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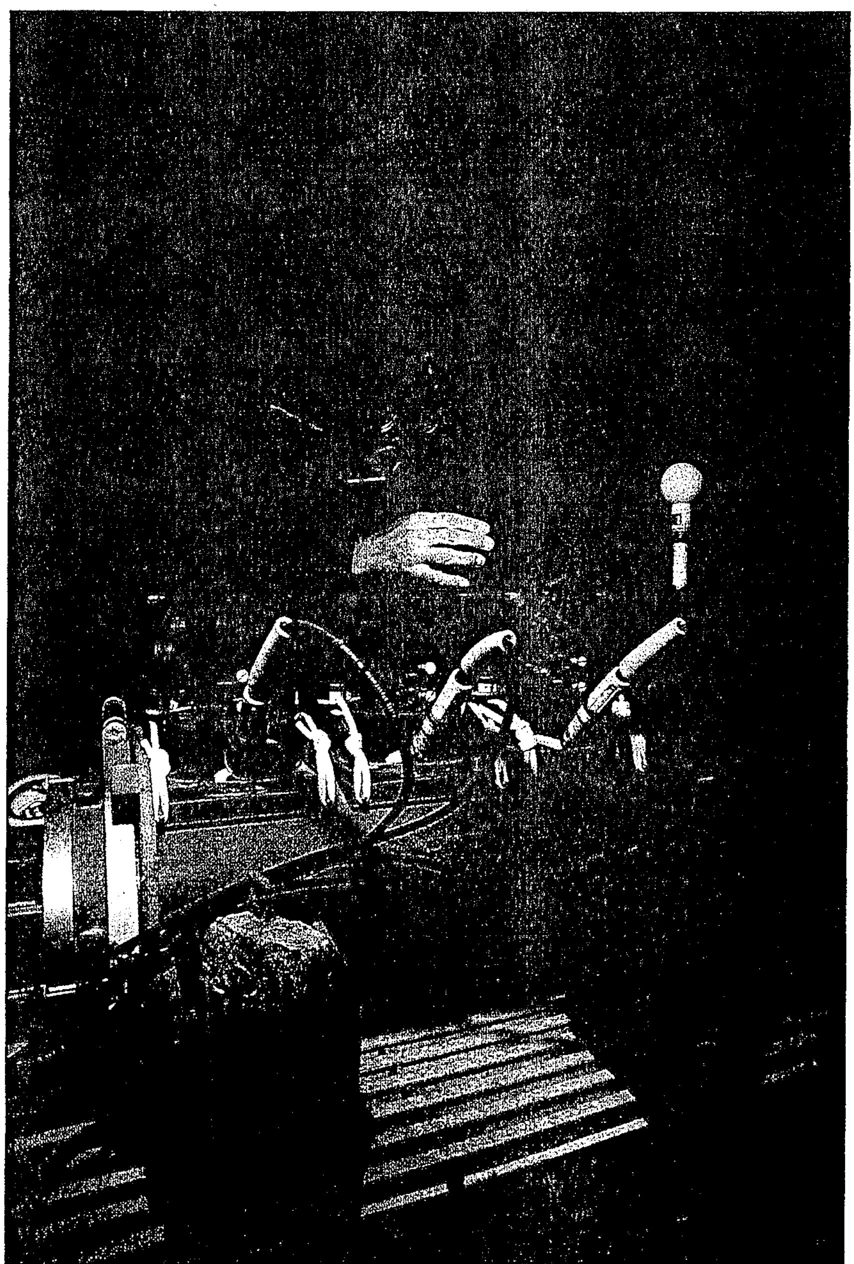


PAPER

Smithsonian Institution Underwater Research

Michael A. Lang
Smithsonian Institution
Office of the Under Secretary for Science
Washington, DC

Anson H. Hines
Smithsonian Environmental Research Center
Edgewater, MD

THE SMITHSONIAN MARINE SCIENCE NETWORK

Scientific diving is an integral research tool that has been successfully used at the Smithsonian Institution for over 30 years. In addition to the National Museum of Natural History in Washington, D.C., the Smithsonian operates a unique network of coastal laboratories and long-term research sites on the east coast of North and Central America that extends along the western Atlantic Ocean, and that bridges the Panamanian isthmus from the Caribbean Sea to the Pacific Ocean. Scientific diving activities support Smithsonian research in marine habitats throughout this network. There are four main unifying disciplinary themes to Smithsonian marine research: ***Systematics*** (description of patterns of biodiversity in the sea; ***Evolutionary Biology*** (determination of the patterns and mechanisms of the origin, maintenance and loss of species, and the phylogeny of marine organisms; ***Ecology*** (discovery of the mechanisms that structure and process matter, energy and biodiversity at varying scales of ecological organization in the sea; and, ***Geology*** (determination of the biogeochemical processes in the formation of ocean features.)

Biogeography is a key research element linking systematics, ecology and evolutionary biology. Mechanisms of biogeographic isolation are central elements in evolutionary theory, population dynamics, conservation biology, and patterns of biodiversity. Biogeographic patterns are crucial data in the determination of introduced and native species. Site-specific, long-term measurements of environmental variables allow for analysis of change over multiple time scales, which is necessary to detect patterns in typically noisy ecological data. The Smithsonian Marine Science Network is uniquely positioned to monitor long-term change at its component sites. It has an extensive array of programs involving scientific diving that address many of the most pressing environmental issues in marine ecosystems, including: biological invasions, eutrophication, harmful species and parasites, plankton blooms and red tides, linkages among coastal ecosystems, global warming including sea-level rise, El Niño/La Niña, UV radiation impacts, habitat destruction, fisheries impacts, ecology of key habitats (estuaries, coral reefs, mangroves, sea grasses, wetlands) and biodiversity inventories.

The Smithsonian's marine education programs consist of public outreach and professional training. A series of these activities are aimed at promoting awareness and conservation of marine environments, and communicating the Smithsonian's research findings to the general public. By integrating research with education, the Smithsonian produces tomorrow's discoverers while pursuing today's discoveries. The public is engaged with interactive exhibits, symposia, popular books, lectures, and films about the marine environment. The Smithsonian Marine Science Network contributes to the public interest by disseminating novel environmental information around the globe. Its research helps build a solid foundation for informed decisions about environmental policy, natural resource management, and conservation.

SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER—CHESAPEAKE BAY

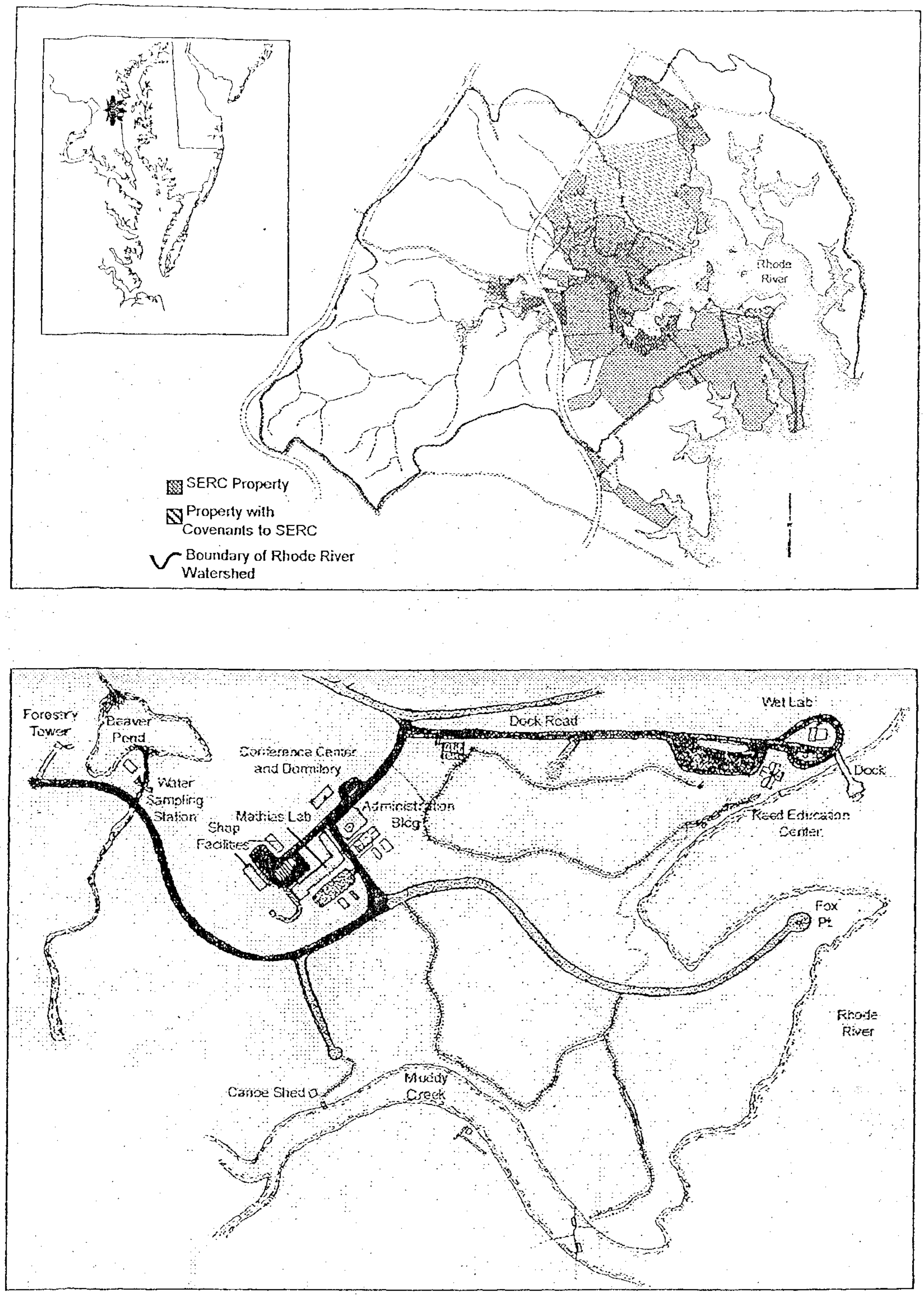
The Smithsonian Environmental Research Center (SERC) advances stewardship of the biosphere through interdisciplinary research and education. SERC, with a resident staff of over 100 scientists, technicians, fellows and students, has experienced significant growth in the last few years. SERC laboratories, educational facilities and main field sites are located 25 miles east of Washington D.C., on the western shore of Chesapeake Bay. The SERC campus includes a growing complex of offices, laboratories, maintenance shops, a library, housing and facilities for public programs. A dock, fleet of research vessels, dive locker, wet laboratory, aquarium room and large fish-weir support estuarine research.

SERC's greatest resource is its main research site on the Rhode River subestuary, which includes over 2,600 acres of land and 16 miles of undeveloped shoreline of the Chesapeake Bay. For 35 years, SERC's long-term studies have focused on the interactions among ecosystems in complex landscapes, tidal marshes and estuaries. With the Rhode River site as its hub, SERC research radiates to sites around the world to address effects of global change, landscape ecology, coastal ecosystems, and population and community ecology. Much of SERC's comparative research extends to the other sites of the Smithsonian Marine Science Network.

Global Change

A major component of SERC's research investigates the environmental consequences

Figure 1 . Smithsonian Environmental Research Center on the Chesapeake Bay (courtesy of SERC).



of human-induced global change. In addition to the "greenhouse effect" of global warming and rising sea level, increased atmospheric carbon dioxide concentrations (due to burning of fossil fuels) markedly affect the rates of photosynthesis and carbon storage in plant communities. SERC has the world's longest running field experiments using chambers to test the effects of CO2 increase on marsh plants at the Rhode River site and on scrub oak communities at Kennedy Space Center in Florida. Studies of harmful ultraviolet solar radiation examine its effects on phytoplankton and macroalgae in the Chesapeake Bay and in polar seas, where UV radiation is intensified due to the formation of "ozone holes". Damage has been documented in the light-capturing ability of plants and marine algae that support Earth's food web. SERC research on biogeochemical cycles show how carbon, nitrogen, phosphorus, and silicate cycles are being altered by human activities related to agriculture, forests and wetlands in the coastal zone.

Ecological Indicators at the Land-Sea Interface

Productivity in coastal waters and estuaries is enriched by nutrient runoff from the land. More than 70 percent of the world's people live in coastal zones. This concentrates development and water pollution around bays and estuaries where the sea's richest fisheries are declining at alarming rates. By relating nutrient discharge from the watershed to phytoplankton growth in the estuary, SERC has gained new insights into the coupling of land and sea. SERC's watershed research in Chesapeake Bay shows that excessive nutrient runoff from agricultural crops and livestock stimulates overproduction of dinoflagellates and other planktonic algae, which block light from reaching aquatic plants and deplete oxygen. Excess nutrients can cause algal blooms that are sometimes poisonous to fish and humans. Other plankton studies alter the traditional portrayal of bottom-up control of marine food chain production. Studies of planktonic protistans show that single-celled parasites may infect larger single-celled hosts. Epidemic outbreaks of these parasites can cause plankton blooms to collapse, effectively short-circuiting the food chain.

SERC has developed new instruments to measure the quantity and spectral quality of light penetration into coastal waters. These radiometers monitor changes in underwater light in response to plankton, particles and chemicals in the water column, and SERC research shows how these measurements serve as good indicators of water quality. Low light penetration limits the presence of submerged aquatic vegetation in shallow water, and loss of sea grasses has been a major loss of habitat for small fish and crustaceans that support commercial fisheries.

SERC has explored connections in Chesapeake Bay's food web leading from plankton production up to commercially important species of fish and crustaceans, like the blue crab. One study examines the value of the shoreline habitat as a refuge from predation by large fish and blue crabs on small fish, grass shrimp and juvenile crabs. SERC experiments show how this refuge is being eliminated by shoreline development. Fisheries in Chesapeake Bay have collapsed under over-fishing and environmental degradation, leaving the blue crab as the only species with a sustained commercial catch. Fundamental aspects of blue crab behavior remain shrouded by the turbid waters in which they live. To record movement and behavior of blue crabs in their natural environment, ongoing SERC research uses diving and innovative biotelemetry devices (Hines *et al.*, 1995; Wolcott and Hines, 1996) that transmit information about crab movement, feeding, fighting, and mating.

Marine Biological Invasions

Invading non-native species introduced by human activities have disrupted ecosystems around the world, causing major ecological changes and enormous economic impacts. SERC is the national center for the study of alien invasive species in coastal ecosystems. Presently, ballast water in commercial ships is the major vector for marine species introductions. Each day ocean-going vessels transport millions of gallons of ballast water containing live plankton. When ballast water is discharged, organisms are released into new environments where, lacking natural predators or other controls, they may become established and wreak ecological havoc. SERC's Invasions Biology Program uses plankton nets to search for creatures stowing away in ballast tanks of ships arriving in Prince William Sound Alaska and the Chesapeake Bay, among other sites. The SERC Invasions Biology Program uses scuba and other sampling methods to analyze broad patterns of marine invasions and their ecological interactions.

SMITHSONIAN MARINE STATION AT FORT PIERCE

Florida, a state of extensive coastlines and subtropical waters, draws numerous marine scientists each year to study its diverse and abundant marine life and coastal environments. The Smithsonian Marine Station at Fort Pierce (SMSFP) is a marine science research center located on the Indian River Lagoon along 156 miles of Florida's central-Atlantic coast. A field station of the Smithsonian Institution, it is administered by the NMNH. Situated in a biogeographic transitional zone between the temperate and sub-tropical provinces, the facility provides access to an extraordinary diversity of marine and estuarine species and to a variety of habitats, including: mangroves, salt marshes and sandy beaches, rocky intertidal substrates, seagrass beds, mud and sand flats, coral reefs, deep coral rubble zones, shallow to deep-water sandy plains, and blue waters of the Gulf Stream. For Smithsonian scientists, the SMSFP provides an important link with other Marine Science Network facilities: in the tropics, stations at the Smithsonian Tropical Research Institute

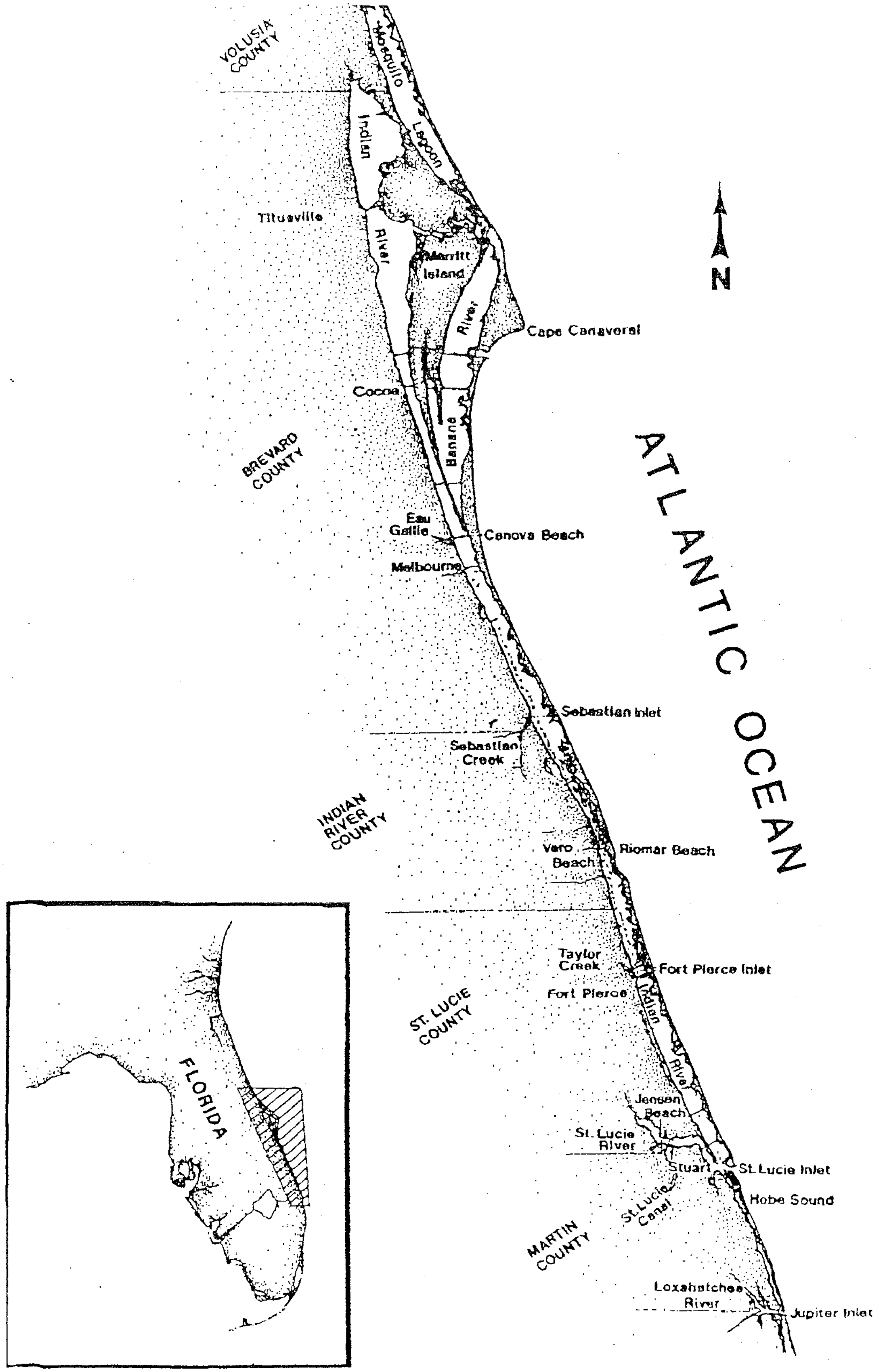


Figure 2. Smithsonian Marine Station at Fort Pierce, located between the Fort Pierce Inlet and the Indian River Lagoon (courtesy of SMSFP).

(STRI) in Panama and Carrie Bow Cay in Belize; in the temperate region, the SERC on the Chesapeake Bay.

The overall mission of the Smithsonian Marine Station is to support and to conduct scholarly research in the marine sciences. Research activities at the Station emphasize studies of biodiversity, life histories, and ecology of marine organisms. The results of this research enable policy makers to make wise environmental decisions in guiding conservation and sustainable management of marine resources, as well as providing the basis for innovative applications in medicine, aquaculture, and the effective balance between development and conservation. Additionally, studies in the physical sciences have included sedimentation processes involved in submerged volcanic eruptions, and the effects of dissolved and suspended substances on the spectral quality and quantity of light (including UV) available to plants and animals in both the water column and on the bottom.

The facilities at the Smithsonian Marine Station at Fort Pierce include an 8,000 square-foot facility that houses an histology laboratory, an electron microscopy lab, a combination electrophoresis/DNA/chemistry laboratory, a photographic darkroom, flow-through seawater tables and aquaria, an industrial shop and offices and laboratories for visiting scientists and fellowship recipients. The 39-foot R/V SUNBURST and two smaller motor vessels are used for scientific diving, dredging and trawling in the Indian River Lagoon, continental shelf and Gulf Stream. The Indian River Lagoon is a long, narrow and shallow estuary adjacent to the Atlantic Ocean, separated by a strip of barrier islands. Biologists at SMSFP have the advantage of working just 20 miles from the Florida current. This stream of warm water from the Caribbean moves northward past Florida's coastline as part of the larger, complex system of currents known as the Gulf Stream. The current carries with it many tropical marine organisms, allowing researchers to work at the interface of the hemisphere's tropical and temperate regions.

Marine Biodiversity

Many components of the SMSFP program study marine biodiversity. SMSFP has developed the Indian River Lagoon Species Inventory, which is accessible electronically on the Internet. The inventory is a relational database that documents the 2,500 species of plants and animals found in the Indian River Lagoon. This estuary likely has the highest biodiversity in the Nation. The on-line database includes summary information for a growing number of these species, including images and data on their taxonomy, distribution, life history, ecology, and special status.

Many other SMSFP projects analyze the systematics, biogeography, natural history and ecology of species in the coastal zone of Florida and adjacent areas. "Caribbean Reef Plants" (Littler and Littler, 2000) is a comprehensive field guide that contains approximately 550 color plates and 2,750 black and white illustrations. It features species descriptions, photographs, and morphological, anatomical, and habitat/distributional data for nearly all algal species found in the Caribbean. A study of the diversity and phylogenetics of nemerteans is also in progress. These are unsegmented, shallow-water worms ranging in size from a few millimeters for interstitial forms to several meters long for subtidal forms. Of the twenty species collected from Florida, half are undescribed. Flatworm collections from southeastern Florida and the Keys sampled 17 different species, most of which are undescribed. Studies on the biology and diversity of isopod crustaceans of the Indian River Lagoon add to material that will be used for an illustrated electronic field key to the isopods. Isopod sampling stations included intertidal and subtidal mud, rubble, sand, oyster beds, mangroves, algal turfs, live sponges, rotten wood, macro-algal clumps and seagrass beds. Other crustacean studies include classifications of xanthid (mud) crabs and callianassid (ghost) shrimps. Resin casts of the burrows of ghost shrimp were found to be highly complex, with numerous perfectly coiled passages descending to the lowest points of the casts. Speculation is that these coils stop predatory eels from swimming into these passages, as such features in prairie dog burrows have been proven to stop snakes from descending into their burrows. Studies of genetic diversity in marine populations are also underway. Distinct populations of the crowned conch, a highly variable species, exist in Florida, Alabama and the Yucatan Peninsula. DNA data is being analyzed to clarify ambiguities in these populations. Deep-sea snails called "slit shells" (Pleurotomariidae) are one of the most ancient gastropod families being studied using Harbor Branch Oceanographic Institution's Johnson Sea-Link submersible to depths of 3000 ft.

Life Histories of Marine Species

Life history studies are another major research theme at SMSFP. With particular emphasis on reproduction, embryonic development and larval biology, these studies focus on many groups, including: sponges, copepods, molluscs, bryozoans, crabs, sipunculids (peanut worms) and echinoderms. The SMSFP research vessel Sunburst is used to sample larval stages in the Gulf Stream offshore, while diving and other studies sample larval stages passing through inlets to the Indian River Lagoon.

Recent studies of crab larvae coming through the inlets recorded numbers of two dozen species' megalopae settling each day for 15 months continuously, including during a direct hit by a hurricane. Other larval studies provide information about control and cues to metamorphosis. Still others measured depth distribution and diversity of cephalopods (squids and octopuses) in the blue waters of the Gulf Stream. Recent experimental studies determine interactions in complex life cycles of trematode parasites that infect birds, snails, and fish.

Ecosystems

Ecosystem studies at SMSFP have focused on various reefs (including corals, oysters and cochina shell), sea grasses, and soft benthos. Presently, ecosystem studies are focused on the role of nutrients and herbivores in regulating the biocomplexity of mangroves along the Indian River Lagoon. Experiments use fertilizer treatments and cages to determine interactive effects of nutrients, crabs' burrowing, and insect herbivores. Long-term studies involve multi-year data sets to document fluctuations in ecosystem processes and population dynamics. For example, decadal studies of foraminiferan populations in soft sediments of the Indian River Lagoon measure marked changes in species composition, abundance and stability of these important benthic protists. At the same time, population and species diversity of planktonic ciliates, dinoflagellates, and other protists are being tracked in the water column of the Lagoon.

THE CARIBBEAN CORAL REEF ECOSYSTEMS PROGRAM (CCRE)—BELIZE

Coral reefs are unique bio-geological structures that thrive in clear, nutrient-poor (oligotrophic) tropical oceans and support a rich and diverse biological community. Reef systems are driven by the symbiosis between scleractinian corals and microscopic dinoflagellate algae (zooxanthellae) as their chief energy source. The largest, best developed, least polluted and commercially exploited coral reef in the Atlantic region is the Belize barrier reef. It is a complex of reefs, atolls, islands, oceanic mangroves, and seagrass meadows that extends over 160km long. For its unique characteristics and unperturbed condition, the Belize barrier reef has been declared a World Heritage Site.

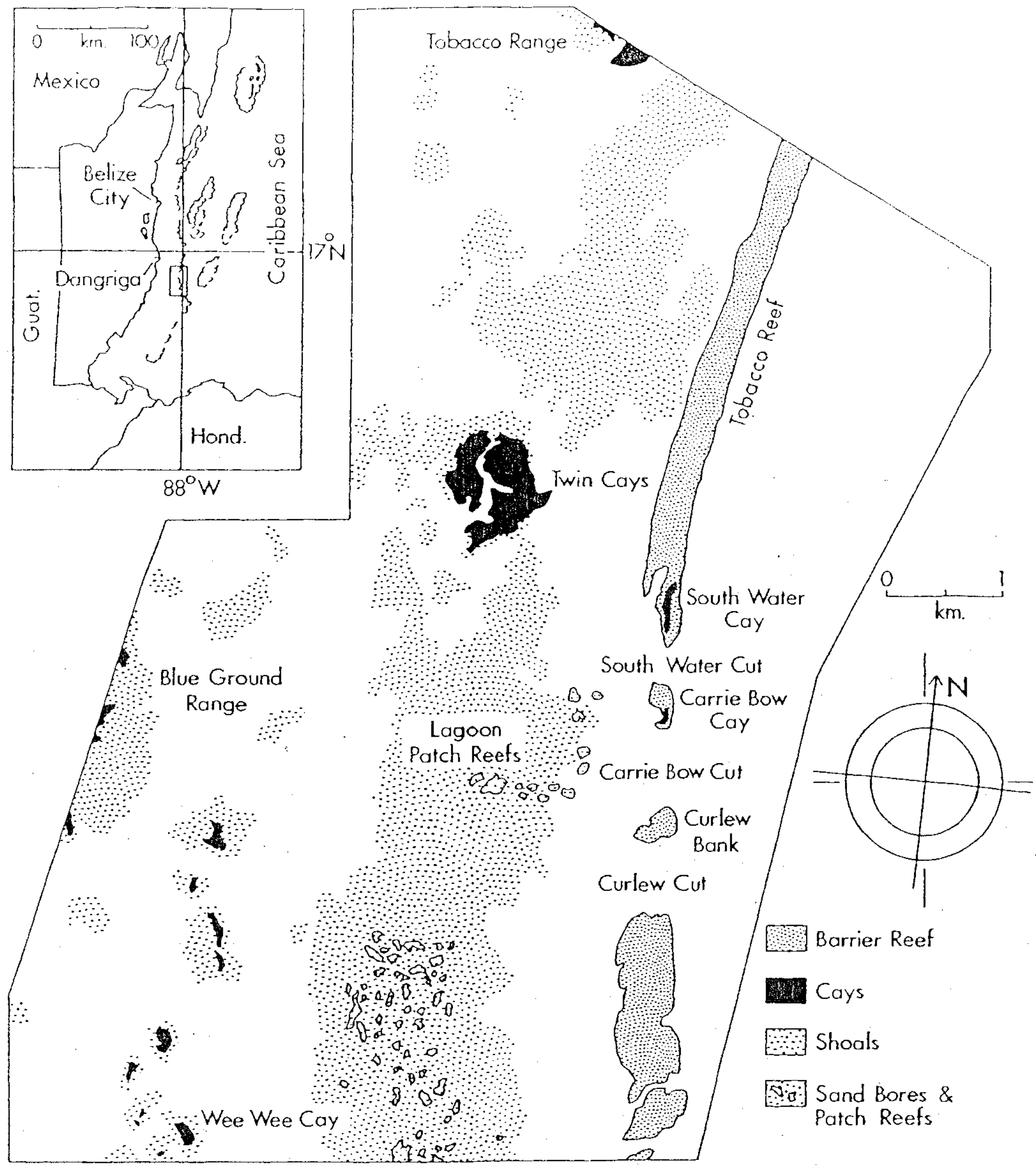
In the early 1970s, a group of 20 Smithsonian NMNH biologists and geologists aided by an international panel of reef experts with field experience in the Caribbean discovered the formidable qualities of the Belize (then British Honduras) barrier reef. After careful comparison with other locations in the western Caribbean, it was chosen as the site of an interdisciplinary long-term study of systematics, ecology, behavior, and evolution of reef organisms and the dynamics and historical development of reef communities (Ruetzler and Macintyre, 1982). Carrie Bow Cay, only 3 hours by plane and boat from Miami, was found to be the ideal logistical base because of its location on top of the barrier reef, only meters away from a variety of habitat types (reef flat, deep spur and groove, patch reefs, seagrass meadows and mangroves), and its undisputed ownership by a Belizean family able to cater to all Smithsonian needs for lodging, food, local transportation, and contact to Government.

In 1985, as part of the U.S. Congress' Caribbean Basin Initiative, the National Museum of Natural History received an increase to its budget base to continue and intensify study of Caribbean coral reef ecosystems. These funds allowed for the expansion of research facilities on Carrie Bow Cay and the update of CCRE equipment. In the years since, CCRE has accomplished the following: amassed thousands of specimens of marine plants, invertebrates, and fishes, which are organized in an enormous data base; assisted the Belize Government in shaping and justifying its coastal conservation policy; participated continuously in the Caribbean-wide reef monitoring network (CARICOMP); established the first meteorological-oceanographic monitoring station in coastal Belize; and, above all, published well over 500 scientific papers in reviewed journals, as well as several books, doctoral dissertations, popular articles, and photo and video documentaries. Between 60 and 80 scientific divers use Carrie Bow Cay each year as a part of on-going CCRE research.

The Carrie Bow Cay Laboratory serves primarily in support of SI marine scientists' research projects and their external collaborators. The CCRE lab is ordinarily closed in September and October each year, lessons taught by seasonal Hurricanes Fifi (1974) and Greta (1978). Hurricane Mitch (1998) could not claim of Carrie Bow Cay facilities what a devastating fire destroyed in December 1997. Improved facilities now include dry and wet labs, housing, generator, compressor, small boats and scuba cylinders, and essential facilities such as solar power, running-seawater system, and weather station.

Several recent projects (Macintyre and Ruetzler, 2000) investigated the Pelican Cays, an undisturbed and highly diverse group of reef-mangrove islands 15km SSW of Carrie Bow Cay. The atoll-like reef structure on which the cays are located is obvious only from the air. Core drilling (to 15m) of the characteristic reef-ridge

Figure 3. Caribbean Coral Reef Ecosystems Program at Carrie Bow Cay, Belize (courtesy of K. Rützler and I. Macintyre, National Museum of Natural History).



system at Manatee Cay showed an open framework construction made up of the branching coral *Acropora cervicornis* and confirmed the original hypothesis that reef ridges are all established on points of high karst relief on the underlying Pleistocene limestone. *A. cervicornis* has disappeared from many Caribbean sites due to white band disease but here it has been replaced by other coral (*Agaricia* spp.) rather than by algae. High levels of herbivory by an echinoid may be responsible for this difference. Studies covered the evolutionary range from microbes to manatees. Several new toxic species of dinoflagellates that occur in blooms (red tide) were identified based on cytological characteristics. A study of benthic macroalgae was completed and will serve to prepare an illustrated field guide. Earlier work on sponges led to a multimedia computer key on mangrove sponges with digitized underwater color photographs. The balance of nutrient release and uptake by abundant sponges and bivalves was found to be a decisive factor in the coupling of seagrass and mangrove prop-root. Also in the mangrove, a sessile ciliate (*Zoothamnium*) symbiotic with chemoautotrophic bacteria was discovered and cultivated on sulfide-producing substrates to measure reproduction and growth rates.

Study of a sponge-inhabiting shrimp (*Synalpheus* spp.) confirmed its eusociality, and advanced social structure, for the first time in a marine animal. Morphological, life-history, and phylogenetic analyses were also conducted on fishes (labrids) and a new blenny was discovered. Another experimental study showed how water flow affects coral shape and growth rates, either by force and direction or by nutrient distribution. Solar radiation, including UV, was measured on the Carrie Bow reef to 39m and in experiments was found to affect rates of photosynthesis and bleaching in symbiotic coral (*Agaricia*) and sponge (*Calyx*). A monitoring program was established to quantify the long-term temperature change effects on the distribution and progress of black-band disease in reef corals.

Mangroves are a dominant coastal ecosystem throughout the tropics and are a major focus at the Carrie Bow Cay station. A large multidisciplinary team of researchers from SERC, NMMH and several collaborating institutions are studying the control of biocomplexity of mangroves on small islands and along the mainland. The program conducts manipulative experiments on nitrogen, phosphorus and herbivores above the water, and also uses scuba to study fouling communities of the mangrove prop-roots subtidally.

SMITHSONIAN TROPICAL RESEARCH INSTITUTE—REPUBLIC OF PANAMA

The Smithsonian Tropical Research Institute's (STRI) marine research program in the Republic of Panama dates to 1964, when STRI established small laboratories on the Pacific and Caribbean coasts within the former Canal Zone. Today, STRI operates marine stations at Bocas del Toro and Galeta Point in the Caribbean and the Naos marine laboratory complex and Coibita Island in the Pacific. The R/V URRACA, a 96-foot nearshore coastal oceanographic vessel, is outfitted with ROV, diving and dredging capabilities and is operated under UNOLS research fleet standards.

At the Panama Canal, the Isthmus of Panama narrows to less than 100km, separating oceans that are very different tropical marine ecosystems. The Caribbean is a relatively stable ocean, with small fluctuations in temperature and relatively low tidal variation. Its transparent nutrient-poor waters are ideal for the growth of reefs, and it ranks just behind the Indian Ocean and the Indo West Pacific in terms of numbers of marine species. The tropical eastern Pacific, in contrast, exhibits much greater fluctuations in tides and temperature, with seasonal upwelling locally and longer term variation due to the El Niño southern oscillation cycle. Its more nutrient-rich waters support commercial fisheries of major importance. The creation of these two distinct marine realms by the rise of the Isthmus of Panama during the last 10 million years also contributed to the formation of the modern biological and geological world. During this interval, the Gulf Stream was established, the mammals of North America conquered a newly connected South America, the Ice Ages began, and modern man arose. The Isthmus played a major role in this history, and set in motion a fascinating natural experiment, as the animals and plants of the two oceans went their separate evolutionary ways.

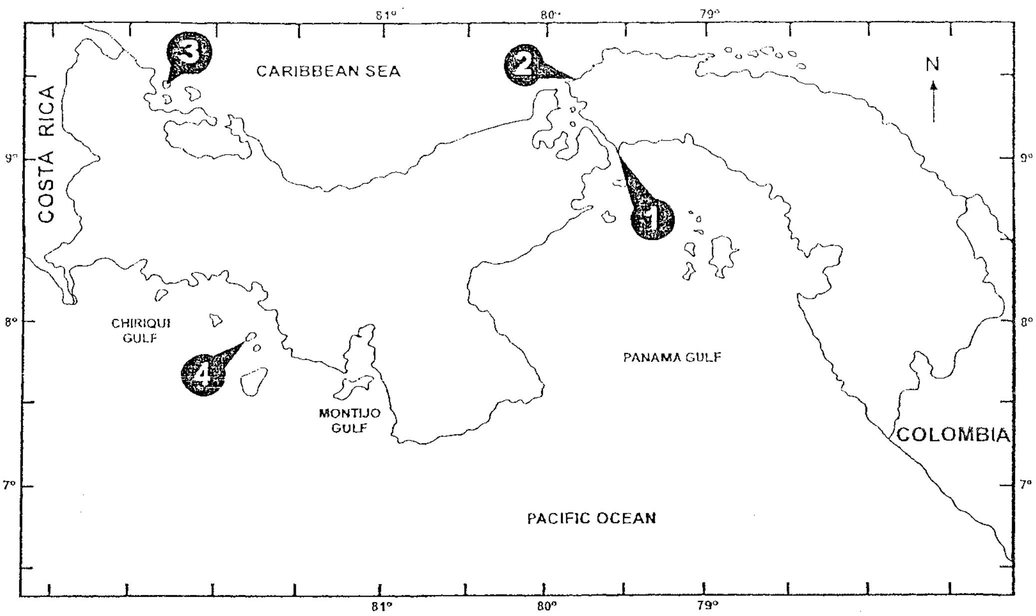
There are also major differences within each ocean. In the Pacific, seasonal upwelling of nutrient-rich waters is strong in the Gulf of Panama, where trade winds blow freely across the Isthmus, but absent in the Gulf of Chiriqui where high terrain blocks these winds. The more stable conditions in the Gulf of Chiriqui support the best development of coral reefs in the tropical eastern Pacific. On the Caribbean side, the San Blas Archipelago is bathed in clear oceanic waters, while the reefs and mangroves of the enormous Chiriqui Lagoon of Bocas del Toro are enriched by run-off from the land. Thus, Panama can be considered a nation of four ocean types, providing unique opportunities for understanding how and why marine ecosystems function as they do.

Understanding the history and ecology of Panama's diverse marine environments has been a major theme of STRI's research over the last three decades. Major programs include between-ocean comparisons of physical and biological oceanography, geological reconstruction of events leading up to and following the rise of the Isthmus, studies of marine biodiversity, and analyses of the vulnerability of marine habitats to natural and anthropogenic change. Marine publications include a dozen books and monographs, and hundreds of papers including more than 25 articles published in the internationally renowned journals *Science* and *Nature*. In celebration of STRI's role in coral reef research, the Smithsonian's 150th anniversary and the International Year of the Reef, the Smithsonian hosted the Eighth International Coral Reef Symposium in Panama in 1996. This meeting brought 1500 reef scientists and managers to Panama from around the world, and resulted in the publication of a two-volume report (Lessios and Macintyre, 1997) and an international traveling exhibit that has already brought STRI's marine discoveries to Miami, Washington DC, Honduras and Jamaica.

Inter-Ocean Comparisons

STRI's Marine Environmental Sciences Program (MESP) collects and analyzes fundamental oceanographic information that provides critical information for studies such as El Niño

Figure 4. Smithsonian Tropical Research Institute in the Republic of Panama 1—NAOS Marine Lab; 2—Galeta Island; 3—Bocas det Toro (Colon Island); 4—Coibita Island.



and coral bleaching. The Panama Paleontology Project in Bocas del Toro seeks to record the history of the divergence between the two oceans over the last 10 million years, and the evolutionary response of marine organisms to these changes. Results from this project are the geological reconstruction of the closure of the Isthmus of Panama 3 million years ago, and the discovery of a major extinction event in the Caribbean about 2 million years ago. Through a combination of molecular and paleontological information, STRI's molecular evolution program has developed a model system for determining the rate at which organisms diverge genetically through time (Panama molecular clock). This allows for the phylogenetic reconstruction of marine life elsewhere in the world.

Tropical Instability

STRI's marine research has clearly shown that tropical marine environments are highly dynamic on many temporal scales. Perhaps the most dramatic revelation of long-term major changes was the demise of the long-spined sea urchin (*Diadema*) throughout the western Atlantic (Lessios *et al.*, 1984; Lessios, 1995). Apparently due to a disease originating near the mouth of the Panama Canal in 1983, 95% of this once abundant organism disappeared over the course of two years. Notwithstanding the high reproductive output of this urchin, recovery has largely failed to occur and many overfished reefs throughout the Caribbean have been smothered under algae freed from the urchin's grazing. This diving research showed how over-fished reefs persisted for years with high coral cover prior to the urchin die-off, but then rapidly succumbed to the decimation of this single keystone species, showing that synergy between multiple stresses on marine environments can have unpredictably severe consequences. The sea urchin saga also demonstrates how even extraordinarily abundant organisms are potentially vulnerable to rapid elimination by diseases that combine the lethality of *Ebola* with the contagion of the common cold.

Marine environments are also subject to man-made disasters in contrast to the urchin epidemic, which was a natural event. The escape of 60,000–100,000 barrels of oil into the mangroves and reefs of Bahia Las Minas (Caribbean) has had unexpectedly prolonged effects (Jackson *et al* 1989). Oil seeps into the sediments around mangroves and returns to coat the coral reefs year after year as heavy rainfalls (exacerbated by the effects of deforestation) slowly wash it out. The skeletons of corals record the history of acute disasters as well as chronic stresses. X-ray analyses of corals done in response to the oil spill document a worrying decline in coral growth over the past century.

Marine Biodiversity

Corals are the building blocks of coral reefs and are renowned for the diversity of organisms they shelter. STRI's studies have revealed that marine tropical environments contain 4–5 times more species on average than has been generally realized. The most abundant and best-studied coral "species" (*Montastrea* spp.) of the Caribbean is in fact a complex of at least three species (Knowlton *et al*, 1992). Even more surprisingly, these species each host a diverse array of symbiotic algal partners, so that the combinatorial diversity of Caribbean reefs is an order of magnitude greater than previously assumed. The ecological importance of this diversity was sharply highlighted during an episode of coral bleaching caused by a Caribbean-wide temperature increase in the summer of 1995. Only certain corals and certain parts of corals bleached and the pattern could be predicted by knowing which algae occurred where (Rowan *et al*, 1997). Thus basic research on patterns of biodiversity have led to important insights into the likely consequences of global warming.

Biotic diversity is expressed at many levels, and one of the most fascinating is animal behavior. Patient observation using scuba has revealed many surprising details of how marine organisms function. Transmitters attached to the backs of sea snakes show that these creatures can spend up to 200 minutes at depths down to 50m. Identification of fishes throughout the eastern tropical Pacific has contributed significant biogeographical and distributional data (Allen and Robertson, 1994). Decoding the meaning of color change in squids has led to new appreciation for the complex communication in these organisms.

Reproduction and Recruitment

For many marine organisms sexual reproduction depends on several steps: the release of eggs and sperm into the sea (where fertilization takes place), the development of a larva from the fertilized egg, and the successful passage from the larval to the adult stage. Some of these stages occur only sporadically and at night. Mass spawning events, in which hundreds of organisms release eggs and sperm simultaneously, have been documented in Panamanian corals and seaweeds. For many corals, the entire year's reproduction is compressed into one or two days about eight days after the August full moon. Recently a Smithsonian scientific diver made the surprising discovery that many green seaweeds also spawn in synchrony just before sunrise (Clifton, 1997).

STRI pioneered studies of the bizarre sex life of reef fishes, where sex change and sex role reversal appear to be the norm rather than the exception, because they maximize the reproductive success of individual fish. Parrotfishes spawn regularly, every day at sunset. But what happens to their larvae, which can spend a month floating in the ocean before settling onto a reef, is less well understood. Giant underwater light boxes are being used to trap larvae and measure the rate at which different species recruit onto reefs. Fish collected from around the Caribbean reveal, through molecular data, that larvae often travel long distances before settling down to a more sedentary adult life.

CONCLUSION

The Smithsonian Marine Science Network and the Scientific Diving Program provide the facilities and support for the efficient conduct of underwater research. The primary objective of the scientific diving effort is the advancement of science. The deliverable is mainly in the form of peer-reviewed publications for dissemination throughout the scientific community. The Smithsonian supports an extensive array of underwater research projects involving scientific diving that address many of the most pressing environmental issues in marine ecosystems, including: biological invasions, eutrophication, harmful species and parasites, plankton blooms and red tides, linkages among coastal ecosystems, global warming, including sea-level rise, El Niño/La Niña, UV radiation impacts, habitat destruction, fisheries impacts, ecology of key habitats (estuaries, coral reefs, mangroves, sea grasses, wetlands) and biodiversity inventories.

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