Virgin Islands Water Resources Research Institute
Annual Technical Report
FY 2011

Introduction

The U. S. Virgin Islands are located between the Atlantic Ocean and the Caribbean Sea in an area about 1,200 miles southeast of Miami, Florida and 80 miles southeast of San Juan, Puerto Rico. The islands are a territory of the United States. The USVI consists of four principal islands, St. Thomas, St. Croix, Water Island and St. John. The USVI occupies a combined area of approximately 137 square miles extending about 60 miles west to east. In general, the islands are of volcanic origin and are consequently relatively mountainous.

Historically, rain water harvesting has been a principal source of potable water for the residents of the USVI with some reliance on ground water. Surface water supplies are virtually non-existent. Desalination satisfies most of the water needs of the population of about 115,000 persons and is the principal provider of water for the islands' limited public water distribution systems. Wastewater disposal continues to be a concern, though recently, major improvements have been made in the wastewater collection and treatment systems.

The Virgin Islands Water Resources Research Institute (VI WRRI) is hosted by the territory's only institution of higher education, the University of the Virgin Islands (UVI). UVI, founded in 1962, is a land-grant, Historically Black College or University (HBCU) with a student population of about 2,700. It has campuses on both St. Thomas and St. Croix and a research station on St. John. UVI is primarily an undergraduate institution but there are also graduate programs in Business, Teacher Education, Public Administration and Marine Science. As is the case throughout the U. S. Virgin Islands community, the university population consists of a diversified mix of persons coming from not only the Virgin Islands and the Caribbean area but from the U. S. mainland and other areas throughout the world as well. UVI maintains many active collaborative relationships with a wide range of universities in order to maximize its ability to serve the needs of the Virgin Islands community.

The VI WRRI is one of the smaller institutes in the U. S. Geological Survey's State Water Institute Program. It has no full-time staff and in order to make maximum use of resources available to it, maintains no distinct facilities at UVI but works collaboratively with other UVI units and entities outside of the university. It has always kept a focus on addressing water resources research issues particularly relevant to tropical island communities and is known for work done in areas such as rain water harvesting, alternative on-site sewage disposal systems and investigation of applicable indicators in tropical water supply systems. The research, information dissemination and training activities conducted by the VI WRRI are guided by an advisory group.

Research Program Introduction

Four research projects were supported during the period March 1, 2011 to February 29, 2012 by the U. S. Geological Survey through the Virgin Islands Water Resources Research Institute (VI-WRRI). Most of the projects were started and completed during the period and one will be completed during the next report period.

All projects addressed issues of particular interest in the U. S. Virgin Islands and provided training opportunities for several students. Through the projects, there was an investigation of the utility of an irrigation strategy, modeling of a possible impact of climate change, quantification of erosion in changing watershed and development of an approach for identification of contaminants in runoff. Research findings for some of the projects have already been presented in publications and other forums. The following are summaries of each of these research projects.

Evaluating Drought Tolerance of Virgin Islands Native Trees Suitable for Landscaping

Basic Information

Title:	Evaluating Drought Tolerance of Virgin Islands Native Trees Suitable for Landscaping
Project Number:	2011VI184B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	VI
Research Category:	Not Applicable
Focus Category:	Drought, Conservation, Water Quantity
Descriptors:	
Principal Investigators:	Michael Morgan, Thomas W. Zimmerman

Publications

There are no publications.

EVALUATION OF DROUGHT TOLERANCE OF VIRGIN ISLANDS NATIVE TRESS SUITABLE FOR LANDSCAPING

Problem and Research Objectives

New urban and residential developments require landscape planting. Research in the Biotechnology and Agroforestry Program at the University of the Virgin Islands Agriculture Experiment Station (UVI-AES) supports the preservation of native flora through investigations into the propagation of native plant species. One of the program's goals is to provide research supporting local plant nurseries growing native plants for their use in landscaping around homes and businesses. The demand for ornamental plants is rising as the islands of St. Croix, St. Thomas, and St. John become more urbanized. Plant nurseries are a growing segment of the local economy. Programs that promote using native, ornamental plants within their native range have recently become successful in several states and a similar approach in the US Virgin Islands is strongly advocated by the US Forest Service (Overton, et al., 2006).

Fresh water is limited on the island of St. Croix. Rainfall is seasonal. There are no perennial streams or lakes to provide fresh water. Fresh water can be obtained by collecting rainwater in cisterns for later use, from wells that tap the subterranean aquifer, or buying it from the Virgin Islands Water and Power Authority. Fresh water provided by the Virgin Islands Water and Power Authority is expensive because it comes from a desalination plant.

Plant nurseries, particularly, those specializing in showy "tropical" plants such as species in the *Heliconaceae*, *Musaceae,* and *Zingiberaceae* families, need abundant water. They cannot depend on rainfall alone in the US Virgin Islands. During the dry season, access to well, municipal water or a pond is necessary to keep these plants alive. In order to remain profitable and stay in business, plant nurseries need to produce plants at a price people are willing to pay, while generating sufficient demand for landscaping plants. Two ways to reduce costs are to closely monitor water use and to grow native plants that are adapted to the dry environment of the U.S. Virgin Islands.

Methodology

Three species of native plants with potential for use as ornamental plants were subjected to three regimes of water stress. The plants were grown in a peat, top soil, and sand (2:1:1) planting substrate, whose soil water will be maintained at field capacity, half field capacity and 1/3 field capacity. Research was performed in a greenhouse at the University of the Virgin Islands' St. Croix campus.

The three species chosen for study were: Kapok or Silk Cotton Tree, (*Ceiba pentandra),* Dog Almond *(Andira inermis)*, and *Senna polyphylla*. This last species does not have a common name. Kapok is a tree that visually dominates the landscape due to its very large size. It makes a good center piece or focal point in a park or large garden. When it flowers at the beginning of the dry season in December, it has showy pinkish white flowers. When it loses its leaves in the dry season, its architecture of heavy branches is on display. Dog Almond has a dense evergreen crown of deep green leaves casting a refreshing shade. When it flowers, showy pink or purple flowers appear in clusters at the tips of the flowers. *Senna polyphylla* is a small tree that grows up to 5m tall. It has with an open spreading crown with long, slightly drooping branches. The species produces bright yellow flowers from an early age and is almost constantly in flower (Jones,1995).

Seedlings were grown in containers for 11 months. They were started from seed. When the seedlings had extended two adult leaves they were transplanted into 11 liter pots filled with a mix of potting mix and sand and top soil in a 2:1:1 ratio (O'Donnell, 1994).

Peat and sand are known to be nutrient poor substrates. Based on the results, applications of fertilizer can be determined. To compensate for any nutrient deficiencies that develop over time, 4 grams of slow release Osmacote ™ 14-14-14 fertilizer was added to the pots 2 weeks after transplant as per (Svenson, 1993, Docherty, 1997, O'Donnell, 1994). Fertilizer was added two more times during the course of the study; then again at the 9 month point and the 11 month point in response to signs of nutrient stress.

The seedlings were allowed to grow and firmly establish themselves in the containers for 4 months prior to the start of the drought experiment. They were well irrigated and fertilized, so that the seedlings are in good health and growing vigorously when the treatments started.

The experiment was set up as a randomized complete block design. The experimental unit was an individual plant. There were 2 blocks. Each block was a greenhouse bench with six individuals of each species for a total of 12 plants per bench. Each plant was randomly assigned a treatment (or level of irrigation) and a place on the bench. Since there were three irrigation treatments, two plants of each species in each block will be subjected to each drought treatment for a total of four plants per treatment.

In order to determine proper irrigation levels, field capacity of the soil needed to be determined first. Field capacity refers to the capacity of a soil to retain plant available water. Excess water drains away. Shortly before the start of the experiment, the plants were left unwatered until the leaves started to wilt. This indicated that the soil in the pots was dry. A subset of pots (with their accompanying soil and plants) was weighed in order to obtain a dry weight. Then the plants were watered until water ran out of the bottom of the plant container. The pots were weighed again to obtain a wet weight. The difference between the wet weight and the dry weight of a pot determines the field capacity of the soil within that pot. One gram of water is identical to the weight of one milliliter of water. Therefore, one liter of water is the same as one kilogram of water (Brady & Weill, 2002). The average field capacity of the pots was three litres of water.

Then, the trees were assigned a watering treatment: field capacity (3L), half field capacity (1.5 L), and 1/3 field capacity (1L). They were watered once a week.

Plant growth was monitored by taking weekly measurements of stem diameter at the root collar, total height, and number of branches. Statistical analysis on the final data set allowed for meaningful comparison of the variables between treatments and among tree species. Analysis of variance (ANOVA) was used to detect statistically significant differences between treatment means. Treatment means were compared using Student's T test against all pairs. Growth biometrics was charted against the different watering regimes. The statistical package used was JMP, version 9, a menu driven version of SAS. Microsoft Excel was used to create most of the graphs.

An undergraduate student in computer science was hired to help with experiment set up, plant production, and data collection. He learned some basic descriptive statistics and how to create graphs and tables using Excel. He worked 35 hours a week during the summer and 20 hours a week during the fall semester.

Principal Findings and Significance

There were biometrical and statistical differences amongst treatments and species. They are described below. While many of the trees experienced water stress, none lost their leaves. See Table 1 below for details.

The *Andira inermis* trees essentially did not grow in height whether they received 1, 1.5 or 3 liters of water a week (P=.1022). A P –value of .10 implies some sort of significance but is not as impressive as a P value of 0.05 (significant) or 0.01 (highly significant). A P-value of 0 .1022 could be considered insignificant or on the cusp of significance.

Towards the end of the study, the *A. inermis* trees that received 3 liters of water had a growth spurt. I believe the growth spurt was in response to fertilizer applied to all the trees in the study on the 13th week, almost at the end of the study. Fertilizer containing NPK and all the required micronutrients was applied to all of the plants in the experiment because of a visible nutrient deficiency. This growth spurt is interesting because it suggests that some nutrient was missing or was in insufficient supply for *A. inermis,* because water was not limiting when the trees received 3 liters of water a week. Nor did the other two species in the experiment reacted to fertilization with a growth spurt. Fertilizer containing NPK and all the required micronutrients was applied to all of the plants in the experiment because of a visible nutrient deficiency. The P-value for *A. inermis* on the 13th week, prior to the application of fertilizer was 0.22 indicating that there was no difference in treatments.

Stem diameter growth was proportional to the water received. The number of branches per tree did not change over time. 11 trees had one stem and one tree had two. None of the trees produced lateral branches.

Table 1. Summary table of experiment results. Three tree species subjected to three different weekly watering regimes.

Species	Treatment	Initial height (cm)	Δ height (cm per week)	Final height (cm)	Water (L) added	mean Δ height (cm per liter added)
Andira inermis	1L	83	.34	87.5	14	.34
A. inermis	1.5 L	93.75	.60	100.75	21	.40
A. inermis	3 L	104.25	1.48	123.5	42	.49
Ceiba pentandra	1L	109.25	1.52	132	14	1.62
C. pentandra	1.5 L	109.5	1.51	132.25	21	1.08
C. pentandra	3 L	111	2.9	154.5	42	1.03
Senna polyphylla	1 L	67.75	2.19	96.5	14	2.19
S. polyphylla	1.5L	56	4.58	121.25	21	3.27
S. polyphylla	3 L	67	5.16	139.25	42	1.84

Ceiba pentandra reacted significantly to the difference watering regimes. The P value for its analysis of variance was 0.0422. The trees grew noticeably when they received 3 litres of water a week. The trees that received either 1 or 1.5 litres per week hardly grew at all.

The Student's T-test used to compare the means of all the pairs ranked the trees that received 3L with an A, while the trees in the other two treatments both received Bs showing that there was no statistical difference in growth response whether the they received 1L of water a week or 1.5 L of water a week. Unfortunately by about the 4th week, all of the trees had A) out grown their pots or B) needed more water to continue growing.

Diameter measurements were excluded from the study because they fluctuated too much and thorns on the stem inferred with stem diameter measurements. A stem could fluctuate by a millimetre or two in diameter, depending whether it was measured before or after watering. A possible explanation for this fluctuation is that the relatively soft wood (.24 grams per cm3 from Reyes, 1992) stores a significant amount of water. A related species *C . trichistandra*, from the tropical very dry forests of coastal Ecuador and Peru, is well known for this; hunters sometimes dig out the roots as an emergency water source during the dry season (Lindao Quimi and Stodhert, 1994). There were no statistical differences in the production of branches, although some trees that received either 1.5L or 3L of water a week had started to put out one or two side branches.

Senna polyphylla kept growing under all three irrigation regimes. All the trees kept increasing in height and diameter proportional to the amount of water received. However, statistically, a P value 0. 0899 only implies a difference amongst treatment, not shows or conclusively proves a difference amongst treatments.

It appeared that watering weekly with 3 litres resulted in the production of significantly more branches than the trees receiving 1 litre or 1.5 litres of water per week, the trees subjected to these two treatments just kept the same number of branches throughout the experiment. However, statistical analysis showed that it was not significantly different than the other treatments, P=.1296. It appears that one particularly branchy tree skewed the results. Also, two of the trees in the 3L treatment began to flower.

Conclusions

All three tree species tolerate low levels of irrigation. Irrigation in this case was performed by a hose and a bucket in the green house, but by extension could be considered as substitute rainfall if the trees were planted outside. None of the trees lost their leaves during the course of the experiment.

However, this study has implications for tree nursery managers. Ideally, they want to produce trees ready for landscape planting in the least amount of time possible with the least amount of water. The treelet or bush, *S. polyphlla*, kept growing bigger under all three watering regimes. It even appears that it could be grown to out planting size just with rain water. Of course, the more water it is given the faster the tree grows to planting size. *A. inermis* just ceases height growth if it does not receive more than three liters of water per week, so this is not a good species to grow in the nursery if water is limiting. *C. pentrandra* is intermediate between the two species; it kept growing up to a certain point and then stopped, as long as it received 3l of water a week. However, it appears that in this case, both plant size and pot size interact with water availability to restrict further growth.

It would be worthwhile to continue this study with other tree species, and with the same species transferred into bigger pots. What was learned here can be improved and built upon. For example, increasing the sample size slightly will hopefully increase the significance of the results. With the experiences gained from the study, the techniques employed can be further refined.

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Lesser Antilles Specific Assessment of the IPCC AR5 Models for the Current Climate

Basic Information

Title:	Lesser Antilles Specific Assessment of the IPCC AR5 Models for the Current Climate
Project Number:	2011VI186B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	FL-02
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Drought, Floods
Descriptors:	None
Principal Investigators:	Vasubandhu Misra

Publications

There are no publications.

LESSER ANTILLES SPECIFIC ASSESSMENT OF THE IPCC AR5 MODELS FOR THE CURRENT CLIMATE

Problem and Research Objectives

The sustainability of a society and in this context of island nations of the Lesser Antilles is critically dependent on the fresh water availability. A significant source of the fresh water in these islands comes from precipitation. Therefore there is considerable interest to understand how precipitation in particular would change as a result of the global climate change. So before the climate model projections over the region of the Lesser Antilles can be analyzed for the late 21st century, it is important to examine the their 20th century simulation. In this research, we are examining the fidelity of reconstructing the Atlantic Warm Pool (AWP) variations in the 20th century in the climate models participating in the Coupled Model Inter-comparison Project 5 (CMIP5) which will be extensively used in preparing the International Panel for Climate Change (IPCC) Assessment Report 5 (AR5). Our previous study (Chan et al. 2011) revealed that the Atlantic Warm Pool (AWP) has a significant influence on the low level tropospheric flow, rainfall and its diurnal variability over the Lesser Antilles. For example, Chan et al (2011) showed that over the larger islands (with area approximately greater than 100 km^2) both daily maximum and minimum 2-meter temperature (T_{2m}) are increased during the large AWP years. However, the change of daily T_{2m} maximum at interannual scales is clearly larger than the daily T_{2m} minimum. This is because during the nighttime, the decoupled boundary layers and land breezes keep the islands essentially isolated. It may also be noted that with the resolution of the CMIP5 models are around 100km grid resolution, which is obviously insufficient to resolve the Lesser Antilles Islands. Therefore it is prudent to analyze the AWP, a large-scale climate feature that has a significant influence on the Lesser Antilles climate.

Wang and Lee (2007) also relate the variability of the AWP to tropical cyclone activity in the Atlantic. They suggest that the AWP acts as a conduit for the observed relationship of Atlantic multi-decadal oscillation and Atlantic tropical cyclone activity. The AWP-induced atmospheric changes of vertical shear and convective instability are identified as the dynamical mechanisms by which the AWP controls tropical cyclone activity in the region. Furthermore, there is a huge gradient of the ocean heat content between the deeper mixed layer in the northern Caribbean Sea and the shallower warm pool depths along the northern coast of South America, which could also possibly influence hurricane tracks and intensification (Enfield et al. 2001). Similarly, in large AWP years, the North Atlantic Subtropical High (NASH) is relatively weak compared to small AWP years. An anomalously strong NASH or an anomalously southward displacement of the NASH, when accompanied by a southward shift of the eastern Pacific ITCZ, would lead to a dry summer in the Caribbean (Giannini et al. 2000). A westward protrusion of the NASH contributes to the Caribbean mid-summer drought (Mapes et al. 2005) and the Caribbean Low Level Jet (CLLJ) and CLLJ’s westward moisture transport (Wang and Lee 2007; Wang 2007; Muñoz et al. 2008). The position and strength of the NASH during summer are also found to be critical to the tracks of tropical cyclones in the region (Wang 2011).

At the end of 2011, only 4 models had their complete 20th century simulation datasets reported at the CMIP5 data portal (http://cmip-pcmdi.llnl.gov/cmip5/data_portal.html). They were NASA's two models (GISS-E2-H and GISS-E2-R), Australia's (CSIR-Mk3.6), and Canada's (CanESM2). In this report we will therefore examine the simulation of the AWP variations in the 20th century of these 4 models. However since the beginning of this year 6 other models have reported their data at the website and many more models are anticipated to report their datasets very soon. In examining the CMIP3 models that had nominal horizontal resolutions of around 200km, which were used in the IPCC AR4, Misra et al. (2009) showed that a majority of these models had a very cold bias in the AWP region. As a result the 28.5^0C isotherm was not even resolved in these model simulations. But given the fact that the CMIP5 models have nearly doubled the resolution of their model compared to CMIP3, and there have been other developments in the physics of the climate models, there is anticipation of improved performance.

Methodology

We have compared the results of the CMIP5 models with the Sea Surface Temperature (SST) Analysis from Extended Range SST version 3b (ERSSTv3; Smith et al. 2008) and the National Centers for Environmental Prediction (NCEP)-Department of Energy (DOE) atmospheric reanalysis (hereafter R2; Kanamitsu et al. 2002). ERSSTv3 is generated using in situ SST data and improved statistical methods that allow stable reconstruction using sparse data. The monthly analysis extends from January 1854 to the present, but because of sparse data in the early years, the analyzed signal is damped before 1880. It is available at 2^0 grid resolution. R2 analysis is available on 2.5^0 grid resolution from 1979 to the present. The analysis scheme used in R2 is the spectral statistical interpolation scheme, which is a three-dimensional variational scheme cast in spectral space (Derber et al. 1991; Parrish and Derber 1992). For analysis of the interannual variations we make sure to improve the linear trends in all the analyzed variables for both the model generated data and the corresponding verification data. Since the AWP has a seasonal peak in August-September-October (ASO) season, we will be specifically examining the CMIP5 results in this season. The analysis of the modeling results in the project will involve using a new technique of Ensemble Empirical Mode Decomposition (EEMD; Wu & Huang 2009). EEMD will be used to decompose the time series of the AWP to estimate its variability in the AR5 models and compare them with the corresponding observations. EEMD is an extension on the Empirical Mode Decomposition (EMD; Huang et al. 1998). EMD is capable of decomposing the local characteristic temporal variations into complete sets of near orthogonal components called Intrinsic Mode Functions (IMFs). The IMFs can be thought of as basic functions, which are determined by the time series itself rather than pre-determined kernels. Thus it is a self-adaptive signal processing method, which is most suited for nonlinear and non-stationary time series. EEMD, a noise-assisted data analysis method, defines its IMFs through an ensemble of trials, wherein each trial involves adding white noise to the time series. This enables the components of the signal in the time series to automatically project onto proper scales of reference established by the background white noise. However the IMFs obtained will consist of the signal and the white noise, which will be rather noisy. But the noise in each trial will be different. Thus this noise component in the IMF can be substantially decreased or eliminated by taking the mean of several trials, thereby retaining the true estimate of the signal in the time series.

Principal Findings and Significance

Mean AWP climate: Figure 1 shows the mean SST for the ASO season for the 20th century with the 28.5^0C isotherm in bold black line. Off the 4 CMIP5 it is apparent that GISS-E2-R and CSIRO-Mk3.6 have a well-defined 28.5^0 C isotherm defined in the Gulf of Mexico and in the Caribbean Sea region. Both GISS-E2-H and the CanESM2 have a cold bias compared to the observations in ERSSTv3.

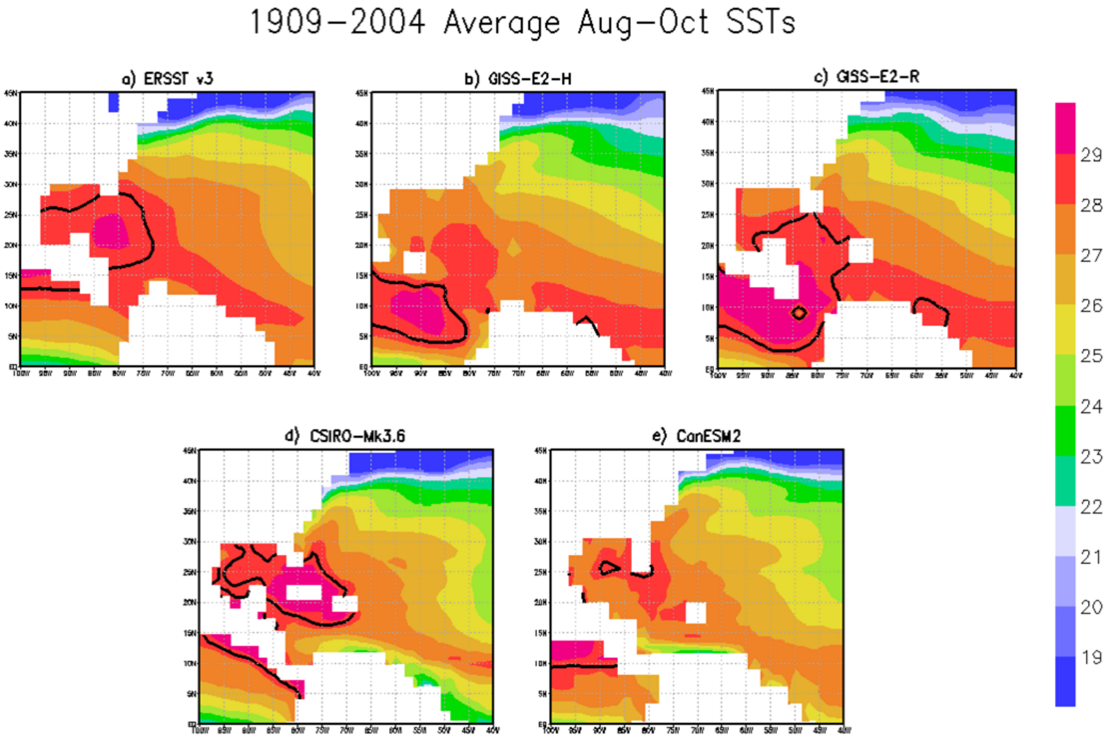

Figure 1: Climatological 1909-2004 August-September-October (ASO) Average SST (°C) in the Atlantic Basin from a) detrended ERSST v3 observations, and b-e) various detrended CMIP5 models. The mean 28.5°C isotherm (heavy black line) is overlaid on top of the shaded SSTs to highlight the size and location of the Atlantic Warm Pool (AWP) in each individual model.

Interestingly, when we examine the seasonal cycle of the AWP (Fig. 2), then all 4 models show a seasonal peak in the area of the AWP in the ASO season. GISS-E2-R and CSIRO-Mk3.6 also get the magnitude of the AWP area that is quite comparable to

ERSSTv3. However, the magnitude of the seasonal peak of AWP area is considerably diminished in GISS-E2-H and CanESM2.

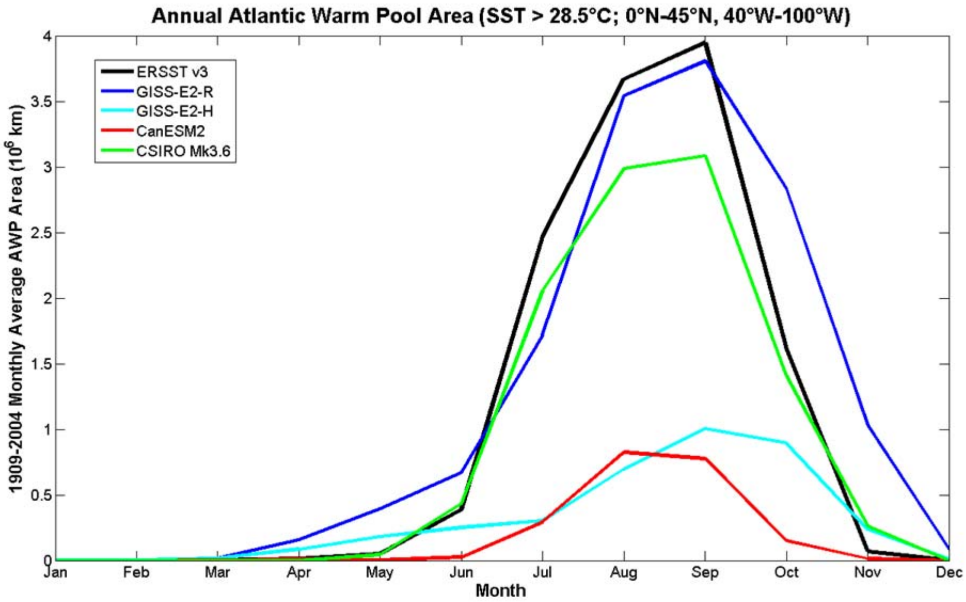

Figure 2: The climatological distribution of the area of the 28.5^{0}C isotherm defining the AWP, as measured by detrended ERSST v3 observations.

Variability of AWP: The AWP is found to be a rich amalgam of variability across many time scales. Besides the interannual variations there are decadal variations and a linear trend of increasing area of the AWP. Wang and Lee (2007) suggest that the AWP acts as a conduit for the observed relationship of Atlantic multi-decadal oscillation and Atlantic tropical cyclone activity.

Figure 3 shows the spectrum

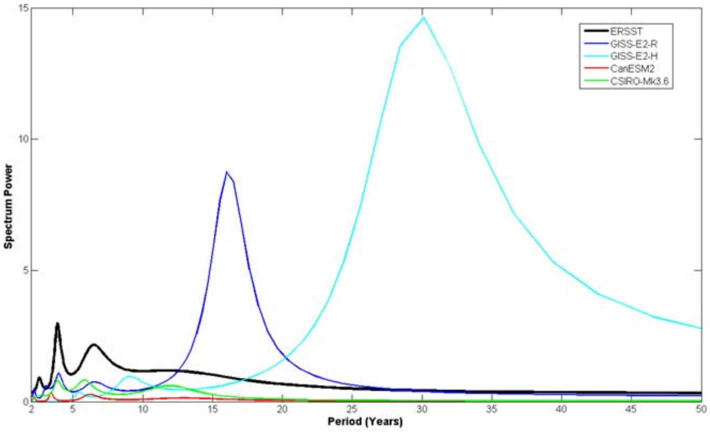

Figure 3: Maximum entropy spectrum (M=10) of the 1909-2004 areal AWP index. To focus on higher-frequency variability, the power spectrum is calculated for the sum of the first three IMFs of the AWP index, obtained through an EEMD.

diagnosed from the Maximum Entropy Method (MEM; Ghil et al. 2002) of the first three IMFS's of the centennial time series of the AWP area. The ERSSTv3 dataset exhibits a relatively strong variability on interannual (ENSO) time scales and at intra-decadal (5-10 year) time scales that correspond to the North Atlantic Oscillation. On the other hand CSIRO-Mk3.6 and GISS-E2-R and CSIRO-Mk3.6 exhibit a spectral peak at around 15 year and 30 year time scales, which correspond to the Pacific-Decadal Oscillation and the Atlantic Multi-decadal Oscillation.

Figure 4 shows the lagged correlation of the ASO area of the AWP with the global SST anomalies of the previous seasons of two season lag (February-March-April [FMA]), one season lag (May-June-July [MJJ]) and zero season lag (ASO). The corresponding observational figures from ERSSTv3 are shown in Fig. 5. It is clearly seen that the two models that showed reasonable climatology of the AWP have the variations of AWP erroneously associated with the equatorial Pacific SST variations. In the observations it is clearly seen that the ASO variation is largely independent of the ENSO variations in the equatorial Pacific. The variability is intrinsic to the tropical Atlantic Ocean.

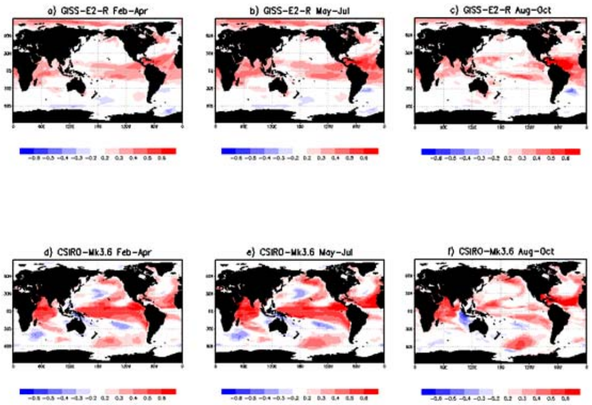

Figure 4: The correlation of 1909-2004 ASO averaged AWP area with a) preceding February-March April (FMA), b) preceding May-June-July (MJJ), and c) contemporaneous ASO global SSTA from GISS-E2-R. d), e), and f) similar to a), b), and c) but from CSIRO-Mk3.6. Only statistically significant values at 95% confidence interval according to t-test are shown.

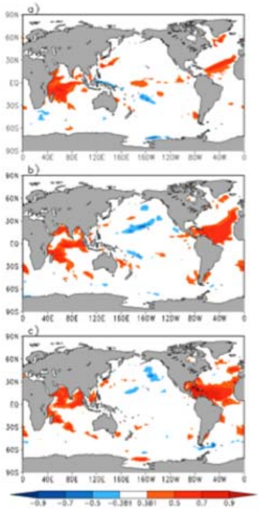

Figure 5: Same as Fig. 4 but for ERSSTv3.

Conclusion

In conclusion, the four models examined in the CMIP5 suite of models indicate that two (CSIRO-Mk3.6 and GISS-E2-R) have reasonable climatology but with erroneous interannual variations. The other two models (GISS-E2-H and CanESM2) have a cold bias that renders them to not have an AWP in the boreal season.

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QUANTIFYING SEDIMENT AND ORGANIC MATERIAL PRODUCTION RATES FROM SURFACE EROSION PROCESSES AND THE EFFECT ON MARINE WATER QUALITY IN SMALL SUBTROPICAL WATERSHEDS ON THE EAST END OF ST. CROIX, USVI

Basic Information

Title:	QUANTIFYING SEDIMENT AND ORGANIC MATERIAL PRODUCTION RATES FROM SURFACE EROSION PROCESSES AND THE EFFECT ON MARINE WATER QUALITY IN SMALL SUBTROPICAL WATERSHEDS ON THE EAST END OF ST. CROIX, USVI
Project Number:	2011VI195B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	U.S. Virgin Islands
Research Category:	Water Quality
Focus Category:	Sediments, Nutrients, Hydrology
Descriptors:	
Principal Investigators:	Kynoch Reale-Munroe, Bernard Fernando Castillo, Carlos E Ramos-Scharron

Publications

1. Cumberbatch, Jewel; Kynoch Reale-Munroe and Bernard Castillo II, 2012. A Threat to our Reefs: Sedimentation in Emerging Researchers National Conference in STEM 2012, Atlanta, GA, A143. (Student presentation at conference)
2. Gubser, Nathan; Kynoch Reale-Munroe and Bernard Castillo II, 2012. Sediment Based Pollutant Regulation and Mitigation in Emerging Caribbean Scientists Annual Spring Research Symposium 2012, St. Croix, VI, 20. (Student presentation at conference)
3. Gubser, Nathan; Kynoch Reale-Munroe and Bernard Castillo II, 2012. Threats to our Reefs: Sediment Based Pollutant Regulation and Mitigation in UVI Research Day 2012, St. Croix, VI, STX-A11. (Student presentation at conference)
4. Reale-Munroe, Kynoch and Bernard Castillo II, 2012. Threats to our Reefs: Quantifying Sediment and Organic Material Production Rates from Surface Erosion Processes in Small Subtropical Watersheds on the East End of St. Croix, USVI in UVI Research Day 2012, St. Croix, VI, STX-A4.

QUANTIFYING SEDIMENT AND ORGANIC MATERIAL PRODUCTION RATES FROM SURFACE EROSION PROCESSES AND THE EFFECT ON MARINE WATER QUALITY IN SMALL SUBTROPICAL WATERSHEDS ON THE EAST END OF ST. CROIX, USVI

Problem

Worldwide assessments suggest that land-based sources of pollution are affecting over 20% of the world's coral reef systems (Bryant, et al., 1998). Within the Caribbean region, a decline in live coral cover has been in part, attributed to localized stressors (Gardner, et al., 2003), out of which increased sedimentation from land-based sources of pollution consistently ranks among the most imminent threats (Rogers, 1990; Rothenberger, et al., 2008; García-Sais, 2008). Many coral reef systems within the Caribbean are at risk from land-based sources of sediment and this has prompted the U.S. Coral Reef Task Force to encourage local governments to develop erosion control strategies to mitigate their impacts.

In October 2010 United States' Environmental Protection Agency (EPA) published a list of impaired and threatened waters in the U.S. Virgin Islands (USVI) that are targeted for the development of future Total Maximum Daily Load (TMDL) limits in the territory. The most common reported causes of pollution in near-shore waters were sedimentation, effluent discharges, dissolved oxygen (DO) deficiencies and bacterial contamination (US EPA, 2010). Of the 33 listed sites in St. Croix, 85% of the reported instances were due to turbidity. While the sole source for some sites were turbidity, most were also impaired by DO deficiencies, fecal *coliform*, phosphorous, etc.

Particulate organic material *via* terrestrial and allochthonous input into estuaries and bays is a critical nutrient source for receiving aquatic ecosystems. Natural sediment and organic material delivery rates from undisturbed watersheds provide a healthy environment for species to thrive in. However, as land use changes affect the rates and volume of terrestrial and allochthonous input into the receiving water column, the aquatic species may also be affected. It has been shown that organisms found in nearshore aquatic ecosystems exhibit spatial relationships to sources of terrestrial sediments and particulate organic material input (Hubbard, et al., 1987; Jeffrey, et al., 2005) and that a general seaward decrease in the accumulation of particulate organic material occurs in sheltered sites close to shore (Galois, et al., 2000).

Massive sedimentation events have been repeatedly observed from runoff being generated on a trail surface and discharged into Boiler Bay. Two such events are shown below (Figure 1). Boiler Bay watershed is located within the St. Croix East End Marine Park (STXEEMP) and is comprised of an array of different aquatic habitats, (seagrass beds, linear reef and sand patches), which contains protected and endangered species (coral, sea turtles, conch, etc.).

Figure 1. Runoff generated from a trail surface and discharged into Boiler Bay. LEFT: Oct. 6th, 2010, RIGHT: May 27th, 2011.

Research Objectives

The specific objectives of the study were:

- To determine and compare terrestrial sediment production rates from disturbed and undisturbed surfaces in East End and Boiler Bay watersheds;
- To quantify the percentage of particulate organic material present in the sediment being produced and
- To link terrestrial sediment production rates to turbidity measurements in Boiler Bay.

Methodology

Terrestrial Erosion

Sediment was collected over a one-year period from seven (7) sediment traps located throughout East End and Boiler Bay (Figure 2) watersheds. Four (4) sediment traps collected material produced from vegetated, undisturbed hillslopes and three (3) collected material from a disturbed trail surface that was once an unpaved road (Figure 3).

Figure 2. Boiler Bay research site with sediment trap locations (in red).

Figure 3. LEFT: Undisturbed hillslope surface and RIGHT: Disturbed trail surface.

Figure 4. Rain gage.

Precipitation was observed using a tipping bucket rain gage (Figure 4). Vegetation cover was determined by point-count methodology described by Parker (1951) and percent slope was obtained by using a clinometer.

Particulate Organic Material

The material was collected using sediment traps and was then analyzed for the percentage of particulate organic material present (%POM) in the sediment samples. Sediment samples that were collected in the field were separated into coarse and fine fractions using a 2-mm sieve (Figure 5, LEFT).

The %POM was determined using a modified Loss on Ignition (LOI_{550}) methodology (Santisteban, et al., 2004) to determine the percent loss of organic carbon in the collected sediment samples (Figure 5, RIGHT).

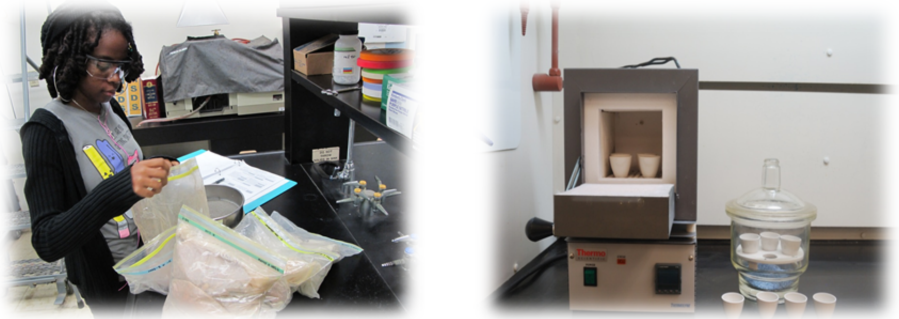


Figure 5. LEFT: Sediment samples being separated into a fine and coarse fraction. RIGHT: Furnace and crucibles used in LOI_{550} analysis.

Turbidity

Six months of baseline water quality data was collected for five parameters (turbidity, temperature, DO, pH and conductivity) using a deployed, optical monitoring system (sonde). The water quality data was collected in an effort to describe what natural conditions were and how turbidity changed in response to terrestrial runoff (Figure 6).

Figure 6. Sonde used to collect water quality parameters.

Principal Findings and Significance

Terrestrial Erosion

Table 1. Erosion summary results table. *Two months of data missing, due to trap failure during extreme rain events.

EAST END BAY Trap ID	Catchment Area (m^2)	Slope (%)	Vegetation Cover (%)	Total Precipitation (cm)	Total Sediment Production (kg)	Average Erosion Rate (kg*m^{-2}*yr^{-1})
EEB-U-4	281	43.0	69.0	176	2.83	9.23E-03
EEB-U-5	192	47.0	76.0	176	2.40	1.14E-02
EEB-U-6	968	53.0	58.0	176	4.68	4.46E-03
EEB-U-7	149	34.0	66.0	176	2.79	1.72E-02
BOILER BAY Trap ID						
WRRI-B*	410	7.00	34.0	181	338*	0.78*
WRRI-D	48.0	12.0	24.0	181	937	18.51
WRRI-K	19.5	15.0	31.0	181	702	34.13

Trail surfaces exhibited mean erosion rates that were 1,680 times higher than the undisturbed hillslopes (Figure 7).

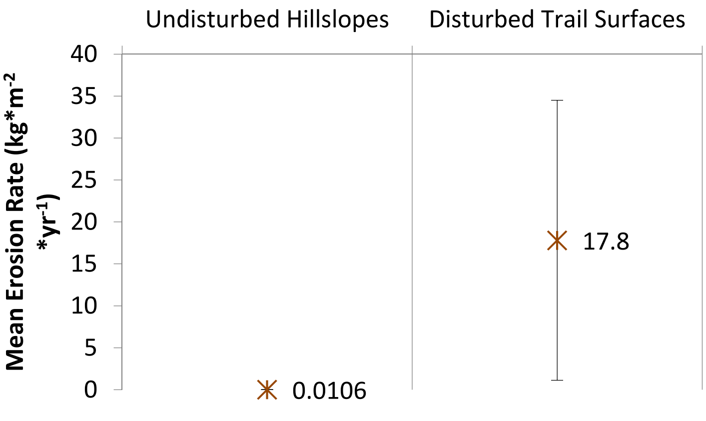


Figure 7. Annual mean erosion rates by surface type.

A power trend line (R-squared of 0.88) characterized the increasing rates of erosion with decreasing vegetation cover (Figure 8, LEFT). A clear relationship was not observed between slope and erosion rates, except among highly erodible trail surfaces (Figure 9, RIGHT).

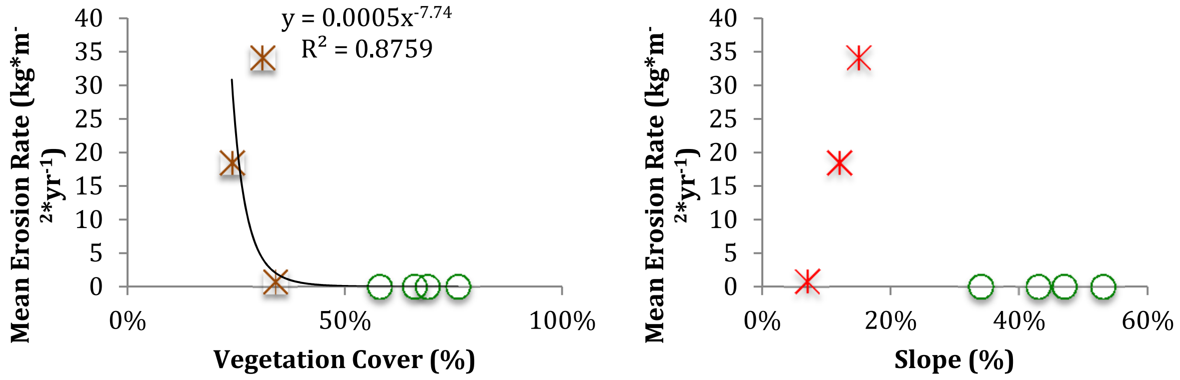


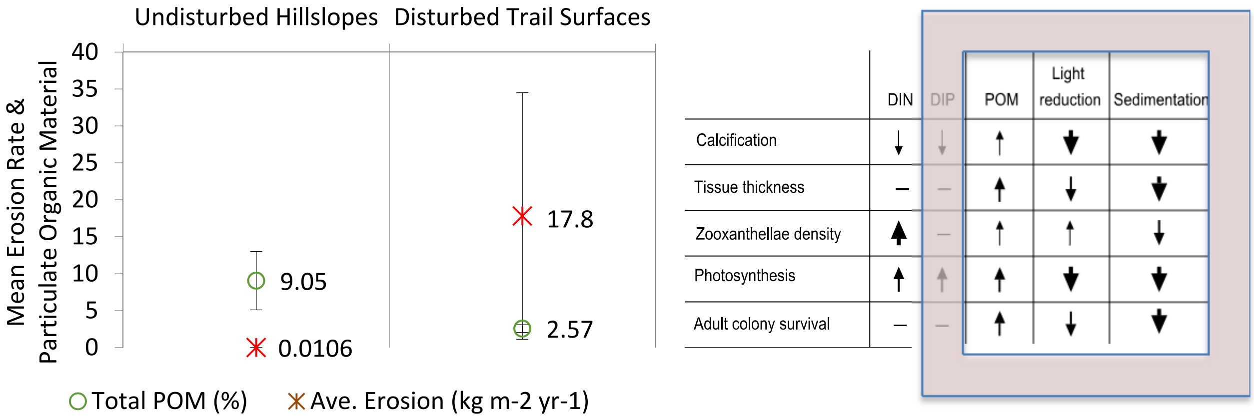
Figure 8. LEFT: % vegetation cover *vs.* mean erosion rates. RIGHT: %Slope *vs.* mean erosion rates.

Particulate Organic Material

Table 2. Organics summary table. Fine, coarse and total %POM.

EAST END BAY Trap ID	Fine POM (%)	Coarse POM (%)	Total POM (%)
EEB-U-4	24.7	2.21	9.90
EEB-U-5	33.1	3.03	13.2
EEB-U-6	15.9	2.01	5.10
EEB-U-7	21.9	1.83	7.88
BOILER BAY Trap ID			
WRRI-B	4.88	1.56	2.51
WRRI-D	5.09	1.83	3.11
WRRI-K	4.73	1.23	2.10

Sediment produced by the trail contained 3.5 times less %POM than undisturbed hillslopes. An inverse relationship was observed between the total %POM and mean erosion rates (Figure 9, LEFT). Fabricus (2005) compiled a plethora of published literature relating POM and sedimentation to direct effects on coral biometrics (Figure 9, RIGHT). POM had a positive effect on coral health and sedimentation an extreme negative effect.



	DIN	DIP	POM	Light reduction	Sedimentation
Calcification	↓	↓	↑	⬇	⬇
Tissue thickness	–	–	⬆	↓	⬇
Zooxanthellae density	⬆	–	↑	↑	↓
Photosynthesis	⬆	⬆	⬆	⬇	⬇
Adult colony survival	–	–	⬆	↓	⬇

Figure 9. LEFT: Inverse relationships between erosion rates and %POM by surface type. RIGHT: Impact of water quality parameters on coral biometrics. Adapted from Fabricus (2005).

Turbidity

Six months of ambient, baseline data for five water quality parameters were collected (temperature, conductivity, pH, turbidity and DO), however, we were not successful in capturing a sedimentation event. Ambient turbidity fluctuated between -1 to 4 NTUs under natural

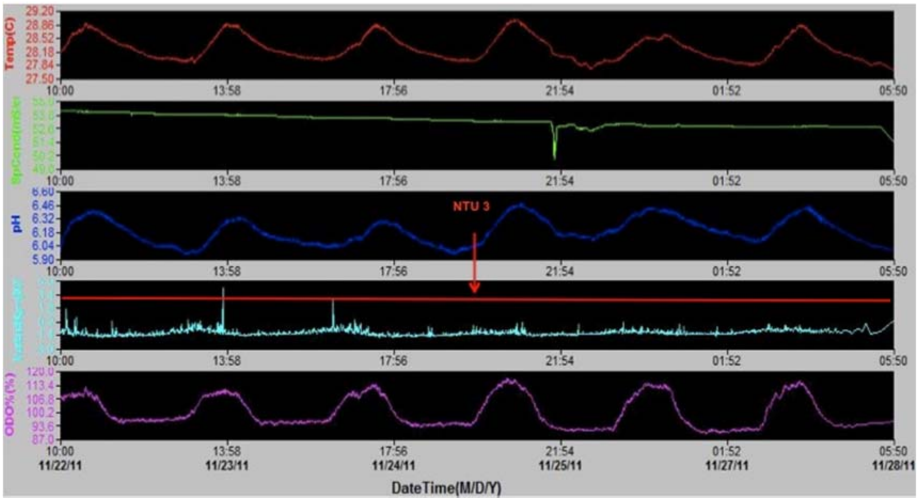


Figure 10. Water quality data. From top to bottom: Temperature, Conductivity, pH, Turbidity & DO.

conditions (Figure 10).

Conclusions

Terrestrial Erosion

Trail surfaces with gentle slopes (mean = 11.3%) exhibited mean erosion rates that were 1,680 times higher than the undisturbed hillslopes, which had exceedingly steeper slopes (mean = 44.3%). When vegetation cover was decreased to about 32%, erosion rates increased dramatically. These results indicate that vegetation may be the primary force controlling erosion rates in the east end of St. Croix. A clear relationship was not observed between surface type (trail & hillslope), slope and erosion rates. This may be a direct reflection of the effect of vegetation cover density on undisturbed hillslopes.

Particulate Organic Material

Results from this study showed that sediment produced from massively eroding trail surfaces contained decreased POM relative to sediment collected from undisturbed hillslopes. Fabricus (2005) showed that POM was reported to have a positive effect on all coral biometric parameters. On the contrary, eroding surfaces (disturbed trail) contained low POM in the sediment and experienced extremely high erosion rates.

Turbidity

Sediment production totaled 659 kg (1453 lbs) from three sediment traps on the disturbed trail surface during the study period. In contrast, the sediment traps located on the undisturbed hillslopes collected a total of 3.2 kg (7.0 lbs). This amount of sediment delivery and with an increased frequency than what would happen in natural, undisturbed conditions may be very detrimental to the coral reefs ecosystem there in Boiler Bay.

We were successful in capturing six months of ambient, baseline data for the five water quality parameters we were looking at (temperature, conductivity, pH, turbidity and DO), however, we were not successful in capturing a sedimentation event. Correlative, diurnal relationships were observed between temperature, DO and pH. Turbidity fluctuated between -1 to 4 NTUs under normal conditions.

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IDENTIFICATION OF WATERBORNE CONTAMINANTS ENTERING THE ST. THOMAS EAST END RESERVE

Basic Information

Title:	IDENTIFICATION OF WATERBORNE CONTAMINANTS ENTERING THE ST. THOMAS EAST END RESERVE
Project Number:	2011VI202B
Start Date:	3/1/2011
End Date:	7/15/2012
Funding Source:	104B
Congressional District:	n/a
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Water Quality, Toxic Substances
Descriptors:	
Principal Investigators:	John F Barimo, Stanley L. Latesky

Publications

There are no publications.

IDENTIFICATION OF WATERBORNE CONTAMINANTS ENTERING THE ST. THOMAS EAST END RESERVE

Problem and Research Objectives

This study meets goals of the St. Thomas East End Reserve (STEER) management plan by providing scientific data to be utilized in ecosystem based management practices to bolster natural resources. Further, improved water quality is deemed to be the overarching aim for STEER (Brown et al., 2010); however, this cannot be fully addressed without first identifying point and non-point sources of contaminants within STEER. Although contaminants may enter the Mangrove Lagoon and Benner Bay through multiple pathways, this study will provide data on the contaminant load for one of the principal watersheds entering STEER. This study also addresses the U. S. Virgin Islands (USVI) Territorial concern that lists the Mangrove Lagoon, Benner Bay and STEER as an Area of Particular Concern due to waterborne contaminants. Precise sampling protocol will be coordinated with the STEER Core Planning Team which includes the USVI Coastal Zone Management Program, the USVI Division of Fish & Wildlife, the Nature Conservancy and the University of the Virgin Islands (UVI), as well as the future STEER coordinator (see attached letter of support). All data collected during this proposed study will be openly shared with this same group of stakeholders.

Water quality data from this proposed study, i.e., organic (hydrocarbons and pesticides) and inorganic (metals) concentrations, will be shared with STEER resource managers which includes USVI Coastal Zone Management Program and the USVI Division of Fish & Wildlife. This study will also complement our collaborative efforts with a National Oceanic and Atmospheric Administration (NOAA) Center for Coastal Monitoring & Assessment (CCMA) which is looking at the contaminant load in adjacent marine waters. Our proposed work will help characterize to what extent that the Turpentine Run watershed contaminant load impacts the STEER estuarine system

The St. Thomas East End Reserve was established as a Marine Protected Area (MPA) to safeguard near-shore seagrass, mangrove and coral reef resources. It is also designated as 1 of 6 *Territorial Areas of Particular Concern* due to the MPA's proximity to the Bavoni Landfill and the island's largest watershed (Brown et al., 2010). Anthropogenic disturbance and watershed transport of contaminants and sediments in near-shore coastal waters have been attributed to the degradation of tropical marine ecosystems (Peters et al. 1997) as well as those within the U.S. Virgin Islands (Rogers and Beets, 2001). Approximately one third of the island's population lives within this watershed which is the largest and most heavily developed watershed on St. Thomas (DPNR 2010 report) which has been exacerbated by a 5-fold increase in the territorial population over the past 50 years (Virgin Islands Bureau of Economic Research 2006).

Methods, Procedures and Facilities

The water and sediment samples will be analyzed by state-of-the-art analytical equipment following standardized EPA methodology. Hydrocarbons, including PAHs, will be analyzed using a gas chromatograph equipped with a Mass Spectrometer detector (GC/MS). Trace heavy metals will be analyzed by Inductively Coupled Plasma Spectrometer equipped with a Mass Spectrometer Detector (ICP/MS). This study will also serve as training in analytical chemistry and phase I of a graduate thesis for an enrolled student who also plans to also look at uptake of contaminants by lagoon biota; however, the later phase II is not part of this proposal. The graduate student will also act as a direct supervisor for undergraduate student workers who will also be directed by project PI's.

Data will be analyzed using conventional statistical methods and identified compounds will be compared to reference sources such as commercial gasoline, dry cleaning fluids and pesticides. Metals detected will be compared to freshly sampled dust samples of African dust and if possible, ash from volcanic activity in the region. Variability due to seasonal factors will be considered as well.

Collection and operation of the analytical instruments will be used as a training tool for UVI students and they are expected to do most of the hands on work with sample collection and analysis, and will be involved with the STEER Core Planning Team regarding the selection of precise sampling locations.

The University of the Virgin Islands has invested in state of the art chemical analysis equipment from the federally funded Department of Education Title III program. Varian GC/MS, ICP/MS and LC/MS were installed within the past two years and are fully operational. This equipment, in conjunction with existing chemical facilities, gives us the ability to analyze metal contaminates in water to the part per trillion (ppt) level and all hydrocarbons including polyaromatic hydrocarbons (PAHs) to the part per billion concentrations. A subset of samples will be split for QA/QC with duplicates analyzed TDI-Brooks International as per protocols utilized by our NOAA collaborators.

We will collect water column samples in the field in various sample stations within Turpentine Run and where this channelized stream enters the STEER estuary. Where feasible we will sample both water and bottom sediments. The sampling will be repeated four times in one year to coincide with rainy and dry periods. Environmental data such as water temperature, salinity, turbidity, etc. will be collected.

Water samples and sediment samples will be analyzed for metals using ICP/MS with particular attention to arsenic, mercury, lead, tin, cadmium and other potentially toxic metals using EPA method 200.8 (EPA 2007). Collected samples will be analyzed by GC/MS using purge EPA methods 601 and 602. Results will be compared to aircraft fuels and other petroleum products to attempt to ascertain sources of the pollutants.

Water and sediment samples for metal analysis will first be digested using a CEM microwave digestion system. Samples will be analyzed in triplicate using Varian ICP-MS.

For water samples, trace organic analysis will be accomplished by using published methods of sample concentration followed by elution. Samples will be passed through a solid-phase extraction columns (SPE) followed by elution with a small quantity of methanol.

The sediment samples will be analyzed by extracting the sediments using methylene chloride followed by evaporation and then dissolution into a known volume of methylene chloride.

Principal Findings and Significance

To date, all that has been accomplished is an initial survey mapping of sample collection points and an initial assessment of analysis protocols (both for the ICP-MS and GC-MS). We plan on completing the project this summer.

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Information Transfer Program Introduction

The major effort in dissemination of information dissemination undertaking by the Virgin Islands Water Resources Research Institute during the reporting period was collaboration with the other water institutes in the Islands Region to execute the Water Resources Sustainability Issues on Tropical Islands Conference. Details of this activity are detailed in the report that follows.

The VI-WRRI continues to serve as a source of information to the general public on matters affecting water resources in the U. S. Virgin Islands. In addition to providing access to printed material, it maintains a website where its publications may be accessed and provides linkages to other sites that might be of interest. The VI-WRRI also provides information to researchers, public officials and others in the USVI, the Caribbean region and elsewhere on current developments and issues in water resources.

Islands' Institutes Water Conference

Basic Information

Title:	Islands' Institutes Water Conference
Project Number:	2011VI203B
Start Date:	3/1/2011
End Date:	2/28/2012
Funding Source:	104B
Congressional District:	Not Applicable
Research Category:	Not Applicable
Focus Category:	Education, Hydrology, Management and Planning
Descriptors:	None
Principal Investigators:	Henry H. Smith

Publications

There are no publications.

ISLANDS' INSTITUTES WATER CONFERENCE

Problem and Objectives

Island states are faced with a unique set of environmental and cultural issues pertinent to the management of water resources. Fresh water resources are under threat on many islands from both overuse and contamination. Ocean waters in these tropical regions are ecologically sensitive and valuable, and similarly threatened by overuse and pollution. On some islands, climate-induced sea level rise and associated increases in storm surge magnitude are degrading groundwater resources. Many island states have been experiencing climate-change based alterations of precipitation patterns resulting in floods and droughts. Sustainable management and protection of island water supplies is even more critical than it is on the continents, as island communities have no recourse to importation in the event of a failure of their water supplies. Island states are heavily dependent on imports such as food, fuel, and manufactured goods to satisfy their resource needs. On most of these islands, population growth is putting increasing pressure on water resources. It is imperative that these threats to the welfare of island communities be addressed by sound scientific research before they reach crisis proportions. Those tasked with resource protection and management need access to scientifically sound research that is specific to island environments.

The above issues are universal to island states yet researchers in these far-flung and isolated places seldom have opportunity to share knowledge and experience with one another. They work largely in isolation. The great distances that separate most island states from larger centers of academia and government means that there is less frequent exchange between the islands' researchers and their colleagues in the major population centers. It is believed that enhanced communication and collaboration between island researchers can provide a vital, synergistic link, which will strengthen all the researchers programs. It is true that the greatest scientific advances usually result from the collaboration of groups of researchers working together.

There are four island-based research centers within the NIWR consortium: Water Resources Research Center (WRRC) in Honolulu, Water and Environmental Research Institute (WERI) of the Western Pacific in Mangilao, Puerto Rico Water Resources and Environmental Research Institute (WRERI) in Mayaguez, and Virgin Islands Water Resources Research Institute (WRRI) in St. Thomas. Each Center addresses similar issues within its region and yet communication between the Centers is infrequent and difficult due to physical and temporal distance. In addition to the four US Centers, there are other water research institutes on non-US islands, such as Samoa, Fiji, Tonga, and Palau, which face similar water problems and issues.

We proposed to organize an intensive three-day meeting of the directors and other faculty members from the island research centers, both US and non-US, in Honolulu as an opportunity to share information about research we are conducting, research needs that we perceive, and collaboration in future research that will address common problems and issues. Grant monies we used to invite recognized experts in water research fields pertinent to the issues faced by island states.

Methodology

The workshop was hosted by the University of Hawai‘i at the Ala Moana Hotel in Honolulu and was attended by about 150 participants. Hawai‘i's WRRC was the primary sponsor and the water centers from Guam, Puerto Rico, and US Virgin Islands were co-sponsors. The program was covered in 2.5 days. A field trip was organized in the last day after the end of the sessions. A book of abstracts was prepared for distribution at the conference. The staff at WRRC prepared the necessary informational materials and handled conference logistics. Details about the program, speakers, conference organization, and others information can be found in the web site: https://sites.google.com/site/wrrcconference2011/

The following committees planned and actively managed the conference.

Regional Organizing Committee

Dr. Chittaranjan Ray
Interim Director, Water Resources Research Center, University of Hawai‘i at Mānoa
Dr. Gary Denton
Director, Water and Environmental Research Institute of the Western Pacific, Guam
Dr. Jorge Rivera-Santos
Director, Puerto Rico Water Resources and Environmental Research Institute
Dr. Henry H. Smith
Director, Virgin Islands Water Resources Research Institute

Local Organizing Committee

Conference Chair
Dr. Aly El-Kadi
Associate Director, Water Resources Research Center, and Professor, Department of Geology and Geophysics, University of Hawai‘i at Mānoa
Conference Co-Chairs
Dr. Roger Fujioka
Former Director, Water Resources Research Center, University of Hawai‘i at Mānoa
Philip Moravcik
Technology Transfer Specialist, Water Resources Research Center, University of Hawai‘i at Mānoa
Dr. Tetsuzan Benny Ron
UH Aquaculture Program Coordinator (OVCRGE) and Affiliate Faculty, Water Resources Research Center, University of Hawai‘i at Mānoa

Technical Advisory Committee

Dr. Roger Babcock
Associate Professor, Civil and Environmental Engineering and Associate Researcher, Water Resources Research Center, University of Hawai‘i at Mānoa
Dr. Clark Liu
Professor, Civil and Environmental Engineering and Researcher, Water Resources Research Center, University of Hawai‘i at Mānoa
Dr. Delwyn Oki
Hydrologist, US Geological Survey, Pacific Islands Water Science Center, Honolulu, Hawai‘i
Dr. Kolja Rotzoll
US Geological Survey, Pacific Islands Water Science Center, Honolulu, Hawai‘i

Keynote Speakers were Gary Gill (Deputy Director for the Environment, Hawai‘i Department of Health) who spoke on "Role of Hawai‘i’s Department of Health in Water Protection as a

Sustainable Resource", and Takashi Asano (Professor Emeritus, University of California at Davis), who spoke on "The Role of Water Reuse in Water Resources Management", and Jennifer Orme-Zavaleta, (Interim National Program Director, Safe and Sustainable Water Resources Program, US Environmental Protection Agency) who spoke on "Building a Research Program to Ensure Safe and Sustainable Water Resources".

The following is the full list of talks presented at the conference. Invited presenters are marked by "*".

Session 1. Wastewater

1. *Wojciech M. Jadwisienczak, The Current and Future Developments in Deep UV Solid State Technology for Water Purification
2. Douglas R. Tait, Dirk V. Erler, Andrew Dakers, Leigh Davidson and Badley D. Eyre, The ecoTrench: A Low Cost, Low Technology On-Site Treatment System for Removing Nutrient in South Pacific Nations
3. Jessie Liu, Noémi D'Ozouville, Josselin Guyot-Tephany and Delio Sarango, Water Management and Practices: Fecal Contamination of Household Water and Health Outcomes in Santa Cruz Island, Galápagos
4. Mohammad H. Golabi and Manuel Duguies, Vetiver Grass System (VGS)—A Green and Low Cost Technology for Small Island's Waste Water Treatment Needs
5. Marek Kirs and Roger S. Fujioka, Application of Microbial Source Tracking Technologies in Recreational Waters Can Reliably Identify Risk from Sewage-Borne Pathogens in Tropical Regions
6. Robert M. Kerns, Lt. Lyle Setwyn, and Danielle Mauga, Bacteriological Contamination of Wells in American Samoa
7. Ginamary Negrón-Talavera and Luis A. Ríos-Hernández, Monitoring the Population Dynamics of Enterococci in Recreational Waters: A 24 Hour Odyssey

Session 2. Flooding

1. *Edward Teixeira, Impact of Disasters in Hawai‘i on Surface Water Systems
2. Paul Hinds and Vincent Cooper, Development of a Surface Runoff Prediction Model for Unplanned Hillside Developments in Trinidad
3. Russell Yost, Aly El-Kadi and John Yanagida, A Water Resources Win-Win Scenario: Capturing Flood Waters from the Kaiaka-Waialua Watershed, North Shore, Oahu
4. Scot K. Izuka, Suspended-Sediment Transport in the Waikele Watershed, O‘ahu, Hawai‘i, During the Storm of December 11, 2008
5. Walter F. Silva-Araya and Federico García-Uribe, Modeling Mixed Flow Conditions in Surcharged Storm Systems

Session 3. Climate

1. *Thomas W. Giambelluca, Qi Chen, Abby G. Frazier, Jon P. Price, Yi-Leng Chen, Pao-Shin Chu and Jon K. Eischeid, Introducing the New Rainfall Atlas of Hawai‘i
2. *Richard J. Wallsgrove, Maxine A. Burkett and David Penn, Hawai‘i's Law & Policy Toolkit: Climate Change Adaptation and Water Resource Management

3. *Melissa L. Finucane, Integrating Physical and Social Sciences to Support Decision Making about Fresh Water Resources on Pacific Islands
4. *Mark Chappell, Potential Saline-Sodic Pedogenesis in Soils from Climate-Change Mediated Sea-Level Rise
5. H. Annamalai, The Current and Future Climate Conditions Over the Pacific Islands
6. Mark A. Lander, The Post World War II Observations of Climate in Micronesia: Sea Level Rise, Temperature Increases and Drying in the East
7. Pao-Shin Chu, Ying Ruan Chen and Thomas A. Schroeder, Trends in Precipitation Extremes and Return Levels in the Hawaiian Islands Under a Changing Climate
8. Steven R. Fassnacht, Sharla A. Stevenson and Graham Sexstone, Climate Change Near Kaloko-Honokohau National Historical Park and Implications for Water Resources Management

Session 4. Water Resources Availability and Management

1. *J. Sansalone, G. Ying and G. Garofalo, Myths, Models and Measurement of Particle Transport and Fate
2. Chester Lao, Role of Deep Monitor Wells in Island Hydrology
3. Delwyn S. Oki, Trends in Groundwater Availability in Hawaiʻi
4. Lauren C. Roth Venu, Ecological Engineering: Building Sustainable Island Communities with Nature in Mind
5. Kolja Rotzoll and Aly El-Kadi, Numerical Simulation of Borehole Flow in Deep Monitor Wells in a Coastal Freshwater Lens, Pearl Harbor Aquifer, Oʻahu, Hawaiʻi
6. Ryan T. Bailey and John W. Jenson, Analysis of Groundwater Resources of Atolls in the Federated States of Micronesia
7. *Martin Roush, The Path to Guam Waterworks Authority Overarching Sustainability: Building Leadership Capacity
8. Papacostas, Evolution of Island Water Rights in Hawaiʻi
9. Juan C. Santamarta Cerezal and Jesica Rodriguez Martín, Advances in Exploitation of Underground Water Resources in Volcanic Islands Experiences and Methods in the Canary Islands, Spain, Europe
10. Shahram Khosrowpanah, The Impact of Guam's Population Growth on Island Water Resources
11. James Roumasset and Christopher Wada, Planning for the Integrated Use of Groundwater, Recycled Wastewater, and Desalination
12. Shane Epting, Hawaiian Mythology and the Benefits of an Ecological Noble Lie: Water Resource Management, Sustainability, and the Curse of Pele

Session 5. Panel Discussion

1. *L. Stephen Lau, Learning About the Natural Waters in Humid Tropical Islands for Sustainable Communities Objectives
2. Travis W. Hylton, Guam Water Resources Management Study

Session 6. Groundwater Recharge

1. Adam G. Johnson, Water-Budget Model and Estimates of Groundwater Recharge for Guam

2. John W. Jenson, Mark A. Lander and Richard H. Randall, Vadose Fast Flow in the Northern Guam Lens Aquifer, Guam, Mariana Islands
3. Steve Parabicoli, The County of Maui's Water Reuse Program: A Key Component of Sustainable Water Resource Management in an Island Environment

Session 7. Surface Water Quality

1. John C. Hayes and Billy J. Barfield, Modeling Runoff, Sediment and Water Quality Practices in an Island Environment Using the model IDEAL
2. Shiang-Min-Chen, Yu-Min Wang and I Tsou, Using Artificial Neural Network Approach for Modeling Rainfall-Runoff

Session 8. Water for Energy

1. *Jan C. War, Economic Development Opportunities for Tropical Islands at the Natural Energy Laboratory of Hawai‘i Authority
2. Keith R. Olson, Historical Perspective of Environmental Monitoring at the Natural Energy Laboratory Hawai‘i Authority
3. Shahram Khosrowpanah and Leroy Heitz, Predicting Hydropower Potential on Ungaged Streams in Kosrae Island, the Federated States of Micronesia
4. Deborah A. Solis, Scott Moncrief, Luis Vega, Philip A. Potter, Renee Kinchla, Tom Cook, Meghan Travers and Antti Koskelo, Assessing Hydroelectric Power Potential in the State of Hawai‘i

Session 9. Submarine Groundwater Discharge

1. Christine A. Waters, Henrieta Dulaiova and Craig R. Glenn, Locating and Quantifying Coastal Groundwater Discharges Potentially Originating from a Wastewater Treatment Facility
2. Daniel Amato, Submarine Groundwater Discharge Increases Marine Macroalgal Photosynthesis
3. Jacque L. Kelly, Craig R. Glenn and Paul G. Lucey, Use of Thermal Infrared to Locate and Study Submarine Groundwater Discharge in the Hawaiian Islands
4. M. Bayani Cardenas, Peter B. Zamora, Kevin M. Befus, Fernando P. Siringan, Dirk V. Erler, Isaac R. Santos, Douglas Tait, Raymond S. Rodolfo and Mark R. Lapus, Off-Shore Electrical Resistivity Imaging for Multi-Scale Characterization of Near Shore Hydrogeologic Processes and Submarine Groundwater Discharge
5. Kevin M. Befus, M. Bayani Cardenas, Travis E. Swanson, Dirk Erler, Isaac Santos and Douglas Tait, Fluid and Heat Fluxes Across the Intertidal Zone
6. Joseph J. Kennedy, Craig R. Glenn and Henrieta Dulaiova, Evaluation of Anthropogenic Impacts on the Groundwater Flow from Two Coastal Springs, Maunalua Bay, South Shore, O‘ahu

Session 10. Groundwater Quality

1. Alan Mair, Robert B. Whittier, Aly I. El-Kadi and Daniel Chang, Adapting Drinking Water Source Vulnerability Assessments for the Hawaiian Islands

2. Gary R.W. Denton and Carmen M. Sian-Denton, A Retrospective Analysis of Water Quality Data for Chemicals of Concern in Guam's Groundwater: Emerging Trends and Future Concerns
3. Joseph Fackrell and Craig R. Glenn, Geochemical Composition of Ground and Nearshore Marine Waters at Ka‘anapali, Maui, Hawai‘i

Poster presentations are listed below.

1. L. Stephen Lau and John F. Mink, Hydrology of the Hawaiian Islands
2. Joseph P. Morris, Alex Anderson, Wojciech M. Jadwisienczak and R. Guy Riefler, Water Disinfection of Bacillus subtilis Spores Using Ultraviolet Light Emitting Diodes
3. Alan Mair, Benjamin Hagedorn, Suzanne Tillery, Aly I. El-Kadi, Kyoochul Ha and Gi Won Koh, Estimating Groundwater Recharge Using a Water Balance Approach for Jeju Island, Korea
4. Brittany Anderson and Jiasong Fang, Assessing Effects of Environmental and Human Land Use Change in a Coastal Wetland Using Lipid Biomarkers and Stable Isotopes
5. Joseph D. Rouse, Goro Kobayashi and Hiroaki Fujii, High-Rate Biological Treatment Coupled with Sludge Reduction
6. Peter B. Zamora, M. Bayani Cardenas, Raymond S. Rodolfo, Hillel B. Cabria, Kevin M. Befus and Ma. Isabel Senal, Tidal
7. Response of the Subterranean Estuary Revealed by Electrical Resistivity Imaging and Hydraulic Monitoring
8. Juan C. Santamarta Cerezal and Jesica Rodriguez Martín, Traditional Systems for Water Harvesting and Soil Conservation in Volcanic Islands. Case Study: The Canary Islands, Spain, Europe
9. Yoko Yamamoto, Sharon LePage, Barbara McLain, Carlos Andrade and Tetsuzan Benny Ron, Sustainability Isn't A New Idea: Teaching Ancient Hawaiian Ahupua‘a Using Virtual Reality
10. Seo Jin Ki, Bunnie S. Yoneyama, Philip Moravcik and Chittaranjan Ray, Use of Self-Organizing Map as an Advanced Bioassessment Tool: Assessment of Effect of Submarine Wastewater Outfall on Benthic Fauna Communities in Sand Island, Oahu
11. Vance Tomasu, Alvina Lutu, Toru Kumagai and David Hafner, University of Hawai‘i Mānoa Drainage Project
12. Yu-Chieh Lin, Yu-Min Wang and I Tsou, Using ANN Approach to Recover the Missing Flow Records by the Data of Adjacent Stations in the Same Catchment
13. Seydou Traore and Yu-Min Wang, GIS Dot Density Mapping Interface for Analyzing Soil Water Holding Capacity Change Due to Organic Matter Amendment in Western African Regions
14. T.M. Gregg, J. Burns, A. Mokiau-Lee, K. Carlson and T. Takabayashi, The Effects of Community Structure and Water Quality on Coral Affliction Prevalence and Severity Around Hawai‘i Island
15. Mara F. Cuebas-Irizarry, Valeria Semidei-Rodríguez, Ginamary Negrón-Talavera and Luis A. Ríos-Hernández, The Dominant Population of Enterococci in Puerto Rico's Waterways
16. Yasson Duque-Amaya and Jorge Rivera-Santos, Headwater Zone Delineation Using GIS: A Decision Making Tool for Sustainable Water Resources Management
17. Headquarters, Pacific Air Forces and Headquarters, Thirteenth Air Force, Joint Base Pearl Harbor-Hickam, Hawai‘i: Operations PACIFIC ANGEL and PACIFIC UNITY

Principal Findings and Significance

The conference emphasized that the issue of sustainability is especially critical for islands due to resource limitation and water vulnerability to contamination. The ever-increasing and competing demands include water supply to urban and rural communities, tourist facilities, industry, and farm animals. Additional non-consumptive uses include hydropower generation, navigation, and recreation.

Further, alternative energy sources, such as bio-energy, have added more strain on water resources. Demands are multiplying due to population growth and urbanization. In some cases, water supplies are unable to deliver water on a 24-hour basis due to high leakage and sometimes wastage. Issues related to the coordinated management of surface water and groundwater are of prime importance. Water resources are particularly sensitive to climate change due to islands' particular nature. Water scarcity and vulnerability to drought, flooding, and other natural disasters considerably increase as island size decreases. Major factors affecting water resources include physical island characteristics, such as size and topography, climate, and human impact.

Climate change can lead to further degradation of water quality, which is already a major problem in many islands. Contamination originates from point and non-point sources. Pollution sources include discharges of untreated or partially treated wastewater and animals farms, inadequate solid waste disposal sites, agricultural chemicals, leakage of petroleum products and toxic chemicals, sediment erosion, and saltwater intrusion. The small size and steep slopes of catchments on high islands enable water and pollutants to move quickly to downstream areas. The highly permeable soils and shallow water tables on small coral islands facilitate the rapid migration of pollutants to the subsurface.

The reversal of these negative impacts is difficult and time consuming. Pollution affects human health due to microbiological contamination and elevated chemical levels in water supplies. High turbidity and suspended solids are experienced by consumers after periods of heavy rainfall. The effectiveness of water supply intakes and treatment systems is compromised by high-suspended sediment loads, leading to higher costs of providing clean, safe water supplies. Sedimentation in water supply reservoirs and rivers lead to disturbances in upstream catchments. Finally, sediments, bacteria, and chemicals are negatively affecting riverine and coastal environments.

The conference presentations, addressing the issues outlined above, are grouped in sessions covering wastewater, flooding, climate, water supply and management, groundwater recharge, surface water and groundwater quality, water for energy, and submarine water discharge. Although most of the presentations are related to tropical islands, some method-oriented presentations were included that could be applied to these islands as well.

USGS Summer Intern Program

None.

Student Support

Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	7	0	0	0	7
Masters	1	0	0	0	1
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	8	0	0	0	8

Notable Awards and Achievements

Publications from Prior Years