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for COASTAL
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NURSING AUDITORIUM

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*First Annual Symposium
for Coastal and Marine
Applied Research*

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GIS-Based Coastal Flood Mapping for Puerto Rico Using ArcView

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In this study we are trying to solve a problem that has existed for many years in Puerto Rico, which is the lack of accessibility to flood maps by the general public. More specifically, we have put together all information regarding coastal flooding due to hurricane storm surge and tsunami in a set of maps based on recently acquired, high-resolution, air photos. For hurricanes this involves the 100-year return period flood due to storm surges, the coastal high-hazard area due to wave action on top of the 100-year flood elevation, and the flooding due to Category 1, 3, and 5 hurricanes. In addition, we have added the potential flood line due to tsunamis (based on the recently finalized tsunami flood mapping produced by the Puerto Rico Tsunami Warning and Mitigation Program). For the north coast of the island, we have also added the line delineating the inland penetration of swash from a series of extra-tropical winter storms in the 1960's, as given in a USGS report. These maps will be made available through the Internet and will result in a better informed public.

An Evaluation of the Main Ports and Bays in Puerto Rico and the US Virgin Islands as to Their Exposure to Hurricane Wave Attack

Aurelio Mercado

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As small islands, Puerto Rico and the US Virgin Islands are extremely dependent on their ports and harbors for most of their needs. Since they are located on the hurricane belt of the North Atlantic basin, these islands are constantly threatened by passing hurricanes. Wind waves can travel thousands of miles from their generating areas and still cause damage. Numerical modeling of ocean wind waves has reached a stage where if given accurate bathymetry it will produce accurate simulations of the transformations undergone by wave trains as they propagate towards shore. In this study we are using the combination of sophisticated wave transformation models and recently acquired high-resolution bathymetry in order to estimate how exposed is the infrastructure lying inside Puerto Rico's and USVI's ports and harbors to hurricane-driven wind waves.

A Pilot Study to Investigate the Possible Linkages Between Submarine Groundwater Fluxes and Amphitheater-Shaped Scarps on the Northern Insular Margin of Puerto Rico

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Two giant amphitheater-shaped submarine scarps are carved out of a northerly dipping carbonate platform on the northern margin of Puerto Rico at a depth of about 3000 m. On the basis of compelling geologic and hydrologic evidence, we hypothesize that submarine groundwater seeps are present along the amphitheater-shaped scarps, and that the seeps represent an important pathway for transferring material from land (e.g. excess nutrients and pollutants) to the coastal ocean. To evaluate the groundwater contribution of the coastal waters off northern Puerto Rico, we conducted a five-day cruise offshore northern Puerto Rico in early April 2005. During the cruise, CTD casts and water sampling were conducted at a range of depths at 29 stations. Temperature and salinity anomalies were noted and water samples were analyzed for four naturally occurring radium isotopes.

Activities of radium isotopes that exceed background oceanic values indicate local additions of radium. Such additions are likely due to fluids passing through rocks or sediments. The source of these fluids may be submarine groundwater discharge (SGD) through shallow permeable sediments or discharge through deep formations (cold seeps). Excess activity of these short-lived isotopes ^{223}Ra and ^{224}Ra (half lives of 11 and 3.6 days, respectively) indicate recent additions of radium to the water. The surface water samples collected near the shore (stations 1, 11, 17, 19, 25, and 26) have excess activities of both isotopes. A deep sample from station 4 (2094 m) has a good signal of both isotopes. Samples from stations 13 (3117 m) and 18 (2805 m) have good signals of ^{223}Ra . Excess activities of long-lived isotopes ^{228}Ra and ^{226}Ra also indicate additions of radium. Here ^{228}Ra excesses are easier to distinguish because the background activity of this isotope in the depth range 1000-3500 m is quite low. Samples from station 13 (3117 and 3469 m) have clear excess ^{228}Ra . The activity in the 3117 m sample is about an order of magnitude higher than samples collected at this depth a few 100 km N of Puerto Rico. The ^{226}Ra in this sample is about 20% higher than expected. Since this sample also had a good ^{223}Ra signal, it is our best case for recent radium additions due to deep fluid flow. Station 4 (2094 m) has 2-3 times more ^{228}Ra than typical samples from this depth. Sample 14 (2805 m) has about the expected ^{228}Ra . Both of these samples have about the expected ^{226}Ra . The surface samples we have measured are all enriched in ^{226}Ra and ^{228}Ra (except station 18) compared to tropical Atlantic water. This indicates radium additions are widespread along the northern coast of Puerto Rico.

Future work includes sampling and isotopic analysis of coastal seeps and wells, and deep-towed camera (TOWCAM) deployments to visually document seep sites.

Development of Rapid Seismic Monitoring Procedures for Incorporation into the Emergent Puerto Rico – Virgin Islands Tsunami Warning System

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The circum-Caribbean region has a documented history of large damaging tsunamis that have affected coastal regions (Lander, 2002; Gusiakov, 2002). These tsunamis have generally been generated or triggered by large earthquakes that deform the ocean floor. In 1867 and 1867 earthquakes caused 20 ft high waves which flooded the streets of Charlotte Amalie, St. Thomas and in 1918 the low lying areas of western Puerto Rico, respectively. Tsunami warning systems are currently in place in other areas of the world (e.g., west coast of the continental United States, Alaska, the circum-Pacific region) and provide alerting and notification in the event of the occurrence of a large and possibly tsunamigenic earthquake.

There has been significant discussion among the seismological and oceanographic community of the need to establish a system of rapid notification for tsunami alerting in the Caribbean region. Many of these discussions have taken place at the University of Puerto Rico. For example during the Intra-Americas Sea Tsunami Warning System Workshop in December 2000 and also, most recently, during the Tsunami Protocol Meeting in January 2003. As a result of these discussions, the Puerto Rico Seismic Network (PRSN) at UPRM installed in January 2003 the EarlyBird system (Whitmore and Sokolowsky, 2002) as part of the emergent Puerto Rico and Virgin Islands Tsunami Warning System (von Hillebrandt and Huérffano, 2004)

Any warning system relies on the rapid calculation of the earthquake location and size, which define the position of possible tsunamigenic events and provide an initial indication of the potential for tsunami generation. The objective of this project is to evaluate the use of waveform data recorded by the PRSN (and IU) in local and regional waveform analysis procedures for the purpose of identifying potentially tsunamigenic earthquakes in a timely manner. As a result, the waveform inversion methods will be incorporated into automated procedures to be integrated into the PRSN analysis systems for use in tsunami alerting.

**Population Composition, Geographic Distribution, and Natural
Hazards: A Preliminary Report on Vulnerability in the
Coastal Regions of Puerto Rico**

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Given its geographic location and climatological conditions, Puerto Rico is highly susceptible to natural hazards (e.g., hurricanes, floods, tsunamis, and earthquakes). Coastal or riverine flood areas and steep mountains characterize much of Puerto Rico. Further, as a result of changing social and demographic patterns, there has been a significant increase in population density, in the proportion of the elderly, the physically disabled population, and in female headed households, and an increasing concentration of residents in flood and/or landslide prone areas. These trends are particularly noticeable along the island's coastline. The primary goal of this project is to construct GIS based maps integrating current coastal flooding (due to hurricanes and tsunamis) maps and 2000 Census data. This will improve our understanding of how social, economic, and demographic factors contribute to the vulnerability of the population living within these areas. An important byproduct of this research will be the production of GIS based coastal flooding vulnerability maps integrating current flood maps, census data on population characteristics, topographic information, road maps and satellite imagery that will be made available to emergency managers, planners, and other public officials throughout the island. This is a collaborative and interdisciplinary research effort between the Disaster Research Center at the University of Delaware, the Center for Applied Social Research (CISA) and the Physical Oceanography Laboratory, both at the University of Puerto Rico-Mayagüez.

La Aportación de la Educación Ambiental Costero-Marina al Desarrollo Sostenible de la Región del Caribe

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Tradicionalmente, el objetivo de los esfuerzos de educación marina, tanto en Sea Grant como en otros programas similares, ha sido impactar el currículo escolar para lograr que los conceptos científicos sean incluidos en las diferentes disciplinas. Las actividades han sido dirigidas a maestros, estudiantes y administradores escolares de diferentes niveles. En términos generales, estos esfuerzos han sido exitosos. Los libros de textos de ciencias y los contenidos curriculares que se utilizan en las escuelas públicas de Puerto Rico ya incluyen información sobre los ecosistemas marinos y costeros del Caribe.

Lograr un desarrollo económico sostenible, que preste la atención necesaria a la conservación y protección de los recursos costeros y marinos, a la vez que generen beneficios económicos, depende considerablemente de que se eduque a los ciudadanos sobre el valor de los servicios ecológicos que prestan los ecosistemas costeros y marinos.

La participación de personas no relacionadas al ámbito escolar en las actividades de educación ambiental costero-marina en la República Dominicana y sus inquietudes por el impacto de las actividades que se generan en turismo, recreación, pesca y construcción en la costa nos llevó a desarrollar actividades educativas para la presentación de conceptos y estrategias de manejo integrado de áreas costeras a diferentes grupos de personas. Se trabajó con personal de áreas protegidas, como el Parque del Este, empresas hoteleras en Bayahibe y funcionarios de la Secretaría de Medio Ambiente.

Los resultados obtenidos fueron: establecimiento de un programa de capacitación de maestros y la continuación de los talleres desde el Acuario Nacional de Santo Domingo; el establecimiento del Programa Bandera Azul de Playas en Bayahibe, con la participación de la comunidad y de las escuelas, y la capacitación de personal técnico para la aplicación de estrategias de manejo integrado de costas en las provincias de Azua y Barahona.

Además de fondos del Programa de Colegio Sea Grant de la Universidad de Puerto Rico, este Proyecto recibió apoyo económico del Programa *Atlantea* de la Universidad de Puerto Rico y de la Secretaría de Medio Ambiente de la República Dominicana. Se recomienda la reanudación de los contactos establecidos en este Proyecto y el establecimiento de nuevos programas para dar continuidad al esfuerzo y lograr la sostenibilidad del mismo.

***Project: Enumeration of Hydrocarbon Degrading Bacteria and
Degrading Kinetics as Indicator of Coastal Water Quality***

**Enumeration of Naphthalene and Phenanthrene Degrading Bacteria as an Indicator
of Hydrocarbon Pollution in Surface Waters of Guayanilla, Puerto Rico:
Impact of Seasonal Variation**

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Coral reefs are sensitive indicators of environmental stress because of their response to disturbances. For the present study four coral reefs were selected based on their proximity to an industrial complex. Additionally, three coastal areas: Guayanilla beach, El Faro beach and a seagrass bed were also sampled while an offshore station was used as control because the area is not impacted by industrial pollution.

Biodegradation potential of PAHs was determined by toxic substrate utilization pattern and by enumeration of hydrocarbon degrading bacteria (agar overlay technique) as an indicator of PAHs pollution. Phenanthrene and naphthalene were used as model PAHs compounds. The study was conducted over one-year period. Samples were collected during both dry and rainy seasons. Water quality variables measured were temperature, turbidity, nutrients, salinity, pH, and dissolved oxygen. The results show that heavy rainfall caused perturbation of sediments, rich organic matter and the substrates necessary for microbial growth and proliferation. The level of dissolved oxygen in the bay water also decreased as a result of an increased biological activity. Increase in number of hydrocarbon degrading bacteria was observed in samples collected during rainy season. Two naphthalene degrading (*Pseudomonas* spp., *Aeromonas* spp.) and one phenanthrene degrading (*Pseudomonas* spp.) were isolated, purified and identified.

Note from UPR Sea Grant

For the purpose of designing the program we used the original titles of the proposals funded by UPR Sea Grant. In some instances the title of the original proposal and/or the co-authors are different from the title and/or co-authors in the abstract. The original title/authors appear in a box above the title of the abstract.

Project: Water Quality and Marine Ecosystem Health Indicators: Development of Statistic Models for Integral Assessment

Indicators of Eutrophication and the Routes of Commercial Craft

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Phosphorescent Bay in La Parguera, Puerto Rico is one of approximately 14 bioluminescent bays that remain in the world and is correspondingly the site of many excursions by commercial vessels. Due to the size of the larger boats and the relative shallowness of the bay, the routes followed by larger commercial craft tend to be consistent. As a result, the bay provides a valuable opportunity to study the distribution of ecological variables in a closed environment with reasonably well-defined routes of commercial boats. Water and sediment variables were measured at 21 testing sites in Phosphorescent Bay and these measurements were used to create maps of ecological indicators throughout this body of water. We found that there is a strong relationship between sediment variables and the routes followed by commercial craft; however, the relationship between water variables and the tracks used by commercial vessels is much weaker.

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Contaminant and Erosion Control Baseline Database for the Puerto Mosquito Watershed, Vieques, PR

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Puerto Mosquito Bay, Vieques Island, is one of the most magnificent examples of the world's few remaining bioluminescent bays. It lies within a basin formed along the southern edge of volcanic upland that comprises much of the bedrock of Vieques. Bioluminescence in Puerto Mosquito is caused almost exclusively by dinoflagellates. This splendor of light may be in peril due to the unsustainable human activities in the surrounding uplands and along the shoreline of this shallow marine environment. With the increased tourist activities and the current development practices within the surrounding area, bioluminescence in this bay may be at risk in the near future resulting from excessive erosion and deposition of sediments and contaminants.

This study was undertaken to understand how natural and human induced factors may affect sediment composition and deposition and how that affects the quality and quantity of light in the water column of the bay. There is no information on how sediment affects the dinoflagellates that produce the bioluminescence. We evaluated the relationship between physical parameters, sediment composition, and land use-land cover of the area by using traditional sampling methods and remote sensing. Sediment was collected monthly over an eight month period using three sediment traps located in the bay. Sediment composition, X-Ray Diffraction, sieving and serigraph analyses were part of the methodology. Temperature measurements were also registered at each trap. The analyses demonstrate that 45% was carbonate material, 33% was terrigenous material, and 22% was organic material. It was also showed that the temperature can change over four degrees along the day in the sampled stations. The results from Puerto Mosquito Bay were compared with the same type of data collected during the same period in La Parguera Bioluminescent Bay in Lajas, Puerto Rico. In La Parguera the carbonate material was only 10%, while terrigenous material was 65% and the organic material was 25%. Temperature follows the same trend as in Puerto Mosquito. This study demonstrated that La Parguera Bay received much more terrigenous material than Vieques Bay during the studied period, suggesting important differences in the processes affecting the sedimentation. In order to evaluate this problem IKONOS images were used to determine the changes in land use and land cover of the surrounding areas in both bays. The analyses showed that La Parguera has less vegetation and more human activity closed to the bay than in Vieques. Such condition in combination with the geology of the areas could explain the sedimentation trends found during this study. A baseline database has been created for Puerto Mosquito and La Parguera bays, but further studies are necessary to fully understand the contaminant and erosion control in these bioluminescent bays.

Heavy Metals and Biomarker Toxicity Assays in Jobos Bay National Estuarine Research Reserve

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Although Jobos Bay National Estuarine Research Reserve (JBNERR) was established in 1981, there is a lack of published studies documenting levels of anthropogenic pollutants in the Jobos Bay area. This study determined the extent of contamination in water, sediments, and biota. From a total of seven metals, fish muscle tissues of *Scomberomorus cavalla* “sierra” and *Lutjanus synagris* “arrayado” obtained As and Hg concentrations ($\mu\text{g/g}$ ww) that surpassed or neared the human health-protection reference tissue values of 2 and 0.5, respectively, ranging from 0.76 to 11.7 for As and from 0.08 to 0.40 for Hg. These two toxic metals were low in *Micropogon undulatus* “roncón” and *Lutjanus analis* “sama”. Average metal concentrations in water samples from Jobos Bay and La Parguera (a reference site) areas were below the environmental quality standards for ocean and estuary water. In sediments, significantly higher average values ($\mu\text{g/g}$ dw) of As (17 vs. 9), Pb (11 vs. 4), Cu (29 vs. 14), Zn (64 vs. 28), and Fe (2.6 vs. < 1 in %) were observed in samples from the Jobos Bay area when compared to La Parguera, but these levels were low as to not represent a concentration above which effects frequently occur in aquatic organisms. When using Fe as normalizer for metals in sediments, only anthropogenic inputs of As were observed in all stations of the Jobos Bay area, even at a moderately severe level. Polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls were detected in sediments of JBNERR, ranging from 103 ng/g to 1,986 ng/g and from no detect to 3.7 ng/g, respectively. The highest total PAHs (1,986 ng/g) and Zn (129 $\mu\text{g/g}$ dw) sediment concentrations corresponded to samples collected next to a former tire recycling center where more than 20,000 used tires burned. DNA damage measured in *Brachiodontes exustus* mantle cells at four field sites in JBNERR, using the alkaline version of the single cell gel electrophoresis or comet assay was consistently higher in the site near the thermoelectric power plant in which the second highest total PAH concentration (704 ng/g) was detected. The Ames Salmonella/microsome mutagenicity assay showed mixed results from five JBNERR sediment samples, suggesting the absence or insufficient amount of mutagenic chemical compounds in sediments as to elicit a mutagenic response. In conclusion, although concentrations of metals in water and sediments, and organic chemicals in sediments of JBNERR were low, anthropogenic activities contribute to these contaminants in this system. Deleterious effects as observed with *B. exustus* and increasing fish tissue-metal concentrations may be the result of contamination. Further studies should be conducted to identify sources of chemical contamination, to provide a human health-risk evaluation from fish consumption, and extend the analysis of organic chemicals to edible fish species.

***Project: Microbiological Parameters that can be Used to Classify Oyster and Clam
Harvesting Waters and Develop Relaying or Purification Treatments
from a Public Health Perspective***

**Microbiological profile of the clam (*Lucina pectinata*), of the mangrove
oyster (*Crassostrea rhizophorae*) and of their harvesting waters in
Boquerón and Lajas, Puerto Rico**

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The microbiological profile of the clam (*Lucina pectinata*), the mangrove oyster (*Crassostrea rhizophorae*), and their harvesting waters in the southwestern zone of Puerto Rico, was determined by the analysis of fecal coliforms, *Salmonella* spp., *Vibrio* spp., and total plate count. Samples were collected from two areas of the southwest of P.R. (Boquerón and Lajas) between the months of July 2003 to June 2004. Density of fecal coliforms were found to range between 0.48-1.97 log₁₀ cfu g⁻¹ or ml⁻¹; whereas, the density of vibrios were between 0.48-5.04 log₁₀ cfug⁻¹ or ml⁻¹. Total counts fluctuated between 2.40-5.61 log₁₀ cfu g⁻¹ or ml⁻¹. *Salmonella* was not detected in any of the samples. The majority of the samples were in compliance with the regulations of the National Shellfish Sanitation Program (NSSP). No significant correlation was found between the density of vibrios and salinity, pH, dissolved oxygen or temperature. These studies provide a baseline on the microbiological profile of these bivalve species and their harvesting waters.

Note from UPR Sea Grant

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Island Wide (Puerto Rico), U.S. and British Virgin Islands Distribution and Impact Study of Triazine Constituents in Anti-fouling Paints on Inshore Marine Communities, and the Development/Incorporation of Bioassays for Assessment of Marine Pollution

Kelly K. Carbery⁽¹⁾, Ernesto Otero⁽¹⁾, Richard Owen⁽²⁾ and James Readman⁽³⁾

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Irgarol 1051® is a *s*-triazine herbicide used in popular slime – resistant antifouling paints that is known to be acutely toxic to corals, mangroves, and sea-grasses, have been shown to decrease photosynthesis at low concentrations (<50 ng l⁻¹). We present the first large-scale assessment of Irgarol 1051® (Irgarol) abundance in the coastal waters of the Northeastern Caribbean (Puerto Rico and U.S. Virgin Islands; PR and USVI). Widespread low level contamination throughout the coastal waters of Puerto Rico was found, (Irgarol was present in 68% of 60 samples) reaching concentrations of 5-50 ng l⁻¹ in 43% of the collected aqueous samples. Contamination by Irgarol in the coastal waters of the U.S. Virgin Islands was also widespread (93% of 29 samples), with significantly higher concentrations found at several locations (386 ng l⁻¹ at Pillsbury Sound, 1300 ng l⁻¹ at Benner Bay). The higher levels found in the USVI than in Puerto Rico suggest faster acceptance of the antifoulant in the former market and/or faster introduction through visiting vessels than in the latter. The proximity of contaminated locations to managed coral reef habitats and seagrass beds, underscore the importance for continued monitoring of Irgarol and its degradation products, to understand future trends and thus develop management approaches. At present we are adapting fluorescence response assays to determine Irgarol effects on natural and/or concentrated microalgae assemblages that may be used as preliminary assessment of Irgarol impacts on aquatic systems.

Keywords: Irgarol 1051®, Anifouling Paint, Herbicide Pollution, Coral Reef Degradation, Northeastern Caribbean, Environmental Risk

Project: Continuation with Reduced Sampling of Environmental Monitoring Research of Open Ocean Aquaculture in Culebra

Environmental and Social Impact of Sustainable Offshore Cage Culture Production in Puerto Rican Waters

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This project was the first large-scale environmental evaluation of open-ocean submerged cages in the Caribbean to assess the technological feasibility and possible environmental effects involved in adapting cutting-edge technology to culture Lutjanus analis (mutton snapper) and Rachycentron canadum (cobia) in submerged open-ocean cages in Puerto Rico. The study provides “base-line” information that will be useful as the open-ocean aquaculture industry expands. The information obtained from this project provides a basis for Puerto Rican authorities and the private aquaculture industry to evaluate the feasibility of this operation. This project used the “shotgun” approach to select the most important water and sediment quality variables and their effects on the local environment. The study determined if the cages served as fish aggregation devices (FADs), the concentrations of nutrients in the water and sediment; effects on the benthic community, and the rate of biofouling growth. Currents were monitored at the control site located 375 m from the cage site. Results indicated no evidence of anaerobic sediments beneath the cages, inorganic nitrogen near the cages was similar to background levels, macroinvertebrates populations and sediment were only affected directly beneath the cages just before harvest when feeding rates were highest. Many wild fish (40 species) were attracted to the cages. As more cages are installed, especially if stocking rates are increased, focus should be on the sediment, especially just before harvest; possible effects on distant coral reefs, and to determine the positive or negative interactions by having wild fish attracted to the cages. Because biofouling grows rapidly (and needs to be cleaned biweekly), it should be evaluated to remove nutrients from the water column to ameliorate effects on the environment. Knowledgeable residents near the project had a positive attitude concerning the open-aquaculture project; however, 55% of the members of the general community of Culebra did not have general or specific knowledge about the open-ocean aquaculture project and did not have specific information about the advantages or disadvantages in relation to the impact on economy, fishing, fishermen, or community life. It is important to increase their knowledge by developing an informative program.

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**Species Identification of Snapper Larvae (Family Lutjanidae)
Based on Mitochondrial DNA Analyses**

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Lutjanidae is one of the largest teleostean families. The majority of the species found in the western Central Atlantic area belong to the subfamily Lutjaninae. Distinguishing the lutjanine larvae from each other is difficult despite published larval descriptions. Taxonomic identification of these larvae to the species level represents one of the main bottlenecks in our understanding of their early life cycle. Such information is of vital relevance in the assessment of marine protected areas (MPAs) as management options to restore the declining stocks of commercially exploited fishes. To address this problem, we are in the process of identifying mitochondrial DNA (mtDNA) restriction fragment length polymorphisms (RFLP) diagnostics to lutjanids. Adult specimens have been obtained from catches of local fishermen at the Parguera Fishing Village, southwest Puerto Rico. Larvae were obtained from plankton tows using a 202 µm mesh net. We quantified mtDNA variation through the use of polymerase-chain-reaction (PCR) amplification of fragments corresponding to 450 bp of the 12S rRNA gene, followed by digestion with restriction enzymes. Seven haplotypes have been observed; four of them have been found in only one species of the adult specimens and one for unknown larvae. One haplotype of the analyzed larvae matched with that of the adult of *Lutjanus griseus*. We consistently found a morphologically distinct type of lutjanid larva not previously described which molecular haplotype and occurrence might be compatible with *Lutjanus apodus*. So far, the procedure that we are undertaking is producing results that suggest that specific haplotypes will be identified for most of the species.

Quantitative Assessment of Nursery Habitats for Fishery Stock Enhancement

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This study compared distribution, growth, and differences in otolith micro-chemistry of juvenile yellowtail snapper (*Ocyurus chrysurus*) at three sites (Mangrove Lagoon, Sprat Bay, and Brewer's Bay) in St. Thomas, USVI. Each site was represented by a distinct nursery habitat type as follows: Mangrove Lagoon (mangrove roots), Sprat Bay (*Thalassia* seagrass), and Brewer's Bay (*Syrigodium* seagrass/ *Dictyota* drift algae). Fish transects were completed each month within the representative nursery habitat types at each site and on the adjacent coral reef from May 2000 through October 2001. Brewer's Bay nursery habitat and its adjacent coral reef had higher densities of newly settled reef fish (all species) than Mangrove Lagoon or Sprat Bay habitats. Older stages of reef fishes were similar among sites and habitats. Newly settled yellowtail snapper (< 3 cm) were most common in nursery habitats and decreased in abundance in the 4-10 cm and 10-20 cm size classes at all sites except Mangrove Lagoon where juvenile fish (4-10 cm) were most abundant. On coral reef habitat, juvenile yellowtail snapper in the 4-10 cm size class were more abundant than smaller or larger size classes at all sites. Settlement patterns for *O. chrysurus* show that Brewer's Bay nursery habitat had significantly more newly settled fish ($p < 0.01$) than Sprat Bay and Mangrove lagoon. Yellowtail snapper from Brewer's Bay had significantly wider otolith increments and thus faster growth rates than fish from Sprat Bay or Mangrove Lagoon. Condition factor, the relationship between weight and length, was significantly lower for fish from Mangrove Lagoon than fish from Sprat Bay or Brewer's Bay ($p < 0.001$). ICP-MS analysis of sagittal otoliths were sampled for 6 different chemical signatures relative to the concentration of Calcium (Ca). These elements were: Magnesium (Mg), Manganese (Mn), Copper (Cu), Sr (Strontium), Barium (Ba), Lead (Pb). Mn, Sr and Pb showed significant differences between sites, Mg and Mn showed significant differences between years, Sr and Ba showed significant interaction between site and year and Cu showed no significant differences. Based on this preliminary analysis Pb seems to be a likely candidate for determining the contribution of nursery habitats to the yellowtail snapper fishery.

Assessment of Red Hind (*Epinephelus Guttatus*) Breeding Population Structure and Spawning Habitat

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Tag and release fishing, fish transects and ultrasonic imaging were used to evaluate population characteristics and habitat use patterns of a red hind (*Epinephelus guttatus*) spawning aggregation within the Red Hind Bank Marine Conservation District (MCD), St. Thomas, U.S.V.I. The spawning population showed considerable within-month and between-month variation in population size- and sex-structure. Males appeared to arrive at the aggregation site first in December and remained on the spawning site between spawning peaks. Although females represented a large proportion of the catch early in the aggregation periods in January and February they seemed to depart the spawning site between spawning peaks. Spawning occurred in January and February and size frequency distributions suggested that an influx of small females occurred during the second spawning month. An overall sex ratio of 1 : 2.92 (male : female) was recorded for the whole reproductive season. However, the sex ratio differed between months and days within months. More females per male were recorded in January than in February when the sex ratio was male biased. Fecundity estimates for this species predicted very high potential fecundities ($2.6 \times 10^5 - 2.2 \times 10^6$ oocytes). The ultrasound model also illustrated a rapid increase in potential female fecundity with total length. Since the closure of the MCD the size of red hind has increased over 10 cm and the maximum density and abundance more than doubled. Information from tag returns indicated that red hind depart the protected area following spawning and migrated 6 to 33 km to a ca 500 km² area. Protection of the spawning aggregation site may have also contributed to an overall increase in the size of red hind caught in the commercial fishery thus increasing the value of the grouper fishery for local fishermen.

**Project: Reproductive Biology of Caribbean Corals, Current
Status and Information Gaps**

Reproductive Biology and Ecology of Some Caribbean Coral.

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Knowledge of the reproductive biology and the associated processes of dispersal and recruitment is essential for the interpretation of ecological, geographical and evolutionary patterns of marine organisms. Most of the reproductive information available for corals is for Indo-Pacific species. Information on aspects of the reproductive biology for Caribbean species is limited to 18 of the 60+ species of zooxanthellate corals found in the region. However, conflicting and incomplete data for some taxa confuse the interpretation of results. The current deterioration of Caribbean reefs undermines the importance and urgency of increasing our knowledge and understanding of the reproductive biology and ecology of most reef building species and other important reef organisms. The project goals were to characterize the annual gametogenetic cycles and to determine/confirm the sexual reproductive patterns (gonochoric or hermaphrodite), reproductive modes (spawner or brooder), and fecundity for 18-24 important species of Caribbean corals for which there was incomplete/conflicting- or no information available. Over the two years of the project, tissue samples were collected from at least 5 colonies of each species every month for 14 months. Tissues were fixed, decalcified, cleaned, embedded in parafine, sectioned and stained (Heidenhain's azorcarmine-aniline blue) and sealed over glass slides following well established protocols. Some improvements on the protocols were done over the course of the project. Histological tissues for 24 species are archived and stored in the PIs lab. Two graduate students got their Masters degrees participating in different aspects of the project, two more benefited from the equipment and expertise developed from this project using it to develop their projects and recently, another graduate student finished the reproductive analyses of the four species of the genus *Mycetophyllia* found in Puerto Rico. Some of the important results from this project include: (1) the characterization of the complete gametogenetic cycles for the three species of *Diploria* in the Caribbean, which showed that one of them, *D. labyrinthiformis*, spawns in the spring instead of during the summer like the other two species, (2) all three species of *Diploria* and the columnar *Dendrogyra cylindrus* can reproduce asexually by small propagules termed gemmae, a novel asexual reproductive strategy, (3) contrary to some reports, *Colpophyllia natans* spawn in the spring and not in summer like the majority of the favids, (4) all four species of *Mycetophyllia* are hermaphroditic brooders with one gametogenetic cycle per year (instead of several as previously believed), and differential maturation pattern of eggs and spermaries that allow them to brood well developed larvae several times during the winter months. Planulation intensity (number of planulae produced in each cycle) vary in each species, (5) two of the three species of *Meandrina* are hermaphroditic spawners and the other one, an undescribed morph, is a gonochoric spawner. This project also allowed the characterization of the gametogenetic cycles of the new populations of the black sea urchin *Diadema antillarum* in La Parguera. Results have been presented in 6 international meetings by the PI and the students associated with the project, two manuscripts were submitted to peer review journals and are in review, three more manuscripts are close to be ready for submission to peer review journals. The information that is being produced from this project will help in our understanding of the biology, ecology and biogeography of the important reef building species in the Caribbean and aid in the future management of these communities.

Note from UPR Sea Grant

For the purpose of designing the program we used the original titles of the proposals funded by UPR Sea Grant. In some instances the title of the original proposal and/or the co-authors are different from the title and/or co-authors in the abstract. The original title/authors appear in a box above the title of the abstract.

***Project: Effects of the Luis Peña Channel Marine Fishery Reserve
in the Structure of Coral Reef Fish and Epibenthic Communities***

**Long-term Phase Shifts in a Coral Reef Community Within a
No-Take Natural Reserve in Puerto Rico**

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We documented a major phase shift in the coral reef epibenthic community structure within the Luis Peña Channel No-Take Natural Reserve in Culebra Island, Puerto Rico, between 1997 and 2004. The percentage of living coral cover declined by a factor of 31 to 44% at Carlos Rosario Beach (CR), and from 50 to 66% at Península Flamenco (PF). Also, there was an overall decline in coral species richness and in colony abundance. Macroalgal and cyanobacterial cover increased by as much as three orders of magnitude at both sites. Significant temporal variation in community structure was observed using multi-dimensional scaling ordination. ANOSIM tests revealed that reef community structure showed a significant phase shift from coral to macroalgal dominance. Coral reef decline was mostly independent of depth. The key functional groups responsible for these differences were increasing macroalgae and cyanobacteria, and declining filamentous algae. Coral mortality caused by recurrent plague-like disease/syndrome outbreaks was followed by filamentous algal overgrowth, and then by macroalgal and cyanobacterial overgrowth fueled up by recurrent sediment- and nutrient-loaded runoff from cleared lands and steep dirt roads. *Montastraea annularis* and many rare coral species were significantly affected by mortality events. A combination of competitive, bottom-up (e.g., runoff pulses) and top-down mechanisms (e.g., low macroherbivory, increasing damselfish densities) are suggested to trigger community phase shifts following recurrent coral mortality events. Rapidly declining coral reefs in such a small and low-developed island like Culebra suggest that even minor changes in land-use patterns adjacent to no-take MPAs can cause major coral mortality and shift coral- to algal-dominance within less than a decade at a non-sustainable pace.

Note from UPR Sea Grant

For the purpose of designing the program we used the original titles of the proposals funded by UPR Sea Grant. In some instances the title of the original proposal and/or the co-authors are different from the title and/or co-authors in the abstract. The original title/authors appear in a box above the title of the abstract.

Spatio-Temporal Reconstruction of Insular and Regional Climatic Oscillations in the Eastern Caribbean Using Fluorescent Coral Banding

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This study investigates the potential for using changes of interannual luminescence intensity in hermatypic *Montastraea* coral skeletons in the eastern Caribbean. The excitation and emission peaks detected in extractive samples spectra were used to investigate interannual luminescence variations. The results were compared with instrumental records of regional precipitation in Mona Island and Canoan Island, which are highly influenced by the Orinoco River. These results suggest that luminescent lines in massive corals are a highly robust proxy record of mainland influence on reefs.

Evaluation of the Effects of Sedimentation and Nutrients on Coral and the Long Term Monitoring of Recovery after Environmental Mediation

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To determine the effect of degrading or improving water quality on coral reefs, we have set up an experiment as part of a broader investigation of coral in which we are determining the effects of sediment and nutrient stress on living coral cover. We selected sites on the shelf off Mayagüez, Puerto Rico where four sites of coral reefs are impacted by terrigenous sediment and/or nutrient influx, and one clean water site. To measure recovery of individual coral removed from stress conditions and the effect of stress conditions on healthy corals, we transplanted corals from stressed environments into the clean water environment. These transplants were onto concrete slabs to avoid local bottom effects. Coral from the clean area were also transplanted as controls. We transplanted coral from the clean environment into stressed conditions to observe the effects on these coral. Alizarin Red-S was used to mark the corals at the time of transplant. Twelve species of coral were transplanted from clear water to stressed habitats and four of these species were transplanted from stressed environments to clean water. Photographs were taken bi-monthly to observe changes. At the end of the study, growth rates were measured. The study ran for two years, showing the following effects: (1) Coral are more resistant than expected when subjected to nutrient or sediment stress, (2) The coral transplanted to environments impacted by sewage showed the most significant negative impact. (3) Few coral colonies died within the first month (transplant effect), but the rest survived showing a high success in the transplant procedure, (4) Stressed coral moved into the clean environment showed only slightly higher growth than the rest of the coral, (4) *Montastraea cavernosa* colonies reproduced asexually actively right after transplantation.

Aspergillosis Disease of Sea Fans: Pathogens, Environment and Stress

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Which fungi cause aspergillosis of sea fans?

Sea fans in the Caribbean are being attacked by a disease. This disease has been identified as an aspergillosis, and the pathogen was identified as the fungus *Aspergillus sydowii*. However, it is not clear why the disease appeared suddenly: was the pathogen recently introduced, has it become more virulent, or are the sea fans more susceptible for other reasons? These questions cannot be addressed until the fungal flora of healthy sea fans is known. We are isolating fungi from healthy and diseased colonies of the sea fan *Gorgonia ventalina* and identifying them by morphology and sequencing of the ITS region. The reported pathogen *A. sydowii* has not been isolated in an extensive sampling of sea fans in Fajardo and Culebra. However, other fungi are common. In one study, *Penicillium* spp. were significantly more common in healthy tissue and *Aspergillus* spp. were significantly more common in diseased tissue. *Aspergillus flavus* was only been isolated from diseased tissue, and one isolate produced aflatoxins in pure culture. *A. flavus* is ubiquitous in soil and vegetation and an opportunistic human pathogen; aflatoxins are among the most carcinogenic compounds known. We are growing *Gorgonia* colonies in aquaria to inoculate with these fungi. The hypothesis is that several species of *Aspergillus* and other fungi can be pathogenic on sea fans, and aflatoxin-producing strains tend to be more pathogenic. We suspect that these fungi are opportunistic pathogens and mostly cause disease in sea fans that are susceptible for other reasons.

Restoration of Gorgonian (Soft Coral) Populations

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Gorgonians (also known as soft corals and octocorals) represent a visually dominant feature of coral reefs of the Caribbean. As with many other coral reef organisms, gorgonians are threatened by a variety of anthropogenic and natural factors including ship groundings, disease and storms. The goal of this project is to design and test a procedure to restore gorgonian populations based on life history theory as well as results of a long-term (20 y) monitoring study. Gorgonians are "recruitment limited" in the sense that population sizes are mainly determined by the successful settlement and survival of newly-recruited colonies. In addition, annual survivorships of old (large) colonies are high (>90%) with basal fracture and detachment being the major causes of mortality. These ecological characteristics easily conform to the "bet-hedging" interpretation of life history pattern. Based on these considerations, gorgonian populations can be potentially restored by the "artificial recruitment" of colony branches with special attention paid to techniques that minimize probabilities of detachment or fracture. Preliminary results indicate that this approach is successful although some aspects of the transplant methodology need improvement.

Key words: gorgonians, coral reefs, restoration, recruitment

Seed Money
Abstracts

Thermal Acclimation Potentials in Two Pocilloporid Corals

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This study investigated the physiological acclimation potentials of *Pocillopora damicornis* from Kaneohe Bay and *Pocillopora meandrina* from a thermal outfall (5° C higher than ambient) and a control site at Kahe, Hawaii. Colonies were exposed to three different temperatures (29° C, 32° C and 33° C) for five days. Ambient control temperatures during that time were 29° C. Samples (n = 3) were taken at 0800, 1200 and 1600 each day from each treatment. Light levels were 1000 – 1500 $\mu\text{mol quanta m}^{-2} \text{s}^{-1}$ in the morning (0800) and 25-60 $\mu\text{mol quanta m}^{-2} \text{s}^{-1}$ during the afternoon (1200 and 1600). ELISAs using catalase antibodies and the ferric reducing/ antioxidant potential (FRAP) assay showed similar patterns. Antioxidant concentrations were highest in the morning for *P. damicornis* and *P. meandrina* Outfall samples while there was no significant change through the day for *P. meandrina* samples from the control site in Kahe. Photosynthetic efficiency (Fv/Fm) was measured at 2300 and 0400 each night using pulse amplitude modulation (PAM) fluorometry. There was no decrease in Fv/Fm in the control tanks, but Fv/Fm decreased with time for all species at 32° C and 33° C. The reduction in photosynthetic efficiency at 32° C was significantly slower in *P. meandrina* from the Outfall than from the Kahe sites (ANCOVA; P < 0.05).

On day 5, 100% of the Kahe and *P. damicornis* samples were bleached in the 32° C treatment. None of the Outfall samples in the 32° C tank were bleached on day 5. Although none of the samples could tolerate 33° C for more than 3 days, the Kahe samples bleached faster than the Outfall samples. If the experiment had been run longer, bleaching tolerance levels could have been tested for the Outfall samples. How long could the Outfall samples tolerate 32° C while the other samples were visibly suffering at that temperature?

**Bacterial flora associated with the biomedically relevant tunicate
*Ecteinascidia turbinata***

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Marine invertebrates are a source of bioactive compounds. It has been shown that many of the bioactive compounds isolated from marine invertebrates proceed from microorganisms that are closely associated to them. The tunicate, *Ecteinascidia turbinata* produces the cancer fighting compound ET-743. It has been reported that a compound from bacterial origin can be used as a precursor for the production of ET-743 (Cuevas, *et al*, 2000). Therefore, it is possible that ET-743 or a precursor comes from bacteria closely associated to *E. turbinata*. In this research we have used the technique of denaturing gradient gel electrophoresis (DGGE) to determine the number of closely associated bacterial species in different samples of *E. turbinata* collected from the south west coast of Puerto Rico. We have also used sequencing and phylogenetic analysis to show diversity of bacterial species that are closely associated to the tunicate.

Propagation and establishment of *Avicennia germinans* seedlings in the disturbed subtropical coast of Jobos Bay, National Estuarine Research Reserve, Puerto Rico

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This study examines key factors that modulate the establishment and development of *Avicennia germinans* (black mangrove) in hypersaline soils. The study was carried out in two sites, a disturbed site called Mar Negro and a control site, Aguirre. Abiotic and biotic factors were measured during a year. An estimation of seed production and retention in different inundation levels were done. *A. germinans* seedlings were cultivated in different salinities to evaluate their tolerance. Plants that survived these treatments were planted in the study sites and monitored for six months. Part of these plants were planted in PVC tubes used as protection against inundation. Salinity in sediments was significantly different between sites except during the driest and wettest month. Salinity changed from 30 to 165 PS (practical salinity) in Mar Negro and from 16 to 33 PS in Aguirre. At the control site 0.45 seed/m²/year were established meanwhile, the establishment in Mar Negro was 0.1 seed/m²/year. The saplings survivorship was 96% in Mar Negro and 54% in Aguirre during the wet season. After two months of dry season it diminished to 72% and 12%, respectively. Plants in PVC tubes showed a better survivorship in both sites and dry and wet seasons. Low establishment rates were due to low seed production and retention. Seed production and recruitment must be improved and high inundation levels controlled to guarantee seedlings establishment and plants development. Intensity and duration of wet and dry seasons had a main role in *A. germinans* survivorship and growth. A report of *Junonia evarete* larvae feeding on *A. germinans* was made for the first time at this location. Larvae herbivory made plants more susceptible to high salinities and high inundation levels.

Evaluation of the Environmental Impact (Water And Sediments) of an Open-Ocean Cage Culture Operation With Spiny Lobster (*Panulirus Argus*, Latreille, 1804) in Rincón, Puerto Rico

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A baseline study was conducted from April 2004 until September 2004 to evaluate the most important physicochemical and biological variables near a proposed aquaculture site to culture *Panulirus argus* (spiny lobster). Boriquen Aquaculture installed one open-ocean cage before this study, and they will install eight more cages at their site located about 4.5 km northwest of Rincón, Puerto Rico. Lobsters are being collected from the area and feeding is once every three days. Thus a study is essential to evaluate the environmental impact on the water column and sediments in the preliminary phase of this system. These results will serve as baseline data for comparisons with future studies in the area and for evaluating the possible environmental effects from this project. Two samples were made at four stations around the cage site and at a control site located 400 m southwest of the stations at the cage site. At each station, water samples were taken at two depths (10 m and 34 m) to evaluate chemical variables (ammonia-N, nitrite-N, nitrate-N, and phosphate). Two sediment samples were taken using a PVC core-sampler with an opening of 0.062 m² for organic matter, grain size analysis, and biological variables (macroinvertebrate population). The organisms were identified to family level. Meteorological data was downloaded from a station located in Aguadilla before, during, and after the sampling period. Results obtained during the first sampling indicate that ammonia-N was the most abundant nutrient with no differences between the two depths. Phosphate concentrations were lower than ammonia-N, and were different for station depths. Nitrite and nitrate indicated no detectable concentrations. The nutrients at these stations were not different from the control site. The sediments were characterized by the presence of crustaceans, mollusks, polychaetes, and echinoderms. In general the stations and control site had no predominant groups. Predominant grain size was coarse sand. Results indicate no major environmental effects by having only one lobster cage. Work should continue as more cages are added.

**Accumulation and Elimination of Copper by the
Flat-Tree Oyster *Isognomon alatus***

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Oysters have been used as monitoring species around the world. The Flat-tree oyster, *Isognomon alatus* is the most prominent bivalve of the red mangroves in the Bioluminescent Bay, Lajas. Studies of copper (Cu) accumulation and depuration (elimination) were conducted in the laboratory and field, respectively. We found that *I. alatus* is a strong accumulator of Cu, and capable of depuration in their natural habitat. These characteristics made this bivalve a good bioindicator of metal pollution in Puerto Rico. In the accumulation experiments the oysters were exposed to various Cu concentrations (0.5, 1, 1.5, 2, 3, and 3.87 ppm) during 2-5 days. After 5-6 days of depuration in their native environment, the depuration rates let us estimate that the contaminated oysters could reach copper concentrations of native oysters after approximately 10 days, which also indicates that copper levels in the Bioluminescent Bay are very low.

**Fracasos en el Manejo y Degradación de Arrecifes de Coral: Amenazas
Para la Recuperación de las Pesquerías Arrecifales en Áreas
Marinas Protegidas de No Captura.**

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Las áreas marinas protegidas (AMPs) de no captura son una herramienta muy útil para facilitar la recuperación de las poblaciones sobre-explotadas de peces arrecifales. El objetivo de este estudio fue el de documentar los patrones espaciales y temporales de variación en la estructura de la comunidad béntica y de peces arrecifales en la Reserva Natural de No-Captura del Canal Luis Peña (RNCLP), en la Isla de Culebra, PR. Dicha reserva se designó en el 1999. Las comunidades bénticas y de peces arrecifales se monitorearon desde el 1996 utilizando transectos fijos lineales y censos visuales estacionarios aleatorios, respectivamente. Se documentó una pérdida neta de 46% en la cobertura de corales, un incremento de 683% en la cobertura de macroalgas y un 279% en la cobertura de cianobacterias. Los patrones observados resultaron significativos a través del tiempo y a través de las zonas de profundidad. Dicho cambio de fase se ha asociado al impacto de los pulsos frecuentes de escorrentías altamente sedimentadas y cargadas de nutrientes, así como a brotes de enfermedades o síndromes de corales, los cuales, en la mayoría de las ocasiones, coinciden con la ocurrencia de eventos extremos de escorrentías. Las comunidades de peces dentro de las áreas núcleo de los arrecifes de coral de la RNCLP mostraron valores promedio mayores de riqueza de especies, abundancia total, biomasa total, biomasa de herbívoros totales y raspadores, y de carnívoros totales, generalistas, piscívoros y planctívoros, que en aquellos arrecifes localizados en el borde o afuera de la RNCLP. Sin embargo, la biomasa de 36% de las especies de peces ha disminuído a través de dicho período de 7 años, con 19% de éstos habiendo disminuído >50%. Se ha observado también una disminución en $H'n$ y $J'n$ como resultado de la dominancia en la biomasa de algunos grupos funcionales (ej. herbívoros raspadores y no desnudadores). En el caso de la zona del borde sur de la RNCLP (impactada frecuentemente por pulso de escorrentías), se ha documentado un cambio de fase dramático en la estructura de la comunidad de peces. Dichos cambios pueden estar influenciados por la pérdida de corales y el cambio de fase en la comunidad béntica hacia la dominancia de las algas. A pesar de que algunas especies depredadoras (ej. meros, pargos) han mostrado incrementos significativos en biomasa, al nivel de los grupos funcionales de depredadores, ninguno de éstos han mostrado incrementos significativos luego de la designación de la RNCLP. Al presente, la RNCLP aún carece de un plan de manejo y de patrullaje continuo, y su oficial de manejo trabaja solo a tiempo parcial en Culebra, lo que ha contribuído al incremento reciente en las actividades de pesca ilícita. Los efectos de las AMPs de no-captura pueden ser altamente variables dependiendo de la escala en los que se midan. El cumplimiento inicial causó un incremento rápido en la abundancia y biomasa de muchas especies, pero la recuperación de las comunidades de peces ha fallado al nivel de la mayoría de los grupos funcionales. Estos resultados sugieren que la degradación de los arrecifes de coral debido factores externos a la RNCLP, en combinación con una serie de fracasos de manejo, pueden prevenir la recuperación de las comunidades de peces. Ésto podría tener implicaciones de manejo significativas en el mantenimiento de los procesos ecológicos al nivel del ecosistema en los arrecifes de coral.

Distribution and Population's Density of Exotic Australian Redclaw, *Cherax Quadricarinatus* in Puerto Rico

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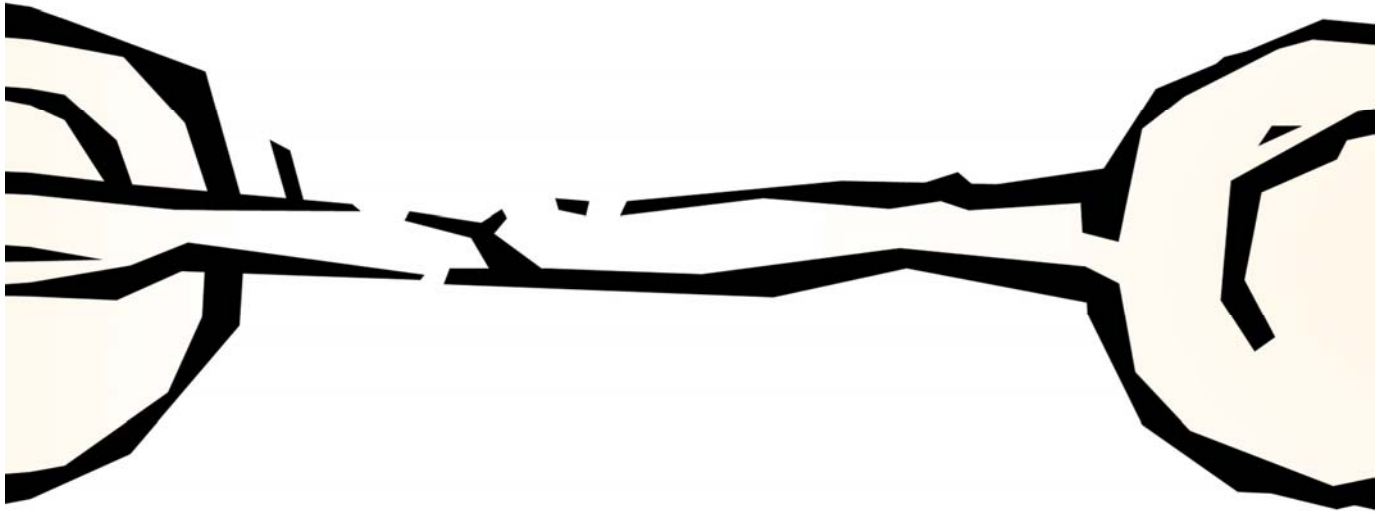
The crustacean *Cherax quadricarinatus* (Red Claw) is a native crayfish from Queensland, Australia. This species, cultivated widely throughout the world in aquaculture, was introduced illegally into Puerto Rico at the beginning 1997 (Williams et al, 2001). They escaped in 1998 during Hurricane Georges and subsequently were also found in the Lajas valley. There are no studies concerning this species in Puerto Rico. The general objective of this investigation is to contribute to the knowledge of the distribution and population density of the *Cherax quadricarinatus* in Puerto Rico. The specific objectives are to establish the range within Puerto Rico's stream, to evaluate crayfish population *Cherax quadricarinatus* within the impacted area, and to determinate the preferred habitat. Water quality parameters (pH, conductivity, dissolved oxygen concentration, water temperature, turbidity) will be taken, along with GPS readings and depth at each sampling site. The area of study includes the principal streams in the northern part of Puerto Rico, from the municipalities of Bayamón to Río Grande and Lajas. These streams have been selected due to the proximity to the Loíza River where the escape originated. The streams selected are Río Bayamón, Río Espíritu Santo and Río Grande de Loíza. The next procedure will be to make a parasitic analysis. The research duration will be one year for each station. This research will determine the crayfish's distribution in Puerto Rico, their population density, and possible impact on other native crustaceans and fishes in the rivers and river mouths of Puerto Rico. To date, a total of 1, 0, 6, and 0 redclaw per sample have been sampled or observed (from fishermen) for the rivers Gurabo, Bayamón, Caño Lajas, and Espíritu Santo, respectively. By comparison, a similarly sized species, *Macrobrachium acanthurus*, was found (9/sample) only in Bayamón River and *Macrobrachium faustinum* (6.5/sample) only in Espíritu Santo River. More work is needed for this ongoing study before making assumptions or conclusions.

Characterizing Reef Fish Assemblages and Habitat Connectivity for MPA Design Criteria

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A major function of marine protected areas (MPA) is the maintenance of relatively undisturbed areas that may be used as controls to study important questions related to the ecology of marine systems. At local scales networks of marine reserves benefit ecosystem structure and function by linking corridors for ecological exchange through ontogenetic migrations, also termed habitat connectivity. The goal of this study is to provide the ecological data relevant to the question of what are the critical habitats that need to be protected for coral reef fishes in order for the completion of ontogenetic migrations. The following questions will be addressed: (a) What is the distribution of the shallow water habitats known to be important for coral reef fishes (nursery grounds)? (b) Are juvenile fish randomly distributed in nursery ground habitats? and (c) Is the distribution of adults determined by the size or distance from nursery ground habitats? These studies will be conducted at Mona Island, which is considered to support semi-closed populations of some coral reef species and may be acting as a biogeographical stepping stone within the Greater Caribbean. Mona is located 74 km from the west coast of Puerto Rico and has a limited insular shelf with a discrete amount of shallow water habitat and juvenile coral reef fishes must remain at Mona as they undergo ontogenetic migrations. Preliminary results of 330 underwater visual surveys (30mX2m belt-transects) suggest higher densities of juvenile coral reef fishes on the exposed side of Mona (eastern) as well as differences in density per habitat for some families. The habitat with the greatest density of juvenile Haemulids and Lutjanids per size class changed with increasing size of fishes. Seagrass with patches or rubble as well as bedrock habitats were preferred by Haemulids and Lutjanids < 15 cm fork length. Further surveys of deeper water habitats will help determine the connectivity of coral reef habitats within the Mona Island Natural Reserve.



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