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UNUSUAL KARST PHENOMENA FROM CAT ISLAND, BAHAMAS

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Cat Island, Bahamas, contains some unusual island karst features. Cat's Cradle, a blue hole in east-central Cat Island, is a progradational collapse structure that breached a large eolian calcarenite dune. The subaerial walls of the collapse are stepped at 3 m elevation, with the upper wall wider than the lower wall. This upper wall contains a complete ring of flank margin caves that open inward to the blue hole. If the mixing model for flank margin speleogenesis is correct, then the blue hole was marine during the 6 m high MIS 5e sea-level highstand. A 2 km long section of the east coast of Cat Island is a late Pleistocene back-beach breccia facies, indicating strand plain progradation, followed by wave erosion of that plain to create back-beach breccia, and subsequent continuing progradation of the strand plain. The fresh-water lens followed that progradation and created flank margin caves within the breccia facies, indicating the rapidity with which flank margin cave speleogenesis operates, as the entire sequence of rock deposition and dissolution had to be accomplished within the ~ 9 ka long MIS 5e event. Big Cave, in central Cat Island, is found at 55 m elevation on a shoulder of Mount Alvernia, the highest point in The Bahamas at 62 m elevation. The cave has all the small and large scale bedrock morphologies found in flank margin caves, but cannot be a flank margin cave in the traditional sense given its elevation above any possible Quaternary sea-level highstand. Cave genesis within freshwater lens perched on a terra rossa paleosol has been offered as a possible explanation.

DISTRIBUTION, COMPOSITION AND SIGNIFICANCE OF ENCRUSTERS ON CORALS FROM PLEISTOCENE REEFS IN THE BAHAMAS: EXAMPLES FROM SAN SALVADOR AND GREAT INAGUA ISLANDS

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The Pleistocene coral reef exposed at the Cockburn Town Fossil Reef site (west coast of San Salvador Island, Bahamas) lies ~3 m above present sea-level, and the succession is separated by the Devil's Point erosional discontinuity into Reef I and II. These deposits from the Cockburn Town Member of the Grotto Beach Formation (Eemian; MIS 5e) are an important source of information about paleoenvironmental conditions and sea-level fluctuations during the last interglacial highstand. Our field and petrographic work analyzed the abundance, distribution, and succession of various types of encrusters on corals from Cockburn Town Fossil Reef. Stable isotope analysis was conducted to provide insights into the depositional and diagenetic history of these deposits. The transition from clean fragments of branching acroporid corals to the occurrence of coral fragments with thick (up to 8-9 cm) encrustations made by red crustose coralline algae, foraminifera, serpulids, stromatolites and clotted microbialites has been interpreted as a change in Reef I development from bank barrier to restricted backreef and lagoonal environments in response to sea-level changes. Reef II corals are dominated by domal forms and lack thick encrustations. A comparison is made with The Gulf site (south coast of San Salvador) where similar succession of encrusters is observed in storm generated and transported boulders of Pleistocene coral material. The top of the reef here

is exposed at sea-level and outcrops are not available. Another comparison is made with a reef exposure at Devil's Point (west coast of Great Inagua Island, Bahamas), which is also separated into Reef I and II, but corals in these outcrops have only typical taphonomic modifications with very thin algal encrustations. A Reef II exposure of *Acropora palmata*, however, has a crust up to 2 cm thick made of red algae, serpulids, and foraminifera, but lacking microbialites. Displaced boulders from Matthew Town Marina excavation (west coast of Great Inagua), revealed *Orbicella annularis* with microbial and algal encrustations similar to those on San Salvador. Our ongoing research aims at better understanding such important differences and similarities among Pleistocene coral reefs and at evaluating Holocene stromatolites and coralline algal facies from elsewhere in the Bahamas as potential encruster analogs.

SIZE DISTRIBUTION AND POPULATION FLUX OF *ISOGNOMON ALATUS* FROM 2015 AND 2018 IN TWO INLAND LAKES OF SAN SALVADOR ISLAND, BAHAMAS

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The Flat Mangrove Oyster (*Isognomen alatus*) is often found in mangrove marshes growing on or around the intricate aerial root network of red mangrove trees. Work with *I. alatus* is limited and literature provides little when assessing their response to fluctuation in the environment. The purpose of this study was to examine the size distribution of *I. alatus* in Oyster Pond and Osprey Lake on San Salvador Island, Bahamas. While these water bodies are spatially close and similar in size, they vary in terms of salinity and dominate vegetation. At each water body, samples of at least 100 oysters were collected randomly. The hinge length of individuals was recorded and compared to 2015 sample results. Both Oyster Pond and Osprey Lake had a significant change in hinge length from 2015 to 2018. We believe that hurricane action during the three-year time span damaged the Red Mangroves, thereby impacting *I. alatus* populations. In Oyster Pond, the damaged habitat caused older individuals to die, which lead to high recruitment and populations of smaller individuals. Surprisingly, no live oysters were found in Osprey Lake; however, the lake bottom was covered in shell remains from *I. alatus*. We hypothesized that the population measured in 2015 had low recruitment and weak establishment. However, additional ecological information for *I. altatus* is necessary in order to draw further conclusions on the population fluctuations found in San Salvador's inland lakes.

CHARACTERIZATION OF POLAR ORGANIC CONTAMINANTS IN WATER BODIES OF SAN SALVADOR ISLAND

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Synthetic organic compounds are omnipresent and are found in many household and personal products. These compounds enter aquatic systems through discharge and disposal and are classified as environmental contaminants. Diffusive gradients in thin films for organics (o-DGT) passive samplers capture aqueous contaminants. Two types of agarose gels are used as the thin films, a diffusive gel (all agarose), and a binding gel (agarose with HLB). The housing for a binding/diffusive gel set was designed and 3D printed using ABS. Four housing units serve as a single sampler. The center of the sampler contains sensors to monitor environmental conditions in collaboration with Dr. Corey Stilts. The samplers will be deployed for 14 days in the ocean and fresh and saline lakes on San Salvador Island, The Bahamas. Following deployment, binding gels will be brought back to Elmira College and analyzed by methanol extraction followed by gas chromatography-mass spectrometry.

HIGH-RESOLUTION IMAGERY OF BOULDER FIELD MOVEMENT IN HURRICANES IRENE (2011), JOAQUIN (2015), AND MATTHEW (2016) ON SAN SALVADOR, THE BAHAMAS

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Located along the northeast edge of the Bahamian archipelago, San Salvador Island (SSI) sees a high frequency of Atlantic hurricanes that track through the Caribbean. This makes the island an excellent location for studying geomorphological processes and changes to the coastal environment. In this study, we report on our monitoring of the coastal erosion and boulder movement along the southern rocky coast at the location called the Gulf on SSI after Hurricanes Irene, Joaquin, and Matthew. Hurricane Irene tracked north of Hispaniola and traveled NW through the Bahamas as a Category 3 hurricane on August 24, 2011 passing SW of SSI. SSI was directly affected by Hurricane Joaquin over a two-day period on Oct. 1-2, 2015 when the storm travelled SW from Bermuda, passed SE of the island then turned, intensified to a Category 4 hurricane, and then passed across the island from the SSW. The Category 4 Hurricane Matthew traveled north between Cuba and Hispaniola and then passed NW through the Bahamas as a Category 4 on October 6, 2016 similar to Hurricane Irene. To map the hurricane-related changes in the coastal environment, we utilized two different aerial imaging techniques to photograph the boulder field at the Gulf. In June 2015 and March 2016, we utilized a kite-mounted camera, and in June 2016 and 2017, we utilized a DJI Quadcopter 3 mounted with 12 Megapixel, 4K video camera to collect aerial data. We preprogrammed flight paths designed to acquire 70% image overlap using a smartphone app designed by Pix4D. All data were processed using Agisoft PhotoScan to render both a high-resolution, digital orthomosaic, as well as a georeferenced digital elevation model (DEM). These datasets were compared to satellite imagery from Google Earth. Our time series data from June 2015 before Joaquin to March 2017 after Matthew allow us to determine how the coastline changed. Our field research provide ground-based photographic and orientation data on boulder location, imbrication, and beach conditions. The high-resolution, low-altitude imagery allowed us to map the boulder field, measure the evidence of storm surge height by flotsam lines surrounding the boulder field, and calculate boulder movement by matching erosion scars to boulder position, and boulder size to position. We also noted where road construction debris provided boulders that had moved. It is clear that boulders that are exposed along the wave-cut platform at low tide of the Pleistocene Cockburn Town Reef have been transported up the cliff and inland in storm event based on boulder identification. We have previously noted that coastal reentrants are the location of coves where wave action is focused and thus increase lift. Coastline retreat where cliffs collapse downward are located along these coves and provide large boulders which are available for transport upward. These coves become the staging ground for boulders to be elevated in extreme storm events. Our data show that the coves have a greater storm surge height and transport boulders farther landward. The pronounced landward movement of the entire boulder field during Joaquin is likely due to the unique intensity, storm track direction, and duration of the hurricane.

NORTH POINT SAN SALVADOR ISLAND REINTERPRETED: EVOLUTION AND INTERNAL ARCHITECTURE OF EOLIAN DOME DUNES

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Earlier studies of calcarenite features in the Holocene North Point Member, Rice Bay Formation at North Point, San Salvador Island, Bahamas indicated unequivocal sedimentation by wind. Further evidence based on sedimentary architecture from this study supports a new interpretation of eolian dunes that deposited the North Point Member. Primary architectural elements are wind-ripple strata in sets bounded by discordant erosional surfaces. They comprise >90% of stratification, forming topset, brinkset, and especially foreset strata herein termed wind-ripple crossbeds. Secondary elements are bedsets of mainly sandflow strata mixed with wind-ripple and grainfall strata. Such bedsets are scarce, ~1 m thick, and herein termed slipface crossbeds. Dip azimuths span nearly 360 degrees for bedset bounding and reactivation surfaces, wind-ripple and slipface crossbeds, and dune flanks. Furthermore, dominance of wind-ripple crossbeds, scarcity of slipface crossbeds, and overall mound-swale landscape of the present-day North Point peninsula that mimics Holocene dune landscape suggest the build-up of eolian dome dunes, a rarely developed dune type in sand-sized siliciclastic and carbonate sediment and sedimentary rocks. Deeply eroded exposures show cores of juvenile dome and lobate dunes buried by overlapping mature domes and interdome swales. In the path of unobstructed Northeast Trade Wind, low mounds of rippled sand enabled growth of small dome and lobate dunes. On this foundation, mature dome dunes merged laterally to build the peninsular ridge at North Point. Evidence for periodic rainfall and elevated water table during build-up of the Holocene dome dunes at North Point is recorded by climbing adhesion ripples preserved in interdome swales. They definitively indicate moist, wind-transported ripple sand. First discovered by this study on San Salvador, they are preserved in the North Point Member and in the Pleistocene Grotto Beach Formation. Crest orientation, northeastward climb of adhesion ripples, crest orientation and southwest climb of wind ripples, and strata of juvenile lobate dunes convex to the southwest show a wind flow to the southwest, consistent with Northeast Trade Winds prevailing during Holocene time. Rainfall and coastal moisture rendered the dune sand cohesive so that avalanches or grainflows on dome flanks rarely happened.

ANCHIALINE PONDS, A REFUGE FOR MARINE DIVERSITY: A QUICK BIOTIC SURVEY OF 10 ANCHIALINE PONDS ON THE ISLAND OF ELEUTHERA

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In the Bahamas, the inland ponds serve as refuges for unique species that are often uncommon in the open coastal environments. These salt-water habitats are sheltered, and protected by natural barriers from all manner of environmental threats. While many of these habitats are species-poor, some have undergone a remarkable process of spot-colonization and population explosion where one or two species dominate, creating incredibly simplified, but productive marine communities. Each pond also represents a laboratory of adaptive change as organisms respond to the unique characteristics of their particular pond-habitat through natural selection. On a recent trip to Eleuthera, my team made a rapid survey covering ten anchialine ponds in ten days. The goal of this preliminary, non-invasive survey, was to evaluate how rich the various ponds were in species diversity, and to begin investigating the unique adaptations of some of their resident invertebrates. The species richness in several of these ponds was beyond anything we have seen before, and argues both for more investigation and documentation, and for advocacy for their preservation or conservation as the island develops.

DEVELOPMENT OF BOTH WATER-BASED AND LAND-BASED

ENVIRONMENTAL SENSORS USING ARDUINO MICROPROCESSORS

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This project involved the development, coding, and construction of low-cost environmental sensors for use on land and water habitats. The sensors are built using the Arduino mini pro architecture. These low-energy small devices allow for the creation of small sensors capable of lasting days in the field. They are powered by a 9V battery. The land-based sensor is housed in a 3D printed case and is capable of monitoring and recording time-stamped data to a microSD card. The water-based unit is encased a waterproof 3D printed case and will measure water temperature, conductivity, and turbidity. This data will be recorded as a time-stamped data recording to a microSD card in the sensor.

A NOVEL TOOL FOR SCIENCE EDUCATION: THE STUDENT PRODUCED AUDIO NARRATIVE (SPAN)

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This poster will detail the process of participating in a NSF Improving Undergraduate STEM Education grant, including collaborations with Kutztown Univ., Penn State Univ., MIT, Albright Coll. and various community colleges (E.g., HACC). Students were encouraged to use their smartphones to record stories involving the geosciences. Assignments included audio collages, workforce explorations, public service announcements, documentaries, science "minutes", or place-based explorations. These projects were called Student Produced Audio Narratives (SPAN)s. Instruction involved teaching students how to record, produce sound-logs, outline their projects, and prepare the final script. Then the narratives, interviews, sound effects, music, and natural sound recordings were combined using Audacity™ software to form final projects. To date, the narratives have generally been well received. However, limitations such as student individual needs and tensions between completing learning objectives and creating free-form narratives are potential pitfalls. The novelty, varied opportunities and low barrier to entry may make SPAN projects ideal for application in remote field environments like that on San Salvador, Bahamas.

RECENT UPDATES TO THE LUCAYAN TRAIL FIELD GUIDE

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The Lucayan Trail located off the site of the Gerace Research Center on San Salvador Island has served as a key place for research in the last several decades. In 1994, a field guide entitled *The Natural History of Northeastern San Salvador Island: A New World Where the New World Began* (Godfrey et al., 1994) was published and has since been utilized by researchers working on the Lucayan Trail. Four working groups in a 2018 UTC Faculty-led trip conducted a biological survey examining similarities and differences in the environment created over the past 24 years due to hurricane damage and general evolutionary changes, particularly in plant life, animal life, and water quality. The primary strategy involved taking samples and photographs of unfamiliar vegetation and identifying them using resources such as books and digital publications. Some bodies of water were more accessible than others for snorkeling, though all sites were at least sampled for water quality and data were compared to previous studies. The four working groups each had their own hypotheses in regards to their specific part of the trail; however, it was commonly assumed that there would be a shift in species richness/biodiversity over the last 24 years, especially following Hurricane Joaquin in 2015. Notable findings from the working groups include: an increased presence of ammonia (0.5ppm) in Osprey Lake, an additional conduit

formation at Purslane Pit, the absence of flamingos, the addition of a smaller trail, a decrease in sponge spicule and hydroid presence in Pain Pond, limited cave access, misidentification of three epiphyte species noted in the original guide, and the presence of several previously undocumented plant species. All research groups contributed their suggestions and edits to the original trail guide which will be discussed more extensively in the following presentation.

MINECRAFT AS A TEACHING TOOL FOR CAVE CARTOGRAPHY

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In the field of Geology, specifically the field of karst landscape studies, cave investigation and analysis is a critical component to the understanding of the landscape. The current process to train new speleologists to conduct fieldwork is not practical in many geographic locations. It can be difficult to train a multitude of individuals to cave map due to constraints caused by the scarcity of caves in certain regions, the cost of the necessary equipment, and the physical constraints posed by the cave. We proposed that by using the current advancements in gaming technology we can mitigate and remove a few of the obstacles. For the purpose of this study we chose to use the computer game Minecraft because it can simulate a variety of cave environments in an online setting, it is widespread with over one hundred million users, and it requires only a computer or mobile phone to operate. Minecraft could be implemented as an educational tool to introduce and practice cave cartography outside of a cave setting and expose younger generations to mapping caves in an enjoyable and interactive way. This is important as one of the most difficult tasks in training students and geologists in cave cartography is practice. By using Minecraft to practice the math and process of mapping we avoid the need to travel or prepare the necessary tools. Students and scientists alike can be better prepared for field experiences which may reduce error and the expense of time lost in the field due to training activities.

GENERATION AND TRANSPORT OF LARGE ROCK BOULDERS BY STORM WAVES ALONG THE HIGH-ENERGY SOUTHERN COAST OF SAN SALVADOR ISLAND, BAHAMAS

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Documenting changes in morphology and distribution of coastal boulder ridges and the direction and amount of transport of individual large boulders provide useful information about the intensity and effects of storms in The Bahamas. We have been monitoring a boulder ridge on a cliff-bench, 3-5 m above mean sea level, between The Gulf and The Cut along the high-energy southern coast of San Salvador Island since January 2012. Twelve large boulders (~700-4500 kg; with all but one >1000 kg) were initially photographed, located with GPS coordinates, measured, and characterized by composition (subtidal calcarenite, coral rubblestone, eolianite, lithified paleosol), shape, and degree of roundness. The boulders were eroded from the seaward rocky coast, transported and deposited by high-energy storm waves. Our continuing monitoring in January 2013, 2016, and 2017, after Hurricanes Sandy (October 2012), Joaquin (October 2015), and Matthew (October 2016), documented drastic modifications to the boulder ridge. We were not able to relocate 2 boulders post-Sandy, and only 5 of the remaining boulders were relocated with certainty after Joaquin, which passed directly over the island as a high category 3 hurricane with 120-130 mph sustained winds. Storm waves overtopped the coastal cliffs, causing erosion at the leading edge and extensive

landward movement of boulders. This modified the formerly sharp-crested, narrow boulder ridge into a larger, broad boulder field, ~6.3 ha in area and stripped of vegetation. New boulders, as large as 3 m in diameter, were generated, and blocks from prior storms, estimated to weigh 1-3 tons, moved up to 26 m inland. The principal coastal road was damaged and inundated by debris. The southern edge of the boulder ridge moved landward by 4-5 m exposing an underlying Pleistocene/Holocene boundary terra rossa paleosol, which stands out in aerial images and marks the extent of storm erosion. Post-Hurricane Matthew, which passed too far from the island to have a major impact, 11 new boulders and high-resolution drone aerial imagery were added to our monitoring program to expand our database and allow continuing documentation and communication of information on vulnerability to hurricanes with stakeholders on San Salvador and elsewhere in the Bahamas. A January 2019 survey of the key boulders revealed only minor changes in positions of smaller boulder-cobble debris since 2017.

NEW ADVANCES IN LONG-TERM MONITORING OF STORM-DEPOSITED BOULDER RIDGES ALONG ROCKY SHORELINES OF SAN SALVADOR ISLAND, BAHAMAS

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Since January 2012 we have been monitoring two boulder ridges on San Salvador: 1) Singer Bar Point (SBP, length ~790 m) along the reef- and lagoon-protected northern coast; and 2) The Gulf (TG, length ~460 m) on the high-energy southern coast. This long-term monitoring aims at documenting changes in ridge morphology and distribution, and the direction and amount of movement of individual boulders to gain insights into the intensity and effects of storms. The largest boulders from each site were photographed, GPS-located, measured, and characterized by composition and morphology. Boulders at SBP are generally smaller (15 total; ~150-4000 kg; with most <1500 kg) than those at TG (12 original; 12 added by 2017; ~700-6500 kg; most >1000 kg). Our monitoring from January 2013, 2016, and 2017, after Hurricanes Sandy (October 2012), Joaquin (October 2015), and Matthew (October 2016), respectively, indicated only modest modifications at SBP, and major changes to TG: we were unable to relocate 2 boulders post-Sandy, and only 5 of the 12 original boulders were relocated after Joaquin. Two of those, ~2 tons each, were transported NNW by 20 and 26 meters. Even though documentation of boulder movement allows calculation of minimum flow velocity needed to initiate their transport, the lack of adequate tagging made it challenging or impossible to relocate individual boulders after major storms. This problem will be addressed by application of RFID (radio frequency identification) tagging in June 2019 and January 2020, before and after the 2019 hurricane season, respectively, and far into the future, as passive tags are inductively charged by the reader and can remain operational for decades. Drilling to insert small tags (23 and 32 mm long, and <4 mm in diameter) is minimally invasive and will also allow tagging of pebbles and cobbles. This is especially important for monitoring at SBP where large boulders have not been moved much by waves in the recent past, but smaller clasts do move actively. In conjunction with continuing high-resolution drone imaging, the use of tagging that can uniquely identify an object within a large population will significantly increase our database and improve our long-term monitoring efforts.

BIOTURBATED AND SUBAERIALLY ALTERED SUBTIDAL PLEISTOCENE LIMESTONE IN THE BAHAMAS: PETROGRAPHIC AND STABLE ISOTOPE ANALYSIS

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Pleistocene subtidal ooid-skeletal-peloidal grainstone of the Cockburn Town Member, Grotto Beach Formation, at Harry Cay on Little Exuma Island contains well-developed *Ophiomorpha*, *Conichnus*, *Planolites* and *Skolithos*. Samples of these trace fossils were analyzed petrographically and for stable isotopes to determine extent of modification of matrix sediment, which was initially lithified in the marine realm, but later experienced meteoric diagenesis and formation of a caliche cap. *Ophiomorpha* from Harry Cay was compared with Pleistocene samples from San Salvador, Rum Cay, Great Inagua, Great Exuma and Grand Cayman Islands, as well as Holocene examples from San Salvador and Lee Stocking Islands. Pleistocene *Ophiomorpha* wall pellets have more micrite than host rock, indicating that callianassid shrimp tracemakers concentrated mud during burrow construction. Stable isotope values of *Ophiomorpha* range -1.5 to -4 ‰ VPDB $\delta^{18}O$ and 0 to 3.5 ‰ VPDB $\delta^{13}C$, with complete overlap among multiple sites and substantial overlap with calcarenite host rock and burrow fills. Holocene *Ophiomorpha* has higher values, typical of unaltered marine carbonate, clustering ~0 ‰ $\delta^{18}O$ and 4.5 ‰ $\delta^{13}C$. Some *Ophiomorpha* tubes are filled with caliche similar to the cap at Harry Cay. $\delta^{18}O$ values of these caliche fills overlap with *Ophiomorpha* walls, but their low $\delta^{13}C$ values (-8 to -9 ‰) reflect soil-derived ^{12}C. $\delta^{13}C$ values of some calcarenite fills are between those of burrow walls and caliche, forming an inverted J trend indicative of meteoric diagenesis, with burrows providing fluid pathways. This resulted from preferential meteoric diagenesis of micrite in burrow walls as supported by their $\delta^{18}O$ values being lower than associated matrix, and their calcitic composition compared to mixed aragonite-calcite host rock. *Planolites* traces appear finer-grained than the host rock, suggesting that ballanoglossid worms, the probable tracemakers, can sort sediment while ingesting it. *Conichnus* contains sand grains that appear more loosely packed than host sediment, indicating that burrowing activity, possibly by sea anemones, created a porous fabric. *Skolithos* tubes were too thin to examine petrographically, but isotopic composition of calcarenite within these three trace fossils is not systematically different from the host rock, reflecting similarity in their composition and diagenesis despite textural and fabric modifications by burrowing organisms.

INTERNAL DISCONTINUITIES AND THE DEPOSITIONAL HISTORY OF EEMIAN REEF DEPOSITS (COCKBURN TOWN MEMBER, GROTTO BEACH FORMATION) ON SAN SALVADOR ISLAND, BAHAMAS

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In addition to coral geochronology and the mid-reef Devil's Point erosional discontinuity, depositional features within the Eemian Cockburn Town Member fossil reef deposits yield insights into paleoenvironmental changes potentially associated with sea-level fluctuations during the last interglacial. On San Salvador, lower reef (Reef I) exposures in Cockburn Town exhibit a facies transition from coral floatstone/bafflestone/framestone to coral-microbial bindstone, whereas the upper reef (Reef II) is dominated by coral-mollusc-corallinacean rudstone (with essentially no microbialite). Although minor sub-horizontal discontinuities pervade Reef I deposits, a quarry exposure displays at least 17 inclined, progressively shallowing, grainstone-draped discontinuities that define decimeter-scale lateral accretion surfaces. Each accretion deposit contains branching coral fragments coated by laminated micritic microbialite and poorly-laminated/clotted sandy microbialite, and suggests episodic introduction of coral clasts. Microbialite-coated corals are separated by discontinuous, mm- to cm-scale drapes of ooid-peloid-skeletal grainstone similar

to foreshore deposits. Reef I features suggest the following history of reef development: 1) establishment of branching coral stands in a bank-barrier setting; 2) development of backreef and lagoonal subenvironments; 3) subsequent restriction, likely from a minor sea-level drop or a stillstand; 4) coating of coral clasts by microbial communities thriving in the backreef; 5) repeated introduction of new coral clasts via storms from reef-front settings followed by microbial coating; and 6) gradual migration of foreshore sand draping the shallow backreef. Repeated episodes of Reef I microbialite development, microbialite abundance and thickness, and the truncation of Reef I by the Devil's Point discontinuity (>60 cm of relief), indicate a significant period of backreef restriction followed by erosional truncation (sea-level drop). In contrast, Reef II deposits contain extensively bored and coral-encrusted discontinuities overlain by rudstone beds of coarse, pristine coral and mollusk rubble that suggest episodic but rapid accumulation of reef debris in an unrestricted, energetic nearshore setting. Reef II is capped by a sharp, low-relief erosional discontinuity (wave-cut bench?) overlain by foreshore sands bearing traces that reflect the hardground nature of this discontinuity. Recognizing a similar facies distribution within the Eemian reefs elsewhere, in order to confirm a eustatic sea-level origin for the Devil's Point discontinuity, is complicated by the extent of backreef exposures and different tectonic histories. Yet similar coral-hosted microbialites have been observed in the Sue Point outcrops and in storm-transported boulders at The Gulf (both San Salvador), and in blocks quarried during marina enlargement on Great Inagua.

MAPPING CULTURAL GEOGRAPHY OF SAN SALVADOR ISLAND, THE BAHAMAS, CIRCA 1800 TO 2010

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The rich and unique cultural heritage of The Bahamas is experienced through both tangible and intangible resources, such as buildings, landscapes, archaeological remains, and social events and expressions. Cultural geographers and archaeologists have studied cultural heritage resources of The Bahamas for at least the past three decades; however, little has been said regarding their preservation, promotion, and interpretation. An important first step in the process of safeguarding and promoting such resources is identification and inventory. The inventory can then be evaluated in terms of what heritage resources are significant and why their preservation and interpretation matters to Bahamians. Cultural mapping is an important tool in the process of evaluation. This project serves a glance into how heritage resource managers can use Geographic Information Systems (GIS) to enhance the process of identification, evaluation, and interpretation of cultural heritage resources in The Bahamas. The mapping and findings presented are based on a 2017 case study of the Bahamian island of San Salvador. As an active cultural landscape, the island's heritage resources include historic plantations, archaeological sites, historic buildings, active cemeteries, and public parks/green spaces. These resources are evaluated, through mapping, in terms of an established framework of historic periods, patterns, and themes in Bahamian history and cultural development.

AN INDEX FOR DESCRIBING ANT COMMUNITY DIFFERENCES USING SPECIES' ARRIVAL AND RECRUITMENT AT BAITS

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Monitoring changes in ant communities can be difficult in habitats where using common trapping methods is not possible. To address this problem, we developed an index based on an ant species' presence at baits as well as their time of arrival and recruitment to baits. In this study, we compared the index across three distinct habitats on San Salvador Island, The Bahamas. We found that a species' index value changed depending on

habitat and the changes appear to reflect actual differences in the ant community among sites. We also discuss the importance of not including bait dominance in the index.

TESTING THE TATOR INDEX: A NEW 3D PRINTED PITFALL TRAP

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Over the last 6 years the Kjar lab has used behavioral observations of ant species at baits to describe differences among sites on San Salvador Island, The Bahamas. The island is entirely composed of calcium carbonate rock and this makes trapping ants by common methods very difficult. In order to test the TATOR (Time of Arrival and Time of Recruitment) index's ability to describe an ant community we will be using a new pitfall trap designed by the Kjar lab and produced here at Elmira College. The pitfall trap is modular in design with a funnel and lid. The traps will be placed in the Palmetto habitat in multiple locations on San Salvador Island. We will leave the traps for 48 hours and then compare ant incidence and richness to the results of the behavioral observations underlying the TATOR index.

GENOTYPING PARATRECHINA LONGICORNIS USING GENERAL PURPOSE AGAROSE AND MICROSATELLITE MARKERS

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Identifying colony level genetic differences requires rapidly evolving sequences of DNA (Microsatellite Markers). These regions of DNA range from 50 to 400 base pairs and consist of repeated AT sequences. Polymerase frequently makes mistakes when copying these repeated sequences. Normally, we would amplify the sequences using PCR (Polymerase Chain Reaction), tag the product with a fluorescent probe using an additional PCR step, and finally visualize the products on a large, long-run Polyacrylamide gel. This is expensive, time consuming, and Polyacrylamide is carcinogenic. Here we attempt to genotype Paratrechina longicornis using general purpose agarose and avoid the second PCR and Polyacrylamide gel steps, reducing the time, cost, and danger associated with this technique.

DO CONCH FISHERY DISCARDS FACILITATE OCTOPUS POPULATIONS?

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Common octopuses (*Octopus vulgaris*) shelter in crevice dens during the day. In a previous study of *O. vulgaris* diet at San Salvador, we found significant variation in octopus den type among locations that corresponded to differences in apparent octopus abundance (Kuhlmann and McCabe 2014): at most locations, octopuses denned primarily in solution holes or other natural crevices but were widely dispersed, but at one location where the benthos is dominated by seagrass and lacks exposed rock, octopuses denned almost exclusively in conch shells discarded by the fishery and seemed more abundant than at other locations. I hypothesize that, in the seagrass habitat, food is abundant but shelter, in the absence of human-provided conch shells, is limiting for the octopus population; in other habitat types, shelter is abundant but another factor, possibly food, is limiting. Thus, shells discarded by the conch fishery may be allowing octopuses to exploit a food-rich habitat that would otherwise be unavailable because of the lack of crevice shelters. I conducted a year-long shell addition experiment to test this hypothesis. I predicted that adding empty conch shells in seagrass habitat (lower shelter) would increase octopus abundance; adding shells in mixed hard-bottom habitat (higher shelter) would not increase octopus abundance. One year after adding shells, octopus abundance had increased on sites with added shells in seagrass but not on hard-bottom

addition or any control sites, supporting the hypothesis. Statistical support of this conclusion was hampered by very low numbers of octopus overall, so I plan to test this hypothesis again with a more robust experimental design.

INVESTIGATION OF FLORAL DIVERSITY AND THE SPATIAL DISTRIBUTION OF PLANTS IN COASTAL ECOSYSTEMS, AND THEIR EFFECTS ON PLANT-POLLINATOR DYNAMICS AT COMMUNITY AND METACOMMUNITY SCALES

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There are six coastal plant communities in The Bahamas, determined by their distance from the ocean, substrate composition, and relative degree of disturbance. These communities are dynamic, ever subject to wind and water, including significant disturbances due to tropical storms and hurricanes. Coastal plant communities are important ecologically and economically; they reduce erosion by stabilizing sediments, and protect inland communities by absorbing the energy of storm surge. To better understand interactions between plants from different communities that share pollinators, we investigated the species composition, relative species abundance, and spatial distribution in four of the six community types. In this preliminary study, we surveyed seven 100 m^2 plots on San Salvador, two each in the *Coccothrinax*-shrub, beach-foredune, and rock terrace communities, and one in the shrub-thicket community. All plants were identified, their canopies mapped, and the total canopy coverage for each species was estimated for each plot. To compare the relative floral diversity, as perceived by insect pollinators, the relative canopy coverage of each species was used to calculate a Shannon Diversity Index for each community. Our preliminary results demonstrate that the *Coccothrinax*-shrub and shrub-thicket communities have the greatest canopy coverage and floral diversity. These data will be compared to insect visitation records to determine whether pollinator diversity is correlated with floral diversity, or if the presence of communities with greater floral diversity influences pollinator diversity in adjacent communities with less floral diversity.

FEASIBILITY OF BIODIESEL USE AT THE GERACE RESEARCH STATION, SAN SALVADOR, BAHAMAS: HEALTH AND ENVIRONMENTAL PERSPECTIVES

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This academic study analyses the environmental and human health implications of adding a biodiesel facility to the Gerace Research Centre (GRC), San Salvador, Bahamas. The study examines implications from start to finish including constructing the facility and ending with replacing diesel with biodiesel. Conclusions were made by conducting personal interviews and critically analyzing other materials on biodiesel. The biodiesel will be produced on the GRC campus. It will require developing a new building from a previous concrete foundation and additional storage sheds. The new building will store the various chemicals and the biodiesel maker, the Freedom Fueler Deluxe. The biodiesel will be cooking oil based which is different from typical algae biofuel which is more widespread and commonly used. Biodiesel will be made with used cooking oil donated by various businesses around the island. A certain part of the vehicle?s engines will also need to be replaced if the car model is before 1993. The study found replacing diesel with biodiesel would be excellent for the environment and not cause human harm. Initially, biodiesel emits 20-60 percent fewer greenhouse gasses than fossil fuels and 70-90 percent fewer long-term (New Delhi, 2009). This is significant and will drastically reduce the carbon footprint of

the GRC and eventually the island of San Salvador. This will also reduce the current environmental impacts of traditionally transporting diesel to the island.

ENCRUSTING FORAMINIFERA FROM PLEISTOCENE CORAL REEFS ON SAN SALVADOR AND GREAT INAGUA ISLANDS IN THE BAHAMAS

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Pleistocene coral reefs (Grotto Beach Formation, Cockburn Town Member) from San Salvador and Great Inagua Islands, Bahamas, offer important insights into paleoenvironmental and sea level changes during the last interglacial highstand (Eemian; MIS 5e). Field and petrographic observations provide information on distribution and abundance of encrusting organisms, their role in taphonomic modifications of corals, and the environmental transition from healthy to microbially encrusted reefs. Stromatolites, clotted microbialites, red crustose coralline (RCC) algae, serpulids, and foraminifera form several cm thick encrustations on *Acropora*, *Pocillopora*, and *Orbicella* corals. Identification of encrusting foraminifera is commonly based on surficial morphology, but many examples are embedded within other encrusters and had to be studied in thin sections. The result is a set of criteria for the recognition of the following four foraminiferan species present at all study sites: 1) *Homotrema rubra* is the most common type, characterized by red tests of variable morphology (globose, hemispherical, flat, branching, spiny), up to 8 mm in diameter (d), and made of multiple layers of chambers (d=40-200 µm) with continuous or perforated walls 20-60 µm thick; 2) *Gypsina plana* comprises ~5% of the total specimen count; its discoidal tests are up to 3 mm wide and consist of few layers of elliptical chambers (d up to 1.4 mm) with convex upper surface and perforated septae 60-200 µm thick; 3) *Carpenteria utricularis* has plano-convex, trochospiral tests (d ~2 mm) of conical or globose morphology and a highly convex umbilical side; its chambers are up to 1 mm in diameter and have 50-400 µm thick septae; and 4) *Planogypsina acervalis* is the rarest species; it has thin discoidal tests and elliptical chambers (d up to 300 µm), with thin septae (20 µm) organized in a single layer. Corals are almost exclusively directly encrusted by RCC algae, which in turn are encrusted by foraminifera and serpulids, and commonly covered by more algae. *Homotrema* and *Carpenteria* are also embedded within thicker microbialites, and their abundance decreases away from the coral surface. The prevalence of *Homotrema* and the paucity of *Gypsina* suggest that the encrustation took place in a near-shore, high energy, well-lit marine environment.

EVALUATING THE USEFULNESS OF GOOGLE EARTH HISTORICAL IMAGES TO ASSESS IMPACT OF HURRICANES IN THE BAHAMAS

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This exploratory study relates historical satellite imagery to information about intensity and pathways of hurricanes in the Bahamas to assess amount and style of modifications by major storms during the present times of globally rising sea level. Examples include severe beach erosion, damage to roads, washovers of beach sand and rock boulders into interior settings, and conversion of coastal lakes to lagoons with creation of new inlets. Specifically, this research evaluated the usefulness of Google Earth historical imagery for documenting hurricane impact. Google Earth historical imagery has been available since about 2001, with variable coverage

throughout the Bahamas. Seven major hurricanes (i.e., sustained winds >111 mph or Category 3 and higher on the Saffir-Simpson scale) impacted the Bahamas during this time: Frances (2004), Ike (2008), Irene (2011), Sandy (2012), Joaquin (2015), Matthew (2016), and Irma (2017). Google Earth imagery of all islands impacted by these hurricanes was examined, and some of the most impressive examples from hurricanes Ike, Joaquin, Matthew, and Irma on San Salvador and Great Inagua islands are documented and supplemented by field photos and high-resolution drone images. Google Earth proved to be a useful tool for such documentation, but the variable timing of image acquisition is not ideal for recording hurricane impact before natural and human-assisted recovery processes begin. Google Earth images also have limited resolution compared to high-resolution drone images, which are particularly useful, but can be difficult and expensive to acquire. Generating drone images also is dependent upon the ability to travel to impacted areas in a timely manner after major storms. Google Earth was especially useful for historical documentation of examples of storm impact that were previously identified in the field, but it was generally challenging to locate new examples, which could potentially be examined on site in the future. Overall, our methodology and results represent a useful means for documenting and communicating information about vulnerability to hurricanes with local residents, developers, and other decision- and policy-makers in the Bahamas.

THE ROCK ISLANDS OF BELAU (PALAU), WESTERN PACIFIC: AN EXAMPLE OF DROWNED POLYGONAL KARST

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The Belau (Palau) Islands are located in the western Pacific (midway between Guam and New Guinea), an independent country in the former western Caroline Islands. The archipelago extends for 160 km in a north-south arc, with 414 km2 of land area. The northern islands are mostly volcanic, but the southern islands are Miocene to Pleistocene limestones which are heavily karstified. The signature feature of the southern archipelago are the Rock Islands, which rise from lagoons as steep-sided towers, some free-standing, others grouped so as to create internal depressions, many which have become inland water bodies. The overall appearance is of a cockpit or polygonal karst that has been drowned as a result of Holocene sea-level rise. Given that for over 90% of the Quaternary, sea level has been lower than the lagoon, these karst features evolved primarily in a subaerial condition. In their current environment, bioerosional notching over a 3 meter tidal range has over-steepened the hills, initiating collapse that has amplified the hills? verticality. Flank margin caves in various stages of erosional removal are found at 1 to 6 m above sea level, consistent with the last interglacial sea-level highstand (MIS 5e), and minimal tectonics or subsidence since. In this case, karst features have helped resolve a debate regarding tectonic motion in the last 100 ka. Some towers contain progradational collapse caves, formed by collapse of deeper caves to elevations above modern sea level. Those deeper caves formed when lower glacioeustatic sea levels exposed the entire carbonate platform, such that conduit flow developed to form large epigenic cave systems. The island caves display significant archeological and historical features, especially from WWII.

DENUDATION IN QUATERNARY EOLIANITES AND THE FORMATION OF PINNACLE TOPOGRAPHY

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Eogenetic Quaternary eolianites may contain a denudational topography of upstanding rock pinnacles and columns. Examples are shown from Australia, The Bahamas, Bermuda, and

Rodrigues Island. These features have irregular spacing, are decimeters to meters in relief, and usually have a footprint dimension smaller than their height. Many are capped with a red, resistant micritic deposit interpreted to be a remnant terra rossa paleosol. These pinnacles are the product of an inversion of topography, initiating as small dissolutional pits in the eolianite, which collect soil and other surface debris, utilized by the rooting of plants that subsequently become rhizomorphs and microbiolites. The soil infill results in the micritization of the pit walls and bottom, creating a resistant lining. As overall denudation proceeds, the pit infills and the micritic lining projects above the lowering land surface as round, columnar features. Continued denudation results in the exposure of the pit bottom, where the terra rossa paleosol is the thickest, the most strongly cemented, and hence the most resistant part of the local landscape. The pit bottom now completes the inversion of the topography by becoming a pinnacle top. Eventually, the terra rossa cap is removed (some times by simply sliding off), and a sharp, pointed pinnacle forms,which continues to degrade, as does the surrounding landscape. The inherited inverted topography thus persists long after evidence of the causation by pit formation has disappeared. The scale of the pinnacles indicates five or more meters of denudation, consistent with denudation rates calculated from first principles and from field examples. Deposition of new eolianites can result in overprinting, creating columns and pinnacles from several denudation cycles, commonly tied to glacioeustasy.

FLANK MARGIN CAVES OF THE TURKS AND CAICOS ISLANDS: IMPLICATIONS FOR PLATFORM GEOLOGY

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The Turks and Caicos Islands (TCI) are the southeastern extension of the Bahamian Archipelago with important subtle tectonic distinctions revealed by their flank margin caves. Many TCI caves have pronounced joint control, which is not observed in the simple carbonate islands to the northwest. Dissolutional passages were observed at elevations up to 12 m, twice as high as expected for MIS 5e, ~120 ka; other workers report dissolutional passage elevations to 17 m and stalagmite U/Th dates >195 ka. These data contradict prior interpretations from this archipelago that only cave passages from MIS 5e exist. The TCI platforms lie ~100 km from the North American/Caribbean plate boundary and seismic and bathymetric data suggest minor tectonic uplift may have occurred; isostatic rebound as a result of karst denudation may also play a role. The common occurrence of joint-oriented passages coupled with the age and elevation of some caves support a tectonic component. Recent work on West Caicos has shown that pre-MIS 5e subtidal deposits older than MIS 5e exist in the TCI. While West Caicos fossil coral data for that highstand is problematic, no pre-MIS 5e subtidal deposits are known in the archipelago north of Mayaguana Island. As elsewhere in the archipelago, karst denudation, at greater values than previously reported, has stripped most pre-MIS 5e deposits from the platform surface; the West Caicos example was protected by pre-MIS 5e eolian deposition. That denudation may have resulted in isostatic rebound, as has been reported for Florida and The Bahamas. One cave on Providenciales intersects a complex deposit displaying back beach breccia facies and a tempestite deposit consisting primarily of the shells of the conch, Strombus gigas, sandwiched between two eolian units.

FLANK MARGIN CAVES IN COASTAL CARBONATES, CAPE RANGE, AUSTRALIA: INTERPRETING TECTONIC AND GLACIOEUSTASY OVERPRINTS

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Flank margin caves are common at Cape Range, Australia (northwest coast of the continent), a north-northeast-striking anticlinal ridge 315 m high, 130 km long, and 32 km wide that extends into the sea, consisting of Miocene carbonate rocks with a series of coastal terraces of Pliocene and Quaternary carbonates. Inland coast-parallel escarpments, representing former sea cliffs, and deep valleys cutting the limbs of the anticlinal ridge host many cave entrances at a variety of elevations. Caves initiated with the first tectonic-driven subaerial exposure in the Miocene and continued through to the last Pleistocene interglacial. The lowest and oldest unit, the Mandu Formation, a chalky and marly limestone, contains many tafoni (pseudokarst) caves with simple, single chamber plans and widths up to 15 m and heights up to 10 m. The higher, purer Miocene limestones and the younger Pliocene and Pleistocene coastal terrace limestones host numerous flank margin caves from 300 m elevation in the Miocene rocks to sea level in the Quaternary rocks. These caves have entrances up to 30 m wide and heights of 6 m, with single-chamber caves being common, but complex caves entered by small entrances lead to large phreatic chambers, eliminating both sea cave and tafoni as speleogenetic mechanisms. The close association of these caves with sea cliffs and incised valleys argues against a deep hypogene origin, which would leave a cave pattern unrelated to the surface configuration. Miocene uplift tapered off into the Pliocene. The flank margin caves in the paleo sea cliffs represent the outcome of the interplay of tectonic activity and glacioeustasy over a 300 m vertical range, with lowstands causing valley incision, while highstands raised the fresh-water lens and allowed cave development in the valley walls.

DEPOSITIONAL HISTORY OF TRIANGLE, FRENCH, AND CLEAR PONDS ON SAN SALVADOR, THE BAHAMAS

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Three lakes located along the perimeter of San Salvador Island and isolated from the ocean by a dune and beackrock barrier were investigated through sediment coring campaigns. We collected ten cores and seven C-14 dates from Triangle Pond (TP), nine cores and five C-14 dates from French Pond (FP), and three cores and four C-14 dates from Clear Pond (CP). The TP stratigraphic record shows that the lake basin was created by a physical barrier between the Pleistocene dune ridge and the sea before 3500 yr BP. This event likely corresponds to the lithification of paleointertidal zone beachrock. Interbedded carbonate mud and sand deposited in an restricted tidal lagoon mark a period of hurricane activity that ends with a large coarse to fine grained, peloidal, bioclastic carbonate sand. At about 2000 yr BP, a 10-50 cm-thick peat was deposited during rising sea level likely within a mangrove swamp. The lack of sandy interbeds in the peat suggests a reduction in storminess or isolation of the basin during lowstand conditions did not permit deposition of tempestites. The peat deposition ends abruptly at 500 yr BP with a packstone sand layer and is capped by algal mat deposition. A similar sedimentary sequence is recorded in the upper part of FP pond deposition with a bioclastic sand overlain by a peat that is capped by algal mats that begin to be deposited ca. 500 yr BP. The phase of hypersaline conditions and algal mat growth in TP and FP marks the complete isolation of these lakes from the sea. The base of the longest CP core contains a peat dated to 5000 yr BP. This is overlain by a meter of carbonate wackestone likely deposited within a restricted lagoon that ended ca. 2800 yr BP with the deposition of a 20-cm-thick, coarse sand. Deposition shifted to a more sand-

dominated environment with a distinct sand bed dated to 1500 yr BP that marks the beginning of a mud and sand lamination interval until ca. 1000 yr BP. The upper bioturbated 40 cm of the core contains a sandy lower section and an upper fossil hash with abundant gastropods and mollusks representing the current brackish conditions.

REEF RESTORATION EXPERIMENTS FOR ISOLATED AND REMOTE ISLANDS AND COMMUNITIES: PART I

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In response to more than 20 years of observed decline in the health of coral patch reefs around San Salvador Island, Bahamas, we have initiated experiments in reef restoration. Reef restoration is a growing industry in the United States, Australia, and other nations with substantial economic resources; however, many nations and communities that are home to coral reefs are isolated, economically stressed, and/or are located in a geo-politically unstable locations. In order to evaluate reef restoration efforts that could be undertaken in remote locations by a local population, we have embarked on a series of experiments to both increase coral populations, including endangered species, and reef rugosity (three dimensionality). Our experiments, to date, have been based on large-scale commercial reef restoration practices - but have been adapted for isolated and remote communities. The experiments were further adapted to be low cost and use materials and equipment regularly available to isolated communities. The experiments included: construction and placement of concrete rugosity enhancing devices, coral transplants, and rescuing of corals that have become dislodged due to storm events or other activities. To date, we have realized some encouraging results regarding the structural integrity of the rugosity enhancing devices, transplant of endangered species, and improvements in planning and logistics. In this paper we document the following: need for lower-cost reef restoration experiments; our methods and results to date; and identify future experiments. This paper is intended to be an ongoing series that identifies the progress of reef restoration techniques.

GEOCHEMISTRY AND MICROBIAL DIVERSITY COMPARISON OF TWO NATURAL HYDROCARBON SEEPS ON THE ISLAND OF BARBADOS

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In an effort to characterize the diversity of microorganisms that feed on petroleum hydrocarbons, microbial communities of two natural crude oil and bitumen seeps that occur on the island of Barbados were compared. The two natural macro-seeps are characterized by different environments: siliciclastic versus carbonate, fresh water versus salt water, and crude oil versus bitumen seepage. Samples were analyzed for microbial diversity and water geochemistry to determine if the possibility of microbial degradation of hydrocarbons has occurred. It was found that the two locations are similar at the phylum level yet differ greatly at the genus level, with the fresh water location being more diverse than the salt water location. Several hydrocarbon degrading bacteria were identified at both locations, implying at least some degree of degradation has occurred. Several unclassified species were also detected, thus opening the door for further research into what role each new species may play in the seep environments of Barbados.

ADDITIONAL TRIAL FARM RUINS AND OTHERS OF INTEREST

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In January and April 2019, seven days were spent cutting trails and exploring the ruins around the Trial Farm complex, located in the S.E. Corner of San Salvador, near Breezy Hill.

The main set of ruins were explored and written up by Kathy Grace and Ron Shaklee in 1993. Our survey found additional buildings along the ridge top: six dwellings and three kitchen areas. The architecture and debris fields around the buildings reveal twentieth century materials. Aerial photographs from 1942 reveal that the buildings and surrounding area were cleared out and occupied, however 1968 aerial photographs do not reveal any cleared out areas. This perhaps indicates that the buildings were not occupied in 1968. Two additional and separate areas along the ridge line revealed plantation era construction and debris fields near the buildings. One area revealed a dome-shaped masonry oven. Neither of these areas show up in the 1942 and 1968 aerial photographs as being in use. In addition, an unreported outhouse was found at the Trial Farm complex that was written up by Grace and Shaklee. A similar style outhouse was found near a building of the Montreal settlement, which appears to have been occupied in 1942, based upon aerial photographs. Both of these outhouses were built using the slip form masonry technique.