Comparison of Pre- and Post-Hurricane Aquatic Species Presence, Abundance, and Biomass in El Yunque National Forest Rivers

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Introduction

Hurricane Maria made landfall on Puerto Rico as a powerful category 4 hurricane in September 2017, bringing catastrophic damage to much of the island. The mountainous terrain of El Yunque National Forest was not spared from Maria's destructive winds and rains. Roads and facilities were damaged, power was lost, and many water supply intakes located on the forest were damaged by flood waters and landslides. While restoring water intakes and safe access to the national forest and its facilities took top priority, El Yunque National Forest also recognized the need to assess the ecological impacts from the hurricane.

El Yunque's rivers and streams are home to several species of shrimp, fish, and crab. All of the native species of shrimp and fish spend some portion of their lifecycle in saltwater and some in freshwater. Nearly all of the native shrimp and fish are amphidromous; adults reproduce in freshwater rivers and streams, larvae drift to estuaries, and post-larvae migrate back upstream into freshwater. The single exception to the amphidromous life history is American Eel (*Anguilla rostrata*), which is catadromous, living most of its adult life in freshwater but migrating to the Sargasso Sea to reproduce. The Puerto Rican crab (*Epilobocera sinuatufrons*) is restricted to freshwater habitats and adjacent riparian areas (Cook et al. 2008). Several introduced species also occupy El Yunque's streams, but none of these exhibit diadromous life histories.

The literature contains limited information describing the impacts of hurricanes on freshwater biota in Puerto Rico. Covich et al. (1996) found that post-hurricane displacement of some shrimp species in a small headwater stream resulted in local changes in density following Hurricane Hugo in 1989, but across the entire study reach shrimp populations were stable or increased. Similarly, Covich et al. (2006) found no significant flood-related long-term changes in *Macrobrachium* shrimp density over a 15-year period that spanned both Hurricane Hugo in 1989 and Hurricane Georges in 1998. Smith and Kwak (2015) observed reduced fish density across several species and size classes in the two weeks following 2011's Hurricane Irene, but they did not observe changes in the structure of fish assemblages (e.g. species richness, heterogeneity, or rank order). Taken in total, these studies suggest the frequent flood disturbances experienced by fish and shrimp in El Yunque may result in short-term and localized changes in density, but in the long-term the native fish and shrimp assemblages are resilient to hurricane flooding. However, both Covich (1996) and Covich (2006) were based on data collected from a 1.2 km reach of a headwater stream (Río Prieto), and data from Smith and Kwak (2015), although collected over a longer stream reach (10.7 km), was restricted to Río Mameyes, one of the only undammed watersheds in Puerto Rico with a mostly intact native fauna and few introduced fish species.

Pre-Maria biotic assemblage and stream habitat data are available for the majority of El Yunque's watersheds. The most extensive sampling was completed between 2005 and 2010 as part of an island-wide assessment of fish populations and habitat (Kwak et al. 2007; Kwak et al. 2013) (Figure 1). During each of these assessments, several habitat parameters were measured, 3-pass electrofishing was used to estimate fish population density and biomass, and the presence of shrimp species was noted. The focus was on fish-bearing waters and most watersheds were represented by 1 - 2 samples collected from low elevation reaches near or outside of El Yunque's proclamation boundary. A notable exception was Río Mameyes, which was sampled extensively, including several sites within the boundary. Roghair el al. (2014) mirrored Kwak's 3-pass sampling approach, but extended sampling upstream in several watersheds and only calculated density and biomass for American Eel, noting the presence of other fish and shrimp (Figure 1). The El Yunque National Forest also completed aquatic biota surveys at several long-term sample sites prior to the hurricane, however data associated with these sample sites was mostly lost when the forest headquarters building and storage areas were damaged by Hurricane Maria. Attempts to recover El Yunque data have not been successful to date.

In January 2018, staff from El Yunque National Forest contacted the Forest Service Southern Research Station (SRS), Center for Aquatic Technology Transfer (CATT) to plan for a post-hurricane assessment of aquatic fauna. Following a site visit in March 2018, CATT biologists, SRS scientists, and scientists from the US Geologic Survey, North Carolina Fish and Wildlife Research Unit worked to develop a sampling design to safely and efficiently re-sample as many pre-Maria sample sites as possible. Our primary goals were to compare pre- and post-Maria: 1) assemblage structure, 2) population density, 3) biomass, and 4) stream habitat. We also collected tissue samples from species within each watershed to be used in the development of environmental DNA (eDNA) screening tools.

Methods

Sample sites

Selection

Post-Maria sample sites were selected from the suite of pre-Maria sample sites based on stream size, accessibility, and accurate location information (Figure 1). We targeted streams that could be sampled by a 4-person team using 1 – 2 backpack electrofishing units, typically 10 m or less in wetted width and less than 1 m in depth. Some pre-Maria sites were inaccessible due to loss of infrastructure or safety concerns. We only selected sample sites with pre-Maria GPS or location descriptions that allowed us to reliably locate the sampling area. In total, we selected 12 sites from Kwak (2007; 2013) and 10 sites from Roghair (2014) and sampled the sites from August – October, 2018 (Tables 1 and 2). The sites covered 12 of El Yunque's 14 watersheds (Figure 1).

Layout

Kwak et al. (2007) established standardized approaches for delineating sample reaches and Augustin Engman (North Carolina Fish and Wildlife Research Unit) provided additional clarification and refinement of the reach layout approach based on his experience with the Kwak field team. Our sample reaches were 100 – 200 m long and encompassed at least 1 pool-riffle sequence. We avoided road crossings or other features that can alter local stream habitat or species distributions when laying out the sample reach. Detailed sample reach layout instructions are available in Appendix A.

Sampling

Kwak et al. (2007) established standardized approaches for sampling wadeable streams (electrofishing and stream habitat) in Puerto Rico. Augustin Engman (North Carolina Fish and Wildlife Research Unit) provided additional clarification and refinement of the sampling approach based on his experience with the Kwak field team.

Electrofishing

We placed blocknets at the downstream and upstream end of the sample reach (100-200 m) prior to electrofishing. After blocknets were secured, we began electrofishing at the downstream blocknet with 1 (stream < 5 m wetted width) or 2 (stream > 5 m wetted width) backpack electrofishers and proceeded upstream. Each electrofisher was outfitted with a dipnet and 2 dipnetters were used when sampling with 1 or 2 electrofishers. Fish captured in dipnets were placed in a bucket, then transferred to a holding pen. We concluded the pass and recorded the total shock time for each electrofisher when we reached the upstream blocknet. Each fish we collected was identified to species, then measured for total length (mm TL) and weighed (0.1 g). We repeated this process for two additional passes, making a total of three passes through the sample reach. We also collected non-fish species, including shrimp, crab, and crayfish. The presence of all non-fish species was recorded. Detailed electrofishing methods are available in Appendix A.

Stream habitat

The stream habitat inventory was typically completed the day after electrofishing. We divided the sample reach into 10 equally spaced sections for transect placement. Along each transect (perpendicular to flow direction) at 10 evenly spaced (visually estimated) sampling points we measured water velocity (m/s), depth (cm), and recorded the dominant instream cover and substrate type. We also recorded the streambank angle and riparian cover type for both sides of the stream, as well as the wetted width, for each transect. Detailed stream habitat inventory methods are available in Appendix A.

Data Analysis

Assemblage structure

We compared pre- and post-Maria species presence and calculated the Jaccard similarity coefficient (Schroeder and Jenkins 2018) for each sample site. The Jaccard coefficient was calculated as:

$$Sj = a / (a + b + c)$$

where: Sj = Jaccard's similarity coefficient; a = number of species in pre-sample and post-sample; b = number of species present in post-sample, but not in pre-sample; and c = number of species in pre-sample, but not in post-sample. Sj = 1 where the same species are collected in both pre- and post-Maria samples, and is 0 where there are no species in common between pre- and post-Maria samples.

Fish density and biomass

We acquired the original pre-Maria 3-pass electrofishing data from Augustin Engman for all but 1 sample site, Quebrada Palma. For Quebrada Palma we report the pre-Maria fish density and biomass results from Kwak 2010. For all other sample sites we calculated pre- and post-Maria estimates for fish density and biomass using the CarleStrub method within the removal function of the R (R Core Team 2018) package 'FSA' (Ogle 2018), run in RStudio (RStudio Team 2016). The CarleStrub method provides population estimates for multi-pass electrofishing even where the number of fish collected in each successive pass does not decrease. Prior to estimation we placed fish into 10 cm size classes. For fish density, we first calculated a population estimate and variance for every size class of each species at a given sample site. We then summed the population estimates and variances across size classes to produce the total population estimate and variance for each species at a given sample site. The population estimate and variance were then divided by sample site area to produce a density estimate, expressed as fish/ha. We calculated the standard error as the square root of the variance. We calculated change in density as (+1 added to densities to avoid dividing by zero):

((Post-Maria Density + 1)-(Pre-Maria Density + 1)) / (Pre-Maria Density + 1)

For biomass, we first calculated the average weight and variance for each 10 cm size class, then multiplied the average weight by the population estimate from the population density calculations to get a total weight estimate for each 10 cm size class. The variance for each 10 cm size class weight estimate was calculated as (Population Estimate^2 * Weight Variance) + (Mean Weight^2 * Population Estimate Variance). We summed estimated weights and variances across all size classes and divided by sample site area to produce the total biomass of each species at a given site, expressed as kg/ha. We calculated the standard error as the square root of the variance. We calculated change in biomass as (+1 added to biomass to avoid dividing by zero):

$$((\text{Post-Maria Biomass} + 1)-(\text{Pre-Maria Biomass} + 1)) / (\text{Pre-Maria Biomass} + 1)$$

Stream habitat

For quantitative habitat characteristics (wetted width, depth, and water velocity) we compared the mean pre- and post-Maria values. The mean was calculated from 100 data points (10 transects each with 10 samples per transect per site) for depth and water velocity; and 10 data points (10 transects) for wetted width. For qualitative habitat characteristics, the dominant substrate for each site was determined as the modal substrate from 100 data points. We were unable to compare pre- and post-Maria values for riparian cover type, bank angle, and dominant instream cover type due to using different categories and/or methods than Kwak et al. (2007).

Results

Assemblage structure

We collected samples at 22 sites (Figure 1, Table 2). The number of native fish species collected post-Maria was greater than or equal to the number collected pre-Maria at 17 sites (Figure 2). The number of native species decreased by more than 1 species at only 1 site. All sites had at least 1 native fish species present in both pre- and post-Maria samples. The highest native species richness was at 2 post-Maria sites on Río Sabana, where 7 – 8 species were collected. All other pre- and post-Maria sample sites had 6 or fewer native fish species. The most commonly encountered native fish species in both pre- and post-Maria samples were Mountain Mullet (*Agonostomus monticola*), Sirajo Goby (*Sicydium spp.;* a 3-species complex (Engman et al. 2019) we were unable to distinguish in the field), River Goby (*Awaous banana*), and American Eel (*Anguilla rostrata*) (Figure 3). Mountain Mullet, Sirajo Goby, and River Goby were found at 18 post-Maria sites. American Eel were the only native fish species that was found at fewer post-Maria than pre-Maria sites, but they only decreased by 1 site. The Jaccard similarity coefficient for native fish was 1.0 at 9 sites and was less than 0.5 at only 2 sites, Quebrada Palma and Río Sabana at rkm 7.5 (Figure 4).

Exotic fish were present at 5 pre-Maria sites and 11 post-Maria sites (Figure 5). Exotic fish were lost from 2 previously occupied sites and gained at 8 new sites post-Maria. A site on Río Canovanillas had the highest number exotic fish species in both pre- (4 species) and post-Maria (6 species) samples. The most commonly encountered exotic fish species in both pre- and post-Maria samples was Guppy (*Poecilia reticulata*) (Figure 3). Guppies were found at 4 pre- and 10 post-Maria sites. The Mozambique

Tilapia (*Oreochromis mossambicus*) was the only other exotic fish species found at more sites post-Maria (2 sites) than pre-Maria (1 site). The Jaccard similarity coefficient for exotic fish was greater than 0 for only 1 site, Río Canovanillas (Figure 6).

The number of native shrimp species collected post-Maria was greater than or equal to the number collected pre-Maria at 20 sites (Figure 7). We collected 2 fewer shrimp species from Quebrada Tabanuco, and 3 fewer from Río Canóvanas. Almost all native shrimp species were collected from more post- than pre-Maria sites (Figure 8). The lone exception was *Xiphocaris elongata*, which was collected from 20 sites in both pre- and post-Maria sampling. The Jaccard similarity coefficient for native shrimp was between 0.1 and 0.9 for all sample sites (Figure 9).

Detailed assemblage tables are available in Appendix B.

Fish density and biomass

We were able to plot change in density and biomass for 6 native fish species. The remainder of the species were present at too few sites to produce plots. Density decreased at the majority of sample sites for all native species with the exception of River Goby (Figure 10), which increased its density at over half of all sites. Biomass decreased at the majority of sample sites for all native species with the exception of American Eel and River Goby (Figure 11), which increased their biomass at over half of the sample sites. Among pre- and post-Maria sites, Sirajo Goby had the highest average density (fish/ha), while Mountain Mullet had the highest average biomass (kg/ha). The density and biomass estimates included several outliers displayed as large increases in population density at a small number of sites for American Eel, Mountain Mullet, River Goby, and Sirajo Goby.

Stream habitat

We were able to compare pre- and post-Maria wetted width, water depth, water velocity, and substrate (Table 3). Post-Maria wetted widths were mostly within 2 m of pre-Maria widths, with the exceptions of Quebrada Palma (decreased by over 5 m) and Tributary to Río Blanco (increased by over 5.5 m). Pre- and post-Maria average water depths were similar, with a maximum increase of only 12 cm. The average water velocity at all sample sites in both sample periods was 0.2 m/s or less and there were no notable post-hurricane changes in water velocity. Substrate categories varied between pre- and post-Maria surveys, with pre-Maria surveys including several sub-categories (e.g. coarse gravel, medium gravel). Most sites had slightly more coarse substrates during the post-Maria survey. The most notable changes were at sites dominated by silt during the pre-Maria survey that were dominated by boulder post-Maria (Quebrada Tabonuco and Rio Herrera).

Detailed habitat tables are available in Appendix C.

Discussion

Previous studies of El Yunque's streams suggested they are relatively robust to the effects of hurricanes, and our results generally corroborate that view. There were slight changes in channel dimensions, water depth, or substrates at some sites, but overall habitat appeared to be relatively stable. While there were some changes in species composition at individual sample sites, many native species were collected from more sites after the hurricane than before. At most sites change in species composition was minor and could just as easily be attributed to detectability (electrofishing efficiency) as the hurricane, but at sites where larger changes were detected some additional investigation or monitoring may be warranted.

While stream habitat and species composition were relatively stable, population density and biomass remained depressed at several sites even though our fish samples were collected approximately 1 year post-hurricane. At a few sites we saw large percentage increases in species abundance. The large percentage increase in American Eel at Quebrada Grande 5.9 and in Mountain Mullet at Río Canovanillas 23.5 was because there were 0 individuals of the respective species captured at these sites in 2007 but several were collected in 2018. At other sites where density and biomass increased significantly the increase was related to our analysis approach. For example, our analysis produced large population estimates with low confidence at Quebrada Grande 5.9 and Río Canovanillas 23.5 due to the way the CarleStrub method in R handles bad depletions. Regardless, at sites where population numbers or biomass remain depressed, recovery to pre-hurricane levels is contingent on maintaining or restoring habitat connectivity (including dewatering), water quality, and habitat quality. As infrastructure such as road crossings and water intakes continue to be repaired it is important to keep these needs at the forefront of the discussion.

Perhaps our most troubling finding was the addition of exotic species to the fish community at several sample sites. Exotic species are unfortunately ever-expanding on the island and the range expansions observed here may be more generally part of their onward march as opposed to any direct result of the hurricane. We collected tissue samples from exotic and native species in every drainage we sampled. These tissue samples are stored at the Forest Service National Genomics Center for Wildlife and Fish Conservation and can be used to develop eDNA monitoring tools in the future. The emergence of eDNA sampling as a tool for monitoring fish distributions provides a pathway for citizen scientists to join in exotic species monitoring, alongside more traditional fish sampling approaches. Regardless of approach, additional monitoring for exotic species is warranted given their increased presence in El Yunque's watersheds.

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Figures

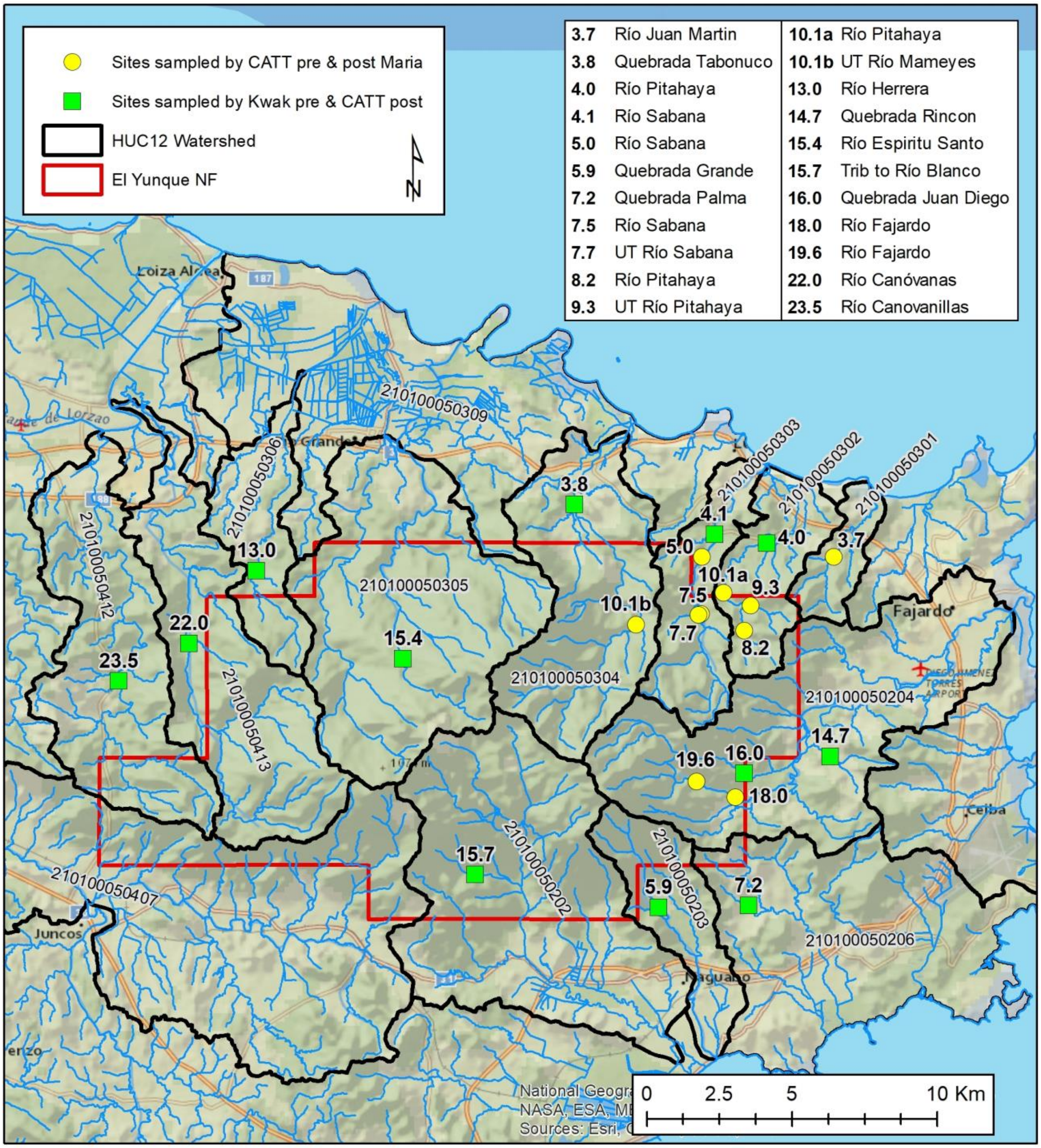

Figure 1. Sample site locations, El Yunque National Forest, Puerto Rico.

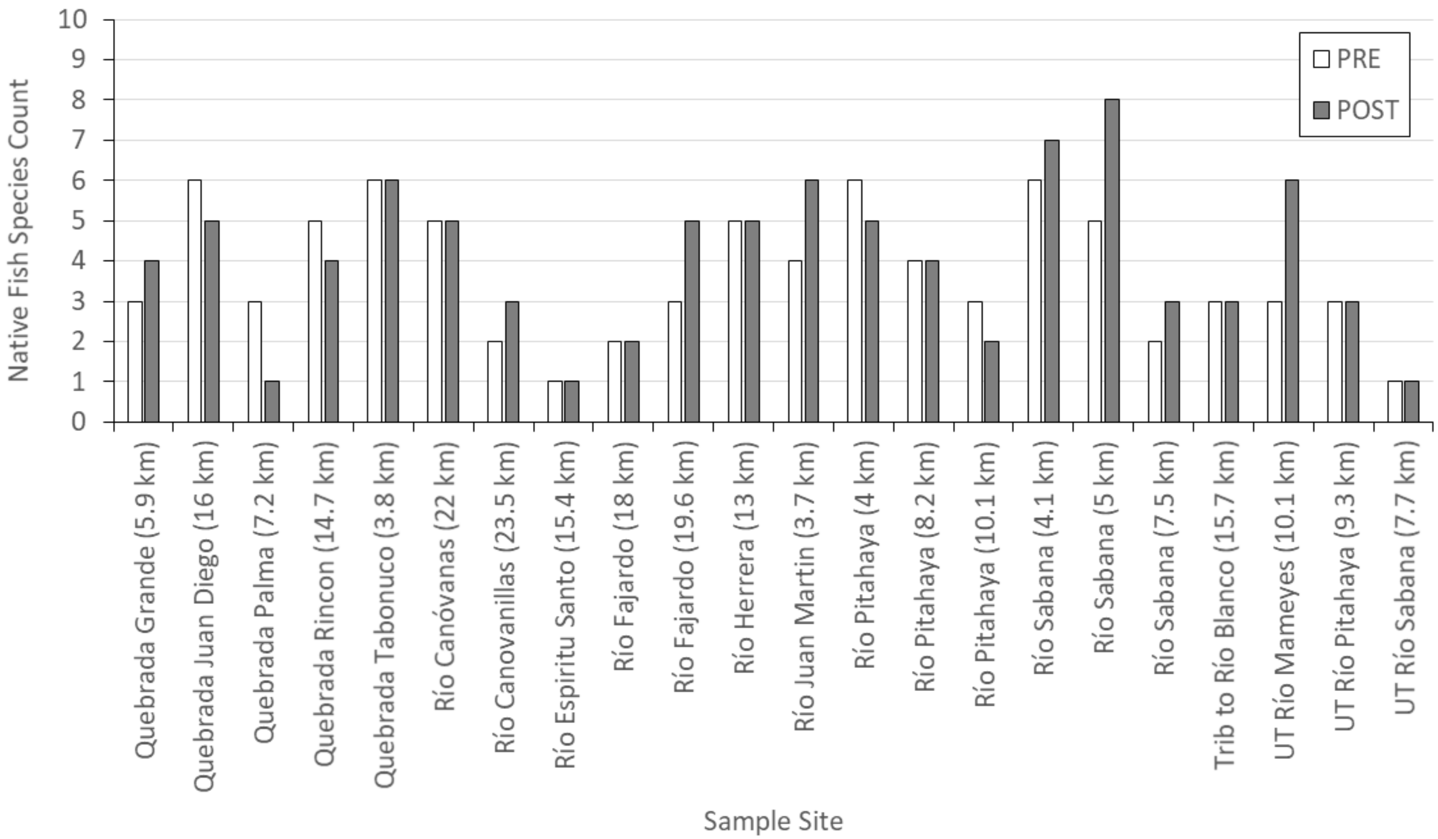

Figure 2. Number of native fish species collected at sample sites pre- and post-Maria.

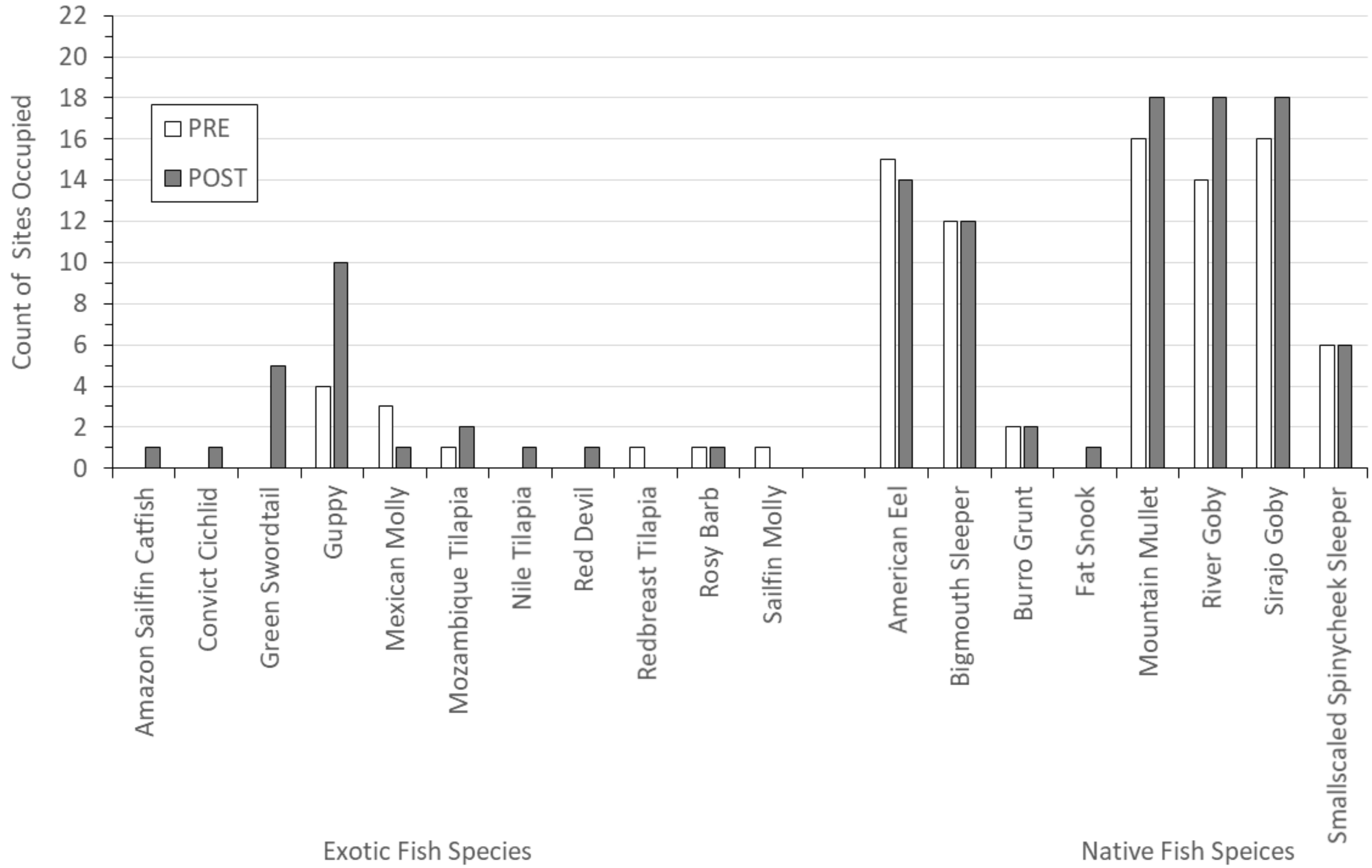

Figure 3. Number of sample sites occupied by exotic and native fish species pre- and post-Maria.

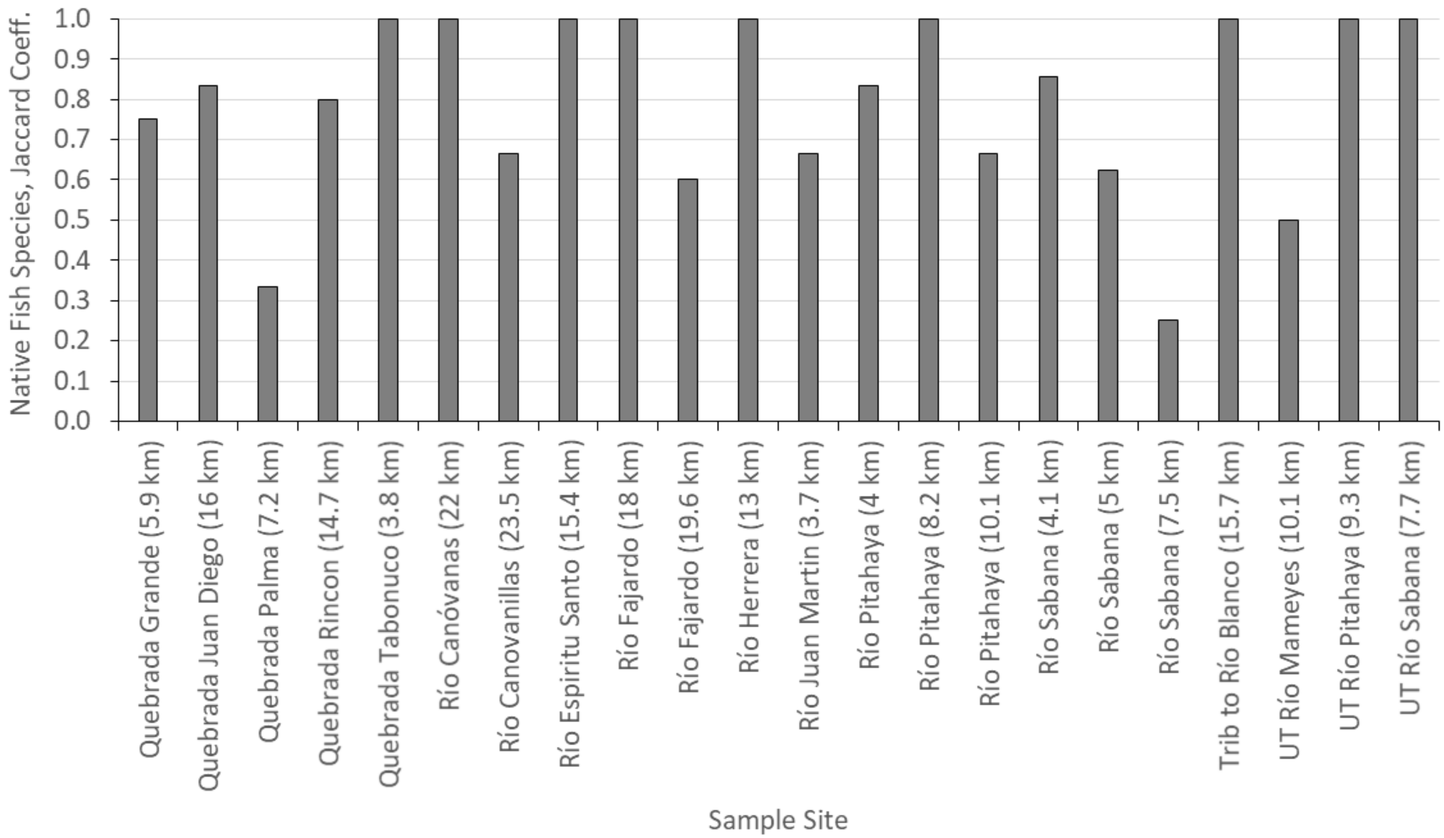

Figure 4. Jaccard similarity coefficient between pre- and post-Maria collection of native fish species. A Jaccard coefficient of 1.0 means pre- and post-Maria samples contained identical species assemblages; a coefficient of 0 would indicate pre- and post-Maria samples had no species in common.

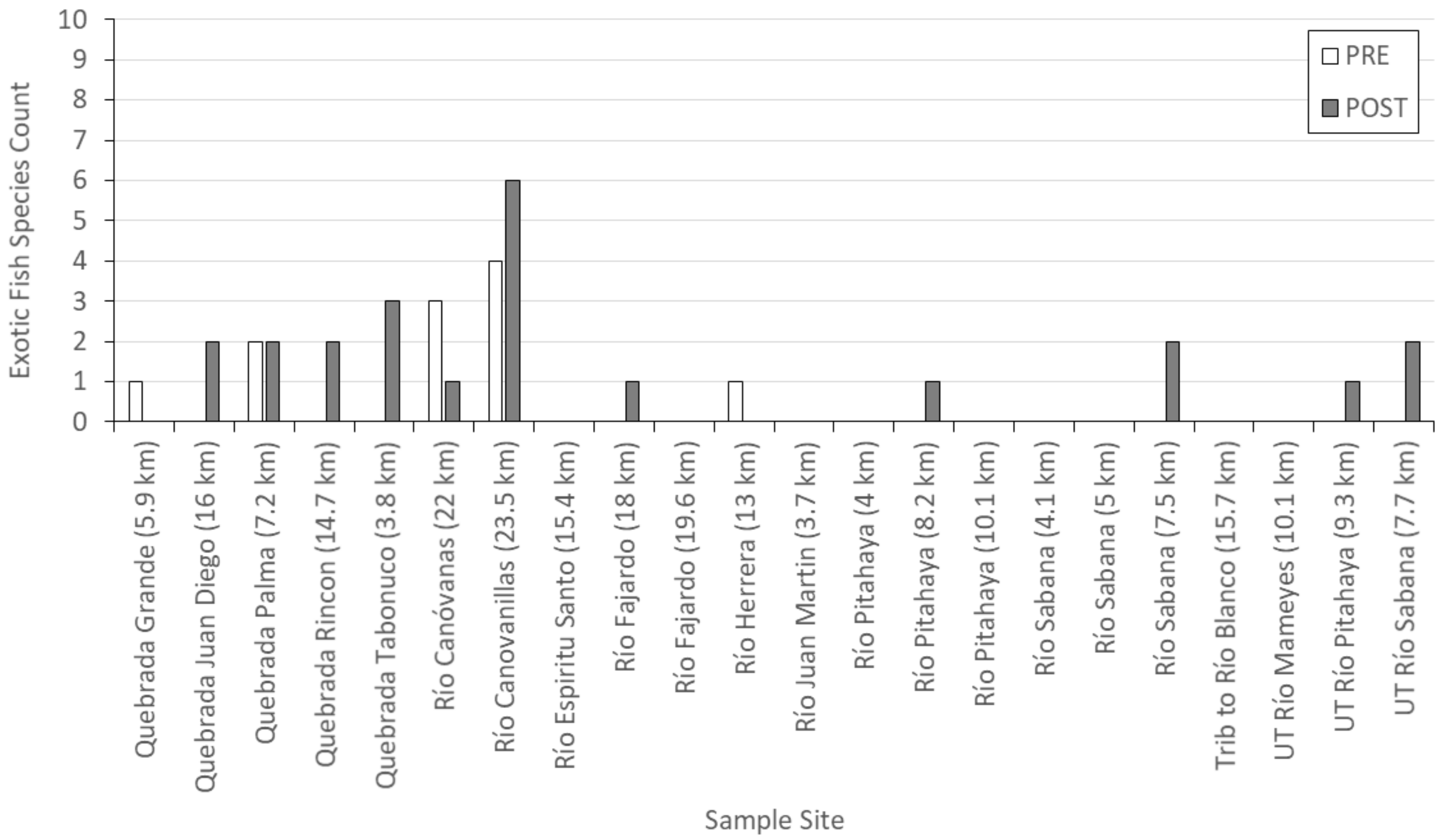

Figure 5. Number of exotic fish species collected at sample sites pre- and post-Maria.

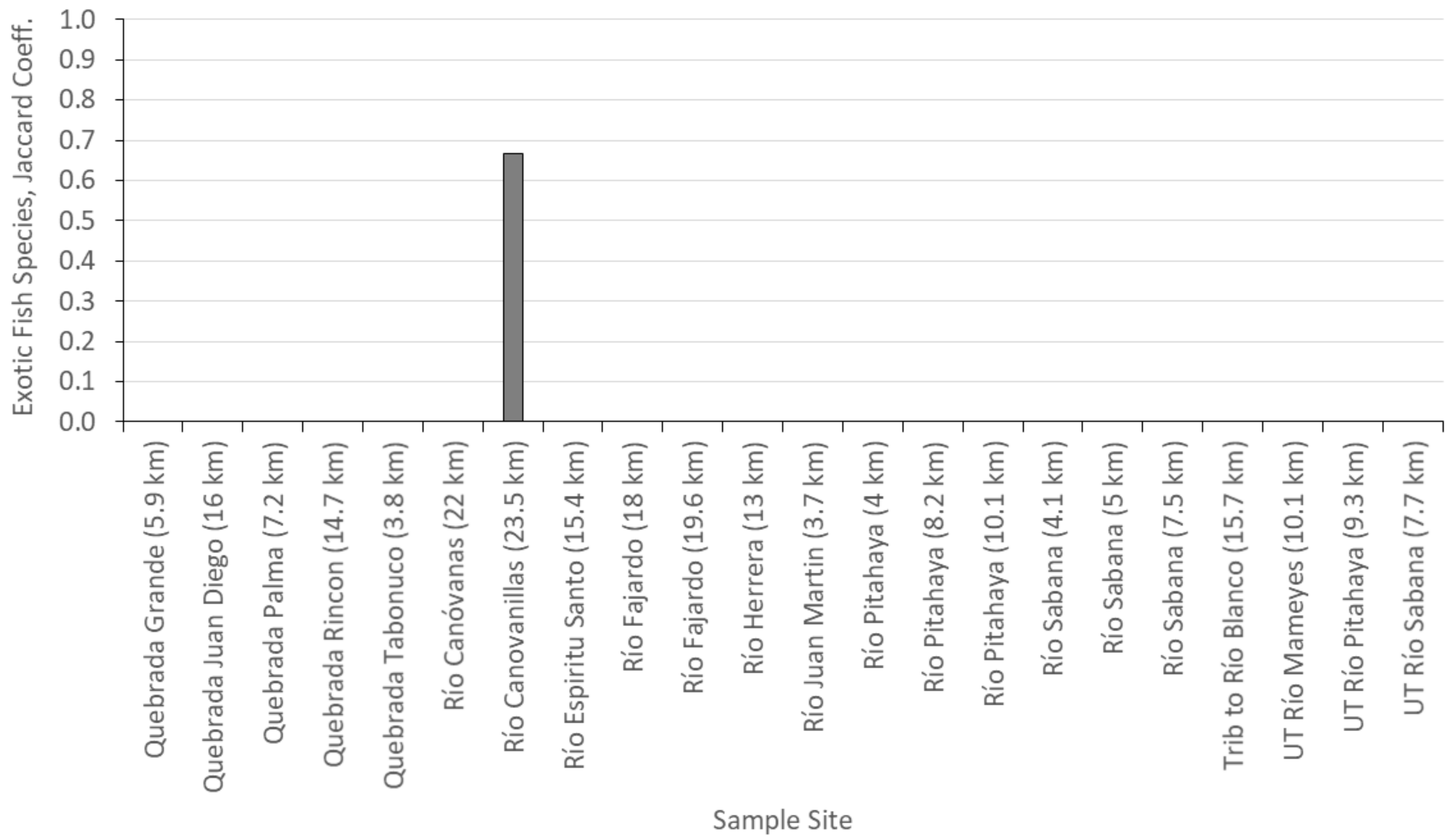

Figure 6. Jaccard similarity coefficient between pre- and post-Maria collection of exotic fish species. A Jaccard coefficient of 1.0 means pre- and post-Maria samples contained identical species assemblages; a coefficient of 0 indicates pre- and post-Maria samples had no species in common.

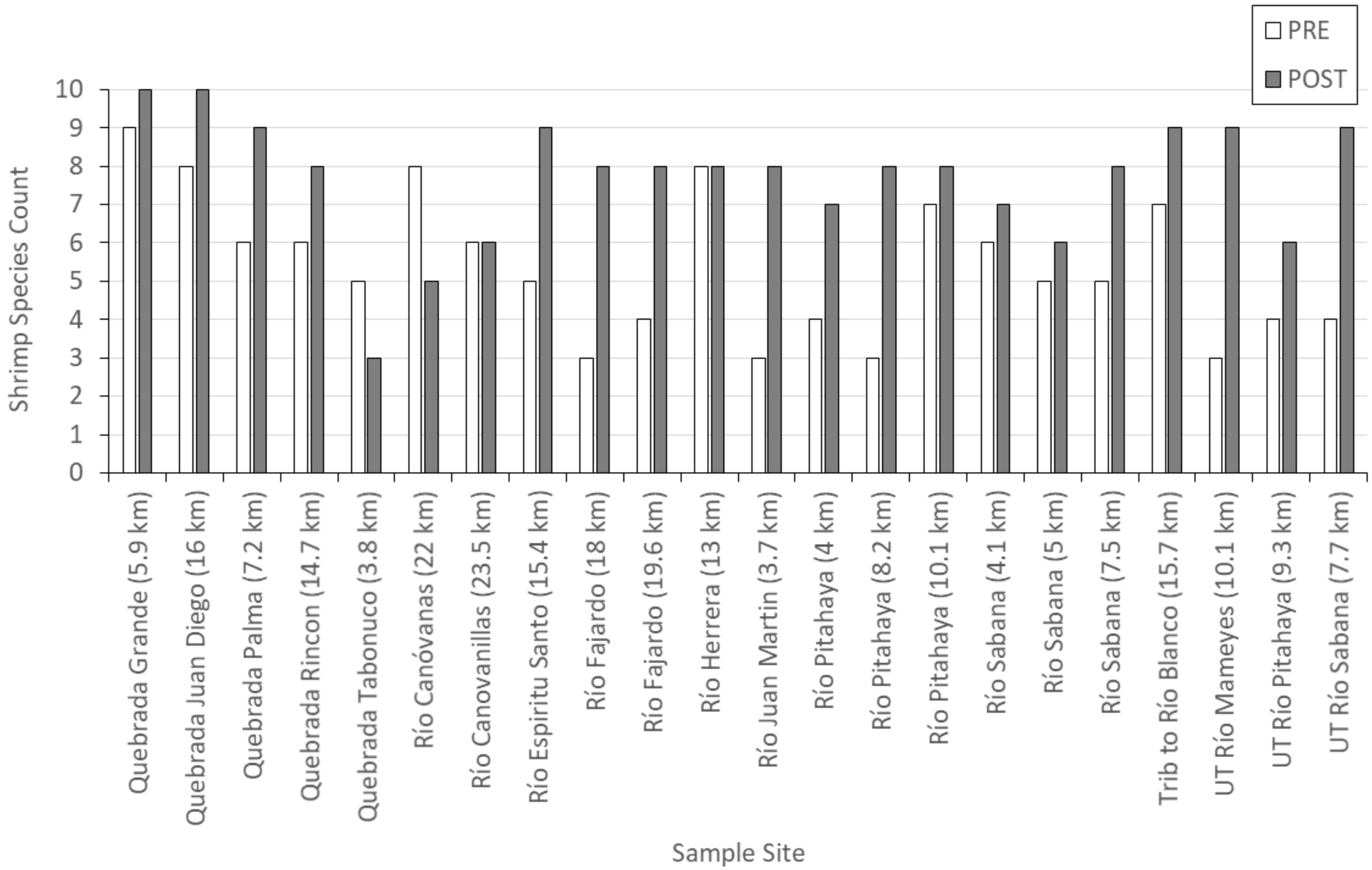

Figure 7. Number of native shrimp species collected at sample sites pre- and post-Maria.

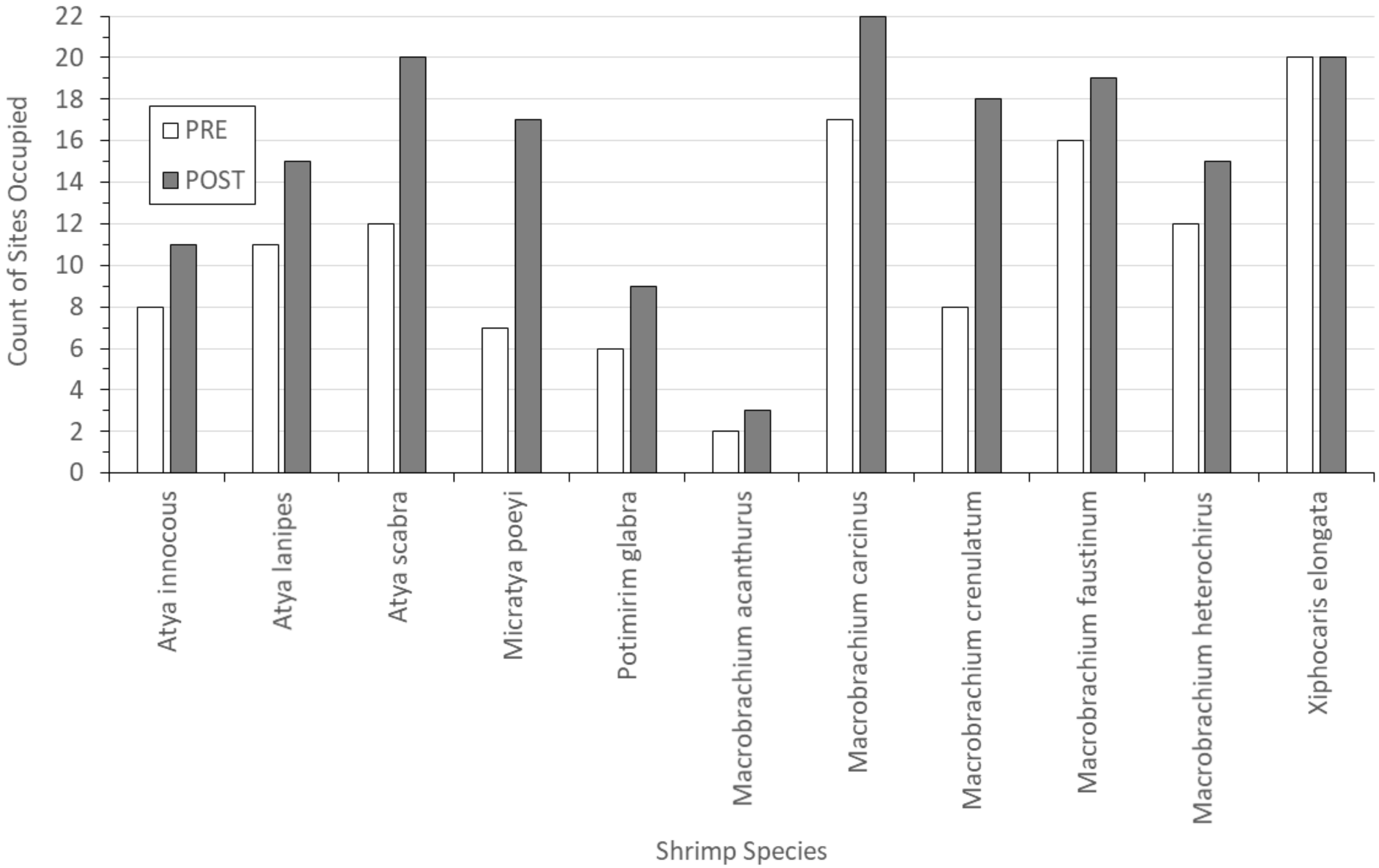

Figure 8. Number of sample sites occupied by native shrimp species pre- and post-Maria.

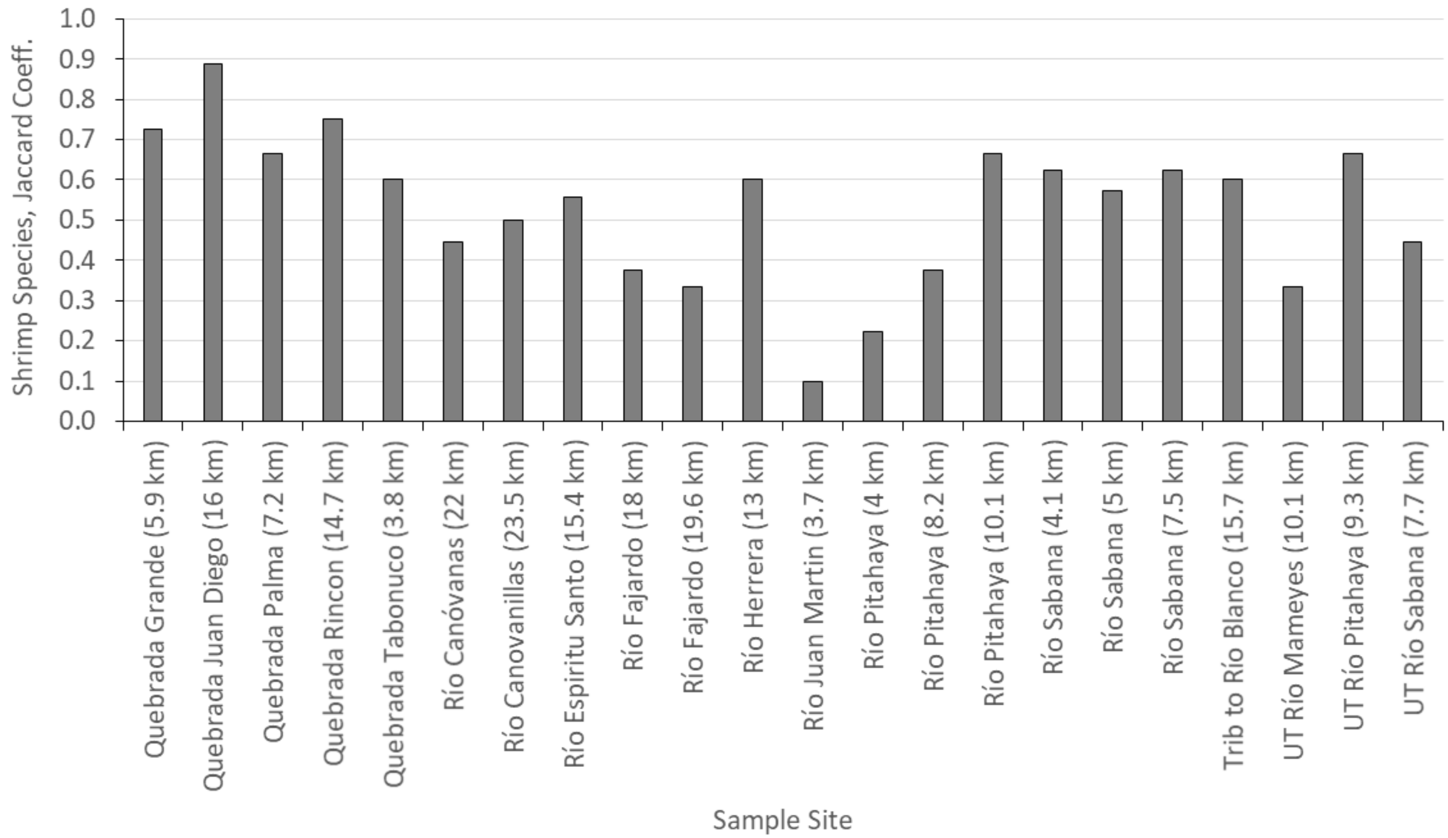

Figure 9. Jaccard similarity coefficient between pre- and post-Maria collection of native shrimp species. A Jaccard coefficient of 1.0 means pre- and post-Maria samples contained identical species assemblages; a coefficient of 0 would indicate pre- and post-Maria samples had no species in common.

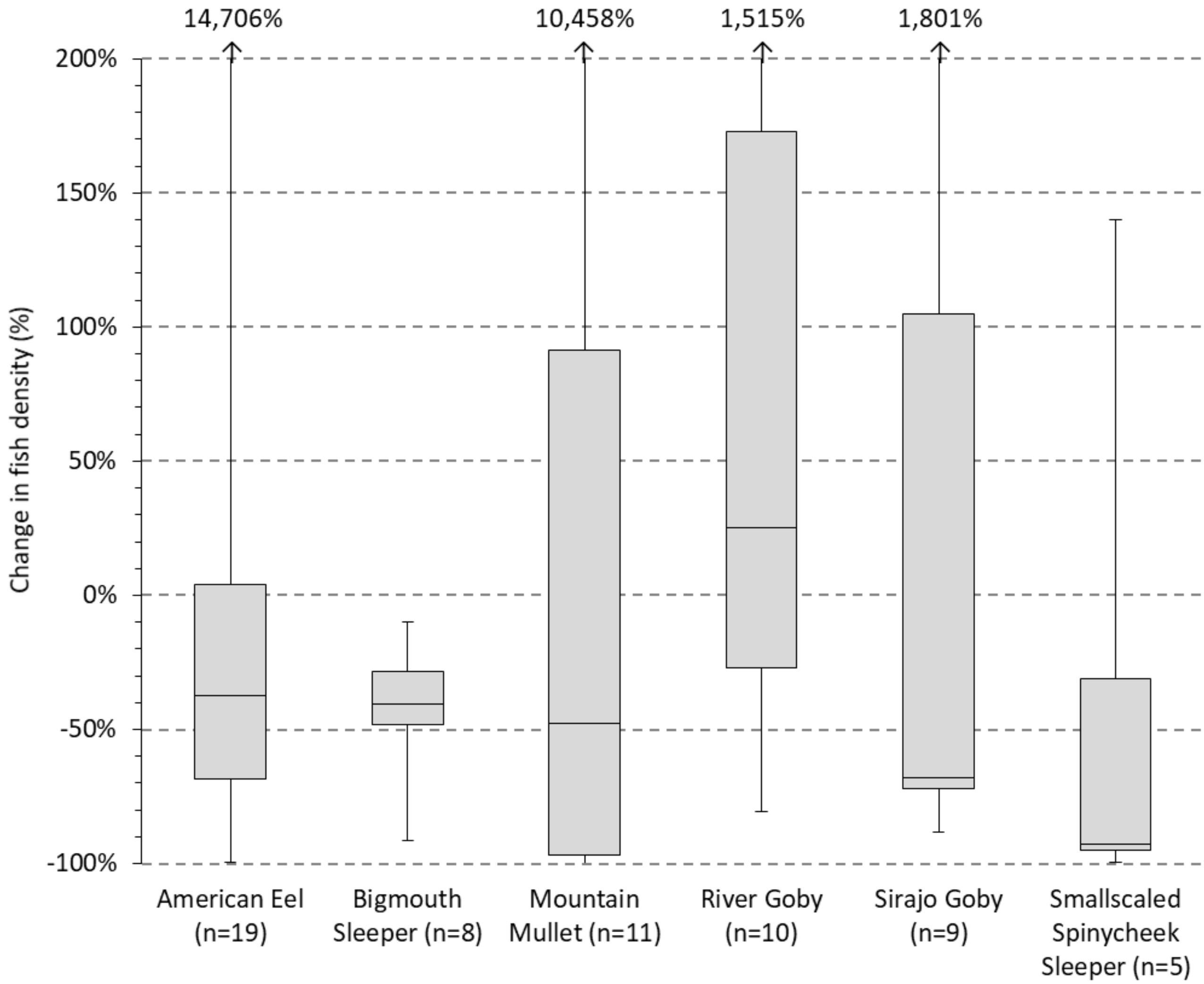

Figure 10. Change in fish density at pre- and post-Maria sample sites. Sample number (n) is the number of sample sites included in the box plot (i.e. number of sites where a pre- and post-Maria population density could be calculated for a given species). Top and bottom of box plot are the 25th and 75th percentiles; line in middle of box is the 50th percentile; whiskers extend to the minimum and maximum values.

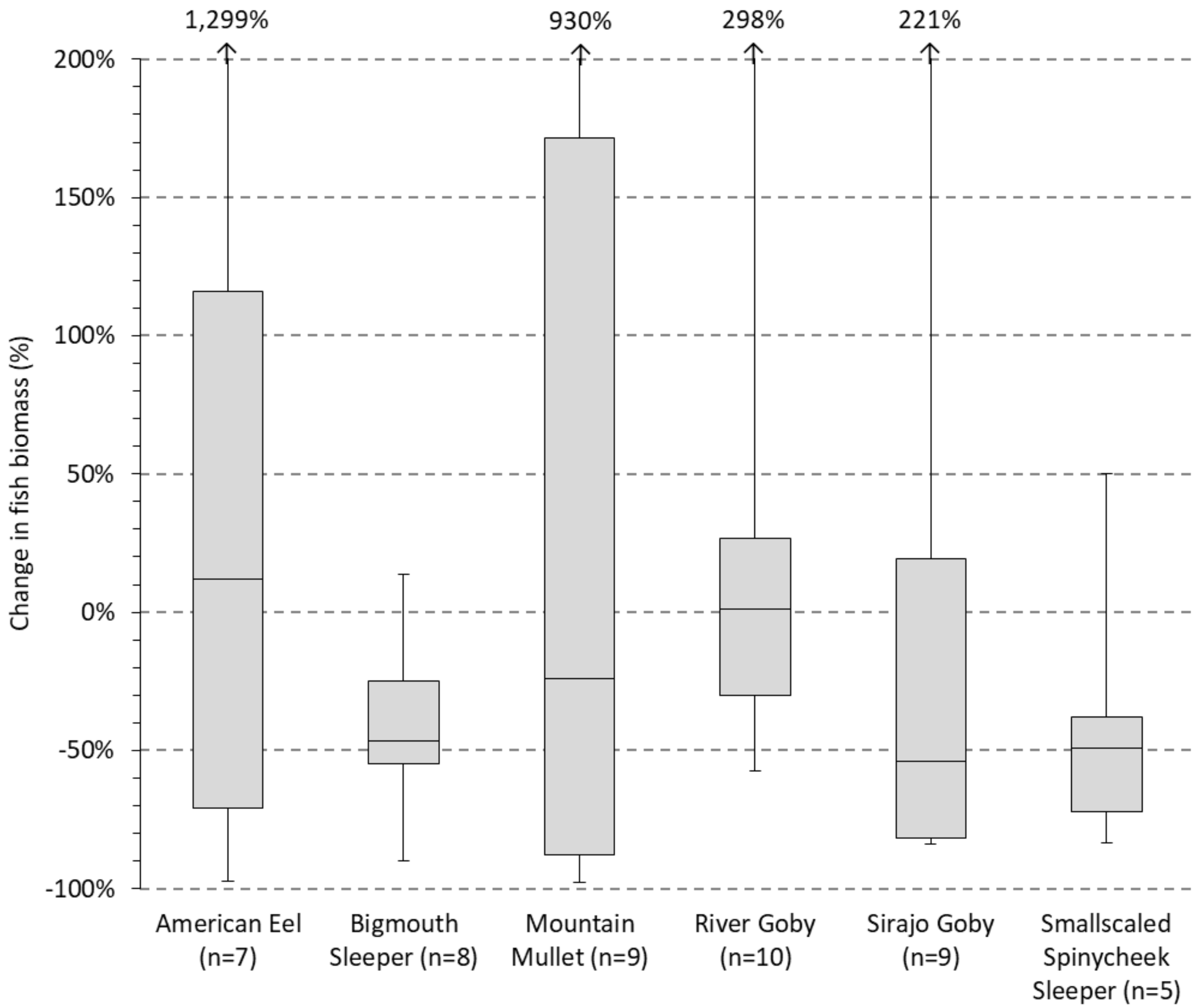

Figure 11. Change in fish biomass at pre- and post-Maria sample sites. Sample number (n) is the number of sample sites included in the box plot (i.e. number of sites where a pre- and post-Maria biomass could be calculated for a given species). Top and bottom of box plot are the 25th and 75th percentiles; line in middle of box is the 50th percentile; whiskers extend to the minimum and maximum values.

Tables

Table 1. Summary of pre-Maria sample sites.

Stream	Kms to River Mouth	HUC12 Watershed	GPS Coordinates	Sample Date	Reach Length (m)	Mean Width (m)	Sampled By	3-Pass	Presence-Absence
Quebrada Grande	5.9	210100050203	N18.23424 W65.74301	03/12/07	150	4.2	Kwak (10A)	fish	shrimp
Quebrada Juan Diego	16.0	210100050204	N18.27630 W65.71620	03/09/07	150	3.7	Kwak (7A)	fish	shrimp
Quebrada Palma	7.2	210100050206	N18.23579 W65.71552	07/14/10	150	7.7	Kwak (9A)	fish	shrimp
Quebrada Rincon	14.7	210100050204	N18.28229 W65.69012	03/11/07	150	2.6	Kwak (7B)	fish	shrimp
Quebrada Tabonuco	3.8	210100050304	N18.35965 W65.76954	03/14/07	150	5.3	Kwak (4A)	fish	shrimp
Río Canóvanas	22.0	210100050413	N18.31809 W65.88926	03/21/07	150	9.2	Kwak (1E)	fish	shrimp
Río Canovanillas	23.5	210100050412	N18.30542 W65.91063	03/26/07	150	5.9	Kwak (1D)	fish	shrimp
Río Espiritu Santo	15.4	210100050305	N18.31130 W65.82251	03/23/07	150	15.1	Kwak (3A)	fish	shrimp
Río Fajardo	18.0	210100050204	N18.26948 W65.71948	04/15/14	130	9.0	CATT	eels	fish, shrimp
Río Fajardo	19.6	210100050204	N18.27359 W65.73040	04/18/14	95	11.0	CATT	eels	fish, shrimp
Río Herrera	13.0	210100050306	N18.33910 W65.86759	03/22/07	150	4.9	Kwak (2A)	fish	shrimp
Río Juan Martin	3.7	210100050301	N18.34344 W65.68839	04/24/14	105	2.4	CATT	eels	fish, shrimp
Río Pitahaya	4.0	210100050302	N18.34834 W65.71056	03/13/07	150	4.6	Kwak (5B)	fish	shrimp
Río Pitahaya	8.2	210100050302	N18.33346 W65.72269	04/19/14	119	5.4	CATT	eels	fish, shrimp
Río Pitahaya	10.1	210100050302	N18.32198 W65.71646	04/21/14	118	6.0	CATT	eels	fish, shrimp
Río Sabana	4.1	210100050303	N18.35009 W65.72593	03/08/07	150	7.6	Kwak (5A)	fish	shrimp
Río Sabana	5.0	210100050303	N18.34366 W65.72962	04/17/14	100	11.0	CATT	eels	fish, shrimp
Río Sabana	7.5	210100050303	N18.32638 W65.73015	04/16/14	120	10.3	CATT	eels	fish, shrimp
Trib to Río Blanco	15.7	210100050202	N18.24556 W65.79948	03/09/07	150	2.9	Kwak (11A)	fish	shrimp
UT Río Mameyes	10.1	210100050304	N18.32217 W65.74979	04/22/14	100	4.8	CATT	eels	fish, shrimp
UT Río Pitahaya	9.3	210100050302	N18.32904 W65.71517	04/22/14	110	5.0	CATT	eels	fish, shrimp
UT Río Sabana	7.7	210100050303	N18.32561 W65.73035	04/17/14	115	6.0	CATT	eels	fish, shrimp

Table 2. Summary of post-Maria sample sites.

Stream	Kms to River Mouth	HUC12 Watershed	GPS Coordinates	Sample Date	Reach Length (m)	Mean Width (m)	Sampled By	3-Pass	Presence-Absence
Quebrada Grande	5.9	210100050203	N18.23424 W65.74301	09/11/18	100	6.1	CATT	fish	shrimp
Quebrada Juan Diego	16.0	210100050204	N18.27630 W65.71620	08/28/18	105	3.1	CATT	fish	shrimp
Quebrada Palma	7.2	210100050206	N18.23579 W65.71552	09/05/18	100	2.3	CATT	fish	shrimp
Quebrada Rincon	14.7	210100050204	N18.28229 W65.69012	08/27/18	115	3.6	CATT	fish	shrimp
Quebrada Tabonuco	3.8	210100050304	N18.35965 W65.76954	09/10/18	113	6.0	CATT	fish	shrimp
Río Canóvanas	22.0	210100050413	N18.31809 W65.88926	09/27/18	100	9.3	CATT	fish	shrimp
Río Canovanillas	23.5	210100050412	N18.30542 W65.91063	09/26/18	100	7.7	CATT	fish	shrimp
Río Espiritu Santo	15.4	210100050305	N18.31130 W65.82251	08/13/18	113	13.1	CATT	fish	shrimp
Río Fajardo	18.0	210100050204	N18.26948 W65.71948	09/20/18	100	7.9	CATT	fish	shrimp
Río Fajardo	19.6	210100050204	N18.27359 W65.73040	10/25/18	96	9.2	CATT	fish	shrimp
Río Herrera	13.0	210100050306	N18.33910 W65.86759	08/22/18	105	6.7	CATT	fish	shrimp
Río Juan Martin	3.7	210100050301	N18.34344 W65.68839	09/04/18	100	2.7	CATT	fish	shrimp
Río Pitahaya	4.0	210100050302	N18.34834 W65.71056	10/22/18	100	6.4	CATT	fish	shrimp
Río Pitahaya	8.2	210100050302	N18.33346 W65.72269	08/20/18	100	6.8	CATT	fish	shrimp
Río Pitahaya	10.1	210100050302	N18.32198 W65.71646	08/07/18	100	6.2	CATT	fish	shrimp
Río Sabana	4.1	210100050303	N18.35009 W65.72593	10/04/18	100	9.5	CATT	fish	shrimp
Río Sabana	5.0	210100050303	N18.34366 W65.72962	10/09/18	104	10.8	CATT	fish	shrimp
Río Sabana	7.5	210100050303	N18.32638 W65.73015	09/24/18	100	10.6	CATT	fish	shrimp
Trib to Río Blanco	15.7	210100050202	N18.24556 W65.79948	10/12/18	100	8.5	CATT	fish	shrimp
UT Río Mameyes	10.1	210100050304	N18.32217 W65.74979	09/12/18	100	5.7	CATT	fish	shrimp
UT Río Pitahaya	9.3	210100050302	N18.32904 W65.71517	08/17/18	100	4.0	CATT	fish	shrimp
UT Río Sabana	7.7	210100050303	N18.32561 W65.73035	08/09/18	113	3.8	CATT	fish	shrimp

Table 3. Summary of stream habitat parameters inventoried at sample sites pre- and post-Maria.

Stream	Kms to River Mouth	Mean Wetted Width (m)		Mean Depth (cm)		Mean Velocity (m/s)		Dominant Substrate	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Quebrada Grande	5.9	4.2	6.1	5	17	0.04	0.10	Small Boulder	Gravel
Quebrada Juan Diego	16.0	3.7	3.1	13	15	0.06	0.14	Coarse Gravel	Boulder
Quebrada Palma	7.2	7.7	2.3	9	12	0.07	0.01	Very Coarse Sand	Gravel
Quebrada Rincon	14.7	2.6	3.6	12	14	0.06	0.04	Small Cobble	Cobble
Quebrada Tabonuco	3.8	5.3	6.0	11	22	0.06	0.11	Silt	Boulder
Río Canóvanas	22.0	9.2	9.3	12	25	0.10	0.14	Large Cobble	Boulder
Río Canovanillas	23.5	5.9	7.7	13	17	0.03	0.07	Fine Gravel	Gravel
Río Espiritu Santo	15.4	15.1	13.1	16	20	0.20	0.24	Medium Boulder	Boulder
Río Fajardo	18.0	9.0	7.9	--	32	--	0.14	--	Boulder
Río Fajardo	19.6	11.0	9.2	--	29	--	0.30	--	Boulder/Bedrock
Río Herrera	13.0	4.9	6.7	23	22	0.04	0.07	Silt	Boulder
Río Juan Martin	3.7	2.4	2.7	--	15	--	0.02	--	Gravel/Boulder
Río Pitahaya	4.0	4.6	6.4	18	22	0.09	0.24	Coarse Gravel	Cobble
Río Pitahaya	8.2	5.4	6.8	--	18	--	0.16	--	Boulder
Río Pitahaya	10.1	6.0	6.2	--	12	--	0.27	--	Boulder
Río Sabana	4.1	7.6	9.5	9	19	0.07	0.13	Medium Gravel	Boulder
Río Sabana	5.0	11.0	10.8	--	20	--	0.10	--	Boulder
Río Sabana	7.5	10.3	10.6	--	31	--	0.04	--	Boulder
Trib to Río Blanco	15.7	2.9	8.5	11	15	0.04	0.10	Large Boulder	Boulder
UT Río Mameyes	10.1	4.8	5.7	--	8	--	0.04	--	Boulder
UT Río Pitahaya	9.3	5.0	4.0	--	15	--	0.12	--	Boulder
UT Río Sabana	7.7	6.0	3.8	--	17	--	0.14	--	Gravel

Appendix A:

Stream Monitoring Methods Manual El Yunque National Forest, Puerto Rico

Stream Monitoring Methods Manual
El Yunque National Forest, Puerto Rico

United States Department of Agriculture Forest Service
Southern Research Station
Center for Aquatic Technology Transfer
1710 Research Center Drive
Blacksburg, VA 24060-6349
https://www.srs.fs.usda.gov/catt/

C. Andrew Dolloff, Team Leader

Document prepared by:
Brandon Fair, Colin Krause, and Craig Roghair

March 2019

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Outline of El Yunque Protocol

The El Yunque sampling method is comprised of the following steps:

1. Sample site
    - Navigate to a pre-determined sample site
    - At the site, select a sample reach of 100m to 200m that includes at least 1 riffle-pool habitat sequence
    - Set block-nets at upstream and downstream end of reach
        - 2 team members walk upstream along streambank (avoid walking in channel as much as possible) using a measuring tape to measure 100m to 200m
        - Place upstream block-net between habitat units (e.g. riffle and pool) or at a natural constriction point
        - Place fish holding pen in slow-moving part of stream above upstream block-net and put a few stones inside to anchor it to the bottom
        - Meanwhile, the other 2 team members unpack and place the downstream block-net
        - Take a GPS waypoint and photo at the downstream blocknet.

2. Fish/Shrimp
    - Complete 3 passes with backpack electrofisher
    - Workup fish after each pass; recording pass number, species, total length, and weight
        - 3 DNA tissue samples will be taken from each species of fish and shrimp per watershed.
        - Note the presence or absence of shrimp and freshwater crab species
    - Place fish/shrimp from each pass in holding pen after they are worked up (separate holding pens for each pass)
    - Release fish/shrimp after all 3 passes are worked up
    - Fish identification team, following completion, will then measure reach length and begin habitat measurements

3. Habitat/Discharge
    - Divide sample reach length into 10 equal sections
    - In each section, record the wetted width of a transect
    - Divide each transect into 10 equal segments and visually estimate 10 data points across the wetted width
    - Measure velocity, depth, dominant substrate, and dominant instream physical cover at each data point
    - For each transect, record right and left bank angle (as facing upstream), right and left riparian cover, and wetted width

    Note: Record if a transect is suitable for calculating total stream discharge (See Section 4 for information on a suitable transect)

Section 1: Contacts & Safety Information

Internal Contacts

Jessica Ilse (Forest Biologist)
787-549-0084 cell
jilse@fs.fed.us

Augustin Engman (Post-doctoral Scholar)
787-587-6911 *cell*
gusengman@gmail.com

Dawn Stender
503-515-8132 cell
dstender@fs.fed.us

External Contacts

You may in the course of your assigned duties have the opportunity to interact with individuals interested in learning more about Forest Service management activities. The most direct route for the public to obtain additional information is through their local District office:

Forest	Office	Front Desk
El Yunque National Forest	Palmer	(787) 809-0534

The Forest Service also provides these talking points for use at your discretion:

If you encounter a hostile/threatening person(s):
- Apologize and leave immediately, do not argue
- Report to District office and your supervisor
- Alert your team at tailgate safety meeting

If you encounter an irritated person, consider these talking points:
- Explain that our work is helping to ensure the Forest is a source of clean water for drinking and recreation
- The Forest Service manages land for multiple uses and users
- The Forest Service values your input
- Consider contacting your local District office to share your opinion (see numbers above)
- If they become hostile at any point, apologize and leave; do not argue

If you encounter someone that is interested in learning more about what you are doing:
- Share what you are doing
- Explain that our work is helping to ensure the Forest is a source of clean water for drinking and recreation
- Provide a local contact for follow up (see numbers above)

Local Hospital Numbers

Hospital HIMA San Pablo-Fajardo
404 General Valero
Fajardo, Puerto Rico 00738
787-655-0505 office

Hospital HIMA San Pablo-Humacao
3 Calle Font Martelo
Humacao, Puerto Rico 00791
787-656-2424 office

NeoMed Center, Inc. - Gurabo Center
941 St. Rd. Salida, Bo Jaguas
Gurabo, Puerto Rico 00778
787-737-2311 (office)

Check-out / Check-in

Check-out and check-in are an essential part of our safety program. Provide a designated contact with the following information each day before going into the field:

- **Names of each person on your team**
- **SPOT unit number**
- **Vehicle make/model or number**
- **Work location(s)**

Only go to a new location if you are able to update your plans with your contact. Always work with a partner – never go into the field alone.

Check in with the designated contact at the end of each day. Have a set time of day when you are expected to be back at the duty station. If your team will return after this time, 'delayed all ok" messages will be sent every 30 min until the team is back and then a check-in message is sent.

Tailgate Safety Meetings

Tailgate safety meetings are performed to remind personnel of potential chemical, physical, and environmental dangers associated with a particular job (see Appendix B for tailgate safety form). The meetings are completed prior to work (as well as weekly thereafter, or after any safety issues arise) so team members are aware of potential hazards. It is important to conduct meetings together as a team typically at the vehicle prior to going into the field. At the completion of the meeting everyone on the team signs the tailgate safety form which is later provided to the team's supervisor.

Regional Safety

The El Yunque National Forest location provides additional safety concerns. Team members should be aware of the following before preforming fieldwork:

1. Weather
    - High temperatures for this region can be around 90 F with high humidity; dehydration is a concern; drink adequate amounts of water
    - Thunderstorms occur frequently and potentially dangerous tropical storms are possible in the area; watch the forecast closely for signs of major storms. Be aware of potential flash flooding and landslides. Placing a stick in the ground at the water's edge is a good way to monitor for any increases in depth. Watch for an increase in floating debris. Stream sampling may be delayed if there are high flows or dangerous weather systems in the area.

2. Terrain
    - El Yunque National Forest contains many high gradient streams, which may have slick rocks, waterfalls, and cascades. Never attempt to climb anything requiring special safety equipment or that's beyond your ability.
    - The team leader should be aware of these challenges and discuss with Jessica Ilse and CATT leaders when to decide that collection of quality data is compromised; have backup plans for the day.
3. Animals/Insects
    - Many species of bees, wasps, spiders, lizards, and ants live in El Yunque National Forest and the surrounding area. It's very important to be aware of your surroundings and to inform others if a potentially dangerous animal/insect is seen.

Section 2: Site Selection

Pre-Maria fish and shrimp data are available for the majority of El Yunque's watersheds. The most extensive sampling was completed between 2005 and 2010 as part of an island-wide assessment of fish populations and habitat (Kwak et al. 2007; Kwak et al. 2013). During each of these assessments, 3-pass electrofishing was used to estimate fish population density and biomass, and the presence of shrimp species was noted. The focus was on fish-bearing waters and most watersheds were represented by 1 - 2 samples collected from low elevation reaches near or outside of El Yunque's proclamation boundary. A notable exception was Río Mameyes, which was sampled extensively, including several sites within the boundary. Roghair et al. (2014) mirrored Kwak's 3-pass sampling approach, but extended sampling upstream in several watersheds and only calculated density and biomass for American Eel, noting the presence of other fish and shrimp. The El Yunque National Forest also completed aquatic biota surveys at several long-term sample sites prior to the hurricane, however data associated with these sample sites was mostly lost when the forest headquarters building and storage areas were damaged by Maria. Attempts to recover El Yunque data have not been successful to date.

Post-Maria sample sites will be selected from the suite of pre-Maria sample sites based on stream size, accessibility, and accurate location information. We will target streams that can be sampled by a 4-person team using 1 – 2 backpack electrofishing units, typically 15 m or less in wetted width and less than 1.5 m in depth. Some pre-Maria sites are inaccessible due to loss of infrastructure or safety concerns. We will only select sample sites with pre-Maria GPS or location descriptions that allow us to reliably locate the sampling area. Our goal is to collect post-Maria samples from as many of El Yunque's watersheds as project funding will allow.

Section 3: Fish Inventory

Header Information
Be sure to record all header items completely and accurately. The header includes information for both the habitat and fish inventories.

1.	Site ID	• site identifier created from date sampled (e.g 8/27/2018 = **20180827**) **Note: Does not change if revisited.** • Second site identifier will contain a letter at the end (e.g. **20180827b)**
2.	Site ID NC State	• if previously sampled by NC State, put ID here
3.	Stream Name	• record full name (no abbreviations)
4.	Date	• MM/DD/YY
5.	Team	• full name (no abbreviations) of each team member present
6.	Waypoint	• create a waypoint on the GPS when you are positioned at the downstream block-net • record the waypoint label on BOTH the GPS and datasheet
7.	Photo ID (start→up)	• photo ID number for photo taken at the reach start (downstream block-net) looking upstream
8.	Shock Time Pass 1 (sec)	• shock time (sec) for pass 1; multiple electrofishers entered separately in this field
9.	Shock Time Pass 2 (sec)	• shock time (sec) for pass 2; multiple electrofishers entered separately in this field
10.	Shock Time Pass 3 (sec)	• shock time (sec) for pass 3; multiple electrofishers entered separately in this field
11.	Shock Settings	• electrofisher settings (e.g. 400V DC)
12.	Shrimp/Crab Presence	• select all species of shrimp/crab present in stream
13.	Location	• sample reach location details such as upstream or downstream of a bridge, waterfall, culvert, etc. • also note any site access information (trails, roads, identifying features, etc.) that will be helpful for future teams finding the site
14.	Comments	• general site comments

Fish/Shrimp Sample (3 Pass Depletion)
When laying out the sample reach it should avoid road crossings or other features that could alter stream habitat or fish distribution.

Collect a 3 pass depletion fish sample using the following approach:

1. **Reach Layout:**
   a. A minimum 100 m and maximum 200m sample reach encompassing a riffle-pool sequence is laid out by 2 team members with a measuring tape walking along the bank to avoid disturbing fish and sediment
   b. Block-nets (⅛ - ¼ inch mesh) are placed at the down and upstream ends
      – **Block-nets should be placed between habitat units when available** (e.g. between a riffle and pool), or at a place of natural passage restriction (i.e. narrow section of stream)
      Note: Reach Layout is not the same as Reach Length (described in Section 4: Habitat Inventory)

2. **Electrofishing, Pass 1:**
   a. Electrofishing should proceed from downstream to upstream
   b. Use 1 backpack electrofisher for streams measuring ≤5 m and 2 for streams >5 m
   c. Have 2 dip-netters and 1 bucket person

d. Set Aqua Shock Solutions electro-fishing unit to **DC** (DC electrical current elicits taxis, an involuntary muscular response that causes fish to swim towards the anode); adjust voltage to obtain ~8 amps and adjust accordingly for fish response and water depth (increase voltage if fish escape electrical field; decrease if mortality occurs)
e. Set electrofisher timer to zero seconds before each pass; at completion of each pass record shock time (min & sec; record time for each shocker separately per pass for multiple electrofishers), as well as shocker settings (e.g. 400V DC)
f. Complete pass 1 through the sample reach
g. Workup fish and shrimp, taking DNA tissue samples (if needed) at upstream block-net and then place in holding pen

3. **Electrofishing, Pass 2:**
   a. Repeat steps 2a - 2g
   b. Shock time should be close to that of Pass 1 (i.e. equal effort)
   c. Complete pass 2 through reach
   d. Workup fish and shrimp above upstream block-net and then place in holding pen

4. **Electrofishing, Pass 3:**
   a. Repeat steps 2a – 2g
   b. Shock time should be close to Pass 1 and 2
   c. Complete Pass 3 through reach
   d. Workup fish and shrimp above upstream block-net and then place in holding pen

5. **Fish Handling:**
   a. Fish mortality can be a problem, particularly during warm temperatures
      – Avoid overcrowding buckets with too many fish
      – Separate large predatory species from smaller species
      – Keep fish in buckets with oxygenated water; aerate with pump or regularly change water
      – Place fish in empty holding pen if available
      – Keep fish out of direct sun if possible

6. **Fish Workup:**
   a. Record pass number, fish species, total length (mm), and weight (g)
   b. Observe for and note the presence of shrimp and freshwater crabs
      - Do not expend excessive effort netting shrimp and freshwater crab species, but document species present
   c. Collect 3 specimens of each fish and shrimp species/watershed for DNA tissue samples
      - Fish DNA samples are stored in manila coin envelopes.
      - Shrimp DNA gill samples are held in small vials of Ethyl Alcohol
   d. Release fish/shrimp from holding pens after all 3 passes have been worked up

Section 4: Habitat Inventory

Habitat Inventory Outline

The physical inventory is comprised of the following steps:

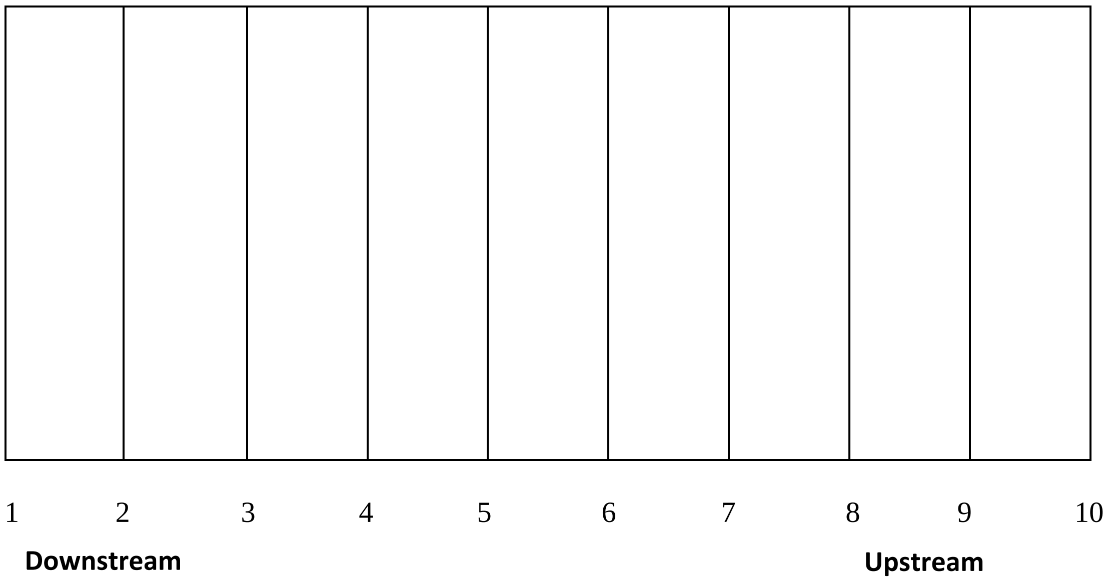
1. Fill out header information (date, team, stream, coordinates, etc.)
2. Create a waypoint on GPS at the downstream block-net
3. Take a photo (containing a person for scale) from the downstream end of the sample reach looking upstream; record photo number; if there are other features to highlight, take additional photos and record numbers
4. Divide sample reach length into 10 equal sections for transect placement (See Transect Location below)
5. At the first transect, stretch a measuring tape across stream perpendicular to flow and note wetted width.
6. Visually calculate 10 evenly spaced transect sampling points along transect (See Sample Point Layout below).
7. Measure velocity (m/s), depth (cm), dominant instream cover, and dominant substrate at each sample point
8. Record left and right (looking upstream) bank angle and riparian cover once for each transect (10 per sample reach)
9. Move to next transect and repeat steps 4-8 (Transects locations do not have to be measured out, and can be equally spaced out visually, e.g 100 m reach requires each transect to be ~10 m apart)
10. Repeat steps for transects until you reach the upstream block-net; data for 10 transects x 10 data point per transect = 100 points maximum should be recorded

Header Information

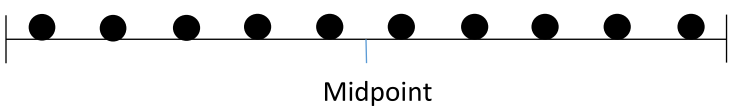
Be sure to record all header items completely and accurately. The header includes information for both the habitat and fish inventories.

1. Site ID	• site identifier created from date sampled (e.g 8/27/2018 = **20180827**) **Note: Does not change if revisited.** • Second site identifier will contain a letter at the end (e.g. **20180827b)**
2. Stream Name	• record full name (no abbreviations)
3. Date	• MM/DD/YY
4. Team	• full name (no abbreviations) of each team member present
5. Reach Length (m)	• distance from downstream to upstream block-net
6. Comments	• general site comments

Transect Location
Each sample reach is divided into 10 evenly spaced transects estimated visually.



Sample Point Layout
Each transect contains 10 evenly spaced data points estimated visually across the wetted stream channel.



Attributes measured at each data point:

Reach Length (m)

Definition: Number of meters (rounded to the whole meter) from the start of the sample reach (lower block-net) to the upstream end of the sample reach (upper block-net).

How to measure: When establishing a reach, 2 team members use a measuring tape walking along the center line of the wetted stream channel (after fish sample is completed) measuring the distance between block nets. Upper block-net is placed at a break between habitat units or constriction point in stream channel. Reach length should be 100-200 m.

Where to measure: Once per sample reach from downstream to upstream block-net.

Equipment used: Measuring tape.

Water Velocity
Water velocity is measured at 10 transects per sample reach and the transect placement should be equally spaced visually. Other habitat parameters (depth, velocity, instream cover, dominant substrate, riparian cover, bank angle, and width) will be recorded along each transect.

Note:

- Our primary goal is to capture variability in water velocity. Not all transects will be suitable for calculating stream discharge.
- Do not record velocity for transect points found underneath undercut banks (e.g. if 2 of the 10 transect points are under a bank, only record 8 flow measurements, all other parameters are still recorded)
- Flow may be traveling upstream in eddies and backwaters. Point flow meter into flow and record as a negative value (e.g. measurement is 0.7 m/s with flow meter pointing downstream. Record as -0.7 m/s)

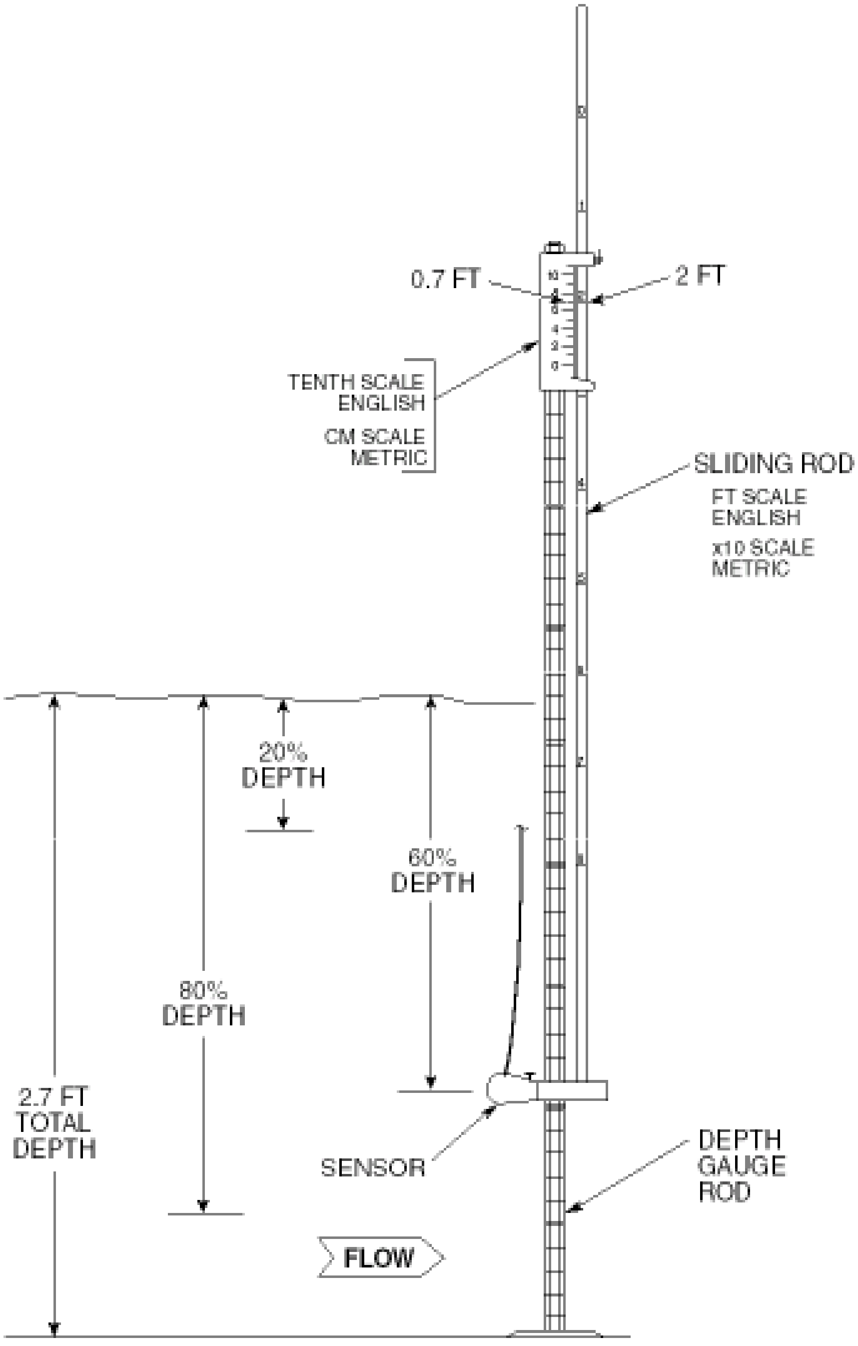
If a transect is suitable for calculating discharge, indicate this in data. Below is a list of characteristics that make a site suitable for calculating discharge. Meeting all of these selection criteria is often not possible. The team should choose the best available cross section based on these characteristics.

A relatively straight channel with parallel edges upstream and downstream of the cross section
Defined edges on both sides of the cross section
Uniform shape; roughly parabolic, trapezoidal, or rectangular in shape
Free of vegetative growth, large cobbles, and boulders
Free of eddies, slack water, and turbulence
Flow distributed evenly across the channel
Depths greater than 15 cm (0.5 ft), 6 cm (0.2 ft) is the minimum we can measure
Depth no greater than 75 cm (2.5 ft)
Sites should not be immediately downstream of sharp bends or vertical drops

Depth and Velocity: Measure the depth and velocity at data point along the transect. Measure the velocity at 60% of the depth for depths ≤ 1 m and both 20% and 80% for depths > 1 m. To set the sensor at 60% of the depth, line up the decimeter on the sliding rod with the centimeter scale on the top of the depth gauge rod. Information on setting up rod below.

Using the Top-Setting Rod

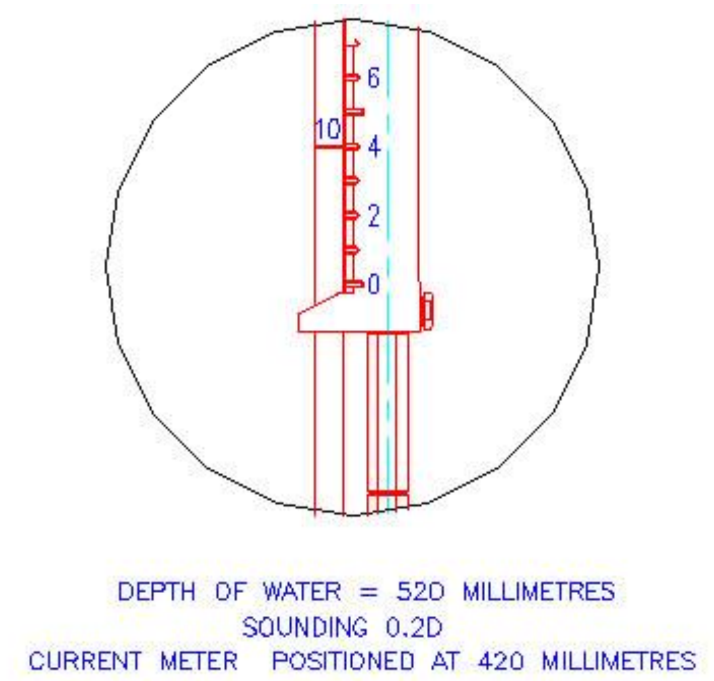
The black flow sensor on the top-setting rod must be facing upstream into flow as shown below, except in situations where flow is moving upstream such as backwaters and eddies. Flow meter will face downstream into flow in these situations.



For depths measuring 6 cm to 100 cm (0.2 ft to 3.3 ft) record one velocity reading with probe set to 0.6 of the total depth from the water surface (0.4 of the total depth from the bottom). For depths of >100 cm (>3.3 ft) record 2 velocity readings with the probe set to 0.2 and 0.8 of the total depth from the water surface. Examples of how to set the probe to 0.2, 0.6, and 0.8 depth are shown below:

Setting at 0.2d
Example 1: The sounding has been read at **52** centimeters on the GRADUATION ROD

1. Using a multiplier of 2, the calculated reading is **104** cm (i.e. multiplier ‘2.0’ *sounding ’52 cm’)
2. To set the current meter at 0.2 of the 52 cm sounding, depress the TRIGGER and slide the SUSPENSION ROD until the graduation mark ‘**10**’ on the suspension rod is in line with graduation ‘**4**’ on the VERNIER SCALE (sliding rod).



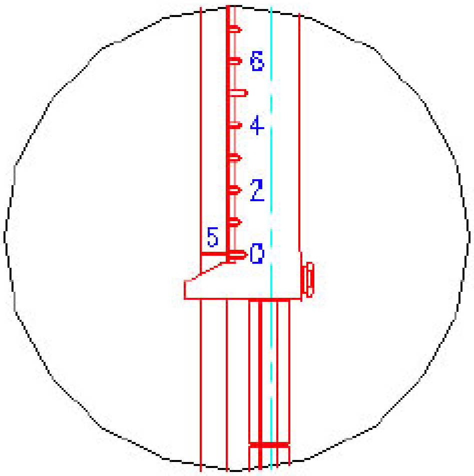
3. Release the trigger.
4. This will position the current meter at 42 cm on the GRADUATED ROD (0.2 of sounding)

Setting at 0.6d

Example 1:

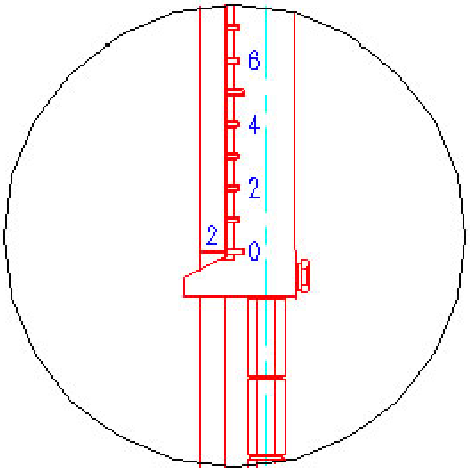
<u>Metric Rod</u>

- Water depth 50 cm
- Record 1 velocity reading
- Set to 0.6 from surface (20 cm from streambed)
- Line up 5 on sliding rod with 0 on handle



<u>English Rod</u>

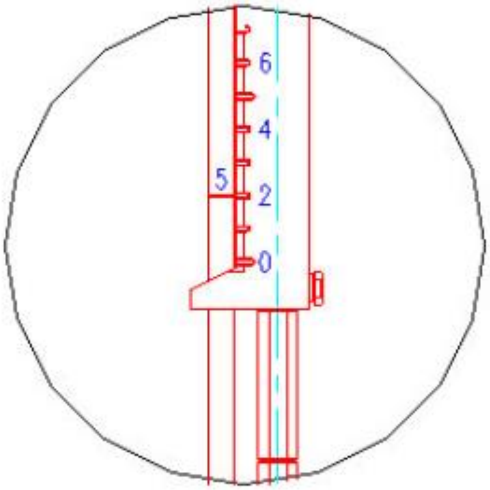
- Water depth 2.0 ft.
- Record 1 velocity reading
- Set to 0.6 from surface (0.8 ft from streambed)
- Line up 2 on sliding rod with 0 on handle



Example 2:

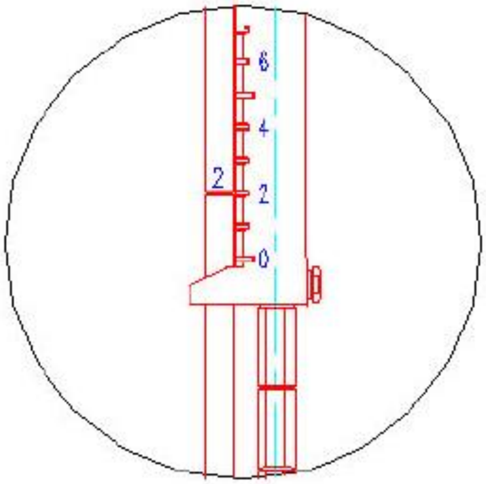
<u>Metric Rod</u>

- Water depth 52 cm
- Record 1 velocity reading
- Set to 0.6 from surface (21 cm from streambed)
- Line up 5 on sliding rod with 2 on handle



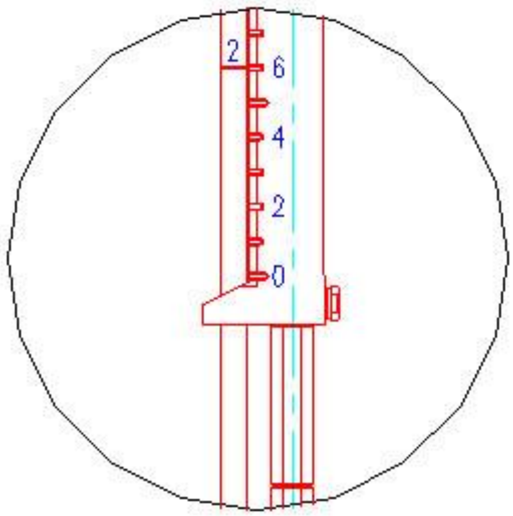
<u>English Rod</u>

- Water depth 2.2 ft.
- Record 1 velocity reading
- Set to 0.6 from surface (0.88 ft from streambed)
- Line up 2 on sliding rod with 2 on handle



NOTE: Our equipment cannot obtain velocity readings where water depth is less than 6 cm (0.2 ft.). If water depth is less than 6 cm in a segment, record the depth on the datasheet and record the water velocity as 0 m/s. If the flow is moving upstream, e.g. backwaters and eddies) point the flow meter into current and record as a negative value (0.7 m/s = -0.7 m/s).

Setting at 0.8d
Example 1: The sounding has been read at 5.2 decimetres or 520mm on the GRADUATION ROD
1. The calculated reading is **’26** cm**’** (i.e. multiplier ‘0.5’ * sounding ’52 cm’)
2. To set the current meter at 0.8 of the 52 centimeter sounding, depress the TRIGGER and slide the SUSPENSION ROD (sliding rod) until the graduation mark ‘**2**’ on the suspension rod is in line with graduation ‘**6**’ on the VERNIER SCALE.



DEPTH OF WATER = 520 MILLIMETRES
SOUNDING 0.8D
CURRENT METER POSITIONED AT 110 MILLIMETRES

3. Release the trigger.
4. This will position the current meter at 11 centimeters on the GRADUATED ROD (0.8 of sounding)

Depth (cm)

Definition: Vertical distance to the nearest 1 cm from the channel bottom (i.e. top of substrate) to the water surface.

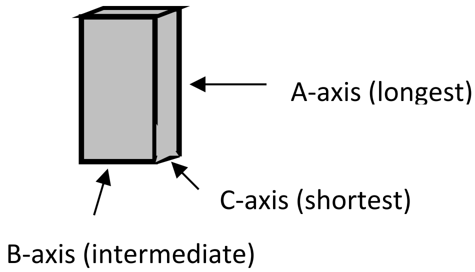
How to measure: Water depth is measured with the top-setting rod at each transect data point by holding rod at a visually estimated point along a transect.

Where to measure: At each transect data point.

Equipment used: Top-setting flow rod.

Dominant Substrate

Definition: Substrate is the inorganic material making up the bed of the wetted stream channel. Individual substrate particles are measured on their intermediate, or b-axis. The b-axis determines the minimum size sieve hole through which a particle can be pass through.



How to measure: Visually determine the dominant substrate present at each transect data point within the immediate area around the base of the flow meter rod; choose from the following substrate categories:

Type	Size (mm)	Description
Silt & Clay (SC)	<0.059	Silt is slippery, clay is sticky and hold together when in a ball
Sand (S)	0.06 – 1	Grainy, does not hold form when rolled into ball
Gravel (G)	2-63	Sand to fist-size
Cobble (C)	64-256	Fist to head-size
Boulder (B)	>256	Head to building-size
Bedrock (BD)		Parent material for stream substrate
Concrete (CT)		Man-made structures

Where to measure: At each transect data point within a transect.

Equipment used: Visual estimate.

Instream Cover

Definition: Natural features either on or below the water surface that obscure overhead viewing and provides shelter for aquatic organisms.

How to estimate: Visually determine the dominant cover type present at the transect data point within the immediate area of the flow meter rod; choose from the following cover categories:

Cover Type	Definition
No Cover	
Woody Debris (WD)	Logs, branches, or small sticks
Rootwad (RW)	Aquatic or terrestrial roots
Leaf Litter (LL)	Fallen leaves from terrestrial trees/plants
Undercut Bank (UB)	Bank overhangs the water surface
Plant (P)	Living terrestrial or aquatic vegetation
Boulder (B)	Head to building size rocks (250->4000mm)
Cobble (C)	Fist to head-size rocks (64-250mm)
Trash (T)	Man-made materials or objects

Where to estimate: At each transect data point.

Equipment used: Visual estimate.

Bank Angle (<45º, >45º, 90º, -<45°, ->45° for left and right bank)

Definition: Slope of stream bank from bankfull elevation to top of bank for incised channels or water's edge to top of bank for stable channels (recorded as slope category <45º, >45º, 90º, -<45°, and ->45°)

How to measure: Visually estimate, however if uncertain use the following method. Place the bottom of the topsetting rod at bankfull (or water's edge for stable channel) then lay the top of the topsetting rod against the bank. Flat (i.e. level) banks (0º) are recorded as <45º and vertical banks are recorded as 90º

If bank is undercut, push bottom of topsetting rod as far beneath bank as possible, then pull up on other end of rod until it contacts the underside of the undercut bank. -<45° is anything from the water surface to 45°, and ->45° is from 45° to 90°.

Where to measure: Left and right bank of each transect in sample reach.

Equipment used: Visual estimate, and/or clinometer and topsetting rod.

Riparian Cover

Definition: Type of land coverage found within 50m of either bank.

How to estimate: Visually estimate by looking at land coverage within 50 m of both left and right banks.

Cover Type	Definition
Residential	Houses, businesses, and buildings present
Forested	An abundance of trees, shrubs, and vegetation present
Agricultural	Signs of livestock or crop production
Road	Dirt, gravel, or paved surface present

Where to measure: Once per transect for the left and right bank.

Equipment used: Visually estimated.

Wetted Width (m)

Definition: Width of the *transect* as estimated visually, used to calculate stream area. Wetted width is the distance from the edge of the water on one side of the main channel to the edge of the water on the opposite side of the main channel.

How to estimate: *Stretch a measuring tape across main channel from the water's edge on one side to the water's edge on the opposite side perpendicular to the flow.*

Where to measure: Every visually estimated transect.

Equipment Used: Measuring tape

Appendix A: SPOT Device Instructions

SPOT Device Safety Plan

Before Going into Field

Turn on SPOT device

1. Press and hold On/Off button until it blinks green
   - On/Off button will blink green every 3 seconds when on
2. Check battery life
   - If battery life is less than 30%, On/Off button will flash red, change batteries

Check Out

1. Press and hold OK button until it blinks green
2. GPS light will blink green when SPOT sees satellites and continues while obtaining GPS location
3. Once GPS location is obtained the message **"Check-in, all OK"** is sent to field team leader(s) and supervisor(s)
4. If successful the GPS light and Message Sending light will both blink green for 15 sec (Message Sending light will then continue to blink for 1 hr)
5. If no GPS signal is found the GPS light will blink red; move to a location with clearer view of sky; SPOT will keep looking for up to 15 min; if no GPS location is found in 15 min your message will not be sent

Using SPOT in Field

Delayed

1. If everything is okay and you are fine, but you are delayed and will not return to the duty station (or hotel) by the specified return time, press and hold the Custom Message button until it blinks green
2. Once GPS location is obtained the message **"Delayed, all OK"** is sent to field team leader(s) and supervisor(s)
3. Resend the "Delayed, all OK" message every hour until you return to the duty station (or hotel)
4. If successful the GPS light and Message Sending light will both blink green for 15 sec (Message Sending light will then continue to blink for 1 hr)
5. If no GPS signal is found the GPS light will blink red; move to a location with clearer view of sky; SPOT will keep looking for up to 15 min; if no GPS location is found in 15 min your message will not be sent

Help (Non-Life Threatening Situation)

1. Press and hold Help button until it blinks green
2. Once GPS location is obtained the message **"Help needed (non-life threating) Please send assistance to my location"** is sent to field team leader(s) and supervisor(s)
3. If successful the GPS light and Message Sending light will both blink green for 15 sec (Message Sending light will then continue to blink for 1 hr)
4. If no GPS signal is found the GPS light will blink red; move to a location with clearer view of sky; SPOT will keep looking for up to 4 min
5. If no GPS location is found in 4 min your message will be sent, but without GPS location; in this case the GPS light blinks red and Message Sending light blinks green for 15 sec (Message Sending light will then continue to blink for 1 hr)
6. To CANCEL, press and hold the Help button until it blinks red; then let SPOT work until Help button stops blinking; the Message Sending light will then blink green indicating it has sent the cancel message

SOS/911 (Life Threatening Emergency ONLY)

1. Press and hold SOS button until it blinks green
2. Once GPS location is obtained the International Emergency Rescue Coordination Center is alerted and they notify emergency responders in your area
3. If successful the GPS light and Message Sending light will both blink green for 15 sec (Message Sending light will then continue to blink)
4. If no GPS signal is found the GPS light will blink red; move to a location with clearer view of sky
5. The first message will be sent within 1 min of activation with or without your GPS location
6. If no GPS location is found in 4 min your message will be sent, but without GPS location; in this case the GPS light blinks red and Message Sending light blinks green for 15 sec (Message Sending light will then continue to blink)
7. To CANCEL, press and hold the SOS button until it blinks red; then let SPOT work until Help button stops blinking; the Message Sending light will then blink green indicating it has sent the cancel message

Track Progress

1. Do not use unless instructed to do so by your team leader
2. Press and hold Track Progress button until it blinks green
3. GPS light will blink green when SPOT sees satellites and continues while obtaining GPS location
4. Once GPS location is obtained a waypoint is sent to an online map every 10 min
5. If successful the GPS light and Message Sending light will both blink green for 15 sec (Message Sending light will then continue to blink for 1 hr)
6. If no GPS signal is found the GPS light will blink red; if no GPS location is found in 4 min SPOT will not send this particular waypoint
7. To CANCEL, press and hold the Track Progress button until the light turns off

After Returning from Field

Check In

1. Press and hold OK button until fit blinks green
2. GPS light will blink green when SPOT sees satellites and continues while obtaining GPS location
3. Once GPS location is obtained the message **"Check-in, all OK"** is sent to field team leader(s) and supervisor(s)
4. If successful the GPS light and Message Sending light will both blink green for 15 sec (Message Sending light will then continue to blink for 1 hr)
5. If no GPS signal is found the GPS light will blink red; move to a location with clearer view of sky; SPOT will keep looking for up to 15 min; if no GPS location is found in 15 min your message will not be sent

Turn off SPOT device

1. Press and hold On/Off button until it stops blinking green

Additional Notes

To maximize the chances of your message going through:

- Turn SPOT on 5 min before sending a message (this allows SPOT to know its current location)
- Ensure SPOT has a clear view of the sky
- Leave SPOT in the same place for at least 20 min after sending a message.

Check-In, Non-Emergency Help, and Custom Message

- Press and hold the appropriate button for at least 2 sec (non-emergency help messages can be cancelled by pressing and holding the button again for at least 3 sec)
- Pre-programmed messages are sent to the contact list with a GPS location
- SPOT attempts to send check-in messages every 5 min for 20 min
- SPOT attempts to send non-emergency help messages every 5 min for 1 hr

SOS Button (for use if you have a life threatening emergency and need immediate help)

- Press and hold for at least 2 sec (to cancel: press again and hold for at least 3 sec)
- Emergency signal and location is sent to SPOT's Emergency Response Center
- SPOT will contact the appropriate emergency responders as well as the primary and secondary contacts listed on the account for that unit

Appendix B: Tailgate Safety Form

Tailgate Safety Sheet

Forest/District : **SRS RWU 4353**

Briefing Project: ______________________________

Briefing Administrator: ______________________________

Date: ______________________________

Topics Covered:

☐ Cuts/lacerations	☐ Heat Exhaustion	☐ Sunburn
☐ Dehydration	☐ Hypothermia	☐ Swift-water
☐ Drowning	☐ Insect sting, snake bite	☐ Traffic on roadway
☐ Electrocution	☐ JHA for fieldwork	☐ Vehicle Backing
☐ Falling debris	☐ Lightning	☐ Vehicle Speeding
☐ Falls/Twists/Sprains	☐ Poisonous plants	☐ Vehicle Stuck
☐ Flashflood	☐ PPE	☐ Vehicle visibility

Other: ______________________________

____

____

Attendees: *name* *signature*

name	*signature*

Appendix C: Equipment List

Category	Item	Qty	√
Electronics	Field GPS w/ camera		
	Vehicle GPS		
	AA Battery charger		
	GPS/Camera charger		
	Ipad chargers		
	Ipads		
	Laptop		
	Powerstrip		
	Rechargable Batteries		
	SPOT units & lithium batteries		
	Vehicle power inverter		
Efish	Backpack electrofishing unit		
	Block nets		
	Buckets		
	Dipnets		
	Efish batteries		
	Efish battery chargers		
	Efish probes		
	Mesh zip bags		
	Pelican case for efish batteries		
	Shocker rain cover		
Fish Workup/ DNA	Aquarium nets		
	AQUI-S & 1/4 Teaspoon		
	Envelopes		
	Ethyl Alcohol		
	Fin clip paper		
	Measuring board		
	Scale and extra batteries		
	Scissors		
	RITR voucher labels		
	Glass DNA vials		
	Weighing tray		
	Dissection pick		
	Fine-tip tweezers		
BVET	50 m tape measure		
	Field guide		
	Thermometer		
	Top-setting rod		
	Flow meter		

Category	Item	Qty	√
PPE	Efish gloves		
	Hardhats		
	Waders		
	Wading boots		
	Wading socks		
Packs	Backpack		
	First aid kit		
	Fish ID book		
	Flagging		
	Framepack		
	Markers		
	Pencils		
	RITR paper/notebook		
	Stylus		
	Toilet paper		
	Topographic maps		
	Water filter		
Misc	Emergency phone numbers		
	Extra truck keys		
	Insect repellant		
	Permits & JHA		
	Radio/cell phone		
	Sunscreen		
	Tools/fix-it kits		
	Personal water bottles		
	Ziplock bags		
	Duck tape		
	Zip ties		
	Soldering Iron		
	Packing wrap		

Appendix B:

Species Assemblage Tables

Table B1. Fish species presence (X) pre- and post-Maria, species gained post-Maria (X in solid box), and species lost post-Maria (-- in dashed box).

			Fish (exotic)												Fish (native)									
Stream	**Kms to River Mouth**	**Year**	Cichlidae, *Amatitlania nigrofasciata*, Convict Cichlid	Cichlidae, *Amphilophus labiatus*, Red Devil	Cichlidae, *Oreochromis mossambicus*, Mozambique Tilapia	Cichlidae, *Oreochromis niloticus*, Nile Tilapia	Cichlidae, *Tilapia rendalli*, Redbreast Tilapia	Cyprinidae, *Pethia conchonius*, Rosy Barb	Loricariidae, *Pterygoplichthys pardalis*, Amazon Sailfin Catfish	Poeciliidae, *Poecilia latipinna*, Sailfin Molly	Poeciliidae, *Poecilia reticulata*, Guppy	Poeciliidae, *Poecilia sphenops*, Mexican Molly	Poeciliidae, *Xiphophorus hellerii*, Green Swordtail	**Count of Exotic Fish Species Present**	Anguillidae, *Anguilla rostrata*, American Eel	Centropomidae, *Centropomus parallelus*, Fat Snook	Eleotridae, *Eleotris perniger*, Smallscaled Spinycheek Sleeper	Eleotridae, *Gobiomorus dormitor*, Bigmouth Sleeper	Gobiidae, *Awaous banana*, River Goby	Gobiidae, *Sicydium spp.*, Sirajo Goby	Haemulidae, *Pomadasys crocro*, Burro Grunt	Mugilidae, *Agonostomus monticola*, Mountain Mullet	**Count of Native Fish Species Present**	**Count of Exotic AND Native Fish Species Present**
Quebrada Grande	5.9	2007									X			**1**					X	X		X	**3**	**4**
		2018									[--]			**0**	[X]				X	X		X	**4**	**4**
Quebrada Juan Diego	16.0	2007												**0**	X		X	X	X	X		X	**6**	**6**
		2018									[X]		[X]	**2**	X		[--]	X	X	X		X	**5**	**7**
Quebrada Palma	7.2	2010					X					X		**2**	X			X				X	**3**	**5**
		2018			[X]		[--]				[X]	[--]		**2**	[--]			X				[--]	**1**	**3**
Quebrada Rincon	14.7	2007												**0**	X		X	X	X			X	**5**	**5**
		2018									[X]		[X]	**2**	X		[--]	X	X			X	**4**	**6**
Quebrada Tabonuco	3.8	2007												**0**	X		X	X	X	X		X	**6**	**6**
		2018				[X]			[X]		[X]			**3**	X		X	X	X	X		X	**6**	**9**
Río Canóvanas	22.0	2007								X	X	X		**3**	X			X	X	X		X	**5**	**8**
		2018	[X]							[--]	[--]	[--]		**1**	X			X	X	X		X	**5**	**6**
Río Canovanillas	23.5	2007			X			X			X	X		**4**					X	X			**2**	**6**
		2018		[X]	X			X			X	X	[X]	**6**					X	X		[X]	**3**	**9**
Río Espiritu Santo	15.4	2007												**0**						X			**1**	**1**
		2018												**0**						X			**1**	**1**
Río Fajardo	18.0	2014												**0**	X				X				**2**	**2**
		2018									[X]			**1**	X				X				**2**	**3**
Río Fajardo	19.6	2014												**0**	X			X				X	**3**	**3**
		2018												**0**	X			X	[X]	[X]		X	**5**	**5**
Río Herrera	13.0	2007									X			**1**	X			X	X	X		X	**5**	**6**
		2018									[--]			**0**	X			X	X	X		X	**5**	**5**
Río Juan Martin	3.7	2014												**0**	X		X	X				X	**4**	**4**
		2018												**0**	X		X	X	[X]	[X]		X	**6**	**6**

Table B1 continued. Fish species presence (X) pre- and post-Maria, species gained post-Maria (X in solid box), and species lost post-Maria (-- in dashed box).

Stream	Kms to River Mouth	Year	Fish (exotic)												Fish (native)									
			Cichlidae, *Amatitlania nigrofasciata*, Convict Cichlid	Cichlidae, *Amphilophus labiatus*, Red Devil	Cichlidae, *Oreochromis mossambicus*, Mozambique Tilapia	Cichlidae, *Oreochromis niloticus*, Nile Tilapia	Cichlidae, *Tilapia rendalli*, Redbreast Tilapia	Cyprinidae, *Pethia conchonius*, Rosy Barb	Loricariidae, *Pterygoplichthys pardalis*, Amazon Sailfin Catfish	Poeciliidae, *Poecilia latipinna*, Sailfin Molly	Poeciliidae, *Poecilia reticulata*, Guppy	Poeciliidae, *Poecilia sphenops*, Mexican Molly	Poeciliidae, *Xiphophorus hellerii*, Green Swordtail	**Count of Exotic Fish Species Present**	Anguillidae, *Anguilla rostrata*, American Eel	Centropomidae, *Centropomus parallelus*, Fat Snook	Eleotridae, *Eleotris perniger*, Smallscaled Spinycheek Sleeper	Eleotridae, *Gobiomorus dormitor*, Bigmouth Sleeper	Gobiidae, *Awaous banana*, River Goby	Gobiidae, *Sicydium spp.*, Sirajo Goby	Haemulidae, *Pomadasys crocro*, Burro Grunt	Mugilidae, *Agonostomus monticola*, Mountain Mullet	**Count of Native Fish Species Present**	**Count of Exotic AND Native Fish Species Present**
Río Pitahaya	4.0	2007												**0**	X		X	X	X		X	X	**6**	**6**
		2018												**0**	X		X	X	X		--	X	**5**	**5**
Río Pitahaya	8.2	2014												**0**	X				X	X		X	**4**	**4**
		2018									**X**			**1**	X				X	X		X	**4**	**5**
Río Pitahaya	10.1	2014												**0**					X	X		X	**3**	**3**
		2018												**0**					--	X		X	**2**	**2**
Río Sabana	4.1	2007												**0**	X		X	X	X	X		X	**6**	**6**
		2018												**0**	X		X	X	X	X	**X**	X	**7**	**7**
Río Sabana	5.0	2014												**0**	X			X		X	X	X	**5**	**5**
		2018												**0**	X	**X**	**X**	X	**X**	X	X	X	**8**	**8**
Río Sabana	7.5	2014												**0**	X					X			**2**	**2**
		2018									**X**		**X**	**2**	--				**X**	X		**X**	**3**	**5**
Trib to Río Blanco	15.7	2007												**0**					X	X		X	**3**	**3**
		2018												**0**					X	X		X	**3**	**3**
UT Río Mameyes	10.1	2014												**0**	X			X		X			**3**	**3**
		2018												**0**	X		**X**	X	**X**	X		**X**	**6**	**6**
UT Río Pitahaya	9.3	2014												**0**					X	X		X	**3**	**3**
		2018									**X**			**1**					X	X		X	**3**	**4**
UT Río Sabana	7.7	2014												**0**						X			**1**	**1**
		2018									**X**		**X**	**2**						X			**1**	**3**
Site Count Occupied PRE-Maria			**0**	**0**	**1**	**0**	**1**	**1**	**0**	**1**	**4**	**3**	**0**		**15**	**0**	**6**	**12**	**14**	**16**	**2**	**16**		
Site Count Occupied POST-Maria			**1**	**1**	**2**	**1**	**0**	**1**	**1**	**0**	**10**	**1**	**5**		**14**	**1**	**6**	**12**	**18**	**18**	**2**	**18**		
Between Years Count of:																								
Sites Gained			**1**	**1**	**1**	**1**	**0**	**0**	**1**	**0**	**9**	**0**	**5**		**1**	**1**	**2**	**0**	**5**	**2**	**1**	**3**		
Sites Lost			**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**3**	**2**	**0**		**2**	**0**	**2**	**0**	**1**	**0**	**1**	**1**		
No Change			**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**		**13**	**0**	**4**	**12**	**13**	**16**	**1**	**15**		

Table B2. Shrimp and crab species presence (X) pre- and post-Maria, species gained post-Maria (X in solid box), and species lost post-Maria (-- in dashed box).

			Shrimp (native)												Crab (native)		
Stream	**Kms to River Mouth**	**Year**	Atyidae, *Atya innocous*, Basket Shrimp	Atyidae, *Atya lanipes*, Spinning Shrimp	Atyidae, *Atya scabra*, Roughback Shrimp	Atyidae, *Micratya poeyi*, Tiny Basket Shrimp	Atyidae, *Potimirim glabra*, Smooth Potimirim	Palaemonidae, *Macrobrachium acanthurus*, Cinnamon River Shrimp	Palaemonidae, *Macrobrachium carcinus*, Bigclaw River Shrimp	Palaemonidae, *Macrobrachium crenulatum*, Striped River Shrimp	Palaemonidae, *Macrobrachium faustinum*, Bigarm River Shrimp	Palaemonidae, *Macrobrachium heterochirus*, Cascade River Shrimp	Xiphocarididae, *Xiphocaris elongata*, Carrot Nose River Shrimp	**Count of Native Shrimp Species Present**	Pseudothelphusidae, *Epilobocera sinuatifrons*, P.R. Freshwater Crab	Sesarmidae, *Armases roberti*, Armases roberti	**Count of Native Crab Species Present**
Quebrada Grande	5.9	2007	X	X	X		X		X	X	X	X	X	**9**	X		**1**
		2018	X	--	X	**X**	X	**X**	X	X	X	X	X	**10**	X		**1**
Quebrada Juan Diego	16.0	2007	X		X	X			X	X	X	X	X	**8**	X		**1**
		2018	X	**X**	X	X	**X**		X	X	X	X	X	**10**	X		**1**
Quebrada Palma	7.2	2010	X		X			X	X		X		X	**6**			**0**
		2018	X	**X**	X	**X**	**X**	X	X		X		X	**9**	**X**		**1**
Quebrada Rincon	14.7	2007			X	X	X			X	X		X	**6**	X		**1**
		2018		**X**	X	X	X		**X**	X	X		X	**8**	X		**1**
Quebrada Tabonuco	3.8	2007							X	X	X	X	X	**5**	X		**1**
		2018							X	--	X	X	--	**3**	--		**0**
Río Canóvanas	22.0	2007	X		X	X	X		X	X	X	X		**8**	X		**1**
		2018	--		X	--	--		X	X	--	X	**X**	**5**	--		**0**
Río Canovanillas	23.5	2007	X	X	X						X	X	X	**6**	X		**1**
		2018	--	X	X				**X**	**X**	X	--	X	**6**	X		**1**
Río Espiritu Santo	15.4	2007	X	X					X			X	X	**5**	X		**1**
		2018	X	X	**X**	**X**	**X**		X	**X**		X	X	**9**	X		**1**
Río Fajardo	18.0	2014							X		X		X	**3**			**0**
		2018		**X**	**X**	**X**	**X**		X	**X**	X		X	**8**	**X**		**1**
Río Fajardo	19.6	2014		X					X		X	X		**4**			**0**
		2018	**X**	--	**X**	**X**			X	**X**	X	X	**X**	**8**	**X**		**1**
Río Herrera	13.0	2007	X		X	X	X		X	X		X	X	**8**	X		**1**
		2018	X	**X**	X	X	--		X	X	**X**	--	X	**8**	--		**0**
Río Juan Martin	3.7	2014		X							X		X	**3**			**0**
		2018	**X**	--	**X**	**X**	**X**		**X**	**X**	X	**X**	--	**8**	**X**		**1**
Río Pitahaya	4.0	2007					X	X		X			X	**4**	X		**1**
		2018		**X**	**X**	**X**	--	--	**X**	X	**X**		X	**7**	X		**1**

Table B2 continued. Shrimp and crab species presence (X) pre- and post-Maria, species gained post-Maria (X in solid box), and species lost post-Maria (-- in dashed box).

			Shrimp (native)												Crab (native)		
			Atyidae, *Atya innocous*, Basket Shrimp	Atyidae, *Atya lanipes*, Spinning Shrimp	Atyidae, *Atya scabra*, Roughback Shrimp	Atyidae, *Micratya poeyi*, Tiny Basket Shrimp	Atyidae, *Potimirim glabra* , Smooth Potimirim	Palaemonidae , *Macrobrachium acanthurus* , Cinnamon River Shrimp	Palaemonidae , *Macrobrachium carcinus*, Bigclaw River Shrimp	Palaemonidae , *Macrobrachium crenulatum* , Striped River Shrimp	Palaemonidae , *Macrobrachium faustinum* , Bigarm River Shrimp	Palaemonidae , *Macrobrachium heterochirus* , Cascade River Shrimp	Xiphocarididae, *Xiphocaris elongata*, Carrot Nose River Shrimp	**Count of Native Shrimp Species Present**	Pseudothelphusidae, *Epilobocera sinuatifrons* , P.R. Freshwater Crab	Sesarmidae, *Armases roberti* , Armases roberti	**Count of Native Crab Species Present**
Río Pitahaya	4.0	2007					X	X		X			X	**4**	X		**1**
		2018		**X**	**X**	**X**	--	--	**X**	X	**X**		X	**7**	X		**1**
Río Pitahaya	8.2	2014			X				X				X	**3**	X		**1**
		2018		**X**	X	**X**			X	**X**	**X**	**X**	X	**8**	X		**1**
Río Pitahaya	10.1	2014		X	X	X			X		X	X	X	**7**			**0**
		2018	**X**	X	X	--			X	**X**	X	X	X	**8**	**X**		**1**
Río Sabana	4.1	2007	X						X	X	X	X	X	**6**			**0**
		2018	--		**X**	**X**			X	X	X	X	X	**7**			**0**
Río Sabana	5.0	2014		X		X			X		X		X	**5**			**0**
		2018		--	**X**	X			X		X	**X**	X	**6**		**X**	**1**
Río Sabana	7.5	2014		X	X				X		X		X	**5**			**0**
		2018		X	X	**X**			X	**X**	X	**X**	X	**8**	**X**		**1**
Trib to Río Blanco	15.7	2007			X	X	X		X		X	X	X	**7**	X		**1**
		2018	**X**	**X**	X	X	--		X	**X**	X	X	X	**9**	X		**1**
UT Río Mameyes	10.1	2014		X								X	X	**3**			**0**
		2018	**X**	X	**X**	**X**			**X**	**X**	**X**	X	X	**9**	**X**		**1**
UT Río Pitahaya	9.3	2014		X					X		X		X	**4**			**0**
		2018		X			**X**		X	**X**	X		X	**6**	**X**		**1**
UT Río Sabana	7.7	2014		X	X				X				X	**4**			**0**
		2018	**X**	X	X	**X**	**X**	**X**	X			**X**	X	**9**			**0**
Site Count Occupied PRE-Maria			**8**	**11**	**12**	**7**	**6**	**2**	**17**	**8**	**16**	**12**	**20**		**11**	**0**	
Site Count Occupied POST-Maria			**11**	**15**	**20**	**17**	**9**	**3**	**22**	**18**	**19**	**15**	**20**		**16**	**1**	
Between Years Count of:																	
Sites Gained			**6**	**8**	**8**	**12**	**7**	**2**	**5**	**11**	**4**	**5**	**2**		**8**	**1**	
Sites Lost			**3**	**4**	**0**	**2**	**4**	**1**	**0**	**1**	**1**	**2**	**2**		**3**	**0**	
No Change			**5**	**7**	**12**	**5**	**2**	**1**	**17**	**7**	**15**	**10**	**18**		**8**	**0**	

Appendix C:

2018 Habitat Tables

Table C1. Summary of stream habitat parameters inventoried at sample sites post-Maria.

Stream	Kms to River Mouth	Sample Date	Reach Length (m)	Mean Width (m)	Area (m2)	Mean Depth (cm)	Mean Velocity (m/s)	Bank Angle (deg)	Dominant Substrate	Dominant Instream Cover	Dominant Riparian Cover
Quebrada Grande	5.9	09/11/18	100	6.1	612	17	0.10	>45	Gravel	Cobble	Residential
Quebrada Juan Diego	16.0	08/28/18	105	3.1	321	15	0.14	>45	Boulder	Boulder	Residential
Quebrada Palma	7.2	09/05/18	100	2.3	231	12	0.01	>45	Gravel	Plants	Residential
Quebrada Rincon	14.7	08/27/18	115	3.6	413	14	0.04	<45	Cobble	No Cover	Agricultural
Quebrada Tabonuco	3.8	09/10/18	113	6.0	677	22	0.11	>45	Boulder	Boulder	Road
Río Canóvanas	22.0	09/27/18	100	9.3	930	25	0.14	<45	Boulder	Boulder	Agricultural/Road
Río Canovanillas	23.5	09/26/18	100	7.7	765	17	0.07	>45	Gravel	No Cover	Residential/Road
Río Espiritu Santo	15.4	08/13/18	113	13.1	1,477	20	0.24	>45	Boulder	Boulder	Forested
Río Fajardo	18.0	09/20/18	100	7.9	794	32	0.14	<45	Boulder	Boulder	Agricultural
Río Fajardo	19.6	10/25/18	96	9.2	886	29	0.30	>45	Boulder/Bedrock	Boulder	Forested
Río Herrera	13.0	08/22/18	105	6.7	701	22	0.07	<45	Boulder	Boulder	Agricultural
Río Juan Martin	3.7	09/04/18	100	2.7	267	15	0.02	>45	Gravel/Boulder	Plants	Residential
Río Pitahaya	4.0	10/22/18	100	6.4	644	22	0.24	<45	Cobble	Cobble	Forested
Río Pitahaya	8.2	08/20/18	100	6.8	681	18	0.16	<45	Boulder	No Cover	Forested
Río Pitahaya	10.1	08/07/18	100	6.2	619	12	0.27	>45	Boulder	Boulder	Forested
Río Sabana	4.1	10/04/18	100	9.5	952	19	0.13	>45	Boulder	Boulder	Road
Río Sabana	5.0	10/09/18	104	10.8	1124	20	0.10	>45	Boulder	Boulder	Road
Río Sabana	7.5	09/24/18	100	10.6	1060	31	0.04	<45	Boulder	Boulder	Residential
Trib to Río Blanco	15.7	10/12/18	100	8.5	854	15	0.10	>45	Boulder	No Cover	Forested
UT Río Mameyes	10.1	09/12/18	100	5.7	570	8	0.04	>45	Boulder	No Cover	Forested
UT Río Pitahaya	9.3	08/17/18	100	4.0	402	15	0.12	>45	Boulder	Boulder	Forested
UT Río Sabana	7.7	08/09/18	113	3.8	434	17	0.14	>45	Gravel	No Cover	Forested

Table C2. Count of dominant substrate observations (n=100 per sample site; 10 transects and 10 observations per transect).

Stream	Kms to River Mouth	Dominant Substrate Count						
		Silt & Clay	Sand	Gravel	Cobble	Boulder	Bedrock	Concrete
Quebrada Grande	5.9	0	2	**53**	27	18	0	0
Quebrada Juan Diego	16.0	0	0	14	21	**58**	7	0
Quebrada Palma	7.2	9	2	**52**	34	3	0	0
Quebrada Rincon	14.7	16	7	31	**38**	8	0	0
Quebrada Tabonuco	3.8	2	1	35	7	**55**	0	0
Río Canóvanas	22.0	0	1	19	2	**69**	9	0
Río Canovanillas	23.5	7	32	**35**	3	10	13	0
Río Espiritu Santo	15.4	0	9	14	4	**73**	0	0
Río Fajardo	18.0	0	1	11	30	**42**	16	0
Río Fajardo	19.6	0	0	10	18	**36**	**36**	0
Río Herrera	13.0	3	28	4	4	**59**	2	0
Río Juan Martin	3.7	0	0	**32**	28	**32**	8	0
Río Pitahaya	4.0	1	1	44	**49**	5	0	0
Río Pitahaya	8.2	0	0	16	5	**42**	35	2
Río Pitahaya	10.1	0	4	27	7	**57**	4	0
Río Sabana	4.1	0	3	34	27	**36**	0	0
Río Sabana	5.0	0	0	23	10	**65**	2	0
Río Sabana	7.5	0	2	24	0	**57**	17	0
Trib to Río Blanco	15.7	0	2	32	7	**58**	1	0
UT Río Mameyes	10.1	1	0	24	8	**66**	1	0
UT Río Pitahaya	9.3	0	0	25	12	**63**	0	0
UT Río Sabana	7.7	0	2	**49**	36	13	0	0

Table C3. Count of instream cover observations (n=100 per sample site; 10 transects and 10 observations per transect).

Stream	Kms to River Mouth	Instream Cover Count										
		Bedrock	Boulder	Cobble	Concrete	Leaf Litter	No Cover	Plants	Rootwad	Trash	Undercut Bank	Woody Debris
Quebrada Grande	5.9	0	25	**34**	0	0	30	4	1	1	3	2
Quebrada Juan Diego	16.0	0	**52**	17	0	1	24	4	0	0	0	2
Quebrada Palma	7.2	0	3	9	0	0	21	**67**	0	0	0	0
Quebrada Rincon	14.7	0	5	16	0	7	**38**	26	0	0	1	7
Quebrada Tabonuco	3.8	0	**40**	4	0	2	35	14	0	0	2	3
Río Canóvanas	22.0	1	**58**	5	1	1	26	8	0	0	0	0
Río Canovanillas	23.5	0	10	1	0	2	**64**	23	0	0	0	0
Río Espiritu Santo	15.4	0	**78**	5	0	1	13	0	0	0	0	3
Río Fajardo	18.0	4	**51**	20	0	0	22	1	0	0	0	2
Río Fajardo	19.6	3	**51**	15	0	0	29	0	1	0	0	1
Río Herrera	13.0	0	**43**	4	0	5	39	4	0	2	1	2
Río Juan Martin	3.7	0	16	13	0	0	33	**36**	0	0	0	2
Río Pitahaya	4.0	0	12	**40**	0	0	13	28	0	0	0	7
Río Pitahaya	8.2	1	32	7	0	2	**45**	11	0	0	1	1
Río Pitahaya	10.1	0	**47**	13	0	0	36	3	1	0	0	0
Río Sabana	4.1	0	**47**	22	0	0	20	9	1	0	0	1
Río Sabana	5.0	1	**66**	11	0	1	16	3	1	1	0	0
Río Sabana	7.5	0	**64**	9	0	1	22	2	0	0	1	1
Trib to Río Blanco	15.7	0	45	2	0	0	**47**	3	0	0	1	2
UT Río Mameyes	10.1	0	39	5	0	1	**44**	8	0	0	0	3
UT Río Pitahaya	9.3	0	**36**	10	0	1	32	19	0	0	1	1
UT Río Sabana	7.7	0	6	28	0	0	**49**	12	2	0	0	3

Table C4. Count of riparian land coverage type observations (n=100 per sample site; 10 transects and 10 observations per transect).

Stream	Kms to River Mouth	Riparian Count (Left)				Riparian Count (Right)			
		Agricultural	Forested	Residential	Road	Agricultural	Forested	Residential	Road
Quebrada Grande	5.9	0	0	**10**	0	1	0	**8**	1
Quebrada Juan Diego	16.0	0	**4**	**4**	2	0	0	**10**	0
Quebrada Palma	7.2	**4**	0	2	**4**	0	0	**9**	1
Quebrada Rincon	14.7	**8**	2	0	0	0	**5**	0	5
Quebrada Tabonuco	3.8	0	0	0	**10**	1	**7**	2	0
Río Canóvanas	22.0	**10**	0	0	0	0	0	0	**10**
Río Canovanillas	23.5	0	0	**10**	0	0	0	0	**10**
Río Espiritu Santo	15.4	0	**10**	0	0	0	**10**	0	0
Río Fajardo	18.0	**10**	0	0	0	**10**	0	0	0
Río Fajardo	19.6	0	**10**	0	0	0	**10**	0	0
Río Herrera	13.0	2	0	**7**	1	**7**	1	0	2
Río Juan Martin	3.7	0	**7**	3	0	0	0	**10**	0
Río Pitahaya	4.0	0	**5**	**5**	0	0	**10**	0	0
Río Pitahaya	8.2	0	**10**	0	0	0	**9**	0	1
Río Pitahaya	10.1	0	**10**	0	0	0	**10**	0	0
Río Sabana	4.1	0	0	0	**10**	0	2	**8**	0
Río Sabana	5.0	0	0	0	**10**	0	**9**	1	0
Río Sabana	7.5	0	0	**10**	0	0	0	**10**	0
Trib to Río Blanco	15.7	0	**10**	0	0	0	**10**	0	0
UT Río Mameyes	10.1	0	**10**	0	0	0	**10**	0	0
UT Río Pitahaya	9.3	0	**6**	3	1	0	**6**	4	0
UT Río Sabana	7.7	0	**9**	0	1	3	1	**6**	0