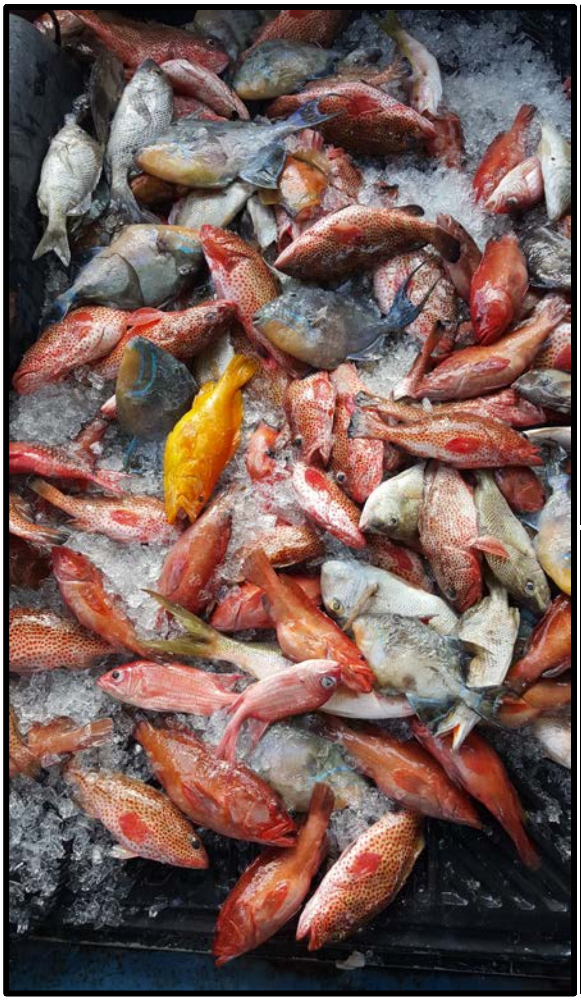
PUERTO RICO PORT SAMPLING AND CATCH VALIDATION PROJECT

(August 2017 – December 2019)

Final Report Part 1 – Executive Summary

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



MER Consultants, LLC

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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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"Trabajando Unidos Para
un Mejor Futuro"

In Cooperation with:

DEDICATION
To the Fishers and Fishing Communities of Puerto Rico

The team of Censo de Pesca would like to dedicate this report and express our deepest gratitude to the fishers of Puerto Rico. We worked alongside them in the extremely difficult times and slow recovery after Hurricanes Irma and Maria devastated the island. They let us into their lives, their homes, their circles, and shared stories of the arts and labor that fishing involves. We listened and learned. These men and women lead lives that we admire and respect, "it's not easy but always rewarding".

Fishers in **Playuela** (a.k.a Crash Boat)


Traditional boat haul in **Pastillo**

Although suspicious of science, and during challenging times, the fishers and industry were overwhelmingly co-operative. To thank them, to express our comradery, and to bring attention to their voice and story, one of our samplers filmed a documentary showing the impact of Hurricane Maria on their lives.


The former Pescaderia in **Playuela** (a.k.a Crash Boat)

Una Plena para los Pescadores y María: **https://youtu.be/2YgnMxK7KRU**

Directed by: Lourdes Lastra

DEDICATORIA

A todos los Pescadores y Comunidades Pesqueras de Puerto Rico.

El equipo del Censo de Pesca le gustaría dedicar este informe y proyecto, y a su ves expresar nuestro más sincero agradecimiento a los pescadores de Puerto Rico. Trabajamos juntos en momentos extremadamente difíciles, luego del impacto y lenta recuperación de los huracanes Irma y María. Nos dejaron entrar en sus círculos, sus hogares y sus vidas, compartiendo sus historas de ardua labor en la industria de la pesca. Los escuchamos y aprendimos mucho. Estos hombres y mujeres lideran vidas que merecen el más profundo respeto y admiración.

Pescador de **La Coal**

"Toño" pescador de **La Princesa,** pescando en la bahia

A pesar de sus sospechas hacia la ciencia, y los momentos dificiles que encontramos, los pescadores y todos los miembros de la industria de pesca se mantuvieron atentos y colaboraodres. Para agradecerles, expresar nuestro mutuo apoyo y recalcar sus voces e historias, una de nuestras muestreadoras realizó un documental mostrando el impacto que el huracán María desplegó en las pesquerías y en sus vidas.

Daños en Barrio **Sardinera, Fajardo**

“Una Plena para los Pescadores y María”: https://youtu.be/2YgnMxK7KRU

Dirigido por: Lourdes Lastra

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EXECUTIVE SUMMARY

In this document, MER Consultants (MER) has the pleasure to report on a large-scale comprehensive port sampling program implemented in Puerto Rico between August 2017 and December 2019. The Gulf States Marine Fisheries Commission (GSMFC) in collaboration with NOAA's Southeast Fisheries Science Center (SEFSC) contracted MER to facilitate the improvement of scientific information gathered for the management of fisheries in the US Territories in the Caribbean (U.S. Virgin Islands/USVI and Puerto Rico) to ensure the cultural, economic, and ecological sustainability of the fisheries. Data shortcomings and the sole reliance on self-reported data for these small-scale, multi-gear, and multi-species fisheries has hindered the ability to set meaningful annual catch limits (ACL). The Puerto Rico Department of Natural and Environmental Resources (DRNA) began a data improvement process in 2009 that stressed the need to validate self-reported commercial landings. The overall objective of the current study was to build upon the results of the 2015-2016 MER pilot study and implement a year-long survey to 1) validate the annual reported species-specific landings and, 2) better understand geographic distribution, seasonal changes and other temporal patterns in variability in fishing effort.

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 locations 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 was severely impacted. Even locations not directly damaged were rendered almost 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 time to regroup while not losing trained personnel. However, the 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.

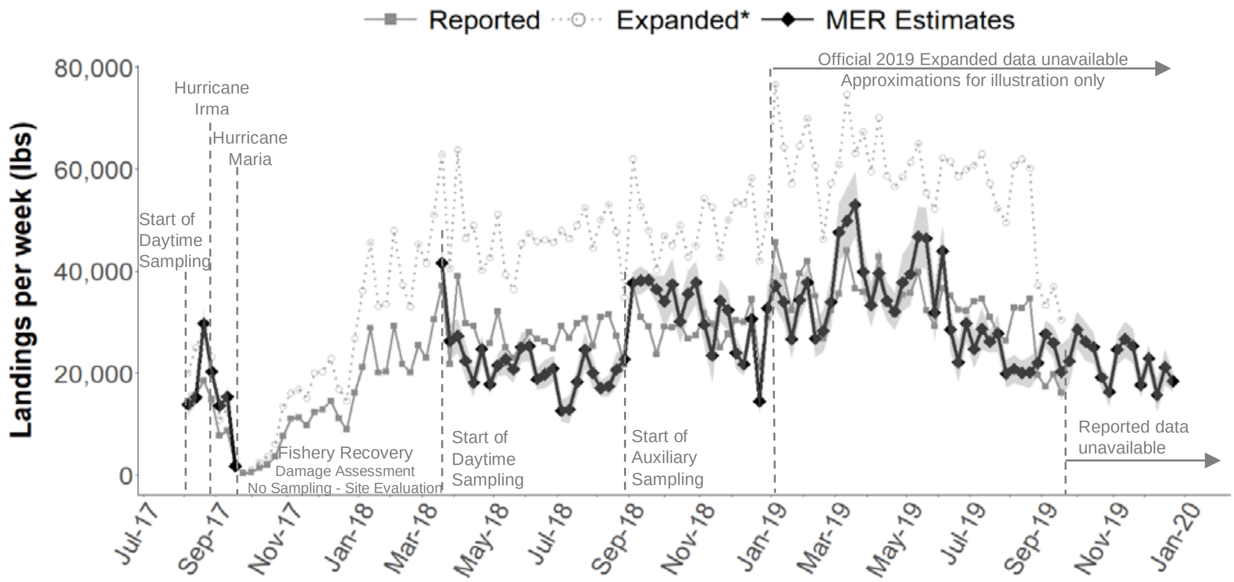

Figure 1. Estimated, reported, and approximate expanded total landings for the entire time period sampled during this project. The shaded area represents the proportional standard error (PSE; standard error divided by the estimated landings) of the weekly estimate. Note that here and throughout this document **'Expanded' is denoted with an "*" to indicate that DRNA expansion factors were only available for 2018 which were used to approximate the expanded 2019 reported landings.**

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 (see Section 3.4). On March 15th, 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 fishing 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 teams on the ground 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 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 referred to as “busroute(s)” throughout this document. Visiting multiple sites on a roving busroute 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 (see Section 3.3.2). We conducted a quarterly analysis of the data and modified stratifications, as necessary (see Section 3.5).

Overall, the project was successful in obtaining detailed daytime catch records for almost 2 years and daytime plus auxiliary information for almost a year and a half from over 50 sites (Figure 1). As in the pilot study, no personal information on individual fishers was collected and cooperation was excellent at all but one site (<2% noncooperation for all other sites). Over the entire time frame of the project (including the 6 weeks pre-Hurricane Maria), samplers completed almost 5,000 sampling assignments, sampled nearly 10,000 trips and observed over 400,000 pounds (lb) of landings (see Table 1 and Table 3; Section 4.1). This translates to ~2 trips sampled per assignment, ~40 pounds seen per trip or ~80 pounds per assignment. Total landings for the entire sampled time period were estimated to be nearly 2.8 million pounds which averages to around 28,000 lb/week.

Table 1. Completed sampling assignments by sampling type, and the number of exploratory trips sampled outside of our statistical design. Exploratory trips are only included in our descriptive statistics and list of species observed. (Reminder: “Islands” refers to sampling on Vieques and Culebra and “Busroutes” refer to roving survey design where multiple sites are visited.)

Region	Daytime	AM Busroutes	PM Busroutes	Sunday Busroutes	AM Site	PM Site	Exploratory Trips
East	969	-	1	27	54	23	13
North	972	53	-	27	-	83	54
South	980	55	-	27	-	81	28
West	1,078	52	53	55	-	48	19
Islands	88	-	-	-	-	-	0
Totals	4,087	160	54	136	54	235	114

The summary below provides bulleted lists of key findings so that the casual reader can quickly extract an overview of the project while also providing fisheries professionals a starting point for understanding this work. The executive summary (Part 1) provides much of the overview narrative for the key topics and some specifics of the findings while the main body (Part 2) contains supporting figures, tables, and information on the points below, as well as detailed results for the top 20 - 25 landed species depending on the analysis. The Appendix (Part 3) contains full species lists with components of variability for simulation modeling or additional work. Note that we are distributing this report in four separate files (Summary – Part 1, Main Body – Part 2, and Appendix – Part 3, and Site Descriptions – Part 4). The section references below refer to the main body of the report and the appendix references are as indicated.

Findings & Recommendations

Effectiveness of the Survey

MER was able to accomplish the following:

- *Site evaluations* – A dynamic and comprehensive list of the principal landing sites for commercially caught fish and invertebrates was compiled and refined throughout the project. Relative usage of sampled sites (e.g., "high" versus "low") was evaluated and refined at least quarterly. Periodic interviews at all known locations (106 sites) provided prioritized lists of additional sites to consider when determining sampling frames for future work (see Section 3 and Site Descriptions - Part Four).

- *Daytime design* – An effort was made to use a single standardized statistical design as much as possible for daytime sampling to facilitate training, ease of implementation, and streamlining of data processing. The design used for 6 of the 8 strata (i.e., for Puerto Rico East, South and West high and low use strata) was two stage cluster sampling where days were picked at the first stage and one site (m=1) was picked at the second stage. This afforded unbiased estimates of the landings and conservative (biased high) estimates of variance. Implementation proceeded smoothly and analysis of the data was straightforward.

- *Puerto Real design modifications* – Cooperation from fishers and processors was excellent with the exception of one landing site (a privately owned Pescaderia) in Puerto Real on the West coast, which did not allow us access for most of the study period. With assistance from Luis A. Rivera (DRNA), MER modified the design for the harbor as a whole, conducted additional effort sampling to count trips and used a ratio estimator (catch per unit effort times total trips) to not only successfully obtain estimates of landings, but also develop an efficient generalizable method for other locations.

- *Puerto Rico North and the auxiliary sampling program designs* – On the North coast and for early morning, early evening, and Sunday sampling, logistical considerations required the use of alternative sampling designs. These included simple random sampling of days when there was only one site in the stratum (Puerto Rico North daytime high use stratum, Puerto Rico North evening survey, and Puerto Rico East morning survey), a roving design resembling a "bus route" design (Sunday sampling), and two stage cluster sampling with a variable number of sites (0 – 2) visited per day (Puerto Rico North low use stratum).

- *Daytime survey precision* – A large-scale survey was implemented with targets for precision derived from the pilot study analyses. Precision goals were largely met (Figure 2). For all strata combined in the full survey period, eight of the top nine species landed had PSE's (proportional standard errors; standard error divided by the estimated landings) of less than 7% of the estimate (the exception being dolphin). Only five of the top 28 species which comprise ~90% of the catch had proportional standard errors (PSE; standard error divided by estimated landings) of >15%. In the top 95% of landings (47 species), only 5% of the landings (16 species) have PSEs > target of 15%. For all strata combined in the annual estimates, seven of the top 10 species still had PSEs less than 7% with silk and lane snapper at 9% and 15%, respectively. Only dolphin at 18% was above the target precision of 15% (See Section 4.3 for annual estimates with daytime and auxiliary sampling combined).

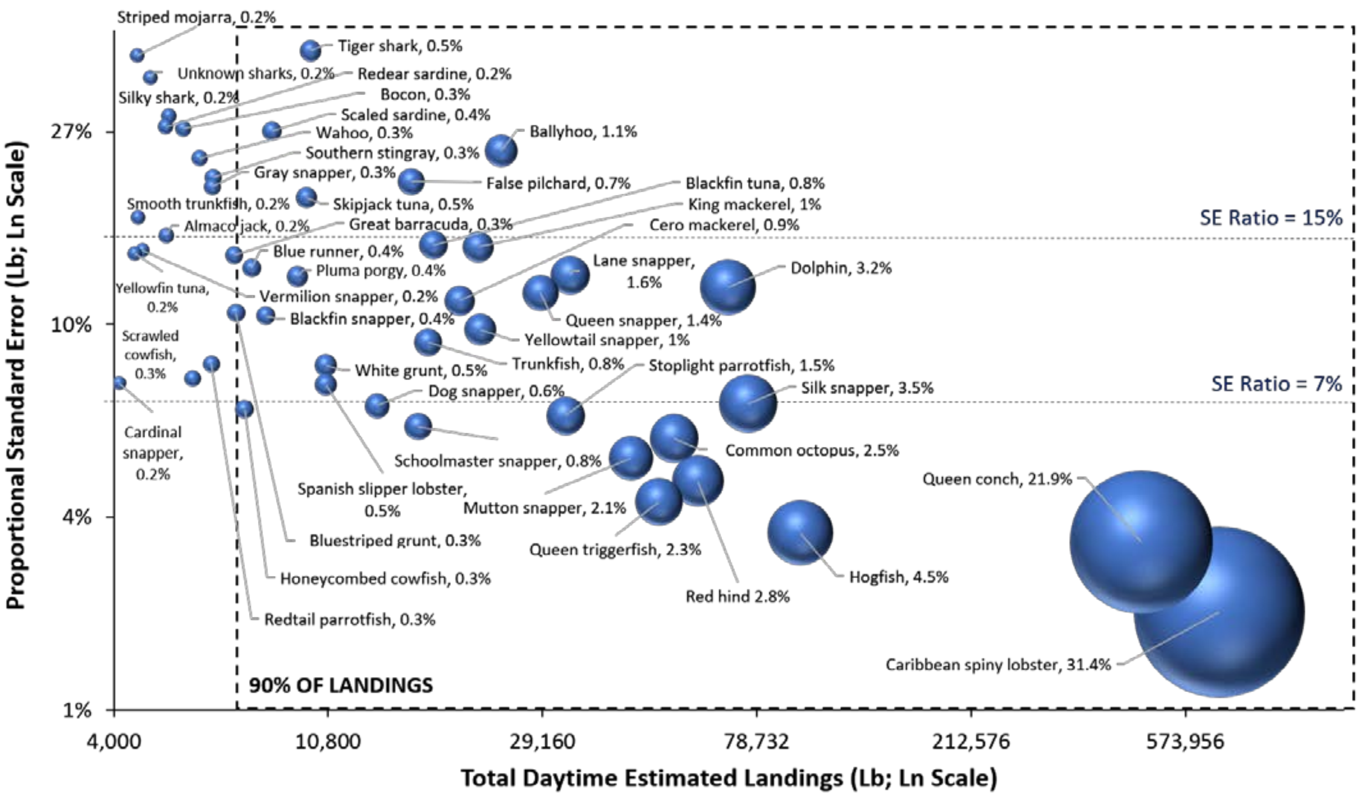

Figure 2. Total landings estimated from primary daytime survey over entire sampling period plotted against PSE (both on ln scale) for the species comprising the top 95% of the landings. Box denotes the subset of species comprising 90% of the landings. Bubble size was determined by percent of the total catch which is also indicated following the species name.

- *Auxiliary survey precision* – Precision of the auxiliary sampling programs (i.e. Sundays, early morning, early evening, and Vieques/Culebra) 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 had PSEs 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.

- *Precision of all sampling* – For the entire time period sampled, PSEs were 1.6% for all of Puerto Rico and 2.5%, 4.3%, 3.3%, 3.4% and 5.3% for the East, North, South, West, and

Islands, respectively. By species, only six of the top 30 species had PSEs larger than the target of 15% (see Table 4 for species specific estimates).

- *Evaluating survey design to inform future work* – An analysis of precision (power analysis) as a function of sampling effort was conducted. There was some scope to adjust sampling effort upward or downward if a better balance of costs and precision was needed. Essentially, modest changes in sampling effort resulted in modest changes in precision (see Table 2 for analysis example and Section 4.6). However, logistical constraints limit the ability to adjust sampling effort without a comprehensive plan, i.e., it was difficult to hire, train and retain qualified personnel for part-time work (e.g., sampling two days per week). Comprehensive simulations including alternative sampling strategies and designs can be conducted once SEFSC and DRNA determine sampling goals and priorities now that all the necessary preliminary estimates of parameters have been obtained.

Table 2. Changes in the daytime PSE of estimated landings for the East given different "n" sampling days per week for the overall top 10 species. Values in the column labelled Daytime SE/Estimated are calculated from the data with the actual n of 5 (i.e., sampling Mon. – Sat.).

Rank	Species	Daytime Estimated	Daytime Variance	Daytime PSE	PSE n=2	PSE n=3	PSE n=4
1	Queen conch	89,268	9,639,147	0.055	0.087	0.071	0.062
2	Caribbean spiny lobster	22,954	9,193,784	0.063	0.099	0.081	0.070
3	Hogfish	1,498	3,668,282	0.089	0.141	0.115	0.100
4	Mutton snapper	10,023	774,067	0.088	0.139	0.113	0.098
5	Stoplight parrotfish	7,501	1,006,684	0.134	0.211	0.173	0.150
6	Queen triggerfish	6,831	702,766	0.123	0.194	0.158	0.137
7	Red hind	6,523	454,810	0.103	0.163	0.133	0.116
8	Cero mackerel	5,390	1,290,465	0.211	0.333	0.272	0.236
9	Yellowtail snapper	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

- *Electronic reporting and rapid sampling development* – MER's reporting software was modified to accommodate three prototype sampling stations which were developed and deployed. The same tablets used by all samplers were integrated with a scale so that images and weights were captured automatically (see Section 5.1). Stand-alone setups, or modular units with tables, were successfully used to capture individual weights and images in a very timely fashion (2-3 seconds/fish). Annotation software was developed and, to date, over 15,000 images of species have been collected and catalogued to facilitate the final stages of the machine learning software development process. Close to 20,000 pictures were recorded as part of the sampler's duties and were used to verify species identifications.

- *Temporal resolution of survey - Lunar cycles* – The project was designed to estimate weekly daytime landings and monthly for auxiliary summaries due mainly to logistics. Initial data explorations found clear signals on a weekly time scale. Between December 2018 and June

2019 there were at least 7 cyclical patterns that appear in both the estimated and reported landings. Note that these were independent data sets; having 7 repeated patterns over a 7-month period strongly suggested a lunar cycle to fishing. This could be very important for the design of efficient sampling programs and therefore we present data weekly throughout (Figure 3).

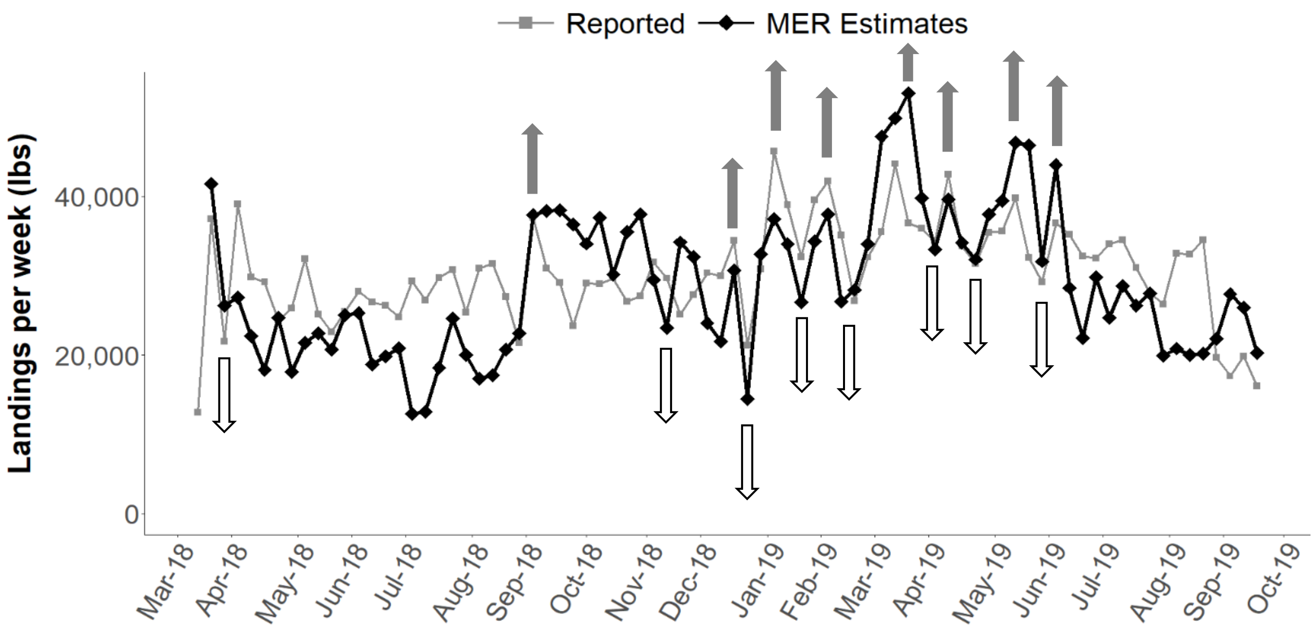

Figure 3. Strong weekly patterns observed in both estimated landings (daytime and auxiliary) and reported data suggesting lunar patterns to fishing activity.

Characterization of the Fishery

- *Trip type*– Recreational and Charter trips were sampled but commercial activity dominated as would be expected given the designed commercial sampling frame. A total of 563 recreational trips were sampled, representing 6% of the total sampled trips. In all regions except for the North coast, commercial trips accounted for 94 – 96% of sampled trips. On the North coast, recreational trips comprised 15%. A total of 563 recreational trips were sampled and rankings (e.g., from number of sampled trips: 1-Rincon/W, 2-Mameyal/N, 3-Puerto Mosquito/N, and 4-El Seco Rampa/W) can be used to support the development of recreational surveys. For the remainder of the report, other than when specified, only commercial trips are presented.
- *Trip type - Gear* – The most common gear recorded was diving with 60% of observed trips overall and between 63 – 87% for all coasts except the North. The North coast was dominated by hook and line trips at 70% and only 13% diving. Traps were mostly used in the South and East coasts with 9% and 1%, respectively.

- *Average pounds per trip* – The overall average landings per trip was approximately 40 pounds (lb). Lobster trips in the East and deep-water snapper trips in the West had the largest landings with averages over 200 lb. Average landings on the North, East, South, and West coasts were 19 lb/trip, 54 lb/trip, 41 lb/trip and 54 lb/trip, respectively.
- *Regional differences in overall landings* – Landings on the East, South and West coasts were comparable but landings on the North coast were approximately 25% of the other coasts (Table 3). Estimated landings in the Islands is from the shorter time series of auxiliary sampling only and is comparable to that in the north coast during the entire project. If the Islands are included in the East coast, then landings were highest in this region (see Section 4.1 for more details on descriptive statistics).

Table 3. Summary of observed and estimated landings, number of sampled trips and species observed in both primary daytime and auxiliary sampling (commercial only). Note that estimated landings for the Islands is from the shorter auxiliary sampling time period only. The number of species reported to DRNA in 2017 – 2019 is also included for comparison.

Region	Total Estimated lb	Total Observed lb	Number of Sampled Trips	Number of unique species observed	Number of unique species reported
East	724,627	165,941	2,165	163	56
North	234,949	33,890	1,200	183	61
South	770,559	99,963	2,300	149	60
West	873,732	117,512	2,871	190	62
Islands	202,035	15,848	222	65	37
Totals	2,805,902	433,154	8,758	267	76

- *Hurricane impact* – An evaluation of Hurricane Maria impacts to the fishery was conducted by comparing the 6 weeks sampled (Aug. – Sept. 2017) prior to the hurricane to the first 6 weeks when sampling resumed (Mar. – Apr. 2018; normally one of the highest landings periods) and the same 6 weeks in 2018 and 2019 (Figure 4). While not evident in the overall catch, the trap fishery was impacted and did not recover to pre-hurricane levels until 2019.

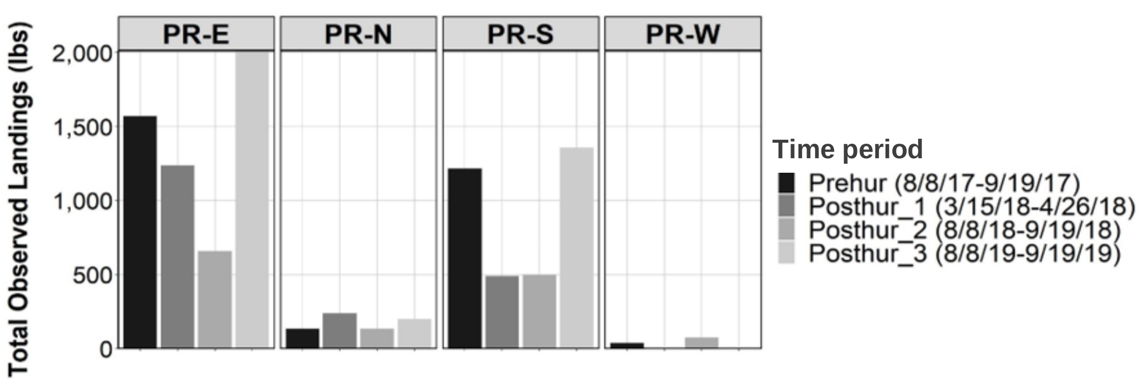

Figure 4. Observed Landings for hurricane impact comparisons. Traps only/All Species (excluding Conch).

- *Principle landing sites* – A total of 50 sites were formally sampled during the project. The statistical design provided estimates per strata, so to compare activity of specific locations we utilized the observed variable of interest (e.g., trips, lb, etc.). Sites were ranked based on the observed average landings per day (Figure 5). The highest average landings per day were on the East coast and Morropo/Vieques at around 300 lb/day. The two West coast Puerto Real sites and Rincon had average landings of around 200 lb/day while the highest usage sites in the South had 150 – 200 lb/day. The North site of Jarealito was the highest at 100 lb/day.

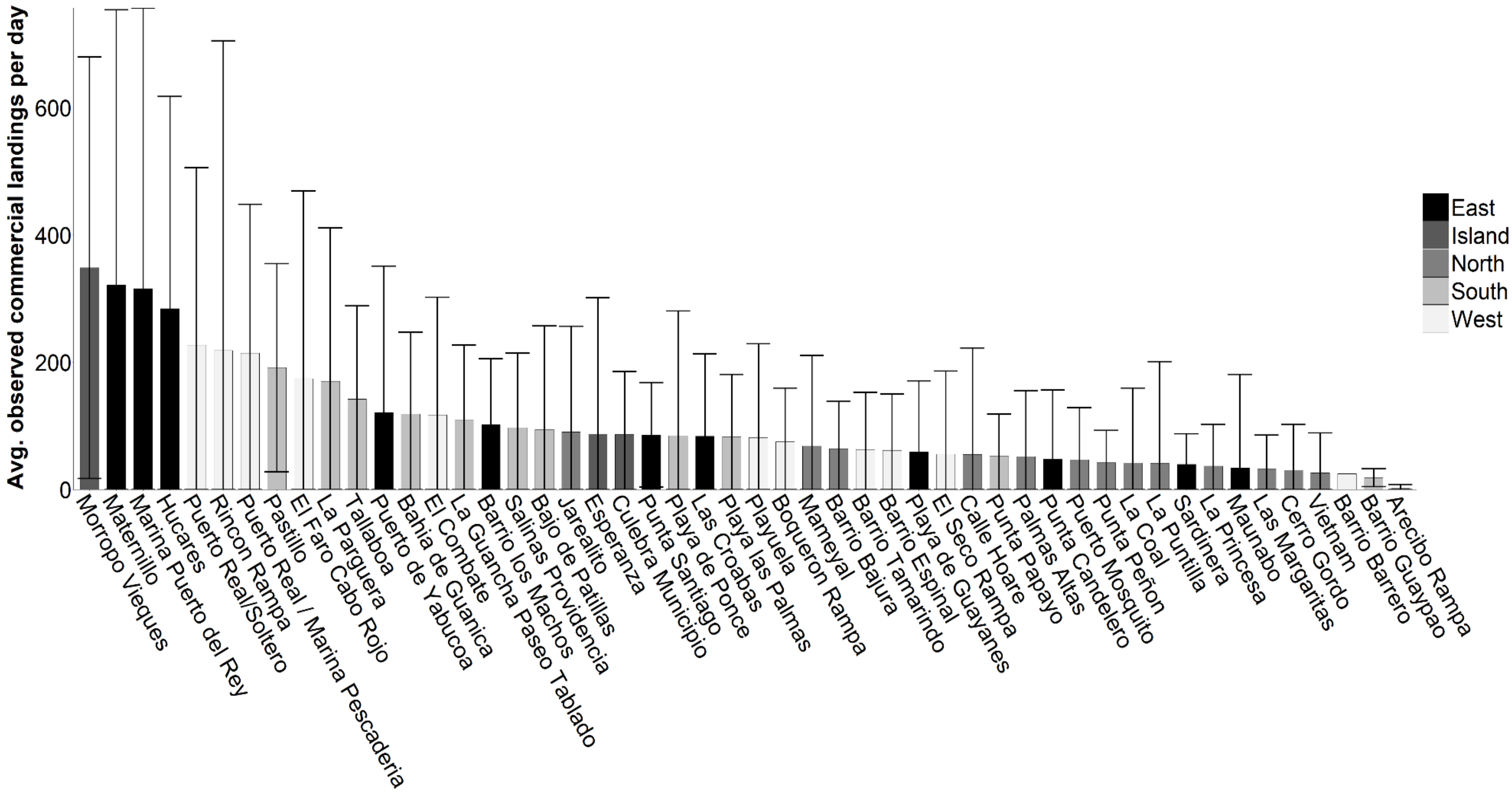

Figure 5. The average observed landings at each sampled site per day +/- 1 standard deviation. Presented in descending order. Each coast is indicated and the three Vieques and Culebra sites are included.

- *Species composition: Many species but dominated by a few –*
    - The fisheries are dominated (~50% of landings) by Caribbean spiny lobster (*Panulirus argus*) and queen conch (*Strombus gigas*). Referred to simply as lobster and conch for the remainder of this document.
    - Samplers identified 267 unique species, 5 genus groupings (e.g., shark *Mustulus spp.)* and 39 family unknowns (e.g., triggerfish unknown).
    - Top 28 species that comprise 90% of estimated daytime landings are listed in Table 4. Auxiliary estimates are presented to show species commonly documented outside of normal daytime hours and how rankings would change.
    - Only 10 – 15 species make up more than 1% of the total estimated landings and over 260 for which estimates are less than 3,000 – 4,000 lb per year (Figure 2).

Table 4. Species composition of the top 90% of the landings as estimated from the primary daytime survey.

Species	Rank: Day Estimate	Day Estimate	Auxiliary Estimate	Total Combined Estimate	PSE (SE/Total Estimate)	Cumulative % of Total Day Estimate
lobster_caribbean_spiny	1	671,899	68,612	740,512	0.02	31%
conch_queen	2	467,755	108,209	575,964	0.03	53%
hogfish	3	96,337	8,480	104,818	0.03	58%
snapper_silk	4	75,604	25,528	101,132	0.06	61%
dolphin	5	68,829	69,287	138,116	0.16	65%
hind_red	6	59,853	13,184	73,037	0.06	67%
octopus_common	7	53,666	1,376	55,042	0.05	70%
triggerfish_queen	8	49,963	4,486	54,449	0.04	72%
snapper_mutton	9	43,897	2,416	46,313	0.05	74%
snapper_lane	10	33,153	3,226	36,379	0.12	76%
parrotfish_stoplight	11	32,463	582	33,044	0.06	77%
snapper_queen	12	28,874	77,774	106,649	0.09	79%
ballyhoo	13	24,106	4	24,110	0.24	80%
snapper_yellowtail	14	21,860	19,650	41,509	0.11	81%
mackerel_king	15	21,674	151,773	173,447	0.12	82%
mackerel_cero	16	19,878	1,177	21,054	0.11	83%
tuna_blackfin	17	17,576	4,521	22,097	0.13	84%
trunkfish	18	17,179	551	17,730	0.09	84%
snapper_schoolmaster	19	16,400	468	16,868	0.06	85%
pilchard_false	20	15,880	228	16,109	0.20	86%
snapper_dog	21	13,549	2,344	15,893	0.07	86%
grunt_white	22	10,692	3,079	13,771	0.08	87%
lobster_spanish_slipper	23	10,687	533	11,221	0.07	87%
shark_tiger	24	9,956	23,602	33,558	0.23	88%
tuna_skipjack	25	9,750	1,823	11,574	0.18	88%
porgy_pluma	26	9,369	712	10,081	0.12	89%
sardine_scaled	27	8,325	703	9,028	0.25	89%
snapper_blackfin	28	8,089	1,498	9,587	0.09	90%

- *HMS species and elasmobranchs* – A total of 383 individual sharks, weighing 7,891 lb and comprised of at least 20 species and four shark unknown groups, were recorded. Two species of skate/rays (southern and spotted eagle rays) and two ray unknown groups comprised a total of 217 individual rays with a total weight of 2,206 lbs. Eighty-two shark samples were sent to David Portnoy (Texas A&M) for genetic analysis and ID verification.

- *Comparison of estimated landings to reported landings* – Self-reported data were provided through early fall of 2019. Annual estimates were calculated for the last full year of available self-reported data and comparative time series were generated for the period of September 1, 2018 – August 31, 2019.
  - The estimated and reported annual landings for all species combined were similar, both with approximately 1.7 million lb (estimated was 1,769,436 lb and reported was 1,692,856 lb) with a difference of just over 76,000 lb. Overall, conch and lobster reported landings were lower than estimated by the survey (see Figure 6 and Table 5).
  - Conch estimates were approximately twice that which is reported but close to the expanded values.
  - Lobster estimates were approximately one and a half times greater than reported and somewhere in between reported and expanded.

- *Time Series of weekly estimates* – A closer look at the time series of weekly estimates for the top 8 species (as ranked by day sampling as in Table 4; lobster, conch, hogfish, silk snapper, dolphin, red hind, octopus and queen triggerfish) illustrated a number of both successes and challenges of developing an entirely comprehensive sampling program capturing all species. Five takeaways are explored below (see Figures 6 - 8 and Table 5):

  1. *Estimates higher than reported* – For conch and lobster, estimated landings tracked the reported landings very well, but at higher magnitudes. The approximate expanded landings appeared accurate for conch, but higher than the estimates. The shaded area which represents the weekly SE overlapped lobster SEs but not for conch. Note that once a total annual estimate was calculated there were significant differences between reported and estimated.
  2. *Estimates close to reported* – The estimates for hogfish, red hind and queen triggerfish closely matched the temporal patterns of what was being reported. In all three time series, there were periods where the estimated and reported diverged for a few months but tracked each other fairly well. The annual estimate for hogfish and red hind was higher than reported at 1.4x and 1.2x, respectively while the estimate for dolphin were very close. The estimated landings for queen triggerfish were lower than reported (0.6 x reported landings) but included five species of triggerfish while the reported data only had one. A triggerfish family grouping would result in similar estimates (see comments on family grouping below and Section 4.4.2).

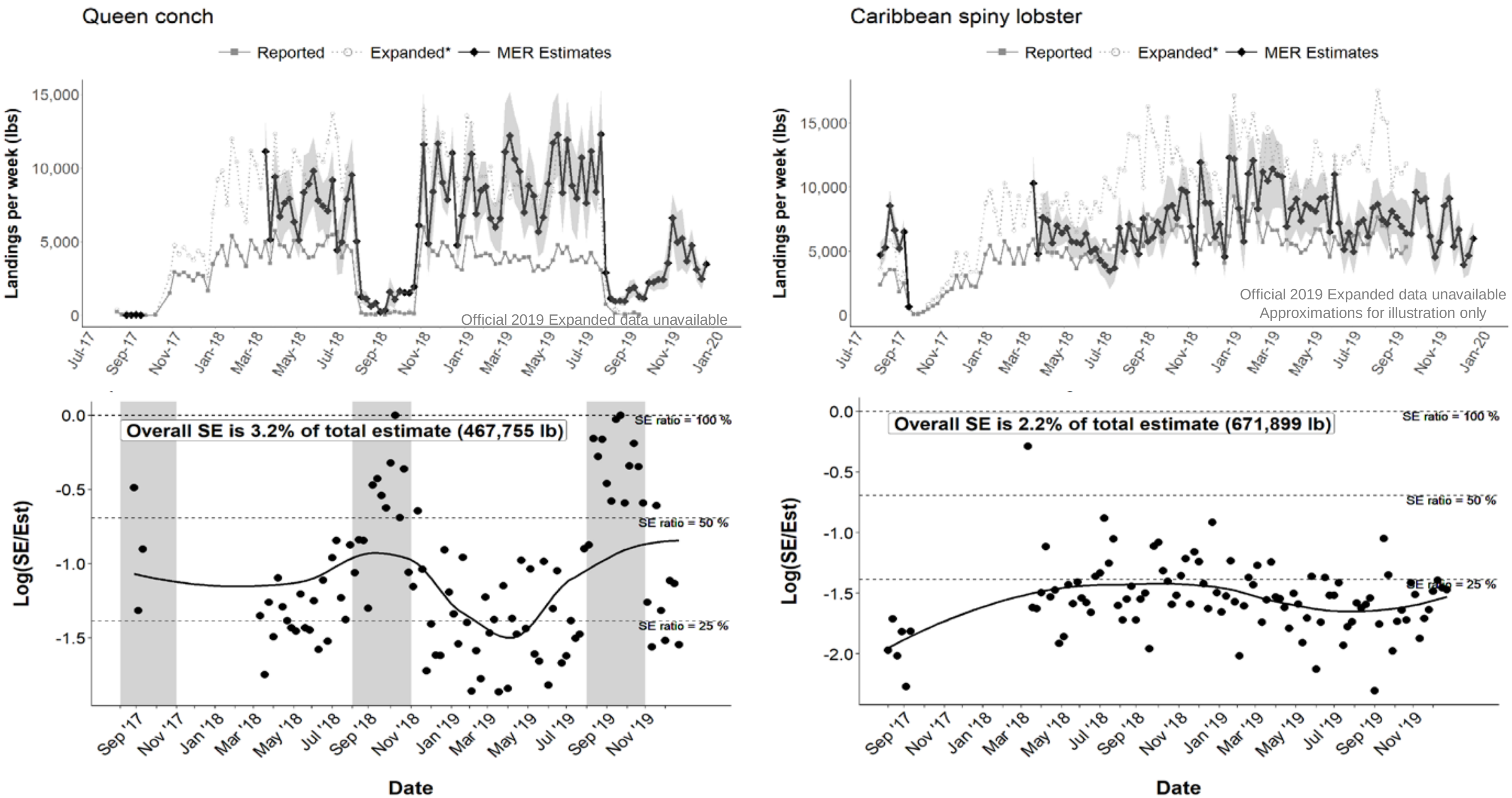

Figure 6. Investigating temporal trends in variability of weekly estimates from Daytime sampling. The y-axis in the lower plots is the logarithm of the standard error divided by the estimated landings, i.e., a measure of the precision of the estimates relative to the magnitude of the landings. For reference, horizontal dashed lines show where the standard error is 25, 50 and 100% of the landings. It should be noted that each point is the result of a weekly estimate; the precision for the year-long survey is much better than for the weekly estimates. The shaded areas on the top time series plots represents the SE of the weekly estimate. The shaded area in the lower left panel is the conch closed season. It is seen that, although there are some conch landings at a low level during the closed season, they are not characterized as precisely as the landings during the open season.

- *Time series of weekly estimates (cont'd)* –
    3. *Estimates much lower than reported* – This is unusual for a survey and raises some red flags as to sectors the survey did not cover. For silk snapper, the reported data are ~3x higher than estimated by the project. This was recognized early in the process and additional work was conducted to determine the reason. While designing the project, it was expected that yellowtail snapper, bar jack, and lane snapper (all species fished around the moon, and late at night) would be missed and alternative plans for sampling would have to be developed. For silk snapper, queen snapper, and other deep-water species, samplers were assigned to known landing sites and trailer counts were performed to get a better estimate on effort. Queen snapper and cardinal snapper required a special permit that could only be obtained by fishers that have reported for 5 years and report at least 1,000 lb annually, which can have a great impact on reporting behavior as there is now an incentive to report landings simply to meet requirements.
    4. *Rare event species* – In the time series for dolphin there appeared to be an "unrealistic spike" in landings early in the time series. This was a result of randomly sampling of a few trips with large landings, but when averaged out with those days where no trips were intercepted the estimated annual landings are similar to reported landings (See section 4.6.2).
    5. *Species grouping matching*– While the port sampling project reported over 267 unique species during the 20 months of the project, the self-reported data from all of 2017 through 2019 includes 76 unique species and 20 family groupings. The self-reported data and the port sampling project used species categories that do not match directly. As in the octopus example below, where 0 lb of common octopus were reported and large amounts were estimated, it will take some careful analysis and consultation with fishers from different regions to determine the best species groupings to use.
- *Correction factors* – Correction factors differed by both the species and the region where they were caught (see Table 5 for illustrative examples calculated from a one-year comparison period of September 2018 – August 2019). DRNA has been making progress from a total Puerto Rico correction factor, which in this case would result in a value of 1, and severely underestimate the landings of conch and lobster which are dominating the fishery. The revised DRNA regional correction factors address this in a non-direct way by applying different factors to different regions, which due to differences in gear and species landed will result in comparable estimates on some coasts (e.g., conch and ~30% of landings appear consistent with our data). The resounding suggestion from this research is to evaluate the species in the reported data and from the port sampling program to determine species specific, or family/species grouping specific factors.

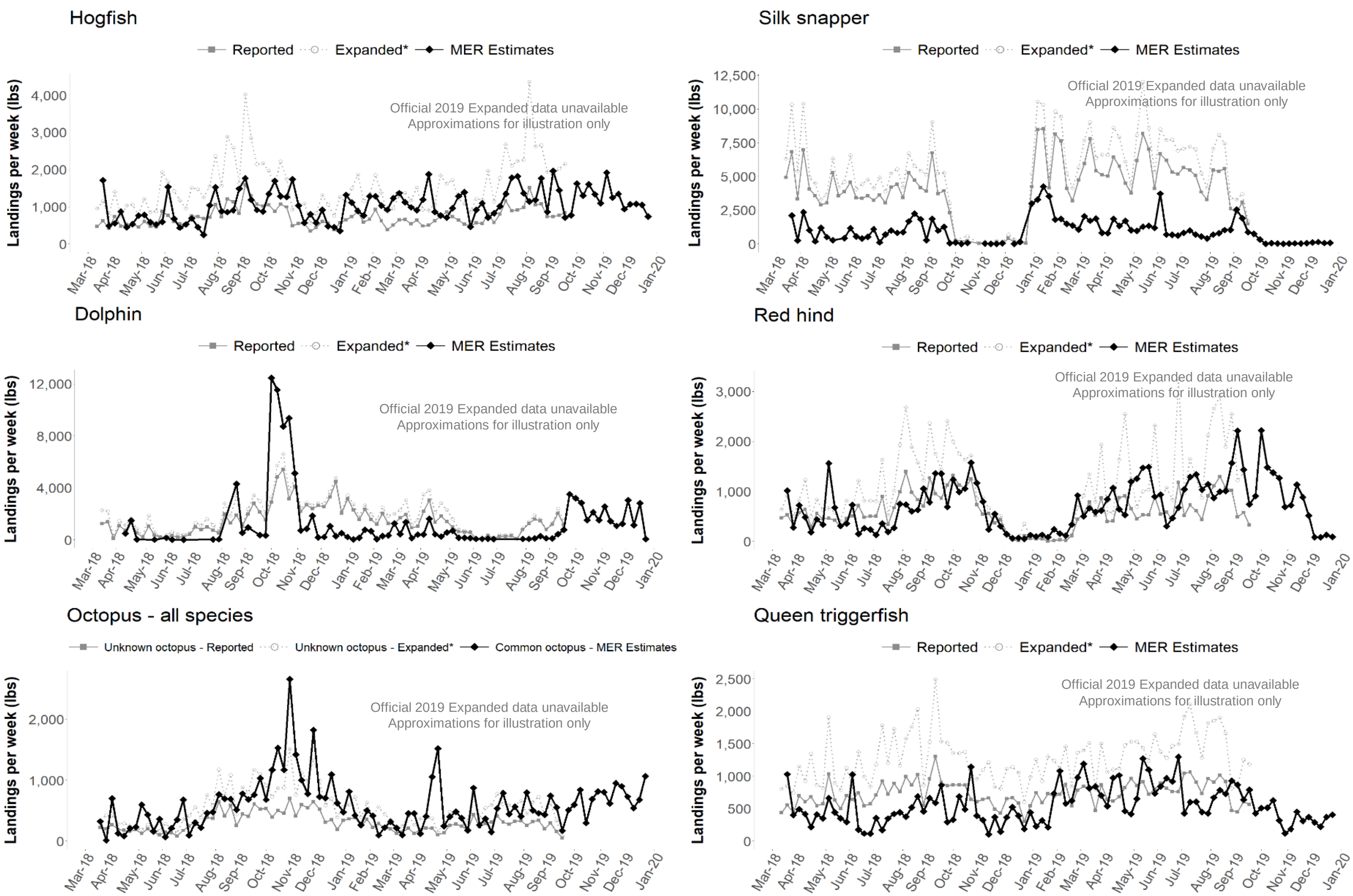

Figure 7. Time series post-hurricane with weekly estimates for the top 6 species (after lobster and conch) landed in all Puerto Rico.

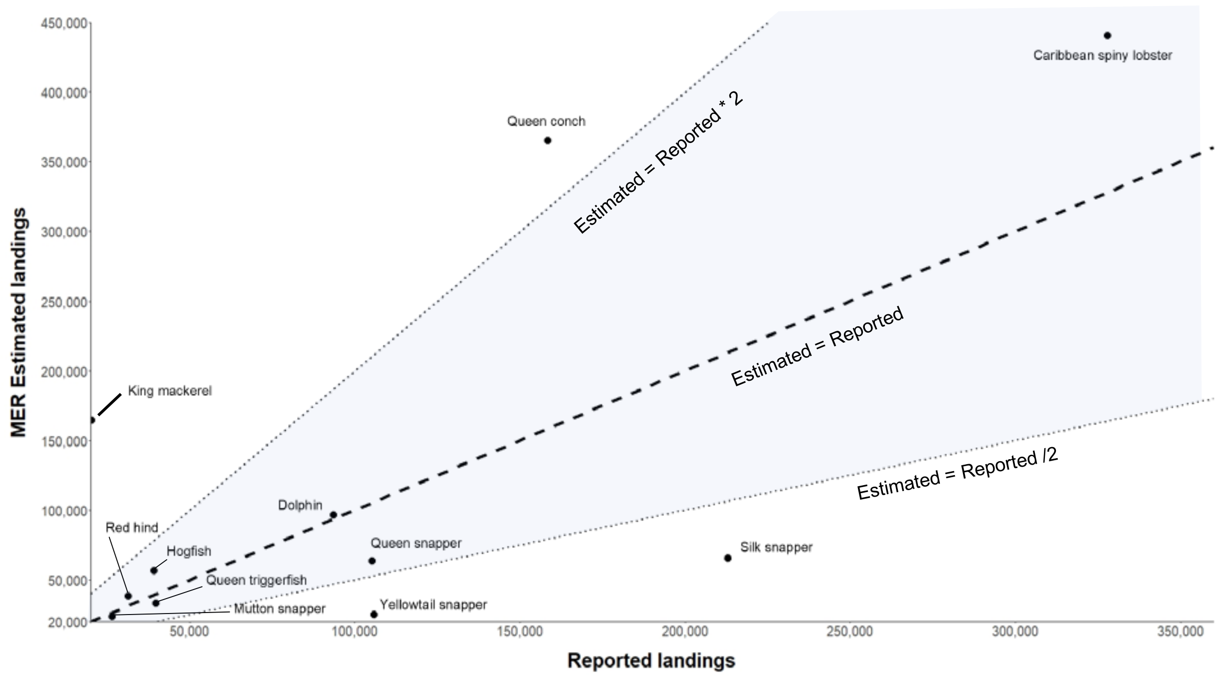

Figure 8. Comparison of estimated landings to reported landings for any species found in both data sets with annual landings of greater than 20,000 lbs.

Table 5. Annual correction factors by region (below, left) and top 10 species landed from daytime and auxiliary sampling combined (below, right). Notes: *Combining East and Islands results in value of 1.6; **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).

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

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

Conclusions/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 from the images collected by our port sampling prototype 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 Section 5.3).

- *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 further 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.

- *Expansion/Correction 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 correction factors. <u>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.</u>

  In terms of species resolution capabilities, 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 based on the results.

- *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/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).

- *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.