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CCRE REPORTS 2007

Caribbean Coral Reef Ecosystems • National Museum of Natural History

August 2008

Carrie Bow Research Area

with most Cays named

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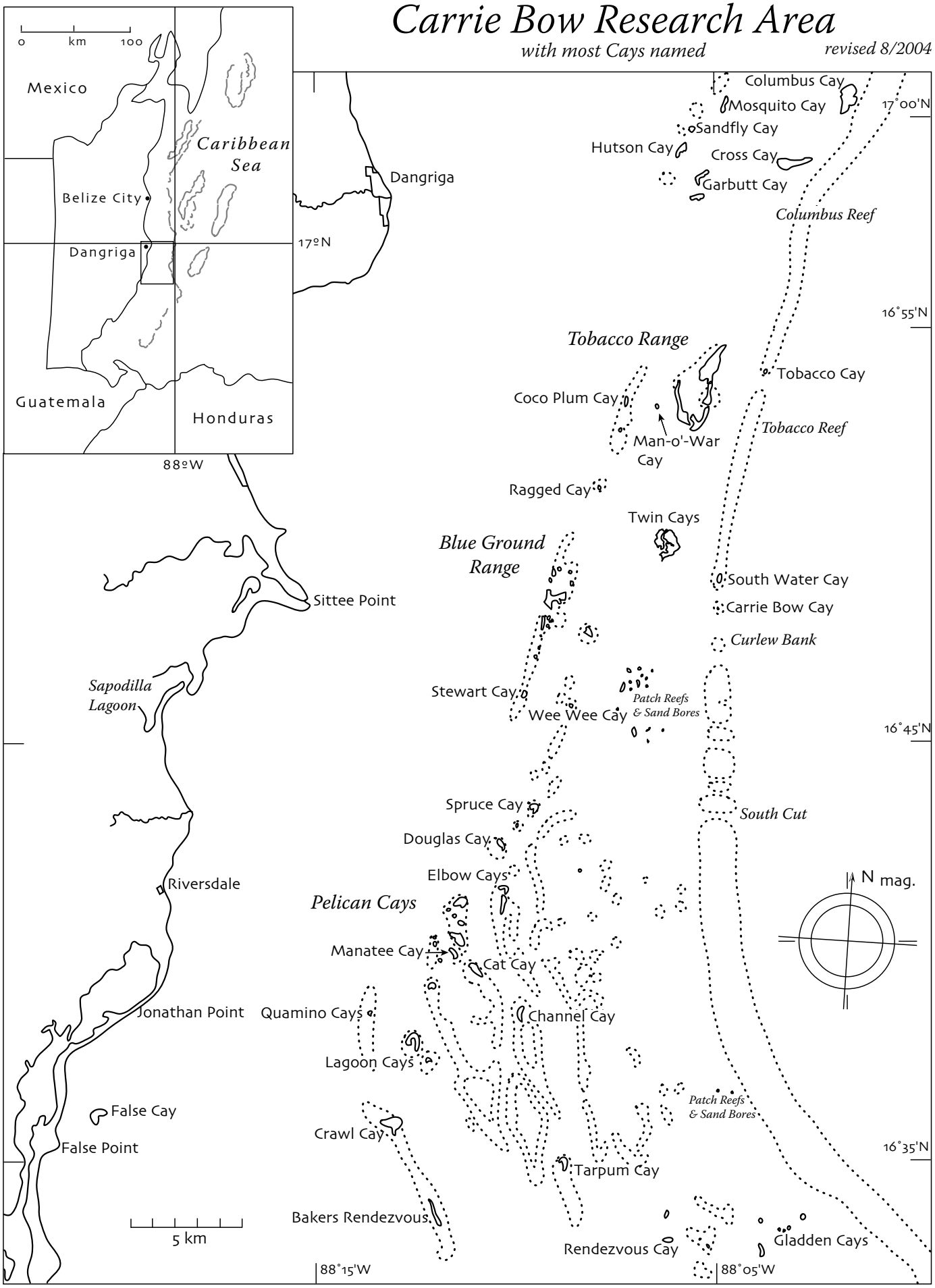

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National Museum of Natural History
Caribbean Coral Reef Ecosystem Program
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CARIBBEAN CORAL REEF ECOSYSTEMS: 35-YEARS OF SMITHSONIAN MARINE SCIENCE IN BELIZE

In the late 1960s, a group of marine scientists from the Smithsonian National Museum of Natural History, Washington, founded a long-term Caribbean coral-reef field program, now known as Caribbean Coral Reef Ecosystems (CCRE). The core group consisted of botanists, zoologists, paleobiologists, and geologists. We were looking for a study location of high geological and biological diversity and minimal anthropogenic disturbance, suitable for long-term research. We settled on the tiny island Carrie Bow Cay on the barrier reef off Southern Belize and established a field station there in February 1972. A great variety of richly populated habitats, from mangrove to fore-reef, occurs within a distance of less than one mile. The Belize mainland coast and three off-shore atolls are in easy reach by small boats. Each year, up to 120 Smithsonian staff and associated scientists, with assisting students and technicians, engage in the study of reefs and nearby mangroves and seagrass meadows. Our expertise is "whole-organism" biology, involving systematics, evolution, paleobiology, ecology, and ecophysiology. Field research is complemented by use of the rich resources of the Smithsonian home base. Today, the CCRE program is member of the Smithsonian's Marine Science Network, which includes costal laboratories in Panama, Florida, and Maryland. Field studies are mainly conducted by diving or wading and observations documented by samples, experimentation, and photography. Three small boats provide transportation to research sites. An oceanographic-meteorological monitoring station on Carrie Bow Cay records parameters such as tide, temperature, radiation, wind, and precipitation; data are made accessible through the Web. Additional sensors and recorders are applied in situ where required. We are also following the CARICOMP protocol for monitoring reef, mangrove, and seagrass communities. The decline of reefs worldwide is accelerating and focus and resources are urgently needed to improve our understanding of biodiversity, community structure and dynamics, and environmental processes that control the ecosystem. The Caribbean is "our" American tropical sea, to which we are connected by weather, ocean currents, and marine resources, as well as by cultural and economic exchange. Fortunately, we were able to document the diversity and complexity of the originally pristine barrier reef complex near Carrie Bow Cay for more than 35 years and in over 800 publications. Despite considerable progress made by the CCRE and other research groups in the Caribbean, there are still many gaps in understanding the components and processes of coral reefs and related systems. Newly advanced methods, such as molecular techniques, will have to be applied and focus put on climate change and other stress factors responsible for the increasingly common occurrence of algal blooms and devastating invertebrate diseases. These topics and more need our full attention to help guide resource management and conservation efforts and preserve the esthetical and economic value of our reefs.

CARRIE BOW CAY AUTOMATED MET-OCEAN MONITORING: A DECADE OF SUCCESS SUPPORTING SCIENTIFIC RESEARCH ON THE MESOAMERICAN BARRIER REEF

Thomas B. Opishinski

In 1997 an environmental monitoring system was established at the Carrie Bow Cay (CBC) Marine Research laboratory in Belize to address the fundamental need for meteorological and oceanographic measurements. Many factors including operational environment, remote location, data accessibility, power restrictions, autonomous operation, and available communications for data transfer influenced the design criteria. In many ways the design criteria established for the system by CCRE in 1996 were both pioneering and vital to the long term success of the system. It was one of the earliest monitoring systems to process and transfer real-time data from a remote geographic location to a web site for public access. To our knowledge it is still the only automated system continuously monitoring both oceanographic and meteorological conditions on the outer Meso-

american Barrier Reef. The system continues to provide a baseline set of data used to examine long term trends, short term and seasonal cycles, and episodic events. This data has proven invaluable to management efforts for regional organizations and research studies for both Smithsonian scientists and an increasing number of organizations worldwide. To meet expanding needs of the users, continuous efforts are taken to improve and add functionality to the environmental monitoring system and supporting web site. This paper provides a general overview of the system, samples of new data offerings (e.g. statistical weather summaries, tidal forecasts and shoreline surveys), samples of data (illustrating trends, extreme weather events and seasonal dependencies), and examples of several projects that have utilized the data from Carrie Bow Cay. Also included is an introduction to some of the features of the newly designed web site (projected late 2007) that will provide interactive data analysis for the user, forecasting and real-time quality control of data.

Acknowledgements

Research Projects

Biodiversity and its Links to the Ecosystem

Algae

Biodiversity of *Gambierdiscus* harmful dinoflagellates in the Belizean coral reef mangrove forest

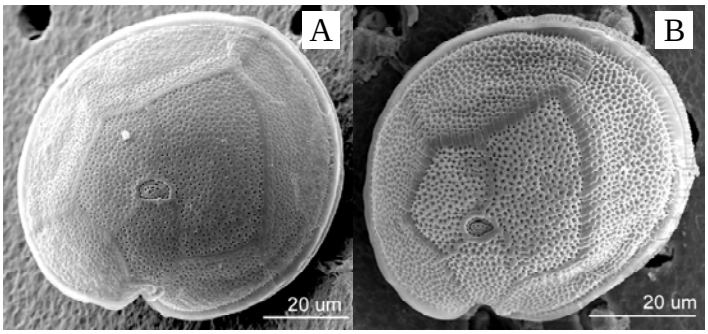
M. Faust, P.Tester, W. Litaker, S. Kibler, M. Vandersea & C. Holland

Research efforts at Carrie Bow have focused upon the distribution and ecology of dinoflagellates within the sheltered mangrove cay embayments and surrounding oligotrophic habitats in the central lagoon of Belize. The ecology and distribution of these dinoflagellates is of concern because some of these species produce the toxins responsible for causing ciguatera fish poisoning (CFP), the largest cause of non-bacterial food poisoning in the world. CFP adversely affects both human health and the development of fisheries resources in tropical regions. We have found that dinoflagellate populations in the embayments contain high concentrations of potential CFP-causing species and are supported by nutrients derived from the mangrove detritus. Single cell isolations have lead to the identification of four new species in the CFP-associated genus *Gambierdiscus*, one new toxin-producing *Prorocentrum* species, and 2 new potentially toxic *Coolia* species. In 2007, we took advantage of the diverse array of habitats in proximity to the Field Station at Carrie Bow Cay to address the following two hypotheses: 1) Ciguatera-associated dinoflagellates are more abundant in naturally eutrophied or human-impacted sites and 2) *Gambierdiscus* species exhibit a preference for specific benthic habitats. Because CFP events are highly variable, both temporally and spatially, understanding species diversity, as well as nutrient and habitat requirements, may prove crucial in determining the conditions and species suites most predictive of CFP events.

Determining Dinoflagellate Abundances and Habitat Preference.

Because ciguatera dinoflagellates are often associated with the benthos and exhibit a very patchy distribution, standard water-column collection methods used to quantify phytoplankton species were not applicable. Instead, we used small anchored squares of fiberglass window screens to which benthic species readily attach. The screens were deployed for 24h at various sampling sites (Fig. 1), then transferred to ziplock plastic bags partially filled with ambient seawater and shaken to dislodge attached cells. Fixed samples of the resulting suspension were retained for cell abundance. Samples were also retained for DNA analysis and single cell isolation of ciguatera-associated dinoflagellates in the genera *Gambierdiscus*, *Coolia* and *Ostreopsis*.

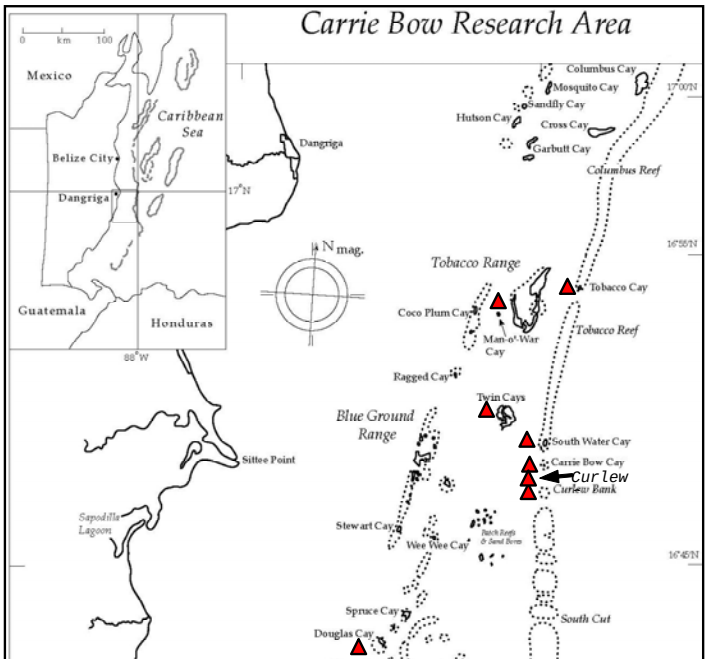
Accumulation of cells on the screens indicated dinoflagellates were common (>7 cells cm2) in samples at all the embayment sites, with maximum abundance (>5000 cells cm2) observed inside Douglas Cay. Microscopic identification of the preserved cells from the 2007 screen samples are still in progress. However, preliminary data for the screens showed that the most nutrient enriched site, Douglas Cay was dominated by *Gambierdiscus* spp., *Prorocentrum* spp. and other dinoflagellates (DC, Fig. 1). At DC, the abundance of potentially toxic *Gambierdiscus* cells was noticeably higher than at open water, high energy sites such as Man-O-War Cay, Carrie Bow, and South Water Cay. The most abundant Prorocentrum species was *P. rhathymum*, which also reached maximal densities inside DC. *Coolia* species were rare compared to previous years. The assemblage observed in DC was different than in the previous 2



SEMs of A) *Gambierdiscus caribaeus* and B) *G. belizeanus*.

years, when DC was marked by blooms of *P. mexicanum* (2005) and *Gambierdiscus* (2006). Our screen sampling also revealed several species of *Ostreopsis* were abundant in high energy, low nutrient environments on the windward side of DC, Carrie Bow Cay, Twin Cays, and South Water Cay. Representative samples are also being examined using SEM to provide additional information on the diversity of species present (Fig. 3). These results require further investigation, but suggest that *Gambierdiscus* and *Ostreopsis* may prefer different benthic environments and implies that sources of ciguatera toxins may be linked to specific habitats.

Because individual *Gambierdiscus*, *Coolia* and *Ostreopis* species are very difficult to distinguish by light microscopy the screen samples are being evaluated using scanning electron microscopy, and species-specific PCR. These molecular assays are based on unique LSU rDNA sequences obtained from single cell isolates derived from samples collected in previous field seasons. Assay specificity was confirmed by testing whether the primers sets amplified other known *Gambierdiscus* species and by cloning and sequencing PCR products amplified from field samples. The SEM and molecular evaluation is ongoing, but preliminary screening has confirmed the presence of *G. caribaeus* and *G. belizeanus*, but not *G. toxicus*. Stations that were negative for *Gambierdiscus* by light microscopy have proven negative using the PCR assays as well. These data do not rule out the possibility that other species of *Gambierdiscus* were present in the samples. Seven other *Gambierdiscus* assays are in the final validation stages and will be used to detect *G. polynesiensis*, *G. australes*, *G. pacificus*, *G. yasumotoi*, *G. ruetzleri*, *G. carolinianus*, and *G. carpenteri* in the field samples.



Study area surrounding Carrie Bow Cay with sampling sites marked (▲).

In summary, the screen cell count data illustrated an abundance of dinoflagellates within lagoon habitats and showed that the screens were an effective way to quantify benthic dinoflagellates. *Ostreopsis* species appear to predominate other CFP-associated dinoflagellates in high energy habitats. In contrast, *Gambierdiscus* are most abundant in high nutrient, low energy mangrove environments. We are concentrating on establishing single cell isolates of *Ostreopsis* to develop species-specific assays. The ability to specifically detect both *Gambierdiscus* and *Ostreopsis* will likely prove crucial for elucidating the mechanisms responsible for the temporal and spatial variability of ciguatera outbreaks.

Belizean coral reef-mangrove forest: A habitat for motile, benthic, toxins producing dinoflagellates

M. A. Faust

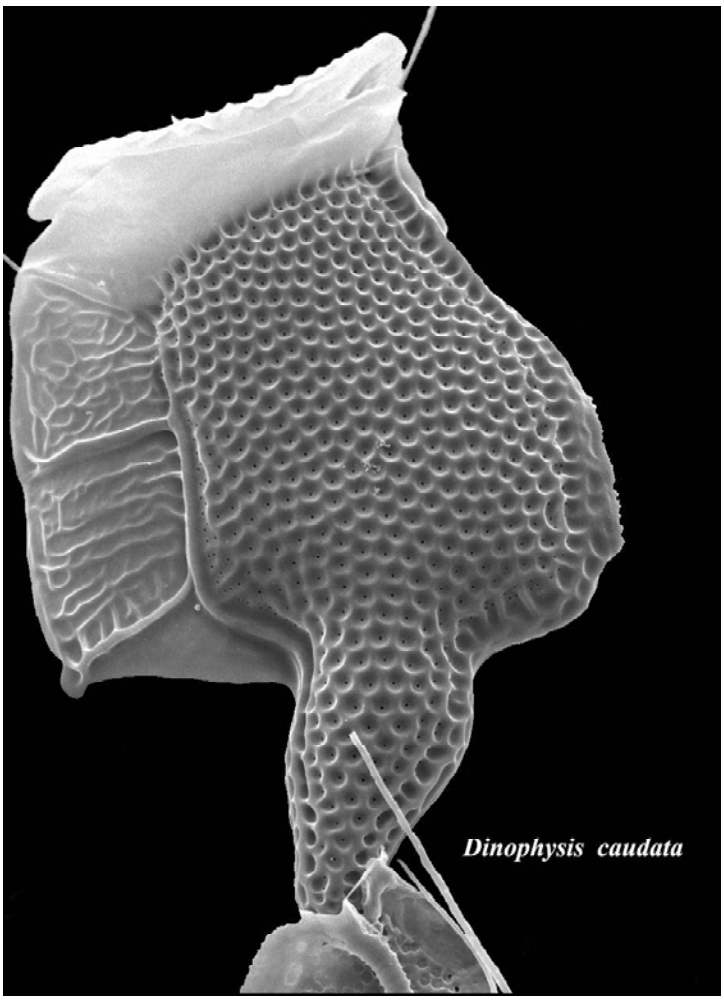
With the continuing decline in the world's coral-reef mangrove natural resources, a question of public concern is how to assess the health of biological communities and ecosystems. The problem is especially problematic since the Atlantic barrier reef ecosystem includes coral-reef mangrove islands, shelter extensive mangrove lagoons, host tourists, and an important fishery resource for the country. Studies however, demonstrate that dinoflagellates are vulnerable and threatened in the Pelican Cays by recent human activities of sediment runoff that caused water column turbidity and the loss of dinoflagellate species which are essential food source for fish and shellfish. Field research has identified numerous harmful dinoflagellates that thrive in sheltered mangrove cay embayments and surrounding oligotrophic habitats in the central lagoon of Belize. The ecology and distribution of these dinoflagellates is of concern because some of these species produce toxins. The aim of the research to develop quantitative molecular assays, namely bar coding single harmful dinoflagellate species some produce the toxins responsible for causing ciguatera fish poisoning, the largest cause of non-bacterial food poisoning in the world.

1) Biodiversity of dinoflagellates at elevated sea water temperatures in coral reef-mangroves Belize

Field research data suggests that elevated water temperatures, 31 to 33O C, selectively changed dinoflagellate species composition favoring *Ostreopsis* species in open water high energy low nutrient habitats and *Gambierdiscus* species in low energy high nutrient habitats. In previous years water temperature was lower ranging from 28 to 29 O C, and rain fall provided additional nutrients to the sea supporting a broader range of dinoflagellate assemblages. Research data however, indicate that 2 to 3O C difference in water temperature in the absence of rain causes significant changes in the biodiversity of benthic and planktonic harmful dinoflagellate species. It is essential knowing the situation which may affect the species-specific biodiversity of dinoflagellates caused by environmental variability in nature. The ecology and distribution of these dinoflagellates is of concern because some of these species produce the toxins responsible for causing ciguatera fish poisoning (CFP). Research established that harmful dinoflagellates are directly affected by elevated water temperature and the proximity of nutrient resources of either natural or anthropogenic origin in the habitats located in the central lagoon Belize.

2) Mixotrophy of harmful dinoflagellates in the Belizean coral reef-mangroves

Research identified mixotrophy of *Ostreopsis* species during field work. Mixotrophy is a process when engulfed whole prey (microalgae, nannoplankton and protists) is found inside the cytoplasm of a dinoflagellate to supplement nutrients to a starving organism. Mixotrophy occurred in *O. labens*, *O. lenticularis*, *O. siamensis* and *O. ovata* assemblages dominated in plankton habitats: Southwater Cay, Man O' War Cay, Carrie Bow Cay and outside water at Twin Cays in high energy and low nutrient waters. These species exhibited cellular plasticity (cell volume increase of 30 to 50 %) during mixotrophic nutrition. Mixotrophy was observed infrequently in *Gambierdiscus toxicus*, *Prorocentrum belizeanum*, *P. hoffmannianum* and *P. arenarium* species in nutrient enriched protected embayment Douglas Cay. This phenomenon represents adaptation and survival of *Ostreopsis* species during absence of rain in oligotrophic warm ocean waters. Results indicate that harmful dinoflagellate *Ostreopsis* species have the potential of being important grazers in the marine food webs when under environmental stress.



This also implies that sources of biotoxins may be linked to specific habitats need further investigation.

3) Taxonomy and phylogenetic relationship in the genus *Coolia*, including two new species, *Coolia* sp. 1 nov. and *Coolia* sp. 2 nov. (Dinophyceae).

Two new *Coolia* species were identified. Both *Coolia* species were morphologically distinguishable: *Coolia* sp.1 nov. has a small cell size, narrow 1' plate, pointed 3' plate, and a short apical pore; Coolia sp. 2 nov. have a medium size, broad 1' plate, and crescent-shaped 3' plate, and short curved apical pore. The morphology of two new *Coolia* species differ from three known species, *C. monotis* Meunier (Type sp.), *C. tropicalis*, Faust, and *C. areolata* Ten-Hug et al. These species is supported by morphological differences and separate phylogenetic analyses of the small subunit rDNA genes. *Coolia* sequences included in phylogenetic analyses were derived from single cell isolates of *Coolia* sp.1 nov., *Coolia* sp. nov. and *Coolia tropicalis*, and *C. monotis* sequence available in GenBank. The phylogenetic analysis of the SSU rDNA gene sequences showed that *Coolia*, *Gambierdiscus* and *Ostreopsis* formed monophyletic groupings consistent with three distinct genera.

4) Vulnerability of dinoflagellates in Pelican Cays, Belize

Pelican Cays are delicate oceanic coral reef-mangrove ecosystem and support high level of dinoflagellate abundance and biodiversity within the Belizean central lagoon. Pelican Cays are representative pristine oceanic cays situated in a remote region without major human perturbations. Dinoflagellate cells collected in Manatee Cay, Pond C in 1996 included 28 genera and 84 species; about 50% of total species were new reports in the Pelican Cays. Data in 2007 found only 6 genera and 17 dinoflagellate species. Field observations, as well recent aerial photographs surveying the area, indicate that since January 2007 clearing of large tracts of land on several cays and destruction of the pond communities is extensive and continuing. Comparison of dinoflagellate species composition, before and after mangrove clearing, indicate dramatic loss in dinoflagellate species and a greatly changed microscopic food web, probably owing it to high turbidity in the water column. Since taxonomic data of dinoflagellates in The Pelican Cays from 1996 to 2007 is available, the vulnerability of organisms could be recognized. Because mangroves, like coral reefs and other tropical shallow-water communities exist near the limit of ecological tolerance of their inhabitants, dinoflagellates appear as significant indicators of changing environmental quality. Research data suggest Pelican Cays as an ideal research site that can provide an early biological warning system for changing ecosystem water quality detrimental to the existence and survival of fish and shell fish.

5) Bar coding harmful dinoflagellate species

Gambierdiscus species are very difficult to distinguish by light microscopy. The morphology of individual cells is evaluated by SEM and species-specific PCR. These molecular assays are based on unique LSU rDNA sequences obtained from single cell isolates derived from samples collected in previous field seasons. Assay specificity was confirmed by testing whether the primers sets amplified other known *Gambierdiscus* species and by cloning and sequencing PCR products amplified from field samples. These molecular assays are based on unique LSU rDNA sequences obtained from single cell isolates derived from samples collected in previous field seasons. Assay specificity was confirmed by testing whether the primers sets amplified other known *Gambierdiscus* species and by cloning and sequencing PCR products amplified from field samples. Seven other *Gambierdiscus* assays are in the final validation stages and will be used to detect *G. polynesiensis*, *G. australes*, *G. pacificus*, *G. yasumotoi*, *G. ruetzleri*, *G. carolinianus*, and *G. carpenteri* in the field samples. The ability to specifically detect both *Gambierdiscus* and will likely prove crucial for elucidating the mechanisms responsible for the temporal and spatial variability of ciguatera outbreaks. This research is a collaborative effort with Dr. Pat Tester's group for identifying the morphology of dinoflagellate species at high resolution SEM microscopy and the genetics of single cell isolates with molecular taxonomy.

Porifera

Towards a DNA taxonomy of Caribbean demosponges: A gene tree reconstructed from partial mitochondrial CO1 gene sequences supports previous rDNA phylogenies and provides a new perspective on the systematics of Demospongiae

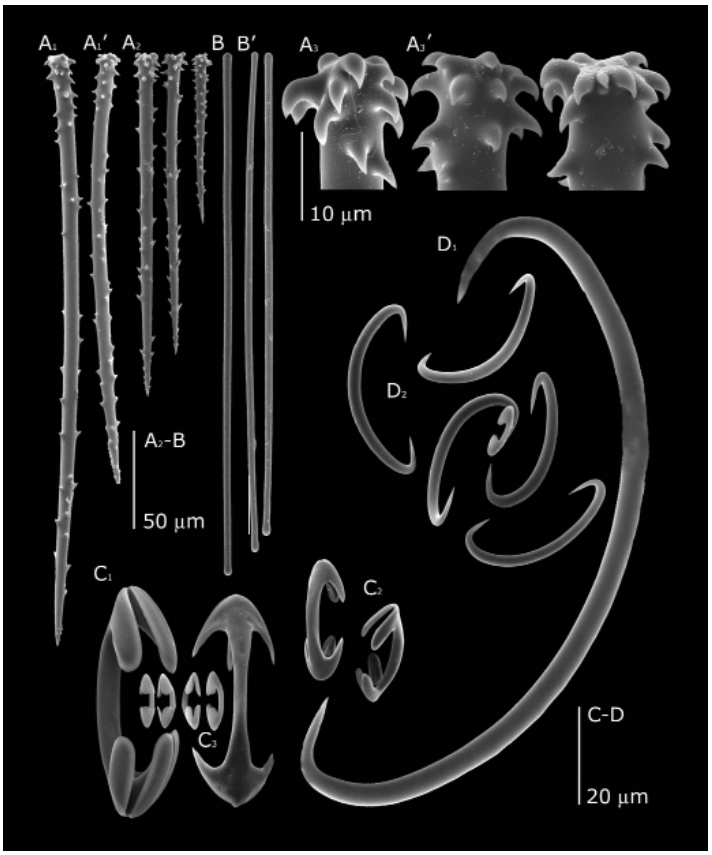
D. Erpenbeck, S. Duran, K.Rützler, V. Paul, J.N.A. Hooper & G. Wörheide

The most comprehensive cytochrome oxidase subunit 1 gene tree was published to date for demosponges based on new sequences. The CO1 barcoding fragment is sequenced for 65 species from the Caribbean Sea, and its gene tree reconstructed. Although its deeper nodes are not particularly well-supported, the gene tree provides a variety of information for new phylogenetic patterns, as well as support for previously published 28S rDNA gene trees. In our analysis Halichondriidae cluster with Suberitidae, supporting previous 28S rDNA data. Chelae-bearing Poecilosclerida are monophyletic but most taxa lacking chelae in this dataset cluster more distantly. Haplosclerida are not resolved monophyletically under this fragment. While some species exhibit distinc barcodes, some genera contain species that share CO1 haplotypes.

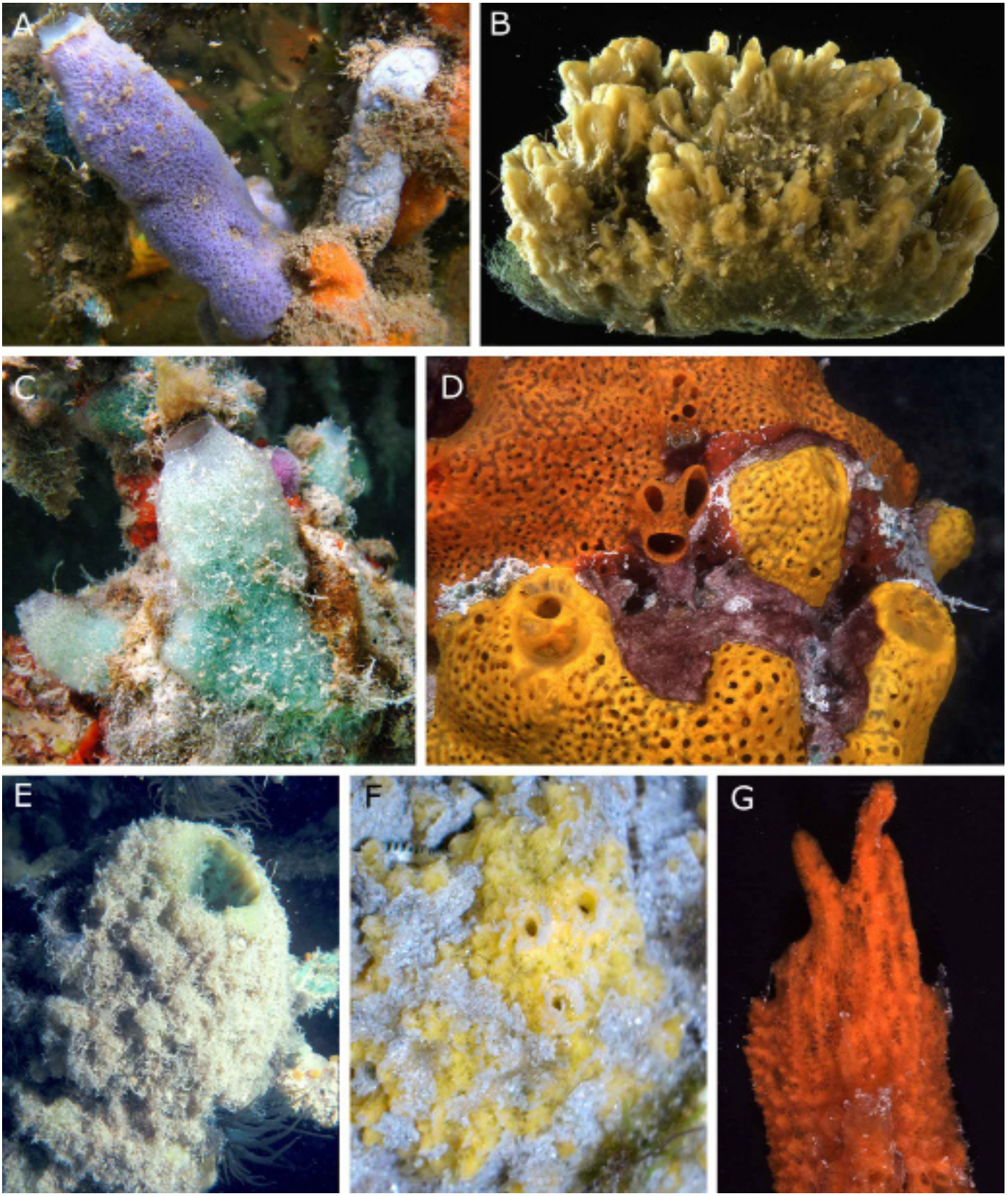
Lissodendoryx: rediscovered type and new tropical western Atlantic species (Porifera: Demospongiae: Poecilosclerida: Coelosphaeridae)

K. Rützler, C. Piantoni & M.C. Diaz

Seven syntypes of Halichondria isodictyalis, type species of *Lissodendoryx*, were rediscovered and studied. By choosing a lectotype and studying it along with the paralectotypes, we find that *L. isodictyalis*, subgenus *Lissodendoryx*, is a Caribbean sponge characterized by smooth megascleres, ectosomal tylotes and choanosomal styles, and one size-class of microscleres comprising arcuate isochelae and sigmas. Having determined these characteristics, we re-erect *Lissodendoryx* (*Lissodendoryx*) *carolinensis* (previously synonymized with *L. isodictyalis*), with the same smooth megascleres but two distinct size categories of microscleres, isochelae and sigmas; and we add a new western Atlantic species, *Lissodendoryx* (*L.*) *spinosa* sp. nov., with coarse spines on the megasclere terminals and with two size-classes of isochelae and sigmas. Other species in the region are *Lissodendoryx* (*L.*) *colombiensis*, with smooth tylotes and robust strongyles, and two categories of microscleres (isochelae and sigmas) accompanied by conspicuous raphids arranged in trichodragmas; *Lissodendoryx* (*L.*) *strongylata*, with smooth tylotes and slim strongyles, one size-class each of isochelae and sigmas, rare and very thin raphids. *Lissodendoryx sigmata* is here assigned to the subgenus *Anomodoryx*, with smooth tylotes exclusively as megascleres, two size-classes of isochelae, and one or two sizes of sigmas; it may represent a species complex far more diverse than previously thought. To this subgenus we add another species, *Lissodendoryx* (*A.*) *amphispinulata* sp. nov., characterized by fine spines ornamenting both tyles of part of the tylotes. A third subgenus, *Ectyodoryx*, is represented by *Lissodendoryx* (*E.*) *acanthostylota* sp. nov., with smooth tylotes and finely spined acanthostyles in two size-classes, as well as two size-classes each of isochelae and sigmas as microscleres. All species studied alive occur in shallow lagoon habitats with mangroves and sea grass (Thalassia) but museum specimen records show that some may reach a depth of 60 m.



Lissodendoryx acanthostylota sp. nov.

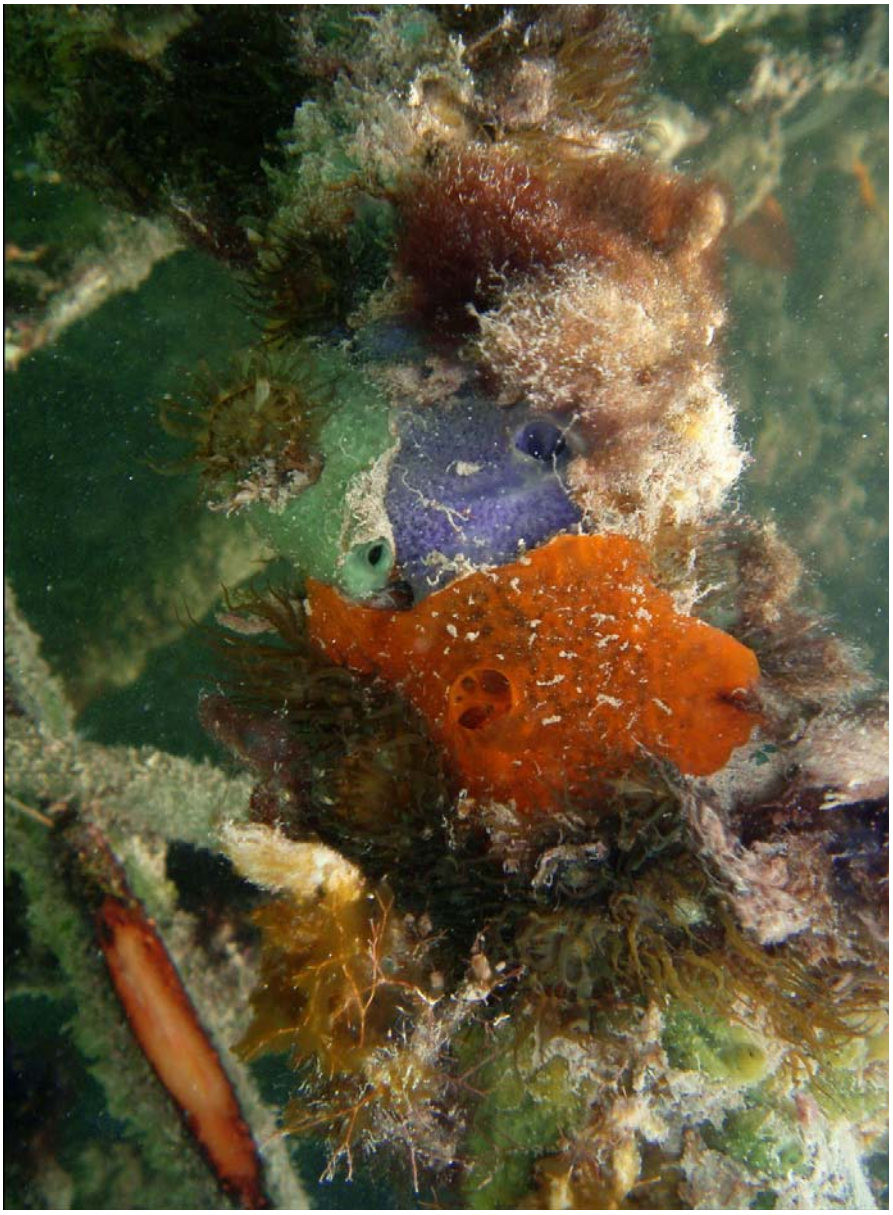


Live specimens of *Lissodendoryx* species illustrating variations in shape and color. (A) *L. isodictyalis* (Carter) in situ; Twin Cays, Belize, mangrove; (B) Same species live in aquarium; Harrington Sound, Bermuda (photo: G. K. Jensen &W. E. Sterrer); (C) *L. carolinensis* Wilson in situ; Twin Cays (photo S. Duran & M. Becerro); (D) *L. colombiensis* Zea & van Soest, two color variants in situ; Twin Cays; (E) *L. spinosula* sp. nov. in situ; Twin Cays; (F) *L. sigmata* (de Laubenfels), var. nov.? in situ; Atlantic Florida; (G) *L. sigmata* (de Laubenfels), live in aquarium; Twin Cays.

Biodiversity and abundance of sponges on the caribbean mangrove roots

M.C. Diaz & K. Rützler

Surveys of diversity and abundance of sponges in Caribbean mangroves were carried out between 2003 and 2007 with support of the Marine Science Network program. The results show that sponges are an important component of the red-mangrove (*Rhizophora mangle*) root epifauna, both in species richness and relative abundance. Sixty-five species were reported from Bocas del Toro (Panama) and 62 from Twin Cays (Belize) mangrove habitats. Three new Haplosclerida species with unusual (filamentous) cyanobacterial symbionts were discovered (genera *Haliclona* and *Xestospongia*) and are currently being described. Field guides for each fauna are being produced with the aim of facilitating the study of marine sponges by non-experts. A comparison of mangrove species composition from Bocas del Toro and Twin Cays shows a high similarity with other well studied Caribbean sites, such as Venezuela (65 species) and Cuba (43). However, since most Caribbean mangrove systems have not been rigorously evaluated taxonomically, a conclusive biogeographic analysis can not yet be attempted. The distribution of sponge species within each studied geographic region indicates that the majority (50-80%) presents a disjunct distribution, being restricted to one or a few sites within a particular locality. The relative abundance of major epibenthic taxonomic groups (such as, algae, cyanobacteria, ascidians, sponges, bivalves) shows great variations in both space (between localities of each region) and time (over the course of one year or more). Recommendations to be considered for future studies of mangrove sponges include, that surveys should cover long fringe distances to account for the disjunct distributions; and that ecological studies relying on abundance or changes in species composition should be based on one given locality and long-term because of large spatial and temporal variations in the relative importance of major taxonomic groups.



Annelida

Diversity of selected polychaetes families in Carrie Bow Cay and Twin Cays

G. Rouse

On my 2006 visit to Carrie Bow I mainly collected sabellid polychaetes for phylogenetic studies using molecular sequence analyses. The family Sabellidae was recently split into Sabellidae and Fabriciidae (Kupriyanova & Rouse 2008) and I focused my efforts at Carrie Bow and Twin Cays to finding a series of fabriciid species that were described from there by myself and Kirk Fitzhugh in the 1990s. I was successful in finding 5 of the 6 species present including specimens of an undescribed species in a new genus; picture attached. Sequencing is now complete and the phylogeny and species de

scription will be published in the coming year.

Taxonomic status, abundance pattern and distribution of *Lysidice* and *Nematonereis* species (Polychaeta, Eunicidae) in the Western Caribbean Sea

M. C. Gambi, C. Vasapollo & K. Fauchald

Differently form other genera within the polychaete Eunicidae, the taxonomic status of *Lysidice* and *Nematonereis* of the Western Caribbean Sea have not yet been evaluated. The cryptic habit of both genera (within dead corals, seagrass meadows and soft-bottoms) probably favoured their relatively high diversification especially in tropical areas, however, only a few species have been reported for the Western Caribbean.

Previous observation on material collected at CBC in a research stay of this team in November 2005, allowed to collect and confirm the occurrence of at least three new species of *Lysidice* whose morphological description is in progress, and which also showed a clear habitat selection: *Lysidice* sp. b and *Lysidice* sp. c were mainly associated to dead coral rubbles, while *Lysidice* sp. a and *Nematonereis* sp. occurred exclusively on the sheaths of the seagrass *Thalassia testudinum*. To confirm taxonomic status of such specie, increase the number specimens for the analysis of their genetic structure, and better define habitat selection and reproductive biology, we needed to make additional observation and collect further material. In addition, for *Lysidice* sp. a and *Nematonereis* sp., associated to *Thalassia* as sheath borers, we performed a pilot study to first evaluate their abundance pattern and spatial variability in selected *Thalassia* meadows.

The aims of our research at Carrie Bow during this second study period of the team (3-17 October 2007) were:

1) collection of *Lysidice* sp. b and *Lysidice* sp. c in coral rubbles at different depths, to better define their morphology and genetic structure and relationships, and to test possible niche separation of the two species;

2) estimate the abundance pattern and the level of spatial variability of the sheath borers *Lysidice* sp. a and *Nematonereis* sp. in selected *Thalassia* meadows submitted to different environmental conditions.

Samples collection has been entirely conducted SCUBA diving by Gambi, Vasapollo, Miller and Keel, and lasted from 4th to 16th October for a total of 24 dives.

Coral dead rubbles were collected at various sites around CBC at depths from 1 to 20 m., both inside the lagoon (e.g., in front of Carrie Bow station, and at sand bores near Wee Wee Cay) and in the outer reef mainly in front of the CBC, at South Cut and Curlew bank. A few mature male specimens of Lysidice were fixed in 2.5% glutaraldheyde for electron microscopy analysis of gamete ultrastructure.

As for the two species associate to *Thalassia testudinum*,

Thalassia sheathborers.

two meadows were selected, which both represent historical sites for long-term monitoring of *Thalassia* in the framework of the CARICOMP program: Carrie Bow Cay and Twin Cays. In each of these locations we accomplish a pilot study to clarify the distribution of borer polychaetes at different spatial scales. We operated according to a nested and hierarchical sampling design where in each location (CBC and TwC) two sub-sites (A and B) were identified at a distance of about 200 m each other; in each sub-site two stations (1 and 2) were established at a distance of 20-25 m each other; in each stations, 3 plots (1 m square) located at a distance of about 2-3 m each other, were considered as replicates. Within each 1 m square plot, between 30 and 40 shoots of Thalassia were sampled (mean 33 shoots per sample) and the shoot density was measured on a 30 x 30 cm frame; in each meadow 20 shoots were also analyzed for leaf morphology. All sampling stations were at 3-4 m depth.

A few other *Thalassia* meadows (sand borers near Wee Wee Cay, Man of War Cay, Twin Cays main channel) were considered for qualitative observations on borer occurrence in different conditions and depths (1 to 10 m). In the laboratory, all the *Thalassia* shoots collected were immediately checked for the presence of borer polychaetes; the collected animals were preliminarily identified at the stereomicroscope and then partially fixed in formalin 4% for morphological analysis, and partially dried for analysis of the stable Carbon and Nitrogen isotopes to define their diet.

As whole we were able to collect many specimens of both species of *Lysidice* associated to coral rubbles, including various mature, schizogamic female and male individuals. Part of these specimens were fixed in absolute alcohol for genetic analyses. As for the *Thalassia* borers we checked their presence in various meadows and found that they occurred in all sites considered but that were occasional at very shallow depth (1-2 m depth at Man of War and within the Twin Cays main channel), while they were particularly abundant at 10 m depth in meadows surrounding sand bores near Wee Wee Cay.

As for the two meadows selected for quantitative sampling, CBC and Twin Cays, in the various stations and replicates we analysed a total of 810 *Thalassia* shoots, finding 206 borer polychaetes, for a mean Index of Borer of 25% (IB = % of the shoots with borers over the total sampled).

Abundance pattern was different in the two studied meadows, with Twin Cays stations showing significantly higher IB values than CBC ones. At Twin Cays IB values ranged between 20% and 38%, while at CBC they were lower, ranging between 20% and 5%.

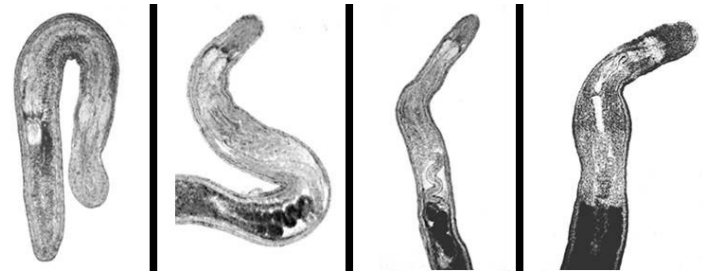
Spatial variability among stations and sub-sites was evident at both meadows, but was higher at CBC, probably related to the fact that this meadow is characterized by a patchy distribution of shoots, it grows under more oligotrophic conditions, and showed lower shoot density (mean 394.4 shoot/m2, at 3-4 m depth), respect to the Twin Cays meadow characterized by more uniform distribution, higher trophic conditions - due to the vicinity with large mangrove swamps - and slightly higher shoot density (mean 458 shoots/m2 at 3-4 m depth).

Nemertine Worms

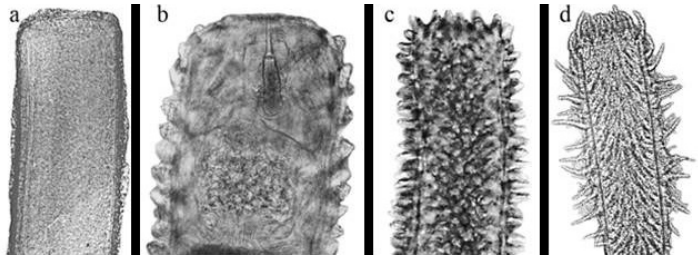
Phylogenetic and phylogeographic studies with the specialized interstitial genus *Ototyphlonemertes* (Hoplonemertea: Nemertea): Tiny worms take on big questions

J. Norenburg, S. Andrade, J.M. Turbeville & A. Tulchinsky

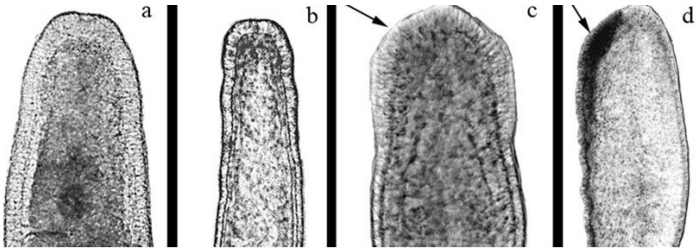
Ototyphlonemertes is a group of 21 recognized species and at least 30 more undescribed morphotypes that occupy the pore space of coarse marine sediments and share a number of features considered to be adaptations to that specialized mode of existence.



Differences in some of gross morphological features evident even at low magnification.



Differing epidermal papillae on everted proboscis.



Caudal adhesive plate (arrows), primarily in surf zones; unique construction of adhesive and releaser glands.

The most conspicuous of these features is a pair of cerebral statocysts, which is a synapomorphy for the genus. There are two groups recognizable based on coordinated features of the statocyst and proboscis stylets – one group has oligogranular statoliths and smooth stylets, the other has polygranular statoliths and spirally sculpted stylets. However, monophyly of the genus or either of these groups had not been convincingly tested. The genus also can be divided into 6 "phylomorphs" based on combinations of morphological features. The probability of convergent morphologies must be considered as significant, because the features that characterize the putative lineages also can be interpreted as having been strongly selected by the specialized mesopsammic habitat. Our goal is testing monophyly of the putative lineages, as well as examining species boundaries. Specimens were collected from much of the world, with particular focus on the Western Atlantic Ocean, Caribbean Sea and Eastern Pacific Ocean. We present results of phylogenetic analysis of sequence data from three genes for about 50 morphs, representing each of the 6 phylomorphs. Our results support monophyly of the genus but not reciprocal monophyly of the two groups defined by statolith structure. In addition to a phylogeny, we have sufficiently fine-grained data for some morphs to begin examining phylogeography.

Crustacea

History of the social shrimp: Insights from long-term research at the Smithsonian's Caribbean field stations

J.E. Duffy, K.S. Macdonald III, C.L. Morrison, R. Ríos & E. Tóth

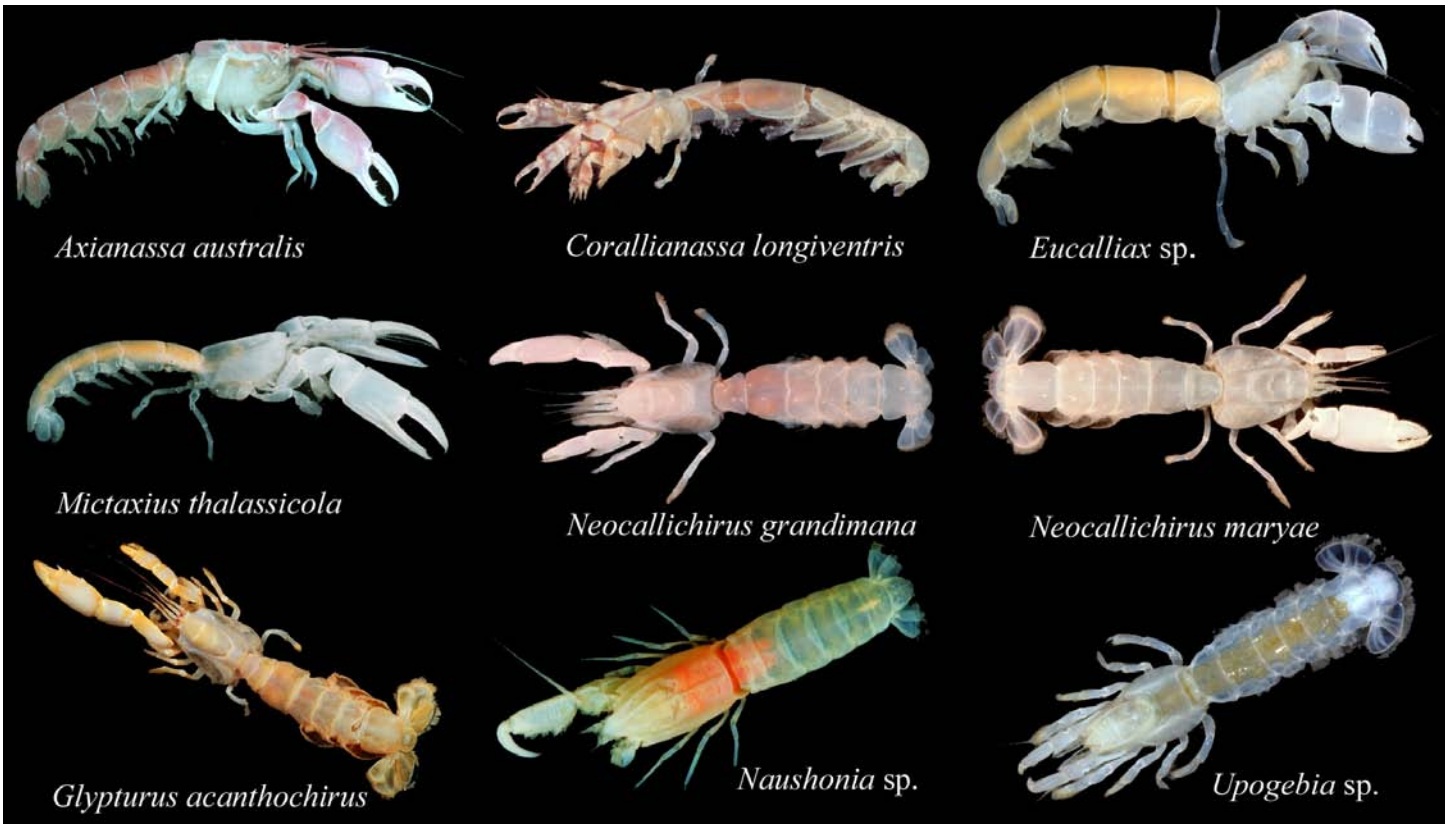
Snapping shrimp in the genus *Zuzalpheus* (formerly *Synalpheus*, in part) are abundant and diverse residents of coral reef ecosystems worldwide and include the only marine animals known to live in eusocial colonies. Research conducted at the Smithsonian's field stations at Carrie Bow Cay and in Caribbean Panama over nearly two decades has revealed much of the previously unknown natural history, ecology, and evolution of these unique and fascinating animals. We have described nine new species and a new genus of alpheids, documented host associations in detail, reconstructed the group's phylogeny, observed behavior in captive colonies, and integrated these data to evaluate the ecological and evolutionary consequences of social

life. Calibration of a molecular clock using three transisthmian species pairs suggests that Caribbean *Zuzalpheus* radiated rapidly ~6 Mya during closure of the Panama seaway. The improved taxonomy has shown that host associations of sponge-dwelling shrimp are much more specialized than previously believed. Comparative studies reveal that eusocial life has had pervasive consequences for shrimp morphological evolution, life history, and ecology. For example, after controlling for phylogenetic relatedness, eusociality is associated with smaller body size, and a switch in the direction of sexual dimorphism toward (paradoxically) relatively smaller females producing smaller clutches of eggs. Eusocial species also attain greater abundance and use a broader range of host sponges, supporting the hypothesis that sociality confers a competitive advantage in the crowded environment of the reef. Ongoing research uses social shrimp as a model for addressing general questions about animal social organization, focusing on how patterns of mating and dispersal influence the fine-scale genetic structure of social colonies, and how genetic relatedness in turn affects the balance between cooperation and conflict.

Obvious invaders and overlooked infauna: Unexpected constituents of the Decapod crustacean assemblage at Twin Cays, Belize

D. Felder, P.C. Dworschak, R. Lemaitre, R. Robles, H.D. Bracken, A.M. Windsor & J. Felder

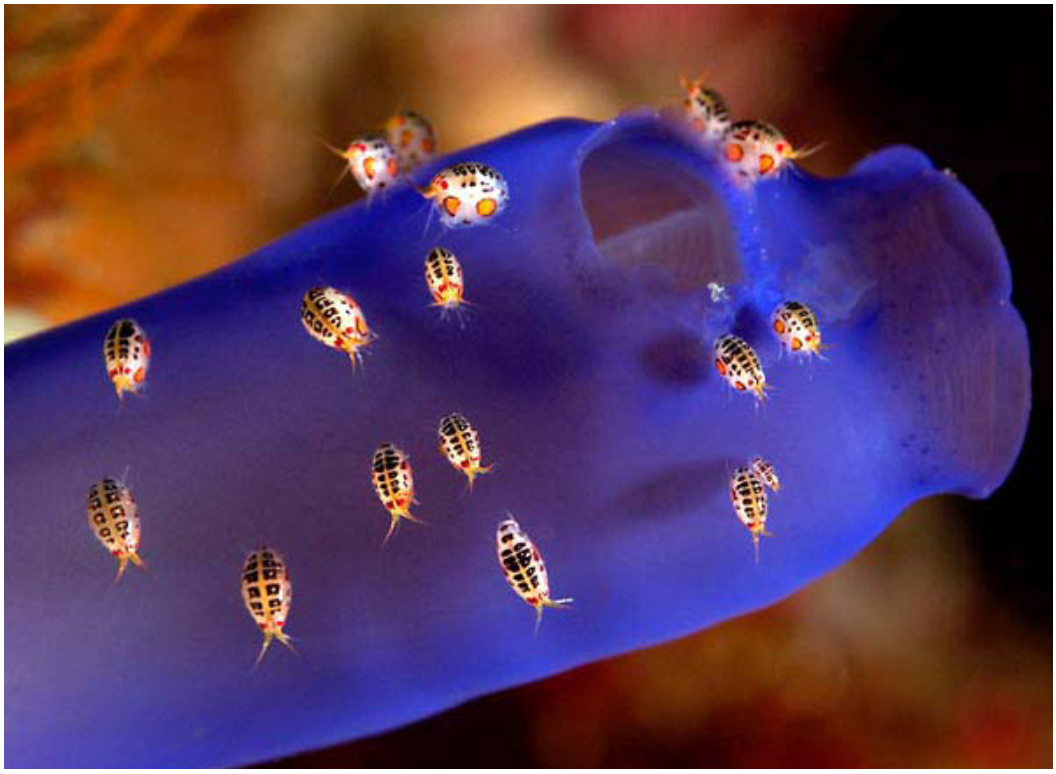
Decapod crustaceans in the vicinity of Carrie Bow Cay and Twin Cays, Belize, have been under study by ourselves and colleagues for over 25 years. In the course of investigations, new species have been discovered and large collections have been assembled, with many systematic problems yet to be resolved. Much of the effort has included photographic documentation of coloration in life, yielding characters of value in identification



Representative thalassinideans distributed in Carrie Bow, Twin Cays and the Stann Creek District, Belize.

of problematic tropical taxa. Especially at Twin Cays, our measure of diversity has been markedly elevated by sampling in shallow subtidal muds with extraction corers (yabby pumps), and this has recently revealed species, genera, and families of thalassinidean decapods not previously known from the region. This also provided opportunity to explore ecological roles of callianassid burrowers, many of which are dominant bioturbators in intertidal to subtidal grassbeds of Twin Cays, producing conspicuous mounds of sediment and constitut-

ing major infaunal biomass. By contrast, a familiar group of conspicuous brachyuran crabs and palinurid lobsters typically dominate macrocrustacean fauna of shallow rocky substrates. However, within the last four years, rocky habitats at Twin Cays have been massively invaded by the nonindigenous portunid crab, *Charybdis helleri*. In 2007, it was found to dominate cavities beneath coral heads in survey areas along the NE shoreline and the SW shoreline, possibly displacing populations of large *Mithrax*, *Menippe*, *Callinectes* and *Panulirus* previously found there in abundance. What we know of this fauna continues to change because of how we sample, but now also because of threats to faunal composition and stability.



Studies of commensal Leucothoid Amphipods of the Carrie Bow Cay and Pelican Cays Region, Beliz

J. Thomas & K. White

As a result of our studies six new amphipod species in the genus *Leucothoe* from the tropical western Atlantic Ocean have been formally described and illustrated in recent publications. Five of these species are named using terms from the traditional Garifuanae language of Belize. Continued extensive field collecting and specialized underwater collecting techniques have documented 43 new invertebrate host records for these new taxa. Four of these new species inhabit interior canals of sponges; *Leucothoe barana* n.sp., *Leucothoe garifunae* n.sp., *Leucothoe saron* n.sp., and *Leucothoe ubouhu* n.sp. A remarkable new species, *Leucothoe flammosa* n.sp., nestles in the gills of seven species of bivalve mollusks. A single species, *Leucothoe wuriti* n.sp., appears restricted to the branchial chamber of two species of solitary ascidians. Detailed illustrations and scanning electron microscopy has enabled comparison of ultrastructure details among all species. More precise taxonomic character morphologies are being developed as a result of these ongoing studies thus allowing improved taxonomic precision within the family Leucothoidae.

The rich ichtyofaunal diversity within the mangal of the Belize offshore Cays

D.S. Taylor, E.A. Reyier, C.C. McIvor & W.P. Davis

We assessed ichthyofaunal diversity within offshore mangrove cays in Belize during three, two-week surveys (2003, 2004, 2005). Nine sampling gears were deployed in pre-defined micro-habitats: fringe, transition, dwarf red mangrove, internal creeks, ponds, and sinkholes. Water quality data (temperature, salinity, DO) were taken during most collections. A total of 2,586 gear sets was completed and 8,131 individuals collected, comprising 75 taxa. Minnow trap data from the various micro-habitats tested indicates some overlap in assemblages. Significant differences in water quality were also noted, with the fringe presenting the best conditions and sinkhole the worst. We also conducted extensive visual surveys around the fringe at a number of cays, tallying an additional 67 taxa. The fringe is the most diverse (128 taxa) and sinkhole least (12 species). An overall total of 142 taxa from 55 families has therefore been documented from the cays, and all but eight were found on Twin Cays alone. This figure is among the highest reported for oceanic mangroves in this biogeographic realm. Our comprehensive approach with a variety of gear-types in a wide range of micro-habitats, combined with visual observation, lends credence to the conclusion that most ichthyological species inventories for the mangal are commonly underestimates.

Taxonomic abundance and composition of the larval ichtyofauna located at the neritic transition on the forereef of Carrie Bow cay, Belize

K.S. Cole

Carrie Bow Cay comprises part of the Belize barrier reef system which marks the transition from oceanic to neritic epipelagic waters in this region of the western Atlantic. Prevailing north-easterly trade winds generate a north-to-south current that sweeps along the ocean side of the barrier system, providing a steady stream of ready-to-metamorphose fish larvae. Quantification of the larval ichthyofauna, based on repeated sampling of the Carrie Bow forereef over the last three years, has yielded an unexpected pattern of taxonomic abundance and composition of the larval ichthyofauna. Among the 15,000+ larvae collected, sorted, identified and counted, there was an overwhelming numerical dominance of relatively cryptic species. Larvae of two species, Ctenogobius saepepallens (the dash goby, Family Gobiidae) and the speckled worm eel, *Myrophus* punctatus (F. Ophichthidae) typically comprised over 50% of all collected specimens. Interestingly, both of these species live in burrows, are relatively inconspicuous, and would not be seen during traditional visual fish surveys. Given the nature of these findings, the ecological importance and relative contribution to energy flow for some cryptic fish species occupying coastal and reef habitats of Belize has likely been greatly under-estimated.

Family Gobiidae. *Nes longus*: early pigmentation larval.

Does color pattern drive speciation in hypoplectrus coral reef fishes?

E. Bermingham & O. Puebla

Theory shows that speciation in the presence of gene flow occurs only under narrow conditions. One of the most favorable scenarios for speciation with gene

flow is established when a single trait is both under disruptive natural selection and used to cue assortative mating. We demonstrate the potential for a single trait, color pattern, to drive incipient speciation in the genus *Hypoplectrus* (Serranidae), coral reef fishes known for their striking color polymorphism. We provide data demonstrating that sympatric *Hypoplectrus* color morphs mate assortatively and are genetically distinct. Furthermore, we identify ecological conditions conducive to disruptive selection on color pattern by presenting behavioral evidence of aggressive mimicry, whereby predatory *Hypoplectrus* color morphs mimic the color patterns of non-predatory reef fish species to increase their success approaching and attacking prey. We propose that color-based assortative mating, combined with disruptive selection on color pattern, is driving speciation in *Hypoplectrus* coral reef fishes

Unidentified larva.

Sympatric speciation by hybridization in a marine fish

L.A. Rocha

Mechanisms that lead to speciation remain among the most debated topics in evolutionary biology, and sympatric speciation is especially difficult to demonstrate in nature. Because of their peculiar biogeography and their rare ability to produce sounds, fishes of the genus *Haemulon* serve as a great subject for tests of speciation hypotheses. Collectively known as grunts, the genus is comprised of 19 nominal species and occurs in tropical and subtropical reefs along both sides of the Americas. Aiming to elucidate the phylogenetic relationships among the species of *Haemulon*, a combined total of ~2,000 base pairs from two mitochondrial genes (cytochrome b and cytochrome oxidase I), one nuclear intron (TMO-4C4) and one nuclear gene (RAG2) were obtained from all nominal species. Our data also indicate that the trans-isthmian *H. steindachneri* is composed of two species, one in each side of the Americas, and we propose the revalidation of the Atlantic species. The closure of the Isthmus of Panama seems to have played a role in the diversification of *Haemulon*, however, many sister species pairs have completely overlapping geographical distributions, indicating that vicariance is not the only process driving speciation in this genus, and that sympatric speciation by sound recognition is possible. Finally, the species *H. carbonarium* seems to have originated through a hybridization event between

H. macrostomum and *H. flavolineatum*. These three species form a strongly supported group in the phylogeny, however, mtDNA groups H. carbonarium with *H. macrostomum*, whereas nuclear DNA groups *H. carbonarium* with *H. flavolineatum*. A detailed morphological analysis shows that many morphological characters in *H. carbonarium* are intermediate between *H. macrostomum* and *H. flavolineatum*, indicating a probable hybrid origin for *H. carbonarium*. If supported by additional ongoing analyses, this will be the first case of sympatric speciation by hybridization in a vertebrate animal.

Paleobiology, Microevolution and Biogeography

Biogeographic variation in the recruitment of native and invasive marine sessile invertebrate species

R.W. Osman

The biogeographic variation in the timing and rates of recruitment of sessile marine invertebrates is being examined by contrasting recruitment to panel substrates exposed at sites in southern New England (Connecticut), Chesapeake Bay (Maryland and Virginia), Indian River Lagoon (Florida), and Belize. Panels were exposed for 1 week periods at several sites in Connecticut and for 2 week periods at all other sites. The general patterns observed were: 1) that recruitment rates were often inversely correlated with diversity with the highest rates seen in Chesapeake Bay and the lowest in Belize, 2) seasonal variability in recruitment varied latitudinally, 3) the timing of peak recruitment shifted latitudinally for some invasive species and this timing shift can be related to temperature, 4) annual and within-region variability in recruitment can be extremely high, and 5) this variability can be related to temperature for some invasive species but not for native species. The most dramatic pattern to date is for the bryozoan Bugula neritina which recruits in the winter in Florida and the late summer in Connecticut. From historical data it appears that in recruits in the late spring in North Carolina. The temperatures at these different recruitment times are similar among sites, suggesting that recruitment patterns reflect biogeographic variation in temperature. Within regional differences in recruitment can also be quite dramatic with sites separated by <1 km often differing by an order of magnitude in their recruitment. These differences were seen in all regions. In addition, differences between sites in species composition were more prevalent at low-latitude sites. The within-region and biogeographic variation in recruitment suggest that both invasion success and the impact of climate change on recruitment and its consequences will be complex.

Reproductive, Molecular and Developmental Biology

Microbial ecology of corals: Investigating bacterial communities in early stages of Caribbean corals

K.Sharp

Coral cover and diversity worldwide are heavily threatened by environmental changes and outbreaks of coral bleaching and disease. Healthy scleractinian corals have been shown to harbor diverse assemblages of microbes, but neither the specificity of these associations nor the mechanisms that maintain them across host generations is well-understood. In order to implement effective management strategies and conservation concerning unhealthy and diseased corals, it is critical to learn more about the diversity and functions of bacterial assemblages in healthy corals. To date, there are only a limited number of examples in which the role of bacteria on coral health is well-understood. Some corals, including the Caribbean corals *Porites astreoides* and *Favia fragum*, brood larvae within adult colonies, releasing fully developed swimming planulae into the water column. In this study, bacteria were found in the planula larvae of both *P. astreoides* and *F. fragum*. Molecular techniques were used to identify microbes associated with larvae, and sequence-specific oligonucleotide primers were designed to survey multiple samples for the presence of particular bacterial species. Fluorescence in situ hybridization (FISH) and microscopy were used to localize particular species within the larvae and determine relative abundance of certain groups of bacteria. Egg-sperm bundles released from Montastrea and Acropora, which, in contrast, reproduce via mass-spawning, did not appear to contain bacteria or archaea. These results reveal new insight into mechanisms by which marine invertebrates maintain complex

microbial assemblages during embryogenesis and early development. In addition, the localization of bacteria in the larvae present the possibility for a bacterial role in larval settlement of some coral species.

Acropora prolifera (far right) is an hybrid formed by *A. palmata* (left) and *A. cervicornis* (middle).

Development and evolution of the musculature in sipunculan worms

A. Schulze & M.E. Rice

The taxonomy of the Sipuncula, a small phylum of benthic marine worms, is partially based on the number and degree of fusion of the introvert retractor muscles as well as the arrangement of the body wall musculature. The majority of sipunculan species develop indirectly, passing through a lecithotrophic trochophore and a planktotrophic pelagosphera larval stage. Some species show abbreviated development in which the pelagic phase may be completely skipped. Here we examine myogenesis in four species that represent different developmental modes, using F-actin staining with fluorescent-labeled phalloidin in conjunction with confocal laser scanning microscopy. All examined species have smooth body wall musculature as adults and less than the full set of four introvert retractor muscles. All go through stages with four introvert retractor muscles that eventually fuse into the reduced number in the adult. The circular and sometimes the longitudinal body wall musculature is split into bands that later fuse to form a smooth sheath. We have also reconstructed the ancestral states of the introvert and body wall musculature using Bayesian statistics. Our reconstructions suggest with high probability that the ancestral sipunculan had four introvert retractor muscles, longitudinal musculature split into bands and a smooth sheath of circular body wall musculature. We conclude that the plesiomorphic condition in sipunculans is four introvert retractor muscles. This condition is retained in the larvae of all sipunculan species examined in this study and by previous authors. We also found that crawling larvae have more strongly developed body wall musculature than swimming larvae which propel themselves by means of their metatrochal cilia.

Hibridization dynamics in the threatened Caribbean coral genus, *Acrophora*

N.D. Fogarty

Since the 1970's, Caribbean acroporids have decreased by 80-98% prompting their enlistment as threatened under the Endangered Species Act. Caribbean acroporids consist of two species, *A. palmata* and *A. cervicornis*, which form a hybrid (*A. prolifera*). Although hybrids were not given protective status, they may play an important ecological and evolutionary role in the fate of this reef-building genus. At sites throughout the Caribbean where both parent species are present, hybrid abundance forms a continuum from absent or rare to dense stands. It is unclear if this variation in abundance occurs as a result of differences in the strength of reproductive isolating barriers, variation in success of asexual fragmentation, or differential fitness (i.e. susceptibility to disease, predation, and bleaching) of hybrids. Carrie Bow Island, Belize has a population of at least 75 hybrid colonies. Molecular analysis at six loci showed that these colonies are composed of two genets that have fragmented and reattached in this shallow (< 1m) turbulent habitat. *A. palmata* and *A. cervicornis* gametes were collected in situ during a simultaneous spawning event. Fertilization and viability experiments revealed that there is no statistical difference in fertilization success, larval survival, or metamorphosis between conspecific and heterospecif-

ic crosses. Gamete comparisons of one hybrid colony with the parent species showed hybrids have larger eggs, less sperm and an intermediate number of eggs per bundle. Preliminary analysis suggests these hybrids host a different zooxanthellae clade that may allow them to persist in this extremely shallow, stressful environment. Despite low genetic diversity among the Carrie Bow hybrids, the population is robust due to the hybrid's ability to persist and reproduce asexually in a stressful habitat. Further, these hybrids are fertile and capable of producing an F2 generation or backcrossing with the parent species, which may lead to genetic introgression between the parent species.

Modular variation and phenotypic plasticity in the gorgonian coral *Pseudopterogorgia bipinnata* along the Western Caribbena

J.A. Sánchez, D.D. & N. Manrique

One of the most intriguing aspects of evolution is whether habitat-induced phenotypic variation can lead to genetically fixed morphotypes. The gorgonian coral *Pseudopterogorgia bipinnata* (Gorgorniidae: Octocorallia) provides a great opportunity to explore phenotypic plasticity and morphological variation in a coral reef organism. We studied the variation of different morphological traits including the different types of microscopic sclerites (0.1-0.2 mm of length variation), polyp aperture and spacing (1-20 mm), and branches and internodes (1-20 mm), which are all repetitive modules throughout the colony. In addition, we studied the genetic variation of the Internal Transcribed Spacer 2 (ITS2, rDNA) using a combined approach with Denaturing Gradient Gel Electrophoresis (DGGE) and DNA sequencing of the different copies found at each individual colony. We examined colonies from Carrie Bow Cay (Belize), Bocas del Toro (Panama) and Cartagena (Colombia), which included most reef habitats (1-35 m in depth) and several morphotypes. Only one feature did not change at all across habitats despite an order of magnitude difference in other features such as branch length and lesser, but significant, differences in the remaining traits. We distinguished three *P. bipinnata* morphotypes: shallow exposed, shallow to mid-depth (moderately exposed) and low water motion in deep-water (<20 m) morphotypes, which were independent of genetic variation. The three phenotypes did not exhibit clines and were seldom seeing side-to-side sharing the same environment at overlapping zones. Ecotypes can make some traits exhibit phenotypic plasticity but are not so extreme to make these traits fixed in the species genome. In need of further screening, genetic assimilation can be a viable event for octocorals, where habitat seems to be a conditioning factor for niche separationts.

Cellular biomarkers as a measure of sub-lethal stress in coral larvae

R. Ritson-Williams & V.J. Paul

As coral reefs across the Caribbean decline in coral cover, coral larval recruitment is a key process that will aid in the recovery of coral reef communities. Elevated temperature

Plexaura flexuosa spawning.

is known to inhibit larval coral recruitment, however few experiments have evaluated the mechanisms of temperature stress on coral larvae. Short term exposure of *Porites astreoides* larvae to elevated temperatures (+3.5°C for 4.5 h) induced significantly more reactive oxygen species and upregulated the enzymes catalase and superoxide dismutase compared to 27°C seawater temperatures. In addition the larvae had reduced settlement and increased mortality after the heat treatment. Our results indicate that even short term exposure to thermal stress can induce antioxidant enzyme activity and causes a lethal and sublethal reduction in recruitment of coral larvae.

Coral recruitment in the gardens of good and evil

R.Ritson-Williams, S. Arnold, R.S. Steneck & V.J. Paul

Coral reefs are losing coral cover on a global scale, but improving natural coral recruitment is one management strategy that could reverse this trend. In order to better understand where and why coral larvae settle we tested settlement preferences of corals in the field and in the laboratory. Our field research suggests that settling coral larvae select some biological substrates such as coralline algae, which they settle on and near. Of the three spawning coral species that we tested in the laboratory, each one had different settlement rates in response to different species of coralline algae. Sponges, invertebrates and macroalgae, which can overgrow coralline algae in the field, are known inhibitors of coral recruitment. Increased herbivory may be a mechanism to shift the benthic community composition away from coral recruitment inhibitors towards facilitiators such as coralline algae, thus providing managers a strategy for improving the benthos for higher rates of coral recruitment

From larvae to lineaged: Investigations of the shorefish diversity in the tropical Atlantic

C. C. Baldwin, D. G. Smith & L. Weigt

The identities of pelagic larval stages constitute the largest gap in our knowledge of the coral-reef fish fauna of the tropical Atlantic. This fundamental taxonomic information is necessary before larvae can be used in studies of, for example, evolution, fisheries biology, and ecology. Over the past 15 years, we have identified larvae of numerous Belizean fishes by rearing net-collected larvae at the Smithsonian's marine station at Carrie Bow Cay. More recently, we have begun matching larvae to adults using mitochondrial cytochrome oxidase 1 sequences (DNA Barcodes). As well as greatly enhancing our ability to provide species identifications of larvae, the molecular data from Belizean fishes reveal more species diversity in many genera than our present classifications suggest. Because much of the Belizean fish fauna is believed to occur throughout the Caribbean and other areas of the tropical Atlantic, we are expanding our DNA barcoding efforts to other geographical areas. In addition to re-analyzing species diversity of cryptic reef fishes throughout the tropical Atlantic, the ultimate goals of our work include reconstructing species-level phylogenies of a diversity of tropical Atlantic shorefish genera, from which we can investigate patterns of morphological divergence and speciation.

Ecology, Population Dynamics, and Ecophysiology

Nitrogen and Phosphorus limitation to the growth and clonal reproduction of *Batis maritima*, a dominant understory plant in Florida and Belize mangroves

D.F. Whigham

Batis maritima is a halophyte that is a dominant understory plant in mangroves throughout much of the Caribbean. It occurs as far north as North Carolina on the Atlantic coast and southern California on the Pacific coast. In many habitats *Batis* forms a continuous canopy cover that has the potential to influence the recruitment and growth of mangrove seedlings. Little is known, however, about this abundant and potentially important species in mangrove ecosystems. The goal of this initial project was to evaluate nitrogen (N) and phosphorus (P) limitation on the growth and asexual reproduction of *Batis* at MSN sites in Belize and Florida where mangrove growth has been shown to be limited by different nutrients. Fertilization studies at both sites demonstrated a strong response to P in Belize and a

positive but less pronounced response to N fertilization at the Ft. Pierce site. A greenhouse experiment at SERC in which N, P and N+P were applied to Batis seedlings demonstrated the lack of N and P reduces growth compared to the presence of both nutrients. Preliminary interpretations are that sites at Carrie Bow have sufficient nitrogen to support a strong growth response to the addition of phosphorus. In Florida, there is sufficient phosphorus in the substrate to support Batis growth as the addition of N resulted in a significant, but relatively small growth response. The relatively small response to N addition in Florida may be due to salt stress as salinities at the sites where the study was conducted are annually 80-100 ppt, a level that requires halophytes to use much of the available N to maintain sufficient osmotic values to continue to be able to maintain an adequate water balance.

Nutrient over-enrichment differentially affects growth and hervivory in mangrove forests along lititudinal and tidal gradients

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 human activities including nutrient over-enrichment. Our goal was to determine if enrichment with nitrogen (N) or phosphorus (P) interacts with forest structure and latitude to alter growth, nutrient dynamics, and patterns of herbivory. We established a series fertilization experiments across more than 2000 km and 18º of latitude from the Indian River Lagoon (IRL), Florida to Twin Cays, Belize to Bocas del Toro, Panama. At each site, we fertilized individual trees with one of three treatment levels (control, +N, +P) in two zones (fringe, dwarf) along transects perpendicular to shorelines and measured their responses at 6-mo intervals for 4 yr. Growth was measured as shoot elongation, and herbivory was measured as a function of folivory, loss of yield, and tissue mining. Results showed that all sites were nutrient limited, but patterns of nutrient limitation varied by zone and latitude. At IRL, growth was N-limited from the fringe to the dwarf forest; at Twin Cays, the fringe was N-limited, but the dwarf forest was P-limited; at Bocas del Toro, the fringe was N-limited, but the dwarf forest was both N- and P-limited.

Nutrient enrichment had dramatic effects on herbivory that varied by treatment, zone, latitude, and species. Our studies show that responses to eutrophication of mangrove ecosystems will depend on site characteristics, the species considered, and the nature of nutrient limitation. Predicting how herbivores 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.

Assessment of coral reefs using herbivory/nutrient assays and indicator groups of benthic primary producers. The ecology of *Batis maritima* in mangrove

M.M. Littler & D.S. Littler

Rapid assessment protocols for determining and monitoring the status of any given coral reef are provided and include measuring: (a) standing stocks of func-

tional indicator groups, (b) herbivore populations, (c) water-column nutrient levels, (d) tissue C:N:P ratios, (e) algal physiological-response assays, and (f) herbivory assays. These measurements can reveal quantitative tipping-point levels beyond which resilience to undesirable phase shifts begins to become critically reduced. Universal tipping-point approximations are reviewed for inorganic nutrients, and posited for the first time for herbivory. The relative roles of top-down and bottom-up controls in determining benthic community structure and the health of coral reefs are especially important management concerns. This paper specifically addresses the top-down effects of herbivory and bottom-up effects of nutrient enrichment on critical indicator groups; i.e. reef-building corals, crustose coralline algae, dense turf algae, and frondose macroalgae. A predominance of (a) massive corals and calcareous coralline algae relative to frondose macroalgae and algal turfs indicates a healthy spatially heterogeneous condition reflecting low nutrients and high herbivory. An abundance of (b) frondose macroalgae illustrates the least desirable condition of elevated nutrient levels and reduced herbivory, possibly reflecting pollution in concert with destructive herbivore fishing practices. High coverage of (c) coralline algae suggests healthy high herbivory levels, but problems with elevated nutrients that are inhibitory to some corals. Domination by (d) dense turf algae indicates desirably low nutrient levels, but an inadequate herbivory component. The experimental results demonstrate flaws in some of the previously published manipulative methods and provide insights for the improvement of in-situ nutrient studies on coral reefs. The fast growth and turnover rates of fleshy algae compared to other reef organisms highlight their value as early-warning indicators of reef degradation.

The nutritional content of bottlenose dolphin prey from the shallow waters of Belize

K.L. West, O.T. Oftedal & C.W. Potter

Bottlenose dolphins (Tursiops truncatus) are commonly sighted in the shallow waters of Turneffe Atoll, Belize. This represents one of the few tropical marine environments where photographic identification and behavioral studies have been conducted for T. truncatus. The foraging behavior of dolphins in this area and fish species prevalence has also been previously described. Our study involved in the collection of 337 potential prey items near Turneffe Atoll for comparison in nutritional content between seasons and years. The prey obtained during 3 collection trips represented 5 orders, 19 families, 22 genera and 35 different species from Turneffe Atoll. A maximum of 6 replicates of each prey species collected during a single sampling trip to Belize (totaling 260 samples) were analyzed for proximate composition, including a determination of dry matter, crude protein, fat, and caloric, calcium and phosphorus content. Comparisons indicated significant differences between seasons for the Blue-striped Grunt, White Grunt, Lane Snapper and the Schoolmaster Snapper. In the case of the Blue-striped Grunt, ash was greater during the winter. Dry matter was significantly greater in the winter for the Schoolmaster Snapper. Both protein and ash were greater in the winter in the White Grunt. All proximate components were significantly different among seasons when considering the Lane Snapper where dry matter, protein and ash were greater in the winter while fat and caloric energy were found to be greater in the summer. In addition to determining the nutritional content of potential prey in Belize waters, biopsy darts of tissue were obtained from 15 dolphins during a field sampling trip in the summer of 2007. Dolphin biopsy samples and potential prey items will be analyzed for fatty acid composition and stable isotope signatures to provide insight into the diet composition of bottlenose dolphins in Belize.

Species Interaction and Behavior

The life cycle, phylogeography, and comparative mitochondrial genimics of Placozoans from Twin Cays

A.Y. Signorovitch

Placozoans are microscopic marine invertebrates that are distributed along tropic and subtropic latitudes. They possess only four somatic cell types, a dorsal-ventral polarity, no definite shape, and are the simplest known free-living animals. Here I describe findings of three separate studies that utilized placozoans collected from the mangrove island of Twin Cays, Belize. In the first study, the margins of Twin Cays were surveyed for placozoans during the summers of 2003 and 2004. Sampled isolates were haplotyped at the mi-

tochondrial 16S rDNA and mapped to their collection sites along the island's margins to form the basis of the first high-resolution phylogeographic study of placozoans. Twin Cays was found to be home to an unprecedented diversity of placozoans, including sympatric highly diverged species. The second study aimed at detecting molecular signatures of sexual reproduction through a molecular population genetics approach. Although never observed, it is now known that placozoans do indeed reproduce sexually as demonstrated by patterns of allele sharing between individual placozoans. Lastly, a select group of highly divergent Twin Cays placozoans was used in a comparative study of whole mitochondrial genomes (mtDNA). While the majority of animal mtDNAs are ca. 15-20 kb, all placozoans so far examined possess genomes well above this range, from 32-43 kb. Based on these data and other complete mtDNAs, phylogenetic analyses of the Lower Metazoa revealed that all members of the Phylum Placozoa belong to the earliest diverging animal group.

An overview of symbiont-bleaching in epiphytic foraminiferans

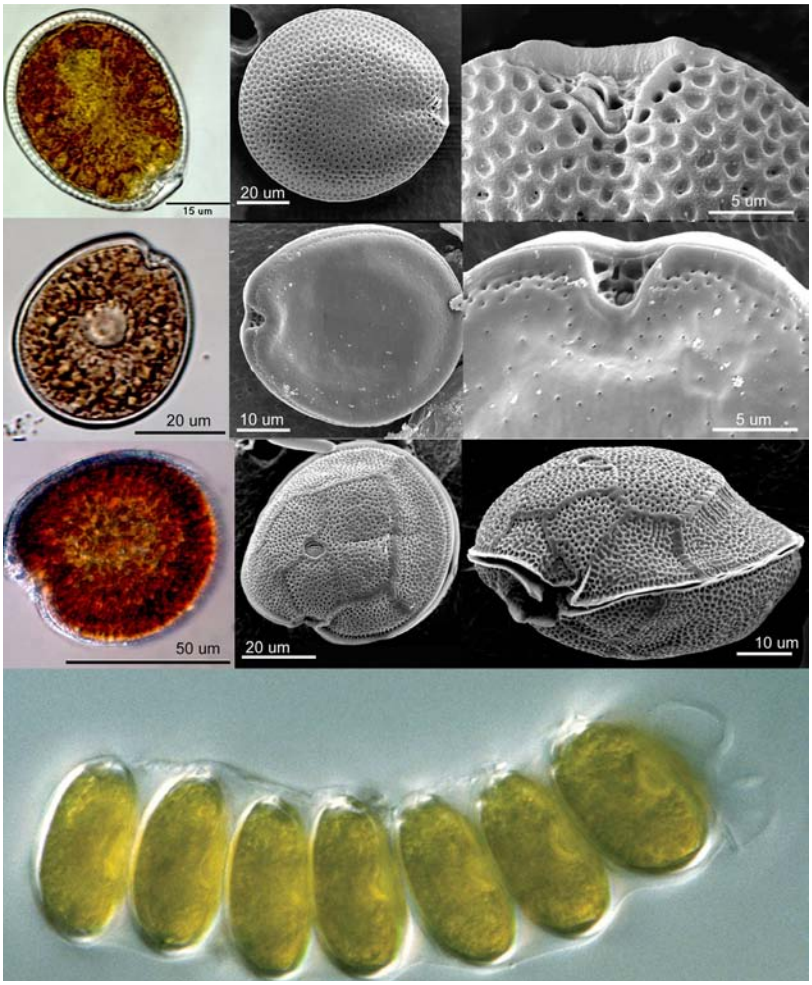
S.L. Richardson

Sorites dominicensis is a disk-shaped foraminiferan that lives attached to phytal substrates in tropical to subtropical, shallow-water habitats. This species harbors dinoflagellate endosymbionts (*Symbiodinium* sp.) that are closely related to the zooxanthellae in corals and other cnidarians. Symbiont bleaching has been observed in field populations of *S. dominicensis* collected from turtle grass (*Thalassia testudinum*) meadows in the Florida Keys, the Indian River Lagoon, Florida, and Belize. The degree of bleaching for each specimen is assessed using a relative scale: healthy, pale, mottled, or white. Healthy individuals possess a distinct yellowish-brown coloration to their cytoplasm. Pale individuals possess a light, yellowish coloration to their cytoplasm. In both healthy and pale individuals, cytoplasmic coloration is evenly distributed throughout the foraminiferal test. Mottled specimens possess large patches of white cytoplasm interspersed with regions of healthy cytoplasm. Individuals are recorded as being totally bleached if they possess completely white tests. Field studies involve surveying several hundred individuals (~500) from each population, or collecting site, and recording the incidence of bleaching. Bleaching rates vary from 0.3-19%, with the lowest rates of bleaching to date observed in populations living in the tannin-stained waters of Boston Bay, within the mangrove islands of Twin Cays in Belize (7/07). The highest rates of bleaching to date were observed in the same population, a few days later after a period of intense rainfall. High rates of bleaching (18%) were observed in July 2005, in populations living on the reef flat off Carrie Bow Cay, a site that experiences subaerial exposure during extreme low spring tides, and water temperatures as high as 40 ºC. Other environmental factors that appear to trigger bleaching in foraminiferans include: increased irradiance, exposure to UV and blue wavelengths of light, freshwater influx, and periodic disturbance by hurricanes.

Ciguatera fish poisining in the Caribbean

P. Tester, M. Faust & W. Litaker

Tropical dinoflagellates of the genus *Gambierdiscus* are known to produce toxins that cause ciguatera fish poisoning (CFP). Humans are susceptible to CFP through food web concentration of toxins found in contaminated reef fish. CFP is the most commonly reported marine toxin related illness and can be fatal. CFP occurs circumtropically and it is endemic in the Caribbean region. Annually 3% of the population of the US Virgin Islands and 4.4% of the households surveyed in St. Thomas are affected while 7% of the residents of Puerto Rico have experienced at least one episode of CFP in their lifetime. While CFP is a threat to public health throughout the Caribbean, it is generally managed by local, traditional knowledge of the native fishers of the seasonality of occurrence and locations of local reefs known to be ciguateric. Also, the custom, some times formalized and sometimes not, of avoiding large, top predators like barracuda factors into the management of CFP. With increasing ocean temperatures the validity of local and traditional knowledge may fail to provide adequate guidance and increase the potential for CFP. A goal of our research is to develop quick, reliable, economical, and quantitative method of



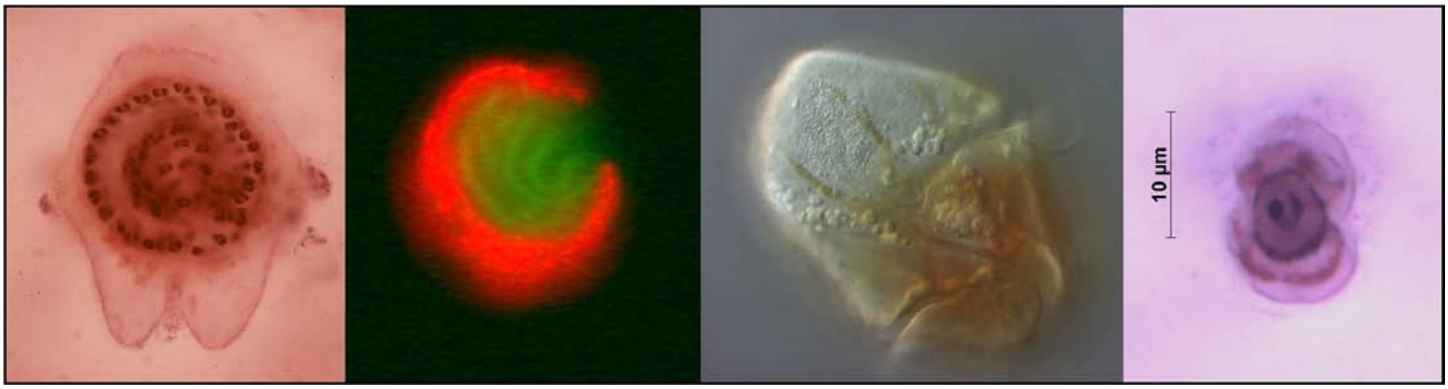
Light (color) and scanning electron micrographs (grayscale) of Ciguatera-associated dinoflagellates from Belize. Top panel, *Prorocentrum* sp. nov. (Carrie Bow Cay); second and bottom panels, *Prorocentrum* sp. nov. (Twin Cays); third panel, *Gambierdiscus* sp.

detecting *Gambierdiscus,* in natural assemblages. Comparative distribution and abundance data from the Caribbean Coral Reef Ecosystems field station at Carrie Bow Cay, Belize and a CFP "hot spot" in the eastern Caribbean will be presented.

Interplay between dinoflagelate toxins, membrane sterol composition and parasitism by *Amoebophrya*.

X. Bai & D.W. Coats

Parasitic dinoflagellates of the genus Amoebophrya infect many bloom-forming dinoflagellates, including several toxic species. These parasites can spread rapidly through host populations and have been linked to the decline of red tides. The fate of host toxins during bloom decline caused by parasitism is unknown. Equally unresolved is the performance of parasites in host strains that differ in toxin content. The ichthyotoxic dinoflagellate *Karlodinium veneficum* produces karlotoxins (KmTX) that permeabilize cell membranes, resulting in cell death through osmotic lysis. Membrane sterol composition appears to govern sensitivity KmTX, with a preponderance of 4?-methyl sterols (gymnodinosterol) providing immunity to the toxin. Like its host, *Amoebophrya* sp. ex *K. veneficum* possesses gymnodinosterol and is presumed to be immune to KmTX. We examined the effect of purified KmTX on several host-parasite systems, the ability of *Amoebophrya* to infect non-toxic to highly toxic *K. veneficum*, and toxin levels of parasitized *K. veneficum* over the infection cycle. Addition of purified KmTX to culture medium had no effect on survival or infectivity of *Amoebophrya* ex *K. veneficum*, but caused mortality and reduced infection of *Amoebophrya* from other host species. Parasite prevalence was positively correlated with *K. veneficum*

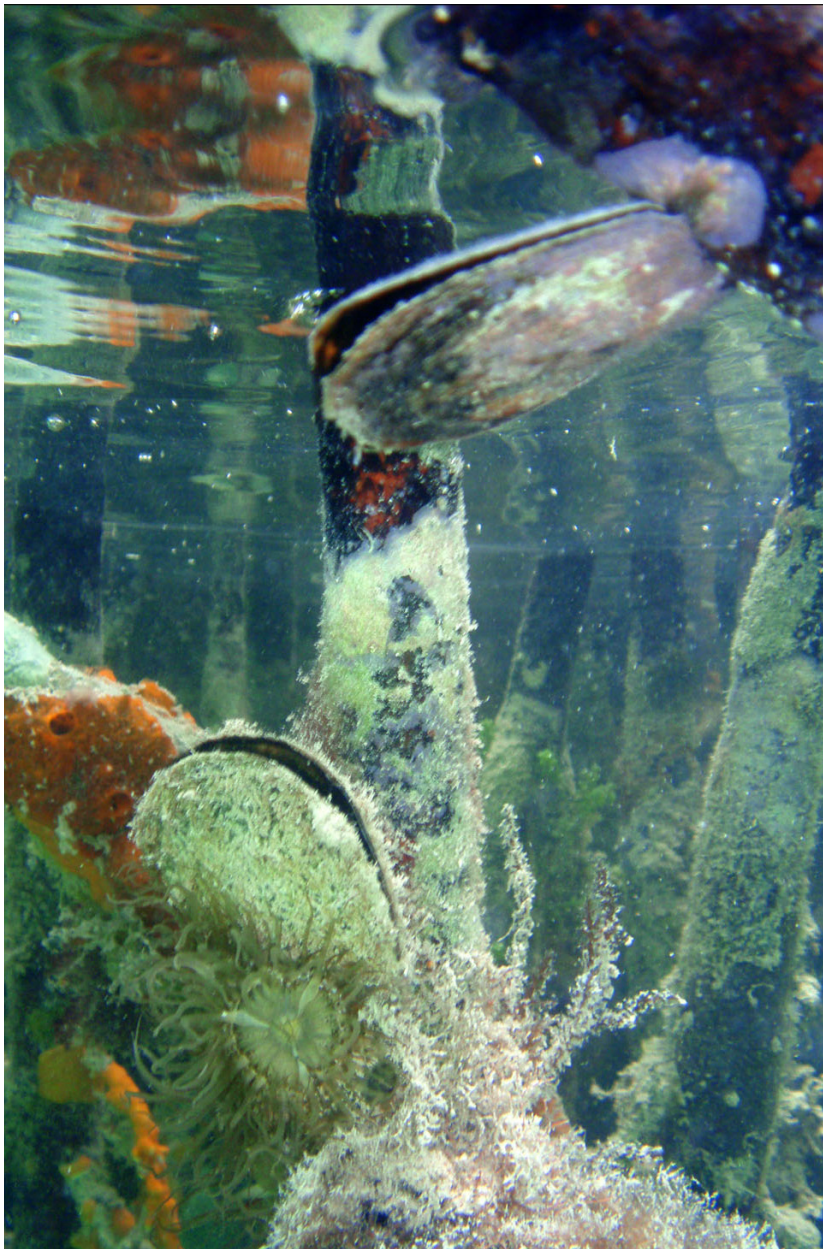


(A) Stained beehive of *Amoebophrya* ex *Aka. sanguinea*; (B) Autofluorescence of *Amoebophrya* ex *Alex. tamarense*; (C) Differential interference contrast of *Amoebophrya* ex *G. instriatum*; (D) Stained early infection of *Amoebophrya* ex *K. veneficum.*

toxicity, suggesting that *Amoebophrya* is more likely to control toxic blooms than non-toxic blooms. KmTX ml-1 increased with growth of *K. veneficum* in control cultures, but declined in infected cultures as the parasite completed its life cycle. On a cellular basis, toxin content of infected and uninfected cultures differed little during the experiment, suggesting that the parasite does not actively catabolise host toxin. Rather, infection appears to promote degradation of toxins via death of host cells and subsequent bacterial activity. Thus, this parasite may limit the occurrence of toxic *K. veneficum* blooms in marine and estuarine environments, while simultaneously functioning as a pathway for dissipation of host toxin.

Life history and morphological strategies of sponges drive community dynamics on mangrove roots, with help from predators, competitors, and pathogens

J.L. Wulff



Descriptions of the rich sponge faunas inhabiting mangrove roots at various Caribbean sites are unanimous in pointing out the heterogeneity of species distribution and abundance patterns at all scales, from very local (e.g., adjacent roots) to regional. Abiotic factors have often been implicated by correlation, but the possibility that ecological interactions, and life history and morphological strategies of the sponges, also play key roles has not been examined comprehensively. I have been exploring the processes underlying these patterns by probing community dynamics with experimental manipulations and time-series censusing at sites in Belize (Twin Cays), Panama (near the Bocas del Toro station), and the Florida Keys (Long Key). Established communities on roots have been fully censused (by volume) yearly for 3 years, initially bare artificial roots (suspended pvc pipes) have been monitored for recruitment and subsequent community development for up to 5 years, and small, asexually generated (by razor blade) individuals of the 7 –9 most abundant sponge species have been placed on artificial roots and subsequent community dynamics monitored for up to 2 years. Patterns of community development on initially bare pvc pipes suggest that trade-offs between recruitment efficiency and competitive ability may be responsible for at least some among-root heterogeneity. Even though community dynamics on pipes to which individuals of the most abundant species had been added were not influenced by the stochastic effects of larval recruitment, heterogeneity of sponge distribution and abundance among pipes was still very high. When sponge species were sorted into categories defined by different morphological strategies for gaining and holding onto substratum space, it became clear that presence or absence of representatives of these morphological categories influenced community dynamics substantially. Interactions with predators, pathogens, and non-sponge spatial competitors played surprisingly important roles in creating differences among pipes that began with identical inhabitants.

Comparisons of chemical mediated marine plant-herbovore interactions on Florida, caribbean and Pacific reefs and consequences for reef communities

V.J. Paul, R. Ritson-Williams, L.J. Walters, I.B. Kuffner & M.A. Becerro

Overgrowth of corals by macroalgae and benthic cyanobacteria is of increasing concern on coral reefs worldwide. Algal species that have proliferated in reef habitats often contain natural products that deter generalist herbivores. On reefs in Guam, Florida, and Belize, we determined the palatability of common reef algae to reef fishes. In Belize, we also studied the feeding preferences of the sea urchin Diadema antillarum. Some macroalgae were not eaten by fishes even when left in areas of high herbivory for 1-2 days. Cyanobacteria were not readily consumed by reef fishes. Interspecific variation was observed in the susceptibility of different species of *Dictyota*, *Halimeda*, and *Caulerpa* to herbivory. Diadema antillarum individuals were less discriminating than reef fishes and consumed some of almost all species offered to them. For example, fish were strongly deterred by some brown algal extracts, while the urchins readily consumed them. Herbivorous reef fishes and *D. antillarum* have different algal preferences (often driven by chemical defenses) and can have differential effects on algal community composition. Fish and urchins can control a mixed community of algae on Caribbean reefs better than either one alone. Due to the macroalgal dominance observed on reefs today, competition between corals and macroalgae is a topic of great interest. Past research has shown that adult corals are very good competitors with macroalgae, but it is at the early life-history stages, as larvae and new recruits, that corals are thought to be inferior competitors. We directly tested this hypothesis in controlled field and laboratory experiments with different species of coral larvae. Species of *Lyngbya* and *Dictyota* as well as extracts of some of these species caused either recruitment inhibition or avoidance behavior in coral larvae. On reefs experiencing increased algal abundance, the restocking of adult coral populations may be slowed due to recruitment inhibition caused by algal natural products

Sympatric speciation by hybridization in a marine fish

L.A. Rocha

Mechanisms that lead to speciation remain among the most debated topics in evolutionary biology, and sympatric speciation is especially difficult to demonstrate in nature. Because of their peculiar biogeography and their rare ability to produce sounds, fishes of the genus *Haemulon* serve as a great subject for tests of speciation hypotheses. Collectively known as grunts, the genus is comprised of 19 nominal species and occurs in tropical and subtropical reefs along both sides of the Americas. Aiming to elucidate the phylogenetic relationships among the species of *Haemulon*, a combined total of ~2,000 base pairs from two mitochondrial genes (cytochrome b and cytochrome oxidase I), one nuclear intron (TMO-4C4) and one nuclear gene (RAG2) were obtained from all nominal species. Our data also indicate that the trans-isthmian *H. steindachneri* is composed of two species, one in each side of the Americas, and we propose the revalidation of the Atlantic species. The closure of the Isthmus of Panama seems to have played a role in the diversification of *Haemulon*, however, many sister species pairs have completely overlapping

geographical distributions, indicating that vicariance is not the only process driving speciation in this genus, and that sympatric speciation by sound recognition is possible. Finally, the species *H. carbonarium* seems to have originated through a hybridization event between *H. macrostomum* and *H. flavolineatum*. These three species form a strongly supported group in the phylogeny, however, mtDNA groups *H. carbonarium* with *H. macrostomum*, whereas nuclear DNA groups *H. carbonarium* with *H. flavolineatum*. A detailed morphological analysis shows that many morphological characters in *H. carbonarium* are intermediate between *H. macrostomum* and *H. flavolineatum,* indicating a probable hybrid origin for *H. carbonarium*. If supported by additional ongoing analyses, this will be the first case of sympatric speciation by hybridization in a vertebrate animal

Does color pattern drive speciation in hypoplectrus coral reef fisheries?

E. Bermingham & O. Puebla

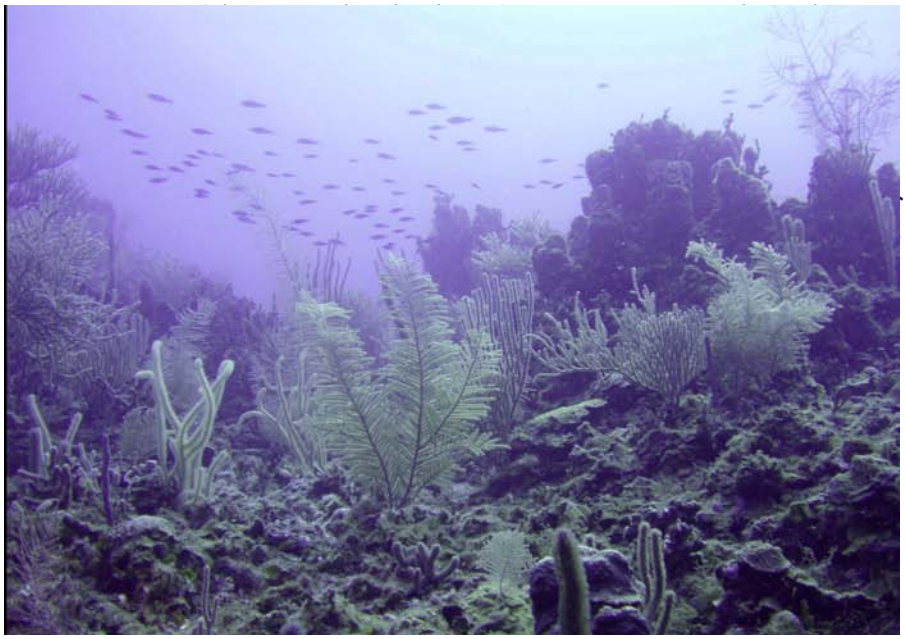
Theory shows that speciation in the presence of gene flow occurs only under narrow conditions. One of the most favorable scenarios for speciation with gene flow is established when a single trait is both under disruptive natural selection and used to cue assortative mating. We demonstrate the potential for a single trait, color pattern, to drive incipient speciation in the genus *Hypoplectrus* (Serranidae), coral reef fishes known for their striking color polymorphism. We provide data demonstrating that sympatric *Hypoplectrus* color morphs mate assortatively and are genetically distinct. Furthermore, we identify ecological conditions conducive to disruptive selection on color pattern by presenting behavioral evidence of aggressive mimicry, whereby predatory *Hypoplectrus* color morphs mimic the color patterns of non-predatory reef fish species to increase their success approaching and attacking prey. We propose that color-based assortative mating, combined with disruptive selection on color pattern, is driving speciation in *Hypoplectrus* coral reef fishes

Processes across Ecosystems & Conservation

Patterns of the water movement over the forereef at Carrie Bow Cay

K.H. Koltes & T.B. Opishinski

Since 1993, meteorological and oceanographic conditions, including water and air temperature, rainfall and turbidity, have been monitored as part of the CARICOMP program at Carrie Bow Cay (CBC). In 1997, an automated monitoring system was established at Carrie Bow Cay (under CCRE funding) that provides an independent set of weather conditions and water quality measurements. Qualitative observations following Hurricane Mitch and other major weather systems that produced heavy rainfall along the Belizean coast indicated that turbid, low-salinity water typically passes over the forereef at CBC within 1-2 days. Qualitative observations also indicated that these pulses were occurring with more frequency and intensity since CARICOMP monitoring began in 1993. To better characterize specific water masses on the forereef, light meters were installed at the CARICOMP site in 13.5m of water as a proxy for measuring turbidity (water quality). Light intensity (L/m2) has been recorded on the forereef intermittently since Dec 2002. Light intensity was analyzed along with other CARICOMP measurements and data from the automated monitoring system. As expected, strong correlations exist between the light intensity and other forereef measurements as well as conditions measured on the shoreward side of the reef (e.g., temperature, incident radiation, rainfall, etc.). Under normal weather conditions, conditions on the forereef are fairly stable. Following major weather events, signatures of different water masses can be seen in the oceanographic records, including upwelling of deeper ocean water and/or input of riverine (coastal)



water. The appearance of both water mass types correlates strongly with weather conditions.

Biophysical controls on habitat stability of Caribbean mangrove ecosystems

K.L. McKee

Habitat stability of mangrove and other coastal wetlands depends upon the capacity of the system to maintain soil elevations relative to sea level. Although some mangrove wetlands develop in alluvial habitats with abundant mineral sediment, mangrove systems in sediment-deficient settings are dependent upon biogenic processes of vertical land-building. Plants contribute directly to soil formation through accumulation of organic matter, but few data directly link specific biological processes to elevation change in coastal systems. This type of information is necessary, however, to accurately predict future responses of coastal wetlands to sea-level rise and interactions with other biophysical controls on soil elevation. Biogenic processes are particularly important for the oceanic mangrove island-type of setting common throughout the Caribbean Region. Work conducted along the Caribbean coastlines of Belize, Florida, Honduras, and Panama focused on processes of mangrove peat formation and plant production-decomposition in relation to modern rates of elevation change, vertical accretion, and shallow subsidence. Elevation change was measured with Surface Elevation Tables (SETs) along with root accumulation and surface accretion of organic and inorganic material

Euthophication and fisheries: A global perspective

D. Breitburg, D. Hondorp & L. Davias

Both nitrogen loadings and the number of coastal systems experiencing hypoxia have increased worldwide. Numerous studies have shown the potential for negative effects of hypoxia, but scaling up from effects at the local or individual scale to population, system-wide, and fisheries effects is not straightforward for mobile species. Cross-system comparisons of >35 estuaries and semi-enclosed seas in industrialized nations suggest that the relationship between nitrogen loading and fisheries landings is unaffected by the spatial extent of hypoxia. N loading and fisheries landings were positively related up to about 15,000 kg N km-2 y-1, the point represented by Chesapeake Bay. The positive relationship between N and landings of mobile demersal species was unaffected by hypoxic extent. The increased demersal:pelagic ratio in eutrophic systems reported in other studies is highly dependent on fisheries regulations, the increased catch of pelagics in some highly enriched systems, and a very high pelagic:demersal ratio in a single system – the Black Sea. Mean trophic level of catch and mean size of species in the fishery also did not differ between systems with and without extensive hypoxic or anoxic areas. Nutrient enrichment creates a spatial mosaic of prey-enriched and physiologically stressful habitats. Spatial averaging of enriched and degraded habitats, and preferential use of enriched habitat, may reduce system-wide negative effects. Tur-

bidity may reduce piscivore capture success as well as the abundance of macrophytes that provide a predation refuge. Fisheries exploitation also keeps most species below carrying capacity, potentially reducing the realized consequences of habitat loss. Our analyses suggest that improving water quality is likely to increase populations and fisheries landings only at the local scale and for particularly susceptible species. Such improvements may be especially critical in developing countries where discharge of raw sewage creates more severe and long-lasting oxygen depletion and human populations are more dependent on local resources.

Latitudinal diversity gradient drives community response to heterogeneity and shapes marine biodiversity at small scales

A.L. Freestone & R.W. Osman

One of the clearest patterns in ecology is the latitudinal diversity gradient, where species diversity increases at lower latitudes. This large-scale gradient in regional diversity may also have important impacts on community dynamics and the maintenance of diversity at small scales. Recent studies have shown that in

sessile marine invertebrate systems, communities in less diverse higher latitudes are more 'regionally enriched,' that is communities at small scales are more representative of the regional species pools. More diverse tropical environments, however, tend to have a smaller percentage of the regional species pool represented at small scales. Therefore, we hypothesized that at temperate latitudes, if species are more uniformly distributed, then a diversity-promoting mechanism will have less of an effect than in tropical latitudes where there are proportionately more species available to colonize local habitats. Habitat heterogeneity, specifically structural heterogeneity, can both promote community diversity and shape community composition. Species themselves can create structural heterogeneity (e.g., coral reefs), and thus 'engineer' their environments. We hypothesized that species-induced structural heterogeneity will increase diversity in tropical communities, but not in temperate communities. In four regions of the North Atlantic Ocean and Caribbean Sea, we used mimics of ecosystem engineering species to manipulate structural heterogeneity in sessile marine invertebrate communities. We deployed settlement panels in Connecticut, Virginia, Florida (SMSFP), and Belize (Carrie Bow Cay) with four treatments varying in their type of structural heterogeneity. We monitored diversity of the experimental communities up to one year after deployment. As hypothesized, we found a striking and consistent latitudinal gradient in the effect of structural heterogeneity on community diversity, ranging from a negative effect in our northern-most region to a positive effect in our southern-most region. These exciting results represent one of the first large-scale experimental demonstrations that marine community dynamics shift with latitude, differentially shaping biodiversity patterns..

Biogeography of marine invasion: Current status and future predictions

G.M. Ruiz, P. Fofonoff, B. Steves, K. Larson, L. McCann, A. Whitman Miller & A.H. Hines

Biological invasions are a significant force of change in coastal ecosystems. Invasions have occurred throughout Earth's history, but the scale and tempo has increased strongly in recent time due to global trade. Available data suggest there is a strong latitudinal pattern in recent marine invasions, with more non-native species documented in temperate marine communities

than polar or tropical systems. This geographic pattern of invasion may reflect historical biases in search effort and taxonomic knowledge. Contemporary surveys suggest these patterns are robust across mid- and high-latitudes, when controlling for search effort. For example, a standardized survey of sessile invertebrate assemblages in estuaries of western North America found a significant decrease in non-native species richness with increasing latitude (32 to 61oN). Several mechanisms may explain the observed invasion pattern across latitudes, operating alone or in combination, such as differences in (a) propagule supply, (b) biotic resistance to invasion, (c) environmental resistance to invasion, and (d) disturbance regime. To date, the relative importance of these mechanisms across geographic regions has not been evaluated, but each may be expected to change over time. Of particular interest and concern are the interactive effects of climate change and human activities on marine invasions, especially at high latitudes. Current climate change models predict not only an increase in sea surface temperatures but also a rapid reduction in sea ice in the Artic. Combined with human responses, climate change is predicted to cause directional shifts in invasion biogeography, including increased invasion opportunity at high northern latitudes.

Decimating mangrove forests for commercial development in the Pelican Cays, Belize: long-term ecological loss for short-term gain?

I.G. Macintyre, M.A. Toscano, I.C. Feller & M. Faust

The unique, biologically diverse and delicate ecosystems of Pelican Cays, Belize, are in serious danger from sediment suffocation related to the recent clear-felling of mangroves for commercial development in what is currently designated Southwater Cay Marine Reserve. Field observations in the Pelican Cays in March 2007 revealed extensive clear-felling of mangroves and covering of exposed peat surfaces with sediment dredged from the adjacent seafloor to create false sand cays. On Manatee Cay, introduction of dredge spoils taken from the nearby seabed has resulted in fine sediment plumes spilling into the adjacent ponds, smothering the attached benthic communities on mangrove roots and burying Thalassia bottom communities. In addition, comparative studies of microalgal (phytoplankton) assemblages in a Manatee Cay pond before and after mangrove clearing indicate a dramatic loss in this group owing to high turbidity observed in the water column and signaling a serious impact to this aquatic ecosystem. Continuing clear-felling, burning and dredge and fill operations were taking place on Fisherman's Cay, with additional survey lines cut on Fisherman's, Manatee, and Cat Cays. A series of aerial photographic surveys from 2003 to 2007 document the extensive loss of mangroves on both Manatee and Fisherman's Cays. Additional clearing of mangroves has occurred on Northeast Cay, Bird Cays, and Ridge Cay resulting in a total of 15.3 ha or more than 29% on the mangrove community that have been destroyed to date in the Pelican Cays. The conversion of mangrove ecosystems for residential, tourism, and commercial uses is obviously widespread and increasing in Belize, as well as elsewhere in the global tropics. This pressure is having an adverse effect on the health of coral reefs and biomass/viability of commercial fisheries, which, ironically, are essential for tourism, not to mention local livelihood.

The healthy Mesoamerican reef ecosystem initiative: An opportunity to enhance collaboration and application of environmental data

M. McField

The Healthy Mesoamerican Reef Ecosystem Initiative is a collaborative international initiative that generates user-friendly tools to measure the health of the Mesoamerican Reef (MAR) Ecosystem, and delivers scientifically credible reports to improve decision-making that effectively sustain social and ecosystem well-being. The Initiative is becoming recognized and respected as an independent and scientifically rigorous partnership that works to improve management decisions that affect the Mesoamerican Reef at the regional, national, and local level. The Healthy Reefs conceptual framework is built upon the fundamental elements of reef ecosystem structure (biodiversity, community structure, abiotics, habitat extent) and function (reproduction, herbivory, coral condition, reef accretion and bioerosion), while also integrating human stressors and social dimensions. Suites of indicators have been selected that measure these different components. Combinations of indicators can be evaluated to answer a wide variety of applied and basic research questions on multiple spatial scales. One example of using these indicators to answer practical management questions is the evaluation of impacts of the 2005 Bleaching event in Belize. Water temperatures surpassed 30ºC for much of the summer, resulting in a coral bleaching index of four degree heating weeks, the highest since 1998 (which reached an index of eight). Approximately 30-40% of the corals bleached but the passage of eight tropical storms intermittently contributed to lowering water temperatures and reducing the cumulative thermal stress. In summer 2006, we joined forces with TNC and WWF to carry out the largest reef assessment ever conducted in the MAR, involving over 330 sites (141 in Belize). The Belize survey assessed over 5,614 corals, finding minimal coral mortality (<1.5%) or disease (<2%). However, the mean coral cover remains low (about 10%) showing no signs of recovery from the recent declines. The partnership is now working to synthesize these and other indicators into an annual report card for the region.

Biotic turnover on reefs of the Caribbean and eastern Pacific: Holocene surprises and future projections

R.B. Aronson, I.G. Macintyre & W.F. Precht

Although coral reefs are degrading globally at present, widespread mass mortalities of dominant, framework-building corals first occurred in the Caribbean and eastern Pacific in the 1980s. Real-time observational data can be combined with millennial-scale paleobiological records to explore the geological implications of ecological phase shifts in both regions. Populations of acroporid corals died off catastrophically from disease in the Caribbean during the 1980s–90s, and their loss depressed coral cover regionally. Coring studies in Belize and Jamaica revealed that the *Acropora*-kill, and the ensuing replacement of *Acropora* by coral taxa that are not framework builders, were unprecedented events in at least the last 3000–4000 years. Rates of vertical reef accretion have been slowed or halted over the last 25 years. In the eastern Pacific, populations of *Pocillopora damicornis* were bleached

and killed by the 1982–83 El Niño event. Coral mortality and subsequent bioerosion of reef frameworks suggested that centennial-scale recurrences of strong El Niños are responsible for the slow accretion rates of eastern Pacific reefs. Off the Pacific coast of Panamá, *Pocillopora* recovered rapidly after 1983 in some places. Where it did not recover the *Pocillopora* rubble was colonized by *Psammocora stellata*, which is not a framework builder. Coring studies in progress in the Gulf of Panamá are showing that *Pocillopora*-kills and shifts to Psammocora had occurred previously during the past 3000–4000 years; however, Pocillopora growth was suppressed continuously for centuries, depressing vertical reef accretion for far longer than the return time of individual, strong El Niño events. These depressed rates of reef growth can be used to parameterize models of vertical accretion under long-term scenarios of biannual to annual coral bleaching, predicted to commence in the next several decades.

The dunamic hydrology of an overwashed mangrove island

D.W. Urish, R.M. Wright & W. Rodriguez

The tidally induced hydrodynamics in an overwashed mangrove island, in conjunction with the topography, greatly affect the ecosystem and vitality of the resident mangrove systems. This is evident from a 20 year study on the small archipelago of Twin Cays lying along the Belizean Barrier Reef. This study concentrates on the interior hydrology of West Island of Twin Cays, a 21.5 ha island characterized by a vigorous fringe of red mangrove (Rhizophora mangle L.) and a depressed central portion. The dominant water feature is a large shallow pond interconnected by channels in direct communication with the surrounding reef lagoon. Sparse dwarf red mangrove dominant in this pond. Poor flushing creates water temperatures ranging from 25o C in the winter to 40o C in the summer. High evapotranspiration creates a hypersaline condition of 45 ppt salinity in summer. In winter with the infusion of fresh rain water, the pond changes to a brackish water of less than 5 ppt . Additionally, of primary significance to the vitality of the mangrove ecosystem is the duration of the flooding-exposure cycle, viz. the hydroperiod. The temporal and spatial characteristics of the interior flow system were investigated using extensive field measurement and the employment of animated computer graphics produced from dye flow studies. While for the past 8000 years the mangrove growth has managed to keep up with rising sea level, the future is in doubt because of anticipated greatly increasing sea level rise rates. The islands of Twin Cays, with its history of comprehensive observational research, remains an important location for observing and measuring changes in the mangrove systems as they occur in a world of dramatic coastal change.

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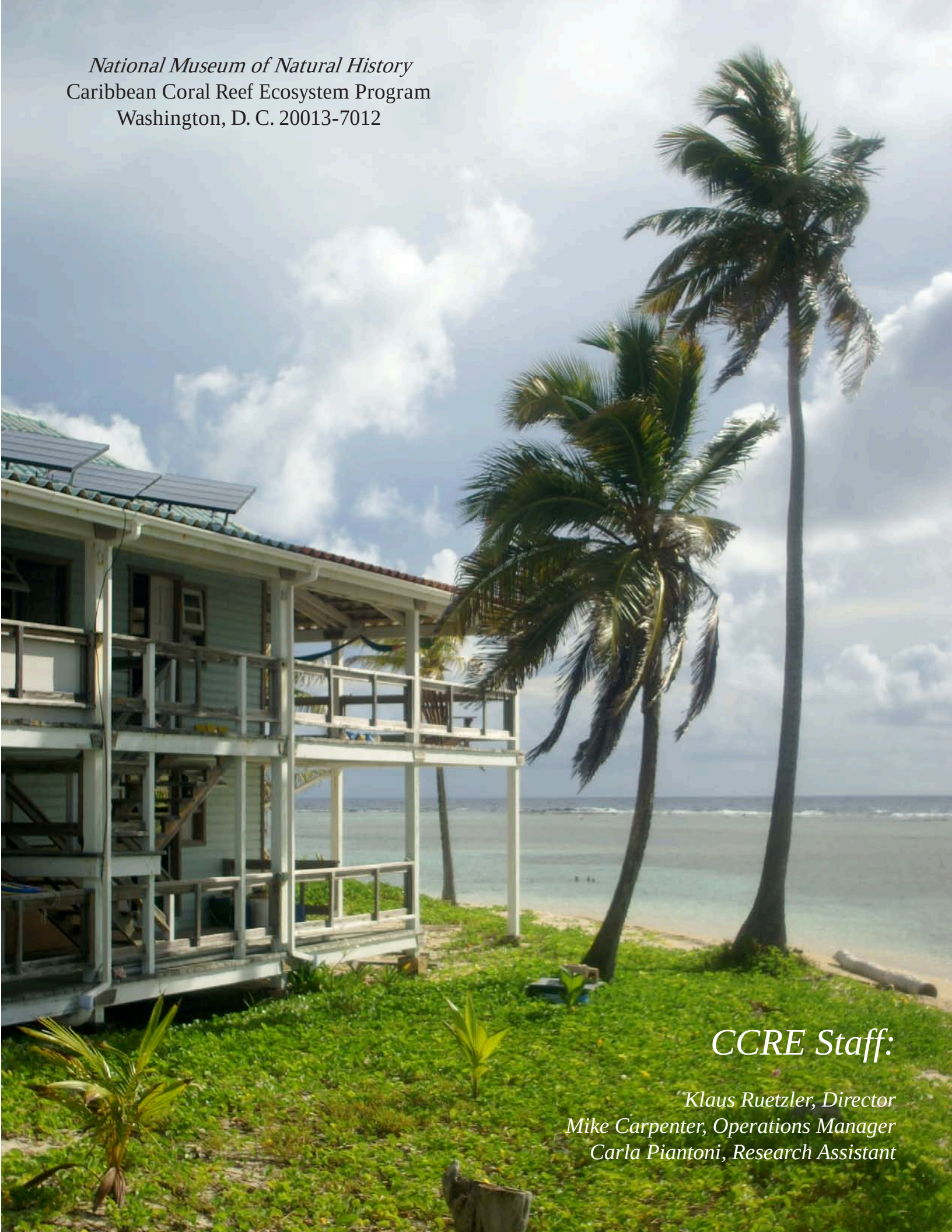

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