ISSN 1092-194X

FLORIDA MARINE RESEARCH INSTITUTE **TECHNICAL REPORTS**

Benthic Habitats of the Florida Keys

National Oceanic and Atmospheric Administration

Florida Fish and Wildlife Conservation Commission

FMRI Technical Report TR-4

2000

Cover photo of Sombrero Reef Light by Bill Sargent, Florida Marine Research Institute

BENTHIC HABITATS of the FLORIDA KEYS

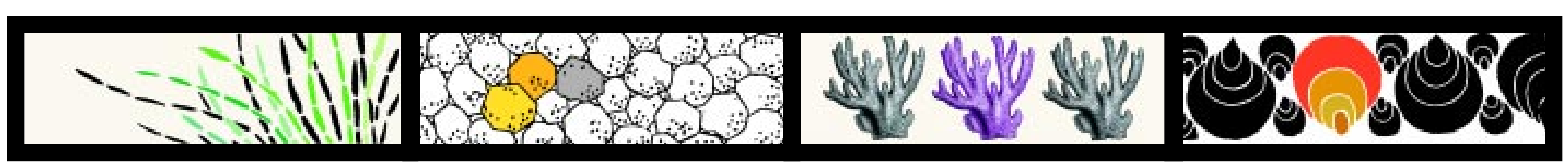
ABSTRACT

This atlas represents the culmination of a six-year federal and state effort to map the types and extents of benthic habitats within the Florida Keys National Marine Sanctuary. The partnership involved the National Geodetic Survey (NGS) and the Office of Ocean Resources Conservation and Assessment's (ORCA) Strategic Environmental Assessment Division (SEA), both of the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service (NOS); the Florida Fish and Wildlife Conservation Commission's (FWC) Florida Marine Research Institute (FMRI); and the Florida Keys National Marine Sanctuary (FKNMS). NGS staff conducted aerial photo missions and digitized the habitat information from the photographs; SEA staff built the geographic information system (GIS) coverages, reviewed the digital data, and helped design and develop the atlas. Two contracted ecologists and FMRI staff classified the habitats, designed the maps, and produced this atlas. This project was also supported by the Sport Fish Restoration Program using funds made available through the U.S. Fish and Wildlife Service.

This atlas contains 32 color maps depicting the benthic habitats at a scale of 1:51,500. In addition to showing the locations and extents of different habitat types in the Florida Keys, the atlas provides a brief description of the Florida Keys region, summary information on the extents of the ecological habitats by subregion, and a detailed description of each habitat type. For purposes of organization and presentation, the Florida Keys are divided into three regions: the Upper Keys, the Middle Keys, and the Lower Keys and Dry Tortugas. A CD-ROM containing the digital files for the maps in this atlas are available through NOAA's SEA division and FMRI.

This project represents the most ambitious benthic-mapping project of the region to date. The data can serve as a baseline for research and for monitoring projects undertaken by scientists, managers, and the academic community and to support resource-assessment activities and management decisions. The Florida Keys are a unique national resource that must be preserved. Mapping of benthic habitats is an integral component of the ecosystem-management approach that has been adopted to protect the Keys' marine ecosystem, which includes Florida Bay; Biscayne Bay; and the Florida Keys National Marine Sanctuary, the nation's largest marine protected area. Such maps and associated information are critical in managing the sanctuary and in maintaining the economic viability of the South Florida region.

2000



ACKNOWLEDGMENTS

Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute

The mission of the FWC is to protect, conserve, and manage Florida's fish and wildlife. FMRI, which is an institute within FWC, conducts marine research and monitors Florida's coastal resources. To support FWC objectives, FMRI researchers study different aspects of environmental and biological resources within Florida's coastal ecosystems. Staff members accomplish this in collaboration with academic, nonprofit, and private marine research institutions. FMRI provides the technical facilities necessary to conduct such comprehensive environmental research in a timely manner, thus ensuring that the scientific needs of resource managers are met.

National Oceanic and Atmospheric Administration
Special Projects Office

The mission of the Special Projects Office is to provide expertise, products and services that help the National Ocean Service (NOS) to design and implement an effective program of coastal stewardship throughout the agency. This includes exploring ways to leverage the agency's considerable expertise into a force that directly supports and influences the sound management and protection of coastal areas. NOS Special Projects is in a unique position to bridge the gap between NOS scientific efforts and coastal management policy issues.

Sport Fish Restoration

This project was supported by the Sport Fish Restoration Program using funds made available by the U.S. Fish and Wildlife Service. Your purchase of fishing equipment and motorboat fuels supports sportfish restoration and the development of boating access facilities.

Kenneth D. Haddad, Chief of FMRI; Daniel J. Basta, Chief of ORCA's Strategic Environmental Assessments (SEA) Division; and Captain Lewis A. Lapine of NGS recognized that the aerial photographs used by NGS's Remote Sensing Division to delineate shoreline could also be used to delineate benthic habitats. In 1992, a cooperative agreement between the aforementioned was signed to undertake the project of classifying, digitally compiling, and mapping the benthic habitats of the Florida Keys. This atlas is the result of that collaborative effort.

Many people deserve recognition for their contributions to this project. Frank Sargent, a remote sensing specialist at FMRI, managed the project. He reviewed all of the aerial photographs and prepared the photos for interpretation and delineation. He also assisted with the ground-truthing and classification of benthic habitats and with quality assurance and quality control. Ecologists Jay Zieman, a contractor for NOAA, and Curtis Kruer, a contractor for FMRI, were responsible for ground-truthing and classifying the benthic habitats.

Billy Causey, George P. Schmahl, Rob Finegold, Bill Valley, and Steve Baumgartner were involved in the early phases of designing the project and in accomplishing the fieldwork. Staff of the Florida Keys National Marine Sanctuary (FKNMS) helped organize and provided input to the 1991 workshop that launched this effort. They also provided expertise in habitat identification and logistical support during the aerial photography missions and ground-truthing surveys.

Edward Allen, NGS Remote Sensing Division, and James Dunford Jr., NGS Observation and Analysis Division, planned, organized, and coordinated the logistical support necessary for conducting the photographic missions. During these missions, observations were made of geodetic control, tide stations, and water levels.

David Miller and P.L. "Chip" Evans Jr., both of the NGS Remote Sensing Division, converted the aerial photographs of benthic habitats into digital data. They also exhaustively checked the digitized data from each photo to ensure that the perimeters of all benthic habitat areas were accurately depicted and that each area was correctly identified as one of the more than 40 distinct types.

Amy Clark and Steve Rohmann, of NOAA's Special Projects Office, incorporated the digitized benthic-habitat data into a geographic information system. Together with Marilyn King, now with NOS's Center for Coastal Monitoring and Assessment, they reviewed the digital data in detail to ensure that all benthic habitats were correctly identified and, where necessary, were combined across different geographic regions.

FMRI staff performed the final review of the digital data to make sure that all benthic habitats were accurately depicted and identified. This group included Frank Sargent, Tim Leary, and Chris Anderson. These staff members were responsible for producing the final map plots.

Maureen Warren of the Special Projects Office and Jonti Phillips and Henry Norris of FMRI were responsible for the layout and design of the atlas and the production of the text pages. Special thanks to Billy Causey, Curtis Kruer, and G.P. Schmahl, of the FWC and FKNMS, for contributing text on specific benthic habitats. FMRI's Katie Fitzsimmons, Judy Leiby, Jim Quinn, and Dave Crewz wrote sections of additional text and provided editorial review. SEA Division's David Remer provided initial desktop publishing support, and Pam Rubin, along with FMRI's Kelly Donnelly, provided editorial review. FMRI was responsible for the final production of the atlas. Chris Friel of FMRI and Daniel Basta of the Special Projects Office supervised the project.

Comments on this atlas or questions regarding the CD-ROM should be directed to either Kenneth Haddad at FMRI or Steven Rohmann at the Special Projects Office at the addresses below.

Kenneth D. Haddad
Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute
100 Eighth Avenue, S.E.
St. Petersburg, FL 33701

Steven O Rohmann, Ph.D.
Special Projects Office
National Ocean Service (N / SP1)
National Oceanic & Atmospheric Administration
1305 East West Highway
Silver Spring, MD 20910-3281

Bill Sargent, FMRI

◆ Uses for This Atlas

The maps in this atlas provide baseline information about the locations and distributions of benthic habitats throughout the Keys. These maps can be used (manually or by digital overlay) in comparative analyses with other data sets. Such comparative analyses can reveal patterns and indicate where changes have occurred in the mapped Keys' habitats because of natural and / or anthropogenic influences. As well as serving as a valuable management tool, these maps are a useful source of information for managers, analysts, and scientists in both the public and private sectors.

◆ Related Products

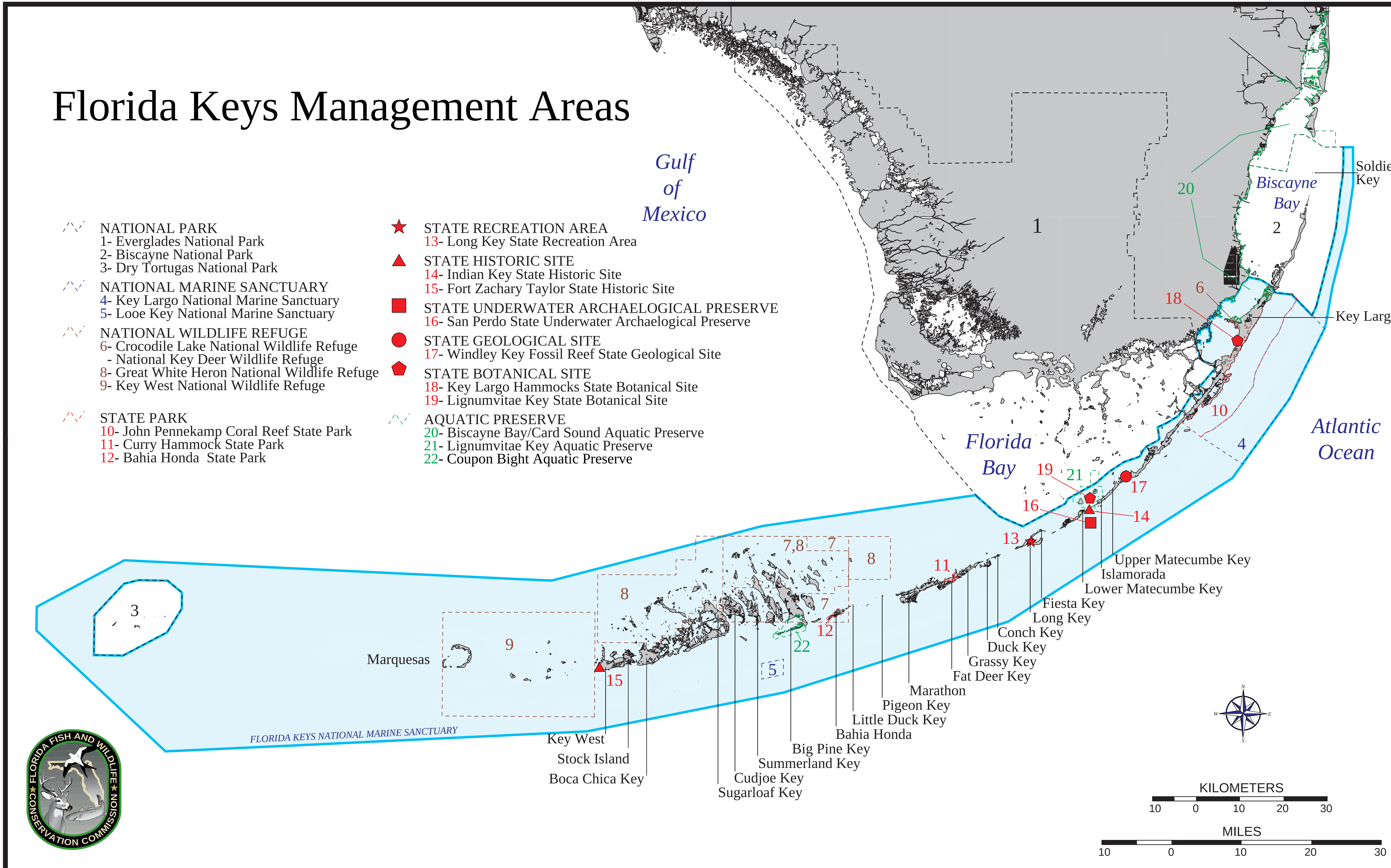
A CD-ROM that contains the atlas GIS files; a high-resolution, digital map of the Keys' shoreline; software necessary for viewing the atlas maps; and brief introductory text about the files and the data is available from NOAA.

◆ How the Atlas Is Organized

This atlas is organized into four main sections. The Introduction describes the atlas study area. The Atlas Development section describes how the benthic database and maps were created. A summary of the types and distribution of benthic habitats is provided in the Benthic Habitats section. The last section contains 32 maps showing the types and distributions of benthic habitats in the Upper Keys (Key Largo to Upper Matecumbe Key), Middle Keys (Upper Matecumbe Key to Pigeon Key), and Lower Keys (Little Duck Key to the Dry Tortugas.)

TABLE OF CONTENTS

Florida Keys Management Areas



INTRODUCTION

The Florida Keys are a unique national resource that must be preserved. Mapping of benthic habitats is an integral component of the ecosystem-management approach that has been adopted to protect the Keys' marine ecosystem, which includes Florida Bay and Biscayne Bay in addition to the Florida Keys National Marine Sanctuary, the nation's largest marine protected area. Such maps and associated information are critical in managing the Sanctuary and in maintaining the economic viability of the South Florida region. This atlas provides baseline data that scientific researchers and managers can use to compare with other data in support of resource-assessment and management activities.

Florida Keys Region

The Florida Keys archipelago extends from Soldier Key in Biscayne Bay southwest to the Dry Tortugas, a distance of more than 320 km. The Keys are bounded on the north and west by the relatively shallow waters of Biscayne Bay, Florida Bay, and the Gulf of Mexico. All of these bodies of water contain areas of mud shoals and seagrass beds. Hawk Channel lies to the south, between the mainland Keys and an extensive coral reef tract 8 km offshore. The Straits of Florida lies beyond the coral reef and separates the Keys from Cuba and the Bahamas.

The Florida Keys lack the wide expanses of sandy beaches characteristic of much of the Atlantic coast. In fact, beaches of any significant size and width are rare. Of the 2,990 km of total shoreline in the Keys, fewer than 50 km (less than 2%) are considered to be sandy beaches. This paucity of sandy beaches is principally due to lack of sediment sources in the Keys, which are mainly composed of old calcium carbonate reefs.

◆ Environmental Setting

Unique marine environments, including seagrass meadows, mangrove-fringed islands, and extensive living coral reefs, are located adjacent to and surrounding the Keys. These environments support rich biological communities that give this area special national significance. The marine environment of the Florida Keys supports more than 6,000 species of plants, fishes, and invertebrates. It also contains the largest seagrass communities in the northern hemisphere and the nation's only coral reef tract that lies adjacent to the continent.

◆ Spatial Characteristics

More than 1,700 islands, with a total area of approximately 266 km², make up the Florida Keys. These islands have little relief (generally less than one meter) and are inhabited from Soldier Key to Key West. Key Largo (65 km²) and Big Pine Key (27km²) are the largest islands.

In this atlas, the Keys have been divided into three regions: the Upper, Middle, and Lower Keys. The Upper Keys (Maps 1-8) extend southwest from Broad Creek (North Key Largo) at the border of Dade and Monroe counties to Upper Matecumbe Key. The Middle Keys (Maps 9-15) extend from Upper Matecumbe Key to Pigeon Key. The Lower Keys (Maps 16-32) extend west from Little Duck Key to the Dry Tortugas .

◆ Recreation & Tourism

Boating is an integral part of life in the Florida Keys. From Key Largo to Key West, there are 163 marinas, 5,714 wet slips, and 3,066 dry slips. There are approximately 200 boat ramps, 28 of which are publicly operated and maintained (Monroe County Planning Department, 1997-1998). Scuba diving and snorkeling are also popular recreational activities, in part because of the area's many shipwrecks and extensive coral reefs. Twenty to 30% of all tourists visiting the Keys scuba dive or snorkel during their visit. The majority of significant dive spots, including the protected waters of the Key Largo National Marine Sanctuary and John Pennekamp Coral Reef State Park, are located in the Upper Keys. These sites, and the Looe Key National Marine Sanctuary in the Lower Keys, are popular because of their accessibility and the number of dive operations located nearby (NOAA, 1996).

The waters surrounding the Keys are world renowned for sport fishing, and the opportunity to fish for species such as marlin, tarpon, and bonefish has made the area a popular fishing destination. The impact of fishing on the Keys' economy is enormous. Recreational fishing brings an estimated $500 million to the local economy each year (NOAA, 1996). Fishing-for-hire services are also an important component of the Keys' fishing and tourism industry. Several services are available to tourists, including backcountry and reef expeditions. In backcountry expeditions, a guide transports one or two fishermen to known fishing grounds in a 5- to 6-m-long shallow-draft boat. The fishermen pole their boats through clear, shallow water and search for bonefish, permit, and tarpon. In reef expeditions, charter boats transport fishermen to popular reef sites for hook-and-line fishing.

◆ Commercial Fishing

The Florida Keys are among the richest fishing grounds in the Gulf of Mexico and give rise to an extensive commercial fishing industry. Commercial fishing is the fourth-largest industry in the region and accounts for almost 10% of Monroe County's private-sector employment . The Keys provide diverse aquatic habitats for 90% of the region's commercially important species during at least one stage of their life history (NOAA, 1996).

In southwest Florida (including Monroe County), decapod crustaceans (shrimp, stone crab, spiny lobster), snappers, groupers, king mackerels, and Spanish mackerels dominate commercial catches. In Monroe County, the total annual commercial landings for these species average almost 15 million pounds. In recent years, crustaceans have accounted for 81 to 92% of the total catch value, and finfish made up the remainder. Approximately 88% of the nation's spiny lobsters are harvested in Monroe County. In commercial fisheries, Key West (Stock Island) and Marathon typically lead the Keys in landings and value, bringing in 75% of the Keys' poundage and 83% of the value in 1990. The traditionally high value of Key West's landings made it the 25th most important fishing port in the United States in 1990 (NOAA, 1996).

Marine-Life Collecting. In addition to the recreational and commercial fishing industries, a new "marine-life" fishery has recently been recognized as economically important. This fishery supplies small fishes, invertebrates, and live rock to wholesalers, retailers, and public aquaria throughout the world. About 260 species are harvested, including the juveniles of a small number of species managed in other fisheries. Rock beauty, angelfish, and butterfly fish are the most frequently collected fish species in Monroe County. Estimated annual economic value of this marine-life fishery is approximately $30 million. The true economic value of this fishery has not been determined, partly because of its recent recognition, the wide variety of species involved, and the reluctance of fishermen to release financial data (NOAA, 1996).

◆ Threats to the Environment

Evidence that the Keys' marine environment is deteriorating includes the decline of key species, the invasion of algae into seagrass beds and coral reefs, and an increase in coral diseases and bleaching. Recent increases in phytoplankton blooms, sponge and seagrass die-offs, and fish kills in Florida Bay are further examples of the degradation of this marine system. In Florida Bay, these conditions have been largely blamed on toxic eutrophication of nearshore and confined waters. Nutrient-enriched waters induce phytoplankton blooms and increases in epiphyte growth. Phytoplankton blooms and concentrations of epiphytes directly shade seagrasses and reduce the quantity and quality of light reaching the seagrasses and benthic communities. This decrease in light quantity and quality is the primary cause of seagrass die-offs and declines in water quality.

INTRODUCTION

Human population in the Keys can fluctuate considerably: during the course of a year, more than 80,000 people live in the Keys and more than three million people visit. Continued development of the Keys to support this population threatens seagrass and coral reef habitats. During the construction of facilities, terrestrial vegetation and mangroves, which act as filters to absorb nutrients and sediment-laden runoff, are removed. The removal of such vegetation results in nutrient-enriched waters that induce phytoplankton blooms and contribute to a decline in water clarity and quality.

Boating Impacts. From 1993 to 1994, approximately 500 vessels were reported aground in the FKNMS. Large vessels that have run aground have damaged or destroyed more than 8 hectares (ha) of coral reef habitat (NOAA, 1996). More than 12,140 ha of seagrasses in the Florida Keys have been damaged by the props (which dredge and scar the seagrass beds) of recreational boats. The Windley Key area, in the Middle Keys, contains some of the most heavily scarred seagrass beds in South Florida. Damage to seagrass beds occurs principally in nearshore and shallow-water areas and is concentrated around channels and canals, particularly those leading to populated areas. Improperly placed anchors also damage fragile benthic communities, especially along the reef tract.

Diving & Snorkeling. Numerous attractive dive sites are found in the Keys; among the most popular of these are the coral reefs. Unfortunately, corals are easily damaged, and uninformed divers and snorkelers can quickly cause damage that takes years to repair. People who stand or walk on corals, break off pieces for souvenirs, and grab them for locomotion while swimming often damage the delicate reefs. Inexperienced divers and snorkelers can also harm the coral communities by stirring up clouds of sediment while treading water. Overuse of certain dive areas and an overabundance of divers may also stress the reef community.

Recreational & Commercial Fishing. Certain fishing methods can harm benthic communities. Seagrass communities are adversely affected by repeated netting or trawling. Hook-and-line fishing and spearfishing have little effect on seagrass beds, but they can significantly affect corals and hardbottom communities. The hooks and monofilament line left behind by fishermen can become lodged in or wrapped around the fish, birds, and other animals living around these benthic communities. Fishermen who trap marine animals and collect sponges and tropical fish can damage seagrass beds, as well as coral and hardbottom habitats.

Florida Keys National Marine Sanctuary

Congress established the Florida Keys National Marine Sanctuary (FKNMS) in November 1990 to protect the region's valuable and unique resources. Mounting ecological threats to the Keys' coral reef ecosystem prompted this designation. Such threats included exploratory oil drilling, seagrass die-offs, coral bleaching and coral disease, declining reef-fish populations, deteriorating water quality, and groundings of large ships on the reef tract.

The sanctuary comprises approximately 9,500 km² of water and submerged lands. The sanctuary's boundary extends east from the northeastern point of Biscayne National Park to the 300-foot isobath and follows this isobath south and west to the Tortugas Bank. From there, the boundary extends east and north, enclosing the Middle and Lower Keys and portions of Florida Bay. The sanctuary's boundary merges with the southern boundary of the Everglades National Park until that shared boundary intersects the shoreline. From there the border of the sanctuary follows the shoreline northward until it meets the Biscayne National Park boundary, and finally it follows the south and east boundaries of the park all the way back to the northeastern point of the park. The sanctuary's landward boundary is the mean high-water line. Approximately 5,500 km² of sanctuary waters are under state jurisdiction. Numerous federal and state parks and preserves are located within the sanctuary's boundaries. Although located within the sanctuary's boundaries, the Dry Tortugas National Park is not part of the sanctuary. (See Managed Areas Map at the beginning of this section.)

Existing Management & Other Conservation Areas

Government and private organizations currently protect, preserve, and regulate numerous sites in more than 9,800 km² in and around the Florida Keys for purposes of environmental conservation, recreation, and scientific research. These sites may be entirely submerged, entirely upland, or have both a land and water component. Some sites serve as protective barriers, preventing damage to sensitive environmental habitats. Other sites, encompassing ecosystems that have already been damaged, are protected from further degradation. Additional protection is afforded to preserve archaeological and historical sites.

Federally protected areas in the Keys include four national wildlife refuges, three national parks, and two national marine sanctuaries. Biscayne National Park, Everglades National Park, Crocodile Lake National Wildlife Refuge, and the Key Largo National Marine Sanctuary are located in the Upper Keys. The Looe Key National Marine Sanctuary, Great White Heron and Key West National Wildlife refuges, National Key Deer Refuge, and the Dry Tortugas National Park are located in the Lower Keys. There are 13 protected areas under state management in the Keys. In the Upper Keys, they are Biscayne Bay / Card Sound Aquatic Preserve, John Pennekamp Coral Reef State Park, San Pedro State Underwater Archaeological Preserve, and Key Largo Hammocks State Botanical Site. In the Middle Keys, they are Long Key State Recreation Area, Indian Key State Historic Site, Lignumvitae Key Aquatic Preserve, Lignumvitae Key State Botanical Site, and Windley Key Fossil Reef State Geological Site. In the Lower Keys, they are Coupon Bight Aquatic Preserve, Fort Zachary Taylor State Historical Site, Bahia Honda State Park, and Curry Hammock State Park.

State-protected areas in the Keys are managed by Monroe County and local communities. Numerous preserves and community parks provide recreational facilities and waterfront access via boat ramps. Most of these preserves and parks are located in the Middle and Lower Keys.

Private organizations such as the Nature Conservancy, the Florida Keys Land and Sea Trust, the National Audubon Society, and the Monroe County Land Authority manage a number of smaller preserves and conservation areas.

ATLAS DEVELOPMENT

Data for the maps in this atlas were generated by FMRI and NOAA staff, along with ecologists contracted by NOAA and FMRI. The aerial photographs used in producing the maps were taken and digitally compiled by NOAA's NGS staff. Contracted ecologists and FMRI staff developed the classification scheme. FKNMS staff provided support for the photo interpretation, delineation, and ground-truthing activities and for reviewing the benthic classifications. NGS staff digitally compiled the photographic information. Staff from SEA converted the NGS digital files into a Geographic Information System (GIS) and then performed QA / QC on those files. Staff from both FMRI and ORCA designed and produced the atlas.

◆ **Aerial Photography**

Natural-color aerial photographs of the Florida Keys region were taken by NOAA's Remote Sensing Division during flights made from December 1991 through April 1992. A Wild RC-30 camera mounted in a Cessna Citation II Fanjet aircraft was used. The source photography had a nominal photo scale of 1:48,000 (1 cm = 480 m). Each photograph covered an area of approximately 160 km^2. An 80% endlap and 60% sidelap of adjacent photographs ensured that coverage would be complete and that an adequate number of reference locations would be present for photogrammetric measurements. Approximately 450 photos provided monoscopic coverage and were used to delineate benthic habitats.

◆ **Establishing a Habitat-Classification Scheme**

Two recognized ecologists, both with local knowledge of the Florida Keys and extensive expertise in marine habitats, along with FMRI staff, developed the hierarchical classification scheme used in this atlas. The habitat-classification scheme is composed of 24 classes of benthic communities in 4 major habitat categories: corals, seagrasses, hardbottom, and bare substrate. Dredge zones, banks, and restoration areas located within these communities are also denoted.

◆ **Photointerpretation**

Photos were interpreted by the two ecologists and FMRI staff. They determined and then delineated the types of benthic habitats found in the aerial photos. The minimum habitat area delineated was 0.5 ha. However, patch reefs (herein considered part of the coral reef benthic habitat) of less than 0.5 ha were delineated as points. Ground truthing was conducted to verify that benthic habitats were properly identified on the aerial photographs. Researchers were able to ground truth most benthic communities while snorkeling; scuba gear enabled them to ground truth for those communities located in deeper or turbid waters. Field information about the benthic habitat and site GPS locations was recorded. The ecologists and FMRI staff reviewed photos for content and accuracy and then sent them to NOAA for digital compilation.

◆ **Digital Compilation of Aerial Photographs**

NGS cartographers inspected each photograph for completeness of delineations, photo discrepancies, and areas of turbidity. Cartographers used a stereographic analytical plotter with NOAA's in-house software to digitize and label the benthic communities and shoreline features seen on the aerial photos. In many cases, the cartographers were able to provide additional detail because of the three-dimensional views permitted by the analytical plotter. The compiled data were checked by NGS staff.

Quality Control. Data were reviewed in three phases: 1) a review of digital data to ensure line and attribute completeness, 2) a comparison between the 1:48,000-scale maps of the compiled data and the original source photos, and 3) a comparison between the 1:24,000-scale maps of the compiled data and the original delineated photos to determine the positional accuracy of polygonal shapes and attributes.

Positional Accuracy Standards. Aerial photographs used to generate the digital data for the maps in this atlas were taken between December 1991 and April of 1992. Thus, the atlas represents the distribution of benthic habitats in the Keys over this time period. The horizontal accuracy of well-defined points (clearly identifiable, immobile objects such as the tops of radio towers or the corners of wharves) is within 2 m. The horizontal accuracy of continuous data (e.g., benthic habitats) ranges from 5 to 10 m, depending on the habitat class. Certain benthic features, such as patch reefs and spur-and-groove reefs, have a horizontal accuracy of 5 m. These habitats are composed of massive rock and coral formations that are stable in position over time and are resistant to all but the most powerful physical forces. Coral reefs, once established, tend to remain for decades or centuries.

Other habitats-such as seagrass beds, hardbottom communities, and bare substrate-are less stable. These benthic features are positionally accurate to within 10 m. Physical factors such as water currents and hurricanes and biological factors such as seasonal growth and die-off affect the distribution and stability of these benthic habitats along the ocean's floor. Plant densities within seagrass communities may increase or decrease over a period of months or years. Hardbottom habitats may become covered by sediment and then by seagrasses.

◆ **GIS Data Layers**

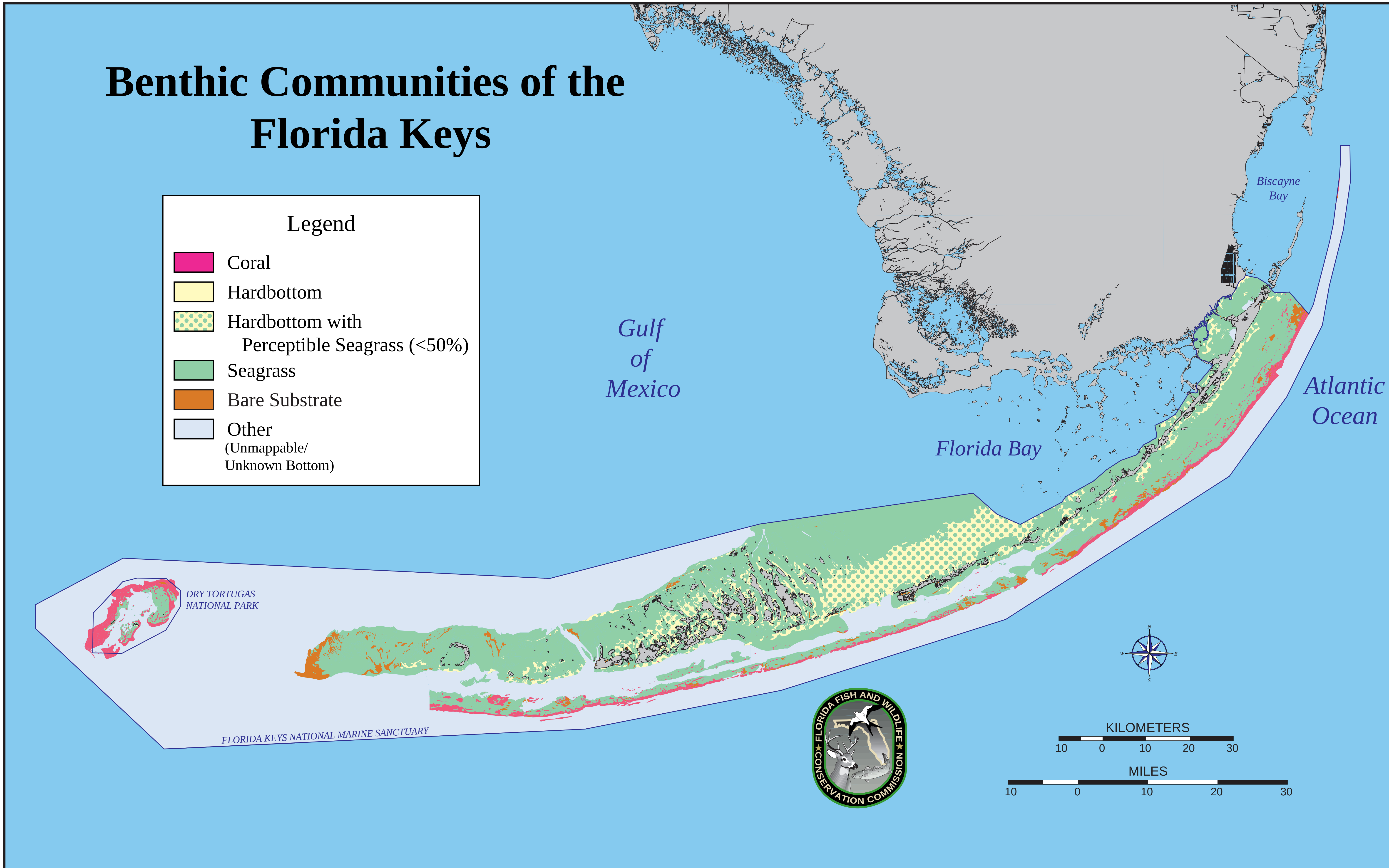
To ensure that the digital data sets in this atlas were geographically and attributionally correct, SEA staff used a series of data-translation and topology-construction steps while incorporating the data into a GIS, a sophisticated computer mapping and analysis software. All the individual GIS digital data sets were then combined to form several regional mosaics. Each region's data set was sent to FMRI for final quality control and assembly. FMRI inspected these data sets to ensure that no errors remained. The regional data sets were then joined together to make an FKNMS-wide, benthic-habitat data set. The resulting data set was inspected one last time, with particular scrutiny paid to the regions of overlap, where errors would most likely occur. The delineated aerial photos were referred to at every step of this process.

◆ **Map Production**

This atlas consists of 32 benthic habitat maps produced at a scale of 1:51,500. They are numbered from 1 to 32 and cover all areas in the Keys that were photographed and delineated. (Complete coverage of benthic habitats for the entire FKNMS is not available.) As the following maps show, many areas are classified as either “unmappable” or “of unknown bottom” because of turbid water conditions or the depth constraints of the aerial photos. Aerial photography of Hawk Channel that was conducted in 1995 under less turbid conditions may provide additional useful data that will be included in future versions of this atlas. (For further information on the status of these data contact FMRI.) The first 8 maps cover the Upper Keys, the next 7 cover the Middle Keys, and the final 17 cover the Lower Keys. These habitat maps were designed primarily to show the locations, distributions, and scopes of benthic communities in the Florida Keys. Each map also shows a limited amount of such information as the locations of major reefs, channels, aids to navigation, and every 10-mile marker on U.S. Highway One. This ancillary information basically serves to help orient the reader. In addition to the habitat maps, there are several index and locator maps of various scales. Also, a fold-out legend, found on the last page of the atlas, has been printed on both sides so that the reader can interpret the maps even when the atlas is folded back on itself.

ATLAS DEVELOPMENT

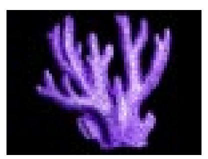
The initial maps were designed in ArcPlot, a module within Environmental System Research Institute's (ESRI) ArcInfo GIS software. Each map was then separated into individual map layers (land, water, benthics, etc.) and coverted into Abobe Illustrator format. The maps were then reassembled in Adobe Illustrator (vers 7.0) on the PC for futher refinement, particulalry text placement and color selection. The final maps were combined with the atlas text in Adobe Pagermaker (vers 6.5). The resultant atlas file and associated images were sent to a print shop for final atlas production.


Benthic Communities of the
Florida Keys
Legend
Coral
Hardbottom
Hardbottom with
Perceptible Seagrass (<50%)
Seagrass
Bare Substrate
Other
(Unmappable/
Unknown Bottom)
Gulf
of
Mexico
Florida Bay
Biscayne
Bay
Atlantic
Ocean
DRY TORTUGAS
NATIONAL PARK
FLORIDA KEYS NATIONAL MARINE SANCTUARY
FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION
KILOMETERS
10 0 10 20 30
MILES
10 0 10 20 30

BENTHIC HABITATS

There are four major classes of benthic habitat found within the Florida Keys and the waters of Dade and Monroe counties mapped in this atlas: corals, seagrasses, hardbottom, and bare substrate. The coral reef habitat of the Keys is one of the largest of its type in the world. Seagrasses, most predominant along the northwestern side of the Keys in Florida Bay and the Gulf of Mexico, are important as protective nursery habitats and for their primary production. Hardbottom habitats of the Keys are thought to be the remnants of previous shorelines. Bare-substrate, or soft bottom, habitat is composed of current-swept sediments, which make up a large portion of the Keys region and surrounding waters.

Corals



The Florida Keys reefs are similar in many respects to reefs in the Bahamas and the Caribbean. Most modern reefs have developed over the last 8000 years, after continental shelves and preexisting platforms were flooded by the rise in sea level following the Wisconsin Ice Age (Ginsberg and Shinn, 1964; Hoffmeister, 1974; Kinzie, 1996; Shinn et al., 1977). The conditions necessary for coral reef development include normal oceanic salinity (32-36 ppt), water temperatures between 18 and 28 °C, low concentrations of nutrients, sufficient light to support photosynthesis, and a rocky or hard substrate to serve as a foundation.

The coral reef habitat of the Florida Keys supports a diverse spectrum of invertebrates, fish, and reptiles. The reef's three-dimensional limestone structure provides food and shelter for numerous organisms, including many commercially and recreationally important finfish and lobster and other shellfish. The principal builders of the reefs are the coral polyps themselves, which deposit a calcium carbonate exoskeleton immediately beneath the living tissue. Thus, coral reef 'growth' often refers to a reef's volumetric growth, which occurs when inorganic minerals are deposited. The actual living tissue of interconnected polyps is a layer on the surface of what appears to be a very large organism but which is, in fact, mostly nonliving matter (Darwin, 1842; Wells, 1957; Stoddard, 1969; Hoffmeister, 1974). Calcareous algae (Wells, 1957), bryozoans, and additional skeletal debris can also contribute to reef growth by becoming cemented to the reef mass by algae and other naturally occurring marine cements.

Coral reefs are very efficient, biologically productive environments. Nutrient cycling is the basis for the enormous biological productivity of the coral reef ecosystem and occurs throughout the coral reef habitat. An example of nutrient cycling is seen in the symbiotic relationship corals have with the microscopic, unicellular algae located within the tissues of the coral polyps. Coral polyps provide the algae with shelter, food, and CO_2 produced during the process of respiration and calcification. The algae use the coral's wastes and CO_2 in the process of photosynthesis and provide the coral with oxygen and organic carbon. It is thought that the algae also facilitate calcification in corals when they remove CO_2 during the process of photosynthesis (Stanley, 1981). Without these algal endosymbionts, the corals probably could not thrive and build large reefs in nutrient-poor tropical and subtropical waters.

The nearshore to offshore gradient of reef communities in the Keys is as follows: hardbottom, patch reef, and platform margin reef. Seagrasses often occur in and are adjacent to all three of these reef communities (Marszalek et al., 1977; Jaap, 1984; Jaap and Hallock, 1990; Chiappone, 1996). Well-defined coral reef systems flourish in the Upper and Lower Keys. The Middle Keys have poorly developed coral reef systems. The difference in reef development is primarily due to environmental conditions. The Middle Keys, with their numerous channels, have the most exposure to the influences of the waters of Florida Bay and the Gulf of Mexico (Shinn, 1963; Shinn et al., 1977), whose temperature and salinity variations upset the delicate balance of conditions necessary for reef development and survival (Ginsburg and Shinn, 1964) in Atlantic waters.

w **Patch Reefs**

Patch reefs are discrete coral communities that are typically dome-shaped and circular, although they may form a line. Many patch reefs have an unvegetated area, known as a "halo," around their perimeter. This halo is primarily created by reef inhabitants, such as fish and echinoderms, that graze on the seagrass and vegetation nearby. Patch reefs may rise from a relatively shallow lagoon or from the shelf floor at some distance from the shoreline. They may range in size from tens to thousands of square meters and occur in depths of 1 to 20 meters. Coral species, sizes, and abundances within a patch reef may vary considerably from reef to reef, but the principal species involved in patch reef construction are *Siderastrea siderea*, *Colpophyllia natans*, and *Montastraea annularis* (Jones, 1977; Jaap, 1984; Jaap and Hallock, 1990).

Patch reef abundance is greatest in the Upper Keys, lowest in the Middle Keys, and intermediate in the Lower Keys. Most patch reefs in the Upper Keys are just off Key Largo and Elliott Key. Patch reefs are also present in the Marquesas and Dry Tortugas. A few patch reefs are located offshore in the Gulf of Mexico between the Content Keys and the Bay Keys.

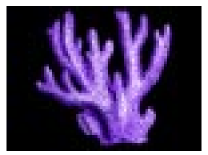
Patch reefs can generally be found in two distinct zones on either side of Hawk Channel: one zone is on the hardbottom margin of the seaward side of the chain of islands, and the other is along the inside series of offshore bank or platform margin reefs (see Figure on next page). For purposes of benthic mapping, no distinction was made between inshore and offshore patch reefs.

Patch Reef Types in This Atlas

1. *Individual Patch Reef*
Isolated, single reef with or without a halo.

2. *Aggregation of Patch Reefs*
More than one patch reef, usually too close together to map individually or where halos coalesce.

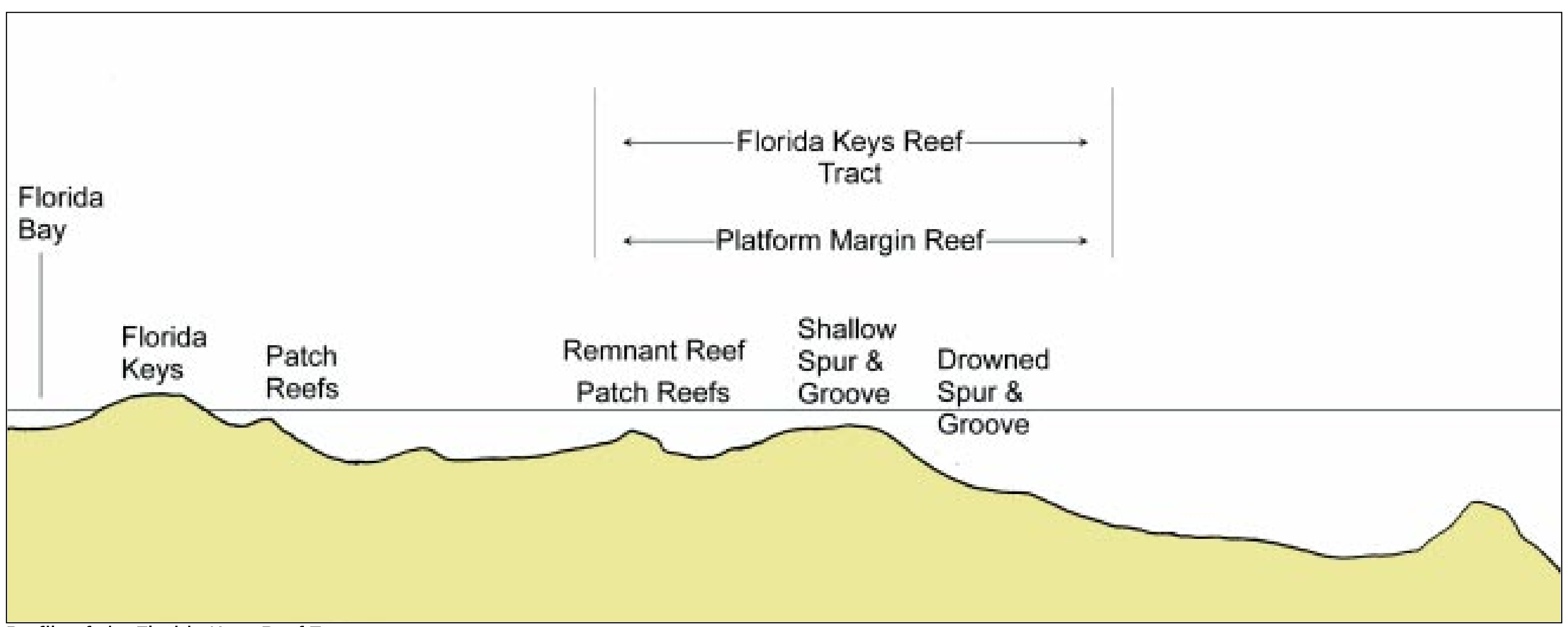
Florida Marine Research Institute



3. *Halo*
A barren, essentially unvegetated, whitish zone around a patch reef. Halos are possibly caused by the grazing activity of fish and echinoderms. Halos are not always present around patch reefs.

4. *Aggregation of Patch Reefs with a Halo*
A collection of patch reefs with halos too small to delineate.

5. *Coral or Rock Patches in Bare Sand*
Areas predominantly composed of sand or a thin veneer of sand over low-relief rock found on the reef tract or adjacent to spur-and-groove and drowned spur-and-groove reef formations. Scattered throughout these areas of sand are small coral or rock patches ranging in composition from a single gorgonian, sponge, or small coral head to an assemblage of coral that may measure from a few meters to 10 m across. These patches of rock or coral make up a low %age of the total cover but are highly distinctive. They are found predominantly in the area from Big Pine Shoal to Sombrero Light.



Profile of the Florida Keys Reef Tract

w **Platform Margin Reefs**
This term is used to describe the coral reefs that form a quasi-continuous structure along a platform margin or shelf edge or similar dropoff removed from any coastline. They are typically elongate reefs and can also be called "bank" reefs (spur-and-groove, drowned spur-and-groove, or low-profile remnant reef). Platform margin reefs are found from 12 to 18 kilometers offshore and at depths of a few centimeters below sea level to 30 m or more.

Florida's platform margin reefs are located in a shallow zone of water seaward of Hawk Channel and parallel to the axis of the Florida Current. Some shallow margin reefs in the Keys are characterized by distinct morphological features known as spur-and-groove formations. Spur-and-groove formations are made up of a series of coral ridges (both living and nonliving coral) that are bisected by surge channels with sandy bottoms; these ridges lie perpendicular to the Keys. Common sessile animals of these reefs include the hard corals *Acropora palmata* and *Agaricia agaricites* and the hydrozoan *Millepora complanata* (fire coral).

The Keys' platform margin reefs are roughly comparable to the barrier reefs of the Caribbean but lack the higher relief characteristic of true barrier reefs. The Keys' platform margin reef forms less than 10 m of vertical relief and is biologically less diverse and smaller than true barrier reefs are.

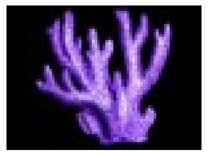
The platform margin reef tract of the Keys extends from the northern boundary of the FKNMS to west of the Marquesas; it is also found in the Dry Tortugas. The Keys reef tract is composed of a diverse assemblage of coral communities variable in both morphology and species composition. In this atlas, the Keys' platform margin reef tract includes all coral reef formations except patch reefs. The majority of well-developed platform margin reefs are concentrated in the Upper Keys (for example, Carysfort, the Elbow, French, and Molasses) and the Lower Keys (for example, Looe Key; Eastern, Middle, and Western Sambos; Eastern Dry Rocks; Sand Key; and Western Dry Rocks). A few occur in the Dry Tortugas.

Platform Margin Reef Types in This Atlas

1. *Shallow Spur and Groove*
Well-developed platform margin reefs found on the "fore-reef" of the reef tract. These reefs grow upward and outward with a vertical relief of up to 4 m and may reach lengths of more than 1000 m. Their high vertical relief in shallow water (0 - 10 m) gives shallow spur-and-groove platform margin reefs a distinctive signature in aerial photographs.

2. *Drowned Spur and Groove*
Older platform margin reefs that are not actively growing and are often buried in sand that migrated from shallower zones of the reef tract. These reefs typically have a low profile of 0.5-1.5 m and are longer than the shallow spur-and-groove reefs. These drowned spur-and-groove platform margin reefs have a signature in aerial photographs similar to that of the shallow spur-and-groove reefs.

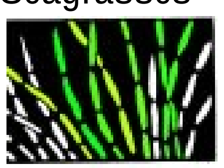
3. *Remnant - Low Profile*
Reefs that lack distinctive spur-and-groove characteristics. The vertical relief of these reefs varies from less than 0.5 m to 2 m. These remnant reefs consist of coral and hardbottom features; support soft corals, sponges, seagrass; and are usually found growing parallel to the reef tract, though they often form transverse features that grow perpendicular to the reef tract.



4. *Back Reef*
Landward of spur-and-groove type platform margin reefs. The back reef is typically a rubble zone (rubble is the remains of coral and other reef features broken down into smaller bits from wave actions) found in shallow (< 2 m) waters that are exposed to wave energy. It is often colonized by heartier corals (numerous soft corals and pioneering elkhorn, fire coral, and other branching hard corals) that flourish in higher-energy environments. The density of these corals in the back reef zone may vary from widely spaced individuals to dense colonies.

5. *Reef Rubble*
A feature of platform margin reefs found landward in the shallow (1-6 m), high-energy areas of a reef tract. Unstable pieces of the reef fractured from wave action exist in these areas with little or no visible colonization, seagrasses such as *Thalassia* or *Syringodium* may exist there. This reef rubble may form transverse features that extend perpendicular to the line of the reef tract.

Seagrasses



Seagrass communities are a dominant component of the underwater landscape of the FKNMS. Distribution of seagrass communities is influenced by the interaction of factors such as water quality (which includes salinity and clarity) and depth, sediment depth, and current velocity. Seagrasses can tolerate a broad range of environmental conditions and can be found anywhere from calm, sheltered waters to the open ocean.

Seagrasses can form dense, broad communities known as "meadows," which usually occur in low-energy environments. When seagrass meadows in low-energy environments are disturbed by higher-energy natural influences or other outside forces, seagrass growth can become patchy. Patchy seagrass beds occur where depressional basins or creek-like features in the seabed accumulate sediment or contain organic peat deposits from mangrove communities that existed during times of lower sea levels. The thicker accumulation of sediment allows seagrass to develop and to grow more densely. Patchy seagrass beds are found inshore throughout the sanctuary

Sudden catastrophic removal of vegetation in seagrass beds by bursts of high-energy wind or currents or by human activities can result in holes or depressions called "blow outs." Blowouts can occur anywhere within a seagrass community and can eventually become revegetated with seagrass or with algae that may accumulate in the bottom of these depressions. Blowouts from natural causes rarely occur in low-energy environments. Most are found in high-energy environments or in transitional environments, where there is a change from low- to high-energy, or they can be caused by hurricanes, by prop wash from large vessels, and even by the activities of treasure hunters.

Seagrasses are one of the most productive natural systems in the world. They provide food and shelter for a majority of the commercially and recreationally important fisheries in the Keys. Three species of seagrasses dominate within the sanctuary: *Thalassia testudinum* (turtle-grass), *Syringodium filiforme* (manatee-grass), and *Halodule wrightii* (shoal-grass). These seagrasses make up more than 95% of the total plant biomass in the sanctuary (Zieman, 1982, 1990). Two species of *Halophila*, *H. decipiens* (paddle-grass) and *H. engelmannii* (star-grass), are also widely distributed. *Halophila decipiens* is tolerant of low-light conditions and thus can be found in the deeper water of the Lower Keys. Because of their relatively small size, the two *Halophila* species have little standing crop, but their high rates of production and turnover may make them important contributors to the area's primary production.

Shoal-grass is widely distributed throughout the Keys, although it is less common than turtle-grass and manatee-grass. Principal areas of shoal-grass occurrence in the Keys are north of Vaca Key, south of Long Key, and in the Quicksands area (Fourqurean, 1997). Shoal-grass is the smallest in size of the three seagrasses discussed here and has thin, flat blades. It is more tolerant of exposure than the other species and are thus more common in the shallowest water. Shoal-grass can occur at greater depths (15 m), but it is usually less dense.

Turtle-grass is the dominant species in the sanctuary and throughout the Keys. Turtle-grass forms dense, extensive communities. It is the most robust of the three species and has broad, flat blades. Turtle-grass can occur throughout a range of water depths but is most dominant at intermediate depths.

Manatee-grass is also highly abundant in the Keys. It is found in deeper and higher-current waters; communities are found extensively in 2-to-3m depths from near Arsenicker Keys (Florida Bay) to Big Pine Key and to north of Marathon (Vaca Key). Manatee-grass has a wiry leaf that is circular in cross section, which makes it more tolerant of high-current waters.

Benthic algae can often be found scattered throughout seagrass beds. Some species of algae are considered 'epiphytes' and are attached directly to the seagrass blades. Others can be trapped in the seagrass bed by the seagrass blades and are called drift algae. Still other species of benthic algae use soft sediments as a substrate and can be found scattered throughout sparse seagrass beds. Important genera of these algae include *Halimeda* spp., *Penicillus* spp., *Caulerpa* spp., *Udotea* spp., *Avrainvillea* spp., and *Rhipocephalus* spp. The only algae that consistently use sediments as substrate are the mat-forming algae and members of the order Siphonales, which attach to the substrate with rhizoids.

Mike Durako, Florida Marine Research Institute

Seagrass Types in This Atlas

1. *Moderate to Dense, Continuous Beds*
Seagrass beds containing a single species or a mix species of *Thalassia*, *Syringodium*, or *Halodule*. They are widespread in depths ranging from intertidal to approximately 10 m.

2. *Sparse, Continuous Beds*
Low-density beds of seagrass (less than 50 shoots/m²) typically found in shallow, protected bays, where their spread is limited by physical conditions or substrate.

3. *Moderate to Dense, Discontinuous Beds*
Seagrass beds containing a single species or a mix of the species of *Thalassia* , *Syringodium*, or (occasionally) *Halodule*. They are widespread in depths from intertidal to approximately 10 m. The moderate- to high-energy regimes that contain such beds are usually found on the reef tract and near entrances to tidal channels and passes. Blowouts are dispersed throughout these beds within the high-energy environments. These beds are associated with channels where a great deal of water exchange occurs between the Gulf of Mexico, Florida Bay, and the Atlantic Ocean. This water movement promotes robust growth of the beds.

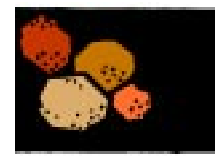
4. *Dense Patches in a Matrix of Sparse Seagrass*
Sparse seagrass beds in which more than 50% of the area is composed of patches of dense seagrass.

5. *Dense Patches in a Matrix of Hardbottom*
One of the most common categories. Hardbottom areas in which more than 50% of the area is composed of dense seagrass patches.

6. *Predominantly Sand/Mud with Small, Scattered Seagrass Patches*
Areas of bare sediment in which less than 50% of the area is composed of small, scattered seagrass patches. Algae are commonly present and may be adrift or attached to the sediment or seagrasses. Sediment composition may vary from sand to mud: in offshore areas, sediment tends to be sandy, and in inshore areas, it tends to be muddy.

7. *Predominantly Macroalgae Cover with Scattered Seagrass Patches*
Relatively continuous areas of macroalgae that have seagrass patches scattered throughout. The algal cover is predominantly *Halimeda* spp. and *Pencillus* spp. This community occurs most commonly on the north side of the Marquesas Keys.

Hardbottom



Hardbottom habitats of the Keys are solid, flat, low-relief, exposed-rock substrate composed of Key Largo Limestone (from the west end of the Newfound Harbor Keys off Big Pine Key to the north edge of the sanctuary), Miami Oolite (Big Pine Key and west), or rubble that is exposed or covered with a thin layer of sediment. Abundant in shallow waters, hardbottom-habitat depths range from intertidal to approximately 7 m in deep tidal channels and the inside edge of Hawk Channel. These habitats may include a thin veneer of carbonate sand or mud too thin and unstable to support seagrass. Seagrasses may occur in circular depressions (solution holes or peat beds) within the hardbottom community in areas where sufficient sediment is available.

Hardbottom habitats of the Keys support numerous species of soft corals (sea fans and sea whips), stony corals, macroalgae, various calcareous algae, sponges, and invertebrates such as crabs, worms, and brittle stars. The loggerhead sponge, *Spheciospongia vesparium*, is relatively common; octocorals generally include *Pterogorgia* spp. and *Pseudopterogorgia* spp. Stony corals often present are *Porites porites*, *Siderastrea radians*, and *Favia fragum*. Algae frequently attached to hardbottom include the green algae *Halimeda* spp., *Udotea* spp., *Penicillus* spp. (calcareous), and the brown algae *Sargassum* spp. Other genera of importance are the red algae *Laurencia* spp., *Gracilaria* spp., and *Eucheuma* spp. and the brown algae *Dictyota* spp. Hardbottom is an important refuge habitat for mobile juvenile organisms because of its crevices and solution holes. Fishes, lobsters, and turtles commonly reside and feed in hardbottom areas.

Nearshore hardbottom is the dominant ecological community on both sides of the Keys within the sanctuary and extends seaward to a depth of approximately 5.5 m. The community ranges from the intertidal rock of the Lower Keys' backcountry to the highly diverse, inshore hardbottom area on the ocean side. Mapping of hardbottom features for this project included only the inshore communities landward of Hawk Channel.

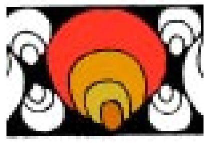
Hardbottom Types in This Atlas

1. *Soft Corals, Sponges, and Algae*
Benthic communities with variable species composition; species composition of an area often depends upon sediment accumulation, water depth, and exposure to winds and currents. Soft corals are usually more common in deeper zones. The shallowest zones (<1 m) may include only attached or drift algae or may also include solitary hard corals (e.g., *Porites* spp., *Siderastrea* spp., and *Manicina* spp.)

2. *Hardbottom with Perceptible Seagrass*
Includes solitary hard corals and soft corals, but most often is made up of sponges and benthic algae (attached or adrift). Less than 50% of the area has seagrasses, which are usually found in patches in depressions and basins where adequate sediment has accumulated.

Florida Marine Research Institute

Bare Substrate



In the Florida Keys, bare substrate is mainly composed of calcareous sand and mud. This habitat is home to numerous carbonate sand-producing algae and various invertebrates, such as polychaete worms and echinoderms (NOAA, 1996).

Areas of bare substrate may be associated with the reef tract and occur within discontinuous seagrass beds. Bare substrate, or unvegetated substrate, found within seagrass beds are referred to as a blowout. Blowouts are often the result of catastrophic disturbances caused by high winds and wave energy. The largest concentration of blowouts is found along the reef tract, the bottom of Hawk Channel, and west of the Marquesas. It should be noted that sparse seagrass, algae, or an ephemeral diatom film is undetectable on aerial photographs but may occur in these blowouts nevertheless.

Bare substrate can be composed of calcareous sands derived from calcareous algae such as *Halimeda spp*. *Halimeda* dominates the sediment composition (80%) in the Upper Keys, is less dominant in the Middle Keys (50%), and is least dominant in the Lower Keys (20%), where sediments consist more of coral-derived sediments in addition to oolites, mollusk pieces, and urchin fragments (Shinn et al., 1989; Jaap, pers. comm.). In and around the Marquesas, the sediment is principally composed of *Halimeda* fragments. West of the Marquesas, the sediment is composed of mud and silt.

Calcareous muds compose the bare substrates of Florida Bay, the nearshore areas of the Keys, and Hawk Channel at depths of 8 to 10 m. Bare-substrate areas within Hawk Channel may be subject to high turbidity, which precludes any growth of submerged aquatic vegetation.

Bare substrate can also be composed of large areas of loose sand (composed of plant and animal skeletons); these sand areas can occur along, and directly behind, the outer reef tract; for example, at White Banks off Key Largo. These areas are habitats for the erect shaving brush green algae (*Penicillus* spp.) and segmented green algae, as well as for foraminifera, bivalves (clams), gastropods (snails), polychaetes (worms), and echinoderms (sea urchins). A large portion of the sanctuary's Gulf of Mexico region, especially west of Key West, contains bare substrate habitat, where the sediment may be up to 7.6 m thick (NOAA, 1996).

w **The Quicksands**

West of the Marquesas is a vast, current-swept sand flat referred to as The Quicksands. Sand waves as high as 2.7 m have been reported in this area of high current velocities. Shifting sands have prevented the development of extensive reef habitats, although seagrasses are present, as are major growths of the carbonate sand-producing algae *Halimeda spp.* At the westernmost tip of The Quicksands is Halfmoon Shoal, which is separated from the Rebecca Shoal reef community by a broad pass that is 17 to 18 m deep. From Rebecca Shoal west to the Dry Tortugas, the depth of the passage is approximately 24 m, and the bottom is current-swept sand (NOAA, 1996).

Bare Substrate Types in This Atlas

1. *Carbonate Sand*

Coarse carbonate sediments usually found in areas exposed to currents and wind energy, which continually sort and remove finer fractions of the sediment.

2. *Carbonate Mud*

Fine carbonate sediments found in deep-water, depositional environments (Hawk Channel) that are protected from wind and wave energy.

3. *Organic Mud*

Mud composed of detrital drift seagrass and algae that build up in intertidal and shallow waters of windward shorelines. The continual deposition and resuspension of organic matter limits development of benthic communities on natural as well as disturbed shorelines. This is a common feature on the windward shorelines of Big Pine Key, No Name Key, and Little Pine Key.

Larry Benevenuti

Frequency of Occurrence of Benthic Habitats

The table below provides the areal extent of the major classes, as well as unmappable or unknown areas, and land areas within the Florida Keys. Because Dry Tortugas National Park is not part of the Florida Keys National Marine Sanctuary, acreage calculations for the park are listed separately. Unknown Bottom / Uninterpretable includes deep access channels, dredge pits, and deep-water habitat where photo interpretation and delineation of habitat are not possible, for example, Key West Harbor and Garrison Bight.

Seagrasses are the dominant benthic community within the Florida Keys, accounting for approximately 71% of all mapped benthic communities. Hardbottom covers almost 20% of the mapped area. Corals account for 6%, and bare substrate totals 3% of the total mapped area

HABITAT	FLORIDA KEYS NATIONAL MARINE SANCTUARY			DRY TORTUGAS NATIONAL PARK			TOTAL MAPPED AREA		
	HECTARES	ACRES	% Mapped Bottom Habitat	HECTARES	ACRES	% Mapped Bottom Habitat	HECTARES	ACRES	% Mapped Bottom Habitat
Coral - Patch Reef	3,000	7,400	1	710	1,760	5	3,710	9,160	1
Coral - Platform Margin Reef	21,080	52,070	5	8,040	19,870	60	29,120	71,940	7
Hardbottom	1,190	2,950	<1	0	0	0	1,190	2,950	<1
Hardbottom with Perceptible Seagrass (<50%)	81,440	201,230	20	20	40	<1	81,460	201,270	19
Seagrass	289,540	715,470	71	4,440	10,970	33	293,980	726,440	70
Bare Substrate	13,570	33,520	3	210	520	2	13,780	34,040	3
Total Mapped Habitat	409,820	1,012,640	100	13,420	33,160	100	423,240	1,045,800	100
Unknown Bottom/ Uninterpretable	69,120	170,810		6,410	15,830		75,530	186,640	
Total Bottom Habitat	478,940	1,183,450		19,830	48,990		498,770	1,232,440	
Land	33,370	82,450		40	100		33,410	82,550	
Total Area (excludes open water)	512,310	1,265,900		19,870	49,090		532,180	1,314,990	

UPPER KEYS

Physical Environment

The Upper Keys extend from Soldier Key to Upper Matecumbe Key. However, for the purposes of this atlas, we refer to the Upper Keys as extending from Key Largo to Upper Matecumbe Key. The Upper Keys have the largest land mass of the three regional divisions of the Keys. The land masses of the Upper Keys act as a buffer to protect the eastern, subtropical Atlantic waters of the Keys from the seasonally variable waters of the Gulf of Mexico and Florida Bay. Key Largo Limestone composes the Upper and Middle Keys and was formed by the lithification of a coral reef that developed 100,000 to 125,000 years ago. The limestone extends below the surface from Miami to the Dry Tortugas. It is exposed at the surface from Soldier Key to Newfound Harbor Channel, west of Big Pine Key, a distance of 180 km. The formation ranges in thickness from 23 m to 52 m and contains fossilized corals. The high porosity and permeability of the limestone allows groundwater and pollutants to be transported throughout the Keys (NOAA, 1996).

The nearshore waters of the Upper Keys are fringed by mangroves, which perform many biological functions, including shoreline stabilization and sediment entrapment and filtration, and provide food and habitat for several recreationally and commercially important species of fish and invertebrates. The prop-roots and aerial roots of the mangroves also serve as habitat for a wide variety of sponges, tunicates, oysters, and other sessile marine life.

Human Activities and Uses

Both permanent-resident and seasonal-resident populations have grown throughout the Florida Keys. According to 1990 census figures, approximately 26% of the permanent residents and 38% of the seasonal residents live in the Upper Keys. Annually, more than 900,000 visits are made by tourists to the Upper Keys. The Upper Keys also receive a large number of weekend visitors from Miami and other parts of South Florida. Key Largo has a greater concentration of marinas than does any of the other Florida Keys. Snorkeling is the top-rated summer activity. During the winter months, wildlife viewing and nature study draw almost 200,000 visitors to this region (NOAA, 1996).

Protected Areas

Conservation lands in the Upper Keys are located principally on Key Largo. Everglades National Park, Biscayne National Park, and Crocodile Lake National Wildlife Refuge are three of the federally protected areas in or adjacent to the Upper Keys. State-protected areas include John Pennekamp Coral Reef State Park, Key Largo Hammocks State Botanical Site, and Biscayne Bay / Card Sound Aquatic Preserve. John Pennekamp State Park was established in 1960 to protect 19,733 ha of underwater habitat off Key Largo. Key Largo National Marine Sanctuary was created in 1975 to protect an additional 25,900 ha of underwater habitat; these waters have since been incorporated into the Florida Keys National Marine Sanctuary. The Florida Keys Land and Sea Trust manages three small sites (< 1 square km each) in the Upper Keys.

Environmental Concerns

Preserving water quality is essential to maintaining the richness and diversity of the Keys' varied environments. Water quality can be negatively affected by the pollutants associated with land-based runoff, ocean dumping of hazardous material, and oil spills. Potential pollutant inputs from Miami and Metro-Dade County into Florida and Biscayne bays strongly influence the water quality of the Upper Keys. On the Atlantic side of the Upper Keys, the deflection of the Florida Current along the Upper Keys sets up eddies seaward of the reef tract, sending cool, nutrient-enriched waters to the reef tract through core upwellings, but the swift movement of these eddies also provides flushing, which helps reduce the threat of nutrient over-enrichment in the Upper Keys.

In addition to these marine conditions, changes to terrestrial habitats can affect nearshore habitats. The Upper Keys are the most heavily populated islands of the Keys. More than 75% of the original deciduous forests in the Upper Keys have been cleared on some islands (for example, on south Key Largo and Plantation Key). Mangrove losses of almost 50% have occurred on Plantation Key, and a 44% loss has occurred on south Key Largo. In addition to deforestation, habitat fragmentation has occurred. In the Upper Keys, the average size of deciduous forests has decreased from almost 51 ha to just under 3 ha and that of mangrove forests has decreased from 67.5 ha to 2 ha (Lott et al., 1996).

Benthic Habitats

The benthic habitats of the Upper Keys are affected by a variety of environmental conditions, including the Keys' landmass orientation and elevation. The emergent Upper Keys form an almost continuous barrier that separates the seasonally variable waters of Florida Bay from the tropical Atlantic Ocean waters. Seagrass communities, the dominant benthic habitat in the Upper Keys, compose approximately 78% of the mapped benthic communities. Corals and hardbottom each make up approximately 10% of the mapped habitats, and bare substrate makes up the remaining 4%.

Coral reefs are dependent on a marine environment that has a narrow range of temperature and salinity fluctuations, clear water (for better light penetration), and low levels of nutrients. The Upper Keys, with their continuous land barrier, are better suited for coral reef development than the Middle and Lower Keys are and have a large abundance of patch reefs and well-developed bank reefs.

In the Upper Keys, the coral reef tract is located approximately 10 km offshore and forms an almost continuous coral community that parallels the Keys land mass. The reef tract contains periodic, shallow spur-and-groove reefs that nearly break the water's surface. Because the conditions in the Upper Keys are conducive to reef development, 12 major shallow reefs have formed along the outer reef tract, from Carysfort Reef at the north end to Crocker Reef at the south. These shallow-reef communities are frequently connected to deeper, transitional coral reef communities. Intermediate and deep reef communities are found seaward of the reef tract. The benthic habitats between Crocker Reef and Alligator Reef are principally transitional reef communities and scattered patch reefs. Seagrass communities also occur along the outer reef tract. Together, these areas compose a biologically diverse reef community that supports many important recreational and commercial fisheries.

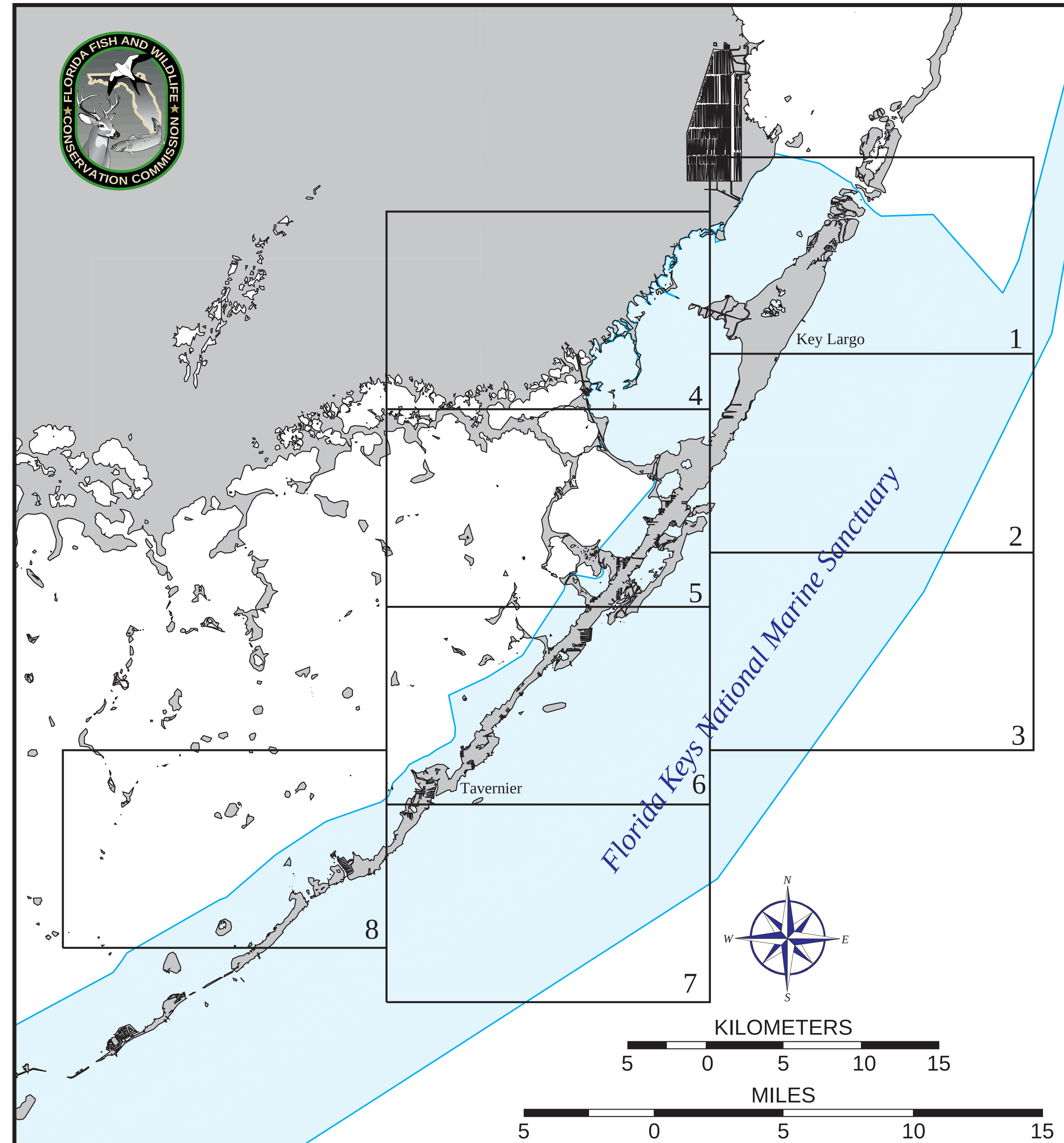
Hawk Channel, the area lying between the shoreline and the reef tract, has a habitat dominated by seagrasses-such as turtle grass, manatee grass, and shoal grass-and patch reefs. Hawk Channel is generally shallower in the Upper Keys than it is in the Middle to Lower Keys. Within this channel, discontinuous bands of inshore, offshore, and mid-channel patch reefs parallel the Keys. These reefs can range in size from a few small coral heads to enormous stretches of coral reef habitat. The channel is extremely important as a foraging area and habitat for the wide variety of organisms that inhabit the reef.

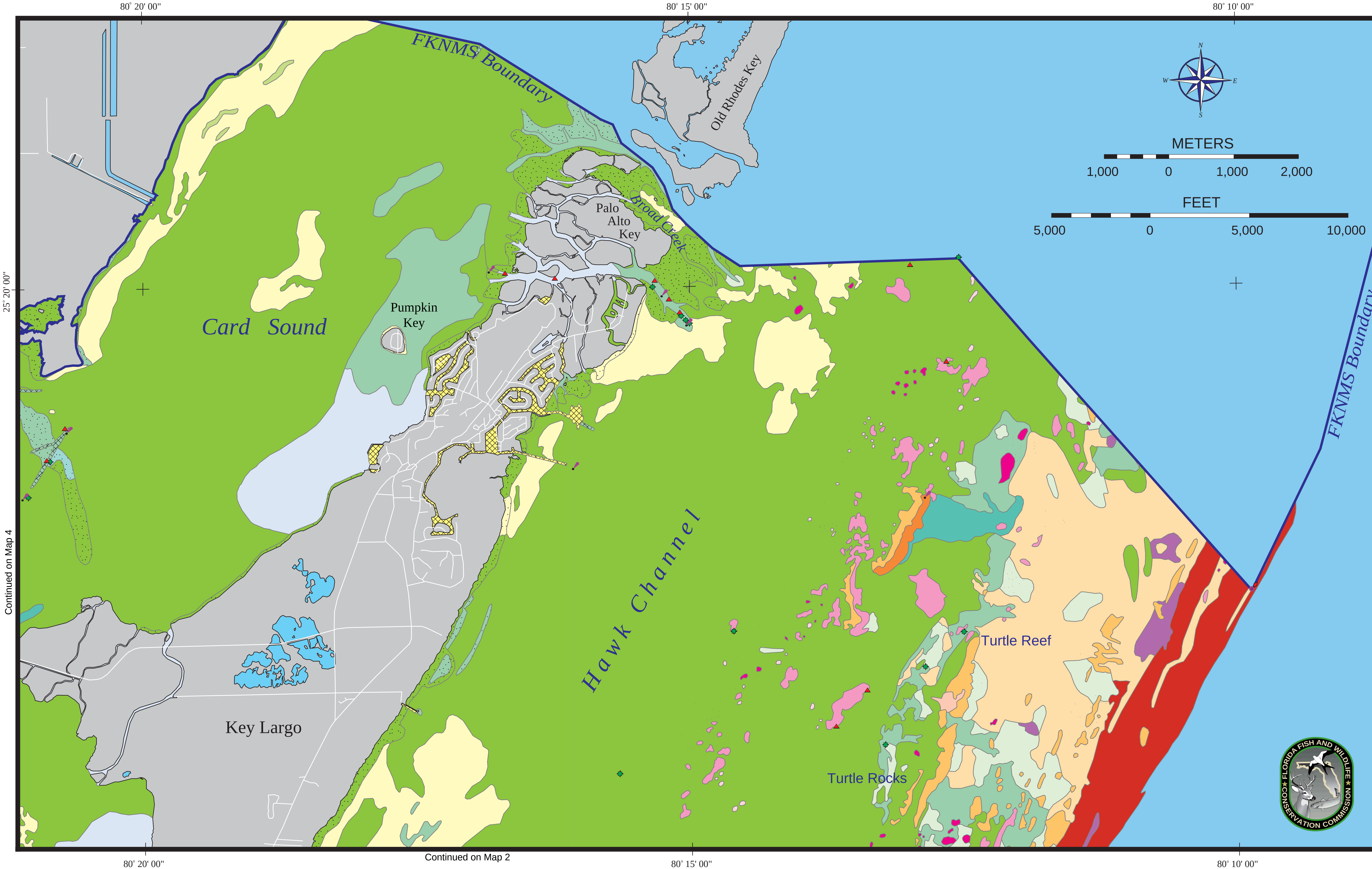
UPPER KEYS

Frequency of Occurrence of Benthic Habitats

The table below provides the areal extent of the four major habitat classes in the Upper Keys. In general, the distribution of benthic habitats in the Upper Keys mirrors the overall distribution of benthic habitats in the Florida Keys.

HABITAT	HECTARES	ACRES	% MAPPED BOTTOM HABITAT
Coral - Patch Reef	1,130	2,800	2
Coral - Platform Margin Reef	6,850	16,920	9
Hardbottom	10	30	<1
Hardbottom with Perceptible Seagrass (<50%)	7,620	18,820	10
Seagrass	57,810	142,850	76
Bare Substrate	2,430	6,000	3
Total Mapped Habitat	75,850	187,420	100
Unknown Bottom/ Uninterpretable	1,080	2,670	
Total Bottom Habitat	76,930	190,090	
Land	9,410	23,250	
Total Area (excludes open water)	86,340	213,340	

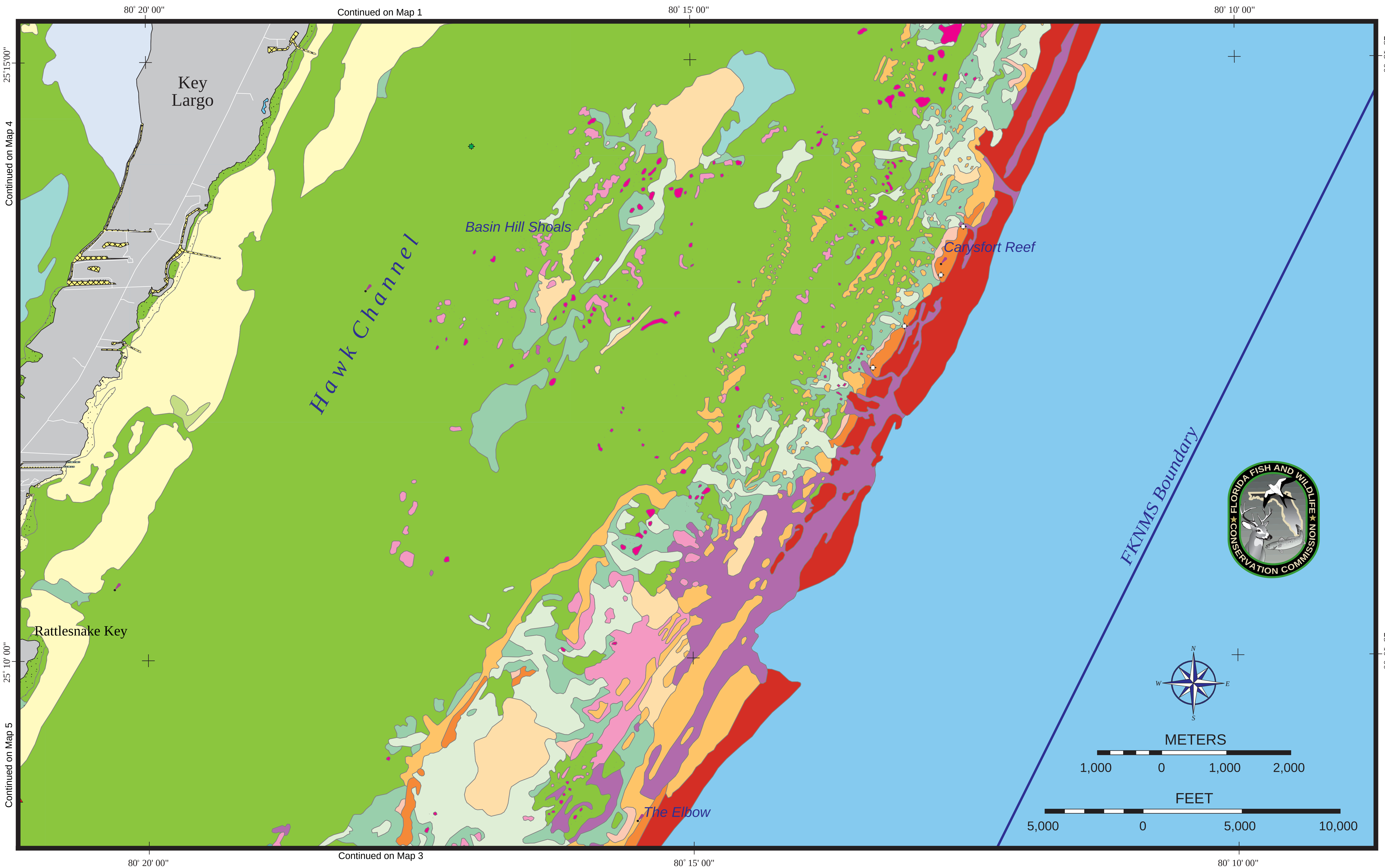




Continued on Map 4
Continued on Map 2

Continued on Map 1

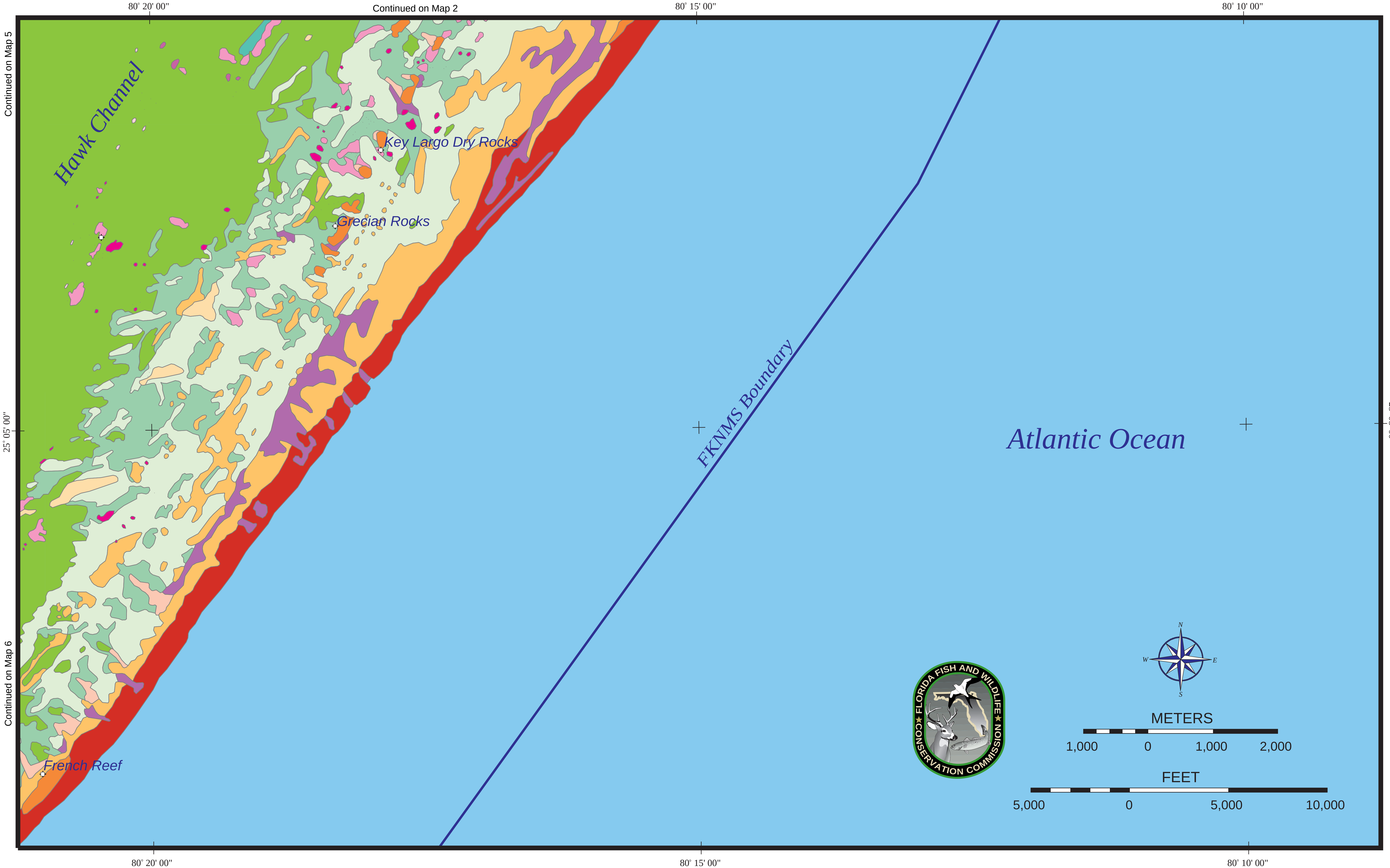
Continued on Map 4

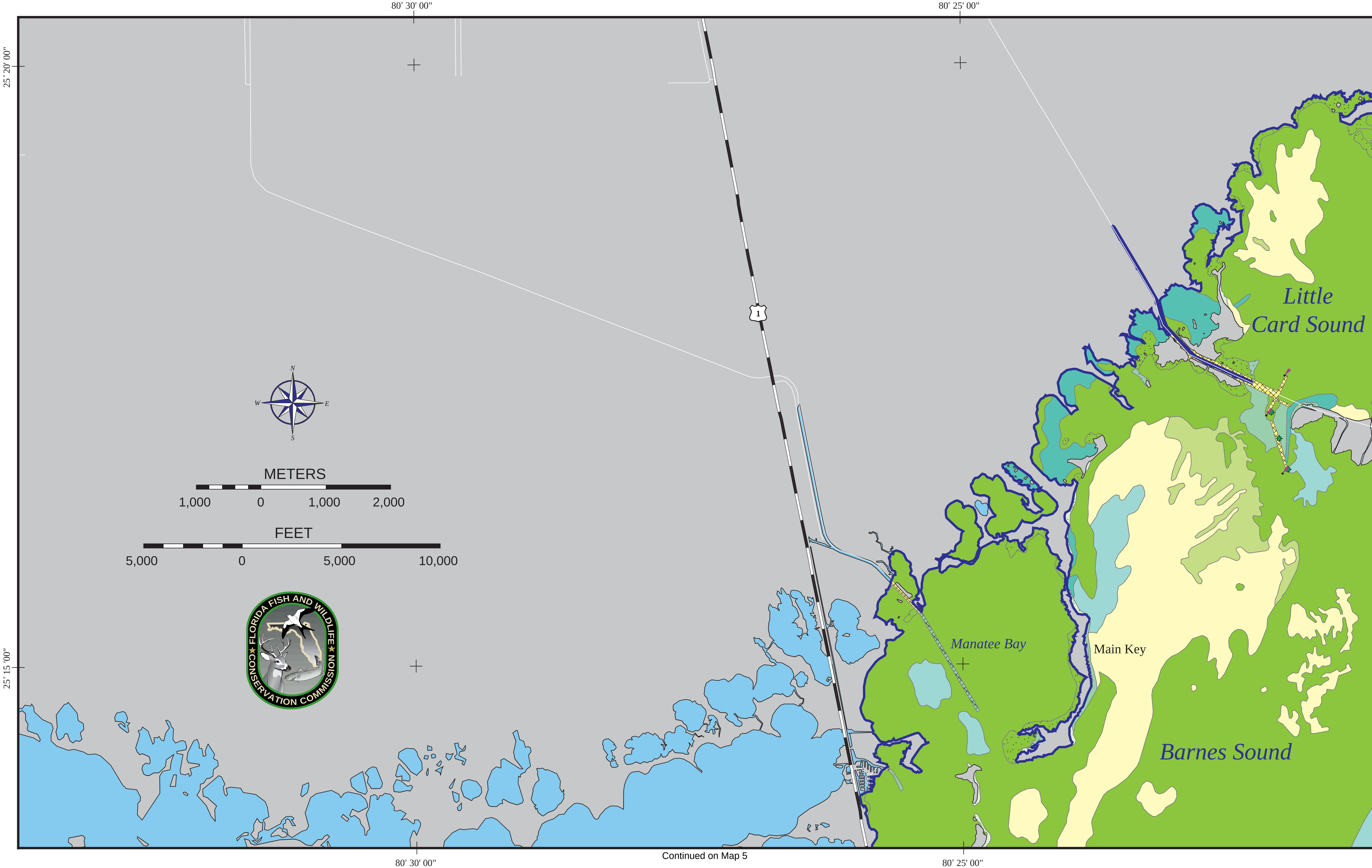


Continued on Map 5

Continued on Map 3

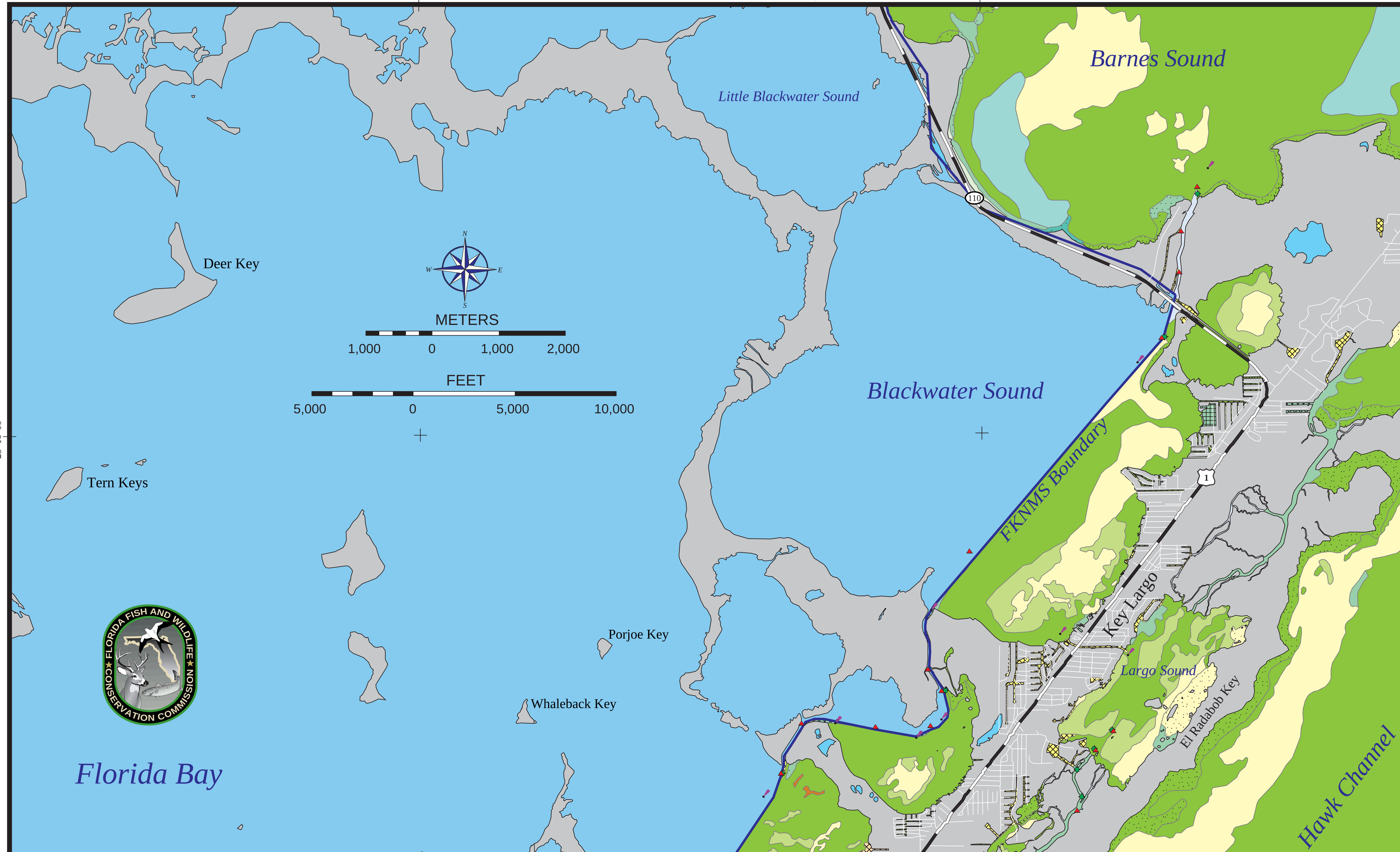
Continued on Map 2
Continued on Map 5
Continued on Map 6





Continued on Map 1
Continued on Map 2
Continued on Map 5

Continued on Map 4

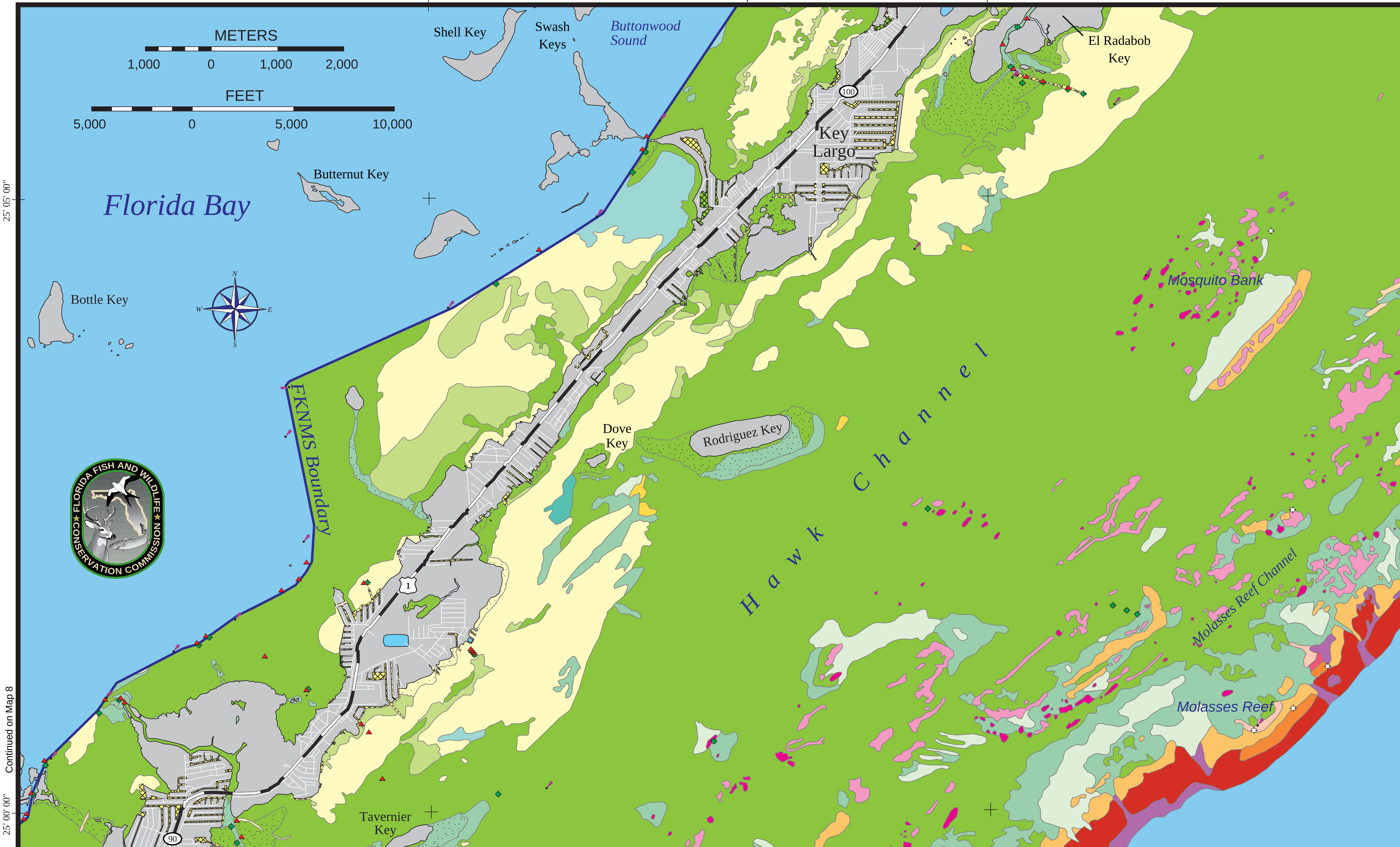


Continued on Map 2

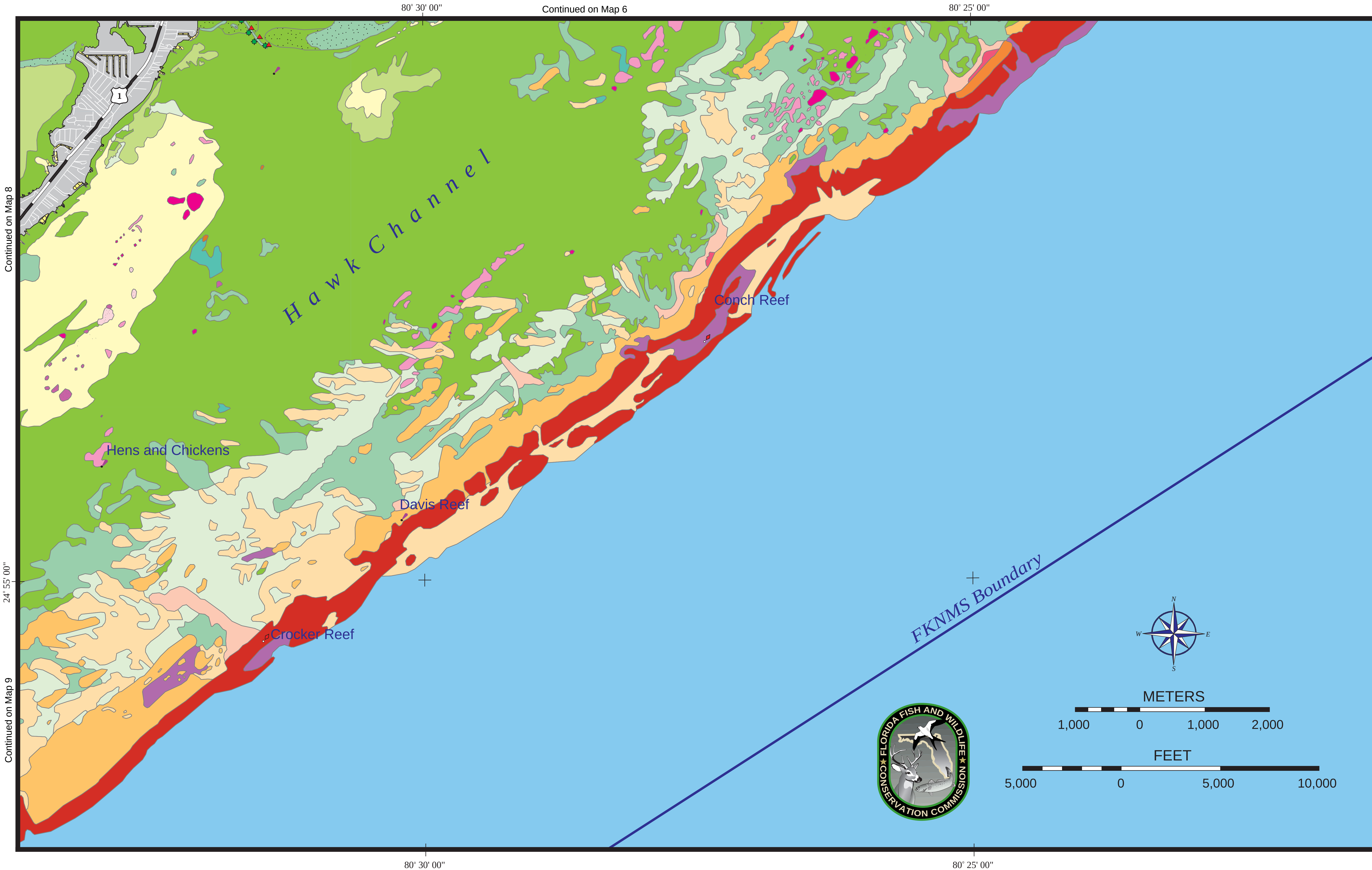
Continued on Map 3

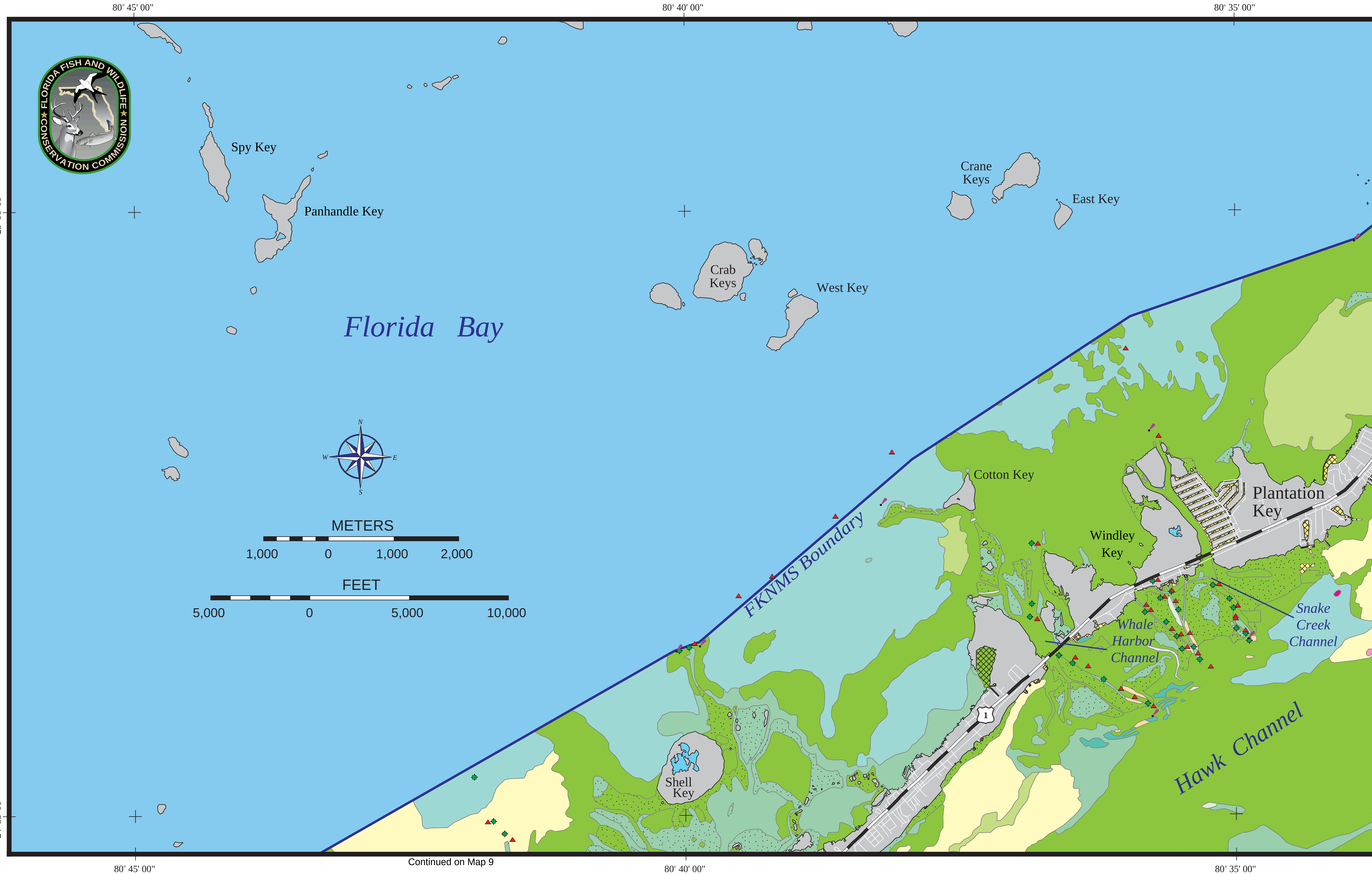
Continued on Map 6

Continued on Map 5



Continued on Map 3
Continued on Map 8
Continued on Map 7


80° 30' 00"
Continued on Map 6
80° 25' 00"
Continued on Map 8
Continued on Map 9
24° 55' 00"
24° 55' 00"
1
Hawk Channel
Conch Reef
Hens and Chickens
Davis Reef
Crocker Reef
FKNMS Boundary
N
W
E
S
METERS
1,000
0
1,000
2,000
FEET
5,000
0
5,000
10,000
FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION
80° 30' 00"
80° 25' 00"



Continued on Map 9

MIDDLE KEYS

Physical Environment

The Middle Keys extend from Upper Matecumbe Key to Pigeon Key and, like the Upper Keys, are composed of Key Largo Limestone. Most of the "pocket beaches" of the Keys, which are composed of fine-grained fragments of shell, coral, and coralline algae, are located in the Middle Keys. Although smaller in size than the Upper Keys, the Middle Keys are similar in shape and are separated by numerous wide channels. Several major passes and tidal channels between Lower Matecumbe Key and Big Pine Key connect Florida Bay and the Gulf of Mexico to the Atlantic Ocean. These passes allow warm, high-salinity water (in the summer) or cold, low-salinity water (in the winter) from Florida Bay to invade the reef tract. These conditions are not as conducive to the development of coral reefs as are the conditions found in the Upper Keys. Thus, reef development is limited in the Middle Keys (NOAA, 1996).

Climatic conditions such as heavy rainfall, drought, summer heat, and winter cold fronts influence temperature, salinity, nutrient supply, and turbidity in the shallow waters adjacent to the Middle Keys. Extreme variations in these parameters affect the distribution of organisms from the nearshore habitats to the outer bank reefs. Sessile, benthic epifauna in areas exposed to wide seasonal variations are hardier and more capable of withstanding a broader range of environmental stresses than are the epifauna in more stable areas. Faunal communities in the nearshore habitats of the Middle Keys have such survival advantages because of their seasonally variable habitats (NOAA, 1996).

Human Activities and Uses

By 1990, the permanent-resident population of the Middle Keys was more than 15,000, and the seasonal-resident population for this region was more than 13,500 (NOAA, 1996). Annually, approximately 700,000 tourists visit the Middle Keys. Snorkeling is the top-rated summer activity; sight-seeing and attractions draw more than 125,000 visitors to this region during the winter season (Leeworthy and Wiley, 1996).

The population in the Middle Keys is concentrated in Key Colony Beach and Marathon. Key Colony Beach and Layton (on Long Key) are two of only three incorporated cities in Monroe County (Key West is the third). Key Colony Beach is a waterfront community with many seasonal and permanent residents. The city is located on approximately 285 acres of filled land. Most homes are built on waterfront or canalfront property.

Marathon is one of the three largest communities in the Florida Keys and is a major tourist resort and retirement area. It is characterized by continuous development from the west end of Grassy Key to Knights Key. Marathon also has Boot Key Harbor, a fast-growing community of hundreds of permanently moored live-aboard boats.

Protected Areas

Most of the areas under federal and state protection or conservation are found in the Upper and Lower Keys. The Florida Keys National Marine Sanctuary and Everglades National Park are the only federally protected or managed areas in the Middle Keys. State-managed areas in the Middle Keys include Windley Key Fossil Reef State Geological Site, Long Key State Recreation Area, Lignumvitae Key State Botanical Site, Indian Key State Historic Site, Lignumvitae Key Aquatic Preserve, Curry Hammock State Park, Indian Key State Historic Site, San Pedro Underwater Archaeological Preserve, and Curry Hammock State Park. Most protected areas in the Middle Keys are managed or sponsored by local governments or by private interests such as The Nature Conservancy, the National Audubon Society, and the Florida Keys Land and Sea Trust. Marathon is one of two keys with the most parks, six, in Monroe County. There are no protected lands within the cities of Key Colony Beach and Layton.

Environmental Concerns

As the population density in the Keys has grown steadily since the 1940s, the land available for development has dwindled. Key Colony Beach and Layton currently have no capital facilities constraints that would limit population growth within their boundaries. The proportion of residential development in Key Colony Beach is one of the highest in the Keys (58%), explaining the city's reliance on Marathon for commercial use. The density of artificial waterways and canals is high throughout these developed areas of the Middle Keys. Such heavy development in the Middle Keys area, and the Keys in general, threatens habitats in several ways: terrestrial vegetation is removed; nearshore waters are polluted; and marine resources are damaged through the careless acts of boaters, divers, and fishermen.

In the summer of 1987, an extensive seagrass die-off that began in Florida Bay, located north of the Middle Keys, caused a significant loss of seagrass beds. This trend has persisted at a slower pace since 1990. A possible explanation for the die-off is the deteriorating water quality caused by the nutrient enrichment of nearshore waters from land-use runoff (fertilizers, toxins). Nutrient-enriched waters support phytoplankton blooms and epiphyte growth, which shade seagrass communities and thus reduce their light source. Other possible explanations for the die-off include a reduction in the fresh water (because of periodic droughts) that has historically drained into Florida Bay and the fact that relatively few hurricanes have dramatically altered the temperature, turbidity, or nutrient and salinity conditions in the area over the last 20 years (NOAA, 1996). Whatever the cause, this increase in organic content in the water reduces water clarity and dissolved oxygen concentrations, stressing seagrass communities.

Benthic Habitats

Seagrasses compose the dominant benthic habitat in the Middle Keys, making up more than half (approximately 56%) of the mapped benthic communities. Hardbottom communities compose just over one-third (35%) of the mapped habitats, followed by corals (4%), and bare substrate (3%). However, due to several limiting physical factors, some of these benthic communities are less diverse and sparser in the Middle Keys than in the Upper and Lower Keys (NOAA, 1996).

In the Middle Keys, dense seagrass meadows are found shoreward of the reef tract. Patchy seagrasses adjacent to and eastward from these seagrass meadows occur in a continuous pattern north and south of the reef. Patchy seagrass growth also occurs next to islands in Florida Bay and the Atlantic Ocean. Extensive seagrass banks occur along the northwestern boundary of sanctuary waters (north of Marathon and Duck Key), with patchy seagrass beds alongside these banks.

Hardbottom communities dominate along the bayside from Little Duck Key to Lignumvitae Key, where they give way to dense, patchy seagrass beds. Because of the depth of Hawk Channel in the Middle Keys and the turbid conditions when the aerial photography was taken, only half of Hawk Channel was mapped in this region.

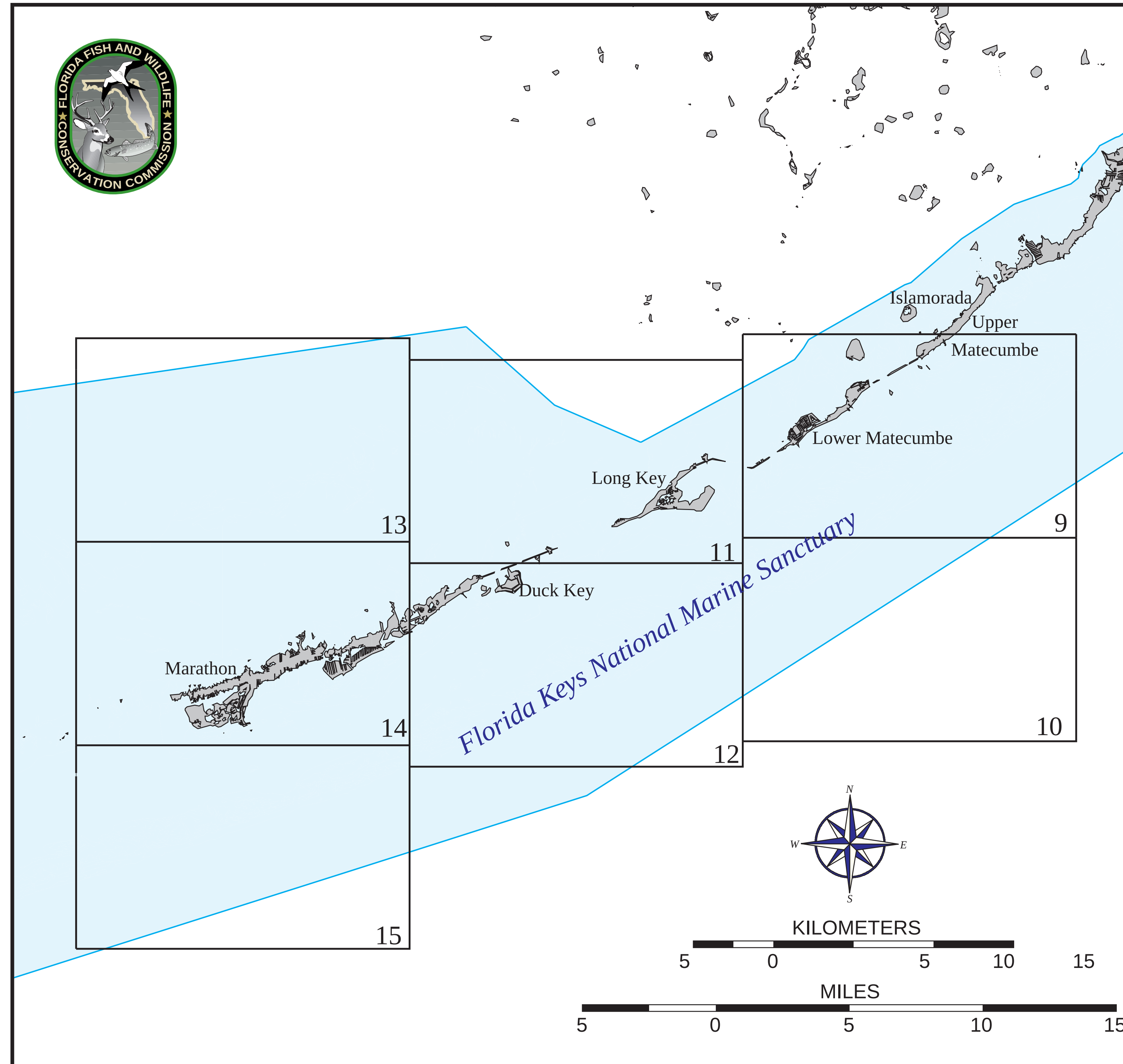
MIDDLE KEYS

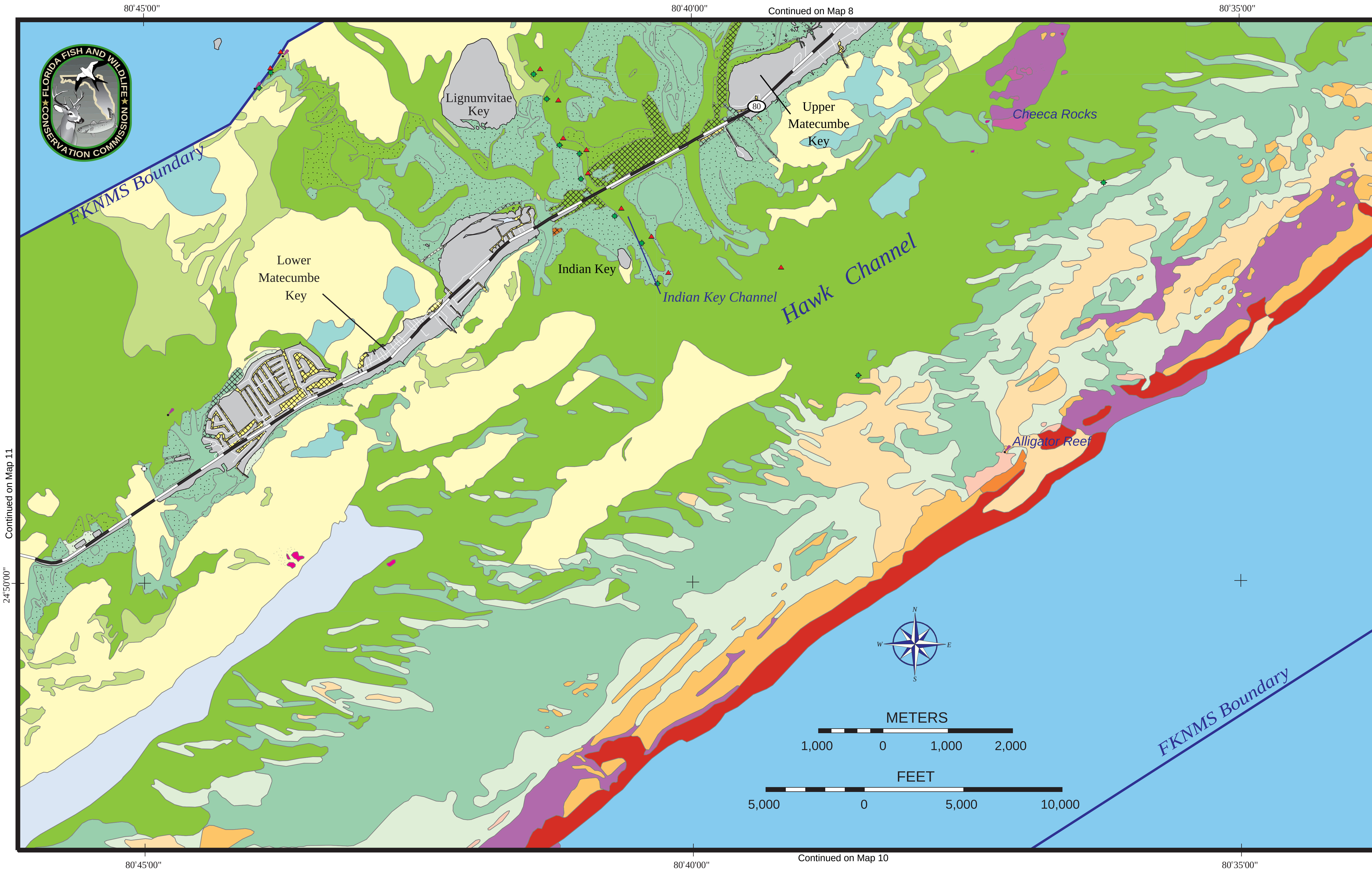
Coral reefs are less developed in the Middle Keys than in the Upper and Lower Keys. This is because in the Middle Keys, waters flow through the many wide channels connecting the Gulf of Mexico and Florida Bay to the Atlantic Ocean, affording the reefs in the Atlantic tropical waters little protection from the variations in temperature, salinity, and clarity of waters of the Gulf of Mexico and Florida Bay. There are three significant shallow spur-and-groove formations within the Middle Keys: Alligator, Tennessee, and Sombrero reefs. Intermediate and deep reefs are virtually continuous along the Middle Keys. Landward of these reefs are numerous remnant reefs that may occur as unique, isolated habitat or as long, narrow bands, often found parallel to one another. Patch reefs are few, and most are located south of Vaca Key and Duck Key. Bare substrate (primarily sand) is found in many areas behind the bank reef and in some nearshore areas.

Frequency of Occurrence of Benthic Habitats

The table below provides the areal extent of the four major habitat classes in the Middle Keys.

HABITAT	HECTARES	ACRES	% MAPPED BOTTOM HABITAT
Coral - Patch Reef	170	410	<1
Coral - Platform Margin Reef	4,230	10,440	4
Hardbottom	550	1,360	1
Hardbottom with Perceptible Seagrass (<50%)	37,540	92,760	34
Seagrass	64,000	158,150	59
Bare Substrate	2,600	6,420	2
Total Mapped Habitat	109,090	269,540	100
Unknown Bottom/ Uninterpretable	17,840	44,080	
Total Bottom Habitat	126,930	313,620	
Land	4,440	10,960	
Total Area (excludes open water)	131,370	324,580	





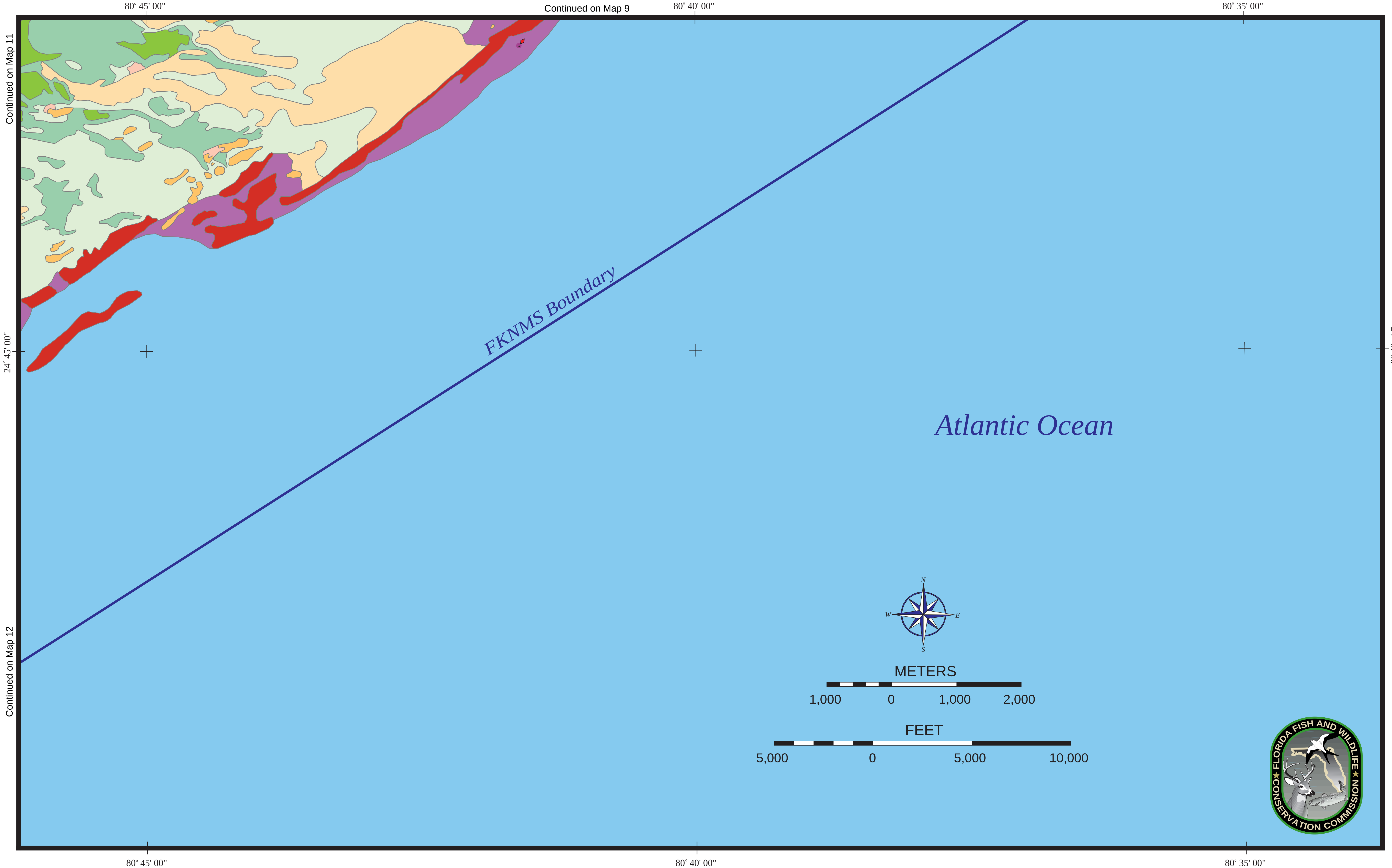
Continued on Map 8

Continued on Map 7

Continued on Map 11

Continued on Map 10

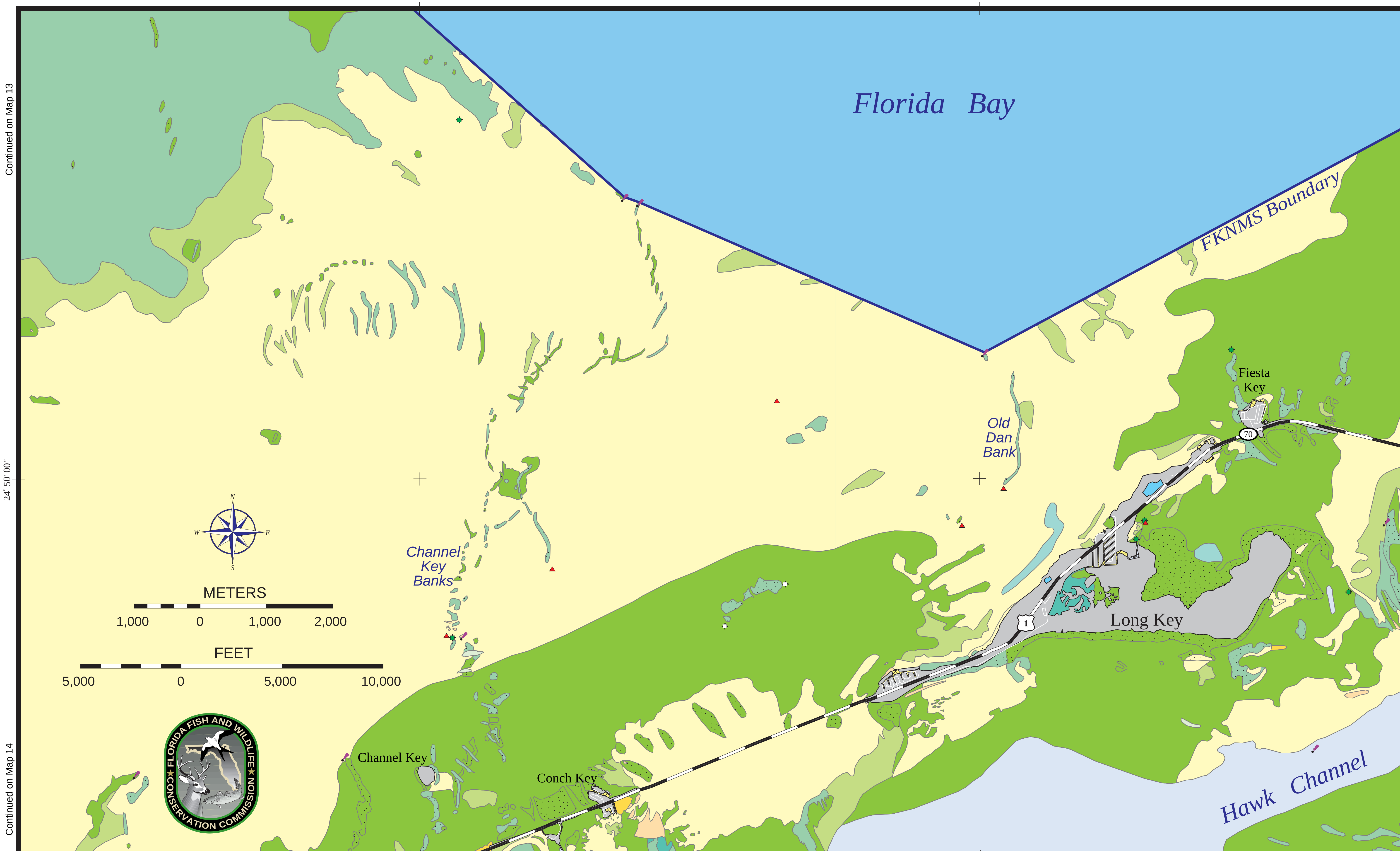
Continued on Map 9
Continued on Map 11
Continued on Map 12



80° 55' 00"
80° 50' 00"

Continued on Map 13
Continued on Map 9

24° 50' 00"

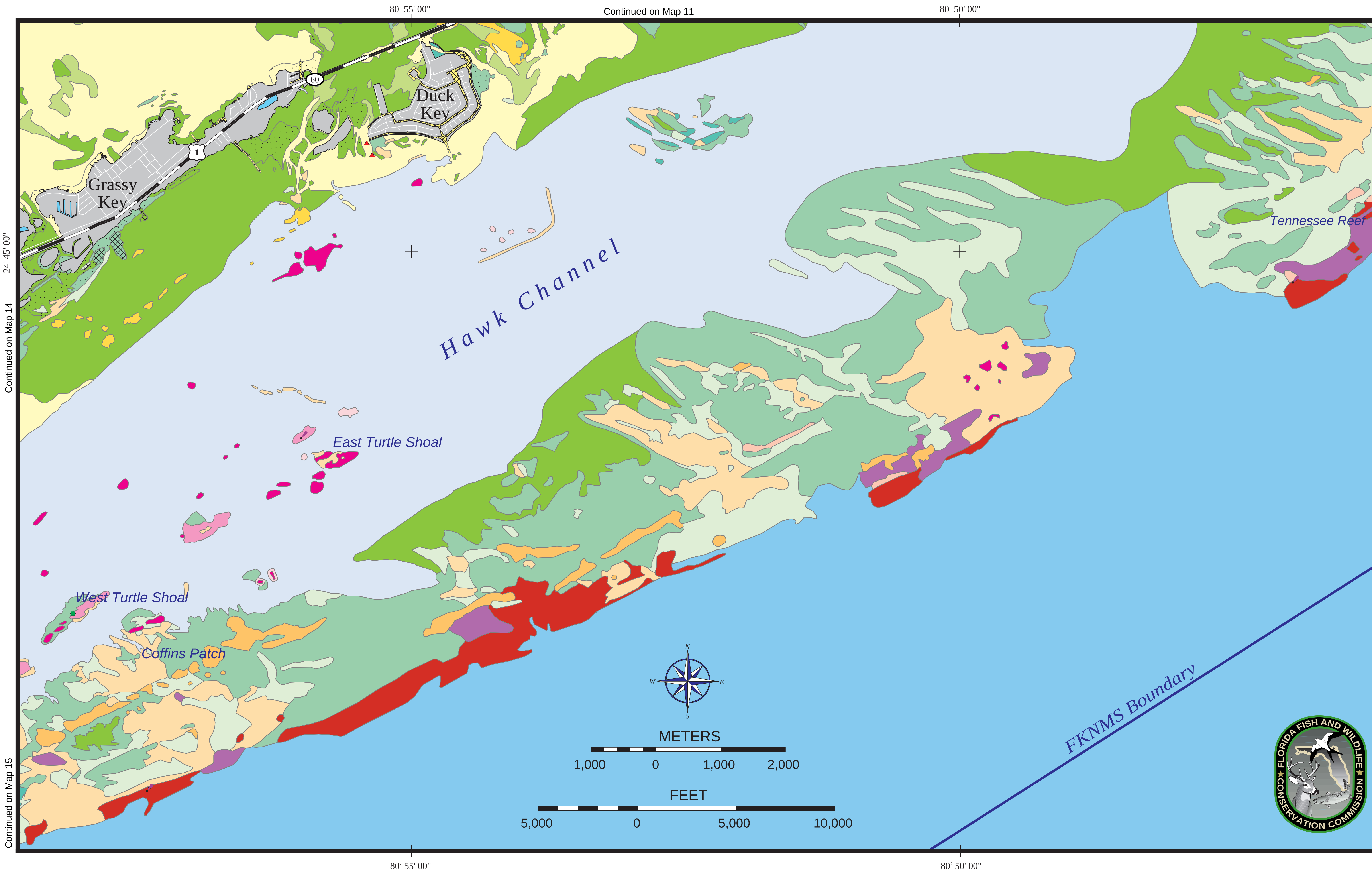


24° 50' 00"

Continued on Map 14
Continued on Map 10

80° 55' 00"
Continued on Map 12
80° 50' 00"

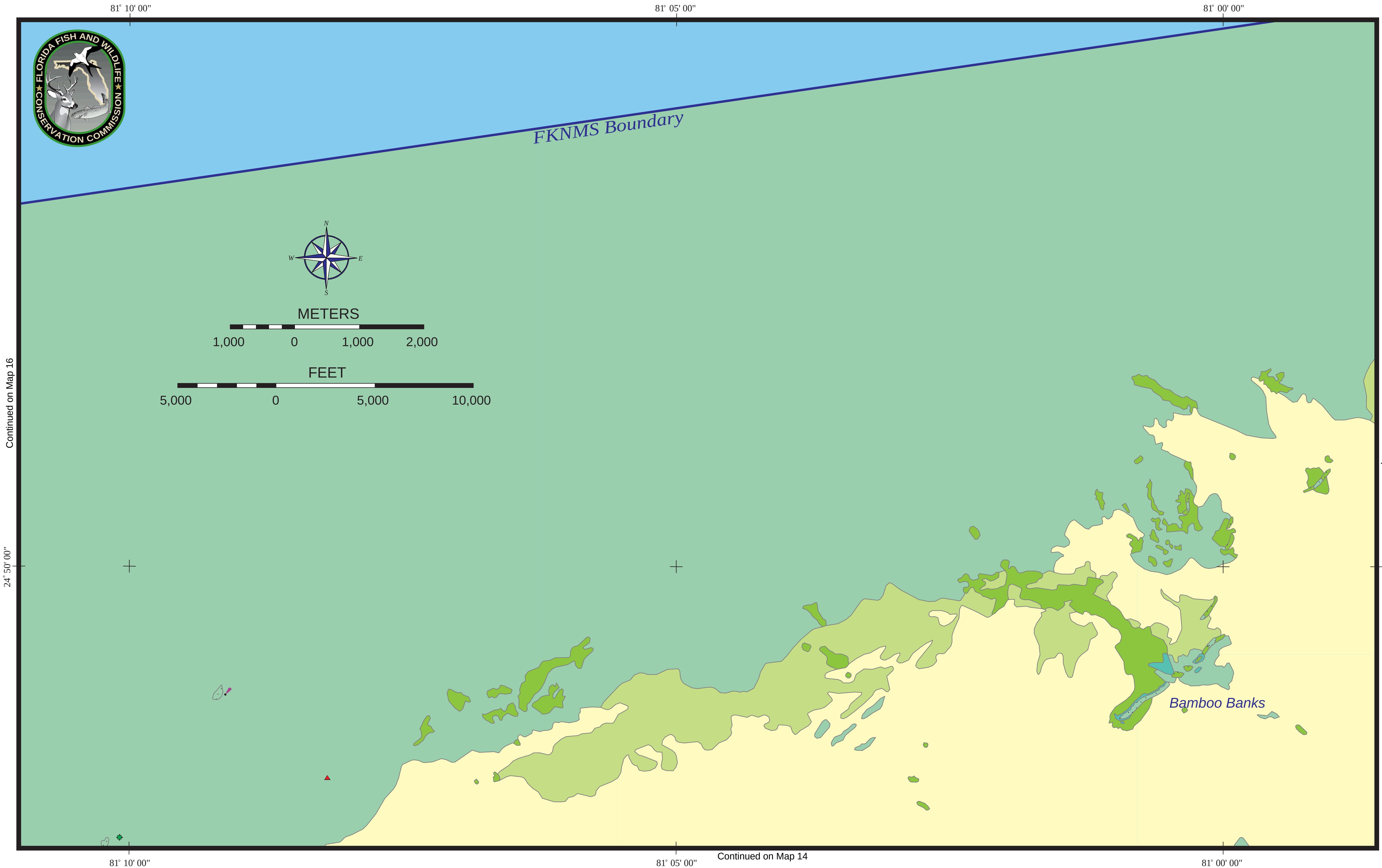
Continued on Map 11



Continued on Map 14

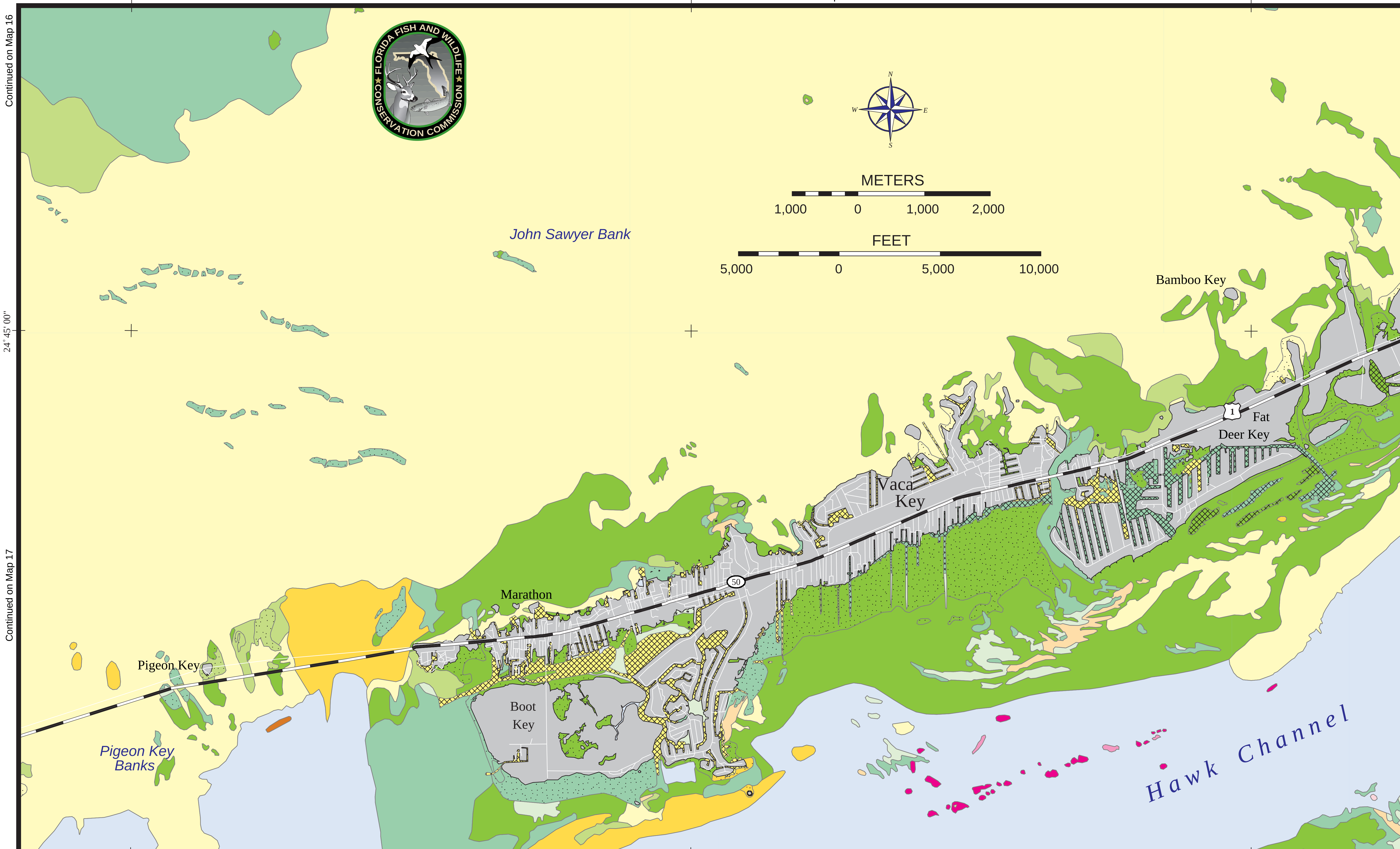
Continued on Map 15

Continued on Map 10



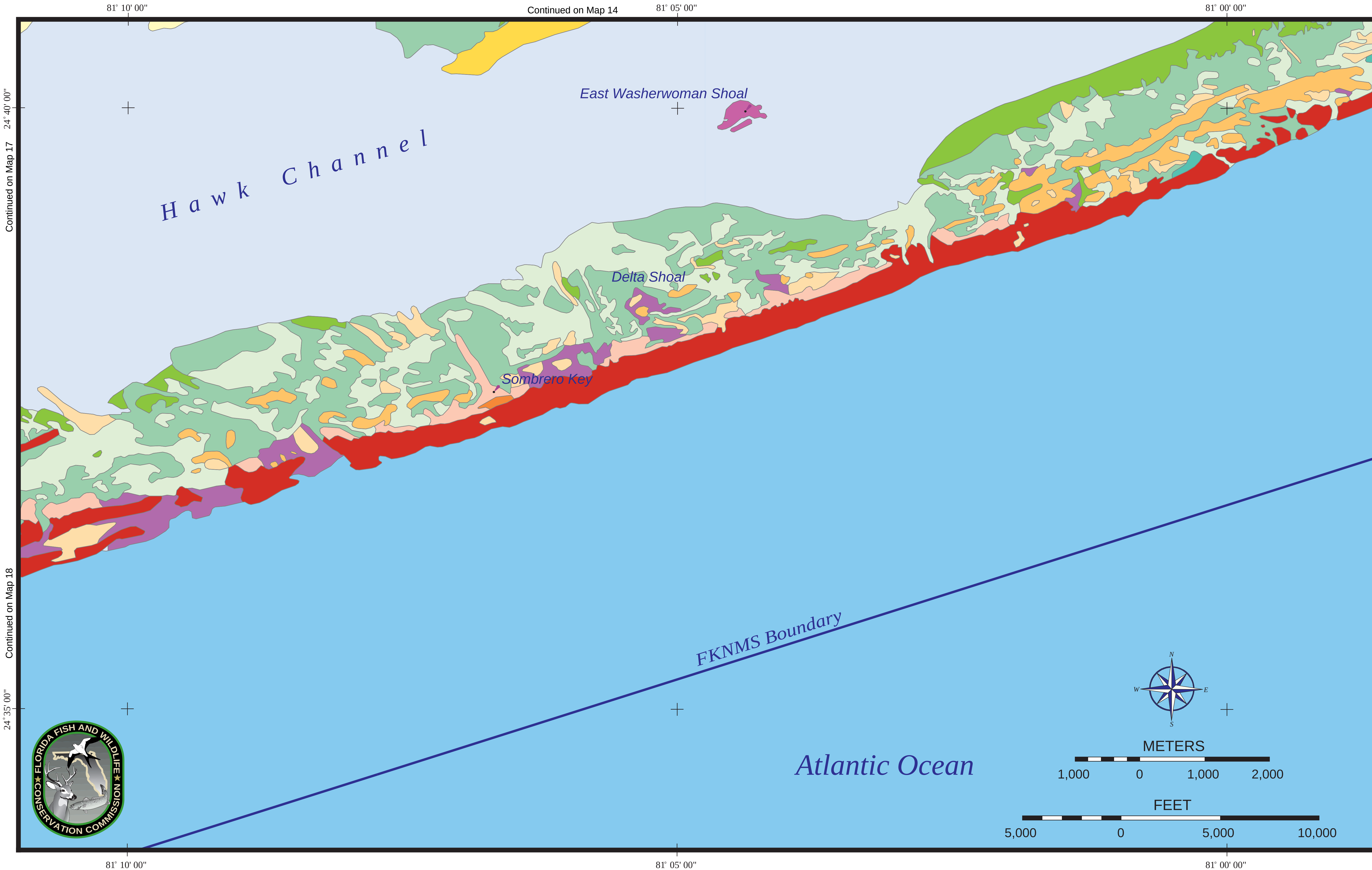
Continued on Map 16
Continued on Map 11
Continued on Map 14

Continued on Map 13
Continued on Map 16
Continued on Map 11



Continued on Map 17
Continued on Map 12
Continued on Map 15

Continued on Map 14



LOWER KEYS

Physical Environment

For this atlas, the Lower Keys extend from Pigeon Key to the Dry Tortugas. The area between Big Pine Key and Key West is characterized by a complex system of shallow bays and basins surrounded by hundreds of mangrove-fringed keys and developed shorelines. The Lower Keys form the widest land mass in the sanctuary (NOAA, 1996). In general, the islands are broad and flat and are separated by long, narrow channels. The Lower Keys are made up of the Miami Oolite, a series of lithified shoals that developed as part of the Key Largo Limestone. Highly porous, this formation is a southward-thickening wedge that reaches a maximum thickness of 10 m on the northern part of Stock Island. The islands west of Key West are mostly composed of unconsolidated sand, not the lithified coral banks and oolite sand that make up the rest of the Florida Keys.

Hawk Channel is deeper, by up to several meters, in the Lower Keys than it is in the Upper and Middle Keys. The channels between the Lower Keys are remnants of the original tidal channels that developed in the sand shoals. Several deep-water passes promote the exchange of Gulf of Mexico and Atlantic Ocean waters. Although these passes allow for water exchange, the land mass protects the reef tract from variable Gulf water conditions even though the Gulf of Mexico waters influence the Lower Keys region more directly than they influence either the Middle or Upper Keys region. One important offshore feature of the Straits of Florida is the Pourtales Terrace, a well-defined plateau that borders the Lower Keys. Currents associated with this terrace have a significant effect on the reef tract in this region (NOAA, 1996).

Human Activities and Uses

According to 1990 census figures, approximately 55% of the permanent-resident population and 38% of the seasonal-resident population are located in the Lower Keys (NOAA, 1996). Annually, approximately 1.7 million visits are made by tourists to the Lower Keys. Of these, 1.4 million visits are made to Key West. The City of Key West, with its large and relatively deep harbor, has historically been a hub of population and activity in the Keys. Prior to 1940, more than 90% of the Keys population was located in Key West.

Throughout the year, wildlife viewing / nature study and sight-seeing / attractions are the top-rated activities in the Lower Keys (Leeworthy and Wiley, 1996).

Protected Areas

The Lower Keys have the largest proportion of protected lands in the Keys. These lands include the National Key Deer Refuge and the Great White Heron and Key West National Wildlife refuges. State-protected areas include Bahia Honda State Park, Fort Zachary Taylor State Historical Site, and Coupon Bight Aquatic Preserve. Numerous local parks are also found in the Lower Keys, including two bird sanctuaries and a canoe trail managed by the City of Key West. Private lands under protection in the Lower Keys include a state-funded "Save Our Rivers" property on Big Pine Key and four small sites managed by the Florida Keys Land and Sea Trust. In 1981, the Looe Key National Marine Sanctuary (NMS), now part of the FKNMS, was established off Big Pine Key to protect approximately 1,800 ha of underwater habitat. Located within the FKNMS, although not part of it, is the Dry Tortugas National Park. Established as Fort Jefferson National Monument in 1935, the park contains 19,009 ha of protected underwater habitat (NOAA, 1996).

Environmental Concerns

Key West currently has no capital facility constraints that would limit growth within its boundaries. Concentrated residential, commercial, and industrial development on Stock Island and in the city of Key West have had adverse effects on the Lower Keys resources. A sewage treatment facility and an incineration plant operated by the City of Key West are two municipal sources of pollution in the Lower Keys. Such pollution of nearshore water causes phytoplankton and algae blooms, which reduces light penetration, to develop. This reduction in light quantity and quality impedes the growth and development of regional communities such as seagrass beds and coral reefs. For example, the number of seagrass beds, common elsewhere in the Keys, has declined in the Lower Keys, as has the number of well-defined coral reefs. In addition to nearshore, anthropogenic influences, water from the gulf filtering through the Dry Tortugas and major tidal passes in the region has a significant effect on the conditions in the Lower Keys. The seasonally controlled, cooler waters of the gulf are not conducive to reef growth. Also, adverse conditions "upstream" in the Middle Keys and Florida Bay can significantly affect the resources of the Lower Keys.

Benthic Habitats

The major benthic communities common throughout the Florida Keys are well represented in the Lower Keys, as are several significant, unique marine communities not found in the Upper and Middle Keys (e.g., the Quicksands, a bare-substrate habitat, and the Lakes Passage, a shallow and expansive seagrass habitat surrounding islands that are found between Key West and Boca Grande) (NOAA, 1996).

Seagrasses, the dominant benthic habitat in the Lower Keys, make up almost 75% of the mapped benthic habitats. Hardbottom composes approximately 16% of the mapped habitats; corals, 5%; and bare substrate, 4%.

Seagrass abundance is variable throughout much of the Lower Keys, and its overall abundance has declined. The Lakes Passage area is predominantly covered with seagrasses. In shallow-water areas on the gulf side ("backcountry") of the Lower Keys, turtle-grass (*Thalassia testudinum*) is the most common and most densely growing seagrass. The presence of the less common *Halophila* spp. has been documented only in the Lower Keys, where it has been found in relative abundance in the deep-water (24-30 meters) areas between Rebecca Shoal and the Dry Tortugas. In Hawk Channel and the backside of the reef tract between Looe Key and Key West, seagrass occurrence is uncommon. Seagrass is also relatively uncommon in the Quicksands area west of the Marquesas.

The coral reef tract in the Lower Keys extends from Looe Key reef to Cosgrove Shoal, south of the Marquesas. The best-developed section of the reef occurs between Looe Key and the Sambos, where excellent examples of spur-and-groove formations are found. Reef growth is enhanced here because land masses help protect this section of the Lower Keys from the seasonal water influences of the Gulf of Mexico. Reef growth declines from Sand Key to Cosgrove Shoal and farther west. The reef line west of Cosgrove Shoal can best be described as hardbottom with scattered live head corals and abundant gorgonians and sponges. Reef growth is again luxuriant farther west, in the vicinity of the Dry Tortugas, a circular group of islands that resembles an atoll. Reefs in this area are well developed but different from those in the Florida reef tract to the east. They are not of the typical spur-and-groove type and have very little elkhorn coral (*Acropora palmata*), a primary reef-builder in other parts of the Keys.

Landward of the reef tract, Hawk Channel contains many large coral heads and well-developed patch reefs. To the north, a series of linear reefs, oriented east-west and composed of patch-reef fauna,

LOWER KEYS

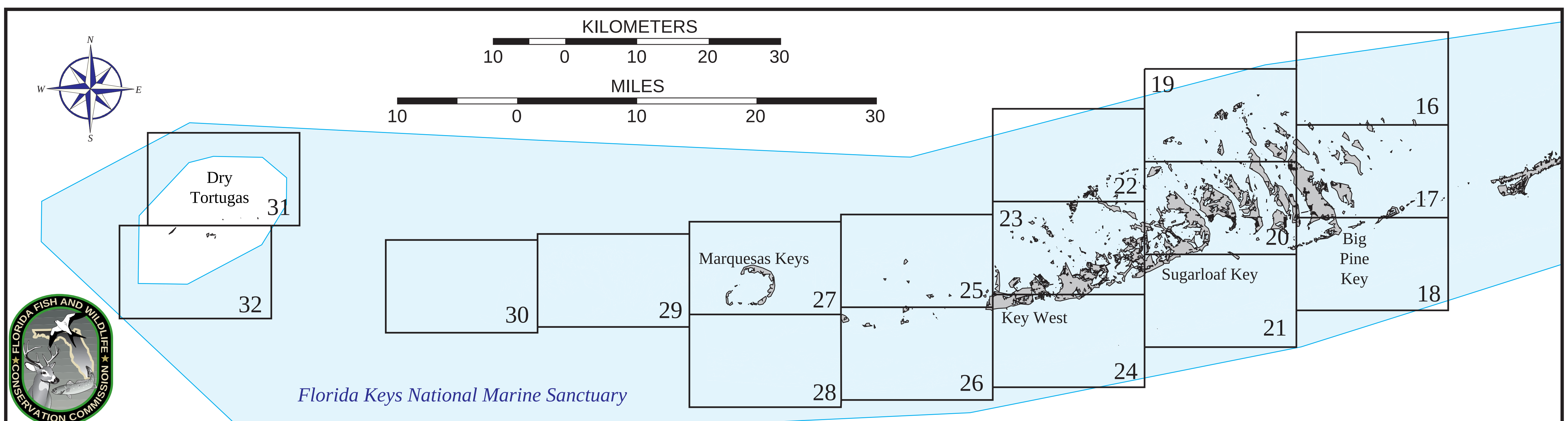
extends between Ellis Rock, north of the Marquesas, and New Ground Shoal. A series of patch reefs and coral heads on the Gulf of Mexico side of the Lower Keys extends from the Content Keys (north of Big Pine Key) to Smith Shoal (northwest of Key West). A scattering of topographic high points that show considerable patch-reef development occur in the deeper-water area between Rebecca Shoal and the Dry Tortugas. A significant coral bank concentration, known as the Tortugas Bank, lies west of the Dry Tortugas.

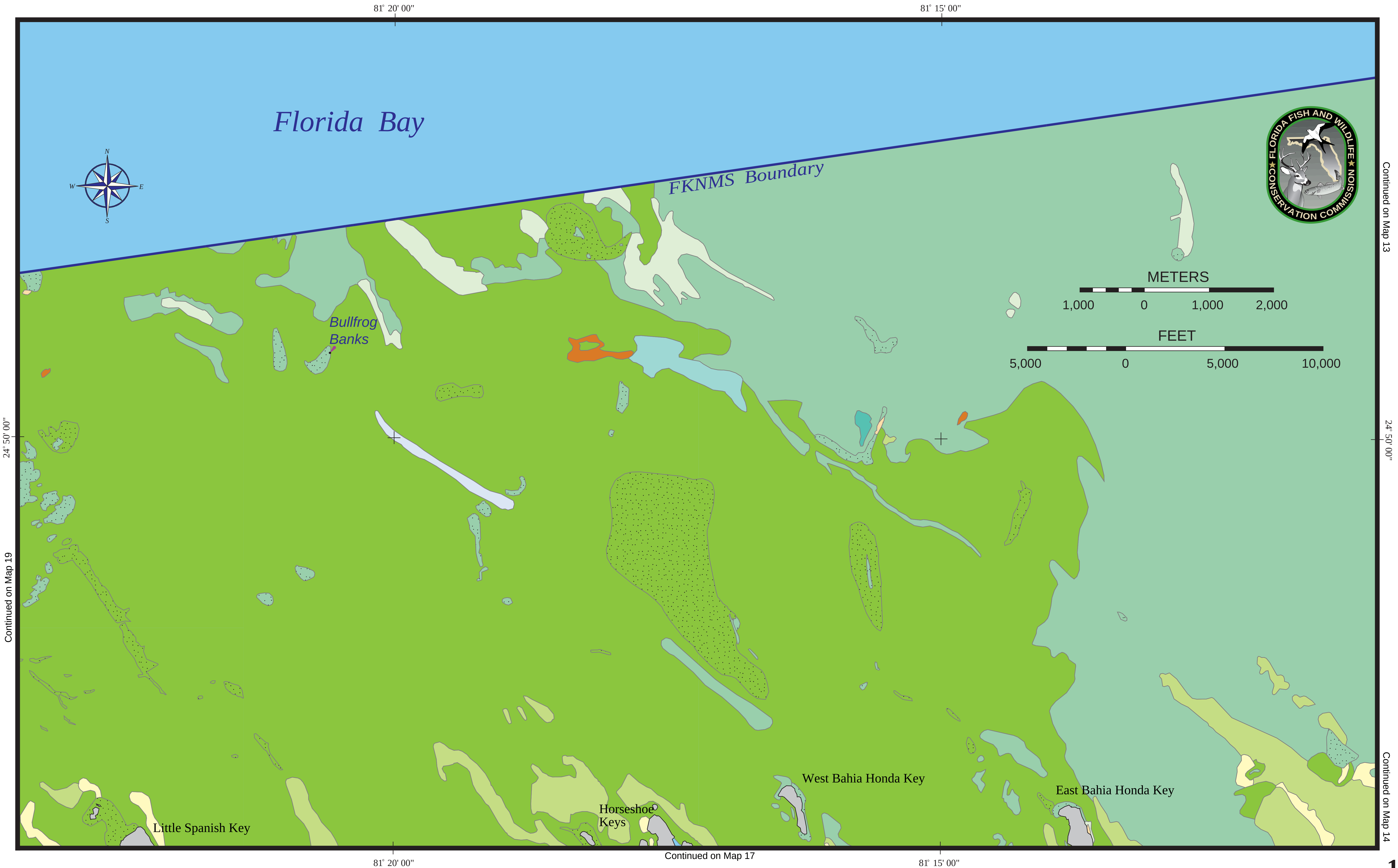
The area between the Marquesas, a circular accumulation of carbonate sand and mangrove islands, and Halfmoon Shoal, 20 miles to the west, is dominated by extensive current-swept sands that form sand waves as high as 2.7 meters. This area, appropriately named the Quicksands, contains sand formations up to 12.2 meters deep that are made up of the carbonate skeletons of the calcareous alga *Halimeda*.

Frequency of Occurrence of Benthic Habitats

The following table provides the areal extent of the four major classes of habitats in the Lower Keys. In general, the overall distribution of benthic communities in the Lower Keys mirrors that of benthic habitats in the Florida Keys.

	FLORIDA KEYS NATIONAL MARINE SANCTUARY			DRY TORTUGAS NATIONAL PARK		
HABITAT	HECTARES	ACRES	% MAPPED BOTTOM HABITAT	HECTARES	ACRES	% MAPPED BOTTOM HABITAT
Coral - Patch Reef	1,700	4,190	1	710	1,760	5
Coral - Platform Margin Reef	10,000	24,710	4	8,040	19,870	60
Hardbottom	630	1,560	<1	0	0	0
Hardbottom with Perceptible Seagrass (<50%)	36,280	89,650	16	20	40	<1
Seagrass	167,730	414,470	75	4,440	10,970	33
Bare Substrate	8,540	21,100	4	210	520	2
Total Mapped Habitat	224,880	555,680	100	13,420	33,160	100
Unknown Bottom/ Uninterpretable	50,200	124,060		6,410	15,830	
Total Bottom Habitat	275,080	679,740		19,830	48,990	
Land	19,520	48,240		40	100	
Total Area *(excludes open water)*	294,600	727,980		19,870	49,090	



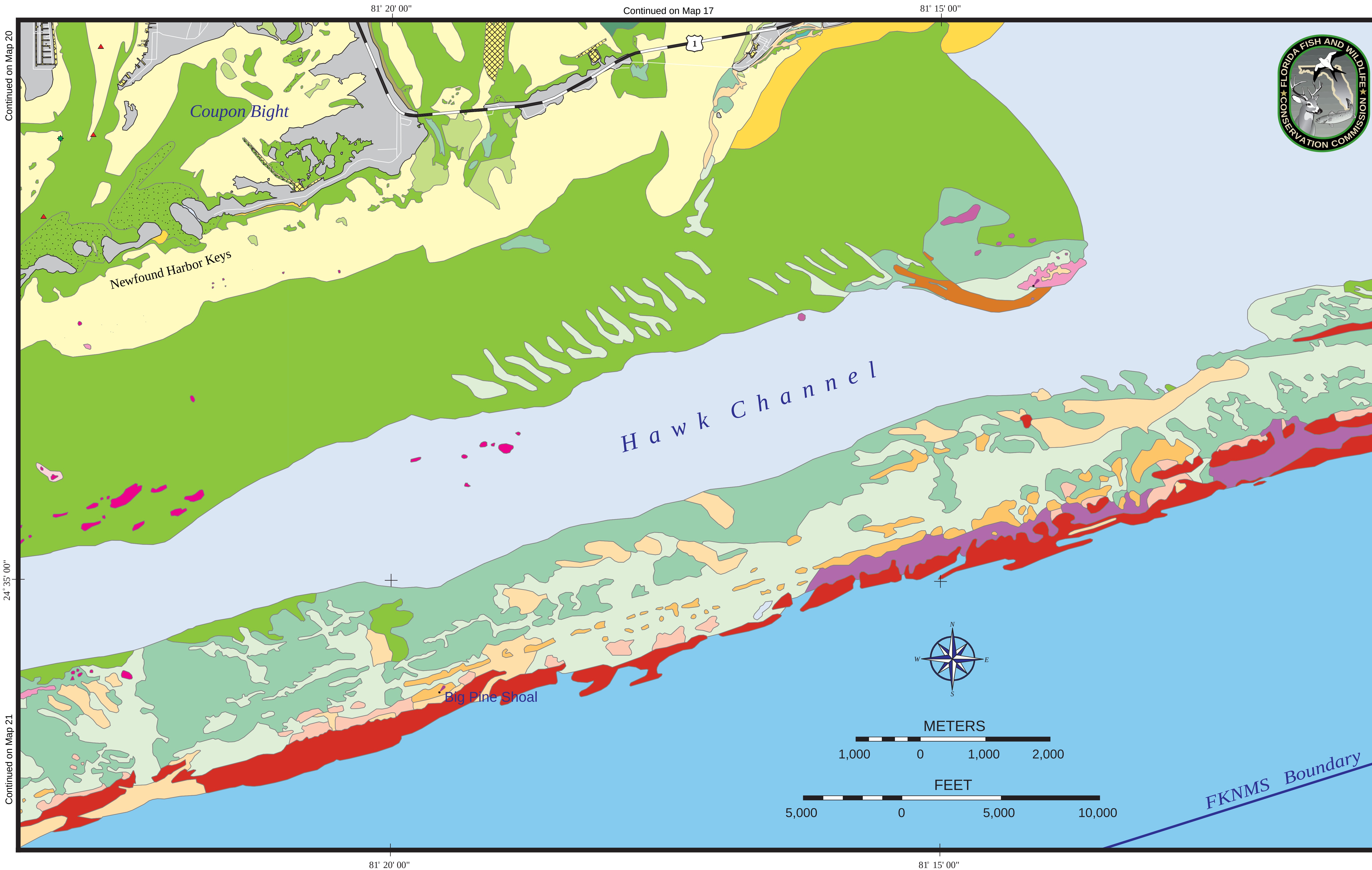


Continued on Map 13
Continued on Map 19
Continued on Map 14
Continued on Map 17

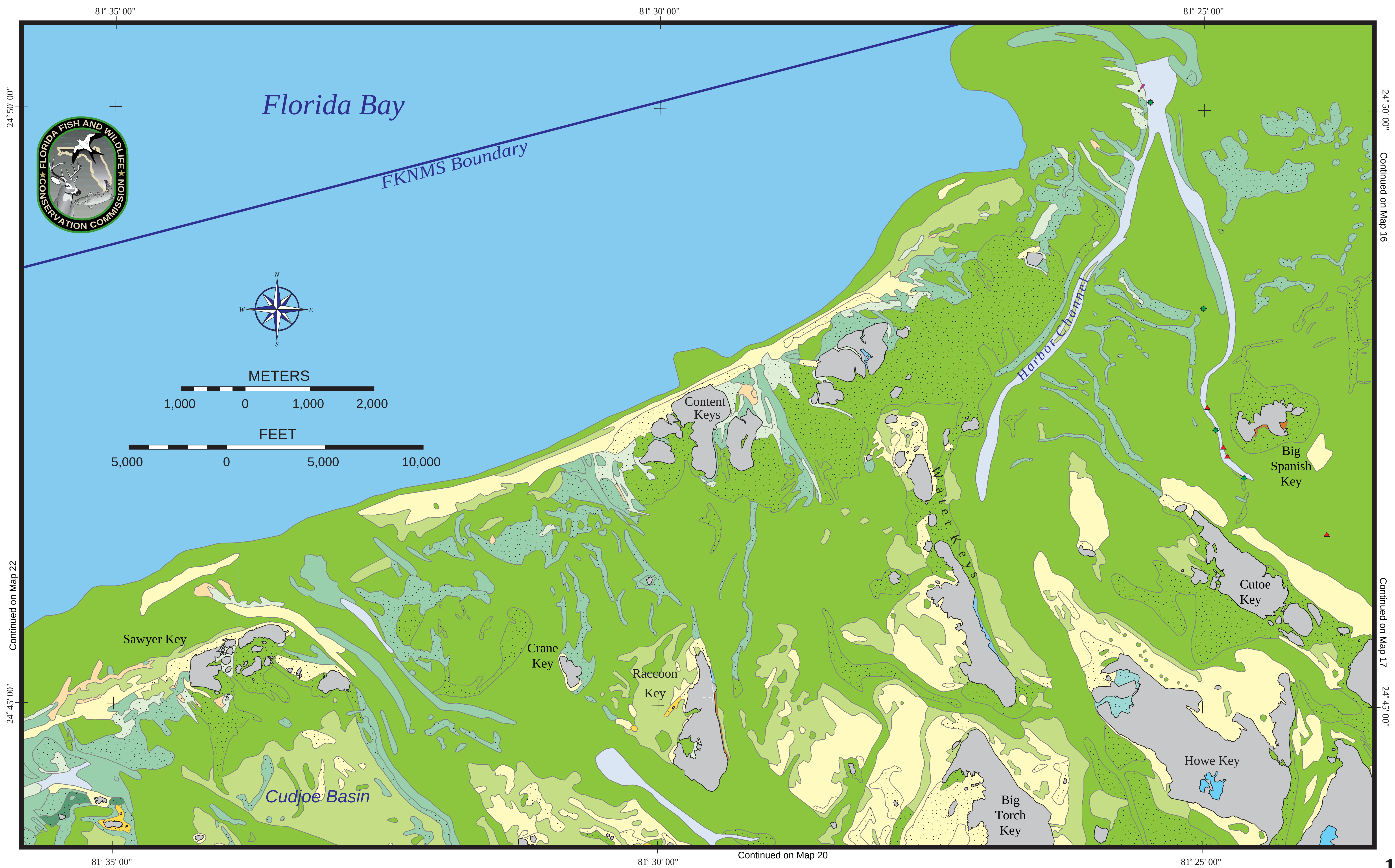
Continued on Map 16

Continued on Map 14
Continued on Map 19
Continued on Map 20
Continued on Map 15
Continued on Map 18

Continued on Map 17



Continued on Map 20
Continued on Map 21
Continued on Map 15



Continued on Map 16
Continued on Map 17
Continued on Map 22
Continued on Map 20

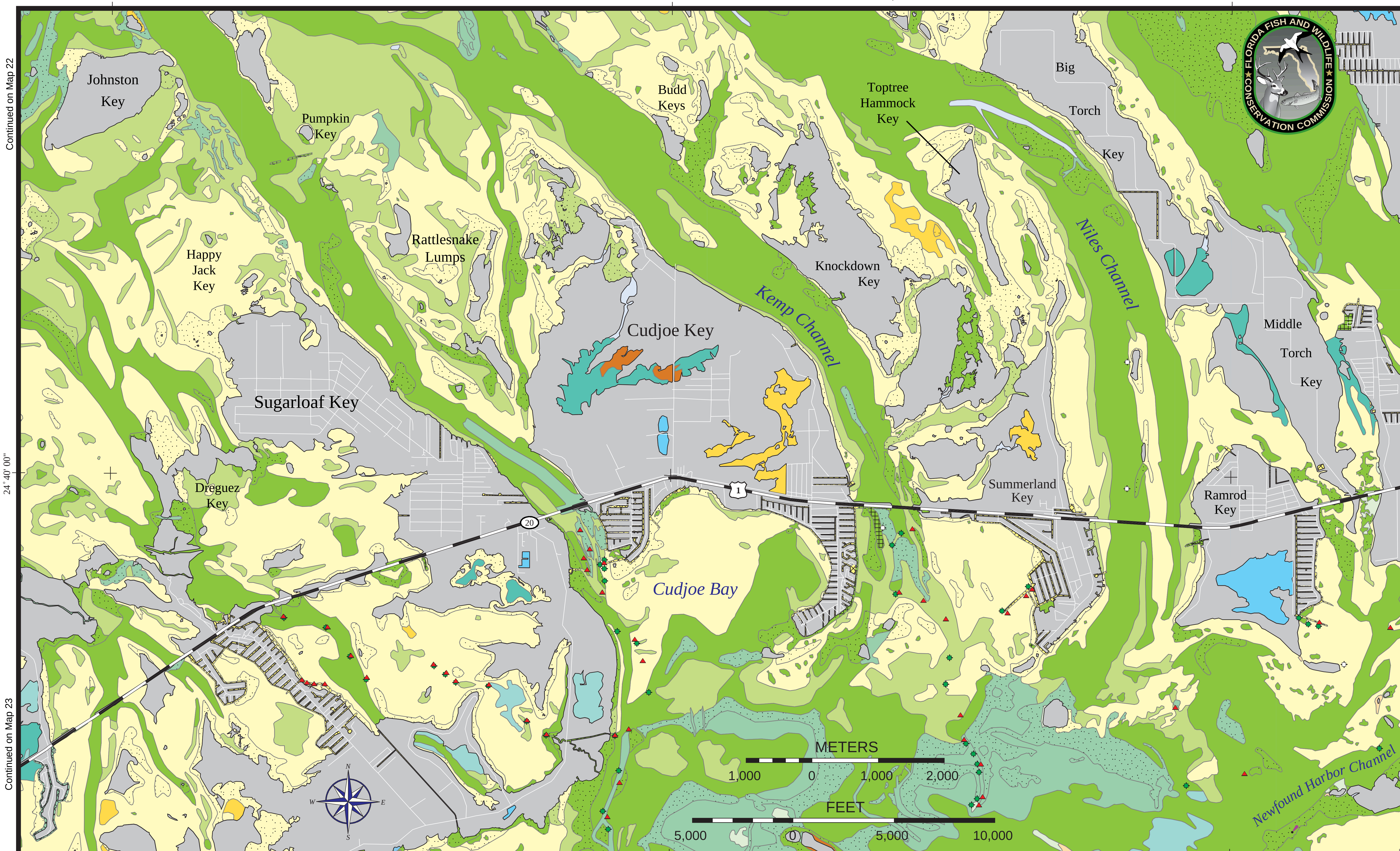
Continued on Map 19

Continued on Map 22

Continued on Map 23

Continued on Map 17

Continued on Map 18



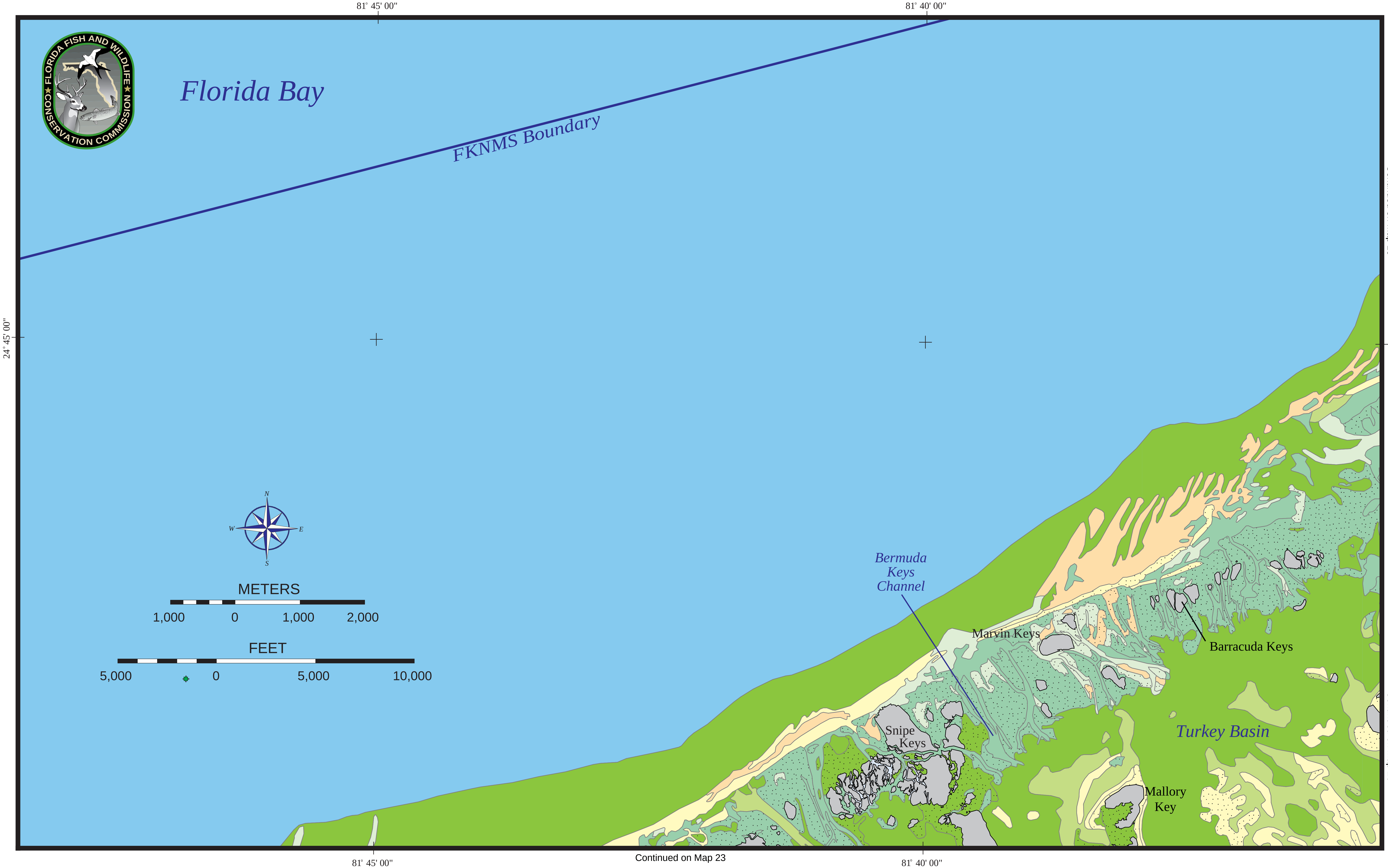
Continued on Map 21

Continued on Map 20

Continued on Map 23

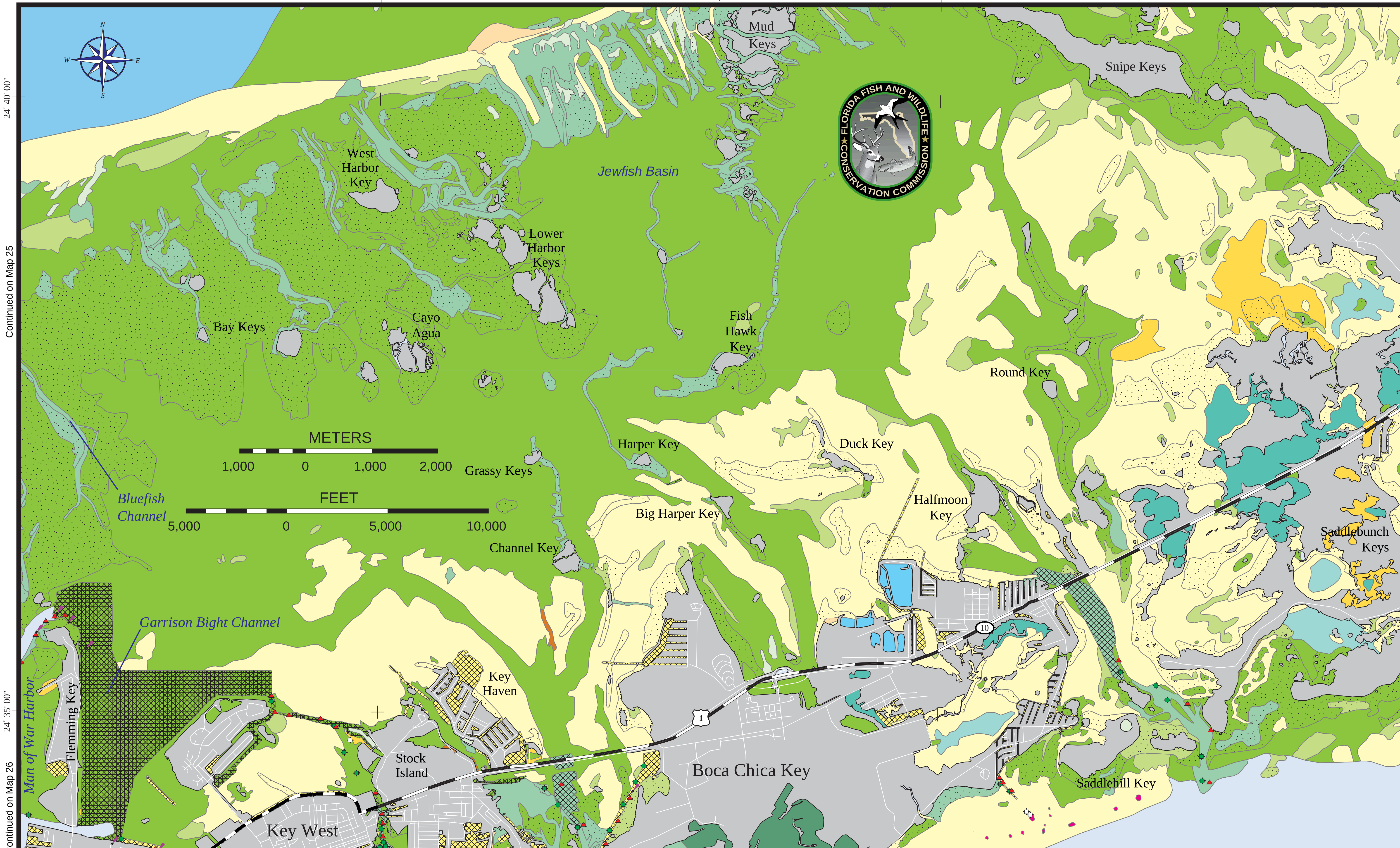
Continued on Map 24

Continued on Map 18



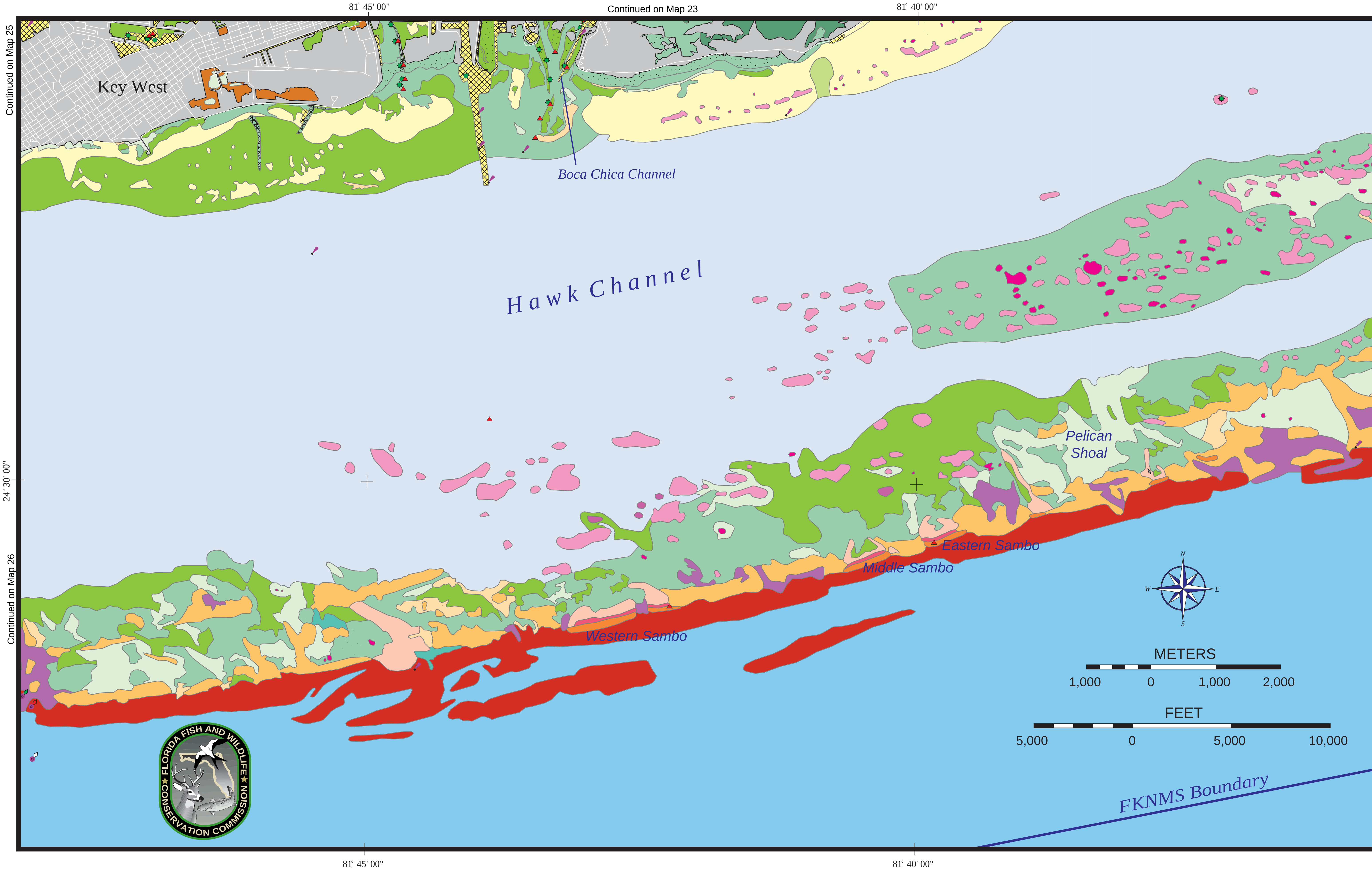
Continued on Map 19
Continued on Map 20
Continued on Map 23

Continued on Map 22



Continued on Map 25
Continued on Map 26
Continued on Map 20
Continued on Map 21
Continued on Map 24

Continued on Map 23



Continued on Map 25
Continued on Map 26
Continued on Map 21

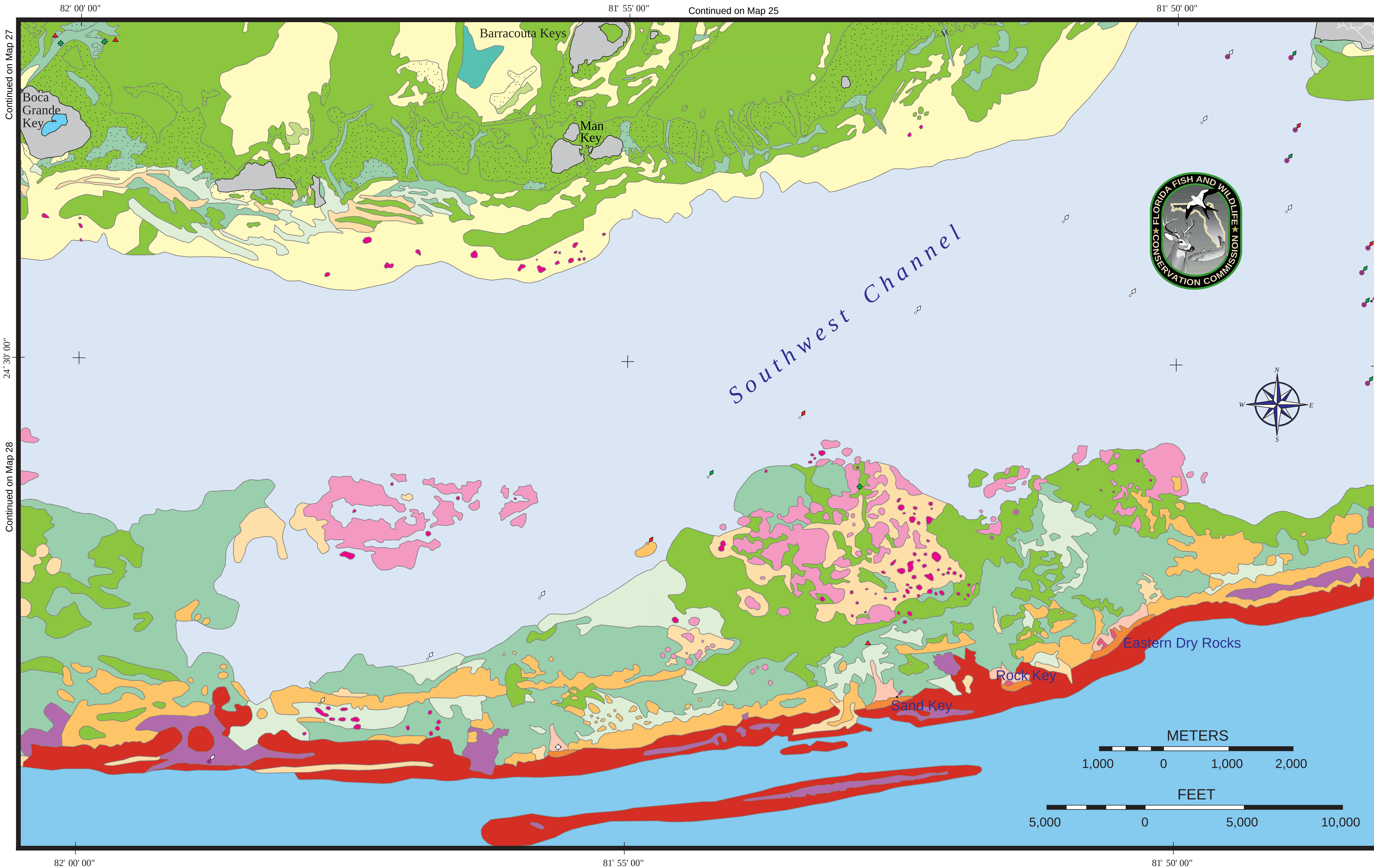
82°00'00" 81°55'00" 81°50'00"

24°35'00" 24°35'00"

82°00'00" 81°55'00" 81°50'00"

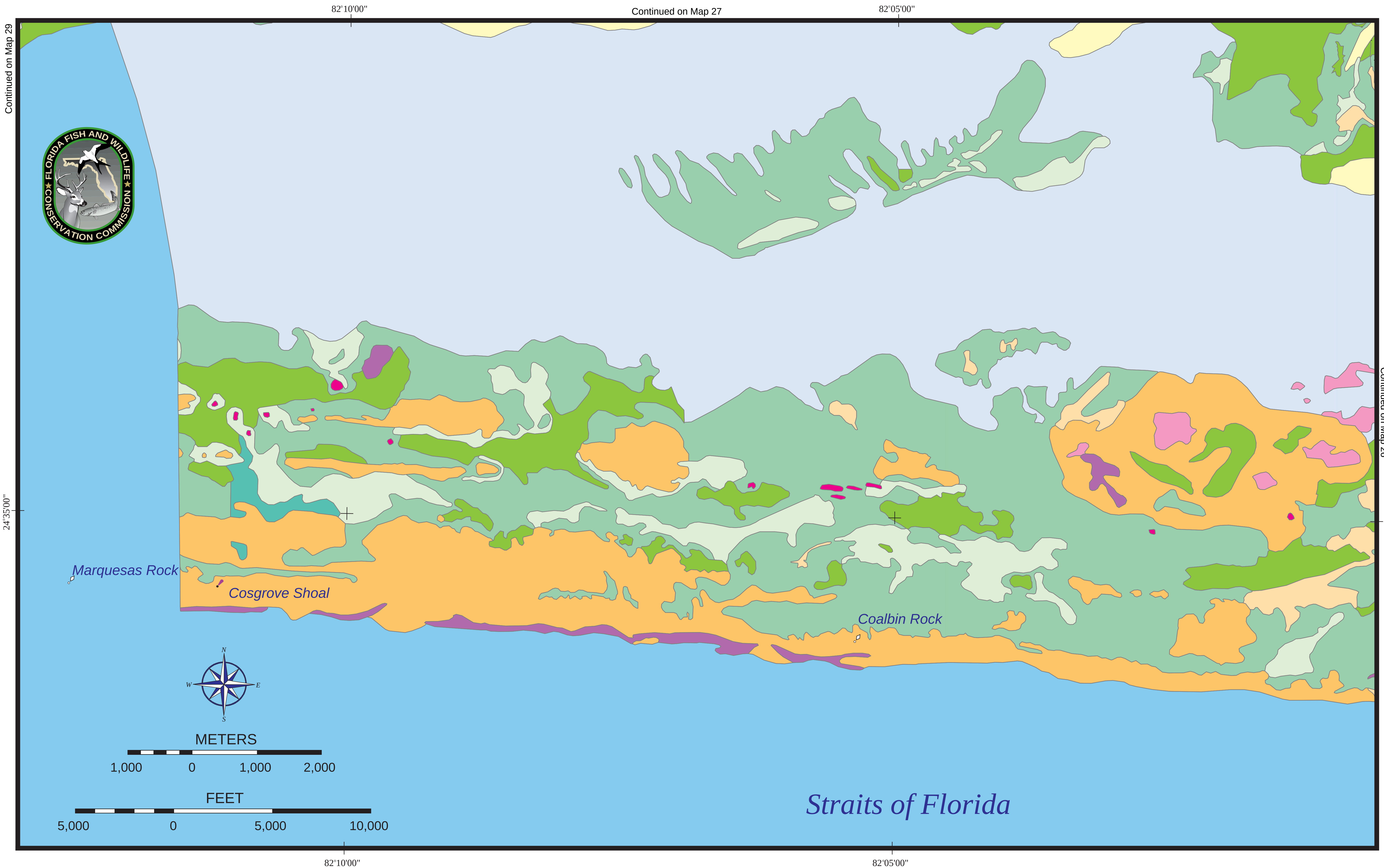
Continued on Map 27
Continued on Map 23
Continued on Map 24
Continued on Map 26

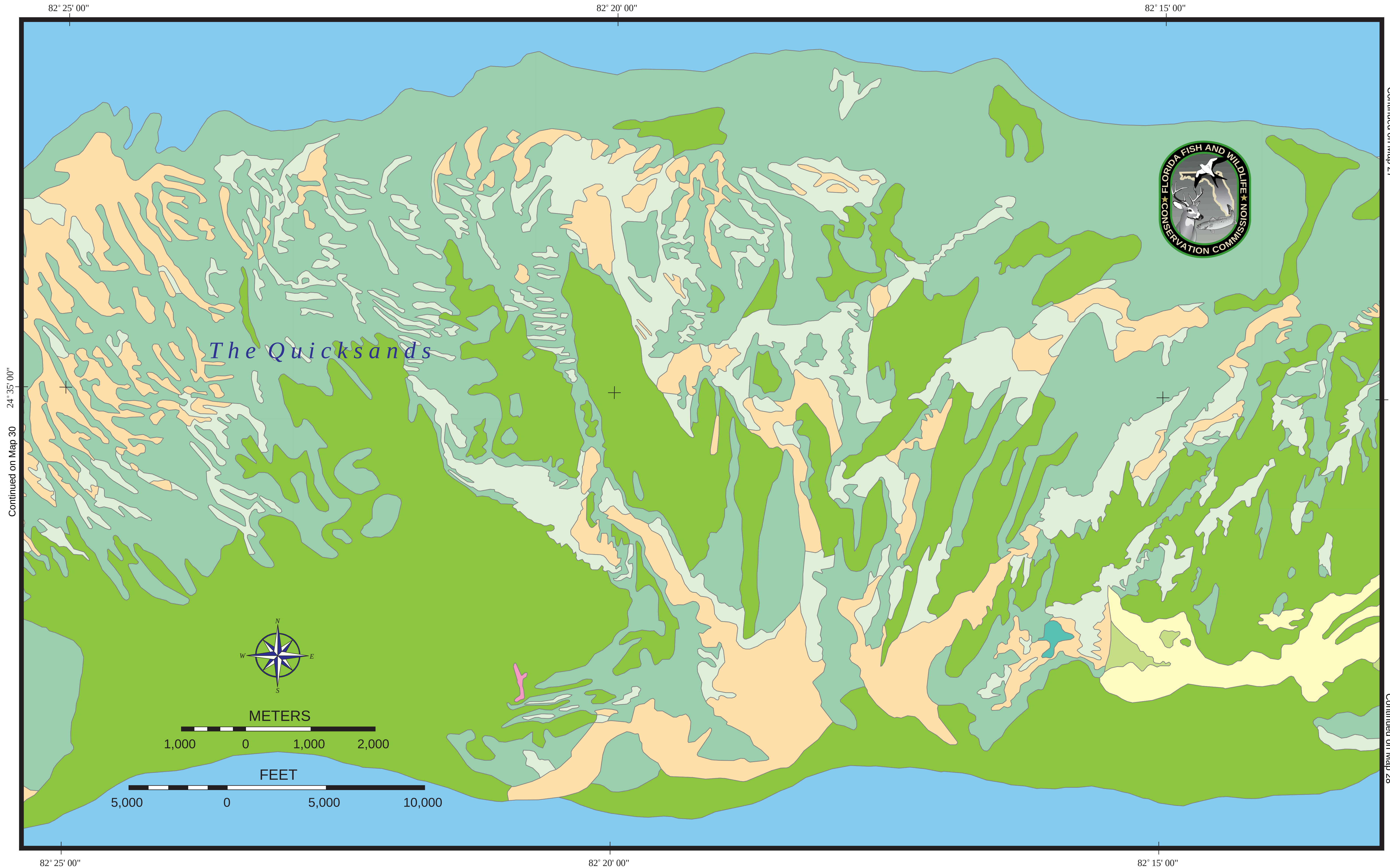
Continued on Map 25
Continued on Map 27
Continued on Map 28
Continued on Map 24

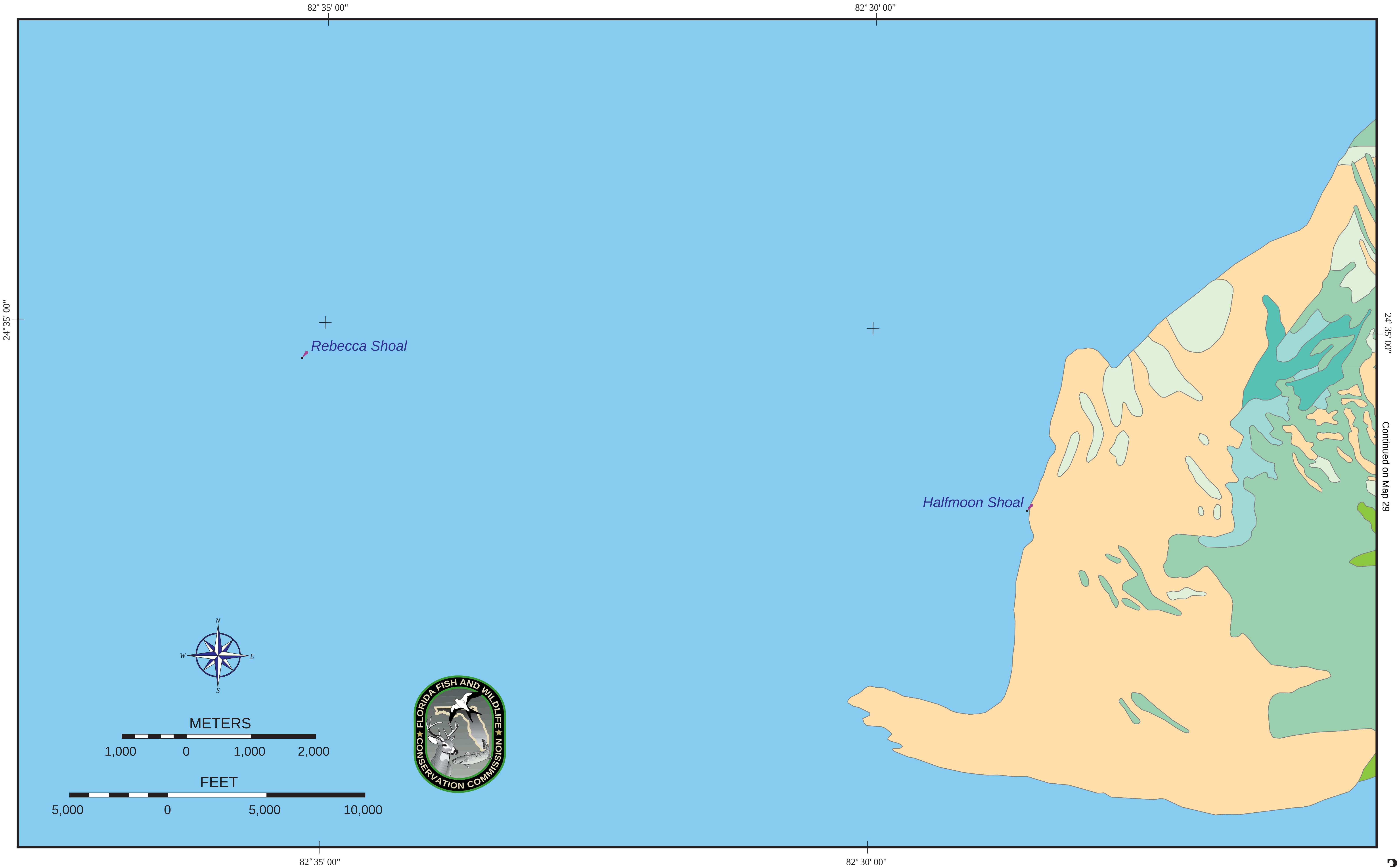


Continued on Map 29
Continued on Map 25
Continued on Map 26
Continued on Map 28

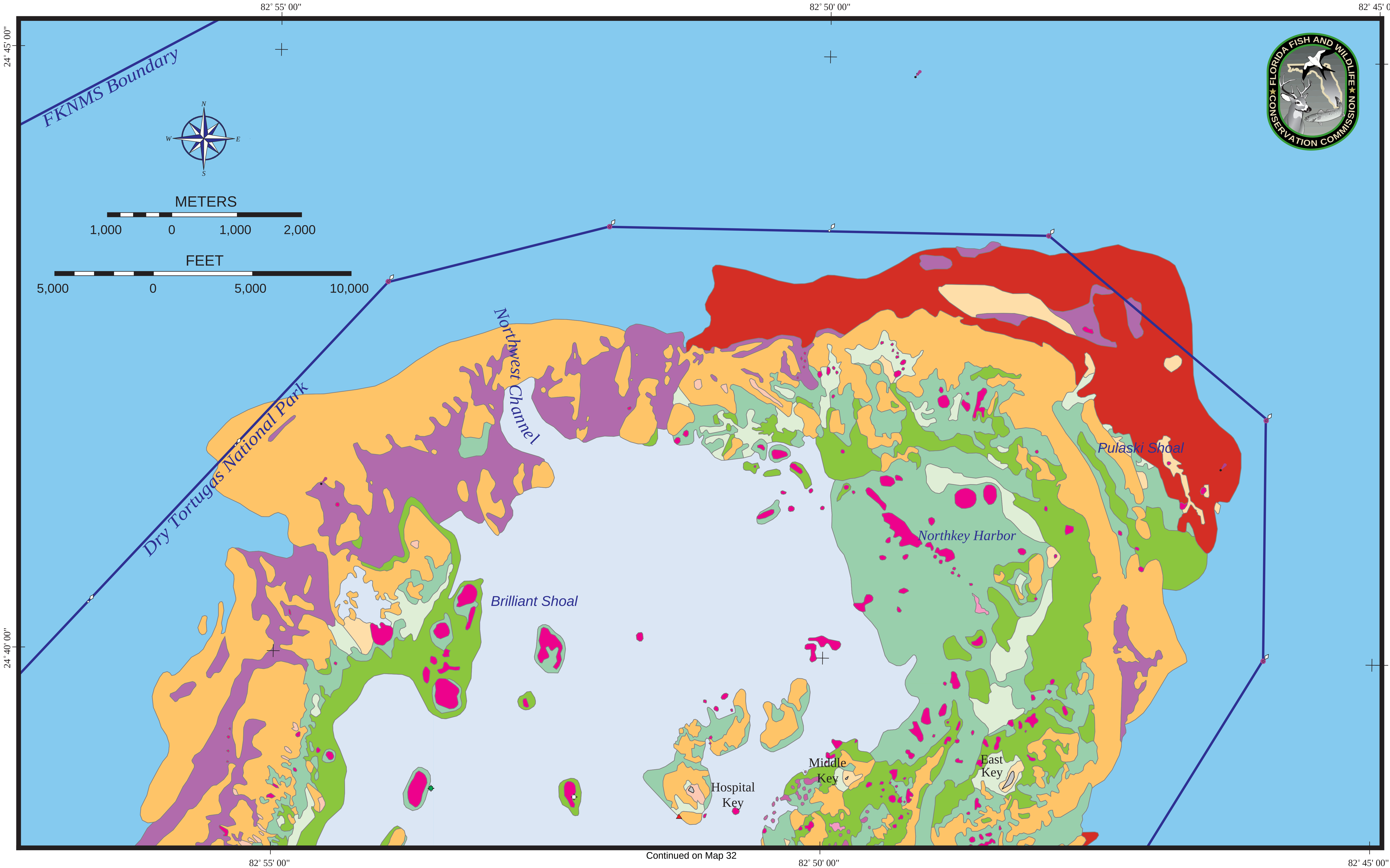
Continued on Map 27
Continued on Map 29
Continued on Map 26




82° 25' 00"
82° 20' 00"
82° 15' 00"
Continued on Map 27
Continued on Map 30
Continued on Map 28
24° 35' 00"
The Quicksands
FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION
N
E
S
W
METERS
1,000
0
1,000
2,000
FEET
5,000
0
5,000
10,000

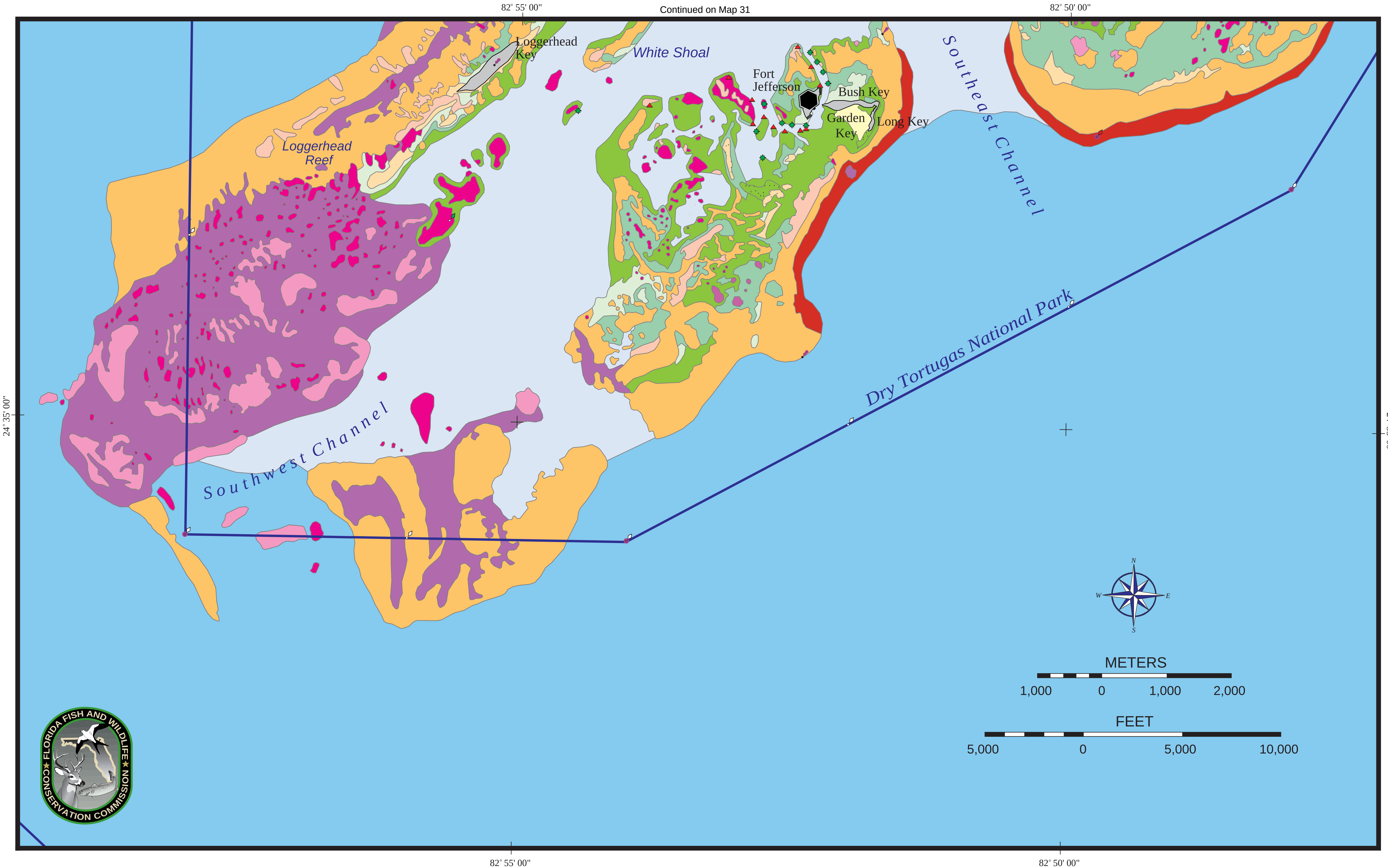


Continued on Map 29



Continued on Map 32

Continued on Map 31



GLOSSARY OF TERMS

Alcyonarian	Any of the members of the Subclass *Octocorallia* in the Phylum *Cnidaria*, also known as gorgonians or octocorals.
Back Reef	Referring to the area landward of the fore-reef and reef crest.
Barrier Reef	Reef adjacent to land masses and separated from them by a lagoon or channel of variable extent.
Bay	A partially enclosed inlet of the ocean.
Benthic or Bottom-dwelling	Defining a marine or freshwater organism living on the bottom, whether in shallow or deep water.
Biotope	An area characterized by uniform environmental conditions and biota.
Cnidarian	Any of the members of the animal phylum defined by a radially symmetrical body plan and diploblasticity.
Community	A natural association of organisms defined according to certain features of the environment.
Competition	The interaction among organisms for a common resource that is limited or in short supply.
Coral Reef	Massive limestone structure built up through the constructional cementing and depositional activities of hermatypic fauna (*e.g.*, hard corals) and flora (*e.g.*, coralline algae).
Coralline Algae	Any of the red algae belonging to the family *Corallinaceae* that secrete a calcareous shell or coating.
Density	The number of individuals per unit area or volume in ecological studies.
Ecotone	An area of intergradation between two biological communities or associations.
Epifauna	The marine benthic fauna living on the substrate or on other organisms.
Eurytopic	Refers to an organism tolerant of wide variations in the physical environment, as in temperature or salinity.
Foraminifera	An order of brackish and marine unicellular organisms usually enclosed in a shell.
Fore-Reef	The seaward edge or front of a reef.
Fringing Reef	A coral reef that forms immediately adjacent to a land mass.
Gorgonians	Alcyonarians of the Subclass *Octocorallia* that have spiculate internal skeletons; commonly called sea fans or sea whips.
Hard Coral	Colonial and solitary anthozoans and milleporid hydrocorals of the Phylum *Cnidaria* that deposit a calcium carbonate exoskeleton. Also referred to as stony corals.
Herbivore	An animal that consumes plant matter; an example of a reef herbivore is the spotlight parrotfish, *Sparisoma viride*.
Hypersaline	Used to describe waters of greater salinity than typical (35 ppt.) sea water.
Hypothermal	Indicating lower than normal water temperature resulting from an atmospheric cold front; very common in the Florida Keys, particularly in nearshore environments from November to March.
Infauna	The fauna living within sediment in marine or freshwater environments.
Mangrove	Common name for any of several species of inshore tropical trees or shrubs that dominate the mangal associations. Three species occur in south Florida: red (*Rhizophora mangle*), black (*Avicennia germinans*), and white (*Laguncularia racemosa*).
Octocoral	See alcyonarian.
Oligotrophic	Containing little nutrient material.
Photoautotrophic	Refers to an organism that is capable of deriving energy from inorganic substances by chemical reactions (*e.g.*, photosynthesis) induced by light.
Reef	A submarine mound or ridge constructed of or formed by marine organisms depositing calcium carbonate.
Reef Tract	A reef system, such as the Florida Keys Reef Tract.
Salinity	The total amount of dissolved salts in sea water, ex pressed in parts per thousand (ppt).
Seagrass	Collective name for marine flowering plants of the families Potamogetonaceae and Hydrocharitaceae. The three common species in the Florida Keys and environs are turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), and manatee grass (*Syringodium filiforme*).
Sessile	An organism that is fixed in place.
Species Diversity	In ecology, a numerical measure combining the number of species in an area with their relative abundance.
Species Richness	In ecology, refers to the total number of species in an area.
Sponge	Organism belonging to the Phylum Porifera. Class Demospongeae are most abundant on reefs and are characterized by internal spicules (skeletal structures) and a diversity of morphotypes and shapes (*e.g.*, encrusting, boring, vase, tube, massive).
Spur and Groove	A system of coralline spurs or fingers and sand grooves oriented perpendicular to the predominant swell. In the Florida Keys, high-relief spurs were built by elkhorn coral (*Acropora palmata*) during the Holocene but are currently dominated by coralline algae, turf algae, the hydrozoan *Millepora complanata*, and the colonialoanthid *Palythoa caribaeorum*.
Turbidity	Condition of reduced water clarity caused by the presence of suspended particles.

REFERENCES

Agassiz, A. 1885. The Tortugas and Florida reefs. *Memoirs of the American Academy of Arts and Sciences* **11,** 107-134.

Agassiz, L. 1852. Florida reefs and coast. *Annual Report Supt. Coast Survey for 1851*, 107-134.

Bagby, M. 1978. *The ecology of patch reef gorgonians of the coast of Key Largo, Florida*. Miami, FL: Florida International University. 28 pp.

Bayer, F. 1961. *The shallow-water octocorals of the West Indian region*. The Hague, Netherlands: Martin Nijhoff. 373 pp.

Bright, T.J., W. Jaap, and C. Cashman 1981. Ecology and management of coral reefs and organic banks. In *Proceedings, environmental research needs in the Gulf of Mexico*, 53-160. Miami, FL: National Oceanic and Atmospheric Administration.

Cairns, S. 1977. *Guide to the commoner shallow-water gorgonians of Florida, the Gulf of Mexico, and the Caribbean region*. Sea Grant Field Guide 6. Miami, FL: University of Miami Press. 74 pp.

Cary, L. 1918. The Gorgonacea as a factor in the formation of coral reefs. *Carnegie Institute of Washington Publication* **213,** 341-362.

Chiappone, M. 1996. *Marine benthic communities of the Florida Keys. Site characterization for the Florida Keys National Marine Sanctuary*, Vol. 4. Zenda, WI: The Preserver, Farley Court of Publishers. 63 pp.

Dahl, A., B. Patton, S. Smith, and J. Zieman, Jr. 1974. A preliminary coral reef ecosystem model. *Atoll Research Bulletin* **172**, 6-36.

Darwin, C. 1842. *On the structure and distribution of coral reefs and geological observations on the volcanic islands and parts of South America visited during voyage of HMS Beagle*. London: Ward Lock and Co. 549 pp.

Davis, G.E. 1982. A century of natural change in coral distribution at the Dry Tortugas: A comparison of reef maps from 1881 and 1976. *Bulletin of Marine Science* **32(2)**, 608-623.

Dustan, P. 1977. Besieged reefs of the Florida Keys. *Natural History* **86(4)**, 73-76.

Enos, P. 1970. Carbonate sediment accumulations of the south Florida shelf margin. *Shell Development Company Technical Report*. **EPR 29-7–F**, 114 pp.

Fourqurean, J.W., M.J. Durako, and J.C. Zieman. 1997 (unpublished report). *Florida Keys National Marine Sanctuary water quality protection program: Seagrass status and trends monitoring. Annual report to the Environmental Protection Agency for fiscal year 1996*. Miami, FL: Florida International University. 35 pp.

Ghiold, J. and P. Enos. 1982. South Florida patch reefs in carbonate production of the coral *Diploria labyrinthiformis. Marine Geology* **45**, 281-296.

Ginsburg, R.N. and E.A. Shinn. 1964. Distribution of the reef building community in Florida and the Bahamas (abstract). *Bulletin of the Marine Association of Petroleum Geology* **48**, pp. 527.

Grassel, F. 1973. Variety in coral reef communities. In *Biology and Geology of Coral Reefs*, Vol. 2, O. Jones and R. Endean (eds.), pp. 247-270. New York City: Academic Press.

Halley, R.B. 1979. Guide to sedimentation for the Dry Tortugas. *Southeastern Geological Society* **21**, pp 98.

Hoffmeister, J.E. 1974. *Land from the sea*. Miami, FL: University of Miami Press. 143 pp.

Hubbard and Pocock, 1972. Sediment rejection by recent scleractinian corals: a key to paleo-environmental reconstruction. *Geologische Rundschau* **61**, 598-626.

Kinzie, Robert A. III, 1996. Reefs Happen. *Global Change Biology* **2**, 479-494.

Leeworthy, V.R. and P.C. Wiley. 1996. Visitor Profiles: Florida Keys / Key West. Silver Springs, MD: NOAA, Strategic Environmental Assessments Division. 159 pp.

Lott, C., R. Dye, K.M. Sullivan. 1996. *Historical Overview of Development and Natural History of the Florida Keys. Site Characterization for the Florida Keys National Marine Sanctuary and Environs*, Vol. 3. Zenda, WI: The Preserver, Farley Court of Publishers. 49 pp.

Jaap, W.C. 1984. *The ecology of south Florida coral reefs: A community profile*. U.S. Fish and Wildlife Service, Office of Biological Services, FWS / OBS 82 / 08. Washington, DC: U.S. Government Printing Office. 138 pp.

Jaap, W.C. and P. Hallock. 1990. Coral reefs. In *Ecosystems of Florida*, R.L. Myers and J.J. Ewel (eds.), pp. 574-616. Orlando, FL: University of Central Florida Press.

Jones, J.A. 1977. Morphology and development of southeast Florida patch reefs. In *Proceedings of the Third International Coral Reef Symposium* **2**, 231-235.

Kissling, D.L. 1965. Coral distribution on a shoal in Spanish Harbor, Florida Keys. *Bulletin of Marine Science* **15(3)**, 599-611.

Lecompte, M. 1937. Some observations on the coral reefs in the area of Dry Tortugas. *Carnegie Institute of Washington Annual Report of TortugasLab*, 96.

Marszalek, D., G. Babashohh, M. Noel, and P. Worley. 1977. Reef distribution in south Florida. In *Proceedings of the Third International Coral Reef Symposium* **2**, 223-230.

Matthai, G. 1916. Preliminary report on the comparative morphology of recent *Madreporaria* around Tortugas. *Carnegie Institute of Washington Year Book* **14**, 209.

Monroe County Planning Department. Marine Facility Survey. Unpublished 1997-1998.

National Oceanic and Atmospheric Administration. 1996. *Florida Keys National Marine Sanctuary Final Management Plan/Environmental Impact Statement*; volume II. Silver Spring, MD: NOAA. 245 pp.

Opresko, D. 1973. Abundance and distribution of shallow-water gorgonians in the area of Miami. *Bulletin of Marine Science* **23(3),** 535-558.

Pourtales, L.F. 1880. Report on the results of dredging in the Gulf of Mexico by the U.S. coast steamer *Blake*. Report VI: Corals and Antipatharia. *Bulletin of the Museum of Comparative Zoology Harvard College* **6**, 95-120.

Robertson, P.B. 1963. (unpublished master's thesis). *The marine rock-boring fauna of southeast Florida*. Miami, FL: University of Miami.

Sargent, F.J., T.J. Leary, D.W. Crewz, and C.R. Kruer. 1995. *Scarring of Florida's seagrasses: Assessment and management options*. FMRI Technical Report TR-1. St. Petersburg, FL: Florida Marine Research Institute. 37 pp. plus appendices.

Shinn, E.A. 1963. Spur and groove formation on the Florida reef tract. *Journal of Sedimentary Petrology* **33(2)**, 291-303.

REFERENCES

Shinn, E.A., J.H. Hudson, R.B. Halley, and B. Lidz. 1977. Topographic control and accumulation rate of some Holocene coral reefs: south Florida and Dry Tortugas. In *Proceedings of the Third International Coral Reef Symposium **2**, 1-7.*

Shinn, E.A. 1980. Geologic history of Grecian Rocks, Key Largo Coral Reef Marine Sanctuary. *Bulletin of Marine Science* **30(3)**, 646-656.

Schmahl, G.P. and J.T. Tilmant. 1980. An initial characterization of macroinvertebrate populations associated with patch reefs in Biscayne National Park. *Florida Scientist* **43**, 6.

Smith, F.G.W. 1943. Littoral fauna of the Miami area: *I. Madreporaria. Proc. Fla. Acad. Sci*. **6(1)**, 41-48.

Stanley, Jr GD. 1981. Early history of scleractinian corals and its geological consequences. *Geology*, 9, 507-511.

Stephenson, T.A. and A. Stephenson. 1950. Life between the tide marks in North America I: The Florida Keys. *Journal of Ecology* **38(2)**, 354-402.

Stoddard, D.R. 1969. Ecology and morphology of recent coral reefs. *Biological Reviews of the Cambridge Philosophical Society* **44**, 433-498.

Vaughan, T.W. 1914a. Investigations of the geology and geological processes of the reef tracts and adjacent area in the Bahamas and Florida. *Carnegie Institute of Washington Year Book* **12**, 181-183.

Vaughan, T.W. 1914b. Sketch of the geologic history of the Florida coral reef tract. *Journal of the Washington Academy of Sciences* **4**, 26.

Voss, G.L. and N.A. Voss. 1955. An ecological survey of Soldier Key, Biscayne Bay, FL. *Bulletin of Marine Science Gulf and Caribbean* **5(3)**, 203-229.

Wells, J.W. 1957. Corals. A treatise on marine ecology and paleocology, J. Hedgpeth (ed.), pp. 1087-1104. Ecology. *Geological Society of America Memoirs* ***1,*** 67.

Wells, J.W. 1932. Study of the reef corals of the Tortugas. *Carnegie Institute of Washington Year Book* **31**, 290.

Zieman, J.C. 1982. The ecology of the seagrasses of South Florida: A community profile. U.S. Fish and Wildlife Service, Office of Biological Services. FWS / OBS 82 / 25. Washington, D.C.: U.S. Government Printing Office. 158 pp.

Zieman, J.C. 1990. Coastal and nearshore communities: Seagrass beds. In *Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South area, geologic setting*, N.Phillips and K. Larson (eds.), 657 pp. Jupiter, FL: Continental Shelf Associates, Inc.

METRIC CONVERSION TABLE

Linear Measurement	Area Measurement
1 foot = 0.305 meter **1 meter** = 3.281 feet = 0.001 kilometer **1 kilometer** = 1,000 meters = 0.621 statute mile **1 statute mile** = 5,280 feet = 1.609 kilometers = 0.869 nautical mile **1 nautical mile** = 6,076.12 feet = 1.852 kilometers = 1.151 statute miles	**1 acre** = 43,560 square feet = 4,046.86 square meters = 0.405 hectare = 0.00156 square statute mile **1 hectare** = 2.471 acres = 10,000 square meters = 0.01 square kilometer = 0.00386 square statute mile **1 square kilometer** = 247.105 acres = 100 hectares = 0.386 square statute mile **1 square statute mile** = 640 acres = 258.999 hectares = 2.59 square kilometers = 0.755 square nautical mile **1 square nautical mile** = 847.544 acres = 3.43 square kilometers = 1.324 square statute miles
Mass Measurement	**Unit Abbreviations**
1 pound = 0.0005 ton = 0.454 kilogram **1 ton** = 2,000 pounds = 0.907 metric ton **1 kilogram** = 2.205 pounds = 0.001 metric ton **1 metric ton** = 2,240 pounds = 1.102 tons	foot (ft) hectare (ha) kilometer (km) meter (m) nautical mile (nmi) statute mile (mi) pound (lb) parts per thousand (ppt) square kilometer (km^2) square meter (m^2) square nautical mile (nmi^2) square statute mile (mi^2)

LEGEND

CORALS

Patch Reefs

- Individual Patch Reef
- Aggregated Patch Reef
- Halo
- Aggregated Patch Reef with Halo
- Coral or Rock Patches with Bare Sand

Platform Margin Reefs

- Shallow Spur and Groove
- Drowned Spur and Groove
- Remnant - Low Profile
- Back Reef
- Reef Rubble

SEAGRASSES

Continuous Seagrass

- Moderate to Dense, Continuous Beds
- Sparse, Continuous Beds
- Dense Patches in a Matrix of Sparse Seagrass (>50%)

Patchy Seagrass

- Moderate to Dense, Discontinuous Beds with Blowouts
- Dense Patches in a Matrix of Hardbottom
- Predominantly Sand/Mud with Small, Scattered Seagrass Patches (<50%)
- Predominantly Macroalgae Cover with Scattered Seagrass Patches

HARDBOTTOM

- Soft Corals, Sponges, Algae
- Hardbottom with Perceptible Seagrass (<50%)

BARE SUBSTRATE

- Carbonate Sand
- Carbonate Mud
- Organic Mud

OTHER

- Land
- Inland water
- Open Water
- Unknown Bottom/Uninterpretable
- Unknown Bottom/Uninterpretable Dredged
- Banks
- Dredged
- Restoration

MARKERS

- Daybeacon
- Odd Daybeacon
- Even Daybeacon
- Fixed Lighted Marker
- Special Purpose Buoy
- Green Buoy
- Red Buoy
- Lighted Buoy
- 10 10 Mile Marker