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Carrie Bow Cay Field Station has operated on the Belize barrier reef since 1972. The station is open to scientific visitors year-round and offers unparalleled access to coral reef environments, seagrass meadows, and mangrove forests.

This small and highly functional field laboratory boasts a flow-through seawater system, wet and dry laboratory space, full SCUBA facilities, research vessels, and living quarters.

For more information, visit:

www.ccre.si.edu
Early in their life history, many larval fish and corals are carried offshore by ocean currents where they develop in the open ocean. At the conclusion of their larval stage, they must locate a suitable coral reef habitat on which to settle. This process is a crucial step in the life cycle of reef larvae and helps to replenish reefs with new recruits to maintain a healthy and biodiverse coral reef ecosystem. This project aimed to understand which reef-based chemical cues are utilized by juvenile fish and coral larvae to locate appropriate coral reef habitat during the settlement process.

During the last few years, we have investigated different reef-based cues by delving deep into extracts and behavioral assays for individual organisms found along the Mesoamerican reef tract. This year, we focused on a whole ecosystem approach that encompassed many different experiments. First, we conducted a manipulative coral outplanting experiment from May to November 2019 on six natural patch reefs in the lagoon area around Carrie Bow Cay. Each patch reef was split in half; one side contained outplanted *Acropora cervicornis* and *Porites furcata* corals and the other side was left undisturbed as a control. Throughout the summer recruitment season, we conducted surveys on each patch reef at fixed points to assess changes in reef community and structure. We employed various survey techniques to assess the abundance of diverse organisms including benthic species, cryptic organisms, juvenile fish, and roving fish species. Additionally, in May we deployed 10 settlement tile pairs on each side of the experimental patch reefs. The tiles were left for six months in order to capture recruitment events of multiple stony coral species. Tiles were collected and scored in November to compare coral settlement on both sides of the experimental patch reefs. Finally, using a two-chamber choice flume, we tested juvenile recruits of many species of damselfish, wrasses, parrotfish and grunts to assess their behavioral response to the chemical cues of *Acropora cervicornis* and *Porites furcata*. While results are still being analyzed, preliminary data suggest that cue preference varies drastically by fish species, with longfin damselfish showing the strongest preference for the outplant *A. cervicornis*. 

*Acropora cervicornis* colony in shallow water.
Seagrasses are foundational species that provide a range of services to ecosystems, including habitat provisioning, food, sediment stabilization, and improved water quality. Both top-down (herbivory) and bottom-up (nutrients) factors impact the growth and production of seagrasses across temperate and tropical regions, yet the relative importance of these processes in controlling seagrass ecosystem function remains controversial, particularly across latitudinal gradients in light and temperature. In 2018, we established the *Thalassia* Experimental Network (TEN), a seagrass network involving thirteen institutions and thirteen sites spanning thirty degrees of latitude from Bermuda to Panama. One of these sites is in Belize near Carrie Bow Cay.

In spring 2018, we deployed a standardized caging experiment in a shallow seagrass bed at each site. The experimental array consisted of 50 plots (0.25m x 0.25m), and each plot received a unique combination of treatments in a factorial design: caging (to exclude natural herbivores and predators), simulated grazing (seagrass clipping to two heights), and nutrients (Osmocote fertilizer, nitrogen and phosphorus). We maintained these experiments for one full year. In fall 2018 and spring 2019, we measured seagrass characteristics and collected seagrass samples, including seagrass cover, shoots, and biomass, productivity, associated epifauna and epiphytes, and sediment composition. Our preliminary results show variable strength in natural grazing, and significant effects of clipping and nutrient enrichment on leaf morphology and productivity that vary across latitude. Also, in accordance with our earlier study in 2014, nutrient enrichment reduced seagrass production by increasing epiphyte growth at our northern, subtropical sites; while it enhanced rates of herbivory on nutrient-enriched seagrass at tropical sites.

Final results from our network will elucidate the relative importance of top-down versus bottom-up factors in driving the ecological functioning of seagrasses across gradients in light and temperature. Our results will also allow us to better predict the effects of climate change, including rising sea surface temperatures and the tropicalization of seagrass ecosystems across subtropical locations.
A regional approach to coastal ecosystem management
Steven Canty, Lorae’ Simpson, Candy Feller

Marine fisheries within the Mesoamerican reef ecoregion are highly connected, but to date no regional genetic connectivity studies have been conducted for the red mangrove (*Rhizophora mangle*), an important ecosystem for many fish species. In 2019, Steven Canty conducted field visits to Punta Gorda, Belize City, and Carrie Bow Cay to collect leaf samples from red mangrove forests along the Belizean coastline and cays. These leaf samples will be combined with samples from Honduras, Guatemala, and Mexico to assess the genetic connectivity of mangrove forests throughout the region and provide an assessment of the spatial scales required for effective management of this keystone ecosystem. The genetic analyses, including DNA extraction, are being conducted at the Laboratories of Analytical Biology, within the Smithsonian’s National Museum of Natural History, Washington, D.C.

To complement the regional genetic connectivity approach to mangrove genetic connectivity, a regional mapping of mangrove distribution is being conducted. Field visits by collaborators Dr. Michael Steinberg and Jordan Cissell from the University of Alabama were completed to collect geo-referenced data points of different habitat types. These data points will assist in the training of a model which will use high-resolution satellite imagery to map mangroves throughout the Mesoamerican reef ecoregion. The maps produced by this work will be the first for the region, using high-resolution data and a single methodology, which will facilitate better regional comparisons of mangrove cover between the four countries of the Mesoamerican reef.

Mangrove cays are changing, with some cays, such as Man O’ War Cay within the South Water Caye Marine Reserve, becoming significantly smaller and almost disappearing. Responding to calls from concerned stakeholders, including residents of Dangriga, Steven Canty from the Smithsonian Institution and Dr. Lorae Simpson from the University of Alabama have been collecting sediment cores to assess sediment condition on various cays along the Belizean coastline. These analyses will provide estimates of carbon sequestration rates to help us understand how mangrove sediment dynamics have changed over time. Combined, these protocols will allow an assessment of how mangroves are adapting to sea level rise and can be used to determine which stage of adaption a forest is in: accretion (actively keeping pace with sea-level rise), maintenance (net neutral change), or submergence (slowly subsiding). Scaling up the sea level resilience model to the region will be key in recognizing mangrove forests as a conservation priority and identifying those in need of management interventions.
Using regional and local algal cover to predict variation in microbial communities on coral surfaces

Julie Meyer and Anya Brown

Declining coral cover is a problem throughout the Caribbean, where environmental stresses and disease have drastically reduced coral populations over the last several decades. As coral reefs degrade, coral cover is replaced by macroalgal cover, which in turn alters coral microbiomes and further contributes to the decline of the reef ecosystem. The negative interactions between coral and algae are likely facilitated by changes in coral microbial communities, where stress can be visualized as an increase in the diversity of coral microbiomes when pathogens and opportunistic taxa replace the typically dominant symbionts. The objectives of this project were to 1) characterize the coral and algal cover at six reef sites around Carrie Bow Cay on the Mesoamerican Barrier Reef and 2) to characterize changes in microbiome diversity and the presence of key taxa associated with environmental stress and/or disease in elkhorn corals (Acropora palmata) and staghorn corals (A. cervicornis).

Coral and algal cover was determined at six sites around Carrie Bow at both regional scales and local scales. At each site, we ran four transects to determine regional coral and algal cover, and up to 20 small quadrats to characterize local cover. Macroalgal cover ranged from 10-40% at the site-level (regional) scale. Macroalgal cover at the local scale was documented with photographs of small quadrats.

A total of 185 coral mucus samples were collected along with 66 macroalgae samples, 1 cyanobacterial mat, 21 sediment samples, and 18 water samples. At each site, we collected mucus samples of corals both in contact and not in contact with the macroalga Dictyota. We primarily focused on Acropora corals to compare to samples from around the Cayman Islands. However, at three sites we also collected Porites samples to compare with samples taken in the Pacific.

In addition to the Acropora and Porites mucus samples collected for the macroalgal interactions study, we collected mucus samples of several boulder corals as a “pre-disease” baseline before stony coral tissue loss disease (SCTLD) reaches Carrie Bow. Mucus samples were collected from five colonies each of Orbicella annularis, O. faveolata, Montastraea cavernosa, Dichocoenia stokesi, and Siderastrea siderea. Each colony was tagged and photographed at the time of sample collection. Characterization of microbiome communities from all samples exported from Belize are ongoing at the University of Florida.
Sponges dominate Caribbean reefs now that reef-building corals have been declining for decades. Sponges feed by filtering huge volumes of seawater, providing a mechanism for transferring organic carbon back to the benthos as they turn-over the water column. A new theory has been proposed about benthic-pelagic coupling on coral reefs called the “sponge-loop hypothesis” that is potentially the most important new concept in marine ecology in many years, because it seeks to explain Darwin’s Paradox: how do highly productive and diverse coral reefs grow in desert-like tropical seas? Similar to the famous microbial-loop of the 1980s, the sponge loop hypothesis proposes that sponges on coral reefs absorb the large quantities of dissolved organic carbon (DOC) exuded by carbon-fixing seaweeds and corals and return it to the benthos as particulate organic carbon (POC) in the form of shed cellular detritus. But does the sponge-loop hypothesis apply to the sponge species with the greatest biomass and capacity for seawater filtration? On the fore-reefs of Carrie Bow Cay, we continued our tests of the sponge-loop hypothesis for common barrel, vase and tube-forming sponge species. We conducted sampling of seawater going into and coming out of sponges on the fore-reef, in conjunction with lab-based experiments and collection of seawater before and after successive incubations of seaweed and sponges in containers. The DOC from these seawater samples were extracted on site and are undergoing metabolomics analyses to determine how sponges alter the individual metabolites in DOC, and to examine whether sponges may be consuming seaweed-derived DOC. We also collected samples of both reef detritus and potential detritus producers for stable isotope and genetic eDNA analyses to determine the fraction of reef detritus that can be attributed to sponges. The results of these projects will be important in determining how DOC is transferred from the water column to the benthos as part of the carbon cycle in coral reef environments, where the effects of global climate change and ocean acidification may be tipping the competitive balance toward non-calcifying organisms such as sponges.
2019 MarineGEO field campaign
Scott Jones, Leah Harper, Emmett Duffy, Valerie Paul, Tim Hawthorne, Bo Yang, Maggie Johnson, Alex Lowe, Maggy Benson, Emily Nixon

Now in its fifth year, the annual MarineGEO (Marine Global Earth Observatories) Field Campaign collects critical biodiversity data that contribute to a global network of marine research sites. Belize serves as an important node in this network due to the high biodiversity found in the region, as well as the wealth of historical data collected there. The aim of MarineGEO is to create a long-term, open-source ecological database of coastal marine habitats and biodiversity to determine habitat trajectories over time and inform research direction and management decisions. To do this, we 1) monitor common marine habitat condition and extent, 2) quantify biodiversity in each habitat, and 3) use standardized experimental approaches to quantify ecosystem processes that drive observed patterns. Our primary questions are: 1) What is the condition of major marine habitats around Carrie Bow Cay? 2) How much biodiversity is associated with each habitat type? 3) How do ecological processes (e.g.: consumption rates) vary among habitats?

In the span of a very busy two and a half weeks, researchers conducted a rigorous set of protocols to examine each important tropical habitat surrounding Carrie Bow Cay, including mangroves, seagrasses, patch reefs, sand flats, and fore reef. Intensive assessments of mangroves and seagrasses measure productivity, growth, and biomass, while an exhaustive survey of fish and invertebrate diversity is conducted at each habitat using Reef Life Survey protocols (www.reeflifesurvey.com). Important ecological processes like herbivory and predation are measured with fish-feeding assays deployed at each habitat. The data generated from these efforts are impressive: thousands of feeding assays have been recorded and hundreds of fish and invertebrate species have been documented. These projects play an important role in advancing MarineGEO’s efforts to monitor coastal ecosystems. Additionally, MarineGEO collaborated with researchers at Citizen Science GIS (http://www.citizensciencegis.org/). The team conducted drone flights to map the local seascape and were coupled with a series of georeferenced transects, along which divers collected underwater photoquadrats to validate habitat designations based on the drone imagery.

Finally, the scientific team worked to engage with the public during the campaign by participating in a live webcast with "Smithsonian Science How" (https://naturalhistory.si.edu/education/distance-learning/) and by hosting a live presentation for community members and University of Belize students in Dangriga, Belize.
Ocean acidification and warming pose grave consequences to the earliest life stages of threatened Caribbean acroporid corals and their hybrid
Nicole Fogarty, Kory Enneking, Sharla Sugierski, Bryce Corbett

Anthropogenic increases in carbon dioxide emissions have altered global oceanic chemical properties by increasing temperature and decreasing pH [ocean acidification (OA)]. These stressors of climate change pose major threats to mature corals. However, only a handful of studies have examined the effects of thermal stress and OA on the early, potentially most vulnerable, life stages of corals. This project examines the ability of endangered acroporid corals to withstand these environmental stressors throughout three early life history stages: fertilization, survivorship and settlement.

In August 2019, researchers from the University of North Carolina Wilmington collected Acropora cervicornis and A. palmata gametes from reefs nearby Carrie Bow Cay field station during the annual synchronized spawning event. Gamete bundles were brought back to the lab for immediate separation before fertilization. Crosses of each coral taxon were formed by combining sperm and eggs from unique genotypes (hybrids were created with A. cervicornis eggs and A. palmata sperm). Fertilization crosses were conducted under ambient conditions (28.5°C, pH 8.18), high temperature (30°C, pH 8.18), ocean acification (28.5°C, pH 8.0), or ocean acification + warming (30.0°C, pH 8.0). Fertilization in the high temperature treatment was extremely low and the resulting larvae were not abundant enough to conduct a replicated settlement experiment. Thus, the acroporid larvae fertilized at ambient conditions were subjected to treatment (high-temp, OA) conditions after 36 hours to examine the subsequent life history stages. Larval survivorship and settlement were lower under stress treatment conditions. Coral reef recovery is dependent upon fertilization success for recruitment of genetically diverse larvae. Without successful fertilization, as a result of low adult densities or environmental stressors, natural recovery is impossible and restoration efforts using a combination of sexually and asexually derived acroporids are needed for recovery.
In our continuing quest to elucidate the taxonomy, global distribution and evolution of marine meiofauna, with emphasis on the phyla Gnathostomulida and Nematoda, our team (Dr. Sterrer, with one assistant and Dr. Ott, with three assistants/students), collected 28 benthic samples.

For the Gnathostomulida portion, these samples yielded more than 100 specimens of special interest. Among others, observations of juvenile *Austrognathia* sp. confirmed their diet of the Gammaproteobacterium *Beggiatoa*; and some 90 specimens were preserved. The latter were sent to Dr. Chris Laumer (Wellcome Trust Genome Campus, UK) for DNA analysis, except sample #21, which went to Dr. Kazuo Inaba (Shimoda Marine Research Center, Japan), with whom I am collaborating on the ultrastructure of cilia in Gnathostomulida and Porifera.

The Nematoda study focused on the subfamily Stilbonematinae, which is remarkable for its symbiosis with sulfur-oxidizing Gammaproteobacteria. From the above samples, 117 specimens belonging to 10 genera were collected, photographically vouchered and preserved. For molecular phylogeny, 38 specimens were fixed in alcohol, and for morphological investigations, 51 specimens in paraformaldehyde and 28 in glutaraldehyde. The majority of these specimens will be processed in the Department of Limnology and Bio-Oceanography at the University of Vienna. Some specimens will be sent to the Max Planck Institute for Marine Microbiology for metagenomic analysis.

In addition, experiments to elucidate the nature of the deep-purple pigment of the glandular sense organs (gso) in one genus of Stilbonematinae (*Melanostigma* n. gen., to be described in 2020) were conducted using oxidizing (potassium bi-chromate) and reducing (ascorbic acid) agents. For element analysis (EDAX), 15 specimens of *Melanostigma* were air dried on carbon-coated stubs. First tests at the University of Vienna revealed unexpected high Br concentrations in the gso of these worms. Further tests are in progress.
Coral larvae encounter three major early-life-history bottlenecks, each characterized by large declines in percent coral survival. Coral survival drops during the planktonic larval, larval settlement, and juvenile recruit life-history stages. High mortality during each of these stages can adversely affect local recruitment on degraded reef environments, which may already experience low recruitment. Restoration strategies can employ techniques to enhance survival through the juvenile recruit stage, giving coral a better chance for long-term survival. Facilitating coral survival through each of these stages, however, requires a thorough understanding of the environmental factors influencing survival during each phase.

Environmental parameters influence coral settlement at three spatial ranges: 1) on a large spatial scale, involving larval dispersal and transport, 2) on a local scale, directing larvae towards a particular reef or reef-area, and 3) at small-scales, influencing final substrate selection. The number of variables influencing settlement increases at smaller spatial scales. When larvae are less than a meter from the reef, as many as nine major abiotic and biotic factors influence their behavior. This research addresses some of those nine factors, by testing the influence of ambient structure — which provides shading from ultraviolet radiation, protection from herbivores, and shelter from hydrodynamic flow — on coral recruitment and benthic community development.

This research was carried out over the past year with funding support from the National Geographic Society. The study concluded June 2019, when all experimental substrates were removed from the reef off Carrie Bow Cay, Belize. Images of settlement substrates are currently being analyzed to determine whether species composition of organisms recruiting to the tiles differs with ambient structure.

Results from this study will provide fundamental knowledge of stony coral recruitment preferences, while highlighting recruitment patterns of other benthic organisms. Understanding benthic recruitment of non-coral species is essential to predicting whether structure inadvertently influences recruitment of coral competitors, which could hinder coral survival on reefs. Pending results will contribute to the knowledge needed to protect reefs along the Belize Barrier Reef, and beyond.
Decline of urchin populations associated with loss of rugosity on the forereef at Carrie Bow Cay
Karen Koltes, John Tschirky, Joanna Walczak, Karen Bohnsak, and Ana Zangroniz

Monitoring surveys were conducted in July 2019 as part of the Caribbean Coastal Marine Productivity (CARICOMP) program. CARICOMP was launched at Carrie Bow Cay in 1993 as part of a regional scientific effort to study land-sea interaction processes, to monitor for change on a local and regional scale and to distinguish anthropogenic change from natural variation, and to provide appropriate scientific information for management.

CARICOMP surveys have been conducted at Carrie Bow Cay at least once a year since 1993 with the exception of 1998-1999, after the station was destroyed by fire in December 1997. Following the CARICOMP protocol for monitoring coral reefs, we established 2 sub-plots on the inner forereef slope at depths ranging from 12 to 15m. At each sub-area, five permanent 10m transects were established using stainless steel poles.

Transects are surveyed using the linear chain method in which a light chain is draped over the substrate underneath a measuring tape stretched between the two transect poles. The number of links of each organism or substrate type is recorded and organisms are identified to species where possible. In addition to providing data on benthic community structure (e.g., percent coral cover), the chain method also provides an estimate of rugosity, a measure of the three-dimensional structural complexity of a reef. Rugosity is an important ecological parameter as areas of highly complex architecture provide more habitat for reef fish, corals, algae, and motile and sessile invertebrates. Rugosity is calculated as the ratio of the total chain length (total number of links) draped over the substrate divided by the horizontal distance (10m). Reef flattening (loss of rugosity) is among the major problems currently faced by Caribbean coral reefs.

In our 2018 CCRE annual report, we reported on the loss of rugosity on the forereef at Carrie Bow Cay following a series of bleaching events and Hurricane Mitch, a Category 5 hurricane that struck Central America in October 1998. The inner forereef slope in the 12-15m depth range suffered significant damage, with rugosity declining by about 25% from an average of 1174 links/transect between 1993 and 1997 to a low of 887 links/transect by 2003 (Figs. 1 & 3). It has recovered little in the intervening years. We report here that the loss of rugosity on the inner forereef slope has been accompanied by a decline in the population of urchins.

In 1983-1984, Diadema antillarum, the long-spined sea urchin, suffered a catastrophic die-off across the Caribbean region. Up to that point, it had been the most abundant, widespread and ecologically-important herbivore on the shallow-water coral reefs of the western Atlantic and Caribbean Basin. In 1994, CARICOMP program directors agreed to add an urchin census to the standard coral reef protocol to track the potential recovery of D. antillarum and/or the populations of other urchin species. Urchins are surveyed by counting all individuals within 0.5m on each side of the chain on each of the 10 transects. The individuals are identified by species and the density (urchins/m$^2$) is calculated.

The Carrie Bow Cay transects are among the deepest of the CARICOMP network of monitoring sites. Diadema antillarum have been rare at these depths since monitoring began in 1994 and all individuals recorded on the CARICOMP transects have been juveniles. Pencil urchins (Eucaridis tribuloides) also occur in low densities. By far the most common urchin is the reef urchin, Echinometra viridis. E. viridis is an important grazer on fleshy algae in the Caribbean region. Its abundance is reduced by predatory fish, especially the jolthead porgy (Calamus bajonado), the queen triggerfish (Balistes vetula), the ocean triggerfish (Canthidermis sufflamen) and the hogfish (Lachnolaimus maximus). Because of this predation, the reef urchin avoids open reef areas, hiding in crevices during the day and emerging at night to graze in areas close to its crevice.

In the 3-year interval (1994-1997) prior to Hurricane Mitch in October 1998, the mean total density of urchins on Carrie Bow Cay transects was 55 urchins/m$^2$. Since Hurricane Mitch, the mean total density of urchins on Carrie Bow Cay transects has declined to 23 urchins/m$^2$.
the CARICOMP transects was 6.7/m$^2$. The majority of these were *E. viridis* (5.5/m$^2$), followed by *D. antillarum* (0.8/m$^2$) and *E. tribuloides* (0.5/m$^2$). In the 3-year interval following Hurricane Mitch (1999-2002), the population of urchins had declined by 50% to a mean total density of 3.3/m$^2$. By 2015, the total population of urchins had declined to near zero. Almost all of the loss is attributed to the disappearance of the reef urchin, *E. viridis* (Fig. 4).

Long-term studies have shown that the loss of *D. antillarum* following its mass-mortality in 1983 contributed to a phase-shift of Caribbean reefs from coral-dominated to alga-dominated communities. This was due at least in part to the persistent indirect effects of the increase in macroalgae, including decreased larval recruitment and survival of juvenile corals and coral disease. Recent studies have shown that macroalgal interference in the recruitment and survival of juvenile corals is reduced on reefs in marine protected areas where the populations of the herbivores *Diadema* and/or parrotfish have recovered or increased.

While *E. viridis* is a small urchin relative to *D. antillarum*, it has been recently shown to play an important role in grazing algae on reefs in Panama, particularly in areas where populations of *D. antillarum* are absent or have not recovered. At the CARICOMP sites where *E. viridis* is the dominant species, the decline of this urchin likely exacerbates the ability of these reefs to recover from catastrophic events and chronic stressors.

The results of these studies demonstrate the value of long-term monitoring programs like CARICOMP in documenting the ways in which major environmental perturbations such as Hurricane Mitch continue to shape conditions on the barrier reef around Carrie Bow Cay even after two decades.
A nematode symbiont keeps its chromosome oriented towards the host

Sylvia Bulgheresi, Philipp Weber, Tobias Viehböck, and Gabriela Paredes

All living organisms must segregate their genetic material precisely. Model free-living bacteria, such as Escherichia coli, replicate their chromosome by starting at the origin of replication (ori) and finish at the terminus (ter) at the level of abundance must be maintained and ensheath much of the worm's surface. However, active mechanisms have been proposed for other bacteria, such as Caulobacter crescentus and Vibrio cholerae.

Although DNA segregation has been studied for several free-living bacteria, nothing was known about this process in bacteria that are constantly attached to a host, and it was thanks to our field trips that we published our findings on the chromosome segregation of the marine nematode symbiont Candidatus T. oneisti. This rod-shaped bacterium has only been found attached, via one of its poles, to the cuticle of Laxus oneistus, an interstitial roundworm that inhabits sand. Ca. T. oneisti is committed to have each daughter cell in constant contact with its host. To accomplish this, it has evolved a remarkable trait: it grows in width and divides longitudinally. Thus, the progeny of many generations of cells are arranged tightly upright, like guards on duty, and ensheath much of the worms surface. After discovering that Ca. T. oneisti segregates its chromosome along the short axis, we found that newborn cells, just like their mothers, always position their ori and ter right next to each other at midcell, suggesting that a specific chromosome orientation towards the host is kept transgenerationally. We hypothesize that it might be advantageous for Ca. T. oneisti to position genetic loci near the pole attached to the host to facilitate interactions with the nematode and also to confine loci in the distal half of the cell. If this is indeed the case, then the longitudinal mode of cell division of the symbiont might have been selected for as a mechanism to accomplish this specific localization of the different chromosomal loci.

What factors control distribution and abundance of sponges living in coral reef, seagrass meadow, and mangrove habitats?

Janie Wulff

Although sponges play many required functional roles in coral reef and mangrove ecosystems that are not duplicated by any other organisms, relatively little is known about population and community dynamics of sponges. Variation among sponge species in both roles, and vulnerabilities to environmental challenges, means that identifying sensitive species is important. The oneistus species was evaluated by measuring volume. With respect to understanding how increases and decreases of particular organisms might influence ecosystem health, lumping together all sponge species in a single category “sponges” makes no more sense than lumping together barracudas, gobies, surgeon fishes, and stingrays as “fishes”. Very high species diversity and unusual shapes have impeded inclusion of sponges in long-term monitoring programs, but our lab has been maintaining censusing plots in coral reef, seagrass meadow, and mangrove sites near Carrie Bow Cay for many years, with every sponge individual identified to species and measured with respect to volume. Many surprises about sponge assemblage dynamics and the consequences of sponge loss have been revealed by our time-series census data. Because sponges vanish when they die, mortality events can only be recorded when observed in progress or if they occur at a site where sponges have been previously censused, resulting in chronic (and possibly enormous) underestimates of sponge mortality. Mass mortality of coral reef sponges at the Blue Ground Range, due to a dense phytoplankton bloom in 2011, was revealed by our censusing.

A primary focus of field work at Carrie Bow Cay in 2019 was continuation of the coral reef censusing to document both recovery from that 2011 loss of more than 2/3 of the sponge biomass, as well as documenting subsequent mortality events. Continued censusing of sponges on mangrove prop roots at Twin Cayes allowed detailed documentation of a mass mortality event in April/May 2018 that was caused by thick sargassum mats. This even resulted in loss of the protective function of sponges against isopods that diminish mangrove survival (by burrowing into prop roots) as well as a nutrient exchange mutualism between sponges and mangroves. Re-monitoring all of our mangrove and reef censusing plots in 2019 allowed us to determine which sponge species have been able to recover, and which species have not. Concern about large losses of sponges from Belizean coral reefs has prompted us to explore ways of promoting sponge restoration at coral reef restoration sites.

Photos of complete mortality on mangrove prop root sponge Tedania ignis (left) and almost complete mortality in Dysisdas etheria (right). The blue tissue is what remains of the living sponge. Both species were affected by large Sargassum mats retained among mangrove roots at Twin Cayes.

The nematode worm, Laxus oneistus, can be found inhabiting marine sediments near Carrie Bow Cay. Bacterial symbionts ensheath the body of the worm.
Bioluminescent ostracods: use of light for defense and courtship displays
Gretchen Gerrish, Vanessa Gonzalez, and Megan Litster

In January 2019, Gretchen Gerrish led a research trip to Belize at the Carrie Bow Cay Field Station that included an additional faculty leader from University of Wisconsin-La Crosse (Megan Litster), a Smithsonian collaborator (Vanessa Gonzalez) and 5 middle school and high school teachers for a 10-day research experience for teachers (RET). The trip was preceded by classroom visits to interact with each teacher’s students. Students were involved in planning research objectives for our trip and analyses of results. Follow-up visits to classrooms for student presentations and collaborative work on a research publication following the 2019 field season are ongoing. The experience was formative for many of the teachers and acted to break the barrier to field-based project development in the teachers’ science instruction.

Teachers had specialties in education with emphases in mathematics, chemistry, anatomy, and environmental science. To some of the individuals, field-based inquiry was an intimidating barrier to cross with their students. Teachers were first introduced to the luminous ostracod system through a development workshop and then through classroom visits by lead researchers. The 10-day field trip in Belize was formative for many of the participants. During the trip, all teachers participated in snorkeling at night to collect animals and data. The teachers would Skype back to their classrooms and interact digitally to train their students while in the field. Follow-up projects included all levels of artistic, scientific and conservation projects in the teacher classrooms.

Feeding, light pollution, and temperature experiments resulted in non-conclusive findings but will be used in planning future experiments. Data on behaviors surrounding the lunar eclipse are being used in preparation of a peer-reviewed scientific journal article. We are also working to prepare two scholarship of teaching and learning articles about the experience our teachers had in field-based science.

Outreach partnership brings students to the Mesoamerican Reef
Scott Jones and Lisa Mulcahy

In an effort to increase interaction with Belizean students, the CCRE program partnered with ReefKeeper Belize to coordinate a series of field trips from schools in Stann Creek district out to the barrier reef, including a stop at Carrie Bow Cay Field Station. Throughout April and May 2019, just over 100 school-aged students visited Carrie Bow Cay and were treated to a tour of the station, met researchers working in the field, and participated in hands-on activities with living reef creatures.

Lisa Mulcahy founded the nonprofit ReefKeeper Belize in 2014 in part to provide more marine science learning opportunities for school-aged children. Despite the region’s proximity to the Mesoamerican Reef, one of the largest reef systems on the planet, not enough youth are able to see it for themselves.

Drawing upon the naturally abundant diversity of the reef ecosystems right around the research station’s labs, staff prepared touch tanks with local fauna, and set up microscopes with corals, crustaceans and nudibranchs for the students to examine. Young visitors also got a clear view of the reef’s protective effect by simply walking upstairs to the station’s back veranda, which overlooks the water.

Students from the Stann Creek area examine live organisms under microscopes in the lab at Carrie Bow Cay.
This year marks the ninth year Caribbean Coral Reef Ecosystems (CCRE) staff and collaborators have conducted the South Water Caye Marine Reserve (SWCMR) Reef Assessment Program. At over 100,000 acres, SWCMR is one of the largest marine reserves in Belize and encompasses the waters around the Smithsonian’s Carrie Bow Cay Field Station. The reef assessment project aims to identify effects of the no-take conservation zone around Carrie Bow Cay on the recovery of fish and coral populations. In June 2011, permanent transects were established inside (12 transects) and outside (12 transects) the area’s boundary and have been surveyed annually since. This amounts to over 336 unique surveys on the reefs around Carrie Bow Cay.

Reef monitoring efforts typically measure the diversity, abundance, and biomass of key reef organisms as indicators of reef health. CCRE’s assessment program is designed to evaluate similar ecological metrics, so as to be compatible with other monitoring efforts elsewhere in Belize and the western Atlantic Ocean. But researchers have also added some assessments that yield information about key ecological rates and states that are thought to contribute to reef resilience, recovery in the face of negative impacts. One example of the measured rates is the grazing rates of herbivores, such as parrotfishes and surgeonfishes, which help keep algae from overgrowing the reef. Researchers also monitor the “states” of the benthic community, such as the health status of important reef-building corals, as well as coral recruitment and growth dynamics. This approach provides more comprehensive ecological monitoring, and informs models of reef dynamics that will be used to generate new insights into reef community structure in response to different reserve management regimes. This study is designed to take advantage of the strengths and capabilities of the Carrie Bow Cay Field Station and produce important information that will be applied to habitat management in the newly formed SWCMR no-take area.

In 2019, Dr. Seabird McKeon was assisted by a small group of undergraduate students from the St. Mary’s College of Maryland. The group visited Carrie Bow Cay to learn field methods and conduct original research in reef biology and ecology, with a particular emphasis on herbivory by crustaceans. The students visited examples of seagrass beds, mangrove forests, and coral reefs. In reef environments, they learned survey methods including transects, quadrats, and towboard surveys. They also benefited from the presence of other visiting researchers in learning about complex marine symbioses and were able to assist the visiting station managers in offering informative tours of the island when they were not actively doing research.

Our primary observational experiment surveyed the relative abundance of herbivorous crabs living in the protection of Stichodactyla helianthus sea anemones. The banded anemone crab Mithraculus cinctimanus, and its relatives M. sculptus and M. coryphe graze on algae around anemones and stay near the shelter the anemones provide, creating a ‘halo’ of herbivory in the immediate proximity of the anemone that inhibits algal overgrowth. The small shrimps Thor amboinensis and Periclimenes rathbunae are also found under the shelter of S. helianthus anemones. We surveyed the abundance of these crabs and the size and density of algae within and outside of their grazing zones.

We used circular tiles to enclose 3g of Dictyota cf. menstrualis algae using mesh. At ten individual anemones, we attached one tile within and one tile outside of the established grazing zone. On the final day of our stay we removed the chips and weighed the algae. This information will be used with previous work to evaluate the role of crustacean herbivores in controlling algal overgrowth on Belizean reefs. Future efforts will use similar experiments over a longer period of time and refine the method of algal attachment.

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