Effective Dispersal of Caribbean Reef Fish is Smaller than Current Spacing Among Marine Protected Areas

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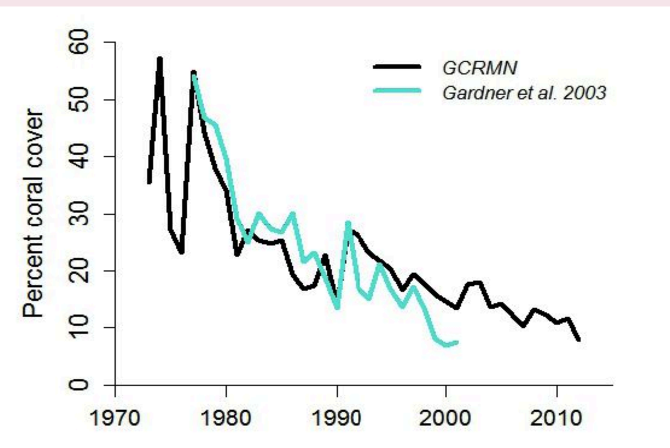
Abstract

Coral reefs are deteriorating at a fast pace. Conservation measures, such as Marine Protected Areas, have been implemented to relieve some areas from local stressors and allow populations to restore to natural levels. Successful networks of *MPAs* can operate if the space among *MPAs* is smaller than the dispersal capacity of the species under protection. Here we tested the power of genome-wide Single Nucleotide Polymorphism data to estimate connectivity across populations in a series of *MPAs* around Puerto Rico and contrasted with 18 microsatellite markers. We found that in the common yellowhead Jawfish, *Opistognathus aurifrons* the maximum effective dispersal is 10 km. *MPAs* exchange migrants likely via intermediate available unprotected habitats through stepping stone dispersal. At scales > 100 km such connectivity is decreased, after the Mona Passage, making the Dominican Republic a genetic mosaic of the genetic variation from the eastern and western Caribbean. The *MPA* network studied is unable to maintain adequate levels of connectivity of these small benthic fishes if habitat in between them is extirpated. Given that overall reef fish diversity is driven by species with life histories similar to that of the yellowhead jawfish, managers face a challenge to develop strategies that allow connectivity and avoid isolation of populations and their extinction.

Coral cover and Reef fish density has decreased in the last decade

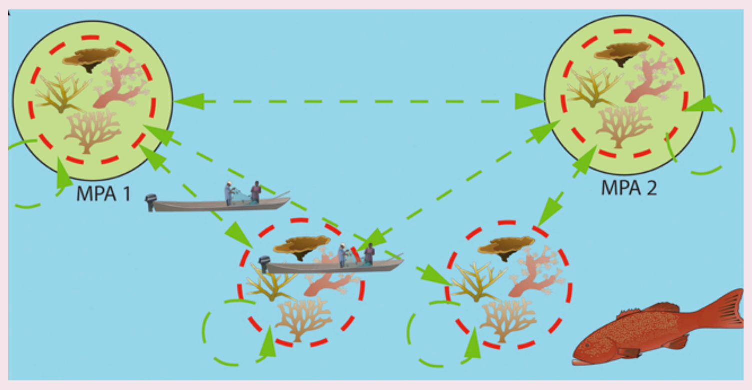


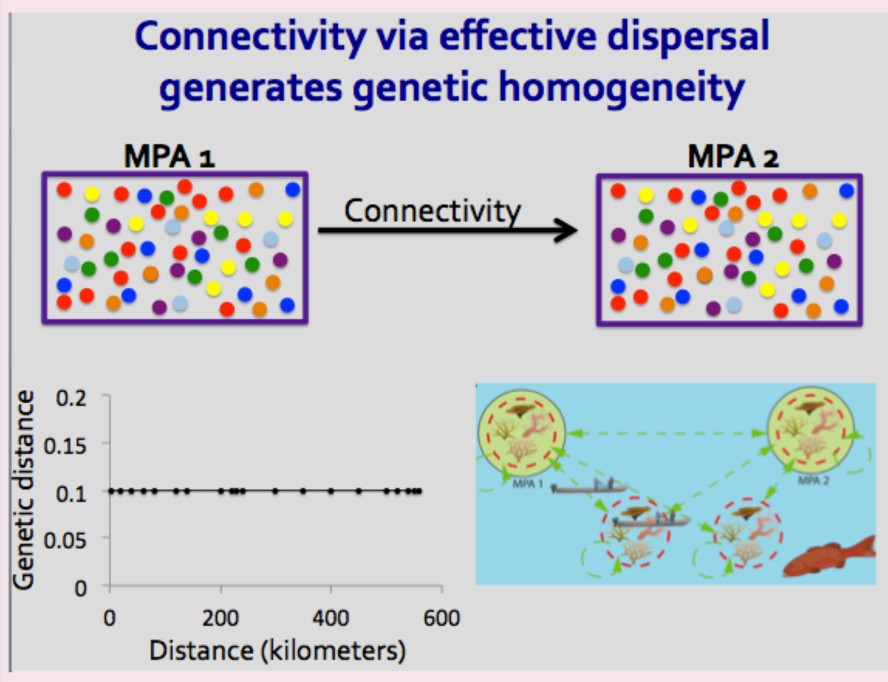
Jackson, et al., 2014

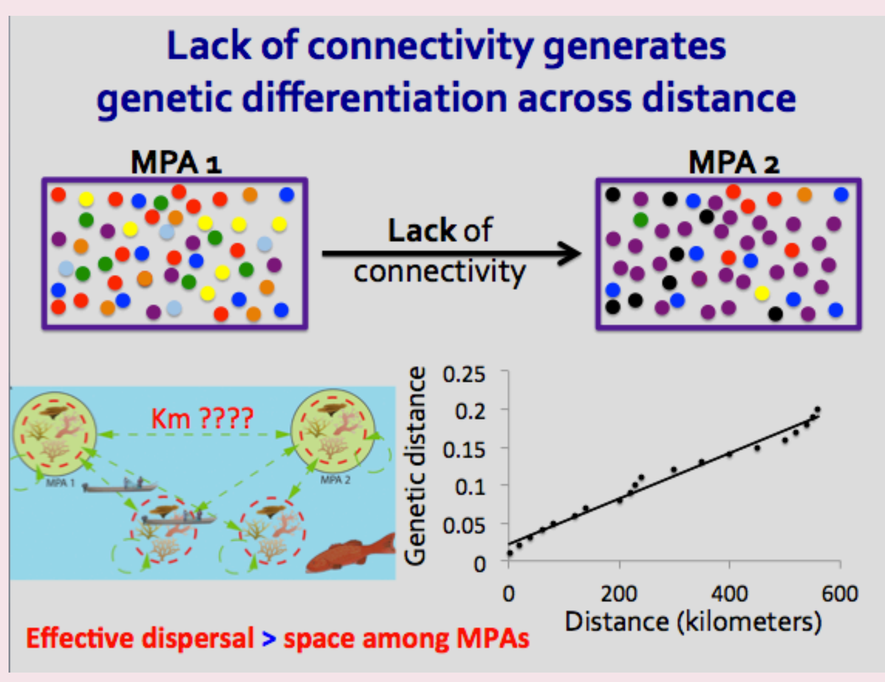
Tropical marine ecosystems have degraded in the last decades as a result of human activities (Mora 2008). This decline is marked in coastal areas, where coral reef organisms have decreased and species commonly seen in the 1970s are rarely observed today, especially commercially exploited species and apex predators (Steneck *et al.* 2009).

MPAs preserve biodiversity when working as networks

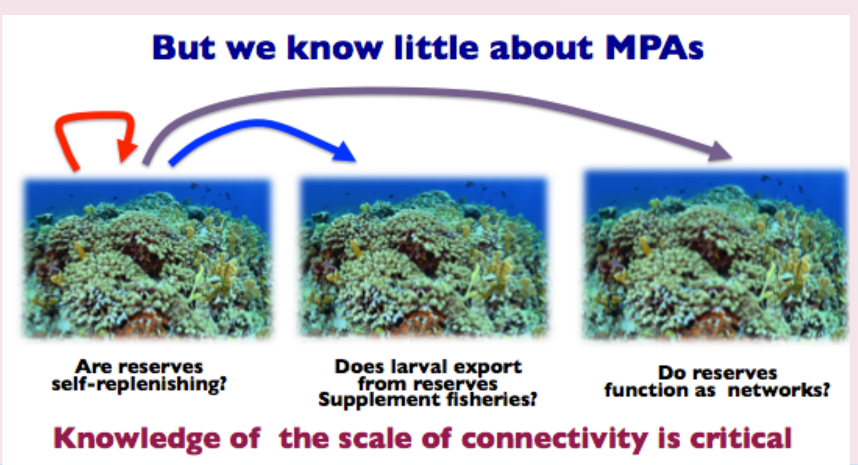
One conservation initiative to restore marine populations is the designation of networks of Marine Protected Areas (*MPAs*), which in their most restrictive form are no-take. No–take *MPAs* are fishing-free spaces that, when properly implemented and managed, can restore populations if no other stressors are present. These *MPAs* act by increasing the population spawning potential of overexploited species (Roberts & Polunin 1991).





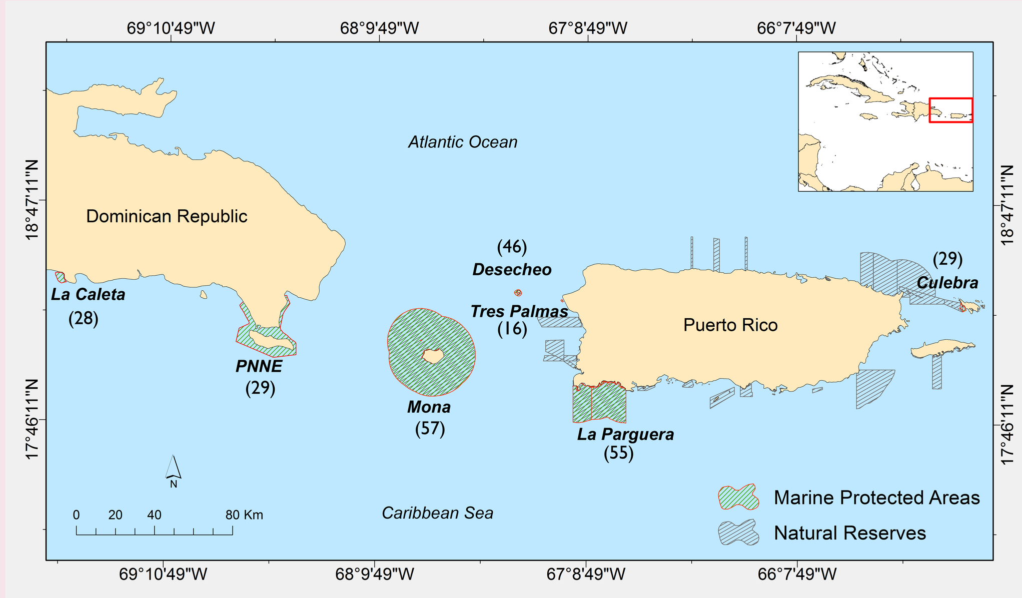


The magnitude and spatial scale of larval dispersal determine the degree of connectivity among marine populations, providing information on the ideal reserve size and the minimum spacing among reserves to achieve both self-recruitment and maintain connectivity and diversity (Sale et al. 2005). Determining the scale of this effective movement of larvae is critical to designing successful MPA networks.



Connectivity and effective dispersal in a network of *MPAs* around the Mona Passage

To evaluate genetic connectivity at fine spatial scales, we sampled populations of the yellowhead jawfish in a network of *MPAs* along the Dominican Republic and Puerto Rico.



On average, the geographic distance between any two sampled *MPAs* is 90 km, with the largest distance between the two extremes being 486 km.

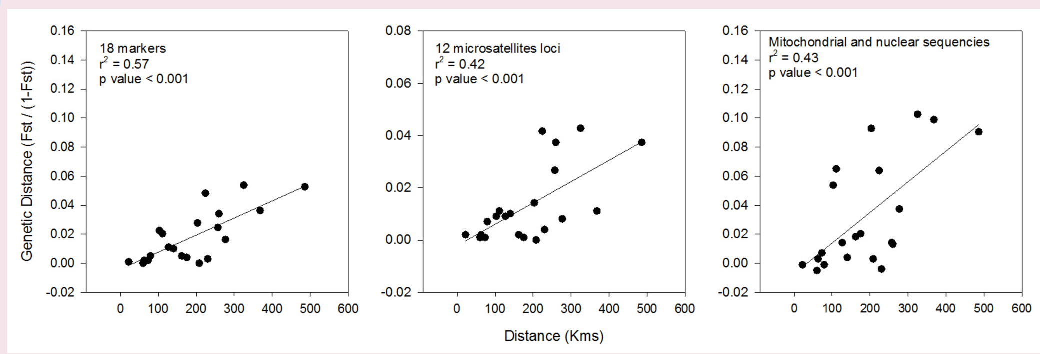
The yellowhead jawfish is a small (<10 cm) sedentary benthic fish that lives in large decorated burrows (30-50 cm) on calcareous sand habitats at depths between 3 – 50 m. It feeds on zooplankton by hovering up to ~1 m above its burrow.

Burrows also serve as mating nests, in which males invite females by lateral displays. Spawning occurs in the burrow and the male orally incubates the eggs (Colin 1971, 1973).

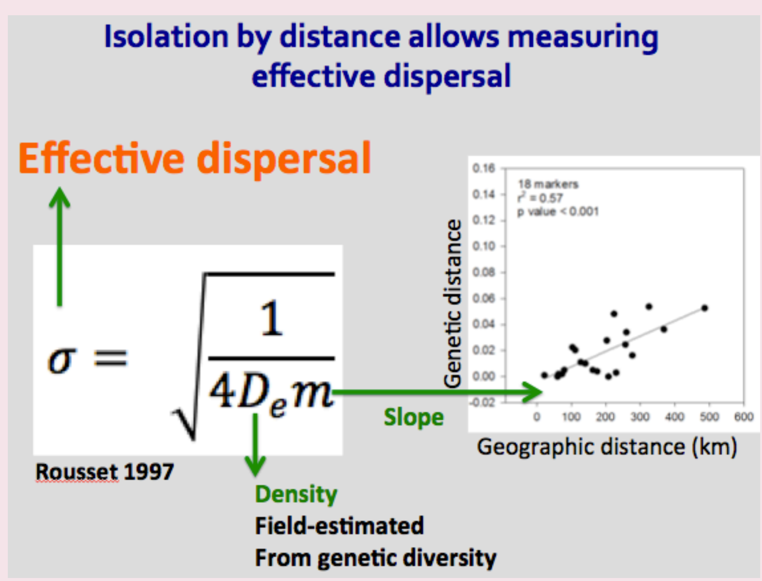
Upon hatching, planktonic larvae are released, presumably in an advanced stage (post-flexion), that stay in the water column for up to three weeks (Ho *et al.* 2012; Young 1982).

All 260 samples were collected by scuba diving using clove oil as anesthetic at depths between 6 to 35 m. We collected morphometric measures for each sample and stored muscle tissue in 100% ethanol at -80 °C for genetic analysis.

Genetic distance increases with geographic distance



The isolation by distance (IBD) analysis suggests geography explains 57% of the genetic variation among populations across this MPA network (r2 = 0.57; p < 0.05).



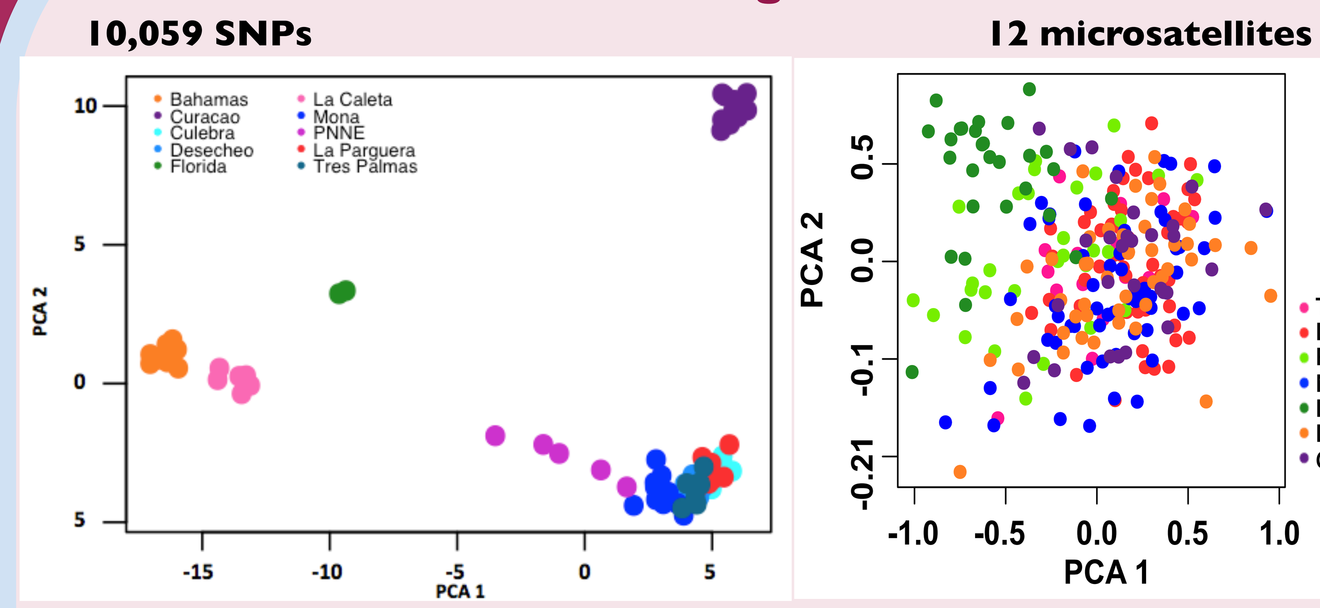
$$\sigma = \sqrt{\frac{1}{4D_e m}}$$

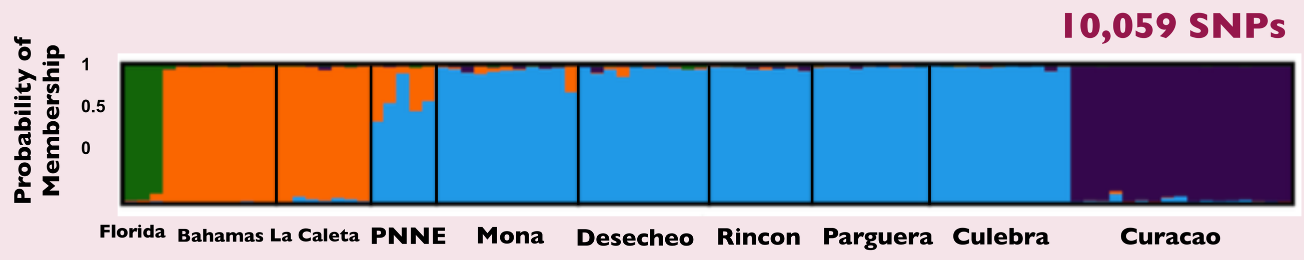
Effective dispersal = 0.2 to 3.39 km

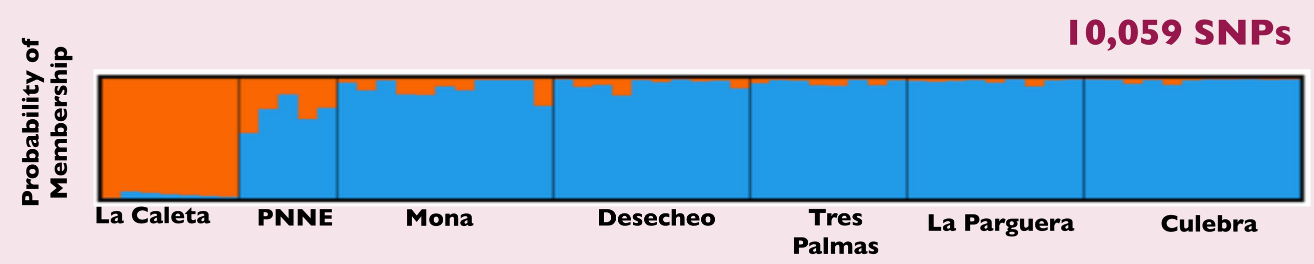
Effective dispersal ~ 9.61 km

Our effective dispersal estimates also suggest the fish would have a neighborhood movement of less than 10 km per generation, providing an upper bound for the largest spacing among successful *MPAs*.

Populations are genetically isolated at localand regional scales

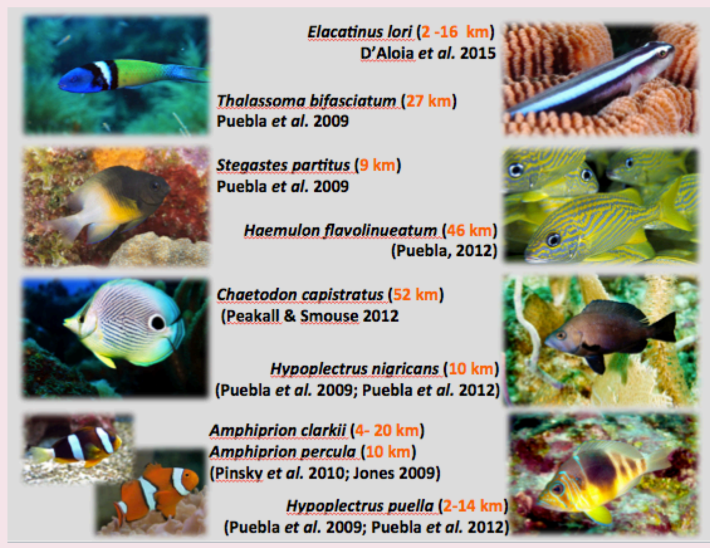






Our PCA and STRUCTURE analysis suggests strong differentiation across the Caribbean. Results from microsatellites and both SNP datasets are similar. Our PCAs have higher resolution, and at least five tight groups can be discerned (Bahamas, Florida, Curaçao, La Caleta and Puerto Rico). We found that samples from PNNE, while close to Puerto Rico are quite spread, with high inter-sample variability. The > 10k SNPs had the highest resolution with reduced within group variation and increase among group distance.

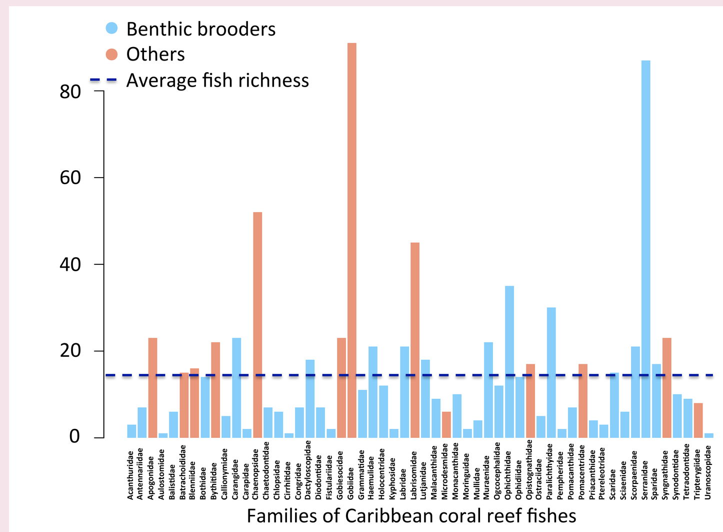
Effective Dispersal in Reef Fishes rarely exceeds > 50 kms



Our dispersal estimates fall within previous estimates of dispersal. The slope in our IBD estimates is also concordant with those inferred by Puebla (2012) in Belize and smaller (i.e. less genetic segregation) than those inferred by Pinski (2010) in the Philippines.

Dispersal estimates contrast with the mean distance among enforced *MPAs* (sampled in this study) within the network, which is 90 km and 37 km for all Management Areas, most designated yet unenforced. This is 9 X (or 4X) the ideal space among MPAs to ensure the direct connectivity desired to achieve a high level of protection.

Brooding fish accounts for at least 40% of the reef fish biodiversity



Fishes with demersal benthic eggs usually <15 cm in length contribute up to 40 % of the total Caribbean reef fish biodiversity. The average species richness is 15.5 species per family, yet 11 of the 13 families with small cryptic fishes exceed this average.

Cryptobenthic brooding fish with small bodies contribute to the highest (> 80 %) number of Caribbean endemics (Floeter *et al.* 2008).

Ensuring that populations of demersal fishes are covered by *MPA* networks would maintain fish biodiversity on reefs in the long-term.

Conclusion

Our study suggests that *MPA* networks with mean average space among *MPAs* of > 20 km are unsustainable in the long-term and may only be currently working thanks to the existence of intermediate unprotected habitats. We hypothesize that the current *MPA* network around Puerto Rico for small benthic fishes such the yellowhead jawfish may on evolutionarily scales expose isolated populations to extinction. Currently, connectivity among *MPAs* is possible through in unprotected intermediate habitats. Continued decline in reef health, however, may result in the disappearance of those habitats, resulting in fragmented isolated populations prone to demographic stochasticity and extinctions. *MPA* spacing of < 10 km would increase connectivity among adjacent *MPAs* and their long-term success.

Acknowledgements

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Coastal Erosion Assessment Using Unmanned Aerial Vehicles (UAVs) at Eastern Puerto Rico

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Introduction:

Puerto Rico's natural resources are extremely vulnerable to the impacts of Climate Change. According to the Intergovernmental Panel on Climate Change (IPCC), it is estimated that about 50% of the population lives within 1.5 km of the coast in the Caribbean (IPCC 2015). Puerto Rico has similar statistics and the impacts of sea level rise, extreme events and coastal inundation have become a real threat to the island. In particular, Puerto Rico's coastal erosion is a major problem for the island because the resource significantly contributes to the economy in the form of construction and tourism. A number of reports such as the "Historical Shoreline Changes in Ricon, Puerto Rico 1936-2006" clearly indicate increased erosion losses in certain parts of the shore. To mitigate these problems, it is vitally important to monitor the erosion over a period of time.

In recent years, Unmanned Aerial Vehicle (UAV) technology has made greater strides in its applications to study and understanding many environmental issues. Future generations of UAV systems will reflect an increased level of autonomy, cost-effectiveness, longer endurance and network capabilities. Essentially, this new data acquisition method will provide researchers with an effective tool to help policy and decision-makers make viable and sustainable decisions for a more resilient coastal community development.

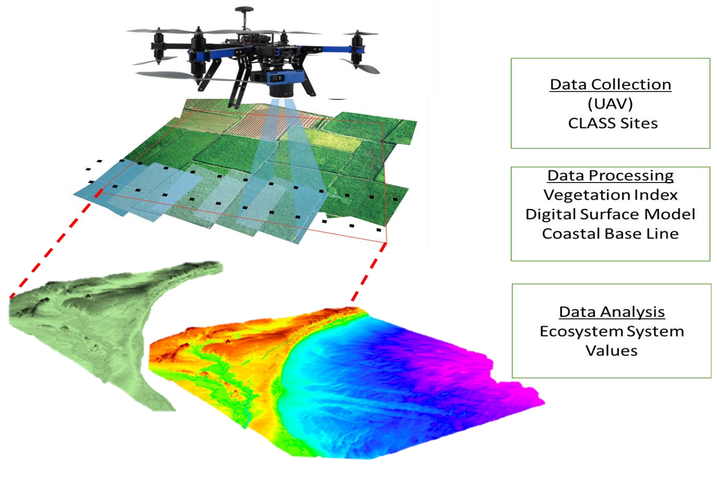

Figure 1. Research Framework using UAVs for Coastal Ecosystem Values

Objectives:

- Demonstrate geospatial skills and technology required to effectively implement coastal conservation strategies.
- Prove the Concept (Alternate Methods): Low Coast UAVs for Coastal Ecosystem Assessment.
- Evaluate the rate of change of coastal erosion at Parcela Suarez, Loiza, P.R.

Study Area:

Figure 1. Parcela Suarez, Loiza P.R
The Study area was selected based on magnitude of coastal erosion impact.

Method:

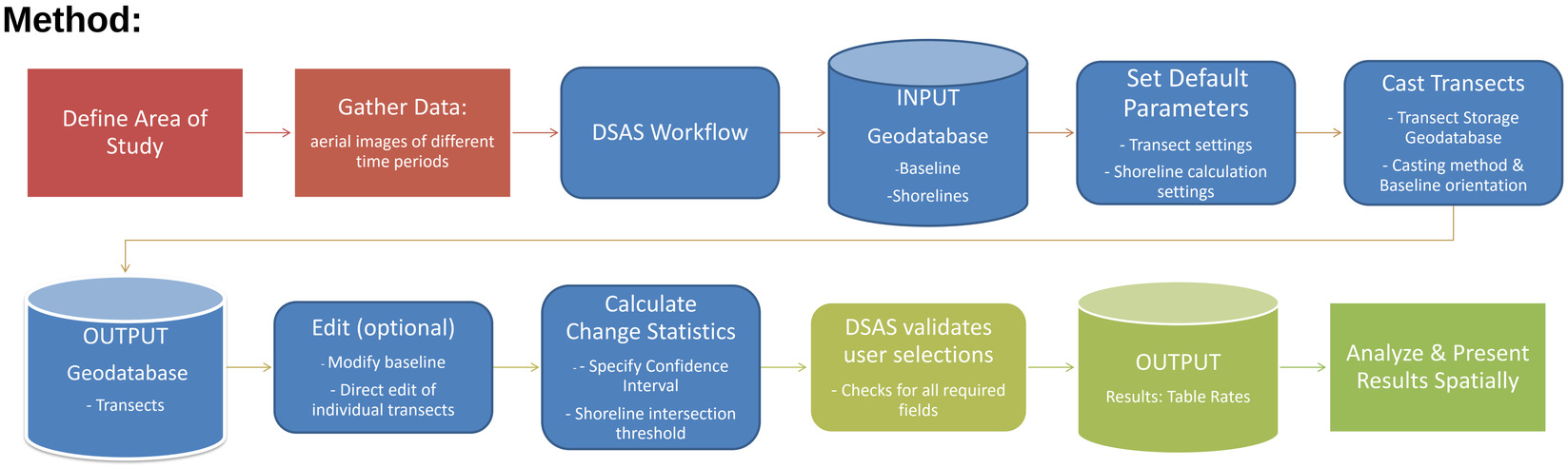

Figure 2. Top-down schematic of research procedure.

For this initial assessment , ArcGIS, Pix4D Mapper and DSAS (Digital Shoreline Analysis System) in synergy with historical and UAV based aerial photography were used to do a Coastal Ecosystem Assessment. The combination of software's were used to determine and analyze rate of change statistical data for the coastal erosion problem. DSAS was used to compute the rate-of-change statistics for a time series of shoreline vector data

Analysis and Results:

This project is a leading step to validate the applicability of UAVs in the study and prediction of shores erosion rate of change. The implementation of this technology will aid federal and local government agencies for the study and prediction of local coastal erosion more efficiently and effectively.

Figure 3. All Shorelines Digitized & Categorize by Date

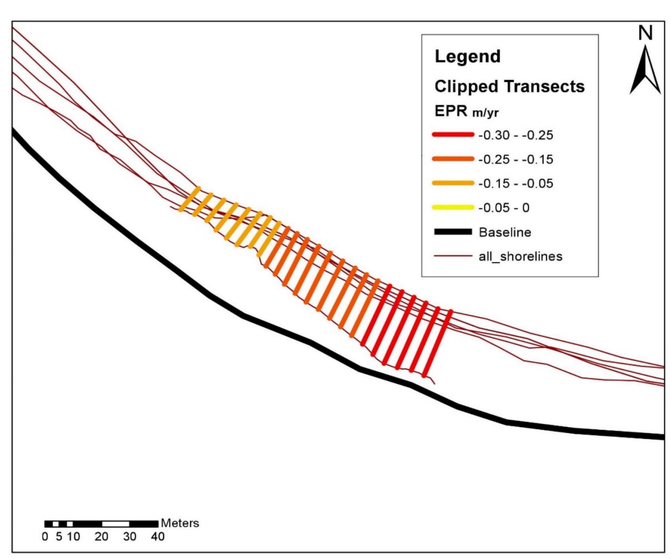

Figure 4. End Point Rates Between Shorelines.
Longer Transects: Areas of Greater Movement In Shoreline Position.
Colors: Indicate Ranges of the Calculated End Point Rate.

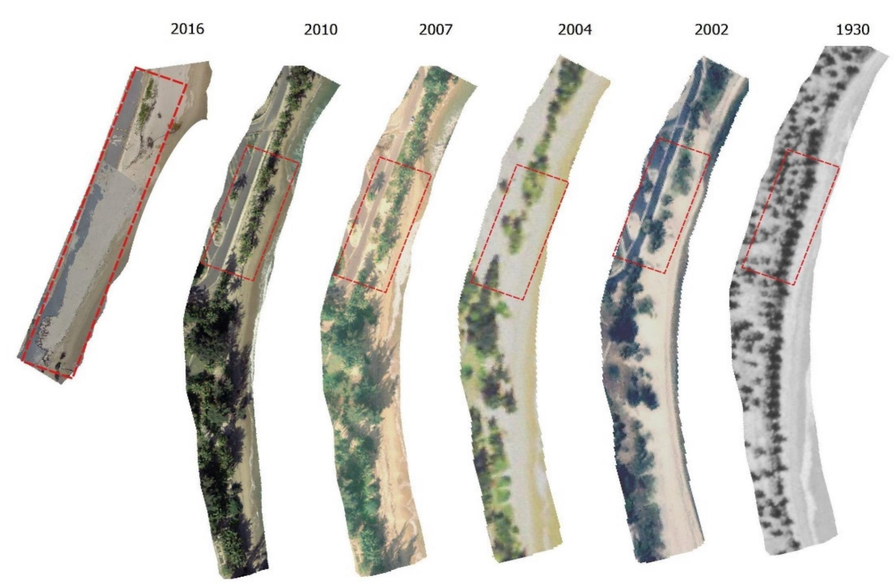

Figure 5. Affected Area Due to Coastal Erosion and Contrast Between Different Years.

Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors.

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PUERTO RICO'S DNER COMMERCIAL FISHERIES STATISTICS PROGRAM: 49 YEARS CONTRIBUTING TO THE CONSERVATION OF FISHERY RESOURCES.

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Abstract

The Commercial Fisheries Statistics Program (CFSP) of the Puerto Rico Department of Natural and Environmental Resources (DNER) has monitored the commercial landings of fish and shellfish in Puerto Rico for the last 49 years. The Commercial Fisheries Statistics Program (CFSP) was implemented in 1967 under the Commercial Fisheries Research and Development Act of 1964 (PL 88-309) to collect data on the commercial fishery. During 1967 to 1979 it was under the Department of Agriculture. During 1971-1991 it was under the Corporation of the Development of Marine and Lacustrine Resources, since 1991 to the present under the DNER. Currently, this program is funded by NOAA Fisheries through the State/Federal Cooperative Fisheries Statistics Program, Interjurisdictional Fisheries Programs and the DNER. The CFSP has the following objectives: commercial Trip Ticket Program, collection of biostatistics data, enter the collected data online to NOAA Fisheries, estimate catch per unit (CPUE) and also realized fishery census. This poster shows data trends and highlights from 49 years of the CFSP.

Introduction

Puerto Rico's commercial fishery is limited to the marine resources. The CFSP estimated that 90% of the commercial fisheries trips are for a period of 12 hours or less. Approximately 70 % of the fishing activity occurs on the coral reef resources. However, the deep water snapper, pelagic species as, tunas, dolphinfishes and wahoo, are important commercial fishing resources. The fishery is multigear and multispecies. Important gears are bottom lines, troll lines, SCUBA diving, traps and nets. Important species are spiny lobster, queen conch, deep water snappers (five species), yellowtail snapper, lane snapper, trunk fishes, mackerels, and groupers, among others. However, since the mid 1980's, Puerto Rico's fishery resources have shown overfishing symptoms. Important overfishing symptoms observed were a decrease in landings reported, change in catch composition, reduction in number of active commercial fishers and reduction in the number of traps used, the most productive gear during 1950-1985 and a reduction in the number of active commercial fishers.

During 2004, the DNER established Puerto Rico's Fishing Regulations 6768, containing closed seasons for reproduction periods and all the known spawning aggregations, bag limits and minimum legal sizes. Later during 2010, changes in the regulations resulted in Puerto Rico's Fishing Regulations 7949. The CFSP collected data that shows the fishery resources have been improved. However, it is important to continue to collect commercial landings data in a daily basis to monitor the trends in this important activity.

Figure 1: Distribution of fishing centers in Puerto Rico

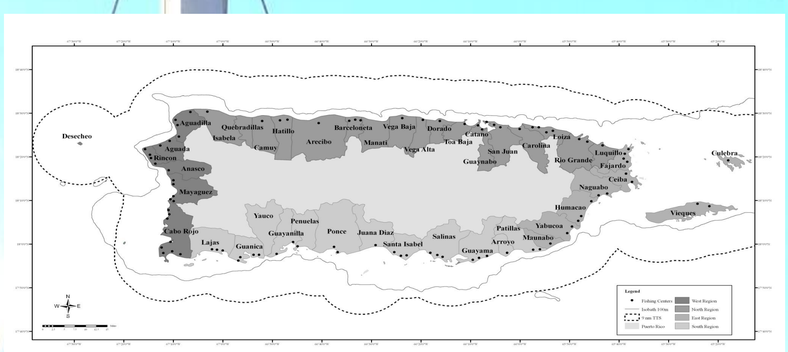
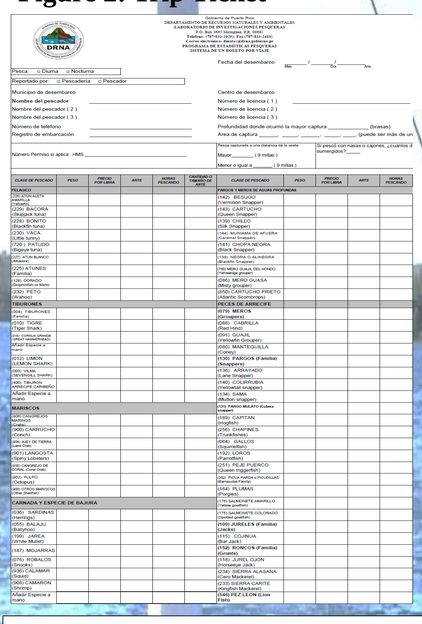
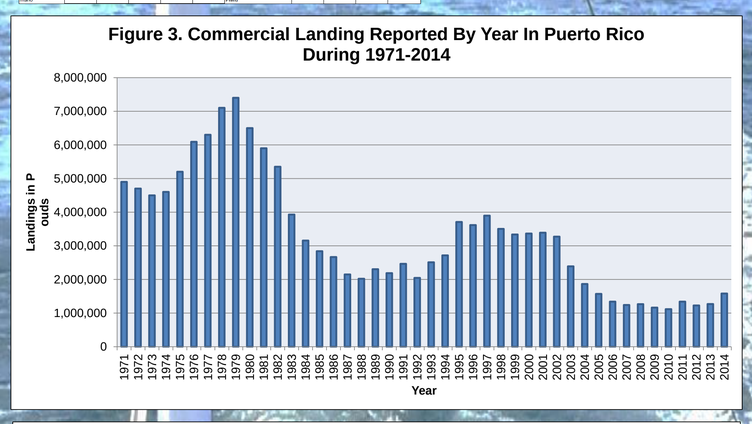
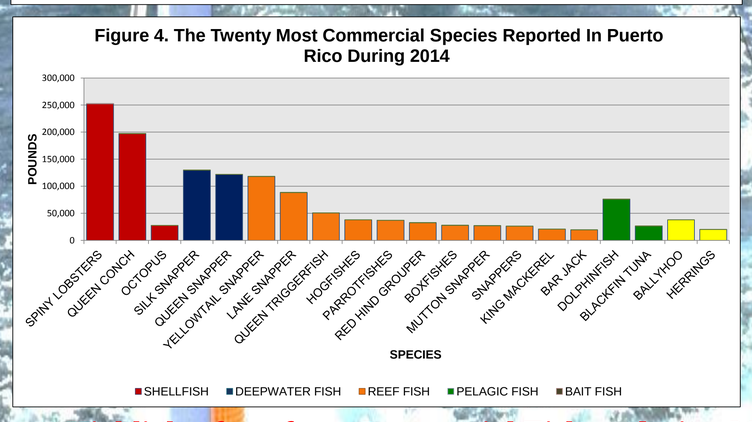
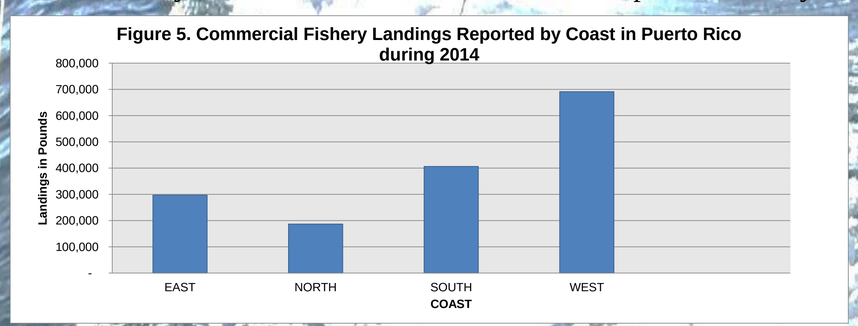


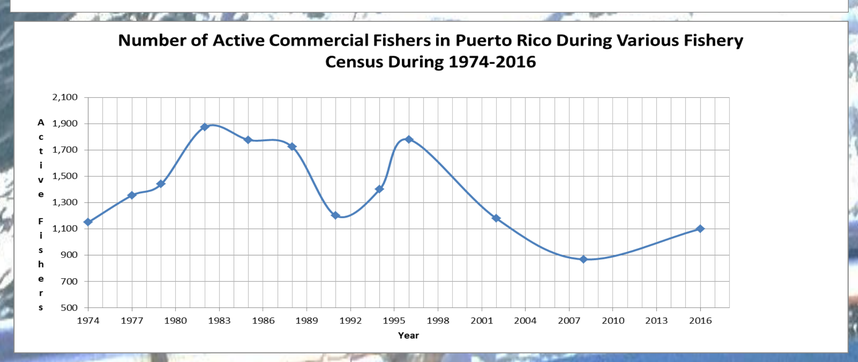
Figure 2: Trip Ticket











Methods

Commercial Landings Data Collection

Commercial fishery landing data were collected from fishers, fish buyers and fishing associations from around Puerto Rico. Commercial fishery statistics has to be submitted to DNER/CFSP as a compulsory requirement of Law Number 278 of November 29, 1998 and the Puerto Rico Fishing Regulations 7949 of November 24th 2010. Port samplers and the principal investigator visited the 90 identified fishing centers at the 42 coastal municipalities including the islands of Vieques and Culebra (Figure 1). Data were collected using a landing trip ticket system on a monthly basis during the project duration. The Trip Ticket System (only one trip reported by one ticket) was established by the CFSP starting in 2003 (Figure 2). Efforts were made to collect the following data: fishing date; name of fisher; commercial fishing license number; fisherman and/or helper (to avoid data duplication); municipality; fishing center (municipality landing area); number of trips; gear type; fishing effort (hours spent fishing); weight in pounds by species or taxonomic family; market value to the fisherman (price in U.S dollars/pound); maximum and minimum fishing depth; and fishing area. Trip tickets were completed using species common names and identification was possible by using an amended version of the bilingual technical report "Common Names of Fishes in Puerto Rico" (Erdman, 1987). A numerical system of species identification was developed to correspond with species codes used in Erdman's publication. Species reported not included in the mentioned publication are added and numbered by CFSP's principal investigator. Catch per unit of effort (CPUE) was determined as the total pounds per trip for landings data. All data is entered online to NOAA Fisheries thru "Caribbean Commercial Landings Software". A correction factor was used in calculations to correct under-reporting.

Biostatistics data Collection

Biostatistics data from finfish and spiny lobster were collected by four port samplers three to four days per week and principal investigator helped four days per month. Each individual was identified by species to determine catch composition. Finfishes were measured in fork length (FL) and spiny lobster in carapace length (CL), both in millimeters (mm), and weighed in grams. Biostatistics data were entered in Trip Interview Program (TIP) developed by NOAA/NMFS Southeast Science Center. Later, the data stored in TIP was converted to .dbf format and analyzed using Microsoft FoxPro and Microsoft Excel. The data collected include date, name of fisherman, fishing area, depth, gear, species, length, weight and effort by gear type.

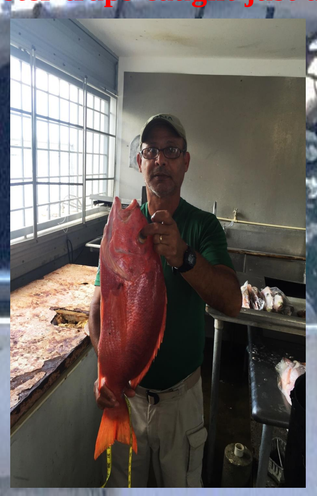
Puerto Rico's Commercial Fisheries Census

Since 1988 the CFSP have been responsible to account all active commercial fishers, vessels, and gears. These events occurred when funds are available. The last census were in 1988, 1996, 2001 and 2008. Currently the CFSP submitted a proposal to obtain the funds to do a new fishery census.

Highlights facts from Commercial Fishery during 2010-2015

During the last five years the gear that reported most landings was hook and line with 42%.Fishing nets captured 12% of the total landings. Scuba divers caught 31% of the total landings. The spiny lobster and the queen conch were #1 and #2 of most species landed in Puerto Rico. The wholesales landings of fish and shellfish are estimated in 7 million dollars/year. The retail and restaurants sales of the landings have been estimated in 21 million dollars annually.

The number of active commercial fishers has been estimated by the Commercial Fisheries Statistics Program (CFSP) as 1,100. The CFSP estimates that in 2014 there were 400 active commercial fishers working full time and they caught probably the 70% of the total catch. The CFSP estimates that 80% of the full time fishers are scuba divers and deep water snapper fishers. During the 1970's fish traps were the most efficient and most productive gear used in Puerto Rico, reporting 70% of the total landings. During the last five years fish and lobster traps caught just approximately 15%.



Analysis of Shoreline Changes in Rincón, Puerto Rico:

Impacts to Oceanfront Infrastructure

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Background and Motivation

Coastal erosion in Rincón, P.R. has raised public and government concern, it affects the local economy because its beaches are Rincón's biggest tourism attraction. This project is intended to provide information to private and public planners to make the best decisions in coastal zone management. The research performed involved analysis and manipulation of USGS' and CRIM's GIS database. The USGS study of shoreline changes prepared by Thieler et al. provides historical data of shoreline position that can be used to predict the expected change and relate it to the CRIM database, which includes parcel and property values, to estimate a vulnerability of ocean front parcels.

Location Map

USGS/CRIM Data

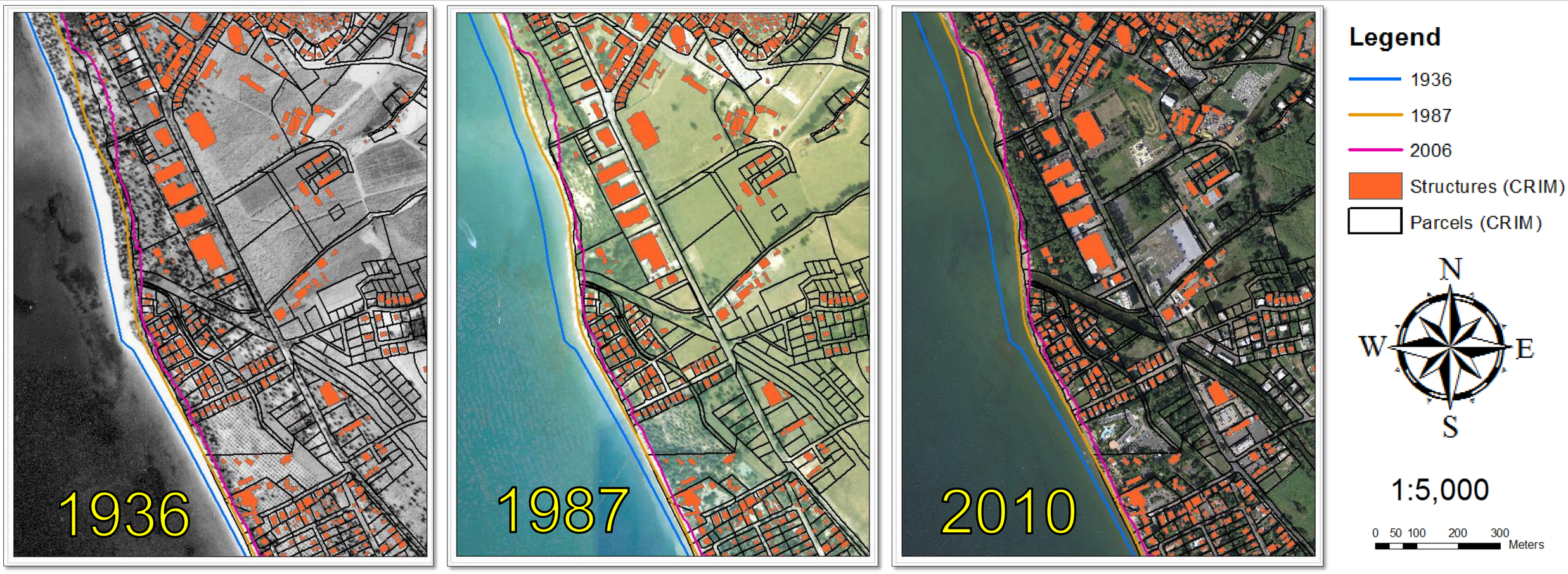


Figure 1: Historical data published by Thieler, E.R., Rodríguez, R.W., & Himmelstoss, E.A. (2007) on USGS Report titled Historical Shoreline Changes at Rincón, Puerto Rico, 1936-2006

Field Data

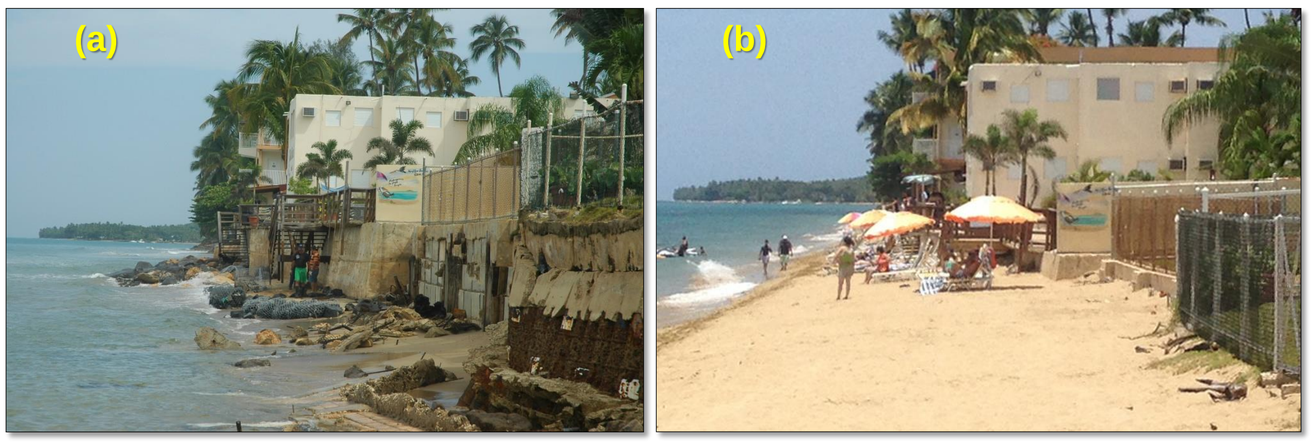


Figure 2: a) Hurricane Isaac (2012) short-term coastal erosion (Picture by Prof. Ruperto Chaparro, August 2012), b) Equilibrium beach condition (Picture by Dr. Luis Aponte, August 2014)

Figure 3: Equilibrium beach condition a) August 21, 2015, tide height of 0.8 ft. above MLLW, b) February 16, 2016, tide height of 0.4 ft. above MLLW

Shoreline Projection and Economical Analysis

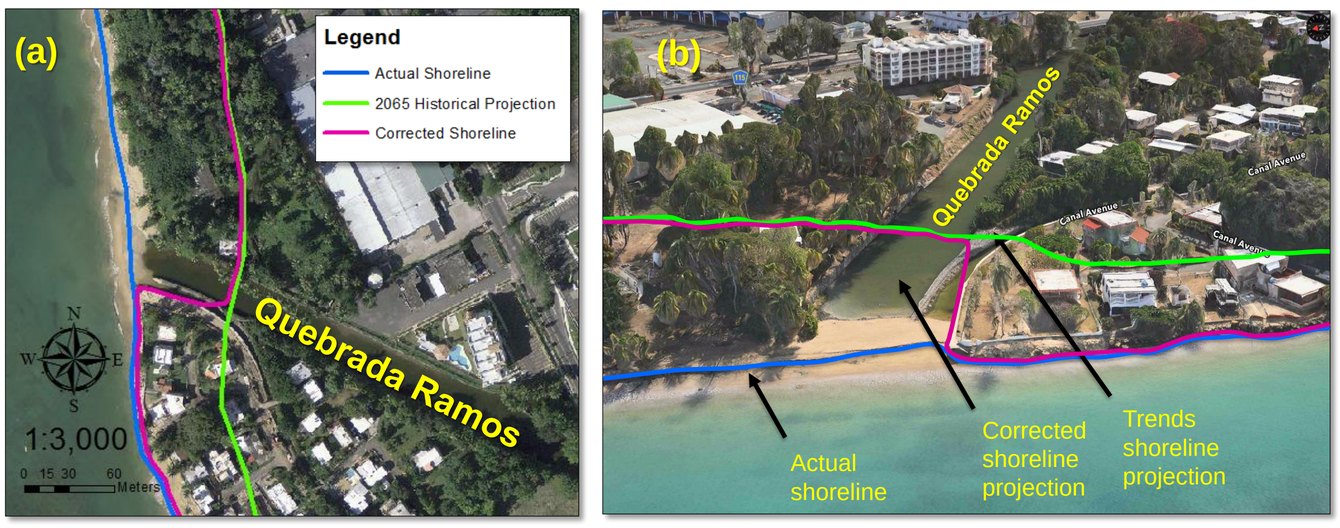


Figure 4: Proposed shoreline projection method, a) Plan view 2010 aerial photograph from the Puerto Rico Planning Board, b) Perspective view from Apple Maps

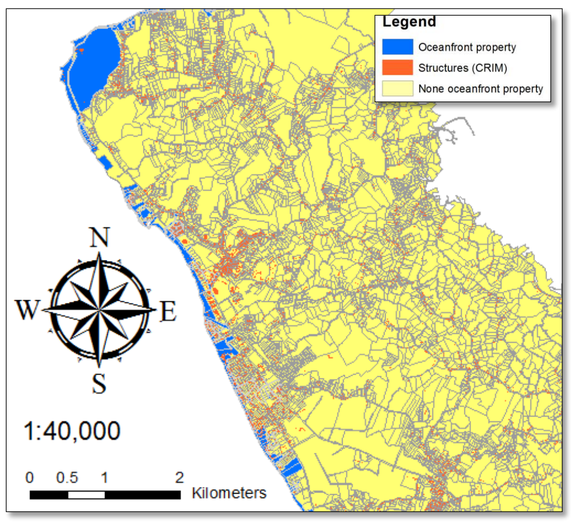


Figure 5: Rincón's CRIM parcel database

Table 1: Distribution of Rincón's property parcels

Location	# of parcels
Oceanfront	937
None oceanfront	9,160
Total	***10,097***

Table 2: Property growth rate estimation

Filter data criteria		Average property growth rate (i)
By percent of change	*1% > i < 10%*	5.3%
By year	*2010 > year < 2015*	5.5%
By zone (Thieler's reaches)	*Reach (A, B, C, D)*	7.8%, 7.7%, 5.1%, 5.1%

Rincón's CRIM database consists of 10,097 parcels as shown in Figure 5, of which 937 are oceanfront. The database provides a base property appraisal value adjusted to the year of 1958. Only 2,738 parcels (27%) contain data regarding sales value and transaction year. Figure 6 presents the methodology used to estimate the average growth rate employing engineering economics; Table 2 shows the results using different criteria, where the average growth rate is approximately 5.3% and ranges from 5.1% to 7.8% per each one of Thieler et al.'s defined reaches. The projection of the expected inland shoreline position based on historical trends will not necessary represent the reality because man-made-barriers will serve as equilibrium-condition (i.e. sea walls, metal sheet piling, and breakwater boulders). A correction with field surveys is required to take into account such barriers and adjust the projection shoreline as illustrated in Figure 4(a); Figure 4(b) is a perspective view showing the adjustment of the projection due to coastal structures barriers that will prevent shoreline movement inland.

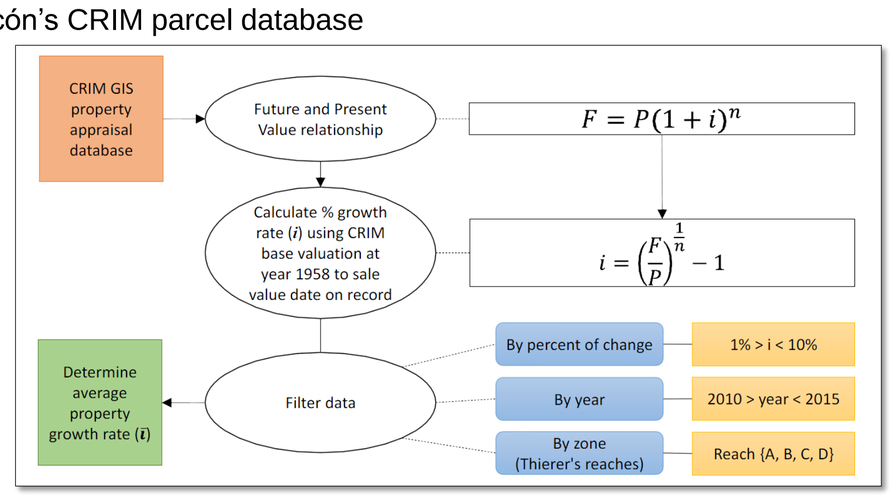


Figure 6: Flowchart of methodology used to determine the average property growth rate for Rincón, PR employing engineering economics

References and Acknowledge

Thieler, R. E., Rodríguez, R. W., & Himmelstoss, E. a. (2007). Historical Shoreline Changes at Rincón, Puerto Rico, 1936-2006. Director

Puerto Rico Planning Board, (2010). Aerial photographs with ± 1 ft, State Plane NAD 83.

Special thanks to Sea Grant of Puerto Rico for support the and funding for this project, and to the Office of the Puerto Rico's Digital Cadastre for providing the CRIM database.

Mapping Ecological Priorities and Human Impacts to Support Management of the Marine Corridor of the Northeast Reserves

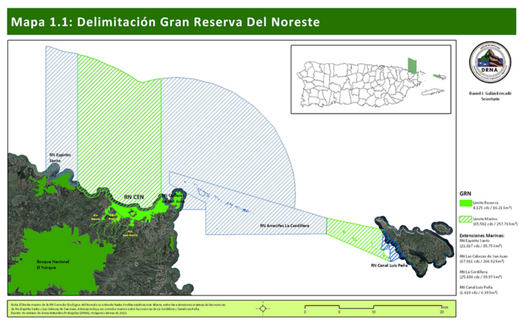
NOAA Biogeography Branch, National Centers for Coastal Ocean Science
funded by Coral Reef Conservation Program

Project Objectives

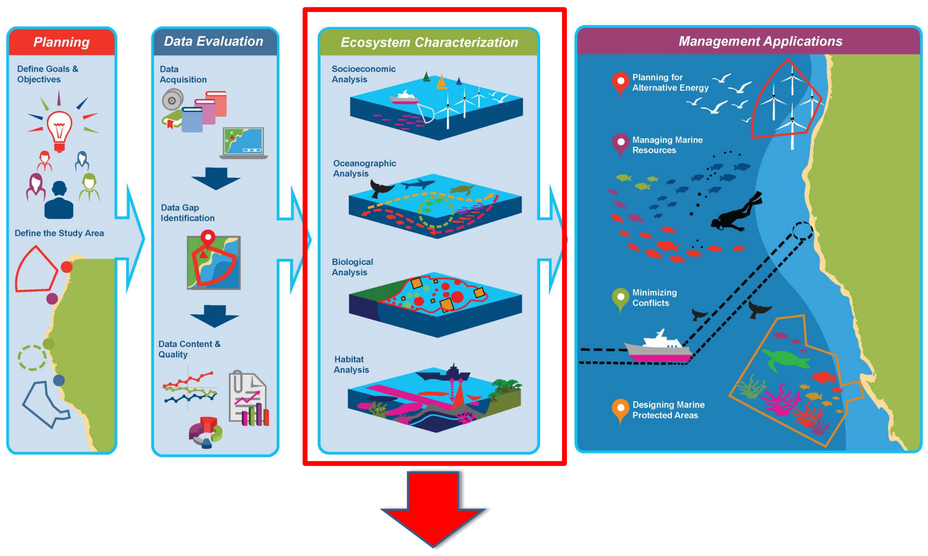
1. Compile a comprehensive spatial database to characterize the ecosystem and provide a robust data-driven foundation to support DRNA in the development of an effective management plan
2. Integrate socioeconomic, physical oceanographic, biological and seafloor habitat patterns to identify ecological priority areas (local and national) and examine the overlap with human uses and stressors to map and evaluate areas of potential concern
3. Build an online map tool 'Data Viewer' to support MPA managers with ecosystem-based decision making and increase community awareness of the broader regional ecosystem

Project area

The **Marine Corridor of the Northeast Reserves** is the first reserve of its kind in Puerto Rico. Its successful implementation and management are important to the people of Puerto Rico. The area is used for a wide range of activities and also encompasses areas with important biodiversity value.



Biogeographic Assessment Framework

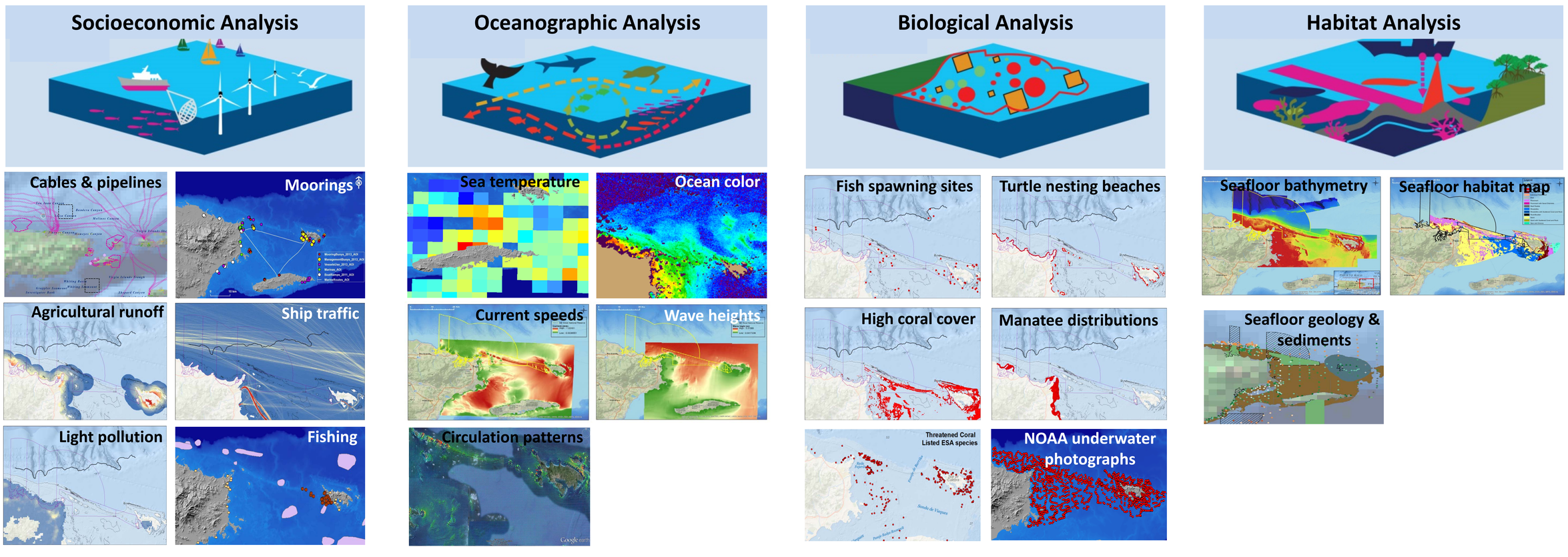


Examples of datasets collected

General Approach

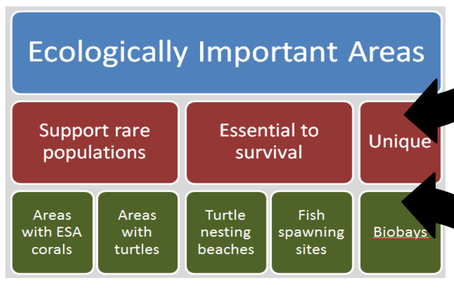
A comprehensive and detailed spatial database is central to modern marine management and required to support effective decision making in the management of multi-use marine protected areas. Identifying and characterizing areas of special concern will ensure that appropriate levels of protection and mitigating activities can be incorporated into the management plan. The Biogeographic Assessment Framework (BAF)* was developed for information synthesis in support of marine spatial planning. This project applied the Biogeographic Assessment Framework to compile, evaluate, integrate and analyze a broad range of multidisciplinary data to characterize the ecosystem patterns and processes across the entire project area.

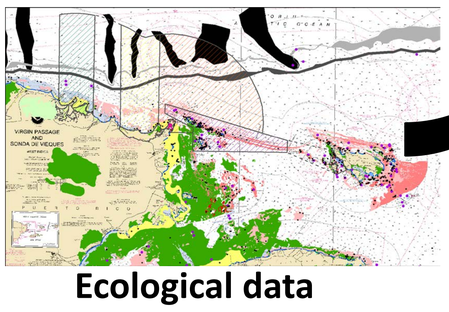
Step 1. Compile spatial data (FY13-15)



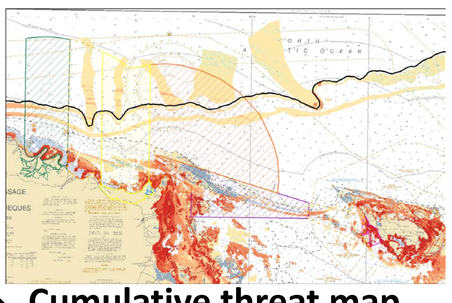
Step 2. Prioritization and Management Tools (FY15-16)

Expert knowledge

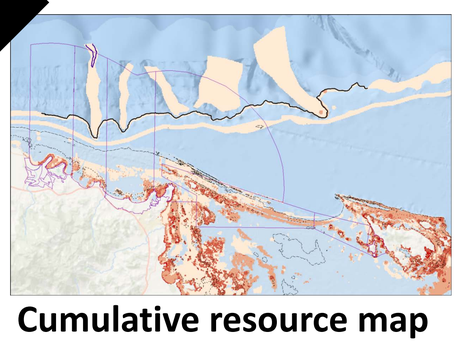




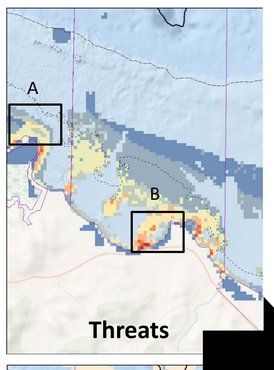
Ecological data

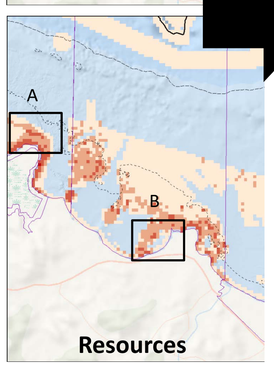


Cumulative threat map

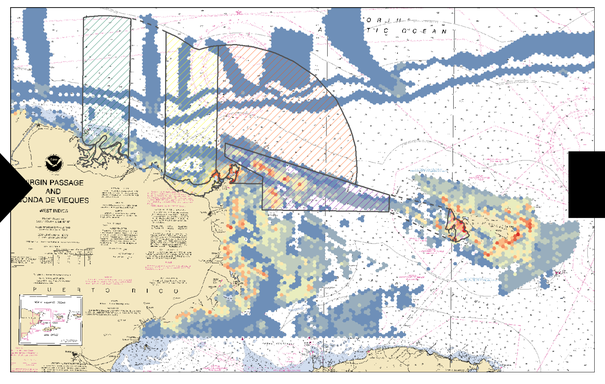


Cumulative resource map



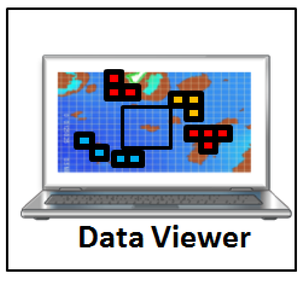


Prioritized areas based on spatial coincidence of ecological importance and cumulative threat



The tool can be used to assess and visualize ocean spaces with potential conflict of interest and spaces with low conflict of interest. For example, where protected and vulnerable species are exposed to threats and stressors from human activity. This tool will support scenario development for ocean zoning and help to prioritize management actions for more effective conservation.

Decision support



Data Viewer

Strategic Planning

* Caldow, Monaco, Pittman et al. 2015. Biogeographic Assessments: A framework for information synthesis in marine spatial planning. Marine Policy 51, 423-432

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Project Team: Simon Pittman; Charles Menza; Dan Dorfman; Angela Orthmeyer; Ayman Mabrouk; Gustav Kägesten; and Antares Ramos

The Puerto Rico Seismic Network Educational and Outreach Program

Dr. Victor Huérfano, Glorymar Gómez, Wildaomaris González, José F. Martínez and Roy Ruiz-Vélez
Puerto Rico Seismic Network, Department of Geology, University of Puerto Rico at Mayagüez

Abstract

The Puerto Rico Seismic Network (PRSN), part of the Geology Department at UPRM, is an ANSS (Advanced National Seismic System) partner. Our mission is to monitoring, investigate and inform about the regional seismic activity, as well as educate about earthquakes and tsunamis in our AOR (Area of Responsibility) in partnership with the Puerto Rico Strong Motion Program (PRSMP). The PRSN manage the PR Tsunami Program (NTHMP), and their education and outreach department directly impacts more than 12,000 people annually, through conferences, meetings, and workshops. Additionally, the PRSN impacts people indirectly via interviews, social media, and press. In 2015, more than 418,000 individuals visited the PRSN web site, the PRSN Facebook, YouTube, and Twitter accounts report 338,900, 651, and 27,800 followers/subscribers respectively. Approximately 650,000 people registered in the 2015 Shakeout earthquake drill, and 140,900 people registered for Caribe Wave 2016 tsunami exercise. The PRSN is an alternate TWFP for PR and along with the AEMEAD, local OMM's and FEMA provides help and support for 44 (plus Bayamon) coastal communities to be recognized as TsunamiReady by the NWS. A tsunami vulnerability assessment has shown that ~248,000 residents live in tsunami prone zones and were impacted with our outreach program. The PRSN also develops educational materials and tools such as: tsunami signs, brochures, flyers, coloring books, web APIs, the tsunami media kit, the TsunamiReady supporter program, tsunami materials for hotels, resorts, tourist and maritime communities, and other initiatives that increase the tsunami and earthquake hazard awareness.

Introduction

The Puerto Rico Seismic Network (PRSN), was installed by the USGS, in 1974, to monitor the seismic activity in Puerto Rico. In 1986, the PRSN was transferred to the Geology Department of the University of Puerto Rico at Mayagüez (UPRM). In 2015, the PRSN was accredited as an Advance National Seismic System (ANSS) partner. To meet our mission, the PRSN operates a state-of-the-art network of seismometers, accelerometers, tide gauges and GPS real time stations. In addition, the PRSN participate in the regional Tsunami Caribe EWS an Intergovernmental Group of the UNESCO. The PRSN has five departments that supports the operations: Geophysics Data Analysis (24/7 service), Information Technology (IT), Research, Administration, Technical and Instrumentation, and the Education and Outreach department, that include TsunamiReady program. PRSN manage the PR-NTHMP grant (The PR component of the National Tsunami Hazard and Mitigation Program); and coordinate the TsunamiReady Program, as well as the PR Shakeout and Caribe Wave exercises. As an alternate Tsunami Warning Focal Point (TFWP) for PR and VI, the PRSN is equipped with the required infrastructure and Technology (Figures 1).

Figure 1a: PRSN new building in the UPRM.

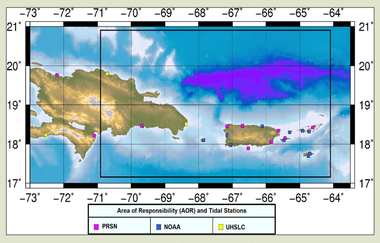


Figure 1b: PRSN area of responsibility.

Figure 1c. PRSN Real Time monitoring system

Education and Outreach

The Education and Outreach department, of the PRSN, is dedicated to develop all the educational materials distributed by PRSN (English / Spanish), figure 2. This department also offer conferences, training and workshops around the island for all kind of public including private sector, schools, communities, and all interested parties. Our mission is to develop "user friendly" materials that will help the public to understand and practice the information and guidelines about earthquakes and tsunamis. The overall goal is to help them to better prepare to respond to an emergency, minimizing life and property loss and damages.

Figure 2: Educational material samples. This samples include brochures, flyers, the k-6, 7-12 Tsunami Curriculum, the Tsunami media kit and flyers.

Population Impacted

Puerto Rico is located in a seismically active zone, with a total of 3.7 million of inhabitants (U.S. CENSUS 2010); all the island is exposed to earthquakes. A tsunami vulnerability assessment has shown that around ~248,000 (7%) residents live inside tsunami prone zones, in addition more that 4M tourist visit the island yearly. That's why the Emergency Agencies, as well as the PRSN, have the mission to educate communities and impact different focal groups with seminars, workshops, exercises, and drills that help increase tsunami and earthquake hazards awareness (Table 1 and Figure 3, 4 and 5).

Table 1: Directly impacted population.

Activity or Media	Impact
Seminars and Workshops (2015)	6,336 people
Media (2015)	83 interviews
Facebook	339,278 followers
Twitter	27,860 followers
Web Page	418,307 visits
Shakeout 2015 Exercise	650,000 registered *
Caribe Wave 2016 Exercise	140,875 registered **

* http://www.shakeout.org/puertorico / ** http://www.tsunamizone.org/caribbean

Train the Trainers

This program, developed by the PRSN, is exclusively designed to help emergency management officers (EMO) that provide conferences about earthquakes and tsunamis to their communities. It will provide a complete package of educational tools that allow EMO to present standard conferences, and lectures, with the appropriate information for different audiences. The educational package will include: the modules that will be used during the training and the Power Point presentations, teaching techniques for different audiences, updated information about earthquakes and tsunamis, links to find official information, examples of presentations that can be used, and assessment techniques. At the end, the participant will be evaluated with a pre/post test that include the "simulated" activation of the tsunami protocol from a hypothetical earthquake/tsunami source. Also, the certified EMO will be required to give a short presentation. We expect, after the training, that EMO will be better prepared, with a standardize up-to-date information, for their earthquakes/tsunamis seminars, conferences or lectures.

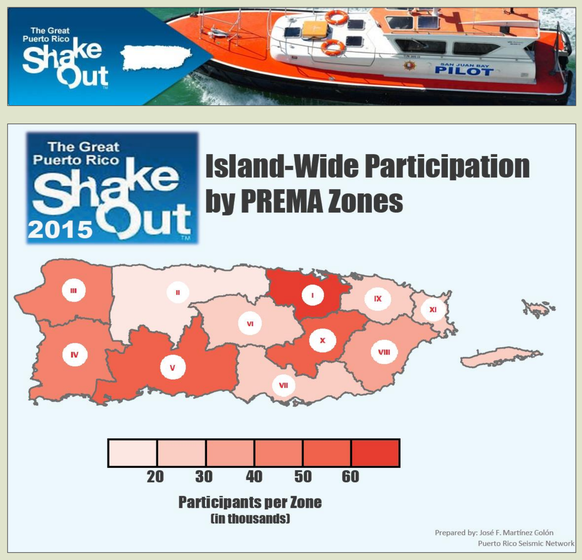


Figure 4: Shakeout Island-Wide participation map. This map shows the number of participants summarized by Puerto Rico Emergency Management Agency (PREMA) zones.

Figure 5: Top 10 list (top) and complete list of participants by category (bottom).

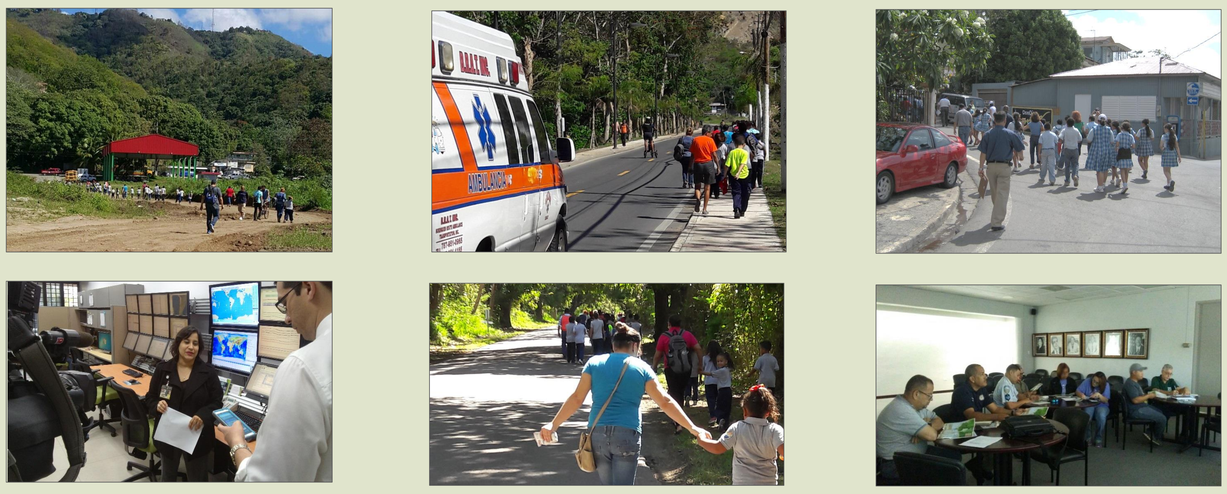


Figure 3: Caribe Wave 2016 tsunami exercise collage. This is the annual tsunami preparedness activity that include emergency communication system test (E.A.S., NOAA Radio, and others), evacuation exercises, table top exercises, and emergency siren test, etc.

TsunamiReady® Program

The TsunamiReady is a voluntary community recognition program created by the National Weather Service (NOAA) as an effort to minimize losses of life and property caused by a tsunami strike and to promote tsunami hazard preparedness. In Puerto Rico, the PRSN manage the NTHMP grant and the TsunamiReady Program, in partnership with the NWS San Juan forecasting Office, FEMA, AEMEAD, OMMES and the Communities. Through this program, we develop a number of tools and educational materials including: tsunami inundation and evacuation maps, web applications, tsunami evacuation signs, seminars and workshops tutorials; brochures, flyers and coloring books; the tsunami media kit, and a tsunami curriculum for schools (figure 6). As 05/10/2016, 45 municipalities are recognized as TsunamiReady by the NWS, 44 of them coastal ones. Currently, the PRSN is actively working to implement the TsunamiReady supporters program to recognize, in particular, the private sector like resorts, supermarkets and facilities located in the tsunami evacuation zone. As part of the TsunamiReady program, and to meet the recognition requirements, we provide to the local 24/7 tsunami warning focal points EMWIN systems, NOAA Radios, and web aggregators to improve the TWC warning reception capabilities. Technical assistance with the tsunami response plan is also provided.

Figure 6: TsunamiReady products.

Figure 7: TsunamiReady supporters practicing evacuation procedures as part of the Caribe Wave/2016.

TsunamiReady Supporters

A TsunamiReady Supporter is an organization, business, facility or local government entity that is actively engaged in tsunami planning and preparedness but does not have the ability to meet all of the formal recognition guidelines. Potential TsunamiReady Supporters include, but are not limited to, businesses, schools, churches, hospitals, shopping centers, malls, utilities, museums, aquariums, villages, small communities, state parks, beaches, harbors, broadcasters/broadcast stations, etc. Currently, we are helping around 8 facilities to become the first TsunamiReady Supporters in Puerto Rico and the Caribbean (Figure 7).

@redsismica

/redsismicadepuertorico

http://www.redsismica.uprm.edu

http://www.prsn.uprm.edu/Spanish/rss/

https://www.youtube.com/user/redsismicapr

Puerto Rico Coral Nurseries Partnerships: A reef resiliency tool and a program to conserve coral species

Nilda M. Jimenez, Marine Ecology Division, DNER
Sean Griffin, NOAA Restoration Center
Edwin Hernández, Sociedad Ambiente Marino, CATEC
Ricardo Laureano, Vegabajeños
Hector Ruiz, Reefscaping

Elkhorn coral (*Acropora palmata*) and Staghorn coral (*Acropora cervicornis*) were listed as threatened species under the US Endangered Species Act in 2006. Their designated critical habitat was established in 2008, and its Recovery Plan published in 2015. However, it is challenging, from the management perspective, to conserve and protect species that face global and local threats, particularly considering human and economic resource limitations that enforcing agencies have. The most practical and successful strategy identified by the Commonwealth of Puerto Rico to accomplish these tasks has been the collaboration with NGOs and private entities.

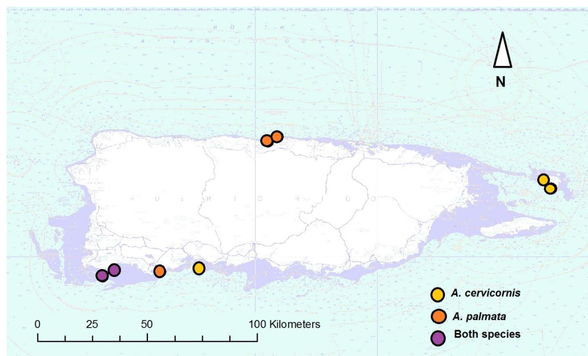


Figure 1. Current location of coral nurseries

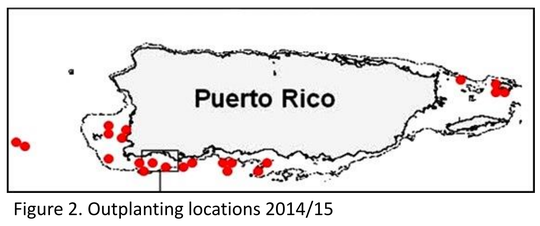
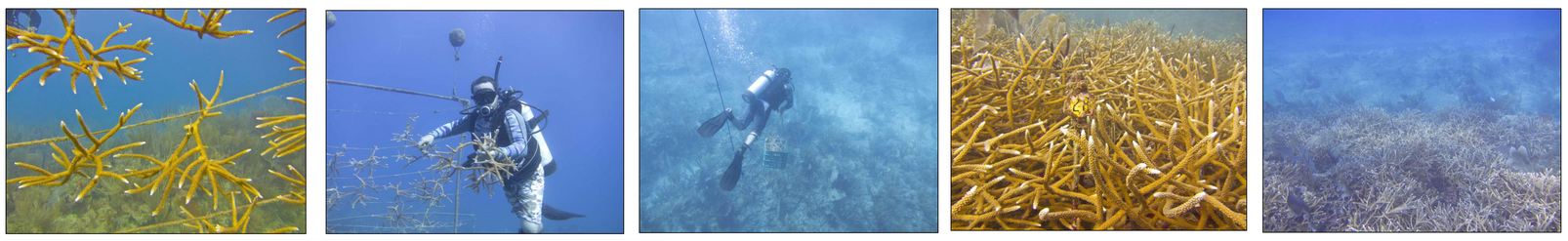


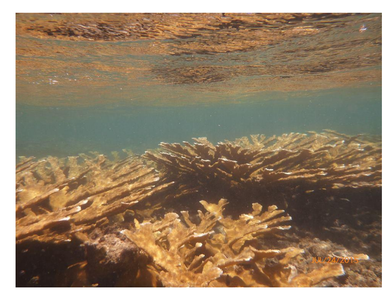
Figure 2. Outplanting locations 2014/15

Acroporid coral nurseries in continuous operation since 2001 have proven to be extremely successful. The first nurseries were developed as an initiative from the academia and located in Guánica. After that, other nurseries have been developed as part of response to grounding events or as part of NGO's or private entities initiatives. At present there are 4 coral nurseries in PR (Parguera/Guánica, Guayanilla, Vega Baja/Manatí and Culebra- Figure 1). In the past, coral farming operated as separate efforts with the same objective of propagating these species to recover depleted coral populations and restore degraded reefs. The State agency in charge of protecting and conserving the natural resources of the Island, the Department of Natural and Environmental Resources (DNER), has adopted these community and private initiatives and created a program to conserve these coral species and as a resiliency tool to restore the coral reefs.

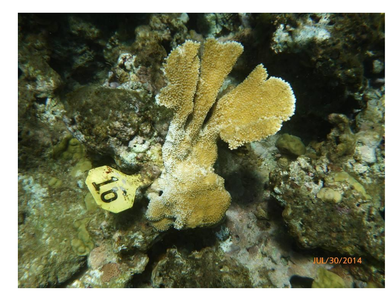


Resilience from the nursery to the reef (Guayanilla)

Fragments of opportunities are grown and monitored at nurseries. Survival and growth rates of grown colonies, and their resilience to different environmental stressors, such as disease and high temperatures are documented. Resilient fragments are later out-planted on open reef substratum, transferring their resiliency to the reef (Figure 2). A subset of the out-planted coral colonies is monitored, and they have shown to have a great percentage of success. Coral fragments harvested from nurseries appear to be more resistant than small recently settled wild colonies. This provides an outburst to the species considered threatened. In addition to the benefits already described, the out-planted corals are serving as fish nurseries.



A. palmata population at Vega Baja



Outplanted coral monitored by VIDAS

The program engaged all actors, at a regional level, in a joint effort that has improved the collaboration and communication among all parties, enhanced the use of resources and supported nursery activities. The permitting process was changed to ~~an~~ implement a letter of agreement system where the methodologies used at the nurseries were standardized, as well as data reporting procedures. A forum is held annually to share results, observations, findings, obstacles, lessons learned and needs.

One of the main obstacles the DNER has faced in the process is the absolute lack of funding to maintain operations. While NOAA has provided some funding for coral nurseries and reef restoration in Puerto Rico, it is not enough. No funds have been assigned to DNER to lead such activities and to maintain this initiative. Different strategies continue to be individually developed and implemented by DNER's partners to maintain operations, including writing proposals targeting the nurseries or other themes that could somehow be related, using volunteers, and engaging the private sector. Notwithstanding, funding sources are highly limited, irregular or unreliable. Considering the extraordinary results and benefits obtained from these nurseries, the DNER is trying to seek recurrent funding sources that could provide stability on their operation. In order to achieve real benefits for coral reef conservation and the communities that depend on them a sustainable and long-term program will be required. Below are some examples of the successful coral farming efforts in Puerto Rico.

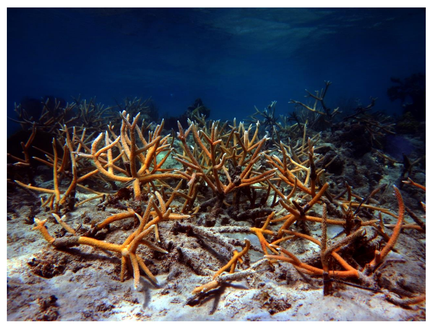
Coral nursery meeting at DNER

Impacted area in Guayanilla 2006

Restored site 2015

A. palmata serving as fish nursery

LACK OF FUNDING HAVE LARGELY AFFECTED OPERATIONS. MOST ACTIVITIES HAVE BEEN LIMITED TO MAINTENANCE, EMERGENCY REPAIR ACTIVITIES AND LIMITED MONITORING. SOME CORAL NURSERY HAD TO BE DECREASED IN SIZE. VOLUNTEER RECRUITMENT AND OUTREACH ACTIVITIES HAVE ALSO BEEN IMPACTED.



Outplanted corals in Culebra

FUCAs in Cabo Rojo

Location	Number of structures	Type
Cabo Rojo (Sand area)	11	FUCA
Lajas (Hard bottom)	20	BUCA
Guánica (Hard bottom)	9	BUCA
Bahía Tamarindo (Sand)	6	HLN
Bahía Tamarindo (Sand)	2	PVC frames
Bahía Tamarindo (Sand)	30	Plastic covered wire mesh
Punta Tamarindo Chico (Sand)	7	HLN
Punta Soldado (Sand)	16	HLN
Punta Soldado (Sand)	30	Concrete blocks + PVC sticks
Vega Baja and Manati	Fix fragments of opportunity	
Guayanilla	35	FUCA

Coral nursery in Culebra

Nursery	Colonies outplanted
Punta Soldado	1200
Tamarino	1500
Guayanilla	1500
Cabo Rojo/ Parguera/ Guanica	882
TOTAL	**5082**

* Does not include Vega Baja and Manati

Outplanted corals- Cabo Rojo

Outplanting *A. palmata*- Parguera

Assessment of the Historical Impact of Land Use and Restoration Activities on Sediment Delivery and Accumulation in Coral Bay, St. John, USVI

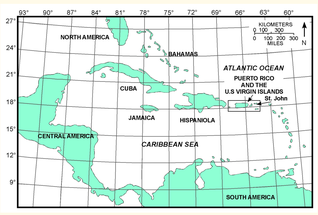
Rebekka A. Larson[1,2] (larsonra@eckerd.edu), Gregg Brooks[1], Sarah Gray[3], Carlos Ramos-Scharron[4], Stephen Cambell[3], Nichole Clark[1]

1 – Eckerd College, St. Petersburg FL
2 – USF, St. Petersburg FL
3 – University of San Diego
4 – University of Texas at Austin

Objective

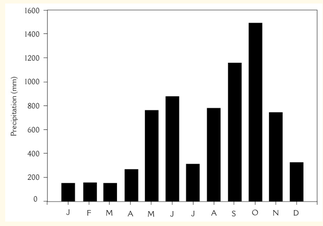
- Characterize terrigenous sedimentation in marine shore and reef environments.
- Assess impacts of anthropogenic watershed development to sedimentation patterns.
- Assess effects of watershed restoration projects, to mitigate terrigenous sedimentation in coastal environment.

St. John, USVI



- Highly vulnerable to sediment erosion
- Rapid transport of sediment downslope to coastal and near-shore marine environments.
- Enhanced erosion and transport - anthropogenic activities (i.e. roads, construction).
- Detrimental impacts of sedimentation on coastal environments

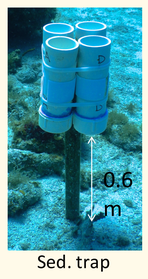
Seasonal Rainfall



-Large dry season (Dec.-April)
-Small wet season (May-June)
-Mid Summer Drought (July-Aug.)
-Large wet season (Sept.-Nov).

Sediment Sampling

Lameshure Bay
"Pristine" – National Park
Coral Bay
Anthropogenicly impacted
Watershed Grab Samples
Nearshore surface samples
Represent terrigenous source
Sediment Traps
Coastal and Reef Sites
Insight into sediment "input"
Coastal Grab Samples
Coastal and Reef Sites adjacent to Traps
Insight into sedimentation/accumulation



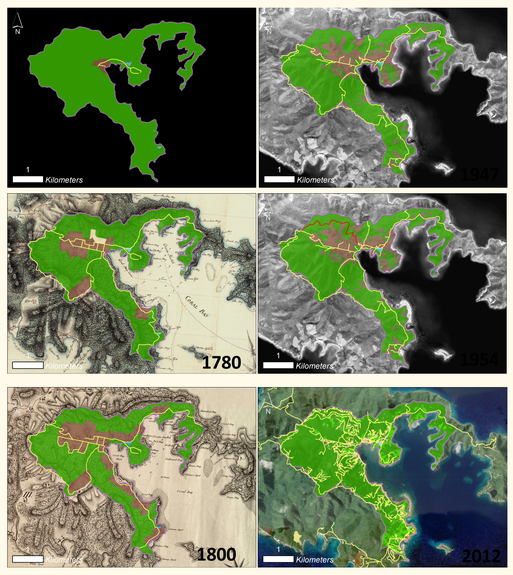
Sed. trap

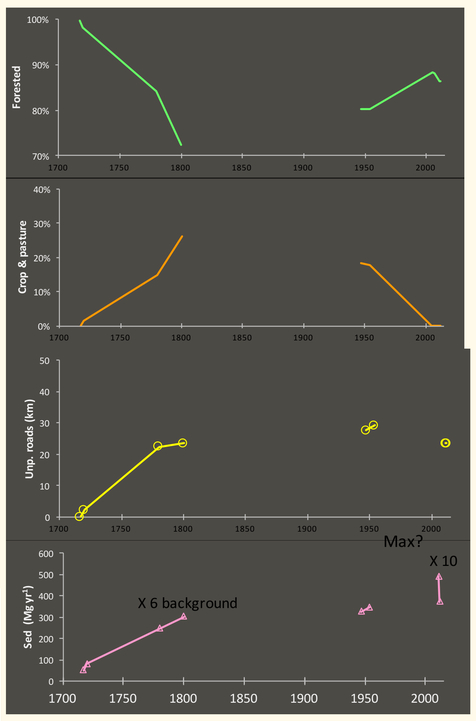
Coral Bay – A Land Use History

- 1718 – 1850
  - Sugar Plantation Era
- 1850 – 1917
  - The Collapse of Sugar
- 1917 – 1940s
  - Dormant economy
- 1950s – present
  - Tourism Era
- ~2010s
  - Watershed restoration

✓ Land cover recreated based on historical maps and aerial photos

✓ Sediment yields estimated by Open-NSPECT & STJ-EROS2 models

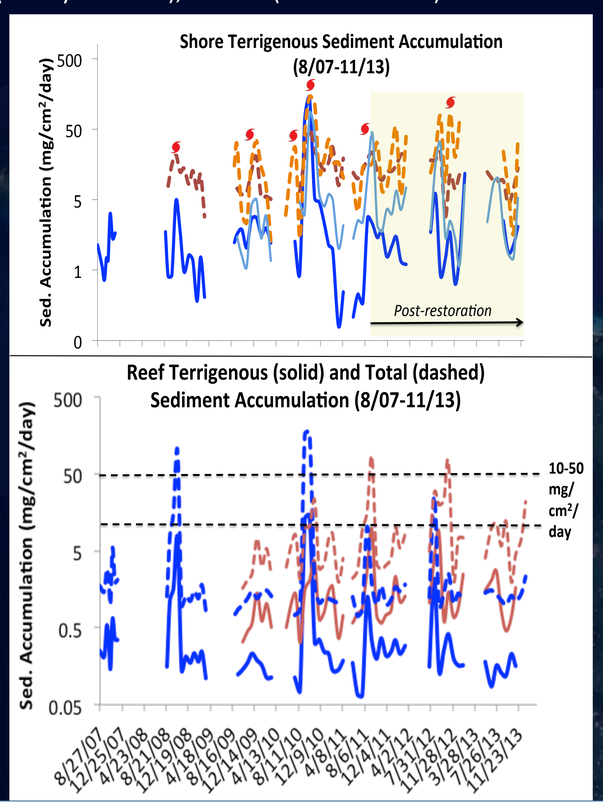




- Currently, unpaved roads generate >90% of the sediment entering the bay
- Watershed restoration activities resulted in a ~100 Mg yr^{-1} reduction in sediment yields

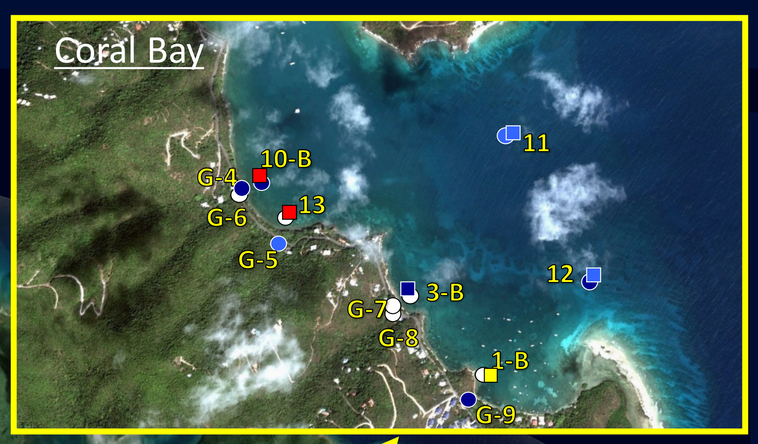
Marine Sediment Traps

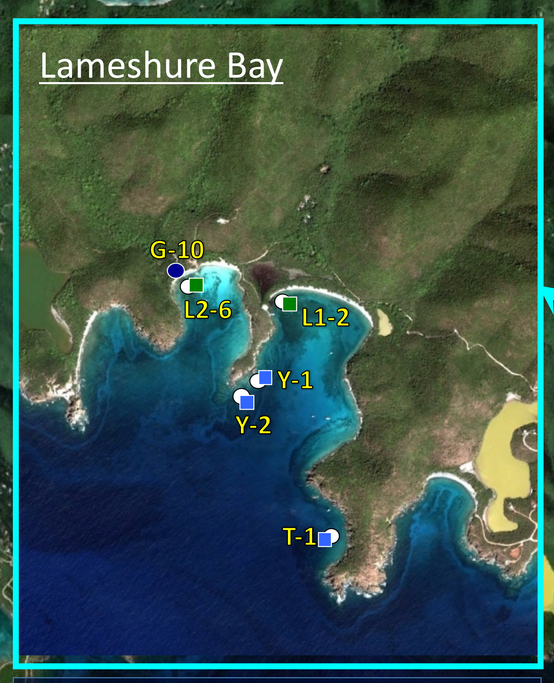
Sediment Traps – Rainy Season terrigenous sedimentation (26 day intervals), 15 sites (shore and reef).



*Terrigenous sediment accumulation in shore and (**below**) 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.*

- Consistently and significantly greater terrigneous sedimentation below developed watersheds with unpaved roads
- Greatest rates of terrigenous sedimentation –major storm events.
- Episodically high total sedimentation rates (>50 or 100 mg/cm2/day) and siltation rates (<75mm) - consistent with rates linked to coral stress.





Maps of 3 study areas showing ^{7}Be activity for sediment grab sites and trap sites.

^{7}Be Activity Map Legend

Surface Grab

- Not Detected
- > 0 – 0.5 dpm/g
- > 0.5 – 1.0 dpm/g
- > 1.0 – 2.0 dpm/g
- > 2.0 – 3.0 dpm/g
- > 3.0 dpm/g

Trap

- Not Detected
- > 0 – 0.5 dpm/g
- > 0.5 – 1.0 dpm/g
- > 1.0 – 2.0 dpm/g
- > 2.0 – 3.0 dpm/g
- > 3.0 dpm/g

Short-lived Radioisotopes – ^{7}Be

- Measured by gamma emission
- Input associated with rainfall

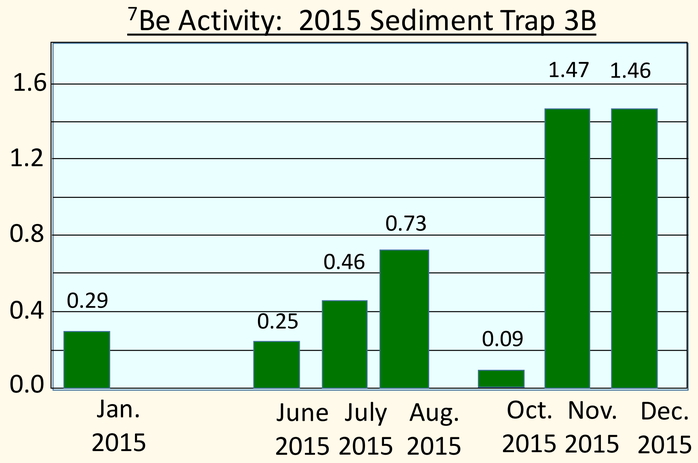
^{7}Be – Seasonal record
- 53 day half life
- deposition within last 1 year

^{7}Be Seasonal Variability

Site 3B sediment trap

^{7}Be activities vary seasonally and initial results show a good correlation of wet season to increased ^{7}Be activity in trap associated with runoff

^{7}Be Activity: 2015 Sediment Trap 3B



^{7}Be Distribution

- Maps showing ^{7}Be activities for grab samples (circles) for watershed and coastal sites, as well as sediment traps (squares)
- Collected in December 2014 and January 2015 following rainy season
- Watershed Grab Samples
  - Low activities or no detection of ^{7}Be
  - ^{7}Be input to watershed associated with rainfall is not accumulating within the watershed
  - Rapid transport of sediment and associated ^{7}Be activity to coast
- Sediment Traps
  - High ^{7}Be activities and/or detection of ^{7}Be at all of sites
  - ^{7}Be activities highest in embayments and close proximity to source
  - Rapid transport of sediment and associated ^{7}Be activity to coast
  - Indicate influence of terrigenous runoff to coastal environment
- Coastal Grab Samples
  - Low activities or no detection of ^{7}Be
  - ^{7}Be input to traps not from resuspension of bottom sediments
  - Indicates sediment input from watershed is not measurably accumulating on this time scale, exceptions in sheltered areas (Coral Harbor) and deep water sites (sites 11 &12)

Conclusions/Future Work

- At Two of three shore sites below restoration projects, terrigenous sedimentation was reduced post restoration. However, it is challenging to separate runoff vs. resuspension-induced sedimentation.
- ^{7}Be can be used in these types of geologic systems to further understanding of terrigenous sediment dynamics.
- Combination of sediment grab sampling and sediment trap sampling can provide insight into terrigenous sediment input to coastal environments as well as the residence time of these sediments i.e. export beyond the coastal system vs sedimentation vs accumulation.
- These insights will be combined with other work including sediment cores to further define sediment dynamics on multiple time scales.
- Ongoing research will include continued monitoring during 2016 (funded by UPR Sea Grant) and analysis of watershed runoff thresholds and terrigenous sedimentation during "equivalent" pre- vs. post- restoration storm events.

Acknowledgements

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Watershed-Marine Linkages: Monitoring how Terrigenous Runoff and Wave-Induced Resuspension Affect Marine Sediment Dynamics in Bays with Coral Reefs, St. John, USVI

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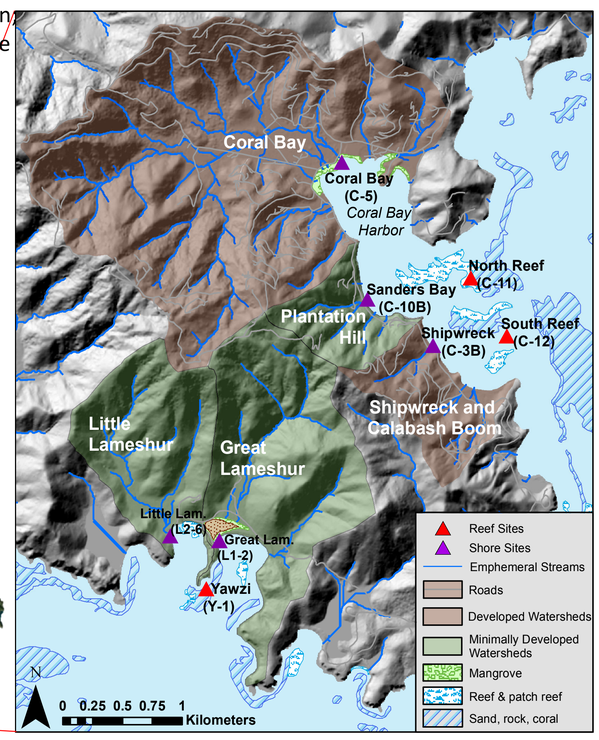
Introduction

In the US Virgin Islands (USVI), land-derived sediments (terrigenous) are thought to be a primary cause of coral reef degradation. Development, such as the building of unpaved roads in steep watersheds adjacent to coral reefs, has increased the volume of terrigenous sediment delivered to marine ecosystems (Brooks et al., 2007; Gray et al., 2012; Ramos-Scharrón and Macdonald, 2005). In addition to runoff from land, wave and current induced resuspension of benthic sediment can increase sediment deposition/turbidity. The lack of perennial streams on St. John, USVI makes it possible to compare marine turbidity/deposition between periods with and without runoff. In addition, the VI National Park protects over half the island from development, providing an opportunity to compare data in marine areas drained by developed vs. undeveloped watersheds (Fig. 1). A six-year (2009-14) monthly-resolution study of marine sedimentation using sediment traps in St. John aims to monitor the effectiveness of watershed restoration projects completed in 2011. However, an ongoing challenge has been to determine the relative contribution to sediment trap accumulation from runoff compared to resuspension.

Objectives

The goals of this integrated terrestrial-marine monitoring study are to:

1. compare the spatial and temporal variability of turbidity and deposition (10-minute resolution) in response to runoff and resuspension;
2. investigate the factors that influence turbidity and deposition; and
3. compare two marine sediment monitoring approaches (sediment traps [monthly resolution] vs. nephelometers [10-minute resolution]).



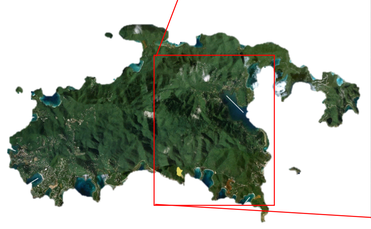
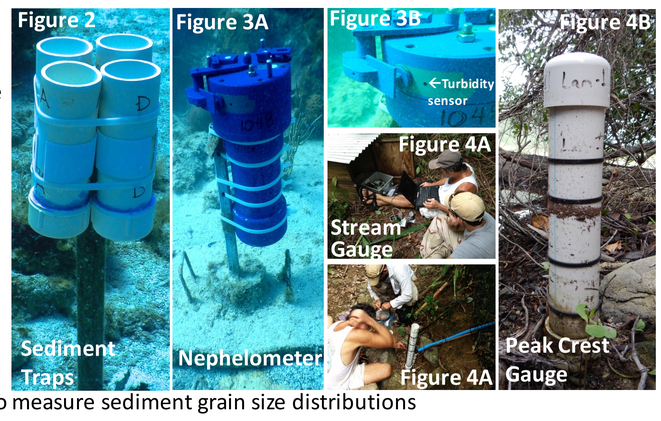


Figure 1. The island of St. John (left) and the study area (right) showing developed (brown shading) and minimally developed (green shading) watershed areas, and marine sampling sites where sediment traps and nephelometers were deployed (triangles). Crest gauges were deployed at the shoreline outfalls of ephemeral streams and a stream gauge was deployed near an ephemeral stream outfall adjacent to the Shipwreck marine sampling site (C-3B).

Field and Lab Methods

1. **Field deployments**. Monitoring was conducted from August 2013 to January 2014 within or below two developed and three minimally developed watersheds at 8 marine sites (3 reef and 5 shore sites) and several ephemeral stream outfalls (Fig. 1).
2. **Sediments**. (26 day resolution). Sediment accumulation rates (mg/cm²/day) were measured by deploying **sediment traps** (Fig. 2) and collecting benthic sediment samples every ~26 days. A Beckman Coulter LS 200 Laser Particle Sorter was used to measure sediment grain size distributions



3. **Turbidity/deposition (10-minute resolution)**. Neph 1000 series **nephelometers** (developed by JCU's Marine Geophysical Lab) measured sediment deposition in mg/cm² (± 5%) turbidity in NTU converted to mg/L (± 2%), and pressure (± 0.01 atm) as a proxy for hydraulic energy (RMS water height) at six of the eight sediment trap sites (Fig. 3).
4. **Runoff stage** was measured using a **stream gauge** (10-minute resolution) (Fig. 4A) near the Shipwreck shoreline and **peak crest gauges** (13-day resolution) (Fig. 4B) at four other ephemeral stream outfalls adjacent to shore sites.

Spatial Variability of Turbidity and Deposition

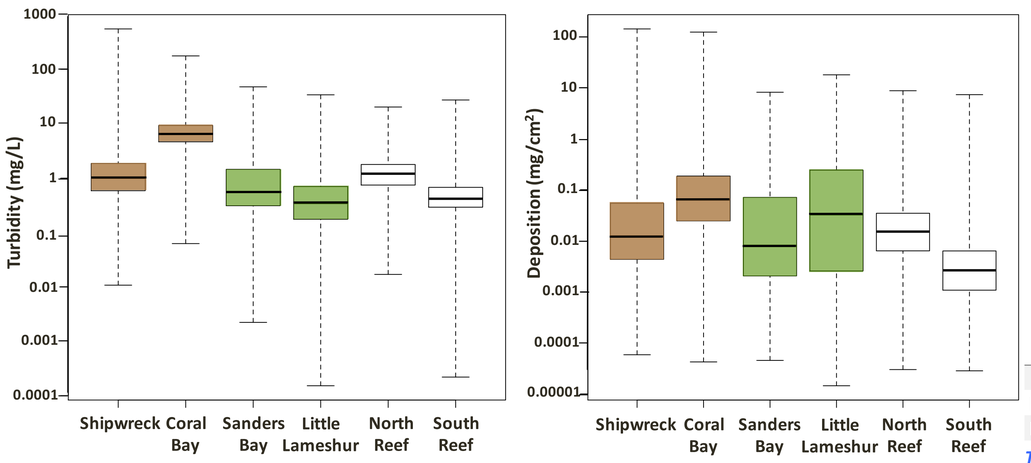


*Figure 5. Median turbidity (**A. left**) and deposition (**B. right**) at developed (brown) and minimally developed (green) shore and reef sites. Boxes indicate 25th and 75th percentiles, whiskers indicate minimum and maximum values; circles indicate outliers.*

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 (Fig. 5). Median and max turbidity and deposition were greater below developed watersheds (Table 1) 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.

	SHIPWRECK/ SANDERS		CORAL BAY/ LAMESHUR	
	Turbidity	Deposition	Turbidity	Deposition
MEDIAN	2	2	18	3
MAX	12	17	5	7

Table 1. Ratio of median and max turbidity and deposition below pairs of comparable developed and minimally developed watersheds.

Sedimentary Response to the Largest Runoff Event of 2013

On 11/21/13, 86mm of rainfall over 9 hours triggered sediment runoff which produced spatially variable short-duration (hours) spikes in turb./dep. (up to 900/17,000 times pre-runoff) at the shore but not the reef sites (Fig. 6). 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 turb./dep. was 6 times greater at Coral Bay than at Shipwreck (Fig. 5), the runoff induced turb./dep. peak was 16/1.5 times less than at Shipwreck (Fig 6). 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.

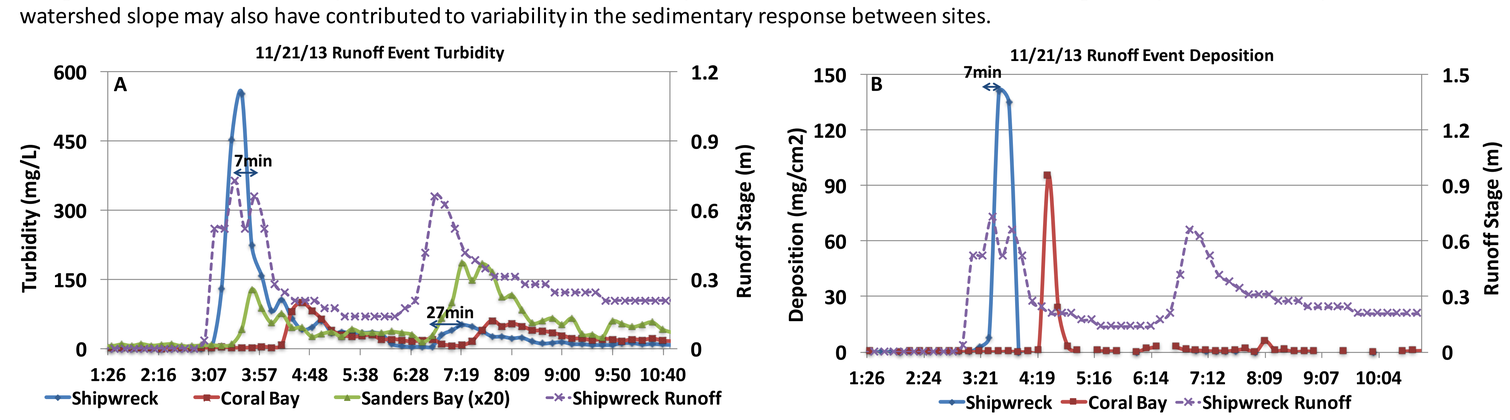


*Figure 6. Turbidity (**A. left**) and deposition (**B. right**) at shore sites, and Shipwreck runoff stage height vs. local time during the 11/21/13 runoff event.*

Runoff vs. Non-runoff (Resuspension)

To compare turb./dep. 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. 7A), and the maximum turbidity and deposition measurements were greater during runoff periods at all sites (Fig 7). This result is consistent with a) greater resuspension and reduced runoff induced turb./dep. at Coral Bay and the reef sites.

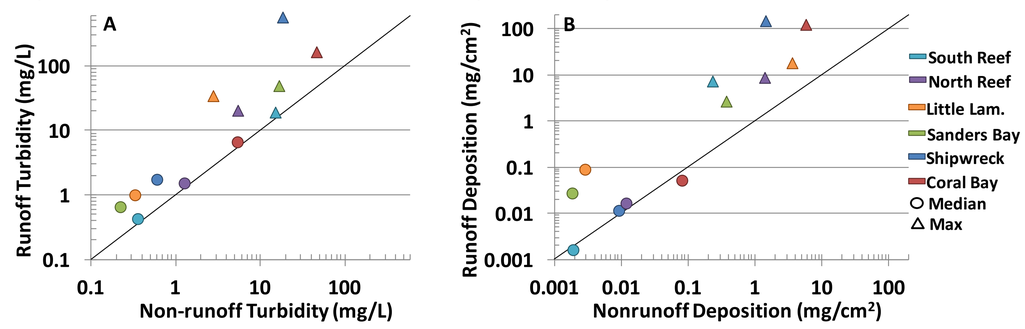


*Figure 7. Median and max turbidity (**A. left**), and deposition (**B. right**) during crest gauge defined runoff and non-runoff periods at shore and reef sites, and an x=y line.*

Other Factors Affecting Turbidity

Grain size. Turbidity was greater at sites with finer-grained sediment (percent silt & clay [<63µm]) because fine grains are more easily resuspended (Fig. 8). However, at some sites, macrophytes (sea grasses) may have reduced the potential for resuspension of fine grains. ***Wave energy.*** Minimum turbidity measurements (5th percentile) during both "runoff" and "non-runoff" periods appeared to increase with increasing wave energy (RMS water height) (Fig. 9). Above an RMS water height of ~0.10m, turbidity exceeded Class B water quality, but only exceeded ~100 mg/L during runoff events (Fig. 9). ***Tidal height.*** Tidal fluctuations were associated with prolonged turbidity cycles that far exceeded Class B water quality standards over days to weeks (Fig. 10). During low tide, greater wave orbital velocities make contact with the seafloor and resuspend benthic sediment.

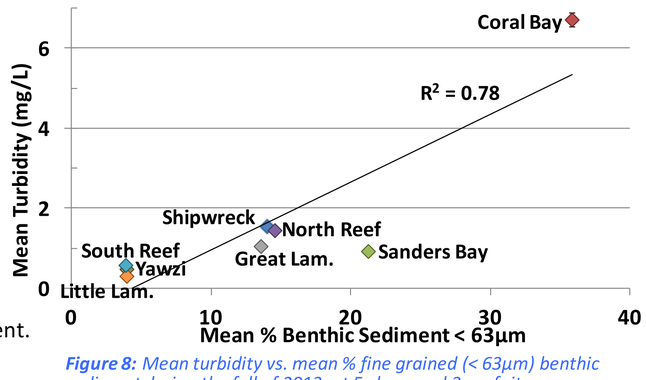


Figure 8: Mean turbidity vs. mean % fine grained (< 63µm) benthic sediment during the fall of 2013, at 5 shore and 3 reef sites.

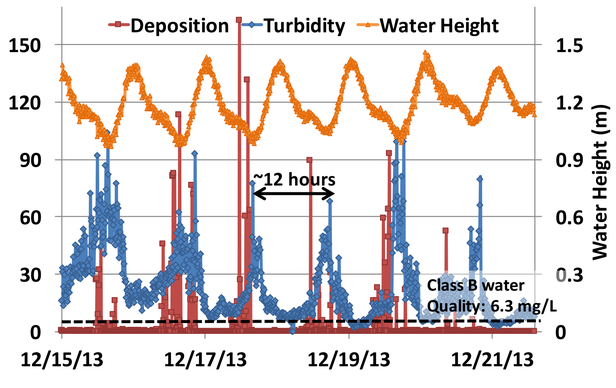


Figure 10. Turbidity, deposition, and water height (tides) at Shipwreck, during period of elevated regional wave height in December of 2013.

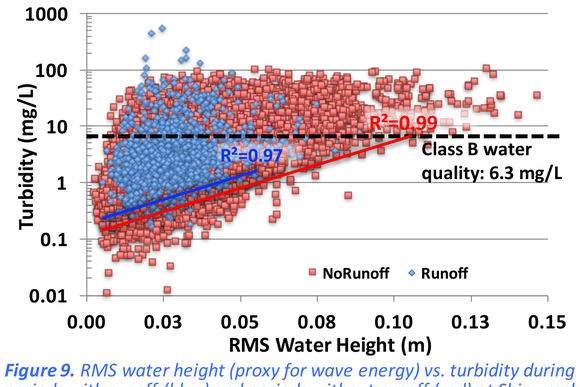


Figure 9. RMS water height (proxy for wave energy) vs. turbidity during periods with runoff (blue) and periods without runoff (red) at Shipwreck. Trend lines and R^2 values correspond to the 5th percentile turbidity measurements during runoff (blue line) and non-runoff (red line) periods.

Comparison of High-Resolution and Time-Integrated Monitoring

Mean 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 (Pearson R values ranged from 0.752 to 0.999). Though it's been suggested that the effectiveness of sediment traps to provide quantitative information are limited (Storlazzi et al., 2011), these data confirm that sediment traps closely mirrored data collected by nephelometers. However, sediment traps cannot record high-resolution variability in turbidity or deposition.

Conclusion

1. Our data demonstrate that: a) watershed development was associated with greater marine turbidity and deposition at marine shore sites; b) runoff resulted in high-magnitude but short-term (hours) spikes in turbidity and deposition, while resuspension resulted in lower-magnitude but long-term (weeks-months) turbidity and deposition; and c) the relative contribution of runoff vs. resuspension to turb./dep. was spatially variable (greater at Shipwreck than Coral Bay). 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, and the success of watershed restoration.
2. Resuspension-induced turb./dep. were associated with a) hydrodynamic energy caused by waves during low tides, b) fine benthic sediment grain size, and c) reduced macrophyte abundance.
3. Over longer time periods (26 days), sediment traps and nephelometer data were strongly correlated, indicating that sediment traps provide useful information for measuring relative changes in sedimentation in shore and reef environments.

Future research using short-lived radio isotopes may prove useful in determining the residence time of sediment in the system, and constraining the transport time for sediment to move from shore sites to the reef.

Acknowledgements and References

Field assistants: H. Hirsch, B. Swansen, M. Rassmussen, P. Strenger, R. Proctor., E. Wilson
Partners: J. Royster, L. Vandiver, D. Booth, Coral Bay Community Council, VIERS, Virgin Islands National Park.
Others: T. Barnes, J. Prairie.
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Ramos-Scharrón, C.E., and L.H. MacDonald. 2005. Measurement and prediction of sediment production from unpaved roads, St John, US Virgin Islands. Earth Surface Processes and Landforms 30:1283-1304.
Storlazzi, C.D., M.E. Field, and M.H. Bothner. 2011. The use (and misuse) of sediment traps in coral reef environments: theory, observations, and suggested protocols. Coral Reefs 30:23-38.

Tsunami Ready International Recognition Program: St. Kitts and Nevis Pilot Project

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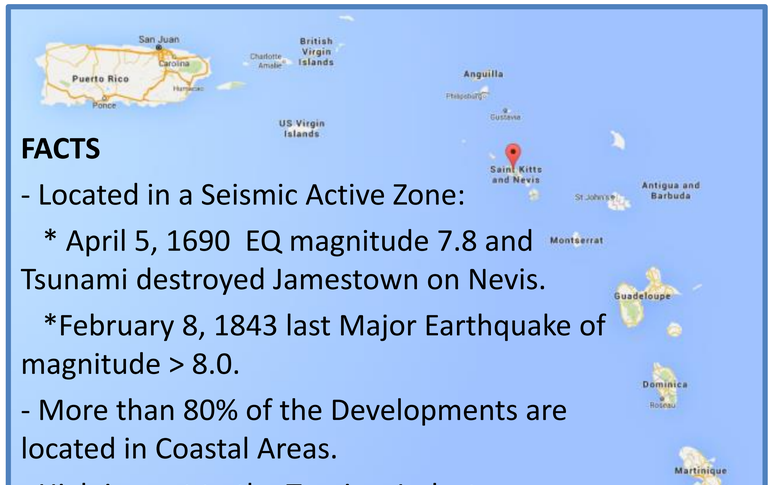
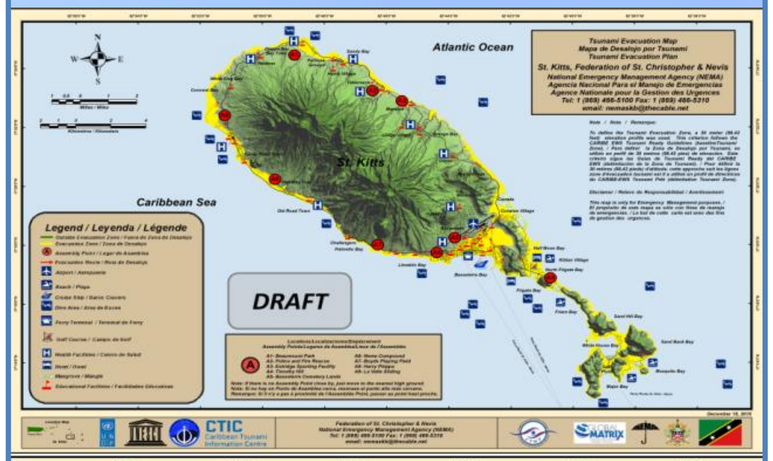
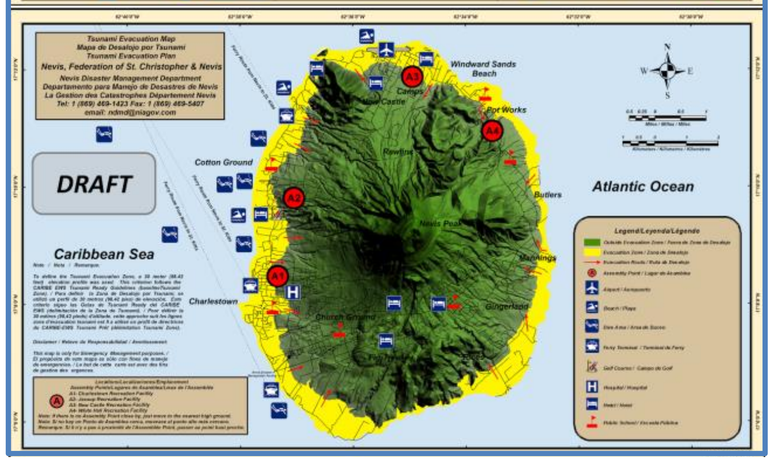


FACTS

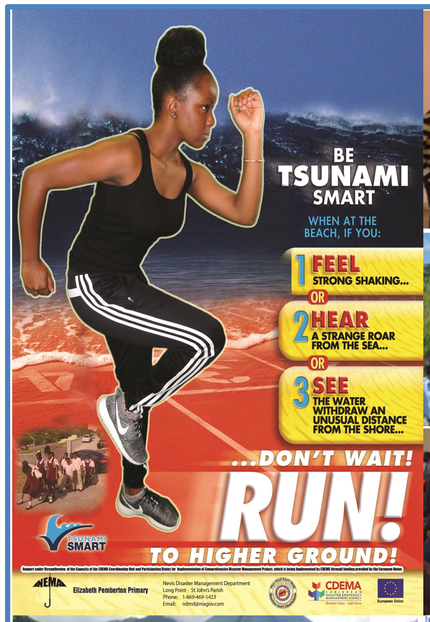
- Located in a Seismic Active Zone:
  * April 5, 1690 EQ magnitude 7.8 and Tsunami destroyed Jamestown on Nevis.
  *February 8, 1843 last Major Earthquake of magnitude > 8.0.
- More than 80% of the Developments are located in Coastal Areas.
- High impact to the Tourism Industry.





Guidelines approved in 2015 at the Tenth Session of the UNESCO ICG/CARIBE EWS (Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions) and further recommended by IOC Executive Council

TSUNAMI READY GUIDELINES	
Categories	*Completed*
MITIGATION	
Mit-1. Have designated and mapped tsunami hazard zones	✓
Mit-2. Have a public display of tsunami information	
PREPAREDNESS	
Prep-1. Produce easily understood tsunami evacuation maps as determined to be appropriate by local authorities in collaboration with communities	
Prep-2. Develop and distribute outreach and public education materials	✓
Prep-3. Hold at least three outreach or educational activities annually	✓
Prep-4: Conduct an annual tsunami community exercise	✓
RESPONSE	
Resp–1. Address tsunami hazards in the community's emergency operations plan (EOP)	✓
Resp–2. Commit to supporting the emergency operations center (EOC) during a tsunami incident if an EOC is opened and activated	✓
Resp–3. Have redundant and reliable means for a 24-hour warning point (and EOC if activated) to receive official tsunami threats	
Resp–4. Have redundant and reliable means for 24-hour warning point and/or EOC to disseminate official tsunami alerts to the public	



Draft Tsunami Warning Information Dissemination Protocol & SOP for Saint Kitts & Nevis

Partnership and support have been critical to the process including funding from UNDP ($5,000) and OFDA/USAID ($30,000).

United Nations Educational, Scientific and Cultural Organization

UNESCO

UNDP Empowered lives. Resilient nations.

USAID FROM THE AMERICAN PEOPLE

CTWP

NDMD

NEMA

SEISMIC RESEARCH CENTRE

CDEMA Caribbean Disaster Emergency Management Agency

CTIC Caribbean Tsunami Information Centre ctic.ioc-unesco.org

GLOBAL MATRIX