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MEASURING DEMOGRAPHIC CONNECTIVITY
A CRITICAL NEED FOR CONSERVATION AND MANAGEMENT OF CORAL REEF FISHES

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Coral reefs are very patchily distributed habitats, and their organisms exist as numerous, relatively small populations. These organisms include many economically valuable fishery species, and coral reef fisheries are important in all countries that are fortunate to have coral reefs. While this fishery value is but one of many provided by reefs, it is a critical one, and management for sustainability of reef fisheries should be a high priority throughout the coastal tropics.

Fisheries management is everywhere a challenge, and one which has recorded many failures. The use of Marine Protected Areas (MPAs) is now widely advocated as an effective management tool, and one that seems particularly appropriate for coral reef systems. To be effective, networks of MPAs should be designed and implemented that will both conserve fishery populations within the MPA boundaries, and enhance fishery yields in the surrounding region through the export of individuals as larvae or older animals. To do this requires that they be designed at a spatial scale that is appropriate to the scale of larval exchange among populations of the most important target species. This is far easier said than done, because of the dearth of information concerning connectivity.

Connectivity is a measure of the extent (both rate and distance) of interchange among local populations, chiefly through the dispersal of eggs and larval stages. Scientists know a lot about the biology of reef species and the hydrodynamics of the coastal ocean, yet we currently cannot state, with numerical precision, the rates of connectivity for any fishery species anywhere on earth. To measure connectivity is a challenging task requiring the collaboration of oceanographers, and biologists of several types, because the dispersal of larval fishes is driven by a number of separate processes, some physical and some biological. Yet, until we develop the tools that will permit us to measure connectivity accurately, we will be using MPAs more as blunt instruments than as finely crafted management tools.

I will discuss the "problem" of connectivity, demonstrate why its solution is so important for the viability of coral reef fisheries and the sustainability of reefs, and present some results from a multidisciplinary study that is beginning to reveal some answers.

NEW SCIENCE AND POLICY APPROACHES TO CORAL REEF PROTECTION AND MANAGEMENT

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The unprecedented decline of coral reefs has been in concert with global deterioration in ocean health from human disturbances including fishing, land-based pollution, and global climate change. We must implement new policy approaches to stewardship of the oceans through a comprehensive national and international effort in resources assessment and ocean use planning beginning with the exclusive economic zones surrounding the nation's coral reefs. The rapidly increasing interest in marine protected areas, particularly marine reserves fully protected from all extractive human use, arises largely from field research on coral reef fishes. More theoretical research suggests that networks of marine reserves strategically located within larger marine managed areas hold great promise in protecting reef biological diversity. However, the answers to the important questions of where to place reserve networks and how much area should be protected requires a better understanding of the distribution of coral reef communities and key human uses. The past decades of oceanography and remote sensing surveys, fisheries science, and *in situ* surveys have provided much information about coral reef distribution, connections to land, linkage by currents, and the distribution and abundance of both benthic and planktonic biological diversity. This information can be assembled in geo-referenced formats to provide stakeholders easily visualized scientific and social rationales for ocean use planning in which marine reserve networks play a critical role. In addition to monitoring and social science studies there are several key areas of future research which are important including connectivity or seascape ecology at large geographic scales, ecological resilience and the functioning of biological diversity, and global climate change. These research programs should be supported by integrated ocean observing systems currently under development.

FOCUSED RESEARCH FOR EFFECTIVE RESOURCE MANAGEMENT

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WIMARCS was created to develop a support system for effective research and conservation projects and programs that protect and conserve marine animals. Through focused research, education, support groups, and awareness, WIMARCS assists our community, students, researchers, and government agencies in conserving our marine environment.

Our primary goal is to support the protection, recovery, and sustainability for endangered or threatened marine species through research, education, and public awareness. We feel an important element in reaching this goal is to not only provide animal and habitat research, but to provide valuable, focused, and innovative research that answers pertinent questions concerning the most effective resource management plans and decisions.

In a time when financial and labor resources are diminished, it is absolutely imperative that focused, effective resource management plans are developed. Providing unfocused research for the purpose of just research is to be avoided in a time when it is urgent that we begin and/or continue the recovery of our endangered and threatened marine species. WIMARCS is dedicated to continuing and developing research to recover and sustain these precious species and their habitat.

Our research on marine turtles and their habitat has not only allowed the world wide sea turtle community to understand nesting behaviors and their requirements, but has provided a local awareness of the importance of these species and their nesting and foraging habitats. Threats to coral reefs and seagrass beds greatly affect the foraging habits of sea turtles and are becoming an ever increasing issue in the USVI.

WIMARCS is also developing research programs to better manage and recover threatened West Indian marine mammals and coral reef species. Understanding and reducing the threats to our oceans and coral reef ecosystems is essential in order to provide responsible resource management for our marine environment.

Effective results of these research projects give us and our research partners the ability to create effective public awareness and education programs. These programs are vital to protecting, recovering, and sustaining our marine species.

As Dr. Sylvia Earle so eloquently phrased it, “It is vital that human society become knowledgeable about the importance of the sea, about why we should care and about what actions we can take that will enable us to secure a healthy ocean and a healthy future for ourselves." WIMARCS believes in this philosophy and will continue to strive to provide the necessary research to meet these goals.

INTEGRATING WATERSHED AND COASTAL MANAGEMENT AND EXPANDING BIOLOGICAL MONITORING EFFORTS FOR THE GREATER PROTECTION OF MARINE RESOURCES IN THE US VIRGIN ISLANDS

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The US Virgin Islands (USVI) Department of Planning and Natural Resources, Division of Environmental Protection (DPNR-DEP) manages and regulates uses of the unique and globally significant natural resources that are found in the USVI. The Division has the responsibility to protect an environment that includes some 50+ islands and keys, 185+ nautical miles of coastline, and expansive coral reef and seagrass communities.

The Government of the USVI initiated coastal water quality sampling in 1968 by the Health Department. Sites were selected following a judgmental design, resulting in a network of fixed monitoring stations within the near-shore waters of the islands. This design targeted sites of particular concern, such as point source discharges, harbors, marinas, and main recreational areas. DPNR-DEP currently collects water quality data at a total of 135 sites every quarter using a motor vessel. Further monitoring is performed by the VI BEACH (Beaches Environmental Assessment, Closure and Health) Program which was established by the Division over a year ago. The VI BEACH Program performs bacteriological weekly water quality sampling at 43 popular bathing beaches to more effectively protect the health of beach goers.

While this approach posses empirical validity and legal defensibility, it has not sufficiently measured the ecological health and well-being of aquatic resources. DPNR-DEP proposes to supplement its water quality assessments with biological monitoring methodologies suitable to coral reef and mangrove forests, which are some of the Territory's most altered communities.

The geo-physical nature of the USVI through the connectivity of all its watersheds to the coast, make integrated coastal management synonymous with watershed system management. Land and water use practices in the USVI are intimately linked to coastal water quality and coastal habitat health. Diagnostic monitoring in coastal waters must strive to make these associations.

The collection and effective use of water quality and biological data are of vital importance to effectuate the mandates and realize the goals of both the Federal Clean Water Act and the USVI Water Pollution Control Act. These Acts set requirements and establish policy for the USVI to "restore and maintain the chemical, physical, and biological integrity of the nations waters" and "to conserve the waters of the USVI and to protect, maintain and improve the quality thereof for public water supplies, for the propagation of wildlife, fish, and aquatic life, and for domestic, recreational, and other legitimate beneficial uses".

DPNR-DEP is undergoing a capacity building and restructuring process that will provide more focus and resources for performing monitoring and assessment activities. These efforts will only be successful with sufficient infrastructure, capacity, networking and support services to perform meaningful scientific assessments in order to provide decision makers with scientifically sound (legally defensible and scientifically reproducible) information on the condition of the environment.

COMPARISON OF A SEASONAL AND PERMANENT CLOSURE FOR PROTECTING RED HIND SPAWNING AGGREGATIONS IN THE US VIRGIN ISLANDS

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Fresh, locally-caught, fish is an important part of the culture of the Virgin Islands and island nations of the Caribbean. Grouper and snapper are two of the most sought after species and, because of this demand, have also experienced the greatest fishing pressure. Many species of groupers and snappers form spawning aggregations, dramatic events where 100's to 1000's of individuals gather annually at specific locations for a few weeks to reproduce. Spawning aggregations are often targeted by local fishermen to maximize profit over a short period of time. Because of their vulnerability to fishing, many spawning aggregations have been completely fished out in the Virgin Islands and elsewhere in the Caribbean. In an effort to protect spawning aggregations fishery managers can establish marine fishery reserves, areas which temporarily or permanently closed to fishing, to protect a spawning population during the spawning season. Several marine fishery reserves in the Virgin Islands have provided protection to spawning aggregations of mutton snapper (*Lutjanus analis*), red hind (Epinephelus guttatus) and yellowfin (*Mycteroperca venenosa*) and Nassau (E. *striatus*) grouper.

Researchers at the University of the Virgin Islands have compared two red hind spawning aggregations which received both seasonal and permanent protection. The red hind bank Marine Conservation District located, in St. Thomas, was closed seasonally in 1990 and closed permanently in 1999 whereas Lang Bank, St. Croix, was closed seasonally in 1995. Tag and release fishing and fish counts using scuba were used to evaluate population characteristics and habitat utilization patterns of the red hind spawning aggregations between 1999 and 2005. The average size of red hind in St. Thomas increased mostly during the seasonal closure period (10 cm over 12 years), but the maximum total length of male red hind increased nearly 7 cm following permanent closure. Average density and biomass of spawning red hind increased over 60% following permanent closure whereas maximum spawning density more than doubled. The larger size and greater number of red hind indicates that the reproductive output (i.e. number of eggs produced) during a spawning season has increased significantly due to protection. Information from tag returns indicated that red hind depart the protected area following spawning and migrated 6 to 33 km to a ca 500 km^2 area. Based on fisherman landings, red hind in St. Thomas are larger than they have ever been in 20 years of records. Protection of the spawning aggregation site may have also contributed to an overall increase in the length of red hind caught in the commercial fishery, thus increasing the value of the grouper fishery for local fishermen.

These types of positive changes were not evident for the St. Croix red hind spawning aggregation. Red hind from the St. Thomas spawning aggregation were significantly larger (38.0 vs. 32.5 cm total length) and nearly 9 times more abundant than in the St. Croix aggregation. The St. Croix spawning aggregation was concentrated in a much smaller area of reef (0.015 vs. 0.24 km^2) resulting in significantly higher average density on St. Croix. Finally, a comparison of fishermen landings over the past 20 years shows that the average length of red hind in St. Croix is smallest it has ever been. This means the reproductive output is significantly reduced relative to historical levels which may hamper recovery of this species in the future. The less effective St. Croix seasonal closure may be due to a variety of factors that differ between the islands including inappropriate placement of the closure boundaries, poaching, lack of enforcement, and possibly differences in the fishery and its regulations such as smaller mesh size on traps and the extensive use of gill nets.

THE EFFECTS OF POLLUTANTS ON REPRODUCTION, RECRUITMENT AND POPULATIONS OF CORALS: DR. DOOLITTLE MEETS SHERLOCK HOLMES

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Tropical coral reef ecosystems possess a high degree of biodiversity that supports their ecological, cultural and economic value. Scleractinian corals are conspicuous and essential elements of these biological communities and their populations persist through the dual processes of reproduction and recruitment of individuals and colonies. Most reef-building corals reproduce during limited mass spawning events annually, during which time their gametes float to the ocean's surface and intermingle. Pollutants carried in freshwater runoff from land-based sources as well as hydrocarbons from maritime activities can interfere with critical chemical cues affecting synchronization among reproductive coral colonies, egg-sperm interactions, larval development, larval recruitment and subsequent acquisition of zooxanthellae. Water-soluble compounds affect specific life-history stages, while lipophilic substances (e.g. organophosphate pesticides) are particularly problematic for recruitment by interfering with settlement cues and metamorphic inducers. Oftentimes, traditional coral reef assessment and monitoring techniques do little more than document coral reef losses, without identifying cause-and-effect relationships. Likewise, assays on adult corals provide limited information on the effects of pollutants, as these miss critical effects on population dynamics. In such studies, 100% survival of larvae but 0% recruitment resulting from interference with metamorphosis translates into 100% mortality from an ecosystem perspective. Corals are important test organisms for a variety of chemicals being used on land as well as in the sea (e.g. antifouling paints), and it is critical to test effects on all life history stages in order to understand and subsequently manage the effects of human activities on coral reefs. Ecotoxicology as well as developing technologies in the areas of genetics and molecular biomarkers provide valuable tools for understanding and mitigating the effects of pollution on coral reef ecosystems. By applying these tools to coral reef forensics, it is possible to identify the particular stressors affecting reefs as well as measure the effectiveness of management efforts.

COASTAL ZONE MANAGEMENT INITIATIVES: MANAGING OUR COASTAL RESOURCES FOR ENVIRONMENTAL AND ECONOMIC SUSTAINABILITY INTO THE FUTURE

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Abstract
The Virgin Islands Department of Planning and Natural Resources' Division of Coastal Zone Management (CZM) is charged with the protection, maintenance, preservation, enhancement and restoration of the overall quality of the environment in the coastal zone (V.I. Code Title 12, Section 904(h)). Managing coastal resources for sustainability can serve to enhance tourism, strengthen fisheries, provide educational opportunities for locals and visitors and enhance the quality of life in the territory. CZM is implementing several initiatives that have the potential for environmental and economic benefits for the U.S.V.I. These initiatives include the APC program, LAS framework, the VI Marine Park Project and the territorial coral reef monitoring program.

Areas of Particular Concern (APC) are areas that have been identified as being significant for cultural, natural, environmental or economic reasons. They may be considered uniquely suited for their wildlife habitat, or have significant aesthetic or functional resource value. Some of these areas are relatively undeveloped and have been identified for special consideration and preservation for environmental or recreational purposes. Currently there are 18 APCs in the program. CZM is actively working to revitalize the APC program, and intends to use the program as a mechanism for watershed-based planning and resource management in the territory. The APC program also has the potential to contribute to a territorial system of marine protected areas.

As part of the National Action Plan to Conserve Coral Reefs, the U.S. Coral Reef Task Force adopted the Puerto Rico Resolution, which calls for the development of three-year Local Action Strategies (LAS) focusing on the conservation of coral reefs. The LAS were designed to be locally-driven initiatives reflecting partnerships and collaborative actions among federal, state, territorial, and non-governmental partners. LAS topic areas chosen by the U.S.V.I. are recreational overuse, land based pollutants, over-fishing and lack of public awareness. The U.S.V.I. chose to direct all LAS activities for fiscal years 2005 to 2007 within the St. Croix East End Marine Park. The larger LAS framework is being used by the U.S. Coral Reef Task Force to more accurately identify local needs, connect national goals with local priorities, and coordinate agency actions to better support local jurisdiction management of coral resources.

The establishment and development of the St. Croix East End Marine Park (STXEEMP) is another of CZM's initiatives to protect and manage our marine resources. Envisioned as a first step in creating a system of territorial marine parks, the STXEEMP was created to "protect territorially significant marine resources, promote sustainability of marine ecosystems including coral reefs, seagrass beds, wildlife habitats and other resources and to conserve and preserve significant natural areas for the use and benefit of future generations" (V.I. Code Title 12, Chapter 1, Section 98). The STXEEMP incorporates portions of four APCs, and has served as a mechanism for the territory to implement several LAS strategies. The park encompasses an area of approximately 60 mi^2 and has been designed as a multiple use marine managed area. Park zones include no-take zones (8.6% of total area), recreation zones (2.8% of total area), a turtle wildlife zone (7.0% of total area) and an open zone (81.6% of total area). Biological monitoring efforts are ongoing within the park, including benthic, invertebrate and reef fish assessments. Draft rules and regulations have been developed for the park and will be distributed for public comment in the near future.

For the past five years, the University of the Virgin Islands' Center for Marine and Environmental Studies, the Division of Fish and Wildlife and CZM have been partners on the territorial coral reef monitoring program. A primary goal of this project is to document trends in benthic marine ecosystems and fishery resources as a basis for improved management and protection. Another major goal has been, and continues to be, documentation of baseline conditions prior to the establishment of a network of marine reserves to allow evaluation of their effectiveness in promoting recovery of fish assemblages and degraded marine habitats. This program utilizes the video monitoring protocol developed by the U.S. Geological Survey in St. John, and is therefore generating data compatible with that collected by federal scientists in the territory. With an increasing number of sites established throughout the territory the program provides a comprehensive assessment of U.S.V.I. reefs and assists managers in gauging the relative effects of human and natural disturbances.

In addition to these initiatives CZM is planning other projects to assist in the sustainable management of the territory's coastal resources. Potential new initiatives and partnerships being explored include mapping and monitoring of Acropora corals, monitoring of commercially important species and enhancing the GIS capability of the division. All of these projects have the potential to increase our capability to effectively protect, maintain, preserve, enhance and restore our coastal resources.

DISEASES OF MAJOR REEF-BUILDING CORALS IN THE US VIRGIN ISLANDS

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Coral diseases are increasing in severity in the Caribbean. Scientists with the US Geological Survey (USGS), National Park Service (NPS), National Oceanic and Atmospheric Administration (NOAA), and University of the Virgin Islands (UVI) are collaborating on studies of the effects of major diseases on two of the most significant reef-building species (elkhorn coral = *Acropora palmata* and star coral = *Montastraea annularis* complex). These major architects of the reef are calcifying organisms that are being replaced by macroalgae that do not build reef-framework. If reefs are going to survive as major physical structures, these and other reef-building coral species must persist through growth and recruitment. Reefs in the US Virgin Islands are now under attack from an unprecedented combination of natural and human-caused stressors, including diseases, storms, sedimentation, and overfishing.

In the Caribbean, the most significant change on shallow reefs in the last four decades was the dramatic mortality (>90% in some areas) of elkhorn coral from white band disease beginning in the 1970s. The cause of white band is still not known. Elkhorn coral has recently been proposed for listing as threatened under the Endangered Species Act. Although much less abundant than 40 years ago, elkhorn coral seems to be increasing at many locations in the USVI. In monthly surveys of elkhorn colonies in Haulover and Hawksnest Bays, St. John, white band disease is seldom seen but white pox, a disease first described in 1996, and other, unidentified conditions are frequently observed. White pox lesions often heal, but some elkhorn colonies have suffered extensive tissue loss and total mortality within a few months from another, unidentified disease. White pox has shown a positive correlation with higher water temperatures. *Serratia marcescens*, a bacterium found in the waste of humans and other animals, has been associated with white pox on reefs in Florida. To date this bacterium has not been found in association with white pox in St. John.

In February 2003, USGS and NPS scientists began monthly monitoring of 67 elkhorn colonies in Haulover Bay. Although the colonies are all within a reef zone about 500 m by 50 m wide, and likely subject to similar environmental conditions, some have grown extensively, while others have suffered partial and total mortality. White pox has affected 87% of the colonies. Analysis of the genotypes of 45 of the 48 remaining colonies in July 2005 showed that most are from sexual recruits rather than clones arising from fragmentation. Some genotypes may be more resistant to diseases than others.

At Tektite Reef in St. John, the site of long-term monitoring by NPS, a severe outbreak of white plague on *Montastraea annularis* (affecting several square meters) occurred last month. White plague has been seen on every sampling date (typically every month) since the study began in December 1997, but such extensive mortality has only been observed once before in September 2000. USGS scientists have just begun experimenting with non-destructive techniques (DNA swabs) for sampling of genotypes and of microbial communities on diseased and “healthy” colonies. Diseases may occur when new pathogens are introduced into the environment or when environmental conditions favor the increase in abundance of existing disease-causing microorganisms.

Coral colonies infected with disease are often subject to other stressors as well. What is the synergy among these? Do corals fractured by hurricanes show greater susceptibility to diseases? Are diseased corals more likely to bleach? Bleaching is evident now, especially where water circulation is low. Bleaching does not always cause total tissue loss, but increased

mortality from bleaching is likely to occur with increased seawater temperatures associated with global climate change.

We often try to separate the stressors affecting coral reefs into natural vs. those caused by people—e.g., anchor damage. It is (usually) easier to manage humans than to prevent hurricanes. Coral diseases do not fit neatly into either of these categories. We do not know if diseases are associated with human actions and therefore possible to manage, for example through improvement in water quality.

The declines in coral cover are not the real issue here—the real issue is the lack of reef recovery. To my knowledge, no reefs have as much living coral as they did 30 years ago. Jeff Miller (NPS) and I have just completed a paper that documents long-term trends on two coral reefs off St. John and the failure of these reefs to recover from declines in living coral and increases in algae. Eventually, the no-take zones in the Virgin Islands may promote recovery of harvested species (fish, lobsters, conchs) and the habitats upon which they depend. However, these protected areas will not reverse reef degradation in the absence of other specific actions to reduce stressors now affecting reefs, and there is currently no defense against coral diseases.

Some of the longest data sets on coral reefs and reef organisms come from the USVI and are the result of research by scientists with the former West Indies Laboratory, UVI, NPS, and USGS. The location of the University of the Virgin Islands is ideal not only for studies that build on the results of this long-term work but for research on some of the most exciting issues in coral reef ecology today. There has been much discussion about “connectivity”, or linkages among different habitats and locations. Design of effective marine reserves requires knowledge of the links between different geographic areas, particularly the exchange and distribution of reef organism larvae. Recent studies of the genotypes of elkhorn coral show what appear to be distinct sub-populations in the eastern and western Caribbean, with a mixing zone in Puerto Rico. A better understanding of regional and local currents is vitally important. Management on a local scale will be even more effective if currents retain fish and coral larvae spawned on local reefs rather than transport them downstream. The unidentified pathogen that caused such significant declines in the population of the black, long-spined sea urchin in 1983-84 appears to have followed current patterns. Studies off St. Croix showed that local eddies helped to retain fish larvae near the island. Currents also carry pathogens and pollutants that may cause or play a role in coral diseases. While the establishment of new no-take zones in the Virgin Islands is very promising, recovery of reef organisms and their habitats (reefs, seagrass beds, and algal plains) may never occur if stressors such as coral diseases which do not recognize the boundaries of marine protected areas continue to kill the corals which create the architecture of the coral reefs in the Virgin Islands.

BIOMEDICAL MARINE PROSPECTING IN THE US VIRGIN ISLANDS

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The primary objective of this project is to identify novel compounds from marine invertebrates of the Caribbean which show activity against human diseases. Samples of marine sponges are collected by SCUBA and returned to the UVI St. Thomas campus for workup. At UVI each sponge extract is tested for cytotoxicity by simple, inexpensive bench-top bioassays such as the *Artemia* lethality test and the potato disk assay. Samples are also submitted to the University of Mississippi, National Center for Natural Products Research (NCNPR) for extensive bioassay screening in anti-cancer, anti-microbial and anti-malarial assays.

The workup of samples includes microanalysis by high performance liquid chromatography coupled with mass spectroscopy (LCMS) to obtain UV and molecular weight data. This data is used to search the literature, and identify known compounds. Priority is given to extracts that contain compounds that are both active and of novel structures. These are purified by liquid-liquid extraction with solvents of differing polarity, followed by traditional chromatography (Flash or High Performance Liquid Chromatography) to obtain pure compounds. Initial characterization of crude extracts and follow-up extracts is performed on the 60 MHz NMR located within the UVI chemistry department. The final elucidation of novel structures will require high-field NMR experiments such as the DEPT, ^{1}H-^{1}H COSY, ^{1}H-^{13}C HMBC and NOESY. These will be performed at the NMR facility at the NCNPR.

Table 1 Active extracts at UVI

Collection Number	GPS Coordinates	Preliminary Taxonomy	Activity LC_{50} (µg/mL)
0410	N18°20.962'W065°04.943'	*Clathria* sp.	0.20 ± 0.01[a]
0412	N18°20.962'W065°04.943'	*Ectyoplasia ferox*	0.21 ± 0.01 [a]
0413	N18°20.962'W065°04.943'	*Callyspongia* sp.	0.30 ± 0.01 [a]
0311	N18°10.093'W064°59.642'	*Pakortis* sp.	0.21 ± 0.01 [a]
0401	N18°20.962'W064°59.590'	*Pseudoceratina crassa*	0.02 ± 0.01 [a] p300 HAT[b]

[a)] brine shrimp cytotoxic [b)] histone acetyltransferase inhibition

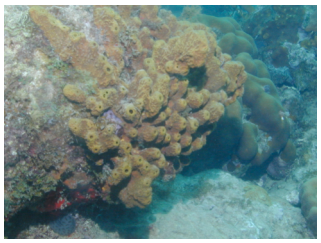
The primary investigator in this study has previously worked on the isolation and characterization of biologically active secondary metabolites from invertabrates.[1,2,3] This work has continued at UVI with the collection of 35 marine sponge species from the Caribbean. Each of these samples have been extracted and submitted for bioassay in UVI brine shrimp lethality tests and in assays with collaborators. Of these extracts, sample number 0401, *P. crassa*, has shown remarkable activity in the Novartis Pharmaceuticals p300 HAT (histone acetyltransferase) assay, an

[1] Clark, D. P.; Carroll, J.; Naylor, S.; Crews, P. *J. Org. Chem.* **1998**, *63*, 8757-8764.

[2] Carroll, J.; Jonsson, E. N.; Ebel, R.; Hartman, M. S.; Holman, T. R.; Crews, P. *J. Org. Chem.*, **2001**, *66*, 6847-6851.

[3] Wood, W. F.; Hanke, F. J.; Kubo, I.; Carroll, J.; Crews, P. *Biochemical Systematics and Ecology*, **2000**, *28*, 305-312.

anticancer screen. As can be seen in Table **1**, four other Caribbean marine sponge extracts show activity in the UVI brine shrimp toxicity assay.



Sample number 0401, of the species, *P. crassa*, (order Verongida) has a number of synonyms. These include *Aiolochroia crassa, Ianthella ianthella,* and *Ianthella ardis*.[4a-f] Its characteristics are that it is yellow to green underwater, dark brown or purple above water, hard to tear and has a conulose surface. The background literature of this sponge is extensive, with many novel and highly active structures mentioned. So far 21 novel compounds and a number of known compounds have been discovered from this sponge. These include Aeroplysinin-1 (**18**), Ianthellin (**19**), brominated tyrosine derivatives (**20**), Moloka'iamine (**21**) and Convoltamydine E (**22**).

The examination of *P. crassa* at UVI has indicated this sponge is a potential source of new chemistry. The active sample 0401 has been fractionated by reverse phase high performance liquid chromatography (rp-HPLC), and three pure compounds have been isolated. Two of these appear to be known by their similarity in molecular weight and proton nuclear magnetic resonance (NMR) data to the known compounds (**18**); Aeroplysinin-1 and (**19**); Ianthellin. The third compound appears to be novel. High resolution mass spectroscopy data gives m/z of 349.97496 which indicates a molecular formula of $C_{12}H_{18}NBr_2O$ (calc'd m/z = 349.97704). The molecular weight and proton NMR data shown in Table **2** of the 0401 compound indicate a novel derivative to the brominated tyrosines previously found in this sponge.

Table 2 Proton NMR comparisons of 0401 compound with known compounds of identical molecular weight.[a]

0401 pure compound	$C_{12}H_{18}NBr_2O$ (**20**)	Moloka'iamine (**21**)	Convolutamydine E (**22**)
δ 4.083 (t)	δ 7.69 (s)	δ 7.30 (s)	δ 12.1 (bs)
δ 3.489 (s)	δ 3.17	δ 3.84 (t)	δ 7.46 (bd)
δ 2.801 (t)	δ 3.85	δ 3.07 (t)	δ 7.08 (bd)
δ 2.604 (t)	δ 3.32	δ 2.92 (t)	δ 3.16 (m)
δ 2.170 (s)	δ 3.32	δ 2.70 (t)	δ 4.01 (m)
δ 0.878 (t)		δ 1.97 (m)	

[a] Abbreviations of NMR couplings are as follows: s; singlet, bs; broad singlet, t; triplet, m; multiplet.

Potential Benefits

Coral reefs play a major role in the economic stability of the territory by providing a food supply, attracting visitors, offering coastal protection from storms and improving the overall quality of life. The degradation of these reefs and their corresponding biological diversity is of concern to the scientists,[5,6] government,[7] and general population of the Caribbean[8]. The potential for discovery

[4] a) Lacy, C.; Scheuer *J. Nat. Prod.* **2000**, *63*, 119-121. b) Costantino, V; Fattorusso, E.; Mangoni, A. *J. Org. Chem.* **1993**, *58*, 186-191. c) Ciminiello, P.; Fattorusso, E.; Magno, S. *J. Nat. Prod.* **1994**, *57*, 1564-1569. d) Ciminiello, P.; Fattorusso, E.; Magno, S. *J. Nat. Prod.* **1995**, *58*, 689-696. e) Albrizio, S.; Cimminiello, P.; Fattorusso, E.; Magno S. *Tetrahedron* **1994**, *50*, 783-788. f) Kassuhlke, K. E.; Faulkner, J. D. *Tetrahedron* **1991**, *47*, 1809-1814.

[5] Gardner, T. A.; Cote, I. M.; Gill, J. A.; Grant, A.; Watkinson, A. R. *Science*, **2003**, *301*, 958-960.

[6] Rogers, C. S.; Beets, J. *Environ. Cons.*, **2001**, *28*, 312-322.

of useful marine products such as pharmaceuticals from marine invertebrates is in danger of being permanently lost. Benefits from this work include the discovery of medicinally useful compounds, education and public outreach by inclusion of UVI undergraduate students in the research and in seminar presentations at the annual UVI undergraduate research symposium. The material outlined in this summary provides excellent training for students interested in learning about pharmacology and organic chemistry. Focus is placed on the importance of local exploration of reefs and the potential that these ecosystems have to provide leads for new pharmaceuticals.

This material is based upon work supported by VI-EPSCoR under National Science Foundation Grant #0346483. Any opinions, findings, conclusions, or recommendations expressed in the material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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[7] Hodge, J. D. In *Costal Views, Virgin Islands Costal Zone Management Program*, **2003**, Vol 2, Iss.7 (and earlier issues)

[8] Davis, O. Reefs Must be Protected for V.I. Future. *The Daily News*, March 28, **1997**, p20, and Davis, O. Put in Place a Serious Water and Land Use Plan. *The Daily News*, Janurary 20, **2000**, p20.

INVESTIGATION OF GENETIC CONNECTEDNESS OF GROUPS OF LONG-SPINED BLACK SEA URCHINS TO IMPROVE MANAGEMENT OF CORAL REEF ECOSYSTEMS

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Goal

To measure the "genetic connectedness" among localized groups of the long-spined, black sea urchin, *Diadema antillarum,* a critical species promoting health of Caribbean coral reefs. Knowing the degree of genetic connectedness among groups of these sea urchins within the US Virgin Islands and the wider Caribbean will help resource managers to better assess the ability of these reefs to resist the many natural and human-induced stresses that threaten them and to improve resource management decisions.

Economic and Social Importance of Coral Reef Ecosystems

Coral reefs provide a variety of vital ecological services for the island states of the Caribbean and the Pacific. Reef fisheries may account for 10 – 25% of the world's catch. An estimated 70 million people rely on coral reef fisheries for livelihood around the world. This number is matched or exceeded by the numbers of people dependent on coral reef-related tourism. In the case of St. Croix, over 70% of its GDP and over 70% of employment are based on reef-dependent tourism. Coral reefs provide a number of other ecosystem services, including coastal protection from storms, a source of future medicines to-be-discovered, the provision of food for commercially-important open-water fish, and various important cultural and spiritual services. In many areas, the white sand beaches on which a large proportion of non-diving tourism depends must be continually supplied from the calcium-containing body parts of coral reef organisms or face rapid depletion.

Ecological Importance of *Diadema* to Coral Reef Ecosystems

A critical, known data gap for the management of coral reef ecosystems in the Caribbean concerns the long-spined black sea urchin, *Diadema antillarum*. A great deal of evidence suggests that this urchin plays an important role in maintaining healthy coral reefs in this region primarily by crawling on the bottom and eating seaweed that might otherwise grow on top of corals. During 1983-1984, these urchins suffered a massive mortality, of approximately 94% to 99%, which swept through the Caribbean. While the pattern of the spread of this mortality is consistent with its being caused by a water-borne pathogen, no one has demonstrated the identity of a specific pathogen responsible for this event. A correlation between the size of *D. antillarum* populations and reef health, observed as a result of the mass mortality and recovery in some locales, supports the critical role of this species in Caribbean reef health.

Immature Urchins Have the Potential to Move Much Further and Faster than Adults

These urchins reproduce sexually by spawning: females release eggs into the sea; males release sperm into the sea; if sperm find eggs of their species, fertilization can occur. A fertilized egg grows to form a small, young animal or larva that can swim. When biologists raise these free-swimming larvae in tanks, they grow for 1-2 months before metamorphosing into the mature adults that crawl on the bottom.

Questions this Research Project Seeks to Answer

Are the growing urchin populations produced by a single population that is widely dispersed?
Or are the adults at each site the offspring of parents who lived there and did not disperse?
Or something in between?

Why Is this Project Worth Pursuing

The question of how far organisms disperse is a fundamental question in ecology and especially difficult to observe directly in marine ecology.

- Because we are basically terrestrial creatures, we can spend limited time underwater.
- Small larvae of many marine animal species are difficult to observe.
- Ocean currents make long-range dispersal of small creatures possible.

Some coral ecologists are hoping to stimulate recovery of Caribbean-Atlantic coral reefs by collecting *Diadema* from many parts of the Caribbean, raising them together in tanks and releasing them into wild reef habitats whose *Diadema* populations are still very low.

- If local *Diadema* populations are genetically different from each other, introduction of artificially mixed Caribbean urchins might irreversibly alter some local, native *Diadema* populations.
- On the other hand, if *Diadema* throughout the Caribbean are part of one genetically homogeneous population, then this restoration strategy would not run the risk of altering local, native populations.
- Assessment of whether genetic differentiation among *Diadema* exists would complement restoration efforts.
- Also, these analyses may reveal the degree of homogeneity in the populations, thus providing guidance as to how sensitive this ecologically critical species is to potential future local extinctions due to disease or various other disruptions.

Experimental Approaches

- Diadema larvae are too small to be following directly in their wild natural habitat.
- Observing the DNA of adult populations is an indirect method of assessing genetic connectedness of populations, which might be explained by dispersal of larvae.
- Limited dispersal can lead to genetic differences between populations.
- But so can selection pressures of different sites and random events in small populations.

Preliminary Results

- Urchins tissue samples were collected from 3 beach sites on St. Croix: Pull Point, Beauregard Bay (Buccaneer Hotel), and Rainbow Beach (north of Fredericksted)
- DNA was isolated and amplified using arbitrarily chosen primers (RAPD PCR technique).
- Preliminary data are consistent with genetic differences between populations at these 3 sites.
- Limitations of these results: The sample sizes were small and data using this technique (RAPD) can be variable and we have not yet repeated these results.

Future Plans

Drs. John McManus and Tom Capo (Univ. of Miami) have generously offered to send us *Diadema* tissue samples from Florida, the Dominican Republic, and Antigua for analysis.
Dr. Gregory Wray (Duke Univ.) has offered to develop for us potentially more reliable DNA tools for studying genetic variation in *Diadema* (microsatellites and SNPs).

This material is based upon work supported by VI-EPSCoR under National Science Foundation Grant #0346483. Any opinions, findings, conclusions, or recommendations expressed in the material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

EVALUATION OF MOLECULAR TOOLS FOR IDENTIFYING SPECIES BOUNDARIES IN CARIBBEAN CORALS OF THE GENUS *PORITES*

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Coral reefs provide physical protection from the surrounding ocean, important sources of food and income, as well as play an essential role in recreation and tourism. They are the most valuable natural resource of the USVI and its tourism based economy, yet like other Caribbean reefs they have greatly changed for the worse over the last 30 years. Coral reef conservation and management requires a clear understanding of the species present in the environment and what their relationship is to one another. For example, knowledge of which species are capable of interbreeding is essential for determining placement, size and number of marine protected areas. Scleractinian corals form the basis of coral reef ecosystems, yet recognition of closely related coral species is often problematic. Species boundaries among some of the most important Caribbean coral species, such as the *Montastraea annularis* species complex, remain difficult to recognize. Molecular data in the form of DNA sequences now provide great promise as a tool for elucidating coral species boundaries and resolving long-standing problems in coral systematics.

The coral genus *Porites,* including mustard hill coral (Fig. 1) and finger coral (Fig. 2), is one of only eight cosmopolitan scleractinian coral genera and is an important component of coral reefs worldwide, including the Caribbean. The taxonomic history of the genus is long and confused due to overlapping intraspecific and interspecific morphological variability. Studies based on skeletal morphology, characters of the living animal, proteins, and a limited number of DNA sequences have incompletely defined species within the genus and their relationships to one another. In the USVI there are six species, referred to here as morphotypes, defined primarily by characteristics of the living tissue, the skeleton, and comparison of protein electrophoretic data. Two morphotypes have massive skeletons (Fig. 1) and differ primarily in the color of the living tissue. Three morphotypes have branching finger-like skeletons and are differentiated by thickness of the branches as well as branching pattern (Fig. 2). The sixth morphotype, *P. branneri*, is encrusting to massive and differs from the others in terms of environment where it is found, and color of the living tissue.

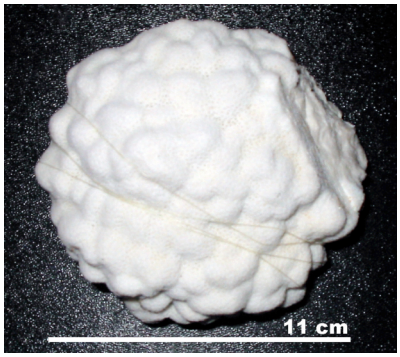

Figure 1. Skeleton of the massive morphotype, *Porites astreoides.*

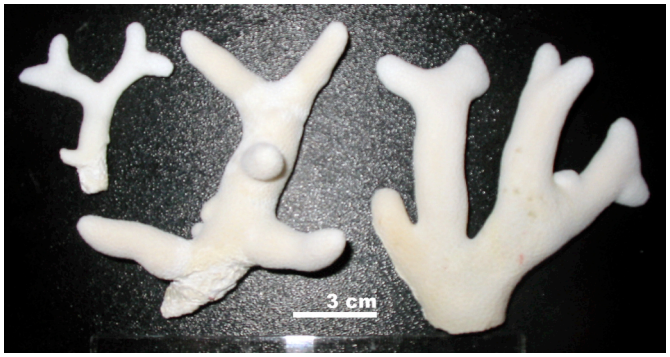

Figure 2. Skeletons of the branching morphotypes (l to r), *P. divaricata, P. furcata, and P. porites.*

To evaluate the effectiveness of molecular data as a tool for elucidating species boundaries within Caribbean *Porites,* DNA sequences from multiple gene regions are being analyzed to determine if morphotypes are genetically differentiated. Ten samples of each of the six different morphotypes of Caribbean *Porites* are being collected and analyzed morphometrically. Three

mitochondrial gene regions (the putative control region and two mitochondrial introns) and two nuclear gene regions (the ribosomal internal transcribed spacer region and a calmodulin intron) are being PCR amplified with coral specific primers from genomic DNA extracted from collected samples. Direct sequencing of these PCR products or sequencing of cloned PCR products yields approximately 2300 bp of DNA sequence. Genetic variability of aligned sequences will be assessed to determine if there is sufficient signal for differentiating morphotypes. If sufficient signal is present in these sequences, phylogenetic analysis of the sequences will determine how the morphotypes are genetically related.

Phylogenetic analysis of these sequences will be used to test the following hypotheses: 1) Morphotypes of *Porites astreoides*, found throughout the Caribbean in two distinct colors, are genetically indistinguishable from each other; 2) *P. branneri*, an encrusting to branching species sometimes considered a variant of *P. astreoides,* is genetically distinct from all other morphotypes but genetically most similar to *P. astreoides,* and 3) the branching morphotypes *P. porites, P. furcata,* and *P. divaricata* are genetically distinct one from the other.

It is likely that gene regions with sufficient variability for distinguishing among these *Porites* morphotypes will also be useful for distinguishing other species of *Porites*. Additionally, the gene regions used in this analysis may also be used in understanding species boundaries among other closely related coral species. Determining genetic connections among coral species may contribute to models of coral reef connectivity being developed by other VI-EPSCoR researchers.

Management and protection of coral reefs, the most valuable natural resource of the USVI, depends on accurate assessment and valuation of the organisms that comprise this complex ecosystem. Recognition of the species present is fundamental to such evaluation as well as to understanding of food chain dynamics. Development of tools such as described here will assist in recognition of coral species and therefore improve our ability to design and implement effective marine protected areas as well as to more completely understand this complex ecosystem.

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COMBINING INFORMATION AND SIMULATION TOOLS FOR CORAL REEF MANAGEMENT UNDER CHANGING CLIMATES

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Climate change is expected to impact already heavily stressed coral reefs around the world through reduction in calcification rates, coral bleaching, storm damage, changes in current patterns, rising sea levels, increased land runoff, and changes in the patterns of reef use by people. In order to ensure that coral reefs are given the best possible chances to adapt to these changes, anthropogenic stressors and perturbations must be reduced. Spatial management must be reoriented to ensure that resistant and resilient coral reef species, and species essential to overall ecological resilience, are afforded particular protection. These goals can best be achieved by providing coral reef planners, managers, researchers and stakeholders with ready access to large volumes of existing information in spatially-explicit form, and by incorporating whatever levels of reliable scenario-testing simulation are feasible.

Data Navigator South Florida is an advanced, online GIS system which provides user-friendly public access to hundreds of data sets by arranging information via decision trees. Satellite data related to climate change is automatically incorporated via third-party websites. Along with partners including the University of the Virgin Islands and the Living Oceans Foundation, we are currently producing similar systems for St. Croix and elsewhere.

Concurrently, we are exploring a number of simulation approaches that could serve as scenario-testing tools (Fig. 1). The models under development include coral-to-coral agent-based models of coral disease, 3-dimensional simulations of benthic ecology, multi-resolution models of reefs and their fisheries, and coupled human-environment interactions.

In order for simulators such as these to become increasingly interoperable and reliably incorporated into decision support tools, it is vital that they be built concurrently with intensive, interdisciplinary field studies. In adaptive resource management, one makes that assumption that any management scheme is only likely to be effective over a limited time frame or set of conditions. Thus, a mechanism is established to periodically evaluate and revised the management plan. So too should coral reef simulation modeling be developed in a successive approximation mode. The process of initial model development highlights the need for particular kinds of information. Once obtained, this information can be used to improve the model, while highlighting other information (data or experimental results) that can further improve the model, etc. This iterative process involving modeling and model-driven research also provides a useful framework for the identification of critical information gaps. This has been the case with forest gap and patch models, which have been under constant refinement via iterative model-driven research and model improvement since their inception over thirty years ago. In order for coral reef modeling to achieve levels of success and utility similar to that of forest modeling, it is important that existing information gaps not serve as excuses to avoid modeling efforts. This is particularly the case for coral reef management in changing climates, where forward-looking modeling is clearly a necessity.

Additionally, it is crucial that the expectations for coral reef modeling not be set to unrealistic levels. A management-oriented coral reef simulation model should not be seen as a tool to determine specifically what will result from a given stress, perturbation, or management intervention. Rather, it should be seen as a tool to help narrow down and map out the expected

state-space of potential outcomes. It should be developed to assist in distinguishing between sets of likely and unlikely outcomes, and as a means to identify potential counter-intuitive results. This approach is analogous to modern hurricane path prediction, which has progressed from single path predictions to 'swaths' of potential paths. This reorientation of thinking about scenario-testing models will both help to focus research efforts appropriately, and prevent a loss of confidence in, and thus support for, simulation modeling.

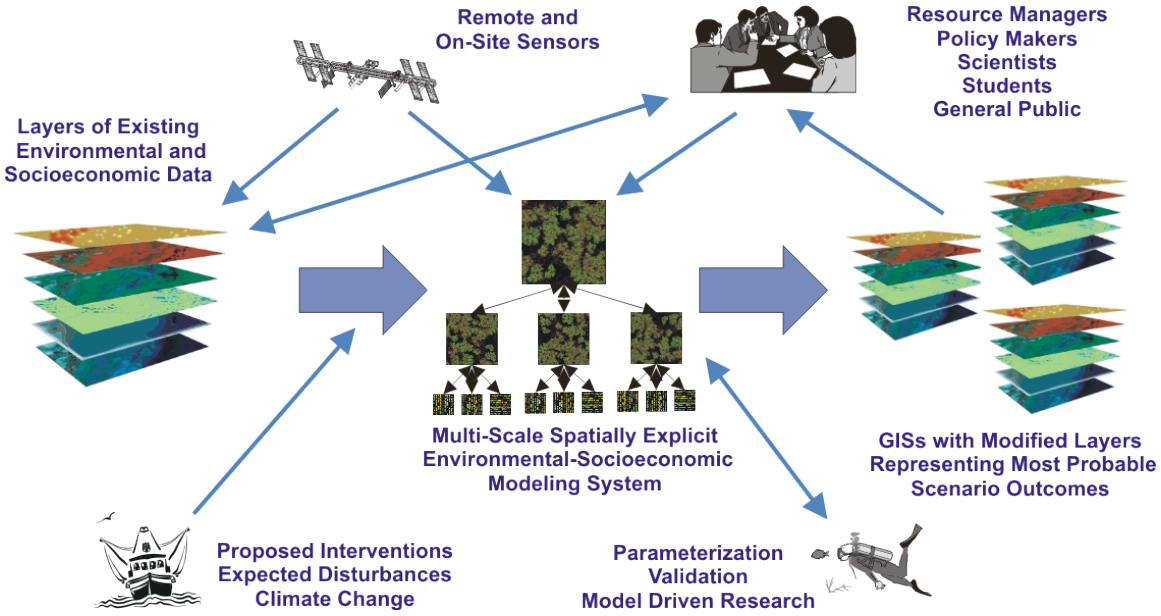

Figure 1. Augmenting an on-line, management-oriented geographic information system with data from remote and on-site sensors, management interventions, simulations, and supportive research.

TOWARDS DISCOVERING INTERESTING PATTERNS WITHIN CREWS DATASET

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US Virgin Islands environmental agencies and decision makers are strongly interested in assessing the impact of climate change and land use on coral health. In order to support this type of assessment, intensive data analysis is required for detecting patterns in vast amount of data. In order to study this phenomena, NOAA Coral Health Watch Coral Health And Monitoring Programs (NOAA CHAMPS) have developed and deployed Coral Reef Early Watch System stations (CREWS) stations worldwide as well as in the region. This system collects and analyzes large amount of environmental data from in-situ location such as the Bahamas Islands, Puerto Rico and St. Croix, U.S. Virgin Islands. Real time environmental data which are collected from selected coral reef sites are analyzed by an expert system in order to predict the effects of atmospheric variables on coral reefs bleaching. One major problem encountered with the system expert approach is that the domain knowledge related to climate change impact on coral bleaching phenomena is limited and not well understood; consequently the expert system have limited predictive capability and more extensive domain exploration is necessary [1,2]. In an attempt to enhance the expert system predictive capability, this work proposes to mine historical bleaching data and to discover yet unknown relationships between environmental variables and bleaching events. Experiments focus on data collected by the North Norman's Reef, Bahamas CREWS located at 23^{o} 47.440' N, 76^{o} 08.357' W. This station exploits Pulse Amplitude Modulated Fluorometry (PAM) technology for assessing coral health. The PAM yield is an important key concept to be integrated into our research since it will be used to infer coral health. The research methology consists of mining CREWS data sets with a semi-automated tool called Weka [3]. Due to domain complexity various category of techniques have been deployed such as clustering, association and classification. Each group attempts to unveil some knowledge such as association rules, classification models, clusters. Figure 1 shows a decision tree classification model obtained on the datasets using the J48 algorithm. Additional results are reported in [4]. Despite some encouraging progress, it is important to mention none of these techniques is suitable detect time series or sequential patterns. CREWS data describe a natural order and closed observations (hourly records) are naturally more closely related. None of the techniques deployed so far take into account this characteristic. An additional problem encountered is due to the fact that no bleaching episodes have been observed. Consequently collected samples are likely to be inappropriate in order to generate suitable classification models. In order to improve model accuracy data samples inducing bleaching episodes needs to be studied also. Finally, only short data samples (72 hours) have been collected and analyzed. This data samples are not representative enough to derive relevant knowledge.

In future research, we expect to make the following contributions: extend data samples (several months) by taking into account episode inducing bleaching events, refine current models (training and testing processes) and deploy sequentiel data mining techniques with the objective of finding time series patterns.

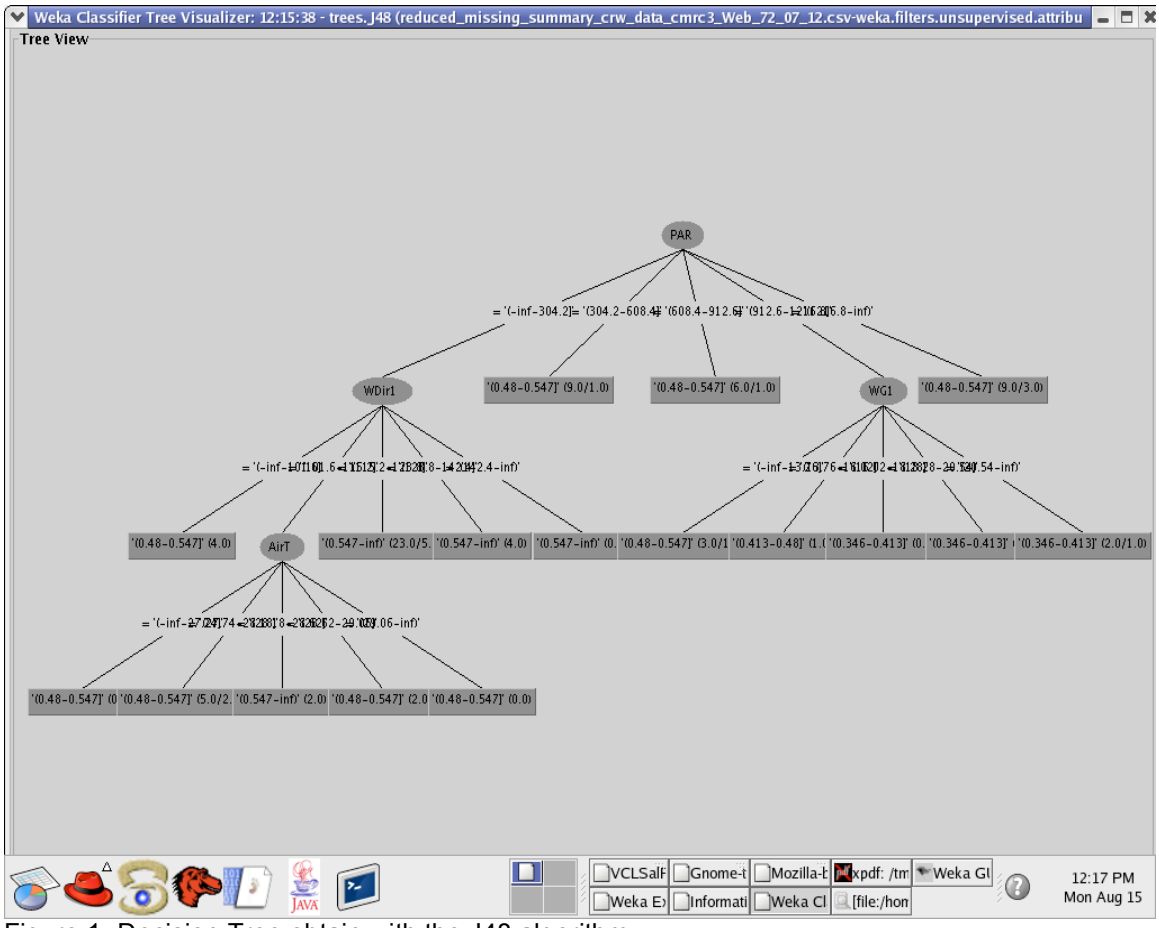

Figure 1- Decision Tree obtain with the J48 algorithm

References

[1] Ole Vestergaard, Ove Hoegh-Guldberg and Umit Unluata “Understanding Coral Bleaching across Four Oceans” Convention of Biological Diversity, SBSTTA 8, March 10-14, 1993.
[2] Dereck Manzello, James C. Hendee and Zandy Hillis-Starr, “An evaluation of environmental parameters coincident with partial bleaching events in St. Croix, U.S. Virgin Islands, accepted at the 11th International Coral Reef Symposium.
[3] I. Witten and E. Frank . *Data Mining: Practical Learning Tools and Techniques with Java Implementation.* Morgan Kaufmann, 2000.
[4] Marc Boumedine, “Finding Descriptive Patterns within CREWS dataset”, Technical Report, NSF VI-EPSCoR, 2005.

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CONNECTIVITY AMONG EASTERN CARIBBEAN CORAL REEFS

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The research I am currently conducting at the University of the Virgin Islands in biological oceanography deals with mechanisms of retention and dispersal among coral reef systems. I base the initial research problems on two specific hypotheses. The first hypothesis states that at low population sizes, a species would favor retaining their larvae in order for the population to be successful. An example for this scenario is the Nassau grouper (*Epinephelus striatus*), which has been overfished from most coral reef systems in the Caribbean by fishermen who target their spawning aggregations. The second hypothesis states that at high population sizes, i.e., overcrowding due to lack of suitable habitat, the species would favor maximizing dispersal in order for the population to be successful. An example for this scenario is the sponge-dwelling snapping shrimp (*Synalpheus* sp.), where due to deteriorating environmental conditions, the sponges (e.g., *Agelas clathrodes*) used by the snapping shrimp are decreasing in numbers around the coral reefs of the US Virgin Islands, thus necessitating the shrimp to maximize dispersal to sustain a viable population within the region. A further complexity within the system includes variable climatic conditions within the Caribbean Sea region, such as the shift between El-Nino and La-Nina conditions. Variations in climatic conditions directly lead to variations in oceanographic conditions that will affect dynamic processes in larval transport. Final settlement of larvae not only depends on the behavior of larvae and ocean transport conditions, but also on reproductive behavior and timing of the spawning adults. Temporal-spatial processes along with complexity of the organism's behavior may lead to the discovery of emergent properties that are not easily observed through simplistic field observations alone. Therefore, this study includes a plankton sampling regime of coral reef systems during key spawning periods, as well as biophysical coupled modeling, augmented with remote sensing imagery.

A major problem with coral reef ecosystems is the rapid decline in biodiversity. Understanding how populations establish, maintain, and replenish themselves is key to maintaining healthy coral reef systems. Most marine animals in coral reef ecosystems inhabit different habitats throughout their ontogeny, which includes a planktonic phase early in their life cycle. Dispersal and retention mechanisms are key questions for research and coral reef management, and have been, until now, poorly understood.

Until recently, successful establishment of biological populations/communities in coral reef systems was thought to be maintained through upstream replenishment by propagules (Roberts, 1997). More recent studies have suggested that this mechanism is too simplistic, and that the majority of propagules may be retained within the local population (Paris and Cowen, 2004; Cowen et al., 2000). Oceanic transport dynamics indicate that the truth may be somewhere in between, with particles drifting in different oceanic layers and being retained and dispersed in varying proportions (Idrisi et al., 2004; Voss et al., 1999). At present, the complexity of submesoscale oceanic current dynamics is not well understood, especially in coastal coral reef areas. The behavior of planktonic larvae is also not well understood with respect to diurnal vertical migration and their sensory capacity to identify suitable habitat for settlement and recruitment.

The debate still continues on whether coral reef systems are open (long-range dispersal) or closed (maximized retention), with most studies focused on the behavior of coral reef fishes (Mora and Sale, 2002; Sale, 2004). Recently, an ecosystems approach to theories of dispersal and retention of fishes, invertebrates and macroalgae is being developed for marine reserve

networks (Guichard et al., 2004) and dynamic reserves utilizing 'ecological memory' as the basis for resilience of ecological communities recovering from disturbance (Bengtsson et al., 2003).

Given that a portion of pelagic larvae will be retained and others will be dispersed, the key research questions are: Under what physical/biological conditions will successful recruitment occur for retained and/or dispersed larvae? How are these coral reef 'networks' connected? Is spawning behavior and timing of the adult population considered 'ecological memory' and how do reproductive activities impact resilience of local and meta-populations?

The main tool used to answer the above questions and generate new hypotheses and questions is the biophysical model developed as part of this study. Here is brief overview of the biophysical model. The physical model system determines the three-dimensional motions of water within the oceanic domain; the dynamics are forced by meteorological and tidal influences. This particular model is the HYbrid Co-ordinate Ocean Model (HYCOM), which uses a set of primitive equations to solve the Navier-Stokes equations as applicable for large scale geophysical flows (Bleck, 2002). Inclusion of tides is a new feature and important to this study since the dynamics are coastal and can have important implications regarding larval dispersal (Wolanski and Spagnol, 2000). The model consists of 15 isopycnic layers plus an upper mixed layer that allows for dipycnal mixing. Embedded within the upper six layers are 28 z-coordinate (fixed depth) layers. This version of the model will be configured for a fine resolution of the Caribbean region (<5km) and will provide pathways and current dynamics to be used in the biological components of the model system. The model will also be run in a nested mode within the 1/12° North Atlantic domain using data available from a 1/12° HYCOM-based ocean prediction system. The set z-coordinate layers facilitate the addition of vertical migration behavior between layers over short distances (10s of meters) in the biological models. Whereas in the older Miami Isopycnic Coordinate Ocean Model (MICOM), this was not possible, especially if the upper mixed layer is very deep. HYCOM will be forced with climatology that represents El-Nino (e.g., 1997-198), La-Nina (e.g., 1988-89), and a transitional period (e.g., 1985-86) to explore the range of climatic variability that can affect oceanographic conditions and physical transport affecting planktonic propagules.

The physical oceanic dynamics generated by HYCOM is used as the environmental framework for two types of biological models coupled to HYCOM. The first biological model is a general Nutrient-Phytoplankton-Zooplankton-Detritus (NPZD) ecosystem model, which is directly coupled to and run simultaneously with the physical model using the same scheme used to drive the temperature/salinity. That is, the NPZD model is developed and run in Eulerian space as coupled conservation advective-diffusive equations in addition to community dynamics equation components (Olascoaga et al., 2005). The unique feature of this NPZD model is the temperature-dependent physiological process functions added to both the P and Z compartments of the coupled ecosystem model. The working version of the NPZD developed in the MICOM has been successfully migrated to HYCOM. The NPZD model will act as food source for key larval species under study. The second biological model tracks particles representing individual organisms. The dispersal routine in this model uses a Lagrangian-Stochastic methodology to track the trajectory of individual particles (larvae) within the ocean model environment as a function of time (Idrisi et al., 2004). The motion is assumed to be forced by the underlying velocity field prevalent in the ocean model environment with an added stochastic term to represent the turbulent term of the particle. The system includes behavior associated with each particle that allows the model to track the number of virtual larvae that settle near a particular reef at the end of the larval phase. Vertical migration between layers is modeled based on field data that should be able to show vertical placement and whether or not the larvae show diel vertical migration. The original model developed in MICOM has been successfully migrated to HYCOM.

This project aims at strengthening science and technology-based economic development of the territory, which depends critically on improving the educational skills of the youth of the Virgin Islands, particularly in science and math. This project will develop a model for strengthening

undergraduate education in science and math by giving students hands-on research opportunities.

More specifically, while UVI has a well-established marine science program that attracts students from all over the United States and internationally, few Virgin Islanders choose a marine science major at UVI. This project will give local students the opportunity to experience marine science research and to consider marine science careers.

The research outcomes of this project will contribute to scientific understanding of the complex relationships between biological populations/communities and the physical environment of coral reef ecosystems. The analytical models developed will allow other BCCR researchers to synthesize their research in a systems framework. The project will contribute valuable information to the overall BCCR research thrust and to the needs of resource managers developing marine protected areas in the territory. And finally, it will provide a model for research on other Caribbean coral reef species and for research on other Caribbean coral reef areas.

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VIRGIN ISLANDS MICROSCALE WEATHER MODELING PROJECT

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An Overview

The Virgin Islands Microscale Weather Modeling Project. or VIMWM Project, seeks to establish specific weather predictions initially for the US Virgin Islands and eventually, for other Caribbean islands. The project will use weather-modeling computer programs (running on UVI's parallel processing Beowulf cluster) to generate daily weather predictions on the sub-kilometer scale for our islands. Physicist, Dr. David J. Smith, heads the project.

Presently, the Advanced Regional Prediction System (ARPS), provided by the Center for Analysis and Prediction of Storms (CAPS) at Oklahoma University, is operational in serial mode. Preliminary forecast runs have been generated for the Virgin Islands region using ARPS. Dr. William Martin of the CAPS program has been instrumental in the installation process. It is anticipated that ARPS will be the primary program used for training UVI students.

In addition to ARPS, the forecast program MM5 is in the initial stages of installation. MM5 is provided by the National Center for Atmospheric Research (NCAR). This program provides a 2-way nesting configuration that will be used for generating local forecasts from global model forecasts. The project is in debt to the assistance of Dr. Cindy Bruyere and the staff at NCAR who provided Dr. Smith with MM5 training at the Foothills Laboratory in Boulder Colorado.

In the coming year, UVI students as well as students in local schools will be recruited to help assess the model predictions. They will provided equipment and trained to monitor basic weather variables. Testing of the model will be done in phases. Initially general climatic predictions will be compared to local climate data and eventually real time predictions will be compared with current weather conditions. Presently, UVI students are assisting with evaluations of both wireless and hand held weather stations to determine the feasibility of the use of theses stations for weather monitoring by primary and secondary school students. Immediate tasks to be assigned to UVI students include 1) the creation of a detailed coastal map file for the region, 2) the conversion of local GIS topographical data (provided by UVI's Conservation Data Center) into a more detailed profile of local topography and soil characteristics, and 3) a survey of local sea surface temperatures (SST) in order to develop of an algorithm for predicting near-shore SSTs.

How ARPS and MM5 Work

Both ARPS and MM5 are a suite of programs that:

- Set up the local topography, vegetation, and soil characteristics
- Estimate initial meteorological variable value in the forecast region
- Integrate global weather forecasts along forecast region boundaries
- Generate specific forecasts for the forecast region

Low resolution local terrain and soil characteristics for each island are available from several national data bases. However, the local GIS database available from UVI's Center for Data Conservation will provide detailed data to 1-meter resolution.

The initial values of fundamental meteorological variables, including temperature, pressure, humidity, precipitation, wind speed and direction will be estimated from a combination of satellite data, radar reports from the Puerto Rico NWS, and global model predictions.

Regional Caribbean forecasts will be created through a process involving a sequence of nested grids, with higher resolution grids contained within lower resolution grids. For example, the results of a 27-km grid global forecast (generated by the NWS) are used to provide boundary input along the 9-km regional grid. In turn, the forecast from the 9-km grid provides the boundary conditions for the 3-km grid. The process is repeated to the finest grid over the Virgin Islands, typically a resolution of 1.0 to 0.5 km.

ARPS and MM5 have many similarities and the fundamental science used in the calculations is the same for each model. ARPS has several initialization and artificial topography options that make it an excellent training tool for students, while MM5 has a 2-way nesting capability that is more convenient and efficient for generating daily forecasts.

Sea Surface Temperatures (SST)

The surface temperature of the sea around us is of great importance to our weather. The greater the temperature, the greater the evaporation rate and the resulting convective activity. The seasonal increases in SST's are a critical component of our hurricane seasons. SST's in the Atlantic and Caribbean are primarily deduced from satellite imagery of the infrared radiation emanating from the ocean's surface. However, this method cannot provide an accurate measurement of the SST's near our shores. One of the major projects in the VIMWM program will be to measure directly SST's near our shores and then compare them to the satellite estimates. A numerical algorithm will be developed that will provide near-shore corrections to the values derived from the satellite imagery.

Professor Roy Watlington, physicist and oceanographer, and Dr. Nasseer Idrisi, BCCR oceanographer, are presently active in research of local ocean currents, and their work will be an integral component of the weather modeling program. Professor Watlington has spearheaded the Anegada Climate Tracers Study (ACTS) program at the University of the Virgin Islands since 1996. Recently, Dr. Idrisi has joined the UVI staff as a research scientist with the BCCR program. Both scientists will be working with Dr. Smith to increase the STT database for their projects and to develop a method of incorporating local SST and ocean current data into local forecast models.

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UNIFIED STUDIES IN COASTAL OCEANOGRAPHY AND CLIMATE CHANGE DYNAMICS

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In the infancy of serious physical oceanographic research at the University of the Virgin Islands, a unified approach has been employed to address regionally important scientific questions immediately at hand. These questions occur both within and outside of the formal action plan of VI-EPSCoR yet meet EPSCoR criteria with respect to serving the needs of the community and contributing to its economy by addressing economically significant issues and building scientific expertise.

At UVI it is acknowledged that specialization and intensification of focus will be necessary to build adequate expertise and to address future questions of great import. Yet, in the initial phase of development of physical oceanographic capability in the Virgin Islands, the projects described below, which address both climate change and coastal environments, are both feasible and necessary to meet local needs.

Coastal Oceanographic Support of biotic aspects of Biocomplexity in Caribbean Coral Reefs research is the primary area of activity in this phase. This includes the measurement of abiotic hydrographic variables such as salinity and dissolved oxygen, currents and waves and development of computational algorithms for data processing and interpretation. Most recently acquired acoustic Doppler current profilers (ADCPs) were deployed and recovered from the site of an on-going fish population study. These data were analyzed as part of the coastal oceanographic aspect of BCCR research. A time series of changing current direction resulted from this deployment and is available for possible correlation to tidal sea level change observed nearby. Collaborators: Richard Nemeth and Kevin Brown of UVI/CMES.

Mare Nostrum engagement of students in monitoring water quality in the marine vicinity of the University's St. Thomas Campus -- The Mare Nostrum concept asserts that UVI oceanographic research conducted with student participation as part of UVI research or academic programs will contribute to the understanding and protection of the embayments adjacent to the University's campus. These include Brewers, Lindberg and Perseverance Bays, the offshore cays, Saba and Savannah islets, and the Southwest Roads. Mare Nostrum allows students in oceanography classes and those about to engage in more specified VI-EPSCoR research to develop the skills necessary for effective oceanographic work focused on understanding and protecting coastal resources. Goals of this program include the assembly and quality validation of extensive contouring of bottom topography and the development of a virtual atlas of currents in the vicinity of the Virgin Islands. Collaborators: Kevin Brown and Nasseer Idrisi (UVI/CMES).

Anegada Climate Tracers Study (ACTS) Since 1996 this study has focused on the climatically significant substances exchanged between the Atlantic Ocean and the Caribbean Sea in the full-depth water column above the sill in the Anegada Passage. The goal in measuring exchanges of salinity, temperature, dissolved oxygen, dissolved inorganic carbon and certain nutrients between the two bodies is to better understand the variability in the climate-stabilizing Deep Western Boundary Current, a filament of which enters the Caribbean only at this location. Student participation in this effort has been great, with ~40 different students having been members of ACTS scientific crews using major research vessels such as the R/V *Ronald H. Brown*, the R/V *Atlantis* and others. Data acquired from these studies contribute to the goals of the current VI-EPSCoR program in that numerous sea surface temperature measurements are included in ACTS datasets. In addition, the processing of these large data sets is used to train UVI students in processing future VI-EPSCoR datasets, which are expected to be large. Sea surface

temperatures (SSTs) measured during twelve ACTS expeditions, 1996-2002, may prove useful in tracking ocean SST trends over this period and in supporting VI-EPSCoR research conducted by David Smith. Collaborators: Smith (UVI), James Happell (University of Miami) and W. D Wilson and R. Wanninkhof of NOAA.

Plume Penetration Modeling -- Understanding a key link in the oceanic stabilization of global climate is the rationale for a modeling effort that is intended to replicate and prognosticate the processes whereby water from mid-depth (~ 2000 m) enters the Caribbean and replenishes its bottom water. Both z-coordinate and sigma-coordinate models have been developed. The z-coordinate version of the INFLOW model has been successful in replicating the dynamics that occur when periods of relatively warm and salty water are succeeded by periods of colder fresher water with the same potential density (σ_0). INFLOW simulates the hydrographic evolution of a receiving basin, such as the Caribbean, to allow deeper penetration of deep plumes with hydrographic characteristics typical of the Deep Western Boundary Current.

The several scientific information needs that are the subject of VI-EPSCoR research can be addressed utilizing much of the same expertise, oceanographic equipment and modeling techniques. Growth and specialization will be advanced by recruiting increased financial support, by increasing the participation of regional stakeholders in integrated ocean observing systems, and by developing new researchers eager to work in this area.

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