Final Project Report (03/30/16)

"Assessment of the impact of watershed restoration on marine sedimentation in the USVI"

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II. EXECUTIVE SUMMARY

Introduction and objectives

Previous research has demonstrated that terrigenous sediment derived from unpaved roads is a significant stressor to coral reefs in the US Virgin Islands. The 10.7 km^2 Coral Bay watershed was the focus of a NOAA-ARRA watershed restoration program completed in 2011, which included: sediment retention structures, road drainage improvements, and limited road paving. This project funded part of the marine monitoring component of an ongoing terrestrial-marine monitoring program with the aim to: a) assess the effectiveness of the ARRA restoration in reducing marine terrigenous sedimentation, and b) to evaluate how watershed runoff and resuspension affect marine sediment dynamics in Coral Bay, St. John, USVI. For this project we a) conducted a 3rd post-restoration season of "tube sediment trap" marine sediment monitoring and, for the first season, added additional high resolution marine sediment sampling approaches (5 nephelometers, current meters and "SedPods"). We also have integrated marine monitoring results with watershed runoff data generated by Dr. Carlos Ramos-Scharrón (funded on a separate grant) in order to link watershed runoff to short-term sediment dynamics.

Research results

Sediment trap data from 2013 were added to sediment trap data from our previous 2008/9-12 tube-sediment trap time series. The key findings of our 6-year times series of sedimentation in St. John were the following:

1. There was consistently and significantly greater marine terrigenous sedimentation at shore and reef sites below developed watersheds with unpaved roads.
2. The greatest rates of terrigenous sediment accumulation linked to major storm events, such as Hurricane Otto in October of 2010.
3. Though relatively low sediment accumulation rates (< 10 $mg/cm^2/day$) persisted for most of the time series, episodically high sediment accumulation rates on some reefs were consistent with rates shown to cause stress to corals (>50 $mg/cm^2/day$). Siltation rates were great enough to cause stress to corals for at least 1/3rd of the sampling periods.
4. At all shore stations below restored watersheds, mean post-restoration marine terrigenous sediment accumulation rates were reduced to between 18-70% of mean pre-restoration values. However, reductions were also measured at the "reference" unmitigated stations post-mitigation so ongoing monitoring and further analysis will be necessary to evaluate whether the observed post-mitigation reduction in marine sediment accumulation is related to the implementation of watershed restoration. The high variability of marine terrigenous sedimentation rates due to sediment resuspension and the low number of number of runoff-generating storms during the post-restoration period (2012-2013) has limited the statistical significance of mean pre- vs. post-restoration terrigenous sedimentation rate comparisons. A more promising approach will be i) to extend the monitoring over

additional season(s), and ii) select sampling periods with roughly equivalent rainfall patterns for pre- vs. post- restoration comparisons. These analyses are underway using data from an additional year of sampling.

To compare the spatial variability of turbidity and deposition, and evaluate how 10-minute resolution turbidity and deposition are affected by runoff and resuspension, our study monitored watershed runoff, marine turbidity and deposition using nephelometers, benthic sediment texture, tides, and wave energy at 5 shore sites and 3 reef sites during the fall of 2013. These analyses analyses supported the following conclusions:

1. Watershed development was associated with greater marine turbidity and deposition at shore sites, likely due to the greater sediment erosion and transport (sediment yield) from abundant unpaved roads in the developed watersheds.
2. Due to the high sediment availability in developed watersheds and short duration of watershed runoff events, runoff produced high-magnitude but short-term (minutes-hours) spikes in turbidity and deposition, which were up to 550mg/L and 140mg/cm^2 (900 and 17,000 times background), respectively. Due to perennial hydrodynamic energy in coastal marine areas in St. John, resuspension of benthic sediment typically resulted in lower-magnitude but long-term (hours-weeks-months) turbidity and deposition, which were up to 104mg/L and 160mg/cm^2 (60 and 4500 times background), respectively.
3. The main factors that explained the spatial variability in the magnitude of the marine sedimentary response to runoff included the degree of watershed development, watershed slope, the success of ARRA watershed restoration, and likely the presence of beach berms, while resuspension-induced turbidity and deposition were associated with hydrodynamic energy caused by waves during low tides, finer benthic sediment grain size, and also reduced macrophyte abundance.
4. Though the relative contribution of runoff and resuspension to turbidity and deposition were spatially variable between sites. Overall, sediment resuspension was a more important contributor to marine sedimentation than runoff. However, the terrigenous composition of the sediment indicates that most of the resuspended sediment is derived from the watershed. Fine sediment from unpaved roads is particularly susceptible to resuspension during typical hydrodynamic conditions. Therefore, once sediment is delivered to the marine environment, there is the potential for it to contribute to poor water quality (turbidity) and sedimentation over multiple resuspension events.
5. Nephelometer turbidity and deposition values averaged over ~26-day sediment trap deployment periods were significantly correlated with sediment trap accumulation rates at the majority of sites. While this indicates that sediment traps are effectively recording relative changes in sedimentation over longer periods, sediment traps still cannot record important short time-scale variability in turbidity or deposition.

This is the first study to use a high resolution monitoring to directly compare turbidity and deposition data collected from below developed and minimally developed watersheds, and to separate resuspension induced turbidity and deposition from runoff-induced turbidity and deposition. Additionally this is the first study to show that time-integrated sediment trap data are consistent with high-resolution turbidity and deposition data at recording the relative temporal changes in sedimentation between sampling period.

The results of this study will help us to better understand the relative contribution of resuspension of benthic sediments vs. terrigenous runoff in affecting marine turbidity and sediment deposition in St. John. While current management policies have been focused on reducing sediment-laden runoff during storm events, the findings of this study may influence management decisions by revealing the role of sediment resuspension in reducing water quality. This study demonstrates the efficacy of time-integrated (monthly resolution) sediment trap monitoring approaches. The Coral Bay watershed restoration and monitoring program may serve as a case study on how to develop effective management and monitoring strategies that may be applied to other areas with similar ephemeral hydrologic behavior.

Outreach

From 7/25/13-3/6/16, we conducted 41 outreach activities. Outreach activities included a) educational outreach to K-12, adults, and college students, b) meetings with collaborators and local environmental mangers, c) published articles in online newspapers and web sites, d) scientific abstracts and presentations at professional meetings, and e) submittal of proposals for projects which build off of this work. Through these activities we reached at least 695 people, including USVI locals, students at all levels, the general public, international scientists and both USVI and international management communities. Products from this grant (see next section) include four journal articles (in preparation), 15 professional meeting abstracts & presentations, one Master of Science theses (to be completed in summer of 2016), one undergraduate research project, two expert witness reports for the local environmental management entity, and three awarded grants for continued work totaling $134,986 with $100,470 in matching funds.

III. INTRODUCTION AND PROJECT OBJECTIVES

From 2008-present, NOAA CRC and ARRA have funded our research team to monitor sedimentation (using tube traps) every 26 days directly below the sites of ARRA watershed restoration projects and in adjacent unrestored and undeveloped "reference" sites for comparison. For this NOAA award our aim is twofold:

1) to complement a 3rd post-mitigation season of "tube sediment trap" marine sediment monitoring (paid for by the non-competitive NOAA grant) with additional approaches (5 nephelometers, current meters and "SedPods") to assess sediment dynamics as a result of terrestrial processes, and
2) to synthesize the marine monitoring results and integrate them with watershed data and modeling results generated by Dr. Carlos Ramos-Scharrón (through a separate grant.

IV. RESEARCH ACTIVITIES

A. Field work and Laboratory Analysis

Our ongoing research in St. John has focused on comparing sedimentation below developed watersheds in CB to undeveloped "reference" sites. These "reference" sites include: a) locations in Great and Little Lameshur Bays (LB) within the VI National Park (Fig. 1) and b) sites below watersheds with limited or no development in CB (Plantation) (Fig. 1). Though the end of the field season funded on this grant (July 2013-Jan. 2014) our USD research team monitored sedimentation/water quality (at regular intervals of approximately every 26 days) for six rainy (Jun-Dec) seasons in Coral Bay and seven seasons in Great and Little Lameshur Bays at 15 sites below 6 sub-watersheds on St. John (Fig. 1).

Sediment trap monitoring & field assistant training

In June of 2013, after setting up the sampling stations, repairing the sediment traps, and setting up the VIERS (Virgin Islands Environmental Resource Station) research lab, we trained field assistant Heidi Hirsh to conduct the field sampling and sediment processing protocols. From June '13-Jan. '14, Heidi Hirsh, collected water and sediment samples at regular intervals (approximately every 26 days) and exchanged our instruments with the help of three local field assistants: Emily Wilson, Roy Proctor, and Phil Strenger.

The variation in total and terrigenous sediment accumulation was determined by deploying sediment trap arrays. For each of the eight collection periods in 2013, sediments (suspended, trapped, and bottom) and water samples were processed at the VIERS laboratory. Following processing in the VIERS laboratory, dried and frozen sediments and water samples were sent to the University of San Diego for further geological analyses. Rain data were also collected from a rain gauge deployed on the roof of the VIERS laboratory (Fig. 1).

Laboratory methods followed previously published protocols[1,2]. Sediments accumulated in the sediment-trap tubes were filtered (< 3 microns), dried and weighed to determine the mass of sediment accumulated per unit area over the time deployed. The % organic matter, carbonate and terrigenous sediment in each sample were determined by Loss on Ignition (LOI)[3]. The proportion (%) of terrigenous sediment was then multiplied by the sediment trap accumulation rate to get the rate of terrigenous sediment accumulation (in $mg/cm^2/day$) in the trap tubes.

Nephelometer and current meter testing and deployment

[1] Gray, S.C., Sears, W.T., Kolupski, M.L., DeGrood, A.M., and Fox, M.D. (2012). Factors affecting land-

[2] Edmunds, P.J., and Gray, S.C. (2014). The effects of storms during 2010 on the shallow reefs of St. John, US Virgin Islands. *Hydrobiologia*.

[3] Heiri OF, Lotter F, Lemke EG (2001). Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. *Jour of Paleolimnol* 25:101-110.

On July 20th, 2013, P.I. Gray and her research team, including her new graduate student, Stephen Campbell, and undergraduate researcher, Tyler Barnes, arrived in the USVI for a 20-day field season at VIERS in St. John. From 7/20/13-8/9/13 the main focus of their activities was to construct deployment housings and test and deploy instrument packages for high-resolution sediment and turbidity monitoring. Each of the instrument packages consisted of one nephelometer and two Marrotte current meters rented from the James Cook University Marine Geophysical Laboratory (http://www.jcu.edu.au/marinephysics/instruments/index.htm). These instruments measure deposition, turbidity, currents and swells at high temporal resolution (minutes). The eight instrument packages were deployed at eight of the sediment-trap long-term monitoring sites (Fig. 2; Table 1).

During the July-August field season, we built and tested the meter deployment platforms and set up the software and logistics to test these instrument packages in the field. Unfortunately, many of the nephelometers were damaged during shipping from Australia so we had to repair them (Fig. 3). The instruments were deployed on platforms that consisted of concrete blocks with steel fence posts (Fig. 3, 4, and 5). They were deployed such that they measured deposition and turbidity at the same height above the sea floor as the sediment traps (60 cm above the sea floor) and were placed within about 5 m of the sediment traps (Fig. 8). The Marrotte current meters were also mounted on fence posts that were either hammered into the substrate or attached to a concrete block footing (Fig. 5).

The nephelometers and Marrotte current meters were deployed in Coral Bay and Lameshur Bay at three reef and five shoreline sampling sites (Fig. 2, Table 1). The shore deployment sites were strategically located near the outfall of ephemeral streams (ghuts) where Dr. Carlos Ramos-Scharrón is monitoring runoff timing and magnitude using crest gauges (Fig. 2, Table 1). These near-shore instrument packages were deployed below sites of ARRA restoration as well as below un-restored or undeveloped “reference” sites for comparison.

The downloaded data was sent to the James Cook University Marine Geophysical lab for processing after each deployment. The instruments were collected at the end of the 2-13 fall field sampling period on 12/30/13 and 1/4/14.

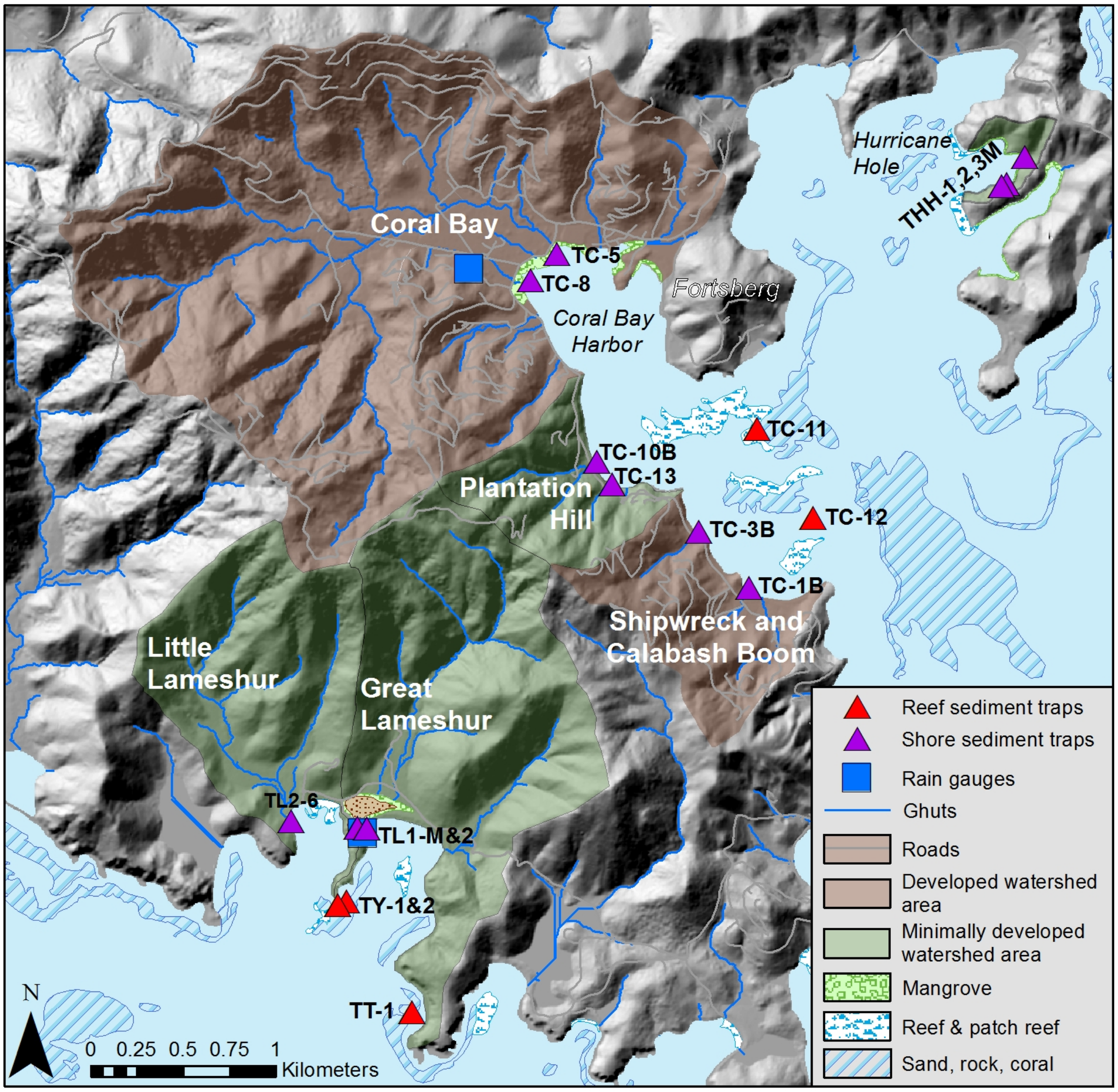

***Figure 1**. Study area in eastern St. John showing the Coral Bay, Lameshur Bay, and Hurricane Hole areas. Developed and minimally-developed watershed areas are shaded in brown and green, respectively. Marine monitoring sites in shore (purple triangles) and reef (red triangles) environments are shown.*

Site Name	Site ID	Latitude	Longitude	Water Depth (m)	Environment	Watershed Classi-fication	Sed. trap deployment date	Nephelo-meter package?**	Gut-outfall crest gauge Site ID
GREAT AND LITTLE LAMESHUR BAYS									
G. Lameshur Mangrove	TL1-M	18.31875	-64.72462	0.7	Mangrove	U	Aug-09		
G. Lameshur	TL1-2	18.31872	-64.72413	0.5	Shore	U	Aug-07	Yes	
E. Yawzi Reef	TY-1	18.31517	-64.72520	6.1	Reef	U	Aug-07	Yes	
W. Yawzi Reef	TY-2	18.31502	-64.72567	7.6	Reef	U	Aug-07		
Tektite Reef	TT-1	18.30975	-64.72192	7	Reef	U	Aug-09		
Little Lameshur	TL2-6	18.31910	-64.72802	1.35	Shore	U	Aug-07	Yes	LL1
CORAL BAY									
Calabash Boom	TC-1B	18.33025	-64.70453	1	Shore	DR	Aug-08		CAL
Shipwreck	TC-3B	18.33300	-64.70707	1.6	Shore	DR	Aug-09	Yes	SWM3
Coral Harbor North	TC-5	18.34658	-64.71415	0.6	Mangrove/bay	DR	Aug-08	Yes	CBM1
Coral Harbor South	TC-8	18.34533	-64.71552	0.6	Mangrove/bay	DR	Aug-08		CBM2/CBM3
Plantation Hill North	TC-10B	18.33645	-64.71222	1.3	Shore	U	Aug-09	Yes	SGM6
Plantation Hill South	TC-13	18.33537	-64.71145	1	Shore	U	Aug-10		NN6
North Reef	TC-11	18.33797	-64.70402	7	Reef	DR	Aug-09	Yes	
South Reef	TC-12	18.33363	-64.70120	11	Reef	DR	Aug-09	Yes	
HURRICANE HOLE									
Otter Creek West Mangrove	THH-1B	18.34980	-64.69118	1.8	Shore	U	Aug-09		
Otter Creek West	THH-2	18.35108	-64.69023	1.5	Shore	U	Aug-09		
Otter Creek East	THH-3M	18.34970	-64.69142	1	Mangrove	U	Aug-10		

* Watershed draining to marine monitoring station is "U", undeveloped or minimally developed or "DR" developed with some ARRA restoration projects.

** Nephelometer instrument package includes one nephelometer, and two Marott current meters.

Table 1. *Location, characteristics, and deployment date at marine monitoring sites where sediment traps have been deployed. Nephelometer packages (1 nephelometer and 2 Marotte current meters) have been deployed at 8 of the sites. The site ID for ghut outfall (shoreline) crest gauges which correspond to 7 of the shoreline marine monitoring stations are indicated.*

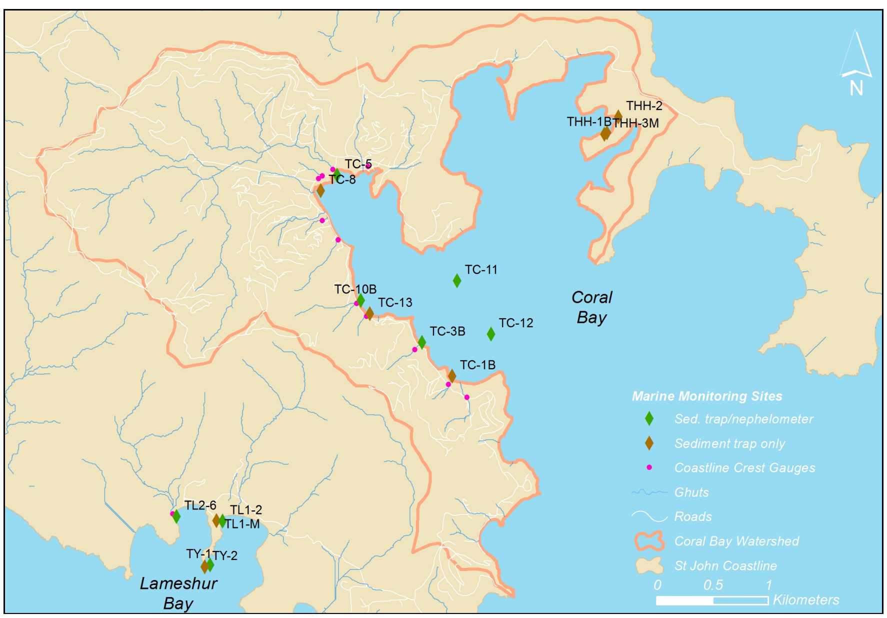

Figure 2. *Map showing the marine monitoring locations (diamonds) with sediment traps and corresponding coastal crest gauges (pink dots). Instrument packages (nephelometer and 2 Marotte current meters) are deployed adjacent to the sediment traps and are located at 8 sites (marked by green diamonds).*

SedPod construction and deployment

Twelve SedPods were constructed at USD in June and early July of 2013 following specifications outlined in Field et al., 2012[4] (Fig. 6). They were sent to VIERS in the USVI where they were cemented and deployed at three reef stations (TY-2, TC-11 and TC-12 [Fig. 1; Table 1]) (Fig. 7). Two SedPods were deployed at each site on cinder blocks such that the SedPod was deployed at the approximate height of the sediment traps and the instrument packages (60cm above the seafloor) (Fig. 7 & 8). Our field testing of these traps during the 2012 field season revealed that it was necessary to deploy two of them at each site in order to obtain enough sediment for later compositional analysis.

The sediment traps were changed and the sediment recovered every 26-day sediment trap sampling period. Thus, there were 8 SedPod recoveries between Aug.-Dec. 2013. Sediment on the SedPods was removed by spraying the surface with jets of water. The recovered sediment was filtered, dried and weighed and the sediment sent back to the University of San Diego for further compositional and textural analysis.

Watershed monitoring by UT Austin collaborators

Watershed runoff data from peak crest gauges and a stream gauge were collected and analyzed by collaborators Dr. Carlos Ramos-Scharrón of UT Austin and Dr. Mathew LaFevor of University of Maryland. Peak crest gauges provided low temporal resolution (~13-day) data on the frequency and magnitude (maximum depth of flow) of runoff events at four ephemeral stream outfalls adjacent to marine shore sites. Data from the crest gauges were collected approximately every 13 days or after each rain event exceeding 2cm of rainfall, from August 20th, 2013, through mid January, 2014, and were located in ephemeral stream beds adjacent to the three shore sites in Coral Bay, and shore site L2-6 in Little Lameshur Bay. The stream gauge was a water level sensor which autonomously collected high-resolution (10-minute) stream-flow data of every runoff event from September 21st, 2013, through December 2013, and was located near an ephemeral stream outfall adjacent to the Shipwreck marine sampling site (C-3B) (Fig. 1). The stream gauge measured electro-conductivity, which was calibrated to determine depth of flow.

[4] Field, M.E., Chezar, H. and C. D. Storlazzi. 2012. *Coral Reefs*: 32:155-159

Figure 3. *Before the nephelometers (blue cylinders above) could be deployed, they had to be repaired and tested. Marrotte current meters (or "lollypop") shown with yellow bulbs on the table below also needed to be tested.*

Figure 4. *Concrete base housings were taken to the seafloor and then nephelometers attached using zip ties. The nephelometers and Marrotte current meters were deployed within 5 meters of the sediment traps (below right).*

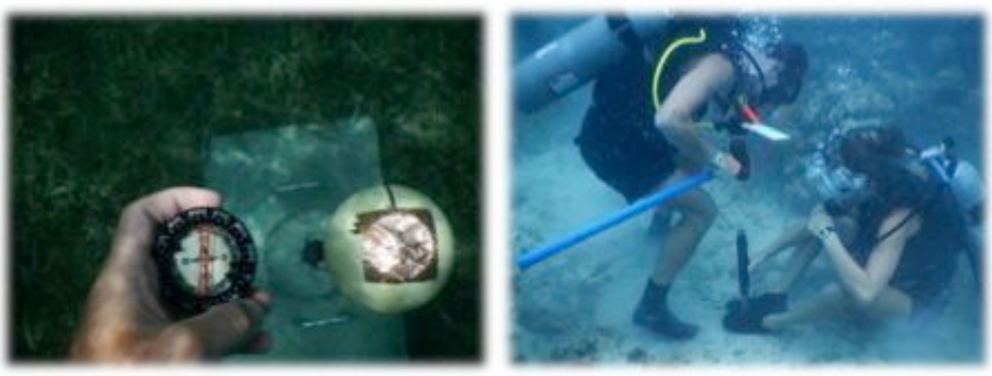

Figure 5. *The Marotte current meters were deployed on fence posts or concrete footings (left) or hammered into the sea floor (right). Their bulbs need to be oriented such that the black line is north.*

Figure 6. *Graduate student Stephen Campbell prepares to open a recovered SedPod (left); SedPod and lid (right).*

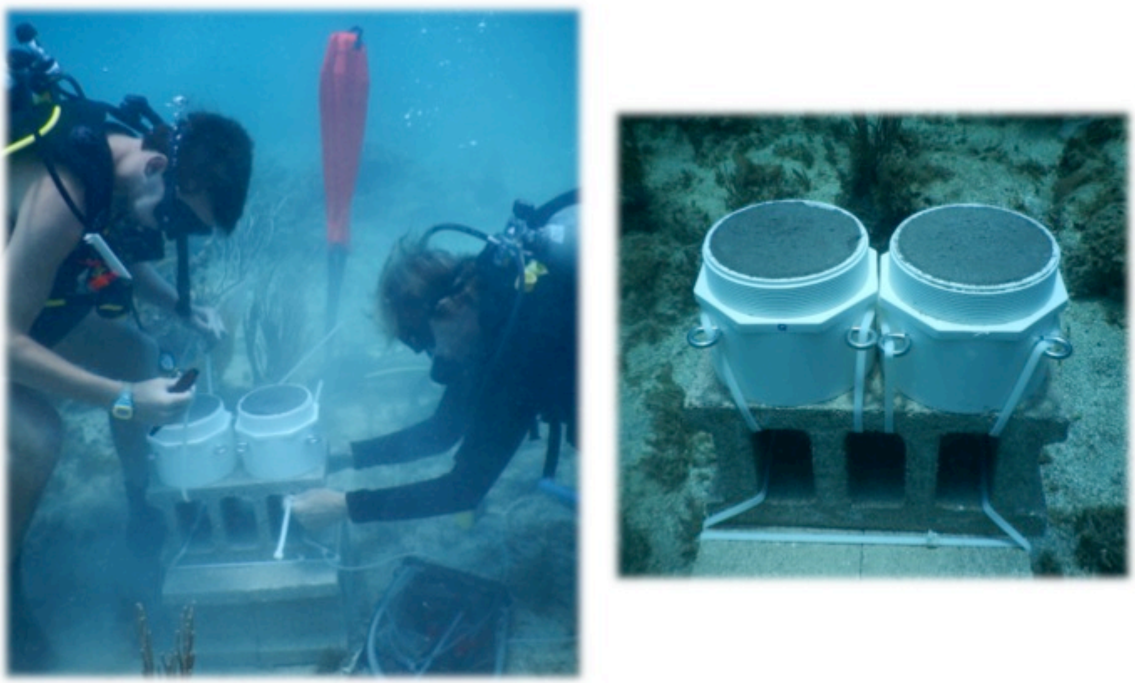

Figure 7. *Two SedPods were deployed at each of three reef sites (TC-11, TC-12, TY-2 [Fig. 1; Table 1]) on concrete blocks such that the top was at the same height as the nephelometers and sediment traps (60 cm above the sea-floor).*

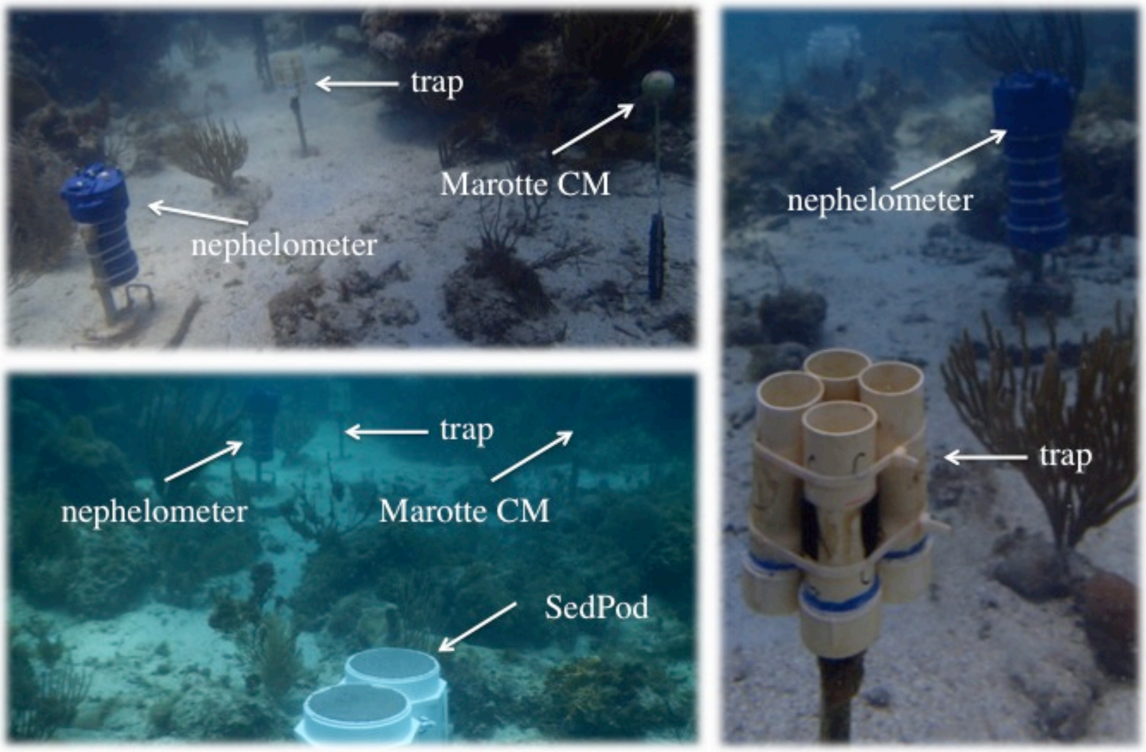

Figure 8. *Instruments and sediment traps deployed at the Yawzi coral reef site (TY-1 [Fig. 1; Table 1]).*

B. Data synthesis

Data from the sediment traps and SedPods have been synthesized for 2013 and integrated inter the longer (2009-14) time series of variations in sediment composition, texture and accumulation rates. The data collected on this grant (2013-14 rainy season) were added to baseline and previous data and analysis of rainfall and storms to compare marine sedimentation pre- vs. post- restoration below the sites of ARRA restoration in the untreated (undeveloped/unmitigated) areas.

USD graduate student Stephen Campbell is completing his Masters of Science thesis using data from this project (to be completed in the summer of 2016). This work has focused on interpreting the fall 2013 nephelometer data and integrating it with terrestrial data collected by our collaborator Dr. Carlos Ramos-Scharrón of UT Austin. The specific goals of his study are to: a) compare the spatial and temporal variability of turbidity and deposition (10-minute resolution) in response to runoff and resuspension; b) investigate the factors that influence turbidity and deposition; and c) compare two marine sediment monitoring approaches (sediment traps [monthly resolution] vs. nephelometers [10-minute resolution]).

A stream gauge (10-min resolution) deployed adjacent to the Shipwreck site provided high resolution temporal data which allowed us to identify periods of runoff in order to characterize the spatial variability in the magnitude of turbidity and deposition in response to runoff. To make comparisons between runoff and non-runoff periods, nephelometer turbidity and deposition data from each site were separated into runoff and non-runoff periods based on the peak crest gauge (~13-day resolution) data from each. Because the timing of runoff and non-runoff periods varied between sites, to make inter-site comparisons, it was necessary to identify and focus on periods when all sites were determined to have runoff or no runoff.

To compare benthic sediment texture to turbidity at each site, the percent benthic sediment less than 63μm from the five collections were averaged. Nephelometer turbidity data from each site were averaged to determine the mean turbidity during the time series for each respective site. 10-minute resolution runoff stage data from the stream gauge deployed at Shipwreck was used to bin nephelometer turbidity and root mean square (RMS) water height (a proxy for wave energy) data from the Shipwreck marine sampling site into runoff and non-runoff periods. A runoff period was defined to start when the first signal of runoff was detected by the stream gauge, and a runoff period was defined to end three hours after the last runoff signal was detected from the stream gauge. The inclusion of a three-hour window after runoff stopped was to account for the lingering affect runoff has on turbidity and deposition, as sediment introduced during a runoff event is not immediately advected away from the site or does immediately deposit on the seafloor at the conclusion of the runoff event. Non-runoff periods were defined to start at the conclusion of a runoff period (three hours after the last runoff signal) and end at the start of the next runoff period (when runoff is first detected by the stream gauge). RMS water height values were compared to turbidity values during both runoff and non-runoff periods.

To compare time-integrated sediment trap accumulation data to high-resolution nephelometer turbidity and deposition data, the total sediment mass from each respective sediment trap was divided by the deployment duration and the area of the tube opening to determine the sedimentation rate in $mg/cm^2/day$. The turbidity and deposition data from each nephelometer were grouped and averaged according to the deployment interval of the corresponding sediment trap, to determine the average turbidity in mg/L and average deposition in mg/cm^2 over the course of the sediment trap deployment. To quantify the relationship between the two monitoring approaches, a Pearson R Correlation test was used to compare the average sedimentation rate from sediment traps with the average turbidity and deposition at each site.

C. Research Findings

Rainfall

Rainfall data collected in Lameshur Bay using our rain gauge deployed at the VIERS lab (Fig. 9) revealed that June-October of 2013 was relatively dry compared to the last 5 years (Fig. 9B) with moderate storm activity in November and December. The greatest cumulative daily rainfall was recorded in Lameshur Bay on Nov. 21st, 2013 (Fig 9A). In spite of some of gaps in data collection at some locations, however, the instruments were freshly deployed at key shoreline locations and collecting data when the largest rain event occurred on 11/21/13. At least two other moderate acute runoff/rainfall events were also captured in the instrumental data (12/1/13 & 12/24/13). In Coral Bay, the major rainfall event (11/21/13) occurred in conjunction with spikes in turbidity at two of the three shore sites and one of the two reef sites, and spikes in deposition at all three shores sites and one of the reef sites. The timing of the moderate rainfall events also corresponded to spikes in turbidity at the two shore sites and the one reef site, and spikes in deposition at one of the two reef sites. The data show that the deposition/turbidity plume dissipated quickly (within a few hours to days).

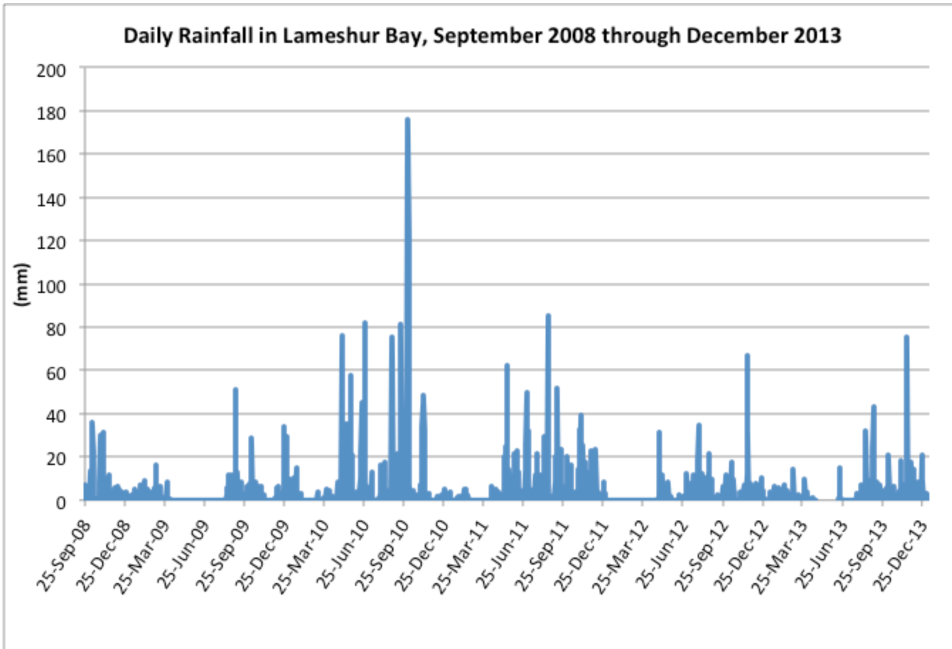

Figure 9A. *Cumulative daily rainfall recorded in Lameshur Bay, St. John, USVI between Sept. 2008-Dec. 2013. The peak rainfall recorded during the fall of 2013 was on Nov. 21st 2013 when mean daily rainfall in Lameshur Bay reached 75 mm.*

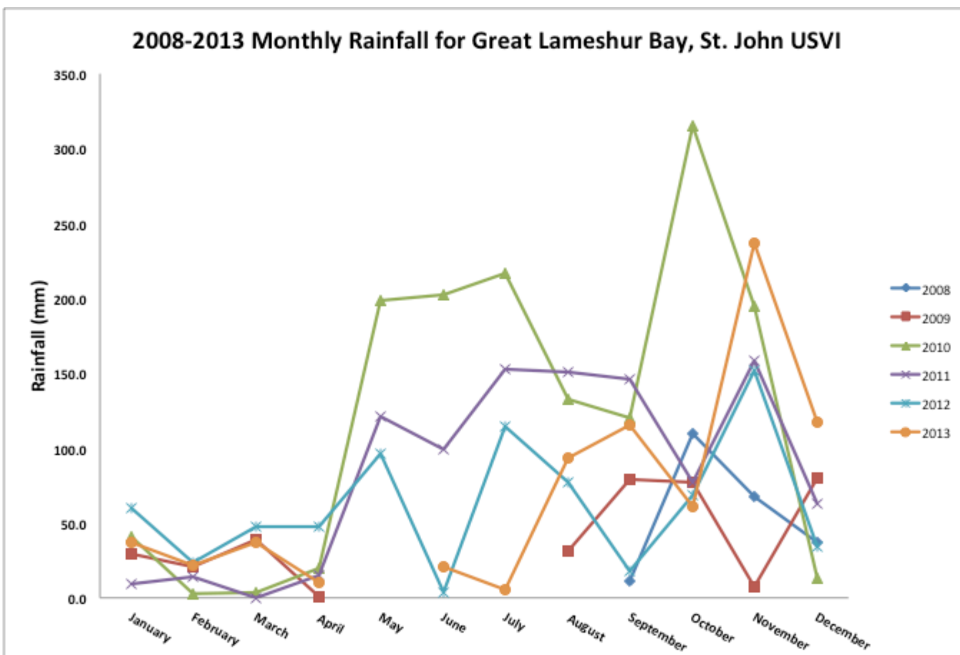

Figure 9B. *Monthly cumulative rainfall data collected at Lameshur Bay, St. John, USVI for 2008-13. 2013 was relatively dry until November of 2013.*

Marine sedimentation (2007-13)

Sediment trap data from 2013 were integrated with sediment trap data from the 2008/9-12 time series to complete a 5/6-year time series. These data lead to the following key findings:

- There were consistently and significantly greater marine terrigenous sedimentation at shore and reef sites below developed watersheds with unpaved roads (Fig. 10A)
- The greatest rates of terrigenous sediment accumulation linked to major storm events, such as Hurricane Otto in October of 2010.
- Though relatively low sediment accumulation rates (< 10 $mg/cm^2/day$) persisted for most of the time series, episodically high sediment accumulation rates on some reefs were consistent with rates shown to cause stress to corals (>50 $mg/cm^2/day$) (Fig. 10B).

At all shore stations below restored watersheds, mean post-restoration marine terrigenous sediment accumulation rates were reduced to between 18-70% of mean pre-mitigation values. However, reductions were also measured at the "reference" unmitigated stations post-mitigation so ongoing monitoring and further analysis will be necessary to evaluate whether the observed post-mitigation reduction in marine sediment accumulation is related to the implementation of erosion control.

Comparisons between marine monitoring methods

For six ~26 day sampling periods at three coral reef sites (n =18), the texture, composition, and total and terrigenous sediment accumulation rates were compared between SedPods and tube traps. Tube sed. trap grain texture was always finer (Fig. 11), the composition was similar (Table 2), and total and terrigenous accumulation rates were always greater than for SedPods (Table 2, Fig. 12). Comparison between sampling periods for different monitoring methods suggest that over the time scale of our sampling periods (~ 26 days), tube sediment traps are recording relative temporal changes in sedimentation that are consistent with other methods (nephelometers and SedPods) (Fig. 13).

Mean nephelometer turbidity and deposition values averaged over ~26 day sediment trap deployment periods were significantly correlated with sediment trap accumulation rates (Pearson R Correlation values ranged from 0.75 to 0.99). Though it's been suggested that the effectiveness of sediment traps to provide quantitative information are limited, these data confirm that sediment traps closely mirrored data collected by nephelometers. However, one limitation of sediment traps is that they cannot record high-resolution variability in deposition and they do not measure turbidity.

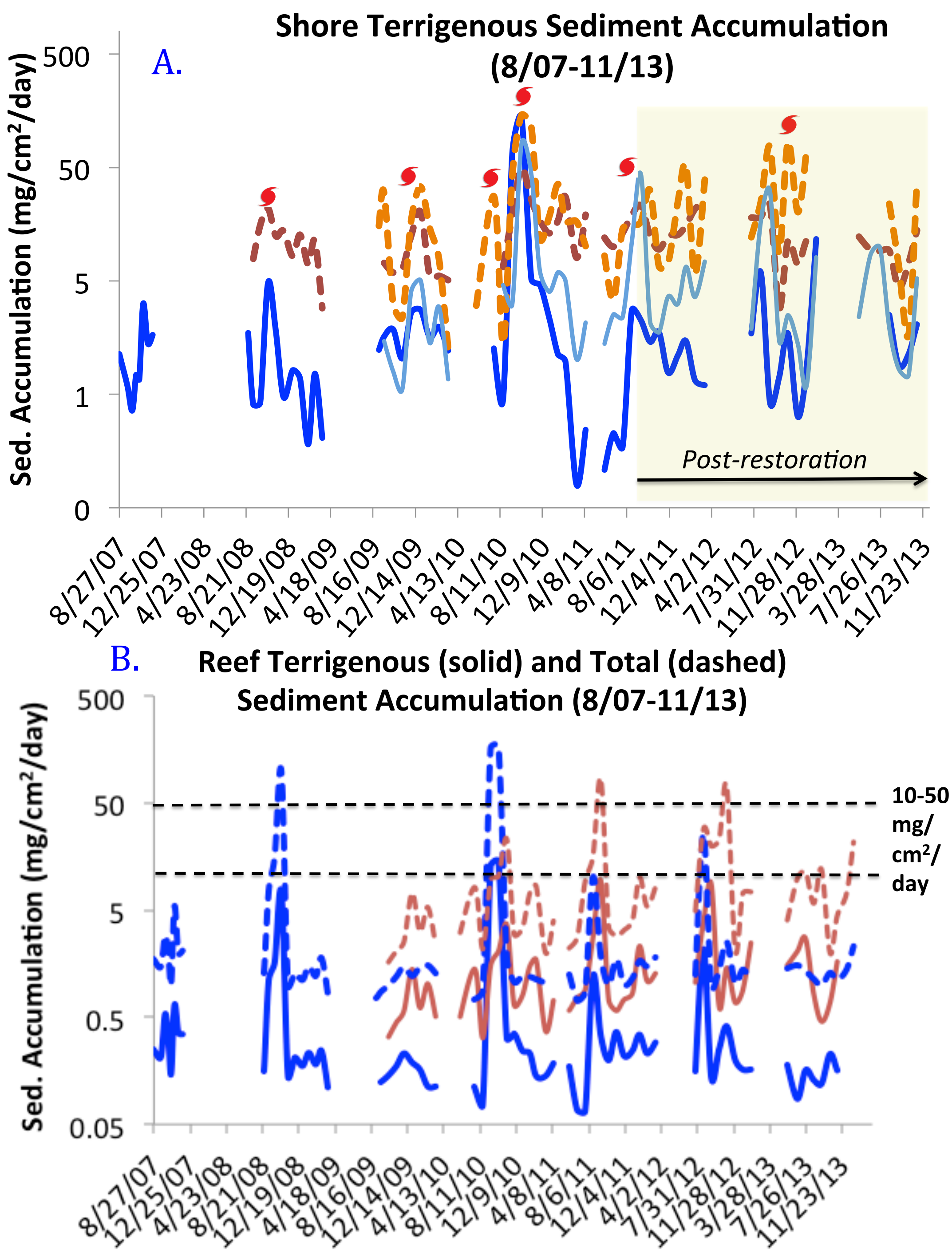

Figure 10*: Temporal variability (8/07-12/13) in (**A**) terrigenous sediment accumulation in shore and (**B**) mean total (dashed) and terrigenous (solid) sediment accumulation at reef sites below developed (dashed) and reference (solid, asterisk) locations. Major runoff events are indicated by the storm symbols and the post-ARRA watershed restoration period in yellow.*

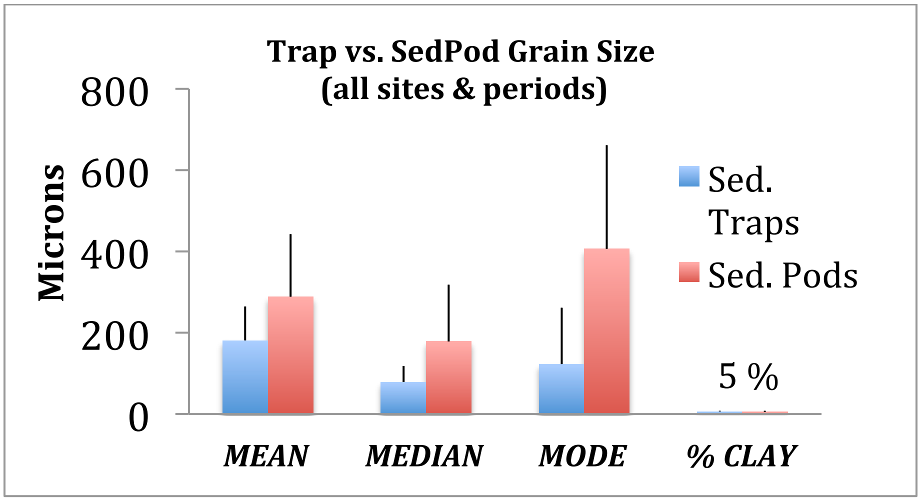

Figure 11. *Comparison of mean textural parameters between SedPods and tube sediment traps.*

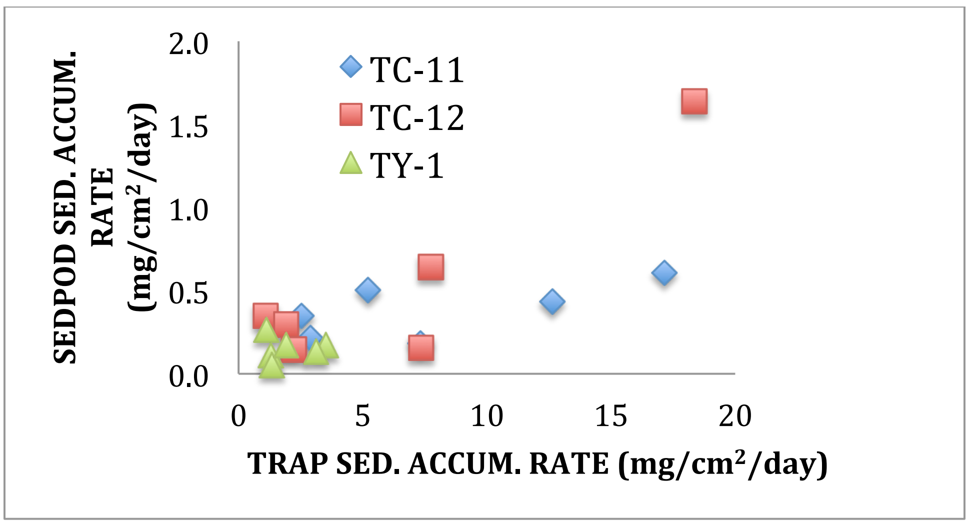

Figure 12. *Sediment accumulation rate for sediment traps vs. SedPods.*

	% Organic		Ratio	% Terrigenous		Ratio
	TRAP	*SEDPOD*	*TRAP/SEDPOD*	*TRAP*	*SEDPOD*	*TRAP/SEDPOD*
Mean	12.9	13.6	1.02	20.8	27.8	0.82
SD	3.7	5.3	0.28	6.9	11.6	0.27
	Sed. Accum. Rate			Terr. Accum. Rate		
	(mg/cm2/day)		Ratio	(mg/cm2/day)		Ratio
	TRAP	*SEDPOD*	*TRAP/SEDPOD*	*TRAP*	*SEDPOD*	*TRAP/SEDPOD*
Mean	5.5	0.4	17.7	1.2	0.1	15.1
SD	5.4	0.4	12.2	1.4	0.1	10.8

Table 2. *Comparison of composition and sediment accumulation rate between SedPods and tube sediment traps.*

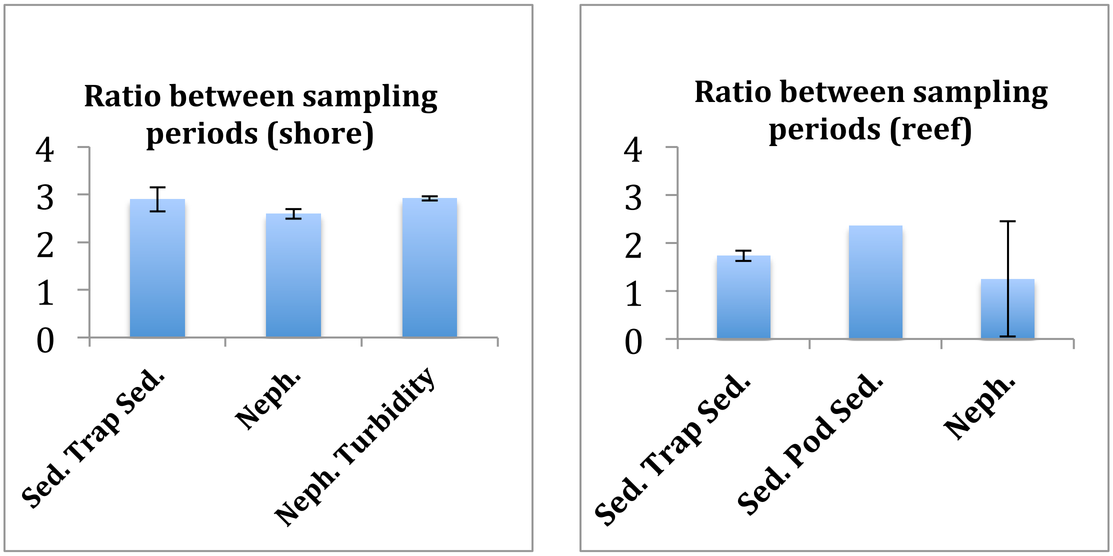

Figure 13. *Ratios comparing sedimentation and turbidity in the shore (left) and reef (right) between two sampling periods for different methods.*

Spatial Variability of Turbidity and Deposition

The median and maximum turbidity and deposition at shore sites were 3 (med.) and 9 (max.) times greater than at the reef sites due to their a) close proximity to stream outfalls, b) greater wave energy and c) finer benthic grain sizes (Figs. 14, 17). Median and maximum turbidity and deposition were greater below developed watersheds (Fig. 14, Table 3) due to the high density of unpaved road in developed watersheds, which deliver fine sediment to the marine environment. Median turbidity only exceeded Class B water quality at the Coral Bay site.

	DEVELOPED_1/MIN. DEVELOPED_1		DEVELOPED_2/MIN. DEVELOPED_2	
	Turb.	**Dep.**	**Turb.**	**Dep.**
MEDIAN	2	2	18	3
MAX	12	17	5	7

Table 3. *Ratio of median and max turbidity and deposition below pairs of comparable developed and minimally developed watersheds (Left$_1$: Shipwreck/Sanders; Right$_2$: Coral Bay/Lameshur).*

Sedimentary Response to the Largest Runoff Event

On 11/21/13, 86mm of rainfall over 9 hours triggered sediment runoff, which produced spatially variable short-duration (hours) spikes in turbidity/deposition (up to 900/17,000 times pre-runoff) at the shore but not the reef sites (Fig. 15). Turbidity spikes below the developed watersheds were up to 56 times greater than below the undeveloped watersheds, most likely due to unpaved roads, which provide a source of easily erodible fine sediment. The second runoff pulse (6:53AM), which was almost as large as the first (3:33 AM) produced a dampened turbidity plume. Although time-series median turbidity/deposition was 6 times greater at Coral Bay than at Shipwreck (Fig. 14), the runoff induced turbidity/deposition peak was 16/1.5 times less than at Shipwreck (Fig. 15). This is consistent with evidence that a) resuspension is a more important process than runoff at Coral Bay, and b) that recent (2011) watershed restoration activities reduced terrigenous runoff from Coral Bay but increased runoff at Shipwreck (due to channelization of sediment through the ephemeral stream). Differences in watershed slope may also have contributed to variability in the sedimentary response between sites.

Runoff vs. Non-runoff (Re-suspension)

To compare turbidity/deposition between runoff and non-runoff periods, data were binned into 7-13 day "non-runoff" and "runoff" periods according to the peak crest gauge data. "Runoff" periods included contributions from both runoff and resuspension, while non-runoff periods only included contributions from resuspension. Median runoff turbidity was over 2.5 times greater than non-runoff turbidity at all sites except Coral Bay and the reefs (Fig. 16), and the maximum turbidity and deposition measurements were greater during runoff periods at all sites (Fig. 16). This result is consistent with a) greater resuspension and reduced runoff induced turbidity/deposition at Coral Bay and the reef sites.

Other Factors Affecting Turbidity

Turbidity was greater at sites with finer-grained sediment (percent silt & clay [<63µm]) because fine grains are more easily resuspended (Fig. 17). However, at some sites, macrophytes (sea grasses) may have reduced the potential for resuspension of fine grains. Minimum turbidity measurements during both "runoff" and "non-runoff" periods appeared to increase with increasing wave energy (RMS water height) (Fig. 18). Above an RMS water height of ~0.10m, turbidity exceeded Class B water quality, but only exceeded ~100 mg/L during runoff events (Fig. 18). Tidal fluctuations were associated with prolonged turbidity cycles that far exceeded Class B water quality standards over days to weeks (Fig. 19). During low tide, greater wave orbital velocities make contact with the seafloor and resuspend benthic sediment.

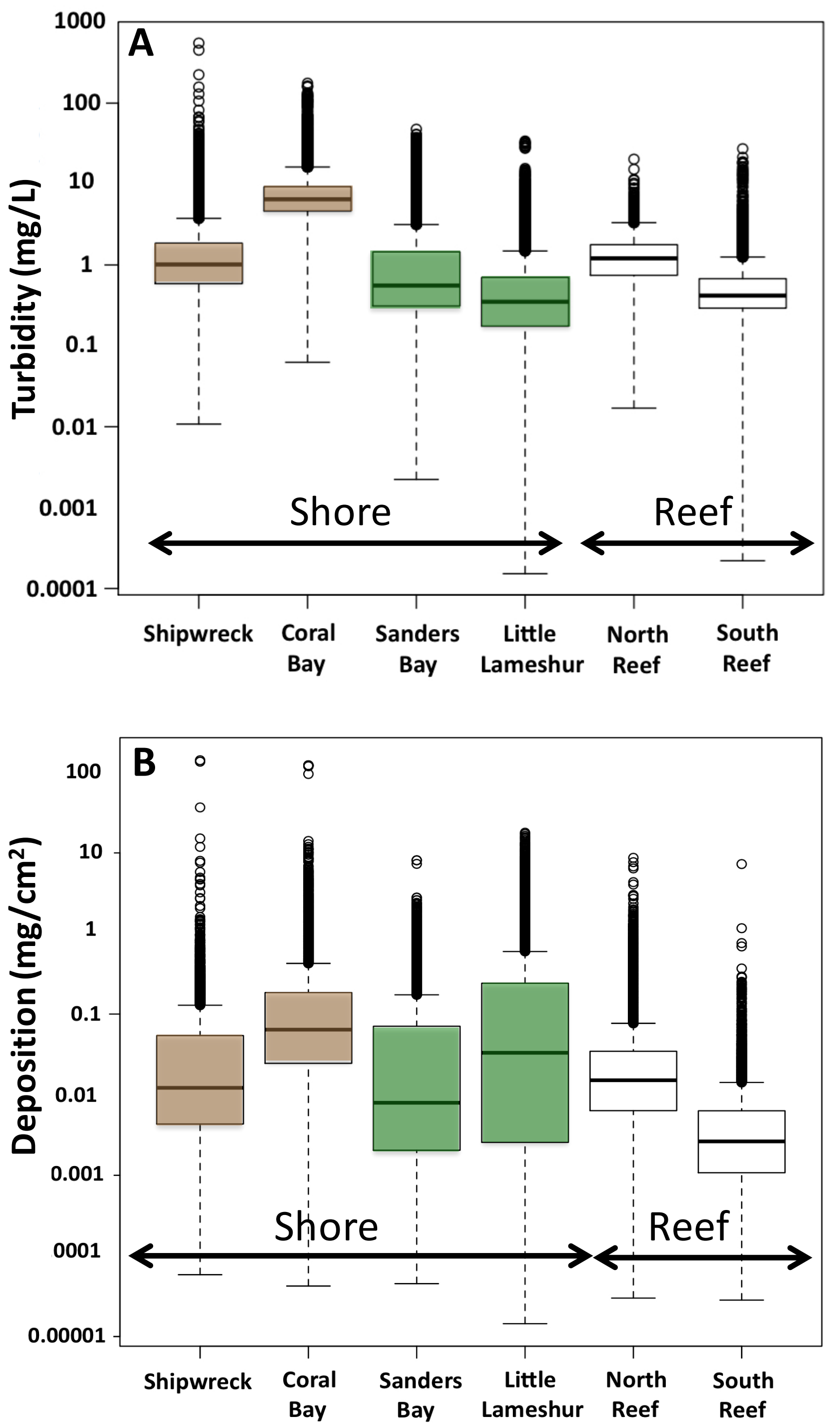

Figure 14. *Median turbidity (A.* ***top****) and deposition (B.* ***bottom****) at developed (brown) and minimally developed (green) shore and reef sites. Boxes indicate 25th and 75th percentiles, whiskers indicate minimum and maximum values; circles indicate outliers.*

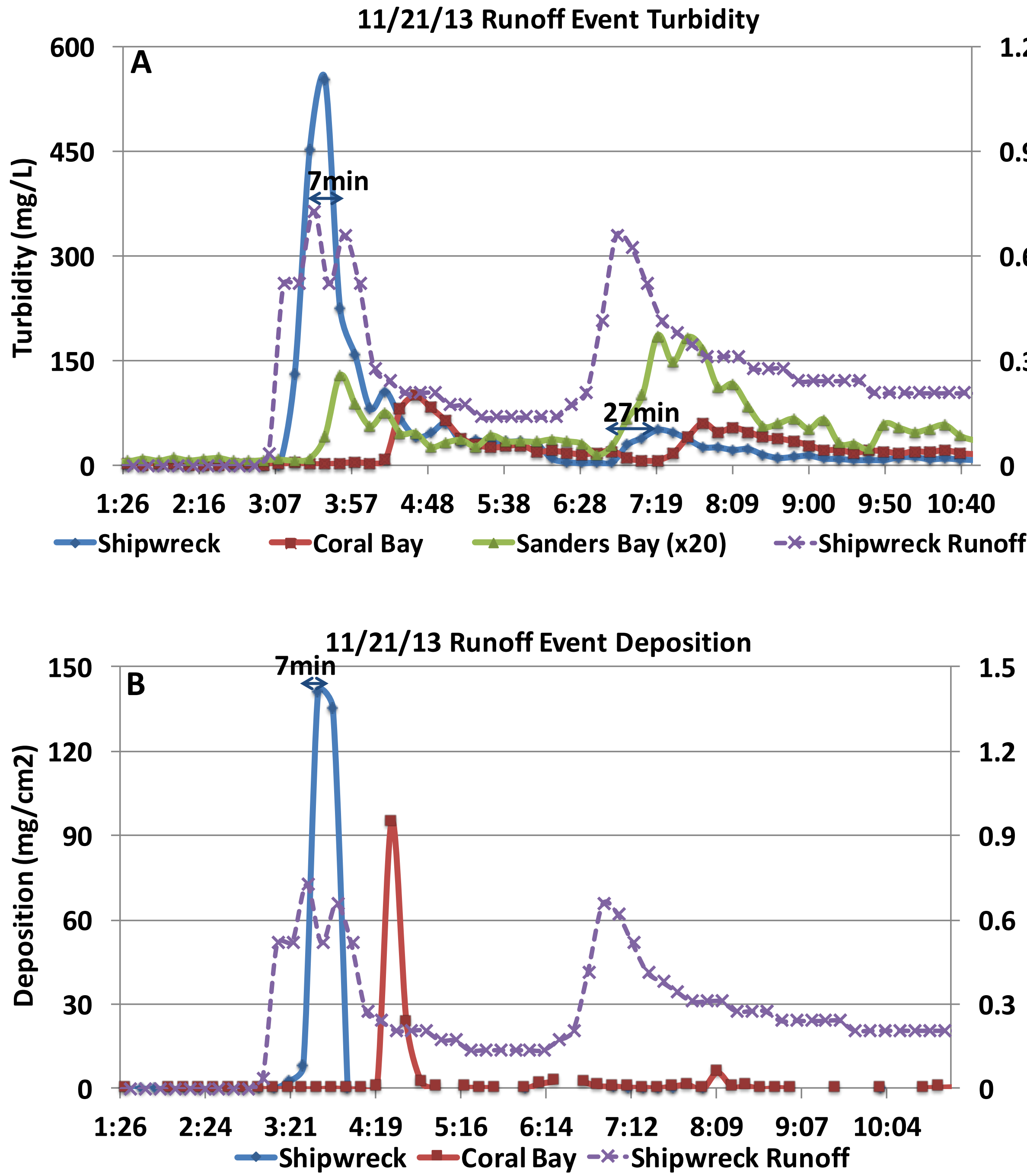

Figure 15*. Turbidity (****A top****) and deposition (****B bottom****) at shore sites, and Shipwreck runoff stage height vs. local time during the 11/21/13 runoff event.*

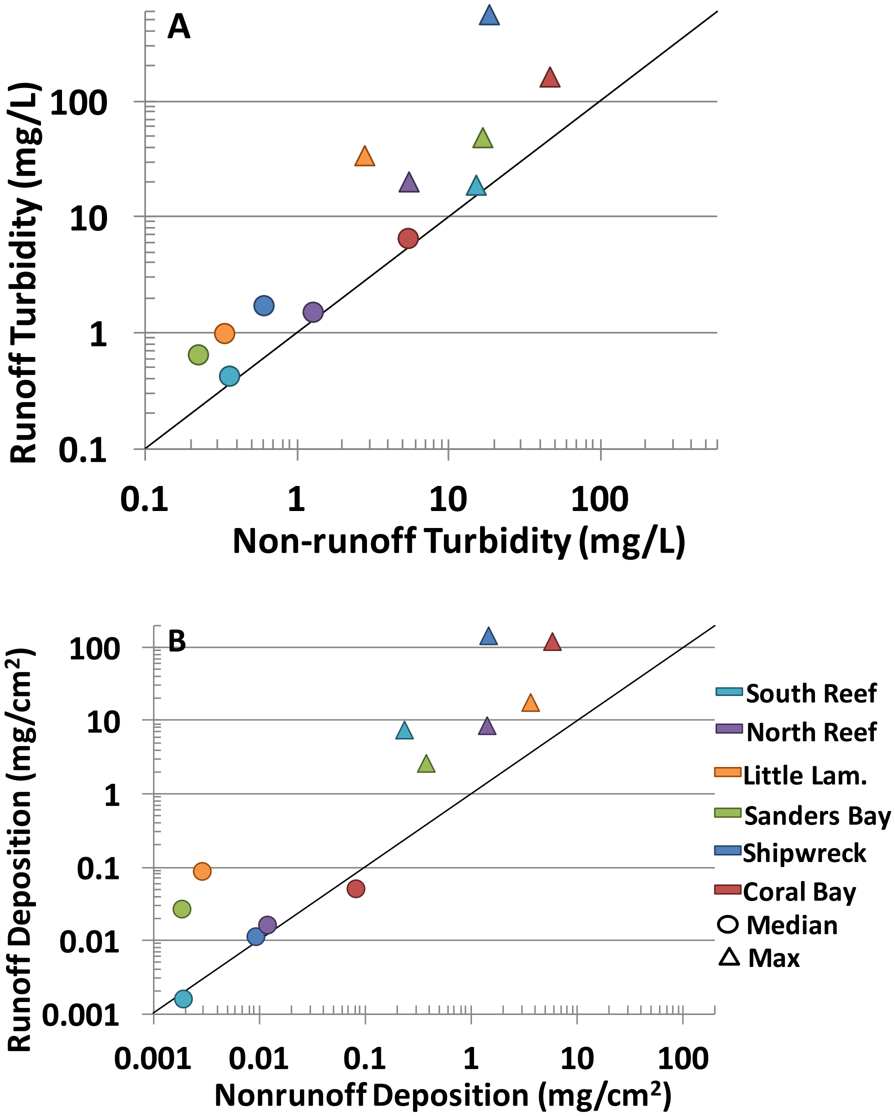

Figure 16. *Median and max turbidity (**above**), and deposition (**below**) during crest gauge defined runoff and non-runoff periods at shore and reef sites, and an x=y line.*

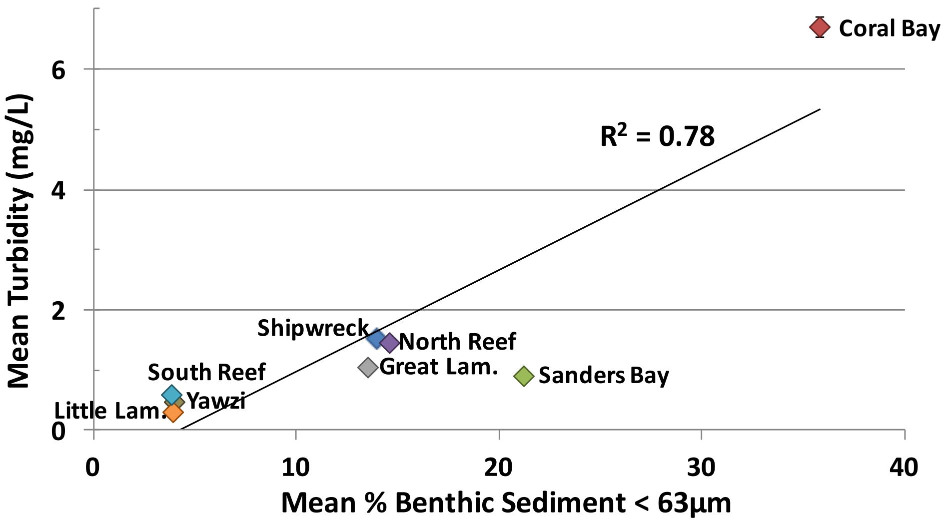

Figure 17: *Mean turbidity vs. mean % fine grained (< 63µm) benthic sediment during the fall of 2013, at 5 shore and 3 reef sites.*

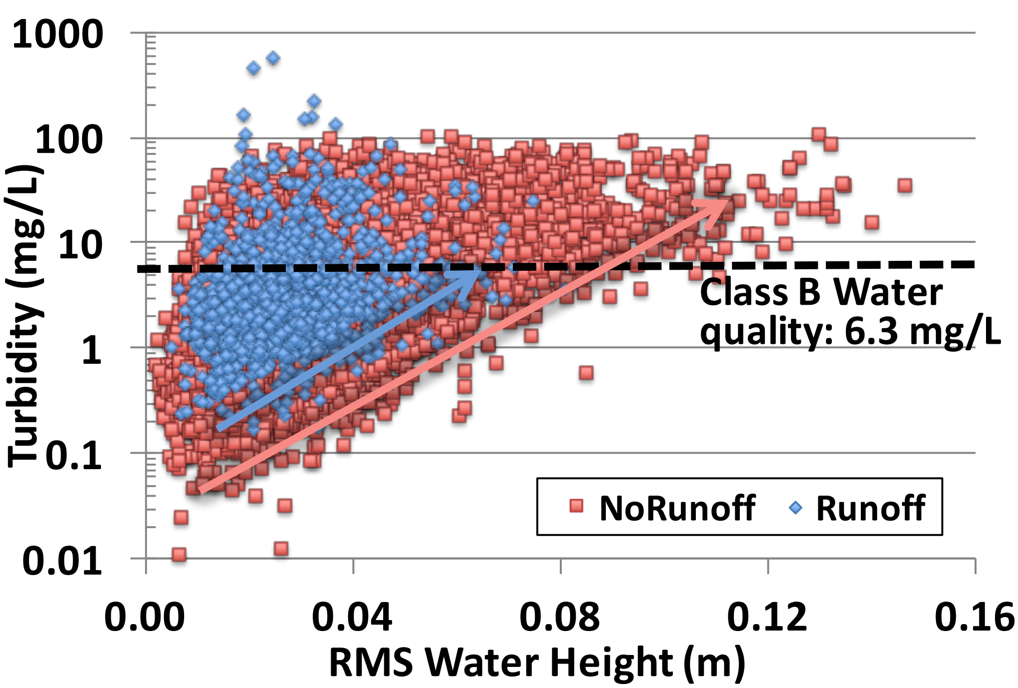

Figure 18. *RMS water height (proxy for wave energy) vs. turbidity during periods with runoff (blue) and periods without runoff (red) at Shipwreck.*

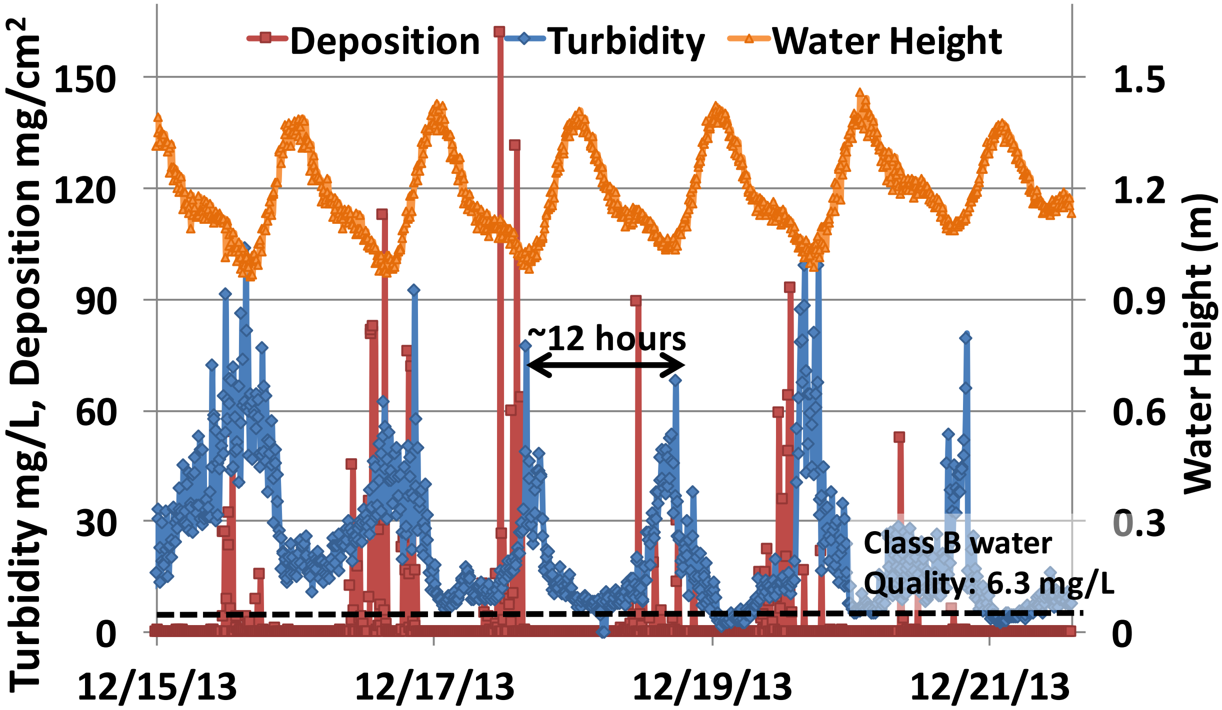

Figure 19. *Turbidity, deposition, and water height (tides) at Shipwreck, during period of elevated regional wave height in December of 2013.*

V. OUTREACH ACTIVITIES

Our outreach activities are summarized in Table 4, illustrated in Figures 20-27 and products are presented in Appendices I & II. From 7/25/13-3/6/16, we conducted 41 outreach activities. Outreach activities included a) educational outreach to K-12, adults, and college students, b) meetings with collaborators and local environmental mangers, c) published articles in online newspapers and web sites, d) scientific abstracts and presentations at professional meetings, and e) submittal of proposals for projects which build off of this work. Through these activities we reached at least 695 people, including USVI locals, students at all levels, the general public, international scientists and both USVI and international management communities. Products from this grant (see next section) include four journal articles (in preparation), 15 professional meeting abstracts & presentations, one Master of Science theses (to be completed in summer of 2016), one undergraduate research project, two expert witness reports for the local environmental management entity, and three awarded grants for continued work totaling $134,986 with $100,470 in matching funds.

Our research team conducted several hands-on science workshops for USVI, US, and Chinese K-12 and college students at VIERS (Figs. 20, 21, 22, 24). In these workshops, we explored how watershed development can affect land-based sources of pollution and demonstrated methods we're using to monitor the sedimentation (Figs. 20, 21, 22, 24). P.I. Gray supervised student research for graduate students Stephen Campbell, who is doing an MS thesis based on this work, Whitney Sears, who completed her MS thesis, undergraduate student Tyler Barnes who conducted undergraduate research and Austin Hirsh, who conducted a high-school honors thesis. Undergraduate student, Tyler Barnes was awarded a SURE grant (Summer Undergraduate Research Experience) to conduct summer research associated with this project. All students presented co-authored research at professional meetings (Table 4. Figs. 25, 26, and 27). The P.I. has also used examples from this project in courses at the University of San Diego.

Sarah Gray and her research team met with collaborators at the Coral Bay Community Council: Sharon Coldron and Patricia Reed and during the course of the grant worked with scientific collaborators Carlos Ramos-Scharrón (UT, Austin), Gregg Brooks (Eckerd College), James Whinney (James Cook University, Australia), Jessica Carilli (UMass, Boston), Peter Edmunds (CSU Northridge), Tyler Smith (UVI), and Trent Biggs (San Diego State Univ.). Dr. Ramos-Scharrón and I were invited to continue our program of integrated marine-terrestrial monitoring during 2014 by NOAA scientists and environmental managers at the NOAA Restoration Center, Julia Royster, Lisa Vandiver, and Daphne McFarland, which resulted in an ongoing program of integrated monitoring through 2014 at our study sites.

During her trips to the USVI in July/August, 2013 and January 2014, Gray met with scientific and community collaborators to discuss a) plans for research collaboration and b) how research activities could contribute to the revision of the Coral Bay Community Council's Watershed Management Plan. P.I. Gray also presented a public lecture to update the people of Coral Bay about our research program and findings (Table 4, Figure 23). In May 2015 collaborator Carlos Ramos-Scharrón spent three days in San Diego during which time we shared data and discussed integrated research publications. We have worked closely with the Coral Bay Community Council (CBCC) to ensure that the data we collected for this project would be of maximum use to their community efforts for watershed management. In particular, our turbidity and sedimentation data has been valuable to the community in order to evaluate two proposed marina projects. At the request of the Coral Bay Community Council, we submitted two expert witness reports with technical feedback/assessment of the projects based on our data.

Two online news articles were published based on this research. Outreach activities included 15 presentations and published abstracts at multiple scientific meetings including: The American Geophysical Union (Figs. 25, 27), the 24th International Union of Forest Research Organizations (IUFRO) World Congress, the EGU General Assembly, the National Council on Undergraduate Research (Fig. 26), The Ocean Sciences Meeting, the 13th International Coral Reef Symposium, and the International Coastal Symposium. (Table 4; Appendix I). In addition, presentations were given at the San Diego Association of Geologists (SDAG) and the University of San Diego.

VI. PRODUCTS

i. Professional meeting abstracts & presentations (Appendix I)

1. Gray, S.C., Ramos-Scharrón, C.E., Sears, W.*, Brooks, G., Larson, R.A., LaFevor, M.C., and Roy, J. (2016). Ridge to reef integrated terrestrial-marine monitoring to assess the impact of watershed restoration on coral reef sedimentation, St. John, US Virgin Islands. *13th International Coral Reef Symposium, June 19th-24th, 2016, Honolulu, HI.*
2. Campbell, S.E., Gray, S.C., Whinney, J., Ramos-Scharrón, C.E., Campbell, S. and LaFevor, M.C., (2016). Watershed runoff and sediment resuspension: factors affecting turbidity and sedimentation in bays with Coral Reefs, St. John, USVI. *13th International Coral Reef Symposium, June 19th-24th, 2016, Honolulu, HI.*
3. Carilli, J., McNally, S., and Gray, S.C. (2016). Assessing Mitigation Efforts To Reduce Sediment Runoff On Coral Reefs In St. John, USVI using coral geochemical proxies. *13th International Coral Reef Symposium, June 19th-24th, 2016, Honolulu, HI.*
4. Carilli, J., and Gray, S.C. (2016). Assessing historic sedimentation on coral reefs in St. John, US Virgin Islands using coral skeletal chemistry. *International Costal Symposium, March 6th-11th, 2016, Sydney, Australia.*
5. Larson, R.A., Brooks, G., Gray, S.C., Campbell, S., and Ramos-Scharron C.E. (2016) ^{7}Be as an indicator of terrigenous sediment input to coastalenvironments: St. John, USVI. *2016 Ocean Sciences Meeting, Feb. 21-26, New Orleans, LA.*
6. Campbell, S.E., Gray, S.C., Whinney, J., Ramos-Scharrón, C.E., Campbell, S. and LaFevor, M.C., (2015). Watershed-Marine Linkages: Monitoring how Terrigenous Runoff and Wave-Induced Resuspension Affect Marine Sediment Dynamics in Bays with Coral Reefs, St. John, USVI. *American Geophysical Union, Fall Meeting, Dec. 14th-18th, 2015, San Francisco, CA.*
7. Gudiño, N.*, Kretzschmar, T., and **Gray, S.C.** (2015). Weathering and soil erosion at watershed scale in St. John, US Virgin Islands. *EGU General Assembly 12 – 17 April 2015, Vienna, Austria (EGU2015-15865).*
8. Barnes, T., Gray, S. C., Hirsh, H.**, Campbell, S.*, Whinney, J., and Campbell, S. (2015). Factors affecting turbidity in bays with coral reefs in the US Virgin Islands: implications for monitoring approaches. *29th Annual National Conference on Undergraduate Research (NCUR), April 16 - 18, 2015, Spokane, WA.*
9. Gray, S. C., Sears, W., Campbell, S., Ramos-Scharron, C. E., Hirsh, H. and Barnes, T. (2014). Monitoring Approaches to Assess the Impact of Watershed Development and Restoration on Land-based Sedimentation in the US Virgin Islands: Lessons Learned. *American Geophysical Union, Fall Meeting, Dec. 15th-19th, 2014, San Francisco, CA.* (https://agu.confex.com/agu/fm14/preliminaryview.cgi/Paper19657.html)

10. Ramos-Scharron, C. E., Gray, S.C., Sears, W., Brooks, G., and Larson, R., (2014). Assessing the short- and long-term effects of land development on watershed erosion and sediment delivery to marine ecosystems of the U.S. Virgin Islands. *American Geophysical Union, Fall Meeting, Dec. 15th-19th, 2014, San Francisco, CA.* *(https://agu.confex.com/agu/fm14/preliminaryview.cgi/Paper19657.html)*
11. Ramos-Scharrón, C.E., Gray, S.C. and Hernández-Delgado, E. (2014). An unusual suspect- the threat posed by unpaved roads to coral reefs of the Eastern Caribbean. *24th International Union of Forest Research Organizations (IUFRO) World Congress,* Oct. 5th-11th*, 2014, Salt Lake City, Utah.*
12. Ramos-Scharrón, C.E., Gray, S.C. and Sears, W. (2014). Efficiency of erosion mitigation strategies in reducing sediment-loading rates from unpaved road networks into coral reef-bearing waters of the Eastern Caribbean. *European Geosciences Union (EGU) General Assembly, 27 April-2nd May, 2014, Vienna, Austria, v. 16: EGU2014-3188.*
13. Campbell, S. E. (2014) Watershed-Marine Linkages and the Roles of Terrigenous Runoff and Resuspension on Turbidity and Sediment Deposition in St. John, US Virgin Islands. *MS Thesis Proposal Presentation, May 21st,2014, , University of San Diego.*
14. Gray, S.C. (2014) Community Update: Watershed-Marine Linkages: The impact of watershed development and restoration on marine sedimentation. *Coral Bay Community Council Sponsored Local Meeting. January 21st, 2014, Coral Bay, St. John, USVI.*
15. Coldren, S.L., Reed, P.C., and Gray, S.C. (2013). A model of science-driven, community-based efforts to mitigate watershed erosion and land-based sedimentation to coral reefs in Coral Bay, US Virgin Islands, *Biennial Conference of the Coastal and Estuarine Research Foundation, 3rd-7th November, 2013, San Diego, CA.*

ii. Reports (Appendix II)

16. Gray, S.C. (2016). "Expert Witness Report Regarding Water Quality Impacts of the Sirius Marina Proposal". Submitted to the Coral Bay Community Council, US Virgin Islands.
17. Gray, S.C. (2015). "Expert Witness Report Regarding Water Quality Impacts of the Summers End Marina Proposal". Submitted to the Coral Bay Community Council, US Virgin Islands.

iii. Journal Articles (in preparation)

18. Sears, W., Gray, S.C., and Ramos-Scharrón, C.E. (2016, in prep.). Factors Affecting Terrigenous Sedimentation in Coastal Bays with Coral Reefs: Implications for Monitoring the Effectiveness of Watershed Restoration. *Coral Reefs.*

19. Harrington, R., Gray, S.C., Ramos-Scharrón, C.E., and O'Shea, B. (2016, in prep). Impact of Development on Ridge to Reef Transport of Terrestrial Elements in St. John, U.S. Virgin Islands. *Marine Pollution Bulletin*.
20. Gray, S.C., Ramos-Scharrón, C.E., Sears, W.*, Brooks, G., Larson, R.A., LaFevor, M.C., and Roy, J. (2016). Ridge to reef integrated terrestrial-marine monitoring to assess the impact of watershed restoration on coral reef sedimentation, St. John, US Virgin Islands. *13th International Coral Reef Symposium, Honolulu, HI*.
21. Campbell, S.E., Gray, S.C., Whinney, J., Ramos-Scharrón, C.E., Campbell, S. and LaFevor, M.C., (2016). Watershed runoff and sediment resuspension: factors affecting turbidity and sedimentation in bays with Coral Reefs, St. John, USVI. *13th International Coral Reef Symposium, Honolulu, HI*.

iv. Grants awarded

22. NOAA Domestic Coral Reef Conservation Program (CRCP) (2014-15). P.I.: Gray, S.C., "Year 2: Assessment of the impact of watershed restoration on marine sediment dynamics in the USVI" ($55,536 with $55,904 in cost share).
23. SURE: Summer Undergraduate Research Experience, Tyler Barnes (2014). Mentor: Gray, S.C. "Evaluating two methods to measure turbidity in near-shore systems: implications for reducing land-based pollution to coral reefs St. John, U.S. Virgin Islands" ($5450).
24. University of Puerto Rico Sea Grant College. Gray, S.C. & Ramos-Scharrón, C.E. and Brooks, G. "Assessment of the Impact of Watershed Development and Restoration on Marine Sediment Dynamics, St. John, USVI" $74,000 with 44,566 in cost share (2016-18).

Table 4. *Log of outreach activities (7/01/13-1/15/16).*

Date	**Location**	**Person involved**	**Type of Event**	**Audience /meeting type & (Number)**	**Comments (Link)**
7/25/13	VIERS, St. John, USVI	Gray & USD team	Workshop for VI youth (11-17) as part of "VIERS Science Camp" demonstrating lab activities	VI middle and high school students (24)	Figure 20
8/5/13	VIERS, St. John, USVI	Gray	Presentation to high-school students	Sea-trek/FATHOMS program for high school students (12)	Figure 20
8/6/13	Coral Bay, St. John, USVI	Gray	Meeting with C. Ramos-Scharrón, S. Coldren, president of the Coral Bay Community Council (CBCC), and P. Strenger and R. Proctor (community field assistants)	Scientific collaborator (1), community environmental manager (1) & community field assistants (2)	
8/7/13	Coral Bay, St. John, USVI	Gray	Meeting with S. Coldren, President (CBCC) and T. Reed to discuss contribution of research to CBCC's Watershed Management Plan	Community environmental manager (2)	
8/10/13	VIERS, St. John, USVI	Hirsh	Project presentation & demonstration/lab tour	Junior Gardening and Ecology group (20 children/12 adults)	
10/27/13	VIERS, St. John, USVI	Hirsh	Guided field work for a high school science research project	1 high school student	Figure 22
11/6/13	St. John, USVI	Gray	Publication of article about research in the *St. John Source* online newspaper	http://stjohnsource.com/content/news/local-news/2013/11/02/noaa-grant-helps-sedimentation-research	
11/6/13	USD, San Diego	Gray	Web link for St. John Source article on the USD "in the news" website.	https://www.sandiego.edu/about/news_center/usd_in_the_news/	

Table 4 (cont.). *Log of outreach activities (7/01/13-1/15/16) (cont.).*

Date	**Location**	**Person involved**	**Type of Event**	**Audience /meeting type & (Number)**	**Comments (Link)**
11/16/13	VIERS, St. John, USVI	Hirsh	Snorkeling field project presentation	Sea Education Association (SEA) college students & professors(15 students, 4 professors)	"Colon-ization to Conser-vation in the Caribbean" Program. Figure 21
11/18/13	VIERS, St. John, USVI	Hirsh	Powerpoint field project presentation	Sea Education Association (SEA) college students & professors(15 students, 4 professors)	"Colon-ization to Conser-vation in the Caribbean" Program. Figure 21
11/19/13	Coral Bay, St. John, USVI	Hirsh	Tour of field sites in Coral Bay, St. John to demonstrate project	Sea Education Association (SEA) college students & professors(15 students, 2 professors)	"Colon-ization to Conser-vation in the Caribbean" Program Figure 21
12/29/13	VIERS, St. John, USVI	Hirsh	Guided field work for a high school science research project	1 high school student	Figure 22
1/21/14	St. John, USVI	Gray	Outreach presentation to the Coral Bay, USVI community	Community members (25)	Figure 23
1/26/14	VIERS St. John, USVI	Hirsh	Project presentation to Chinese students	International (China) high-school students (12)	Figure 24
1/30/14	VIERS St. John, USVI	Hirsh	Workshop for visiting Chinese students	International (China) high school students (12)	Figure 24
2/5/14	VIERS St. John, USVI	Hirsh	Lab tour and presentation: Sierra Club	12 Adults	
5/20/14	USVI and USD	CBCC & Sarah Gray	Webinar/conference call: Coral Bay Watershed Management Plan meeting	USVI environmental managers, government officials, and scientists	

Table 4 (cont.). *Log of outreach activities (7/01/13-1/15/16) (cont).*

Date	**Location**	**Person involved**	**Type of Event**	**Audience /meeting type & (Number)**	**Comments (Link)**
5/21/14	USD, San Diego	S. Campbell	Presentation of Masters Thesis Proposal	Scientists, faculty, and graduate students (30)	
6/16/14	Coral Bay, St. John, USVI	Gray	Met with Coral Bay Community Council environmental manager Patricia Reed to discuss turbidity study and CBCC watershed management plan.	Community environmental managers (3)	
6/21/14	Coral Bay, St. John, USVI	Gray	Met with Coral Bay Community Council President Sharon Coldren	Community environmental managers (1)	
8/12/14-8/14/14	USD	S. Campbell	Stephen Campbell worked with high-school student, Austin Hirsh on his senior science project based on our research	High school student (1)	Figure 22
9/10/14-9/12/14	USD	Gray & Sears	Trained coral reef researcher (Alex Messina, SDSU) to analyzed terrigenous sedimentation by LOI	Coral reef researcher (1)	
10/5/14	Salt Lake City, Utah	Ramos-Scharrón, Gray	Presentation at the *24th International Union of Forest Research Organizations (IUFRO) World Congress*	International Scientists (40)	(http://iufro2014.com/) Appendix I
11/7/14	USD	Barnes	Senior Seminar presentation	Faculty and science students (60)	
12/10/14	Bellarmine Prep. Acadamy, Takoma, WA	Gray, Austin Hirsh	High school student Austin Hirsh presents his honors research project based on sediment studies in the USVI	High school students (40)	Figure 22
12/15/14	San Francisco	Gray, Ramos-Scharrón, Barnes, Campbell, Hirsh	Presented poster at the American Geophysical Union (AGU) Fall Meeting, San Francisco, CA	International scientists (40)	Appendix I, Figure 25
12/15/14	San Francisco	Ramos-Scharrón, Gray	Presented co-authored poster at the American Geophysical Union Fall Meeting, San Francisco	International scientists (40)	Appendix I

Table 4 (cont.). *Log of outreach activities (7/01/13-1/15/16) (cont).*

Date	Location	Person involved	Type of Event	Audience /meeting type & (Number)	Comments (Link)
12/16/14	San Francisco	Gray	Met with NOAA Coral Reef Conservation managers Rob Fergusson and Susie Holst and other "land based sedimentation to coral reefs" researchers to discuss recommendations for future directions and monitoring approaches.	Coral reef managers (2) and researchers (5)	
12/16/14	San Francisco	Gray, Ramos-Scharrón	Four-hour meeting with C. Ramos-Scharrón to discuss ongoing collaborative research and publications	Coral reef researcher (1)	
12/17/14	San Diego	Barnes	Awarded San Diego Association of Geologists "Outstanding Research Award" for his undergraduate research associated with this project.	Scientists (50)	
2/15/15	San Diego	Gray	Submitted Expert Witness report to the Coral Bay Community Council	General public	Appendix II
2/13/15	USD	Campbell	Marine Science Graduate Colloquium presentation	Faculty, scientists, grad. Students (30)	
3/18/15	San Diego, CA	Barnes	San Diego Association of Geologists Meeting	Scientists, professional geologists, general public (50)	
4/12/15	Vienna, Austria	Gudiño & Gray	Presentation to the European Geological Union General Assembly	International Scientists (40)	Appendix I
4/16/15	Spokane, WA	Barnes	Presentation to the 29th Annual National Council on Undergraduate Research (NCUR) Conference	Scientists, students (40)	Appendix I, Figure 26
5/12/15-5/16/15	San Diego, CA	Ramos-Scharrón & Gray	Multi-day meeting to discuss linking terrestrial and marine data & publication plans	2	

Table 4 (cont.). *Log of outreach activities (7/01/13-1/15/16) (cont).*

Date	**Location**	**Person involved**	**Type of Event**	**Audience /meeting type & (Number)**	**Comments (Link)**
10/1/15	San Diego	Gray	Submitted Expert Witness report to the Coral Bay Community Council for Marina development	General public/website (50)	
12/11/15	San Francisco, CA	Campbell, Gray, Ramos-Scharrón, Hirsh	Presentation to the American Geophysical Union Fall Meeting	International Scientists (20)	Appendix I, Figure 27
1/15/16	San Diego	Gray, Campbell, Ramos-Scharrón, Carilli	Three abstracts submitted (and accepted) for the 13th Coral Reef Symposium to be held in Honolulu, HI, 6/19/16		Appendix I
2/21/16	New Orleans, LA	Larson, Brooks, Gray, Campbell	Presentation at the 2016 Ocean Sciences Meeting	International Scientists (30)	Appendix I
3/6/16	Sydney, Australia	Carilli, Gray	Presentation at the International Coastal Symposium	International Scientists (30)	Appendix I

Figure 20. *USD researchers conduct a workshop for USVI and US (below right) middle and high school students attending "Science Eco Camp" and the "FATHOMS" program at the Virgin Islands Environmental Resource Station (VIERS). The USD team demonstrated their research techniques to study land-based sources of pollution.*

Figure 21. *Research Assistant Heidi Hirsh led a 3-day hands-on research workshop for college students attending the Sea Education Association (SEA) "Colonization to Conservation in the Caribbean" program. The students collected and analyzed sea-floor sediments at our developed and undeveloped sampling locations.*

Figure 22. *High school student Austin Hirsh conducted an honors science project studying how bottom sediment differed before and after the Nov. 2013 storm. He is shown collecting a sea-floor sediment sample (above left), organizing his samples (above right) at the Virgin Islands Environmental Resource Station (VIERS) and analyzing sea-floor sediments in a muffle furnace at the University of San Diego (below).*

Figure 23. *Sarah Gray was invited by Coral Bay Community Council President Sharon Coldren to present an update of project research activities to the Coral Bay community on 1/21/14. The community also view posters summarizing our research (above right).*

Figure 24. *Research Assistant Heidi Hirsh led a hands-on research workshop for Chinese high-school students visiting VIERS on 1/26/14. She is demonstrating land-based pollution using a watershed model.*

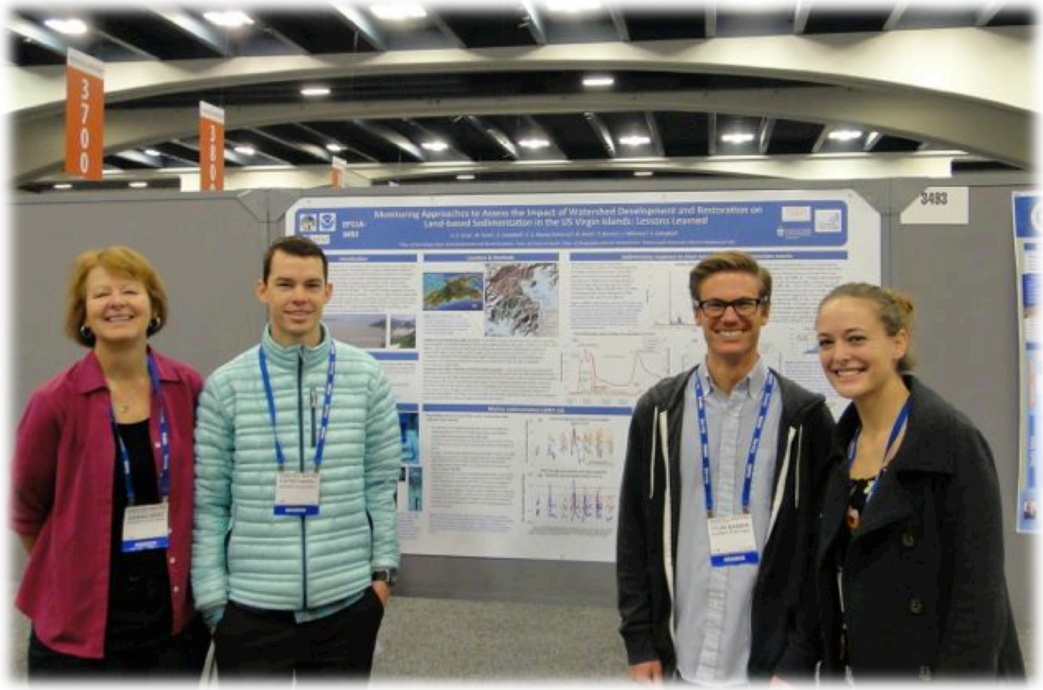

Figure 25. *S. Gray, S. Campbell (MS student), T. Barnes (undergraduate student), and H. Hirsh (former USVI field assistant; now a Stanford Ph.D student) present a poster at the American Geophysical Union in San Francisco, Dec. 15th, 2014 for a session entitled "From Ridge to Reef: Terrestrial Sediment Impacts to Coral Reef Ecosystems".*

Figure 26. *Tyler Barnes, a USD undergraduate, presents a paper at the National Council on Undergraduate Research in Spokane, WA on 4/16/15.*

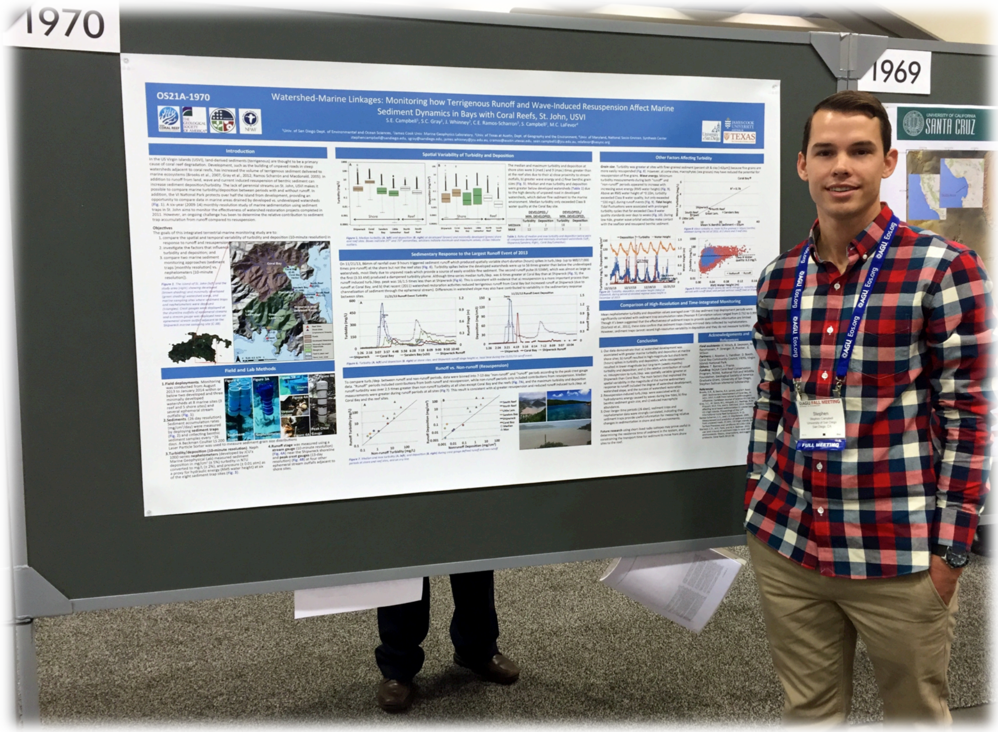

Figure 27. *Stephen Campbell, a USD graduate student, presents his research at the American Geophysical Union in San Francisco, CA 12/11/15.*