.

Species	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
TOTAL	**1767.27**	**118.71**	**6.72**
conch_queen	477.95	51.57	10.79
lobster_caribbean_spiny	337.48	70.57	20.91
tuna_blackfin	147.60	39.88	27.02
snapper_silk	134.49	29.16	21.68
hind_red	123.43	20.14	16.31
Dolphin	88.94	37.83	42.53

The estimates of proportional standard error can be summarized as follows:

Region	Proportional SE for total catch	range of estimates for 6 top species	range of estimates for 5 of 6 top species
North	18.0	14.8 – 75.4	14.8 – 75.2
East	5.4	9.0 – 34.3	9.0 – 25.3
South	6.0	12.7 - 53.0	12.7 – 25.3
West	6.7	10.8 – 42.5	10.8 – 27.0

The estimates for the total catch have good precision with the possible exception of the North Region (see section below on restratification which addresses the problems with surveying the North Region). The standard errors for most of the top landed species are also quite good.

The average landings per day (lbs) for all species combined in the four regions were: 772 (North), 1637 (East), 1469 (South), and 1767 (West). In the pilot study, equal sampling effort was allocated to all four regions. If the North region really contributes less to the landings than the other regions, then some thought might be given to sampling this region at a lower intensity. However, the logistics of accommodating this, such as having part-time versus full-time employees would need to be considered.

4.3.3 Evaluation of the sampling design – USVI

4.3.3.1 Landings by day of the survey and by day of the week

In the USVI, there was no evidence of a trend in landings over the course of the survey (Figure 21). This simplifies interpretation of the survey data. In St. Thomas, observed landings were low on Tuesdays and Saturdays in both the low and high use strata (Figure 21). Landings were low in the St. Thomas low use stratum, but high in the St. Thomas high use stratum, on Mondays. If this pattern holds throughout the year, then there may be some advantage to further stratifying by day of the week.

In St. Croix, all days had comparable landings in the high use stratum, but Mondays and Wednesdays had low landings in the low use stratum. It is not known whether this pattern is persistent over time.

4.3.3.2 Consideration of time of day

Sampling activities were scheduled between the hours of 9:00 am and 5:00 pm. Histograms of trip ending times for St. Thomas were bimodal; for St. Croix the distribution of end times was unimodal (Figure 22). It appears that some landings prior to 9:00 am may have been missed, at least in the St. Thomas high use stratum, judging by the fact that there were considerable landings in the first hour of sampling in the day.

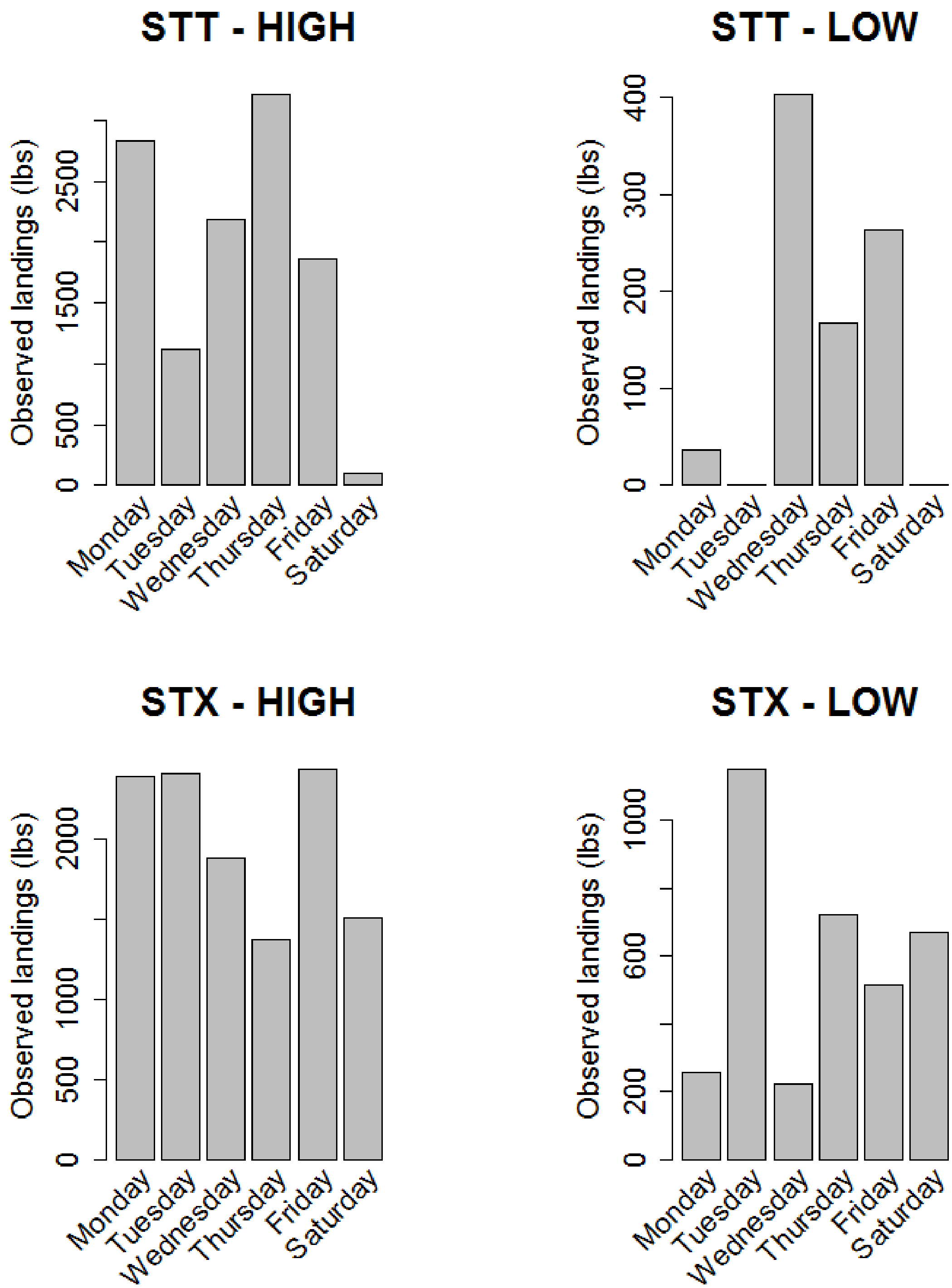


Figure 20. Observed USVI landings versus day of the week for each stratum.

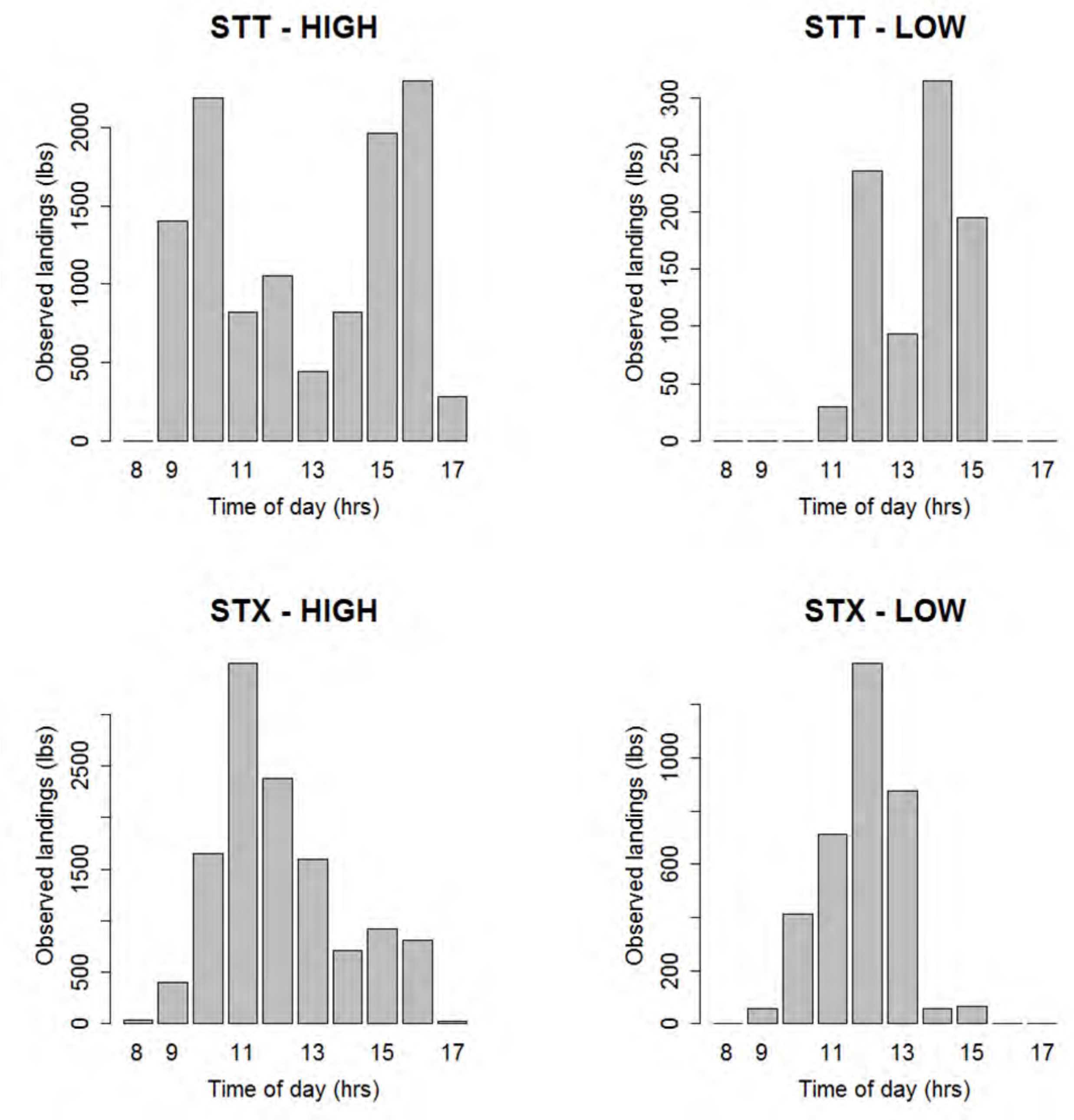


Figure 21. Observed USVI landings versus time of day that trips ended for each stratum.

4.3.3.3 Homogeneity of strata and potential to restratify

Almost all of the sites with high landings were included in the high use strata, the one exception being Christiansted Harbor which was placed in the low use stratum but had estimated landings comparable to what was estimated in the high use stratum (Figure 23). Several sites in the high use strata had low estimated landings: Gallows Bay in St. Croix, and Mandahl and Hull Bay in St. Thomas. Additionally, four sites had minimal estimated landings: Turner Hole in St. Croix and Crown Bay, Magens Bay and Sapphire in St. Thomas.

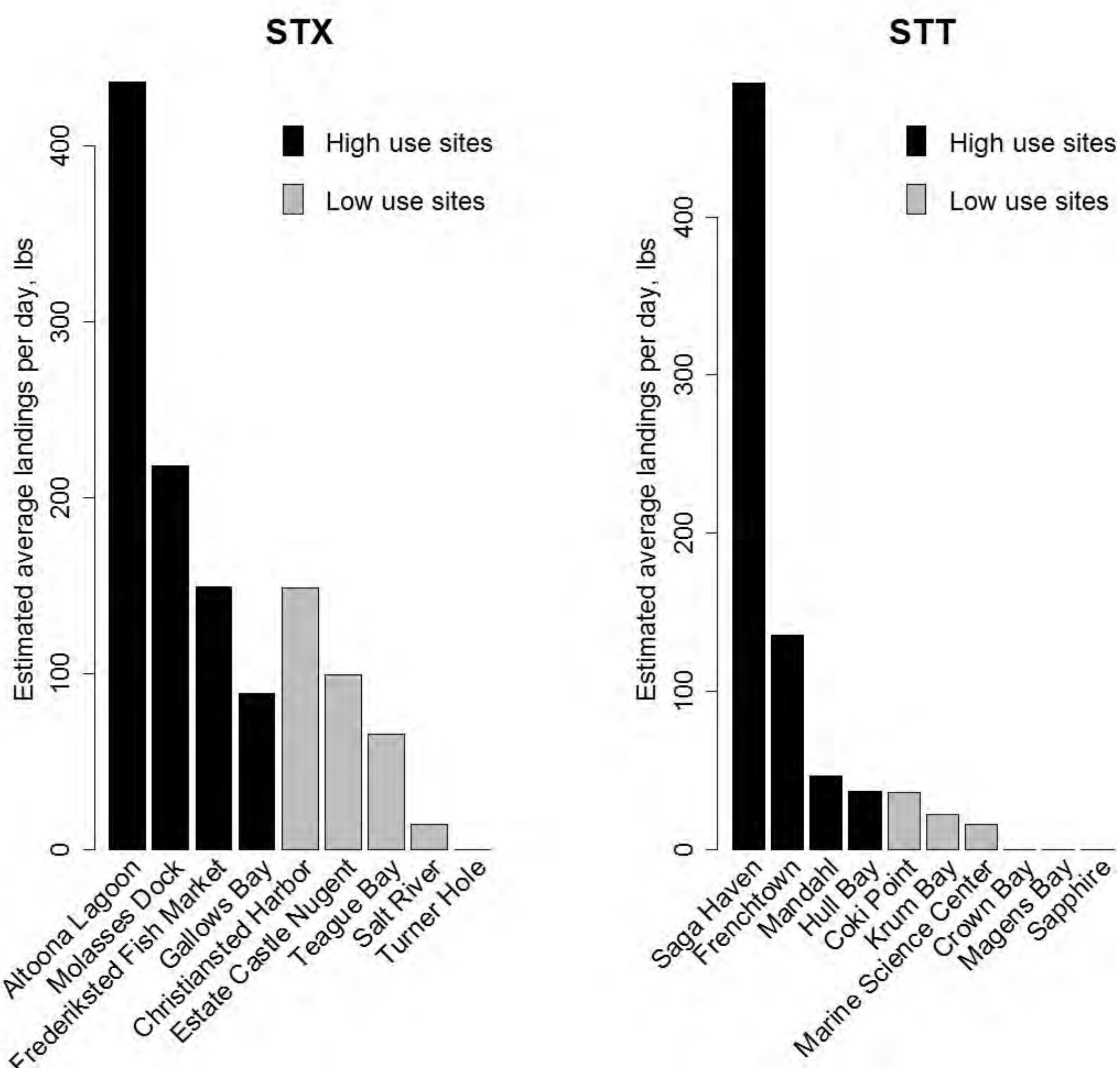


Figure 22. Estimated average commercial daily landings by site for each stratum. St. Croix sites are in the left bar graph and St. Thomas sites are in the right graph.

For St. Thomas, the high use stratum could be redefined to consist of two sites - Saga Haven and Frenchtown (maybe make these two separate strata). Mandahl and Hull Bay could be put in the low use stratum and three low use sites could be dropped from the low-use stratum - Crown Bay, Magens Bay and Sapphire. This would reduce the standard error of the estimated total landings (all species combined) by an estimated 16.3 %. Note that this is based on usage observed over only a 30 day window so usage might be different at other times of the year; hence, one should spot check in a future survey to make sure significant activity is not being missed. Also, the calculation of the benefit of restratification is based on the assumption that the observed usage of the sites represents real differences among sites rather than measurement error. Therefore, the calculated benefits of restratification tend to be overestimated.

For St. Croix, Christiansted Harbor could be reallocated to the high-use stratum and Gallows Bay could be reassigned to the low-use stratum; also, Turner Hole and maybe Salt Pond could be dropped from the survey altogether. In our calculations of standard errors under restratification, we did not see a benefit of restratifying. Again, the caveats given for interpreting the restratification for St. Thomas apply here. The benefits of restratification should be revisited after the first year of an annual survey when more information is available.

We explored the possible benefits of restratification and the dropping of unimportant sites by creating new strata as follows:

<u>St. Croix high use</u>
Altoona Lagoon
Molasses Dock
Frederiksted Fish Mkt
Christiansted Harbor (moved from low use)

<u>St. Croix low use</u>
Gallows Bay (moved from high use)
Estate Castle Nugent
Teague Bay
(Salt Pond dropped)
(Turner Hole dropped)

<u>St. Thomas high use</u>
Saga Haven
Frenchtown

<u>St. Thomas low use</u>
Mandahl (moved from high use)
Hull Bay (moved from high use)
Coki Point
Krum Bay
Marine Science Center
(Crown Bay dropped)
(Magens Bay dropped)
(Sapphire dropped)

The standard errors for the new stratification schemes are shown in Appendix 8 (all four strata separately) and Appendix 9 (region-wide estimates). Results for the top 6 species and the total landings are shown by region in Tables 38 and 39 below. Comparing the results from Tables 19 and 20 (last column), we see some clear advantage to restratifying St. Thomas. For example, the original stratification gives a standard error for the total landings of 19.56 % of the estimate; the revised stratification gives an estimated standard error of 16.38 %. For St. Croix, there does not appear to be much advantage to restratifying.

Table 38. Estimates for the top 6 species and the total landings for St. Thomas, redone with reallocation of some stations to the other stratum. The first numeric column gives the estimated average landings per day (region-wide) in pounds; the second numeric column gives the standard error of the estimate and the last column gives the standard error as a percentage of the estimate. Note that this exercise gives an overly optimistic indication of the benefits to be realized by restratification (see text). The full results are given in Appendix 9.

Species	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
lobster_caribbean_spiny	323.68	37.7	11.65
hind_red	91.76	13.58	14.8
triggerfish_queen	90.03	10.01	11.12
angelfish_gray	37.75	5.43	14.39
grouper_yellowfin	24.81	6.71	27.06
topsnail_west_indian	46.72	15.54	33.27
TOTAL	**910.84**	**149.22**	**16.38**

Table 39. Estimates for St. Croix redone with reallocation of some stations to the other stratum.

Species	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
lobster_caribbean_spiny	427.69	31.09	7.27
dolphin	192.67	32.99	17.13
wahoo	168.15	87.51	52.04
parrotfish_stoplight	138.82	9.75	7.02
parrotfish_redtail	91.29	9.7	10.62
schoolmaster	61.44	10.96	17.84
TOTAL	**1615.66**	**183.74**	**11.37**

In comparing the standard errors for the original and the restratified designs, it is important to note that:

a) The restratification does not provide a better estimate for the period of time we studied (it only gives an indication of how future estimates can be made more precise). The restratification does not provide a better estimate for the period of time we studied (it only gives an indication of how future estimates can be made more precise), and

b) This analysis is likely to overstate the precision benefits of restratification because we are looking at the data and choosing sites to minimize variance based on both noise and signal in the data.

c) A rule of thumb given by Cochran (1977) says that restratification may not be worth the effort if the analysis does not indicate at least a 10% shrinking of standard errors.

4.3.3.4 Allocation of effort to high and low strata

Using the original stratification design, we computed the proportional standard error of the total landings for the stratified design with the number of days allocated to each stratum varying from 100 to 300; in this exercise we held the number of sites visited per day constant at m = 2 sites per day. The full results for St. Thomas and St. Croix (proportional standard error) are given in Table 40.

The results show that, for St. Thomas, the standard error is reduced more if an additional day of sampling is devoted to the high use stratum than if it is devoted to the low use stratum (Table 40).

Table 40. Proportional standard error for three allocations of sampling effort totaling 400 days. n1 = days assigned to high use stratum; n2 = days for low use stratum. Bold entries are the lowest value in the row.

Region	species	$n_{1(high)}=300$ $n_{2\ (low)}=100$	$n_1=200$ $n_2=200$	$n_1=100$ $n_2=300$
St. Thomas	Carib. Spiny lobster	**5.74**	9.72	16.94
St. Thomas	Queen triggerfish	**6.88**	7.79	12.07
St. Thomas	Red hind	**8.16**	11.94	19.3
St. Thomas	Gray angelfish	**8.56**	12.22	19.62
St. Thomas	White grunt	**8.31**	12.09	19.5
St. Thomas	all species	**3.02**	4.35	7.33
St. Croix	Carib. Spiny lobster	5.8	**4.77**	6.47
St. Croix	dolphin	12.54	**8.62**	10.32
St. Croix	wahoo	26.99	17.98	**17.42**
St. Croix	Stoplight parrotfish	**3.94**	5.32	9.16
St. Croix	Redtail parrotfish	**3.68**	5.78	9.9
St. Croix	all species	3.60	**2.67**	3.27

For example, suppose over the course of a 300 day year it is decided to sample 400 days. The possibilities are described in Sections 4.3.3.5 and 4.3.4.5. It is seen that the high use stratum should be sampled every day (300 days) and the low use stratum should be sampled 100 days for a total of 400. This would give a proportional standard error for the total landings of 3% so an approximate confidence interval would be the estimate ± 6%. Confidence intervals for the species with the highest landings are considerably higher in many cases.

For St. Croix, the situation is less clear. For two species, it would be best to devote most effort to the high use stratum; for two, and equal allocation would be best, and for one it would be best to allocate most effort to the low use stratum. Given the uncertainties associated with the pilot survey covering only a 30 day period, it would be advisable to not pick an extreme allocation (almost all effort devoted to a single stratum).

4.3.3.5 Allocation of effort to more days versus more sites.

The optimal number of sites to visit in a day can be calculated as (Cochran 1977 eq 10.26):

$$m_{opt} = \frac{S_2}{\sqrt{S_1^2 - S_2^2/M}} \times relative\ cost$$

where the result is rounded to the nearest integer and the relative cost refers to the cost of sampling an additional day versus an additional site which we take to be 1.0. Applying this, for example, to the total catch in the St. Thomas high use stratum, we have M = 4, S_1^2 = 29,268.28 and S_2^2 = 38,635.53 (from Table 15, last line). Thus, m_{opt} is found to be 1.40 sites per day (after rounding). Results for the top species and for all species combined are shown in Table 41.

Table 41. Calculation of optimal number of sites to visit during a sampling day for the principal species caught and for the total catch.

Species	STT HIGH	STT LOW
lobster_caribbean_spiny	1.251	1.861
triggerfish_queen	2.021	1.799
hind_red	3.473	1.819
angelfish_gray	3.612	1.824
grunt_white	3.360	1.773
Total	1.404	1.828

Species	STX HIGH	STX LOW
lobster_caribbean_spiny	1.934	0.917
dolphin	1.733	0.402
parrotfish_stoplight	0.961	0.839
parrotfish_redtail	1.377	2.361
wahoo	0.082	2.309
Total	1.297	1.346

The results for the optimal number of sites to be visited per day are mixed. For estimating the total catch, the optimal number under the cost model assumed for the calculations is 1 site per day for three of the four strata; it is 2 per day for the low use stratum on St. Thomas. For St. Croix, both high and low use strata, $m = 1$ site per day appears optimal overall. For the St. Thomas low use stratum, $m = 2$ appears to be optimal. For St. Thomas high use stratum, $m = 2$ is optimal for two of the cases and m = 2, 3 or even 4 appears optimal for the other cases. With $m = 1$ it is not possible to obtain an unbiased estimate of the variance. It may be that 1 site could be visited on most days and 2 sites could be visited on some days in order to estimate the variance. The conclusion to devote much more effort to sampling more days than to sampling more sites within a day is likely robust; the actual level of precision that can be achieved is less so as it depends on the absolute values of the variance components rather than just their relative magnitude.

The cost function underlying these calculations is very simple. It allows for a different cost for sampling an additional day versus sampling another site within a day. We set this to 1.0 because factors such as set-up costs are minimal. However, in reality, labor costs are the key issue. It is difficult to hire reliable, trained personnel to work part-time on a variable schedule determined by randomization. Thus, it is logistically convenient to hire staff on a full-time basis. Increasing the number of sites visited per day generally implies increasing the number of staff which is costly. In the case that hiring more staff is greatly more costly than having staff work more days in the year, the cost ratio becomes a very small number which argues for the minimum number of sites visited per day ($m = 1$) (with the caveat that it is not possible to obtain an unbiased estimate of the variance). It may be the case that even having one port sampler per stratum is too expensive. In this case, a sampling program based on a lattice design might be attractive. It allows one to specify the number of days of sampling for each of the strata but recognizes that the high use and low use areas will not be sampled independently (because the port sampler cannot be in two places at one time). However, this design does not allow for all the variance components to be estimated; a design would have to be worked out and evaluated.

4.3.3.6 Choosing the number of days to sample.

We computed the proportional standard error (standard error as a percentage of the estimate) for a wide range of number of days sampled. In doing this, we fixed the number of sites visited per day at either m = 1 or m = 2, and we assumed, for St. Thomas, that the number of days sampled from the high use stratum would be three times the number of days sampled from the low use stratum; for St. Croix, we assumed equal numbers of days would be sampled from the high and low use strata. The constraints on the relative number of days sampled comes from Section 4.3.3.4 above. Results are shown in Figure 24 for St. Thomas and Figure 25 for St. Croix.

In St. Thomas for example, we can see with 100 days of sampling the high use stratum and 33 days of sampling the low use stratum, the standard errors for all cases are at or below 20% implying a 95% confidence interval of better than ± 40% when m=2 sites are visited per day. If only one site is visited per day (m = 1), only the total catch and the queen triggerfish catches are estimated with a precision better than ± 20%. One would have to sample the high use stratum roughly 180 days (and the low use stratum roughly 60 days) to have all cases have a precision better than ± 20%.

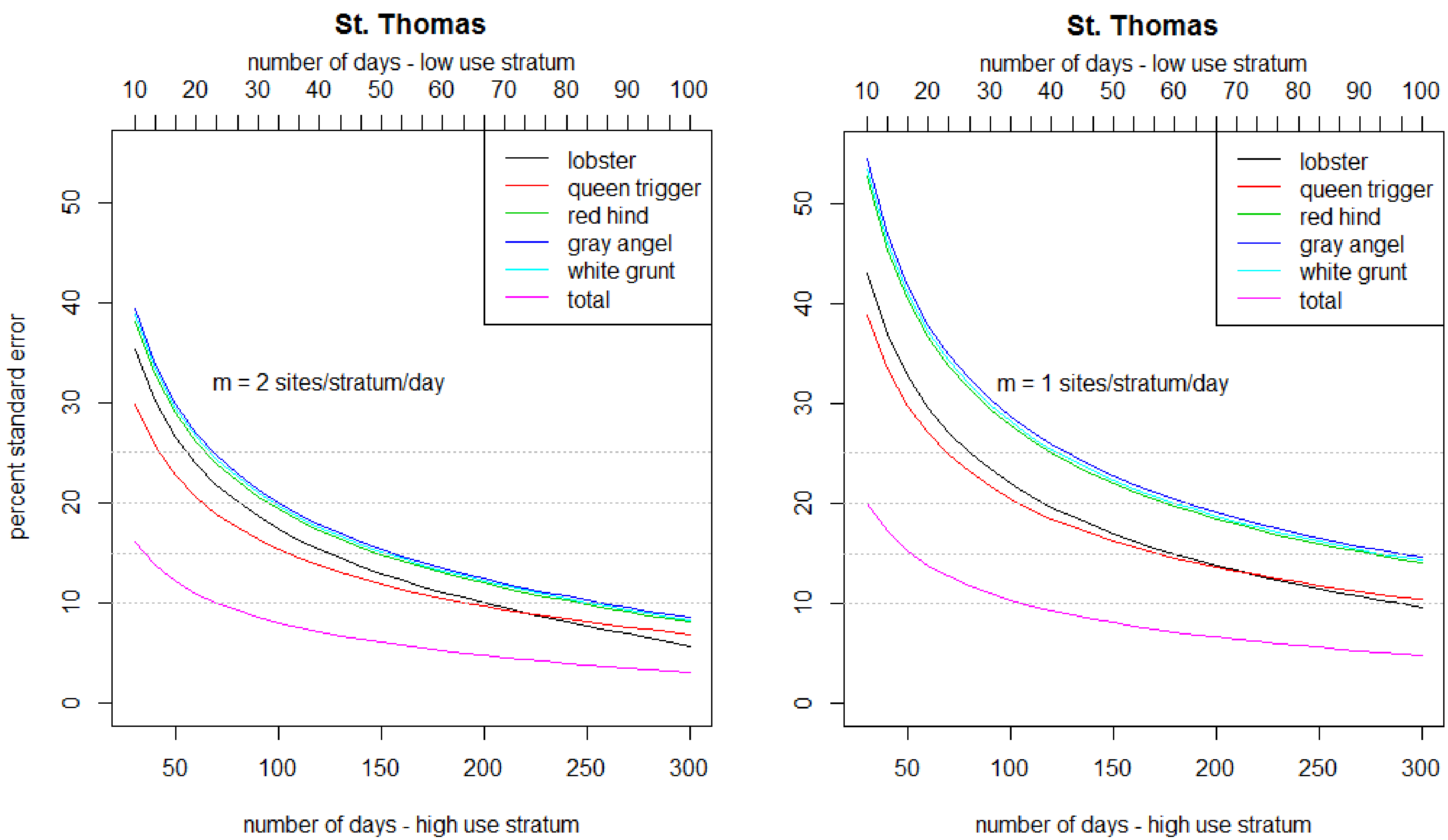


Figure 23. The percent standard error versus sampling effort for the top landed species and total catch in St. Thomas. It is assumed that three times as many days are sampled in the high use stratum as in the low use stratum. Left panel is computed assuming m=2 sites are visited (in each stratum) each sampling day; right panel is computed with m=1 site visited per day stratum.

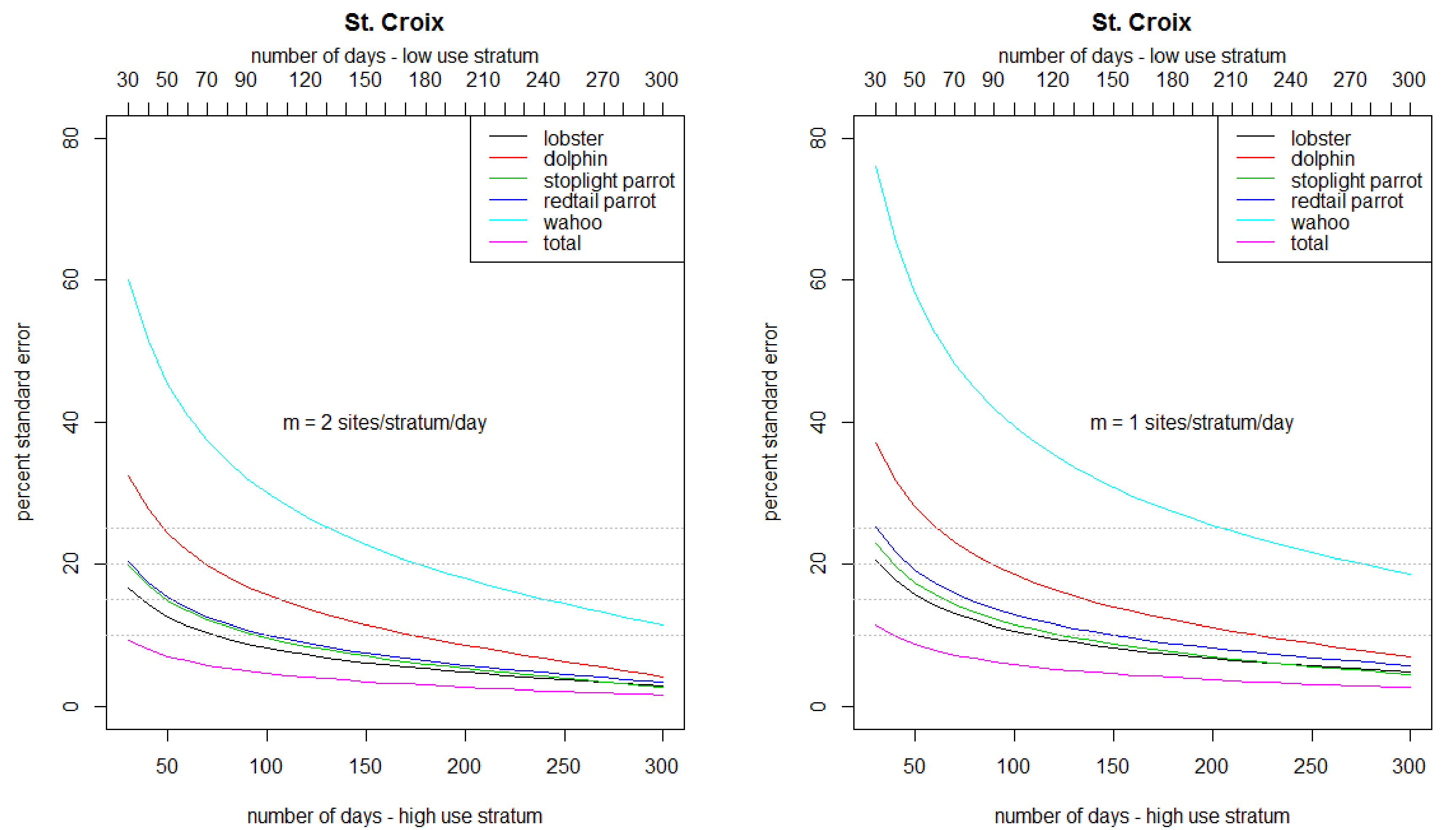


Figure 24. The percent standard error versus sampling effort for the top landed species and the total catch. in St. Croix. It is assumed that the two strata are sampled the same number of days. Left panel is computed assuming m=2 sites are visited (in each stratum) each sampling day; right panel is computed with m=1 site visited per day per stratum.

4.3.3.7 Options for a year-long survey

The maximum width of the 95% confidence interval was calculated for the top 5 species and the total catch. The table below was derived from Figures 24 and 25 by looking for the minimum number of days at which twice the proportional standard error for every species is better than the desired level of precision. The --- symbol indicates the desired precision can't be obtained under the constraints imposed with this design. The ratio of sampling effort for the high use and low use strata is fixed at 3:1.

			Estimate # of days for		
Region	Maximum with of CI*	m	High use	Low use	Number of people days**
St. Thomas	40%	2	101	34	270
St. Thomas	30%	2	157	52	418
St. Thomas	20%	2	261	87	696
St. Thomas	40%	1	187	62	249
St. Thomas	30%	1	283	94	377
St. Thomas	20%	1	---	---	---

* We assume a 95% confidence interval is approximately the estimate 2 standard errors. Thus, the width of the confidence interval is found by doubling the relative standard error.

** For St. Thomas, one person can sample one site

			Estimate # of days for		
Region	Maximum with of CI	m	High use	Low use	Number of people days*
St. Croix	40%	2	242	242	1936
St. Croix	30%	2	---	---	---
St. Croix	20%	2	---	---	---
St. Croix	40%	1	276	276	1104
St. Croix	30%	1	---	---	---
St. Croix	20%	1	---	---	---

* For St. Croix, it appears that for logistical reasons it takes two people to sample one site. If we visit one site per day and want all the principal species and the total catch to have CIs no wider than 40%, we estimate we would need 1 x 2 x (276 + 276) = 1104 person days.

For St. Thomas, one person can sample one site; but for St. Croix at least initially, it appears that for logistical reasons it takes two people to sample one site. Thus, for St. Thomas, if we want all the principal species and the total catch estimates to have a 95% CI no wider than 40 % of the estimates, and we sample two sites per day, we would need an estimated 2 x 100 + 2 x 33 = 266 person days for port samplers (this does not include supervisory personnel). For St. Croix, if we visit one site per day and want all the principal species and the total catch to have CIs no wider than 40%, we estimate we would need 2 x (270 + 270) = 1080 person days.

We note that the estimated sample sizes for St. Croix are very large. This is because the proportional standard errors for one species, wahoo, are extremely high. We reran the calculations requiring the width of the confidence interval for all species except wahoo to be narrower than a specified value and obtained the following results:

			Estimate # of days for		
Region	Maximum with of CI	m	High use	Low use	Number of people days
St. Croix	40%	1	90	90	360
St. Croix	30%	1	139	139	556
St. Croix	20%	1	228	228	912

4.3.4 Evaluation of the sampling design – Puerto Rico

4.3.4.1 Landings by day of the survey and by day of the week.

We plotted landings versus day of the survey to look for trends and periodicities in the data which might affect the performance of the survey (Figure 25 below). None were found. Observed landings by the day of the week was also evaluated and presented in Figure 26 and Figure 27 below. Note that the data in Figure 27 are from a single location for the month of April in which the local dive shop recorded all trips for which they filled tanks. While activity appears to be lower on Saturdays and even lower on Sundays (based on data in Figure 27), there was no obvious pattern which indicates that further stratification by day would result in better estimates.

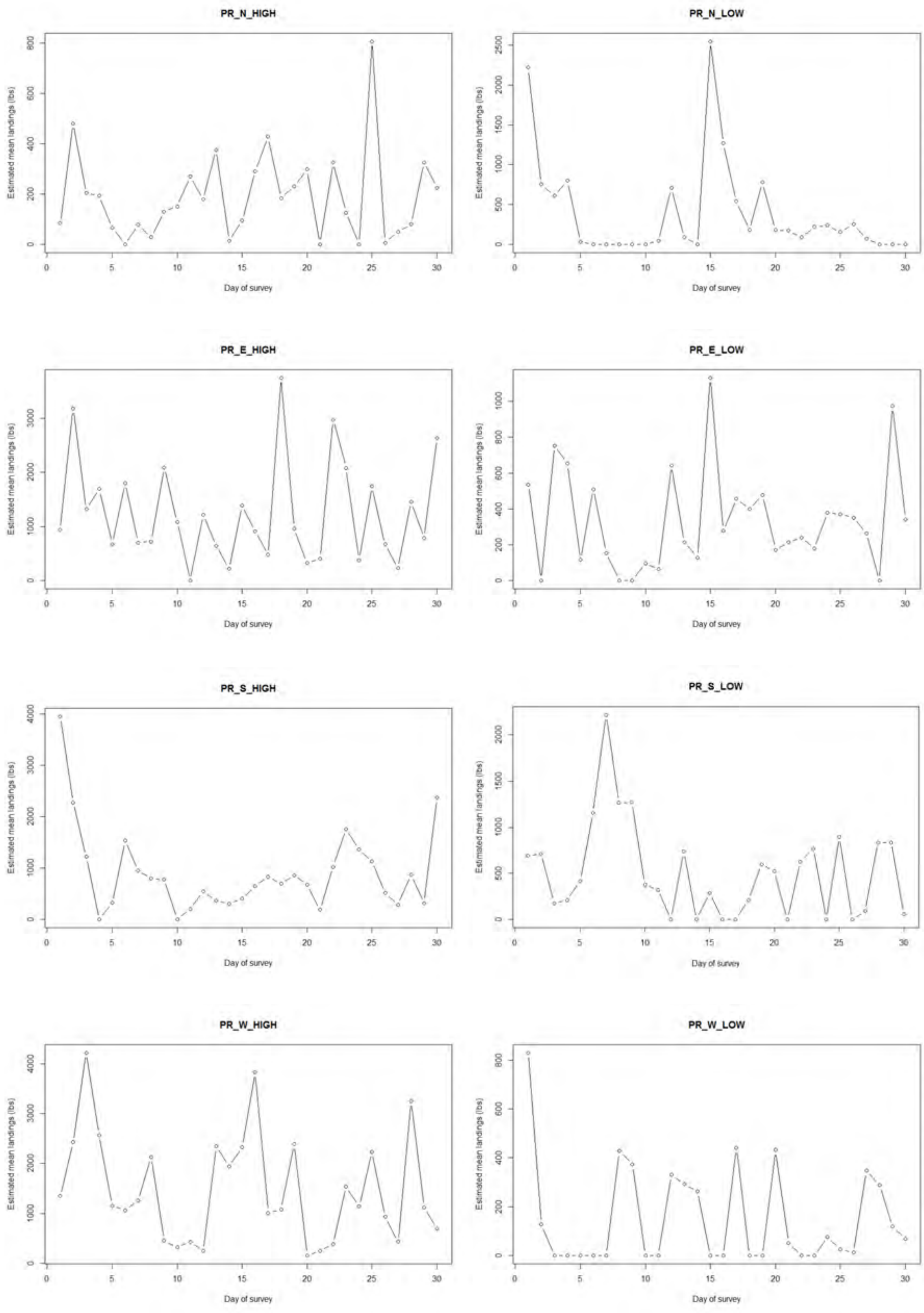


Figure 25. Estimated Puerto Rico mean landings in a stratum versus day of the survey to look for trends and periodicities over time.

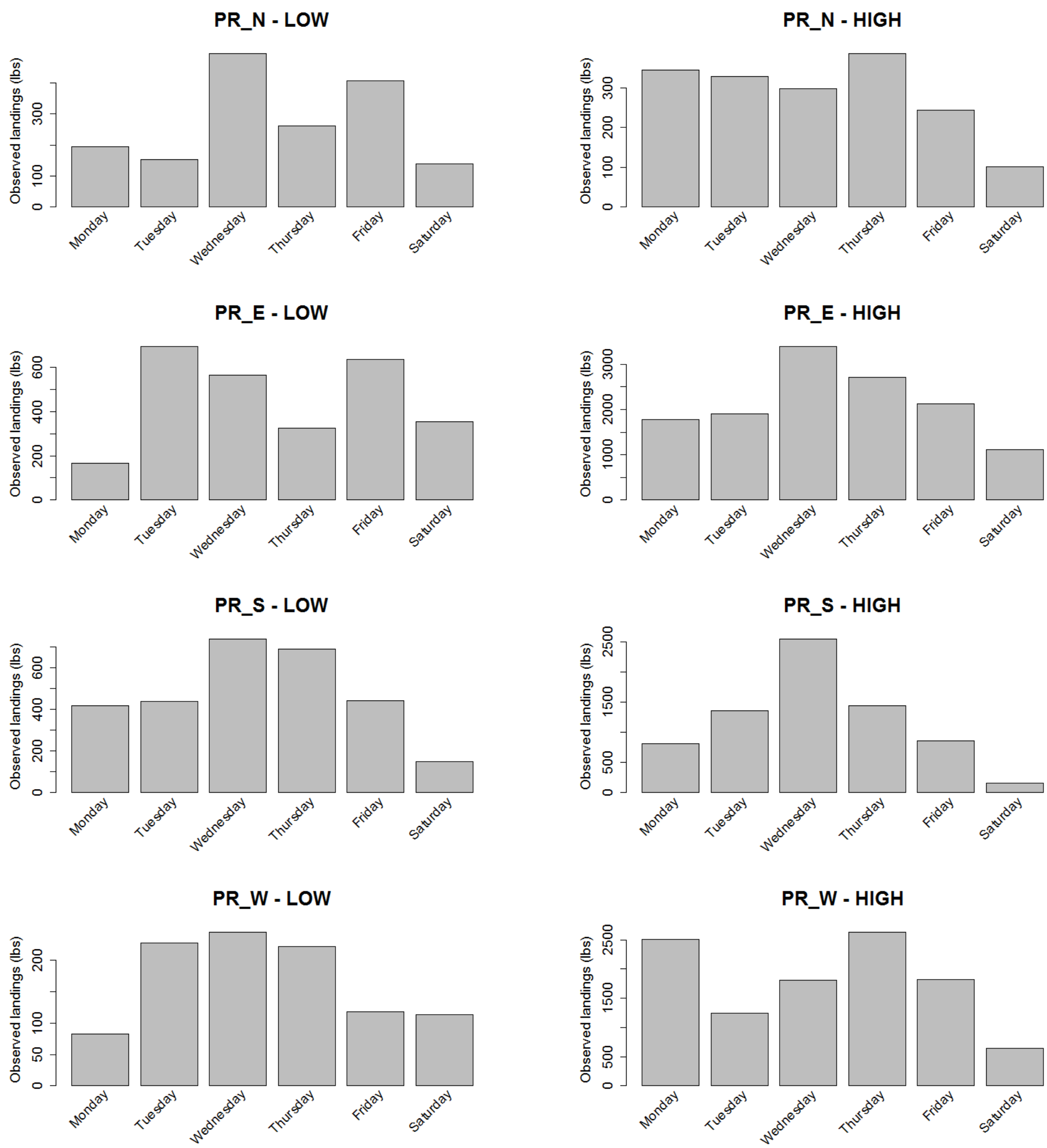


Figure 26. Observed Puerto Rico landings versus day of the week that trips ended for each stratum.

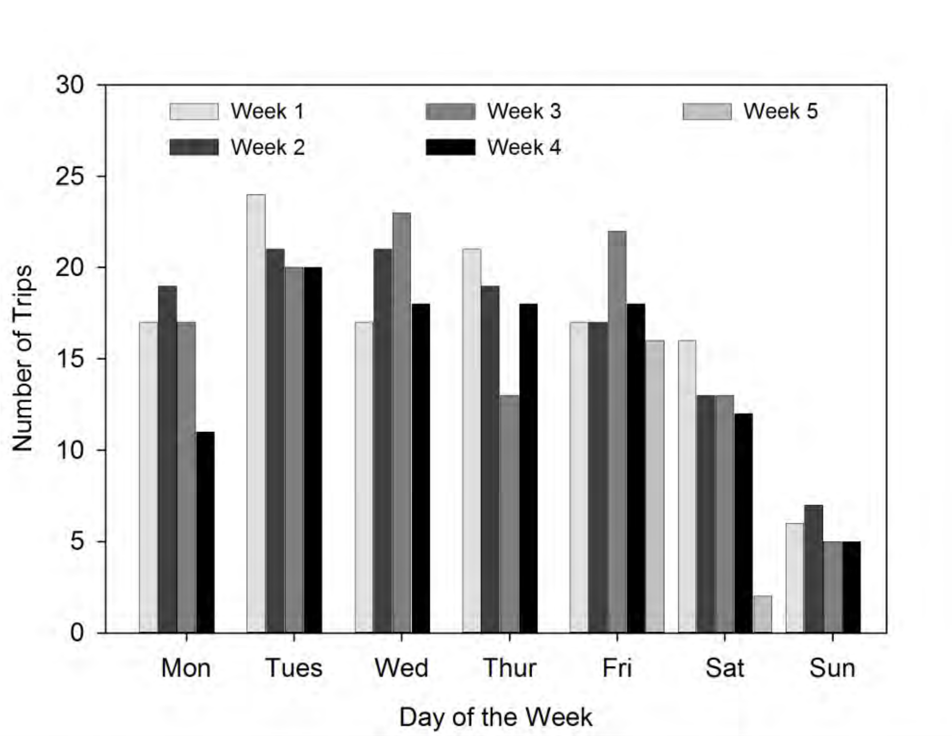


Figure 27. Number of boats getting tanks filled by day of week at the Dive Shop in Puerto Real, Marina Pescaderia.

4.3.4.2 Consideration of time of day

The pattern in time of day at which landings are made is shown in Figure 28 below and Figure 28 above. In all strata, landings occur at all times of the day suggesting the necessity of remaining on site all day. Landings were observed in the first and last hours of sampling suggesting that there may be unaccounted landings before and after the sampling day. This possibility should be checked in a future survey if possible.

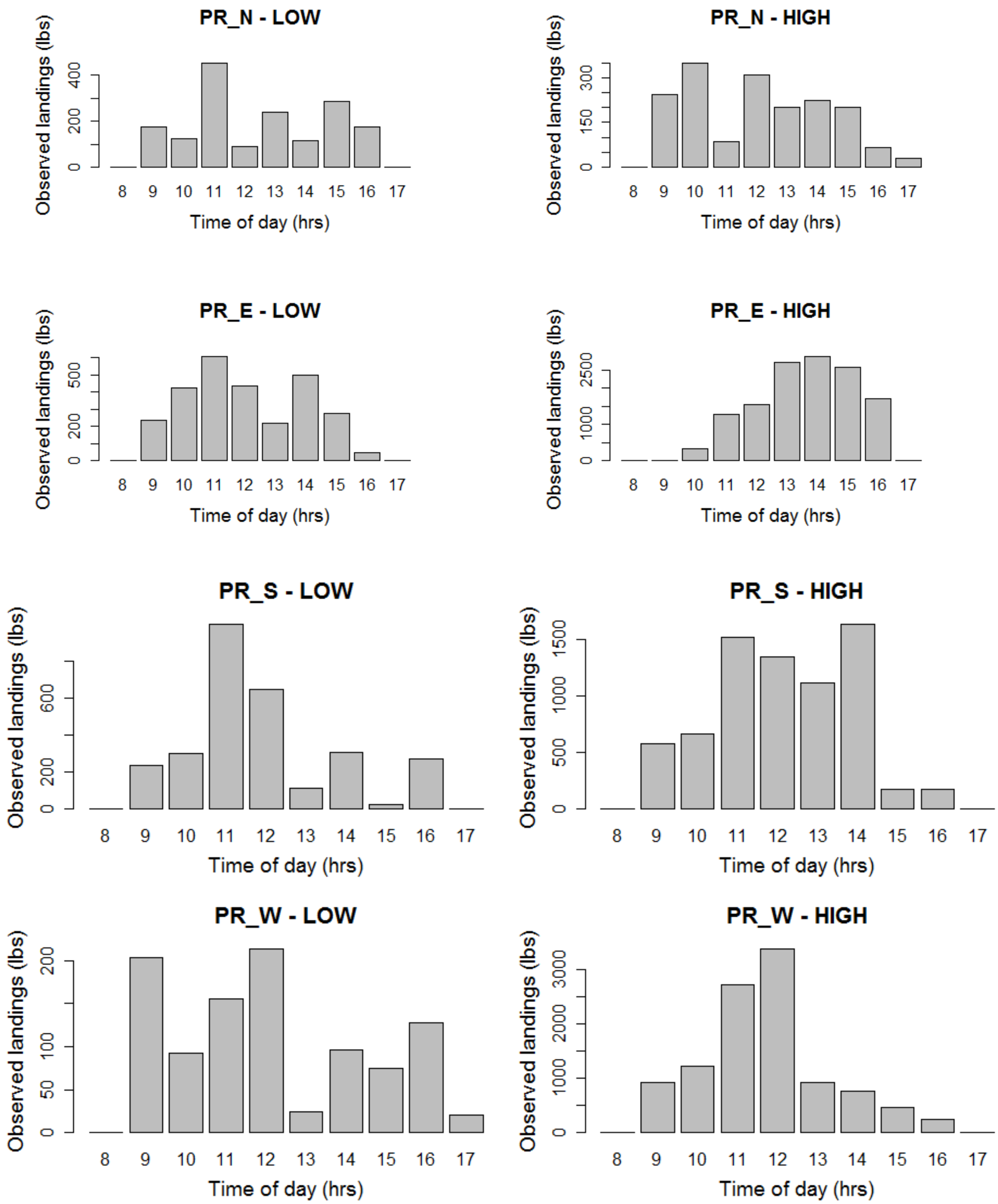


Figure 28. Observed Puerto Rico landings versus time of day that trips ended for each stratum.

4.3.4.3 Homogeneity of strata and potential to restratify – Puerto Rico

The original stratification used for each region of Puerto Rico is shown in Figure 29 and Figure 30 below. It can be seen that for some regions, the stratification seems quite appropriate based on the pilot study results. For example, for Puerto Rico - East, the original stratification was good, with only one site (Barrio Los Machos) being (apparently) misallocated to the high use stratum. Also, only one site (Maunabo) had such low usage that it might be dropped from the survey altogether. The performance of the stratification for Puerto Rico – West was quite similar. In contrast, the stratification for Puerto Rico – North was not very good, with the highest use sites actually included in the low use stratum and some of the sites with the lowest usage included in the high use stratum. The stratification for Puerto Rico – South was similar to that of the North region but not as bad in performance. Thus, it would appear that a reassignment of sites to strata might be warranted for the North and South regions.

We restratified the sites as indicated in Figure 29 and Figure 30 as follows:

- North high use: Barrio Bajura, La Coal, Jarealito, La Princesa, (La Puntilla dropped), (Puerto Nuevo dropped)
- North low use: Palmas Altas, Puerto Mosquito, Punta Peñon, Torrecilla, Vietnam, (Arecibo Rampa dropped), (Calle Hoare dropped), (Cerro Gordo dropped), (Fortuna dropped), (Mameyal dropped), (Parcelas Vieques dropped)
- East high use: Barrio Los Manchos, Hucares, Marina Puerto Del Rey, Maternillo, (Maunabo dropped)
- East low use: Barrio Sardinera, Las Croabas, Playa De Guayanes, Puerto Yabucoa, Punta Candelero, Punta Santiago
- South high use: Bahia de Guanica, Pastillo, Playa de Ponce, Salinas Providencia, Tallaboa, (Playa de Salinas dropped)
- South low use: Bajo de Patillas, La Parguera, La Parguera Rampa, Playa Las Palmas, Punta Papayo, (Bahia de Guayanilla dropped), (Jobos dropped), (Playa de Santa Isabel dropped), (Punta Pozuelo dropped)
- West high use: El Combate, El Faro Cabo Rojo, El Seco Rampa, Playuela, Puerto Real, Rincon Rampa, Soltero Puerto Real
- West low use: Barrio Tamarindo, Boqueron Rampa, (Barrio Barrero dropped), (Barrio Espinal dropped), (Guaniquilla Barrio dropped), (Higuey dropped), (Tres Hermanos dropped)

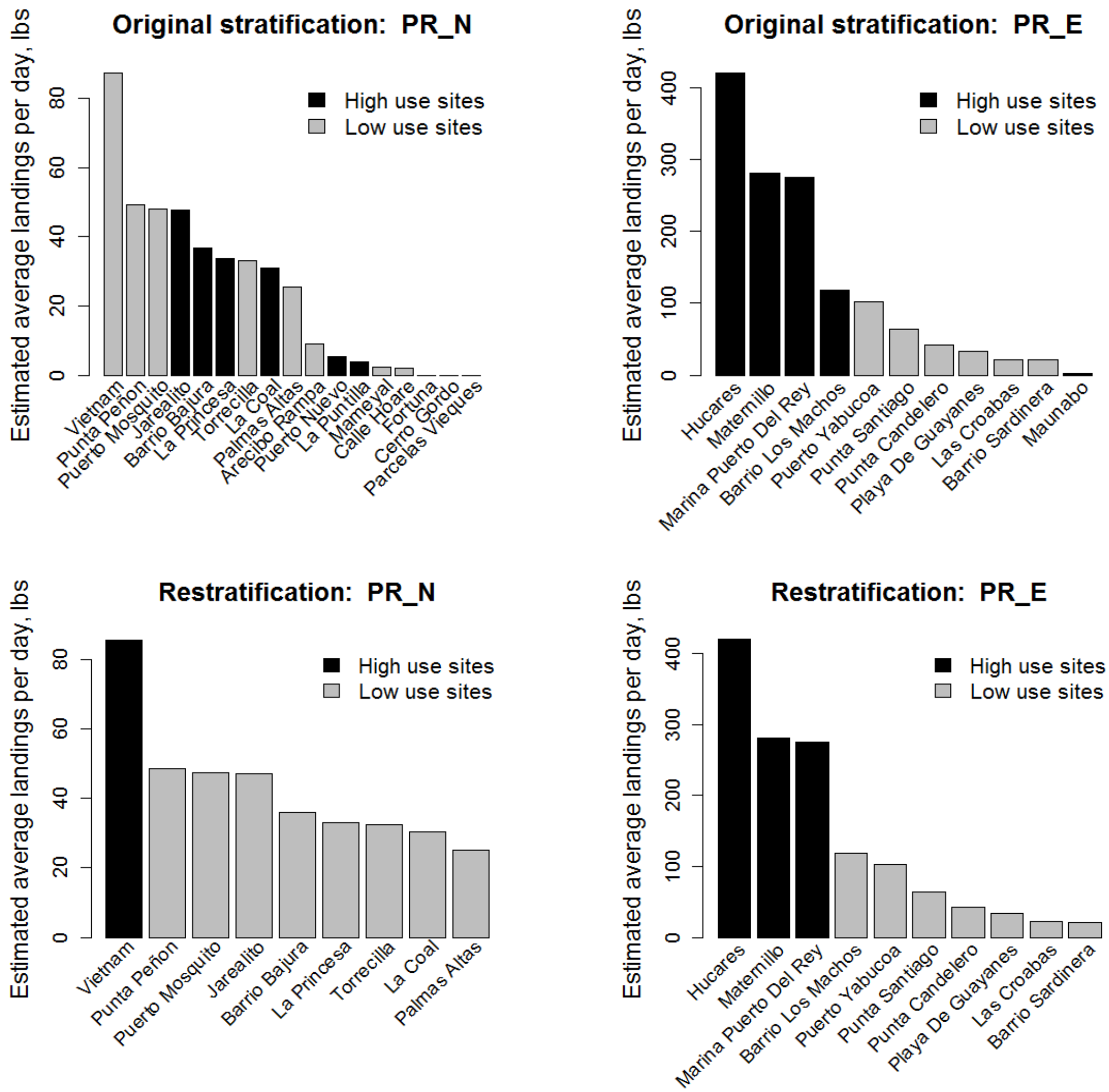


Figure 29. Estimated average commercial daily landings by site arranged in descending order from left to right. The shading of the bars show the original (top) and revised (bottom) stratification for Puerto Rico – North (left) and Puerto Rico – East (right).

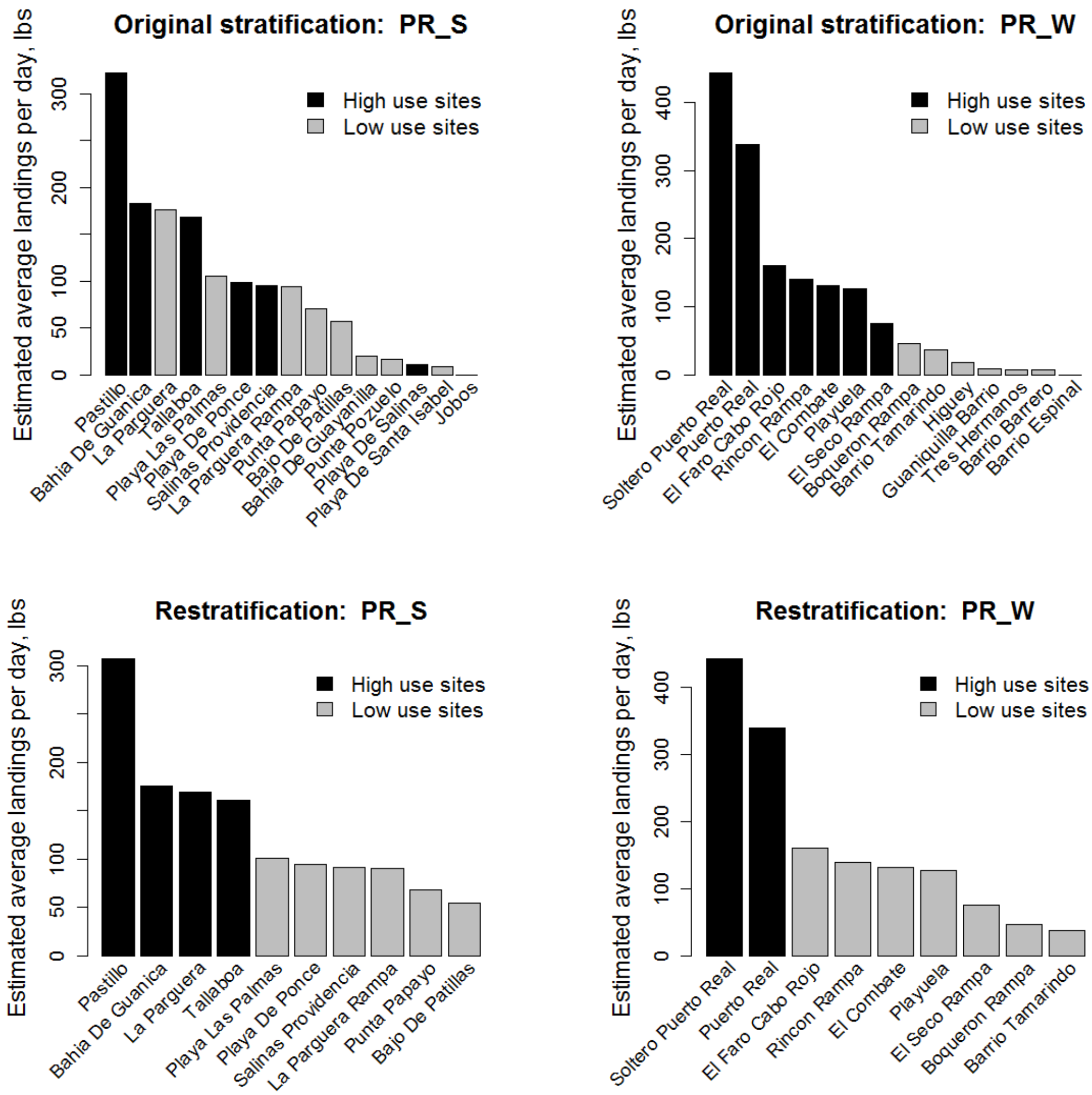


Figure 30. Estimated average commercial daily landings by site arranged in descending order from left to right. The shading of the bars show the original (top) and revised (bottom) stratification for Puerto Rico – South (left) and Puerto Rico – West (right).

The effects of restratification on precision are explored below. Note that for some regions, there were a few sites with very low usage. We recommend that these sites be eliminated altogether from consideration because the estimated amount of landings that would be missed is low: the designated sites to be dropped in are estimated to account for 5.4%, 0.7%, 5.0% and 2.8% of the total landings in the North, East, South and West regions, respectively.

The standard errors for the new stratification schemes are shown in Tables 42 - 45 below. These can be compared to the estimates in Tables 34 - 37.

Table 42. Estimates for the top 6 species (identified under the original stratification) and the total landings for the North region of Puerto Rico, redone with reallocation of some stations to the other stratum. The first numeric column gives the estimated average landings per day (region-wide) in pounds; the second numeric column gives the standard error of the estimate and the last column gives the standard error as a percentage of the estimate. Note that this exercise gives an overly optimistic indication of the benefits to be realized by restratification (see text). The full results are given in Appendix 9.

Species - North	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
TOTAL	**453.7**	**33.0**	**7.3**
snapper_silk	92.2	13.8	15.0
lobster_caribbean_spiny	78.1	13.4	17.1
snapper_blackfin	37.7	5.7	15.0
conch_queen	32.8	9.8	29.8
snapper_yellowtail	25.1	2.4	9.7
snapper_queen	17.0	13.7	80.5

Table 43. Estimates for the East region of Puerto Rico redone with reallocation of some stations to the other stratum.

Species - East	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
TOTAL	**1486.9**	**72.7**	**4.9**
conch_queen	763.0	59.8	7.8
lobster_caribbean_spiny	275.0	27.3	9.9
hogfish	62.8	8.8	14.1
unknown	59.2	22.0	37.1
cero	32.1	9.1	28.3
triggerfish_queen	26.3	5.0	18.9

Table 44. Estimates for the South region of Puerto Rico redone with reallocation of some stations to the other stratum.

Species - South	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
TOTAL	**1513.5**	**85.0**	**5.6**
conch_queen	336.0	38.5	11.5
lobster_caribbean_spiny	291.2	34.6	11.9
Dolphin	116.2	43.8	37.7
snapper_lane	82.8	21.2	25.6
triggerfish_queen	64.8	22.7	35.1
Hogfish	74.7	9.8	13.1

Table 45. Estimates for the West region of Puerto Rico redone with reallocation of some stations to the other stratum.

Species - West	$M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H$	$\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}$	$100 * \frac{\sqrt{V[M_L\bar{\bar{y}}_L] + V[M_H\bar{\bar{y}}_H]}}{M_L\bar{\bar{y}}_L + M_H\bar{\bar{y}}_H}$
TOTAL	**1708.9**	**101.4**	**5.9**
conch_queen	497.8	56.6	11.4
lobster_caribbean_spiny	355.6	47.4	13.3
tuna_blackfin	126.8	32.4	25.6
hind_red	121.3	18.0	14.9
snapper_silk	108.0	22.2	20.6
Dolphin	77.3	24.0	31.1

In comparing the standard errors for the original and the restratified designs, it is important to note that this analysis is likely to overstate the precision benefits of restratification because we are looking at the data and choosing sites to minimize variance based on both noise and signal in the data. A rule of thumb given by Cochran (1977) says that restratification may not be worth the effort if the analysis does not indicate at least a 10% shrinking of standard errors.

Despite this caveat, it would appear that substantial increases in efficiency can be had by adjusting the stratification scheme. For the North, the proportional standard error under the new scheme defined above is 7.3% compared to the 18.1% obtained under the original scheme. For three of the six species, the new scheme offers a lower proportional standard error substantially less than under the original scheme, for two species the new scheme offers slightly higher standard errors (and the new scheme replaces one species with another). For the East region, the proportional standard error is reduced for the total and for 4 of the top 6 species under the new stratification; for two species the standard error goes up. For the South, the new stratification offers lower standard errors for the total catch and 4 of the top 6 species; for 1 species there is an increase, and for 1 species no comparison can be made. For the West, the standard error for the total and for 5 of the species is reduced under the new stratification and for 1 species it is increased (Table 46).

Table 46. Percent change in standard error due to restratification for the total landings in a region and for 6 top species landed. Underlined entries denote a higher standard error under restratification. Bold entries indicate a reduction in standard error of more than 10%.

Region	Species	Standard Error Original Stratification	Standard Error Re-stratification	Percent reduction
PR North	snapper_silk	50.0	15.0	**70%**
PR North	lobster_caribbean_spiny	23.4	17.1	**27%**
PR North	snapper_queen	75.4	80.5	-7%
PR North	conch_queen	21.4	29.8	-39%
PR North	snapper_blackfin	14.8	15.0	-1%
PR North	all species	18.1	7.3	**60%**
PR East	conch_queen	9.0	7.8	**13%**
PR East	lobster_caribbean_spiny	12.0	9.9	**18%**
PR East	hogfish	34.3	37.1	-8%
PR East	hind_red	16.1	14.1	**12%**
PR East	triggerfish_queen	25.3	28.3	-12%
PR East	all species	5.4	4.9	9%
PR South	conch_queen	13.8	11.5	**17%**
PR South	lobster_caribbean_spiny	12.7	11.9	6%
PR South	snapper_lane	13.5	25.6	**-90%**
PR South	dolphin	15.9	13.1	**18%**
PR South	hogfish	53.0	37.7	**29%**
PR South	all species	6.0	5.6	7%
PR West	conch_queen	10.8	11.4	-6%
PR West	lobster_caribbean_spiny	20.9	13.3	**36%**
PR West	tuna_blackfin	27.0	25.6	5%
PR West	snapper_silk	21.7	20.6	5%
PR West	hind_red	16.3	14.9	9%
PR West	all species	6.7	5.9	**12%**

4.3.4.4 Allocation of effort to high and low strata-Puerto Rico

Using the original stratification design, we computed the proportional standard error of the total landings for the stratified design with the number of days allocated to each stratum varying from 100 to 300; in this exercise we held the number of sites visited per day constant at m = 2 and also at m = 1 sites per day (Table 47 and Table 48). The full results for Puerto Rico are given in Appendix 8 for m = 2 and m = 1, respectively.

The results suggest that for the East and West regions, three times as many days should be allocated to the high use stratum as the low use one. For the southern region, a ratio of 1:1 appears best. The North region is different with the results indicating three times as many days should be devoted to the low use stratum as the high use. However, the original stratification does not appear to have been very effective so this result may change under a new stratification scheme. The optimal sampling effort to strata is proportional to the product of the size of a stratum (number of sites) times the variability within the stratum. The variance tends to be a power function of the mean so the high use strata should have higher variances, and thus higher sampling intensity, than the low use strata (given equal stratum sizes). There are roughly equal numbers of high and low use sites in the East region and in the West region whereas there are closer to twice as many low use sites than high use ones in the North and South regions. Thus, it makes sense that the low use strata in the North and South regions should receive more attention than in the East and West regions. Given the uncertainties in the variances but the clear expectation that variances would be higher in the high use than the low use strata, we used a ratio of 3:1 sampling intensity for high to low use strata in the East and West and a ratio of 2:1 for the North and South in subsequent evaluations of scenarios. We note that it is not possible to optimize simultaneously for each of a collection of species. Thus, some compromise is needed and optimum allocation calculations are only approximate.

Table 47. Proportional standard error for three allocations of sampling effort totaling 400 days when m=1. n1 = days assigned to high use stratum; n2 = days for low use stratum. Bold entries are the lowest value in the row.

Region	Species	$n_{1(high)}$ =300 $n_{2\ (low)}$=100	n_1=200 n_2=200	n_1=100 n_2=300
PR North	snapper_silk	46.52	31	**23.82**
PR North	lobster_caribbean_spiny	19.61	**14.94**	15.98
PR North	snapper_queen	68.57	46.21	**35.98**
PR North	conch_queen	25.27	15.61	**12.3**
PR North	snapper_blackfin	36.24	18.19	**2.64**
PR North	all species	16.88	11.28	**8.85**
PR East	conch_queen	**5.29**	6.26	9.34
PR East	lobster_caribbean_spiny	**6.68**	8.89	14.26
PR East	hogfish	**10.06**	11.27	16.56
PR East	hind_red	**16.71**	22.46	34.37
PR East	triggerfish_queen	**12.78**	14.52	20.77
PR East	all species	**3.26**	3.82	5.72
PR South	conch_queen	11.33	**8.89**	9.94
PR South	lobster_caribbean_spiny	9.99	**8.47**	10.63
PR South	snapper_lane	**6.86**	12.07	21.84
PR South	dolphin	37.96	**33.83**	42.25
PR South	hogfish	14.03	**10.26**	10.34
PR South	all species	**4.43**	4.44	6.7
PR West	conch_queen	**5.51**	7.38	11.59
PR West	lobster_caribbean_spiny	**10.5**	13.29	19.62
PR West	tuna_blackfin	**15.85**	17.06	23.65
PR West	snapper_silk	**11.18**	14.04	20.98
PR West	hind_red	**7.97**	11.74	19.29
PR West	all species	**3.45**	4.38	6.6

Table 48. Proportional standard error for three allocations of sampling effort totaling 400 days when m=2. n1 = days assigned to high use stratum; n2 = days for low use stratum. Bold entries are the lowest value in the row.

Region	Species	$n_{1(high)}=300$ $n_{2(low)}=100$	$n_1=200$ $n_2=200$	$n_1=100$ $n_2=300$
PR North	snapper_silk	35.36	22.4	**16.03**
PR North	lobster_caribbean_spiny	14.99	**10.74**	11.3
PR North	snapper_queen	51.11	32.95	**24.19**
PR North	conch_queen	22.52	12.88	**8.68**
PR North	snapper_blackfin	36.23	18.15	**2.04**
PR North	all species	12.9	8.19	**6.04**
PR East	conch_queen	**3.49**	4.46	7.19
PR East	lobster_caribbean_spiny	**4.38**	6.86	11.97
PR East	hogfish	**7.38**	8.07	12.48
PR East	hind_red	**10.24**	15.59	25.65
PR East	triggerfish_queen	**8.3**	9.75	14.76
PR East	all species	**2.17**	2.76	4.47
PR South	conch_queen	8.66	**6.35**	6.99
PR South	lobster_caribbean_spiny	7.15	**6.31**	8.75
PR South	snapper_lane	**4.7**	10.93	20.77
PR South	dolphin	26.85	**23.51**	30.46
PR South	hogfish	10.77	7.4	**7.3**
PR South	all species	**3.28**	3.67	6.09
PR West	conch_queen	**3.64**	5.59	9.46
PR West	lobster_caribbean_spiny	**6.93**	9.18	14.18
PR West	tuna_blackfin	**10.77**	11.67	16.78
PR West	snapper_silk	**7.64**	9.96	15.66
PR West	hind_red	**5.29**	9.34	16.51
PR West	all species	**2.29**	3.14	5.02

4.3.4.5 Allocation of effort to more days versus more sites.

The optimal number of sites to visit in a day was calculated for Puerto Rico in the same way as was done for the USVI (see Section 4.3.3.5). Results for the top species in the catch in each region and for all species combined are shown in Table 49.

Table 49. Calculation of optimal number of sites to visit during a sampling day for the principal species caught and for the total catch in Puerto Rico. Note that for blackfin snapper a result of 0.000 is due to estimated variance among sites being 0. This can arise when a species is rarely caught or rarely identified to species; in this case there may be few days when observations are available at both sites visited and it can happen that equal catches are made at both sites giving a variance of zero.

PR North

Species	High Stratum	Low Stratum
snapper_silk	2.037	1.758
lobster_caribbean_spiny	2.539	1.467
snapper_queen	2.160	2.069
conch_queen	2.139	0.641
snapper_blackfin	1.504	0.000
TOTAL	1.367	1.678

PR East

Species	High Stratum	Low Stratum
conch_queen	1.458	2.149
lobster_caribbean_spiny	0.917	1.932
hogfish	1.695	0.674
cero	1.896	2.985
triggerfish_queen	2.821	2.643
TOTAL	1.335	1.992

PR South

Species	High Stratum	Low Stratum
conch_queen	2.868	1.381
lobster_caribbean_spiny	0.813	2.604
snapper_lane	0.375	2.429
hogfish	2.223	1.469
dolphin	2.246	2.393
TOTAL	1.312	1.733

Table 49 (continued). Calculation of optimal number of sites to visit during a sampling day for the principal species caught and for the total catch in Puerto Rico. Note that for blackfin snapper a result of 0.000 is due to estimated variance among sites being 0. This can arise when a species is rarely caught or rarely identified to species; in this case there may be few days when observations are available at both sites visited and it can happen that equal catches are made at both sites giving a variance of zero.

	PR West	
Species	**High Stratum**	**Low Stratum**
conch_queen	1.093	2.437
lobster_caribbean_spiny	2.649	0.689
tuna_blackfin	3.229	2.518
snapper_silk	1.937	0.476
hind_red	0.847	1.362
TOTAL	1.664	1.464

Overall, the results are mixed, but with more entries in the table above indicating two sites/per day should be visited in preference to $m = 1$ site/day. However, these calculations are based on a particular cost function for sampling additional days versus additional sites in which it is assumed that adding an additional day costs the same as adding an additional site within an existing sampling day. This is overly simplistic as the logistics of covering a specific sampling plan are complicated by survey personnel availability. See discussion under section on optimal-*m* calculations for the Virgin Islands. It should be recognized that, with m = *1*, it is not possible to obtain an unbiased estimate of the variance (which makes it difficult to improve on the study design for the future). It may be that 1 site could be visited on most days and 2 sites could be visited on some days in order to estimate the variance. However, this design would have to be worked out and would benefit from an entire year of sampling. It may also be the case that having one person devoted to sampling each stratum may be cost prohibitive. In this case, a design like lattice sampling may be attractive but this would need to be explored.

4.3.4.6 Choosing the number of days to sample.

We computed the proportional standard error (standard error as a percentage of the estimate) for a wide range of number of days sampled. In doing this, we fixed the number of sites visited per day at either $m = 1$ or $m = 2$, and we assumed, that the number of days sampled from the high use stratum would be three times the number of days sampled from the low use stratum for the east and west; for north and south, we assumed the ratio would be 2:1 (high to low). The constraints on the relative number of days sampled comes from Section 4.3.3.4 Results are shown in Figure 31, Figure 32,Figure 33, and Figure 34.

In general, the labor requirements for the east, south and west regions are similar but the requirements for the north region are much higher. This undoubtedly reflects the design of the sampling program in the north where allocation of sites to high and low use strata was not reflective of actual usage. This greatly inflated the variance for both strata causing the estimated labor requirements to achieve a given precision to be very high. Thus, with neither $m = 1$ nor $m = 2$ can estimates for most species achieve a standard error of 30% of the estimated landings (We refer to this as a precision of 30%).

In the east region, the standard error for red hind is large so that with $m = 1$ port sampler per stratum, it is not possible to achieve a precision of 30%. Disregarding red hind, a precision of 30% can be had for the other species if roughly 265 days are assigned to the high use stratum and one half that many to the low use stratum or 225 days are assigned to the high use stratum and one third that many to the low use. If $m = 2$, a precision of 30% can be achieved for all of the top 5 species if a little over 200 days are sampled in the high use stratum and one third to one half as many days are devoted to the low use stratum. If red hind is disregarded, the number of days required drops to about half (around 125 days for the high use stratum).

In the south region, similar to the situation in the east region, there is one species among the top 5 that has a much higher standard error than the others – dolphin. It is not possible to achieve the 30% target for all species (with either $m = 1$ or $m = 2$ and a ratio of sampling in the high and low strata of either 3:1 or 2:1). Disregarding dolphin, and using $m = 1$ samplers per stratum, 30% precision can be achieved with roughly 180 days and a 2:1 ratio of sampling intensities or 250 days with a sampling intensity of 3:1. If $m = 2$, roughly 160 days of sampling the high use stratum, with one third or one half as many days assigned to the low use stratum, would be necessary to achieve 30% precision for the other four species.

For the west region, with $m = 1$ port sampler per stratum, the high use stratum would have to be sampled almost every day to achieve 30% precision for all species. If blackfin tuna is disregarded, then the high use stratum could be sampled roughly 175 days (with the low use stratum being sampled one third or one half as many days). If $m = 2$, all species can be estimated with standard errors less than 30% if the high use stratum is sampled about 175 days and the low use stratum is sampled one third or one half as many days.

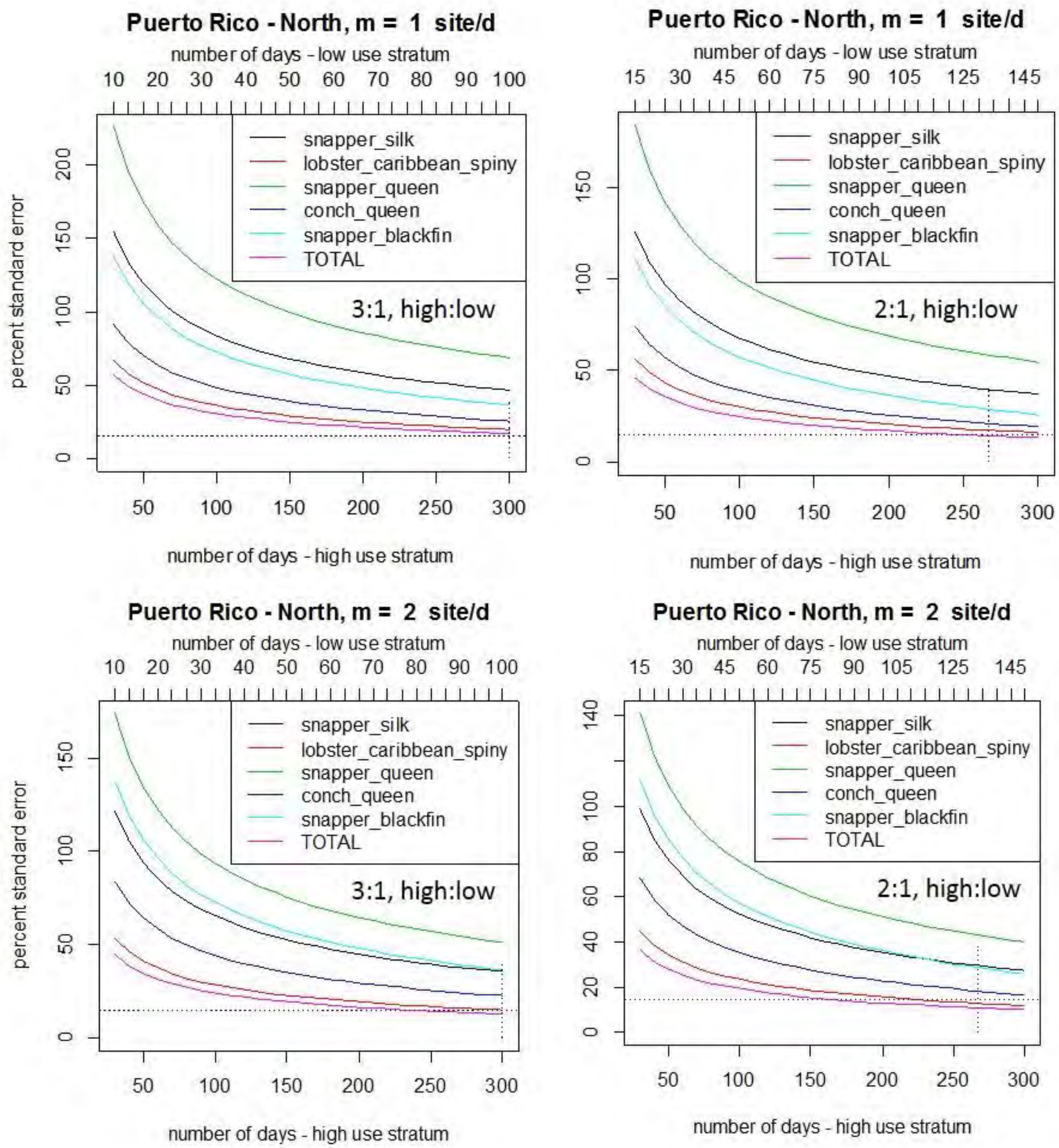


Figure 31. Effect of sample size on the precision of estimates for the top 5 species landed in the North of Puerto Rico and for all species combined. The number of days of sampling the high use stratum is three times the number of days for the low use stratum in the left panels and two times the number of days in the low use stratum in the right panels (See Appendix 12 for full tabular results). The horizontal dotted line denotes a standard error that is 15% of the estimate; the dotted vertical line denotes 400 stratum-days of sampling for the two strata combined.

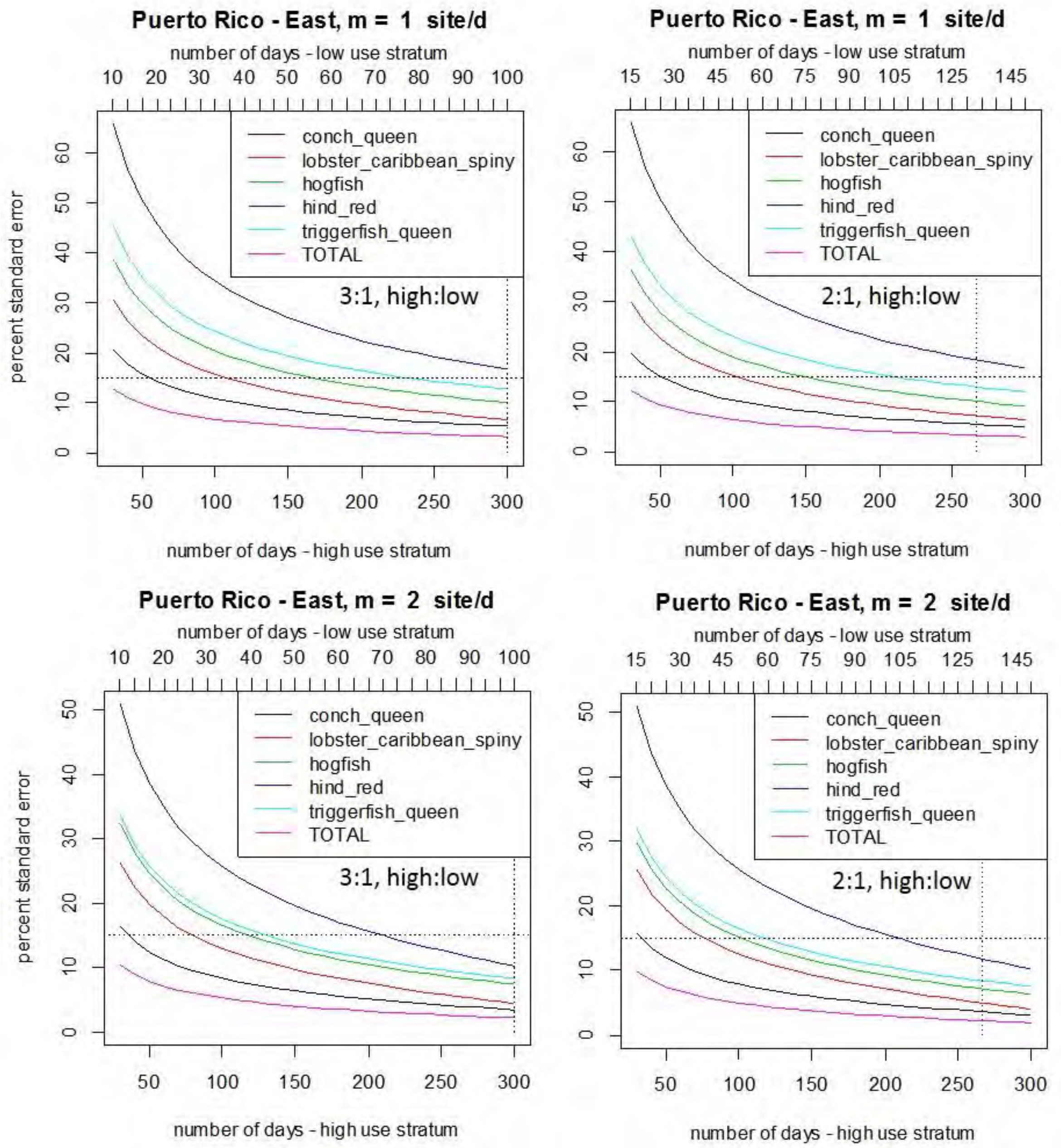


Figure 32. Effect of sample size on the precision of estimates for the top 5 species landed in the East of Puerto Rico and for all species combined. The number of days of sampling the high use stratum is three times the number of days for the low use stratum in the left panels and two times the number of days in the low use stratum in the right panels (See Appendix 12 for full tabular results) The horizontal dotted line denotes a standard error that is 15% of the estimate; the dotted vertical line denotes 400 stratum-days of sampling for the two strata combined.

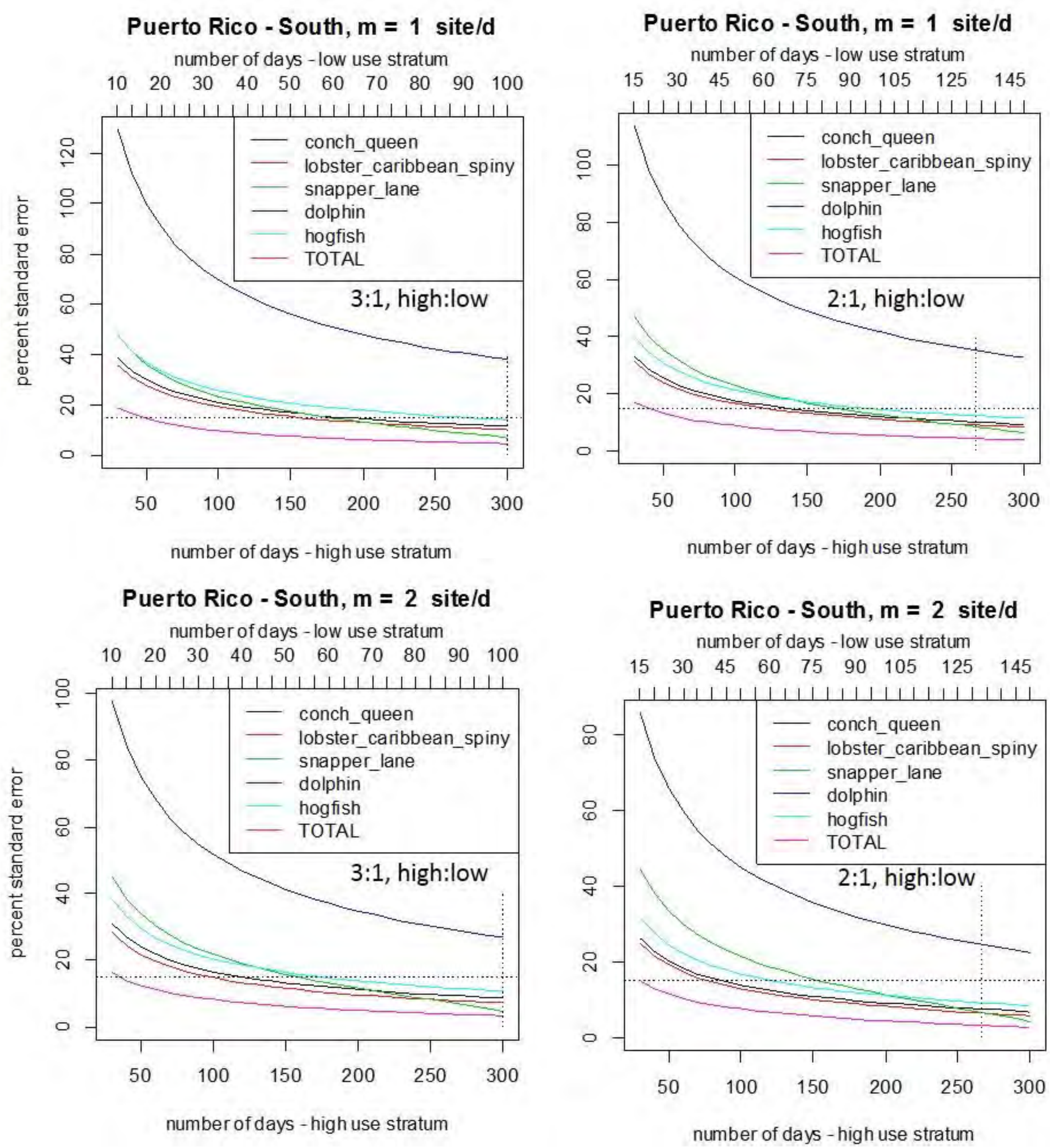


Figure 33. Effect of sample size on the precision of estimates for the top 5 species landed in the South of Puerto Rico and for all species combined. The number of days of sampling the high use stratum is three times the number of days for the low use stratum in the left panels and two times the number of days in the low use stratum in the right panels (See Appendix 12 for full tabular results). The horizontal dotted line denotes a standard error that is 15% of the estimate; the dotted vertical line denotes 400 stratum-days of sampling for the two strata combined

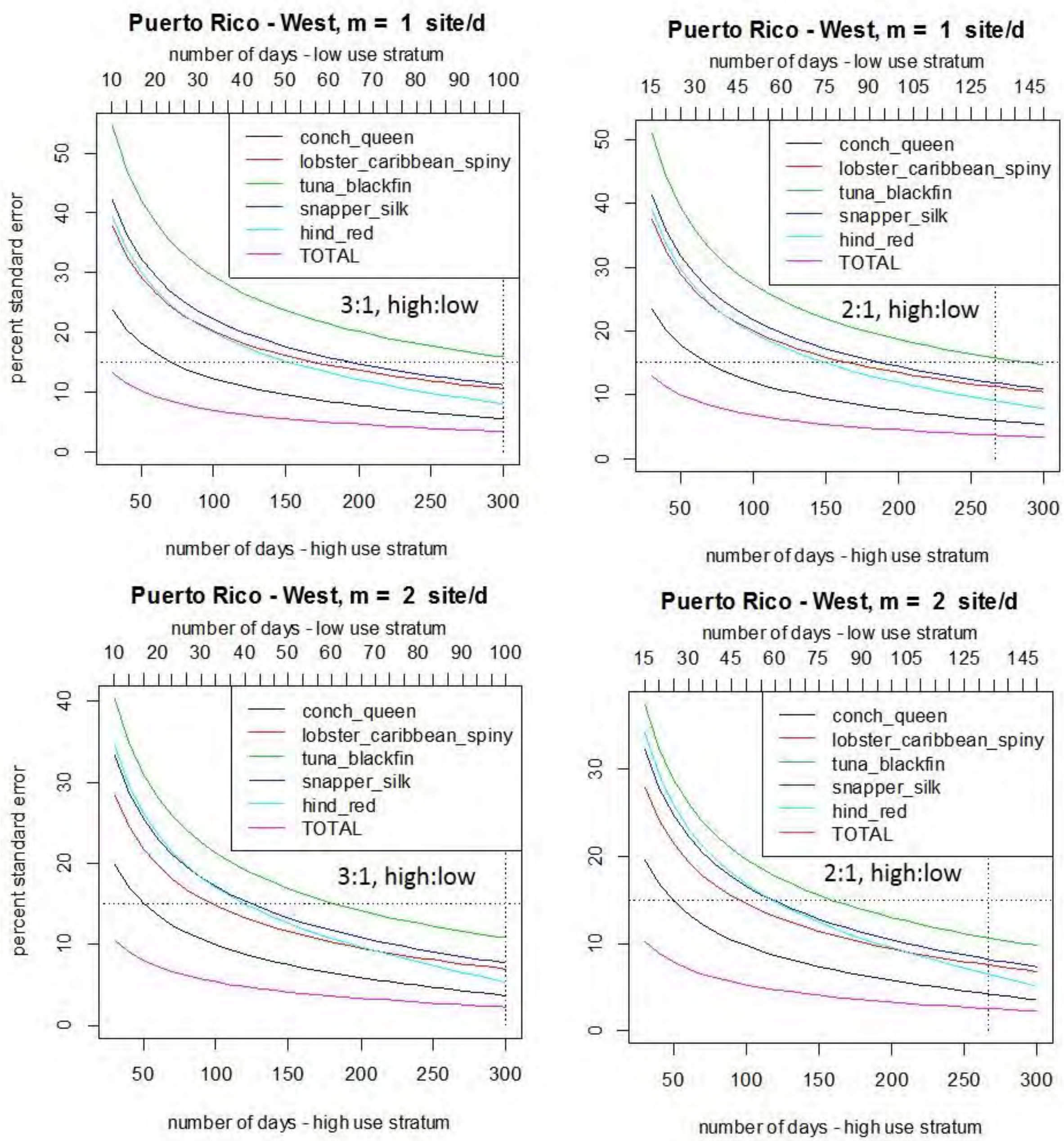


Figure 34. Effect of sample size on the precision of estimates for the top 5 species landed in the West of Puerto Rico and for all species combined. The number of days of sampling the high use stratum is three times the number of days for the low use stratum in the left panels and two times the number of days in the low use stratum in the right panels (See Appendix 12 for full tabular results). The horizontal dotted line denotes a standard error that is 15% of the estimate; the dotted vertical line denotes 400 stratum-days of sampling for the two strata combined.

4.3.4.7 Options for a year-long survey

Samples sizes were determined for achieving a given precision, expressed as a percentage of the estimated landings, for the total catch and for 4 of the 5 top landed species (Table 50). The levels of precision selected were 40%, 30% and 20%. These sample sizes were obtained the same way as was done for the USVI. (We also looked at sample sizes needed for achieving given precision for the top 5 species but these results were erratic because some species had poorly estimated variance components. In doing these computations, the ratio of sampling effort in the high and low use strata was fixed at either 3:1 or 2:1 in accordance with the findings in Section 4.3.3.6. In some cases, the desired precision could be achieved with less than 50 days assigned to the low-use stratum. However, it was felt that a minimum number of days should be assigned to each stratum to avoid erratic behavior of the estimates, to allow verification of the importance of the stratum, and to be able to detect changes in usage patterns over time. Consequently, a minimum number of days of sampling of 50 was imposed.

In order to achieve a precision of at least plus or minus 40% for 4 of the top 5 species and for the total catch, 195 to 215 person-days of effort is required in each of the four regions if m = 1 sampler is used per stratum. If two samplers are used per stratum, 230 to 250 person-days of effort is required. Note, however, that when m = 2, the constraint that a minimum of 50 days must be sampled in the low use stratum becomes operative and this inflates the required sampling effort.

To achieve a 30% precision target, 310 to 355 person-days is required when m = 1; 350 to 410 person-days is required when m = 2, depending on the region.

The 20% precision target cannot be achieved with m = 1. With 2 port-samplers per stratum, 630 to 750 person-days are needed.

Translating these manpower needs into number of employees is not straightforward. For example, the table indicates that for the Western region, 315 person-days would be needed to achieve the 30% target. However, this does not translate into one employee. This is because the 235 sampling days for the high use stratum are chosen independently of the 80 days for the low use stratum. This means that there will be many days when both the high and low use strata are designated to be sampled. The one employee cannot be in two places at the same time so there must be a second employee available. Thus, at least two part-time employees would be needed.

Table 50. Number of sampling days needed to achieve a precision of 20%, 30% or 40% of the estimated landings for the total catch and for 4 of the 5 top landed species in each region, when the number of port samplers per stratum is either *m* = 1 or *m* = 2. The --- symbol indicates the desired precision can't be obtained under the constraints imposed with this design.

			Number of sampling days for			
Region	**Max width of CI***	**m**	**High use**	**Low use**	**People-days**	**Ratio**
North	40%	2	75	<50	250	2 to 1
North	30	2	135	70	410	
North	20	2	250	125	750	
North	40%	1	145	70	215	
North	30	1	240	115	355	
North	20	1	---	---	---	
East	40%	2	65	<50	230	3 to 1
East	30	2	125	<50	350	
East	20	2	235	80	630	
East	40	1	140	<50	190	
East	30	1	230	80	310	
East	20	1	---	---	---	
South	40	2	70	<50	240	2 to 1
South	30	2	130	65	390	
South	20	2	235	120	710	
South	40	1	135	70	205	
South	30	1	225	110	335	
South	20	1	---	---	---	
West	40	2	75	<50	250	3 to 1
West	30	2	130	<50	360	
West	20	2	245	85	660	
West	40	1	145	50	195	
West	30	1	235	80	315	
West	20	1	---	---	---	

* We assume a 95% confidence interval is approximately the estimate 2 standard errors. Thus, the width of the confidence interval is found by doubling the relative standard error.

4.4 Sunday and Night Fishing

4.4.1 USVI

On St. Thomas, only one completed trip and one ongoing trip were sampled over the first seven nights of sampling. Sampling dates, site locations, and results are presented in Table 51.

Table 51. Sunday/night sampling dates, sites, and observations.

Date	Location	Result
September 29th	Frenchtown	0 trips observed
September 30th	Frenchtown	0 trips observed
October 5th	Saga Haven	1 trip observed (fish trap)
October 6th	Saga Haven	0 trips observed
October 14th	Hull Bay	0 trips observed
October 15th	Frenchtown	1 ongoing trip observed
October 20th	Frenchtown	0 trips observed

Due to very low observed activity and low reliability of landing site interview information, no conclusive quantitative information resulted from intercept sampling. DPNR staff were asked to qualitatively characterize Sunday and night fishing activity, and to make recommendations for long-term sampling within that time frame. Questions and responses are presented below.

4.4.2 Night fishing questions

Q1: Are there days of the week when night fishing is more prevalent?

A1: Fishers usually fish for the market sale, so from Wednesday to Friday would be your heaviest fishing days and on Monday and Tuesday would be the slower days.

Q2: Are there any environmental patterns to when and how much people fish at night?

A2: The moon phase, tides, wind and weather play a big part in night fishing. The moon phase: from three days before the first quarter to three days after the last quarter are the best days for night fishing and four days after the last quarter to four days before the first quarter are the slower days. Tides: tides are a big part with night fishing if the tides to strong or to weak the fish don't bit as good so the fishers catch wouldn't be so great. Tide and wind direction is another factor in night fishing depends on the direction of the tide and wind on the night you go fishing could determine whether fishing is going to be good or bad that night.

Q3: Are there any seasonal patterns to when and how much people fish at night?

A3: From the ending of July to October, fish sales are slow due to the tourist season slowing down which causes locals, restaurants and hotels to purchase less fish. From October to July, fish sales increases when the tourist season picks back up.

Table 52. Evaluation of night effort on St. Thomas.

Site	Average number of night trips per month	Range of landing times	Number of boats that night fish
Frenchtown	60	10:30PM - 4:00AM	8-10
Hull Bay	10	10:30PM - 2:00AM	2-4
Mandahl	0	0	0
Saga Haven	3 to 4	11:00PM - 2:30AM	3 (but not often)
Crown Bay	0	0	0
Krum Bay	0	0	0
Magens Bay	0	0	0
Marine Science Ctr	0	0	0
Sapphire	0	0	0
Coki/ Water Bay	8	11:00PM - 4:30AM	2

4.4.3 Sunday fishing questions

Q1: Are there any environmental patterns to when and how much people fish on Sundays?

A1: Effort is low on Sundays unless there's a fishing tournament, recreational fishers or the seine fishers (mostly in Hull bay) are keeping an eye on a school of fish.

Q2: Are there any seasonal patterns to when and how much people fish Sundays?

A2: No.

Table 53. Evaluation of Sunday effort on St. Thomas.

Site	Average number of Sunday trips per month (4 Sundays)	Range of landing times	Number of boats that fish on Sundays
Frenchtown	2	10:00AM - 7:30PM	1 or 2
Hull Bay	2	10:00AM - 6:00PM	2 to 3 Commercial & Recreational
Mandahl	0	0	0
Saga Haven	0	0	0
Crown Bay	0	0	0
Krum Bay	0	0	0
Magens Bay	0	0	0
Marine Science Ctr	0	0	0
Sapphire	0	0	0
Coki/ Water Bay	0	0	0

The evidence of landings occurring before or after the sampling period was collected at most sites, but not all. The lack of evidence presented in Table 52 and Table 53 does not denote there are no landings occurring before or after the sampling from 9 am to 5 pm or on Sundays at each site, instead it relates to the lack of sources to interview at these sites. A directed effort should be designed to detect the presence of fishing activity at sites that denoted no activity over the short term. A different strategy should be designed to verify the potential for activity at these sites over the long term. Many areas were observed with early morning landings the product of night fishing, others had after 5 pm landings the product of day fishing that extended over 8 hours and Sunday fishing was mentioned at other sites. In order to classify sites that were sampled and add other ports where this kind of use is occurring a site/time specific strategy is necessary.

In St. Croix, the interview questions regarding Sunday and night fishing did not produce any reliable results and if taken at face value, would suggest there is some limited fishing on Sundays and only one or two individuals fishing at night. Island managers did a number of drive-by visits to the two primary boat ramps in the evenings and observed a single trailer on two occasions at night. Although trailers were present on Sunday drive-bys, none belonging to the primary commercial fishers were identified and it was impossible to distinguish a commercial versus recreational trailers.

4.4.4 Puerto Rico

In Puerto Rico, a qualitative description of the after hours, night and Sunday fishing was made based on the responses from the Sunday/Night interview questions and an end of season questionnaire developed to elucidate samplers experience at each site. An ‘exit’ survey was prepared for samplers to gather additional information regarding their impression of sites they sampled most frequently and felt confident in characterizing further.

In this survey the samplers noted the facilities and access to landing sites as well as their impression of landings occurring after 17:00 (after-hours), overnight fishing with landings prior to 9:00 am and Sunday fishing that was added to the formal interview protocol. The information from this qualitative survey was added to the data from the interviews to give a score from 0 to 3 for each site. In this qualitative score 0 = no evidence of any landings (either after-hours, overnight or Sundays); 1 = little evidence of these landings; 2 = evidence of landings and 3 = substantial evidence to determine these landings are occurring. See Table 54 for a table of these results.

Table 54. Rank of fishing activity beyond the sampling hours. Night is for fishing that takes place overnight; After hours indicates that fishing is during the day but landings occur after 17:00 hrs; Sunday indicates that landings occur on Sundays. Ranks 0= no evidence of landings, 1= some evidence of landings, 2= evidence of landings, 3= substantial evidence of landings.

Site Name	Region	Stratum	Night	After hours	Sunday
Barrio Los Machos	EAST	HIGH	1	1	0
Hucares	EAST	HIGH	1	2	0
Marina Puerto Del Rey	EAST	HIGH	1	2	0
Maternillo	EAST	HIGH	0	2	0
Maunabo	EAST	HIGH	3	1	0
Barrio Sardinera	EAST	LOW	1	0	1
Las Croabas	EAST	LOW	2	0	1
Playa De Guayanes	EAST	LOW	2	0	0
Puerto Yabucoa	EAST	LOW	2	1	1
Punta Candelero	EAST	LOW	2	1	1
Punta Santiago	EAST	LOW	1	0	0
Barrio Bajura	NORTH	HIGH	1	1	0
Jarealito	NORTH	HIGH	1	1	0
La Coal	NORTH	HIGH	2	3	1
La Princesa	NORTH	HIGH	2	1	0
La Puntilla	NORTH	HIGH	1	1	1
Puerto Nuevo	NORTH	HIGH	0	1	0
Arecibo Rampa	NORTH	LOW	0	2	0
Calle Hoare	NORTH	LOW	3	2	0
Cerro Gordo	NORTH	LOW	0	0	0
Fortuna	NORTH	LOW	1	0	0
Mameyal	NORTH	LOW	0	1	0
Palmas Altas	NORTH	LOW	1	0	0
Parcelas Vieques	NORTH	LOW	1	0	0
Puerto Mosquito	NORTH	LOW	2	3	1
Punta Peñon	NORTH	LOW	0	0	0
Torrecilla	NORTH	LOW	2	2	1
Vietnam	NORTH	LOW	2	1	0
Bahia De Guanica	SOUTH	HIGH	2	1	1
Pastillo	SOUTH	HIGH	1	0	1
Playa De Ponce	SOUTH	HIGH	3	2	1
Playa De Salinas	SOUTH	HIGH	2	1	1
Salinas Providencia	SOUTH	HIGH	3	1	1
Tallaboa	SOUTH	HIGH	3	1	1
Bahia De Guayanilla	SOUTH	LOW	1	2	1
Bajo De Patillas	SOUTH	LOW	2	0	1
Jobos	SOUTH	LOW	0	0	0

Table 54. (Continued) Rank of fishing activity beyond the sampling hours. Night is for fishing that takes place overnight; After hours indicates that fishing is during the day but landings occur after 17:00 hrs; Sunday indicates that landings occur on Sundays. Ranks 0= no evidence of landings, 1= some evidence of landings, 2= evidence of landings, 3= substantial evidence of landings.

Site Name	Region	Stratum	Night	After hours	Sunday
La Parguera	SOUTH	LOW	3	2	1
La Parguera Rampa	SOUTH	LOW	1	2	0
Playa De Santa Isabel	SOUTH	LOW	2	1	1
Playa Las Palmas	SOUTH	LOW	0	0	0
Punta Papayo	SOUTH	LOW	1	1	1
Punta Pozuelo	SOUTH	LOW	2	0	0
El Combate	WEST	HIGH	0	0	0
El Faro Cabo Rojo	WEST	HIGH	0	1	0
El Seco Rampa	WEST	HIGH	2	2	0
Playuela	WEST	HIGH	1	2	0
Puerto Real	WEST	HIGH	2	1	0
Rincon Rampa	WEST	HIGH	1	3	0
Soltero Puerto Real	WEST	HIGH	0	3	0
Barrio Barrero	WEST	LOW	0	0	1
Barrio Espinal	WEST	LOW	1	0	0
Barrio Tamarindo	WEST	LOW	2	1	0
Boqueron Rampa	WEST	LOW	0	1	0
Guaniquilla Barrio	WEST	LOW	0	0	0
Higuey	WEST	LOW	2	1	0
Tres Hermanos	WEST	LOW	0	2	0

5 RECOMMENDATIONS

This section presents recommendations for improving sampling in the future. Recommendations are based on information obtained throughout the pilot project, including feedback from samplers and fishers, observations about the functionality of equipment and technology, logistics issues, and an analysis of data gathered through direct sampling. Recommendations support the primary goal of the study.

5.4 Statistical Design Recommendation

In terms of statistical design and efficiency, we make the following recommendations for scaling the current survey up to a year-long survey:

Restratification - Based on usage observed in the pilot study, we recommend stratum definitions be redefined as follows:

USVI

- St. Croix high use: Altoona Lagoon, Molasses, Frederiksted Fish Market, and Christiansted Harbor (moved from low use; note this is due primarily to dolphin and wahoo landings)
- St. Croix low use: Gallows Bay (moved from high use), Estate Castle Nugent, Teague Bay, (Salt Pond dropped), (Turner Hole dropped).
- St. Thomas high use: Saga Haven, Frenchtown
- St. Thomas low use: Mandahl (moved from high use), Hull Bay (moved from high use), Coki Point, Krum Bay, Marine Science Center, (Crown Bay dropped), (Magens Bay dropped), (Sapphire dropped)

Puerto Rico

- North high use: Barrio Bajura, La Coal, Jarealito, La Princesa, (La Puntilla dropped), (Puerto Nuevo dropped)
- North low use: Palmas Altas, Puerto Mosquito, Punta Peñon, Torrecilla, Vietnam, (Arecibo Rampa dropped), (Calle Hoare dropped), (Cerro Gordo dropped), (Fortuna dropped), (Mameyal dropped), (Parcelas Vieques dropped)
- East high use: Barrio Los Manchos, Hucares, Marina Puerto Del Rey, Maternillo, (Maunabo dropped)

- East low use: Barrio Sardinera, Las Croabas, Playa De Guayanes, Puerto Yabucoa, Punta Candelero, Punta Santiago
- South high use: Bahia de Guanica, Pastillo, Playa de Ponce, Salinas Providencia, Tallaboa, (Playa de Salinas dropped)
- South low use: Bajo de Patillas, La Parguera, La Parguera Rampa, Playa Las Palmas, Punta Papayo, (Bahia de Guayanilla dropped), (Jobos dropped), (Playa de Santa Isabel dropped), (Punta Pozuelo dropped)
- West high use: El Combate, El Faro Cabo Rojo, El Seco Rampa, Playuela, Puerto Real, Rincon Rampa, Soltero Puerto Real
- West low use: Barrio Tamarindo, Boqueron Rampa, (Barrio Barrero dropped), (Barrio Espinal dropped), (Guaniquilla Barrio dropped), (Higuey dropped), (Tres Hermanos dropped)

Number of samplers per stratum per day - In the pilot study, we surveyed two sites each day in each stratum (m=2). This enabled us to determine the within day (i.e., among site) and the between day components of variance. Our analysis shows that choosing m=1 site per day per stratum would generally be optimal (assuming the cost savings would allow for more days to be sampled). However, with m=1 it is not possible to obtain unbiased estimates of the variance of the landings; existing methods would provide overestimates of the variance for this case. So, the survey may be precise but the indication would be that it is not precise. Also, with m=1, one loses the ability to refine the estimates of the variance components and the ability to rank sites (to enable restratification) is impaired. Thus, the patterns observed during the pilot surveys of 2015 and 2016 are assumed to hold for all time and we do not have the ability to refine the design as further sampling experience accrues. We think it is extremely important to include some means of measuring the among-site component of variance at least in the first full year of a continuing (multi-year) survey because the efficiency of the sampling can undoubtedly be improved with additional information.

A key issue is the unit of labor available to do survey work. All the calculations evaluating sampling intensity were done under the assumption that fractional person-years could be devoted to sampling which implies part-time employees. However, port sampling work requires substantial training and skill so that the recruitment, training and retention of part-time employees is a critical limiting factor. We recommend that full-time employees be used as much as possible for any ongoing survey to insure success of the program.

The amount of sampling effort is going to depend on funding availability. Two full time samplers (e.g. ~500 – 600 people sampling days) could be used per region ($m = 1$), but the addition of one half time person would allow information to be collected to improve the design as well as allowing additional studies to be conducted to improve efficiency such as by incorporating an individual-based survey into the overall sampling design. Alternatively, if budget constraints dictate less sampling effort, one full time and one half time sampler could be used. Some work is needed to determine the proper analytical methods for the case where the number of samplers per day is variable.

Allocation of effort to high versus low use strata – For St. Thomas, more effort should be devoted to the high use stratum than the low use. We recommend a ratio of 3:1 for high use days versus low use days. According to our calculations, a more extreme allocation might provide better precision but this is not prudent, in our opinion, because the allocation decision is based on preliminary data from a limited period of the year.

For St. Croix, the results are variable across species so a compromise needs to be made since what is best for one species may not be good for another. We recommend that the high use and low use strata be sampled an equal number of days (ratio = 1:1).

For Puerto Rico, we recommend a ratio of 3:1 for days allocated to high use sites versus low use sites for the East and West; for the South, we recommend a ratio of 2:1. The preliminary indications are that a ratio of 1:3 might be best for the North however this finding is suspect because variance is generally higher when the mean is higher so, even allowing for the difference in size of the high and low strata, we wouldn't expect the optimum allocation to give such weight to the low use stratum. These calculations were done with the original stratification scheme which did not work well in the North; therefore, we recommend that additional calculations be done based on the proposed restratification scheme.

Total number of days – In the USVI, the effects of changing the number of days devoted to sampling was evaluated based on the new allocations to high and low use strata and with the number of samplers per stratum per day fixed at either m=2 or m=1. Graphs were produced that show the precision that can be obtained for various levels of sampling intensity. From these, the estimated number of days needed to achieve a given level of precision can be determined. Those numbers can be used to prepare a table of options, as was done as examples in Section 4.3.3.6 and 4.3.3.7. The same kinds of analyses were done for Puerto Rico. It was seen that with m = 1, standard errors that are 30% of the mean or less can be achieved for most species in most strata. If more species need to meet this criterion, or if a precision better than 30% is desired, then additional personnel will be needed.

Considering temporal changes - Although the pilot study was successful in obtaining estimates for the thirty day period at the selected sites, the allocation of future effort should include a continued evaluation of both sites (and usage) and temporal patterns. Sites that were not included in the pilot study (i.e., St. John, Vieques, Culebra) should be evaluated through at least spot checks and a year-long survey should provide information to make sure patterns of usage observed in the 30-day pilot survey hold over the whole year.

5.5 Sunday and Night Fishing Recommendations

Based on the quantitative and qualitative results from Sunday and night sampling and interviews, we suggest the following considerations for designing a long-term sampling program.

In St. Thomas, it is recommended that Sunday and night fishing activity be targeted using individual-based sampling within the 6 day (Monday through Saturday) sampling frame. While considerable fishing activity is estimated to occur at night (Table 53), this level of activity was not observed through intercept sampling from 6:00PM to 12:00AM at the sites randomly selected. Furthermore, DPNR staff recommended night sampling be done by either early morning (i.e., 4:00AM) intercept, or by "call[ing] prior to them going so that you can either meet them when they return or first thing the next morning." DPNR also recommended calling fishers to capture the very small amount of fishing that may be occurring on Sundays. However, as DPNR notes, "[there] is very little commercial fishing being done on Sundays because most fishers fish to sell at the market during the weekday."

In St. Croix, it is recommended that further investigation of Sunday fishing activity be conducted. Unlike St. Thomas and due to the significant differences in market dynamics, activity comparable to weekdays was observed on Saturdays in St. Croix (see Figure 21). As recommended by DPNR, an individual based approach appears to be the best strategy to evaluate. Once a master list of active fishers has been generated the spot check approach would yield more informative results as individual trailers (and whether they are commercial or recreational) could be identified. Sampling of the catch could then be done by contacting individual fishers. We also recommend the individual based approach for capturing landings from night fishing.

In Puerto Rico, the large number of sites and unique aspects of each location and the type of fishing deems further investigation of a strategy to sample night and Sunday fishing. Table 53 provides a ranking for prioritization of these efforts during a full year survey.

5.6 Logistical Recommendations

In terms of practical logistics for a long-term survey we make the following primary recommendations:

Governance: The first consideration in designing and implementing a long-term survey design in the US Caribbean should be to align the goals of both federal and territorial fishery management efforts. Formalized agreements between DPNR, DRNA, and NOAA, should be investigated and the ability to require fishers to comply with a sampling program should be investigated. The existing biostatistical sampling (i.e. TIP; in the USVI regulations requires fishers to be sampled 4 times a year) combined with port sampling efforts could potentially minimize the amount of times fishers are interacting with samplers and result in greater efficiency of the two programs and overall compliance.

Sampling efficiency – In the USVI, market differences between the two regions resulted in different challenges in sampling; however on both islands two recommendations are common: ice must be available for every fisher sampled and a strategy for more rapid sampling should be developed.

In St. Croix, fishers may need to be sampled in two steps: 1) record trip information as the fishers unload to get a complete count of commercial trips, and 2) follow fishers to market to get an enumeration of the catch composition. Alternatively, additional work could be done to explore if sampling could be done very rapidly (i.e. < 10 min) at the landing site through the use of fixed or mobile sorting stations and camera documentation of the catch. Improvements in sampling strategy could be used on both islands to minimize the time necessary for sampling to be conducted. In addition, and to assist in night fishing sampling in particular, an individual based sampling scheme could be explored.

In Puerto Rico, the necessity for ice and rapid sampling was not as obvious as in the USVI due primarily to smaller average landings per trip. Certain locations, with higher usage and/or those sites with a few larger scale fishers would obviously benefit from both but the need is not island wide. While our ability to sample catch compositions was not greatly impacted, improvements in sampling efficiency will be recognized and appreciated by fishers, and result in increased cooperation and a reduction in the number of refused interviews and the amount of fish in lumped categories such as “parrotfish” or “snappers”.

5.6.1 Rapid sampling

In general, and as a necessity in St. Croix, it is recommended that a rapid sampling method be designed to process a dockside catch of any size in under 5-10 minutes if necessary. It was not uncommon for concerns over sampling time to result in a refusal, in particular at sites where fishers made dockside sales. This is a necessity in St. Croix and central to the success of future sampling efforts.

A rapid sampling method would be implemented by:

- Spreading a catch out on a sorting station
- Taking a picture of the catch for species identification and subsampling verification
- Weighing a subsample (e.g., a quadrant of the station)
- Reviewing pictures, subsampled weights and species, and applying a standardized scaling methodology

Rapid sampling would be facilitated by fixed sorting stations at high-strata locations, and a mobile sorting station for low-strata locations and mobile support. A large table or truck bed tray would allow for quickly dumping and evenly spreading out a large catch, and the mounted digital camera would allow for quick and consistently oriented documentation of the catch. See next two sections for additional details.

In the case of fishers with trailers, many ramps are an intermediate and very quick stop prior to marketing the catch and fishers may have long ways to drive to their residences. For example, fishers can trailer from Quebradillas to the Rincón ramp in order to reach prime fishing grounds located offshore, driving up to three hours roundtrip. Therefore, many times the data collected at a ramp may be of a fisher that lives in another municipality and needs to take fish to a restaurant on their way home. At other ramp sites the catch may be bought directly by a private dealer who is usually waiting and then visiting other sites each day or evening to collect the fish catches. All of these factors limits the time available to intercept and interview a fisher at certain locations. In these areas the interview method needs to adapt to the reality of each site to maximize cooperation from the industry.

5.6.2 Fixed sorting stations at high-landings sites

In the USVI in particular, the volume landed at some sites was more than could be efficiently processed by the sampler with the equipment provided during the pilot phase (i.e., six 5 gallon buckets and a small bench digital scale). While fishers were generally cooperative and understanding of the demands placed on the sampler, her long-term ability to quickly gather complete (i.e., not subsampled) catch data with fishers buy-in would be greatly improved with a fixed sorting station. Such a station could include:

- Large stainless steel utility work table with back and side upturns for dumping a full cooler (usually 120 quarts, 150 lbs.) of fish out for sorting
- Digital scale with separately mounted display
- Mobile job box/chest for storage and transport of scale, forms, etc.
- 120 quart cooler for ice to replenish fishers' supplies
- Lock and cable to secure station and other equipment overnight

A fixed sorting station would improve sampling at 2 sites on St. Thomas (Saga Haven and Frenchtown) and two sites on St. Croix (Altona Lagoon and Molasses). These sites all receive a high volume of landings, and are located in areas that could accommodate a fixed table.

5.6.3 Mobile sorting truck for off-site sampling and backup capacity

In the USVI, two common scenarios limited the ability of samplers to efficiently gather complete catch data: fishers asked samplers to process their catch away from the landing site (e.g., their home, a market), and an extraordinarily large catch was landed at a remote site. In the first scenario, fishers often left without being sampled, or the island manager traveled independently to an offsite location to sample. In the second scenario, samplers often had difficulty efficiently processing the catch with available staff and equipment. While fishers were generally cooperative and understanding of limitations of samplers (e.g., needing to physically stay on site, only having a certain amount of equipment) during the pilot phase, the ability of the team to gather data in the long-term with fishers buy-in would be greatly improved with a mobile sorting truck, operated by an on-call sampler or manager. Such an outfitting could include:

- Ford F-150 XL pickup truck
- Steel truck bed sliding tray to sort fish as pulled off bed
- 120 quart cooler for ice to replenish fishers' supplies

In Puerto Rico, this relatively expensive investment is probably not necessary. Many of the high activity and high landing sites had pescaderia's at, or near, the landing site which could be used for rapid sorting.

5.6.4 Crane scales and scales with separate displays

In all regions, but in particular in the USVI, the type of catch landed at some sites could be more efficiently sampled using two types of scales different from those provided samplers: crane scales and scales with separate displays. Crane scales would improve sampling at sites where large sport fish (e.g., dolphin, wahoo) were landed, as they would allow the sampler to hang the fish rather than try to get them properly onto the flat digital scale. Scales with separate displays would improve sampling at sites where large volumes of crustaceans (e.g., lobster, topsnail) were landed, as they were often landed in very large barrels or bins that could be easily weighed on scales with displays that do not get covered in the process.

5.6.5 Coolers and ice

Fishers at all sites greatly appreciated when a sampler could offer them ice. In St. Croix it was a common demand and stated as a reason for not allowing sampling to occur. Long-term buy-in would be greatly improved if samplers were provided with coolers and a means to stock it themselves with ice. Coolers could be transported with samplers, or left on-site at certain locations. Ice machines, or partnerships with businesses near landing sites should be incorporated into long term sampling plan.

Simply stated, providing ice is a necessity in the USVI.

5.6.6 Individual-based sampling

Throughout the US Caribbean fisheries, one potential option for sampling that is strongly supported by many of the DPNER staff in the USVI is to use an individual-based sampling method. The relatively small and intimate nature of theses fishery makes it possible to weigh a majority of landings with a small number of samplers coordinating closely with fishers. An individual-based sampling method would also have the benefit of increasing coordination and strengthening relationships with fishers.

Individual-based sampling could be implemented by:

- Compiling a roster of fishers and corresponding landing site(s).
- Gathering the contact information for each fisher in the roster.
- Designing a statistical method for sampling each population each week.
- Directly coordinating with selected fishers each week in order to schedule sampling times and locations.

The level of coordination required for individual-based sampling may also foster good working relationships between samplers and fishers. Additionally, the approach makes sense to fishers. In fact, virtually every sampler in the USVI was told at one point by commercial fishers that instead of being on site all day, they should ask when boats would be landing and come back then. A number of fishers even voluntarily exchanged phone numbers with samplers and called to notify them when they would be coming in, what size catch they had, and whether they would be able to sample on-site or would need to go off-site.

In Puerto Rico, this approach could be used to target sampling on specific sectors of the fisheries which are difficult to capture given the sampling time frame. For example, many of the deep water snapper fishers on the west coast land late in the evening and are missed in a 9-5 sampling scheme. Even if sampling times were expanded until sunset, it is likely that some would still be missed. Given that this is a limited entry fishery, a roster of names including information on trailer types (i.e. license plates or type/make) could be used to get estimates of effort via trailer counts and individuals could be contacted to coordinate the sampling of their catch.

The details of an individual-based sampling method would have to be worked out and carefully designed so that a bias towards cooperative fishers did not result.

5.6.7 Training and capacity Building

We recommend developing direct partnerships with UVI, University of Puerto Rico (UPR) and local universities. We found eager students throughout the Virgin Islands and UVI was able to host the training program. If time were available to develop these relationships, sampling personnel could help develop coursework and also provide students with hands on experience and the potential to develop research projects directly related to the fishery monitoring program. This arrangement could reduce costs by utilizing students as samplers, while also building capacity in the region and improving the long-term impact of the project. Courses developed and hosted at the UVI and UPR could serve as a starting point for future training programs and survey projects. The development of this component would involve an initial investment of time and resources from the program manager, but would likely return substantial long-term benefits.

5.6.8 Outreach and communications

In Puerto Rico, it is recommended that project representatives and partners work to improve and increase communication with fishers in two ways. First, given the decentralized and informal network-based fishery in Puerto Rico, it is recommended that outreach and communication efforts be designed specifically to local fishers, in particular regarding the importance of fisheries management and scientific data needs. The DRNA and CFMC Liaison, Helena Antoun, have conducted a series of outreach activities with fishers in their landing areas in this direction (PEPCO meetings). One on one meetings and continuous conversation with fishers at landing sites to discuss these issues may help communicate the importance of correctly gathering scientific data in the field through cooperation with port agents, paying special attention to trip tickets, as well as redress the relationships necessary for improving data quality in Puerto Rico. Helena also reports that the success of her work is based primarily on the cooperation and support of the DRNA port samplers.

Second, tailored outreach and communication is recommended to build relationships with the many fishers that land their catch at locations that may be private, hidden from view or hard to document with traditional methods. Coastlines with mangrove forests, for example, may have numerous landing sites without any visibility from land. In addition, the constructions in the maritime zone that have piers or docks on the seaward side also serve as landing sites that are invisible and inaccessible to sampling. In order to access sites that are private, it is recommended that a significant amount of time be invested in creating agreements with each fisher or owners of these constructions to allow access for samplers to intercept. The use of cameras and tablets by samplers may cause uneasiness among these contacts that can result in the end of sampling, therefore the process must be clearly laid out and explained prior to any sampling in order to avoid the loss of access to that site. To be able to detect areas where landings are occurring that may not be visible to the passer by, a dedicated pilot survey designed for that purpose is required. Aerial surveillance may be used to pinpoint landing sites at locations where visibility is reduced. Other methods such as the use of remote cameras may help detect night use of suspected landing sites.

5.6.9 Leveraging existing facilities and infrastructure

In Puerto Rico, the types of facilities at landing sites vary greatly, and it is recommended that project representatives and partners tailor their sampling procedures to reflect the situation on the ground. At locations with the most infrastructure, fishers' associations operating fish houses (or *villas pesqueras*), it is recommended that samplers cooperate with staff on site to develop a consistent sampling scheme. For example, some fish houses have staff dedicated to help fishers fill out trip tickets daily, and leveraging this assistance in conjunction with sampling can improve the accuracy of landings reports. At sites with a designated fish buyer and maybe a holding facility, but no *villas pesqueras* or fish house, it is recommended that there be significant outreach to gain access to the facilities. These sites provide an opportunity to evaluate landings, since most of the catch, except perhaps what is not marketable, is dropped off there. At sites where there are no facilities other than a ramp, it is recommended that project representatives and partners work with DRNA port agents to help fishers grow accustomed to the sampling procedure. At sites with low landings, it is recommended that a representative make consistent and regular visits to determine the appropriate sampling approach and schedule.

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