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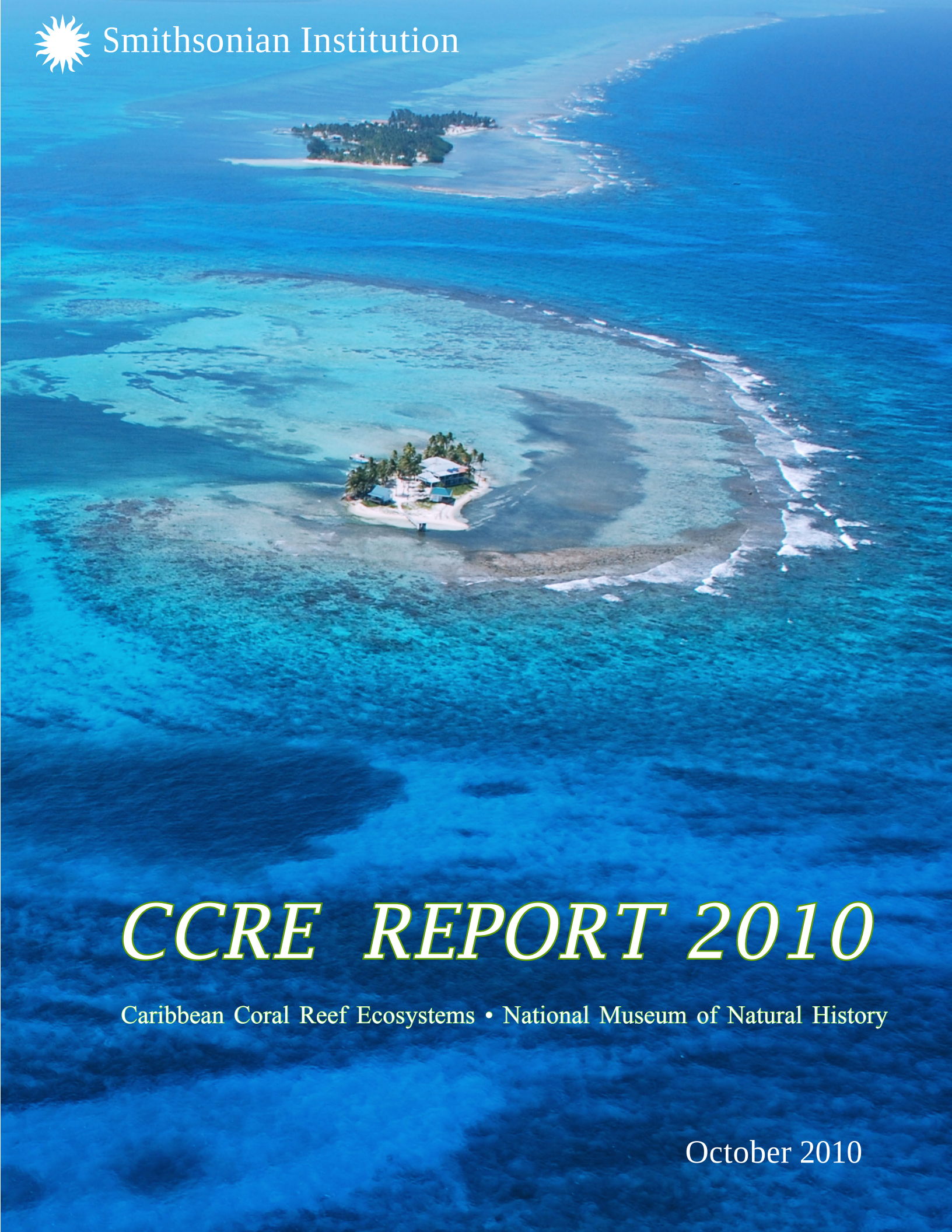


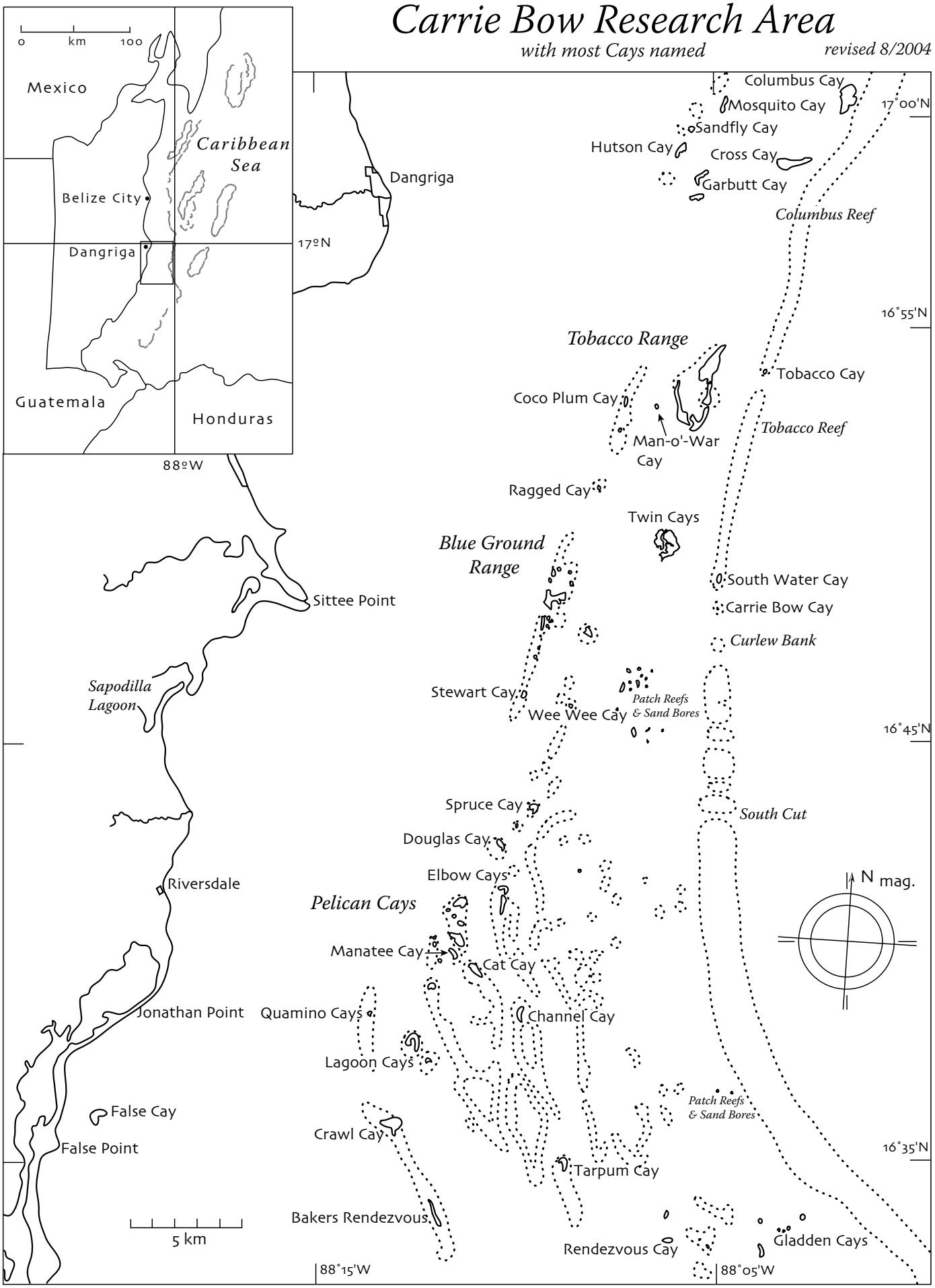
CCRE REPORT 2010

Caribbean Coral Reef Ecosystems • National Museum of Natural History

October 2010

Carrie Bow Research Area

with most Cays named *revised 8/2004*



Smithsonian Institution

CCRE ANNUAL REPORT

2010

Smithsonian Marine Station at Fort Pierce
Caribbean Coral Reef Ecosystems Program
Fort Pierce, FL 34949

October 2010

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CCRE News 2010

It was an exciting year for the Caribbean Coral Reef Ecosystems (CCRE) program under the direction of a new management team. Valerie Paul took over as CCRE Director in October 2009 and was joined by Station Manager Zachary Foltz in December and Program Coordinator Scott Jones in February 2010. Despite the administrative transition, scientific activities at the Carrie Bow Cay field station did not slow down, as over 60 scientists visited the station, in addition to station managers, photographers, and one author. Numerous groups of students, teachers, and tourists visited as well, and were treated to tours and demonstrations by station managers and visiting researchers. Notable guests included U.S. Ambassador Vinai Thummalapally and five others from the U.S. Embassy in Belize on August 30, 2010. This distinguished group was greeted at Carrie Bow Cay by Valerie Paul, Zachary Foltz, Melanie McField, and Therese Rath (owner of the island), after which they toured the research facilities and snorkelled on the reef. The ambassador's visit presented a valuable opportunity to discuss the variety of conservation issues facing the barrier reef and the value of the research conducted at Carrie Bow Cay. Klaus Ruetzler and Michael Carpenter left big shoes to fill- and the current team is working hard to continue their tradition of excellence.

Carrie Bow Cay was in good working order when Zach Foltz assumed his role as station manager, but a few projects became necessary, as is the case with any field station. Internet access was installed, the security systems and safety lighting on the dock and the boats were significantly improved, a replacement engine was installed on the air compressor, and the exterior surfaces of the main laboratory building are being repainted. Additionally, changes are underway to improve the electrical systems on the island: a new diesel generator is on order and should be installed sometime in November or December, a new inverter was installed on the battery bank, and a solar power consultant was brought onboard to help improve the output and efficiency of the solar system.

The Carrie Bow Cay Field Station has already contributed to, and will continue to play an important role in the Smithsonian Institution's 2010-2015 Strategic Plan. Research and outreach activities at Carrie Bow Cay are especially important for addressing the Grand Challenge of Understanding and Sustaining a Biodiverse Planet and also contribute to the Grand Challenge of Valuing World Cultures. Through research activities the CCRE program can address important questions about biodiversity, systematics and ecology of coral reef ecosystems. The new protected status of the reefs and associated habitats around the island will allow direct monitoring of the impacts of human activities on these important marine ecosystems. The Carrie Bow Cay Field Station should play an important role in the new effort to develop MarineGEO - the pan-institutional initiative on marine sciences. The goal of MarineGEO, to Understand Global Marine Biodiversity and its Relationship to Climate Change and Human Interactions, encompasses many of the ongoing research activities of the CCRE Program. Through outreach activities, the program makes contact with numerous tourists, students, and other visitors to the island, works closely with Belize fisheries staff, and trains graduate students and interns who conduct field research on coral reef ecosystems.

Flashbacks

1971 • National Museum of Natural History's I.G. Macintyre (geology & sedimentology), W. Adey, P. Kier, T. Waller (paleobiology), A. Dahl (botany), A. Antonius (postdoctoral fellow, invertebrate zoology), M. Rice, and K. Ruetzler (invertebrate zoology) found the program Investigations of Marine Shallow Water Ecosystems (IMSWE).

1972 • IMSWE search party identifies Carrie Bow Cay on the barrier reef of Belize as ideally located and affordable site for long-term, collaborative field research on tropical coastal ecosystems
• Establishment of principal reference transect across the Belize barrier reef just north of Carrie Bow Cay

1974 • Hurricane Fifi destroys laboratory structures, uproots coconut trees, and reduces the surface area of Carrie Bow Cay by about one third, to 0.4 hectare.

1975 • EXXON Corporation provides grant for study of the coral reef ecosystem at Carrie Bow Cay.
• Marine and terrestrial post-hurricane surveys.• Establishment of all-manual meteorological station.

1976 • Refinement and calibration of profiles and maps with the aid of vertical aerial photographs taken by Royal Signals Detachment helicopter • Introduction of aerial photography by helium balloon for community mapping
• Submersible tide recorder installed at Carrie Bow Cay concrete dock.

1977 • Field trip to Carrie Bow Cay by participants of the Third International Coral Reef Symposium.• Aerial and underwater surveys expanded to cover the entire barrier reef of Belize • Geology team drills first cores to determine reef history • EXXON's The Lamp publishes article on company-sponsored research at Carrie Bow Cay ("Where seaworms glow..").

1978 • Hurricane Greta destroys Carrie Bow Cay field station.

1979 • Post-hurricane survey and rebuilding of laboratory with several improvements • Count of participating scientists and of published scientific contributions both pass the 50 mark; 23 scientific institutions are now collaborating with NMNH.

1980 • EXXON Corporation funds new initiative: comprehensive study of a western Atlantic mangrove swamp ecosystem, now known as SWAMP (Smithsonian Western Atlantic Mangrove Program)
• Mapping of Twin Cays, principal site of SWAMP, by aerial photography and ground truthing.

1981 • Initiation of Art in a SWAMP project where scientific illustrators and scientists collaborate in analysis and pictorial rendition of mangrove communities in time and space • Employment of H. Edgerton underwater time-lapse camera with strobe light (on loan from the inventor) to record day-night activity in benthic communities
• Vibracoring at Twin Cays to determine internal structure and development.

1982 • Publication of The Atlantic Barrier Reef Ecosystem at Carrie Bow Cay, Belize, 1: Structure and Communities. Smithsonian Institution Press (K. Ruetzler & I.G. Macintyre, eds.).

1983 • New weather protected and enlarged seawater system for laboratory experiments installed on Carrie Bow Cay • Series of extremely low tides at noon time were observed to have catastrophic effects on reef and mangrove organisms.

1984 • First automated weather station installed at Twin Cays • Cooperation with Belize Government identifying coastal marine areas suitable for natural resource conservation • Busiest year since program start: 8 months continuing laboratory operation for 45 research staff.

1985 • First year of operation of Caribbean Coral Reef Ecosystems (CCRE), a new program of the National Museum of Natural History. It replaces the old IMSWE project and supplements the ongoing SWAMP program which is supported by a renewed annual grant by the EXXON Corporation.

1986 • Renovations on Carrie Bow Cay to accommodate dry-laboratory space, added living quarters, and boat, diving, and laboratory equipment • Mangrove vegetation map for Twin Cays completed • Published scientific contributions pass the number 200.

1987 • Record visitation of Carrie Bow laboratory, 120 total: 90 scientists and assistants; others dignitaries, including the Prime Minister of Belize, Smithsonian administrators, and media people working on documentaries and news-related productions • Continued facility renovation, including addition of solar photovoltaic system, large seawater tank, two fiberglass whalers, fluorescence microscope, and time-lapse video recorder with underwater camcorder.

1988 • Mangrove workshop for 37 EXXON-SWAMP scientists at Solomons, Maryland, entitled A Mangrove Ecosystem: Twin Cays, Belize.

1989 • Science as Art exhibit at the Smithsonian's S. Dillon Ripley Center displays scientifically important and aesthetically pleasing products from SWAMP mangrove research, such as community drawings, paintings, photographs, and sculpture-like epoxy casts of soft-bottom animal burrows • Vandalized and malfunctioning weather station reconditioned and relocated to the Carrie Bow field laboratory • Increasing problems with anthropogenic stresses at research sites, such as heavy tourist visitation, garbage dumping, and clear-cutting mangrove trees.

1990 • CCRE-SWAMP program represented at first Caribbean Coastal Marine Productivity workshop, Jamaica, CARICOMP is a program for Caribbean-wide monitoring of environmental quality in reefs, mangroves, and seagrass meadows.

1991 • Belize Forestry Department helps stopping disturbances to SWAMP research sites. Belize Department of Natural Resources reviews legislation with intention of declaring Carrie Bow Cay - Twin Cays area protected research site • CCRE-SWAMP program staff participates in developing Belize Tropical Forestry Action Plan and helps designing Institute for Ecology to be based in Belmopan.

1992 • CCRE-SWAMP researchers produce video documentary on mangrove swamp biology • Unprecedented, severe problem with hydrozoan stings to snorkelers and divers in the Carrie Bow area traced to microscopic siphonophorans • CCRE-SWAMP staff and Belize Fisheries Department and Agriculture representatives conduct first workshop for Belize high-school teachers entitled Mangrove Conservation through Education • CCRE-SWAMP lecture series started in Belize City, co-hosted by Belize Audubon Society • CCRE officially joins the CARICOMP network and initiates monitoring program.

1993 • Belize Ministry of Natural Resources grants rights to Twin Cays for mangrove research • Launching of new 8 m (25 ft) research vessel Physalia, funded by a grant from the U. S. National Science Foundation, extends research radius over most of central and southern Belize • Ivan Goodbody pioneers surveys of Pelican Cays, a tunicate heaven at SSW of Carrie Bow.

1994 • Start of collaborative surveys and experimental projects in the Pelican Cays • Pelican Cays workshop, co-hosted by Candy Feller (SERC), at Edgewater, Maryland.

1995 • Finalized lease with the Villanuevas of Placentia to southern portion of Northeast Cay, Pelican group, to establish a field base for future studies • Malcolm Spaulding develops plans for new integrated environmental sensing system with radio- telemetry link to the University of Rhode Island's COASTMAP network.

1996 • Installation by Tom Opishinski of self-contained Endeco-YSI-Campbell monitoring station of meteorological and oceanographic parameters and hookup to Internet • Visit of field party from 8th International Coral Reef Symposium, Panamá.

1997 • Celebration of the 25th birthday of the Carrie Bow Marine Field Station • New U. S. National Science Foundation grant allows purchase of a second 8-m (25 ft) boat to back up the heavily used Physalia (under construction) • International team of seven expert systematists conducts workshop at Carrie Bow Cay to quantify the unusually high sponge diversity of the Pelican Cays • Number 500 reached in CCRE scientific contributions • Carrie Bow Field Station, including laboratories, weather station, kitchen, and living quarters is consumed by an accidental electrical fire which was apparently sparked by a short in the wiring and aided by dry, termite-riddled lumber and strong northerly winds. Luckily, no-one was hurt.

1998 • Island clean-up and design for new field station completed. Construction work initiated but delayed by flooding and coastal erosion from hurricane Mitch • Completed editorial work on CD-ROM containing over 100 representative CCRE scientific papers that resulted from research at Carrie Bow Cay • Cosponsored Smithsonian (STRI) exhibit Our Reefs –Caribbean Connections in Belize City. Contributed large poster describing 25 years of CCRE coral reef research in Belize • Serious coral bleaching and die-off on reefs off Carrie Bow and Pelican Cays observed, partly caused by hurricane Mitch.

1999 • Rededication ceremony for the new Carrie Bow Marine Field Station, in August • BBC team (Bristol, UK) films segments for its Blue Planet TV series, including (with E. Duffy) eusocial shrimps living in sponges.

2000 • Publication of Natural History of Pelican Cays, Belize, in Atoll Research Bulletin (Macintyre & Ruetzler, eds, 2000) • Replacement of environmental monitoring station lost in the 1997 fire • Initiation of Twin Cays Biocomplexity Study funded by an NSF grant (to I. Feller & colleagues).

2001 • Completion of 3-room cottage over the eastern shore of Carrie Bow Cay • Hurricanes Michelle and Iris (October) barely miss Carrie Bow Cay, causing some damage to buildings and heavy beach erosion and devastate

(Iris, in particular) large areas in southern Belize • Signing of MoU with Belize Fisheries Department officially acknowledging the Carrie Bow Marine Field Station as a nationally recognized laboratory • Publication of Golden (50-year anniversary) issue of Atoll Research Bulletin recognizing prominent coral reef scientists through their autobiographies, several of them participants in the CCRE Program.

2002 • Founding of the Smithsonian Marine Science Network (MSN), incorporating the CCRE Program and the Carrie Bow Marine Field Station • Number 600 reached of CCRE scientific contributions • Ranger Station established on southeast Twin Cays by Belize Fisheries Department to oversee South Water Cay Marine Reserve.

2003 • Cristián Samper, recently appointed director of the Smithsonian's Natural History Museum, visits the Carrie Bow station in July, dives on the barrier reef, and snorkels in mangroves habitats • Hurricane Claudette threatens Carrie Bow (July) and necessitates temporary evacuation • Smithsonian Secretary Larry Small visits the Carrie Bow lab in December and dives on the reefs • Twin Cays Mangrove Biodiversity Conference is held at Ft. Pierce, Florida (December), convened by Klaus Ruetzler, Ilka Feller, and Ian Macintyre, and cosponsored by Valerie Paul of the Smithsonian Marine Station at Ft. Pierce.

2004 • CCRE Postdoctoral Fellowship established • Hurricane Ivan causes substantial coastal erosion of Carrie Bow Cay • Atoll Research Bulletin volume dedicated to Twin Cays Mangrove Biodiversity goes to press • Number 700 reached of CCRE scientific contributions • Carla Dietrich takes over from Michelle Nestlerode as CCRE research assistant • Addendum to MoU with Belize Fisheries Department signed, clarifying intellectual property rights and issues of bioprospecting sponges in particular • CCRE Program Administrator Marsha Sitnik (recently, administrative advisor) retires.

2005 • A total of 13 hurricanes formed this season. Three category five hurricanes (Katrina, Rita and Wilma) caused substantial coastal erosion and damage to the Carrie Bow facilities. The record number of 25 named storms in the Caribbean broke the previous record (from 1933) of 21 named storms • An external scientific review of the CCRE Program was conducted and resulted in a strong endorsement of the program's mission and accom plishments • Over 50 new CCRE scientific contributions were published.

2006 • The first Belize National Marine Science Symposium, cosponsored by Belize Fisheries and Forestry departments and the Hugh Parkey Foundation, took place and CCRE was represented with 4 talks and 8 posters, including a review of 35 years of Smithsonian Marine Science in Belize • CCRE hosted the U. S. Ambassador and 35 Embassy staff for a picnic, including a tour of the Carrie Bow lab facilities • More than 130 Smithsonian Asociates, North Carolina teachers, and members of the Sierra Club visited Carrie Bow for guided tours of facilties and ongoing projects • A film crew for a Discovery channel in The Netherlands worked at Carrie Bow to document Gordon Hendler's work on newly discovered brittle-star light-sensing organs • The CCRE program and the Carrie Bow Marine Field Station, along with all other Smithsonian marine programs and facilities, took part in an external review ordered by the Smithsonian Undersecretary for Science; The efficiency and scientific productivity of the program and its field station received excellent marks.

2007 • Hurricane Dean strikes Northern Belize and Yucatan, Mexico (August), Felix passed over Honduras south of Belize (September); both cause major beach erosion at Carrie Bow Cay but no damage to buildings.

2008 • The Belize Minister of Natural Resources and his staff visit our facilities and tour the Pelican Cays to view damage caused my mangrove clear-cutting in this part of the Southwater Cay Marine Reserve.

2009 • Ilka "Candy" Feller was again offered use of Light Hawk, a volunteer pilot-based organization at Lander, WY, to observe and photograph environmental damage to mangrove coast and cays. •Proceedings of the first Smithsonian Marine Science Symposium highlight CCRE's diverse contributions to knowledge of the biology and geology of the Mesoamerican Barrier Reef, Belize •Mike Carpenter retired after 25 years of service as CCRE Operations Manager and will build a new home in the woods of Georgia •Klaus Ruetzler resigned as CCRE Director after 25 years in this position (and a total 37 years as leader of the IMSWE, SWAMP, and CCRE programs). He will be followed by Valerie Paul of SMSFP.

2010 • Director Valerie Paul and new staff at Fort Pierce assume responsibility for CCRE • Michael Carpenter, Zach Foltz, and Woody Lee spend three weeks on Carrie Bow Cay, for training and transition • A new CCRE website is launched: www.ccre.si.edu • U.S. Ambassador Vinai Thummalapally and five others from the U.S. Embassy in Belize visit Carrie Bow Cay on August 30, 2010 • Belize Fisheries establishes the South Water Caye Marine Reserve, with a no-take zone encompassing the area around Carrie Bow Cay (www.swcmr.org).

Acknowledgements

Our research is hosted by the Belize Fisheries Department and we thank Ms. Beverly Wade and Mr. James Azueta and staff for collaboration and issuing permits. The owners and staff of Pelican Beach Resort in Dangriga provided logistical support for our fieldwork.; Earl David and his fine staff provided boat transportation as well invaluable advice and support.

Numerous volunteer managers helped run the field station and assisted in research activities; we greatly appreciate their many efforts: Jerry and Sandy Alanko, Mike Carpenter, Danny Gouge and Cheryl Thacker, Ed and Bonnie James, Dan Miller and Claudette DeCourley, Joel and Linda Moore, Keith Parsons, Gary Peresta, Tom Pezzella, Craig Sherwood.

Back in Fort Pierce, we sincerely thank Joan Kaminski for administrative advice and assistance with many fund management tasks. The Smithsonian Marine Station's Dive Safety Officer, Sherry Reed was a huge help with scientific diving.

In Washington, Klaus Reutzler and Mike Carpenter were always willing to share wisdom stemming from their many years of experience in Belize. Michael Lang and Laurie Penland supervised scientific diving at Carrie Bow Cay Field Station. Marty Joynt was always available to answer our many questions. We also thank the Smithsonian offices of the Undersecretary for Science and the Director of National Museum of Natural History for continued support.

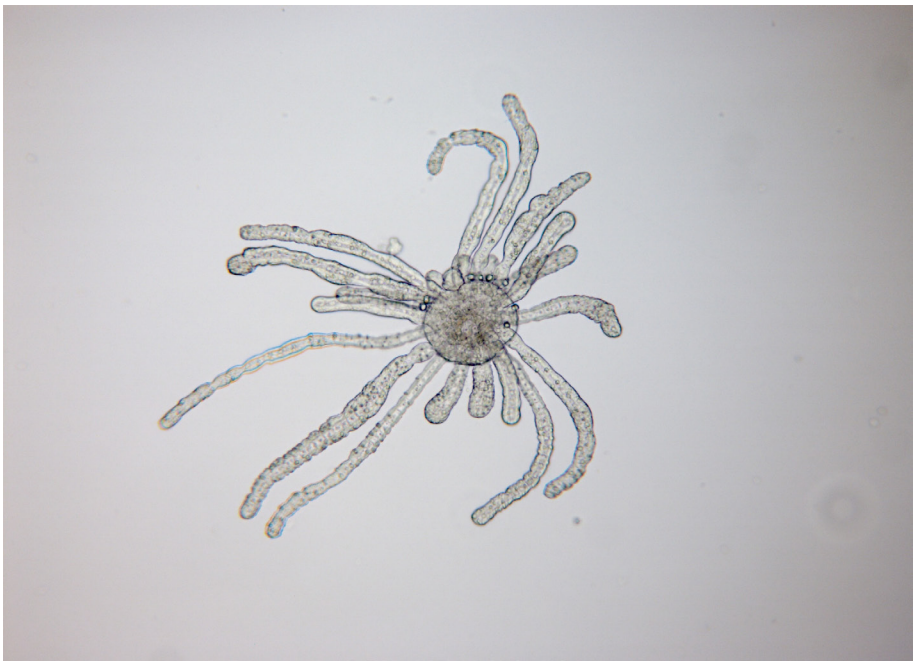
The CCRE program is supported by Federal funding complemented by the Hunterdon Oceanographic Research Fund.

Biodiversity and its Links to the Ecosystem

Meiofauna - Tiny animals take on big questions in marine biogeography

J. Norenburg, R. Hochberg, A. Smythe, A. de Jesus Navarrete, K. Warsaae, K. Jörger

An elite team of six meiofauna experts (USA: Jon Norenburg, Ashleigh Smythe, Rick Hochberg; Mexico: Alberto de Jesus Navarrete; Denmark: Katrine Worsaae; Germany: Katharina Jörger) and two volunteer divers (Daniel Gouge, Cheryl Thacker) occupied Carrie Bow Cay, Belize, for two weeks in January in a quest to document, DNA-barcode and voucher this much understudied but phyletically diverse fauna of marine sands. "Meiofauna" refers to a group of microscopic (0.063 - 0.500 mm), motile fauna that commonly occupy the space in between aquatic sediment particles (interstices). Such a coordinated field project covering a wide range of meiofauna diversity is in itself a rare, perhaps unique, event in the last 30 years. All participants declared the expedition not only a success, but a career highlight. Though this field project, led by Jon Norenburg, benefitted everyone's individual research on their respective favorite phyla, what brought everyone together is a novel group project initiated by Norenburg - biogeography of meiofauna based on coordinated genetic sampling of hundreds of taxa representing most of the animal phyla present in the meiofauna. In fact, this was the first of three marine meiofauna workshops and netted 200+ taxa, representing 13 phyla, to launch the Latin America Meiofauna Project (LAMP), which will hopefully light the way to greater understanding of meiofauna and more global coordinated study of it. The molecular work for the project is funded largely by a grant from the Consortium for the Barcode of Life to Smithsonian's Laboratory for Analytical Biology.

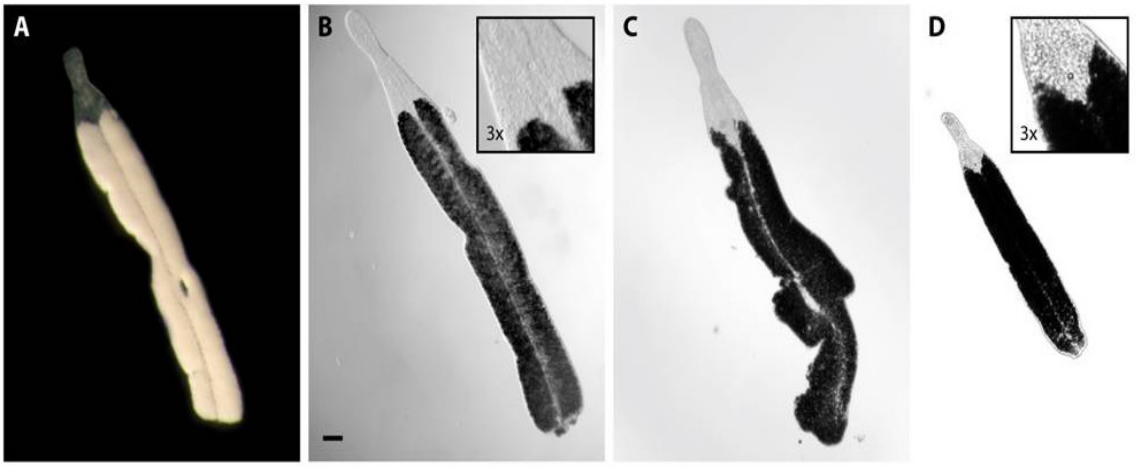


Halammohyrda sp., an interstitial cnidarian collected at Carrie Bow Cay.

Ophyrotrocha sp., an interstitial annelid.

Whereas cryptic species now are well-known as potentially confounding phenomena in most studies of biodiversity, the problem is magnified for meiofauna because of small size, morphological simplicity, miniaturization and convergence. However, the other side of the coin is that hundreds of taxa can be obtained with just a few small, environmentally non-destructive samples, the habitat is relatively easily characterized, and most of the animals share important aspects of life history (such as generation time, low fecundity, and "direct" development). Comparative analysis of DNA sequence data, starting with DNA-barcode genes (which differ among the phyla), can bypass the

problem of comparing long species lists that lack unambiguous morphological criteria to assess the degree of correspondence between listed species (which also may represent multiple cryptic species). For meiofauna these lists are likely to include many undescribed species, and in comparison to non-meiofauna even fewer specialists are available to do the detailed morphological discrimination and descriptions of sampled species. Thus, DNA sequence data provides a temporal tactical advantage in permitting analysis of hundreds of taxa for comparative studies of diversity and biogeography without getting bogged down in alpha-taxonomy. Nevertheless, experience in Belize demonstrated the advantage of experts for sampling knowledgeably the available diversity, while reciprocally providing these experts access to interesting specimens. Furthermore, increased relevance of the collected specimens provides incentive to describe the fauna. The Carrie Bow Cay and future Bocas del Toro expeditions provide the project an intra-Caribbean comparison, which will be followed by a Panamanian trans-isthmian comparison with the addition of a Pacific workshop. In addition to adding hundreds of data points to current hypotheses of marine biogeography across the Panamanian isthmus, this project could provide the first robust geological calibration for evaluating genetic divergence within marine meiofauna, which has been an intractable problem until now.



Paracatenila galateia n. sp. Micrographs of live specimens, all at same scale, scale bar indicates 100 micron. A. Incident light showing smooth silky-white appearance of trophosome. B. Transmitted light showing characteristic shape of extended rostrum and dorsal chord. C. Specimen with irregular outline and constriction. D. Small (juvenile?) specimen.

Paracatenula galateia n. sp. (Platyhelminthes: Catenulida: Retronectidae) from Belize (Central America)

J. Ott and H. Gruber

Flatworms of the genus *Paracatenula* Sterrer and Rieger 1974 (Catenulida, Platyhelminthes) are part of the interstitial meiofauna living in the oxic-anoxic interface of shallow water subtidal sands surrounding Carrie Bow Cay. Adult *Paracatenula* lack a mouth and a gut lumen. Instead, a parenchymatic "trophosome" that appears white in incident light due to sulfur storage of the intracellular bacteria fills most of the body.

A wide variety of different species was discovered in surveys in the vicinity of Carrie Bow Cay field station, Belize Barrier Reef, measuring from 0.4mm to 6mm in length. A large, conspicuous new species frequently found in sub-tidal sands close to the field station is currently subject to intensive studies of its biology and ecology (see also Ott and Dirks, this report). *Paracatenula galateia* is a ribbon-shaped *Paracatenula* up to 6 mm long and up to 320µm wide, with or without a statocyst in the rostrum. It is dorsoventrally flattened and has inclusions with dumbbell shaped bipartite structure, 10-14 µm long and 3 µm wide that may be interpreted as sperm. Phylogenetic analysis based on a concatenated alignment of 18S and 28S rRNA genes from *Paracatenula galateia* and selected *Catenulida* as well as *Macrostomida* shows that (1) all sequences from the genus *Paracatenula* form one clade within the *Catenulida* (2) Sequences from *P. galateia* form a highly supported and well separated cluster within the genus meriting the designation of a new species and (3) there is no separation of sequences from individuals with statocyst to individuals without statocyst, showing that all specimens studied belong to the same species.

Evolutionary Processes

Pairing dynamics and the origin of species

O. Puebla and E. Bermingham

Indigo Hamlets, *Hypolectrus indigo*, with colorful elastomer tag in caudal fin.

All species are the end-product of speciation, the evolution of reproductive isolation between previously interbreeding populations. In the presence of gene flow between diverging populations (in sympatry or parapatry), the evolution of assortative mating constitutes a key component of this process. One overlooked theoretical situation leading to the evolution of assortative mating in the presence of gene flow is provided by pairing dynamics in a context of mutual mate choice. More precisely, theoreticians have claimed that when mate choice is mutual and the stability of mating pairs confers a reproductive advantage, the evolution of assortative mating in the presence of gene flow is not only possible, but a robust outcome. The hamlets (*Hypoplectrus* spp., Serranidae), simultaneously hermaphroditic coral reef fishes of the wider Caribbean, provide an unparalleled opportunity to investigate this potential speciation mechanism empirically. In order to study their pairing dynamics (i.e. the dynamics of the formation and dissolution of mating pairs), more than 50 hamlets have been captured in the spur and groove reef off Carrie Bow Cay, photographed, fin clipped, tagged with Visible Implant Elastomer, released and observed during spawning. The behavioral data is being complemented with genetic analyses and individual-based simulations at the Smithsonian Tropical Research Institute in Panama.

Reproduction and Development

The stem cells of *Paracatenula galateia*

J. Ott & U. Dirks

Flatworms of the genus *Paracatenula* Sterrer and Rieger 1974 (Catenulida, Platyhelminthes) are part of the interstitial meiofauna at the oxic-anoxic interface in shallow water subtidal sands of tropical to warm temperate oceans. Adult *Paracatenula* lack a mouth and a gut lumen. Instead, a parenchymatic "trophosome" containing monospecific intracellular bacteria fills most of the body. The cells harbouring the symbionts are called "bacteriocytes".

Based on the results from extensive sampling on the *Paracatenula* diversity in the vicinity of Carrie Bow Cay field station in 2008 and 2009, we were now able

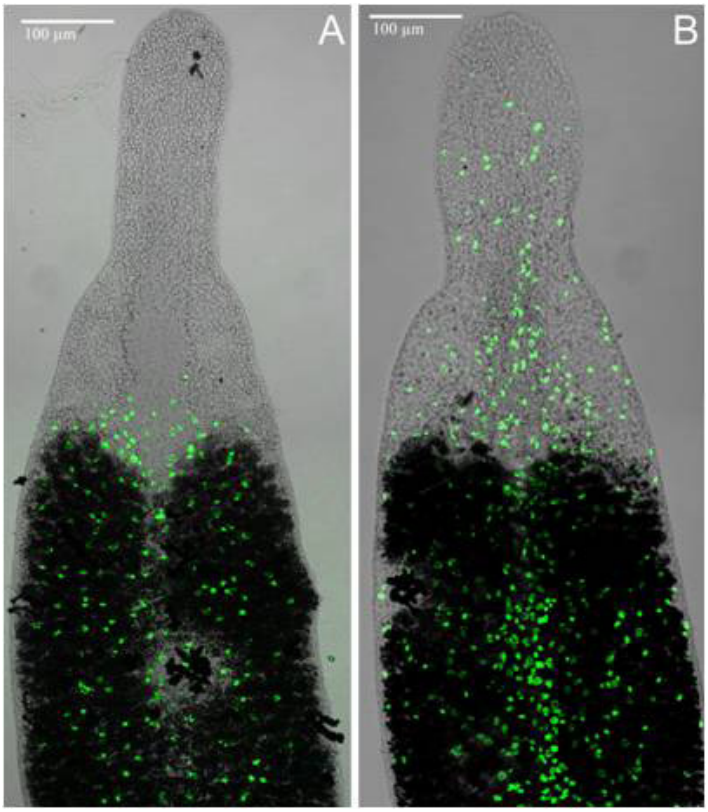


Fig. 1. Stem cell distribution and migration in P. galateia A: Distribution of S-phase neoblasts after 30 min EdU pulse (green). B: Distribution of S-phase neoblasts after 30 min EdU pulse and 96h chase.

to collect large amounts of ones species called *P. galateia* (see Progress Report Ott & Gruber this report) that was found to be the best suited for our experimental approaches.

Flatworms are characterized by an outstanding stem cell system. These stem cells (the neoblasts) can give rise to all cell types including the germ line for the whole life-span. Additionally they are the key component of the exceptional regenerative capacity of many flatworm species. Because neoblasts are the only dividing cells in flatworms, they can be specifically labelled by different nucleotide substitutions that replace thymidine with uridine during S phase of the cell cycle. In 2010 we incubated and labeled *P. galateia* with the thymidine analog EdU (5-ethynyl-2'deoxyuridine). After pulse or pulse-chase incubations the animals were fixed and the different label was stained with fluorescent dye.

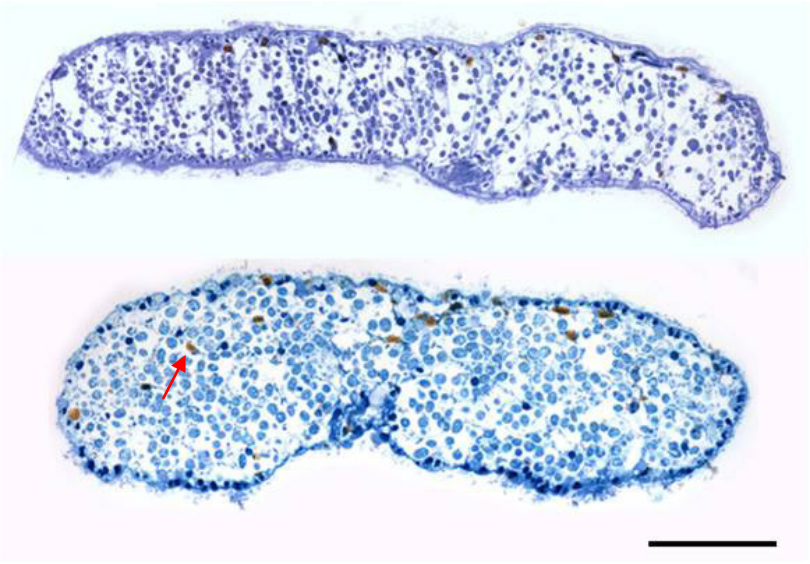


Fig. 2: Cross section of BrdU labelled *P. galateia* LR-white cross section of *P. galateia* with 30 min BrdU pulse (top) and 30 min BrdU pulse followed by an 168h chase (bottom). The BrdU label was stained with HRP-coupled antibody followed by tyramide deposition (brown). The blue background is due to a methylenblue staining. Red arrow points to labelled bateriocyte nucleus.

From the experiments performed on Carrie Bow Cay in 2010 we learned a lot about origin and fate of neoblasts. Like in all other flatworms studied so far *P.galateia* shows no S phase cells in the most anterior body region (the rostrum) after a 30 min EdU pulse. Proliferation is absolutely restricted to the posterior body region where we find them to be evenly distributed in subepidermal positions (fig.1A, 2, top). To study the fate of the labelled cells we then performed pulse chase experiments. We first applied a 30 min EdU pulse to the animals, then washed the EdU away and kept the animals for 96 h in seawater (chase) followed by FA fixation. Analysis of the fluorescent staining of these animals showed that the labelled cells could now be found everywhere in the rostrum. We also investigated the position and the migration of labelled cells on cross sections through the trophosome region. What we found here was a migration of cells in a distal-proximal direction as well as and integration of labelled cells into the epidermis (fig.2). We even were able to find bacteriocytes with a labelled nucleus (Fig.2, bottom) and labelled muscle cells.

In the on-going work on the Carrie Bow samples we are also addressing questions concerning the regenerative power of *P. galateia*. Our first results show a very high capability of regeneration. When decapitating specimens of *P. galateia* with a razor blade the worms are able to rebuild the complete head region (rostrum) within a few days. Currently we are trying to understand the cellular processes of the head regeneration and especially the role of the neoblast stem cells. Since a cultivation of these conspicuous animals is not possible yet, we are looking forward to a return to Carrie Bow Cay to do more research on *Paracatenula*.

Reproductive isolation and hybridization dynamics in threatened Caribbean Acroporid corals

N.D. Fogarty

The Caribbean corals, *Acropora palmata* and *A. cervicornis*, are abundant in fossil records but have recently undergone drastic declines, primarily as a result of disease. *Acropora prolifera*, a hybrid of these species, has no fossil record and was previously considered rare and to occupy nonparental habitats. Now, hybrids have equivalent or greater abundance than the parental species and have expanded into the parental habitat at some sites. Previous molecular studies have demonstrated regional variability in unidirectional introgression of *A. palmata* genes into *A. cervicornis*. The goals of this study were (1) to determine the strength of prezygotic mechanisms and to establish the likelihood of density dependent reproductive isolation, (2) to determine the strength of intrinsic and extrinsic postzygotic barriers, and (3) to ascertain if hybrid populations are composed of rare hybridization events that have asexually fragmented, or if colonies are genotypically distinct suggesting separate hybrid events.

Carribean acroporid corals, Left to Right: *Acropora palmata*, *Acropora prolifera, Acropora cervicornis*

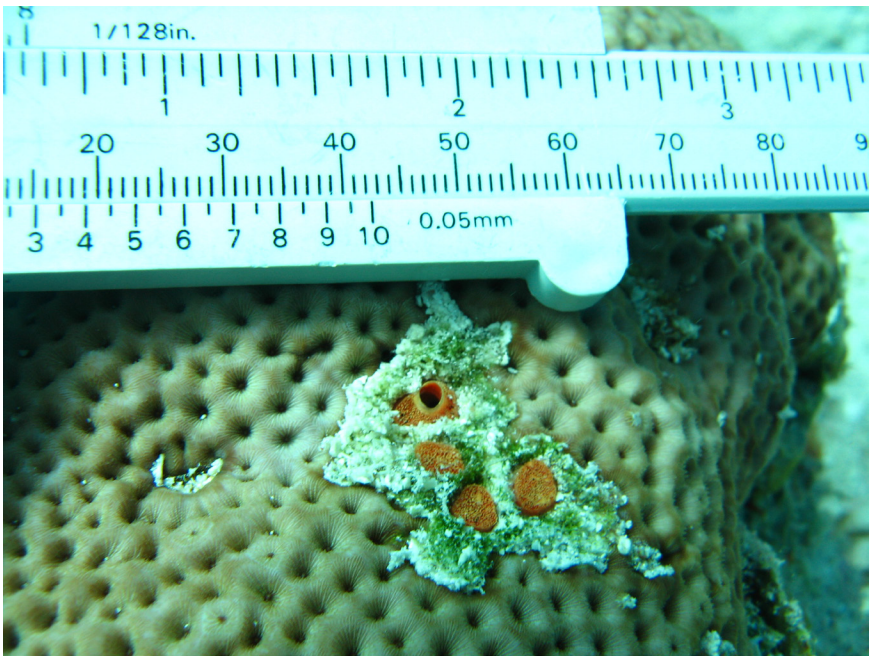
Overall barriers to hybridization in this genus are weak, and the efficacy of these semipermeable isolating mechanisms may depend on density. In addition, hybrids are as viable as the parental species at a variety of life history stages (i.e. larval, settlement, early post-settlement, and adult) and are less or equally susceptible to the typical afflictions, such as disease, predation, parasitism, bleaching, and overgrowth, that has led to their decline. Most hybrid populations are not composed of one genet, suggestive of a rare hybridization event that has asexually propagated, but rather the genotypic diversity varies across sites with up to 17 different distinct genets in one population. Taken together, it appears that hybridization in a threatened Caribbean genus is evolutionarily significant with a range of possible outcomes from the benefit of novel alleles to the swamping of *A. cervicornis'* genome. These outcomes may hinge on the ability of the Caribbean acroporids to withstand the onslaught of threats that this genus currently faces (i.e. Allee Effect, disease, predation, increased sea temperature, ocean acidification, and increased disturbances).

Ecology, Population Dynamics, and Ecophysiology

Increase of excavating sponges on Caribbean coral reefs: recruitment and dispersal

A. Chaves-Fonnegra

In the last three decades coral reef ecosystems have been deteriorating as a result of overfishing, pollution and climate change (Hughes et al., 2003). The most critical result of climate change is an increased frequency of coral bleaching and disease in corals (Glynn, 1993;



New *Cliona delithrix* recruits on a *Siderastrea siderea* colony.

Hoegh-Guldberg, 1999) and other marine organisms (Harvell et al., 1999; Lafferty et al., 2004). Increases of about 1°C in sea temperature have produced mass coral bleaching and death of coral reefs in most marine tropical areas (Hoegh-Guldberg, 1999). Because corals are able to adapt to and survive limited temperature increases, some recovery from bleaching has been observed (West and Salm, 2003). However, most evidence suggests that climate change has exceeded the ability of corals to acclimate, and that reefs around the world will continue to decline (Gardner et al., 2003). Thus, reef ecosystems are facing dramatic changes.

Andia Chaves-Fonnegra recording data at Carrie Bow Cay.

Encrusting excavating sponges clearly are gaining space and their populations are increasing as reef corals decline, and may be sometimes partially responsible for their demise in direct (Schönberg and Wilkinson, 2001; Rutzler, 2002; López-Victoria et al., 2006, Chaves-Fonnegra and Zea, Submitted) or indirect competitive interactions (Márquez, 2005). Indeed, even though with less and less corals, direct competitive interactions may become less frequent, when they occur they are usually resolved in favor of the sponges. Thus, understanding the population dynamics of excavating sponges may be a valuable tool for predicting their expansion on currently deteriorating coral reefs. It will also help to determine impacts on a non-coralline species that are directly dependent on coral ecosystem and that also are exposed to current human-induced changes. The aim of this research is to understand the current increase of encrusting excavating sponges on Caribbean coral reefs. The specific objectives in Belize were: 1) to determine current recruitment and abundance of the excavating sponge *Cliona delitrix* near Carrie Bow through field ecology methods; 2) to collect samples of *Cliona delitrix* with the aim to determine levels of genetic connectivity and dispersal on a broad scale, across Caribbean populations using microsatellite DNA methods.

The current amount of sponge abundance and sponge recruits was quantified in two areas (barrier reef and patch reef). A total of 4 transects, each of $40m^{2,}$ was placed using a measuring tape and a 1m pvc tube (non permanent transects) in each area. Recruits, substrate type, live and dead coral cover and *Cliona delitrix* cover were recorded in each transect. Cover of *C. delitrix* was less than 0.7% in both areas. The density of individuals was 0.27 individuals • m^{-2}, similar to Grand Cayman: 0.23 individuals • m^{-2} (Rose and Risk, 1985), and lower than in San Andrés Island: 0.54 individuals • m^{-2} (Chaves-Fonnegra et al., 2007). However, the average size (max diameter) was lower (2.4cm) than in other areas (San Andrés Island, Colombia: 7 different stations 20.6-37.4cm). A total of 74 individuals, equal or less than 5 cm, were considered recruits. However, these recruits probably come from both *Cliona laticavicola* and *Cliona delitrix* species. Color, shape and growth is similar in early stages for both species, and also between *C. delitrix* recruits and *Cliona laticavicola* adults. Also, spicules are similar

and differentiation in early stages has not been studied. On the patch reef, *Cliona delitrix* was found in a greater proportion on dead thick skeletons of *Agaricia spp*. covered by coralline algae (42.2%), on *Siderastrea siderea* (10.9%), and on live *Montastraea cavernosa* coral (12.5%). On the barrier reef station, the proportion of excavating sponges was greater on old dead corals (no identifiable skeletons, 28.6%) and on *Siderastrea siderea* dead skeletons and live coral (14.3% and 33.3% respectively). This information will be also compared to other sites in Panama and Florida that are currently affected by more anthropogenic disturbances.

A total of 78 samples of *Cliona delitrix* were collected with hammer and chisel at four different stations at Carrie Bow reefs between 25 and 45 feet in depth. Approximately 2x2 cm of sponge tissue sampled was fixed in 95% ethanol and frozen at -20°C; also a small subsample (0.5 cm^2) was fixed in DMSO buffer and kept at room temperature. Samples were transported from Belize to NOVA Southeastern University – Oceanographic Center (Florida, USA). DNA has been extracted and four microsatellite libraries were developed at the Pritzker Laboratory at the Field Museum of Chicago. Currently we are testing and optimizing ten microsatellite primers. We expect to analyze Carrie Bow populations together with Panama, Florida, and Bahamas populations to determine levels of connectivity in a broad scale.

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Effects of insectivorous birds on arthropod communities and mangrove productivity

A. J. Forde, J. D. Parker, I. C. Feller, D. S. Gruner

Mangrove forests of Latin America and the Caribbean provide critical ecological and economic services and are under threat by anthropogenic factors. Resource limitation can regulate the growth of mangroves, but damage by herbivores can also constrain mangrove

productivity. Previous work has shown that in Belizean mangrove forests, herbivorous arthropods reduce canopy cover 50% by girdling branches and reduce plant yield up to 26% by killing buds. Herbivore abundance and herbivory vary greatly across space in mangrove forests. In some cases, nutritional content and growth rate of trees explain this variation. However, the factors that determine the distribution and abundance of many herbivore species in these ecosystems are still unclear.

Insectivorous birds can reduce arthropod herbivore densities and indirectly benefit plant growth, but their effects on terrestrial mangrove food webs have not been studied. We initiated an experiment in January 2010 to test whether predation by birds affects these mangrove arthropods, and whether such predation increases tree productivity by reducing herbivory.

To quantify the effects of birds, we excluded them from mangrove canopies at two sites on Twin Cays. We constructed 1m^3 PVC frames (40 total) around entire nutrient-limited, miniature *Rhizophora mangle* trees and around individual branches of large, fast-growing trees (situated near deposits of flocculent algal/bacterial mats). Half of these frames were covered with propylene netting (birds excluded, treatment), while the other half were left uncovered (birds could enter, control). We searched for arthropods within these units, measured the growth of branches, and recorded levels of herbivory 10 and 20 weeks after we initiated treatments.

Yucatan Vireo at Twin Cays, Belize.

Alexander Forde surveying bird exclosures on Twin Cays, Belize

This study is ongoing, but the data in hand indicate that birds are decreasing the amount of damage inflicted on the buds of fast-growing mangrove trees at one of our sites, but not at the other. This is likely an indirect effect of birds mediated by predation on bud mining caterpillars (*Ecdytolopha sp.*). Herbivores are present at higher densities at the site where birds affect damage levels, and are more abundant on fast vs. slow growing trees, suggesting that effects of predation are density dependent. Differences in bud damage have not yet translated into differences in

productivity among treatments. Twigs of all the large, fast-growing trees continue to produce biomass more than 6 times faster than the miniature nutrient-limited trees. In the future, we will characterize the arthropod communities on our experimental trees, to determine whether bird exclusion alters species composition in these arthropod communities.

(note: you can read Alexander's blog post about his work in Belize at: http://explorers.neaq.org/2010/03/5-birds-moths-and-mangroves-in-belize.html)

Turbidity trends and seagrass distributions in the waters surrounding Carrie Bow Cay, Belize

C. L. Gallegos, W. J. Kenworthy and T. M. Pedersen

Seagrasses have high light requirements, so that degradation of water quality that limits the penetration of photosynthetically active radiation (PAR) underwater has the potential to severely impact the survival depth and areal coverage of seagrass meadows. Seagrass systems are, therefore, a sensitive indicator of habitat loss due to human impacts on the coastal zone.

Water clarity in the waters surrounding CBC has deteriorated. Since the inception of measurements in 1993 (with gaps due to closure of the station) horizontally sighted Secchi distance outside a shallow seagrass bed near Twin Cays has declined at a rate of 0.29 $m \cdot y^{-1}$, while the vertically sighted Secchi depth at a deep station on the fore-reef has declined at a rate of 0.52 $m \cdot y^{-1}$. Episodes of low visibility (<6 m) have always occurred, but appear to be more frequent in recent years, while very clear water with visibility exceeding 18 m has not been observed since 2004.

The cause of the visibility decline has not been identified. It is likely to be due to a change in amounts and/or kinds of suspended solids because visual transparency is more sensitive to light scattering than to light absorption. The objectives of this work are: to quantify the relative contributions of suspended solids, colored dissolved organic matter, and phytoplankton to light attenuation and visibility in the vicinity of Carrie Bow Cay; to improve our estimate of the light requirements of the *Thalassia testudinum* bed at the Blue Ground Range (BGR) site in Lagoon Channel, Belize; to biologically characterize the deep *T. testudinum* bed at the BGR to establish it as a sentinel site for assessing effects of deteriorating water clarity in the lagoon at Carrie Bow Cay. We visited Carrie Bow Cay for 1 week in July 2010. We measured inherent optical properties and light attenuation at BGR, the Twin Cays CARICOMP site, and the water quality monitoring site at the fore-reef. At BGR and Twin Cays we also measured light attenuation in a thin (4.5 cm) layer at the sediment surface, compared with light attenuation higher in the water column measured by sensors separated by 1 m. The sediment-level sensors measure light that would be received by a newly sprouted seedling. Preliminary results indicate that light attenuation in the near-bottom layer was nearly two-fold higher than in

Ph.D. student, Troels Møller Pedersen, installing light attenuation sensors at a sandy-bottom station off Carrie Bow Cay.

the water column at the Twin Cays site where sediment organic content was about 15%, while no difference between near bottom and water column measurements could be detected at other sites where sediment organic content was less than 5%.

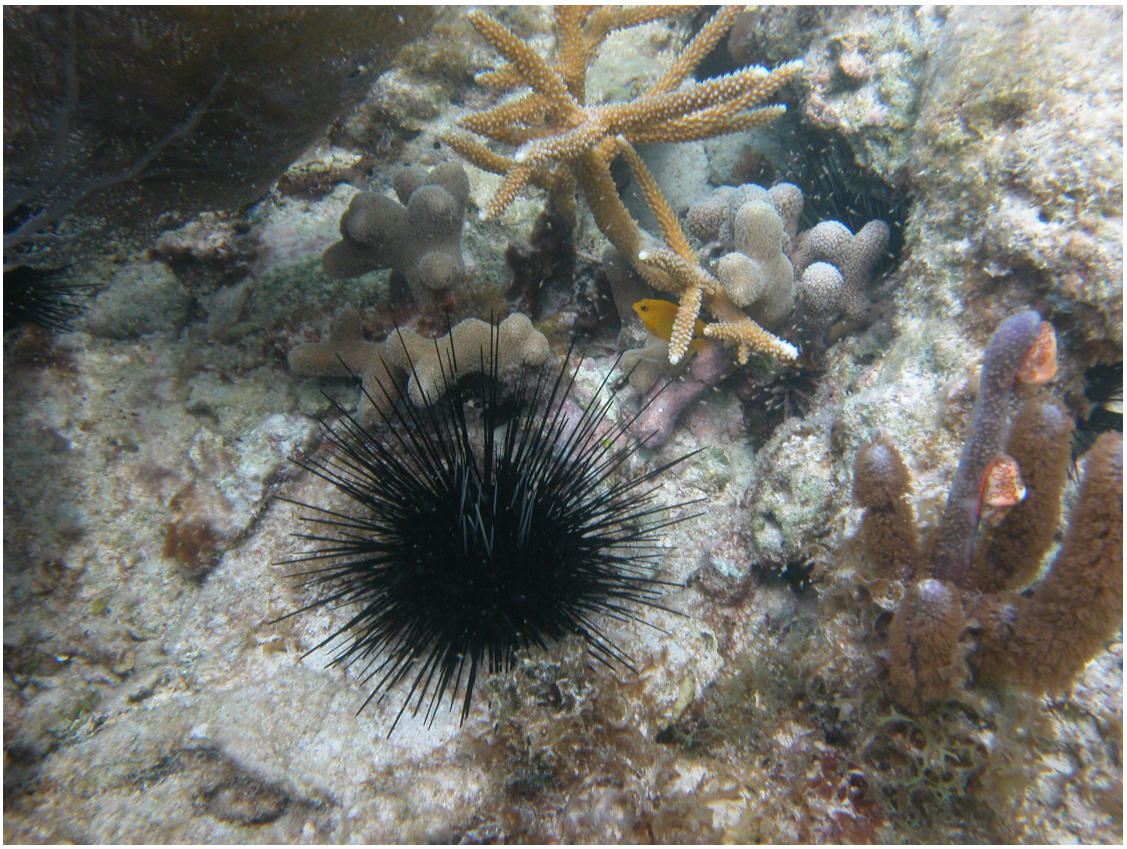
Reconstruction of demographic history of the long-spined sea urchin, *Diadema antillarum*, by means of genetic markers

H.A. Lessios

The sea urchin *Diadema antillarum* was the most important herbivore on Caribbean reefs until 1983, when mass mortality reduced its populations by >97 %, the most extensive and most severe mass mortality recorded in a marine animal. Knowledge of its past demography is essential to reconstruct reef ecology as it was before human impact, which has been implicated as having caused previously high *Diadema* abundance. The fossil record of this species is practically non-existent, so such a reconstruction needs to be done by other means. One way of estimating previous population sizes is based on present-day genetic variation of populations. Such an estimate is made possible by analyzing genetic markers with coalescent methods, i.e. by seeing how far back in time alleles of a population share a common ancestor. The time it takes to produce genetic differences as seen today is a function of effective population size and the mutation rate. By estimating mutation rates from divergence between *D. antillarum* and *D. mexicanum*, separated at a known time by the Isthmus of Panama, and by using estimates of effective population size derived from maximum likelihood and Bayesian coalescence algorithms, we can date the expansion as having occurred either before or after the colonization of the Caribbean by humans. I have developed microsatellite loci to genetically sample populations from the entire Caribbean and thus obtain independent estimates of the time at which populations of *Diadema antillarum* expanded.

A second question that microsatellite data can answer is the source of larvae that are re-colonizing the Caribbean after mass mortality. Microsatellites, because of their high mutation rate and the ability to sample multiple unlinked loci, can determine whether populations are self-seeding, whether larvae become mixed in the plankton and settle indiscriminately, or whether certain populations function as sources of larvae that replenish others.

Carrie Bow is one of the many localities around the Caribbean that I am in the process of sampling. Tissues of *Diadema* were collected in the area around Carrie Bow Cay and in the Pelican Cays, preserved, and shipped to Panama. These samples are now being processed to determine the genetic composition of the Belizean populations and to compare it to those from other areas.



Long-spined sea urchin, *Diadema antillarum.*

An assessment of the relative importance of mangroves as fish foraging habitats

A. Vaslet, I.C. Feller, C.C. Baldwin

This postdoctoral research project focused on fish feeding habits and habitats in the mangrove islet of Twin Cays in Belize. Mangroves are recognized as important habitats for fish communities as nursery grounds and shelters but there are still some questions about their importance as fish foraging habitats. The mangrove food-web was first described by Odum and Heald in Florida in the 1970's. They emphasized the importance of the mangrove litter-fall via a detritus-based food web. The mangrove litter is degraded by microbial communities into more palatable organic matter which can be consumed by organisms present in mangroves, such as annelids, gastropods, crabs or shrimps. These organisms can then be consumed by fishes. However, with the increasing use of stable isotopes of carbon (δ13C) and nitrogen (δ15N) in food web studies, various findings highlighted a debate upon the importance of mangroves as fish feeding grounds. Because stable isotope signatures of an animal reflect the isotope ratios of its diet, these isotopic signatures can be used as "tracers" of organic matter origin in the aquatic trophic chain.

To assess the relative importance of mangroves as fish foraging habitats, fish species were collected in the mangrove ponds and along the mangrove shoreline of Twin Cays during two field trips at Carrie Bow Cay (February and May 2010). The fish species were separated according to their trophic levels (planktivores, herbivores, omnivores, carnivores) and ecological categories (mangrove residents, visitors). Different life-stages (juveniles, adults) were also considered to observe potential ontogenetic changes in their diet and feeding habitats.

There is a natural variation in δ13C of prey items from mangroves (δ13Cmean = -18.8 ± 1.0‰) and seagrass beds (δ13Cmean = -13.4 ± 0.3 ‰) due to different photosynthetic processes between the plants. Thus we were able to compare the relative contributions of the prey items from these two habitats into the fish diets.

Juvenile Schoolmaster Snapper, *Lutjanus apodus,* collected in mangrove habitats for isoptopic analysis.

Three groups of fishes with differing C signatures were observed. Some fishes have depleted C ratios, suggesting that they mainly feed in mangroves. This is the case of the goby *Bathygobius* and the puffer fish (*Sphoeroides testudineus*) that are commonly observed in the mangrove habitat. Some species (such as grunts, snappers or parrotfishes) present C signatures close to those of the seagrass prey items, indicating that they shelter in the mangrove but forage in the seagrass beds nearby. A last group of fish (such as schoolmaster snappers, redear sardines) presents intermediate C signatures between mangroves and seagrass beds, suggesting that these species find their food in both habitats. An ontogenetic trophic migration was ob-

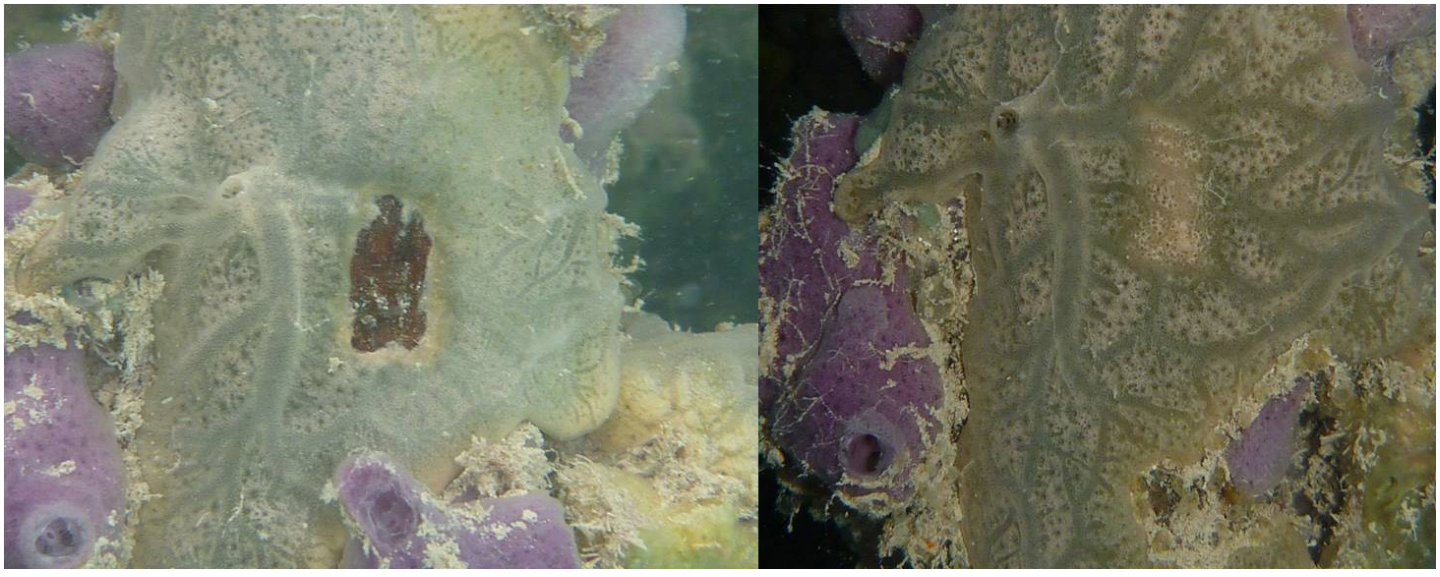
served for the schoolmaster snapper *Lutjanus apodus*. The smaller juveniles of this species present more depleted C signatures (close to mangroves C signatures) than the larger juveniles or adults that have C ratios close to those of seagrass prey items. This difference of C signatures between smaller and larger *L. apodus* specimens highlights a change in their feeding habits and habitats during their ontogeny.

This research pointed out the different foraging habits of fishes observed in the mangroves of Twin Cays. The importance of mangroves as fish feeding grounds is limited to resident and some transient mangrove fishes, whereas seagrass beds represent important feeding areas for juveniles of reef fish species during their mangrove habitat phase.

Regeneration of experimentally generated wounds in sponge species inhabiting mangrove prop roots

J. Wulff

Sponges are particularly adept at regeneration, but comparisons of regeneration among sponge species have consistently revealed substantial differences in style (i.e., relative rates of reconstituting surface features, infilling depressions, regaining lost primary substratum, etc.) and overall time course, raising questions about adaptive significance of variations in regeneration patterns. To answer questions relating to possible constraints on regeneration imposed by skeletal construction and morphology, or by allocation of energy or materials, required comparisons of regeneration among species that represent a spectrum of higher taxa within the demosponges as well as different growth forms and life history strategies. Working at Twin Cays, I have been accumulating data on growth rate, colonization, mortality, susceptibility to predation, and competitive ability for sponge species typical of the Caribbean mangrove prop root community, making this an ideal situation for determining if patterns in regeneration can be predicted by life history and morphological strategies. I experimentally generated wounds that mimic trunkfish bites in 11-16 individuals of each of 13 species that span a range of life histories and growth forms. The species chosen represent 4 orders of the class Demospongiae, and include 4 sets of congeneric species, allowing distinction of patterns related to life history and morphology from those determined by shared evolutionary heritage. I was able to conclude that rates and styles of regeneration are not well predicted by shared evolutionary heritage, and that integral elements of coherent sponge strategies exist for successfully gaining and maintaining a presence in the crowded communities on mangrove prop roots. The results are published in Integrative and Comparative Biology 50:494-505.



Experimentally generated wound on the sponge *Clathria venosa* at 2 days (left) and at 18 days (right).

Fish foraging aggregation off Carrie Bow Cay. Various species are present, including Creole Wrasse *Clepticus parrae* and Yellowtail Snapper *Ocyurus chrysurus*.

Species Interaction and Behavior

Release of DMSP and other natural chemical products through reef-associated trophic events and the corresponding effects on reef fish behavior

J.L. DeBose

Establishing Marine Protected Areas inclusive of both reef fish and pelagic, reef-associated fish is challenging given how little is known of the ecology of the movement patterns in these species. Understanding the sensory ecology of these organisms can both stimulate basic science avenues of investigation and inform management decisions for how to best identify and designate critical habitats and corridors for these species groups. My previous research focused on how fish may use an algal compound - dimethylsulfoniopropionate (DMSP) - to find foraging hotspots in the marine environment. These initial studies revealed that both predatory and planktivorous fish species may use dissolved DMSP to locate areas of transient productivity.

At Carrie Bow Cay, I have been extending these investigations into the plankton assemblage at the center of these foraging events, the variability in the chemical signatures released from these trophic events, and the behavioral responses of fish to the temporal and spatial variation in the released chemical cues. Over the last year, I have collected water and plankton samples, and have documented fish behavior from 32 foraging aggregations in October, February, May and August. One hundred and seven open-circuit scuba dives were conducted over 8 weeks. The majority of aggregations were located off the fore-reefs and walls to the east and south of Carrie Bow Cay. Fish aggregations usually include species such as, creole wrasse (*Clepticus parrae*), yellowtail snapper (*Ocyurus chrysurus*), boga (*Inermia vitatta*) and bar jacks (*Carangoides ruber*).

Researcher Woody Lee carrying Niskin bottles for field experiments examining fish foraging behavior.

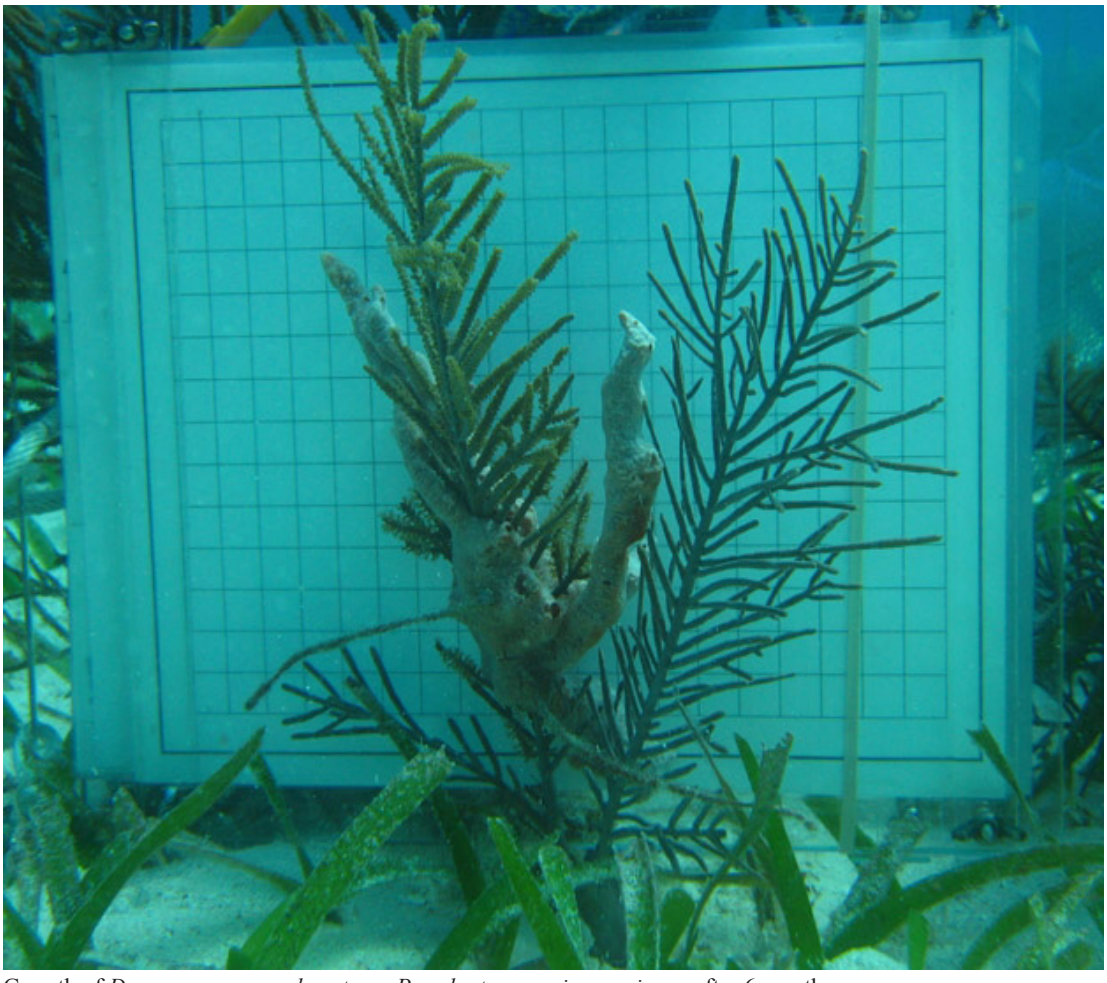
Chemical analyses of the water collected from these aggregations is ongoing, but initial laboratory tests on Florida sergeant majors (*Saxatilis abudefduf*) are revealing that these fish respond to Belize aggregation water over paired controls. Further, initial analyses on DMSP concentrations of aggregations compared to control sites show there is a significant difference between the two, paired locations. This adds to the evidence that fish aggregations may release compounds in the water that other fish find attractive. Next steps include determining specific compounds which might be driving this preference and further investigating the plankton assemblage at the heart of these aggregations. Understanding these chemically-mediated trophic cascades will inform future research into how seasonally variable plankton assemblages and associated chemical signatures drive foraging events and how a changing climate will affect the movement patterns of these important reef species as they follow the transient chemical trail.

Associations and overgrowth of octocorals by sponges

E. L. McLean

Octocorals serve as a great substrate for branching sponges to grow on. Associations and overgrowth of two branching Demosponges continued to be studied in Carrie Bow Cay during January – February 2010. The initial study in July 2009 looked at the frequency of these associations. In 2010, we monitored more specific sponge-octocoral associations measuring their growth (area) and the length along the axis of the octocoral that the sponge had overgrown. The effects and the speed of the sponge attachment were also looked at and contrasted on an experimental set, testing for sponge attachment on live octocoral tissue substrate and bare axis. In addition, other effects of shade and abrasion caused by the sponge fragment in contact with the octocorals were compared to other substrates such as dead bleached pieces of the same sponge species, as well as for a natural commercial sponge. Finally, preliminary observation takes note of the ability of these octocorals to recover when the associated sponge is removed.

The study was based in the patch reef 1.5m south of Carrie Bow Cay along the channel (8 m deep). The Demosponges studied were *Desmapsamma anchorata* and *Iotrochota birotulata*, both branching, ramose species that are very abundant in this area. The octocorals used in the experiments include species that are frequently found in association with these sponges: *Pseudopterogorgia americana* and *Plexaura flexuosa* and one that has not been observed in association, *Plexaurella anceps*.



Growth of *Desmapsamma anchorata* on *Pseudopterogorgia americana* after 6 months.

Differential growth rates for the two sponge species resulted in contrasting overgrowth. Fragments of *D. anchorata* with an average initial area of 7 cm^2 showed wide ranges after the six month period, ranging from 7.8 cm^2 to 83 cm^2. *I. birotulata*, had a more moderate growth, starting at 9 cm^2 and growing to 10-23 cm^2. These differences in growth within and among species appeared to have varied with exposure, i.e.: attachments done inside the protected patch and those closer to the open sandy area. The progress of the growth of the sponge along the axis of the octocoral also varied from decreases in initial length (5 cm) attached along the axis to 3-14 cm of length along the axis *D. anchorata* had faster growth in this respect, and also extended branching fragments along the sides.

Different substrate effects were observed when the various substrates tested (live sponge, bleached sponge piece, natural commercial sponge) were compared- attachment only taking place for the live sponge fragments. On bare octocoral axis, attachment of the sponge is swift for sponge-octocoral species that commonly associate. Attachment of the sponge fragment on *P. anceps* would not take place on the live tissue even after a period of 10 days, but once the live tissue was removed the sponge fragment attached to the bare axis within days.

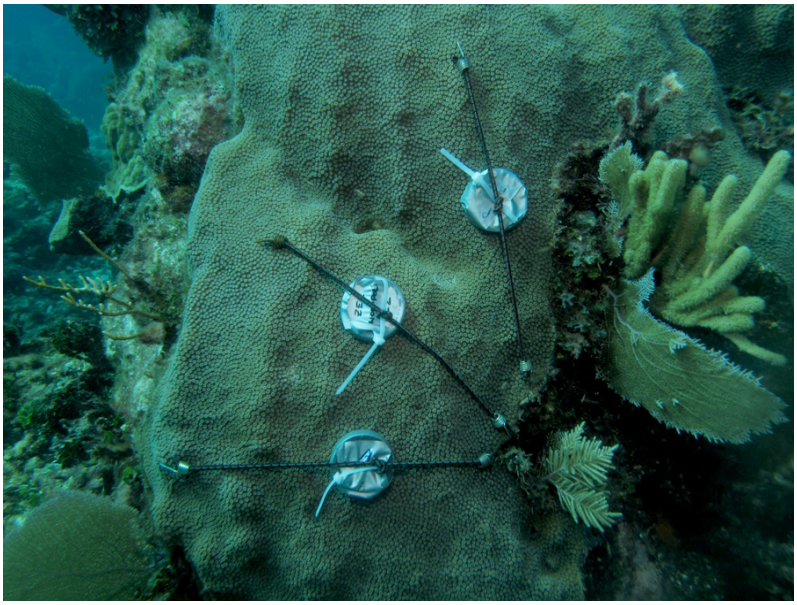
The relevance of these findings is at the base of how these associations begin. Conditioning for attachment plays into the ability of the sponge to recruit on these substrates, having an advantage on bare axis or affected octocoral tissue versus live tissue, but also willing and able to recruit on both. Displacement of the sponge either by physical (i.e., wave action) or biological (i.e., predator) action gives the octocoral the opportunity to recover or to be subsequently colonized by other overgrowing organisms, not to mention some of these octocorals become susceptible to collapse once their frame and base has been ultimately deteriorated.

Coral-algal-microbial interactions on reefs of Belize

V. J. Paul, K. Morrow, C. Ross, S. Arnold, R. Steneck, R. Ritson-Williams

Worldwide coral reefs are being overgrown by macroalgae and benthic cyanobacteria resulting in increased frequency of competition among these algae and corals at all life history stages. Corals are comprised of all three domains of life, including the animal, endosymbiotic zooxanthellae, fungi, endolithic algae, bacteria, Archaea, and viruses. One potential effect of algal competition with corals is a change in the diversity and abundance of coral-associated microorganisms. We tested this in adult corals by placing live algae (*Halimeda tuna*, *Dictyota sp*., *Lobophora variegata*) and algal extracts onto coral colonies of *Porites astreoides* and *Montastraea faveolata* for three days. These samples are still being analyzed for changes in microbial community composition after exposure. Measurements of the enzymes superoxide dismutase and catalase (both used to assess oxidative stress) showed no increased activity of these enzymes in corals exposed to the algae or algal extracts. Quantification of the detoxification enzyme glutathione S-transferase did show an upregulation in some of the treatments with algal extracts, showing some sublethal stress in the adult corals exposed to the treatments.

Macroalgae and cyanobacteria might also impact corals during their early life history stages. To determine if macroalgae and cyanobacteria can inhibit coral recruitment, the effects of macroalgae and cyanobacteria on the survival and settlement behavior of coral larvae were tested. Larval behavior was tested using larval chambers, which are clear acrylic tubes with nitex mesh on each side, which can be deployed on reefs so that larvae are exposed to natural light and water conditions. There were 100 larvae in each chamber with a positive settlement substratum of a chip of the crustose coralline alga *Hydrolithon boergesenii*. In this way we could attach a treatment of live algae or algal extract incorporated into an agar strip directly onto the chip of *H. boergesenii* to test larval settlement behavior in the presence of different algae.



Algal extract plates attached to a colony of *Montastrea faveolata.*

Live *Dictyota* and their extracts were tested against larvae of *Acropora palmata* and *A. cervicornis*. Larvae of *A. palmata* had reduced larval survival in the presence of *D. pulchella*. The extracts of *D. pulchella* reduced the settlement of *A. cervicornis* larvae but did not affect their survival. Live cyanobacteria were also tested against larvae of *A. palmata* and *Diploria strigosa*. Larvae of *A. palmata* consistently had lower survival and settlement in the presence of *Phormidium sp*. Larvae of *D. strigosa* had reduced survival and settlement in the presence of *Hormothamnion enteromorphoides*. Larvae of *D. strigosa* were also tested for their survival and settlement after 24 hours of exposure to water conditioned with different species of cyanobacteria. Larvae of *D. strigosa* had reduced settlement in the presence of water conditioned with *Phormidium sp*. Some macroalgae and cyanobacteria reduced the survival and settlement of coral larvae suggesting that the presence of these macrophytes on reefs could inhibit the recovery process of coral recruitment.

Patterns of polychaete preference for mangrove sponge hosts

A. Strimaitis

Sponges growing on mangrove prop roots provide habitat for smaller invertebrates like crustaceans, echinoderms, cnidarians, and polychaetes. Syllidae polychaetes are generalist predators, but their body color often matches their host, so syllid host choice may not be random. My research activities at Carrie Bow Cay include examining the mangrove sponge host preferences of surface dwelling Syllidae polychaetes using laboratory choice experiments and in situ observations. Preliminary experiments focused

Experimental chambers used to test settlement behavior of coral larvae.

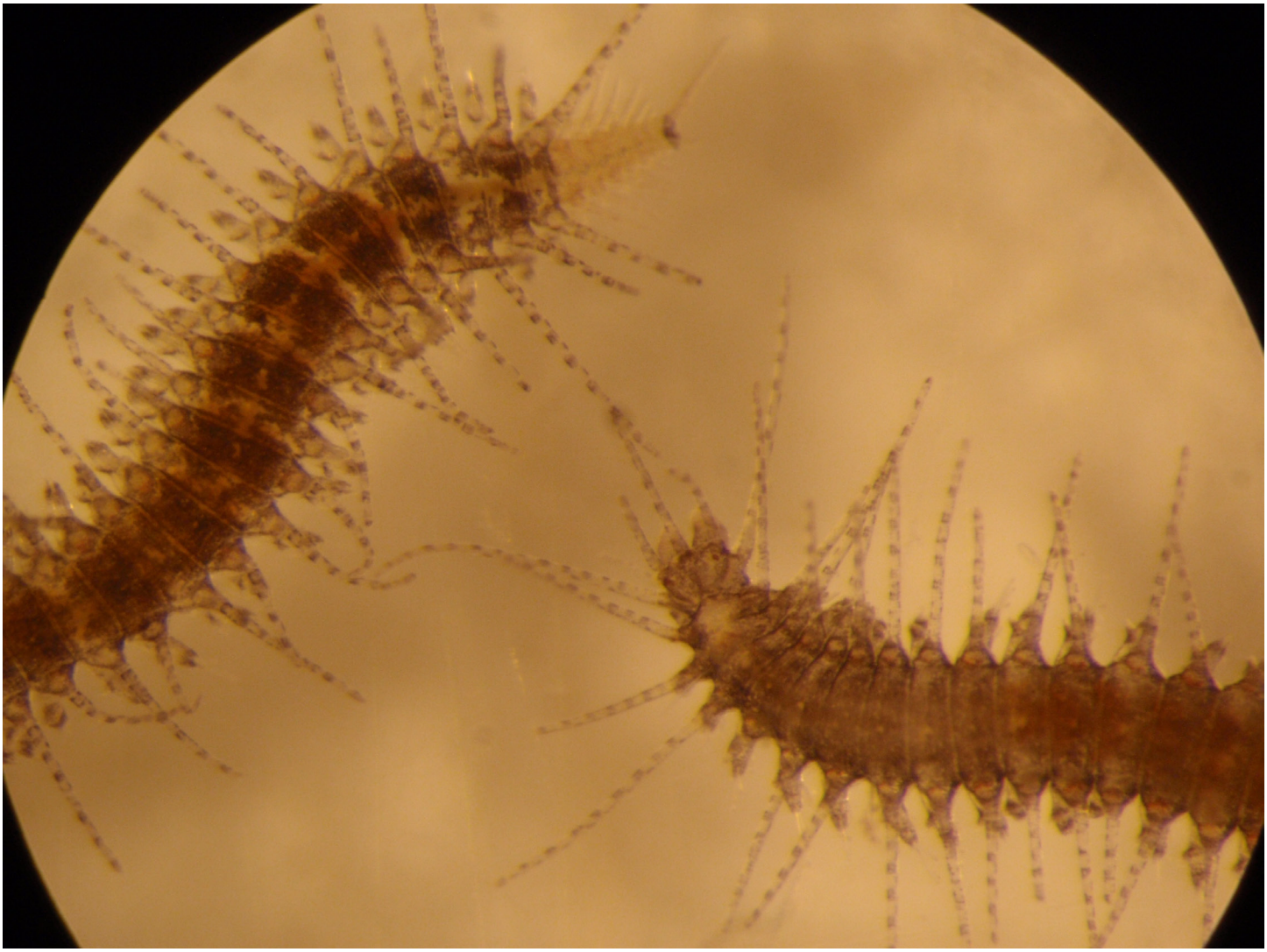
on 5 sponge species from Twin Cays: *Biemna caribea, Halichondria magniconulosa, Tedania ignis, Hyrtios sp.*, and *Haliclona implexiformis*. In situ, *H. magniconulosa* and *T. ignis* hosted the highest polychaete densities at 16 and 10 polychaetes per cm^3 respectively, and *Hyrtios sp*. and *H. implexiformis* hosted the lowest polychaete densities at 1 and 0.5 polychaetes per cm^3 respectively. The color of all polychaetes found on *T. ignis* and *Hyrtios* sp. matched the color of their host. In the laboratory choice experiment, the initial random distribution of polychaetes on the 5 sponge species was not random after 2 hours. *Biemna caribaea* and *Halichondria magniconulosa* hosted greater polychaete densities than *T. ignis*, *Hyrtios sp*., and *H. implexiformis*. The preliminary results indicate that polychaetes do show a preference in the laboratory experiments. The patterns observed in the laboratory do not correspond with patterns observed in situ, which may be because the sponges used in the experiments were not allowed time to heal before the polychaetes were introduced. I plan to continue investigating Syllidae polychaete host preference by offering multiple mangrove sponge species to polychaetes collected from a single sponge host.

Processes Across Ecosystems

Earthquake impacts on lagoonal reefs

R.B. Aronson, I.G. Macintyre, A.G. Macintyre

From 9–16 June 2010, Richard B. Aronson, Ian G. Macintyre, and Allan G. Macintyre documented the massive slumping of the slopes of lagoonal reefs in the Rhomboid Cays of Belize that occurred during the 2009 Honduran earthquake. Photographs, including pictures taken with A. Macintyre's large-format camera, and slope measurements were used to document the slump



Syllid Polychaetes collected from sponge hosts.

surfaces. Samples were also collected to determine the loss of reef framework at sites that have been used for many years for ecological surveys and were thus well documented prior to the earthquake. Observations and radiocarbon dating suggest that massive slumping of these uncemented lagoonal reefs was unprecedented in centuries to millennia.

Richard Aronson with Ian Macintyre behind him documenting the slumped surface of a lagoonal reef in the Rhomboid Cays, Belize.

Latitudinal variations in ecological stoichiometry in mangrove communities: consequences of nutrient loading on canopy and benthic food webs

I.C. Feller & C.E. Lovelock

Mangroves form complex marine ecosystems with spatial differences in structural complexity, biodiversity, biogeochemistry, and hydrology that vary at local and regional scales. Although mangroves provide critical ecosystem goods and services, they are threatened globally by changes in climate and nutrient over-enrichment of the coastal zone. Using latitude and tidal elevation as proxies for climate change and sea level rise, the objective of this project is to determine how excess nutrients interact with these consequences of global change to alter community structure, food webs, and patterns of herbivory in mangrove ecosystems.

We used a series of long-term fertilization experiments across ~ 2185 km and 18º of latitude that have been maintained at three locations along the Atlantic coast (Indian River Lagoon, Florida; Twin Cays, Belize; Bocas del Toro, Panama). At each location, red mangrove (*Rhizophora mangle*) trees are fertilized with one of three nutrient enrichment treatments (control, +nitrogen, +phosphorus) in two tidal elevations (fringe, scrub) along transects perpendicular to shorelines. We determined the abundance of the primary consumers at each fertilized tree and measured herbivory as a function of folivory, loss of yield, and tissue mining. To characterize food webs and elemental stoichiometry of individual organisms, we also sampled marine, benthic, and terrestrial communities at each of the fertilized trees. Sampling is still under way. Elemental and isotope analyses will be conducted when field sampling has been completed. We have shown in previous studies that all sites were nutrient limited, but patterns of nutrient limitation varied by zone and latitude. Nutrient enrichment had dramatic effects on herbivory that varied by treatment, tidal elevation, latitude, and species. Responses to eutrophication of mangrove ecosystems will depend on site characteristics, the species considered, and the nature of nutrient limitation. Predicting how food webs will respond to nutrient over-enrichment requires an assessment of spatial heterogeneity coupled with feeding strategies and species-specific behavior, measured on multiple scales of response.

Sampling for this project will be complete as of December 2010. After that, Feller and Anne Chamberlain (MSN funded research assistant at SERC) will then focus on analyzing all samples (approximately 1000 per site). Feller will also get new knees.

Other Projects

Aerial surveys of coastal ecosystems along the Indian River Lagoon, Florida; the Mesoamerican Barrier Reef, Belize; and Bocas del Toro, Panama

I.C. Feller

Aerial Surveys of the Mesoamerican Barrier Reef System, Belize: Since April 2003, I have been working with LightHawk's Mesoamerica Program to conduct annual aerial surveys of the coastal zone and offshore mangrove cays associated with Belize's Barrier Reef System. To do these surveys, I work with Armando Ubeda, the Mesoamerica Program Manager for LightHawk, and several volunteer pilots. These surveys have been done in collaboration with Faustino Chi, my Ph.D. student at the University of British Columbia. Faustino is also a member of the faculty of the University of Belize. We have used our aerial photographs to track mangrove recovery from hurricanes, to delineate mangrove forest structure and productivity, and to resolve long term shoreline erosion and accretion. We have georeferenced our images and have coupled our aerial surveys with extensive ground truthing, and linked them to satellite and historical imagery. We have shared these images and data widely with other groups, including the University of Belize, the government of Belize, local and international non-governmental organizations as well as other scientists working at the Smithsonian Marine Field Station on Carrie Bow Cay. During these flights, we have also documented an alarming and unprecedented destruction of coastal mangrove forests and cays for development. When we started these surveys in 2003, our photographs revealed that few of the mangrove islands and coastal forests were being cleared. This situation had changed dramatically by 2005 when widespread mangrove clearing was evident even inside the World Heritage Site (the Belize Barrier Reef Reserve System) and marine reserves. By 2008, our survey documented that virtually all the offshore mangrove cays from Turneffe to Gladden Spit were in varying stages of development, ranging from cleared and filled cays to survey lines through forest that delineate areas slated for clearing. Filling of these offshore mangrove cays is accomplished with material dredged from the nearby seagrass meadows and patch reefs, creating further permanent damage to these systems, which is also documented in the aerial photographs. Online real estate advertisements for these cays reveal that an increasing number of land speculators are targeting mangrove areas in Belize. Following our April 2007 survey in which we documented the clearing and filling of several of the islands in the Pelican Cays, we put together a Powerpoint presentation (ppt.) with photographs showing a time series of changes that had occurred since 2003, ground-level and underwater impacts of the damage, as well as plans for the resort development that was underway (we found this on the internet). In the ppt file, we explained the dire consequences of this type of development that become evident when the biogenic origin of the mangrove cays is considered. We used our images to explain that these islands are underlain by deep peat deposits, in some cases more than 30 ft deep. We tried to make clear that these islands are formed and persist only by the continual production and accumulation of mangrove roots. The take-home message in the Powerpoint file was that when the forests are cut, root production ceases, and the cays inevitably erode regardless of how much dredge material is dumped on top of them. We distributed this ppt to staff members of conservation organizations operating in Belize. As these people, in turn, distributed it to their circle of acquaintances, it eventually reached members of the UNESCO World Heritage Commission. As the awareness of this mangrove cutting and excessive development has spread, UNESCO has placed the Belize Barrier Reef System on their Danger List. The World Heritage Committee has requested Belize to institute stricter controls on development and to maintain a moratorium on mangrove cutting. Google Oceans has picked up this story as… "The Tragedy of the Pelican Cays".

In FY2010, we again flew with LightHawk to survey the coastal mangroves of Belize from Sarteneja at the border with Mexico to the Sarstoon River at the border with Guatemala, and the offshore mangroves from the

Aerial photograph taken from a LightHawk flight of a mangrove cay along the Belize Barrier Reef.

Snake Cays in the south to Ambergris Cay in the north. We recorded over 10GB of high resolution images that we have widely shared. These images show that development of the mangroves forests along the coast and on the cays is under severe development pressure. However, it was heartening to see that development activities in the Pelican Cays seem to have been abandoned… at least for the moment.

Caribbean Coastal Marine Productivity program (CARICOMP)

K. Koltes and J. Tschirky

Monitoring of physical and biological variables under the Caribbean Coastal Marine Productivity (CARICOMP) program continued at Carrie Bow Cay (CBC) in 2010. The CARICOMP Program is a long-term, Caribbean-wide initiative to determine the dominant influences on coastal productivity, to monitor for ecosystem change and, ultimately, to discriminate human disturbance from long-term natural variation in coastal systems over the range of their distribution. Continuously monitored physical variables at CBC include air and water temperature, water transparency, salinity, and rainfall. Ecological variables include seagrass productivity (biomass and growth) and coral reef community structure based on repeated sampling of 10 permanent transects established in 1993 at 10-13 m depth on the forereef.

Recent analyses of the relationships among the various physical variables from the CARICOMP program and those collected by the Environmental Monitoring System showed that wind direction was a good indicator of water quality. The role of tides, however, was not included in the analyses due to the complexity of the semi-diurnal, mixed tides around Carrie Bow Cay. To better assess the role of wind and tides in governing water quality and movement, three new arrays of data log-

gers were deployed at Carrie Bow Cay in the spring of 2010. The data loggers measure angular displacement and will be used to calculate the direction of water flow, and its relationship(s) to tidal stage and extreme meteorological and/or oceanographic events.

Preliminary analyzes of the CARICOMP monitoring data for *Thalassia testudinum* communities at both the Twin Cays and Carrie Bow Cay sites show the seasonal variation in productivity associated with changes in insolation and temperature that is typical for most geographic areas. The analyses also indicate, however, that productivity, as measured by areal productivity and turnover rate, has changed at both sites since monitoring began in 1994. Mean areal productivity has increased at both sites, with significant increases during the summer period. Turnover rates have increased significantly during the summer months at Twin Cays and declined significantly at Carrie Bow Cay during the winter months. Leaf area index, an indicator of stress in turtlegrass communities, has increased significantly at the Carrie Bow Cay site during both the summer and winter months. Further analyses of the role of light and temperature are underway.

Target collections of cyanobacteria (new project), and continued monitoring of the taphonomic process initiative

M.M. Littler, D.S. Littler & B.L. Brooks

Taphonomy – This experiment is designed to address the "Conundrum of the Corallines", which arises from the observation that although coralline algae are nearly always abundant (often dominant) in terms of cover on coral-reef systems worldwide, they do not show up abundantly within many fossil coral-reef deposits. We hypothesize that this mysterious disappearance during fossilization is due to differential taphonomic processes. Many rock-boring and limestone-altering creatures abound on coral reefs, including one of the most important groups of limestone altering organisms, the clionid sponges. Even though the calcite deposited by coralline algae is much denser/harder than the aragonite form of calcium carbonate produced by reef-building corals, the former is precipitated within and between cellulose cell walls, which, even after death, may provide an energy source for the boring clionid sponges. Our preliminary 5-yr results indicate that, although a slow process, this appears to be the case, differentially explaining the enigmatic disappearance or alteration of massive/extensive deposits of coralline algae in the fossil record. Thirty samples from the fore-reef crest, 16 from the back-reef site, and 16 from the 15-m deep reef-ridge site were evaluated and left intact for future study. A subset of 6 experimental replicates (sections of corallines versus corals) were scanned and evaluated from the fore-reef crest (see Fig. 1).

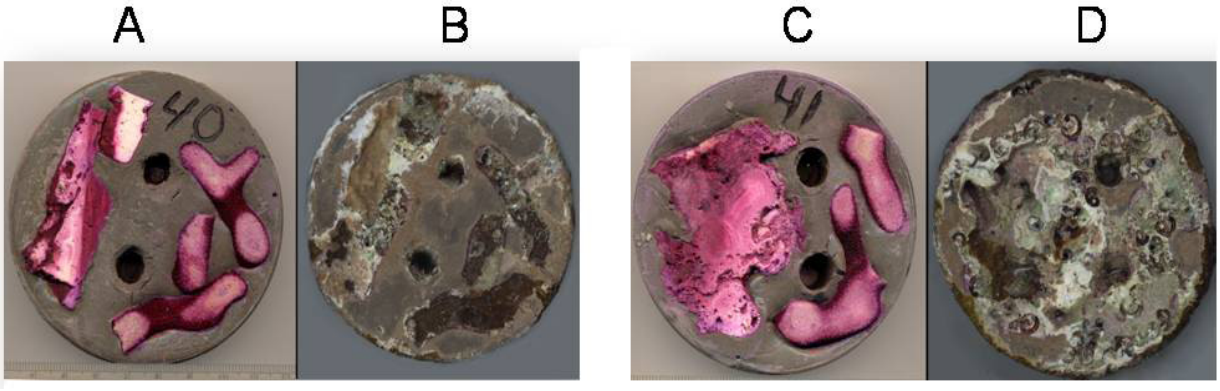


Fig. 1. A&C, Taphonomic pucks initial array. B&D, The same pucks after 4-Yr deployment showing that bio-erosion is more apparent in coralline algae (left sides) containing cellulose cell walls than for the softer calcium carbonate produced by reef-building corals (right sides).

Our team also collected at eighteen different sites ranging from South Reef, Twin Cays, and Tobacco Range to CBC. Over 136 specimens were collected, all were preserved in formalin with accompanying molecular samples (quick-dried in silica gel and frozen) and many specimens were also pressed in the field. More than 1,750 new underwater images of marine plants were taken, 1,266 edited and labeled.

Over 200 of our previously collected molecular samples of *Caulerpa* have been sent to the University of Ghent and then to the Saunders Laboratory, Centre for Environmental & Molecular Algal Research at the University of New Brunswick, Canada for DNA analysis and posting on Genbank, the initial step in our proposed new collaborative project with Dr. Heroen Verbruggen.

Meteorological and Oceanographic Monitoring Program

Tom Opishinski

September 2010 marks the 10th year of continuous operation of the meteorological and oceanographic monitoring system that was installed following the devastating fire that destroyed the Carrie Bow Cay facilities late in 1997(see photo). The Environmental Monitoring System (EMS) on Carrie Bow Cay supports a fully automated system that measures oceanographic (temperature, salinity, turbidity, water level, pH and dissolved oxygen) and meteorological conditions (air temperature, wind speed/direction, relative humidity, atmospheric pressure, rainfall and solar radiation) every ten minutes.

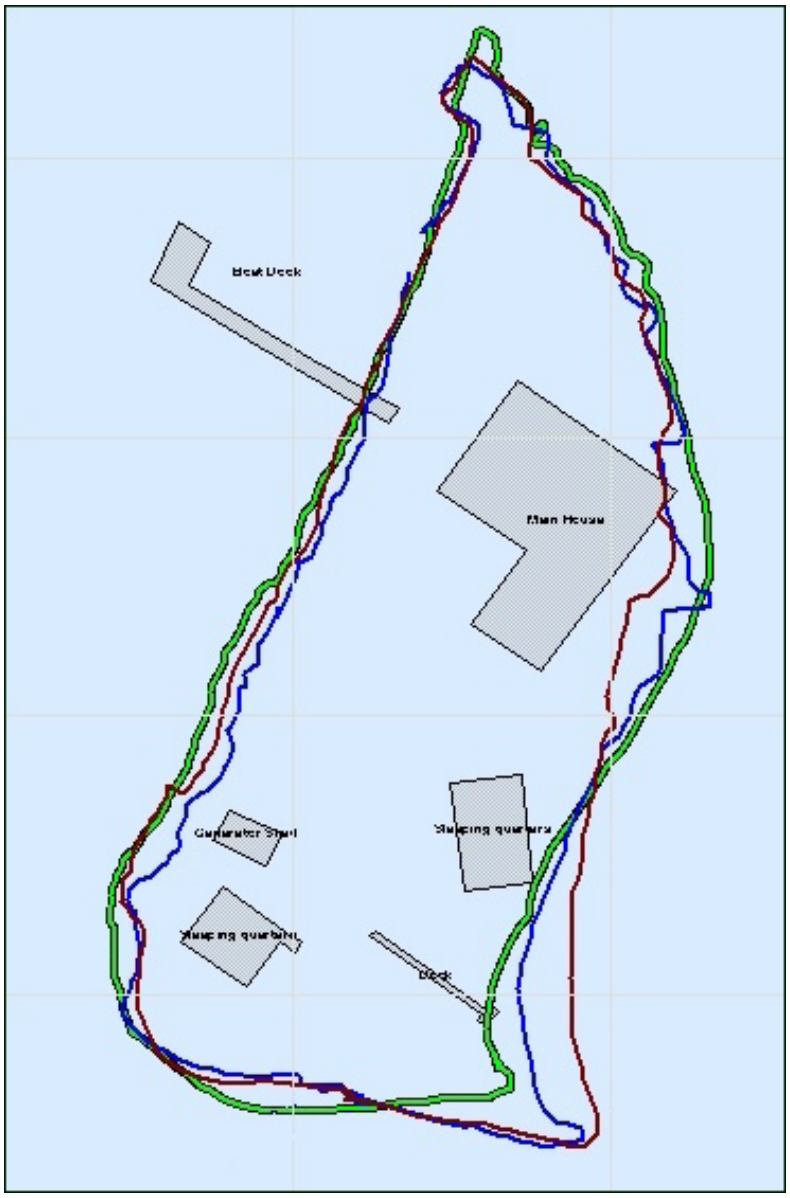
Data is assembled to form a long-term record of conditions on the coral reef and serves as a valuable resource for research projects and management of the Mesoamerican Barrier Reef ecosystems. For example, in 2009, Renken and Mumby[1] utilized data from the EMS to model the dynamics of coral reef macroalgae with their findings published in the Ecological Modelling Journal. Koltes and Opishinski[2] published an analysis representing the first analysis of long-term data records from both the CARICOMP program and those collected by the EMS. The analysis examines relationships, on short and long time scales, between physical parameters and identifies variables that appear to have a significant influence on water quality.

We continued to extend the reach and accessibility of the data products for researchers and the general public by establishing connections with various online data portals and improving the web site. A linking mechanism was created and implemented to allow users of NOAA's nowCoast system (http://nowcoast.noaa.gov/) to connect to the EMS web site. NowCOAST is a GIS web mapping portal providing links to thousands of real-time coastal observations, NOAA forecasts, and

Meterological instrument tower on Carrie Bow Cay.

NOAA weather data products of interest to the marine community. In addition, the British Oceanographic Data Centre added links in their online data portal (https://www.bodc.ac.uk/data/portals_and_links/links/data_and_information.html) to provide direct access to the web site.

The EMS, to our knowledge, is the only system continuously monitoring both oceanographic and meteorological parameters on the Belize Barrier Reef. As such, a rigorous maintenance, calibration and sensor monitoring program is followed to maintain optimal operation of system components and accuracy of the sensors. Several underwater probes were replaced this year to maintain data accuracy. To reduce biofouling of underwater sensors, a new probe guard (made of a brass with high copper content) was installed in place of the standard plastic guard. The copper contained in the guard is a deterrent to biological growth and, along with other anti-fouling measures, has led to significant improvements in the accuracy and stability of the sensor readings.



Repeated shoreline surveys of Carrie Bow Cay.

Data processing of historical (archived measurements) using standardized methods outlined in Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting[3] continued in 2009-2010. Re-processing of the meteorological archives from 2000-2008 was completed and is now available on the web site. Processing of the oceanographic archives is nearing completion and will be posted in 2010.

Shoreline surveys of Carrie Bow Cay were continued in 2009 using the Streamline-GEO survey system and Garmin GPS. GPS surveys began in 2006 and are meant to capture seasonal and long-term changes to Carrie Bow's geography as well as storm-induced erosion. Historical shoreline surveys were conducted under the CCRE program but without the aid of GPS or other advanced survey equipment.

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Continued studies of reef health, fish-coral interactions, and hermit crab behavior on Carrie Bow Cay

R. Rotjan and P. Gawne

Our objectives this year were multi-fold. First, for a project in collaboration with Brian Helmuth that has now been going on for almost a decade, we retrieved and re-deployed temperature loggers along a depth transect. We were successful at finding and redeploying all loggers, and in conducting maintenance on our sub-surface buoys. Secondly, we completed the first transect of an annual study examining the change in fish and coral communities following the implementation of the no-take zone. Specifically, we conducted twenty 30-m belt transects (4 at each of the following 5 habitats: lagoon, upper spur and groove, lower spur and groove, inner reef slope, and outer ridge). Transects measured coral abundance, diversity, and size class (benthos); for fishes, we measured all herbivores, corallivores, and most major carnivores (snappers, groupers, and other predatory fishes). Planktivores will be considered on future transects.

We also conducted some preliminary studies of scarid and chaetodontid feeding choices in order to understand the nutritional basis of food consumption. These tank experiments proved a successful proof-of-concept approach, and we will be continuing these experiments in subsequent visits. These tank feeding experiments are a logical extension of our previous work on Carrie Bow which have resulted in 6 publications thus far on the topic.

Finally, we continued our research on terrestrial hermit crabs (*Coenobita clypeatus*) and shell switching behavior. The results are currently in preparation for publication, and build on our previous work (2 publications on the topic) at Carrie Bow. Work from this trip was also published on the New England Aquarium blog (http://explorers.neaq.org/), with guest posts from Daniel Gruner and Alexander Forde, who were on-island with us.

Left-to-Right: Peter Gawne & Randi Rotjan (New England Aquarium), Bonnie & Ed James (Station Managers), Daniel Gruner (U. of MD), Zach Foltz (CCRE), and Alexander Forde (U. of MD).

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2010 Participants

** served as station manager*

Alanko, Jerry & Sandy, Tilghman, MD 21671*
Arnold, Susie, University of Maine School of Marine Sciences, Darling Marine Center, Walpole, ME 05473
Aronson, Rich, Department of Biology, Florida Institute of Technology, Melbourne, FL 32901
Baker, Ronald, Smithsonian Marine Station, Fort Pierce, FL 34949
Benson, Sam, Smithsonian Environmental Research Center, Edgewater, MD 21037
Birrell, Chico, ARC Centre of Excellence for Coral Reef Studies and School of Marine and Tropical Biology James Cook University, Australia
Brooks, Barrett, Smithsonian Institution, National Museum of Natural History, Department of Botany, Washington, D.C. 20560-0166
Campbell, Tom, Studio 22 Productions, Australia
Carpenter, Mike, Smithsonian Institution, National Museum of Natural History, CCRE Program, Washington D.C., 20560-0163
Chamberlain, Anne, Smithsonian Environmental Research Center, Edgewater, MD 21037
Chavez-Fonnegra, Andia, NOVA Southeastern University Oceanographic Center, Fort Lauderdale-Davie, Florida 33314
Coppard, Simon, Smithsonian Tropical Research Institute, Panama
DeBose, Jennifer, Smithsonian Marine Station, Fort Pierce, FL 34949
DeCourley, Claudette, San Diego, CA, 92130*
Diederick, Laura, Smithsonian Marine Station, Fort Pierce, FL 34949
Dirks, Ullrich, University of Vienna, Austria
Feller, Ilka, Smithsonian Environmental Research Center, Edgewater, MD 21037
Feller, Ray, Smithsonian Environmental Research Center, Edgewater, MD 21037
Fogarty, Nicole, Smithsonian Marine Station, Fort Pierce, FL 34949

Foltz, Zach, Smithsonian Marine Station, CCRE Program, Fort Pierce, FL 34949*
Forde, Alex, University of Maryland, College Park, MD 20742
Gallegos, Charles, Smithsonian Environmental Research Center, Edgewater, MD 21037
Gawne, Peter, New England Aquarium, Boston, MA 02110
Gonzales, Manuel, University of Exeter, U.K.
Gouge, Daniel, Williston FL, 32696*
Gruber, Harald, University of Vienna, Austria
Gruner, Dan, BEES, University of Maryland, College Park, MD 20742
Heindl, Niels, University of Vienna, Austria
Hochberg, Rick, Department of Biological Sciences, Univeristy of Massachusets Lowell, Lowell, MA 01854
Hoffman, William, Smithsonian Marine Ecosystems Exhibit, Smithsonian Marine Station, Fort Pierce, FL 34949
James, Edwin & Bonnie, Tilgman, MD 21671*
Jones, Scott, Smithsonian Marine Station, CCRE Program, Fort Pierce, FL 34949*
Jorgerr, Katharina, Zoologische Staatssammlung Munchen, Germany
Kenworthy, Jud, Smithsonian Environmental Research Center, Edgewater, MD 21037
Koltes, Karen, Office of Insular Affairs, Dept. of Interior, Washington, D.C.
Lee, Woody, Smithsonian Marine Station, Fort Pierce, FL 34949*
Lessios, Harilaos, Smithsonian Tropical Research Institute, Panama
Lessios, Nicolas, Department of Biology, Arizona State University, Tempe, AZ 85287
Lind, Eric, BEES, University of Maryland, College Park, MD 20742
Littler, Diane, Smithsonian National Museum of Natural History, Washington, D.C.
Littler, Mark, Smithsonian National Museum of Natural History, Washington, D.C.
Macintyre, Allan, Smithsonian National Museum of Natural History, Washington, D.C.
Macintyre, Ian, Smithsonian National Museum of Natural History, Washington, D.C.
McField, Melanie, Belize City, Belize
McLean, Elizabeth, Evolution, Ecology, and Behavior, University of Buffalo, Buffalo, NY 14260
Miller, Daniel, San Diego, CA, 92130*
Moore, Joel, Shingle Springs, CA, 95682*
Morneau, Myriam, Smithsonian Tropical Research Institute, Panama
Norenburg, Jon, Smithsonian National Museum of Natural History, Washington, D.C.
Opishinksi, Thomas, Interactive Oceanographics, East Greenwich, RI 02818
Ott, Joerg, Department of Marine Biology, University of Vienna, Austria
Ott, Renata, Vienna, Austria
Parker, John, Smithsonian Environmental Research Center, Edgewater, MD 21037
Parsons, Keith, Atlanta, GA 30316*
Paul, Valerie, Smithsonian Marine Station, Fort Pierce, FL 34949
Pederson, Troels, Smithsonian Environmental Research Center, Edgewater, MD 21037
Penland, Laurie, Scientific Diving Program, Smithsonian National Museum of Natural History, Washington, D.C.
Peresta, Gary, Smithsonian Environmental Research Center, Edgewater, MD 21037*
Pezella, Thomas, Worcester, MA, 01609*
Precht, Bill, PBS&J Ecological Sciences Program, Miami, FL 33172
Puebla, Oscar, Smithsonian Tropical Research Institute, Panama
Reed, Sherry, Smithsonian Marine Station, Fort Pierce, FL 34949
Rihl, Stephanie, Humbolt State University, Arcata, CA 95521
Ritson-Williams, Raphael, Smithsonian Marine Station, Fort Pierce, FL 34949
Rotjan, Randi, New England Aquarium, Boston, MA 02110
Semon, Kate, Smithsonian Marine Station, Fort Pierce, FL 34949
Sherwood, Craig, Deale, MD, 20751*
Smythe, Ashleigh, Biology Department, Hamilton College, Clinton, NY 13323
Spiers, Lindsay, Smithsonian Marine Station, Fort Pierce, FL 34949
Steneck, Robert, University of Maine School of Marine Sciences, Darling Marine Center, Walpole, ME 05473
Sterrer, Wolfgang, Bermuda Natural History Museum, Bermuda
Strimaitus, Anna, Department of Biological Science, Florida State University, Talahassee, FL
Talbot, Ret, Laguna Beach, CA

Tschirky, John, Biodiversity Conservation and Protected Areas Advisor, Conservation International, Arlington, VA
Vaslet, Amandine, Smithsonian Marine Station, Fort Pierce, FL
Worsaae, Katrine, University of Copenhagen, Denmark
Wulff, Colin, Talahassee, FL
Wulff, Janie, Department of Biological Science, Florida State University, Tallahasee, FL

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Smithsonian Marine Station
Caribbean Coral Reef Ecosystems Program
Fort Pierce, FL · Carrie Bow Cay, Belize

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www.si.edu/marinescience/msnet.htm

CCRE Staff:

Valerie Paul, Director

Zach Foltz, Station Manager

Scott Jones, Program Coordinator