*U.S. Geological Survey Open-File Report 97-453*

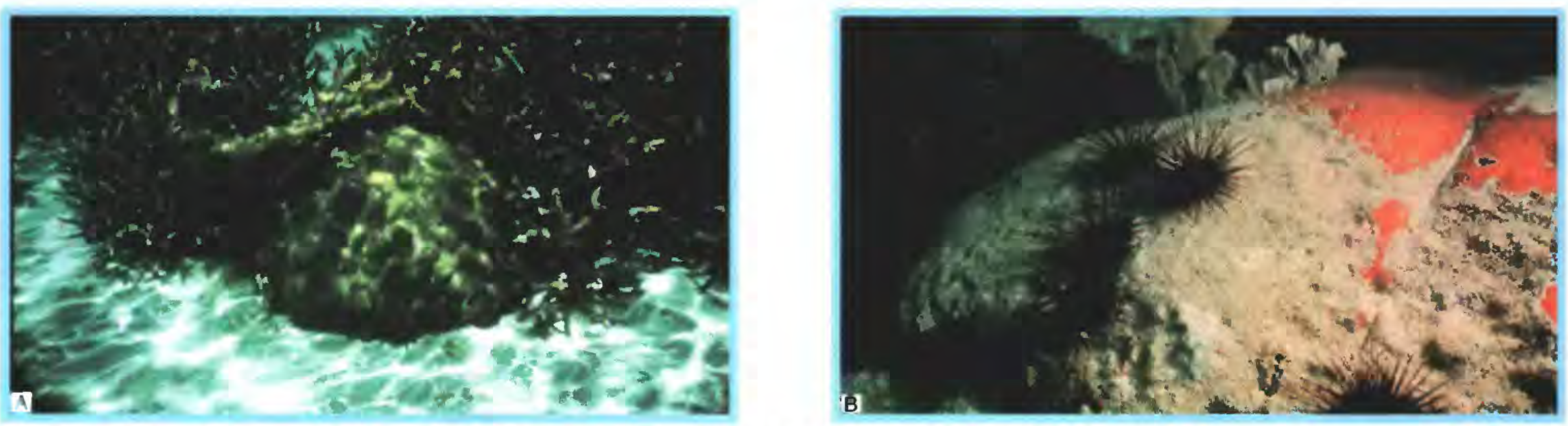
# ENVIRONMENTAL QUALITY AND PRESERVATION—
## FRAGILE CORAL REEFS OF THE FLORIDA KEYS: PRESERVING THE NATION'S ONLY REEF ECOSYSTEM

U.S. DEPARTMENT OF THE INTERIOR U.S. GEOLOGICAL SURVEY

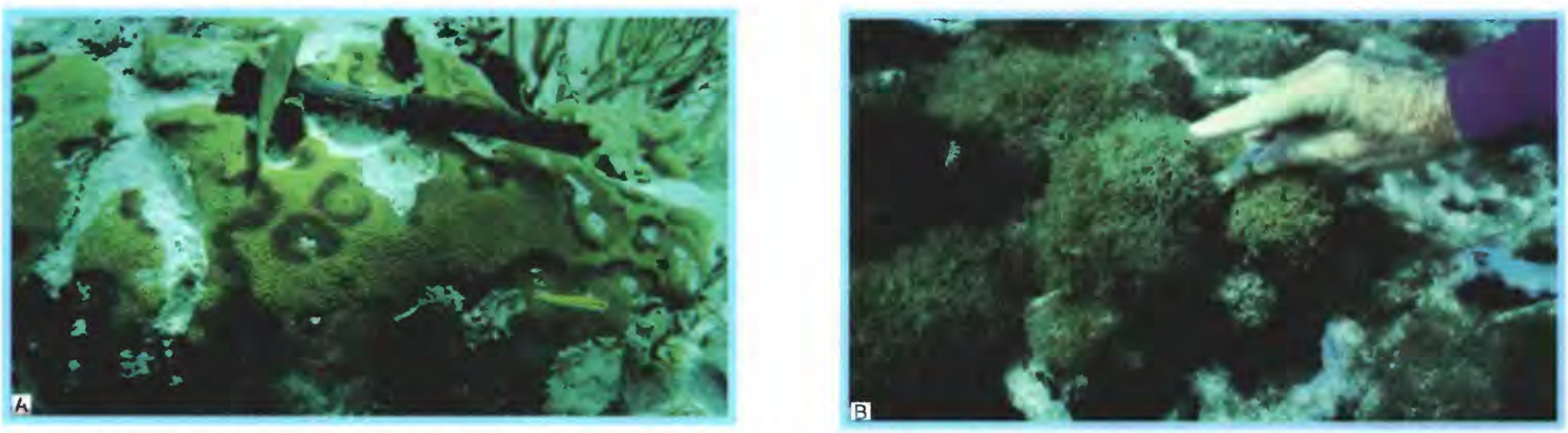
***Any loss of this economically viable and physically essential ecosystem would have a significant, potentially very dangerous economic, health, and safety impact on the densely populated Florida Keys and South Florida mainland.***

*Barbara H. Lidz*

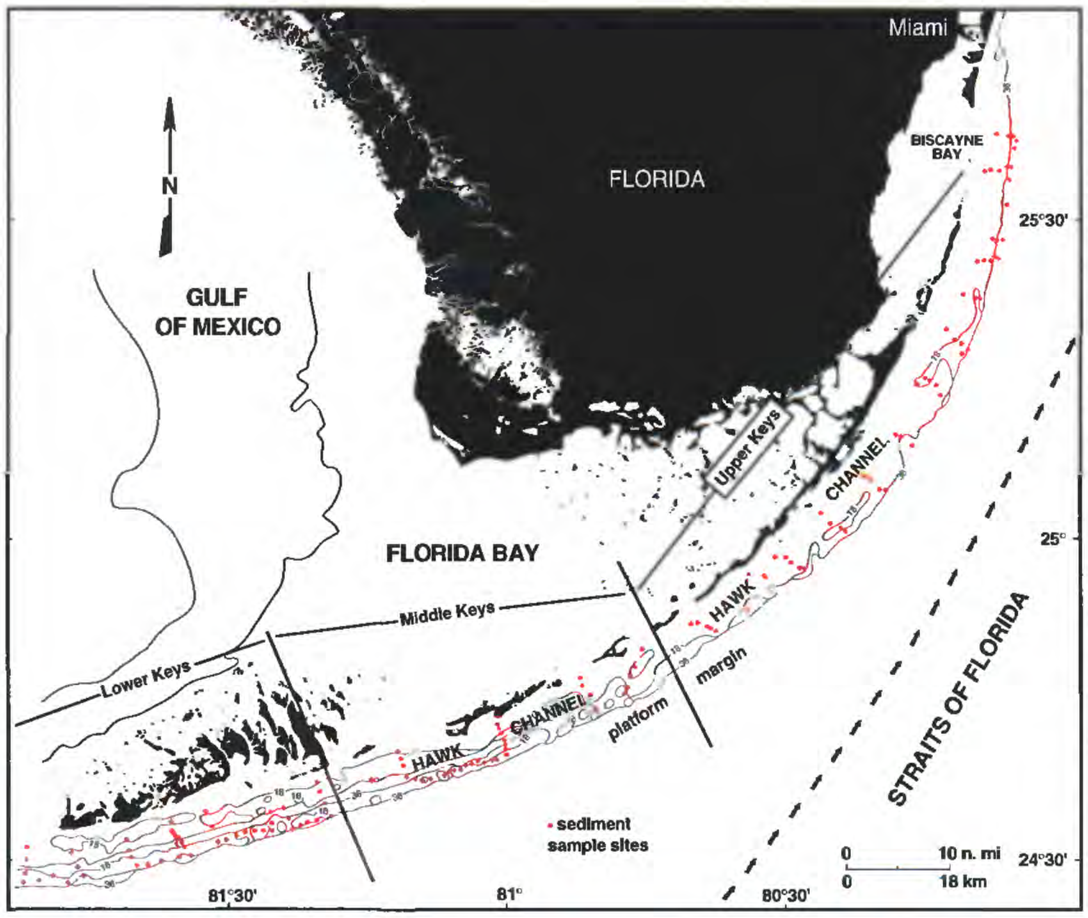
The majority of the Nation's only living coral reef ecosystem lies seaward of the Florida Keys, an arcuate, discontinuous chain of islands off the southernmost tip of the mainland. The reefs and their associated organisms are within the protected boundaries of Biscayne National Park, John Pennekamp Coral Reef State Park, Key Largo National Marine Sanctuary, Looe Key National Marine Sanctuary, and part of the Florida Keys National Marine Sanctuary. The reefs occupy the outer part of the Florida platform extending from the Keys to the platform margin and more than 280 km (150 naut. mi) along the margin. Thousands of individual patch reefs dot the platform interior. A patch reef may be hundreds of feet in diameter or may consist of only one head coral. Offshore, less numerous but larger linear reefs with diverse coral species follow the arcuate edge of the margin, paralleling the Keys. The ecosystem has important recreational and commercial fisheries. The livelihood of each biotic component is interdependent upon one another and on a healthy environment. Most important, however, the physical reef framework along the margin serves as a vital, protective, offshore structural barrier to catastrophic waves and storm surges generated by tropical storms and hurricanes. Increasing human populations along the coast and increasing recreational and commercial usage of these Parks and Sanctuaries are placing enormous stresses on this essential ecosystem. A USGS priority is to provide the scientific (biologic and geologic) information that is required in order to sustain each component and to recognize and mitigate adverse effects on it.



Above - Healthy ecosystem components. (A) Head and branching reef-building corals in clear Florida waters in 1971. Coral reefs are built by tiny coral polyps, simple soft-bodied animals living in colonies like bees. Each polyp constructs an outer skeleton of hard limestone that adds a new layer to the reef. (B) Typical scene prior to 1983. Spiny sea urchins *Diadema antillarum* grazing green algae from dead coral surfaces (white areas). Beige areas are live coral polyps. These scenes cannot be found in the Caribbean today.



Above - Sickened reefs today. (A) Black-band disease on a brain coral on a reef at Rum Cay in the eastern Bahamas in 1990. This and other types of band diseases can destroy a 200-year-old head coral in a single summer. (B) Typical algal overgrowth on coral rubble in Florida, 14 years after a Caribbean-wide die-off of the herbivorous urchin *Diadema*. What caused the die-off is not known.




*A critical equilibrium exists between physical processes and landforms in South Florida, an equilibrium that is crucial to maintaining the fragile coral reef ecosystem.*

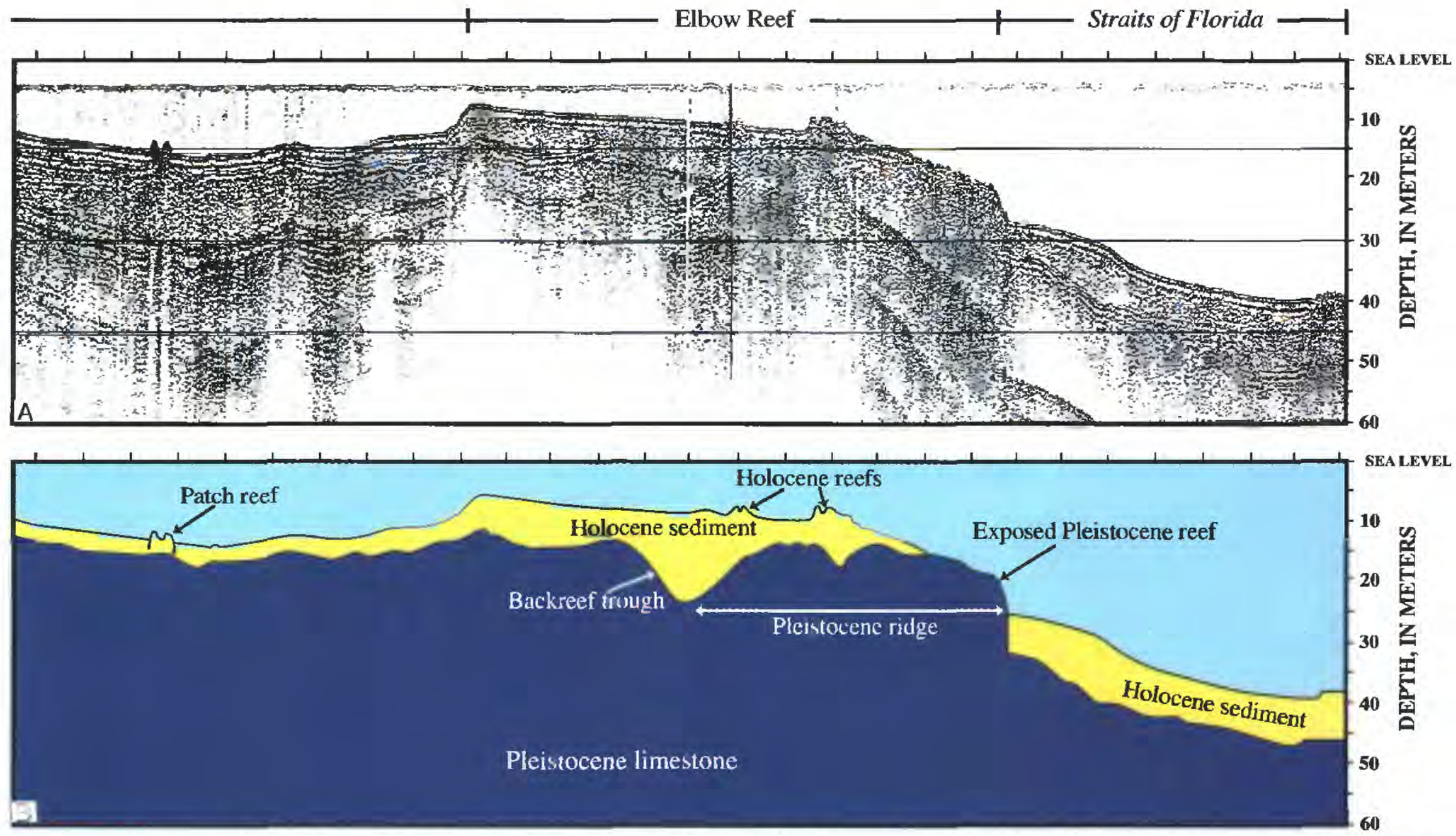
To understand this equilibrium and to develop the essential tools needed for modern ecosystem management and preservation, one must first understand the basic natural linkage among the porous limestone underpinning, location and thickness of the overlying sediment, and the resulting presence or absence of biologic and ecologic habitats. The purpose is to supply accurate fundamental scientific information to educate and guide managers, regulators, commercial industries, and the visiting public in evaluating management alternatives and making informed and sound decisions. The scientific information includes knowledge of how and why the reef resources developed as they did and exist where they do today, how and why each is an integral part of the ecosystem and must be preserved as such, and how and why each can be damaged or destroyed. On a large scale, the geologic information demonstrates the interdependency of pre-existing topography, rising sea level, and the resulting changes in geologic processes and reef evolution as applied to the modern reef ecosystem. On a smaller scale, sediment composition demonstrates the interdependency of corals and other organisms on changes in landforms and geologic processes with rising sea level. Integration of knowledge of these intricate interdependencies, both past and present, with resource-stewardship practices will help achieve the goals of attaining sustainable ecologic, cultural, and socioeconomic systems within the Parks and Sanctuaries.

*Reefs are proxy indicators for a principal, natural agent of environmental change—rising sea level. The known responses to the past rise in sea level can be projected into the future and show catastrophic effects for South Florida.*

Structural and age assessment of the pre-existing bedrock framework that underlies the Keys and reef tract is made to determine where reefs lived during the last 10,000 years, relative to rising sea level, and where they live today. This approach involves mapping the variable bedrock surface and showing how rising sea level gradually flooded the platform and caused reefs and sediments to accumulate in some areas and not in others. To acquire the necessary information, seismic profiles (a type of sound-wave line-drawing "photograph" taken through sediment and rock) are obtained that enable measurements of depth to bedrock and sediment thickness. Peats (plant remains that formed in a water-saturated environment) that accumulated at old shorelines and are now buried beneath reefs, and corals that formed during those 10,000 years are core-drilled for radiometric dating to develop a local sea-level curve and to determine how coral growth patterns, species, and distributions changed. A sea-level curve is a graph that shows the depth below present sea level at which the cored peats and corals are found today versus their age in thousands of years. Landward migration and zonation (different coral species) of reefs are known responses to rising sea level and the ensuing transition from low- to high-energy conditions. Understanding these changes and projecting future shorelines onto topographic maps enables predictions of how small a rise (<2 m, or 6.5 ft) would be necessary to flood more than half the Keys, much of which are currently uninhabitable wetland mangroves. In a rise of ~5 m (16 ft), the Keys would drown, reefs at the margin would no longer be protective barriers against catastrophic storm surges, salt water would infiltrate and contaminate potable aquifer water, and live corals would reestablish growth on the submerged Keys. The Keys themselves were once a linear coral reef 125,000 years ago. In terms of our presently eroding shorelines and vanishing wetlands, the effect of rising sea level, regardless of rate, may well be felt in South Florida within the next 100 years.

*Understanding the basic natural linkage among porous limestone bedrock, sediment thickness, and biologic/ecologic habitats is essential to stewardship-wise resource management, protection, restoration, and preservation.*

Geologic maps show contoured depth to bedrock and sediment thickness. Aerial photomosaics accompany these maps with interpreted distribution and types of livebottom (biologic/ecologic) habitats and locations of barren sand or rock. Managers and regulators use the mapped information to select those sites most accessible but least harmful to the ecosystem for location of fixed navigational structures, anchorage of mooring buoys to bedrock, design and placement of entrenched offshore drainage or sewer outfall pipes, and replacement of lighthouses destroyed by fire or hurricanes. The maps show that lime mud and sands are thickest in bedrock depressions. Because sediments form a barrier to upward movement of pollution-laden groundwater through the limestone, areas where sediment cover is thin or absent (bedrock highs) are those where contaminants would most likely seep into the ecosystem. This information is used to avoid outfall installations near such areas and to increase efforts to enhance local environmental conditions. However, the bedrock highs are also those areas where live corals can best be transplanted directly onto bedrock. Where sediment cover is thick, large cement structures elevated above the adjacent sediment-water contact must first be constructed for coral transplantation. Sediment data are also suitable for selecting optimal areas for




Above - (A) Seismic profile across The Elbow reef at the platform margin off north Key Largo (see Plate Map A for reef location). Note old, bare-rock reef at the margin with the deep sediment-filled backreef trough immediately behind it (landward). The rock reef forms a distinct ridge that extends the length of the margin. Modern sediments and reefs have covered the ridge except on its seaward side. The ridge was a crucial pre-existing influence on the location of modern reefs. (B) Interpretive diagram of seismic record. Pleistocene = pre-10,000 years. Holocene = post-10,000 years.

eagrass restoration. The biologic/ecologic facts are used to weigh he delicate balance between allowing permits to salvage unique 6th, 17th, and 18th century archeological finds (gold-bearing Spanish galleons) or establishing aquatic archeological preserves to ninimize impact, thereby maximizing societal value of both. In offshore areas where sediment is thick and strong currents prohibit formation of livebottom communities other than those of green algae, he sediment thickness information supplies commercial interests vith knowledge about a self-generating (renewable) potential mineral resource (carbonate sands) for use in construction, beach enourishment, and chemical manufacturing (industrial paints, PVC, nd purification of acid smoke-stack emissions).

***nderstanding the basic natural linkage among reef vitality, the oral fraction of the sand, and location opposite land masses or idal passes is also essential to resource management. Variable oral-sand percentages correspond to similar variability in reef itality and may be a tool for measuring coral health.***

Carbonate sands in a reef ecosystem are composed solely of skeleal grains of biota inherent to the ecosystem. Different organisms occupy different niches depending upon location—quiet nearshore vaters vs. offshore surf zones, or opposite protective land masses vs. open tidal passes. Tidal passes link turbid, nutrient-enriched waters rom Biscayne Bay, Florida Bay, and the Gulf of Mexico to the lear, nutrient-poor waters of the reef tract. In Florida, sands are ormed in place and essentially remain in place. Intense wave action of storms and hurricanes redistribute but do not remove the sands rom the confines of their origin. Florida's sands consist of three prinary grains: those of the calcified green alga *Halimeda*, molluscs, nd corals (see Plate). Coral sands are produced when corals are veakened by environmental (disease, turbidity, or contaminants) or nechanical damage (divers, anchors, storms, or ship groundings) and their injured skeletons become targets for attack by other organisms (bacterial diseases, grazing parrotfish and *Diadema*, and boring algae, barnacles, fungi, molluscs, and sponges). Coral grains dominate sands where coral health is poor. *Halimeda* and mollusc sands dominate where coral health is better. The healthiest reefs occur off land masses and the least healthy occur off the widest tidal passes.

Throughout the reef tract, corals are generally perceived as declining. Reef-building corals influenced by clear oceanic waters are being replaced by soft coral-algae-sponge communities influenced by turbid continental waters. Coral-sand percentages mimic this decline by increased amounts in seaward and southwesterly directions. Management and reef researchers can use coral-sand percentages to predict variability and evaluate influence and effects of coastal processes and ecosystem response to human impact and natural sources of change (floods, hurricanes, and rise or fall of sea level). An increased understanding of the close linkage between, and variety in, the physical environments and biological communities is required. Comparison of the percentages of coral grains with known reef vitality along the reef tract suggests that a measure of reef vitality may be possible through monitoring of changes in the coral-sand fraction. Based on coral-grain percentages obtained from sediment samples collected in 1989, the Plate maps show a guideline relation between healthiest reefs and a sand content of <10% coral, declining reefs and a sand content of <30% coral, and senescent (essentially dead) reefs and a sand content of >30% coral. This relation is not apparent near Miami, where many reefs are senescent yet coral percentages are low. The cause is the lengthy absence of the primary biological source of coral sands, *Diadema antillarum*, and the proliferation of algal-molluscan communities due to nutrient enrichment. Sands in approximately two-thirds of the study area from Miami to Key West contain up to or greater than 30% coral grains.

In some areas, notably along the outer margin off the middle and lower Keys, coral-sand grains exceed 60%. These elevated percentages suggest that the reefs are indeed in peril.

## Cooperators

Biscayne National Park
Florida Keys National Marine Sanctuary
John Pennekamp Coral Reef State Park
Key Largo National Marine Sanctuary
Looe Key National Marine Sanctuary
National Oceanographic and Atmospheric Administration
Nature Conservancy
South Florida Ecosystem Program
South Florida Restoration Task Force
State Department of Environmental Protection

Eckerd College
Florida Atlantic University
Florida Institute of Technology
Florida International University
Florida State University
Nova Southeastern University
University of Miami Rosenstiel School
of Marine and Atmospheric Science
University of South Florida, St. Petersburg
University of South Florida, Tampa

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Center for Coastal Geology
St. Petersburg Field Office Information

http://sflwww.er.usgs.gov
South Florida Ecosystem Program Information

Above - A diverse coral assemblage on "Telephone Pole" reef on the shallow shelf off San Salvador's west coast, Bahamas.
Photo courtesy of Dr. H. Allen Curran.



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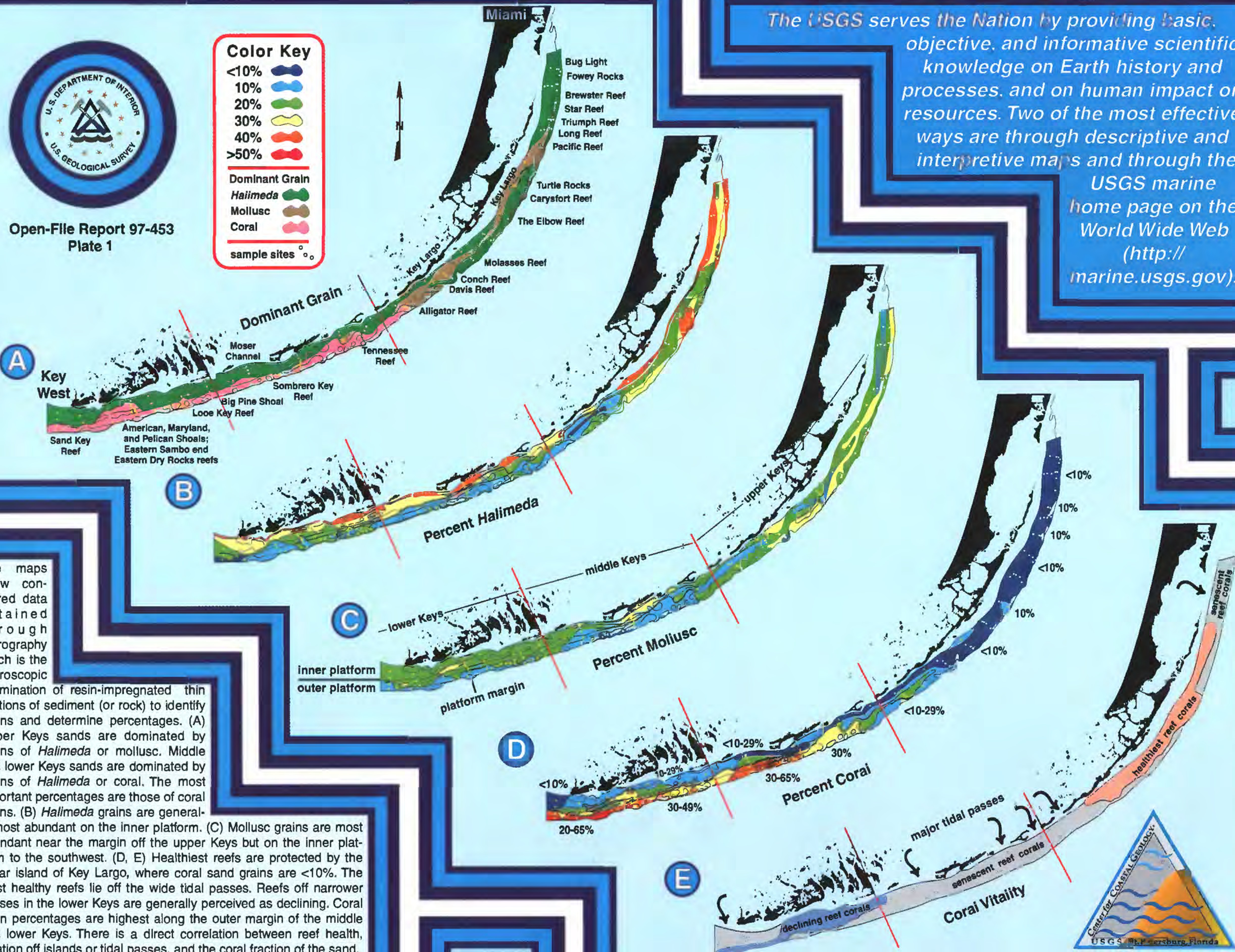


The USGS serves the Nation by providing basic, objective, and informative scientific knowledge on Earth history and processes, and on human impact on resources. Two of the most effective ways are through descriptive and interpretive maps and through the USGS marine home page on the World Wide Web (http:// marine.usgs.gov).

The maps show contoured data obtained through petrography which is the microscopic examination of resin-impregnated thin sections of sediment (or rock) to identify grains and determine percentages. (A) Upper Keys sands are dominated by grains of *Halimeda* or mollusc. Middle and lower Keys sands are dominated by grains of *Halimeda* or coral. The most important percentages are those of coral grains. (B) *Halimeda* grains are generally most abundant on the inner platform. (C) Mollusc grains are most abundant near the margin off the upper Keys but on the inner platform to the southwest. (D, E) Healthiest reefs are protected by the linear island of Key Largo, where coral sand grains are <10%. The least healthy reefs lie off the wide tidal passes. Reefs off narrower passes in the lower Keys are generally perceived as declining. Coral grain percentages are highest along the outer margin of the middle and lower Keys. There is a direct correlation between reef health, location off islands or tidal passes, and the coral fraction of the sand.