

PUERTO RICO PORT SAMPLING AND CATCH VALIDATION PROJECT

(August 2017 – December 2019)

Final Report Part 2 – Main Body

(Submitted to the National Marine Fisheries Service Southeast Fisheries Science Center and Gulf States Marine Fisheries Program)



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This work was commissioned by the United States National Marine Fisheries Service. The landings estimates provided herein have not yet been determined to represent best scientific information available.



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In Cooperation with:



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1 INTRODUCTION

In 2007, the reauthorization of the Magnuson Stevens Act (MSA) mandated the use of biomass-based benchmarks to manage all U.S. fisheries. The U.S. Caribbean has struggled to meet this requirement as the available data is extremely limited and insufficient to conduct quantitative stock assessments. The fisheries in this region are small scale, multi-gear, landing hundreds of different species. With more managed species than any continental U.S. fisheries, the sole reliance on self-reported data has led to very high uncertainty about landings and in the setting of a meaningful annual catch limit (ACL). A series of meetings were held to address the issue starting with a Data Evaluation Workshop in January of 2009 and a Caribbean Fisheries Management Council (CFMC) Annual Catch Limit Plan Working Group (ACLG) meeting in February of 2009. It became apparent that even utilizing average catch as a proxy for quantitatively estimated ACL would be challenging given only self-reported data and that significant changes would have to be made to ensure the cultural, economic, and ecological sustainability of these fisheries.

In response, the Puerto Rico Department of Natural Resources and Environment (DNER) and the US Virgin Islands Department of Fisheries and Wildlife (DFW) held a series of four meetings as part of the “US Caribbean Commercial Data Improvement Project.” Fishers, managers, and representatives from NOAA Fisheries Southeast Fisheries Science Center (SEFSC), the NOAA Southeast Regional Office (SERO), and the Caribbean Management Council met four times between May of 2009 and May of 2010 to think big and recommend the ‘ideal’ data collection program.

The final report outlined a comprehensive and expensive set of recommendations of which validating the commercial catch and effort was a top priority. The panel also recognized that not enough data were available to inform simulation models or power analyses to determine the levels of sampling necessary. The final recommendation was to conduct a short high intensity pilot study to better understand the relative usage and the variance structure of the landing sites and then use this information to design and implement two to three years of data collection. Steve Turner (formerly Division Chief of Data and Statistics at SEFSC) relentlessly pursued funding and we were able to initiate the process with a short survey design project in 2014. Over 100 sites which had records of landings or were recommended by DRNA staff or people knowledgeable with the Puerto Rico Commercial fisheries were evaluated for relative usage as best we could, conducted some simulations and made recommended for the pilot study (MER Estimation Report, 2014). High intensity pilot studies were successfully conducted in the USVI and Puerto Rico in late summer 2015 and spring of 2016 providing enough data on site usage and variability to inform power analyses and recommendations for a yearlong survey. Power analyses were then conducted to evaluate the probable changes in variability given differences in number of days sampled (i.e., a cost benefit analysis to guide additional work; see MER Pilot Report, 2016).

In the spring of 2017 MER Consultants was contracted to utilize the results of the pilot study and conduct a full year of data collection to better understand temporal patterns in variability, changes throughout the year. The primary objective of the Caribbean Fishery Catch Validation project was to estimate annual commercial landings.

Secondary objectives included:

- Periodic (monthly) sampling the islands of St. John, Culebra, and Vieques as an initial investigation of the scale of commercial landings on those islands.
- Periodic sampling of night fishing trips should be attempted to estimate the frequency and variability in the number of night fishing trips.
- Periodic sampling to determine the frequency of Sunday fishing trips.
- Periodic sampling several hours before 9am and after 5pm to better define the hours during which day time off-loading of landings occurs.
- If time and data were available, to evaluate the self-reported landings data obtained from commercial catch records (CCR).

Overall, the project relied heavily on the information in the following reports:

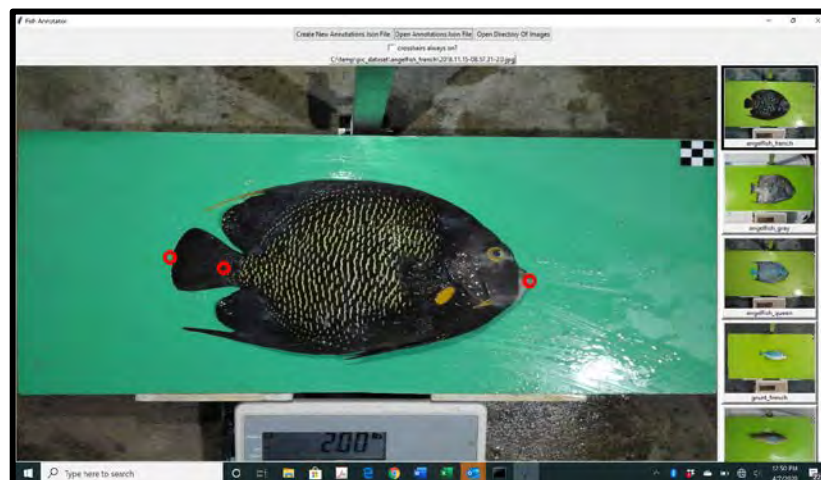
- 2014 MER Consultants report entitled *Design of a Port Sampling Program for the U.S. Caribbean* (Submitted to SEFSC; hereinafter referred to as MER Estimation Report).
- 2016 MER Consultants report entitled *MER Port Sampling Site Descriptions* (Submitted to SEFSC; hereinafter referred to as MER Site Descriptions).
- 2016 MER Consultants report entitled *Caribbean Pilot Port Sampling and Catch Verification Project* (Submitted to SEFSC; hereinafter referred to as MER Pilot Report).

Governance and anonymity of individual fishers. As in the pilot study this project was conducted with full cooperation and support, but ultimately independent of Puerto Rico Department of Natural and Environmental Resources (DRNA; Departamento de Recursos Naturales y Ambientales). With few exceptions¹, 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

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).

cooperation and participation in the project data collection procedures were developed that did not include personally identifiable information (e.g., fisher name or boat registration numbers).

An analysis and sampling framework were developed that did 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 DRNA is mandatory for any form of success and a formal framework for the relationship between contractors and the departments should carefully be considered to maximize the benefits of the sampling program.



2 PROJECT PLANNING AND DEVELOPMENT

This section presents a brief overview of the non-data driven results of the on-the-ground planning and implementation of the project in Puerto Rico. Results are based on our experiences during the entirety of the project 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.

2.1 Coordination and Outreach

All contracting and coordination was initially done by HJR Reefscaping, a local contractor led by Dr. Héctor Ruiz and Dr. Michelle Schärer and with offices in Cabo Rojo. We were able to build off existing relationships in some fishing communities, but overall, most fishers were still unaware of our recent and future projects. Many told us that they cooperate with scientists but never see the results of local fisheries projects.

First on our list, and arguably the most important step in the success of our upcoming project, was to report back to the fishing communities and fishers on the findings of the pilot study. We created simple flyers that not only summarized our findings but also notified people that a longer-term sampling program was being initiated. In sites that we knew to be challenging, or for skeptical people, we made ourselves available for questions and answers and arranged for full PowerPoint presentations at community centers and even at a marina in Puerto Real. This was unconditionally well received in Puerto Rico by the fishers and we had the full cooperation of leadership at the DRNA. These flyers were also used to thank fishers for their participation and encourage them to continue collaborating in our future efforts.

It is important for us to stress that the fishers, fishing communities, scientists, and managers alike would greatly benefit from a significant increase in outreach efforts.

2.1.1 Territorial natural resource agencies

Dr. Todd 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 prior to the 2016 pilot study. Building upon these meetings and in planning for the year-long data collection, a number of 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. Mr. Matos-Caraballo has been critical to the success of the pilot study and the ability to continue this work. The first step was to ensure 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.

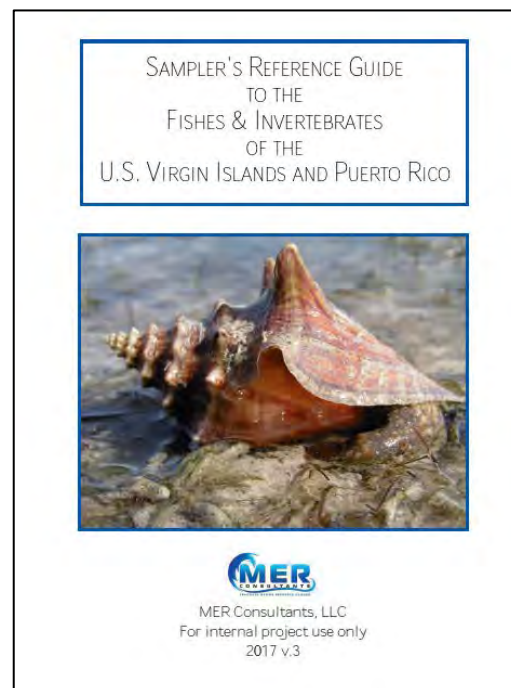
2.2 Materials Development

Overall, the materials utilized were very similar to those used in the pilot study. We have included examples of the updated data sheets for this project and highlight a few key components below (Appendix 2; MER Pilot Report 2016).

2.2.1 Species identification guide

MER Consultants updated the *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:

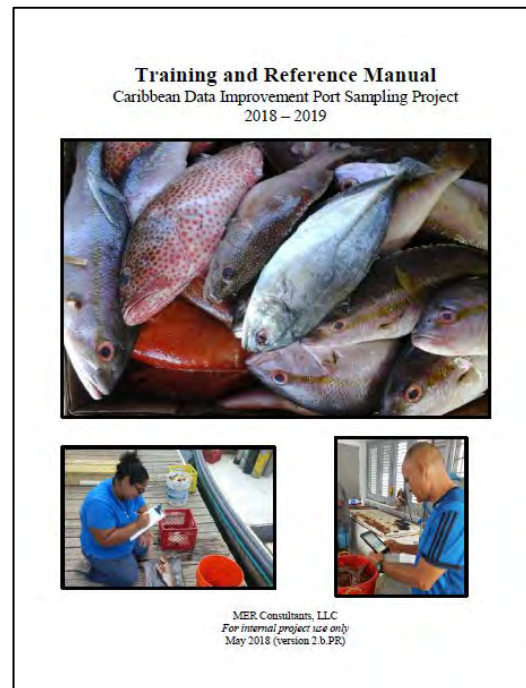
- External anatomy terms and diagrams
- Top 20 species landed in St. Thomas, St. Croix, and Puerto Rico
- Key traits of fish and invertebrate groups (i.e., families)
- Detailed species descriptions organized by group, including common and Latin name, key characteristics, size and representative image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



2.2.2 Training and reference manual

MER Consultants updated the *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. Initially, 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 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 when possible, but not mandatory. Form includes interview questions on activity outside of sampling frame in order to characterize effort not captured during regular sampling. Forms used deliberately during the post hurricane period to determine auxiliary sampling plan.
4. *Site Evaluation Form* – Filled out when evaluating or spot-checking sites with possible fishing activity. Form includes physical characteristics of the site, current fishing activity and short summary of landings at different times of day.
5. *Site Evaluation Interview Form* – Filled out when evaluating or spot-checking sites with possible fishing activity. Similar to Sunday/night fishing form but with detailed information on landings at different times of day. At least three interviews were performed on each site unless no fishing activity or persons were seen on the premises.

2.2.4 Electronic reporting and monitoring

MER Consultants updated two platforms developed in the pilot study 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 the 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 and Figure 9 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 2.3.4 and Figures 11 and 12).
- Recording 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*.

- A “Rapid Sampling” application which links tablet to a scale to capture both an image and the weight on an individual fish.

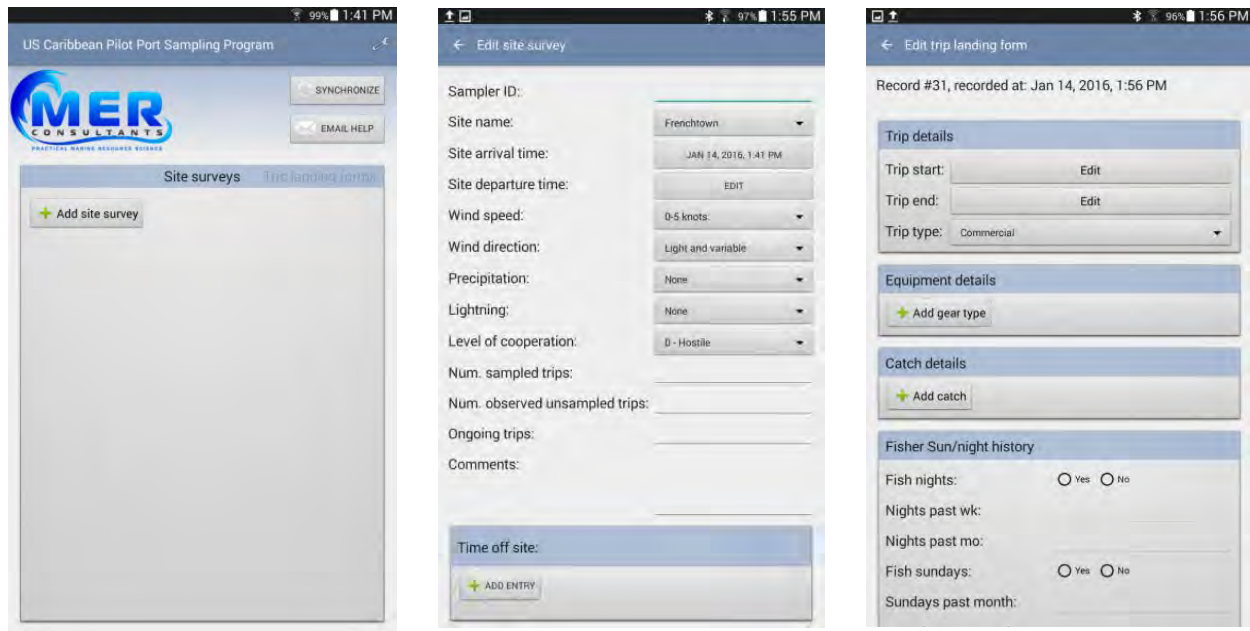


Figure 9. Screenshots for site forms and trip landing forms in the data entry application. . (See Appendix 3 for more examples)

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 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. 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.

2.2.4.3 Smartphones

Following Hurricane Maria, the island manager implemented two simple uses of smartphones. All samplers were able to connect via two specific chat groups. One group was dedicated to ensuring assignments were being correctly executed and the other for the validation of species identification. One of the biggest benefits of this application and constant communication was a sense of community in the group of samplers (Figures 13 and 14).

2.3 Personnel and Training

2.3.1 Island managers

Initially all contracting and training was done by HJR Reefscaping, LLC who also supervised all on the ground logistics for the pilot study. 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, as Island Manager and for support on all aspects of the project. Following the hurricane all contracting was done by Caribbean Marine & Fishery Research Group, LLC (CMFRG); Mr. Marcos Hanke (President and Founder) hired Alejandro Carrera and Vileny Torres to be overall island managers for the project.

2.3.2 Sampling team

A total of 16 samplers were contracted to provide eight samplers per day and fulfill any auxiliary sampling needs. A combination of full and part-time samplers were hired due to logistic considerations. Due to the large geographical area to be sampled, recruiting was targeted across the island so that three local samplers could cover each coast without significant additional travel costs.

Samplers had diverse backgrounds, which was important considering the differences between regions or idiosyncrasies of different sites. For example, fishers trusted some samplers more because they knew them, while other fishers appreciated samplers who may have been relatively removed from local affairs. The application criteria and hiring process allowed the island managers to select individuals who could not only work in the challenging environment but also achieving the scientific goals (e.g., fish identification, using tablets, and data reporting).

2.3.3 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 to all participants, and include:

- Importance of completing procedures according to the statistical design.
- 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 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).(Figure 10)
- 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).
- How to handle difficult questions or challenging situations.

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.

Following Hurricane Maria, additional training sessions were conducted to replace samplers and act as refresher courses and clarification of procedures for auxiliary sampling. A total of five trainings sessions were done throughout the project (Table 6). One meeting with all samplers was held mid-project to refresh and ensure samplers performance. New samplers were closely monitored for any questions or troubles for a period of two weeks.

Table 6. Dates and location for trainings during project

Date	Region	Location	Training type	Number of participants
Aug 1-2, 2017	South	Pescaderia de Ponce	Full training	17
May 19, 2018	East	UPR Humacao	Training (theory) (followed by a day assignment)	3
June 16, 2018	East	UPR Humacao	Training (theory) (followed by a day assignment)	3
Aug 5, 2018	North	Vega Baja	Refresh / Sampling topics	14
Oct 27, 2018	East	UPR-Humacao	Training (theory) (followed by a day assignment)	2
Dec 14, 2018	North	Barrio Bajuras Site	Training (theory) (followed by a day assignment)	1



Figure 10. Fish Identification and sampling training sessions. Most of the top landed species were provided for training of identification. Pool noodles and colored balls were used in an exercise to understand subsampling and the importance of randomness.

2.3.4 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.

At the end of each day, island managers were 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. The first type of data was from fields in the electronic forms (e.g., arrival time, departure time, site breaks) completed by samplers. GPS points were marked to correspond with the filling of certain fields in the electronic form. For example, when a sampler would enter the start time, the app would create a timestamp and mark the GPS location of the tablet, so that the manager could then download and verify the data (Figures 11 and 12).

The second type of data was from the passive system in the application, which created timestamps and recorded GPS points at regular intervals. The accuracy of the GPS was reliable enough to ensure that samplers were on site at the appropriate times.



Figure 11. All GPS locations recorded for a week’s period in all regions of Puerto Rico (Jan. 6 - 12, 2019).

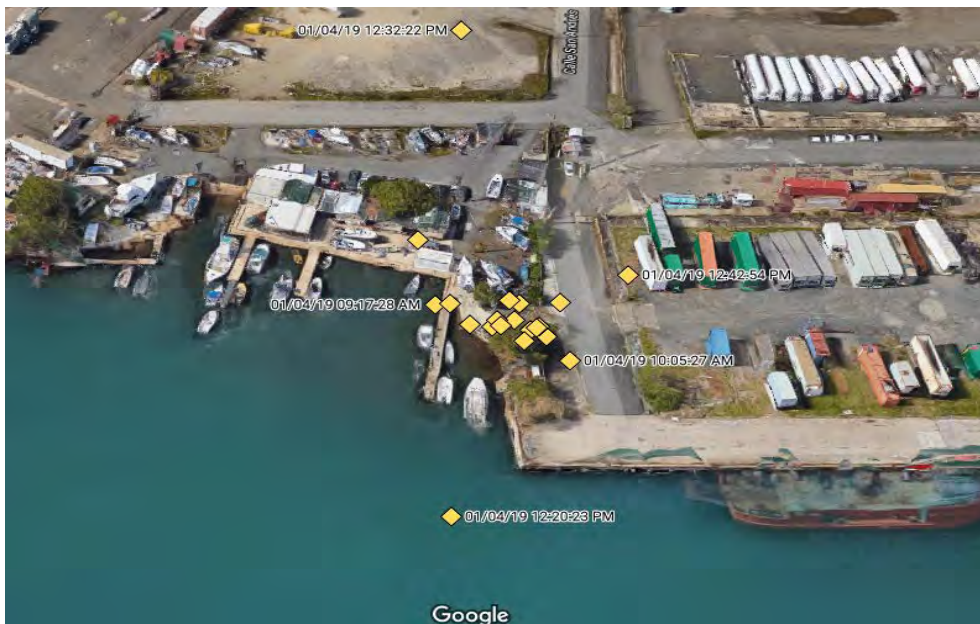


Figure 12. GPS positions recorded for one sampling day (January 4, 2019; La Coal on the North Coast).

An additional level of oversight was added after the hurricanes with a WhatsApp group chat established as “Check In CDP” where samplers were required to send a picture and site name when they arrived at their assignment (Figure 13).

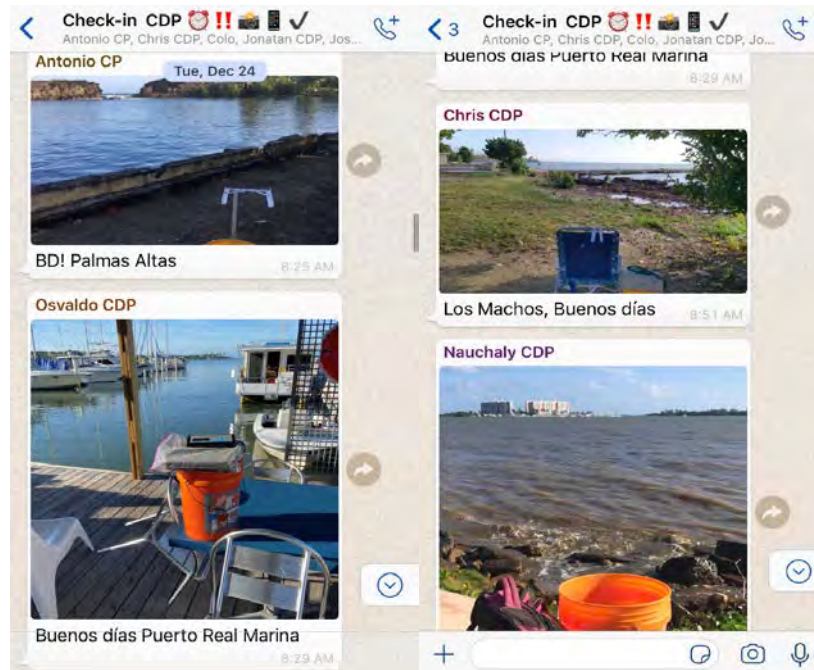


Figure 13. Screenshot of sampler’s site assignment “Check-In” via WhatsApp in Smartphone. Timestamp of “Check-ins” are printed with the picture when submitted. Assignments were checked every day before 9am to make sure samplers were on time and on the right site.

2.4 Quality Control

2.4.1 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 syncing 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. Lastly, the paper forms provided a record for island managers to use to crosscheck for data entry errors or verification of numbers that may have been flagged in the quality control process.

2.4.2 Review of electronic form data

In Puerto Rico, the island manager, Mr. Alejandro Carrera, regularly downloaded and reviewed raw electronic data forms 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. A quality control code was written in R (R core Team 2013) to identify outliers in the data, schedule assignment mismatches, and potential data entry errors. If upon initial review data did not appear complete or accurate, Mr. Carrera inquired directly with samplers, made any necessary corrections, and maintained the master database.

2.4.3 Pictures for species identification/species verification

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. Samplers were also urged to take full cooler pictures so that if any questions arose about the species composition or the sampler was unable to sample, there was at least a record of the top layer of fish. This procedure worked out very well.

Another great addition to procedures was implemented by Mr. Carrera following the hurricane, when he started a “Fish ID” group in “WhatsApp” to upload species pictures and corroborate as a team (Figure 14). This became useful for everyone to refresh species ID and to confirm that identifications were done correctly; as well as to avoid uploading incorrect species into the database. This not only insured better identifications but instilled a sense of community and support for the small group of samplers.

Supervisors provided aid to samplers when species name correction was needed before uploading daily assignments data.

Mr. Antonio Flecha was designated as the team’s species identification expert and assigned to help other samplers with species identification and validate those entered into the system. During the sampling period, he along with island managers, regularly accessed pictures proposed identifications when uploaded into a “Fish ID” group text message (in “WhatsApp”) before being uploaded into the database. Pictures for species were then accessible through the supervisor database in the online data management system (Figure 15).

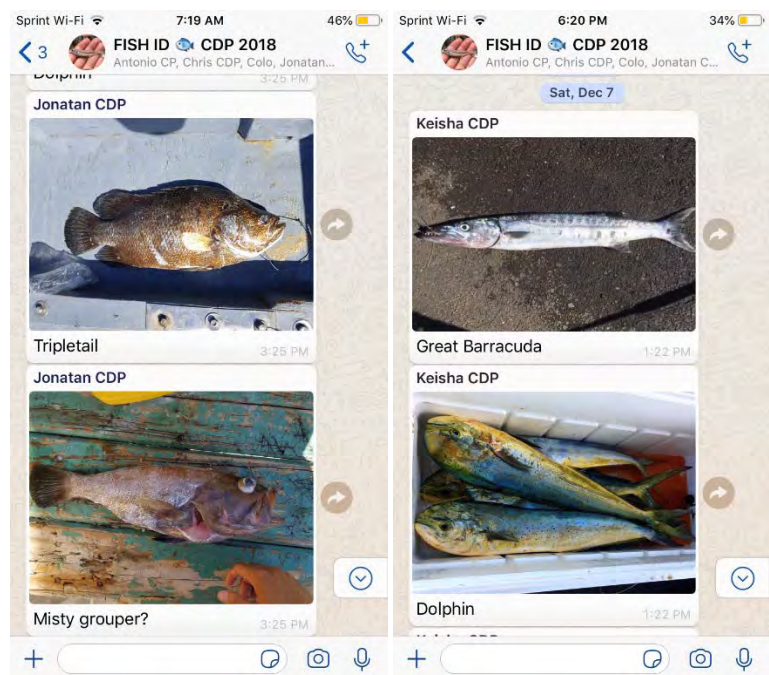


Figure 14. Sampler’s Fish Identification group chat on “WhatsApp”.

Mr. Carrera reviewed species assignments and made any necessary corrections directly in the database, as well as kept records of each change made or any issues (e.g., missing data, unclear pictures) that impeded positive species identification.

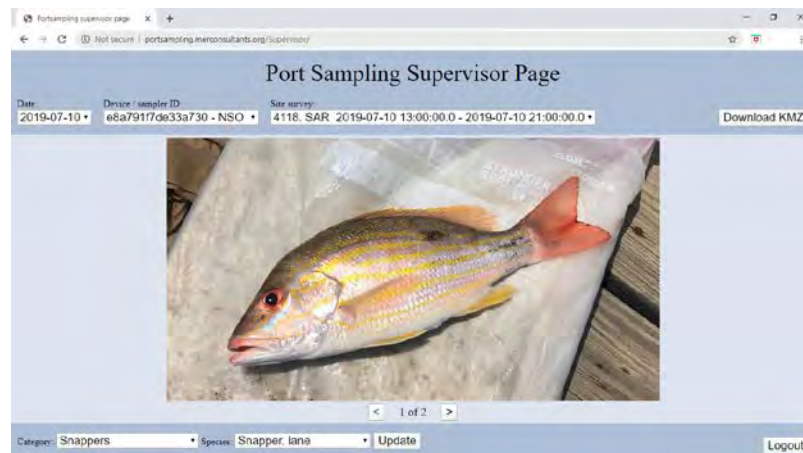


Figure 15. Supervisor fish identification interface in online data management system. Early during the sampling period, individual attention was given to each sampler as to the reliability of their identifications. This allowed supervisors to pay particular attention to specific samplers and provide additional training if necessary.

2.4.3.1 Specific Procedures for shark ID/verification

Due to difficulties in the identification of sharks, additional protocols were implemented to collect extra information. Additional pictures were required of specific orientations as shown in Figure (Figure 16). A minimum of four pictures, if possible, were to be taken of each shark landed, including a full dorsal view to compare origin of fins, an upper picture to compare inter-dorsal ridge, a picture of the tail and a picture of the head to compare different shapes and ratios. Additionally, with the fisher's permission, measurements of "standard length" and "stretched total length" were taken as well as a "fin clip" from each individual to gather DNA samples for analysis.

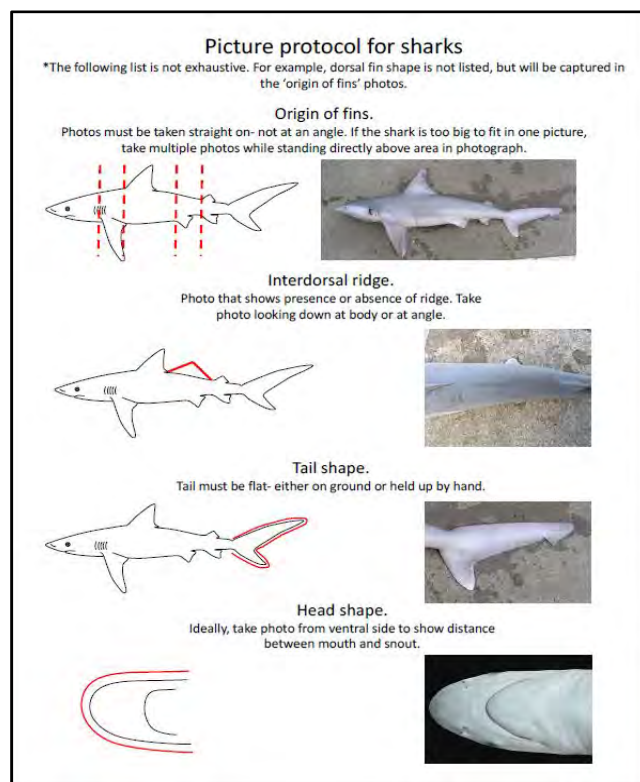


Figure 16. Picture Protocol for Sharks.

2.4.3.2 Expert review of final species determinations

As the project neared completion, we sought out top experts to verify as many of the identifications that were possible. In particular, we focused on species which have not been previously reported in the commercial catch records, those that are particularly challenging, and a quick review of every picture in the database to detect an individual sampler or systematic mis-identifications. Close to 20,000 pictures were reviewed by the following people with the intent as stated:

- Roy Pemberton – Former Director of Fish and Wildlife St. Croix, USVI – Mr. Pemberton reviewed all of the photographs that were available to look for individual samplers whose identifications needed to be carefully re-evaluated. He also conducted a more detailed secondary review of the parrotfish due to a lack of any species-specific reporting, the challenging nature of their identification and the importance of the resulting data.
- Dr. Dean Grubbs, Ph.D., Associate Director of Research, Full Research Faculty, Florida State University Coastal and Marine Laboratory) – Dr. Grubbs is a globally recognized authority on elasmobranchs and reviewed over 1,000 pictures of every individual shark or ray that we were able to photograph.
- Mr. David Snyder, Senior Scientist, CSA Ocean Sciences Inc. Mr. Snyder is a co-author of the 2016 “Marine Fishes of Florida” by Snyder and Burgess. He reviewed over 10,000 photographs which were a subset of the particularly challenging or rare species.
- Dr. Joy Young, Research Scientist, Florida Fish and Wildlife Conservation Commission/Fish and Wildlife Research Institute and President/Founder of Fishery Data Solutions LLC. She authored the ID guide utilized in the project and was used as a secondary set of eyes often throughout the project.

3 SAMPLING AND ESTIMATION METHODOLOGY

3.1 Site selection and sampler assignments

The MER Estimation Report (2014) originally identified 76 sampling sites that needed further investigation of which 57 were selected for the pilot study (Figures 17 and 18). The original site list was generated using DRNA’s official list from Puerto Rico landing reports with a total of 101 sites. Based on our experiences we added an additional five sites for a total of 106 locations in our sampling universe. 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. To be thorough, island managers “spot-checked” each one of the sites to confirm usage periodically.

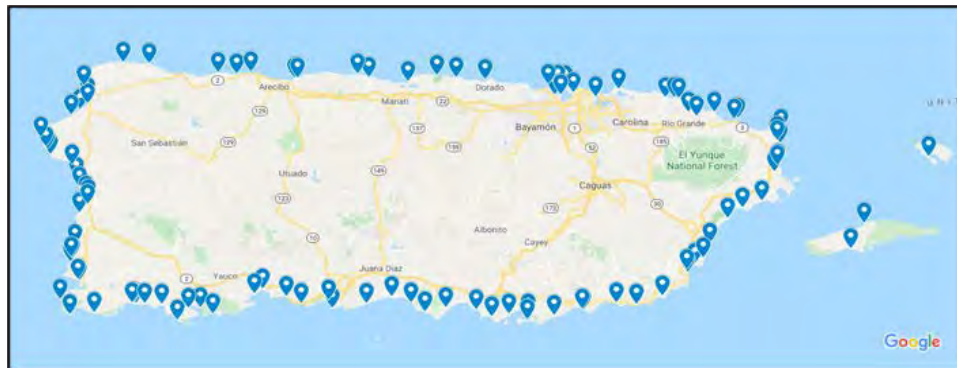


Figure 17. All locations visited during site evaluations prior to initiating project and after Hurricane (Feb/2018, Sep/2019) (106 sites). DRNA provided 101 sites.

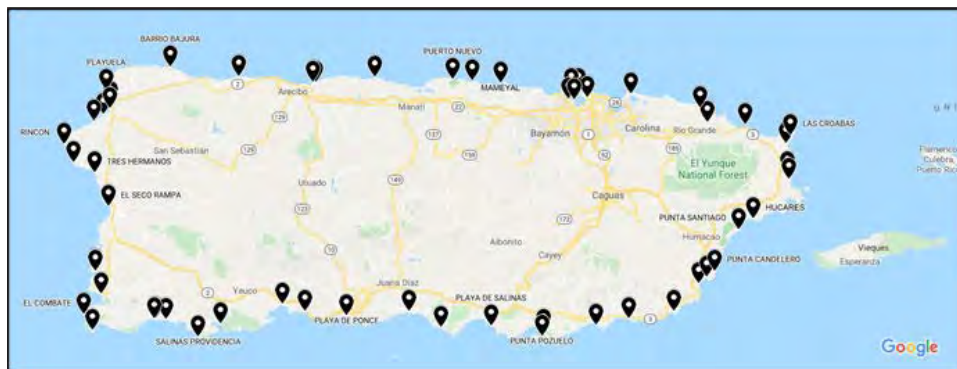


Figure 18. Sites used on Pilot Project 2016 (57 sites).

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 prevented 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. Others had significant changes in fishing activity due to changes after the hurricanes and fishing facilities

Island managers assigned individual samplers to each site 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 and supervisors had to evaluate photographs and reported data with this in mind.

3.2 Final sampling design

The Puerto Rico pilot port sampling surveys conducted by MER Consultants consisted of separate and independent components for each coast (North, East, South and West); each coast was stratified into high-use and low-use sites giving rise to eight independent surveys. Each of the surveys utilized two stage cluster sampling where days were randomly selected at the first stage and sites within days were selected at the second stage. For the current project, we again divided each of the four coasts into high and low-use strata and used two stage cluster sampling for three of the four coasts (the exception being the two strata along the North coast, described below; Figure 19 and Table 7). However, because of budgetary constraints, there was only one site selected for each sampling day at the second stage in each of the six separate surveys.

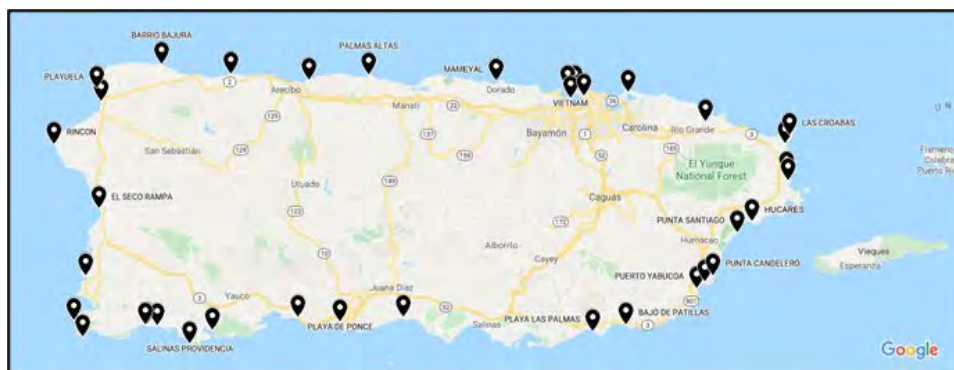


Figure 19. Sites used on 2017 sampling (Pre-Hurricane Maria, Aug-Sept 2017; 39 sites)

Table 7. Site Stratum before Hurricane Maria.

Site Name	Code	Region	Pre Hurricane Stratum (Aug 7 – Sept 18, 2017)
BARRIO BAJURA	BAJ	North	LOW
CALLE HOARE	HOA	North	LOW
JAREALITO	JAR	North	LOW
LA COAL	COA	North	LOW
LA PRINCESA	PRI	North	LOW
MAMEYAL	MAM	North	LOW
PALMAS ALTAS	ALT	North	LOW
PUERTO MOSQUITO	MOS	North	LOW
PUNTA PEÑON	PEN	North	LOW
TORRECILLA	TOR	North	LOW
VIETNAM	VIE	North	LOW
BARRIO LOS MACHOS	BLM	East	LOW
HUCARES	HUC	East	HIGH
LAS CROABAS	CRO	East	LOW
MARINA PUERTO DEL REY	PDR	East	HIGH
MATERNILLO	MAT	East	HIGH
PLAYA DE GUAYANES	PDG	East	LOW
PUERTO DE YABUCOA	PYA	East	LOW
PUNTA CANDELERO	PCA	East	LOW
PUNTA SANTIAGO	PSA	East	LOW
SARDINERA	SAR	East	LOW
BAHIA DE GUANICA	BDG	South	HIGH
BAJO DE PATILLAS	BDP	South	LOW
LA PARGUERA RAMPA	LPR	South	LOW
LA PARGUERA	LPG	South	HIGH
PASTILLO	PAS	South	HIGH
PLAYA DE PONCE	PDP	South	LOW
PLAYA LAS PALMAS	PLP	South	LOW
PUNTA PAPAYO	PAP	South	LOW
SALINAS PROVIDENCIA	SAL	South	LOW
TALLABOA	TAL	South	HIGH
BARRIO TAMARINDO	BTA	West	LOW
EL COMBATE	COM	West	LOW
EL FARO CABO ROJO	FAR	West	LOW
EL SECO RAMPA	SEC	West	LOW
PLAYUELA	PLA	West	LOW
PUERTO REAL, MARINA	PRE	West	HIGH
PUERTO REAL, SOLTERO	SOL	West	HIGH
RINCON RAMPA	RIN	West	LOW

The current project also differs from the previous surveys in that we were asked to investigate fishing activity and landings for islands off the coast (Vieques and Culebra, combined), to investigate landings made on Sundays, and to investigate landings made before and after the core working time (9:00 am – 5:00 pm). We tried to use the same methodology for all coasts but coast-specific features necessitated variations in the design. However, for each of the four coasts, there were separate components for “daytime” (M – Sa; 9:00 am to 5:00 pm), Sundays (9:00 am to 5:00 pm), “early morning” (M – Sa; 5:00 am to 9:00 am) and “night” (M – Sa; 5:00 pm to 9:00 pm). The designs for each component are described below.

3.2.1 Daytime design (East, West, South)

We stratified by the coast (East, South, and West) and by the anticipated usage of the sites (high- and low-use sites) to obtain six strata. We treated each week as a separate survey, i.e., we randomized within a week and computed estimates by week. The stratification by week was used to make sure there were not long periods of time without any sampling and to facilitate tracking temporal trends in landings. We employed two stage random sampling within each stratum. At the first stage, 5 of the 6 days were selected for sampling; at the second stage, one site was selected for sampling all day long (i.e., 9:00 am – 5:00 pm). The number of trips and the catch per trip (by species) were recorded for the day. Where appropriate, the number of trips for which an interview was refused was recorded, as was the number of sampled trips that turned out to be recreational rather than commercial fishing. This design did not allow us to estimate among-day and among-site components of variability. However, it is possible to make a conservative estimate of the variance of the estimated landings (Cochran, 1977).

The sampling unit was the site x day combination, and the variable of interest was the landings during the whole day (for each species). In reality, not all trips could be sampled every day, though most trips were sampled except in the Puerto Real area (see below). A count of trips was obtained for each sampling day and the observed landings were expanded to the total landings for the day by multiplying by the ratio total trips counted/sampled commercial trips (as explained in Section 2.4.2, in some cases an additional adjustment was needed to apportion not-fully-identified catch to species).

The estimated total landings over a week (for any given species) is given by

$$\hat{Y} = NM \frac{\sum_{i=1}^n y_i}{n} = NM\bar{y} \quad (1)$$

where:

\hat{Y} = estimated total landings in the week for the species

y_i = observed landings of the species on day i of the week

N = number of fishing days during the week, generally 6

M = number of sites in the stratum

r_i = expansion factor for unsampled trips, = T_i/t_i where T_i = number of trips counted on day i , t_i = number of commercial trips sampled on day i

n = number of days sampled during the week, generally 5

\bar{y} = average landings per day

Note that \bar{y} as defined in (1) includes the expansion factors r_i . The estimated variance for \hat{Y} , $\hat{V}(\hat{Y})$, is given by

$$\hat{V}(\hat{Y}) = N^2 M^2 \hat{V}(\bar{y}) = N^2 M^2 \frac{\sum_{i=1}^n (y_i r_i - \bar{y})^2}{n(n-1)} \quad (2)$$

3.2.1 Puerto Real

For Puerto Rico West high-use stratum, the situation was more complicated. One site (Puerto Real Soltero, SOL) stopped cooperating with us and refused permission to sample on the dock. There are about five different private piers and docks where fishermen land and sell their catch: SOL, Marina Pescaderia (PRE), Bahia Pescaderia (BPR), Villa Pesquera (VPQ), and South (Fig. XXXX). Each of these locations purchase fish, but fishers are not bound to a specific site since they often change to whoever gives them the best price. Between the five locations, Soltero and Marina Pescaderia have the highest landings but since each is a different location separated by houses and gates, they must be sampled separately. We attempted to collect data from Soltero with the full cooperation of DRNA agent Luis Anibal who was the only one allowed at that site to sample the catch.

Although not allowed access our sampler, when assigned to SOL, could count the number of boats landing from the adjacent dock (Figure 20; Puerto Real Marina, PRE). We examined preliminary landings data from the site before cooperation ended and data collected by the DRNA's Fisheries Lab for a total of 23 samples We examined preliminary landings data from the Soltero before cooperation ended and relied heavily on Luis Anibal and data collected cooperatively by the DRNA's Fisheries Lab for a total of 26 days. The gear type used by the fishers landing at both SOL and PRE was almost 100% diving (Figure 21). We compared the landings per trip at SOL and PRE and found a strong linear relationship (Figure 22). Thus, the landings for SOL were estimated as the count of trips at SOL times the catch per trip at PRE. As

the survey progressed over time, we realized there were increasing landings occurring at two similar, nearby sites, BPR and VPQ) Counts of trips at these two sites could be made from PRE; catch rates at BPR were similar to those at PRE (Figure 22). A whole harbor boat count form was developed so that a sampler assigned to either site could record time of landing, gear used and landing site (Figure 23; See Appendix 2.6). Therefore, catch rates at PRE were applied to counts of trips at BPR and VPQ as well as SOL. This pertained to the period from August 2018 to the end of the survey.

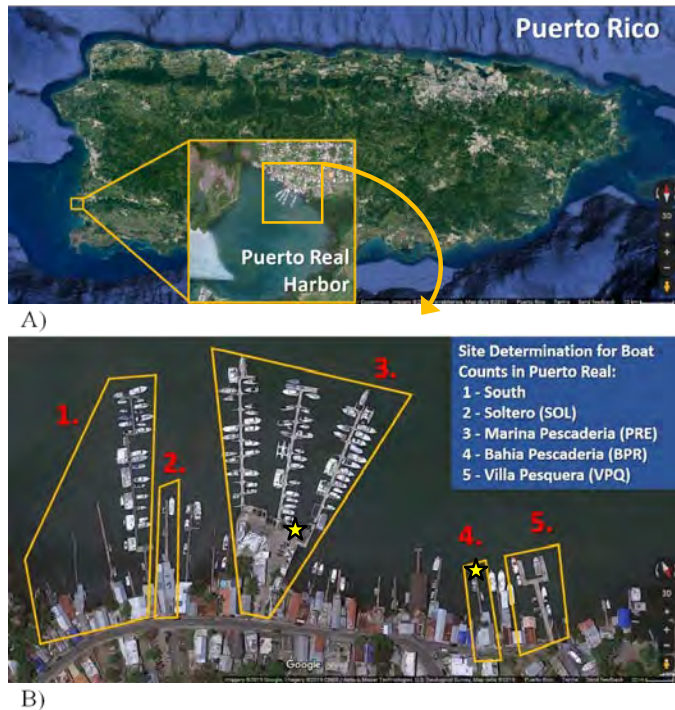


Figure 20. Sites, docks, sampling locations in Puerto Real Harbor, Cabo Rojo. A) Puerto Real Harbor location at West Coast. B) Sites and docks distribution in Puerto Real community. (Boat counts performed at sites marked with yellow star).

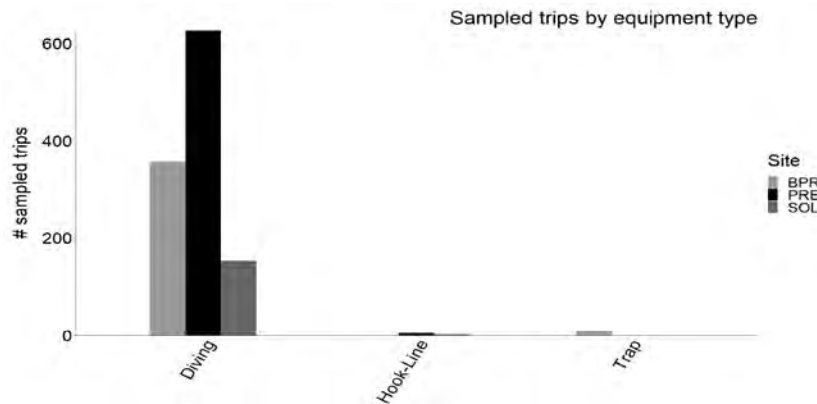


Figure 21. Number of sampled trips by gear type in Puerto Real Harbor.

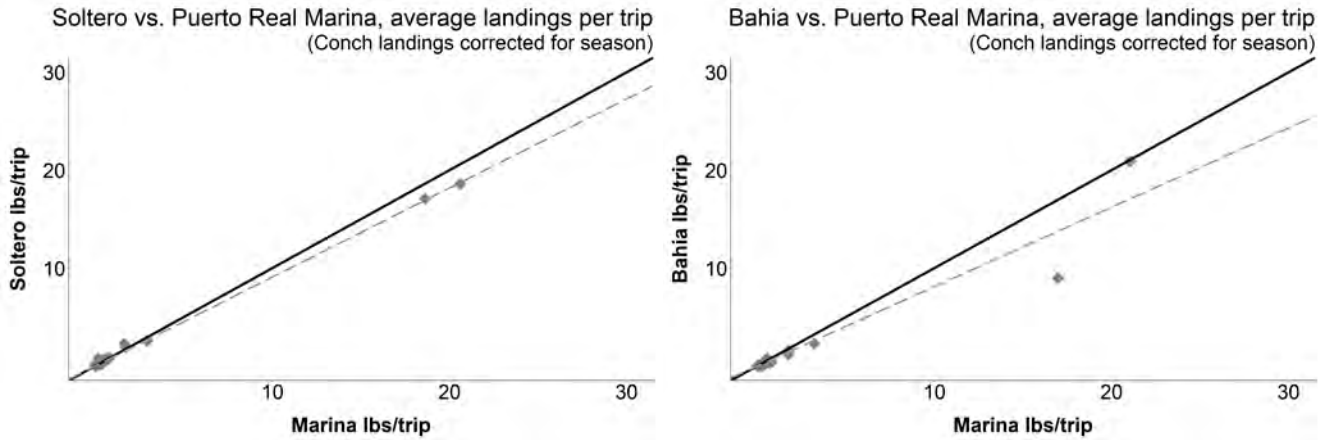


Figure 22. Evaluating site usage in Puerto Real Harbor. Landings per trip at Soltero (SOL) versus at Puerto Real Marina (PRE) and landings per trip at Bahia Puerto Real (BPR) versus at Puerto Real Marina (PRE).

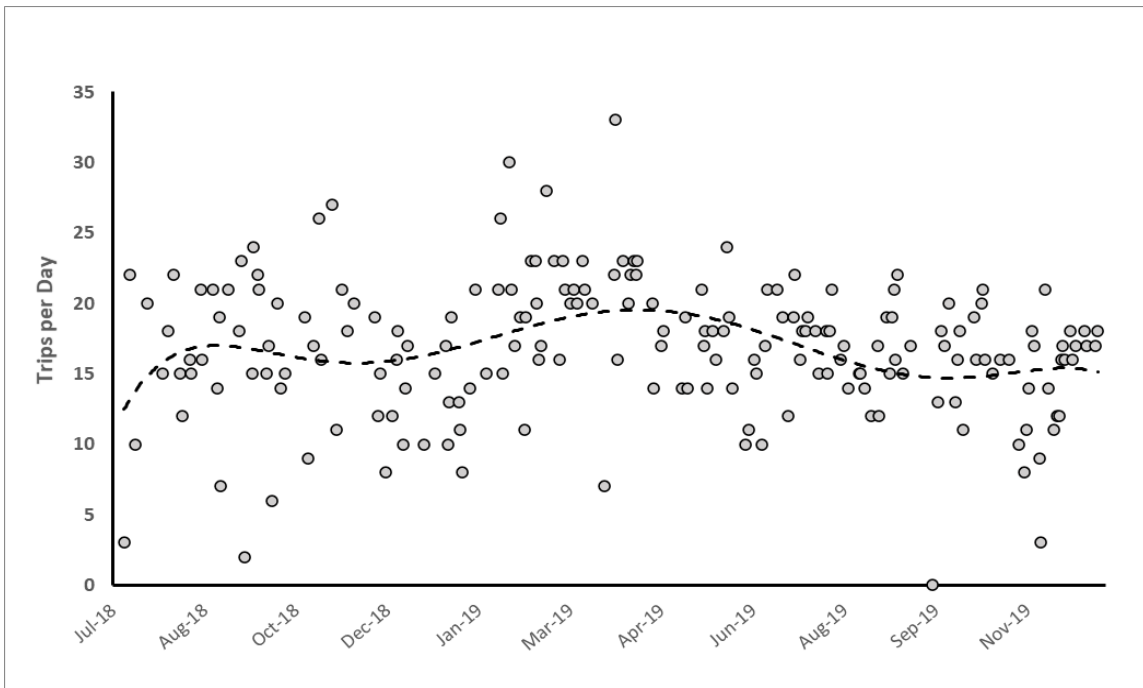


Figure 23. Total trips/day in Puerto Real Harbor (boat count data)

Landings per day at Puerto Real Marina (PRE) were estimated in the usual manner as $y_i r_i$ where the symbols are the same as for equation (1). We used a ratio estimator to impute the landings at the unsampled sites from the count of trips at each site and the cpue estimated from Puerto Real dock. Thus, the landings per day y'_i for SOL, BPE and VPQ were estimated as

$$y'_i = T_i r_i \text{cpue}_{\text{PRE}}; \tag{3}$$

the ' symbol is used to distinguish the estimated landings per day in this special case from that in equation (1), r_i is the expansion factor for commercial trips at PRE from (1), T_i is the number of trips counted at the unsampled site and the symbol cpue_{PRE} denotes the catch per unit effort at PRE averaged over the entire month. The cpue at PRE was calculated as the total observed (commercial) landings at Puerto Real dock for the entire month divided by the number of observed commercial trips during the month. This averaging is done to promote stability.

Thus, for a given sampling day, the landings at the four sites Puerto Real dock, Soltero, BPR and VPQ combined was estimated as

$$\text{Landings at all sites on day } i = r_i (\Sigma \text{trips at Soltero, BPR and VBQ}) \times \text{cpue}_{\text{PRE}} + r_i (\text{observed landings at Puerto Real on day } i) \tag{4}$$

where the symbols are defined as above.

Note that the sampling schedule was created before the problem of non-cooperation arose and we were able to develop an alternative estimation procedure. Consequently, although there were nominally four sites in the high-use stratum (Rincon Rampa, El Faro Cabo Rojo, Soltero and Puerto Real Marina), two of them (Soltero and Puerto Real dock) were combined into a single sampling unit and this unit was sampled twice as often as the other two units (i.e., sampling probabilities were 1/4, 1/4, and 1/2 for the 3 functional sampling units). This weighting of the results towards the combined unit needed to be considered. We did this using the Horvitz-Thompson estimator using weights (1/4, 1/4, and 1/2) to compute the mean catch/day in the stratum. That is, \bar{y} in equation (1) is now calculated as

$$\bar{y}' = \frac{\sum_{i=1}^n y_i r_i}{n p_i} \tag{5}$$

where the ‘ symbol distinguishes this estimator from the one in equation (1), and the p_i are the sampling weights. The total for the week is then estimated as

$$\hat{Y} = N\bar{y}' . \quad (6)$$

After the sampling plan was devised we discovered that there were non-insignificant landings at BPR and VPQ. This was accommodated in the sampling plan by redefining the Puerto Real dock site to be the combined Puerto Real, Soltero, BPR and VPQ landings. The sampling weights remain the same ($\frac{1}{4}$, $\frac{1}{4}$, and $\frac{1}{2}$) where the $\frac{1}{2}$ pertains to the combined Puerto Real, Soltero, BPR and VBQ site.

For the period March 2018 through July 2018, the counts of boats were made inconsistently. However, a linear regression was developed to predict the total number of boats landing on a day (anywhere in Puerto Real harbor) from the count of sampled trips at PRE. This equation was: estimated total = 1.6931 X + 8.8609, where X is the number of sampled trips at PRE. This regression prediction of trips at the four sites in Puerto Real harbor (other than PRE) was substituted for the count of boats for the period prior to August 2018.

3.2.2 Design for Puerto Rico North

For the North coast, we eventually settled on the use of two strata, with the high-use stratum consisting of a single site, Jarealito. Assigning one port sampler to each stratum proved inefficient because the high-use stratum was oversampled relative to the low-use stratum, and because repeated sampling of Jarealito began to annoy the fishers and raised the concern of reduced cooperation. Consequently, starting on July 22, 2018, we sampled the high-use stratum (i.e., Jarealito) only two days per week and sent the port sampler to the low-use stratum for the other three days of the week. The sampling for Jarealito becomes simple random sampling of days while the sampling for the low-use stratum becomes two stage cluster sampling. Because there are two sites sampled two or three days of the week it is possible to estimate the among-site component of variance resulting in unbiased estimates of the variance of the landings in the stratum (the among-site variance is estimated using just those days where two sampling agents were in the low-use stratum, i.e., using either two or three days of the week). Note that the two sampling programs (high-use and low-use) are no longer independent and in theory there should be a negative covariance between the two sets of estimates (if, for example, a port sampler is sent to the low-use stratum on a day when weather precludes most fishing – resulting in a low estimate for the week – then that agent did not go to the high-use stratum on that day – resulting in an estimate for the week that is high). We ignore this aspect because the covariance term is

not estimable under this design. The estimates for each stratum (total landings and variances) are unbiased, and the estimates for the coast (sum of landings for the two strata) are unbiased but the estimated variance for the coast is biased high (precision is better than indicated).

Thus, for the North high-use stratum, the estimated landings are given by equation (1) with $n=2$ days per week spent at the one site (Jarealito). The estimated variance is given by

$$\hat{V}(\hat{Y}) = N^2 \hat{V}(\bar{y}) = N^2 (1 - n/N) \frac{\sum_{i=1}^n (y_{i1} - \bar{y})^2}{n(n-1)} \quad (3)$$

where $1 - n/N$ is the finite population correction with value $1 - 2/6 = 0.67$.

For the North low-use stratum, the procedure is as follows. At the first stage, we pick 5 days to be sampled by the first port sampler. For the second port sampler, we pick 3 days to sample from the remaining 4 days of the week (i.e., the second port sampler spends 2 of the 6 days of the week at Jarealito and 3 of the remaining 4 days in the low-use stratum).

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, for days with 2 sites visited we want the mean of the two observations

$$\bar{y}_i = \sum_{j=1}^m \frac{y_{ij}}{m} = \sum_{j=1}^2 \frac{y_{ij}}{2} \quad (4)$$

For days with 1 site visited, the mean is simply the one observation, i.e.

$$\bar{y}_i = y_{ij} \quad .$$

Note that \bar{y}_i is the average catch per site for day i . We will also want the grand mean which we calculate as the mean of the daily means; the daily means are either single observations (for days in which only one site is sampled) or means of two observations (for days where 2 sites were visited).

$$\bar{\bar{y}} = \sum_{i=1}^n \frac{\bar{y}_i}{n} \quad (5)$$

In the above equation, $n = 5$ or 6 , the number of days of the week with any sampling activity. Note that we DO NOT calculate $\bar{\bar{y}}$ as the mean of all observations because that would weight

days with 2 observations more heavily than days with single observations. So, \bar{y} is the average catch per site per day or the average catch representing all sites and all days.

The estimated total landings is given by $N M \bar{y}$ where N is the number of days in the week (generally 6) and M is the number of sites.

To estimate the second stage variance we compute

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

Here, n is the number of days where you have 2 observations (which will be either 2 or 3 in a week), and m is 2, i.e., the number of sites visited on days when more than one site is visited. Note that this means that $m-1$ in the above equation is 1.

For example, suppose in a week the sampling schedule is:

Day	Mon	Tue	Wed	Thu	Fri	Sat
Sampler 1	---	X	X	X	X	X
Sampler 2	X	---	---	X	X	---

So, there are only $n=2$ days (Thursday and Friday) with $m=2$ sites visited during the day.

The second-stage variance s_2^2 is calculated from the observations on the 2 days. In the above variance equation, $n = m = 2$ (one uses all of the observations in the week to estimate the mean for the week). (It might have happened that sampler 2 was assigned Tuesday, Thursday and Friday, in which case $n=3$, $m=2$.)

To estimate the first-stage variance, s_1^2 , i.e., the day-to-day variability, we have

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

An unbiased estimate of the variance of \bar{y} (the average catch per site per day) can be obtained as

$$\hat{V}(\bar{y}) = \frac{1-f_1}{n} s_1^2 + \frac{f_1(1-f_2)}{mn} s_2^2$$

where

$$f_1 = n/N = \text{fraction of PSUs (days) sampled}$$

$$f_2 = m/M = \text{fraction of SSUs (locations) sampled in a day}$$

Consequently, an unbiased estimate of the variance of the estimated total landings (for a species) is given by

$$\hat{V}(\bar{Y}) = N^2 M^2 \hat{V}(\bar{y}).$$

3.2.3 Unsourced trips and non-commercial fishing trips

In all but the West high-use stratum, the vast majority of counted trips were sampled. However, in the high-use West stratum, unsourced trips were frequent due to the situation in Puerto Real. As explained above, a ratio estimator was used to expand the observed landings to the total.

Another issue that arose was the occurrence of non-commercial fishing trips. These were not counted in the daily observed totals, and the number of unsourced trips (that had to be expanded to the total) was reduced by the proportion of sampled trips that turned out to be non-commercial fishing trips. To illustrate the procedure, suppose we have 15 trips counted in total of which 13 were sampled and 2 were unsourced. Suppose further that among the 13 sampled trips, there were 10 commercial fishing trips and 3 trips that were recreational or charter. Then, if the total observed landings for a species was C, based on sampling n trips, the total over all commercial trips would be C(1 + adjustment) as follows:

$$\begin{aligned} \text{Total catch} &= C \times 1 + C \times \text{adjustment} \\ &= C \times 1 + (C/n) \times \text{number of unsourced commercial trips} \\ &= C \times 1 + (C/n) \times \text{proportion commercial trips} \times \text{number unsourced trips} \\ &= C + (C/10) \times (10/13) \times 2 \\ &= C \times (1 + (20/13)/10) \end{aligned}$$

This estimator is based on the assumption that the unsourced trips are similar to those that are sampled, which is reasonable if trips are unsourced for logistical reasons (two boats arrive at the

same time) rather than because of lack of cooperation. Cooperation was excellent in the survey with the exception of the one site in Puerto Rico West where the owner refused cooperation. For that one site, limited sampling suggested that the landings per trip were similar to those at the adjacent dock.

3.2.4 Methodology for unknown species records

The methodology that was used to assign a species to a record that has a family name, but no specific species (e.g., triggerfish unknown) is as follows:

For each unique region, strata and month combination, where month is a specific year-month, the dataset was subset for all species in that family. For example, the triggerfish family has four unique species – queen, ocean, gray, black, durgon, and Sargassum. If there are specific species that are caught within a unique region, strata, month and equipment type, the catch associated with the family unknown gets divided amongst those species (or single species) based on proportion caught. If there are no species-specific data within that equipment type, then species-specific information is used for the region-strata-month combination. If there is no species-specific information within the specific region-strata-month, the family unknown retains the family unknown designation.

For records which recorded mixed catch or unknown:

The catch associated with an “unknown” species (i.e., unidentified catch without family name) is allocated into species specific catch based on the species composition of a typical trip. A typical trip is identified as a trip with a representative species-specific catch composition within a region-stratum-month-equipment type. More specifically, we developed a “profile” of expected species composition from those trips in the region-stratum-month-equipment type that were sampled at least 80% (i.e., > 80% of the catch was identified) to apportion unidentified catch within the same region-stratum-month-equipment type combination. For example, for a trip with 40 pounds of unidentified catch, the “unknown” catch was divided into specific species catch by calculating the product of 40 pounds x proportion of the catch of each species within the species composition profile in the typical trip. We were able to obtain a typical trip profile within each region, stratum, month and equipment type for each corresponding unidentified catch weight. However, if species-specific information was unavailable for the most specific combination of factors, the profile of a typical trip could be obtained using all trips with > 80% of the catch identified within each region-stratum-gear or region-stratum combination.

3.3 Auxiliary Sampling

As part of the pilot study, 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. This information and additional visits to locations where activities were expected during the off hours time frames were used to prioritize sampling efforts.

3.3.1 Vieques and Culebra

Vieques and Culebra were sampled periodically as an exploratory study to see if landings were appreciable. Sampling was conducted at three sites: One site in Culebra, named *Culebra Municipio* was sampled as a low activity site. Two sites were sampled in Vieques: *La Esperanza* as a low activity site and *Morropo* was sampled as high activity (Figure 24). Initially sampling was done one time per month (from Oct-Dec, 2018) and then two times per month starting in January 2019 since activity appeared to be substantial and logistics allowed for the additional times. Once project was extended, from Sept- Dec 2019, we sampled *Morropo* four times per month to improve our monthly estimates.

For the purpose of getting an idea of the relative magnitude of the landings on these islands, we treated the data the same way we treated the data for the East, South and West coast daytime sampling programs and applied equations (1) and (2).

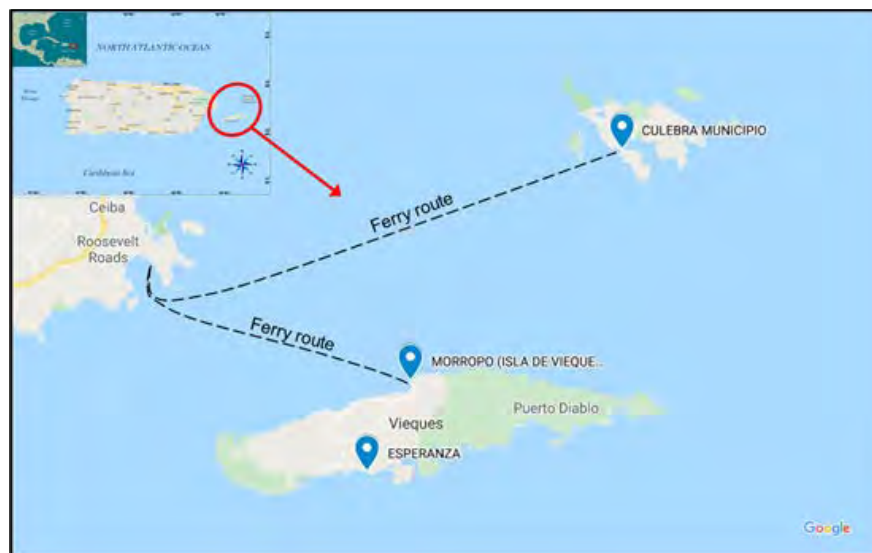


Figure 24. Sites Sampled in PR Islands, two sites located in Vieques, one site on Culebra. (Sampled from Oct 2018 – Dec 2019)

3.3.2 Off-hours sampling (AM, PM, and Sundays)

To sample fishing activity outside of our normal daytime sampling we utilized two strategies: a roving design or alternate design. Sampling was conducted by choosing four days per month for each of AM, PM and Sunday sampling at the sites indicated in Table 8.

Table 8. Off-Hours site stratum for Bus Routes and 4Hrs sampling. AM indicates time periods between 5:00-9:00hr. PM indicates time periods between 17:00-21:00hr. Sunday indicates time periods from 9:00-17:00hr on Sundays. (* indicates sampling had to be modified)

Site Name	Code	Region	Daytime Stratum	AM	PM	Sundays
BARRIO BAJURA	BAJ	North	LOW	4 Hr*	-	-
CALLE HOARE	HOA	North	LOW	BUS	-	-
LA COAL	COA	North	LOW	BUS	4 Hr	BUS
LA PRINCESA	PRI	North	LOW	BUS	4 Hr	BUS
LA PUNTILLA	PUN	North	LOW*	-	-	BUS
PUERTO MOSQUITO	MOS	North	LOW	-	4 Hr*	BUS*
HÚCARES	HUC	East	HIGH	4 Hr*	BUS*	BUS
LAS CROABAS	CRO	East	LOW	-	BUS*	BUS
MARINA PUERTO DEL REY	PDR	East	HIGH	-	BUS*	BUS
MAUNABO	MAU	East	-	4 Hr	-	-
PUERTO DE YABUCOA	PYA	East	LOW	-	4 Hr*	-
BAHÍA DE GUÁNICA	BDG	South	HIGH	BUS	4 Hr	BUS
BAHÍA GUAYANILLA	BGU	South	-	BUS*	-	-
LA GUANCHA	LGU	South	LOW	BUS	-	-
PLAYA DE PONCE	PDP	South	LOW	BUS	4 Hr	BUS
SALINAS PROVIDENCIA	SAL	South	LOW	BUS	-	-
TALLABOA	TAL	South	HIGH	-	-	BUS
BARRIO BARRERO	BAR	West	-	-	-	BUS
BARRIO ESPINAL	BES	West	LOW*	BUS	-	-
BARRIO TAMARINDO	BTA	West	LOW	BUS	-	BUS
BOQUERÓN RAMPA	BOQ	West	LOW	-	BUS	BUS*
CÓRCEGA	CRG	West	-	-	-	BUS*
EL COMBATE	COM	West	LOW **	-	BUS	-
EL FARO CABO ROJO	FAR	West	HIGH **	-	BUS	BUS
EL SECO RAMPA	SEC	West	LOW	BUS	BUS	BUS
GUANIQUILLA AGUADA	GUB	West	-	-	-	BUS*
PARCELAS ESTELA	PES	West	-	-	-	BUS*
PLAYUELA	PLA	West	LOW	-	-	BUS
PUERTO REAL / MARINA	PRE	West	HIGH	-	-	BUS*
RINCÓN RAMPA	RIN	West	HIGH	-	4 Hr	BUS

Roving design. Resembles a bus-route design (Robson and Jones 1989), and involves having the port sampling agent follow a precise route to visit each sampling site during a sampling day. For the AM surveys, the sampling day was four hours long; for the PM surveys it was also four hours and for the Sunday surveys it was eight hours. The procedure for designing the roving survey is as follows:

- 1) Lay out a route that starts at one site, connects all of the sites, and ends back at the first site.
- 2) Determine the total travel time required to follow the entire route and subtract from the length of the day to give the amount of time available for sampling (Table 9; Figures 25, 26 and 27).
- 3) Divide the amount of time available for sampling by the number of sites to determine the time to spend at each site.
- 4) Pick the days that are to be sampled during the month.
- 5) For each day to be sampled, randomly pick the starting place along the route; start at that point and end up at that point at the end of the day.

Table 9. Bus-Routes total sampling and driving times on each region by type of sampling

Type	Region	Number of Sites	Time per site (min)	Total sampling time (min)	Total drive-time (min)
AM	North	3	66	198	42
AM	South	4	30	120	120
AM	West	3	50	150	90
PM	West	3	46	138	102
Sunday	North	3	142	426	54
Sunday	East	3	134	402	78
Sunday	South	3	134	402	78
Sunday	West- North	6	59	354	126
Sunday	West- South	3	124	372	108

For example, suppose we want to set up a schedule for AM sampling in a region with three sites to sample and total travel time of 60 minutes. Then there are 360 minutes in four hours, minus 60 minutes needed for travel, equals 300 minutes available for sampling. And, 300 minutes divided by three sites gives 100 minutes per site. The route is set up as:

A → B → C → A

Thus, if we started at A at 5:00 am (minute 0), we would stay at A for 100 minutes, then travel to B and stay there for 100 minutes, then travel to C and sample for 100 minutes. If we then travel back to A we would arrive there at time = 360 minutes, i.e., 9:00 am (of course, in this particular case, there would be no need to travel from C to A at the end of the day because there would be no sampling at A upon arrival the second time. Consequently, the port sampler could terminate work after completing the sampling at site C).



Figure 25. Sunday Bus routes by region. Note that in the West two separate bus routes were utilized.

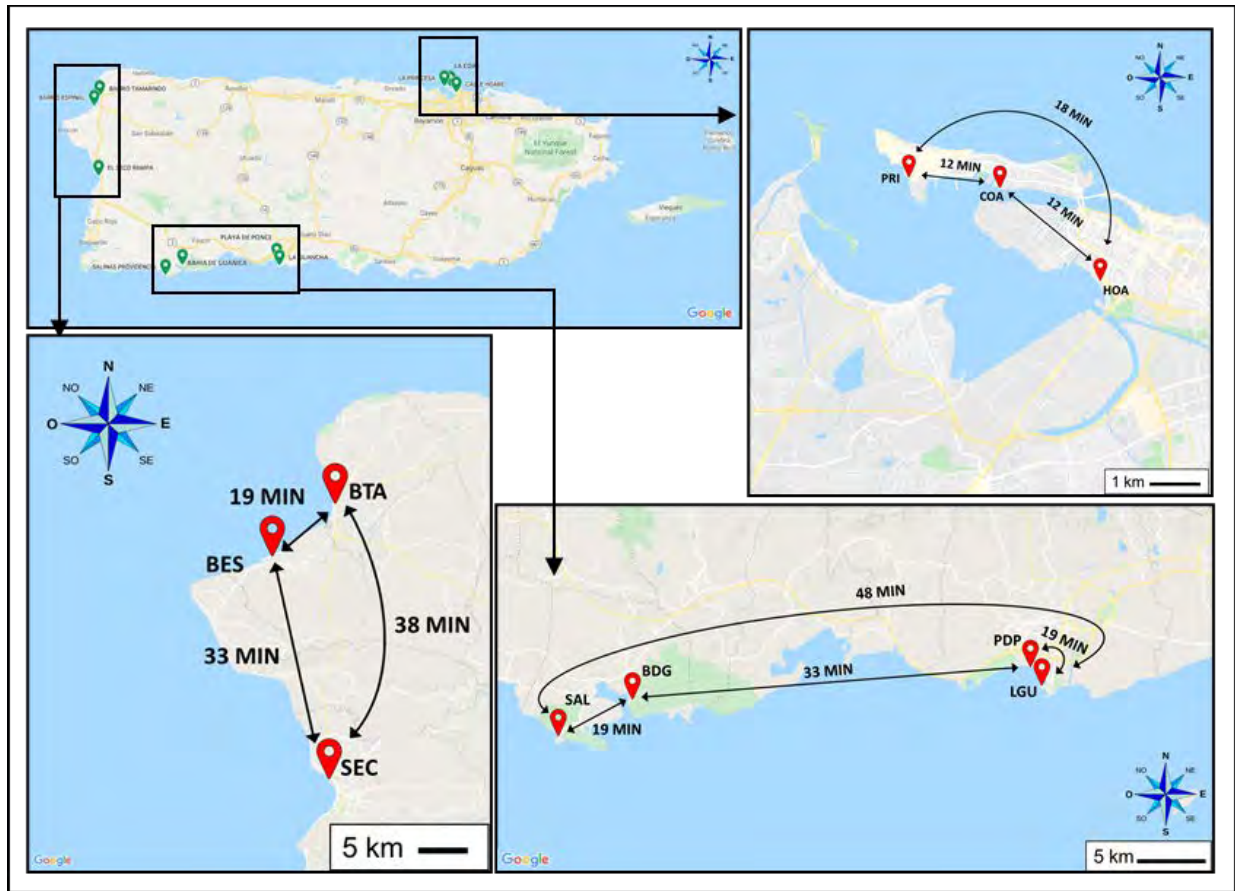


Figure 26. Morning (AM) Bus routes and Sites divided by region.

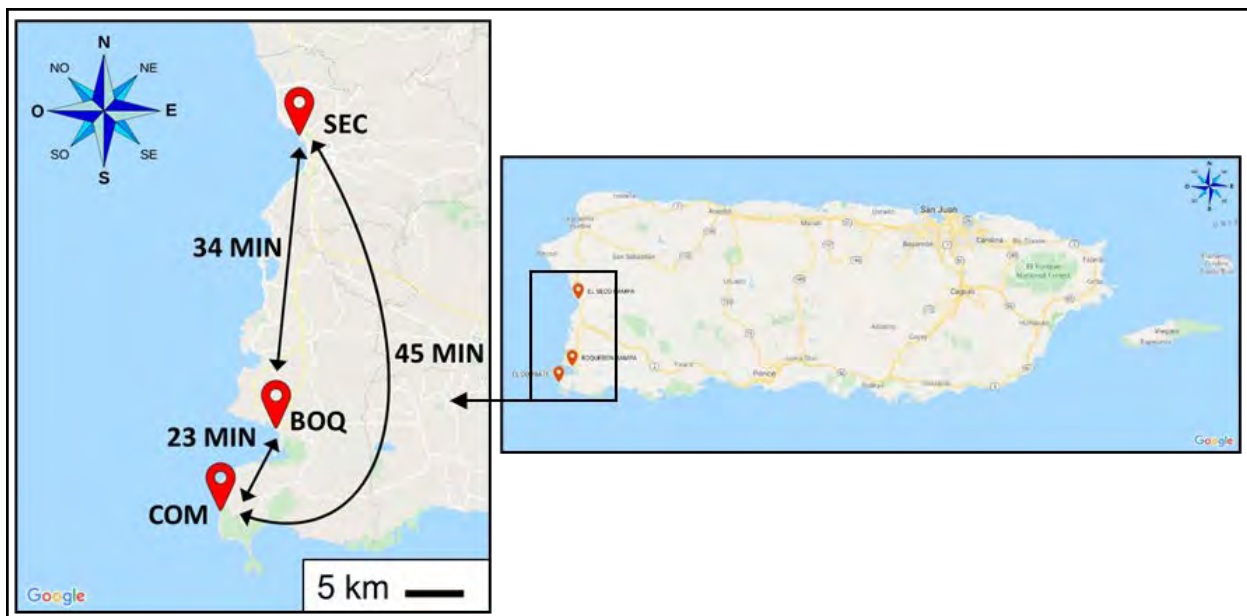


Figure 27. Evening (5pm -9pm) Bus routes and Sites in the West Region.

In practice, we pick a random starting point along the route. For example, we might randomly pick a start 20 minutes into the sampling at site A. In this case, we sample at A for 80 minutes (starting at 5:00 am and staying there until 6:20), then travel to B to sample for 100 minutes, then to C, and then return to A to do the last 20 minutes of sampling.

For a few days, the randomized schedule called for the survey agent to visit a site for just a few minutes either at the start of the day or at the very end of the day. As a practical matter, if the travel time to visit the site was long relative to the sampling time, e.g., 30 minutes of travel for five minutes of sampling, then the sampling was foregone.

Estimation proceeds as follows. By design, each site on the route has equal probability of being sampled at any time. Consequently, the total landings observed during the sampling day is an unbiased estimate of the landings per site during a period of time equal to the total sampling time (i.e., either 4 hours minus travel time or 8 hours minus travel time). The observed landings is expanded upward to the full sampling day (4 or 8 hours) by multiplying by (length of day)/(time spent sampling) and then multiplying by the number of sites to obtain the estimate for the stratum for the sampling day. In symbols, let d_i be the estimated landings for all M sites combined on day i ; let T be the length of the day (either 4 hours or 8 hours), and S be the number of minutes during the day when the agent is sampling, not travelling. Then,

$$d_i = M (T/S) \sum_j d_{ij}$$

where d_{ij} is the observed landings at site j during day i . The mean catch per day is estimated as \bar{d} , the simple mean of the d_i . The estimated variance of \bar{d} is

$$\hat{V}(\bar{d}) = \hat{V}(d_i)/n$$

where $\hat{V}(d_i)$ is the simple sample variance of the n values of d_i . It follows that the total catch \hat{Y} for N days is

$$\hat{Y} = N\bar{d}$$

and

$$\hat{V}(\hat{Y}) = N^2 \hat{V}(\bar{d}).$$

Alternative design. In several cases, the above roving design was not practical and we selected locations which we felt might have highest activity and therefor inform about possible upper bounds on site activity. Thus, we treated these cases separately with alternative designs, as described below (Figure 28).

One site. For AM or PM surveys with only one site, we asked the port agent to work a 12-hour day on four days scheduled for that site during the day during each month. In this way, the sampler would complete the normally scheduled 8-hour working day plus either an AM sampling or a PM sampling. In the event there weren't four days scheduled for daytime sampling at the site, days were selected as necessary from all possible sampling days in the month for the agent to sample the site. This was done for East coast AM sampling and North coast PM sampling. This gave a simple random sample of four early morning dates and four evening dates.

Two sites. For AM or PM surveys with two sites, we randomly picked two days per month to sample one site and two days per month to sample the other site. Each sampling event comprised four hours. In this way, no time was lost travelling between sites. This was done for East coast PM sampling and South coast PM sampling. Estimation proceeded as for simple random sampling.

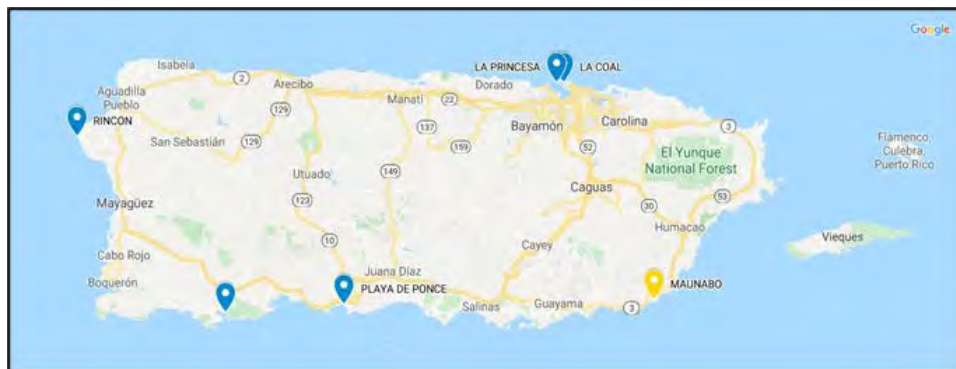


Figure 28. All Off Hours Sites in Puerto Rico. AM = 1 site (yellow pin), PM = 5 sites (blue pins).

In April of 2019, auxiliary sampling was only conducted in Vieques and Culebra due to Holy week and logistic considerations. Estimates for AM/PM/Sundays were calculated as the average of the two months prior and after (February, March, May, and June).

3.4 Hurricane Maria Modifications

The statistical design - well informed from the pilot study and months of careful logistic planning - met the reality of conducting research in the tropics less than a month after port sampling began. On September 6th and then on September 20th, Hurricanes Irma and Maria, respectively, devastated the USVI and Puerto Rico. In terms of the fisheries, very few places were entirely spared from damages made by the storm. Boats and fishing gear were lost. Some landing sites were simply gone, and others had lost hundreds of yards of beach. The ability to launch vessels, use storage facilities, and navigate through certain channels had diminished. Even locations not directly impacted by the damage were rendered useless by the loss of power and inability to run freezers or make ice.

The return to normalcy was not going to be swift, and the only silver lining for the sampling team was that damages and economic impact to the fishery needed to be assessed and they were already trained and on the ground. This worked out very well as DRNA, in consultation with SEFSC, was able to re-task a trained crew already in place, keeping the sampling team employed during this difficult time. This allowed us to regroup while not losing our trained personnel. However, our sampling design was based on the results from the pilot study and relative usage of study sites had been affected by the storms. We communicated with Daniel Matos (DRNA) and monitored the situation by conducting spot checks on sites to determine when the fisheries began to return to some level of normalcy. In late January and early February 2018, it appeared that the fishery in Puerto Rico was operating at around 75% of its previous capacity and we consulted with SEFSC and GSMFC to determine the path forward. Given the situations on the ground in the USVI and Puerto Rico, the additional complexities due to the storms, and remaining budget, it was determined that we should focus the remainder of our work on obtaining at least one year of high-quality data in Puerto Rico.

At the beginning of February 2018, four samplers visited 106 sites (101 provided by DRNA in 2014 and an additional 5 based on observations) to determine changes in effort and which sites should be included in what strata for a modified post hurricane design (Table 10). 41 sites were selected throughout the island to have significant fishing activity (Figure 29). On March 15th, once again, we began sampling with two full time people per coast with the same basic design as prior to the storms.). Given the uncertainty about stratification due to shifting effort, we conducted spot checks at heavily damages sites that may have been recovering or locations which had historically seen some activity. Our electronic reporting system gave us the ability to analyze the data and share pictures of sites daily so there was little disconnect between the on the ground teams and analysts. We conducted two data evaluations on relative usage between March and June in which we were able to remove, add or re-stratify sites given the results.

In August 2018, we were confident that the fisheries had recovered close to normal and that we had collected enough data to be confident in our daytime stratification and overall spot checking

to implement auxiliary sampling and the full-scale program. We began sampling early mornings (denoted AM sampling throughout the report, 5am – 9 am), early evenings (denoted PM, 5pm – 9 pm), Sundays (9am – 5 pm), and Vieques and Culebra (denoted Islands, 9am – 5pm). A variety of survey designs were used with a heavy reliance on a roving survey design. Visiting multiple sites on a roving route during a sampling assignment allowed us to explore a number of sites with questionable activity levels. This was used in conjunction with 4-hour AM and PM assignments at specific sites where we were confident of relatively high activity to collect additional data at or near the upper bounds of activity. We conducted a quarterly analysis of the data and modified stratifications, as necessary.

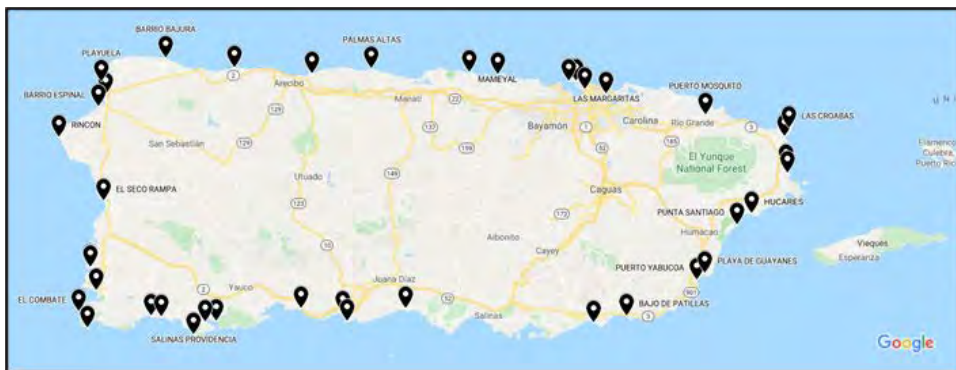


Figure 29. Sites used on startup of 2018 sampling. After-Hurricane Maria (Mar-Oct 2018) (41 sites)

Table 10. Site Evaluation after Hurricane Maria. Site list provided by DRNA and local samplers . Visits to sites, done in Feb/2018. (Pre-Hur. Stratum=strata used on Aug-Sept/2017, Post-Hur. Stratum=strata used on Mar/2018) 101 sites total.

#	Region	Site		Pre-Hur.	Recomend.	Notes on Recommendations	Post-Hur.
		Code	Site Name	Stratum			Stratum
1	North	BAJ	BARRIO BAJURA	LOW	LOW	Keep original strata	LOW
2	North	HOA	CALLE HOARE	LOW	LOW	Keep original strata	LOW
3	North	JAR	JAREALITO	LOW	HIGH	Used as "LOW" to see activity	LOW
4	North	COA	LA COAL	LOW	LOW	Keep original strata	LOW
5	North	PRI	LA PRINCESA	LOW	LOW	Keep original strata	LOW
6	North	MAM	MAMEYAL	LOW	HIGH	Used as "LOW" to see activity	LOW
7	North	ALT	PALMAS ALTAS	LOW	LOW	Keep original strata	LOW
8	North	MOS	PUERTO MOSQUITO	LOW	LOW	Keep original strata	LOW
9	North	PEN	PUNTA PEÑON	LOW	LOW	Keep original strata	LOW
10	North	TOR	TORRECILLA	LOW	DROP	Very low activity	n/a
11	North	VIE	VIETNAM	LOW	DROP	Very low activity	n/a
12	East	HUC	HUCARES	HIGH	HIGH	Keep original strata	HIGH
13	East	PDR	MARINA PUERTO DEL REY	HIGH	HIGH	Keep original strata	HIGH
14	East	MAT	MATERNILLO	HIGH	HIGH	Keep original strata	HIGH
15	East	BLM	BARRIO LOS MACHOS	LOW	LOW	Keep original strata	LOW
16	East	SAR	BARRIO SARDINERA	LOW	SPOT CHECK	Kept as "LOW" to follow changes	LOW
17	East	CRO	LAS CROABAS	LOW	LOW	Keep original strata	LOW
18	East	PDG	PLAYA DE GUAYANES	LOW	SPOT CHECK	Very low activity	LOW
19	East	PYA	PUERTO YABUCOA	LOW	LOW	Keep original strata	LOW
20	East	PCA	PUNTA CANDELERO (PALMAS)	LOW	DROP	Site was completely damaged by hurricane	n/a
21	East	PSA	PUNTA SANTIAGO	LOW	LOW	Keep original strata	LOW
22	South	BDG	BAHIA DE GUANICA	HIGH	HIGH	Keep original strata	HIGH
23	South	LPG	LA PARGUERA	HIGH	LOW	Kept as "HIGH" to follow changes	HIGH
24	South	PAS	PASTILLO	HIGH	LOW	Kept as "HIGH" to follow changes	HIGH
25	South	TAL	TALLABOA	HIGH	HIGH	Keep original strata	HIGH
26	South	BDP	BAJO DE PATILLAS	LOW	LOW	Very low activity	LOW
27	South	LPR	LA PARGUERA RAMPA	LOW	DROP	No Commercial Fishing	n/a
28	South	PDP	PLAYA DE PONCE	LOW	HIGH	Showed more activity than before	HIGH
29	South	PLP	PLAYA LAS PALMAS	LOW	SPOT CHECK	Kept as "LOW" to follow changes	LOW
30	South	PAP	PUNTA PAPAYO	LOW	LOW	Keep original strata	LOW
31	South	SAL	SALINAS PROVIDENCIA	LOW	LOW	Keep original strata	LOW
32	West	PRE	PUERTO REAL / MARINA PESCADERIA	HIGH	HIGH	Keep original strata	HIGH
33	West	SOL	SOLTERO PUERTO REAL	HIGH	HIGH	Keep original strata	HIGH
34	West	BTA	BARRIO TAMARINDO	LOW	SPOT CHECK	Kept as "LOW" to follow changes	LOW
35	West	COM	EL COMBATE	LOW	LOW	Keep original strata	LOW

Table 10. (Continued) Site Evaluation after Hurricane Maria. List provided by DRNA and local samplers. Visits to sites, done in Feb/2018. (Pre-Hur. Stratum=strata used on Aug-Sept/2017, Post-Hur. Stratum=strata used on Mar/2018). 101 sites total.

#	Region	Site Code	Site Name	Pre-Hur. Stratum	Recomend.	Notes on Recommendations	Post-Hur. Stratum
36	West	FAR	EL FARO CABO ROJO	LOW	LOW	Keep original strata	LOW
37	West	SEC	EL SECO RAMPA	LOW	LOW	Keep original strata	LOW
38	West	PLA	PLAYUELA	LOW	LOW	Keep original strata	LOW
39	West	RIN	RINCON	LOW	HIGH	Showed more activity than before	HIGH
40	North	ANC	ANCONES (LOIZA)	n/a	NOT USE	Very low activity	n/a
41	North	ARE	ARECIBO RAMPA	n/a	NOT USE	Very low activity	n/a
42	North	BAC	BARCELONETA BOCA (PUEBLO)	n/a	NOT USE	No Fishing	n/a
43	North	GOR	CERRO GORDO	n/a	LOW	Significant activity, use as "LOW" to see activity.	LOW
44	North	FOR	FORTUNA	n/a	NOT USE	No Fishing	n/a
45	North	HAT	HATILLO BARRIO PUEBLO	n/a	NOT USE	No Fishing	n/a
46	North	JBB	JOBOS BARRIO	n/a	NOT USE	Very low activity	n/a
47	North	CAL	LA CALIFORNIA (LOS TUBOS)	n/a	NOT USE	No Fishing	n/a
48	North	PUN	LA PUNTILLA	n/a	HIGH	Ramp blocked, not using at time	LOW
49	North	MAR	LAS MARGARITAS	n/a	HIGH	Significant activity, use as "LOW" to see activity.	LOW
50	North	MED	MEDIANIA BAJA	n/a	SPOT CHECK	Very low activity	n/a
51	North	PLM	PALMER	n/a	NOT USE	No Fishing	n/a
52	North	PSC	PALO SECO	n/a	NOT USE	No Fishing	n/a
53	North	VEQ	PARCELAS VIEQUES (BOCA HERRERA)	n/a	NOT USE	Landings are from Puerto Mosquito	n/a
54	North	PNU	PUERTO NUEVO	n/a	SPOT CHECK	Very low activity	n/a
55	North	PTM	PUNTA MARACAYO	n/a	NOT USE	No Fishing	n/a
56	North	SUA	SUAREZ	n/a	NOT USE	Very low activity	n/a
57	East	COR	EL CORCHO, NAGUABO	n/a	NOT USE	Very low activity	n/a
58	East	MAU	MAUNABO	n/a	SPOT CHECK	Very low activity	n/a
59	East	PLU	PLAYA LUCIA	n/a	NOT USE	No Fishing	n/a
60	East	PTF	PUNTA FIGUERAS	n/a	NOT USE	No Fishing	n/a
61	Islands	CUL	DAKITY STATION CULEBRA	n/a	SPOT CHECK	Site off island, consider logistics	n/a
62	Islands	ESP	ESPERANZA VIEQUES	n/a	SPOT CHECK	Site off island, consider logistics	n/a
63	Islands	MOR	MORROPO VIEQUES	n/a	HIGH	Site off island, consider logistics	n/a
64	South	AGU	AGUIRRE BARRIO	n/a	NOT USE	No Fishing	n/a
65	South	BGU	BAHIA DE GUAYANILLA	n/a	NOT USE	Very low activity	n/a
66	South	CGO	BALNEARIO DE CAÑA GORDA	n/a	NOT USE	Very low activity	n/a
67	South	BRR	BARRANCAS	n/a	NOT USE	No Fishing	n/a
68	South	BGY	BARRIO GUAYPAO	n/a	HIGH	Site showed some fishing activity	LOW
69	South	FGU	FARO (GUAYANILLA)	n/a	NOT USE	No Fishing	n/a
70	South	GUA	GUARDARRAYA BARRIO	n/a	NOT USE	No Fishing	n/a

Table 10. (Continued) Site Evaluation after Hurricane Maria. List provided by DRNA and local samplers. Visits to sites, done in Feb/2018. (Pre-Hur. Stratum=strata used on Aug-Sept/2017, Post-Hur. Stratum=strata used on Mar/2018). 101 sites total.

#	Region	Site Code	Site Name	Pre-Hur. Stratum	Recomend.	Notes on Recommendations	Post-Hur. Stratum
71	South	JOB	JOBOS	n/a	NOT USE	Very low activity	n/a
72	South	LGU	LA GUANCHA PASEO TABLADO	n/a	LOW	Site showed some fishing activity	LOW
73	South	LMA	LAS MAREAS	n/a	SPOT CHECK	Very low activity	n/a
74	South	MAZ	MANZANILLO	n/a	NOT USE	Very low activity	n/a
75	South	RPJ	RAMPA PUBLICA DE JOBOS	n/a	NOT USE	No Fishing	n/a
76	South	PCO	PLAYA CORTADA	n/a	SPOT CHECK	Very low activity	n/a
77	South	PJA	PLAYA DE JAUCA	n/a	NOT USE	No Fishing	n/a
78	South	PDS	PLAYA DE SALINAS	n/a	NOT USE	Very low activity	n/a
79	South	SIS	PLAYA DE SANTA ISABEL	n/a	NOT USE	Very low activity	n/a
80	South	PPO	PUNTA POZUELO	n/a	SPOT CHECK	Very low activity	n/a
81	South	SAF	SALINAS FORTUNA	n/a	NOT USE	No Fishing	n/a
82	South	TUQ	TUQUE	n/a	NOT USE	No Fishing	n/a
83	South	LMG	LAS MAREAS GUAYAMA	n/a	NOT USE	No Fishing	n/a
84	West	BAR	BARRIO BARRERO	n/a	NOT USE	Very low activity	n/a
85	West	BES	BARRIO ESPINAL	n/a	HIGH	Not enough activity, use as "LOW"	LOW
86	West	BQN	BOQUERON	n/a	SPOT CHECK	Very low activity	n/a
87	West	BOQ	BOQUERON RAMPA	n/a	NOT USE	Very low activity	n/a
88	West	CBA	CANO BOQUILLA	n/a	NOT USE	Very low activity	n/a
89	West	CRG	CORCEGA	n/a	NOT USE	No Fishing	n/a
90	West	GJB	GUANAJIBO BARRIO	n/a	NOT USE	No Fishing	n/a
91	West	GUQ	GUANIQUILLA	n/a	NOT USE	No Fishing	n/a
92	West	GUB	GUANIQUILLA BARRIO	n/a	NOT USE	Very low activity	n/a
93	West	HIG	HIGUEY	n/a	SPOT CHECK	Very low activity	n/a
94	West	JOY	JOYUDA	n/a	NOT USE	No Fishing	n/a
95	West	MAN	MANI	n/a	NOT USE	No Fishing	n/a
96	West	MMS	MARINA MERIDIONAL	n/a	SPOT CHECK	Very low activity	n/a
97	West	PES	PARCELAS ESTELA (RINCON MUNICIPIO)	n/a	NOT USE	Very low activity	n/a
98	West	VPQ	PUERTO REAL/ VILLA PESQUERA	n/a	SPOT CHECK	Very low activity	n/a
99	West	PTP	PUNTA PITAHAYA	n/a	NOT USE	Very low activity	n/a
100	West	RAS	RASQUETA (MAYAGUEZ MUNICIPIO)	n/a	NOT USE	No Fishing	n/a
101	West	THE	TRES HERMANOS	n/a	SPOT CHECK	Very low activity	n/a

3.5 Quarterly Evaluations and Stratification

We conducted a quarterly analysis of the data using average landings per day on each sampled site to evaluate if any changes were occurring as facilities and docks were rebuilt (Figure 30). Sites and stratifications were modified as necessary. A summary of evaluated time blocks and resulting changes can be found in (Tables 11 and 12).

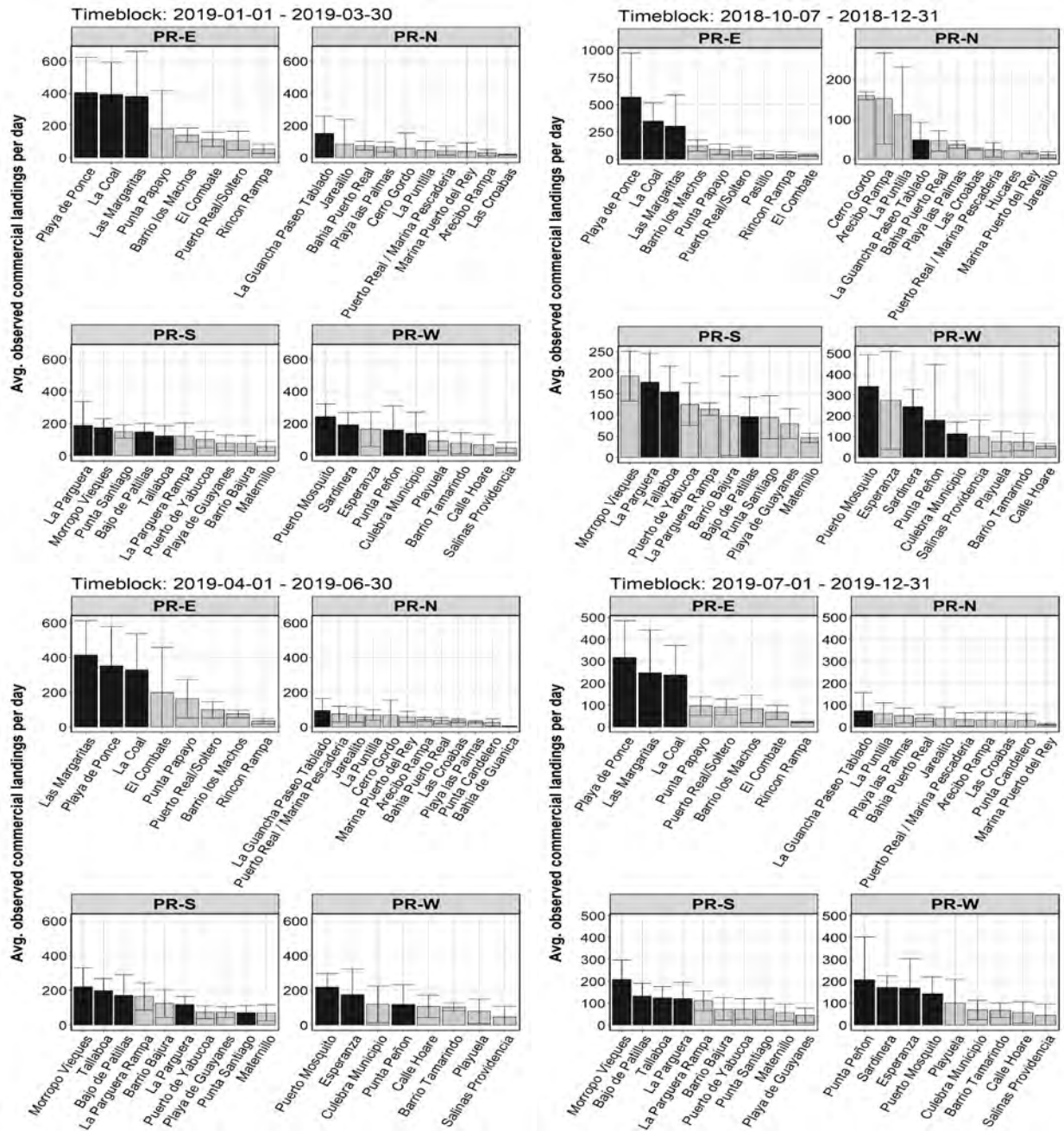


Figure 30. Quarterly Evaluation usage plots. Note last panel is from July until the end of project as stratification did not change in the second half of 2019.

Table 11. Number of sites in each of the eight strata by time period. HIGH and LOW refer to the usage category of the sites.

Time Period	Dates	East HIGH	East LOW	North HIGH	North LOW	South HIGH	South LOW	West HIGH	West LOW
0	Aug/7 - Sept/18, 2017	3	7	0	11	4	6	2	6
1	Mar/15 - Jun/30, 2018	3	6	0	12	5	6	3	6
2	Jul/1 - Jul/21, 2018	3	6	1	10	3	8	4	5
3	Jul/22 - Oct/6, 2018	3	6	1	10	3	8	4	6
4	Oct/8 - Dec/30, 2018	3	6	1	10	3	7	4	5
5	Jan/2 - Mar/30, 2019	3	5	1	9	4	6	4	5
6	Apr/1 - Jun/30, 2019	3	5	1	11	5	5	4	5
7	Jul/1 - Dec/30, 2019	3	5	1	10	4	6	4	5

Table 12. List of sites by region and their stratum designation for each Time Period. (*site had change of stratum between periods)

Region	Site Name	Code	Time Period							
			0	1	2	3	4	5	6	7
North	JAREALITO*	JAR	L	L	H	H	H	H	H	H
North	PALMAS ALTAS	ALT	L	L	L	L	L	L	L	L
North	BARRIO BAJURA	BAJ	L	L	L	L	L	L	L	L
North	LA COAL	COA	L	L	L	L	L	L	L	L
North	CALLE HOARE	HOA	L	L	L	L	L	L	L	L
North	MAMEYAL	MAM	L	L	L	L	L	L	L	L
North	PUERTO MOSQUITO	MOS	L	L	L	L	L	L	L	L
North	PUNTA PEÑON	PEN	L	L	L	L	L	L	L	L
North	LA PRINCESA	PRI	L	L	L	L	L	L	L	L
North	TORRECILLA*	TOR	L	Drop	Drop	Drop	Drop	Drop	Drop	Drop
North	VIETNAM*	VIE	L	Drop	Drop	Drop	Drop	Drop	Drop	Drop
North	LAS MARGARITAS*	MAR	-	L	L	L	L	L	L	L
North	LA PUNTILLA*	PUN	-	L	Drop	Drop	Drop	Drop	L	L
North	ARECIBO RAMPA*	ARE	-	-	-	-	-	-	L	Drop
North	CERRO GORDO*	GOR	-	L	L	L	L	Drop	Drop	Drop
East	HUCARES	HUC	H	H	H	H	H	H	H	H
East	MATERNILLO	MAT	H	H	H	H	H	H	H	H
East	MARINA PUERTO DEL REY	PDR	H	H	H	H	H	H	H	H
East	BARRIO LOS MACHOS	BLM	L	L	L	L	L	L	L	L
East	LAS CROABAS	CRO	L	L	L	L	L	L	L	L
East	PUNTA SANTIAGO	PSA	L	L	L	L	L	L	L	L
East	PUERTO DE YABUCOA	PYA	L	L	L	L	L	L	L	L
East	SARDINERA	SAR	L	L	L	L	L	L	L	L
East	PUNTA CANDELERO*	PCA	L	Drop	Drop	Drop	Drop	Drop	Drop	Drop
East	PLAYA DE GUAYANES*	PDG	L	L	L	L	L	Drop	Drop	Drop
Island	MORROPO VIEQUES*	MOR	-	-	-	-	H	H	H	H
Island	CULEBRA MUNICIPIO*	CUL	-	-	-	-	L	L	L	L
Island	ESPERANZA*	ESP	-	-	-	-	L	L	L	L
South	BAHIA DE GUANICA	BDG	H	H	H	H	H	H	H	H
South	LA PARGUERA	LPG	H	H	H	H	H	H	H	H
South	PASTILLO*	PAS	H	H	L	L	L	H	H	H
South	TALLABOA	TAL	H	H	H	H	H	H	H	H
South	BAJO DE PATILLAS	BDP	L	L	L	L	L	L	L	L
South	PUNTA PAPAYO	PAP	L	L	L	L	L	L	L	L
South	PLAYA DE PONCE*	PDP	L	H	L	L	L	L	L	L
South	PLAYA LAS PALMAS	PLP	L	L	L	L	L	L	L	L
South	SALINAS PROVIDENCIA*	SAL	L	L	L	L	L	L	H	L
South	LA PARGUERA RAMPA*	LPR	L	Drop	Drop	Drop	Drop	Drop	Drop	Drop
South	LA GUANCHA	LGU	-	L	L	L	L	L	L	L

Table 12. (Continued) List of sites by region and their stratum designation for each Time Period. (*site had change of stratum between periods)

Region	Site Name	Code	Time Period							
			0	1	2	3	4	5	6	7
South	BARRIO GUAYPAO*	BGY	-	L	L	L	Drop	Drop	Drop	Drop
West	PUERTO REAL MARINA	PRE	H	H	H	H	H	H	H	H
West	PUERTO REAL, SOLTERO	SOL	H	H	H	H	H	H	H	H
West	EL FARO CABO ROJO*	FAR	L	L	L	L	L	L	H	H
West	RINCON RAMPA*	RIN	L	H	H	H	H	H	H	H
West	BARRIO TAMARINDO	BTA	L	L	L	L	L	L	L	L
West	EL COMBATE*	COM	L	L	H	H	H	H	L	L
West	PLAYUELA	PLA	L	L	L	L	L	L	L	L
West	EL SECO RAMPA	SEC	L	L	L	L	L	L	L	L
West	BAHIA PUERTO REAL*	BPR	-	-	-	H	H	H	H	H
West	BOQUERON RAMPA*	BOQ	-	-	-	L	L	L	L	L
West	BARRIO ESPINAL*	BES	-	L	L	L	Drop	Drop	Drop	Drop
West	VILLA PESQ. PUERTO REAL*	VPQ	-	-	-	L	Drop	Drop	Drop	Drop

3.6 Auxiliary Projects

A number of side projects were either envisioned prior to implementation or were developed as on the ground needs warranted. Brief summaries of the projects listed below are included in this report in Section 5 and full reports are available in the appendices: Part 3 if indicated by an ‘*’.

- Rapid Sampling
- Lobster Fisher Data Collection Initiative
- Auxiliary Trailer Count Efforts at Rincon Ramp
- Shark Genetics Sample Collection Summary*
- “Pescaderia Logs” Pilot Project*
- Site Description Reference Guide (Full guide in *Part 4: Site Descriptions* of the Final Report)

4 RESULTS

4.1 Descriptive Statistics

4.1.1 Overview of sampling

Sampling was conducted from August 7, 2017 to December 30, 2019, a total of 100 weeks (644 sampling days). Sampling period was interrupted for 25 weeks after Hurricane Maria, until the fisheries neared recovery (Sept 19, 2017 to March 14, 2018). A total of 59 sites in Puerto Rico were sampled for Daytime and Auxiliary sampling, with two to three samplers assigned per day, per region. Thus, in Puerto Rico, at least 8 samplers were deployed daily for the 644-sampling day period. A total of 3,995 sampled landing site days during daytime and 639 assignments for auxiliary sampling were completed. The fishing community was generally very cooperative and allowed samplers to document 9,720 trips (Table 13), over 260 species and approximately 433,000 lb of commercial landings.

The East coast had the highest observed landings with over 160,000 lb, and the North coast saw the lowest use with just over 34,000 lb being documented. Observed landings on the West and South coasts were similar at 100,000 lb and 120,000 lb respectfully (Figure 31). The vast majority of landings and trips sampled in all regions were commercial, rather than recreational or charter, as presented in figure 32 and by regions in figures 33 and 34. In terms of gear, diving dominated landings in the East, South, and West, with hook and line only largest in the North. The highest trap landings were seen in the East and South (Figure 35 and 36). Caribbean spiny lobster and Queen conch were the first and second highest observed landed species in all Puerto Rico, respectively. Combined these two species comprised over 50% of the catch. Table 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.

Table 13. Region-level summary of all observed trips from both daytime and auxiliary sampling during the entire period. Includes all trip types: commercial, recreational and charters and unknown.

Region	Sampled Trips	Unsampled Trips	Refused Trips	Total Trips
East	2,344	69	34	2,447
North	1,604	12	17	1,633
South	2,405	117	25	2,547
West	3,129	2,796	151	6,076
Islands	238	18	6	262
All PR	9,720	3,012	233	12,965

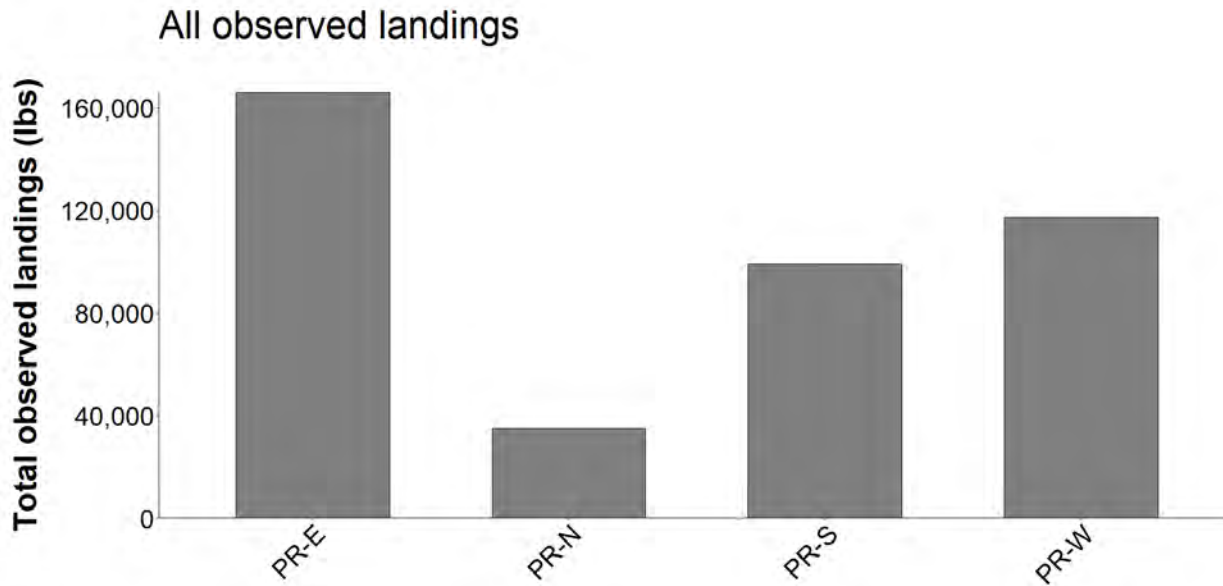


Figure 31. Total observed landings by region during the entire sampled period.

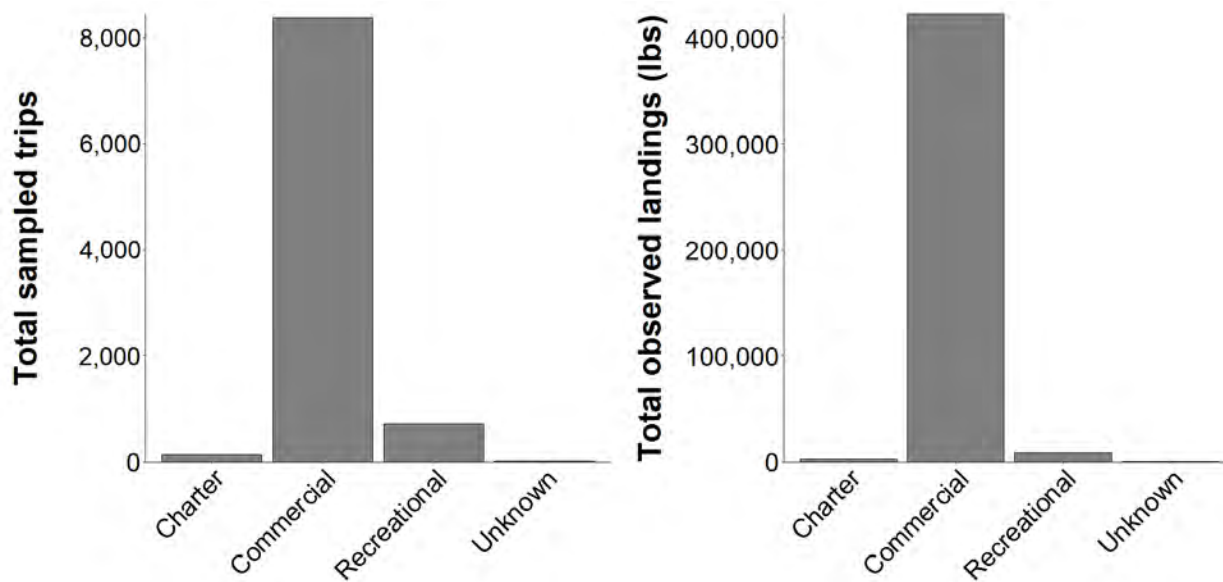


Figure 32. Total number of sampled trips and observed landings by trip type during the entire sampled period.

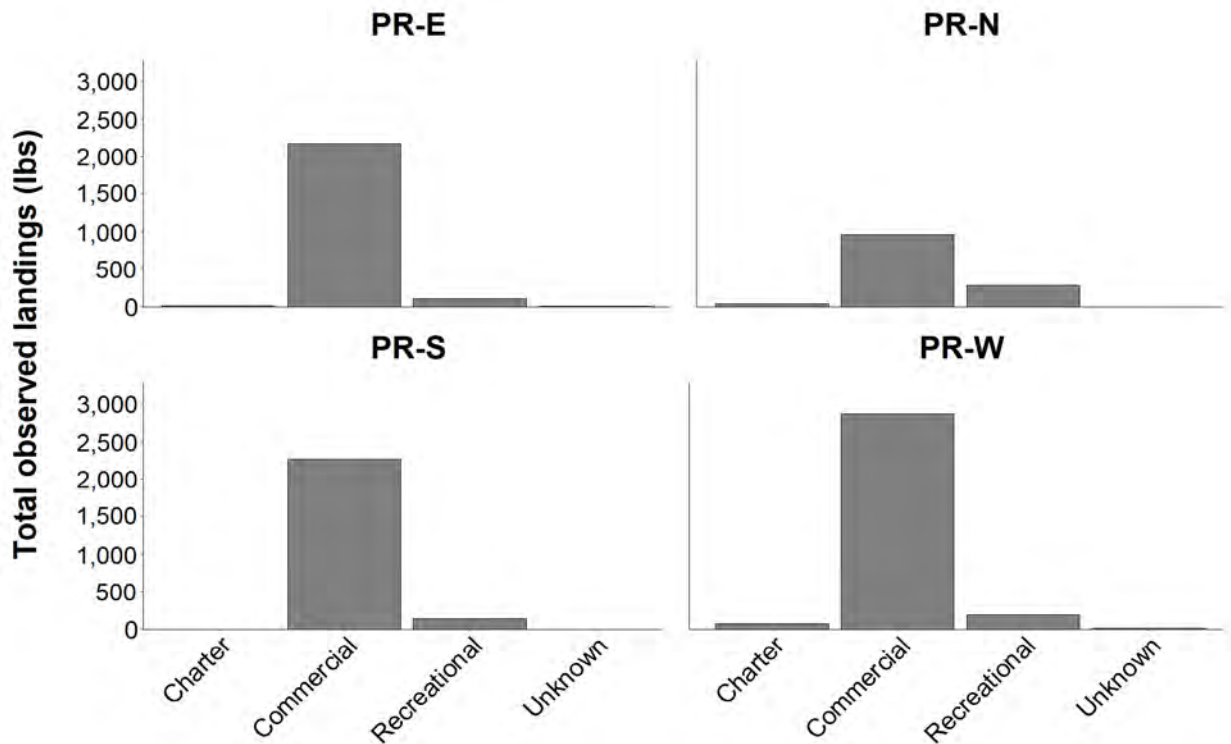


Figure 33. Total trips sampled by trip type for all sampling during the entire sampled period.

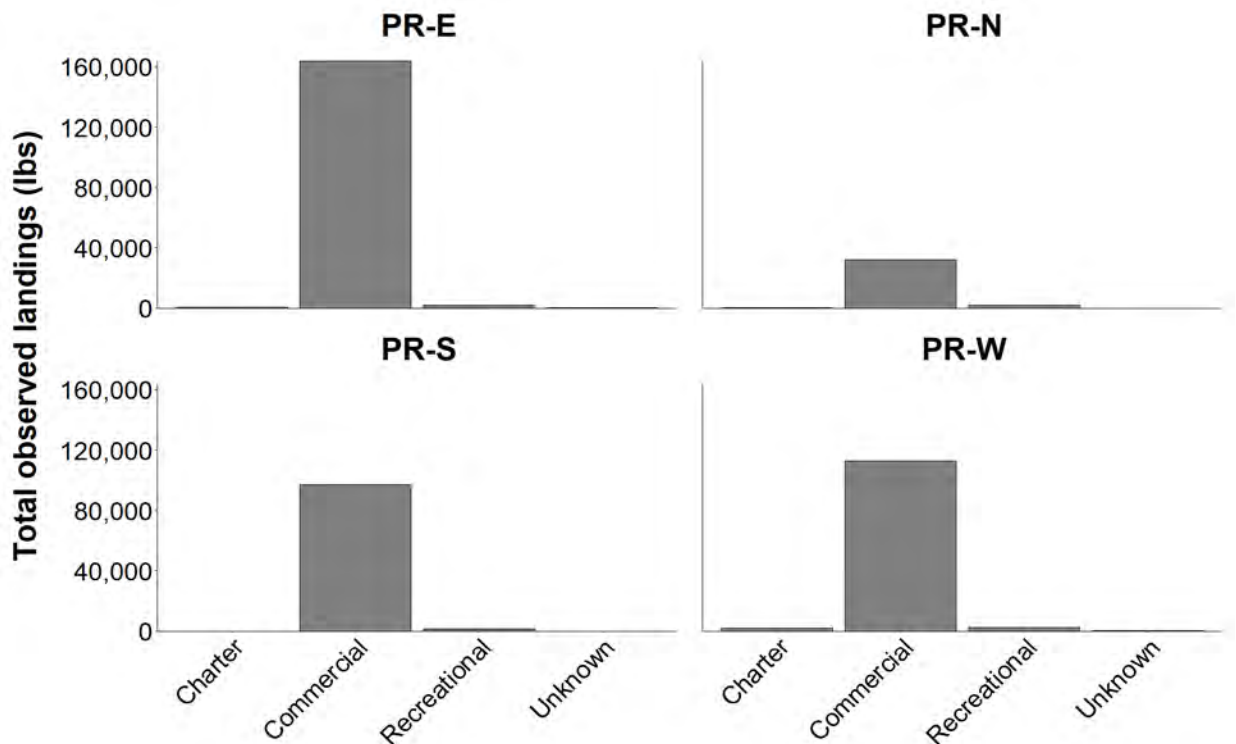


Figure 34. Total observed landings by trip type for all sampling.

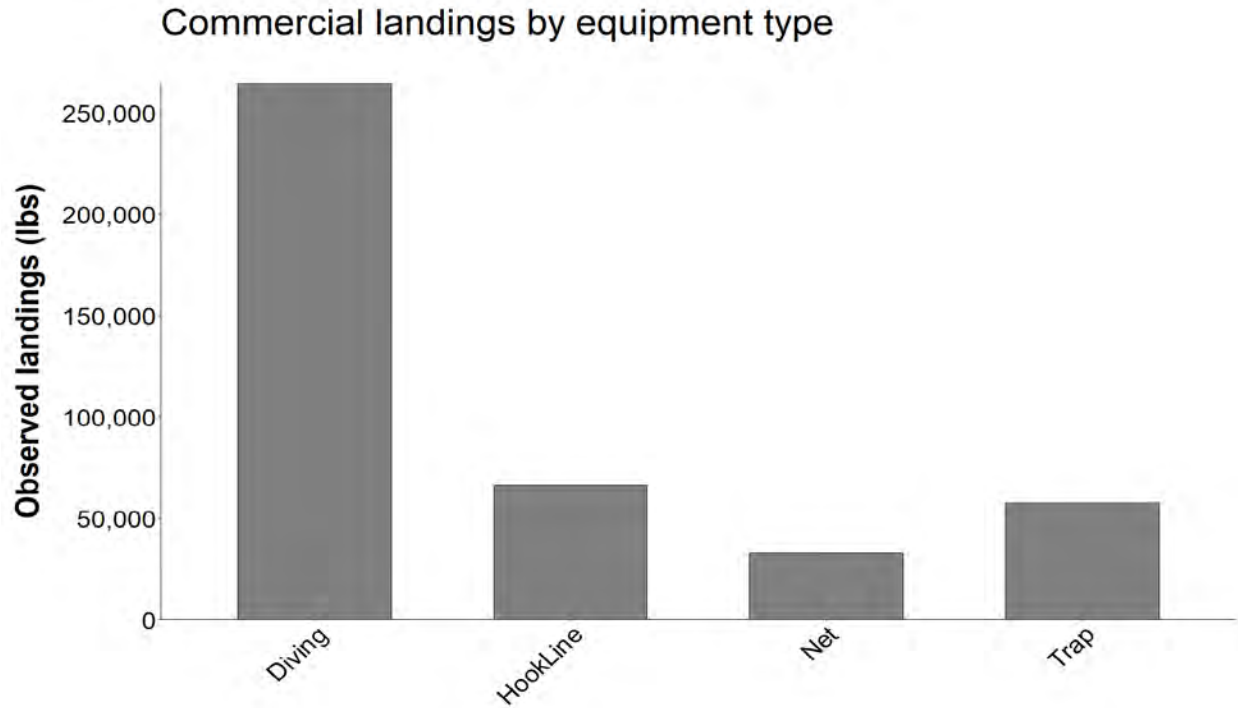


Figure 35. Total commercial observed landings by gear type.

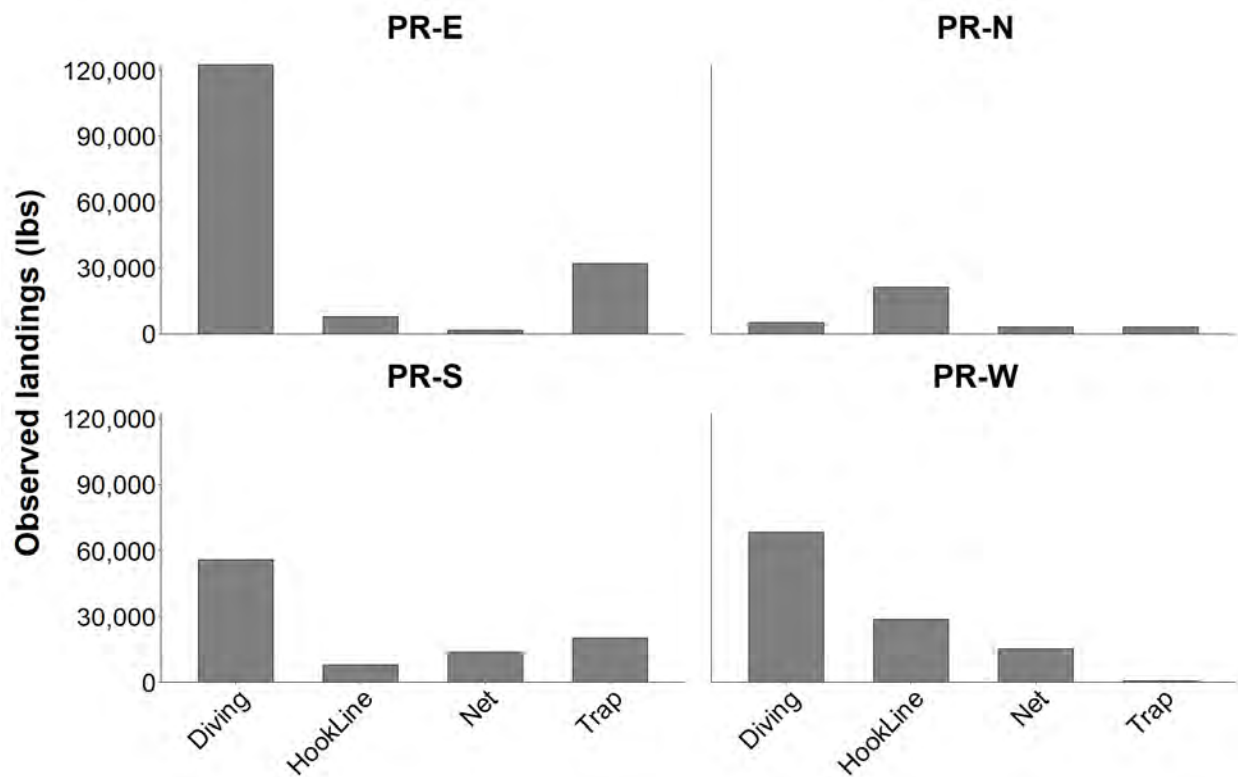


Figure 36. Total observed commercial landings by region and gear type.

Table 14. Total observed weights by species or family grouping during entire project.

All Sampling - All Region - Observed Weight by Species

Rank	Species	Landings (lb)	Cumulative % of Total	Rank	Species	Landings (lb)	Cumulative % of Total
1	lobster_caribbean_spiny	117,796	27.2	44	triggerfish_gray	861	93.8
2	conch_queen	103,547	51.1	45	tuna_yellowfin	817	94.0
3	hogfish	17,750	55.2	46	shark_silky	800	94.2
4	snapper_silk	15,751	58.8	47	trunkfish_spotted	785	94.4
5	snapper_queen	14,029	62.1	48	tunny_little	766	94.6
6	dolphin	13,027	65.1	49	crab_batwing_coral	763	94.8
7	hind_red	9,957	67.4	50	bocon	753	94.9
8	octopus_common	9,602	69.6	51	amberjack_greater	730	95.1
9	ballyhoo	8,943	71.7	52	lionfish	707	95.3
10	triggerfish_queen	8,664	73.7	53	sardine_redear	688	95.4
11	snapper_mutton	8,136	75.5	54	jack_bar	681	95.6
12	unknown	7,214	77.2	55	runner_rainbow	672	95.7
13	parrotfish_stoplight	6,194	78.6	56	mojarra_striped	659	95.9
14	snapper_lane	5,847	80.0	57	goatfish_spotted	634	96.0
15	mackerel_king	5,229	81.2	58	grunt_choice_sailors	630	96.2
16	snapper_yellowtail	5,204	82.4	59	herring_atlantic_thread	628	96.3
17	shark_tiger	4,254	83.4	60	octopus_unknown	598	96.5
18	trunkfish	3,537	84.2	61	porgy_saucereye	569	96.6
19	tuna_blackfin	3,394	85.0	62	coney	565	96.7
20	mackerel_cero	3,140	85.7	63	topsnail_west_indian	509	96.8
21	snapper_schoolmaster	2,968	86.4	64	jack_yellow	506	97.0
22	snapper_dog	2,406	86.9	65	parrotfish_rainbow	487	97.1
23	grunt_white	2,350	87.5	66	grouper_misty	436	97.2
24	pilchard_false	2,164	88.0	67	parrotfish_redfin	435	97.3
25	lobster_spanish_slipper	1,983	88.4	68	snapper_cubera	341	97.3
26	porgy_pluma	1,903	88.9	69	ray_Hypanus_sp.	341	97.4
27	tuna_skipjack	1,825	89.3	70	shark_smooth_dogfish	335	97.5
28	runner_blue	1,664	89.7	71	shark_bull_reef	330	97.6
29	grunt_bluestriped	1,441	90.0	72	trunkfish_smooth	322	97.7
30	ray_southern_stingray	1,383	90.3	73	snook_common	319	97.7
31	snapper_blackfin	1,376	90.7	74	squirrelfish	301	97.8
32	parrotfish_redtail	1,298	91.0	75	ray_spotted_eagle	295	97.9
33	barracuda_great	1,240	91.2	76	triggerfish_ocean	282	97.9
34	snapper_gray	1,184	91.5	77	snapper_wenchman	277	98.0
35	sardine_scaled	1,132	91.8	78	boxfish_unknown	276	98.1
36	mullet_white	1,111	92.0	79	grunt_porkfish	275	98.1
37	wahoo	1,085	92.3	80	grouper_red	240	98.2
38	jack_almaco	1,029	92.5	81	bigeye_bulleye	235	98.2
39	snapper_cardinal	1,014	92.8	82	jack_crevalle	232	98.3
40	snapper_vermilion	1,000	93.0	83	halfbeak_silverstripe	219	98.3
41	cowfish_scrawled	996	93.2	84	parrotfish_queen	216	98.4
42	cowfish_honeycombed	972	93.4	85	angelfish_gray	210	98.4
43	sharks_unknown	908	93.6	86	shark_caribbean_reef	208	98.5

Table 14. (Continued) Total observed weights by species or family grouping during entire project.

All Sampling - All Region - Observed Weight by Species

Rank	Species	Landings (lb)	Cumulative % of Total	Rank	Species	Landings (lb)	Cumulative % of Total
87	jack_horseeye	203	98.5	130	margate_black	52	99.6
88	grouper_yellowfin	197	98.6	131	spadefish_atlantic	52	99.6
89	margate	190	98.6	132	ladyfish	51	99.6
90	snapper_unknown	171	98.7	133	tang_blue	50	99.6
91	pompano_african	165	98.7	134	bream_sea	50	99.6
92	porgy_sheepshead	163	98.7	135	shark_bigeyed_sixgill	50	99.6
93	filefish_unicorn	150	98.8	136	grunt_unknown	49	99.6
94	grouper_unknown	139	98.8	137	scombropros_atlantic	49	99.7
95	snapper_black	135	98.8	138	grunt_cottonwick	47	99.7
96	mojarra_irish_pompano	134	98.9	139	crab_blotched_swimming	45	99.7
97	crab_channel_clinging	126	98.9	140	triggerfish_durgon_black	44	99.7
98	ray_unknown	125	98.9	141	moonfish_atlantic	42	99.7
99	grouper_nassau	124	98.9	142	grunt_spanish	41	99.7
100	shark_bignose	122	99.0	143	herring_dwarf	39	99.7
101	puffer_porcupine	120	99.0	144	hogfish_spanish	37	99.7
102	halfbeak_unknown	119	99.0	145	shark_gulper	36	99.7
103	porgy_jolthead	116	99.1	146	flyingshark_unknown	36	99.7
104	filefish_whitespotted	116	99.1	147	billfish_unknown	35	99.8
105	mojarra_yellowfin	115	99.1	148	tilefish_sand	34	99.8
106	tripletail	111	99.1	149	snapper_mahogany	34	99.8
107	herring_unknown	105	99.2	150	sheepshead	32	99.8
108	triggerfish_filefish_unknown	105	99.2	151	tilefish_blackline	32	99.8
109	crab_blue	105	99.2	152	barracuda_sennet_southern	31	99.8
110	goatfish_yellow	95	99.2	153	shark_squalus_sp	31	99.8
111	permit	93	99.3	154	scad_bigeye	30	99.8
112	porgy_unknown	89	99.3	155	doctorfish	29	99.8
113	shark_blacktip	88	99.3	156	filefish_scrawled	29	99.8
114	tuna_bigeye	87	99.3	157	snail_atlantic_tritons_trumpet	29	99.8
115	shark_hammerhead_scalloped	87	99.3	158	barracuda_guaguanche	28	99.8
116	amberjack_lesser	86	99.4	159	shark_smoothhound_dusky	26	99.8
117	jack_black	84	99.4	160	grouper_yellowmouth	24	99.8
118	parrotfish_unknown	81	99.4	161	shark_night	24	99.8
119	shark_blue	80	99.4	162	anchovy_striped	24	99.9
120	grouper_graysby	80	99.4	163	anchovy_dusky	24	99.9
121	shark_obscurus_grp	79	99.4	164	jack_unknown	23	99.9
122	crab_blue_land	78	99.5	165	grunt_caesar	22	99.9
123	shark_atlantic_sharpenose	67	99.5	166	basslet_fairy	20	99.9
124	angelfish_french	67	99.5	167	shark_blacknose	19	99.9
125	sardine_spanish	66	99.5	168	snail_queen_helmet	19	99.9
126	lobster_spotted_spiny	59	99.5	169	chromis_blue	17	99.9
127	grouper_hamlet_mutton	55	99.5	170	parrotfish_princess	16	99.9
128	grouper_black	54	99.6	171	lobster_smooth_tail	15	99.9
129	conch_milk	53	99.6	172	bass_unknown	15	99.9

Table 14. (Continued) Total observed weights by species or family grouping during entire project.

All Sampling - All Region - Observed Weight by Species

Rank	Species	Landings (lb)	Cumulative % of Total	Rank	Species	Landings (lb)	Cumulative % of Total
173	bumper_atlantic	14	99.9	216	puffer_unknown	4	100.0
174	drummer_whitemouth	14	99.9	217	snook_unknown	4	100.0
175	triggerfish_sargassum	13	99.9	218	tilefish_bankslope	4	100.0
176	cutlassfish_atlantic	13	99.9	219	moray_viper	3	100.0
177	crab_speckled_swimming	12	99.9	220	anchovy_unknown	3	100.0
178	pompanos_permits_unknown	12	99.9	221	palometa	3	100.0
179	grunt_tomtate	11	99.9	222	bonefish	3	100.0
180	drum_sand	11	99.9	223	cichlid_blackbelt	3	100.0
181	moonfish_caribbean	10	99.9	224	grunt_black	3	100.0
182	chub_bermuda	10	99.9	225	tunas_mackerels_unknown	3	100.0
183	florida_pompano	10	99.9	226	crab_flame_box	3	100.0
184	grouper_snowy	10	99.9	227	grouper_spanish_flag	3	100.0
185	grouper_tiger	10	99.9	228	hind_rock	3	100.0
186	brotula_bearded	10	99.9	229	lizardfish_inshore	2	100.0
187	eel_unknown	10	99.9	230	grunt_roughneck	2	100.0
188	squirrelfish_longspine	10	99.9	231	octopus_white_spotted	2	100.0
189	houndfish	9	99.9	232	snook_smallscale_fat	2	100.0
190	needlefish_agujon	9	99.9	233	bigeye_glasseye_snapper	2	100.0
191	jenny_silver	8	99.9	234	snapper_caribbean_red	2	100.0
192	porgy_grass	8	99.9	235	jawfish_yellowhead	2	100.0
193	lookdown	8	99.9	236	parrotfish_redband	2	100.0
194	pomfret_unknown	8	99.9	237	goatfish_unknown	2	100.0
195	snook_tarpon	8	100.0	238	surgeon_ocean	2	100.0
196	barracuda_unknown	7	100.0	239	wrasse_bluehead	2	100.0
197	scorpionfish_spotted	7	100.0	240	eel_spinefin_snake	2	100.0
198	beardfish_stout	7	100.0	241	porgy_whitebone	2	100.0
199	grunt_barred	7	100.0	242	squirrelfish_unknown	2	100.0
200	shark_mustelus_sp	6	100.0	243	drum_shorthead	2	100.0
201	escolar_domine	6	100.0	244	lionfish_unknown	2	100.0
202	shark_genies_dogfish	6	100.0	245	shark_caribbean_sharpnose	1	100.0
203	mullet_redeye	6	100.0	246	angelfish_queen	1	100.0
204	angelfish_rock_beauty	6	100.0	247	lobster_sculptured_slipper	1	100.0
205	moray_spotted	5	100.0	248	drum_blue_croaker	1	100.0
206	bass_harlequin	5	100.0	249	snook_fat	1	100.0
207	puddingwife	5	100.0	250	shrimp	1	100.0
208	grunt_french	5	100.0	251	leatherjack	1	100.0
209	remora	5	100.0	252	rover_crimson	1	100.0
210	lizardfish_shortjaw	5	100.0	253	soldierfish_bigeye	1	100.0
211	grunt_burro	4	100.0	254	barbu	1	100.0
212	grouper_yellowedge	4	100.0	255	tilefish_unknown	1	100.0
213	lizardfish_sand_diver	4	100.0	256	threadfin_littlescale	1	100.0
214	bigeye_unknown	4	100.0	257	grunt_striped	1	100.0
215	drum_unknown	4	100.0	258	soldierfish_blackbar	1	100.0

Table 14. (Continued) Total observed weights by species or family grouping during entire project.

All Sampling - All Region - Observed Weight by Species

Rank	Species	Landings (lb)	Cumulative % of Total	Rank	Species	Landings (lb)	Cumulative % of Total
259	wrasse_yellowhead	1	100.0	302	puffer_sharprnose	0.02	100.0
260	snook_largescale_fat	1	100.0	303	damselfish_bicolor	0.01	100.0
261	drum_sand_seatrout	1	100.0				
262	mackerel_purple_snake	1	100.0				
263	squid	1	100.0				
264	star_brittle	1	100.0				
265	lizardfish_saurida_sp	1	100.0				
266	soapfish_greater	1	100.0				
267	chromis_brown	1	100.0				
268	star_burgundy_sea	1	100.0				
269	bass_tattler	1	100.0				
270	burrfish_web	1	100.0				
271	damselfish_yellowtail	1	100.0				
272	moray_blackedge	1	100.0				
273	shrimp_banded_coral	1	100.0				
274	beardfish_unknown	1	100.0				
275	crab_yellowline_arrow	1	100.0				
276	drum_jackknife	1	100.0				
277	drum_spotted	1	100.0				
278	flatfish_unknown	1	100.0				
279	mojarra_unknown	1	100.0				
280	porgy_littlehead	1	100.0				
281	wrasse_yellowcheek	1	100.0				
282	cobia	0.4	100.0				
283	filefish_orangespotted	0.4	100.0				
284	flounder_peacock	0.4	100.0				
285	hogfish_red	0.4	100.0				
286	snook_swordspine	0.4	100.0				
287	butterflyfish_banded	0.3	100.0				
288	chub_topsnail	0.3	100.0				
289	cherubfish	0.3	100.0				
290	scad_mackerel	0.3	100.0				
291	lobster_red_banded	0.3	100.0				
292	puffer_checkered	0.3	100.0				
293	mojarra_spotfin	0.2	100.0				
294	angelfish_unknown	0.2	100.0				
295	jewelfish_euripos	0.2	100.0				
296	basslet_tobaccofish	0.1	100.0				
297	butterflyfish_spotfin	0.1	100.0				
298	hawkfish_redspotted	0.1	100.0				
299	shellfish_unknown	0.1	100.0				
300	crab_arrow	0.06	100.0				
301	flamefish	0.1	100.0				

4.1.2 Daytime Sampling

Over the course of the entire project we sampled over 9,300 trips and observed almost 436,000 lb during daytime sampling (Table 15). Approximately 90% of the observed trips were commercial with the highest recreational activity having been observed in the North. The North coast however had the lowest amount of observed activity. The South, West, And East all had larger numbers of observed trips (Figure 37). The East overall had the highest observed landings primarily due to the larger average landings per trip and the periodic sampling done on Vieques and Culebra. A breakdown of activity observed and sampled at each site is presented in tables 16, 17, 18 and 19.

In terms of species, lobster and conch comprised greater than 53% of the observed landings and 29 and 48 species made up 90 and 95% of the catch respectively (Table 20). There were some obvious differences by region in terms of both gear type and species. Considerably more conch was landing in the East and South with the lowest amounts. In the North, the fishery is heavily hook and line and lobster and conch were observed less than dolphin and silk snapper (Table 21).

Table 15. Region-level summary of trips and landings for Daytime sampling in Puerto Rico, for all time period.

Region	Sampled Trips	Commercial Trips	Non-comercial Trips	Tot. Obs. Lbs (all trips)
East	2,288	2,128	160	166,164
North	1,515	1,143	388	34,798
South	2,339	2,256	103	99,237
West	2,964	2,730	237	119,441
Islands	238	222	16	16,255
All PR	9,344	8,479	904	435,895

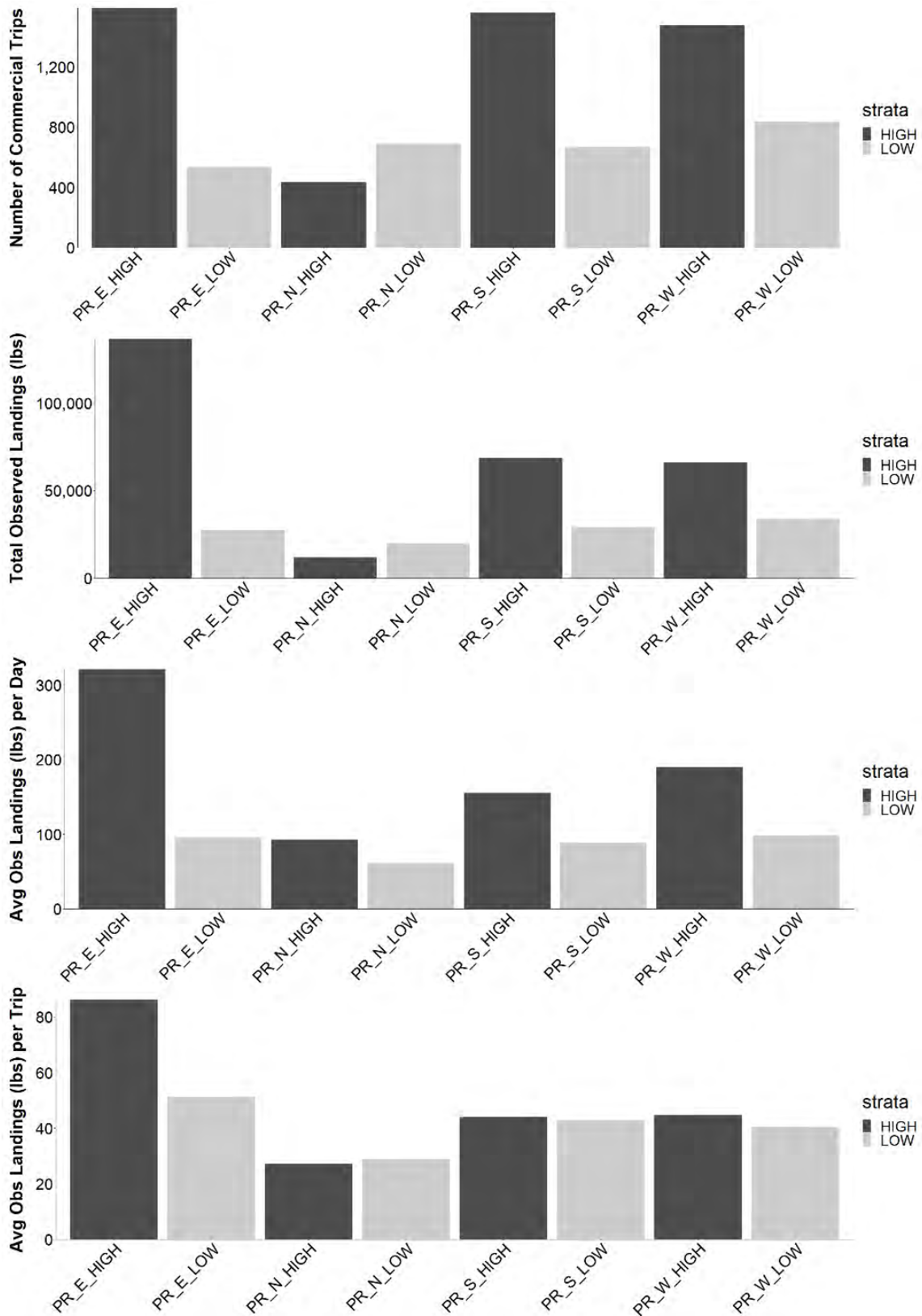


Figure 37. Commercial trips and landings summary for all region stratum.

Table 16. Site level summary of effort and landings for North region.

Strata	Site Name	Site Code	Sampled Trips	Unsampled Trips	Total Trips	Total Days Sampled	Total Obs. Landings (lbs.)	Avg. lbs./day	Avg. lbs./trip
H	JAREALITO	JAR	460	4	464	158	12,094	77	26.3
L	ARECIBO RAMPA	ARE	12	0	12	9	23	3	1.9
L	BARRIO BAJURA	BAJ	57	4	61	82	2,410	29	42.3
L	CALLE HOARE	HOA	144	0	144	68	2,846	42	19.8
L	CERRO GORDO	GOR	17	0	17	34	214	6	12.6
L	JAREALITO	JAR	61	1	62	21	1,408	67	23.1
L	LA COAL	COA	36	2	38	70	797	11	22.2
L	LA PRINCESA	PRI	83	1	84	87	2,026	23	24.4
L	LA PUNTILLA	PUN	27	0	27	38	447	12	16.6
L	LAS MARGARITAS	MAR	54	0	54	76	1,039	14	19.2
L	MAMEYAL	MAM	261	11	272	91	5,683	62	21.8
L	PALMAS ALTAS	ALT	106	2	108	75	2,293	31	21.6
L	PUERTO MOSQUITO	MOS	119	1	120	83	1,775	21	14.9
L	PUNTA PEÑÓN	PEN	72	1	73	65	1,688	26	23.4
L	TORRECILLA	TOR	3	0	3	4	3	1	0.8
L	VIETNAM	VIE	3	1	4	11	52	5	17.4
North Total:			1,515	28	1,543	972	34,798	27	19.3

Table 17. Site level summary of effort and landings for East region.

Strata	Site Name	Site Code	Sampled Trips	Unsampled Trips	Total Trips	Total Days Sampled	Total Obs. Landings (lbs.)	Avg. lbs./day	Avg. lbs./trip
H	HÚCARES	HUC	555	12	567	144	38,822	270	69.9
H	MARINA PUERTO DEL REY	PDR	559	17	576	181	52,765	292	94.4
H	MATERNILLO	MAT	503	30	533	167	45,388	272	90.2
L	BARRIO LOS MACHOS	BLM	130	5	135	91	7,368	81	56.7
L	LAS CROABAS	CRO	139	18	157	88	5,124	58	36.9
L	PLAYA DE GUAYANÉS	PDG	8	2	10	33	304	9	38.1
L	PUERTO DE YABUCOA	PYA	229	5	234	85	9,244	109	40.4
L	PUNTA CANDELERO	PCA	3	0	3	2	96	48	31.9
L	PUNTA SANTIAGO	PSA	88	11	99	90	5,409	60	61.5
L	SARDINERA	SAR	74	3	77	88	1,643	19	22.2
East Total:			2,288.00	103	2,391	969	166,164	122	54.2

Table 18. Site level summary of effort and landings for South region.

Strata	Site Name	Site Code	Sampled Trips	Unsampled Trips	Total Trips	Total Days Sampled	Total Obs. Landings (lbs.)	Avg. lbs./day	Avg. lbs./trip
H	BAHÍA DE GUÁNICA	BDG	294	8	302	125	14,065	113	47.8
H	LA PARGUERA	LPG	421	40	461	126	20,161	160	47.9
H	PASTILLO	PAS	220	21	241	96	14,542	151	66.1
H	PLAYA DE PONCE	PDP	20	1	21	12	1,003	84	50.1
H	SALINAS PROVIDENCIA	SAL	31	2	33	13	863	66	27.9
H	TALLABOIA	TAL	618	22	640	132	18,829	143	30.5
L	BAJO DE PATILLAS	BDP	88	5	93	82	4,507	55	51.2
L	BARRIO GUAYPAO	BGY	6	0	6	23	52	2	8.7
L	LA GUANCHA	LGU	52	1	53	74	4,309	58	82.9
L	LA PARGUERA RAMPA	LPR	3	1	4	5	7	1	2.3
L	PASTILLO	PAS	40	8	48	17	2,695	159	67.4
L	PLAYA DE PONCE	PDP	68	5	73	52	2,356	45	34.7
L	PLAYA LAS PALMAS	PLP	192	12	204	88	6,842	78	35.6
L	PUNTA PAPAYO	PAP	124	6	130	73	3,369	46	27.2
L	SALINAS PROVIDENCIA	SAL	162	10	172	60	5,636	94	34.8
South Total:			2,339	142	2,481	978	99,237	84	41.0

Table 19. Site level summary of effort and landings for West region.

Strata	Site Name	Site Code	Sampled Trips	Unsampled Trips	Total Trips	Total Days Sampled	Total Obs. Landings (lbs.)	Avg. lbs./day	Avg. lbs./trip
H	BAHÍA PUERTO REAL	BPR	366	19	385	82	12,082	147	33.0
H	EL COMBATE	COM	172	12	184	48	6,290	131	36.6
H	EL FARO CABO ROJO	FAR	161	6	167	56	8,809	157	54.7
H	PUERTO REAL, MARINA	PRE	728	84	811	147	31,958	217	43.9
H	PUERTO REAL, SOLTERO	SOL	191	602	793	147	7,569	51	39.6
H	RINCÓN RAMPA	RIN	414	98	512	102	17,274	169	41.7
H	VILLA PESQ. PUERTO REAL	VPQ	2	0	2	2	498	249	249.0
L	BARRIO ESPINAL	BES	13	0	13	31	499	16	38.3
L	BARRIO TAMARINDO	BTA	89	9	98	100	2,775	28	31.2
L	BOQUERÓN RAMPA	BOQ	100	5	105	57	3,785	66	37.9
L	EL COMBATE	COM	169	16	185	52	5,525	106	32.7
L	EL FARO CABO ROJO	FAR	223	18	241	69	11,250	163	50.4
L	EL SECO RAMPA	SEC	175	74	249	91	4,512	50	25.8
L	PLAYUELA	PLA	146	4	150	87	5,891	68	40.3
L	RINCÓN RAMPA	RIN	15	9	24	5	726	145	48.4
West Total:			2,964	956	3,919	1,076	119,441	118	53.6

Table 20. Species Composition of 95% of the observed landings from daytime sampling only.

Daytime Sampling - All Regions - Observed Weight by Species			
Rank	Species	Landings (lb)	Cumulative % of Total
1	lobster_caribbean_spiny	112,536	29%
2	conch_queen	94,655	53%
3	hogfish	17,173	57%
4	snapper_silk	12,920	60%
5	dolphin	10,802	63%
6	octopus_common	9,474	66%
7	hind_red	8,999	68%
8	ballyhoo	8,942	70%
9	triggerfish_queen	8,326	72%
10	snapper_mutton	7,970	74%
11	parrotfish_stoplight	6,153	76%
12	snapper_lane	5,588	77%
13	snapper_queen	5,213	79%
14	unknown	4,841	80%
15	snapper_yellowtail	4,523	81%
16	trunkfish	3,502	82%
17	mackerel_king	3,493	83%
18	shark_tiger	3,485	84%
19	tuna_blackfin	3,054	85%
20	mackerel_cero	3,019	85%
21	snapper_schoolmaster	2,935	86%
22	snapper_dog	2,266	87%
23	grunt_white	2,160	87%
24	pilchard_false	2,137	88%
25	lobster_spanish_slipper	1,950	88%
26	porgy_pluma	1,851	89%
27	tuna_skipjack	1,637	89%
28	runner_blue	1,475	89%
29	ray_southern_stingray	1,357	90%
30	grunt_bluestriped	1,326	90%
31	snapper_blackfin	1,297	90%
32	parrotfish_redtail	1,262	91%
33	barracuda_great	1,205	91%
34	snapper_gray	1,172	91%
35	sardine_scaled	1,092	92%
36	wahoo	979	92%
37	cowfish_scrawled	968	92%
38	cowfish_honeycombed	948	92%
39	mullet_white	912	93%
40	jack_almaco	902	93%
41	sharks_unknown	892	93%
42	triggerfish_gray	859	93%
43	snapper_cardinal	851	94%
44	snapper_vermilion	828	94%
45	tuna_yellowfin	817	94%
46	shark_silky	777	94%
47	trunkfish_spotted	757	94%
48	bocon	750	95%

Table 21. Top 20 Species and observed landings during daytime sampling by region.

North - Daytime Sampling - Observed Weight by Species							
<u>High Stratum</u>				<u>Low Stratum</u>			
Rank	Species	Landings (lb)	Cumulative % of Total	Rank	Species	Landings (lb)	Cumulative % of Total
1	snapper_silk	3,799	32.2	1	lobster_caribbean_spiny	3,077	15.5
2	dolphin	1,748	46.9	2	dolphin	2,904	30.2
3	mullet_white	826	53.9	3	snapper_silk	2,901	44.9
4	triggerfish_gray	665	59.6	4	mackerel_cero	883	49.3
5	snapper_queen	604	64.7	5	conch_queen	848	53.6
6	lobster_caribbean_spiny	488	68.8	6	mackerel_king	777	57.5
7	amberjack_greater	372	72.0	7	mojarra_striped	591	60.5
8	jack_almaco	269	74.2	8	runner_blue	421	62.7
9	shark_tiger	225	76.1	9	herring_atlantic_thread	392	64.6
10	snapper_vermilion	209	77.9	10	snapper_mutton	380	66.6
11	snapper_blackfin	204	79.6	11	snapper_yellowtail	367	68.4
12	shark_smooth_dogfish	188	81.2	12	barracuda_great	363	70.3
13	snapper_cardinal	150	82.5	13	snapper_dog	344	72.0
14	ray_southern_stingray	150	83.8	14	hind_red	278	73.4
15	runner_blue	144	85.0	15	snapper_queen	265	74.7
16	snapper_wenchman	128	86.1	16	snapper_blackfin	237	75.9
17	conch_queen	119	87.1	17	triggerfish_queen	235	77.1
18	shark_silky	104	87.9	18	shark_silky	228	78.3
19	tunny_little	87	88.7	19	snapper_lane	222	79.4
20	barracuda_great	87	89.4	20	snapper_vermilion	219	80.5

East - Daytime Sampling - Observed Weight by Species							
<u>High Stratum</u>				<u>Low Stratum</u>			
Rank	Species	Landings (lb)	Cumulative % of Total	Rank	Species	Landings (lb)	Cumulative % of Total
1	conch_queen	61,221	44.8	1	conch_queen	8,344	30.7
2	lobster_caribbean_spiny	39,255	73.5	2	lobster_caribbean_spiny	7,656	58.8
3	hogfish	5,841	77.8	3	hogfish	2,283	67.2
4	snapper_mutton	3,486	80.4	4	mackerel_cero	926	70.6
5	unknown	2,938	82.5	5	unknown	835	73.6
6	parrotfish_stoplight	2,674	84.5	6	parrotfish_stoplight	785	76.5
7	hind_red	2,618	86.4	7	shark_tiger	640	78.9
8	snapper_yellowtail	2,179	88.0	8	snapper_silk	571	81.0
9	triggerfish_queen	2,115	89.5	9	snapper_mutton	479	82.7
10	grunt_white	1,299	90.5	10	hind_red	378	84.1
11	ballyhoo	1,200	91.4	11	triggerfish_queen	334	85.3
12	snapper_lane	935	92.0	12	octopus_common	266	86.3
13	snapper_dog	749	92.6	13	snapper_schoolmaster	251	87.2
14	parrotfish_redtail	736	93.1	14	snapper_dog	249	88.2
15	snapper_schoolmaster	710	93.7	15	goatfish_spotted	218	89.0
16	porgy_pluma	704	94.2	16	shark_silky	190	89.7
17	mackerel_cero	552	94.6	17	snapper_queen	178	90.3
18	grunt_bluestriped	512	94.9	18	mackerel_king	167	90.9
19	snapper_gray	422	95.3	19	snapper_yellowtail	149	91.5
20	runner_blue	363	95.5	20	snapper_lane	148	92.0

Table 21. (Continued) Top 20 Species and observed landings during daytime sampling by region.

South - Daytime Sampling - Observed Weight by Species							
<u>High Stratum</u>				<u>Low Stratum</u>			
Rank	Species	Landings (lb)	Cumulative % of Total	Rank	Species	Landings (lb)	Cumulative % of Total
1	lobster_caribbean_spiny	26,125	38.2	1	lobster_caribbean_spiny	7,886	27.4
2	octopus_common	7,014	48.4	2	conch_queen	5,848	47.8
3	hogfish	4,230	54.6	3	hogfish	1,892	54.4
4	conch_queen	3,335	59.5	4	pilchard_false	1,832	60.8
5	snapper_lane	3,286	64.3	5	octopus_common	1,290	65.3
6	parrotfish_stoplight	1,813	66.9	6	sardine_scaled	862	68.3
7	snapper_mutton	1,789	69.5	7	bocon	730	70.8
8	triggerfish_queen	1,614	71.9	8	parrotfish_stoplight	683	73.2
9	mackerel_king	1,357	73.9	9	dolphin	671	75.5
10	dolphin	1,355	75.8	10	snapper_lane	651	77.8
11	trunkfish	1,090	77.4	11	triggerfish_queen	571	79.8
12	snapper_schoolmaster	1,065	79.0	12	ballyhoo	512	81.5
13	lobster_spanish_slipper	1,046	80.5	13	sardine_redear	407	83.0
14	snapper_yellowtail	888	81.8	14	snapper_silk	407	84.4
15	porgy_pluma	887	83.1	15	snapper_mutton	384	85.7
16	ballyhoo	826	84.3	16	snapper_schoolmaster	296	86.7
17	grunt_bluestriped	568	85.1	17	hind_red	270	87.7
18	snapper_silk	565	86.0	18	snapper_queen	258	88.6
19	grunt_white	531	86.7	19	ray_southern_stingray	253	89.5
20	hind_red	519	87.5	20	mackerel_king	252	90.3

West - Daytime Sampling - Observed Weight by Species							
<u>High Stratum</u>				<u>Low Stratum</u>			
Rank	Species	Landings (lb)	Cumulative % of Total	Rank	Species	Landings (lb)	Cumulative % of Total
1	lobster_caribbean_spiny	21,862	33.1	1	lobster_caribbean_spiny	6,188	18.3
2	conch_queen	10,654	49.2	2	conch_queen	4,285	31.0
3	hind_red	3,456	54.4	3	ballyhoo	4,071	43.1
4	snapper_queen	2,941	58.8	4	snapper_silk	2,899	51.6
5	triggerfish_queen	2,307	62.3	5	dolphin	2,167	58.1
6	ballyhoo	2,248	65.7	6	hind_red	1,435	62.3
7	hogfish	2,175	69.0	7	shark_tiger	1,308	66.2
8	dolphin	1,873	71.8	8	triggerfish_queen	1,126	69.5
9	tuna_blackfin	1,796	74.6	9	tuna_blackfin	1,100	72.8
10	snapper_silk	1,661	77.1	10	trunkfish	793	75.1
11	shark_tiger	1,313	79.0	11	tuna_skipjack	745	77.3
12	trunkfish	1,300	81.0	12	snapper_queen	730	79.5
13	snapper_mutton	1,017	82.5	13	hogfish	648	81.4
14	tuna_skipjack	795	83.8	14	sharks_unknown	491	82.9
15	cowfish_honeycombed	616	84.7	15	snapper_blackfin	387	84.0
16	octopus_common	571	85.5	16	snapper_mutton	384	85.1
17	tuna_yellowfin	569	86.4	17	ray_southern_stingray	364	86.2
18	runner_rainbow	519	87.2	18	snapper_yellowtail	344	87.2
19	mackerel_king	483	87.9	19	jack_almaco	260	88.0
20	snapper_schoolmaster	460	88.6	20	wahoo	236	88.7

4.1.3 Auxiliary sampling

A total of 639 additional assignments were completed in addition to the normal daytime sampling (Table 22). A summary of observed trips, sampled trips, and total commercial pounds observed by each sampling type is included in table 23. The largest observed lb were documented during the PM single site sampling assignments primarily due to Rincon which is heavily used by the deep-water snapper fishers and trips frequently average over 100 lb. Activity in Morropo/Vieques was also notably high (Table 24). Tables 25 through 28 provide the top 20 rankings for species by auxiliary sampling mode. As would be expected the top few species in daytime sampling in Vieques/Culebra and on Sundays is very similar that observed during our primary daytime sampling. The AM and PM sampling did not have lobster in the top 10 species and no conch were documented. The primary gear for these time periods was hook and line and species from long daytime/deep-water trips (e.g. queen snapper, silk snapper, dolphin, misty grouper) were tops on the PM list, and species from early morning trolling (e.g. king and cero mackerel) or overnight trips (e.g. yellowtail snapper) were tops on the AM list.

Table 22. Auxiliary sampling assignments and type of sampling by region for all time.

Region	AM Busroutes	PM Busroutes	Sunday Busroutes	AM Site	PM Site
East	-	1	27	54	23
North	53	-	27	-	83
South	55	-	27	-	81
West	52	53	55	-	48
Islands	-	-	-	-	-
Totals	160	54	136	54	235

Table 23. Summary of trips and landings for auxiliary sampling by region for all time.

Sampling type	North	East	South	West	All PR	
AM Busroute	Sampled Trips	25	-	17	8	50
	Commercial Trips	25	-	17	7	49
	Tot. Comm. Obs. Landings (lbs.)	1,256	-	1,585	308	3,149
PM Busroute	Sampled Trips	-	-	-	15	15
	Commercial Trips	-	-	-	14	14
	Tot. Comm. Obs. Landings (lbs.)	-	-	-	979	979
Sunday Busroute	Sampled Trips	17	24	18	28	87
	Commercial Trips	11	15	17	21	64
	Tot. Comm. Obs. Landings (lbs.)	638	1,164	720	841	3,364
AM 4hrs.	Sampled Trips	-	22	-	-	22
	Commercial Trips	-	16	-	-	16
	Tot. Comm. Obs. Landings (lbs.)	-	446	-	-	446
PM 4hrs.	Sampled Trips	31	10	11	111	163
	Commercial Trips	21	6	10	99	136
	Tot. Comm. Obs. Landings (lbs.)	387	480	460	8,025	9,351

Table 24. Site level summary of effort and landings for Islands Region by Strata.

Strata	Site Name	Site Code	Sampled Trips	Unsampled Trips	Total Trips	Total Days Sampled	Total Obs. Landings (lbs.)	Avg. lbs./day	Avg. lbs./trip
H	MORROPO VIEQUES	MOR	159	4	163	35	12,201	349	76.7
L	CULEBRA MUNICIPIO	CUL	44	12	56	27	2,383	88	54.2
L	ESPERANZA	ESP	35	8	43	26	1,671	64	47.8
Islands Total:			238	24	262	88	16,255	167	59.6

Table 25. Top 20 Species Composition and Total Weights Observed for Daytime Sampling in Vieques and Culebra.

Island - Daytime Sampling - Observed Weight by Species			
Rank	Species	Landings (lb)	Cumulative % of Total
1	conch_queen	8,635	54.5
2	lobster_caribbean_spiny	4,174	80.8
3	hind_red	902	86.5
4	hogfish	526	89.8
5	triggerfish_queen	333	91.9
6	grunt_white	138	92.8
7	unknown	91	93.4
8	snapper_yellowtail	77	93.9
9	mackerel_king	63	94.2
10	grunt_bluestriped	62	94.6
11	snapper_mutton	58	95.0
12	coney	53	95.3
13	topsnail_west_indian	46	95.6
14	tunny_little	41	95.9
15	runner_blue	40	96.1
16	grouper_nassau	38	96.4
17	porgy_pluma	37	96.6
18	parrotfish_redtail	34	96.8
19	snapper_silk	31	97.0
20	grouper_red	29	97.2

Table 26. Top 20 Species Composition and Total Weights Observed for Sunday sampling.

Sunday Sampling - All Regions - Observed Weight by Species			
Rank	Species	Landings (lb)	Cumulative % of Total
1	lobster_caribbean_spiny	993	29.5
2	unknown	573	46.6
3	dolphin	266	54.5
4	conch_queen	223	61.1
5	mackerel_king	221	67.6
6	snapper_lane	158	72.3
7	snapper_yellowtail	106	75.5
8	tuna_blackfin	105	78.6
9	octopus_common	91	81.3
10	runner_blue	82	83.7
11	shark_tiger	40	84.9
12	hogfish	38	86.0
13	jack_almaco	35	87.1
14	snapper_mutton	33	88.0
15	snapper_silk	28	88.9
16	mackerel_cero	28	89.7
17	sardine_scaled	26	90.5
18	snapper_dog	21	91.1
19	hind_red	21	91.7
20	grouper_black	20	92.3

Table 27. Top 20 Species Composition and Total Weights Observed for AM Sampling.

AM Sampling - All Regions - Observed Weight by Species			
Rank	Species	Landings (lb)	Cumulative % of Total
1	mackerel_king	1,580	41.7
2	shark_tiger	570	56.7
3	snapper_yellowtail	499	69.8
4	herring_atlantic_thread	213	75.4
5	jack_horseeye	66	77.2
6	mackerel_cero	55	78.6
7	grunt_bluestriped	45	79.8
8	unknown	42	80.9
9	snapper_dog	41	82.0
10	moonfish_atlantic	40	83.0
11	grunt_white	37	84.0
12	snook_common	36	85.0
13	hind_red	33	85.8
14	jack_bar	31	86.6
15	grunt_sailors_choice	28	87.4
16	snapper_silk	28	88.1
17	shark_smoothhound_dusky	26	88.8
18	lobster_caribbean_spiny	26	89.5
19	snapper_schoolmaster	25	90.1
20	barracuda_great	25	90.8

Table 28. Top 20 Species Composition and Total Weights Observed for AM Sampling.

PM Sampling - All Regions - Observed Weight by Species			
Rank	Species	Landings (lb)	Cumulative % of Total
1	snapper_queen	4,460	43.0
2	snapper_silk	1,528	57.8
3	dolphin	1,019	67.6
4	unknown	956	76.9
5	grouper_misty	261	79.4
6	tuna_blackfin	219	81.5
7	mullet_white	196	83.4
8	tuna_skipjack	171	85.0
9	shark_tiger	159	86.6
10	snapper_cardinal	153	88.0
11	wahoo	107	89.1
12	snapper_vermilion	84	89.9
13	bigeye_bulleye	81	90.7
14	snapper_lane	72	91.4
15	lobster_caribbean_spiny	67	92.0
16	snapper_dog	65	92.6
17	mackerel_king	60	93.2
18	runner_blue	57	93.8
19	snapper_mutton	56	94.3
20	snapper_blackfin	56	94.8

4.2 Estimated Landings

4.2.1 Estimated landings from all sampling.

The landings that were estimated from all sampling types and for all times sampled are presented for all Puerto Rico and by regions in table 29 below. Landings on the East, South and West coasts were comparable but landings on the North coast were approximately 25% of the other coasts. Reminder that the region ‘Islands’, here and throughout this document, represents results from auxiliary sampling on Vieques and Culebra. If included in the East coast, then landings are highest in this region. The entire time series for all Puerto Rico is in figure 38 while the following figure 39 shows estimates from the auxiliary sampling conducted on the Islands. While we could include this in our estimated landings for the East, we thought it best to show separately as a reminder of both the relatively high magnitude of landings in the islands but more importantly, as a reminder that all auxiliary sampling estimates only began in September of 2018. The remaining time series for each region include all auxiliary sampling components (i.e. AM, PM, and Sundays) in the estimates (Figure 40).

The weekly estimates and reported data for the top 12 species are shown in figure 41. Estimated total landings for all sampling for the species which comprise 95% of the landings are shown in Table 30. Given that our primary sampling effort and lowest SE are from the daytime sampling we present species the top 10 species ranked by estimated daytime landings in each strata in tables 31 and 32.

Table 29. Summary of observed and estimated landings, from both primary daytime and auxiliary sampling for the entire sampled period.

Region	Total Estimated lb	Total Observed lb
East	724,627	165,941
North	234,949	33,890
South	770,559	99,963
West	879,467	117,512
Islands	202,035	15,848
Totals	2,811,636	433,154

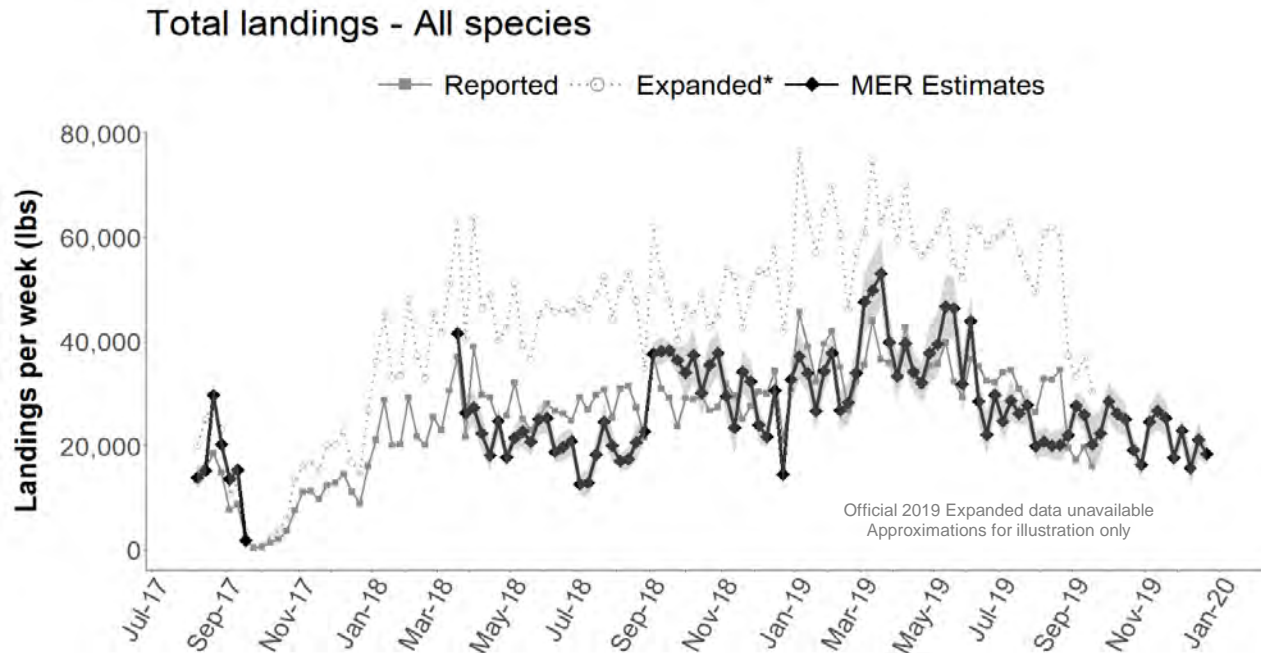


Figure 38. Estimated, reported, and approximate expanded landings for the entire time period sampled during this project. The shaded area represents the proportional standard error of the weekly estimate.

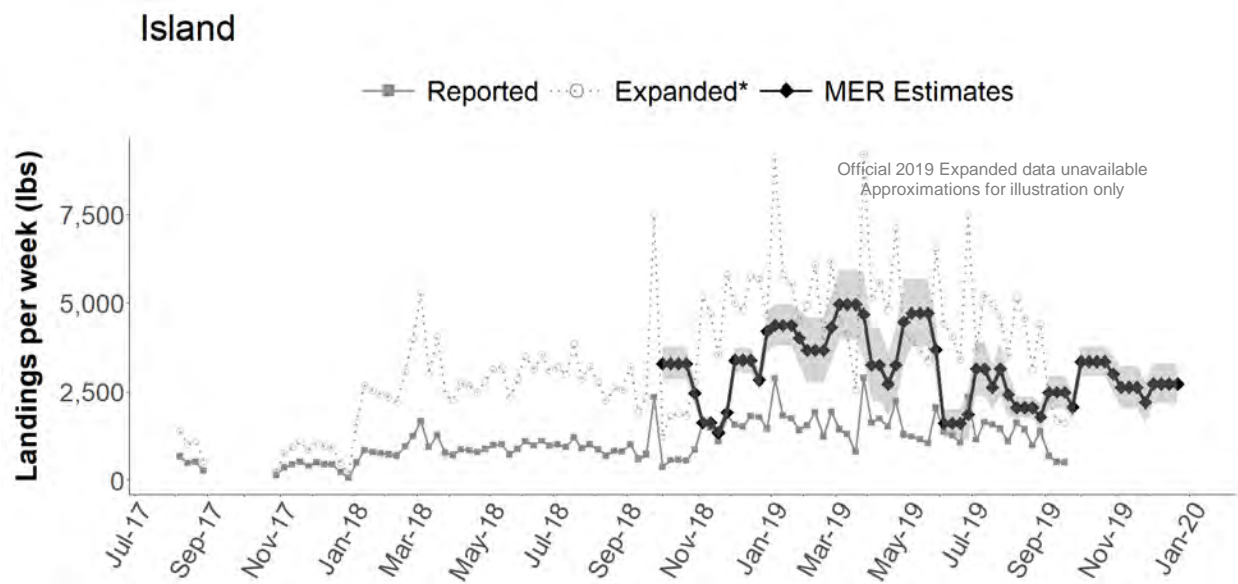


Figure 39. Estimated, reported, and approximate expanded landings for islands Vieques and Culebra the entire time period. The shaded area represents the proportional standard error of the weekly estimate.

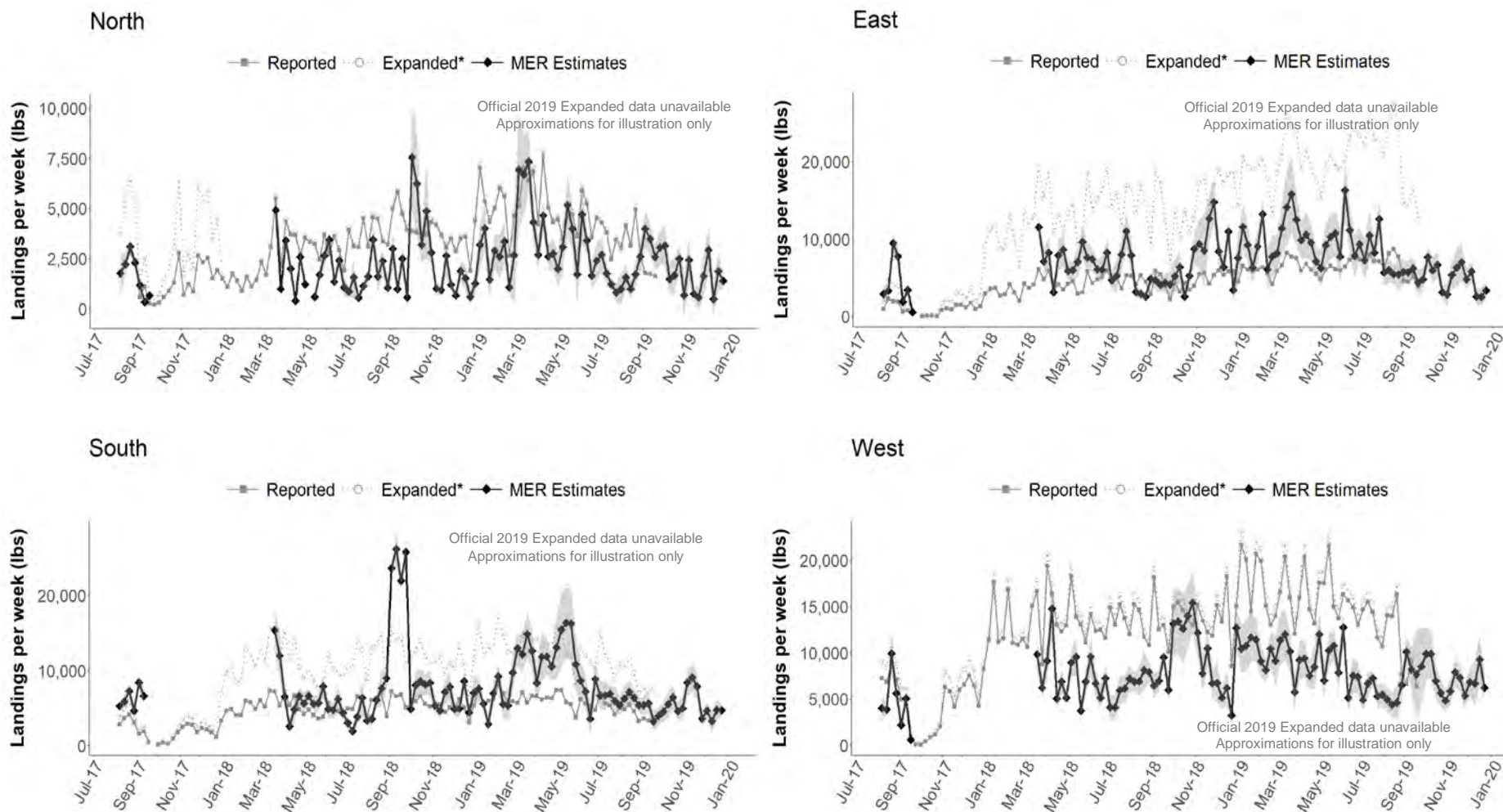


Figure 40. Weekly estimated, reported, and approximate expanded landings by region for the entire time period. The shaded area represents the proportional standard error of the weekly estimate.

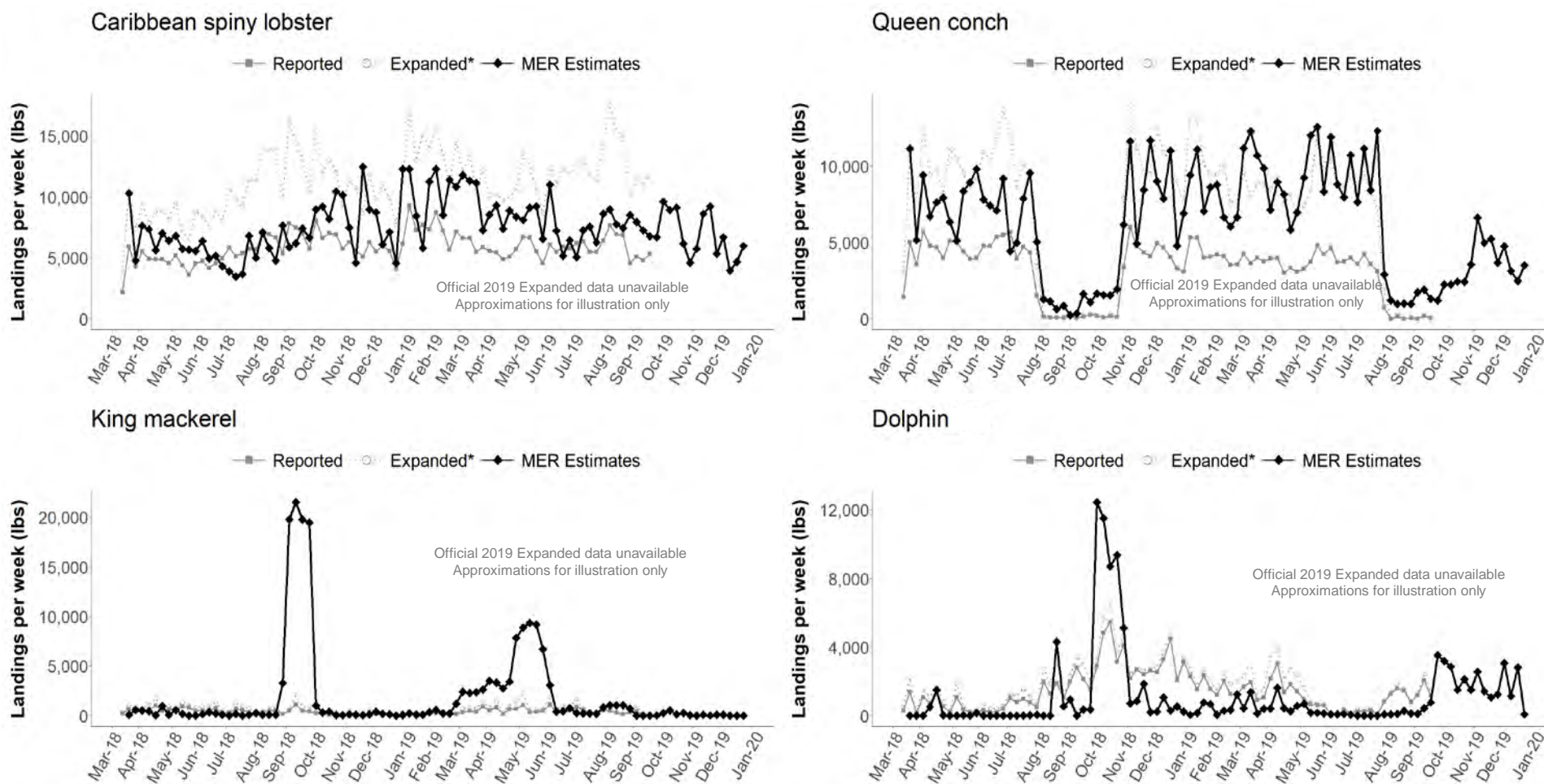


Figure 41. Weekly estimated, reported and approximate expanded landings for the top 12 species (March 2018 – Dec. 2019).

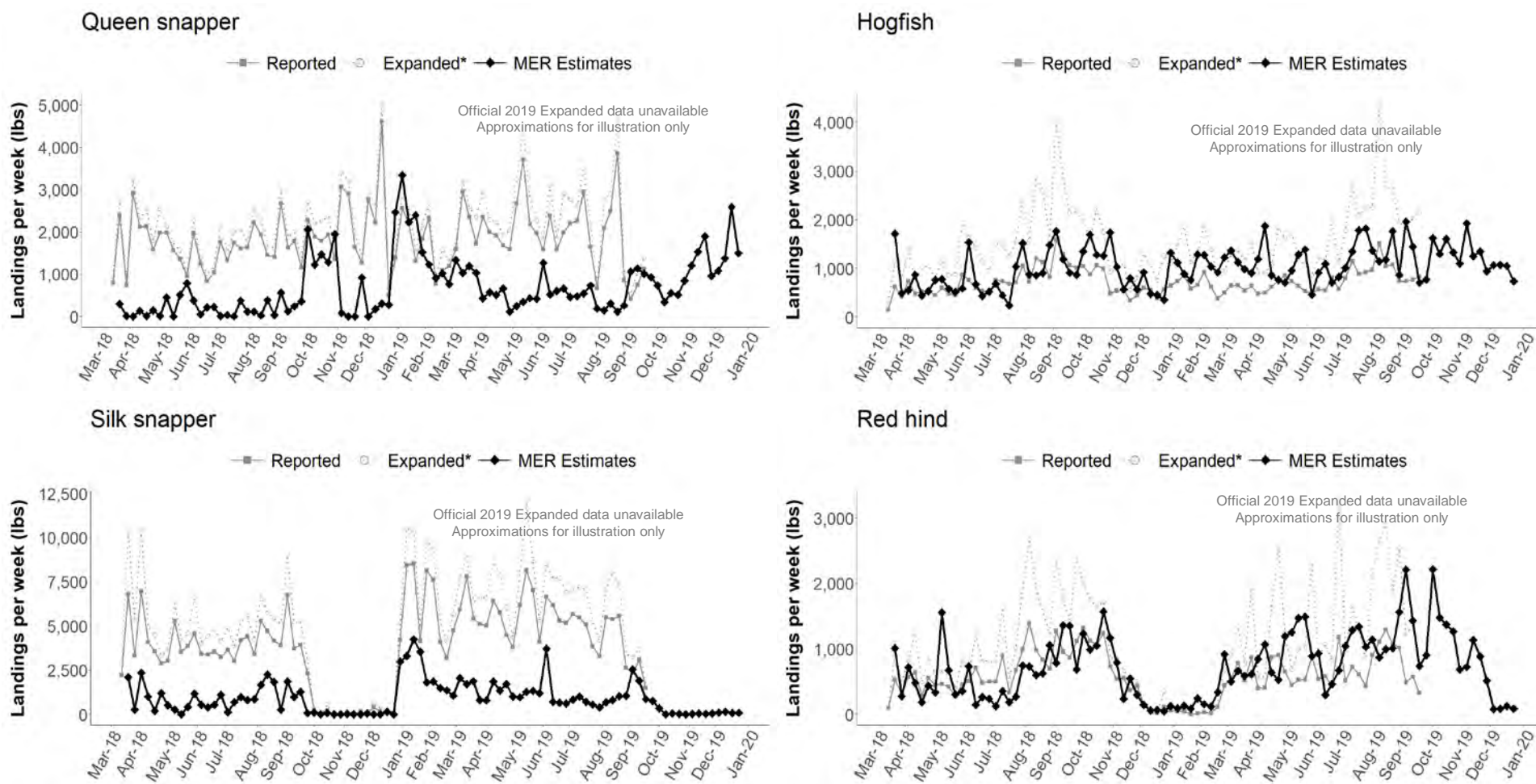


Figure 41 (cont'd). Weekly estimated, reported and approximate expanded landings for the top 12 species (March 2018 – Dec. 2019).

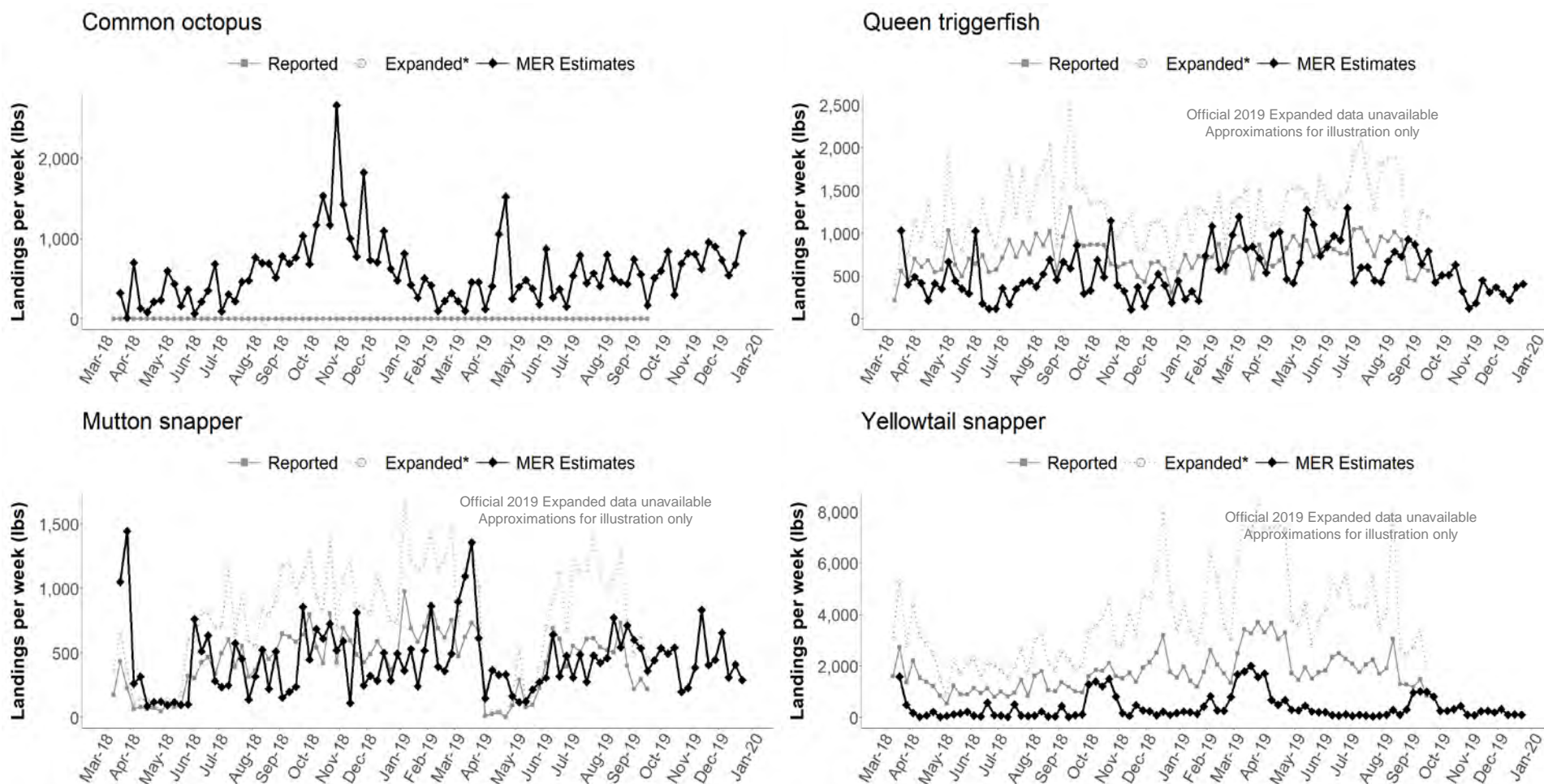


Figure 41 (cont'd). Weekly estimated, reported and approximate expanded landings for the top 12 species (March 2018 – Dec. 2019).

Official 2019 Expanded data unavailable
Approximations for illustration only

Table 30. All-Time, Top 95% Species Rankings for Estimated landings for all Regions.
All Sampling - All Regions - Estimated Weight by Species

Rank	Species	Estimated (lb)	Observed (lb)	Cumulative % of Estimated
1	lobster_caribbean_spiny	740,512	117,796	26%
2	conch_queen	575,964	103,547	47%
3	mackerel_king	173,447	5,229	53%
4	dolphin	138,116	13,027	58%
5	snapper_queen	106,649	14,029	62%
6	hogfish	104,818	17,750	65%
7	snapper_silk	101,132	15,751	69%
8	hind_red	73,037	9,957	72%
9	octopus_common	55,042	9,602	74%
10	triggerfish_queen	54,449	8,664	76%
11	snapper_mutton	46,313	8,136	77%
12	snapper_yellowtail	41,509	5,204	79%
13	snapper_lane	36,379	5,847	80%
14	shark_tiger	33,558	4,254	81%
15	parrotfish_stoplight	33,044	6,194	82%
16	unknown	24,834	7,214	83%
17	ballyhoo	24,110	8,943	84%
18	tuna_blackfin	22,097	3,394	85%
19	mackerel_cero	21,054	3,140	86%
20	trunkfish	17,730	3,537	86%
21	snapper_schoolmaster	16,868	2,968	87%
22	pilchard_false	16,109	2,164	87%
23	snapper_dog	15,893	2,406	88%
24	mullet_white	14,900	1,111	88%
25	grunt_white	13,771	2,350	89%
26	tuna_skipjack	11,574	1,825	89%
27	lobster_spanish_slipper	11,221	1,983	90%
28	herring_atlantic_thread	10,258	628	90%
29	porgy_pluma	10,081	1,903	90%
30	runner_blue	9,899	1,664	91%
31	snapper_blackfin	9,587	1,376	91%
32	sardine_scaled	9,028	1,132	92%
33	grunt_bluestriped	8,595	1,441	92%
34	barracuda_great	8,090	1,240	92%
35	cowfish_honeycombed	7,727	972	92%
36	jack_almaco	7,473	1,029	93%
37	wahoo	7,146	1,085	93%
38	parrotfish_redtail	6,679	1,298	93%
39	ray_southern_stingray	6,649	1,383	93%
40	snapper_gray	6,476	1,184	94%
41	snapper_vermilion	6,343	1,000	94%
42	cowfish_scrawled	6,144	996	94%
43	snapper_cardinal	5,906	1,014	94%
44	bocon	5,578	753	95%

Table 31. Rank of species in terms of Daytime estimated pounds landed by strata for all regions (an * indicates that the species ranking changed when auxiliary sampling estimates are included).

North			East		
Rank	High use Stratum	Low use stratum	Rank	High use Stratum	Low use stratum
1	snapper_silk	dolphin*	1	conch_queen	conch_queen
2	dolphin	lobster_caribbean_spiny*	2	lobster_caribbean_spiny	lobster_caribbean_spiny
3	mullet_white	snapper_silk	3	hogfish	hogfish
4	triggerfish_gray	mackerel_cero	4	snapper_mutton	mackerel_cero
5	snapper_queen	mackerel_king*	5	parrotfish_stoplight	parrotfish_stoplight
6	lobster_caribbean_spiny	conch_queen*	6	hind_red	snapper_mutton*
7	amberjack_greater	mojarra_stripped	7	snapper_yellowtail	shark_tiger
8	jack_almaco	herring_atlantic_thread*	8	triggerfish_queen	snapper_silk
9	shark_tiger	snapper_dog*	9	grunt_white	hind_red
10	snapper_vermilion	snapper_mutton	10	ballyhoo	triggerfish_queen
South			West		
Rank	High use Stratum	Low use stratum	Rank	High use Stratum	Low use stratum
1	lobster_caribbean_spiny	lobster_caribbean_spiny	1	lobster_caribbean_spiny	lobster_caribbean_spiny
2	octopus_common	conch_queen	2	conch_queen	snapper_silk*
3	hogfish	hogfish	3	hind_red	dolphin*
4	snapper_lane*	pilchard_false	4	hogfish*	conch_queen*
5	conch_queen*	octopus_common	5	triggerfish_queen	hind_red*
6	parrotfish_stoplight	sardine_scaled	6	snapper_queen*	tuna_blackfin*
7	snapper_mutton	snapper_lane*	7	trunkfish	snapper_queen*
8	triggerfish_queen	parrotfish_stoplight*	8	ballyhoo*	triggerfish_queen
9	dolphin*	dolphin	9	snapper_mutton*	tuna_skipjack*
10	mackerel_king*	bocon*	10	tuna_blackfin*	snapper_blackfin*

Table 32. Rank of species in terms of auxiliary estimated pounds landed by strata for the Islands.

Rank	All Stratum
1	conch_queen
2	lobster_caribbean_spiny
3	hind_red
4	hogfish
5	triggerfish_queen
6	grunt_white
7	mackerel_king*
8	grunt_bluestriped*
9	snapper_yellowtail*
10	snapper_mutton

4.2.2 Estimated landings by sampling type

The contribution of landings observed during auxiliary sampling was relatively small overall (Figure 42). The AM and PM sampling were the most productive capturing both the late landings of some of the deep-water snapper fishers, but also the early morning hook and line dolphin and king mackerel trips. On both AM and PM assignments, large landings of king mackerel, dolphin and one large tiger shark have been removed from figure 43 to reduce the impact of these rare events (see Section 4.6.2). More analyses should be done on the most efficient way of sampling these components of the landings. The greatest relative contribution can be seen in the sampling done in Vieques and Culebra where the estimated landings make up approximately 25% of the landings for the East region (Figure 44). A concerted effort to sample Vieques at least should be part of any future sampling program. In figure 45 the weekly estimates from daytime sampling are presented divided by 6 (i.e. daily) so that it would be comparable to the one Sunday a week. As expected, Sunday commercial activity was minimal in all sites that were sampled.

The estimated landings for species comprising 90% of the estimates from daytime and auxiliary is presented in table 33. The species are ranked by the total estimated landings but one should note where species rank is different between daytime and auxiliary. Queen snapper, for example is landed late in the evening and was captured by the pm sampling, and the king mackerel was observed 4 times on a couple AM sampling trips and large amounts were expanded – these species warrant closer evaluations. Also note that the reported landings for a number of species are 0, because landings are reported to the family group or lumped with another species instead.

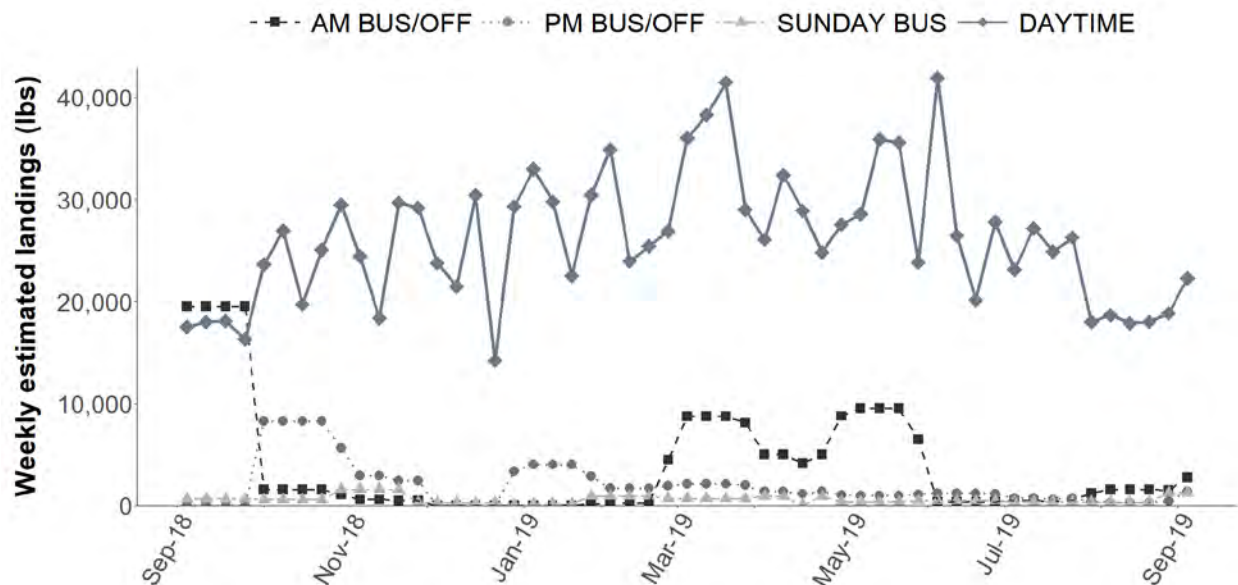


Figure 42. Contribution of each sampling type to the total estimate by week

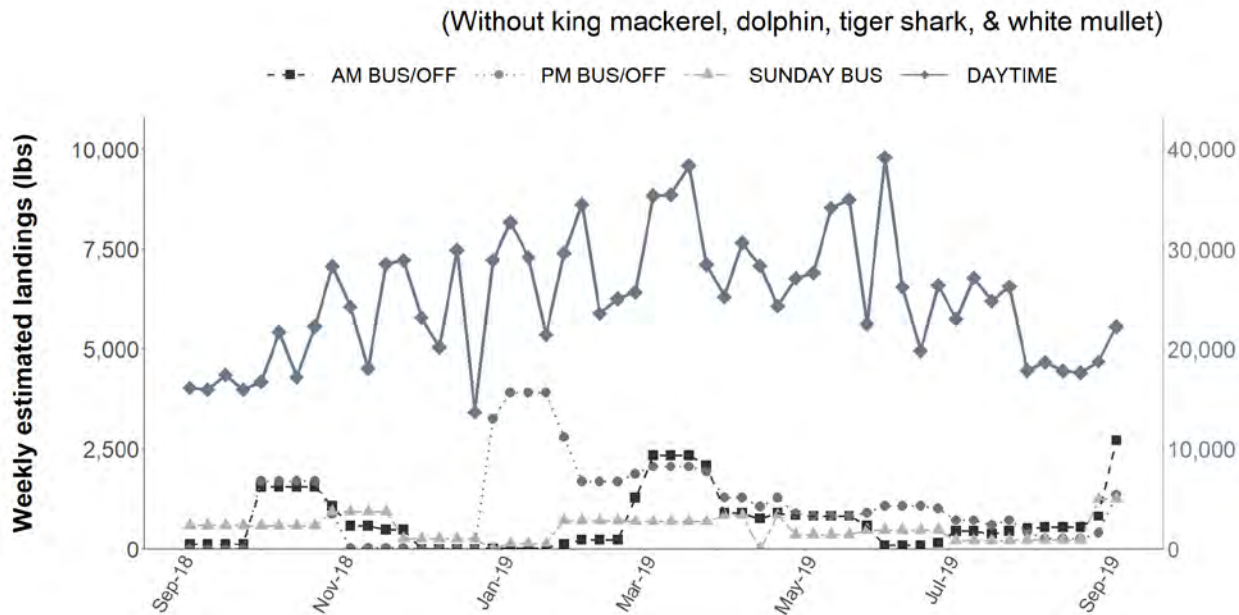


Figure 43. Contribution of each sampling type to the total estimate. Note that on the bottom panel, some rare event species have been removed (see rare event section for more details) for clarity and that total lb are on the secondary axis.

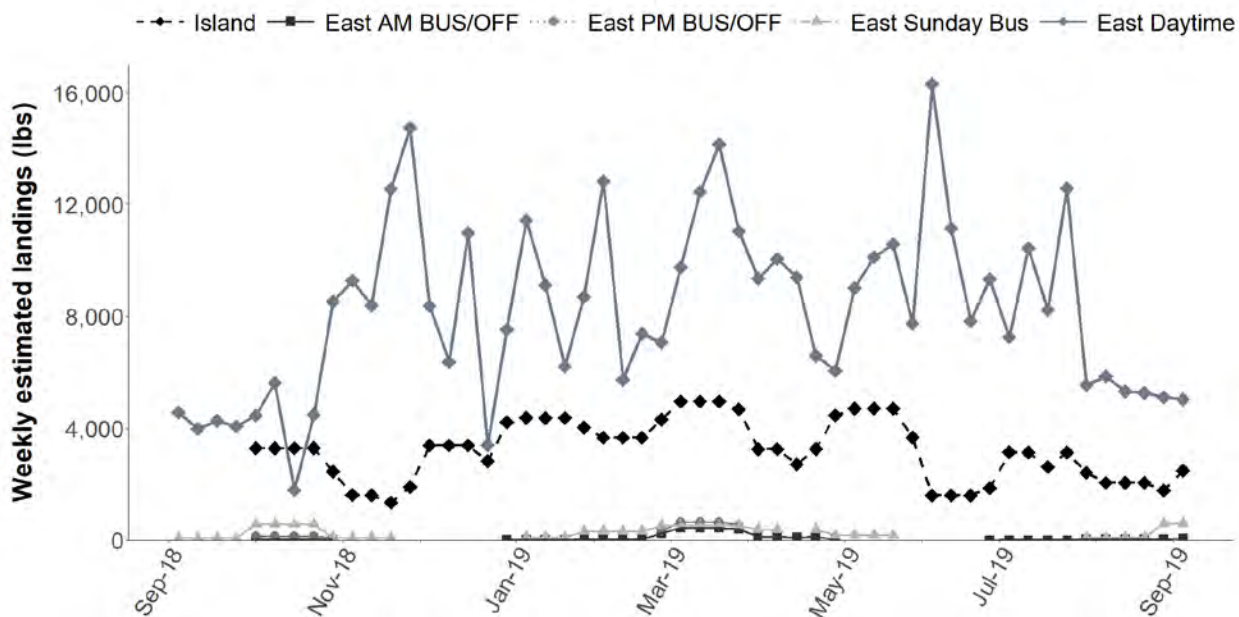


Figure 44. Contribution of Vieques and Culebra sampling in relation to the East estimates. Note that the islands make up approximately 30% of East landings.

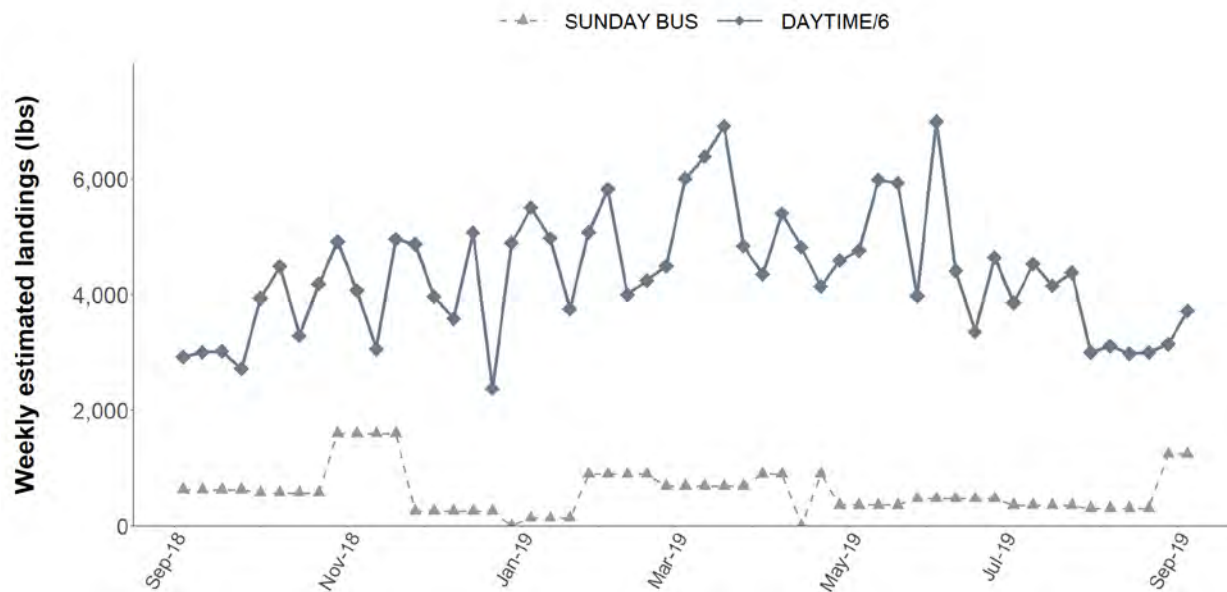


Figure 45. Contribution of Sunday sampling to the total estimates. Total landings estimated weekly is plotted divided by the six days of sampling (i.e. daily estimate) to show how the one Sunday per week contributes to total estimate.

Table 33. Estimates and ranks for species which comprise the top 90% of all estimated landings (** represents confidential data).

Species	Rank: Total Estimate	Rank: Day Estimate	Rank: Auxiliary Estimate	Rank: Reported	Day Estimate	Auxiliary Estimate	Total Combined Estimate	PSE (SE/Total Estimate)	Reported Landings
lobster_caribbean_spiny	1	1	5	1	671,899	68,612	740,512	0.02	703,472
conch_queen	2	2	2	2	467,755	108,209	575,964	0.03	484,542
mackerel_king	3	15	1	17	21,674	151,773	173,447	0.12	50,505
dolphin	4	5	4	7	68,829	69,287	138,116	0.16	180,114
snapper_queen	5	12	3	4	28,874	77,774	106,649	0.09	225,204
hogfish	6	3	12	10	96,337	8,480	104,818	0.03	82,457
snapper_silk	7	4	6	3	75,604	25,528	101,132	0.06	478,972
hind_red	8	6	10	12	59,853	13,184	73,037	0.06	68,735
octopus_common	9	7	30	-	53,666	1,376	55,042	0.05	-
triggerfish_queen	10	8	15	9	49,963	4,486	54,449	0.04	88,838
snapper_mutton	11	9	18	14	43,897	2,416	46,313	0.05	55,880
snapper_yellowtail	12	14	9	5	21,860	19,650	41,509	0.11	221,732
snapper_lane	13	10	16	6	33,153	3,226	36,379	0.12	180,590
shark_tiger	14	24	7	34	9,956	23,602	33,558	0.23	11,019
parrotfish_stoptlight	15	11	42	-	32,463	582	33,044	0.06	-
unknown	16	69	8	48	1,801	23,032	24,834	0.18	4,670
ballyhoo	17	13	144	8	24,106	4	24,110	0.24	114,692
tuna_blackfin	18	17	14	13	17,576	4,521	22,097	0.13	59,380
mackerel_cero	19	16	32	16	19,878	1,177	21,054	0.11	53,824
trunkfish	20	18	44	-	17,179	551	17,730	0.09	-
snapper_schoolmaster	21	19	47	**	16,400	468	16,868	0.06	**
pilchard_false	22	20	66	-	15,880	228	16,109	0.20	-
snapper_dog	23	21	20	-	13,549	2,344	15,893	0.07	-
mullet_white	24	59	11	29	2,846	12,054	14,900	0.66	20,301
grunt_white	25	22	17	51	10,692	3,079	13,771	0.08	4,068
tuna_skipjack	26	25	24	22	9,750	1,823	11,574	0.18	36,814
lobster_spanish_slipper	27	23	45	**	10,687	533	11,221	0.07	**
herring_atlantic_thread	28	50	13	-	3,896	6,362	10,258	0.14	-
porgy_pluma	29	26	39	-	9,369	712	10,081	0.12	-

4.3 Uncertainty

Daytime Survey Precision - A large-scale survey was implemented with targets for precision derived from the pilot study analyses. Precision goals were largely met (Table 34 and Figure 46). For all strata combined in the full survey period, eight of the top 9 species landed had standard errors of the estimated landings less than 7% of the estimate (the exception being dolphin). Only 4 of the top 28 species which comprise ~90% of the catch had proportional standard errors (PSE; standard error divided by estimated landings) >15%. In the top 95% of landings (47 species), only 5% of the landings (16 species) have PSE's > target of 15%. For all strata combined in the annual estimates, seven of the top 10 species still have PSE's less than 7% with silk and lane snapper at 9% and 15% respectively. Only dolphin at 18% is above the target precision of 15%.

Auxiliary survey precision - Precision of the auxiliary sampling programs was generally good, especially when viewed in terms of the low magnitude of the landings in these situations. Six of the top 20 species (65% of total estimated landings in the auxiliary surveys have PSE's estimated below the 15% target with only 4 and 7 species above 30% for the entire 16 months sampled and for an annual estimate, respectively (Table 34 and Figure 47).

Precision of all sampling - For the entire time period sampled the proportional standard errors (standard errors expressed as a percentage of the estimate) were 1.6% for all of PR and 2.5%, 4.3%, 3.3%, 3.4% and 5.3% for the East, North, South, West, and Islands, respectively. By species, only 6 of the top 30 species have PSE's larger than the target of 15% (see table 33 for species specific estimates).

Table 34. All time observed, estimated, and reported landings with proportional standard errors (PSE) for each sampling type.

Region	Total Observed	Total Estimate	Total PSE	Day Observed	Day Estimate	Day PSE	Auxiliary Observed	Auxiliary Estimate	Auxiliary PSE	Reported Landings
East	165,941	724,627	2%	163,851	705,281	3%	2,090	19,346	12%	652,911
North	33,890	234,949	4%	31,609	190,690	4%	2,281	44,259	15%	477,067
South	99,963	770,559	3%	97,199	593,351	2%	2,765	177,208	12%	728,375
West	117,512	879,467	3%	99,923	650,263	2%	17,590	229,204	11%	1,783,056
Island	15,848	202,035	5%	-	-	-	15,848	202,035	5%	162,844
All PR	433,154	2,811,636	2%	392,580	2,139,585	1%	40,574	672,051	5%	3,804,253

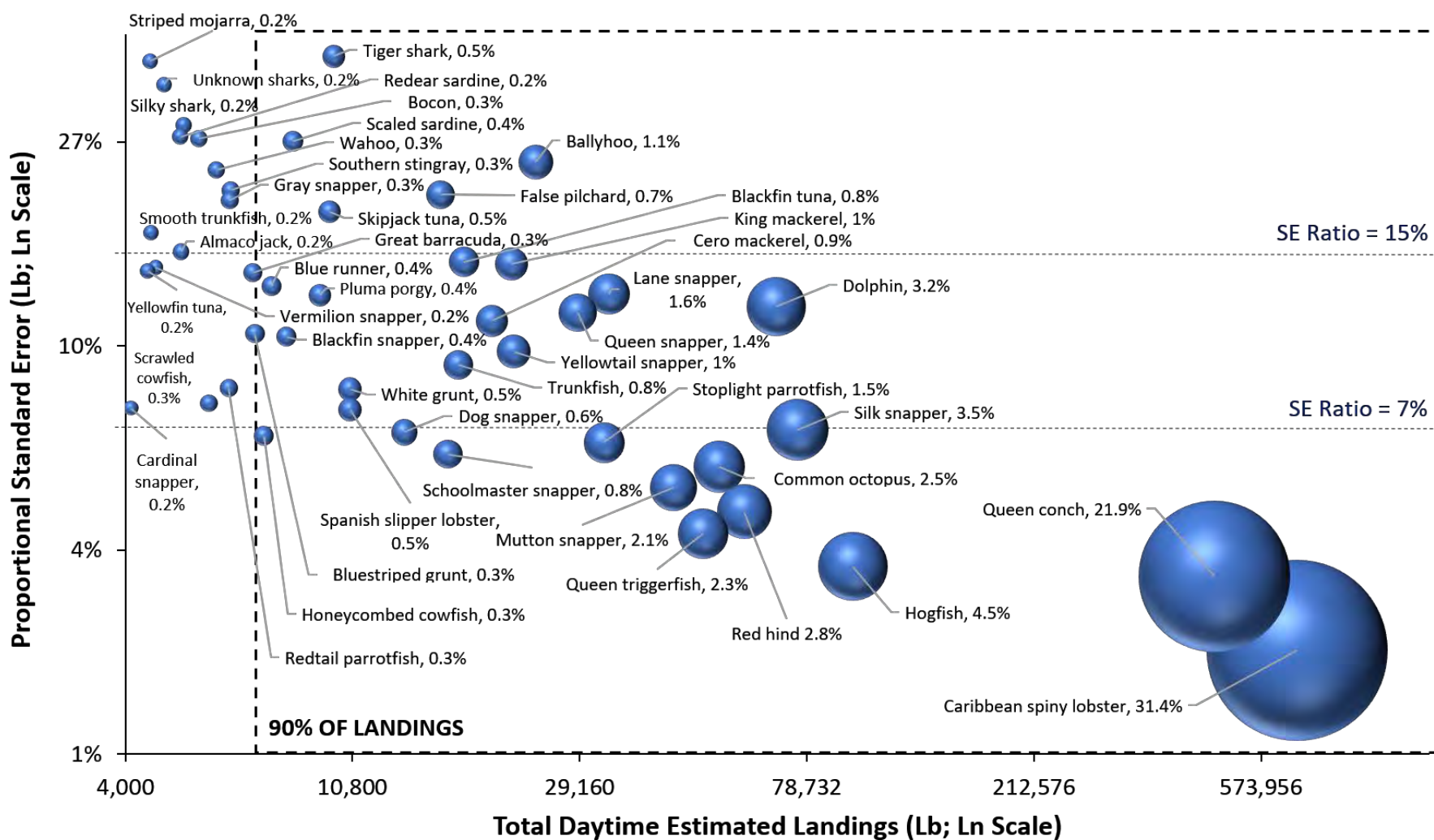


Figure 46. Total landings estimated from primary daytime survey over the entire sampled period plotted against proportional SE (both on Ln scale) for the species comprising the top 95% of the landings. Box denotes the subset of species comprising 90% of the landings. Bubble size is determined by percent of the total catch which is also indicated following the species name.

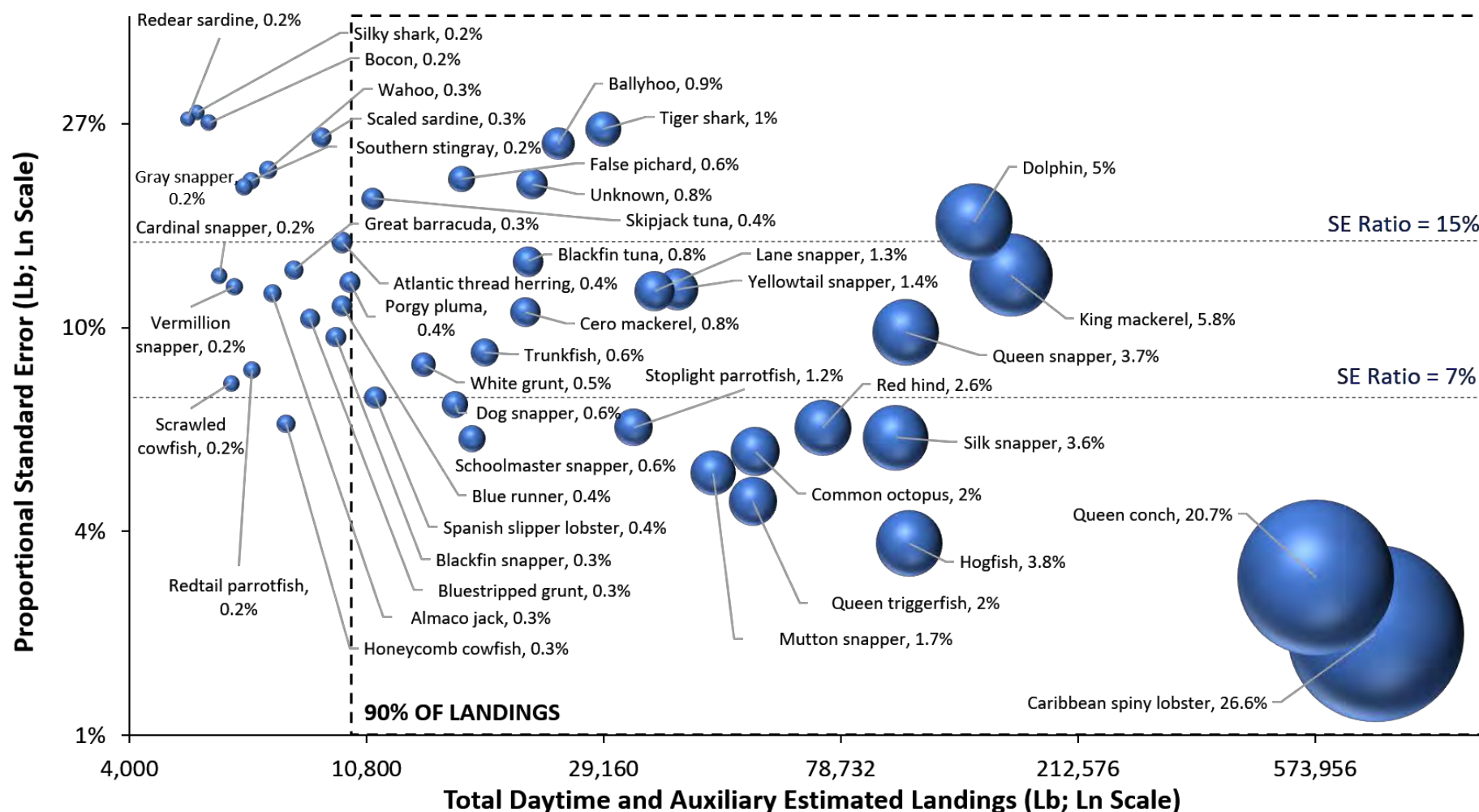


Figure 47. Total landings estimated from daytime and auxiliary sampling over the entire sampled period plotted against proportional SE (both on Ln scale) for the species comprising the top 95% of the landings. Box denotes the subset of species comprising 90% of the landings. Bubble size is determined by percent of the total catch which is also indicated following the species name.

4.4 Annual Landings Estimate compared to Commercial Catch Records (CCR)

4.4.1 Comparison to CCR

The overall purpose of this study was to estimate annual landings to validate or verify the information that is being submitted by the commercial fishers of Puerto Rico. Unfortunately, from a scientific perspective there has been minimal work to determine how these reported data relate to the reality on the ground which has made managing the fisheries by biomass based benchmarks challenging. Given that our project was only able to create estimates for landings and not a census of every landed fish, we present not the “truth”, but the comparison of our statistically designed estimates to the landings data that are self-reported by fishers.

Complete CCR data were available only through September of 2019 so we used the time period of September 1, 2018 to August 31, 2019 for our comparison period. The first thing that was noted as we began analysis was that the reported landings was extremely close to the landings that we estimated which was a little bit of a surprise (Figure 48 and Table 35). Historically, the expansion factors (i.e. correction factor to get from reported landings to actual landings) applied to the reported data has been around a factor of 2 (i.e. 100 lb reported would represent 200 actual landed lb). As the analysis progressed it became obvious that differences were obvious by region but the driving force were the species and gear type used. For example, in the East South and Islands reported landings were lower than our estimates which would be expected, while in the West and North, our estimates were lower than reported (Table 35, Figures 49 and 50).

Regional differences in the composition of the catch can be seen in table 36 through table 41 which present the top 25 species for Puerto Rico as a whole and by region for our one year comparison period. The PSE of the annual estimate were slightly higher than the entire time period (expected given lower total estimates) but the target SEs were still largely met overall (Figures 51 and 52). Please see Appendix 5 for the full species tables of estimates and variances for all of Puerto Rico and by region.

While considerable work still needs to be done to develop correction factors to use in practice, we present a couple illustrative examples. Table 42 shows the correction factors if calculated similarly to the current practice by region. To explore species specific factors, figure 53 and figure 54 plot the reported landings against the estimated landings and the resulting hypothetical correction factors for the top 10 species is shown in table 43. See Section 4.4.2 on family groupings and Section 4.6.2 on rare events for some avenues which should be explored.

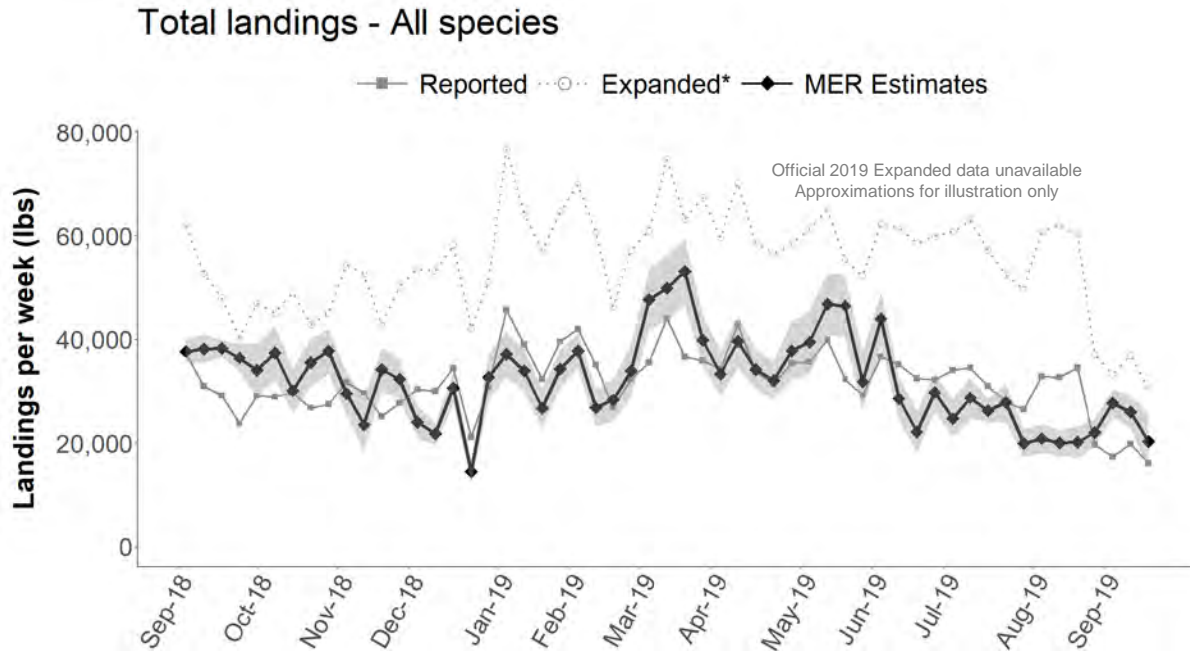


Figure 48. Total Estimated, Reported and approximate Expanded landings (9/1/18 – 8/31/19) for all Puerto Rico and all sampling types. The shaded area represents one SE of the weekly estimates.

Table 35. Total observed, estimated, and reported annual landings (9/1/18 – 8/31/19), with proportional standard errors (PSE) for each sampling type.

Region	Total Observed	Total Estimate	Total PSE	Day Observed	Day Estimate	Day PSE	Auxiliary Observed	Auxiliary Estimate	Auxiliary PSE	Reported Landings
East	102,678	444,477	3%	100,983	428,523	3%	1,695	15,954	13%	308,292
North	20,795	143,842	6%	19,242	109,195	6%	1,554	34,647	17%	228,757
South	56,836	498,382	5%	54,170	321,783	3%	2,665	176,599	12%	299,457
West	66,285	528,005	5%	54,272	345,150	3%	12,013	182,855	14%	781,304
Island	9,848	154,731	6%	-	-	-	9,848	154,731	6%	75,046
AllPR	256,441	1,769,436	2%	228,666	1,204,650	2%	27,775	564,787	6%	1,692,856

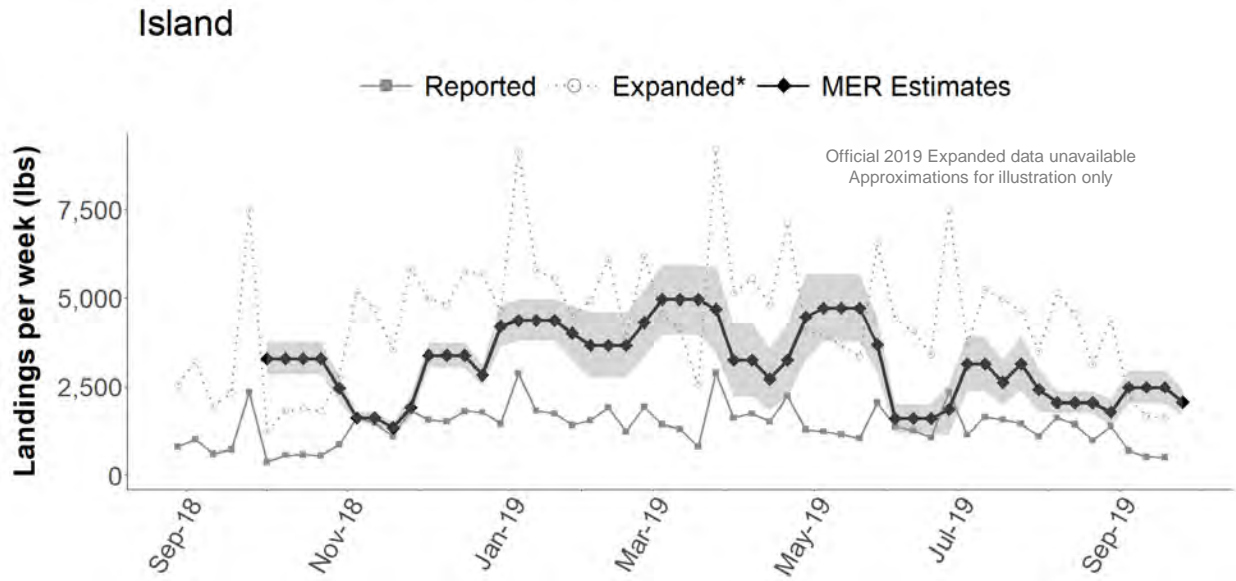


Figure 49. Total estimated, reported and approximate expanded annual landings (9/1/18 – 8/31/19) for the Island (Vieques/Culebra) region.

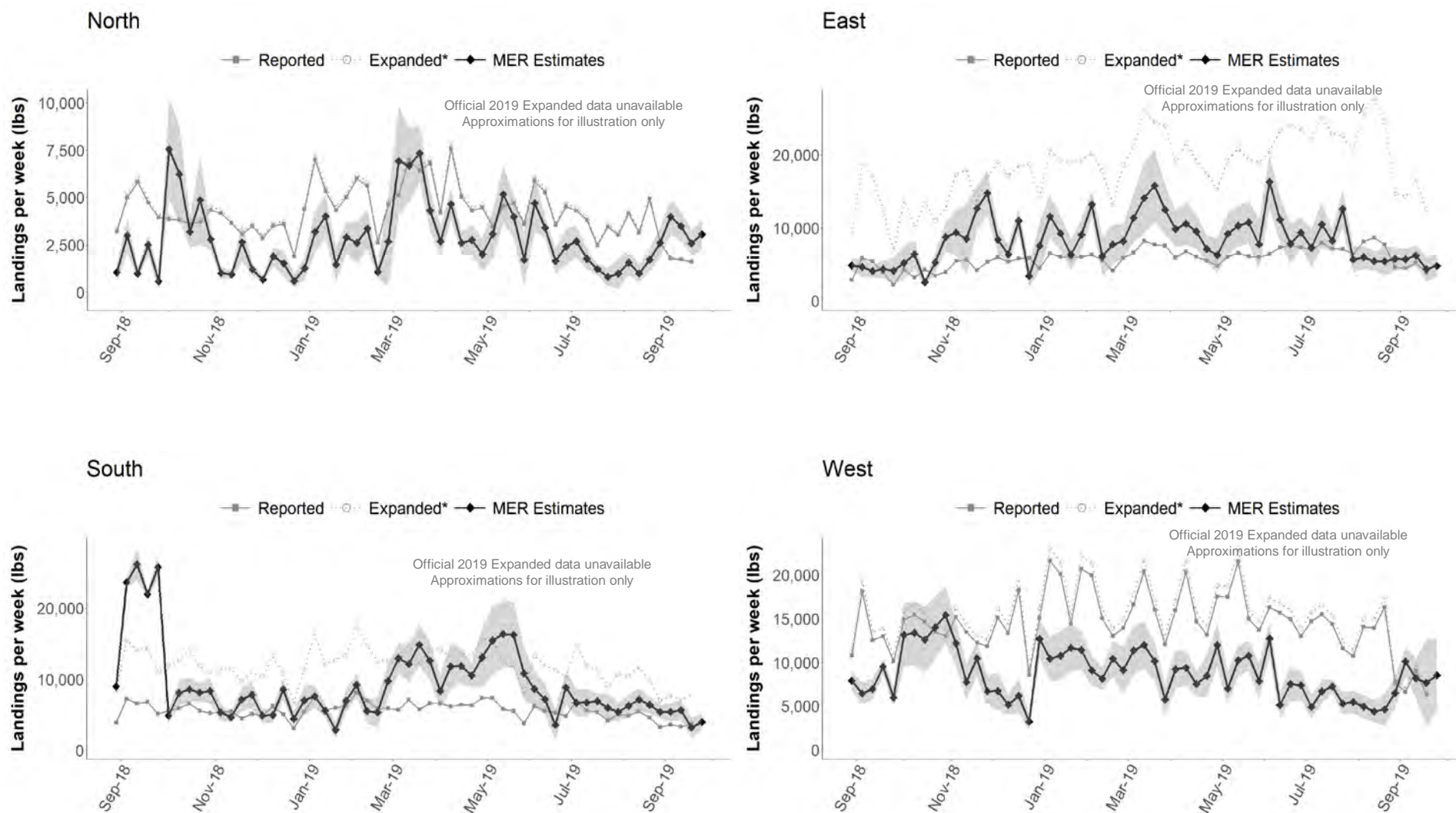


Figure 50. Total estimated, reported and approximate expanded annual landings (9/1/18 – 8/31/19) for each region.

Table 36. Top 25 species as ranked by total estimate for all Puerto Rico. Estimates and corresponding rankings by sampling type and reported landings by species are presented (9/1/18 – 8/31/19; **indicates that confidential data have been removed).

Species	Rank: Total Estimate	Rank: Day Estimate	Rank: Auxiliary Estimate	Rank: Reported	Daytime Estimate	Auxiliary Estimate	Total Estimate	Total Estimate SE	SE/Total Estimate	Reported
lobster_caribbean_spiny	1	1	4	1	385,761	54,732	440,493	13,475	0.03	327,887
conch_queen	2	2	2	3	282,670	83,065	365,734	13,476	0.04	158,297
mackerel_king	3	14	1	19	13,565	151,278	164,844	20,660	0.13	20,151
dolphin	4	6	3	6	31,906	64,782	96,689	21,900	0.23	93,532
snapper_silk	5	4	7	2	44,133	22,516	66,649	4,778	0.07	212,866
snapper_queen	6	11	5	5	16,686	48,671	65,356	7,364	0.11	105,180
hogfish	7	3	12	10	49,617	7,049	56,666	2,854	0.05	39,138
hind_red	8	8	11	11	29,568	9,233	38,800	3,806	0.10	31,409
octopus_common	9	5	26	-	33,558	1,236	34,795	2,542	0.07	-
triggerfish_queen	10	7	15	9	29,601	3,740	33,341	1,984	0.06	39,800
shark_tiger	11	21	6	34	7,545	22,717	30,262	7,470	0.25	5,249
snapper_yellowtail	12	16	9	4	10,013	15,242	25,255	4,290	0.17	105,734
snapper_mutton	13	9	20	15	22,148	1,925	24,073	1,615	0.07	26,522
snapper_lane	14	10	16	7	17,093	2,616	19,710	2,622	0.13	85,478
unknown	15	85	8	47	456	18,092	18,547	3,720	0.20	2,076
parrotfish_stoptlight	16	12	38	-	14,977	552	15,529	1,317	0.08	-
ballyhoo	17	13	131	8	14,530	4	14,534	5,288	0.36	51,394
mullet_white	18	45	10	30	2,398	12,054	14,452	9,898	0.68	8,803
mackerel_cero	19	15	34	13	12,212	780	12,991	1,663	0.13	27,986
tuna_blackfin	20	19	14	17	8,456	4,108	12,564	1,957	0.16	22,060
pilchard_false	21	17	59	-	9,054	228	9,282	2,825	0.30	-
snapper_schoolmaster	22	18	45	-	8,691	369	9,060	764	0.08	-
snapper_dog	23	22	22	-	7,538	1,460	8,998	858	0.10	-
tuna_skipjack	24	23	21	23	7,067	1,727	8,794	1,907	0.22	16,200
trunkfish	25	20	41	-	8,018	501	8,520	777	0.09	-

Table 37. Top 25 species as ranked by total estimate for the North coast. Estimates and corresponding rankings by sampling type and reported landings by species are presented (9/1/18 – 8/31/19; **indicates that confidential data have been removed).

Species	Rank: Total Estimate	Rank: Day Estimate	Rank: Auxiliary Estimate	Rank: Reported	Daytime Estimate	Auxiliary Estimate	Total Estimate	Total Estimate SE	SE/Total Estimate	Reported
snapper_silk	1	1	17	1	19,124	242	19,366	1,785	0.09	54,474
dolphin	2	2	-	2	16,380	-	16,380	4,370	0.27	34,227
lobster_caribbean_spiny	3	3	14	3	13,369	265	13,634	2,545	0.19	19,562
shark_tiger	4	30	1	**	674	12,436	13,111	5,010	0.38	**
snapper_yellowtail	5	23	2	4	1,159	7,073	8,233	3,133	0.38	18,757
mackerel_king	6	5	4	7	4,499	3,223	7,721	1,661	0.22	6,200
mackerel_cero	7	4	22	15	5,238	125	5,363	1,165	0.22	3,994
herring_atlantic_thread	8	18	3	-	1,347	3,770	5,116	943	0.18	-
conch_queen	9	6	15	21	3,409	249	3,658	1,098	0.30	2,623
snapper_dog	10	8	6	-	2,537	935	3,472	683	0.20	-
runner_blue	11	10	7	-	2,061	783	2,845	637	0.22	-
snapper_queen	12	7	-	9	2,672	-	2,672	554	0.21	5,127
snapper_mutton	13	13	8	16	1,935	700	2,635	738	0.28	3,972
barracuda_great	14	11	11	-	2,041	378	2,419	792	0.33	-
mullet_white	15	9	-	18	2,228	-	2,228	1,232	0.55	3,025
amberjack_greater	16	12	31	-	2,008	53	2,061	615	0.30	-
triggerfish_gray	17	14	-	-	1,822	-	1,822	678	0.37	-
snapper_vermilion	18	15	28	14	1,546	60	1,606	208	0.13	3,997
jack_almaco	19	16	-	-	1,545	-	1,545	327	0.21	-
mojarra_striped	20	17	-	-	1,505	-	1,505	414	0.28	-
hind_red	21	21	18	20	1,271	214	1,486	279	0.19	2,745
snapper_lane	22	25	10	5	1,030	385	1,414	344	0.24	6,985
wahoo	23	19	-	17	1,339	-	1,339	699	0.52	3,529
snapper_blackfin	24	20	50	23	1,297	8	1,305	288	0.22	1,906
jack_horseeye	25	44	5	35	326	947	1,273	429	0.34	783

Table 38. Top 25 species as ranked by total estimate for the East coast. Estimates and corresponding rankings by sampling type and reported landings by species are presented (9/1/18 – 8/31/19; **indicates that confidential data have been removed).

Species	Rank: Total Estimate	Rank: Day Estimate	Rank: Auxiliary Estimate	Rank: Reported	Daytime Estimate	Auxiliary Estimate	Total Estimate	Total Estimate SE	SE/Total Estimate	Reported
conch_queen	1	1	4	2	189,268	899	190,167	10,482	0.06	62,337
lobster_caribbean_spiny	2	2	1	1	122,954	6,010	128,964	7,746	0.06	79,660
hogfish	3	3	19	5	21,498	124	21,622	1,916	0.09	13,139
snapper_mutton	4	4	13	12	10,023	166	10,189	884	0.09	5,686
parrotfish_stopligh	5	5	15	-	7,501	160	7,661	1,007	0.13	-
triggerfish_queen	6	6	35	11	6,831	42	6,873	839	0.12	6,099
hind_red	7	7	22	13	6,523	97	6,621	674	0.10	4,965
mackerel_cero	8	8	10	6	5,390	242	5,633	1,138	0.20	10,238
snapper_yellowtail	9	9	17	3	4,917	132	5,050	1,378	0.27	33,756
ballyhoo	10	10	-	17	4,320	-	4,320	4,320	1.00	3,132
snapper_silk	11	13	3	4	3,144	937	4,081	2,310	0.57	18,030
grunt_white	12	11	14	33	3,701	162	3,864	565	0.15	678
shark_tiger	13	12	18	**	3,600	130	3,730	3,602	0.97	**
unknown	14	-	2	45	-	3,120	3,120	1,430	0.46	129
snapper_dog	15	14	28	-	2,682	60	2,742	366	0.13	-
snapper_lane	16	15	48	7	2,595	21	2,616	304	0.12	10,086
octopus_common	17	17	8	-	2,270	297	2,567	988	0.38	-
snapper_schoolmaster	18	16	16	-	2,412	153	2,565	295	0.12	-
porgy_pluma	19	18	31	-	1,992	56	2,048	261	0.13	-
grunt_bluestriped	20	21	6	**	1,470	373	1,842	343	0.19	**
goatfish_spotted	21	19	65	22	1,653	1	1,654	549	0.33	1,288
runner_blue	22	20	39	-	1,589	34	1,623	477	0.29	-
mackerel_king	23	24	5	20	1,170	426	1,596	391	0.24	2,326
parrotfish_redtail	24	22	51	-	1,451	14	1,464	209	0.14	-
cowfish_screwled	25	23	38	-	1,389	38	1,427	216	0.15	-

Table 39. Top 25 species as ranked by total estimate for the South coast. Estimates and corresponding rankings by sampling type and reported landings by species are presented (9/1/18 – 8/31/19; **indicates that confidential data have been removed).

Species	Rank: Total Estimate	Rank: Day Estimate	Rank: Auxiliary Estimate	Rank: Reported	Daytime Estimate	Auxiliary Estimate	Total Estimate	Total Estimate SE	SE/Total Estimate	Reported
mackerel_king	1	10	1	14	5,782	146,366	152,148	20,562	0.14	6,244
lobster_caribbean_spiny	2	1	4	1	113,384	3,715	117,099	5,683	0.05	72,329
conch_queen	3	2	16	5	37,194	381	37,575	3,535	0.09	14,284
octopus_common	4	3	8	-	28,581	930	29,511	2,333	0.08	-
hogfish	5	4	18	11	17,768	297	18,065	1,327	0.07	8,911
snapper_lane	6	5	5	2	12,449	1,639	14,088	2,541	0.18	32,183
shark_tiger	7	-	2	**	-	9,845	9,845	3,946	0.40	**
snapper_yellowtail	8	19	3	3	2,729	6,398	9,127	2,534	0.28	22,765
pilchard_false	9	6	-	-	8,385	-	8,385	2,813	0.34	-
triggerfish_queen	10	7	-	8	7,976	-	7,976	1,076	0.13	10,756
parrotfish_stoplight	11	8	33	-	7,025	15	7,040	842	0.12	-
dolphin	12	12	7	6	5,588	942	6,530	2,356	0.36	12,231
snapper_mutton	13	11	9	15	5,755	594	6,349	904	0.14	5,429
ballyhoo	14	9	-	4	5,784	-	5,784	2,520	0.44	18,083
sardine_scaled	15	13	23	-	5,347	106	5,454	1,787	0.33	-
snapper_schoolmaster	16	14	27	-	4,281	34	4,314	660	0.15	-
snapper_silk	17	20	17	7	2,708	343	3,051	630	0.21	11,084
lobster_spanish_slipper	18	15	20	**	2,858	157	3,015	501	0.17	**
snapper_queen	19	21	14	18	2,496	419	2,915	856	0.29	4,530
bocon	20	18	25	-	2,789	55	2,844	1,061	0.37	-
porgy_pluma	21	17	31	-	2,792	17	2,809	725	0.26	-
trunkfish	22	16	-	-	2,802	-	2,802	638	0.23	-
sardine_redear	23	22	-	-	2,264	-	2,264	922	0.41	-
ray_southern_stingray	24	23	-	-	2,220	-	2,220	1,127	0.51	-
grunt_white	25	24	21	32	1,984	145	2,128	345	0.16	748

Table 40. Top 25 species as ranked by total estimate for the West coast. Estimates and corresponding rankings by sampling type and reported landings by species are presented (9/1/18 – 8/31/19; **indicates that confidential data have been removed).

Species	Rank: Total Estimate	Rank: Day Estimate	Rank: Auxiliary Estimate	Rank: Reported	Daytime Estimate	Auxiliary Estimate	Total Estimate	Total Estimate SE	SE/Total Estimate	Reported
lobster_caribbean_spiny	1	1	12	1	136,054	1,264	137,318	7,011	0.05	137,292
dolphin	2	8	1	5	9,741	63,840	73,582	21,329	0.29	45,956
snapper_queen	3	6	2	3	10,567	48,252	58,819	7,284	0.12	92,041
conch_queen	4	2	9	4	52,798	1,731	54,529	3,324	0.06	52,750
snapper_silk	5	4	3	2	19,156	20,482	39,638	3,712	0.09	129,188
hind_red	6	3	21	14	19,966	338	20,304	1,565	0.08	14,881
unknown	7	42	4	37	456	14,972	15,428	3,434	0.22	1,222
triggerfish_queen	8	5	-	10	13,787	-	13,787	838	0.06	17,528
mullet_white	9	-	5	41	-	12,027	12,027	9,820	0.82	921
tuna_blackfin	10	9	6	8	7,996	3,863	11,859	1,942	0.16	21,408
hogfish	11	7	-	15	9,954	-	9,954	667	0.07	13,453
tuna_skipjack	12	10	10	13	6,376	1,727	8,103	1,873	0.23	15,429
trunkfish	13	11	31	-	4,734	104	4,839	418	0.09	-
snapper_mutton	14	12	39	18	4,435	48	4,483	650	0.14	10,675
ballyhoo	15	13	-	7	4,426	-	4,426	1,718	0.39	29,478
shark_tiger	16	14	22	26	3,271	306	3,576	1,468	0.41	4,255
jack_almaco	17	23	8	-	1,319	2,133	3,452	415	0.12	-
cowfish_honeycombed	18	15	45	-	2,761	30	2,791	217	0.08	-
wahoo	19	17	27	17	2,507	178	2,685	972	0.36	10,786
mackerel_king	20	19	17	22	2,115	554	2,668	1,003	0.38	5,005
octopus_common	21	16	-	-	2,549	-	2,549	203	0.08	-
snapper_blackfin	22	18	25	27	2,230	186	2,416	483	0.20	3,763
herring_atlantic_thread	23	-	7	-	-	2,291	2,291	918	0.40	-
snapper_yellowtail	24	26	16	11	1,207	736	1,944	463	0.24	16,824
amberjack_greater	25	21	24	-	1,661	232	1,894	752	0.40	-

Table 41. Top 25 species as ranked by total estimate for the Islands. Estimates and corresponding rankings by sampling type and reported landings by species are presented (9/1/18 – 8/31/19; **indicates that confidential data have been removed).

Species	Rank: Total Estimate	Rank: Day Estimate	Rank: Auxiliary Estimate	Rank: Reported	Daytime Estimate	Auxiliary Estimate	Total Estimate	Total Estimate SE	SE/Total Estimate	Reported
conch_queen	1	-	1	1	-	79,805	79,805	6,855	0.09	26,303
lobster_caribbean_spiny	2	-	2	2	-	43,477	43,477	5,800	0.13	19,044
hind_red	3	-	3	4	-	8,583	8,583	3,382	0.39	5,940
hogfish	4	-	4	5	-	6,511	6,511	1,491	0.23	2,430
triggerfish_queen	5	-	5	6	-	3,698	3,698	1,150	0.31	1,250
grunt_white	6	-	6	-	-	1,703	1,703	639	0.38	-
snapper_yellowtail	7	-	7	3	-	902	902	224	0.25	13,632
grunt_bluestriped	8	-	8	-	-	884	884	324	0.37	-
mackerel_king	9	-	9	12	-	710	710	360	0.51	376
runner_blue	10	-	10	-	-	607	607	287	0.47	-
tunny_little	11	-	11	-	-	552	552	294	0.53	-
snapper_silk	12	-	12	**	-	513	513	363	0.71	**
coney	13	-	13	10	-	428	428	209	0.49	481
snapper_mutton	14	-	14	8	-	417	417	208	0.50	760
trunkfish	15	-	15	-	-	397	397	121	0.30	-
grouper_red	16	-	16	-	-	381	381	219	0.57	-
parrotfish_stopligh	17	-	17	-	-	377	377	44	0.12	-
cowfish_honeycombed	18	-	18	-	-	339	339	93	0.27	-
parrotfish_redtail	19	-	19	-	-	307	307	167	0.54	-
grouper_yellowfin	20	-	20	15	-	304	304	239	0.79	218
lobster_spanish_slipper	21	-	21	-	-	301	301	134	0.45	-
porgy_pluma	22	-	22	-	-	287	287	220	0.77	-
tuna_bigeye	23	-	23	-	-	281	281	281	1.00	-
tuna_blackfin	24	-	24	-	-	245	245	143	0.59	-
grouper_nassau	25	-	25	-	-	240	240	173	0.72	-

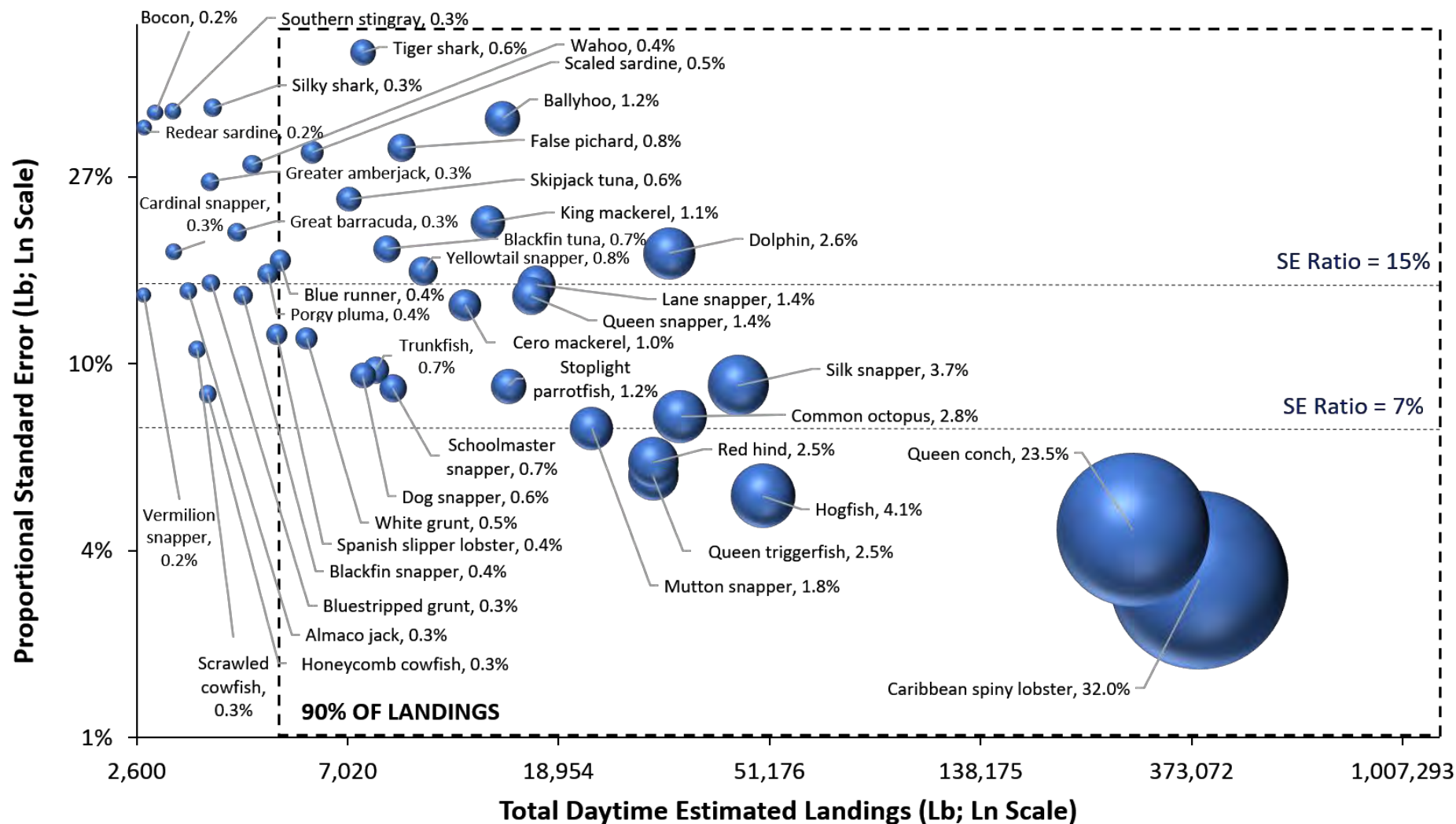


Figure 51. Total landings estimated from primary daytime survey over our annual period plotted against proportional SE (both on Ln scale) for the species comprising the top 95% of the landings (9/1/18 – 8/31/19). Box denotes the subset of species comprising 90% of the landings. Bubble size is determined by percent of the total catch which is also indicated following the species name.

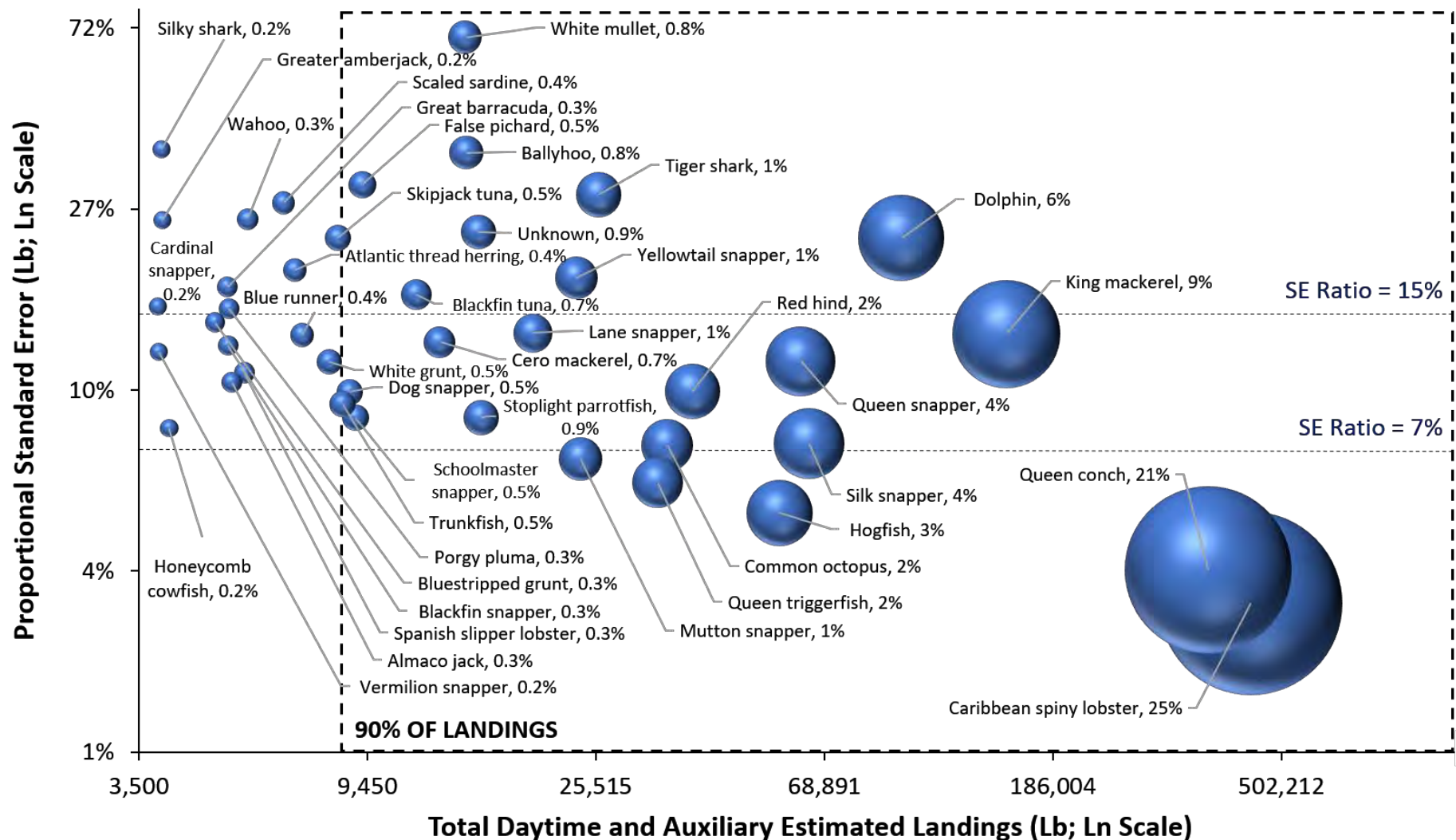


Figure 52. Total landings estimated from daytime and auxiliary sampling over our annual period plotted against proportional SE (both on ln scale) for the species comprising the top 95% of the landings (9/1/18 – 8/31/19). Box denotes the subset of species comprising 90% of the landings. Bubble size is determined by percent of the total catch which is also indicated following the species name.

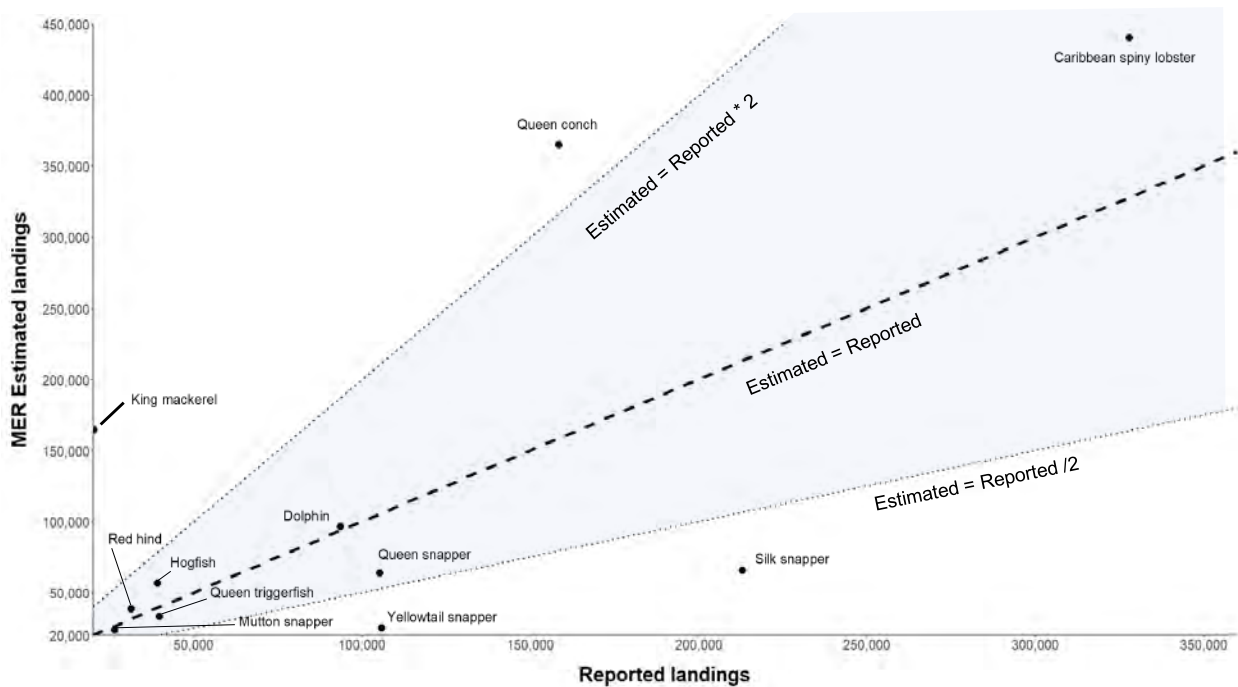


Figure 53. Comparison of estimated landings to reported landings for any species found in both data sets with annual landings of greater than 20,000 lb (9/1/18 – 8/31/19)).

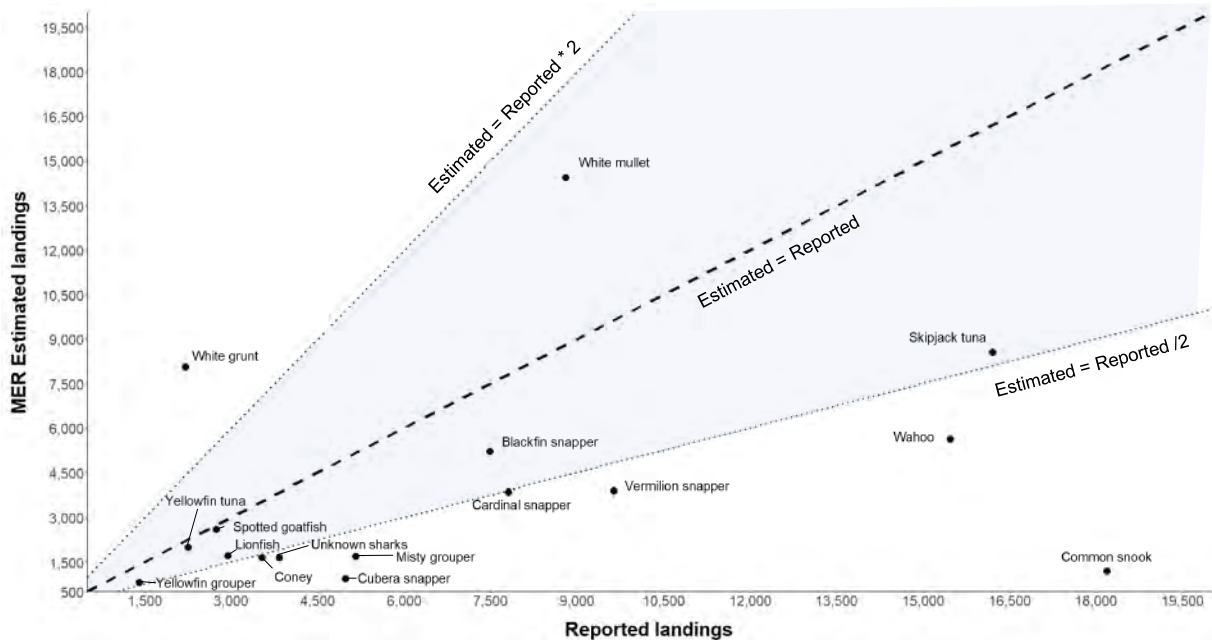


Figure 54. Comparison of estimated landings to reported landings for any species found in both data sets with annual landings of between 500 and 20,000 lb (9/1/18 – 8/31/19). Note that only species names that matched directly are included – see next section on family Groupings.

Table 42. Annual correction factors by coast from both primary daytime and auxiliary sampling. Note that Island is presented separately but would normally be combined into the East region. We present as such to highlight the differences in reporting but also because of the differences in sampling the East (primary sampling) and the Islands (auxiliary).

Region	Total Estimated Landings	Reported Landings	Correction Factor
East*	444,477	308,292	1.4
Islands*	154,731	75,046	2.1
North	143,842	228,757	0.6
South	498,382	299,457	1.6
West	528,005	781,304	0.7
PR Total	1,769,436	1,692,856	1.0

Table 43. Annual correction factors from both primary daytime and auxiliary sampling for the top 10 Species as ranked by estimated landings. **King mackerel estimate is daytime only - see rare event species section; ***Species ID issues need to be resolved - i.e. no common octopus reported; only queen triggerfish reported whereas MER includes 5 species)

Species	Correction Factor
Caribbean spiny lobster	1.3
Queen conch	2.3
King Mackerel**	0.7
Dolphin	1.0
Silk snapper	0.3
Queen snapper	0.6
Hogfish	1.4
Red hind	1.2
Common octopus***	--
Queen triggerfish***	0.8

4.4.2 Family Groupings for comparison to low resolution species reporting

The species composition and number of species in particular of the sampled data and reported data are markedly different with 267 species recorded by samplers and only 76 being reported during the entire sampling period. 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). During our one-year comparison period the number of species reported and that observed by samplers 233 and 64 (Table 44). This is not unexpected and the sampling data can be used to evaluate the family or unknown groups to better inform managers as to the most appropriate indicator species. We provide a number of examples below that illustrate why the use of groupings for comparisons are critical to our understanding of the survey results in comparison to the CCR's. The most obvious examples are in figure 55 for octopus and for parrotfish in figure 56. For both octopus and parrotfish, the only reported data were to octopus_unknown and parrotfish_unknown categories. A simple name matching approach to determining appropriate correction factors will thus be problematic. Examples for triggerfish, boxfish, groupers, and snappers are below (Figures 57 - 60).

In some cases grouping will have to be tailored to take into account the question at hand. For example, the all grouper plot (Figure 60) is comprised of virtually all red hind so the signal of other species is going to be missed. Alternatively, the exploration into the snapper fisheries should take into account which species are deep water and which are night fisheries.

We present illustrative examples of how the correction factors could be calculated given the results of our data and the rough family groupings in table 45. Figures 61 and 62 also plot reported and estimated landings for the family groupings to illustrate how the consolidation of species changes the results presented in the previous section (Figures 53 and 54)

Table 44. Total Number of species observed for annual estimates

Region	Total Species Observed	Total Species Reported
East	140	51
North	149	54
South	132	50
West	152	52
Islands	59	23
All PR	233	64

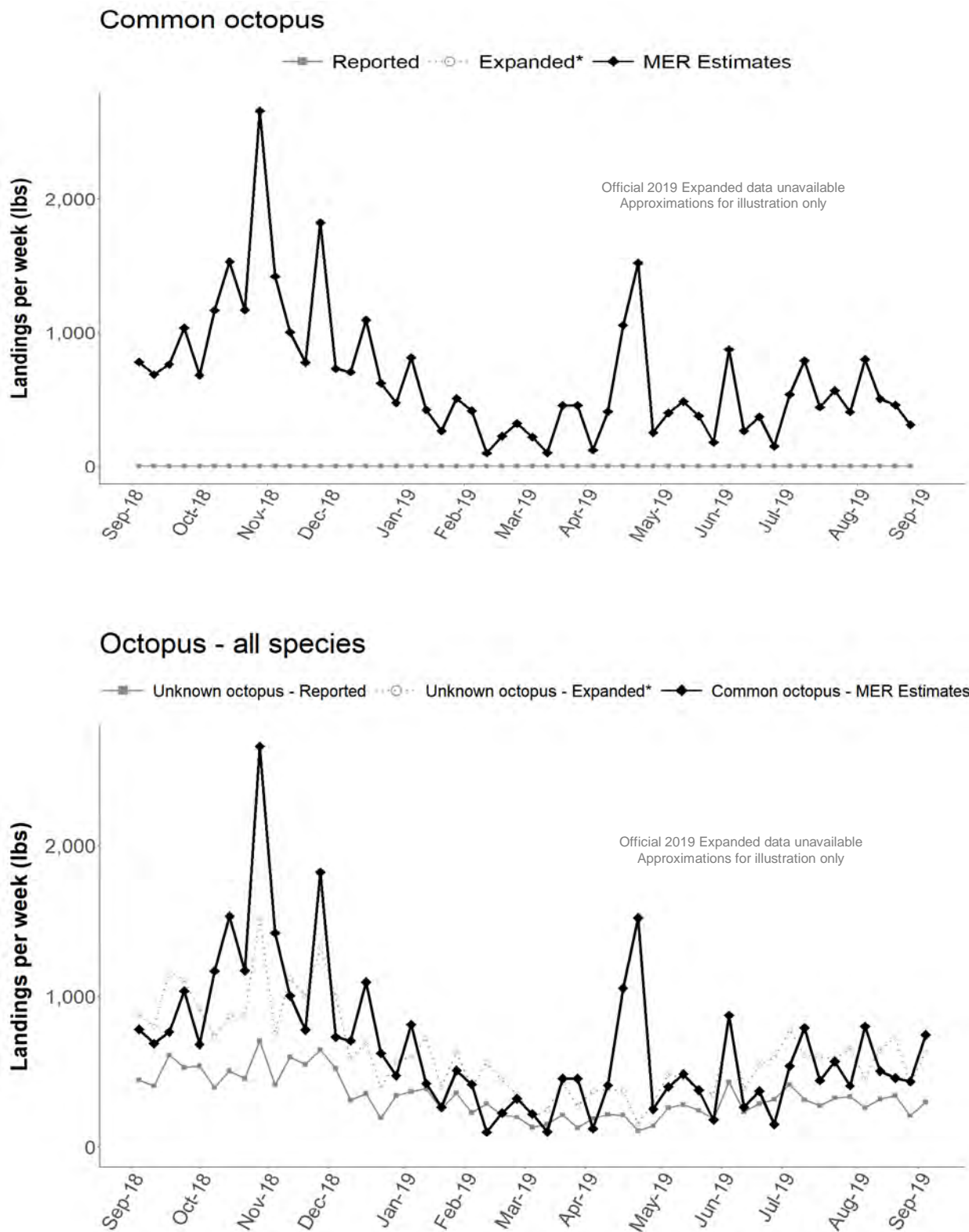
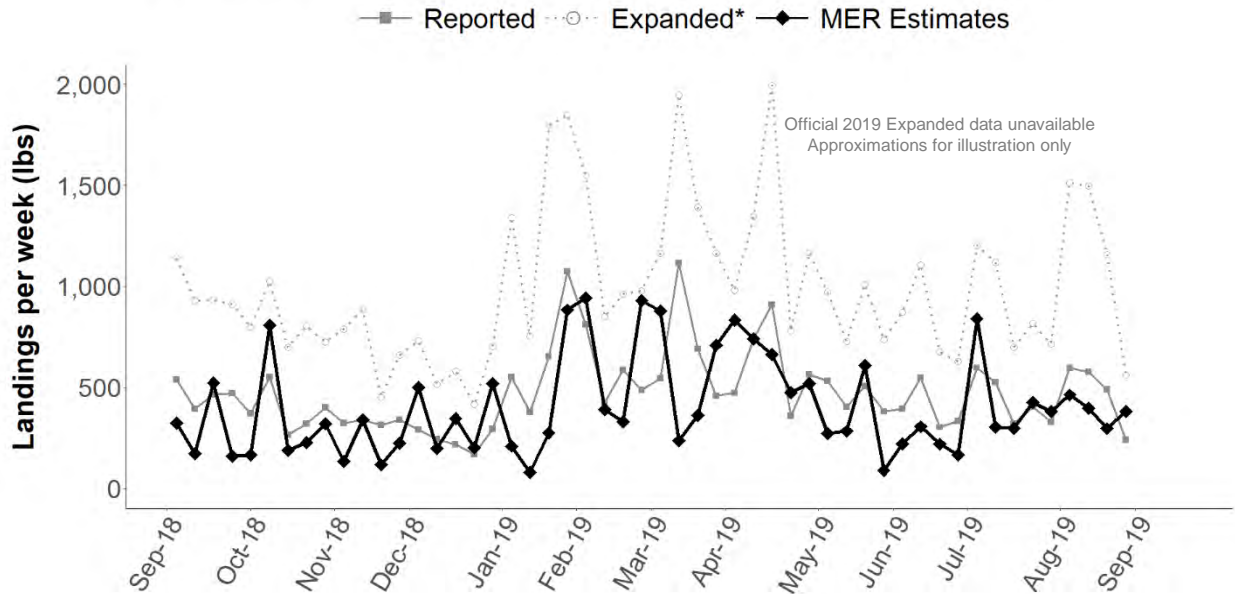
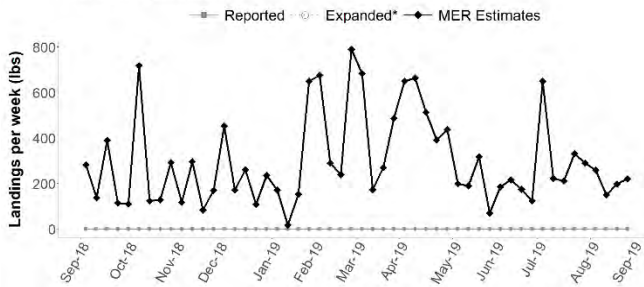


Figure 55. An Octopus example. Panel: One-year time series for the species: Common Octopus (note that only octopus unknown was reported). Bottom Panel: Reported octopus unknown plotted against the species Common Octopus from the survey.

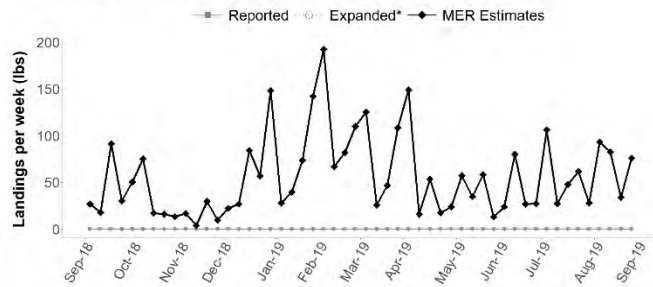
Parrotfishes



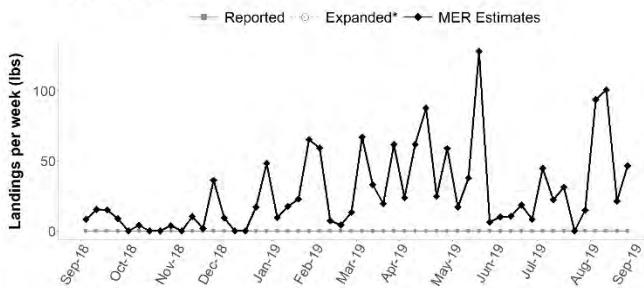
Stoplight parrotfish



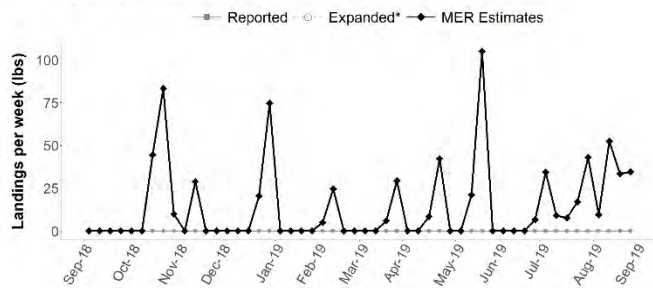
Redtail parrotfish



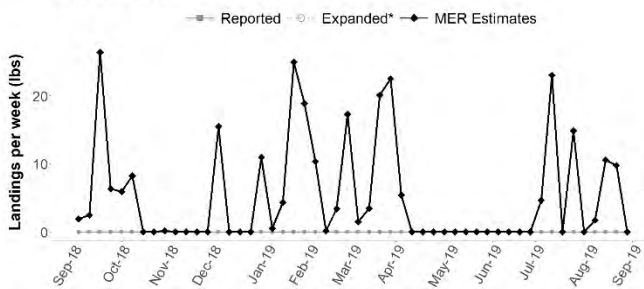
Redfin parrotfish



Rainbow parrotfish



Queen parrotfish



Parrotfish, unknown

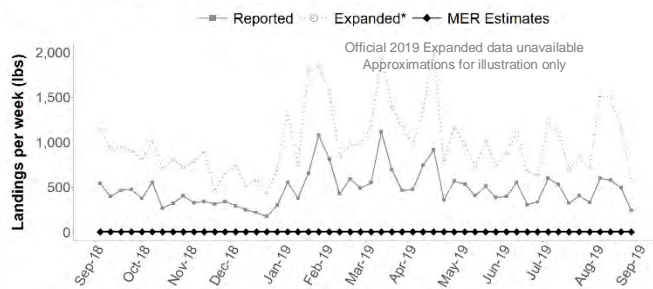


Figure 56 Time Series plots for Parrotfish family grouping and component species.

Triggerfishes

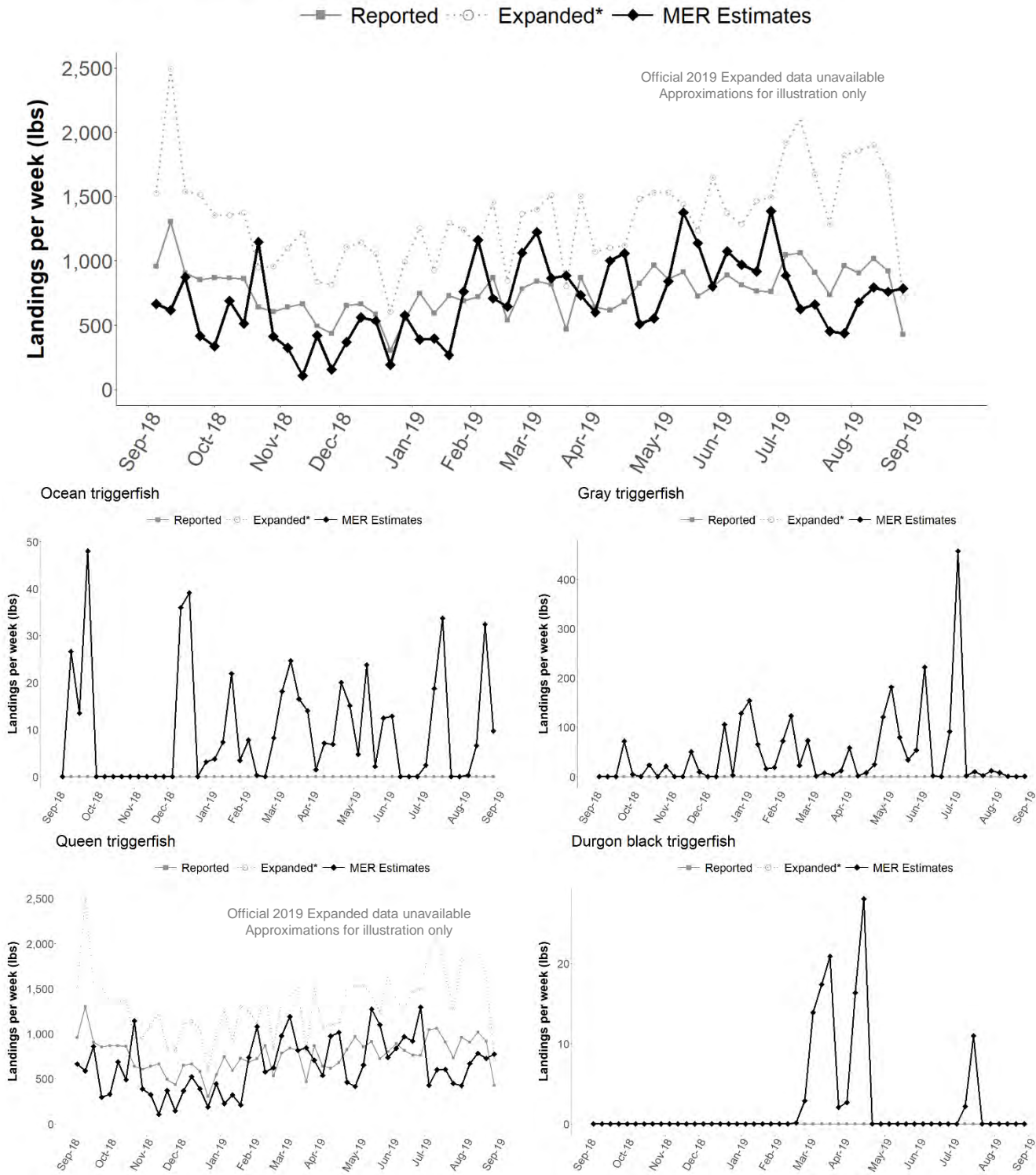
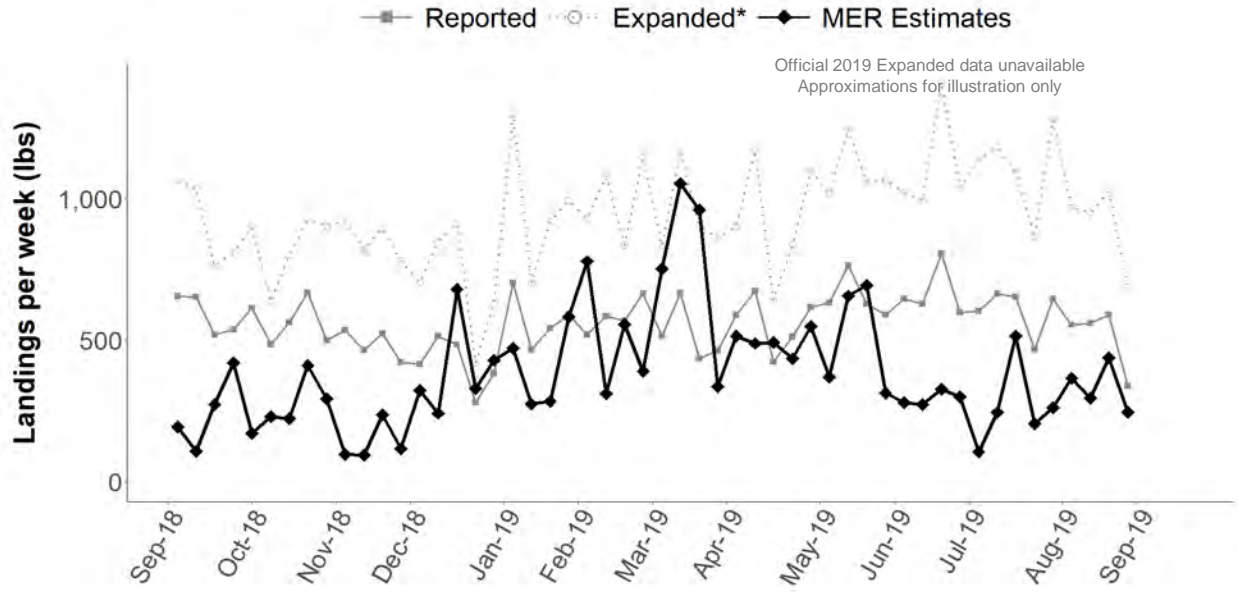
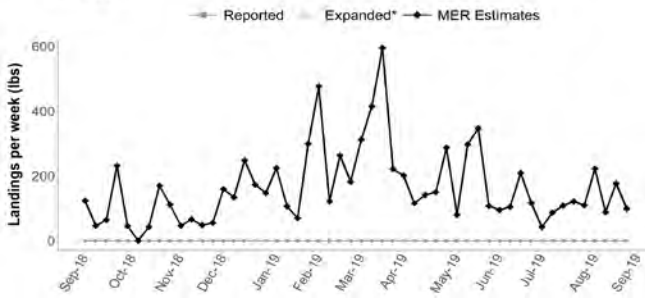


Figure 57. Time Series plots for Triggerfish family grouping and component species.

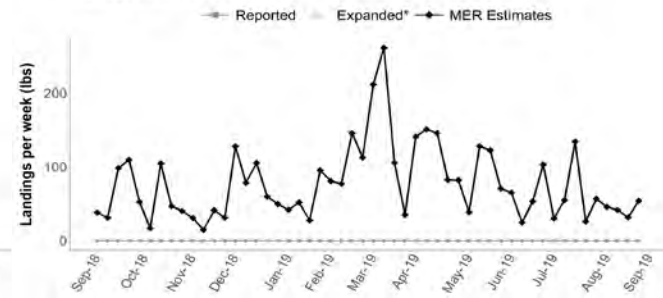
Boxfishes



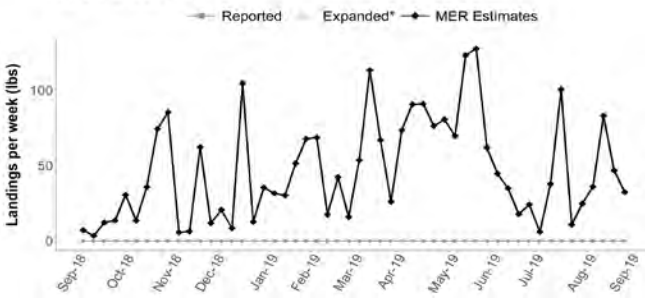
Trunkfish



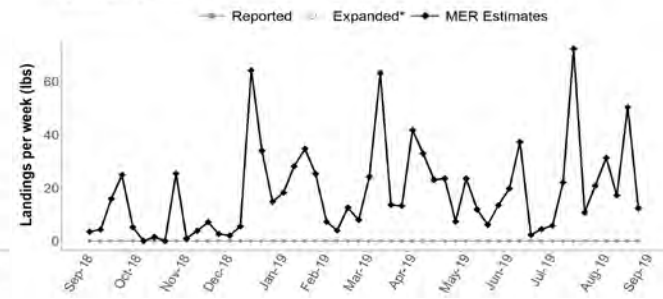
Honeycombed cowfish



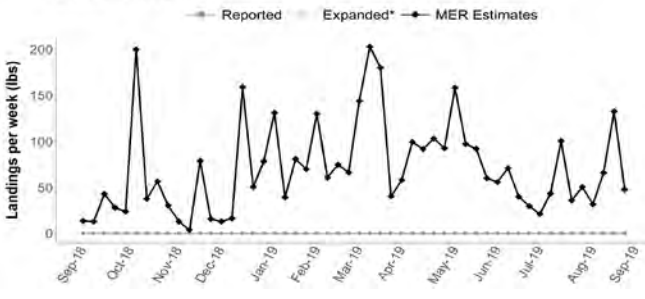
Spotted trunkfish



Smooth trunkfish



Scrawled cowfish



Boxfish, unknown

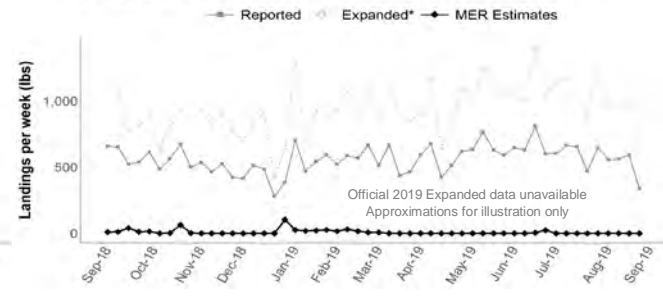


Figure 58. Time Series plots for Boxfish family grouping and component species.

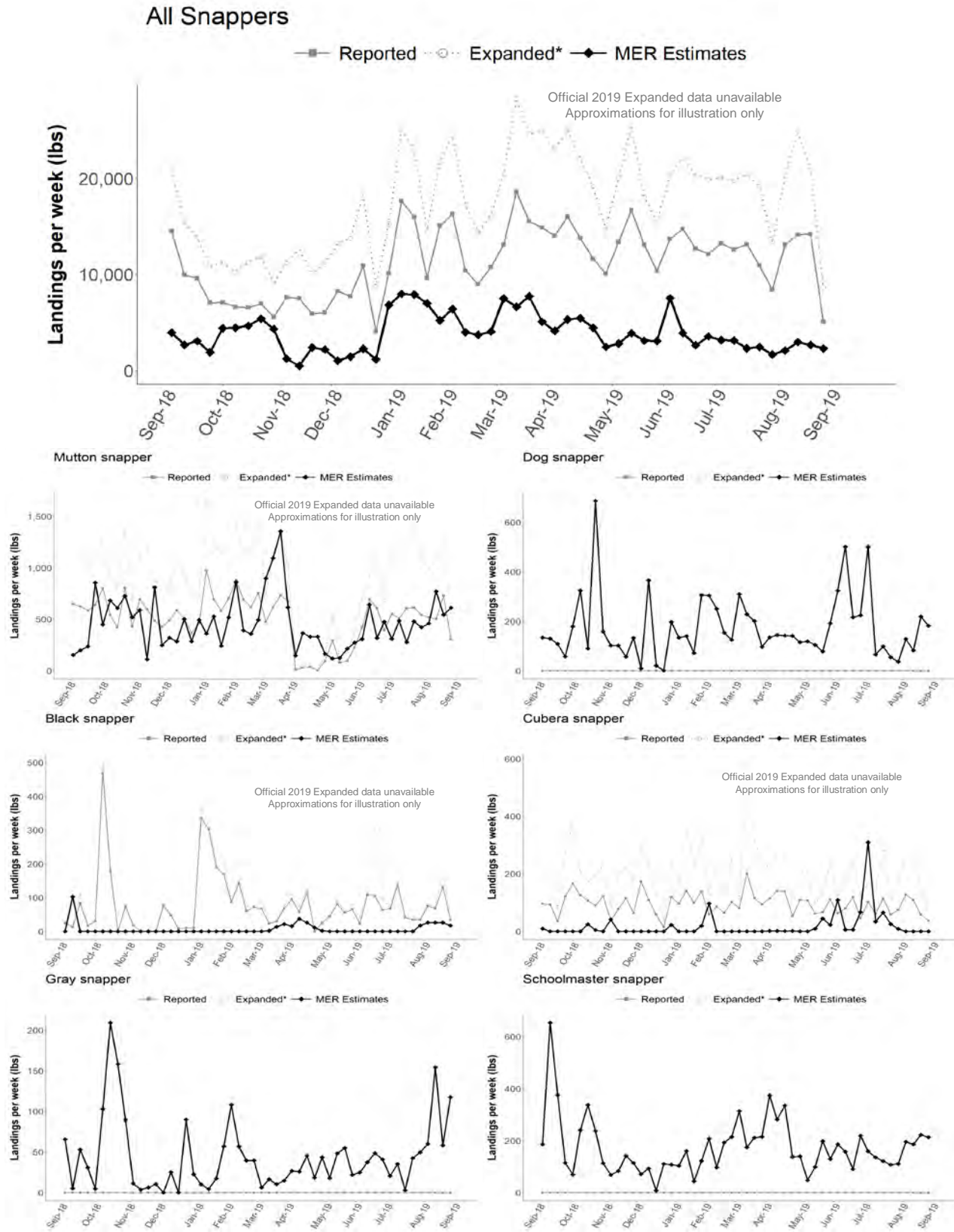


Figure 59. Time Series plots for Snappers family grouping and component species.

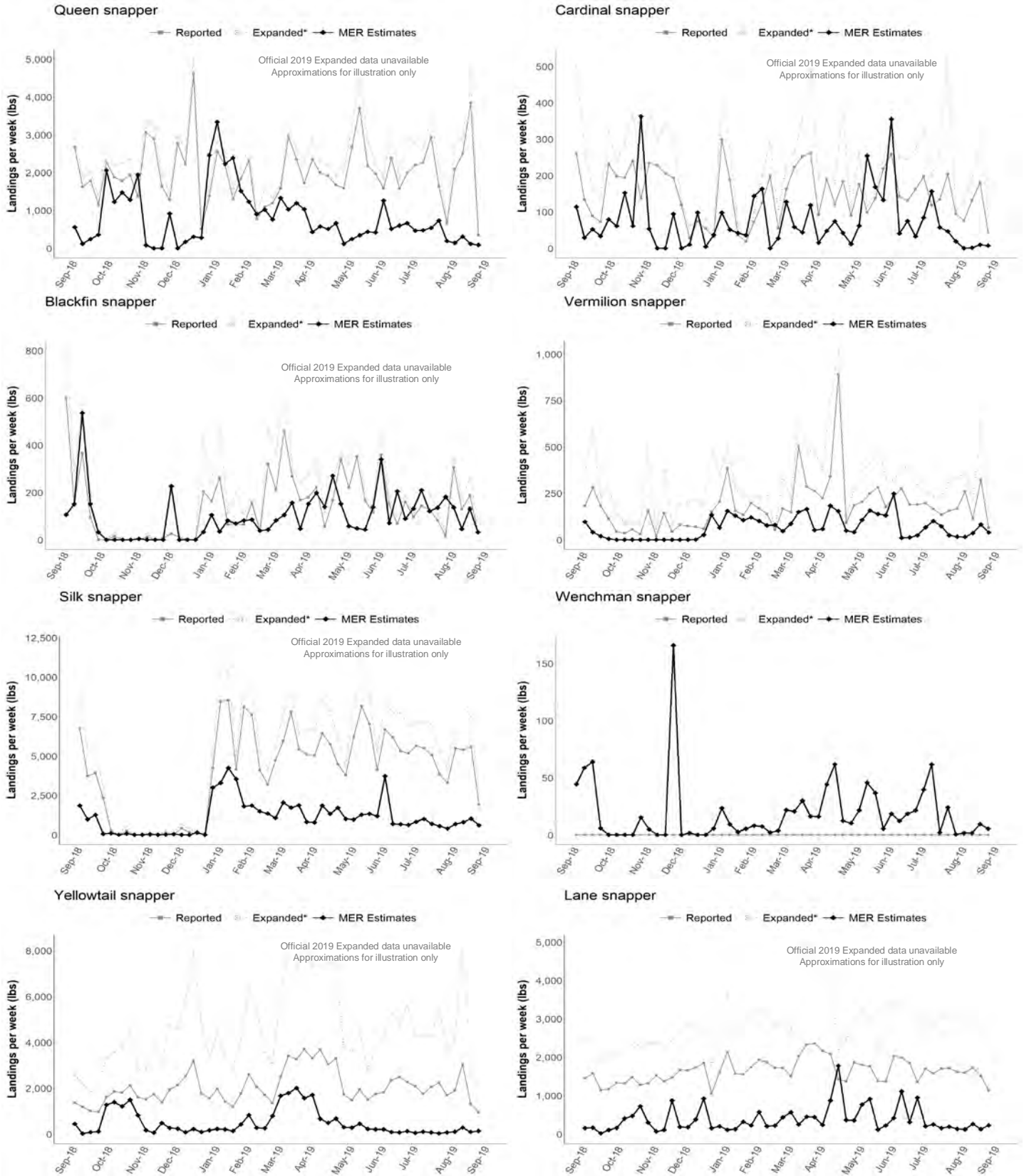


Figure 59. (Continued) Time Series plots for Snappers family grouping and component species.

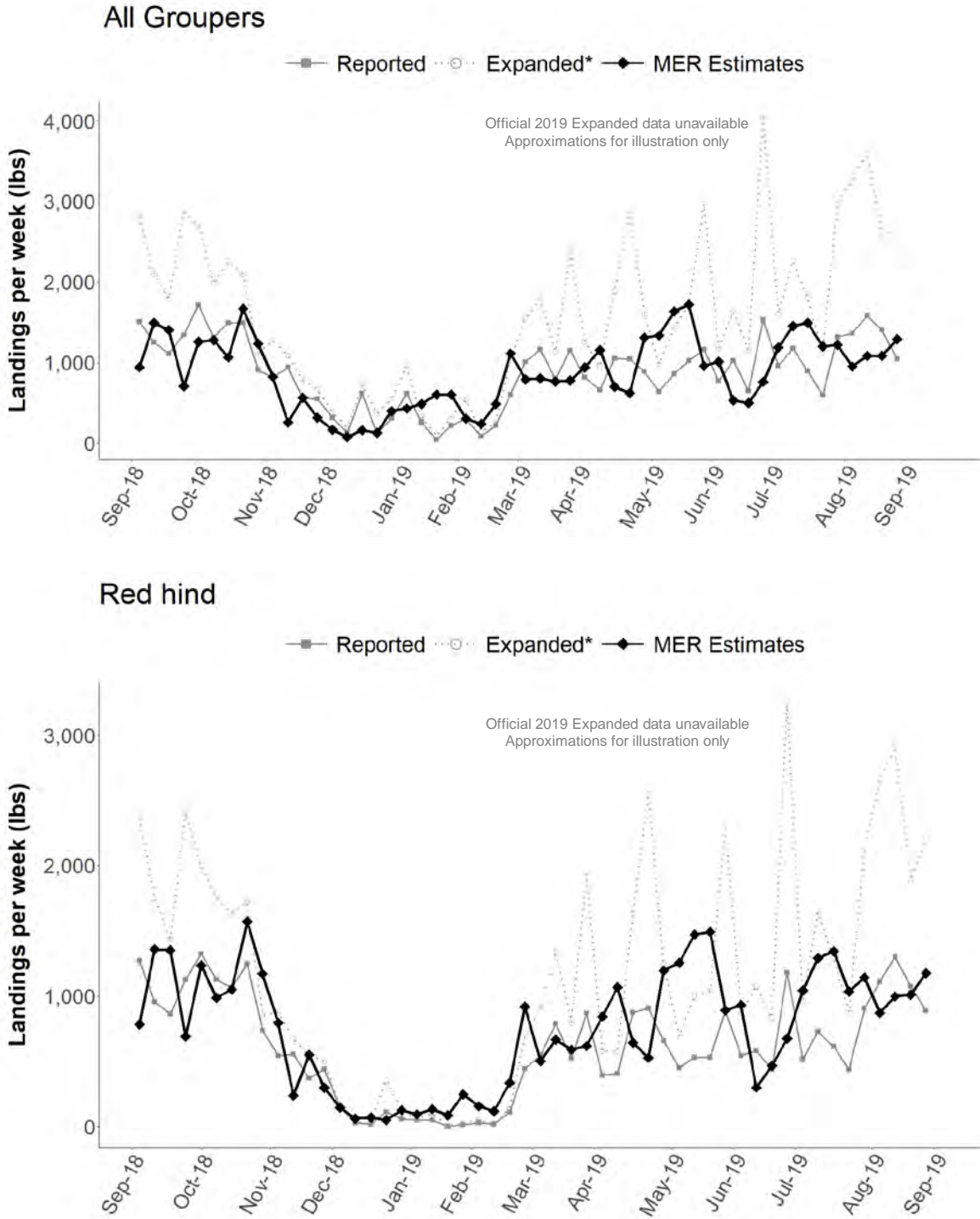


Figure 60. Groupers Family Groupings -Only red hind is presented to illustrate that the All Groupers category is dominated by red hind.

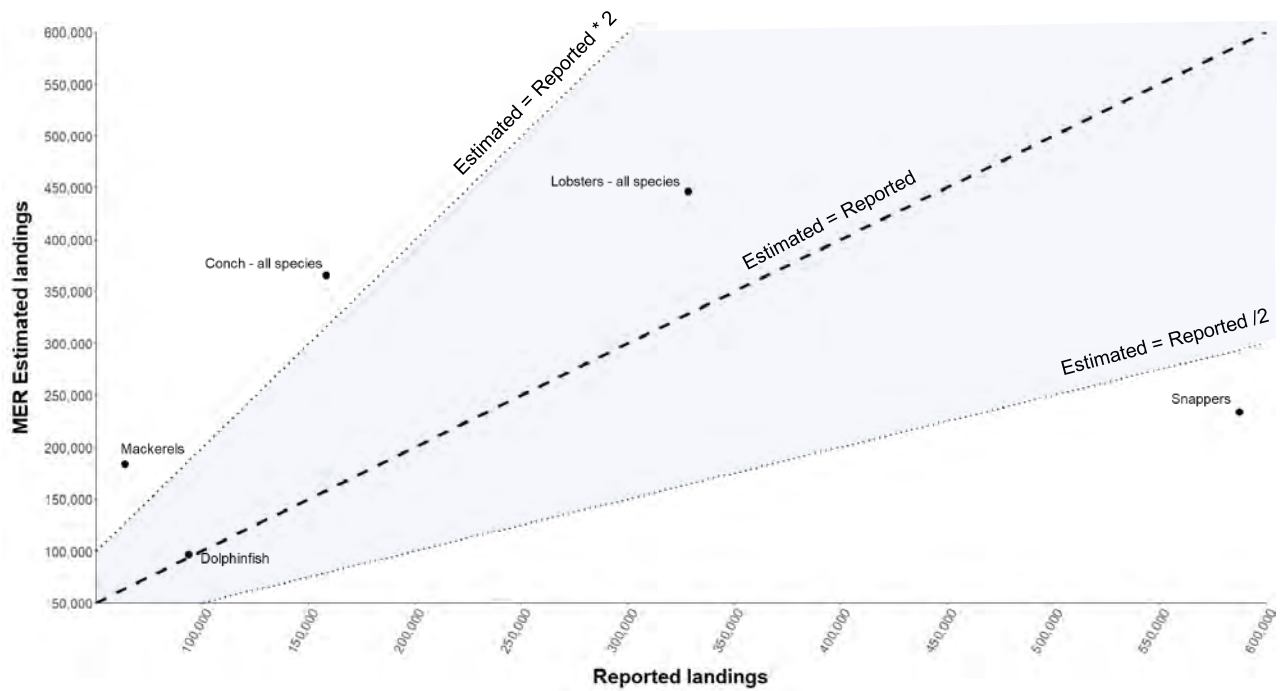


Figure 61. Comparison of estimated landings to reported landings for species groupings with annual landings of greater than 50,000 lb (9/1/18 – 8/31/19).

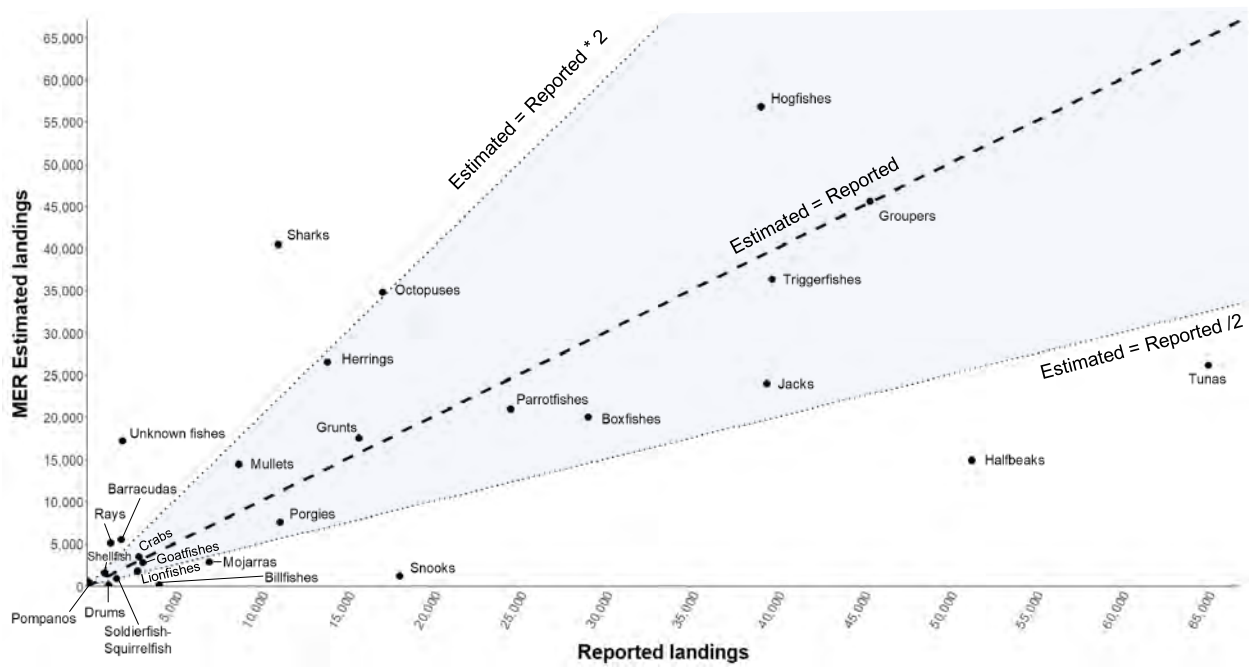


Figure 62. Comparison of estimated landings to reported landings for species groupings and landings below 65,000 lb (9/1/18 – 8/31/19).

Table 45. Example of calculating correction factors by family groups for all Puerto Rico from all sampling types during our one-year comparison period. Note that expanded data for 2019 were unavailable so approximations were made from the reported data and 2018 expansions.

Family Group	MER Estimated Landings	Reported Landings	Expanded* Landings	Reported Correction Factor	Expanded Correction Factor	Cumulative % Reported Landings
Lobsters	445,314	327,812	635,692	1.4	0.7	0.26
Conch	365,465	158,399	372,166	2.3	1.0	0.48
Snappers	201,838	587,280	918,690	0.3	0.2	0.60
Mackerels	180,163	63,684	113,158	2.8	1.6	0.71
Dolphin	66,088	93,307	114,109	0.7	0.6	0.75
Hogfishes	56,584	39,063	84,160	1.4	0.7	0.78
Groupers	45,456	45,557	82,090	1.0	0.6	0.81
Sharks	40,497	11,120	14,786	3.6	2.7	0.83
Triggerfishes	36,276	39,795	69,428	0.9	0.5	0.86
Octopuses	34,755	17,176	32,467	2.0	1.1	0.88
Herrings	26,243	14,008	22,053	1.9	1.2	0.90

4.5 Hurricane Impact on Fisheries

We conducted a cursory investigation of the data to determine if we could detect changes in the fisheries due to Hurricane Maria. We compared the 6 weeks prior to the hurricane in August and September of 2017 to the first 6 weeks when sampling resumed (March and April 2018) and then to the same 6 weeks in August and September of 2018 and 2019. The first six weeks we sampled after the hurricane were in March which is right before Holy Week and should represent some of the largest landings of the year. Overall landings did not exhibit that pattern suggesting some obvious impacts at least initially. Conch is only in season for some of the time periods so we removed conch for comparison in figure 63 for all species combined and then for the top four species in figure 64. We present the time period for comparison by gear in figure 65. While not evident in the overall catch, the trap fishery was impacted which is consistent with the reported number of lost traps. The number of trap trips didn't recover to pre-hurricane levels until 2019 which is possibly due to the recovery funds allowing a large number of traps to be built and distributed.

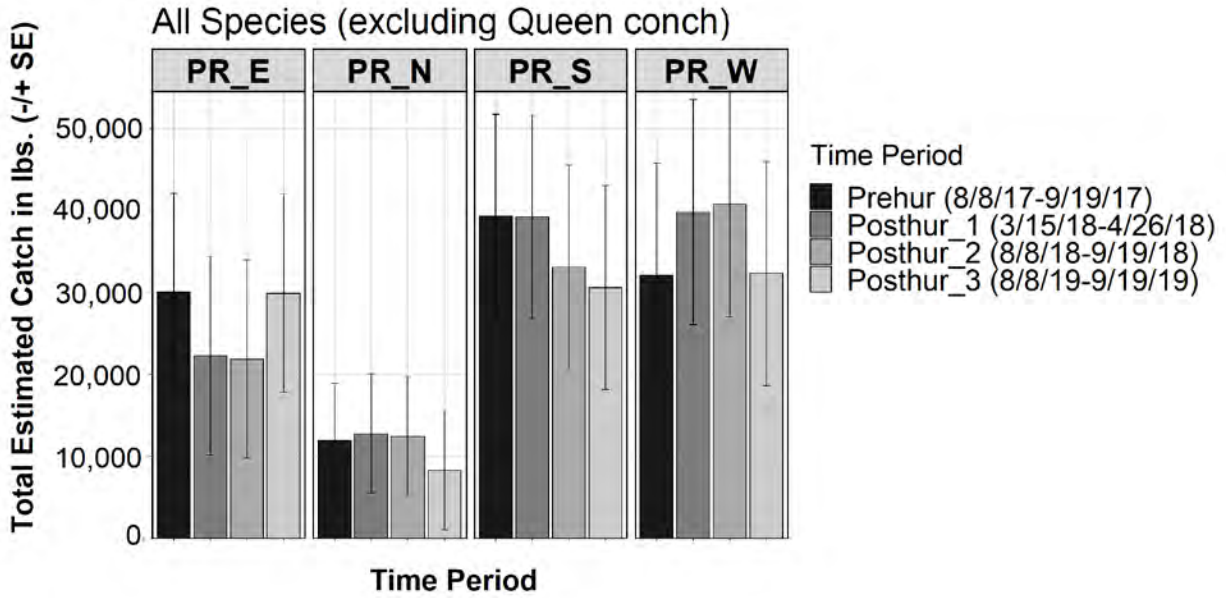


Figure 63. Exploratory analysis on hurricane impact on all species except for queen conch. The six weeks sampled prior to the hurricane is compared to the first 6 weeks sampling started in March 18 and the same 6 weeks in August and September of 2018 and 2019.

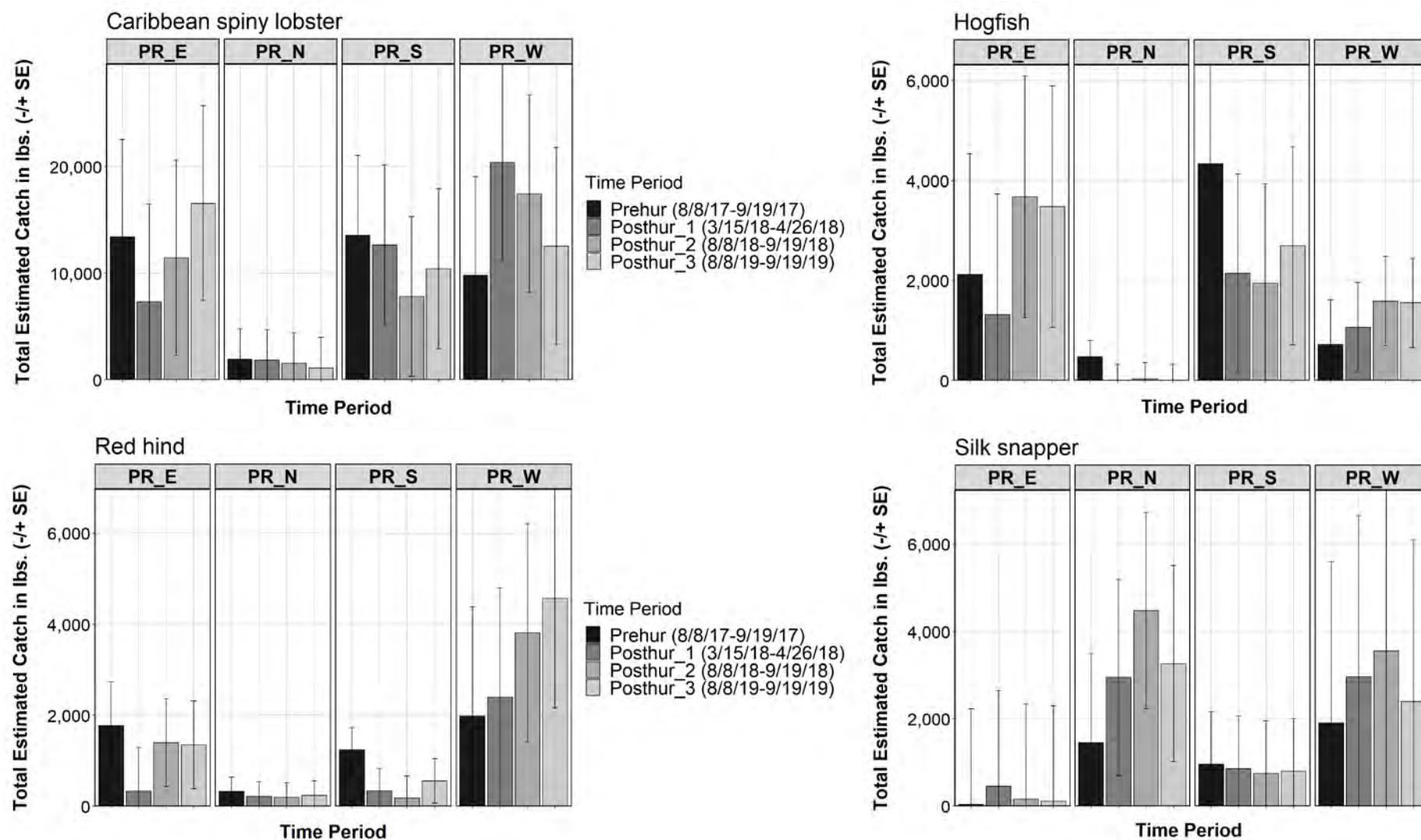


Figure 64. Exploratory analysis on hurricane impact on four of the top landed species.

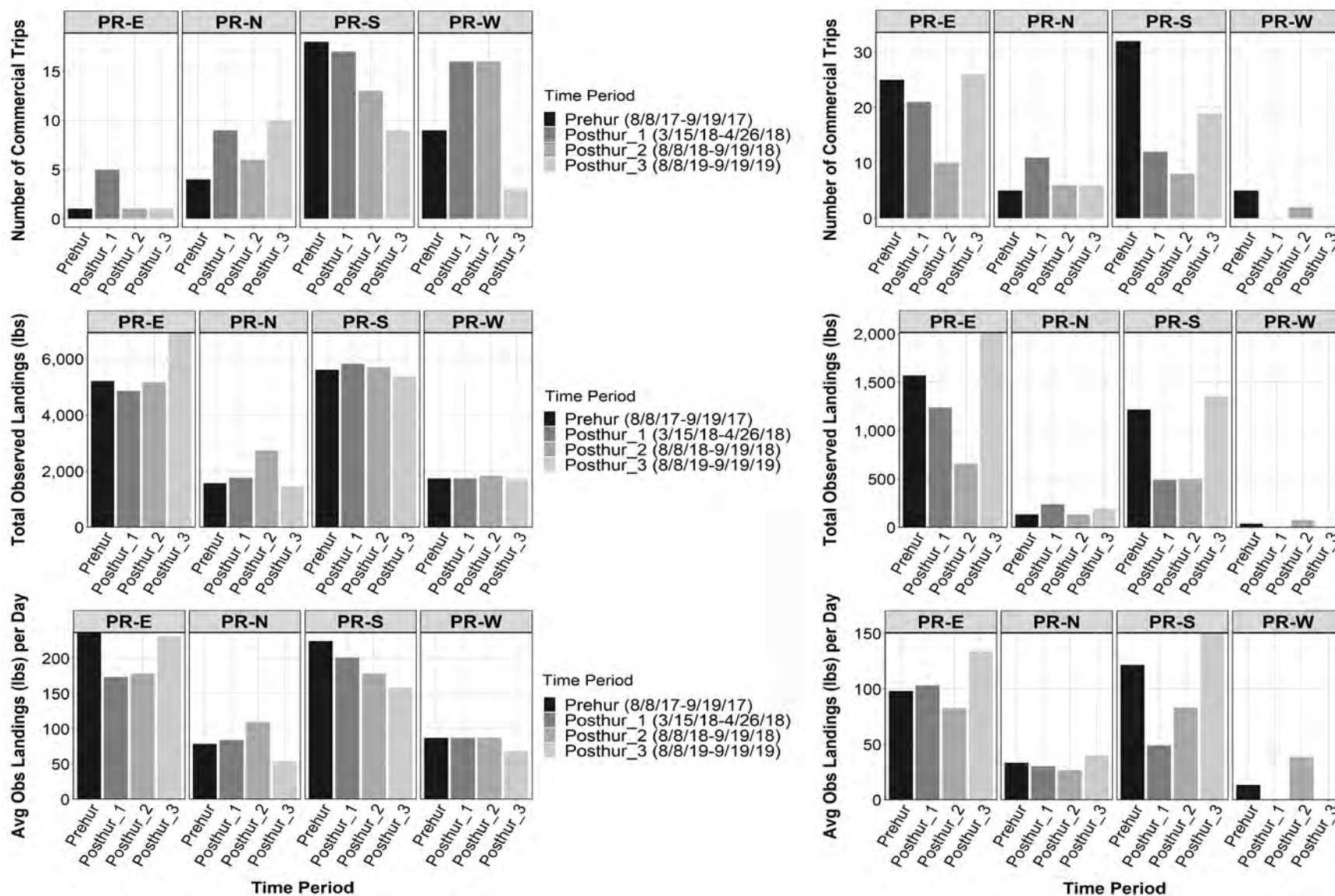


Figure 65. Exploratory analysis on hurricane impact by gear type. All gear in the left pane, trap only trips in the right pane.

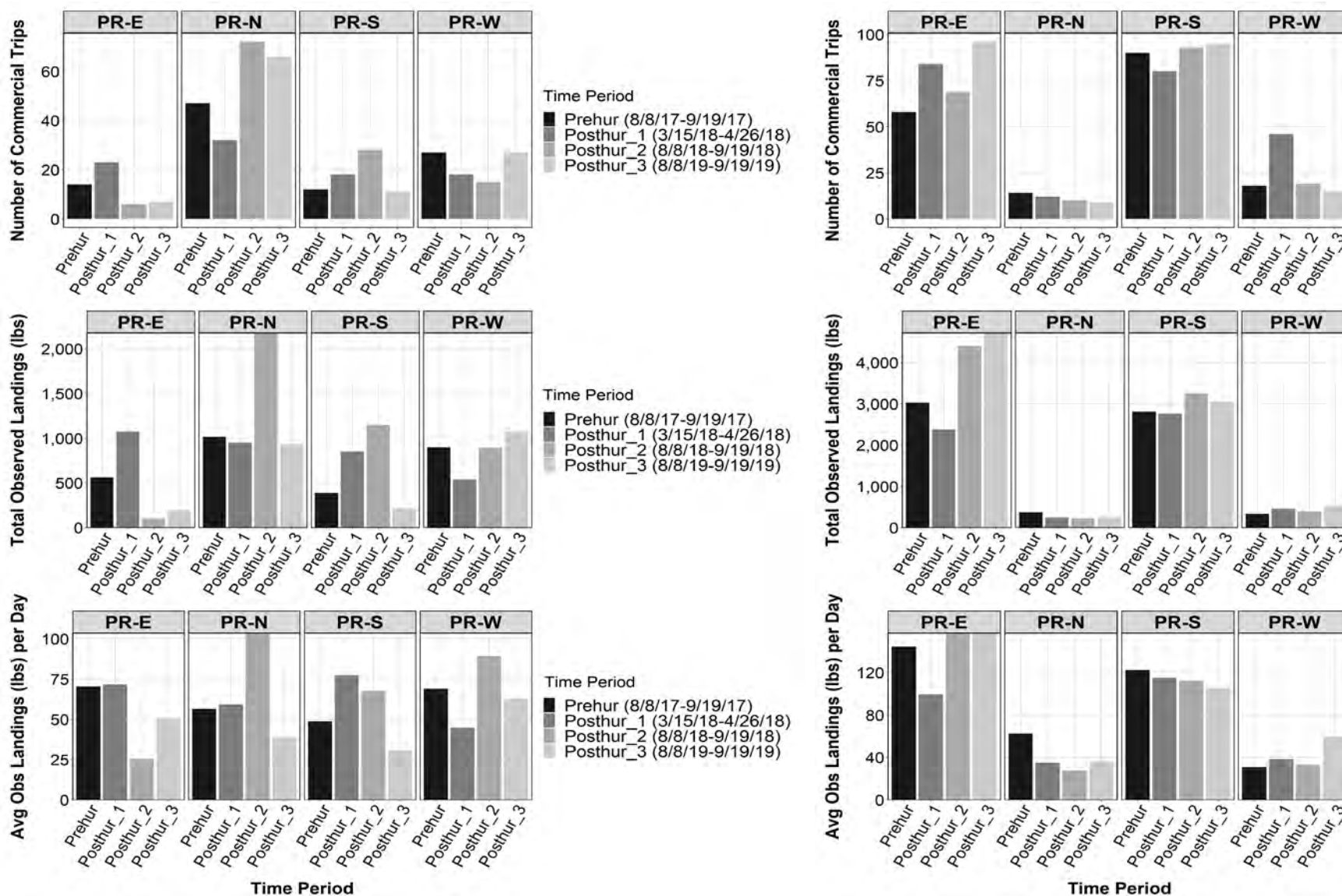


Figure 65. (Continued) Exploratory analysis on hurricane impact by gear type. Hook and line in the left pane, diving in the right pane.

4.6 Evaluation of Survey Design

The results of the pilot study provided some guidance as to the amount of effort that would be necessary to achieve target precisions of PSE's of 15% (Figure 66; From MER Pilot Report 2016). This large-scale survey was implemented with these targets for precision in mind and as discussed in the uncertainty section they were largely met. We provide a few additional components below to guide future work.

4.6.1 Time of day, day of week, and week of year evaluations.

We evaluated the time when vessels were observed landing, the day of the week they landed and the variance estimated during the entire project looking for patterns which could affect estimates (Figures 67 and 68). We found nothing of concern but there are a few things worth noting. First in the West and North a secondary peak in observed landings is seen at the end of the time frame that was sampled. This was expected due to the longer trips that are common in the deep-water snapper fishery. Due to the results of the pilot study, where we noted that ongoing trips in Rincon were likely due to this fishery, we included a PM site specific assignments to the Rincon ramp, and additional data collections on trailer counts to allow for further evaluations into this pattern and the differences between the reported and our estimated landings for this fishery.

One of the primary concerns with the results of the pilot study was that variability could change drastically during the course of the year. We evaluated the standard error of our estimates for every week of the project (Figure 69) and only found patterns related directly to the changes in magnitude of landings. For example, in the closed season for conch when landing were minimal, very high PSE resulted but these are insignificant given that estimates were so low.

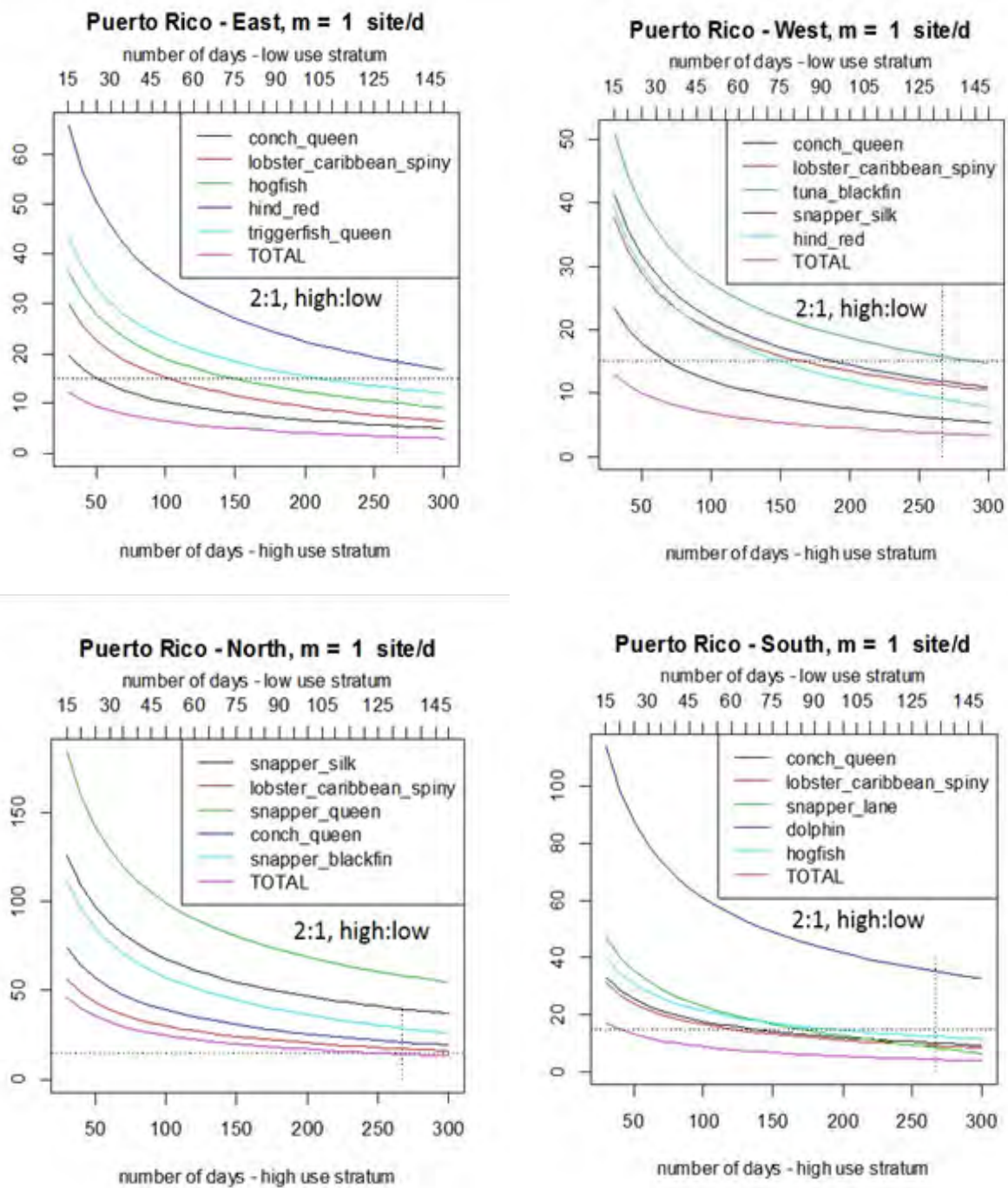


Figure 66. Pilot study power analysis which predicted PSE's given our basic sampling effort that are consistent with our results.

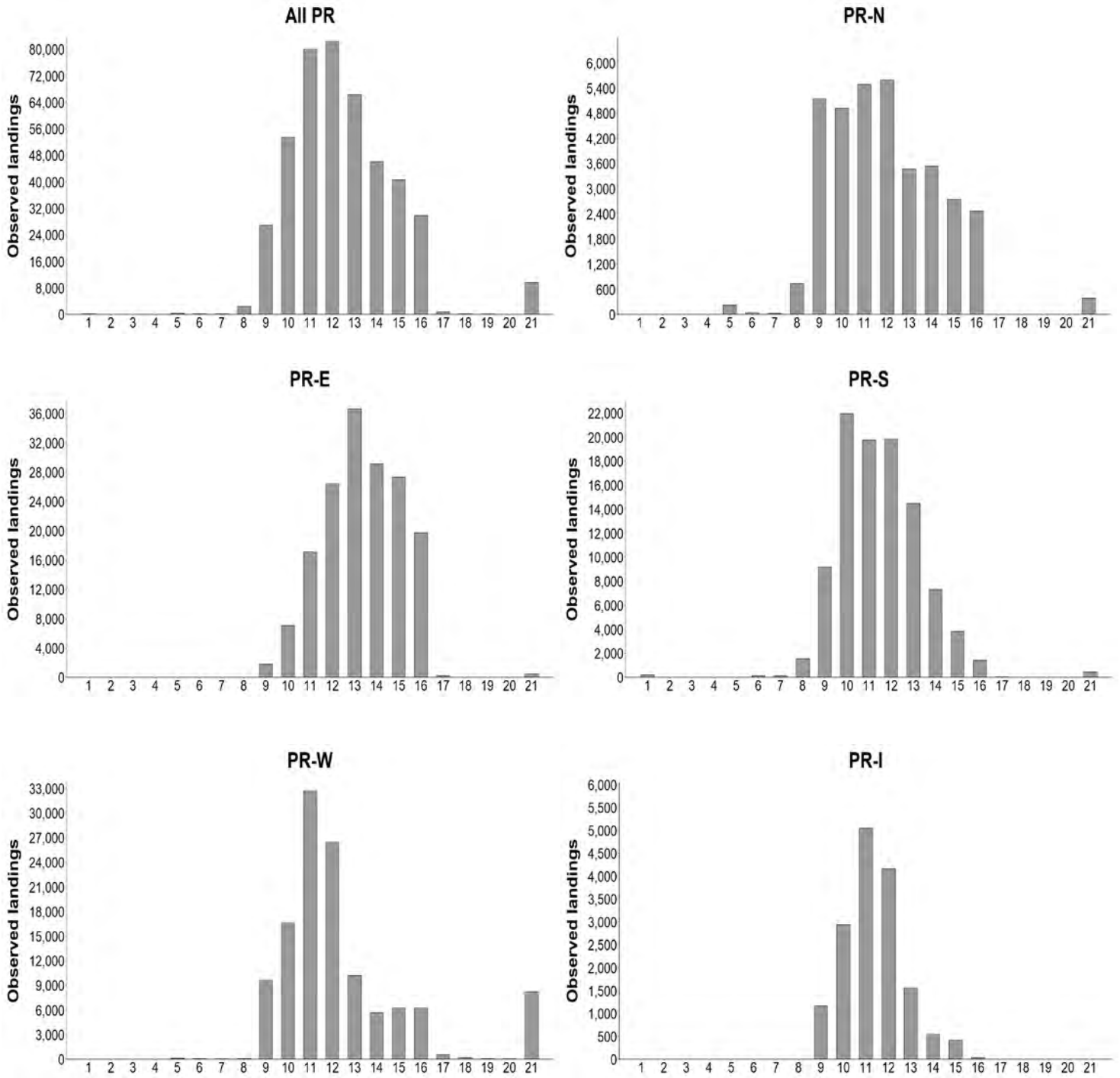


Figure 67. Total Observed Landings by Time of day for all sampled days by region.

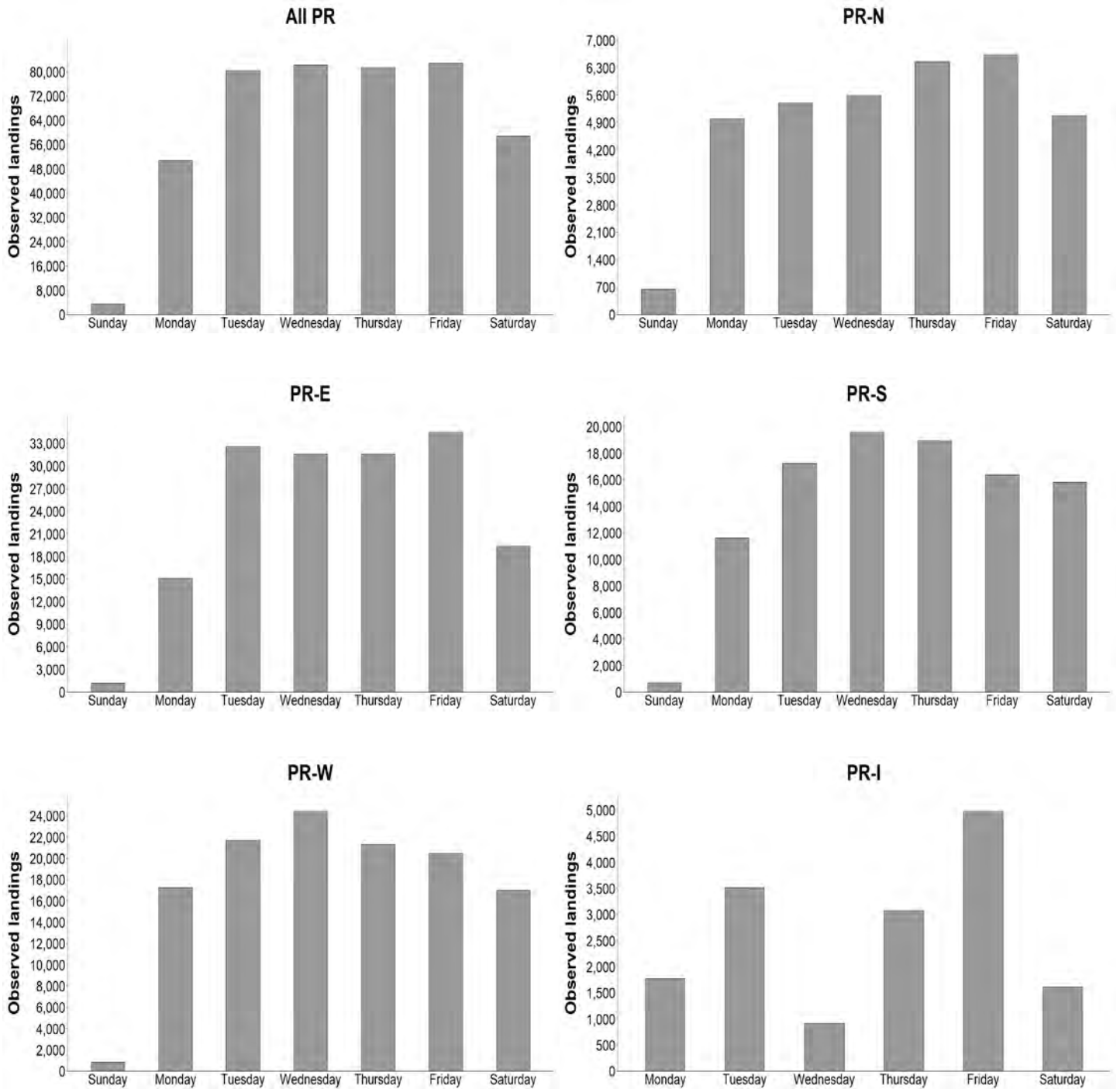


Figure 68. Total Observed Landings by day of week for all sampled weeks by region.

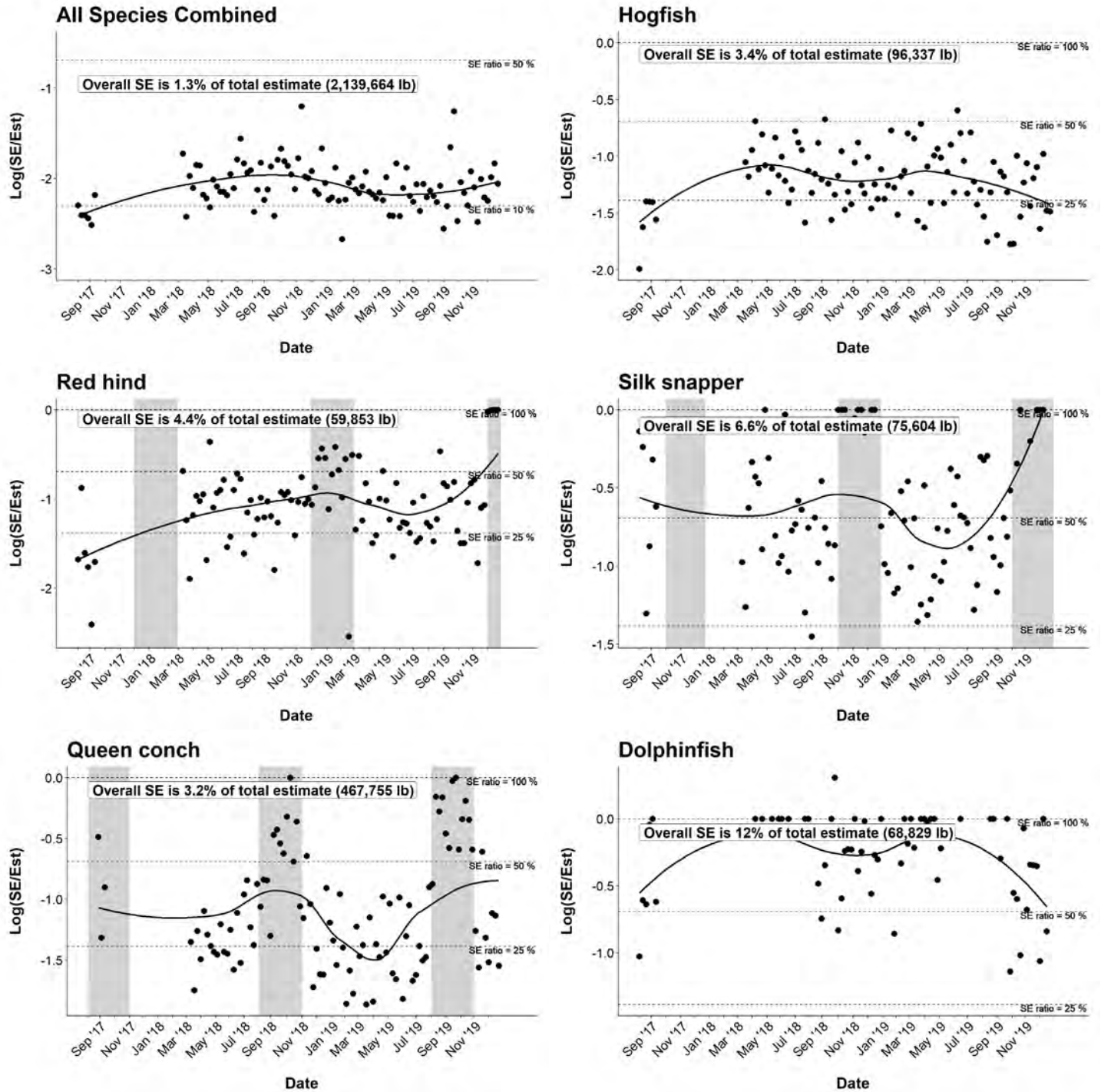


Figure 69. Evaluating temporal trends in primary daytime weekly PSE estimates. Note that ‘Overall SE’ in box represents the PSE for the entire time period sampled.

4.6.2 Rare Event Species

It is well known in sampling theory that rare events pose a challenge for providing precise estimates of means and totals. In the context of Puerto Rico port sampling, rare event distributions are of two types. First, a species may be caught regularly in small numbers on most days and, rarely, there can be very large landings such that the distribution has a very long tail on the right. Second, a species may have a large number of days with no catch but, on those days with landings, the distribution can be spread around a large mean. If a small sample of days is taken from a distribution with rare events, the result is likely to be a large variance due to the estimated mean being either well above or well below the actual mean depending on whether rare events are encountered or not. Furthermore, estimates of the mean or total from a distribution with rare events tend to be unstable in the sense that additional sampling is likely to have a strong impact on the estimated mean or total.

In this study we noted a few species where estimates from the auxiliary sampling warrant a closer evaluation if one wanted to use the numbers for management. In figure 70 through figure 72 we present the time series for: king mackerel in the South, tiger shark in the North, white mullet for all PR and dolphin for all PR. While we would only consider removing the auxiliary sampling estimates for king mackerel and tiger shark, these 4 species provide good examples of how a large species caught infrequently, seasonally caught coastal pelagics and large net landings require special consideration. The tiger shark is the most obvious example of the effect of two large been documented during two AM busroutes (Figure 70). A 420 lb individual in the North resulted in estimates of over 10,000 lb for the month of March, while one 150 lb individual resulted in estimates of close to 8,000 lb in the South during the same month. While the inclination to simply remove these two individuals, it should be noted that there are other tiger shark landings that were documented during this month and the estimated landings from both the auxiliary and daytime survey should be considered carefully prior to use.

For king mackerel the situation is a little more complicated as numerous landings were observed during the ‘runs’ and only a few situations where estimates are questionable (Figure 71). First, and most importantly, two trips landing over 300 lb were documented in a single AM busroute survey in the South in September of 2019. This was the first busroute at the start of our auxiliary sampling and the only one in the month which resulted in a heavily expanded estimate of over 50,000 lb for the month. A second event occurred in May when we documented a single 720 lb catch during the AM busroute which resulted in 40,000 lb estimate for the month.

In the case of white mullet and dolphin numerous landings were recorded and the obvious spikes are shown in figure 72. Note that the dolphin peak occurs at the same time as the reported landings. This suggests increased probability of intercepting a trip and the higher expansion factors for these two species are more likely to be accurate. In fact, for dolphin we observed 53 commercial trips and over 3,000 lb in October and November of 2018.

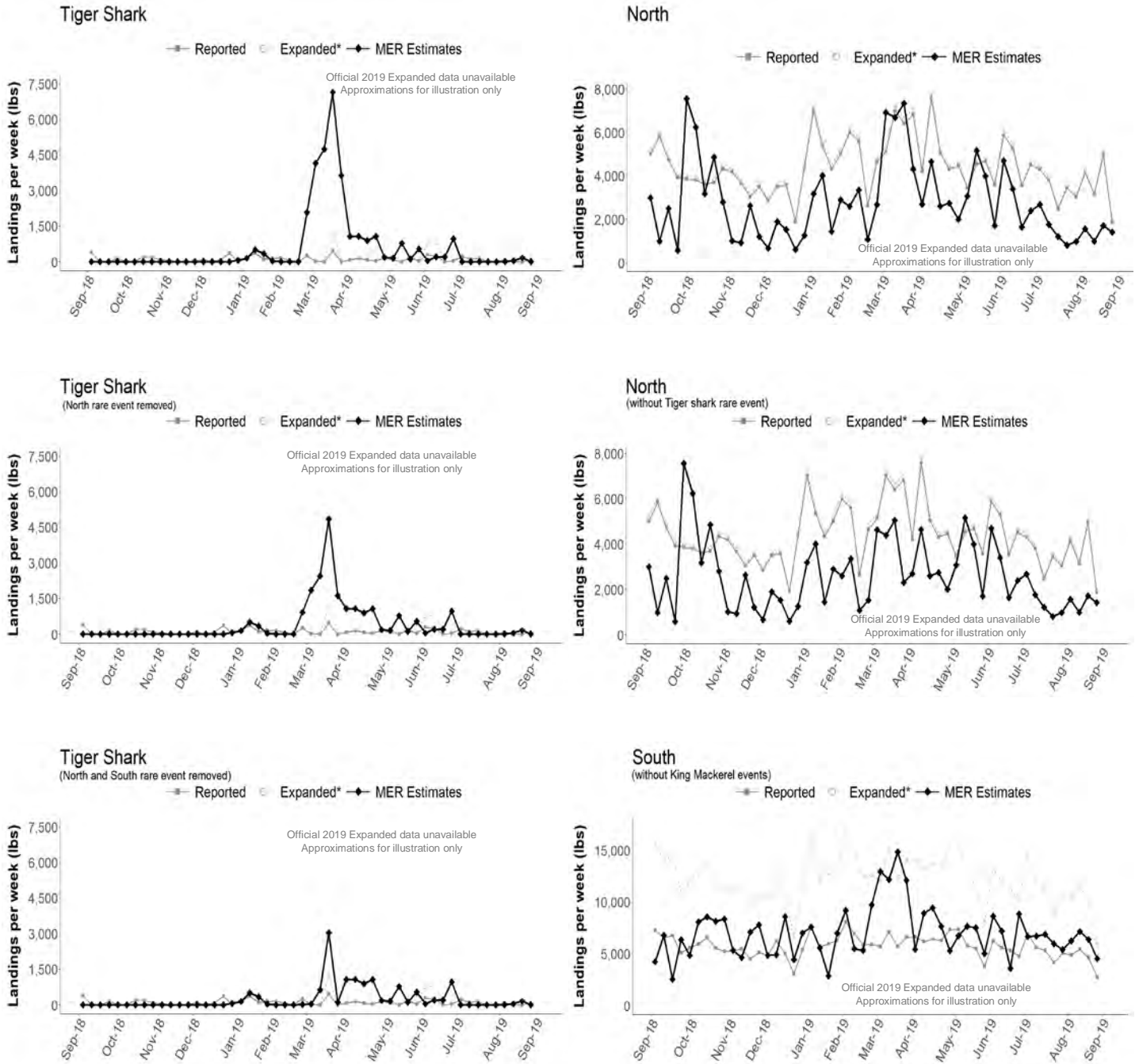


Figure 70. Left Side of panel: The estimated landings of Tiger shark in all of Puerto Rico: all data (top), with one 420 lb individual from the North removed (middle) and with another 150 lb individual from the South removed. Right side of panel is the corresponding region plots – note that the bottom right (South) plot only excludes all king mackerel to show March peak.

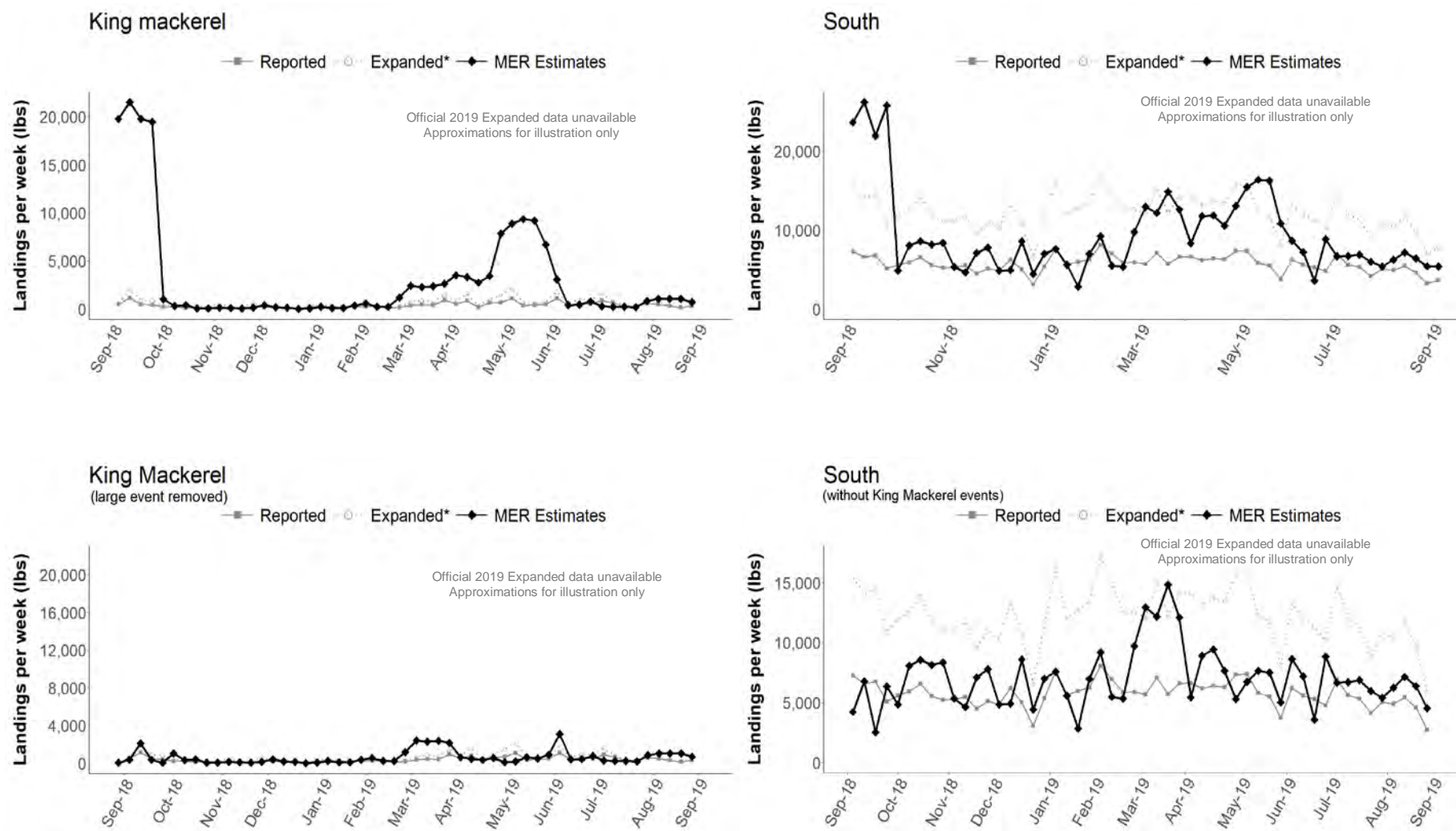


Figure 71. Left Side of panel: The estimated landings of king mackerel in all of Puerto Rico: all data (top), with estimates from two South AM busroutes removed. Right side of panel is the corresponding plot and changes for the South region (note the change of scale).

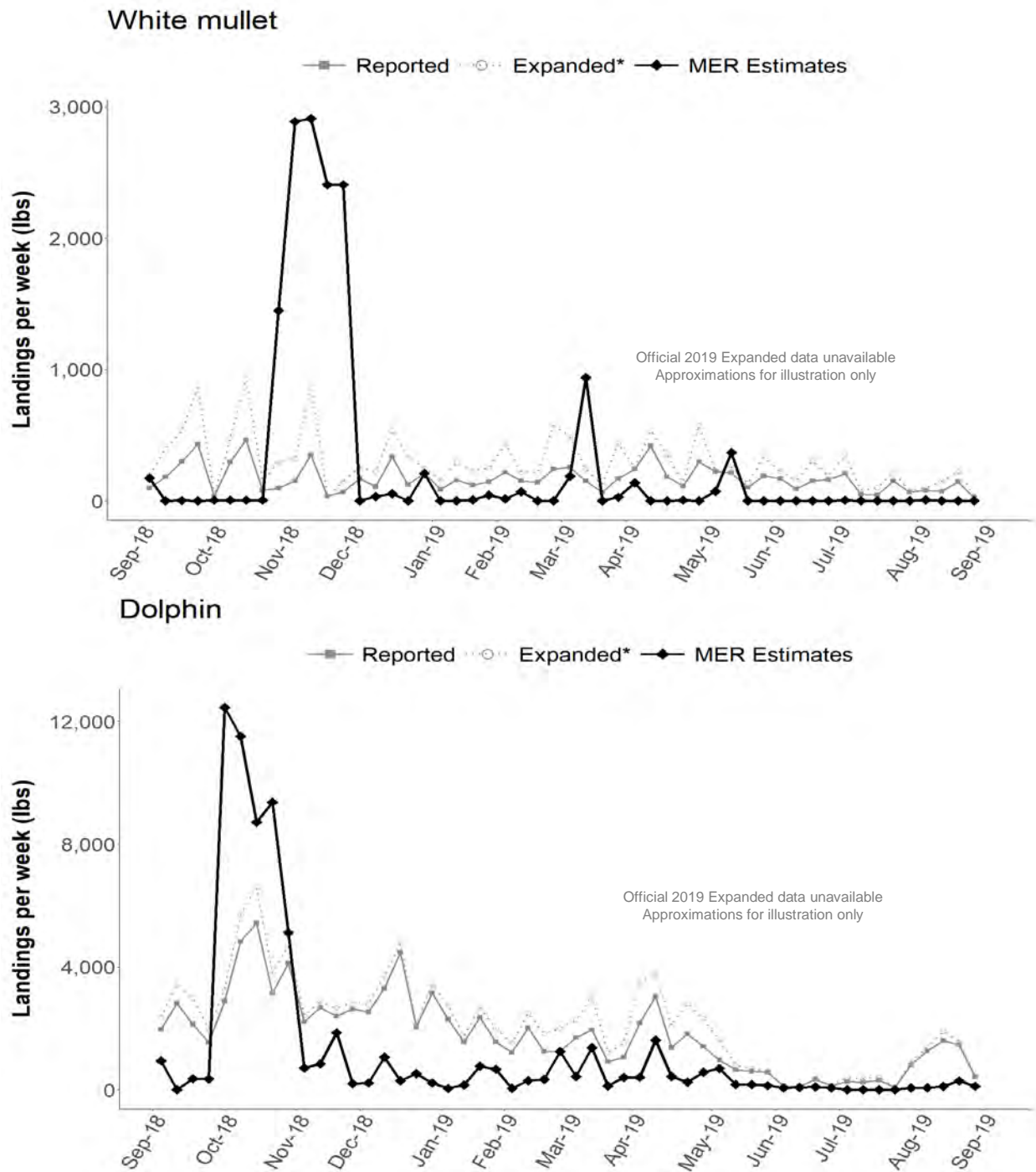


Figure 72. One-year time series for white mullet and dolphin to illustrate high estimates in single months that may be more credible than other rare event scenarios.

4.6.3 Analysis of Precision as a Function of Sampling Effort

Here, we first consider the effects of changing sampling effort on the three main types of sampling design used in the 2017 – 2019 MER port sampling survey of Puerto Rico.

4.6.3.1 Daytime sampling, Puerto Rico East, South and West

In the original design used in the pilot project, there were two port samplers for each stratum. This was deemed too expensive and the current investigation was budgeted to have one port sampler per stratum. In theory, one could set the number of days sampled per week at 2, 3, 4, 5, or 6. However, logistical considerations limit the options in practice. That is, if one offers employment of just 2 or 3 days per week, it may be difficult to attract and retain qualified applicants. It may be feasible to have a port sampler work 4 days a week in a stratum, especially if a fifth day of employment can be offered doing other duties, such as off-hour (AM, PM, Sunday) sampling.

Estimates are made by week and then summed over the year. The estimated catch in a week is given by (1)

$$\hat{Y} = NM \frac{\sum_{i=1}^n y_i r_i}{n} = NM \bar{y}$$

with estimated variance given by (2)

$$\hat{V}(\hat{Y}) = N^2 M^2 \hat{V}(\bar{y}) = N^2 M^2 \frac{\sum_{i=1}^n (y_i r_i - \bar{y})^2}{n(n-1)}$$

where the symbols are as defined in section 2.4.1.1. Thus, the estimated variance is a constant times the inherent variability of landings per catch (i.e., the sample variance of the observations) divided by the number of days of sampling, n . We can calculate the ratio of the standard error of the estimates for a survey with n days of sampling per week compared to the current survey with $n = 5$ days per week (Table 46). (To compare 3 days to 5 days, the ratio of standard errors is $\sqrt{5/3}$. If n is reduced to 3 days per week, the standard error would go up about 30%; for $n = 4$, the increase is about 12%.

Table 46. Ratio of the standard error of the estimates for n days compared to for the 5 days per week used in the current survey.

<u>n</u>	<u>s.e.(n)/s.e.(5)</u>
3	1.291
4	1.118
5	1.000
6	0.913

The effects of adjusting the number of days sampled on the precision of the estimates for the top 20 species for each coast is shown in tables 47, 48, and 49. Here, we have combined the high-use and low use strata to give coast-specific estimates. However, the same relative changes apply to each stratum separately.

Table 47. Changes in the SE/Estimated landings ratio for different “n” sampling days per week for the top 20 species in daytime sampling for PR-East. Values in the column labelled Daytime SE/Estimated are calculated from the data with the actual n of 5.

Rank	Species	Daytime Estimated	Daytime Variance	Daytime SE/Estimated	SE/Est. n=2	SE/Est. n=3	SE/Est. n=4
1	conch_queen	89,268	9,639,147	0.055	0.087	0.071	0.062
2	lobster_caribbean_spiny	22,954	9,193,784	0.063	0.099	0.081	0.070
3	hogfish	11,498	3,668,282	0.089	0.141	0.115	0.100
4	snapper_mutton	10,023	774,067	0.088	0.139	0.113	0.098
5	parrotfish_stopligh	7,501	1,006,684	0.134	0.211	0.173	0.150
6	triggerfish_queen	6,831	702,766	0.123	0.194	0.158	0.137
7	hind_red	6,523	454,810	0.103	0.163	0.133	0.116
8	mackerel_cero	5,390	1,290,465	0.211	0.333	0.272	0.236
9	snapper_yellowtail	4,917	1,892,568	0.280	0.442	0.361	0.313
10	ballyhoo	4,320	18,662,400	1.000	1.000	1.000	1.000
11	grunt_white	3,701	306,144	0.149	0.236	0.193	0.167
12	shark_tiger	3,600	12,960,000	1.000	1.581	1.291	1.118
13	snapper_silk	3,144	4,592,972	0.682	1.078	0.880	0.762
14	snapper_dog	2,682	132,949	0.136	0.215	0.175	0.152
15	snapper_lane	2,595	92,374	0.117	0.185	0.151	0.131
16	snapper_schoolmaster	2,412	76,069	0.114	0.181	0.148	0.128
17	octopus_common	2,270	887,233	0.415	0.656	0.536	0.464
18	porgy_pluma	1,992	67,163	0.130	0.206	0.168	0.145
19	goatfish_spotted	1,653	301,381	0.332	0.525	0.429	0.371
20	runner_blue	1,589	226,481	0.300	0.474	0.387	0.335

Table 48. Changes in the SE/Estimated landings ratio for different “n” sampling days per week for the top 20 species in daytime sampling for PR-South. Values in the column labelled Daytime SE/Estimated are calculated from the data with the actual n of 5.

Rank	Species	Daytime Estimated	Daytime Variance	Daytime SE/Estimated	SE/Est. n=2	SE/Est. n=3	SE/Est. n=4
1	lobster_caribbean_spiny	113,384	31,871,804	0.050	0.079	0.064	0.056
2	conch_queen	37,194	12,481,135	0.095	0.150	0.123	0.106
3	octopus_common	28,581	5,343,926	0.081	0.128	0.104	0.090
4	hogfish	17,768	1,759,585	0.075	0.118	0.096	0.083
5	snapper_lane	12,449	6,206,076	0.200	0.316	0.258	0.224
6	pilchard_false	8,385	7,910,276	0.335	0.530	0.433	0.375
7	triggerfish_queen	7,976	1,157,492	0.135	0.213	0.174	0.151
8	parrotfish_stoplight	7,025	708,076	0.120	0.189	0.155	0.134
9	ballyhoo	5,784	6,351,323	0.436	0.689	0.562	0.487
10	mackerel_king	5,782	4,778,105	0.378	0.598	0.488	0.423
11	snapper_mutton	5,755	720,295	0.147	0.233	0.190	0.165
12	dolphin	5,588	4,981,006	0.399	0.632	0.516	0.447
13	sardine_scaled	5,347	3,191,732	0.334	0.528	0.431	0.374
14	snapper_schoolmaster	4,281	434,868	0.154	0.244	0.199	0.172
15	lobster_spanish_slipper	2,858	245,966	0.174	0.274	0.224	0.194
16	trunkfish_spotted	2,828	393,069	0.222	0.351	0.286	0.248
17	porgy_pluma	2,792	525,939	0.260	0.411	0.335	0.290
18	bocon	2,789	1,124,996	0.380	0.601	0.491	0.425
19	snapper_yellowtail	2,729	173,976	0.153	0.242	0.197	0.171
20	snapper_silk	2,708	357,872	0.221	0.349	0.285	0.247

Table 49. Changes in the SE/Estimated landings ratio for different “n” sampling days per week for the top 20 species in daytime sampling for PR-West. Values in the column labelled Daytime SE/Estimated are calculated from the data with the actual n of 5.

Rank	Species	Daytime Estimated	Daytime Variance	Daytime SE/Estimated	SE/Est. n=2	SE/Est. n=3	SE/Est. n=4
1	lobster_caribbean_spiny	136,054	48,977,051	0.051	0.081	0.066	0.058
2	conch_queen	52,798	10,672,167	0.062	0.098	0.080	0.069
3	hind_red	19,966	2,413,030	0.078	0.123	0.100	0.087
4	snapper_silk	19,156	7,031,762	0.138	0.219	0.179	0.155
5	triggerfish_queen	13,787	702,244	0.061	0.096	0.078	0.068
6	snapper_queen	10,567	4,456,046	0.200	0.316	0.258	0.223
7	hogfish	9,954	445,103	0.067	0.106	0.087	0.075
8	dolphin	9,741	8,082,704	0.292	0.461	0.377	0.326
9	tuna_blackfin	7,996	2,329,226	0.191	0.302	0.246	0.213
10	tuna_skipjack	6,376	2,674,061	0.256	0.406	0.331	0.287
11	snapper_mutton	4,435	421,138	0.146	0.231	0.189	0.164
12	ballyhoo	4,426	2,950,980	0.388	0.614	0.501	0.434
13	trunkfish_unknown	3,552	82,332	0.081	0.128	0.104	0.090
14	shark_tiger	3,271	1,996,099	0.432	0.683	0.558	0.483
15	cowfish_honeycombed	2,761	46,717	0.078	0.124	0.101	0.088
16	octopus_common	2,549	41,144	0.080	0.126	0.103	0.089
17	wahoo	2,507	916,077	0.382	0.604	0.493	0.427
18	snapper_blackfin	2,230	219,129	0.210	0.332	0.271	0.235
19	mackerel_king	2,115	929,430	0.456	0.721	0.589	0.510
20	snapper_schoolmaster	1,681	50,397	0.134	0.211	0.172	0.149

4.6.3.2 Roving design (busroute-like sampling)

The results presented above for daytime sampling pertain equally to the roving design. A switch from 4 days of sampling per month to n days changes the standard error by the factor $\sqrt{4/n}$. The standard errors relative to $n = 4$ are given in table 50. This is shown graphically in figure 73. It should be noted that these calculations can be applied to AM or PM sampling but, for Sunday sampling, the number of Sundays sampled per month can't exceed the number of Sundays in the month. (Because there is a within-day component of variability, we can't apply a finite population correction for the proportion of the Sundays that are sampled.)

Table 50. Ratio of the standard error of the estimates for n days compared to those for the 4 days per month used in the current survey.

n	s.e.(n)/s.e.(4)
2	1.414
3	1.155
4	1.000
5	0.894
6	0.816
7	0.756
8	0.707

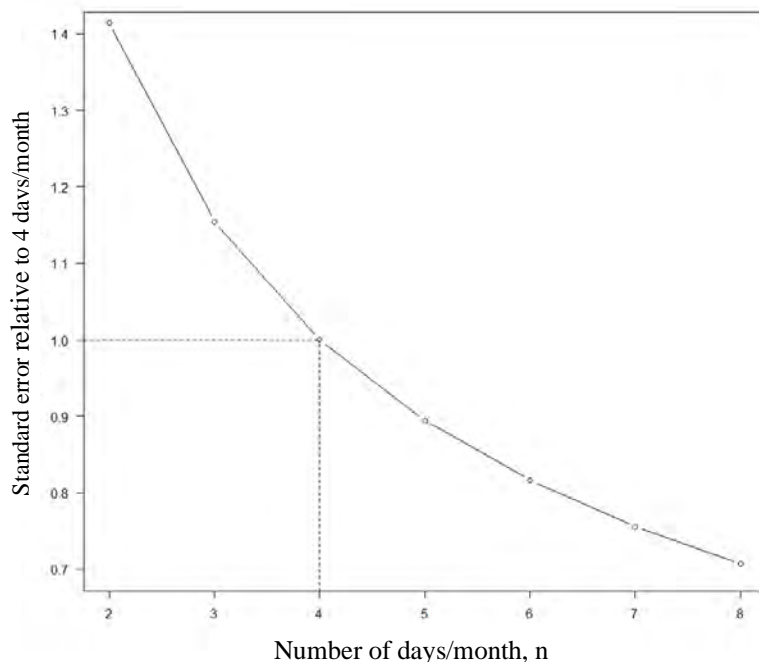


Figure 73. Change in standard error as a function of number of days per month sampled relative to the 4 days used in the current survey.

4.6.3.3 Sampling when there is only one site in the stratum.

This situation occurs in Puerto Rico North high use stratum, East Coast AM sampling, and North Coast PM sampling. The estimated variance of the estimated landings is given by

$$\hat{V}(\hat{Y}) = (1 - \frac{n}{N})N^2\hat{V}(y)/n.$$

It is seen that changing the value of n changes both the denominator and the finite population correction. In table 51, we show the standard error relative to sampling 4 days per month on the assumption that there are 30 days in the month.

Table 51. showing the ratio of the standard error of the estimates for n days compared to those for the 4 days per month used in the current survey when there is only one site in the stratum and simple random sampling of the days is used.

<u>n</u>	<u>s.e.(n)/s.e.(4)</u>
2	1.468
3	1.177
4	1.000
5	0.877
6	0.784
7	0.711
8	0.650

4.6.4 Potential Alternative Sampling Designs

Here we discuss briefly some other types of design that might be used and describe necessary studies to decide on final designs for future surveys.

The principal design used for daytime sampling was two-stage cluster sampling with $m = 1$ cluster (site) selected at the second stage. However, for the Puerto Rico North low use stratum we used two-stage cluster sampling with a variable number of clusters ($m = 0, 1$ or 2) selected at the second stage. This provided the opportunity to estimate the among day and within day (among site) components of variance.

Another possibility is to do away with the high-use and low-use stratum structure to the sampling and select sites from the combined list of sites for the two strata. Since there is variability in usage among sites, a selection strategy based on non-uniform sampling probabilities might be

used to good advantage. Specifically, ppz (probability proportional to z which, in this case, would be anticipated usage) sampling can be used to select sites at the second stage (i.e., in a day). Thus, if there are 3 sites which are believed to account for 50, 30 and 20% of the landings, then on any day one site is selected with probabilities $\pi = 0.5, 0.3$ and 0.2 . The estimated total landings for the day C is estimated as

$$\hat{C} = \frac{Y_i}{\pi_i}$$

where \hat{C} is the estimate for the day, Y_i is the landings at site i , and π_i is the probability of selecting site i . This has some intuitive appeal – if a site is believed to account for half of the daily landings at all sites it seems reasonable that the estimate for the total of the landings should be around twice what was observed at the site. In fact, this affords an unbiased estimate of the total landings even if the sampling probabilities are not close to the actual proportions of the landings at the sites. However, the variance depends very much on the reliability of the sampling probabilities. In essence, this design can afford estimates with very high or very low precision. The variance depends very much on how well the sampling probabilities reflect the actual proportions of landings at the sites, and both the average relative proportions and the day-to-day variability in the proportions are important in determining performance of the estimator. In particular, when sampling probabilities π are very small, the variance can become huge.

Thus, in selecting a design for future sampling work, it would be worthwhile to conduct simulation studies to determine the performance of the different designs. Specifically, the performance of the 2-stage cluster design with $m = 1$ site selected at the second stage should be compared to the design with $m = 2$ sites selected on some days in terms of the actual variance and the ability to estimate the variance of the estimated landings. These designs should also be compared to ppz sampling at the second stage with $m = 1$ and $m = 2$ sites selected at the second stage. (If the high use and low use strata are combined, then there are two port samplers available to sample the combined stratum unless a decision is made to reduce the number of port samplers.) Preliminary information is available from this study to conduct Monte Carlo simulation studies of all of these sampling options. Guidance is needed, however, from the SEFSC and other stakeholders on goals (program components), desired or acceptable levels of precision, and budget in order to limit the number of possibilities simulated.

4.6.5 Estimating Uncertainty – A note about standard errors

A note about standard error/estimate ratios

A curious phenomenon arises when a species is recorded in the landings only once (and in only one month). Then the ratio of the standard error of the estimated total landings for the species divided by the estimated landings for the species becomes a constant that depends only on the design parameters (number of days sampled, number of sites in the stratum, and number of days

in the month), i.e., it does not depend on the magnitude of the landings. This is demonstrated as follows:

Suppose 4 days are sampled in the month, and the recorded catches for a species are X , 0, 0, and 0. That is, the species is seen on only one of the four days, and the amount seen is any number X . The estimated landings for the month C_{tot} is given by $C_{tot} = b\bar{c}$, where b is the expansion factor (that depends on the design) and \bar{c} is the mean of the 4 observed catches.

Clearly, $\bar{c} = (X + 0 + 0 + 0)/4 = X/4$.

The estimated variance of the estimated landings is

$$\hat{V}(C_{tot}) = b^2 \hat{V}(\bar{c})$$

and $\hat{V}(\bar{c})$ is given by

$$\begin{aligned} \hat{V}(\bar{c}) &= \frac{\sum_{i=1}^n (C_i - \bar{c})^2}{n(n-1)} = \frac{(X - \frac{X}{4})^2 + (0 - \frac{X}{4})^2 + (0 - \frac{X}{4})^2 + (0 - \frac{X}{4})^2}{4(3)} \\ &= \frac{(X - \frac{X}{4})^2 + 3(\frac{X}{4})^2}{12} = \frac{(X(1 - \frac{1}{4}))^2 + 3X^2(\frac{1}{4})^2}{12} \\ &= \frac{X^2((1 - \frac{1}{4})^2 + 3(\frac{1}{4})^2)}{12}. \end{aligned}$$

If we take the standard error of $\hat{V}(\bar{c})$ we get X times a constant.

If we then look at the ratio of $\hat{V}(\bar{c})/\bar{c}$ the X drops out, which means that, for the special case where only one catch was recorded over multiple days, the ratio of standard error/estimate is a constant (regardless of how much was landed). Note that this does not mean the variances are the same. For example, one species may have had 20 pounds landed and another may have had 2000 pounds. If these two species were landed on only one day, and the ratio was, say, 0.6, then the first species would have a standard error of 20×0.6 and the second species would have a standard error of 2000×0.6 .

5 AUXILIARY PROJECTS

5.1 Rapid Sampling Development

Lead and Prepared by: Todd Gedamke

This project addresses a long standing and critical component of collecting fishery-dependent data in any fishery. The question and challenge is simple: To collect data in the most efficient way possible to reduce the burden the fishers/fishery and maximize the benefits of investments into the scientific process. In the US Caribbean we were faced with a unique problem which led to developments which could revolutionize the way port sampling is collected everywhere. Simply sorting the multi-species catches (at times > 15 species) was taking too long given that fishers also sold their catch the same day and samplers found themselves in between fishers and their money. As one would expect fishers refused to be sampled and without legal requirements, no data were collected. We developed a cheap system to capture images and weights which can be reviewed after sampling therefor increasing the speed of sampling. The use of technology is developing rapidly and even for these small-scale fisheries extracting additional information from these images is now within reach.

Over the last decade, advances in computer vision technology allow anyone with a smartphone to use an application to attempt to identify almost any plant, animal, insect, or location from a photograph. In the world of fisheries, integrating this technology began over 30 years ago in the North Pacific where quantifying bycatch, discards, and species of concern is critical to management and the value of the fisheries justified working with cutting edge expensive technology. It is clear that this technology represents the future of aspects of data collection in fisheries. The EM Innovation Team (partnership among the Alaska Fisheries Science Center, the Pacific States Marine Fisheries Commission, FishNext Research LLC, and the University of Washington) has made incredible advances in developing systems that can survive the deck of a long-liner in the Bering Sea while capturing video to identify and measure fish that never even reach the deck of the boat.

Our challenge in the US Caribbean was different, simpler, and land based. Fundamental data on landings was lacking and port sampling the multi-species catches rapidly was difficult. We developed a prototype port sampling station that integrates the existing EM tablet with off the shelf inexpensive items to record the weight and an image of each fish against a standardized background (Figure 74 and Figure 75). Thus, our image processing and computational needs are simple in comparison to at-sea applications. We worked with software developers to test video capture, backgrounds, lighting needs, and the use of our camera prior to collecting over 15,000 images of common species found in Puerto Rico. We developed a basic annotation software and a sub-set of these images are annotated for length in software which using a basic histogram classification to assist technician in assigning species (Figure 76). We are poised to

leverage and develop existing fisheries products to automate length calculations in open-source frameworks (i.e. Python and TensorFlow/Keras) and provide all annotated images to the automatic species ID development project by Wallace et al. in Galveston.

While developed for a specific problem in the US Caribbean, this system has broad potential applications to ALL port sampling projects. It improves/allows for:

- Rapid sampling of multispecies catches where sorting takes up most of the sampling time.
- Overall, the ability to collect length frequency information in a more timely fashion in multiple arrangements facilitating fisher cooperation.
- An abundance of paired length weights relationships which may allow for regional analyses to determine fitness or reproductive potential.
- Almost real time data submission allows for numerous applications for:
 - training/new samplers
 - remote oversight and species id verifications via pictures
 - and overall, reducing cost of a port sampling program.
- Adding to a cataloged image library which will facilitate the Galveston teams efforts at automated species ID and will surely help in the next development in technology which we're only imagining at this time.

In general, our objectives are as follows:

- Complete prototype and proof of concept for a simple, inexpensive modular, and portable semi-automated port sampling station. The current working prototype automatically captures an image and weight and was developed to allow for faster sampling in the small-scale multi-species fisheries of the US Caribbean by eliminating sorting from the process.
- As that stated by EM Innovative Team member in March 2018 NOAA article: "Our approach is to come up with open source software and hardware that other people can start from and move forward. Our hope is to put out something that can be built on." (<https://www.fisheries.noaa.gov/feature-story/developing-machine-vision-collect-more-timely-fisheries-data>).
- Refine the hardware and software to allow for better data flow, automated length calculations, analyst ready outputs and contribute to the annotated image library which will be used to train species identification work in the SEFSC/Wallace project.
- Demonstrate that high quality, verifiable, and timely reporting of port sampling data can be accomplished in the very challenging multispecies small-scale fisheries of the US Caribbean.

Our first prototype for the rapid sampling equipment was developed on June 2018 and used in the field starting July 7 2018. A Tablet (Samsung Galaxy SM-T230NU) was mounted above the scale (AND FG-60KBM) using a telescopic arm. The scale and tablet were linked via Bluetooth using a “FireFly RS232”, so that when the scale stabilized it triggers tablet to take a picture and records the weight of the fish in the picture filename (*.jpeg). Under ideal conditions the process takes approximately 2 seconds for each fish.

Two different prototypes have been developed for different locations. To date, over 15,000 pictures have been captured.



Prototype 1



Prototype 2



Prototype 2

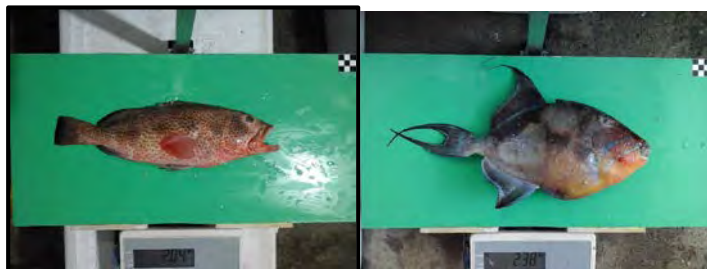
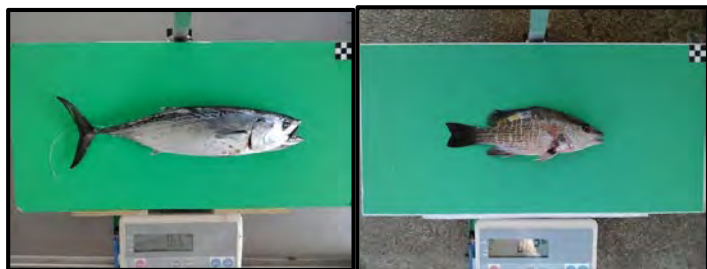


Figure 74. Rapid sampling port sampling station prototypes and example pictures from the system.

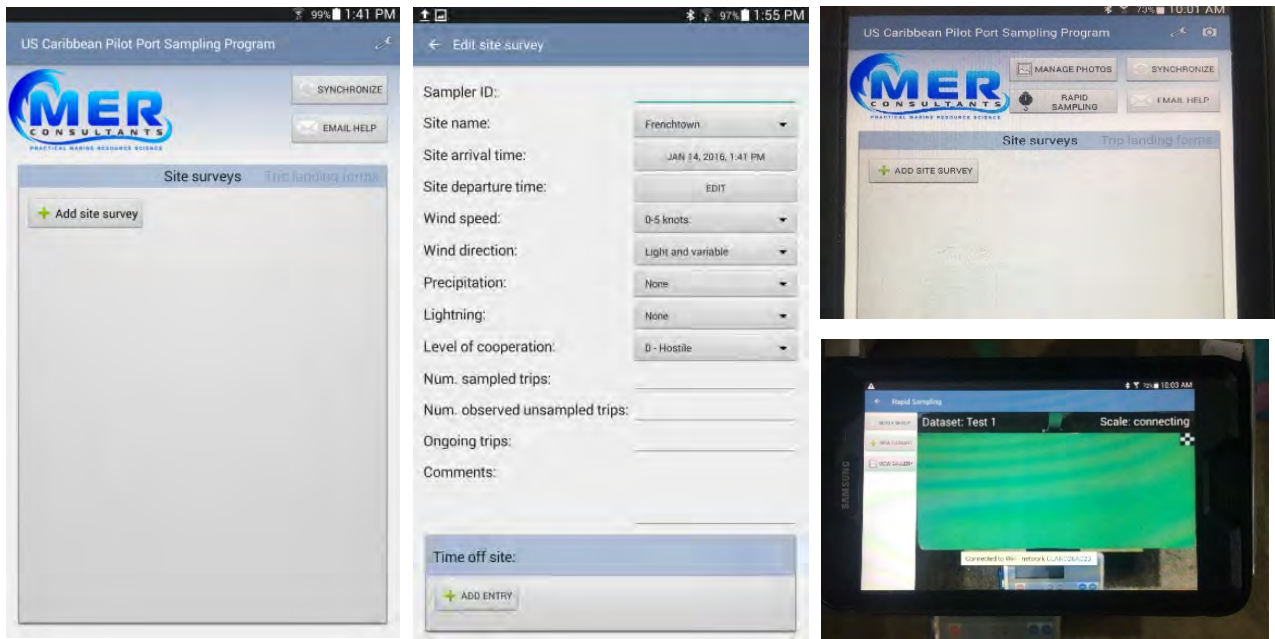


Figure 75. Site survey home screen in data entry application and Rapid sampling/Photo capture module on right.

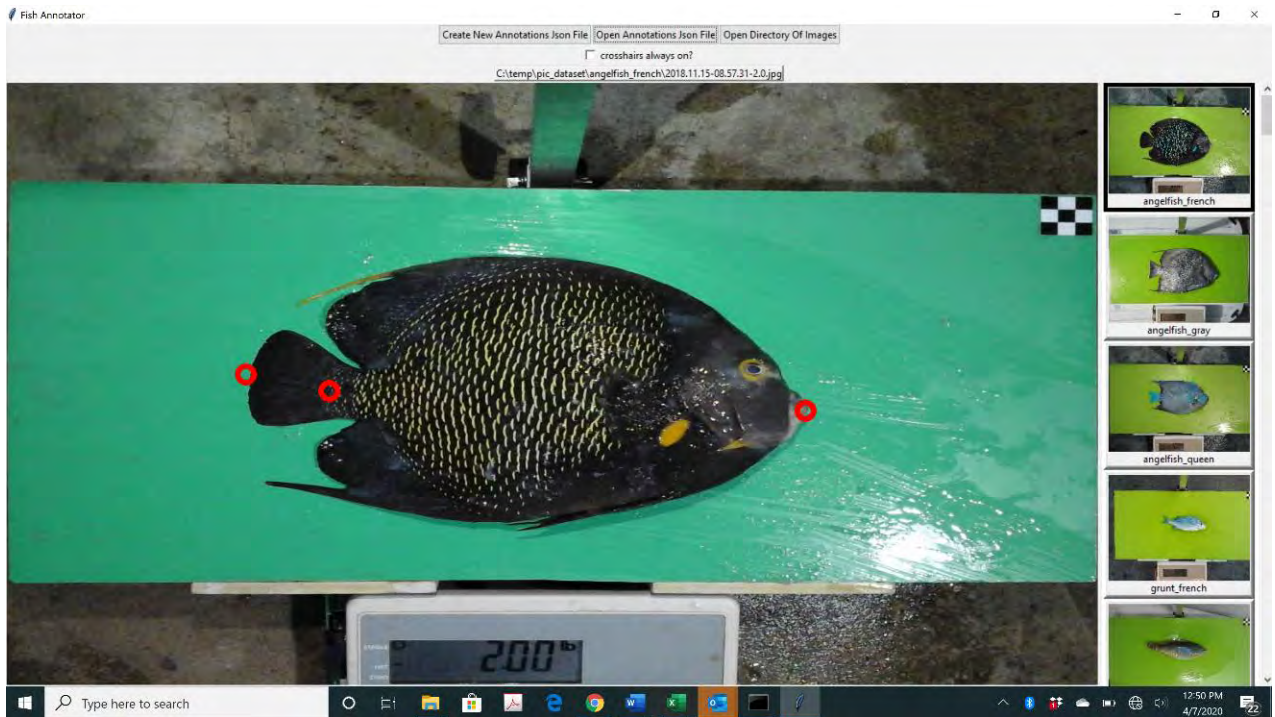


Figure 76. Annotation software was developed using Python and a basic spectral analysis of each photo to suggest species. Annotation points are indicated by red circles and suggested species are in the right thumbnails.

5.2 Pescaderia Logbook Pilot Project

(Full report in Appendix 6.2)

Lead and Prepared by: Neishmarie Soto Ortiz

Recognizing the importance of local seafood markets in gathering and selling what fishers daily obtain, we developed a pilot project that would help them as well as the science community understand the way they work and use information provided by fish houses for future reference. The idea was proposed with the intention that every fish house would develop a self-reporting method that would give them better tools to understand the resources they use. Our project consisted on identifying certain fish houses (“Pescaderias”) willing to participate in a 3 months period data collection and instruct them on recording daily information from the catch landed by their local fishers.

From a list of nineteen potential fish house around the island suggested by samplers from “Censo de Pesca”, nine were willing to cooperate. The fish houses were divided into coasts and visited weekly by one sampler from the area. Originally, the form designed to collect daily catch were determined to be on the species level, but many fish house owners argued that it would be too difficult to record in that way; and they would not be willing to take the time to fill out our forms. Therefore, with their suggestions different forms (class, family, species) were created depending on the location and adjusting for the species more commonly landed in the area (so that a big list with unnecessary species get in the way of the reporting needed). Every form used required: name of the market, name of person in charge, date, total pounds per day and total trips, followed by each category of species with the weight. Data collection was done during the months of April, May, June, and July of 2019. Even though the project consisted of three months July was recorded as an extra month.

Overall, a total of 104,594 lb were recorded between all nine fish houses (Site % from total; “La Puntilla”-29%, “Playa de Ponce” – 18%, “Bahia de Guanica”-14%, “Tallaboa”-11%, “Boqueron”-9%, “Salinas Providencia”-8%, “Tres Hermanos”-7%, “Combate”-3%, “Las Croabas”-2%) and 72 categories were reported including species, families and classes. Of these categories the top 20 represent the 88% of the total catch. The categories with the most reported lb are Lobsters, Mackerels, Silk Snapper, Queen Conch, Hogfish and Triggerfish; (20%, 13%, 8%, 7%, 4%, 4% respectively form total lb). The months with the highest values reported were April and May with 30,490lbs and 31,258lbs.

Of the nine fish houses, only two classified landings correctly by species. These two also reported everything without the help of any sampler. The rest had to be modified to the way they are used to report (family, class, etc.) in order to obtain any information from them; also, they needed to be reminded more often and the sampler had to collect the information from the fish house using their logbook and do the proper corrections like translating species name or adding the numbers together. One of the considerations to be made in order to use this data for statistical

purposes is that not all catch delivered to a fish house represents the area where it is located. For example, in “La Puntilla” which is a large-scale distributor, they receive fish from different parts of the island. In addition, some errors were reported categorizing species correctly by the persons in charge of the local, therefore a self-reporting program from fish houses will not be effective unless proper species identification is instructed. Also, to strengthen species identification and create awareness about the importance of fisheries statistics, training and workshops for the fishing community would be necessary or considering making it mandatory to report or offering some sort of compensation for them to feel that are being helpful. We found difficult to achieve complete collaboration from the fish houses because some were skeptical and uninterested in changing the way they usually report. Most complained about participating without receiving any monetary compensation or that they do not have enough personal to carry out said task as well as doing their usual work. A self-reporting system would be beneficial but training personal or assigning a trained sampler would be needed to make all data uniform and comparable.

5.3 Rincon Trailer Count (Deep-Water Snapper Fishery)

Lead and Prepared by: Jonathan Hernandez and Anthony Crespo

The West coast of Puerto Rico has some of the highest reported numbers of fish landings that include DWS (Deep Water Snapper) species. In the past years, a total of 128 DWS fishers have reported their official catch records to the Fishing Investigations Statistics Program of the DRNA (Department of Natural and Environmental Resources). Along the West coast, there are approximately 79 DWS fishers among the municipalities of Aguadilla, Aguada, Rincón, Añasco, Mayaguez and Cabo Rojo, with a majority of the DWS fishing activity occurring in Rincón. Many commercial fishermen that use the Rincon Ramp are local, but others travel from the Western towns/municipalities of Aguadilla, Aguada and Añasco, and Northern towns/municipalities of Arecibo, Camuy, Quebradillas, among others. In order to improve our understanding of fishing patterns (e.g. landing times, trips/day) in the DWS fishery, a pilot exploratory trailer count survey was established.

The Rincon study site features a ramp and parking premises for boat trailers belonging to fishermen and other recreational boats. Based on previous data and local knowledge, the typical hours of arrival for DWS trips are between 4:00 PM and 9:00 PM and tend to be long (e.g., x hours per trip).

A common method for collecting effort data for landed and ongoing fishing trips is to count boat trailers parked next to the ramp during predetermined time points. Using a local sampler’s knowledge of fishing practices in the area, four types of fishing modes were determined based on the type of trailer parked at the ramp: DWS, commercial, recreational, and unknown. Even

though DWS trips are considered commercial, these modes were separated in order to provide specific effort data for the DWS fishery. Additionally, charters were recorded as recreational trips. When the sampler was unable to identify the fishing mode or if it was a pleasure trip with no fishing activity, it would be recorded as unknown.

The sampler was assigned to the Rincon Ramp study site for a 3-month period between November 2018 and February 2019. The sampler was unable to perform trailer counts on 11 days, which resulted in data gaps. To improve resolution, the sampling period was extended through March 2019, for a total of 4 months.



Figure 77. Example photograph of boat trailers taken at the Rincon Ramp site during each visit.

During the study period, the sampler visited the site 3 times per day at 9 AM, 5 PM, and 7 PM to count boat trailers parked near the ramp using a provided datasheet (Figure 1). Time points were established to determine the number of trips occurring at the beginning of day (9 AM), daytime trips occurring during “normal” hours (5 PM), and evening trips (7 PM). Each trailer was identified into one of the four categories (Commercial, Deep Water Snapper, Recreational, Unknown) and a photograph of the parking lot was also taken during each site visit (Figure 2).

During the 132-day sample period, a total of 962 landed fishing trips were recorded (Table 1). On average, 8.08 total fishing trips occurred per day, with 1.78 DWS trips and 6.30 non-DWS trips per day (Table 2). During the sample period, total trips by day showed increase and decrease of all trip types simultaneously, which may suggest good fishing days patterns (Figure 2).

Of the 962 total trips, 212 or 23% were DWS trips and 750 or 77% were non-DWS trips (i.e., commercial, recreational, or unknown) with commercial trips comprising a majority of the non-DWS trips of 34% (Figure 4).

Table 52. Summary of trip effort in Rincon Ramp during trailer counts.

	Total DWS Trips	Total Non-DWS Trips	Total All Trips
Total trips	212	750	962
Average/day	1.78	6.30	8.08
Median	1	6	7
# zero days	48	6	5
# no data days	11	11	11
Max trips	10	16	22

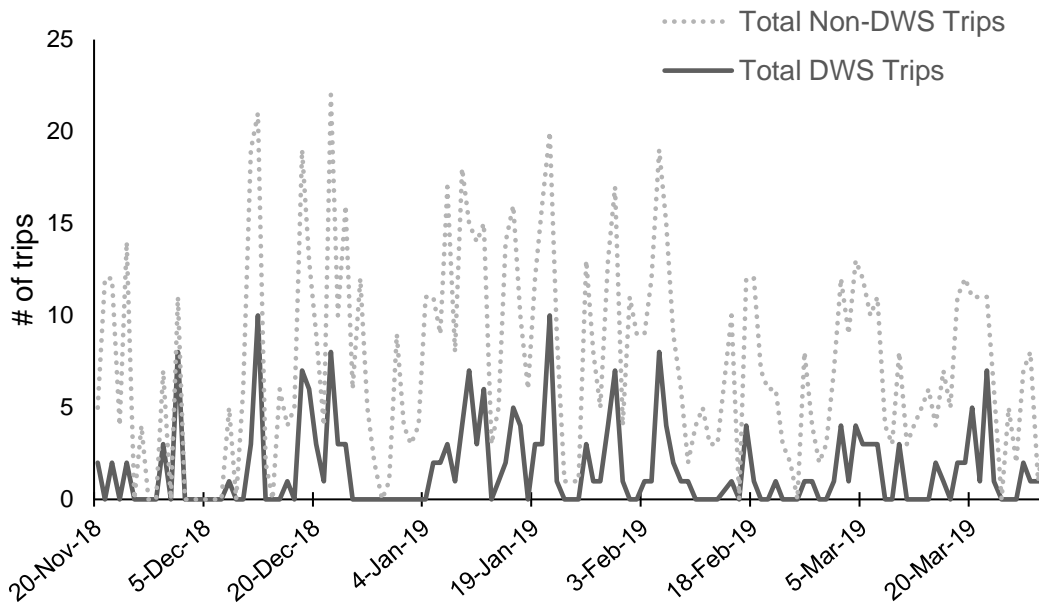


Figure 78. Number of recorded deep-water snapper (DWS) trips and non-DWS trips by date.

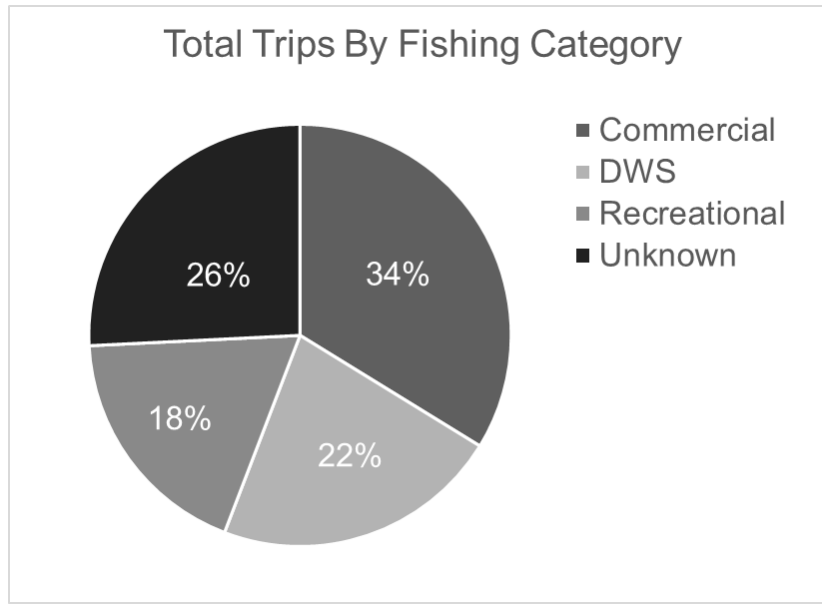


Figure 79. Breakdown of total fishing trips by category.

5.4 Lobster Fisher Data Collection Initiative

Lead and Prepared by: Alejandro Carrera and Marcos Hanke

Over the past few years, the lobster fishermen of Puerto Rico have expressed a strong desire to collect additional data on their fishery to allow the data to represent more accurately what they are seeing on the water. Prior to Hurricane Maria, several attempts were made to begin collecting data as part of this Fisher Data Collection Initiative. Preliminary data forms were developed and in consultation with SEFSC staff at CFMC meetings some modifications were made, but the project only saw minimal participation. Following the hurricanes, and after the recovery period fisherman kept the same interest to collect such important data and requested help in many public forums. Fishers requested guidance to facilitate the implementation of this project and “Censo De Pesca” offered to provide assistance and Marcos Hanke began engaging the fishing community. After meetings and conversations with industry leaders Brian Matias, Carlos Velazquez, Vanessa Ramirez, Ricardo Miranda, Roberto Silva and Nelson Crespo, the whole group agreed that this project can be successful. Some small changes were necessary, those to better fit the local needs and help the implementation of this project.

- We recorded a short video explaining how to fill the form and we made it available to the fishers.
- Lobster project was presented at the last CFMC meeting in San Juan. One video inviting fishers to participate was posted at the Council social media.
- Note: Many fishers including some that submitted the initial interest and characterization forms are still recovering from the hurricanes, building traps, and deploying new gear in the water. It is likely that greater participation will occur over time.

Comments:

The hardest part for the initial implementation for this project is overcoming the pervasive distrust of government and fishery managers and an overall lack of understanding of the benefits of better data.

Gaining the trust of the fishing community and educating them on the importance of improved data collection program will simply take time. With each engagement between the “Censo de Pesca” personnel, the dialog is improving and allowing this idea to mature among the fishing community. The message will continue to be that a Fisher data collection initiative can empower the fishing Industry of Puerto Rico.

Lastly, it is important to mention that the main lobster fishers have bigger boat that facilitate the data collection process. Also, they have more skill on data collection and probably better understanding of the importance of this effort. It will take a little more time for smaller scale fishers to follow up, but it is extremely important to included them and keep the inclusive effort, which at minimum will be a great outreach to the community.

A larger scale organized cooperative effort utilizing fishers from around the island to collect both fishery- independent and fishery dependent lobster data might be the best way to help the integrate the fishers into the scientific process and professionalize the industry. This of course would take directed funds and a dedicated scientific manager; however the timing of this effort is good given that fishers have been exposed to more sampling efforts than before.

5.5 Site Description Reference Guide

(Full report in Part 4 of Final Report)

Lead and Prepared by Alejandro Carrera and Lourdes Lastra

As in the pilot study an updated site description document was developed to facilitate any fisheries research being conducted in Puerto Rico. Each site has their own dynamic and sometimes, changes like weather conditions, hurricanes, fishing closures or even fish abundance may affect how fishers change their fishing strategies and affect the places they use. Assessments to each site is important to give more precision and understandings of the fishing activity in Puerto Rico as well as guide sampling projects to design better strategies to collect data. This project provided general information like site location “GPS”, conditions, usage, time and frequency of fishing trips, common trip types and catch composition. A list of locations to visit was generated using DRNA’s site list and local knowledge of samplers on each coast.

Samplers were instructed to fill a “Site Description Form” (Appendix 2) that included details necessary to describe the sites visited, evaluate for fishing activity and provide determination/suggestion if site had significant or no activity. For the general site conditions, it was important to determine how good are the structures of docks, ramps, moorings, “fish houses”, access or roads, even public facilities. This was accompanied by photos if possible, to give a visual perspective of the sites and their conditions. To evaluate fishing activity, (specially on sites that activity may not be so obvious) when the site was visited, we conducted at least 3 interviews forms to fishers, buyers, or any observer present with knowledge (Appendix 2). Interviewee was asked the number of fishing trips per month, type of catch and average pounds per trip. These questions were divided into 5 groups by times ranges: AM (5am-9am), Day (9am– 5pm) PM (5pm – 9pm) Night (9pm-5am) and Sundays (in general).

A total of 106 sites visited and described, 32 sites were found with no fishing activity and 20 sites had not significant landings (less than 1,000lbs/month). 54 sites were found with significant landings (above 1000lbs/month) (Table 53). Each site visited had different features that may benefit or have disadvantages for fishers to perform their work. For example, sites without ramp or docks are less probable to have fishing activity because is more complicated for the fisher. If they can, fishers move or use other sites with better facilities.

All this data gave more information about the distribution of locations with fishing activity. Our study and can be a guide for future initiatives that want to revisit and monitor changes in the fishing activity in Puerto Rico. This allows, in the future for researchers or persons with similar interested to have a guide that shows each site by location with the information pertinent to fishing activity around the island of Puerto Rico and its adjacent islands (Vieques and Culebra).

Table 53. List of sites visited with total commercial pounds landed in a month by time of day and Sundays. (Daytime = 9am– 5pm, AM = 5am-9am, PM = 5pm – 9pm, Night = 9pm-5am and Sundays in general) (Data collected from interviews to persons on site; (“-” = no data available.)

Site Name	Region	Daytime (lb)	Am (lb)	Pm (lb)	Night (lb)	Sunday (lb)	Total landings by month (lb)
MARINA PUERTO DEL REY	East	17,400	0	400	0	800	18,600
MATERNILLO	East	11,375	0	0	600	0	11,975
LA PARGUERA	South	8,107	510	165	720	400	9,902
GUANIQUILLA BARRIO (AGUADA)	West	600	0	7,910	0	1,330	9,840
CALLE HOARE	North	3,096	2,436	0	3,300	480	9,312
RINCON	West	3,528	0	5,184	0	532	9,244
PLAYA DE SANTA ISABEL	South	4,550	0	0	3,900	600	9,050
HUCARES	East	6,975	0	0	1,782	180	8,937
PUERTO REAL MARINA	West	8,190	77	180	0	480	8,927
PLAYA DE PONCE	South	1,591	4,270	0	2,958	80	8,899
ARECIBO RAMP	North	6,480	700	0	0	900	8,080
PUERTO YABUCOA	East	6,080	0	0	1,680	0	7,760
SALINAS PROVIDENCIA	South	4,992	280	611	1,131	141	7,155
SOLTERO PUERTO REAL	West	6,708	0	0	0	294	7,002
EL FARO GUAYANILLA	South	3,900	1,040	1,040	600	0	6,580
BAHIA PUERTO REAL	West	6,240	0	0	0	0	6,240
BAHIA DE GUANICA	South	4,080	800	320	268	111	5,579
TRES HERMANOS	West	540	0	-	4,800	100	5,440
LA PUNTILLA	North	1,443	2,640	550	660	25	5,318
PUERTO MOSQUITO	North	1,260	3,330	143	570	0	5,303
JAREALITO	North	2,400	1,973	165	100	400	5,038
CERRO GORDO	North	4,500	0	0	0	420	4,920
PASTILLO	South	4,750	0	0	100	0	4,850
TALLABOA	South	4,368	0	0	43	336	4,747
LA COAL	North	85	450	567	3,021	154	4,277
EL FARO CABO ROJO	West	1,914	1,474	600	0	0	3,988
PLAYA LAS PALMAS	South	3,045	8	200	330	140	3,723
MAMEYAL	North	2,205	720	0	480	0	3,405
PUNTA PAPAYO	South	3,219	0	0	54	81	3,354
LA GUANCHA	South	1,809	1,071	0	264	180	3,324
LAS CROABAS	East	2,485	0	0	0	720	3,205
PUNTA SANTIAGO	East	2,880	0	0	0	150	3,030
PLAYA CORTADA	South	2,860	0	0	0	140	3,000
MAUNABO	East	1,110	1,688	0	0	0	2,798
EL SECO RAMP	West	1,377	820	440	0	0	2,637
FROILAN	South	2,080	0	0	480	0	2,560
PLAYA DE SALINAS	South	1,820	0	0	720	0	2,540
FORTUNA	North	2,100	0	360	0	0	2,460

Table 53 (Cont'd) List of sites visited with total commercial pounds landed in a month by time of day and Sundays. (Daytime = 9am– 5pm, AM = 5am-9am, PM = 5pm – 9pm, Night = 9pm-5am and Sundays in general) (Data collected from interviews to persons on site; (“-” = no data available).

Site Name	Region	Daytime (lb)	Am (lb)	Pm (lb)	Night (lb)	Sunday (lb)	Total landings by month (lb)
MANZANILLO	South	2,080	0	0	0	320	2,400
GUANQUILLA	West	805	0	1,450	0	140	2,395
PARCELAS BELTRAN (SUNBAY)	East	800	0	0	1,200	320	2,320
BARRION LOS MACHOS	East	2,280	0	0	0	0	2,280
BAJO DE PATILLAS	South	1,950	0	0	212	0	2,162
CANGREJO	South	1,739	17	20	364	12	2,152
MORROPO	Island	1,040	1,040	0	0	0	2,080
BARRIO BAJURA	North	2,070	0	0	0	0	2,070
PALMAS ALTAS	North	1,120	0	0	600	280	2,000
BOQUERON	West	1,357	0	561	75	0	1,993
CULEBRA	Island	999	520	146	200	100	1,965
EL COMBATE	West	1,180	0	0	580	40	1,800
LA PRINCESA	North	1,333	0	180	21	153	1,687
BARRIO TAMARINDO	West	980	60	360	100	100	1,600
PLAYUELA	West	1,026	120	0	160	162	1,468
PALO SECO	North	1,200	0	0	0	0	1,200
PUERTO NUEVO	North	1,080	0	0	0	0	1,080
ESPERANZA	Island	552	234	80	100	0	966
LAS MARGARITAS	North	264	0	640	0	0	904
PUNTA PENON	North	900	0	0	0	0	900
BARRIO AGUIRRE	South	320	320	0	240	0	880
VILLA PESQ. PUERTO REAL	West	366	299	0	161	0	826
COSTA AZUL	North	800	0	0	0	0	800
TORRECILLA	North	720	0	0	0	0	720
PLAYA DE GUAYANES	East	400	0	300	0	0	700
BARRIO GUAYPAO	South	650	0	0	0	0	650
MARINA MERIDIONAL	West	0	345	0	300	0	645
CAÑO BOQUILLA	West	600	0	0	0	0	600
PUNTA PITAHAYA	West	350	240	0	0	0	590
SAN JACINTO	South	0	60	0	240	240	540
BARRIO ESPINAR	West	100	360	30	0	0	490
HIGUEY	South	-	280	-	60	0	340
BAHÍA DE GUAYANILLA	East	169	0	0	132	0	301
BUENA VISTA (SECTOR PLAYA)	West	180	0	0	0	120	300
BARRIO BARRERO	West	240	0	0	0	0	240
LA CALIFORNIA	North	240	0	0	0	0	240
MARINA PUERTO CHICO	East	50	0	0	0	100	150

Table 53 (Cont'd) List of sites visited with total commercial pounds landed in a month by time of day and Sundays. (Daytime = 9am– 5pm, AM = 5am-9am, PM = 5pm – 9pm, Night = 9pm-5am and Sundays in general) (Data collected from interviews to persons on site; (“-” = no data available).

Site Name	Region	Daytime (lb)	Am (lb)	Pm (lb)	Night (lb)	Sunday (lb)	Total landings by month (lb)
BARRION SARDINERA	East	100	0	0	0	0	100
BALNEARIO DE BOQUERON	West	0	0	52	0	0	52
EL MANÍ	West	0	0	0	0	0	0
GUANAJIBO	West	0	0	0	0	0	0
EL TUQUE CLUB DEPORTIVO	South	0	0	0	0	0	0
PALMER	North	0	0	0	0	0	0
PARCELAS VIEQUES	North	0	0	0	0	0	0
PARCELAS SUARES	North	0	0	0	0	0	0
MEDIANIA BAJA	North	0	0	0	0	0	0
ANCONES	North	0	0	0	0	0	0
CORCEGA	West	0	0	0	0	0	0
PARCELAS ESTELA	West	0	0	0	0	0	0
PUNTA FIGUERAS	East	0	0	0	0	0	0
PLAYA LUCIA	East	0	0	0	0	0	0
PUNTA MARACAYO	North	0	0	0	0	0	0
HATILLO PUEBLO	North	0	0	0	0	0	0
BARRIO JOBOS	North	0	0	0	0	0	0
VIETNAM	North	0	0	0	0	0	0
LA BOCA	North	0	0	0	0	0	0
JOYUDA	West	0	0	0	0	0	0
RASQUETA	West	0	0	0	0	0	0
LA PARGUERA RAMPA	South	0	0	0	0	0	0
PUNTA CANDELERO	East	-	0	-	-	-	-
EL CORCHO	East	-	0	0	0	-	-
PLAYA DE JAUCA	South	-	-	-	-	-	-
LAS MAREAS SALINAS	South	-	-	-	-	-	-
SALINAS FORTUNA	South	-	-	-	-	-	-
GUARDARRAYA	South	-	-	-	-	-	-
BARRANCAS	South	-	-	-	-	-	-
PUNTA POZUELO	South	-	-	-	-	-	-
BAHÍA JOBOS (PUERTO DE JOBOS)	South	-	-	-	-	-	-

6 RECOMMENDATIONS

Overall, our primary recommendation is simple: Territorial fisheries departments and NOAA should formalize a plan and an agreement to continue a comprehensive monitoring program. The data set collected during this project is rich with information that assessment scientists, fisheries and coral reef biologists, and managers can utilize almost immediately. Multiple analyses are obvious given the results (e.g., lunar and weather factors on fishing efforts; direct comparisons of species compositions reported to observed) that will not only allow for more efficient, higher quality information to be collected in the future, but also allow for greater use of what was collected in the past. Understanding why self-reported landings have dropped by 75% in some US Caribbean fisheries or if fishers may be over reporting to meet license requirements should be a top priority. Simply stated, it is impossible to manage a fishery based on a single self-reported data stream and coordination of the end users of the data will allow for analyses of these results to maximize efficiency. Our specific recommendations are as follows:

- *Governance* – The primary logistic recommendation for better data collection is almost identical to that of the pilot project: improved governance and coordination. Decisions need to be made about future data needs and how these relate to future port sampling. A formal agreement between NOAA and DRNA should be completed to determine roles and responsibilities for monitoring. NOAA, HMS, recreational, commercial, and coral reef programs should coordinate prior to engagement with DRNA. For example, an overall agreement as to whether and how to include early morning, evening and Sunday sampling, and the islands of Vieques and Culebra should be forged. Sampling in these situations requires separate surveys at an additional expense so the benefits and costs need to be evaluated.
- *Survey design* – The two-stage design appears to be an attractive choice for future daytime sampling work. However, simulations should be conducted and parameterized based on the expected budget and current survey results, to determine how well the conservative variance estimator works and to explore the benefits of sampling $m=2$ sites on some days. Now that information about relative usage of sites is available, other possibilities should be considered such as ppz sampling (sampling with probability proportional to z where z is, in this case, anticipated usage at a site). Simulation studies are needed to determine if this alternative is attractive.
- *Extending impact of survey program* – In addition to combining recreational, commercial, HMS, and coral reef program needs, an obvious consideration is to enhance future port sampling work with the collection of biological samples for age, growth, maturity and stock identification work. This will require careful planning to obtain representative results without jeopardizing the core program of estimating total landings by species.

- *Rapid sampling and utilization of technology* – The development of software to automate length information in collaboration with SEFSC should be a top priority. Length frequencies can be captured randomly as part of the port sampling process, providing assessment scientists critical information, while also bolstering a library of images for the development of automated species identification. Coordination within SEFSC and digital image analysis experts at SEFSC/Galveston should be prioritized.
- *Quantifying effort* – Methods to quantify effort should continue to be developed. While field testing of cameras was successful, this approach to quantifying fishing effort (i.e., trips) was rejected due to the possibility of vandalism or resentment of fishers to government “spying” and risks to the overall project. Expanded boat counts were successful in Puerto Real, and a 4-month exploratory project collecting trailer count data in Rincon will be useful when evaluating auxiliary sampling options (see Auxiliary Project - Rincon).
- *Challenging species/special considerations* – Certain species are difficult to sample because they are “rare event” species which are caught in large numbers (or are large animals; e.g., tiger shark) but only sporadically, or are landed largely at night. Additional analyses of these results given SEFSC priorities, and experimentation will be necessary to design practical, cost-effective surveys for these species. A cost-effective method, if it can be implemented with statistical rigor, would be to involve fishers in a self-reporting-and-verification program. For example, yellowtail snapper fishers might phone in when they are returning to port and port samplers could arrange to meet a number of trips. These recommendations were covered in the pilot project report as individual based sampling and will require coordination with territorial fisheries agencies, as some requirement to comply will likely be necessary.
- *Analyses of weather and lunar cycles* – Fishing effort appeared to be cyclical and given the size of the vessels, obviously dependent on weather. Many days, samplers knew before they left for the site that no activity would occur (e.g., tropical storms). Given the time series that is now available, these should be explored as potential factors in a sampling design. For example, if the 6 am forecast is determined to be predictive of effort, sampling effort can be adjusted accordingly. Given our results some post stratification and exploration of these factors can be conducted.

For example, on days with severe weather, the amount of landings is generally quite low or even zero. If not accounted for, this inflates the variance. To deal with this, one can post-stratify sampling days into severe weather days (e.g., days with winds above 30 mph or days with heavy seas) and non-severe days. The mean landings per day are then calculated for each weather-based stratum.

In order to implement this post-stratification, it is necessary to obtain a list of all the severe-weather days, and to calculate 1) the number of severe weather days, and 2) the mean landings per day and standard deviation for severe-weather and non-severe weather days

(separately). The computations are simplified if it turns out the landings are essentially zero on severe-weather days.

- *Expansion factors, family grouping and species compositions* – Given that samplers identified over 270 species and matching to DRNA self-reported data is challenging at best, an intensive effort should be conducted to determine how best to compare results and develop refined expansion factors. Comprehensive analyses of historical reported data in terms of species and gear types in addition to coast and/or sites should be conducted before final decisions on calculating the most reliable and consistent expansion factors.

In terms of species delineation, the most obvious approach would be to lump everything back into family groups but this would take the data set backwards rather than forward. A concerted and in-depth effort to evaluate the self-reported data will have to be conducted to determine if there are regional or fisheries differences in how certain species are reported (e.g., the East coast trap fishers may report all snapper as silk snapper, and in the bandit reel hook and line deep water snapper fishery, they report to species accurately). Coordination with NOAA educators and outreach programs should also be initiated.

- *Deep water snapper (DWS) reporting validation* – If examination of family groupings does not give insights as to the significant differences between estimated and reported landings for the DWS fishery, a very careful, detailed evaluation of the reported data should be conducted prior to expanding or developing a DWS specific survey. The reporting requirements (i.e., 5 years of statistics and an average/total of 1000 lb/year of silk and/or other snapper species) is clearly an incentive to “claim turf” and overreport these species. The initial evaluation of site rankings from DRNA self-reported data, estimated landings and sampler observations on sites we did not sample (e.g., large reported landings from sites with little evidence of any fishing) suggests this may be occurring. “Stories” of the 10,000-pound trip and of misreporting are rampant garnering some anger from those on the East coast, for example, who did not obtain the special permit. This is a perfect example for the importance of outreach (see below).

An individual based sampling approach would work very well in this situation but the coordination and governance structure would have to be carefully worked out. Our specific recommendation from the pilot project: “...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.

- *Fishing community outreach and inclusion in the process* – One of the biggest accomplishments of this project was gaining the trust of the fishers that allowed samplers to enumerate their catch. The Puerto Rico lobster fishers have initiated a data collection program on their own and would like to be included in the scientific process. Overall, the fishing community is suspicious of science and particularly of the “statistics” being used to guide their future. The results of this study can provide a common language for scientific representatives or educators to illustrate how this process can work to provide more realistic information to the decisions that impact their future.

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