CARRIE BOW RESEARCH AREA

1. Mosquito Cay
2. Columbus Cay
3. Sandfly Cay
4. Hutson Cay
5. Cross Cay
6. Garbutt Cay
7. Tobacco Cay
8. Cocoa Plum Cay
9. Man of War Cay
10. Ragged Cay
11. Stewart Cay
12. Wee Wee Cay
13. Spruce Cay
14. Douglas Cay
15. Elbow Cays
16. Quamino Cays
17. Lagoon Cays
18. Channel Cay
19. False Cay
20. Crawl Cay
21. Tarpum Cay
22. Bakers Rendezvous
23. Gladden Cays
24. Rendezvous Cay

Sapodilla Lagoon

Riversdale

Pelican Cays

Tobacco Range

South Water Cay

Carrie Bow Cay

Curlew Bank

Sittee Point

Dangriga

Hopkins

Tobacco Reef

Columbus Reef

5 km

88°15'W

88°05'W

N mag.
Before the devastating fire of 1997, CCRE-affiliated investigations once again produced a rich and valuable array of data on reef ecosystems and their inhabitants. Belize’s mangrove systems received a good deal of attention in both 1996 and 1997 and were shown to be home to unique and highly diverse sponge populations that have sparked worldwide interest. Sponge studies in the mangroves of Twin Cays and Blue Ground Range are expected to shed further light on the chemical and pharmaceutical potential of sponges. Another study collected the first quantitative evidence to show that the submerged mangrove prop roots and mangrove island margins of Twin Cays and Blue Ground Range are the habitat as well as nurseries of spiny lobsters. The prop roots of the red mangrove on Twin Cays also provided two excellent examples of aggregative behavior in zooplankton: the swarming behavior of the copepod *Dioithona oculata* and the shoaling and schooling behavior of the mysid *Mysidium colombiae*. The biodiversity of teredinids (shipworms) native to the Belize mangrove system was described, along with microbial processing (enzymatic degradation) and the utilization (bacterial production and biomass) of organic matter in surface waters of the eutrophic Lair bay in the red mangroves of Twin Cays and its oligotrophic lagoon. Experimental treatment of mangrove forests at Twin Cays showed complex patterns of nutrient availability and differences in nutrient dynamics across three mangrove zones. The results of this work will help assess the impact of human activity in the area, especially the rapid growth of shrimp farming in some of the dwarf mangrove forests. Mangrove peat analysis, undertaken to reconstruct the history of the vegetation at Pelican Cays, revealed a successional sequence ultimately driven by changes in sea level, but with mangrove vegetation clearly playing a major role in soil formation and vertical growth of these islands through root production and decomposition processes. A highly successful member of the mangrove ecosystem is the siphonalean green algae, particularly abundant in the Pelican Cays, which was shown to have a mechanism for mobilizing protoplasm out of older epiphytically impaired blades and coordinating reallocation to form new siphon extensions; this leads to rapid blade proliferation at relatively low cost to the plant. At the same time, the photosynthetic and filter-feeding populations of this region are highly susceptible to damage from boat wakes, physical contact, sedimentation, and eutrophication. Baseline and inventory information are being collected to ensure that a sound conservation/management plan is formulated for this region.

Some investigators remarked on the visible decline in the health of Belize’s reefs. Recent surveys have shown a marked increase in the proportion of dead corals on Carrie Bow reefs over the past 17 to 25 years, especially among *Acropora palmata* and *A. cervicornis*. Large tracts of these species are now standing skeletons. A new problem detected in the past two years is that blue-green algae, brown algae, and sponges have begun growing over the corals off Carrie Bow Cay. The good news, however, is that the extent of Black Band Disease has not increased significantly. The reef communities off Pelican Cays, however, have suffered a drastic change in composition since 1986, when White Band Disease destroyed *Acropora cervicornis*. The *Agaricia tenuifolia* that has taken its place has quite different mechanical properties, which CCRE researchers are exploring to determine whether these changes could cause a catastrophic collapse of the reef communities along the flanks of Pelican Cays. This could be a problem for lagoonal reefs in other parts of Belize and the Caribbean.
Other innovative work over the past two years explored the physical mechanisms by which corals interact with their physical environment. One early finding is that the density of branches within a coral colony can significantly modify the amounts of light, oxygen, and food taken up by the coral, and that the effects of coral shape and branch spacing can in some cases outweigh those of water depth, which is usually thought to be the primary determinant of coral shape and light interception on coral reefs. Zooxanthellae populations respond primarily to the characteristics of the local microhabitat, which are in turn influenced by the interaction of the host’s morphology with the ambient environment. Biomechanical studies also provide an unprecedented level of predictability for anticipating the effects of changes in the physical environment on subtidal biota, such as can occur through human-induced disturbance or long-term changes in global climate.

Several studies concentrated on the role of bacteria in the reef ecosystem. Experiments conducted on bacterial assemblages indicate that UV in the sunlight spectrum could disturb DNA synthesis in bacterial cells. At the same time, sunlight-induced DNA damage in natural communities of bacteria may be repaired by photoreactivation, and this strategy may be essential for the maintenance of standing-stock bacterial cells in surface waters. Natural solar radiation was also suspected of enhancing bacterial production in oligotrophic lagoon waters as well as eutrophic mangrove waters of Twin Cays. The metabolism and production of bacteria in these waters appear to be strongly dependent on substrate availability, primarily floating detritus, which supplies the water with particulate organic matter, and dissolved organic matter. Marine chroococoid cyanobacteria were measured in the coastal waters of Belize to determine why the lagoonal waters of Pelican Cays support an unusually rich and diverse reef fauna. The oceanographic conditions surrounding Pelican Cays, including the possibility of groundwater nutrient inputs, are believed to be involved in the support of this community. Brittle stars from various habitats were examined to determine where they contain symbiotic bacteria, as described for temperate species. Bacterial symbionts were also studied in thalassinosid species, and the mechanisms of interaction between nematodes of the subfamily Stilbonematinae and their symbiotic bacteria.

An intriguing finding of 1996 was eusocial behavior in shrimp at Carrie Bow, the first report of advanced cooperative behavior in a marine animal. Large males defend the colony, including juveniles, against intruders, while a single “queen” reproduces. Preliminary results of an echinoderm survey at 10 cays suggest that the richness of sea stars, brittle stars, sea urchins, sea cucumbers, and feather stars is positively correlated with shelf depth in the lagoon, that characteristic suites of mangrove cay species are associated with specific microhabitats and substrates, and the composition of the lagoon fauna may be influenced by the proximity of cuts in the barrier reef (and localized hydrographic conditions). By contrast, data collected thus far suggest ascidian populations are not particularly rich, except at the mouth of a lagoon southwest of Manatee Cay. It appears that significant changes have occurred in the ascidian populations at Cat Cay. This possibility will be explored further to determine if these are long-term changes and if they may have any connection with human interference.

The substantial body of information CCRE studies are producing is especially significant from a long-term perspective. An ongoing study of the larvae of coral-reef fishes off Carrie Bow Cay is providing valuable information on fish life history, which is part of the essential groundwork of phylogenetic and ecological investigations. In situ observations on Carrie Bow of guarding male behavior of the bicolor damselfish immediately prior to and during hatching of embryos demonstrated that males exhibit increased fanning and contact behavior toward their eggs on the night of hatching. These observations and those of
bridled goby suggest that the timing of hatching in both cases evolved primarily to maximize the time available for larval dispersal away from the reef and associated diurnal reef predators. Courtship and aggressive displays were studied in tube blennies (Chaenopsidae), a family of fishes largely restricted to the Caribbean and tropical eastern Pacific, and it was found that some behavioral displays are conservative characters and can provide insight into the evolutionary relationships of chaenopsids. In a study of massive sponge-dwelling fishes around Carrie Bow, several species never reported as sponge inhabitants were collected from samples of stinker sponges. Other new fish species were documented over the past two years include a chaenopsid fish, *Emblemariopsis ruetzleri*, and a new cardinalfish, *Apogon robbyi*, (Perciformes: Apogonidae).

One disturbing observation of the past two years is that populations of larger reef fish such as grouper, snapper, and triggerfish may be drastically declining on the Belizean Barrier Reef, along with the populations of lobster and conch. Quantitative data are not yet available on this change, but these early warning signs give added significance to CCRE studies.

**Introduction**

The year 1997 was remarkable for us in many ways. Scientifically it was highly successful as many significant field projects were launched or carried to conclusion. Because 1997 had been declared the International Year of the Reef we aimed to share our enthusiasm for this unique environment with students and the general public on many occasions, through lectures, poster sessions, and demonstrations, on site in Belize and here at the National Museum of Natural History. Another reason to celebrate was that our field station, the logistical base and catalyst of our program, had reached the respectable age of 25 years (1972–1997). But the gods must have decided that a rejuvenation of this venerable facility was in order. On 6th December 1997 an accidental electric fire aided by old, termite-riddled lumber and fanned by a strong northerly wind turned most of the station to ashes—laboratory, kitchen, living quarters, even full wooden water vats, all except a small cottage and the generator hut which were isolated to the south of the island. At least a dozen coconut palms were burned or damaged. Valuable equipment was lost (uninsured due to Government policy), including library, microscope, solar system, weather station, computers, balances and spare engines.

Because of the fire the year 1998 was lost as far as fieldwork is concerned because program funds had to be rededicated to cover replacements. Project Phoenix, as we call the rebuilding process, is well on its way and we expect to resume a full field work schedule in mid-1999. This is after an additional delay caused by hurricane Mitch whose eye luckily did not reach Belize but who still caused complete flooding of Carrie Bow Cay, loss of 20 or more coconut trees, and substantial erosion of its shore.
Flashbacks


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

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

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

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

1977 • Field trip to Carrie Bow Cay by participants of the Third International Coral Reef Symposium.
• Aerial and underwater surveys expanded to cover the entire barrier reef of Belize.
• Geology team drills first cores to determine reef history.

1978 • EXXON’s The Lamp publishes article on company-sponsored research at Carrie Bow Cay (“Where seaworms glow.”).

1979 • Hurricane Greta destroys Carrie Bow Cay field station.

1980 • EXXON Corporation funds new initiative: comprehensive study of a western Atlantic mangrove swamp ecosystem, now known as SWAMP (Smithsonian Western Atlantic Mangrove Program).
• Mapping of Twin Cays, principal site of SWAMP, by aerial photography and ground truthing.
• Initiation of Art in a SWAMP project where scientific illustrators and scientists collaborate in analysis and pictorial rendition of mangrove communities in time and space.
• Employment of H. Edgerton underwater time-lapse camera with strobe light (on loan from the inventor) to record day-night activity in benthic communities.
• Vibracoring at Twin Cays to determine internal structure and development.

1981 • New weather protected and enlarged seawater system for laboratory experiments installed on Carrie Bow Cay.
• Series of extremely low tides at noon time were observed to have catastrophic effects on reef and mangrove organisms.
• First automated weather station installed at Twin Cays.
• Cooperation with Belize Government identifying coastal marine areas suitable for natural resource conservation.
• Busiest year since program start: 8 months continuing laboratory operation for 45 research staff.
• First year of operation of Caribbean Coral Reef Ecosystems (CCRE), a new program of the National Museum of Natural History. It replaces the old IMSWE project and supplements the ongoing SWAMP program which is supported by a renewed annual grant by the EXXON Corporation.

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

1989 • Science as Art exhibit at the Smithsonian’s S. Dillon Ripley Center displays scientifically important and
aesthetically pleasing products from SWAMP mangrove research, such as community drawings, paintings, photographs, and sculpture-like epoxy casts of soft-bottom animal burrows.

- Vandalized and malfunctioning weather station reconditioned and relocated to the Carrie Bow field laboratory.
- Mounting problems with anthropogenic stresses at research sites, such as heavy tourist visitation, garbage dumping, and clear-cutting mangrove trees.

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

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

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

1993  
- Belize Ministry of Natural Resources grants long-term rights to Twin Cays for exclusive use in mangrove research.
- Successful mangrove education workshop repeated under auspices of Belize Ministries of Natural Resources and Fisheries and Agriculture.
- Launching of new 8 m (25 ft) research vessel Physalia, funded by a grant from the U. S. National Science Foundation, extends research radius over most of central and southern Belize.
- Ivan Goodbody pioneers surveys of Pelican Cays, a “tunicate heaven” one hour by boat SSW of Carrie Bow.

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

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

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

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

1998  
- Island clean-up and design for new field station completed. Construction work initiated but delayed by flooding and coastal erosion from hurricane Mitch.
- Completed editorial work on CD-ROM containing over 100 representative CCRE scientific papers that resulted from research at Carrie Bow Cay.
- Cosponsored highly successful exhibit “Our Reefs–Caribbean Connections” which opened in Belize City. This traveling exhibit was developed by the Smithsonian Tropical Research Institute, Panama, on the occasion of the 1997 International Year of the Reef. CCRE contributed a large poster describing 25 years of coral reef research by this program in Belize.
- Serious coral bleaching and die-off on reefs off Carrie Bow and Pelican Cays reported by Karen Koltes and Rich Aronson (nearly 100 % for Agaricia tenuifolia in some areas) as a result of sustained periods of high temperature and low water movement. Devastating physical impact by hurricane Mitch (5–6 m waves) on shallow coral spurs was also observed.
Acknowledgments

We gratefully acknowledge the Belize Ministries of Natural Resources and of Fisheries and Agriculture, including the Coastal Zone Management unit, for hosting our studies, collaborating in research and educational activities, and for providing research and collecting permits. Noel Jacobs is thanked for representing Belize Fisheries on our CCRE Steering Committee (1996, 1997). He and the other members of the committee (identified below in the list of CCRE participants) have greatly improved the efficiency and objectivity of our program. The Belize Audubon Society and the owners and staff of Pelican Beach Motel, Dangriga, provided local support. We are particularly indebted to Therese Rath for local management and Tony Rath for photography and computer consultations. Jimmie Smith, Islands from the Sky, provided many excellent aerial photographs. Numerous volunteer station managers and local craftsmen helped maintain and improve the Carrie Bow laboratory facility.

Back in Washington, we thank Vicky Macintyre for her skillful editorial work. Marsha Sitnik, Judy Sansbury, Nancy Shorey, Abelardo Sandoval, and Dorothy Ceasar (Biodiversity), Mike Lang and Cheryl Thacker (Scientific Diving Program), Marty Joynt (Invertebrate Zoology), and Danielle Bielenstein and Yvette Butler (NMNH Director's Office) provided substantial administrative and logistical support to the program. Dr. Janie Wulff (Middlebury College, Vermont) ably represented the program during the Our Reefs exhibit (which she helped design) launch in Belize City. Grants from the U. S. National Science Foundation, the Christensen Foundation, and the Smithsonian Atherton Seidell and Biodiversity fund contributed substantially to several of our research and educational projects.

Last but most emphatically, we wish to thank those individual and corporate donors who contributed toward the rebuilding of the Carrie Bow field station after the devastating fire. Financial aid was provided by Christine Allen, Dr. Olav Giere, Dr. Hans Pulpan, Mr. Kjell Sandved, Ms. Linda Ward, Dr. Kerstin Wesson and the YSI Foundation. Generous donations-in-kind were made by British Air, Dolan-Jenner Industries, Makita USA Inc., March Manufacturing Inc., Mettler-Toledo and Stanley Works.
Biodiversity, Morphology & Developmental Biology

RESEARCH PROJECTS

Maria A. Faust

Study of heterotrophic dinoflagellates

Dinoflagellates were studied from three Belizean habitats: the water column at South Water Cay, Carrie Bow Cay, and Manatee Cay; attached to red and brown macroalgae and artificial surfaces (plastic screens) at South Water Cay and Carrie Bow Cay; and submerged sand at South Water Cay. All samples contained assemblages of heterotrophic, thecate dinoflagellate species exhibiting phagotrophic nutrition. Phagotrophy was most frequent in planktonic populations, followed by cells in sand, and the lowest in cells attached to macroalgae. The dinoflagellates under study were able to capture and engulf a broad range and size of living organisms, representative of their phagotrophic lineage, and gain their nutrition through ingestion of other microorganisms. The food vacuoles contained 7-8 ingested prey in D. rotundatum and the prey appear to be photosynthetic nanoplankton. One large, round, partly digested photosynthetic prey was present in Pyrophacus steinii. The round and colorless prey varied in size in Protoperidinium oblongum. Phagotrophic dinoflagellate cells exhibited cellular plasticity, a large golden brown prey was present in Peridinium globosus, and about 20 picoplankton in S. microcephalus (Fig. 5). In natural populations, some cells were observed without food vacuoles, others with empty round food vacuoles, and food vacuoles with prey or partly digested prey.

Mark M. Littler & Diane Littler

Algal biodiversity and unique habitats of the Pelican Cays

The Pelican Cays represent low-energy environments dominated by photosynthetic and filter-feeding populations. Most are physically delicate and highly susceptible to damage from boat wakes, physical contact, sedimentation, and eutrophication. Few of the sheet-like and wiry green algae indicative of eutrophic bird islands or anthropogenically polluted systems are present. This study is part of an ongoing effort to collect the baseline and inventory information urgently needed to ensure that a sound conservation/management plan is formulated for this region. An innovative floristic approach was used to collect data: each taxon was given a general morphological description followed by a more technical anatomical diagnosis, with a cluster of about four habit and anatomical line drawings next to each description. The product will be a fully illustrated flora that can also serve as a field-guide to the marine plant life of the Pelican Cays. Information collected at Pelican Cays to date reveals high plant diversity: 190 species of marine plants (84 Rhodophyta, 75 Chlorophyta, 23 Phaeophyta, 5 Cyanophyta, and 3 Magnoliophyta). This biodiversity in such a small area is probably the result of the coming together of complex mangrove, coral, seagrass, and algal biomes under stable pristine seawater conditions.

Phil Taylor, Jack Fell & Loren Coen

Genetic determination of species diversity in the genus Lobophora

Lobophora variegata (Lamouroux) Womersley (Phaeophyta, Dictyotales, Dictyotaceae) in its various reported forms is one of the most abundant macroalgal species of the Belize barrier reef system, occurring as a conspicuous biomass dominant in mangrove, reef, and seagrass. The goal of this study is to develop evidence to test the assertion that the reported forms are in fact distinct genetic entities and perhaps separate species. The genetic diversity in L. variegata is being examined following some earlier and equivocal studies of the environmental determinations of form.

Karen L. McKee

Reconstruction of vegetation history at the Pelican Cays based on peat analysis

A key to mangrove peat was developed on the basis of diagnostic root/rhizome characters for the dominant plant species present on Belizean cays. The key includes detailed descriptions and illustrations of plant roots, among them the three dominant mangrove species (Rhizophora mangle, Avicennia germinans, and Laguncularia racemosa) and eight herbaceous species (Batis maritima, Salicornia fruticosa, Distichlis spicata, Spartina patens, Sporobolus virginicus, Sesuvium portulacastrum, and Thallasia testudinum). Buried, decomposing roots of known origin were collected and identified with the key to mangrove peat in a double-blind trial. The results were used to determine relative dominance by species through the soil profile. In the double-blind trial, it was possible to correctly identify to species all samples (n = 10) of R. mangle and A. germinans roots that had been buried and decomposing for two years, in spite of variation in color and degree of decomposition owing to differences in site environmental conditions. In many cases, root fragments in the peat cores were large enough for field identification with a hand lens. The focus on roots was justified by the observation that > 75% of the peat was composed of root material. Although leaf and wood fragments were observed, they did not prove to be reliable because they could have originated elsewhere, were more decomposed than roots produced in situ, and constituted a small percentage by volume of the peat. The identifications revealed a successional sequence ultimately driven by changes in sea level, but the mangrove vegetation clearly plays a major role in soil formation and vertical growth of these islands through root production and decomposition processes.
Susan L. Richardson

**Foraminiferans epiphytic on Thalassia blades: distribution, settlement, growth and reproduction**

Several species of single-celled foraminiferans are found living attached to seagrasses in the shallow marine environments of Belize. Samples of the seagrass *Thalassia testudinum* were collected from several sites off Carrie Bow Cay and in the Pelican Cays. Organisms were removed for study by scraping them off the seagrass leaves with a razor blade. Both the seagrass leaves and the scrapings were dried in an oven and weighed. Preliminary results indicate that for the samples collected from the back-reef lagoon off Carrie Bow Cay, the weight of the epiphytes (= attached organisms) comprise 10.73–31.26% of the total weight of the epiphytes + seagrass. Additional samples of seagrass and sediment were collected for a comparative quantitative survey of the epiphytic species with the sediment-dwelling foraminiferal species living in seagrass beds. A preliminary survey of the species attached to the seagrass collected from Cat Cay revealed seven species of epiphytic foraminiferans occur in association with calcareous algae, spirorbid worms, and hydroids on the seagrass blades. An overall density of 1.61 foraminiferans/cm² of seagrass surface was calculated for this locality and the population of epiphytic foraminiferans is approximately 70,000 individuals per m² of seafloor. Preliminary observations suggest that the epiphytic fauna is distinct from the sediment-dwelling fauna in seagrass environments.

Belinda Alvarez de Glasby, Cristina Diaz, Klaus Rützler, Rob van Soest, Kathleen Smith, Janie Wulff & Sven Zea

**Study and workshop on sponges of Pelican Cays: Carrie Bow Cay**

Sponge specialists from Colombia, the Netherlands, New Zealand, and the United States met for a field workshop on Carrie Bow Cay to try to resolve a number of systematic questions about Caribbean sponges and to collaborator in proposals that will help conserve these pharmacologically important fauna and their mangrove habitats. The sponge populations of Belizean mangroves have drawn worldwide attention for their unique character and extremely high biodiversity, which is thought to have developed because of the minimal influence of terrestrial freshwater in these mangroves. During the workshop, participants collected specimens from 150 species at Twin Cays (Hidden Creek, Cuda Gut and Sponge Haven), Blue Ground Range and the Pelican Cays group (including Cat Cay, Manatee Cay, and Fisherman’s Cay) and kept daily records of their identity, distribution, and estimated abundance. All the material collected was properly fixed and preserved and will be catalogued and deposited in the National Museum of Natural History, Smithsonian Institution. The results of this survey are expected to contribute to the conservation of these delicate ecosystems and to shed further light on the chemical and pharmaceutical potential of sponges. These organisms are a source of chemical compounds with toxic or antibiotic properties, probably developed in response to predation and competition for space because of their sessile condition.

Klaus Rützler

**A new, non-toxic member of Neofibularia (Porifera) overgrowing reef corals**

During a survey of sponges from the spur-and-groove system off Carrie Bow Cay, a gray-green turf-like encrustation was discovered that upon closer microscopic examination turned out to be a sponge. This unusual species belongs to the genus *Neofibularia* although it has a very different morphology than other members of this group. A skin test of fresh material on a diver (courtesy Karen Koltes) revealed that this sponge does not have the dermatitis-producing properties known from all other species of *Neofibularia* (also expressed in their specific names), such as *N. nolitangere*, also from the Caribbean, and *N. irrata*, from the Pacific. However, the sponge could have important effects on the reef community as it appears to be closely associated with dead or dying coral. The new species from Belize and another new (yet highly irritating to humans) form from a cave in Bermuda are now being studied by electron microscopy.

Martha L. Robbart

**Coral Abundance and Health at Wee Wee Caye**

Under the auspices of Smith College, a survey of live coral cover was conducted around Wee Wee Caye, an island within the backreef of the barrier reef, (7 km southwest of Carrie Bow Caye). Data were collected during May-June 1997 using a transect-line method. Percent live coral cover was recorded along each transect at two meter intervals, using a PVC pipe marked in increments of 10cm. Percent live coral cover ranged from 8.1% to 12.8. Shannon Weiner and Simpson indexes were used to assess diversity of the site and make comparisons to other reefs in the Caribbean. Since May of 1997 two bleaching events, (summers of 1997 and 1998) and hurricane Mitch have impacted the area. A comparative study will be conducted in May 1999.

*Note: Martha Robbart has recently joined the CCRE program as administrative assistant and data manager.*

Wolfgang E. Sterrer

**Toward a world biodiversity database of Gnathostomulida**

Thanks to the opportunity for repeated and intensive sampling since 1974, the gnathostomulid fauna of the Carrie-Bow region is now the best known in the world, boasting 25 species, of 45 species recorded from the (sub)tropical northwestern Atlantic (Sterrer 1998; CCRE contribution no. 538), and a total of about 80 that are known to date. A surprisingly high percentage of these species has circumtropical distribution. Detailed knowledge of the
Belizean gnathostomulid fauna will provide the nucleus for a world biodiversity database of this enigmatic worm phylum.

Kristian Fauchald, Hua Lu, V. Radashevsky & Linda Ward
Studies on polychaete worms
[No details available]

Fredrik Pleijel
Diversity of hesionid polychaetes
Live polychaetes (mainly Hesionidae) were collected around Carrie Bow Cay and at Pelican Cay. Specimens were preserved for general-purpose studies, SEM, and DNA-sequencing. Preliminary results indicate 15 members of Hesionidae, of which 5 are previously undescribed, and approximately 500 specimens. Some other polychaete groups were collected as well.

Damhnait McHugh
Systematics and reproductive biology of terebellid polychaetes
An inventory of the terebellid polychaetes from Carrie Bow Cay and Twin Cays was undertaken, and the reproductive biology of one species, Paraeupolymnia carus, was studied in detail. Eleven species of terebellids, representing three subfamilies, were collected from coral rubble, Thalassia beds, and mangrove roots, and fixed for the purposes of taxonomy and molecular analyses. Mature specimens were fixed for subsequent examination of gamete ultrastructure. Paraeupolymnia carus is a small terebellid (< 2 cm) known only from Twin Cays, that broods its larvae in the maternal tube. Up to 60 larvae were observed in a single brood, and as many as three broods per female. The oocytes in this species reach a maximum size of approximately 220 µm and fecundity estimates range up to 10,000 in large specimens. In situ fertilization allowed a full description of the direct larval development of this species, which extends over several days. In males, sperm stages were fixed for comparison of sperm ultrastructural characters of Paraeupolymnia with those of other small terebellid species with similar reproductive modes. The reproductive biology of this monotypic genus will add to ongoing studies of the evolution of terebellid life histories.

Richard F. Modlin & Marian L. Lewis
Development, morphology and physiology of the Mysidium columbae statocyst
Histological studies in the laboratory identified the location of the caudal statocyst gland in the tissue of the uropodal endopod. Preparations are being made to analyze the elemental content for calcium, sulfur, and fluorine ions, on and in the vicinity of the proteoglycan granules associated with the caudal statocyst gland. An electron microprobe x-ray microanalytical system associated with the scanning electron microscope will be used for this purpose. The presence of these ions would suggest that the gland sequesters the minerals necessary for the production of the statolith.

Ivan Goodbody
Ascidian fauna of the Pelican Cays
This study was devoted in part to extending a survey of the submerged ridges between islands in the Pelican Cays group, particularly those in the southern half of the system, south of Cat Cay in the east and Little Cat Cay in the west. In addition, data were obtained on ascidian populations in a world biodiversity database of this enigmatic worm phylum.
lagoon at Little Cat Cay and a “hidden” lagoon in the southwest of Manatee Cay. Eight sites were surveyed: three are on the main ridges and have too much mobile sediment for significant populations of ascidians; four are small patch reefs with significant amounts of coral and related ascidian populations; and one is a small patch reef close to the Western Ridge where ascidians are not particularly rich. The lagoon southwest of Manatee Cay is home to twelve species of ascidian fauna, including *Ascidia nigra*, *A. interrupta*, *Eudistoma olivaceum*, and *Didemnum psmathodes*. *Ecteinascidia turbinata* seems to be confined to an area around the entrance to the lagoon. Nevertheless this is the largest concentration of *E. turbinata* thus far seen anywhere at Pelican Cays or the Twin Cays-Tobacco Range area. Like Lagoon Cay, Little Cat Cay, is dominated by solitary species, and not by colonial forms as occur at Cat Cay and Manatee Cay. Preliminary results suggest there may have been significant changes in the populations of ascidians at Cat Cay. This possibility will be explored further to determine if these are long-term changes and if they may have any connection with human interference.

Carole C. Baldwin & David G. Smith

Identification of the fish larvae of Belize and a search for “missing” fish species

The primary goal of this ongoing study is to identify larvae of the coral-reef fishes of Carrie Bow Cay, Belize. This information is required before larvae can be used in studies of other types, especially those concerned with phylogeny and ecology. Techniques refined in previous years for identifying to type, rearing, preserving, and photographing larvae collected in a moored plankton net off Carrie Bow were continued this year. One of the main goals was to obtain additional information needed to complete a study on gobioid larvae; unfortunately, the number and diversity of ichthyoplankton samples were quite low in general this year, possibly because fieldwork began one week later in the lunar cycle than in the preceding year. Although catches were low, the collections included at least 25 larval types never obtained before. These unusual larvae may have been transported past Carrie Bow during the period of a prolonged, unstable air mass around the area that was accompanied by winds of variable direction and speed. Among the new larval types were several new gobids, scarids (parrotfishes), apogonids (cardinalfishes), labrids (wrasses), two unknown percoid larvae, an ophidioid (cuskeel), a scrombid (mackerel or tuna), a *Bregmaceros* (codlet) and, most significantly, six new types of larval blennioids; the last is remarkable because, despite the abundance of adult blennioids in the area, blennioid larvae have always been poorly represented in samples from earlier collections.

Carole C. Baldwin & David G. Smith

Continuing studies of early life history stages of fishes at Carrie Bow Cay, Belize, Central America: taxonomy, photography, and preservation

Techniques refined in preceding years for identifying to type, rearing, and preserving fish larvae collected in a moored plankton net off Carrie Bow were continued. About 35 larval types were maintained in the rearing facility, and all types were sketched and photographs made of their live coloration. Information on coloration is critical because many of the larval types can only be distinguished on the basis of patterns of orange and yellow chromatophores. Subsampling of the rearing cages indicates the presence of two previously unidentified species of larval Gobiidae, and one Pomacentridae (damselfish). The remaining types represent 10 additional families.

Christine E. Thacker & David G. Smith

Identification and ontogeny of microdesmine gobies at Carrie Bow Cay, Belize, I

Larvae of three species of the gobioid subfamily Microdesminae were collected with a moored plankton net at Carrie Bow Cay, Belize. One of these had been reared to completion in past years and was known to be *Cerdale floridana*. Two others—a common, relatively small species with low fin-ray counts—and a rarer and larger species with high fin-ray counts, were also raised and will be described after completion of rearing experiments still in progress. Scanty knowledge of microdesmine species worldwide suggests that these two types are undescribed species. The late stage near-settlement larvae collected in this study were also subsampled to provide information about the larval transformation process and were photographed while fresh to reveal characters and pigment patterns generally lost in preserved specimens.

Christine E. Thacker & David G. Smith

Identification, ontogeny, and distribution of microdesmine gobies at Carrie Bow Cay, Belize, II

The objectives of this study were to continue the capture and rearing of microdesmine goby larvae and to sample habitats outside Carrie Bow for the cryptic, benthic microdesmine adults. Protocols of past seasons were used in the collection of larvae, with the addition of light traps, and hand-net procedures with quinaldine. Larvae were anaesthetized, photographed, and typed and approximately 35 species were maintained in rearing cages in aquaria. In past years, larvae of five microdesmine species were obtained, of which four were identified on the basis of correlation with characters of known species. Two of the four identified species are very common in the current samples: *Microdesmus bahianus* and *Cerdale floridana*. The other two, and the one unidentified type, are comparatively rare and were not encountered this year. Attempts to sample adults were unsuccessful, despite the use of several techniques throughout the Belize Cays. It has been documented that the distribution of adults of this subfamily is generally very patchy and sparse; this year or time of year may have
been a poor one for microdesmines, because the number of larvae in plankton samples was drastically lower than in previous years.

Kathleen Cole, Dave Johnson, Carole Baldwin & David G. Smith
Timing of hatching, role of the guarding male in the hatching process, and description of early, post-hatching larval stages in two gobies and a damselfish

Collections of newly hatched larvae of the goby, Coryphopterus glaucofraenum, and the bicolor damselfish, Stegastes partitus, have provided specimens for morphological descriptions of the very early larval stages of these two species. In addition, the collection of a newly settled individual belonging to the C. personatus/hyalinus complex has provided enough larval characters to identify one pre-settlement larval form of Coryphopterus to this species complex. Embryos of the bicolor damselfish, once fully developed, hatch within an hour of sunset. In situ observations of guarding male behavior of the bicolor damselfish immediately prior to and during hatching of embryos demonstrated that males exhibit increased fanning and contact behavior directed towards their eggs on the night of hatching. This increase may be in response to increased movements of ready-to-hatch embryos, or the first freeswimming movements of newly hatched larvae, or both. Experimental switching of different-aged embryos produced by different males showed that males either do not recognize or do not alter their parenting behavior toward eggs that are not their own.

Kathleen Cole, Carole Baldwin & David G. Smith
Gonad ontogeny, paternal behavior associated with hatching, and distinctive morphological features of early post-hatching and post-settlement stages for several species of Caribbean gobies and a damselfish

Recently hatched larvae of three goby species—Coryphopterus lipernes, Gobiosoma saucrum, and G. oceanops—were examined for the presence of retained larval morphological features that may link them to unidentified larval gobies collected at Carrie Bow. Nocturnal observations of the bridled goby, C. glaucofraenum, showed that embryos hatch shortly after sunset. The guarding male may facilitate hatching through contact behavior directed toward the embryos. These observations parallel those for the bicolor damselfish, Stegastes partitus, and suggest that the timing of hatching in both C. glaucofraenum and S. partitus evolved primarily to maximize the time available for larval dispersal away from the reef and associated diurnal reef predators. As part of a study on the evolution of sexual patterns within gobid fishes, collections consisting of a complete series of juvenile developmental stages as well as adults were made for three goby species: Gobiosoma oceanops, G. xanthiprora, and G. saucrum. Gobiosoma is a particularly important goby genus for this study since sexual patterns are known for only a few species, none of which were collected here. Subsequent histological examination will determine the sexual pattern of the three collected species and provide comparisons with patterns of gonad ontogeny documented for other Gobiosoma species and other goby genera.

Kenneth A. Tighe
Association of chlopsid eels and sponges

The original description of the chlopsid eel, Kaupichthys nuchalis Bölte 1967 noted occurrence of the species from sponges, particularly in a cylindrical species of the genus Callyspongia. Another record (from Venezuela) (Cervigon 1986) was from Aplysina archeri. This project was designed to determine the role of sponge hosts in the life cycle of the eel. A number of sponges with morphology suitable for fish inhabitants was collected but K. nuchalis was found only in one species, Callyspongia vaginalis. Other sponge-dwelling fishes and eels not associated with Porifera were collected and preserved for identification at the Museum. Samples were also taken for deposit in the tissue collection in the Department of Vertebrate Zoology.

D. M. Tyler & J. C. Tyler
Natural history of the sea fan blenny, Emblemariopsis pricei (Pisces, Chaenopsidae) in the western Caribbean

This major project on the life history of the sea fan blenny, Emblemariopsis pricei, was completed. The organisms’ dark-headed breeding males live in holes in living coral and females, non-breeding males, and juveniles live on sea fans.

J. C. Tyler & D. M. Tyler
A new species of chaenopsid fish, Emblemariopsis ruetzleri, from the western Caribbean off Belize (Blennioidei), with notes on its life history

A new species of chaenopsid blenny was discovered at Carrie Bow Cay. The new species, Emblemariopsis ruetzleri, has a life history with interesting differences from its sea fan blenny congener.

C. R. Gilbert & J. C. Tyler
Apogon robbyi, a new cardinalfish (Perciformes: Apogonidae) from the Caribbean Sea

A new species of apogonid cardinal fish was found in the shot-holes west of Carrie Bow Cay. The species was described and a wide variety of habitats in addition to the open sand bottom were documented.

J. C. Tyler & I.C. Feller
Caribbean marine occurrence in mangroves of a typically freshwater synbranchiform fish

The capture of the swamp eel Ophisternon aenigmaticum in the hypersaline waters of Twin Cays is the
first marine record for any of the New World species of Synbranchiformes, with dispersal from the mainland through sea water sometime in the past 7,000 years the likely explanation for its island occurrence.

J.C. Tyler & D.M. Tyler
Survey of the massive sponge-dwelling fishes around Carrie Bow Cay

This survey of the massive sponge-dwelling fishes around Carrie Bow Cay was undertaken to determine whether the assortment from this western Caribbean location might differ from the better-known sponge-fish fauna of the eastern Caribbean. Although the loggerhead sponges proved to be relatively scarce in number, those sampled to date have yielded the expected high frequency of occurrence of Evermannichthys metzelaari, but these specimens were more similar to specimens from the Antilles than the few specimens that had been collected previously at more western localities such as Providence and off Nicaragua. The stinker sponges also yielded the expected high frequency of occurrence of Risor ruber. The morphology of these specimens varies so greatly even within a single sponge that one can question whether they can all represent the same species; this is also the case in Antilles collections of this obligate sponge-dwelling goby. Several species of fishes that have never before been reported as sponge inhabitants were collected from these samples of stinker sponges.

SPECIES INTERACTIONS & BEHAVIOR

Kaori Ohki
Possible role of virus(es) in the existence of Trichodesmium in the lagoonal waters of Carrie Bow Cay

To test the possible effect of lysogenic viruses on Trichodesmium spp., healthy bundle-shaped colonies (dark, reddish-brown in color) from Carrie Bow Cay were treated with mitomycin C. Healthy and unhealthy colonies (yellowish-green in color) were collected separately from fore-reef and lagoonal waters and then prepared for examination under a transmission electron microscope. Colonies were treated with mitomycin C and samples were removed at timely intervals during incubation.

When Trichodesmium colonies were incubated with mitomycin C > 1 µg/ml, the trichome bundles in each colony became loose and cells turned yellowish-green. Cells were completely lysed after 24 to 36 hours of incubation. A similar process was observed when colonies were treated at lower concentrations (0.1 to 0.5 µg/ml), although the incubation time to complete lysis took 36 hours or longer. It is known that mitomycin C induces a lytic cycle of lysogenic viruses (phages) not only in bacteria, but also in cyanophytes. Observations of Trichodesmium during incubation with mitomycin C suggest that infection of lysogenic viruses occurs in the cyanophyte. Under the transmission electron microscope, the ultrastructure of the treated cells was very similar to that of cells in unhealthy colonies collected from lagoonal waters: although the gas vesicles seemed still intact, holes were scattered in the cytoplasm; and arrangement of thylakoids, which are located in the peripheral part of the cell, became irregular. It is not yet clear whether lysogenic viruses occur in Trichodesmium. More detailed investigations are in progress using TEM to search for virus particles in mitomycin C-treated cells.

Maria A. Faust
Study of mixotrophy in dinoflagellates

Mixotrophy—a feeding behavior of photosynthetic microalgae that have chloroplasts but at times ingest living prey organisms—was investigated in four phototrophic dinoflagellate genera in mangrove, open-water, and sand habitats at Pelican Cay, Twin Cays, and Carrie Bow Cay. Mixotrophic organisms may have a competitive advantage over photosynthetic species in that they may obtain particulate food during limited light conditions. The dinoflagellates examined appear to ingest small microalgae, nanoplanктon, and ciliates that are abundant in the water. The average size of captured cells was smaller than the mixotrophic dinoflagellate species. The average size of prey organisms was usually smaller than the mixotrophic dinoflagellate species, and may indicate that the dinoflagellates feed selectively. The number of dinoflagellates with captured prey ranged from 7 to 13 attached to screens, from 5 to 12 percent in net samples, and from 4 to 9 percent in sand. The captured prey in dinoflagellates was intact and enclosed within their cell wall and digested later. Dinoflagellates thus engulf the entire prey organism. The site of ingestion within Ostreopsis species was found to be a ventral opening, an orifice, considered the feeding apparatus. Mixotrophy, however, was seldom observed in plankton samples examined from Twin Cays and Douglas Cay. These two cays are detritus-driven and nutrient-rich, and dinoflagellate assemblages are very different in species composition from the oligotrophic waters of Manatee Cay dominated by oceanic species. In addition, parasitism was observed for the first time among tropical, benthic dinoflagellate species. Two morphological types of colorless nanoplanктon attached to the surface of Prorocentrum lima.

Mark M. Littler & Diane S. Littler
Ecology and biology of siphonalean green algae

This study focused on the siphonaceous green macroalgae Avrainvillea longicaulis and its susceptibility to epiphytic overgrowth. A population survey was conducted to quantify the proliferation of new thalli on epiphytized versus nonepiphytized primary blades of the macroalgae, and the cover and growth of epiphytes on older thalli of the same plants were assessed by scoring point-intercept
transects across close-up video samples. In addition, an experiment was conducted to test whether the specialist crab *Thersandrus compressus* benefits the host plant by removing harmful epiphytes. The findings strongly support the hypothesis of protoplasmic abandonment. A new mechanism for epiphyte reduction, which does not involve intercalary meristems, was found. The strategy of protoplasmic abandonment is unique to siphonaceous macroalgae owing to their lack of restrictive crosswalls. Siphonalean green algae often dominate the standing stocks and productivity of Caribbean mangrove island ponds, and are also abundant in virtually all calm-water reef habitats. *Avrainvillea* is particularly abundant in the Pelican Cays.

The mobilization of protoplasm out of older epiphytically impaired blades of *A. longicaulis*, and coordinated reallocation to form new siphon extensions, leads to rapid blade proliferation at relatively low cost to the plant. The strong negative effects (i.e., decreased growth, increased mortality) of herbivory by the specialist crab *Thersandrus compressus* indicate that it does not beneficially control epiphytes in *A. longicaulis*. The other alternative hypothesis, that allelopathic secondary chemicals may play an antifouling role, also was not supported.

Michael P. Lesser

**Use of noninvasive fluorometry to assess photosynthetic performance and environmental stress in scleractinian corals and photoautotrophic sponges**

Samples of brittle stars from various habitats (e.g., reef rubble, turtle grass, sponges) were collected and fixed for electron microscopy to use with other samples in a survey of the subcuticular space of ophiuroids, to determine whether they contain symbiotic bacteria as described in the literature for temperate species. To date, thick sections of the ophiuroid and sponge material have been obtained to determine if adequate fixation was accomplished. Thin sections are currently being made for staining and observation with the electron microscope.

Brian Helmuth, Briana Timmerman, and Ian Macintyre

**The interplay of host morphology and symbiont microhabitat: consequences of aggregation structure of the coral Agaricia tenuifolia**

Biomechanical approaches derived from engineering theory were used to examine the physical mechanisms by which corals interact with their physical environment. Measurements were taken of zooxanthellae population densities, chlorophyll levels from branches of the coral *Agaricia*, light levels within the colonies as a function of branch spacing and distance from branch tips, and the degree of plasticity in the responses of both coral host and symbiont to experimentally altered light conditions. One early finding of this work is that the density of branches within a coral colony can significantly modify the amounts of light, oxygen, and food taken up by the coral, and that this leads to a physiological response by the zooxanthellae. Equally important, the effects of coral shape and branch spacing can in some cases outweigh those of water depth, which is usually thought to be the primary determinant of coral shape and light interception on coral reefs. Information on the physical basis of the effects of organism morphology on processes such as feeding, light capture, and dislodgement provides a quantitative means of untangling and predicting the relative importance of the various interactions between an organism and its environment. Biomechanical studies also provide an unprecedented level of predictability for anticipating the effects of changes in the physical environment on subtidal biota, such as can occur through human-induced disturbance or long-term changes in global climate.

Katrina Vanura

**Mechanisms of interactions between Stilbonematinae (Nematoda) and their symbiotic bacteria**

Sediment samples with and without worms were collected to study the mechanisms of interaction between nematodes of the subfamily Stilbonematinae and their symbiotic bacteria. Some specimens were prepared for electronmicroscopical and immunological analysis. In addition, sediment with live worms was collected in jars, to simulate a sulfide system. The bottom of each jar was filled with a carbon and sulfur source (dry seagrass and gypsum) and inoculated with sulfidic sediment containing sulfur-reducing bacteria. The jars were placed in an aquarium to establish a sulfide gradient. These microcosms are currently under study to determine the nature of the symbiosis.

Katrina Vanura

**Ectosymbiotic bacteria on Stilbonematinae (Nematoda) and their occurrence in the natural microbial community of sediment**

Sediment samples were collected using a corer and were divided into cm-subsamples from 0 to 10 cm depth. The samples were checked for worms, and worm-free sediment was used for DNA extractions. For this, the samples were washed twice with phosphate buffer (120 mM in saline isonic to seawater). Then 1 ml CTAB and 100µl proteinase K (10 mg/ml) were added followed by incubation at 65°C overnight. The liquid was transferred to a fresh tube and the DNA purified by repeated extraction with chloroform-isoamylalcohol (24:1) Finally, isopropanol was added for precipitation of the DNA. The DNA was spun down, dried, resuspended in TE buffer and stored frozen until further experiments. In addition, sediment samples that were checked for worms were frozen for further study. Also, worms of different species were extracted from the sediment, sorted, and frozen for later sequencing of the DNA of the ectosymbiotic bacteria.
Schooling behavior of the mysid *Mysisidium columbiae*: role of vision in schooling behavior and metabolic costs of maintaining position

Zooplankton are, by definition, small animals that drift with the currents. However, many planktonic species are capable of overcoming the effects of currents and form aggregations that maintain their position within preferred habitats. These aggregations may also offer some protection from predation and enhance opportunities to findmates. Such aggregations occur among the prop roots of the red mangrove on Twin Cays, Belize, in the swarming behavior of the copepod *Dioithona oculata* and the schooling behavior of the mysid *Mysisidium columbiae*. The schooling behavior of mysids was studied by filming in situ and by examining their visual capabilities in the laboratory. A quantitative laboratory study was also begun to assess the role of vision in the schooling behavior of *M. columbiae*, the visual threshold and visual acuity of these mysids, and the energetic costs of maintaining schools in areas of strong currents. The behaviorally complex aggregations of mysid schools appear to use vision to help maintain position within the mangrove prop root habitat and perhaps to maintain interindividual spacing within schools. The results also suggest a considerably poorer visual acuity than in larval fish of similar size, which can perceive objects of less than 1°. This indicates that the compound eyes of these mysids are not capable of high-resolution vision but may function as good motion detectors for objects of sufficient size. Mysids are fed on voraciously by a wide range of planktivorous fish, and mysid survival may depend on their ability to maintain their position within the prop root habitat during daylight hours in spite of currents and turbulence that would tend to disperse them.

Schooling behavior of the mysid *Mysisidium columbiae*: role of vision in schooling behavior and metabolic costs of maintaining position
Aerial views of Carrie Bow and Twin Cays (top, May 1998) and Cat Cay, Pelican Cays (bottom)
Fire at Carrie Bow, December 1997
Hurricane Mitch, October 1998
Reconstruction on Carrie Bow, October 1998—April 1999.
Ryszard J. Chróst

Effect of natural high solar radiation on DNA and protein synthesis in pelagic bacteria and their secondary production in coastal lagoon waters

Experiments were conducted to determine how natural high solar radiation affects rates of synthesis of DNA and proteins in natural bacterial assemblages collected from coastal waters off Belize. Observed inhibition of thymidine incorporation by bacteria grown in water exposed to high solar radiation for 3 hours indicates that UV in sunlight spectrum could disturb DNA synthesis in their cells. This means that bacterial division rates were slower owing to the inhibition of semireplication of DNA. However, UV acting on organic substrates dissolved in water changed the chemical structure and made them more accessible for bacteria. DNA damage in microbial cells was repaired by light-dependent (photoreactivation) as well as light-independent (dark repair) mechanisms. Both DNA repair and better substrate supply stimulated higher division rates (higher rates of thymidine incorporation) and growth (higher rates of protein synthesis and larger cells) of bacteria. These results indicate that sunlight-induced DNA damage in natural communities of bacteria may repaired by photoreactivation, and that this strategy may be essential for the maintenance of standing-stock bacterial cells in surface waters.

Philip A. Hastings

Phylogeny and behavioral evolution in chaenopsid blennies

The evolution of courtship and aggressive displays was studied in tube blennies (Chaenopsidae), a family of fishes largely restricted to the Caribbean and tropical eastern Pacific. Behaviors of the following 9 species were videotaped at Carrie Bow Cay: Acanthemblemaria aspera, A. greenfieldi, A. maria, A. paula, A. spinosa, Chaenopsis limbaughi, Emblemaria pandionis, Emblemariopsis pricei, and Emblemariopsis sp. This brings the total number of species videotaped to date to 27. Courtship in the species of Acanthemblemaria at Carrie Bow Cay is similar to that of congeners, consisting of a relatively simple “jack-in-the-box” display in which males lunge directly out of, and into, their shelters. Courtship in the species of the related genera Emblemaria and Chaenopsis is similar (males perform a “flick,” erecting their dorsal fin while lunging from their shelter), but details of this display vary greatly within this group. Aggressive displays of the Carrie Bow Cay chaenopsids are also similar to those of related chaenopsids from other localities. These results imply that some behavioral displays are conservative characters and can provide insight into the evolutionary relationships of chaenopsids.

C. L. Smith & J. C. Tyler

The signaling behavior of the sailfin blenny, Emblemaria pandionis, in the western Caribbean (Pisces: Chaenopsidae)

This was a comprehensive study of the signaling behavior and life history of the sailfin blenny, Emblemaria pandionis.
Steve L. Morton
Temporal changes in species composition and ecology of phytoplankton from unique lagoonal ecosystems of Manatee Cay, Pelican Group

Hydrographic data (salinity, temperature, and in situ fluorescence) were analyzed for a unique lagoonal cay within the Pelican Cay system. The surface temperature ranged from 29.2°C to 29.4°C. A noticeable colder layer of water (28.8°C) was found between approximately 2 and 4.5 m. The salinity profile shows this same water mass having a higher salinity (36.2 psu) than the surface (35.8 psu). Therefore Manatee Cay can be thought of as three separate water masses. Fluorescence of the surface layer is low (<1 µl chlorophyll a/L). A large distinct peak is observable at 5.5m to 6.0m (4.2 µl chlorophyll a/L). A second large peak was detected at 10.2 m. Both peaks are visible between the 10:30 A.M. profile and the 11:00 profile. This peak was measured during the 11:30 profile but moved down the water column to 6.2-6.8 m. The maximum intensity of the peak decreased to 2.8 µl chlorophyll a/L. Discrete water samples are currently being quantified for phytoplankton biomass. However, unquantified observations of the fluorescence peak samples showed a large population of the dinoflagellate, Gymnodinium sanguinium. The abundance of G. sanguinium would account for the movement of the fluorescent peak.

Other dinoflagellates were also observed from these samples. The large fluorescent pool found near the bottom (>10 m) was dead and dying diatoms, mainly Chaetoceros sp.

Charles L. Gallegos & Sharyn S. Hedrick
Growth rates of marine chroococcoid cyanobacteria in the waters surrounding Carrie Bow and Pelican Cays

The growth and production of marine chroococcoid cyanobacteria were measured in the coastal waters of Belize to determine why the lagoonal waters of Pelican Cays support an unusually rich and diverse reef fauna. The oceanographic conditions surrounding Pelican Cays, including the possibility of groundwater nutrient inputs, are believed to be involved in the support of this community. Assessments were made of both biomass (abundance and volume) and growth rates of cyanobacterial picoplankton in waters around Pelican Cays and the results were compared with similar measurements around Carrie Bow. The evidence shows higher rates of production at Fisherman’s Cay in the Pelicans, but additional observations are required to establish the generality of the patterns and to define the seasonality.

Tracy A. Villareal
Nutrient-phytoplankton relationships in the Belizean coastal lagoon

Temperature and salinity profiles were examined along six transects in the Belizean coastal lagoon (2 north-south and 4 east-west) to obtain information on the relationship between hydrography and phytoplankton distributions. Although the diatom bloom in the lagoon was not large at the time, high fluorescence values near the bottom suggested that a bloom event may have occurred recently. Freshwater input was evident in the surface layer during the first transect, but had been dispersed by the second transect ten days later. Temperature-salinity relationships suggest that oceanic water intrudes into the coastal lagoon in areas west of a major pass in the barrier platform and creates distinct boundaries between water to the north and south. The surveys indicate that the coastal lagoon is highly dynamic with transient fronts possibly resulting in the diatom blooms noted previously.

Michael P. Lesser
Photobiology of sponges at Carrie Bow Cay: photosynthesis and UV radiation-absorbing compounds

UV and visible radiation (300-700 nm) was measured using a LiCor underwater spectroradiometer, principally on the inner reef down to 24 m and the outer ridge down to 35 m. In addition, samples were collected for the analysis of UV-absorbing compounds (in progress) and absorption spectra. The absorption spectra will be used in conjunction with photosynthesis measurements on Calyx podotypa to determine the minimum quantum requirements for this sponge. The results to date suggest that the sponge Calyx podotypa and its cyanobacterial symbionts were photoinhibited at the high irradiances of measurement, despite the use of neutral density filters during the experiment, which attenuated 85% of ambient solar irradiance. This sponge has a high rate of photosynthesis compared with other symbiotic sponges and therefore is likely to have low minimum quantum requirements. Its distribution and abundance suggest a “shade-adapted” photoacclimation strategy.

Arnfried Antonius
The health of coral reefs around Carrie Bow Cay

The coral reefs around Carrie Bow Cay were investigated to determine the extent of their health problems, particularly coral diseases. Preliminary results suggest that the proportion of dead corals on Carrie Bow reefs has increased enormously in the past 17 to 25 years. Acropora palmata and Acropora cervicornis populations, in particular, now show substantial tracts of standing skeletons. Another serious problem not detected in the past is that corals are being overgrown by other organisms, notably blue-green algae, brown algae, and sponges. Interestingly, the extent of Black Band Disease has not increased significantly, although this is a seasonal phenomenon, and the situation during the period of the survey (the summer months) could differ in other seasons. A new phenomenon was also detected: coral tissue bleaching, which is rampant down the reef slope to considerable depths. Although no quantitative data on fish populations are available, visual observations alone indicate a staggering decline in populations of larger reef fish such as grouper, snapper, and
triggerfish. Lobster and conch populations, too, have practically disappeared. The Atlantic Barrier Reef near Carrie Bow Cay is obviously suffering severe degradation. Spearfishing and collecting, primarily by local fishermen rather than tourists, is obviously having an adverse effect. Water chemistry may also be changing and promoting the coral-encrusting organisms. Although local tourism probably contributes to the problem, this may be a general problem throughout the Caribbean. To prevent further degradation, whole sections of the Barrier Reef at a time should be closed off to fishermen, collectors, and perhaps even tourists. This would at least help restore populations of reef-dwelling organisms.

Richard B. Aronson

Threat to reef communities on the flanks
Pelican Cays

This research concentrated on two questions: the possibility of a catastrophic collapse of reef communities along the flanks of the Pelican Cays, one of many rhomboid shoals in the central lagoon of the Belizean barrier reef; and the factors controlling the construction of coral communities on rhomboid shoals. Because water flow is limited around the rhomboid shoals, submarine cementation does not occur and the reefs are unconsolidated. Coring studies in progress suggest that Acropora cervicornis (staghorn coral) was the dominant framework builder and space occupier along the flanks of the reefs for at least the past three to four millennia. The ability of growing Acropora colonies to interlock and baffle sediment resulted in rapid vertical accretion and steep topographies as the reefs grew to keep pace with rising sea level. After 1986, however, the Acropora populations were virtually exterminated in the central lagoon by White Band Disease. Since herbivory levels were and are relatively high owing to high densities of the sea urchin Echinometra viridis, Acropora was replaced by Agaricia tenuifolia (lettuce coral) rather than by fleshy macroalgae.

The mechanical properties of A. tenuifolia are quite different from those of Acropora. A. tenuifolia colonies grow in an inverted trapezoidal morphology. As a result, there is a critical slope angle at which catastrophic collapses (avalanches) should theoretically occur. Observations indicate that both coral cover and post-1986 vertical accretion rates are negatively influenced by steep reef slopes, with the measured critical slope angle as predicted by theory. Steep antecedent topography, which is the legacy of Acropora dominance, may halt the future development of these reefs. If communities on steep slopes are unable to keep up with rising sea level, those portions of the reefs will eventually drown. The interaction of antecedent topography, changes in community composition, and the mechanical properties of the replacement community could irreversibly alter the trajectories of unconsolidated, lagoonal reefs in Belize and elsewhere in the Caribbean.

Brian Helmuth, Briana Timmerman & K. P. Sebens

Localized photoadaptation within coral aggregations: the interplay of host morphology and symbiont microhabitat

The coral Agaricia tenuifolia Dana forms aggregations in which rows of thin, upright blades line up behind one another. Surveys conducted in Belize indicate that the spacing between blades increases with decreasing light. Light measurements were made with a small, inexpensive light meter designed and built for this study, and the resulting data were used to quantify the effect of branch spacing on light levels within colonies at varying distances from branch tips. Concurrently, zooxanthellae densities and chlorophyll levels were measured within coral branches from colonies with tight (3 cm) vs. wide (6 cm) branch spacing collected at 15 m. Light levels decreased significantly with tighter branch spacing and dropped in regions farther removed from the branch tips. Chl a/c2 ratios increased significantly with distance from the branch tip in tightly spaced colonies, indicating very localized photoacclimation within individual branches. Widely spaced colonies displayed significantly lower chl a/c2 ratios and significantly higher zooxanthellae densities than did tightly spaced branches. These results suggest that zooxanthellae populations respond primarily to the characteristics of the local microhabitat, which are in turn influenced by the interaction of the host’s morphology with the ambient environment.

Kenneth P. Sebens & Tom Shyka

Water flow and nutrient effects on corals and associated communities in the Pelican Cays

Water movement, prey abundance, and nutrient concentration were investigated for their effect on several aspects of the biology of reef corals and other benthos around the Pelican Cays. This region has a great variety of habitats and flow regimes, from protected lagoons to channels between reefs. Flow measurements in two of the lagoons revealed that the corals there experience a relatively low flow environment. The flow speed in many locations was < 5 cm•sec-1. In certain locations, however, the flow speed can reach 15 cm•sec-1. The nutrient concentrations in and around the lagoon were variable but generally elevated compared with fore-reef sites. Nitrate + nitrite and ammonium concentrations were found to be elevated along the coral ridge at the opening of the lagoons. Ammonium concentrations were at times elevated at the bottom of the lagoons. Phosphate concentrations were generally low, but elevated concentrations were found at various sites in the lagoons. Oxidation of organic matter within the reef matrix, flux from lagoon sediments, production from prop root communities and nitrogen fixation are possible sources of the observed elevated nutrients.

Coral growth rates were determined for selected species (Agaricia tenuifolia, Acropora cervicornis, Porites porites, ...
and *Millepora complanata* using buoyant weighing and transplanting techniques. Growth rates for *Agaricia tenuifolia* in the Pelican Cays were as high as 100% for a three-month period and were significantly higher than growth rates measured in a variety of environments at Carrie bow Cay. The results suggest a positive relationship between flow speed and growth rates for *Agaricia tenuifolia* in the Pelican Cays.

**Edward J. Buskey**

**Zooplankton aggregations in the mangrove prop root habitats**

The prop roots of the red mangrove on Twin Cays, Belize, provide two excellent examples of the aggregative behavior in zooplankton: the swarming behavior of the copepod *Dioithona oculata* and the shoaling and schooling behavior of the mysid *Mysidium columbiae*. These behaviors help zooplankton increase their chances for finding mates and reduce their chances of being swept into open waters by tidal currents (where predators are abundant). This investigation is part of a continuing study of the adaptive behaviors of microscale zooplankton aggregations, which during the past four years has concentrated on the swarming behavior of the copepod *Dioithona oculata*, both in situ and in the laboratory, with a view to elucidating the role of photoreception in swarm formation and maintenance. Some attention was also given to the costs and benefits of swarming behavior to judge its adaptive value. The present study takes up in greater detail the costs of swarming behavior to *Dioithona oculata* by measuring its respiration rates at various swimming speeds and begins a quantitative study of the schooling behavior of *M. columbiæ*, by examining the roles of sensory perception, especially vision and photoreception, in mysid schooling behavior, and its adaptive value to the mysids.

**Charles A. Acosta & Mark J. Butler**

**Mangroves as habitat for juvenile spiny lobsters**

Tag-recapture and tethering techniques have provided the first quantitative evidence that submerged mangrove prop roots and mangrove island margins serve as nurseries and habitats of juvenile spiny lobsters. Island geomorphology (both the width of the island margin and its depth), substrate types (seagrass, sponges, soft and hard corals, macroalgae), and the density of potential lobster shelters (crevices in sponges, corals) appear to play a strong role in the selection of habitat. Mangrove islands surrounded by shallow water support larger juvenile lobster populations than islands bordered by deep water. Shallow margin islands such as those of the Twin Cays and Blue Ground range accumulate individuals through the high survival of new recruits settling on prop roots and the immigration of substantial numbers of larger juveniles from surrounding shallow water habitats. By contrast, populations associated with mangrove islands surrounded by deep lagoons, such as tile Pelican Cays, may be more dependent on the magnitude of settlement, as opposed to immigration, for their growth.

**Raymond D. Clarke**

**Metabolic rates and correlates of dominance in some Caribbean blennies (Osteichthys: Chaenopsidae)**

Strategies for coexistence among species living in the same habitat can be readily studied in tube blennies, a group of small fishes that live in holes in coral skeletons. They divide the habitat quite precisely, thus avoiding competition for hiding places, which allows more species to coexist. This study is investigating the properties of individual fish that might make them winners in fights for the most desirable shelter holes. One of these properties is metabolic rate: the faster a fish burns energy, the faster it moves and the better fighter it is. When the metabolic rates of seven species from two genera were measured, the two species that occupy the most desirable habitat (*Acanthemblemaria spinosa* and *Emblemariopsis pricei*) were found to have the highest metabolic rates per unit weight. Two species, the spinyhead blenny (*Acanthemblemaria spinosa*) and the roughhead blenny (*A. aspera*), were studied in detail by having them fight in small aquaria. The winners were significantly longer, weighed more, and had higher indices of condition (weight/length) and higher total metabolic rates. All of these factors are positively correlated with one another. Winners did not have greater size-specific metabolic rates; these rates were negatively correlated with fish size. Because there is virtually no overlap in metabolic rates between spinyheads and roughheads of a given size, and because several measures are positively correlated, it will be extremely difficult to determine the effect of metabolic rate alone on the fighting ability of these species.

**PROCESSES, LINKING SPECIES AND ENVIRONMENT**

**Ryszard J. Chrost**

**Microbial enzymatic degradation of organic matter and bacterial secondary production in surface waters of eutrophic bay with floating detritus (The Lair, Twin Cays) and oligotrophic lagoon**

Microbial processing (enzymatic degradation) and the utilization (bacterial production and biomass) of organic matter were studied in surface waters of a eutrophic Lair bay in the red mangroves of Twin Cays and its oligotrophic lagoon. The metabolism and production of bacteria in these waters were found to be strongly dependent on substrate availability. Two main factors are suspected of triggering this production: floating detritus supplies the water with particulate organic matter, which is solubilized and degraded by enzymes produced by bacteria; and the dissolved organic matter is photo-oxidized by natural solar radiation.
Both processes provide bacteria with readily assimilable substrates for their metabolism and productivity. Microbial enzymatic activities of β-glucosidase and aminopeptidase, enzymes hydrolyzing model organic compounds (carbohydrates, proteins), were ~5- and 1.6-times lower, respectively, than those measured in a eutrophic bay. In the Lair, floating detritus appearing during afternoon hours greatly enhanced both enzyme activities (glucosidase and aminopeptidase activities increased about twofold) in comparison with activities detected in samples collected in the morning. Enzyme activity in lagoon waters, however, did not appear to vary greatly in morning and afternoon samples. Samples collected in the afternoon showed higher secondary production, biomass, and growth rates of bacteria were higher in the lagoon and Lair water samples taken during afternoon than in morning samples. Natural solar radiation appeared to enhance bacterial production in both environments.

Tracy A. Villareal
**Nutrient Cycling in Mangrove Cay Phytoplankton**

Water samples from Twin Cays (The Lair) were examined to determine nutrient values in mangrove phytoplankton. Six enrichment assays were conducted under various combinations of N, P, and Si. Trace metals and vitamins were added in excess. Biomass was measured as changes in chlorophyll a. Alkaline phosphatase was measured using a fluorometric technique on both raw water samples, and phosphate concentrations were measured manually. In all cases the control bottles were not significantly different from any of the experimental bottles. Net growth was consistently less than 0.2 div/day. Alkaline phosphatase activity was present at all stations, with highest levels noted in the open waters over the barrier platform. Phosphate values were consistently less than 0.05 µm except for samples taken along the shore on Southwater Cay. These samples had elevated phosphate values exceeding 0.1 µg/l and were in zones that coincided with maximum benthic dinoflagellate abundance. The poor growth noted in all bottles was inexplicable. The high alkaline phosphatase activity suggests inorganic phosphorus was limiting; however, since no enrichment response was noted it is not possible to determine which, if any, nutrient was limiting. Ancillary samples were taken for examination with an antibody assay for the presence of the species causing the Texas Brown Tide (*Aureoumbra lagunensis*). The species was not present at Carrie Bow Cay, Manatee Lagoon or at Tobacco Cay.

David L. Correll
**Initial survey of overall nitrogen and phosphorus dynamics on the barrier reef**

Surface water samples from a number of locations in the vicinity of Dangriga and three short peat cores from mangrove forests on Twin Cays provide some data on the nutrient pool in this area of Belize. Rain samples had a surprisingly high nutrient content, especially phosphorus. This could have been the results of fires on the mainland with the smoke having a fairly high phosphorus content. While nitrate and ammonium concentrations were significant, they were low by eastern North American standards. The dissolved phosphate content of ocean currents was uniformly below our detection limit of 1 part per billion, but both dissolved and particulate organic-P was present in significant concentrations. The sample from South Water Cut had the highest concentrations of available nutrients. This was a current leaving the reef. The two mainland rivers sampled had significant levels of nitrate, ammonium, and organic-P, but the concentrations were lower than expected. Also, phosphate and organic-C concentrations were very low. Two hundred meters off the mouth of Stann Creek and 2,000 meters from the mouth of the Sittee River, nitrate levels were similar values. The tidal cycle study of Hidden Creek on Twin Keys found no significant concentrations of dissolved phosphate at any time and very low nitrate concentrations, but somewhat higher levels of ammonium and organic-P. Not surprisingly, the three peat cores differed somewhat in their composition, but in all three cases the surface peat had the highest concentration of total-P and TKN per dry weight of peat. However, there was no correlation between decrease in nutrient concentration and increase in depth. This is an indication that in recent years nitrogen and phosphorus accretion in the peat have not accelerated noticeably. The atomic ratio of TN to TP ranged from 109 to 254, but there was no clear pattern of change with depth. All these values are well above the Redfield ratio of 16, indicating a phosphorus-starved condition, as might be expect from earlier nutrient studies in this region. If peat is accreting at a rate of about 2 mm per year to keep pace with sea level rise, then these mangrove forests are accumulating about 600 g of phosphorus and 45.8 kg of nitrogen per ha in the peat.

Anastazia T. Banaszak & Patrick J. Neale
**Photosynthetic responses of symbiotic reef corals to exposure to ultraviolet (UV) radiation**

We used pulse-amplitude modulation fluorometry (PAM) to determine whether there are differences in the photobiological response of symbiotic algae from various coral species at different locations around Carrie Bow Cay, Belize. Our data indicate that protective mechanisms are active and functional, therefore ecologically relevant levels of UV radiation are not responsible for bleaching in coral colonies around Carrie Bow Cay.

Karen Koltes & John Tschirky
**Monitoring production and health of reef communities**

During 1996 - 1997, four visits were made to Carrie Bow Cay as part of the CARICOMP (Caribbean Coastal and Marine Productivity) program. The CARICOMP program, based on a cooperative network of marine laboratories, parks and reserves, focuses on understanding productivity,
structure and function of coastal ecosystems in the Caribbean Basin through long-term research and monitoring. Data generated are used to assess the status and health of the region’s ecosystems, including disease outbreaks in marine species, coral bleaching events, and oceanographic and meteorological changes. Variables monitored at Carrie Bow Cay include meteorological (air temperature, rainfall) and oceanographic parameters (forereef water temperature at the surface and a 10 m, lagoon water temperature at 2 m, light attenuation over the forereef and seagrass beds, salinity), reef community composition (% cover; urchin density, soft coral density, fish species diversity and abundance), and seagrass productivity and biomass. 

Mangrove productivity, determined from litter fall and biomass gain, has been monitored in the past, but owing to vandalism, plots have not been monitored consistently during the past two years. The Data Management Centre, Kingston, Jamaica, summarizes the CARICOMP data into annual reports and regional overviews provided to all cooperators. Seven manuscripts summarizing data from all CARICOMP sites were presented at the 8th International Coral Reef Symposium in 1996 and published in the symposium proceedings. A volume of site characterizations for all CARICOMP sites, including Carrie Bow Cay, was prepared in 1997 for publication by UNESCO.

Ilka C. Feller, Dennis F. Whigham, John O’Neill & Karen L. McKee
Characteristics of mangrove forest ecotones at Twin Cays

In Belize and elsewhere in Central America, dwarf mangrove forests are rapidly being converted to shrimp farming without concern for the impact of mariculture on these forests. The general impression appears to be that these areas are not as important as other mangrove ecosystems in maintaining water quality, protecting shorelines from erosion and storm damage, providing nurseries or habitat for marine organisms, producing and exporting organic matter, and retaining sediments. This study was undertaken to examine growth differences and within-stand potential in coral reef communities. Marine Ecology Progress Series 172: 53-60 (1998).


J. A. Ott
Microgradients associated with macrofauna burrows and the distribution of microinvertebrates with bacterial symbionts

Sediment samples from Cassiopeia Cove, South Water Cay, and Carrie Bow Cay were studied to determine the meiofauna and molecular character of the microbial community in these areas. In locations where dense burrows of thalassinid crustaceans occur, Perspex cores were obtained from the sediment surface (oxidized and RPD), from sediment in 10–20 cm depths (reduced), and sediment lining the burrows (oxidized and RPD). The thalassinid species extracted from the three areas were Glyptopus acanthochirus, Neocallichirus grandimum, and Corallianassa longiventris, respectively. Fauna samples are currently being sorted, identified, and described. In addition, a number of samples were studied alive on Carrie Bow using videomicroscopy.

RECENT PUBLICATIONS


Aronson, R.B.: Decadal-scale persistence of predation


Mathis, W.N.: A review of the *Hodgins* group of Paracanace


Rützler, K., and C. Feller: Mangrove swamp communities: An approach in Belize. In: Mangrove Ecosystems in Tropical America: Structure, Function and Management, A. Y. nez-
Arancibia, ed., EPOMEX Serie Científica, Universidad Autónoma de Campeche (in press).


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