Khaled bin Sultan Living Oceans Foundation

Atlas of Shallow Marine Habitats of Cay Sal Bank, Great Inagua, Little Inagua and Hogsty Reef, Bahamas

A. Bruckner, J. Kerr, G. Rowlands, A. Dempsey, S. Purkis, and P. Renaud

Khaled bin Sultan
Living Oceans
Foundation

Khaled bin Sultan Living Oceans Foundation

Atlas of Shallow Marine Habitats of Cay Sal Bank, Great Inagua, Little Inagua and Hogsty Reef, Bahamas

A.W. Bruckner, J. Kerr, G. Rowlands, A. Dempsey, S. Purkis, and P. Renaud

Khaled bin Sultan
Living Oceans
Foundation

Front cover: Aerial view of Cay Sal Island. Image by Andrew Bruckner.

Back cover: True color WorldView-2 satellite imagery draped over depth model. Image by Jeremy Kerr.

Khaled bin Sultan Living Oceans Foundation
8181 Professional Place
Landover, MD, 20785 USA

http://www.livingoceansfoundation.org/

Published by: Panoramic Press, Phoenix, AZ

First published: October 2014

All research conducted in support of this Atlas was completed under Research Permit MAF/FIS/17 issued by the Bahamas Department of Marine Resources (Fisheries).

The maps in this Atlas are not intended for use in navigation.

Designed by Andrew Bruckner and typeset by Art Webb.

Coral reef images are provided by Andrew Bruckner, Ken Marks, Jeremy Kerr, and Philip Renaud. Terrestrial images are provided by Andrew Bruckner and Sam Purkis. Terrestrial basemaps used in development of habitat maps and bathymetric maps are from: ESRI, i-cubed, USFSA, USGS, AEX, GeoEye, AeroGRID, Getmapping, IGP.

Citation: Bruckner, A., J. Kerr, G. Rowlands, A. Dempsey, S. Purkis, and P. Renaud (2014) Khaled bin Sultan Living Oceans Foundation Atlas of Shallow Marine Habitats of Cay Sal Bank, Great Inagua, Little Inagua and Hogsty Reef, Bahamas. Panoramic Press, pp. 304.

ISBN-978-0-9835611-1-8

Acknowledgements

This Atlas is the result of a collaborative research project between the Khaled bin Sultan Living Oceans Foundation (KSLOF), the National Coral Reef Institute (NCRI), Nova Southeastern University, and the Bahamas Government. In particular, thanks to Tamica for logistical support; Eric Carey for assistance in convening several key meetings with Bahamian experts and organizations and for identifying key research sites and needs; and Roland Albury from the Department of Marine Resources, Ministry of Agriculture and Marine Resources for the assistance with the permit application process and the many changes we proposed throughout the project.

Numerous scientists contributed to various aspects of the work completed during the Bahamas research missions. Specifically, we are grateful for assistance of the Department of Marine Resources (represented by Indira Brown), as well as the Bahamas National Trust (represented by Krista Sherman and Lindy Knowles) and The Nature Conservancy, Caribbean (represented by Agnessa Lundy and Tavares Thompson). KSLOF also appreciates the skill and dedication of the highly qualified international scientific divers that aided the Foundation in data collection. These scientists were from the following institutions and organizations: Nova Southeastern University, University of Queensland, Michigan State University, Atlantic and Gulf Rapid Reef Assessment, and Reef Environmental Education Foundation. The science team from Cay Sal is shown on the top center and from Great Inagua on the bottom center.

The Atlas would not have been possible without the generous support of His Royal Highness Prince Khaled bin Sultan bin Abdulaziz. Prince Khaled bin Sultan has been an avid supporter of the Living Oceans Foundation's Global Reef Expedition starting with the first mission of the GRE in the Bahamas during 2011. Since the inception of the GRE, Prince Khaled has provided the research team with full access to the M/Y *Golden Shadow* (center photograph) for use as the research platform for the four Expeditions, with additional support for airborne surveys with the Cessna 208 amphibious sea plane, the Golden Eye. We are also grateful to the pilots of the Golden Eye for facilitating data acquisition. High spatial resolution (2.4m pixel) multispectral WorldView-2 imagery was obtained from DigitalGlobe, Inc., Longmount, Colorado, USA. Special thanks to the capable officers and crew of the M/Y *Golden Shadow* who made each day run as smoothly and seamlessly as possible.

All geographic information system (GIS) database products and figures presented in the report were produced by Gwilym Rowlands and Alexandra Dempsey. Photographs are by Andy Bruckner, Ken Marks, Jeremy Kerr, Sam Purkis and Phil Renaud. The maps and information contained in the Atlas were reviewed by Abdulaziz Abuzinada, Mohamed Faisal, Bernhard Riegl, John McManus, Shawn McLaughlin and three anonymous reviewers.

Khaled bin Sultan
Living Oceans
Foundation

Preface

The Khaled bin Sultan Living Oceans Foundation (KSLOF) Atlas is a product developed from information collected during research missions to Cay Sal Bank (4/26/11-5/18/11), and Great Inagua, Little Inagua and Hogsty Reef (8/1/11-8/24/11), Bahamas during 2011. Research was undertaken by scientists from KSLOF, the National Coral Reef Institute (NCRI), University of Queensland, University of Miami (RSMAS), Atlantic and Gulf Rapid Reef Assessment Program (AGRRA), Florida Aquarium, University of Michigan, the Bahamas Department of Marine Resources (Fisheries), the Bahamas National Trust, the Nature Conservancy, Bahamas, and College of the Bahamas. The research included two components: habitat mapping and characterization of coral reef community structure and health. Habitat mapping involved initial acquisition of WorldView-2 (WV2) high resolution satellite imagery, followed by aerial reconnaissance and photography, and field work to collect "groundtruth" and geophysical data (continuous bathymetry measurements, drop camera videos, sediment sampling, and low frequency sub-bottom sonar profiles of the seafloor's sub-bottom). Coral reef assessments focused on characterization of: 1) the benthos, including substrate type and cover of benthic organisms; 2) coral community structure, population dynamics and health; 3) fish community structure; and 4) resilience indicators, with emphasis on herbivory and algal growth studies, coral recruitment, coral diseases, and patterns of coral reef recovery.

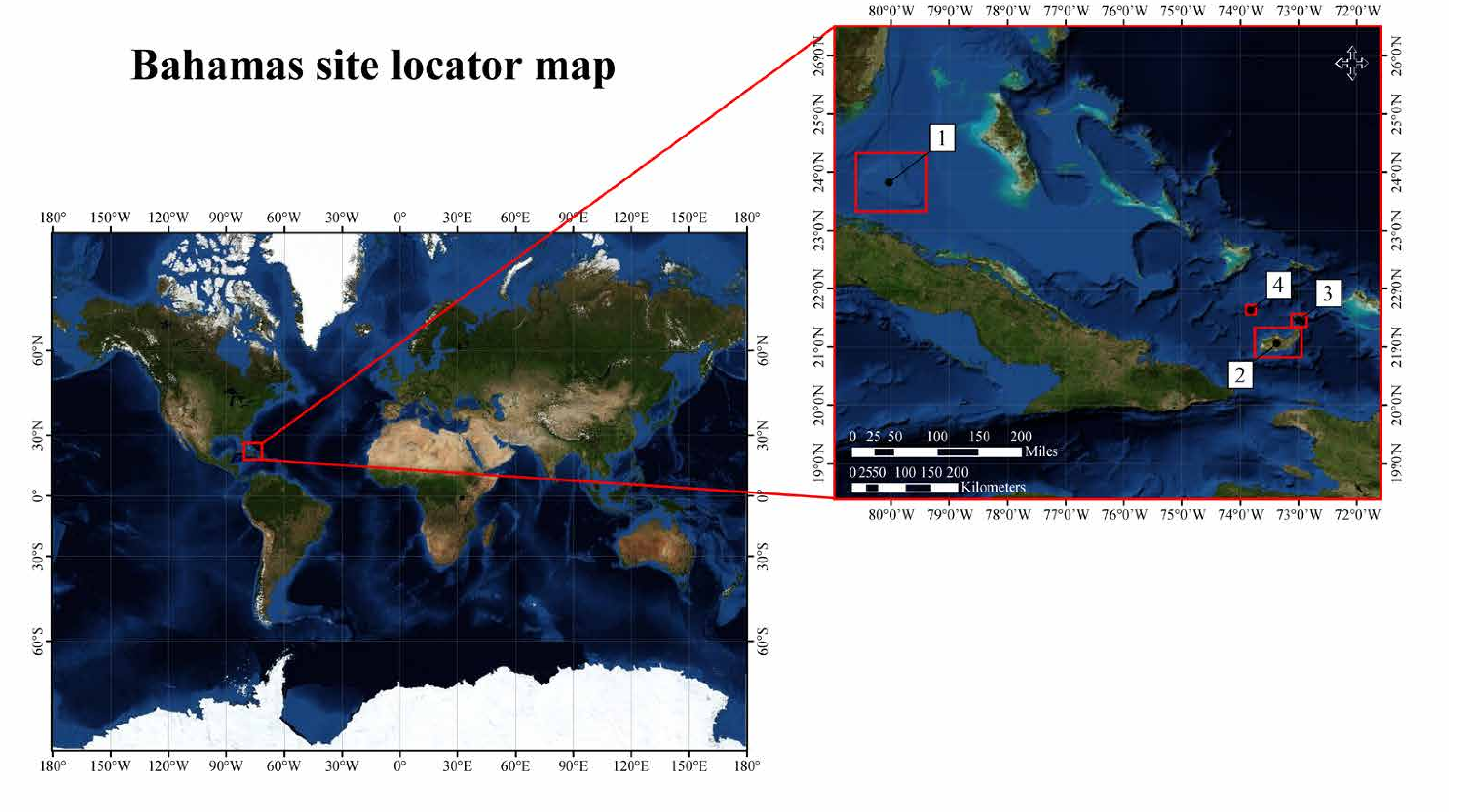
A total of 23,407 sq. km of WorldView-2 Satellite Imagery was acquired for the four areas included in this Atlas. Continuous bathymetry was recorded over a 572 km track and 1157 drop camera videos were taken. All groundtruth data were linked to a differential geographic positioning system (dGPS).

The Atlas starts with a general background of the Bahamas, including a discussion of the geology, climate and oceanography. An explanation of the remote sensing and groundtruthing efforts used to develop the habitat and bathymetric maps is presented next. This is followed by information on the major habitat types and coral reef organisms that occur within the Bahamas. A brief discussion of some of the large scale natural stressors that have effected the reefs is presented. The final habitat classes depicted on the habitat maps are identified and their key features are summarized, along with representative images from Cay Sal, Hogsty Reef, and Great and Little Inagua. The Atlas is then divided into four sections, one for each region. These include an overview map showing the satellite imagery, habitats and bathymetric maps for the entire region, followed by higher resolution maps at a scale of 1:24,000 for the region. Specific information on each region along with aerial images, above water images and underwater scenes are shown. All images presented in this Atlas were taken in the Bahamas.

Andrew W. Bruckner, BSc, MS, Ph.D.
Chief Scientist, Khaled bin Sultan Living Oceans Foundation
August 2014

Table of Contents

Bahamas site locator map



Message from

HRH Prince Khaled bin Sultan

Chairman and President

Khaled bin Sultan Living Oceans Foundation

The Commonwealth of the Bahamas is an archipelago consisting of 700 islands and about 2,000 cays and islets. Although their combined land area is similar in size to the state of Connecticut, it has a massive Exclusive Economic Zone (EEZ) of approximately 630,000 square kilometers that includes 1.2% of the world's coral reefs. The Bahamas' economy relies heavily on maritime industries and tourism and they have demonstrated impressive leadership in ocean conservation initiatives.

When the Khaled bin Sultan Living Oceans Foundation initiated the Global Reef Expedition project in 2011, the Bahamas government volunteered to be the first country on our world-wide itinerary. The most important criteria for selecting countries to be included on the Global Reef Expedition itinerary was evidence of strong political will to conserve ocean health and interest in our assistance. The Bahamas met those criteria enthusiastically and the collaboration was formed.

In consultation with the Bahamas National Trust and the Ministry of Marine Resources, we determined that the best use of our research vessel and scientific expertise would be to map and survey the remote Cay Sal Bank and Great/Little Inagua Islands. These important marine resource regions were mostly devoid of scientific studies and therefore had been assigned high priority for scientific surveys.

This Atlas of Cay Sal Bank, Great and Little Inagua, and Hogsty Reef represents the culmination of extensive field-work, satellite imagery analyses, and data interpretation. I have frequently stated that my goal is to provide the tools to facilitate scientist's work in remote ocean regions. Therefore, it gives me great pleasure to see the results of their labor as evidenced in this detailed Atlas. As I present this Atlas to the Bahamas and the world at large, I do so with the hope that it serves as a catalyst for further ocean conservation efforts.

Message from

CAPT Philip G. Renaud, USN(ret)

Executive Director

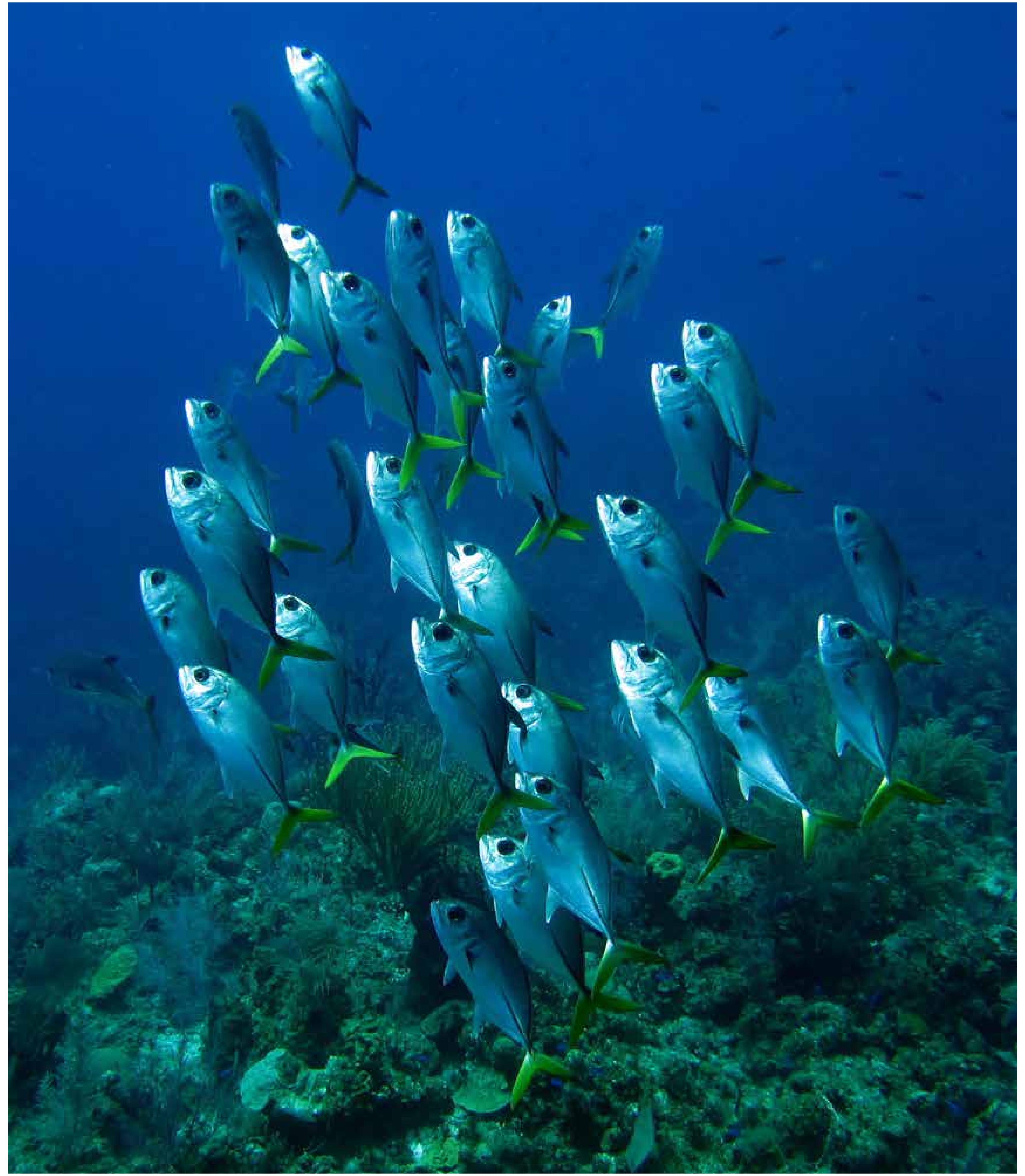
Khaled bin Sultan Living Oceans Foundation

This remarkable Atlas is a product of Science Without Borders® in action! The complex planning and months of fieldwork were a collaborative effort between Khaled bin Sultan Living Oceans Foundation, the Bahamas National Trust, the Department of Marine Resources, The Nature Conservancy, Nova Southeastern University, Atlantic and Gulf Rapid Reef Assessment and others.

We combined sophisticated remote sensing technologies (i.e. satellite imagery) with "ground-truthing" techniques in the field to create the high-resolution habitat and bathymetry (i.e. depth) maps contained in this Atlas. What you will see within this Atlas is only the tip of the iceberg, so to speak. The full power and potential of these maps resides in a digital Geographic Information System (GIS) database we developed that requires specialized software, computer systems, and training to fully exploit. We produced this paper Atlas to facilitate common access to the maps and to open a gateway to the full GIS for those interested in adding value to other scientific or management projects by including our habitat and bathymetric maps. Contact the Foundation if you are interested in learning more about the GIS.

My hope is that this Atlas, and other outputs from our surveys and mapping of Bahamian coral reefs, will be frequently consulted and used to promote sustainability of coral reef ecosystems. With our rapidly changing climate imposing large scale threats on the health of coral reefs, it is critical and urgent to reduce various human made stressors such as over-fishing and pollution. One of the fundamental tools needed to manage any geographically disbursed resource is a good map. I am confident you will agree that the maps in this Atlas are "good" indeed and that the resolution and accuracy surpass any previous mapping efforts.

We are indebted to the vision and generosity of His Royal Highness (HRH) Prince Khaled bin Sultan for establishing the Khaled bin Sultan Living Oceans Foundation and for enabling sophisticated scientific research towards the goal of improving and sustaining health of our world's oceans.



INTRODUCTION

The Bahamas extend approximately 1600 km from the Little Bahamas Bank in the northwest to Navidad Bank in the southeast, covering an area of approximately 122,000 km^2 (Trumbull 1988, Banks 1999, Sullivan Sealey and Bustamante 1999). The islands are aligned northwest to southeast, extending over 6 degrees of latitude and 9 degrees of longitude. The islands cover more than 1400 km linear distance from just south of Florida to southeast Cuba. The Bahamas represents the largest shallow water bank system in the insular Caribbean/Western Atlantic. There are 13 major islands, approximately 700 smaller islands and cays and some 2500 islets, with a total land area of about 13,880 km.

Most of the land in the northwestern portion of Bahamas is found atop three shallow (<10 m) carbonate platforms or banks, Little Bahama Bank, Great Bahama Bank, and Cay Sal Bank. The islands are low-lying, less than 10 m elevation, with a maximum elevation of 61 meters.

The southeastern Bahamas consists of smaller platforms, made up of a series of smaller islands and shallow water reefs extending from Crooked Island to Navidad Bank. These islands are separated from one another by deep water basins and troughs of up to 4000 m. To the south is the western extension of the Puerto Rico Trench, Cuba and Hispaniola. To the north and east, slopes plunge to oceanic depths. The southeastern islands have a slightly higher elevation than the islands in the northern Bahamas.

All of the islands of the Bahamas are composed primarily of Late Quaternary shallow-water and eolian carbonates (e.g. limestone), less than 500,000 years old, that sit on top of oceanic and/or continental crust. In some locations carbonate sediments are up to 5.4 km thick. The modern sediments on the banks are mostly non-skeletal ooids, peloids, and carbonate muds (Purdy, 1963b; Traverse and Ginsburg, 1966) and do not contain any significant siliclastic component.

The carbonates were formed by both physical and biogenic processes and deposited in a spectrum of environments ranging from lakes and dunes to deep-sea basins. Most of the limestones that make up the islands of the Bahamas were deposited during sea level highstands (corresponding with climatically warm interglacials periods) that occurred in the Pleistocene and Holocene. During such highstands, the banks were partly flooded by seawater. Through deposition by algae, benthic foraminifera, coral and molluscs, and the inorganic precipitation of calcium carbonate, large amounts of sediments were produced. Some of this was deposited on the platform surface, and some was transported off the platform allowing the islands of the Bahamas to build laterally. During times of lowstands (cold glacial intervals), weathering and pedogenesis result in the development of soils. With burial and diagenesis, these soils became paleosols (calcretes buried beneath other sediments and lithified into rock).

Topography and surface features of the Bahamas
The islands are flat, and mostly low relief, with gentle hills or ridges. The hilly parts are made up mostly of large sand dunes (eolianite dunes), beach ridges and fossil coral reefs. The marine carbonate grains that form the eolianite dunes are inorganically precipitated or biotically produced during periods of high sea level stands (when the banks are underwater), forming into beaches. During periods of low sea level they are then blown by wind onto the island to form dunes. Since the dunes are rich in carbonate, they start to cement subaerially almost immediately, especially if there's plenty of rain to mobilize the carbonate and precipitate it into cements. The conversion of sand to rock also proceeds during high sea level stands. In general, a higher coastal ridge occurs along the exposed (bankward) side of the islands. Fossil coral reefs are often found along the shoreline, such as Devil's Point off Great Inagua, occurring to an elevation of about 4 m above present day sea level.

The surface of the islands is very porous with a thin layer of soil and little surface water. There are no freshwater rivers in the Bahamas due to the high permeability of the limestone surface. Most of the creeks are created by tidal flow of seawater. Shallow saline to hypersaline lakes occupy areas between the ridges, especially on larger islands. Lake Windsor (also called Lake Rosa), in Great Inagua, is the largest lake in the Bahamas. Karst processes have resulted in a jagged surface, subsurface caverns, and numerous blue holes, both on land and in the adjacent shallow marine environment.

Modern day reefs and associated habitats
The archipelago encompasses close to 15% of all shallow water coral habitats in the Tropical Western Atlantic. Coral reefs cover an estimated area of 3,150 km^2. They fringe most of the bank margins on the north and east coasts and the bank edges. Most of the shallow water bank systems contain sand, seagrass, mangrove and hardground habitats. True, accreting reefs are found primarily on the bank margins, with small patch reefs on the banks in areas with high circulation, and a few atoll-like reefs and bank-barrier reefs. Reef development in the Bahamas has been limited by exposure to hurricanes on the windward sides of the banks, by unusually cold winters in the northern Bahamas, and by turbid, high salinity waters on the leeward bank margins.

A large school of Schoolmaster Snapper on Cay Sal (bottom center).

While much of the coastline consists of eolian dunes, beachrock, rubble, and mud flats, there are many spectacular sandy beaches with characteristic tropical western Atlantic vegetation. A seven mile beach off the west coast of Little Inagua is shown above.

Coral reefs have also been highly altered over the last three decades as a result of a number of large scale natural disturbances hat have also affected the Caribbean and Florida. The most drastic changes are the result of a region-wide decline in *Acropora* populations primarily due to white band disease (mostly in the 1980s), die-off of herbivorous sea urchins (*Diadema antillarum*) in 1982-1983, mass bleaching events in 1995 and 1998, and hurricane impacts. Losses of corals and *Diadema* have been associated with increases in macroalgal coverage and many reefs have experienced extensive blooms of *Microdictyon marinum a*nd other species of macroalgae. More recently, massive framework corals, especially the *Montastraea* (*Orbicella*) *annularis* complex have undergone a precipitous decline from disease and bleaching.

Human inhabitants
Only 25 larger islands are inhabited by people. Most of the population is concentrated in Nassau, Marsh Harbor and Freeport. Approximately 1000-1200 people live in Great Inagua, mostly in Matthew Town. Cay Sal, Hogsty and Little Inagua are uninhabited. Although the human population of the Bahamas is fairly low, human impacts have degraded coastal water quality and contributed to local destruction of habitats. The greatest human threats to coral reefs include overexploitation of fishes, conches and lobsters, the use of destructive fishing gear and techniques, increased pollution in nearshore waters off populated areas, and alteration of the coastline associated with coastal development, marinas, and dredging. In more remote locations such as the Inaguas and Cay Sal, poaching by foreign fishing vessels is also of concern.

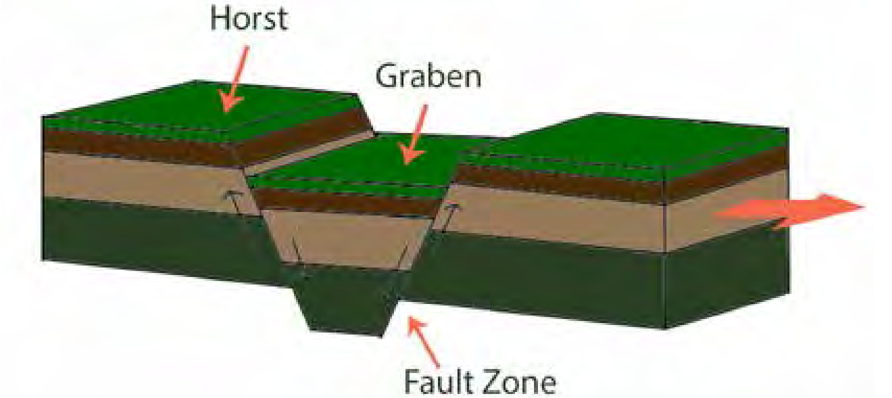
Geology

Tectonic development

The Bahamas archipelago consists of a chain of carbonate platforms that are believed to have begun forming approximately 200 million years ago as a result of plate tectonics activity, following the opening of Atlantic Ocean as Pangea split apart. The earth's crust is made up of a number of separate tectonic plates that move very slowly, over millions of years. The Caribbean Sea was formed as the Caribbean plate began to move slowly eastwards, pushing into the Atlantic and forcing up a ridge of rock. At the eastern edge of the Caribbean Sea, the ridge rose above the sea, forming a chain of islands and volcanoes which today make up the Lesser Antilles.

Northwestern Bahamas

The Northwestern Bahamas is thought to have formed as a horst and graben (Mullins and Lynts 1975). Briefly, the submarine platform upon which the northwestern Bahamas sits is continental and was originally part of Africa. Rifting (pulling apart of the earths crust and lithosphere) of North America from Africa and South America began in the vicinity of the northwestern Bahamas during the Late Triassic. The Bahama Platform rifted from Africa along a large right-lateral shear. It rotated approximately 25 degrees northeast relative to the Caribbean plate during the Cretaceous period, developing as a transcurrent-type continental margin (a fault system at the edge of the continental margin) preceded by the uplift of the continents that initiated the deep Bahama Channels as grabens were formed. During the incipient development of the deep Bahama channels, Late Triassic continental sedimentary rocks (arkosic rudites and arenites) were deposited at the base of these grabens.



Horst and grabens are regions that lie between normal faults and are either higher or lower than the area beyond the faults. A horst represents a block pushed upward by the faulting, and a graben is a block that has dropped due to the faulting. In the Bahamas, the graben formed the deep channels between the banks and the horsts are the banks. Figure by Haili Bruckner.

An alternate theory is that the Bahamas are remnants of a much larger platform (Meyerhoff and Hatten 1974). The clockwise rotation of North America as it separated from South America and Africa during the Jurassic period caused the counterclockwise bending of the entire peninsula of Mexico and Central America, and the subduction of the Caribbean plate into the Cuban trench. This triggered volcanic eruptions that provided the foundations for the Cuban volcanic arc and a thick and widespread ignimbrite sheet (fist-sized pumice fragments floating in a finer grained matrix of ash) behind the arc, in the area now occupied by Florida and the Bahama Banks.

Deep Bahamas Channels

Unlike the shallow water carbonate sediments found on the Bahama Banks, the deep Bahama channels contain late Cretaceous chalks and other Pre-Cretaceous deep water carbonate sediments (Mullins and Lynts 1976). Due to restricted water circulation during the Early to Middle Jurassic time, salt and organic-rich shales were deposited in the channels. The onset of more open marine conditions between the late Jurassic to Holocene promoted the deposition of deep-water carbonate and bioclastic turbidite sediments. Most of the intraplatform relief of the northwestern Bahamas appears to be the result of the build-up of the banks relative to the channels during regional subsidence.

Southeastern Bahamas

Unlike the northwestern Bahamas, the basement rocks that underlie the islands in the southeast are thought to be oceanic crust, and the area is not believed to have been a transitional region during the opening of the North Atlantic basin. These islands were formed after the northwestern Bahamas by carbonate build-up on the oceanic crust, along a subsiding fracture zone (Pitman and Talwani 1972). The carbonate banks in the southeastern Bahamas were at different elevations and they subsided at different rates during the late Cenozoic, suggesting that the channels separating the islands correspond to major faults (Kindler et al. 2011).

Formation of carbonate banks

The current landscape of the Bahamas is largely constructional and is greatly influenced by glacioeustatic sea-level fluctuations during the great ice ages (Carew and Mylroie 1997). Carbonate deposition occurred on the flat bank tops during sea-level highstands when shallow lagoons dominated much of the landscape. The Bahama Platform became exposed during sea-level lowstands as a result of four major glacial advances during the Pleistocene. During these ice ages, the sea level dropped below the bank margins, carbonate sedimentation ceased, and wind produced large winnowed eolianite dunes (sand dunes). These were solidified into rock subaerially, especially during periods of rainfall, and also when the sea level flooded back over the land. When the sea level fell once more the old sand dunes became the hills found on the islands today.

Present-day morphology and geology of the southeastern Bahamas, including Hogsty, Great Inagua and Little Inagua, are very similar to the northern Bahamas. These islands are low-lying and composed of shallow-water reef material and lithified Pleistocene/Holocene sands. The topographic highs include both unlithified and lithified eolian ridges that are thought to be primarily Pleistocene-Holocene features, with a few dunes that are presently forming.

Aerial photograph of underwater sand waves on the northern end of Cay Sal Bank.

Sediment deposits

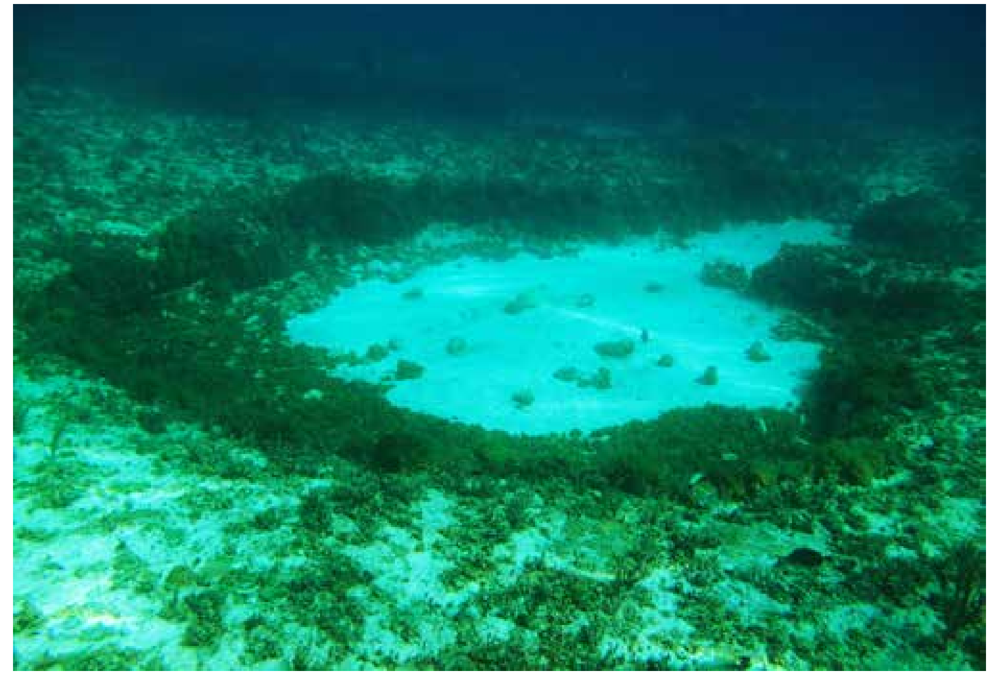
The Bahama Banks originated at a latitude with warm, shallow waters that encouraged the growth of a variety of corals and other calcifying organisms whose skeletal remains were deposited as sediments. In addition to coralgal sediments, a substantial portion of modern sediments are inorganically precipitated, non-skeletal materials classified as ooids, peloids, grapestone and aggregate, and carbonate muds. An ooid is a small spherical granule that has a small nucleus surrounded by concentric layers of calcium carbonate. Peloids are round, sand-sized grains of micro-crystalline carbonate that precipitated around a nuclei of fecal pellets, algae and mud clasts. They are sometimes found clumped together, in a formation known as a grapestone.

Ooids tend to form in warm, shallow waters supersaturated with respect to aragonite, in areas with a relatively flat topography and strong tidal currents. All of these conditions are present on the Little and Great Bahamas Banks. Cool water from the Gulf Stream passes over the shallow Bahamas banks, experiencing an increase in temperature and salinity which results in a decrease in the solubility of calcium carbonate. As the water continues across the banks evaporation lowers the carbon dioxide content, and water turbulence repeatedly rotates the grains, facilitating the deposition of this substance in concentric layers around a sedimentary nuclei. Ooids primarily occur around Little and Great Bahamas Banks, and were not found around Cay Sal, Hogsty or the Inaguas.

The origin of the muds remains unclear. One theory is that they are caused by spontaneous precipitation within areas of sediment laden water known as whitings (Cloud, 1962; Shinn et al., 1989). The whitings result from either bottom sediments stirred up by currents, fish, or other physical mechanisms, or conversely through the direct precipitation of $CaCO_3$ (Cloud 1962; Broecker and Takahashi 1966; Morse et al. 1984; Shinn et al. 1989, Morse et al. 2003).

The precipitation of both ooids and the presence of whitings may be induced by microbes, especially through the photosynthetic activity of cyanobacteria. These organisms remove CO_2, thereby raising the saturation state of aragonite and inducing the precipitation of calcium carbonate.

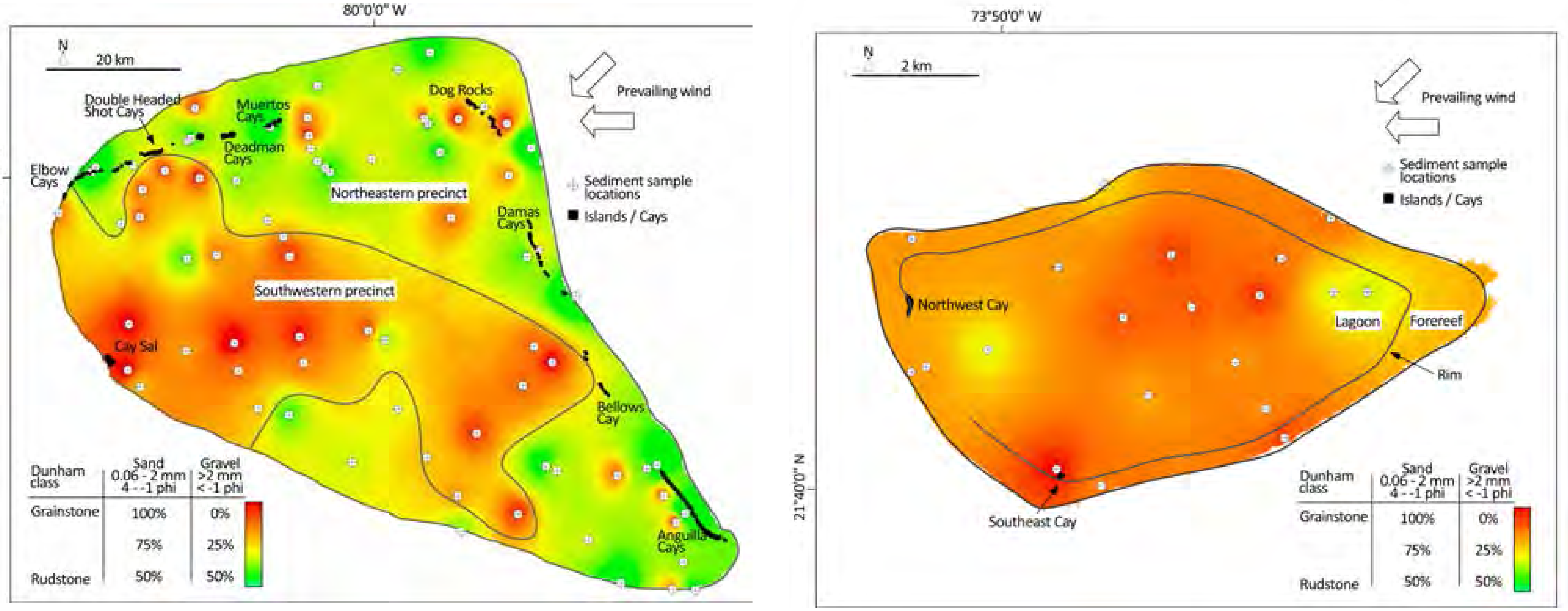
Aerial photograph of whitings on the leeward (west) side of Andros.



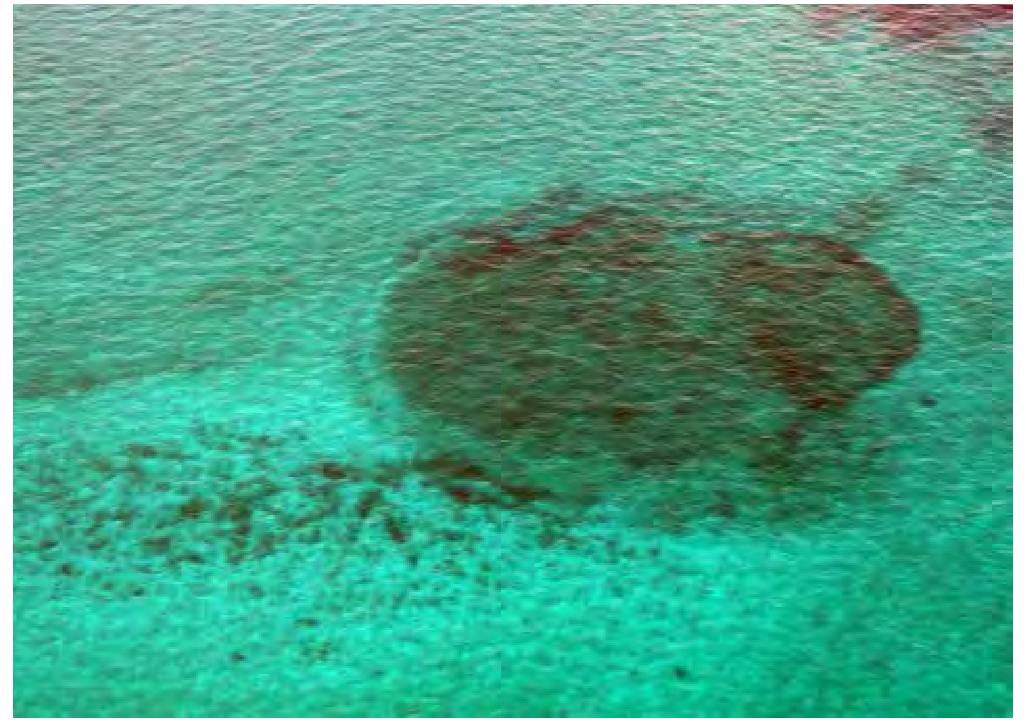
A small blue hole on Cay Sal Bank that has been infilled with sand. The perimeter is surrounded by a rim of algal-covered platform-topped reef.

Karst topography

The Bahamas are known for their spectacular blue holes. During the interglacial stages, when the banks were dry land, underground streams and rain dissolved away the limestone. The streams carved out vast cave systems which occasionally collapsed, leaving wide circular sink holes. As sea level rose, the sink holes filled with water. Weather altered the landscape into karst formations of caves, sink holes, and solution pits. Because of the great porosity of the limestone, water from rainfall and runoff is rapidly delivered underground through these conduits, resulting in a scarcity of freshwater rivers and streams in the Bahamas.



Grain-size distribution map for Cay Sal Bank (bottom left) and Hogsty Reef (bottom center). For Cay Sal, data were interpolated from 90 surficial sediment samples. The platform-top can be partitioned into two precincts on the basis of grain-size. The northeastern precinct is more grainy than the southwestern, a gradient consistent with influence of prevailing trade winds.



An inland blue hole at Great Inagua (top right). Aerial photograph of a blue hole on Cay Sal Bank that has been infilled. Sediment has been colonized by seagrass. Sinkholes on Cay Sal appear to act as a trap to the east-west transport of sediment across the platform. When a sinkhole is fully infilled, seagrass meadows will develop in the buried throat, which in turn, act as a baffle to water flow, capture sediment, and serve to maintain the leeward zone of reduced sediment stress. Seagrass meadows remain confined to the throats of the buried sinkholes as the outlying sediments are nutrient limited (Purkis et al . 2014) (bottom right).

Climate and Oceanography

Air temperature

The climate of the Bahamas is sub-tropical, with two distinct seasons and a marked climatic gradient from a cooler, wetter northwest to a warmer drier southeast. During the spring, which extends from May through November, the climate is dominated by warm, moist tropical air masses moving north through the Caribbean. Midsummer air temperatures in New Providence range from 23.3 to 31.7°C (74 to 89°F) with a relative humidity of 60 to 100%. In winter months, extending from December through April, the climate is influenced by the movement of cold polar masses from North America. Temperatures in New Providence during the winter months range from 16.7 to 25.0°C (62 to 77°F). Air temperatures are slightly lower in the more northerly islands and higher in the southern islands. While there has never been a freeze reported in the Bahamas, the temperature in northern islands can fall to 2.8°C (37°F) during Arctic outbreaks that affect nearby Florida. Although snowfall is absent from most of the Bahamas, snow mixed with rain was reported in Freeport in January 1977, when temperatures dropped to 5°C (41°F). In Great Inagua, winter temperatures range from 19 to 23°C (73°F) , while summer temperatures can reach 33°C (91°F) in July.

Rainfall, evaporation and salinity

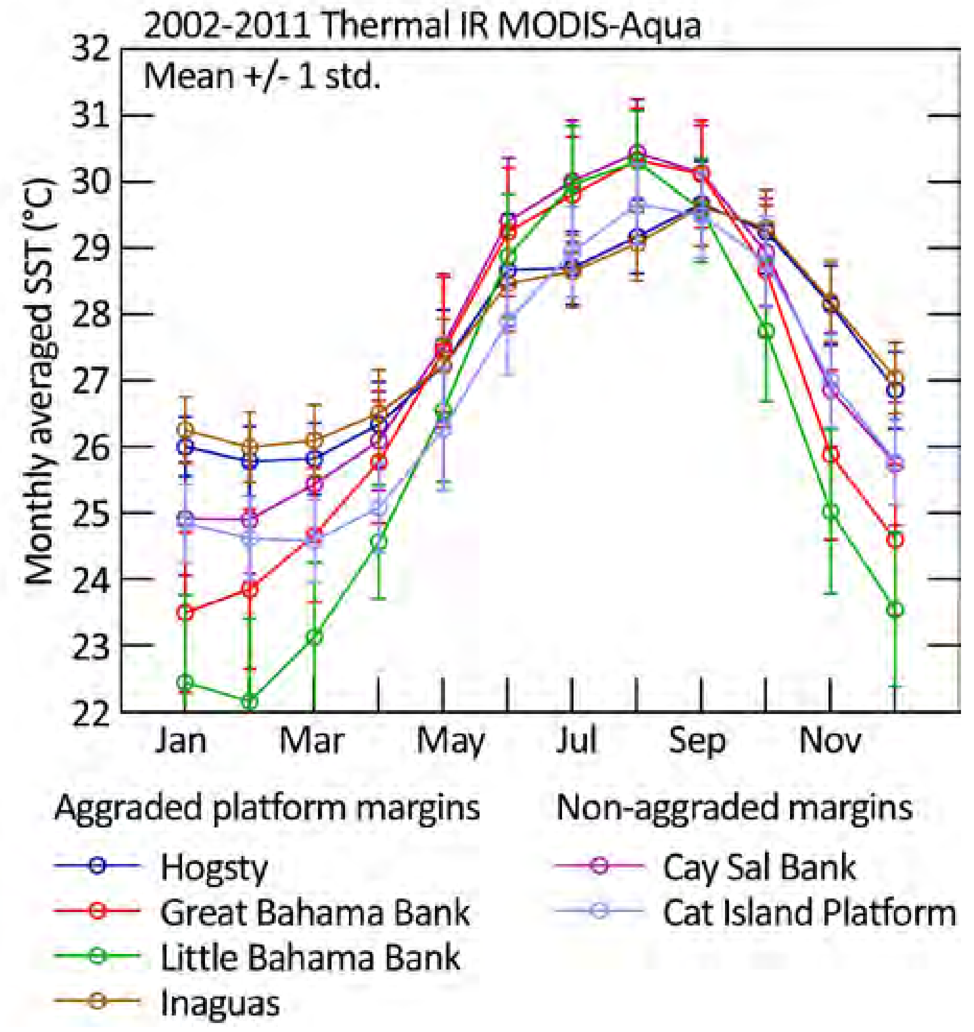
Rainfall is locally variable, with a pronounced gradient from about 1500 mm (60 in.) per annum in the north, to about 750 mm (30 in.) in the southeastern island of Inagua. Most of the rainfall occurs during the hurricane season, from June to November with two peaks during May–June and August–October. In the larger northern islands rainfall during May and June results primarily from convection currents. The second peak in rainfall is largely caused by tropical depressions, tropical storms, and hurricanes, and may account for up to one quarter of the total annual rainfall. Cold fronts from the north can bring winter rains; as front systems progress southward across warm waters of the banks, winds moderate and it rains in the northern Bahamas.

Rainfall often occurs in short-lived, fairly intense showers accompanied by strong gusty winds. More westerly parts of larger islands tend to receive more convective rainfall than easterly parts of small islands as clouds developed over land are displaced by trade winds.

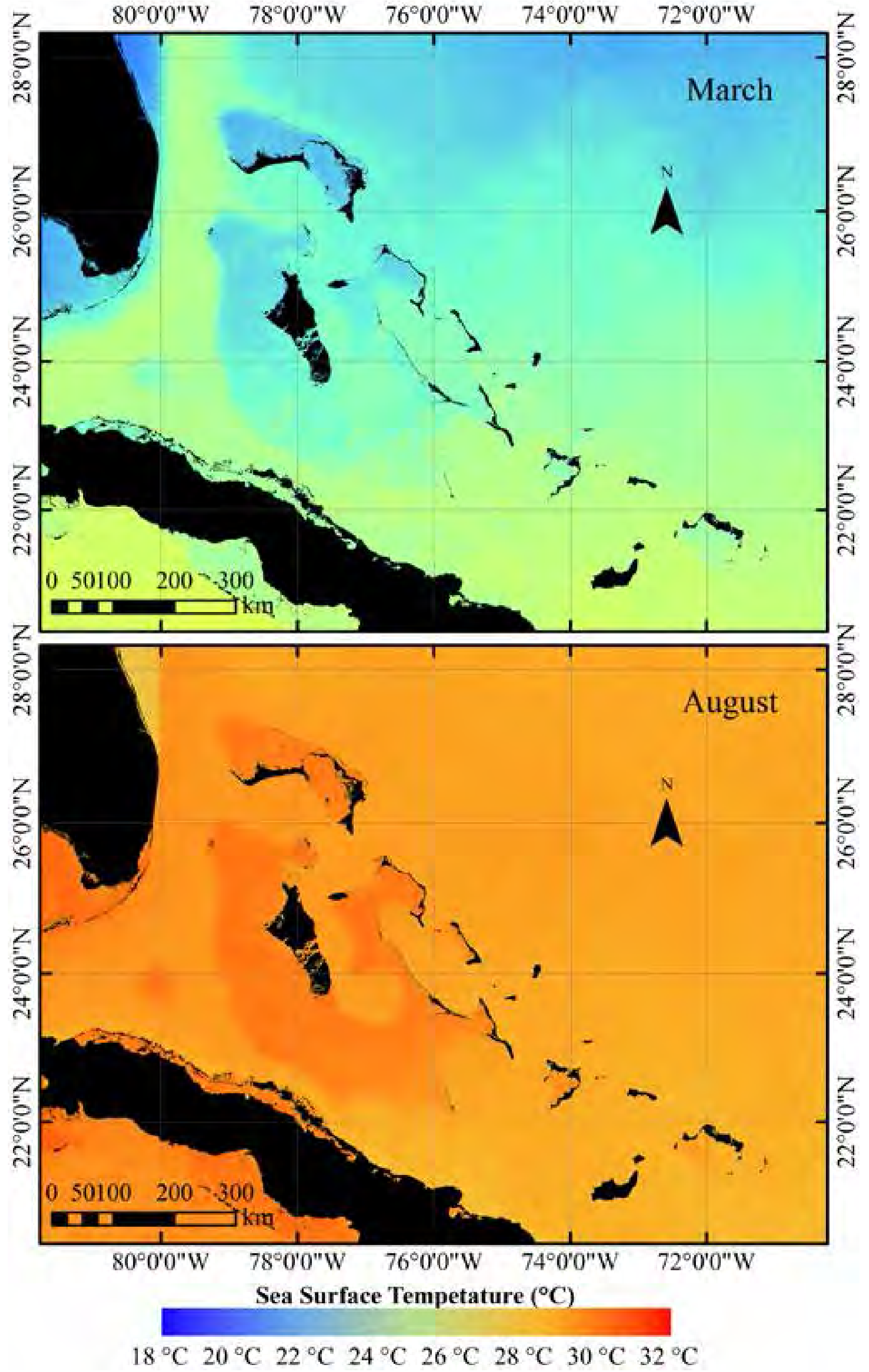
Salinities in open ocean areas are normally around 35-36 ppt, with variations controlled primarily by the major water currents. Coastal areas may have slightly higher salinities, especially the shallow bank waters which are typically hypersaline, ranging from 38 ppt to 43 ppt (Pitts and Smith 1993). During summer months, the effects of solar radiation and high evaporation on relatively shallow waters of the Bahama Banks can further raise the salinity with respect to offshore waters. During the ebb cycle of the tides, the warm high salinity plume of water is flushed through narrow tidal channels and flows onto the narrow shelf, before mixing with deeper water. Differences in rainfall between the northern and southern islands also effect salinity, with wider fluctuations in shallow coastal areas in the north.

Water temperatures

The Bahamas exhibit both seasonal and latitudinal variations in sea surface temperatures (SST), and variations depending on the size of the platform. In New Providence, sea surface temperatures normally vary between about 21°C in Feb/March and 31-32°C in August. Water temperatures at Cay Sal range from about 24.4° C to 29° C. Mean SST in the southern islands range from a low of 26° C between January and April and a high of 30°C in August and September. Monthly averages for the Bahamas over a 9 year period are shown below for Cay Sal Bank, Hogsty Reef, Great Inagua, Cat Island, and Great and Little Bahama Bank.



Plot of mean monthly SST for the six areas in the Bahamas (circles) +/-1 standard deviation (error bars) for the period Jan. 2002–Dec. 2011. The largest platforms (Great and Little Bahama Bank) display cooler winter temperatures than the smaller platforms. Hogsty and the Inaguas, both small platforms examined in this Atlas, report warmer winters and cooler summers than the large systems. The platforms with non-aggraded margins (Cay Sal Bank and Cat Island platform) show no difference in ocean climate to those with aggraded margins. Source: Purkis et al. 2014.



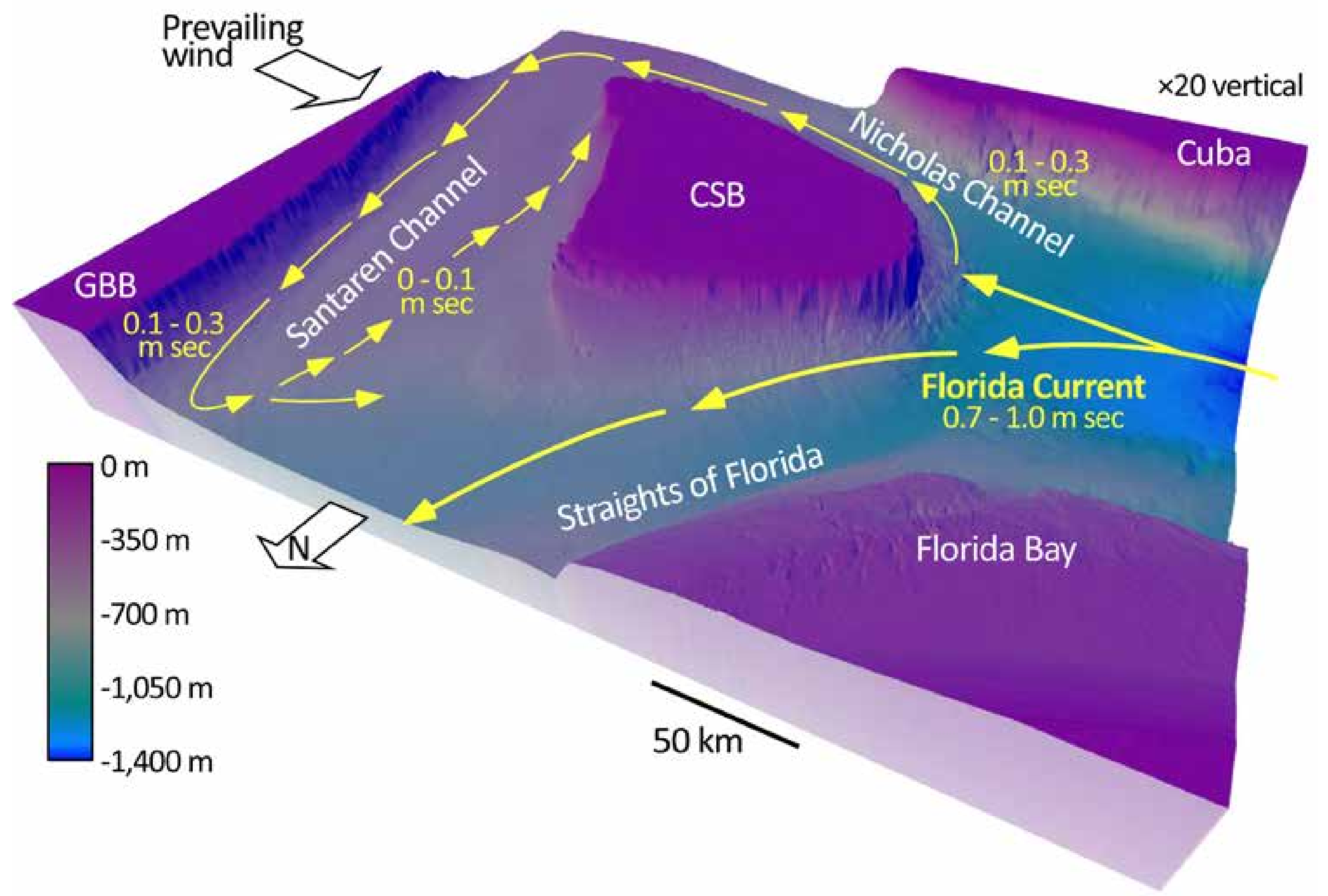
Sea surface temperatures for the Bahamas. Mean monthly temperature averaged across years (2006-2013), with cloud areas left out of averaging. One of the coldest months of the year (March, top figure) and the warmest (August, bottom figure) are shown. Data Source: Aqua MODIS SST 11 nighttime L3 monthly composite (http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=MODIS_DAILY_L3).

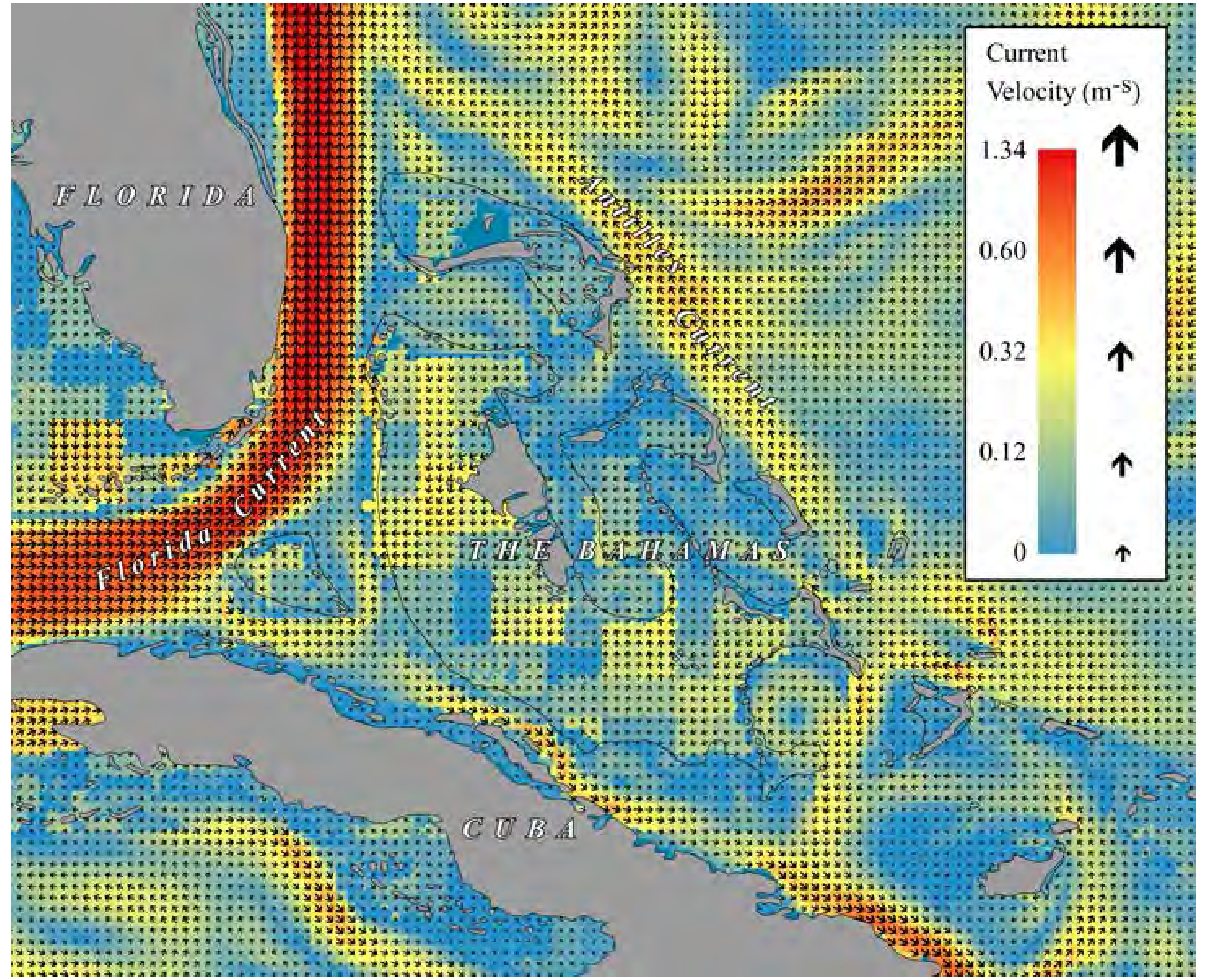
Water currents and circulation

Water masses that flow past the Bahamas have origins in both the north Atlantic and south Atlantic. The North Equatorial Current (NEC) is a broad, westward flowing current that forms the southern limb of the North Atlantic subtropical gyre. It originates off the northwestern coast of Africa where it is fed by cooler waters flowing from the northeast Atlantic. Northeast tradewinds push the current westward, eventually joining the South Equatorial Current near Brazil. Upon reaching the greater Caribbean, the NEC turns north. Part of it flows between the islands in the Lesser Antilles into the Caribbean, were it becomes the Caribbean Current. Some of the flow also continues north, becoming the Antilles Current.

The Caribbean Current slowly makes it way to the northwest corner of the Caribbean, where it is squeezed into the Yucatan Channel between Mexico and Cuba. It enters the Gulf of Mexico, becoming the Loop Current, rotating clockwise before exiting through a channel between Cay Sal Bank and the Florida Peninsula. At this point it becomes the Florida Current, flowing into the Atlantic where it joins the Gulf Stream. The speed of the Florida Current varies both seasonally and spatially. North of Cay Sal, it ranges from 0.53-1.6 m/sec. while the average speed between the Bahama Banks and Southeast Florida is 1.3 m/sec. Near-surface current flow across the platform-top of Cay Sal Bank at a rate of only 0.1 m/sec, an order of magnitude slower than the adjacent Florida Current, and in an east-west (westward) direction, suggesting that trade winds (easterlies) influence the flow on the bank and not the Florida Current.

The Antilles Current flows northwestward along the north side of the Greater Antilles islands. Part of the current passes along the eastern edge of the Bahamas archipelago and the remainder passes through the Old Bahama channel, between the Bahamas and Cuba, and continuing north between the east side of Cay Sal Bank and the west side of the Great Bahama Bank. As it flows past Cay Sal Bank, the velocity ranges from 0.17-0.35 m/sec. These currents eventually merge with the Florida Current and the Gulf Stream, continuing up the east coast of North America. The Antilles current shifts its location between the northern and southern part of the Bahamas islands in summer and winter. This creates a north to south variation in water temperatures with cold periods sufficient to reduce species diversity and coral reef development.





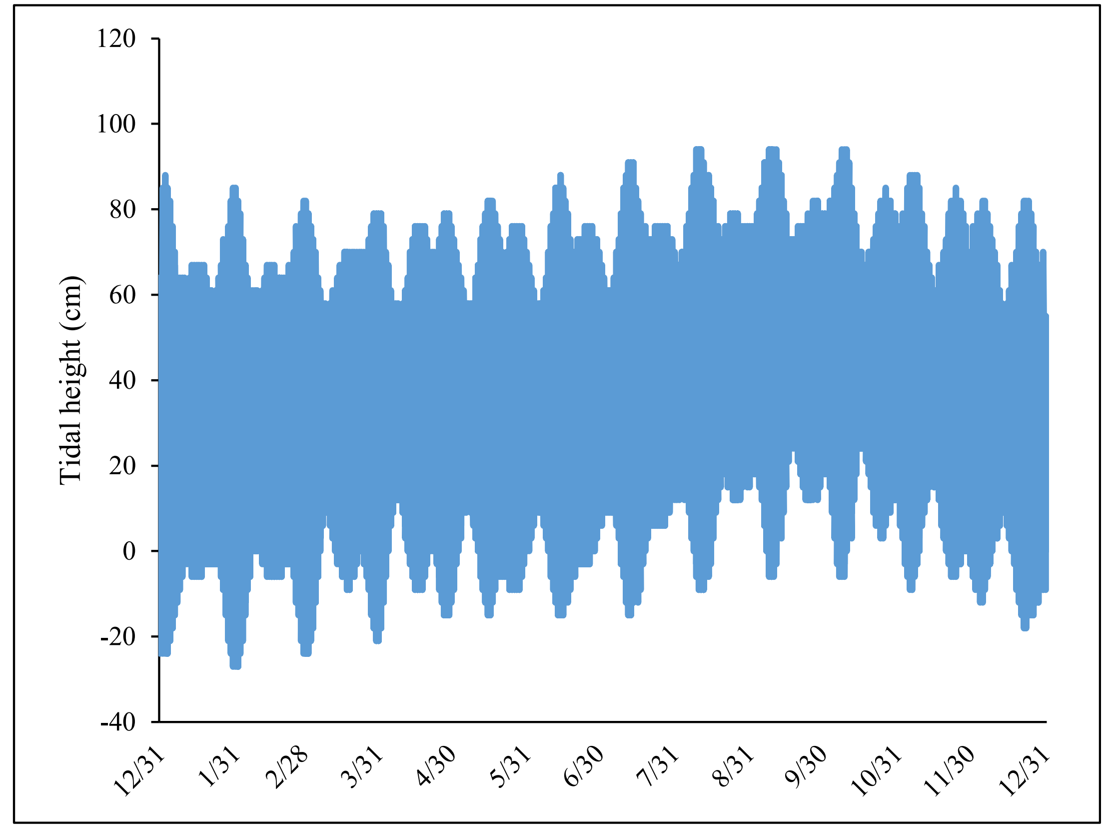
Water movement around the Bahamas (above). Arrows indicate direction of flows, while velocity is indicated by the size of arrows and background color. Data are presented as monthly means for October of 2006. Data Source: Fusion of HYCOM and OSCAR data, compiled by Matthew Johnston.

Lying in the trade wind belt, Hogsty Reef and the Inaguas are subject to a near constant westward drift. Seasonal variations in the sea, swell, and currents correspond closely to the variations in the wind. Trade winds (easterlies) also influence the predominantly westward water flow over Cay Sal Bank.

Annually averaged surface currents (vectors and color for speed) for the Cay Sal Bank (CSB) and surrounding waters for 2010 computed with the Florida Straits, South Florida and Florida Keys Hybrid Coordinate Ocean Model (FKeyS-HYCOM). The Florida Current (FC) does not incur onto the platform top of the CSB. Source: Purkis et al. 2014 (left).

Waves and tides

The Bahamas have a semi-diurnal tidal regime. The mean daily tidal amplitude is ~80 cm with a monthly range of 40-150 cm. The tidal range at Hogsty Reef is about 60 cm, with a slightly greater range during spring tides. A maximum tidal range of 133 cm is recorded for Little Inagua. The tidal cycle for Cay Sal is shown below.

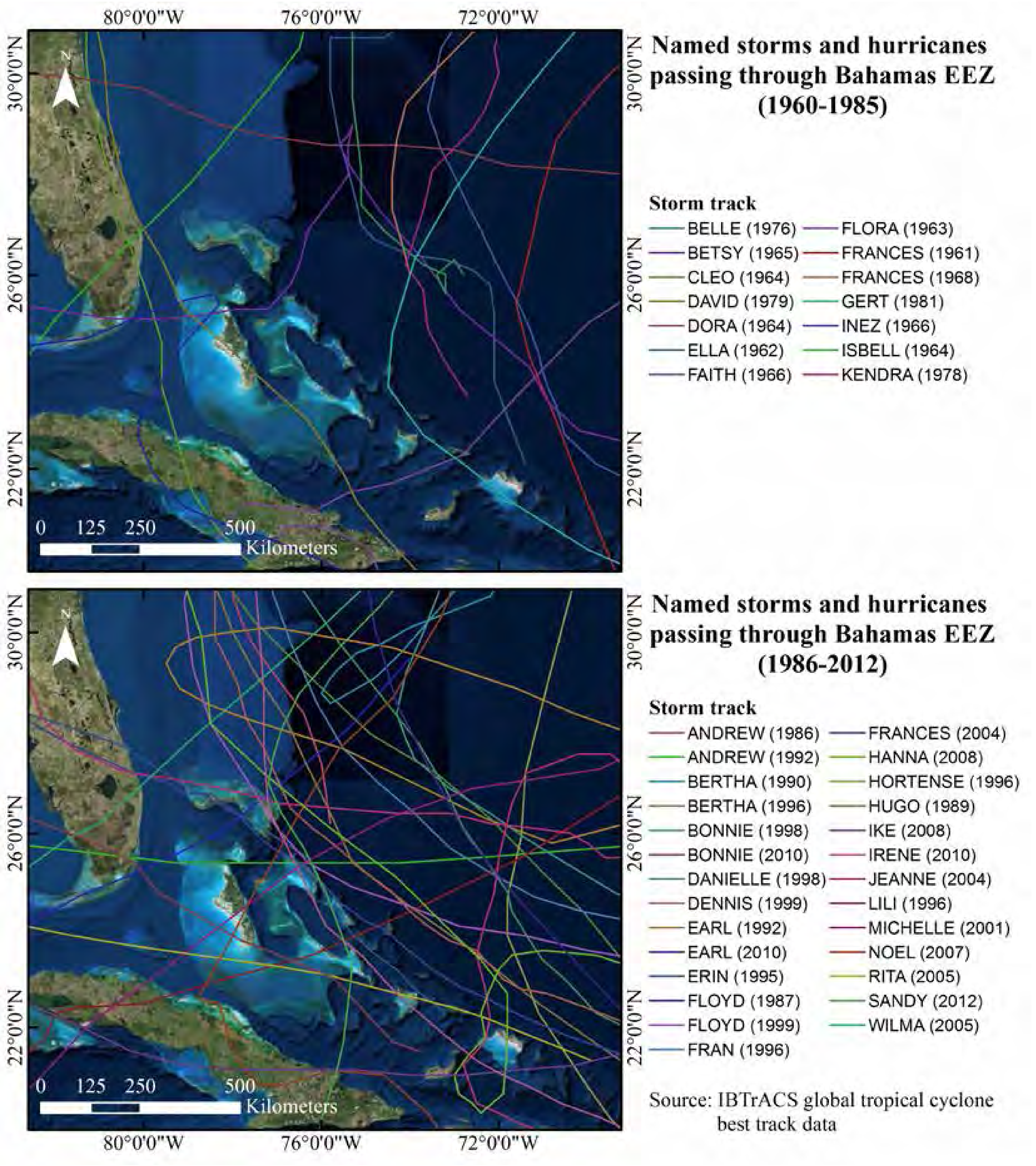


The tidal cycle recorded at Elbow Cay, Cay Sal Bahamas during 2013.

Seasonal climatic cycles and local wind systems

In Northeastern Bahamas, winds are predominantly easterly throughout the year but tend to become northeasterly from October to April and southeasterly from May to September. These winds seldom exceed 7 m/sec except during hurricane season. In southern Bahamas, around Hogsty, Great Inagua and Little Inagua, winds are predominantly from the east-northeast, except in June, July and August, when they are from the east-southeast. Maximum wind velocities occur in November through January (average of 5.8 m/sec) and minimum values occur in May (average, 4.4 m/sec).

The Bahamas lies within the North Atlantic Hurricane belt. Although the hurricane season officially lasts from June to November, most hurricanes in the Bahamas occur between July and October. Typically, the Bahamas gets brushed or hit by a hurricane once every three years, and gets hit by a major hurricane once every 12 years. In terms of frequency and severity, three islands in the Bahamas, Andros, Abaco and Grand Bahama, are ranked in the top 5 for all cities/islands in the Atlantic Basin, being surpassed only by Grand Cayman. The tracks of hurricanes that have impacted the Bahamas since 1960 are shown in the two figures to the right. Recent hurricanes to have affected the Inagua region include Hurricane Irene (2011), Hurricane Tomas (2010), Hurricane Ike (2008) and Hurricane Kate (1985), with the most severe damage attributed to Hurricane Ike. Cay Sal Bank has been brushed or hit by only three hurricanes since 1960.



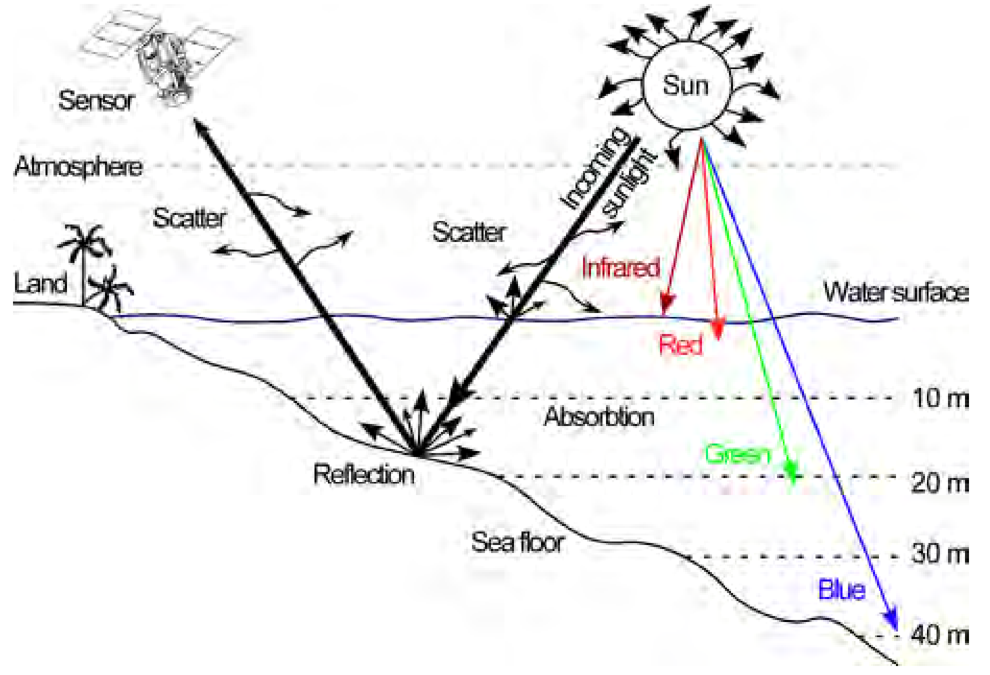
Source: IBTrACS global tropical cyclone best track data

The path of hurricanes and tropical storms that passed by the Bahamas between 1960-1985 (top) and 1986-2012 (bottom).

Remote sensing principles

The vast majority of the maps presented in this Atlas were produced using images collected from a passive visible-infrared spectrum satellite through a process known as remote sensing. Remote sensing involves the collection and interpretation of information about the landscape, sea and atmosphere from a distant vantage point. Images are typically gathered from aircraft, satellites, and boats using aerial photography, airborne hyperspectral sensors, satellite based multispectral sensors, radar altimetry, laser bathymetry and sonar. The use of remote sensing techniques to map coral reefs has been greatly enhanced in recent years. New multispectral and hyperspectral high resolution sensors are based on a common principle that coral reefs modify light in a different manner than their surroundings. Reef habitats look different than sand flats, algal meadows and grassbeds when viewed from above, due to the way the sun's light (the visible portion of the electromagnetic spectrum) is reflected.

There are numerous challenges with this approach, however, as water changes both the magnitude and distribution of energy with respect to wavelength, with acute effects increasing with depth. Along its path to the Earth's surface, a large portion of sunlight is scattered by the particles and gases within the atmosphere. A considerable portion of the downwelling light fails to penetrate the water due to strong interactions at the surface. This component of the light field is reflected back into the atmosphere, and is not used in remote sensing. Partial reflection, as well as refraction, occurs at the water surface. If this air-water interface is rough, reflection off the surface can be high and penetration of light into the water is low. Referred to as sun-glint or simply 'glint', this problem is particularly pronounced if the sun is low to the horizon or the water surface is rough at the time of image acquisition.



A schematic diagram depicting the fate of photons in shallow tropical water (above). Only the signal that reflects off of the seafloor contains viable information used by the sensor to interpret the benthic character.

If the water is calm and clear, and the sun is high above the horizon, a sizable fraction of the light penetrates the water surface and propagates down towards the seabed. A portion of the light field that penetrates water column interacts with the water's surface on its return from the bottom, being reflected back into the water column and lost. The component of the light field ultimately used in remote sensing is the fraction which passes into the water column, interacts with the seabed and then is reflected back, crossing the air/water interface. Light is absorbed differentially as it moves through a body of water. Infrared light, that is light with a wavelength between 700 nm and 30,000 nm, is fully absorbed at the water's surface. Red light (600-700 nm) may penetrate a few meters, green light (500 – 600 nm) around 20 meters, and blue light (400-500 nm) reaches a maximum depth of several hundred meters, but is useful in a remote sensing case to depths of only ~40 m. Turbidity in the water column, by virtue of an increased scattering of light from suspended particulates, reduces the depth of light penetration. Remote sensing images taken under extreme turbidity and/or surface roughness are rendered useless for mapping purposes as even the very shallow seabed is obscured.

A portion of light, albeit typically only a fraction of that which originally downwelled onto the sea surface, may be reflected upwards, back through the water column, water surface, and atmosphere, before being intercepted by an overflying remote sensor. To further complicate matters, the upwelling light that is able to cross the air/water interface is refracted due to differences in the optical density of air and water, resulting in changes in the magnitude and directional properties of the light, further reducing the amount of light that is available to be intercepted by the sensor. Fortunately this does not change the spectral distribution (e.g. color) of the light.

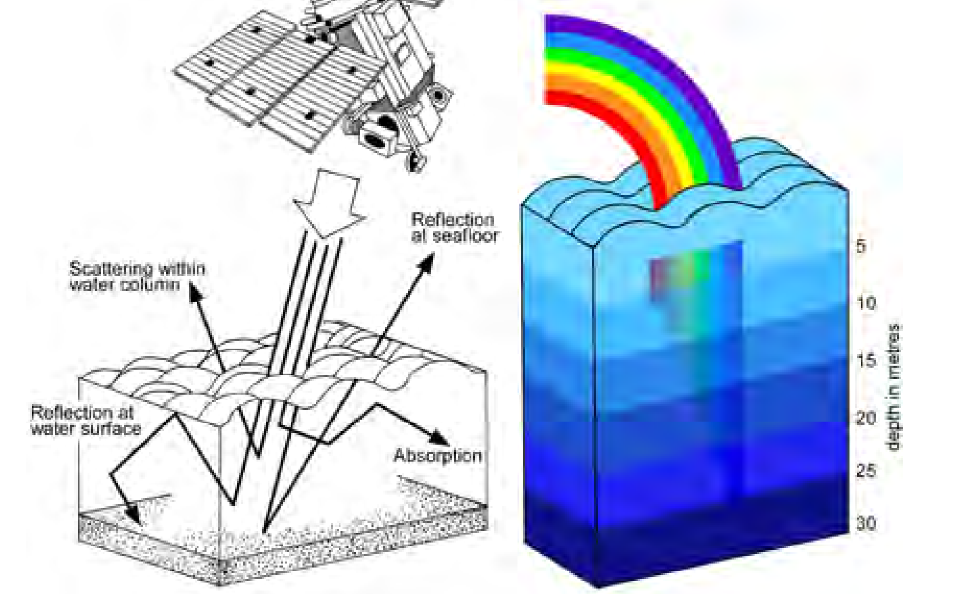
Remote sensing of coral reefs

Central to the practice of mapping seafloor habitats using optical sensors is the fact that different seabed types have different reflectance characteristics. Dense seagrass beds, for example, by virtue of their chlorophyll content, predominantly reflect light in the green portion of the spectrum, while absorbing red and blue light. In contrast, sand has a high reflectance across all wavelengths of visible light, though increases in magnitude towards the red portion of the spectrum. Because light must pass through the atmosphere, surface interface and water column twice on its way from source to sensor, seafloor habitat mapping using optical sensors is constrained to clear calm tropical waters with a maximum operating depth of approximately thirty-five meters.

Modern instruments used for mapping usually operate in a push-broom fashion. Sunlight reflected back from the Earth is recorded by a linear-array of optical sensors. The resultant digital image is a rectangular grid where each cell, commonly referred to as a 'pixel', is characterized by a digital number. This number corresponds to a measurement of the light from a defined area on the ground. The size of area that may be sensed at any one time (the swath width) may be enlarged by increasing the size of the sensor array, raising the altitude of the sensor above the ground, or widening the instantaneous field-of-view of the instrument. As the sensor is raised above its target, however, each pixel in the resultant image becomes larger. Aircraft sensors typically have the highest spatial resolution as they are closer to the target than satellite sensors.

An important attribute of optical sensors is the level of spectral detail, or 'spectral resolution' they provide. Sensors are commonly characterized as either multispectral or hyperspectral. Multispectral sensors measure light across a handful of discrete portions of the electromagnetic spectrum. Each of these portions is termed a 'band'. Hyperspectral sensors have several hundred narrow and contiguous bands, such that the entire visible spectrum may be covered in great detail. This increased spectral resolution allows for enhanced discrimination of spectrally similar seabed habitats (such as the separation of algae from seagrass). Orbiting satellites, which travel at great speed and altitude above the surface of the Earth, are typically multispectral. These sensors do not remain over one spot long enough to allow for detailed spectral measurements without sacrificing spatial resolution.

The swath width of imagery acquired from aircraft is considerably smaller than that of a satellite. The same aerial coverage is acquired in seconds by satellite and days by aircraft. Consequently, there is a trade-off of imagery acquisition time versus spatial and spectral resolution. GPS sensors measure position, while a gyroscope is used to measure pitch, roll and yaw of the aircraft. Geo-positional accuracy, while high, is typically less easy to obtain as compared to imagery collected using the more stable platform of a satellite.



A schematic diagram depicting the dominant fates of photons in optically shallow water (left). Only the signal that has reflected off of the seafloor contains viable information that can be used by a remote sensing instrument to interpret benthic character. Depth at which color vanishes (right). Sunlight is rapidly attenuated by water molecules, plankton and suspended detritus. Blue light penetrates to the greatest depth and persists for several tens of meters into the water body. Red light, conversely, is extinguished within a few meters of the surface. Figures modified from Purkis and Klemas (2011).

Bahamas Habitat Mapping

This Atlas presents two types of maps that visualize the seafloor for select sites in the Bahamas. The more common of the two is a thematic map delineating benthic habitats, and the less common is a topographic map representing the seafloor's surface topography. When taken together, these maps enable researchers to visualize the 3-dimensional complexity and benthic community of the seafloor. Each map was created by combining information on the spectral properties of the seafloor gathered by powerful satellite-borne sensors with data gathered in the field. The following text describes the satellite imagery and field data used for habitat mapping and the methodology applied to produce the thematic and topographic maps.

Physical phenomena affecting seafloor mapping

Each satellite image records radiance, or the amount of light, reaching the sensor at the time of fly-over; however, observations for the same location at different times and from different angles may not provide similar values. This is problematic when combining multiple images to create thematic and topographic maps because it creates inconsistency in the resulting products. Fortunately, a conversion from at-sensor radiance to surface reflectance removes these differences.

The conversion from at-sensor radiance to surface reflectance must account for absorption and scattering in the atmosphere and the observation and illumination angles. Molecules and particulates absorb and scatter light as it travels through the atmosphere, and these effects are described by Rayleigh scattering and Mie theory (Gordon 1993). The former describes the scattering of light by molecules whose diameters are much smaller than the wavelengths of photons, and it is the phenomenon that causes the sky to appear blue during the day and red around dawn and dusk. The latter accounts for the absorption and scattering of light by particles, such as water droplets in the air. The haze created by fog and smog is a prime example of this phenomenon. The magnitudes of the atmospheric effects are functions of the path length, or the distance light travels on its journey from the Sun to the satellite. This distance varies from image to image due to the relative positions of the Sun and satellite with respect to the Earth during observation. The shortest path length possible occurs when both the Sun and satellite are directly overhead; however, this is rarely the situation. More commonly, the Sun illuminates the Earth's surface at an angle based on the time of day and the day of the year, while the satellite simultaneously observes the planet from orbit at an off-nadir angle (i.e., off to one side). Thus, path length varies from image to image, and geometry provides the equations needed to calculate this parameter for each scene. With knowledge of the atmosphere and relative positions of the Sun, satellite, and Earth, the at-radiance is converted to surface reflectance. For terrestrial areas, this is enough to allow thematic mapping from multiple images. For marine applications, the influence of the ocean-atmosphere interface requires another processing step.

Ocean waves cause a phenomenon called sun-glint, which is an excess of reflected light. Pixels contaminated with sun-glint appear over-saturated (i.e., too bright), and excess light must be removed before mapping the seafloor. Visible light readily transmits through water while near-infrared light penetrates no more than a few centimeters into the water column. Over deep water, brightness values in the NIR bands result from sun-glint and provide a relative measure of excess light in a pixel. A statistical model correlates a near-infra red band with a visible band to remove sun-glint in the latter. It is at this point in the processing chain that the satellite imagery is ready for production of the thematic and bathymetric maps. Before describing the mapping techniques, the physical phenomena associated with the water column that constrain seafloor mapping are discussed.

The water column scatters and absorbs light in a manner similar to the atmosphere; however, light attenuates much quicker in water than in air. This constrains seafloor mapping in several ways. To start, only light in the visible spectrum (400 nm – 700 nm) penetrates the water column sufficiently to provide information on the seafloor. At wavelengths greater than 700 nm, water is nearly opaque. Further, light in the visible spectrum attenuates at different rates resulting in blue light (~400 nm) having the greatest penetration into the water column. Green light (~550 nm) penetrates less than blue light and further than red light (~700 nm), which is nearly absent after ~5m.

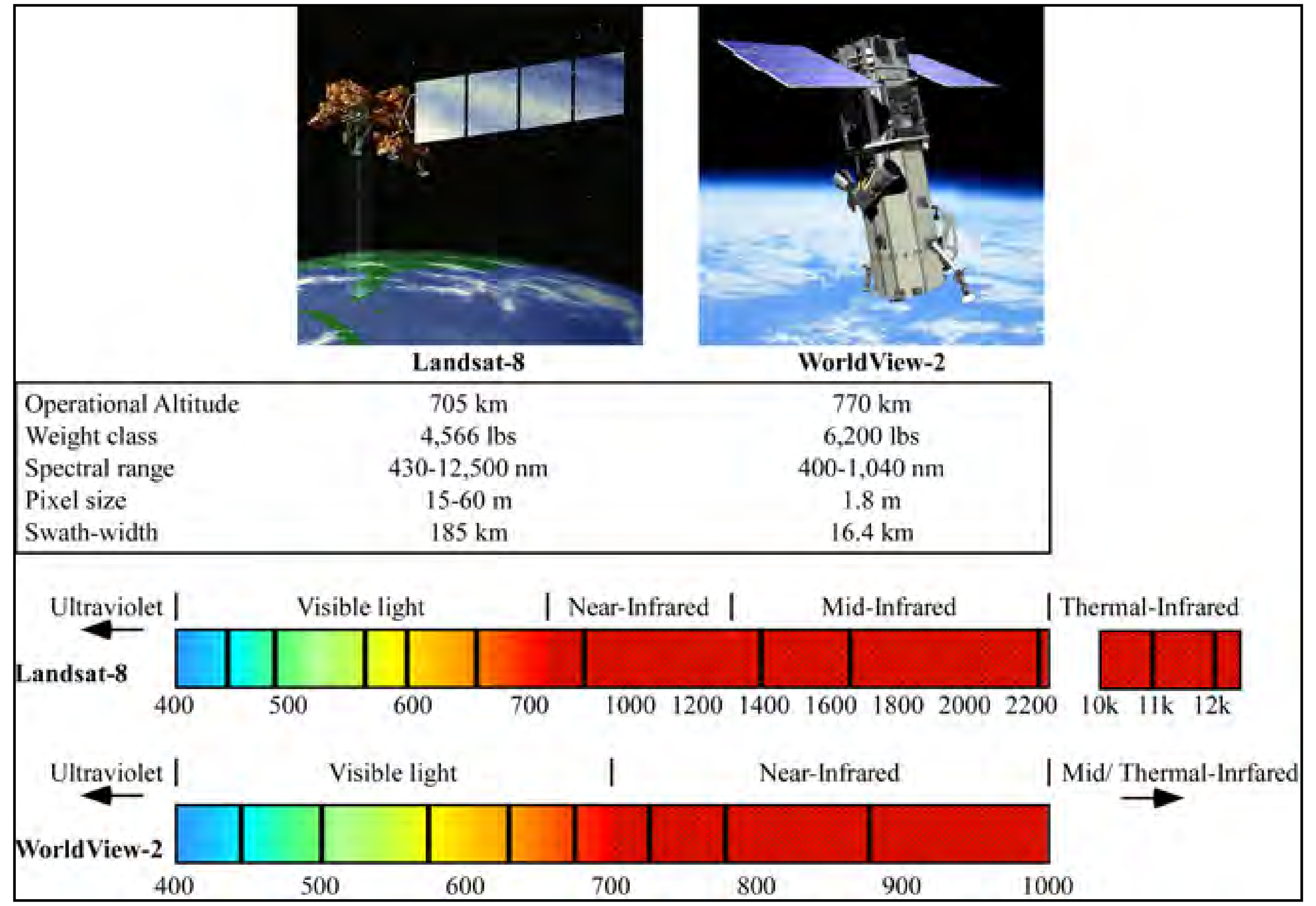
Besides light attenuation in the water column, benthic cover influences the observed spectral values in a pixel because each class reflects light across the visible spectrum differently. Spectral measurements of major benthic cover classes shows that three broad spectral classes are distinguishable: coral, sand, and vegetation. Further splitting of these classes is difficult because the spectral differences between subclasses are very fine, and there is substantial variability in reflectance properties within each group. The combined effects of light attenuation and seafloor reflectance provide a daunting challenge when mapping the seafloor; however, understanding these two phenomena allows researchers to find innovative methods for estimating water depth and classifying the benthos. The methodology adopted for the maps in the Atlas requires a substantial ground-truth data-set for ensuring reliability in the products, and the following text outlines the data gathered during the field campaign.

Optical sensors used for this project

WorldView-2 (WV2) satellite imagery is the basis for all maps presented in this Atlas. The satellite, owned and operated by DigitalGlobe, Inc, orbits the Earth at an altitude of 770 km and images the planet's surface using eight multispectral bands and a single panchromatic band. Six of the eight multispectral bands encompass the visible spectrum (400 – 750 nm) while the remaining two bands cover the portion of the near infra-red spectrum from 750 nm to 1050 nm. Each pixel has a spatial resolution of 2-m by 2-m, thus covering a 4 sq m area, and each image has a spatial extent of several kilometers. Furthermore, the satellite has a revisit time of 1.1 days, meaning it is able to observe the same location on the Earth's surface nearly every day. The fine spatial resolution, large spatial coverage, quick revisit time, and number of spectral bands position the WV2 satellite as the best platform for mapping coral reef systems from space currently available.

Each WV2 image was evaluated for quality prior to purchase. Scenes with excessive sea-surface-glint, cloud cover, or other factors that obscured bottom features, were avoided. Imagery was delivered as a georectified product. The images were converted from 16-bit digital numbers (DN) to remote sensing reflectance (%) just above the water's surface. Only light between 400 nm and 700 nm penetrates the water column sufficiently to provide usable information on the benthos' composition, thus only the five spectral bands within this region were used for benthic habitat mapping.

Landsat ETM+ (NASA / U.S. Geological Survey) is an older satellite platform launched in 1999. Although Landsat has a coarser spatial resolution of 30 m^2 as compared to WV2, the data were used for navigation and site-selection in the field, as well as for habitat classification on occasions where cloud obscures reef features in the WV2 scenes. Landsat data were also used as a terrestrial base layer.



	Landsat-8	WorldView-2
Operational Altitude	705 km	770 km
Weight class	4,566 lbs	6,200 lbs
Spectral range	430-12,500 nm	400-1,040 nm
Pixel size	15-60 m	1.8 m
Swath-width	185 km	16.4 km

Landsat includes five bands in the visible, four in reflective IR range and two in the thermal IR range. WorldView-2 operates in the panchromatic mode or multispectral mode with a spectral resolution of six bands in the visible region and two in the near infra-red (band centers shown as black lines).

Preprocessing of imagery

Image pre-processing was performed on raw data in order to increase the accuracy and interpretability of the image prior to classification. This included four steps: 1) radiometric correction of variations in the image resulting from environmental conditions such as haze. Land and cloud were masked out of the imagery and a correction for sea-surface glint was applied prior to habitat classification; 2) geometric correction to compensate for the Earth's rotation and for variations in the position and altitude of the satellite; 3) terrain correction of relief distortions; and 4) image enhancement techniques to improve visual interpretability.

Ground-truthing

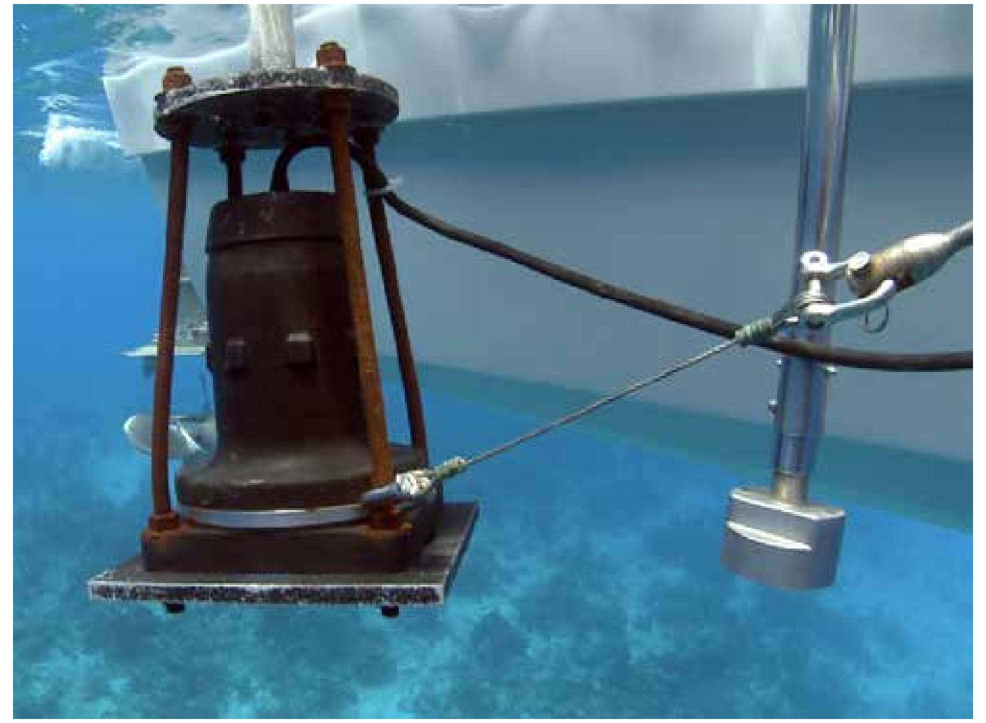
Ground-truthing is the collection of pertinent field data within a study site to ensure map reliability. The ground-truth data for maps in this Atlas include acoustic depth measurements, videos gathered by a tethered camera, and digital photos. Researchers primarily use a small boat for the acquisition of depth soundings and videos allowing access to shallow areas and the ability to cover large areas in a short time. SCUBA diving is the primary method for capturing digital photos. The latter approach allows for more detailed description of seafloor features yet restricts the number of sites visited in a day. The field campaign maximized the spatial extent of data across the platforms and observable depths (shallower than 30 m) while maintaining safe operating conditions. The final ground-truth data-set provides information on which to train and to validate mapping algorithms while providing a visual baseline of the benthos against which future benthic studies can be compared.

Depth soundings

The water-depth derivation model requires in situ measurements to produce reliable maps of the seafloor topography. A single beam sonar system mounted vertically on the side of a small boat continually collected depth soundings directly below the boat while the ground-truth team surveyed the platform. The instrument is a 200 kHz hydrographic, survey-grade, acoustic sounder that emits an acoustic ping ten times per second, listens for the returning echo of each ping, and estimates depth by comparing the amount of time between ping emission and echo reception. Recorded depths have an accuracy of ±10 cm. A differential GPS unit provides a highly accurate geographic position for each depth sounding allowing it to be tied to a pixel in the satellite image.

Digital Videos and Photos

Digital videos and photos record the seafloor's characteristics as observed by researchers during the field campaign. Each digital video is a 30-60 second clip of the benthic community. A tethered camera lowered over the side of the small boat and connected to a laptop aboard the vessel captured the videos. Each clip includes the position of the image, the boat speed and heading, and the time of recording. SCUBA divers collect digital photographs using cameras in water tight housings. The photographs mark features of interest and help researchers identify dominant members of the benthic community. Both videos and photographs support the habitat classification scheme and the training of the classification algorithm.

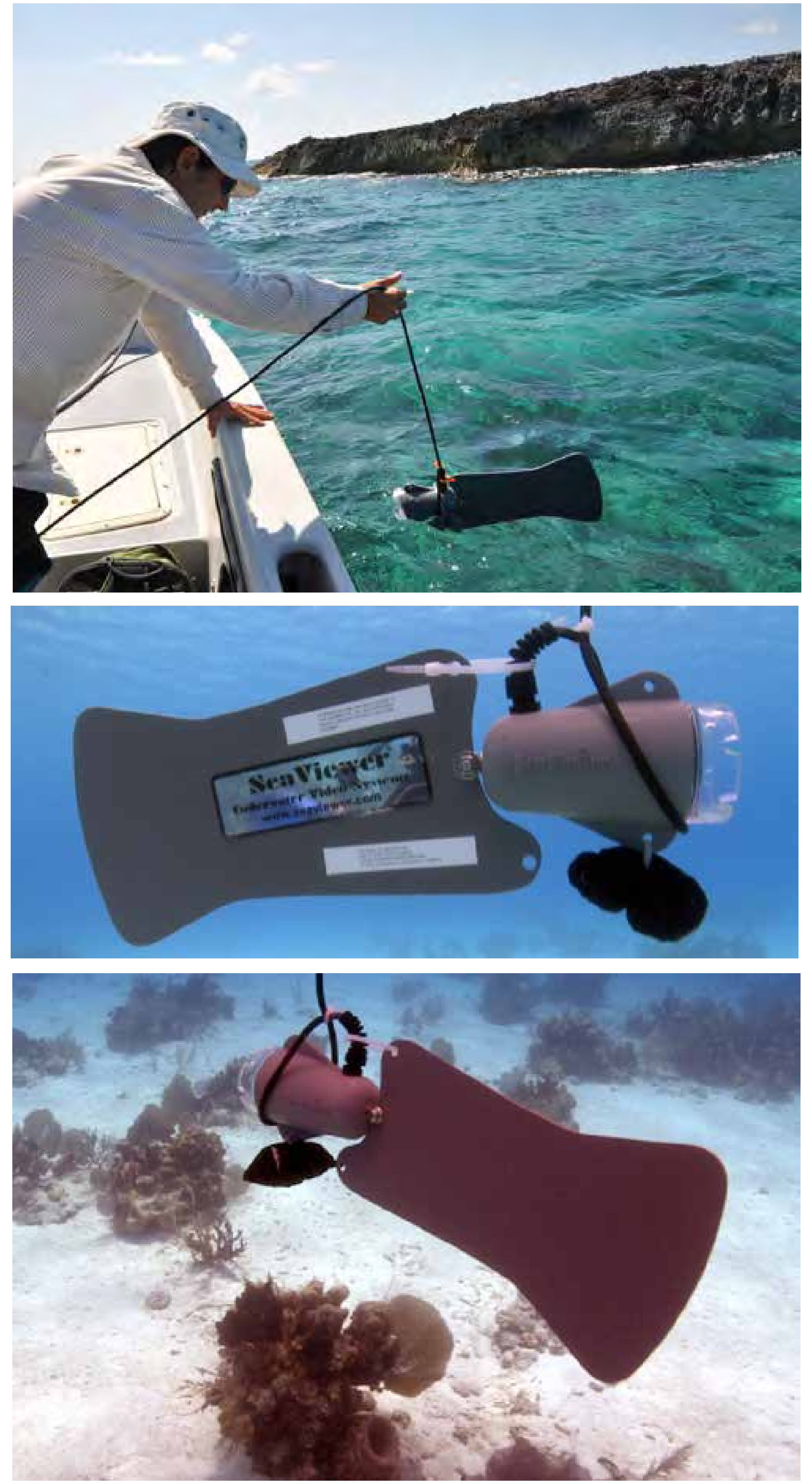


Acoustic sub-bottom profiler (left) and acoustic depth sounder (right) deployed from survey vessel's side (top center). For the sub-bottom profile, a cable transmits data to a laptop aboard the boat while a second cable stabilizes the transducer during travel along the transect line. The cable for the acoustic depth sounder is housed within the metal pipe that attaches it to the boat.

Measuring water depth

The map producer employed a statistical model to correlate the ratio of the blue and green spectral bands in a WorldView-2 satellite image with depth soundings gathered during the field campaign. The model assumes that a ratio of these two spectral bands removes the effects of seafloor reflectance and thus the only variable controlling the ratio's value is water depth. For each depth sounding, the spectral values of the blue and green bands for the associated pixel are extracted, and a linear regression between depth and band-ratio is fit. The regression coefficients are applied to the entire image to create a topographic map. The predicted depths' accuracy are generally within ±50 cm for depths shallower than 5 m and increases to ±1.5 m at 20 m.

The mapping team uses the satellite imagery displayed on a rugged laptop to identify features of interest as they navigate across the study site (bottom center).



SeaViewer tethered video camera used to characterize habitats. Deploying the tethered video camera (top right); sideview, underwater (right center); and the camera being "flown" above the reef (bottom right).

Thematic mapping

The bulk of maps present in this Atlas are thematic maps delineating the habitats found on the seafloor. The thematic maps result from a combination of object-based supervised classification, contextual editing, and expert correction of misclassifications. The final products provide baseline information on the spatial distribution of benthic habitats across a large spatial extent (10s to 100s of km) at a fine spatial scale (2 sq m) for previously unmapped areas.

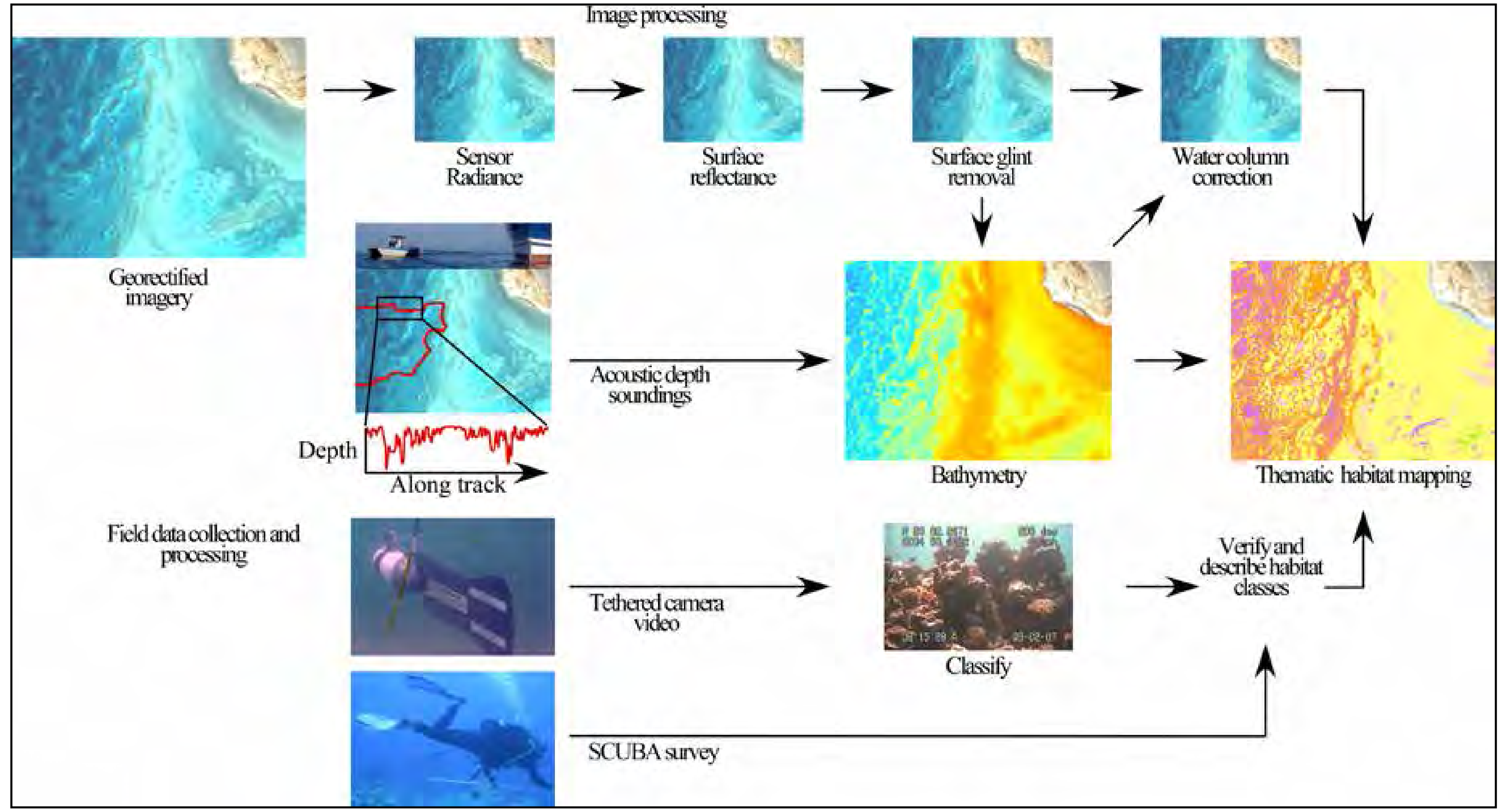
Object-based supervised classification

When observed from a bird's-eye-view, the seafloor is a mosaic of features, and the goal of classification is to assign a meaningful label to each feature in the image. It is possible to classify an image manually; however, the large spatial extent and fine-grained nature of the satellite imagery used for this Atlas preclude such an approach because the required time and effort is infeasible. The alternative is to automate the classification process. Several methods exist for automation, and object-based supervised classification is one of the most common approaches. For this method, the producer uses knowledge of the real world, developed by collecting and reviewing ground-truth data, to create a data-set that trains a computer algorithm in how to classify an image. The algorithm uses heuristics to parse the data and returns a classification scheme that matches the training set. The producer applies this scheme to the entire image and evaluates the resulting thematic map. At this point, the producer may either modify the training set to improve the training data and perform the classification again or to accept the resulting thematic map.

The maps in this Atlas result from an object-based approach using binary decision trees that differs from the traditional nearest neighbor, pixel-based approaches. In the latter, pixels are the minimum mapping unit, and each pixel is assigned to the habitat class whose spectral properties it most resembles (i.e., the pixel's nearest neighbor). The object-based differs in that the minimum mapping unit is a group of neighboring pixels with similar spectral properties. Objects fundamentally provide a greater number of diversity of properties. For a select pixel in a WV2 image, only the spectral brightness for each band is available. From there, one can begin creating other values such as band ratios. Comparatively, the mean, median, mode, minimum, maximum, and standard deviation of the spectral observation within an object for each spectral band are available. Just as with pixels, one can begin creating other values for which to assign classes to the mapping units, but the producer now has more basic values to work with. This does not mean every new possible combination of the various statistics are useful, but the overall number of values from which to draw from has substantially increased. Unlike the nearest-neighbor classification, a binary decision tree instead splits clusters into smaller groups in a way that minimizes the overlap between the classes and avoids over-fitting the data. Neither approach is perfect though, and the thematic maps require additional editing.

Contextual editing

The inclusion of additional information not directly available from the multispectral satellite imagery to improve thematic maps is contextual editing. Classification approaches relying primarily upon the spectral properties of seafloor features may not distinguish enough classes to support an end-user's research or policy needs. Contextual editing refines the thematic map by identifying features that have similar spectral properties yet experience different environments or have different benthic communities. Thus, the maps provide more information to the end-user than would be available by an automated classification alone. Furthermore, the producer corrects misclassifications based on their knowledge of the system ensuring the maps' reliability.



Work flow for deriving water depth and producing benthic reef habitat maps. WorldView-2 satellite imagery is prepared for analysis through a series of processing steps, yielding images of high radiometric quality and consistency. Field data provide ground control to facilitate the training of mathematical algorithms.

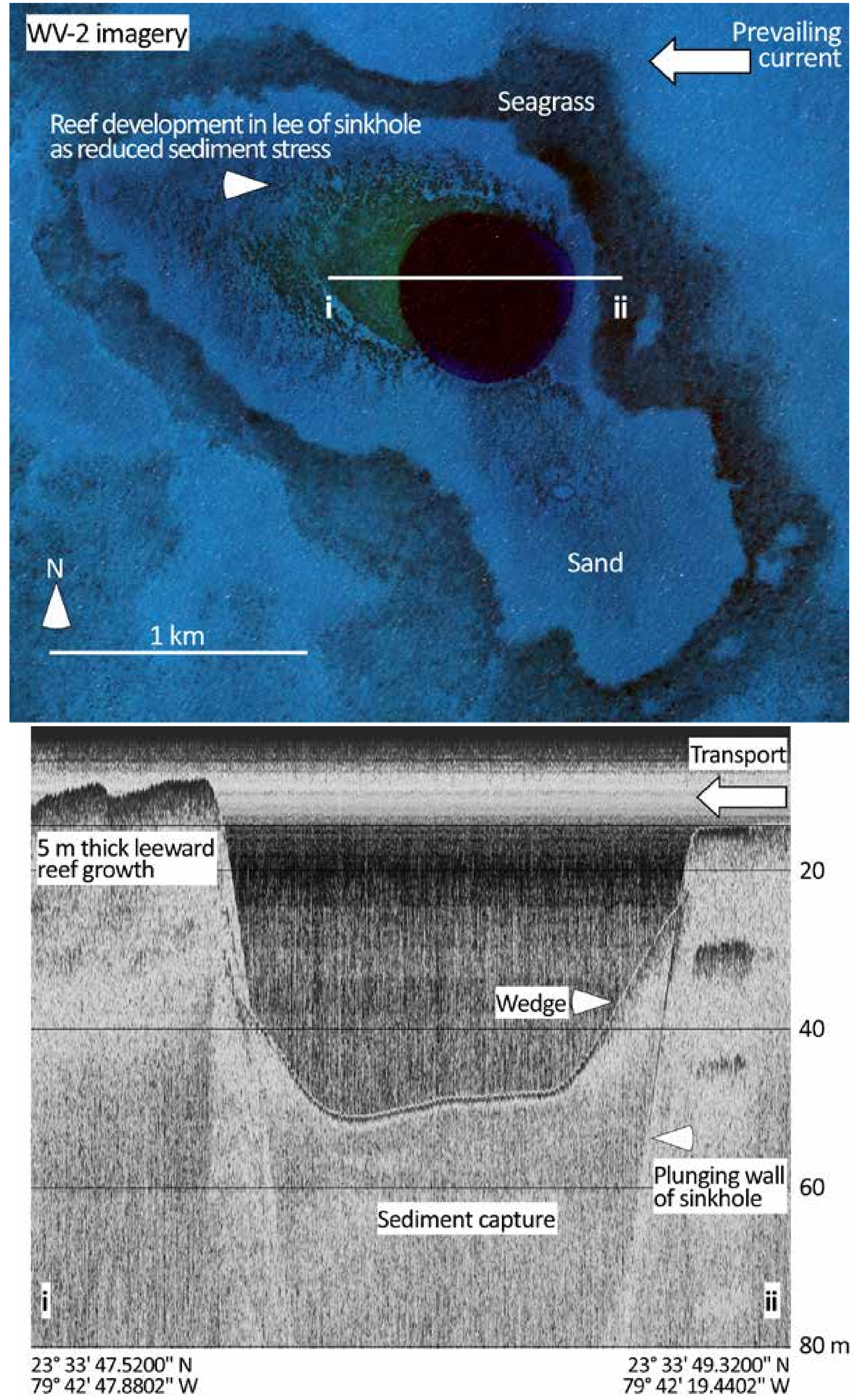
Data conversion

Habitat classifications were converted to GIS-ready vector-based map products using remote sensing and GIS software. Pixel-based products, termed 'rasters', were converted into vector-based data. Under this system of storage, clumps of adjacent pixels that comprise a single patch of habitat are grouped as a single vector shape or polygon. Because only information relating to the boundary coordinates of the polygon is stored, such data is less intensive and easier to use for a number of applications. So called 'shape files' are easily integrated with web based geographic media for distribution to the masses. Attributes may be subsequently appended to a habitat polygon. Aside from a description of the relevant habitat class, such attributes might include geometric measures, for example area or perimeter of the habitat patch; measures of environmental context, such as distance from shore, or distance from an urban center; measures of human use, for instance fishing pressure across the habitat patch or recreational scuba; localized environmental data including meteorological measurements, water depth across the polygon, water temperature, or results from fine-resolution seafloor survey. In short, anything that can be measured and appended with a spatial coordinate can be brought into a GIS. As a GIS-ready product, the marine habitat data presented in this Atlas are primed for more in-depth exploration.

Final products

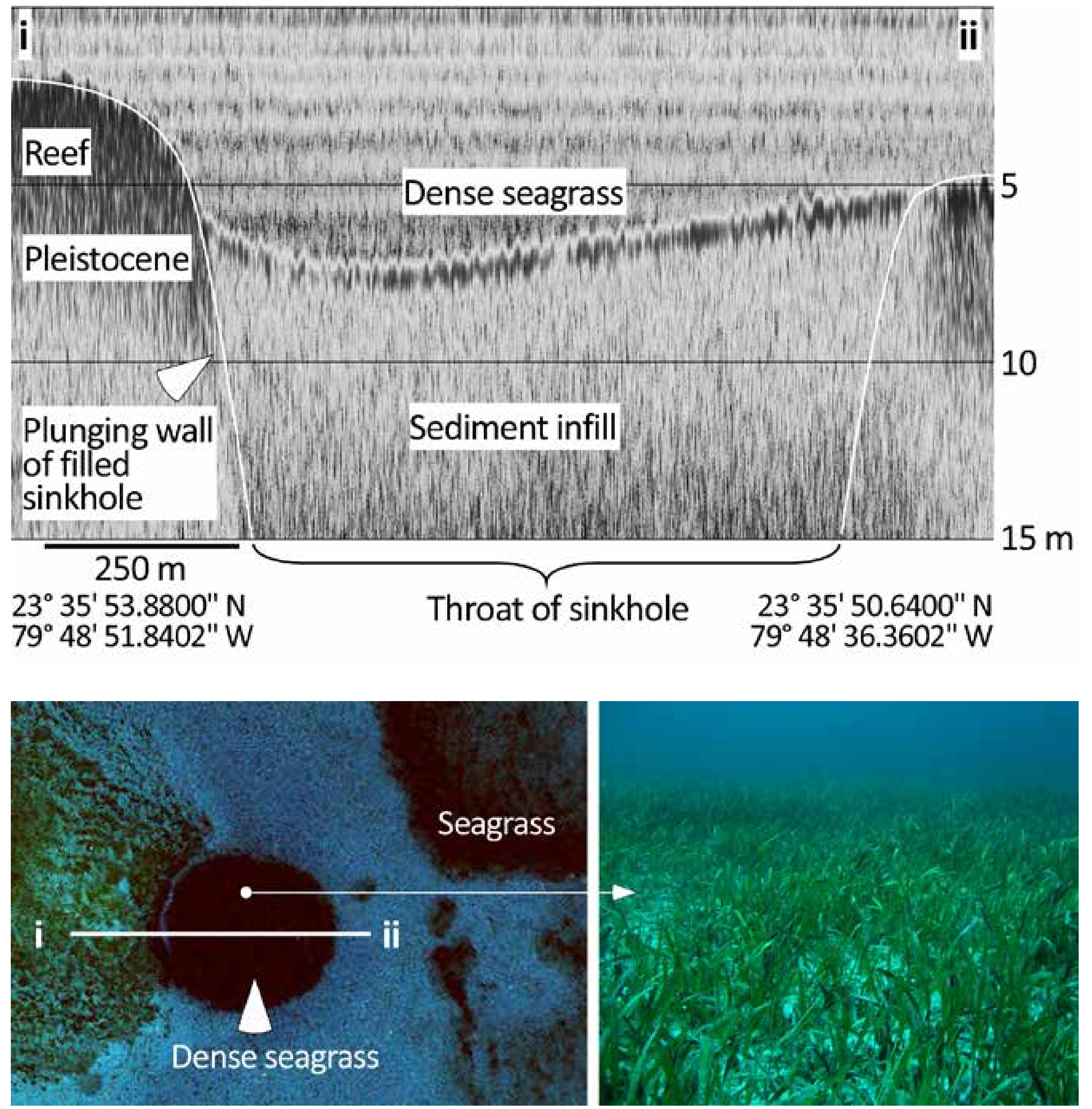
A GIS software application is used to capture, display, store, manage and analyze digital geo-spatial data. Perhaps most simply, GIS can be thought of as the marriage between mapping and database technologies. Because GIS supports both a data storage and data exploration, information from such seemingly disparate sources can be brought together and analyzed within their true spatial context. A GIS-ready habitat map represents the precursor to a more synoptic view of the marine system. It allows for more enhanced ecological investigation, but beyond this improved marine spatial planning and management.

The final maps are layers in an ever-growing GIS stack maintained by the Khaled bin Sultan Living Oceans Foundation and provided at no-charge to the Bahamian government and the public. The data are maintained in both a raster and vector format. Although the two structures essentially present the same information, the two versions enables end-users to be more flexible in how they integrate the data into their research and policy decisions.



Sub-bottom profiling

A portable sub-bottom profiler was used to detect sediment layers beneath the surface. This type of information is extremely valuable, as it can be used to determine the underlying geology of an area and its sedimentary history. The instrument was able to detect different sediment layers at a resolution of 6 cm with up to 40 m sub-seabed penetration. In addition, the profiler could double as a deep water depth sounder, providing bathymetry measurements to 800 m with an accuracy of ± 0.5%. To obtain viable sub-seafloor information, either a 10 kHz or 3.5 kHz transducer was used, depending on depth and substrate hardness. Transects were routed perpendicular to slopes, bisecting lagoon systems and other geomorphological features identified from satellite imagery as potentially containing suitable reef structures below the sediment layer.



WorldView-2 satellite imagery showing the placement of a subbottom profile across an unfilled karst depression (blue hole) (top left). Sediment infill is asymmetric. The sediment wedge is more substantial on the eastern (upwind) margin of the sinkhole than the western (bottom left). A similar profile is seen in the bottom center, but this profile bisects a sinkhole that has been completely infilled by sediment (top right). The buried throat of the depression is colonized by a dense meadow of seagrass (bottom right). All figures are from Purkis et al. 2014.

On Cay Sal Bank, sub-bottom profiles run normal to the platform-margin provide evidence of thick (up to 20 m) accumulations of sands on the southern and western flanks while the platform-top is largely devoid of sediment. Pleistocene bedrock, which can be traced from the platform-top, beneath the bank-edge sand body and down the flanks of Cay Sal Bank contains numerous karst depressions that often attain widths of several hundred of meters. Some of these are sink holes (blue holes) that are over 100 m deep, while others have become infilled with sediments. These infilled sink holes provide important habitat and feeding grounds for many animals, as they often support seagrass meadows.

Terrestrial Vegetation

The Bahamas are often divided into three regions based on the climate and the associated vegetation. Large islands in the Northern Bahamas (Grand Bahama, Biminis, Berry Islands, Abacos, North Andros, and New Providence) were historically covered primarily by Caribbean pine (*Pinus caribaea*) woodland with a broadleaf shrub and palm understory. Central Bahamas (South Andros, Eleuthera, Cat Island, the Exumas, Ragged Islands, Long Island, Rum Cay, Conception Island and San Salvador) mostly contains broadleaf "coppice", dense, low semi-evergreen forest. The Southern Bahamas (Crooked Island, Acklins Island, Samana Cay, Mayaguana, Little Inagua and Great Inagua) is the driest part of the Bahamas and vegetation is mostly dry shrubland. Most of the plants and animals found in the Bahamas originated in the Greater Antilles, being transported from Cuba and Hispaniola during low sea level stands. Some plants also arrived via birds and as flotsam, such as the four species of mangroves that occur in the Bahamas.

Coastal vegetation in the Bahamas. Scrub vegetation along a rocky island in Abaco (top left). Coconut palm and low lying scrub vegetation at Cay Sal (bottom left). Red mangroves colonizing a rocky islet in Abaco. A dense Caribbean pine forest is in the background (top center). Shrubland and beach vegetation along a sandy beach in Great Inagua (bottom center).

A single Caribbean pine (left) next to an invasive Australian pine on a rocky shoreline in Abaco, Bahamas (top right). Typical beach vegetation at Cay Sal Island (bottom right).

Rocky shoreline on an exposed island in Abaco (top left). Sandy beach in the Exumas (bottom left).

Shallow coastal and marine habitats

The Bahamas support a variety of coastal and marine habitats such as mangroves, seagrass beds, mud flats, hypersaline lagoons, sandy substrates and coral reefs with numerous linkages and trophic interactions among these habitats.

Mud flats

Mud flats or "swashes" with little or no permanent vegetation are an important feature of the intertidal zone. These extensive low lying areas of Holocene lime muds occur primarily along leeward shores.

Sandy intertidal and subtidal

The beaches of the Bahamas are composed primarily of carbonate sand of biological origin with fragments of shell and coral, and of chemical precipitation. On sandy bottoms throughout shelf, lagoon, and lagoon-margin environments, burrowing activity by thalassinidean shrimp often results in the development of distinctive sediment cones or mounds. These sediment cones commonly coalesce with time to form large composite mounds with surfaces stabilized by the development of microbial mats.

Rocky shorelines

Rocky shores are typically karstified eolianite and coral rubble, often colonized by maritime vegetation. The rocky intertidal is characterized by four distinctive zones described based on the colors each zone reflects,yellow, gray, black, and white. Each zone has a characteristic species assemblage that is controlled at its upper end by the degree and duration it is submerged due to tidal cycles and at its lower end by competition and predation. The yellow zone is only exposed during the lowest spring tides the water, and is submerged part of the time when the tides rise. The gray zone is the next up the shore and is exposed to the water when the tides are high. The black zone is above the gray and is only underwater during spring high tides and storms. The white zone separates the black zone from shoreline vegetation and is only underwater during heavy storms.

Rocky habitats in the shallow subtidal are typically pavement overlain with a few centimeters of sediment with sparse seagrass, isolated corals or dense macroalgae including *Microdictyon marinum* in protected areas and *Sargassum* and *Turbinaria* in exposed environments.

A mudflat community surrounded by mangroves at Little Inagua (top right) and a sandflat at Cay Sal with dense colonization of macroalgae, including *Udotea, Penicillus* and *Dictyota* (bottom right).

Seagrass beds

Grasses adapted to life under the sea about 100 million years ago, invading the sea at four different times, which has resulted in 4 distinct families (50 species, 12 genera) Seagrasses are found worldwide from the tropics to the Arctic, being absent only from Antarctica. The highest diversity is in the tropics; most found in soft bottoms, but one genus from the IndoPacific (*Thalassodendron*) is able to grow on rocky substrates. Like terrestrial grasses, seagrasses are true flowering plants (angiosperms) with roots and blades. They are the only group of flowering plants able to withstand complete and continuous submersion and produce flowers and seeds underwater. Seagrasses often form vast meadows, but they can also be sparse and widely dispersed. Roots connect under the sediment to form a complex rhizome system that traps and stabilizes sediment. The depth range of seagrasses is limited by light levels and quality of light, but temperature, sediment nutrients and microbial interactions also affect seagrass growth.

Flower from *Thalassia testudinum.*

Distribution

In the Bahamas, dense seagrass beds are limited to shallow, sunlit water along sheltered coasts with sandy or muddy bottoms, with sparse seagrass continuing to depths of 40 m (e.g. *Halophila*). Typically, colonization of soft substrates undergoes a characteristic pattern of succession starting with rhizophytic algae (e.g. *Caulerpa*), followed by *Halodule* (shoal grass) and sometimes *Syringodium* (manatee grass), both of which are considered earlier pioneering species. Once the environmental conditions become suitable, these species may be replaced by *Thalassia testudinum* (turtle grass), the climax species and also the most common seagrass found in the Bahamas.

Thalassia typically has the highest biomass in shallow low energy sites, but occurs from the low tide level to depths of approximately 10 m on sand and rubble-covered bottoms. *Syringodium filiforme* (manatee grass), has a similar geographical distribution. It usually grows intermixed with *Thalassia*, but can grow in monospecific meadows or patches from the upper sublittoral to more than 20m and becomes more common than *Thalassia* in deeper higher energy sites. Both manatee grass and turtle grass can survive in salinities of 20-36 parts per thousand (ppt).

Halodule wrightii (shoal grass), is found throughout the wider Caribbean region growing on sand and mud from the intertidal down to 5 m. Although shoal grass commonly occurs in estuarine waters with salinities of 10-25 ppt, it also forms dense patches in high salinity areas exposed to wave energy or in tidal flats. In protected estuarine environments and areas influenced by mangroves, seagrasses often consist of monospecific beds or alternating patches of *Thalassia* and *Halodule.*

The two species of seagrass in the genus *Halophila* occur in the Bahamas, *H. engelmanni* and *H. decipiens*. Both are small and delicate and require less light than other genera They can be found in very deep waters or very shallow areas with turbid conditions. *Halophila decipiens* occurs to depths of 40m, while *H. engelmanni,* a species restricted to the Bahamas, Florida, the Greater Antilles and the western Caribbean, is found only to depths of 5 m.

Importance

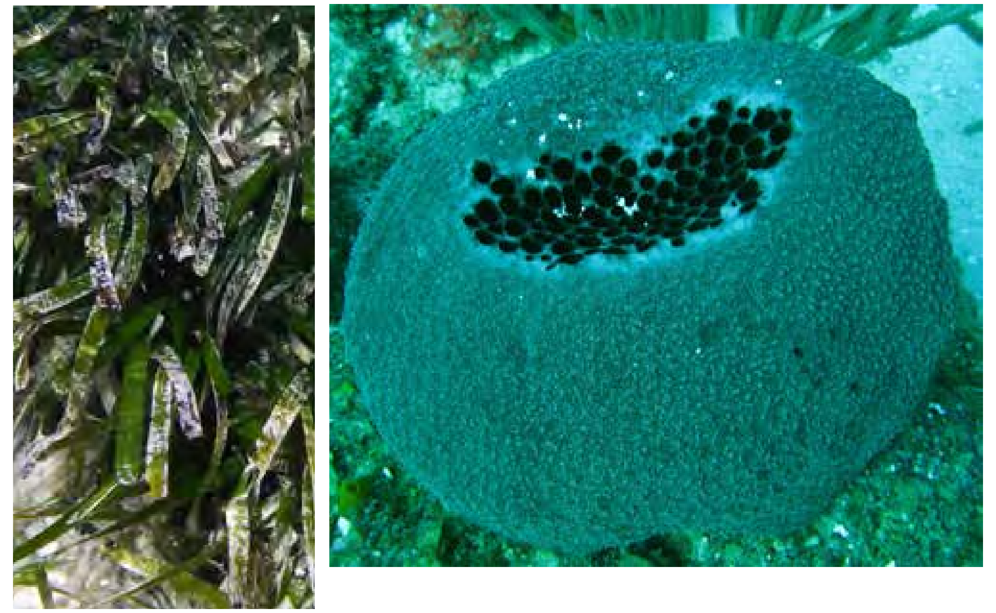
Seagrass beds play important roles in the tropics, and benefit many other species and habitats. The extensive root and rhizome system of turtle grass helps to stabilize the loose sandy or muddy sediment and prevents erosion during periods of heavy wave action. The leaves also reduce water currents, causing sediments to drop out of the water column and collect between the plants, effectively removing them from the water column. Seagrass blades usually have a coating of microscopic algae including diatoms and nitrogen fixing cyanobacteria. The fixed nitrogen produced by the cyanobacteria is transferred to the seagrass, increasing its growth and productivity. Seagrasses are considered to be open systems, exporting leaves and other components of organic material to other habitats.

Primary production of seagrasses in Bahamian waters is largely limited by the availability of nitrogen and phosphorus. A consistent source of these limiting nutrients can increase rates of seagrass and macroalgal growth. In addition to possible nutrient sources from mangroves, coastal runoff, and other organisms present in the seagrass bed (e.g. cyanobacteria), and microorganisms that recycle nutrients from the sediment and detritus, some invertebrates contribute to the nutrient cycle. *Ircinia felix*, the stinker sponge, is a nitrifying sponge that converts nitrogen into nitrate or nitrite, a form seagrasses can directly use. Some sponges may also provide sources of phosphorus as well.

Seagrass beds also have an important nursery function for commercially valuable crustaceans, fishes and molluscs. Some species use seagrass beds for their entire life, others use it as a nursery or breeding ground. Many species only use it as juvenile habitat and some make daily migrations between grassbeds and the reef. Burrowing organisms such as worms and gastropods find protection below the interwoven net of roots and rhizomes from predators that might otherwise be able to dig them out. A number of animals also attach to seagrass blades such as anemones, hydroids, sponges, bryozoans and tunicates which in turn attract other animals like molluscs, polychaetes and crustaceans.

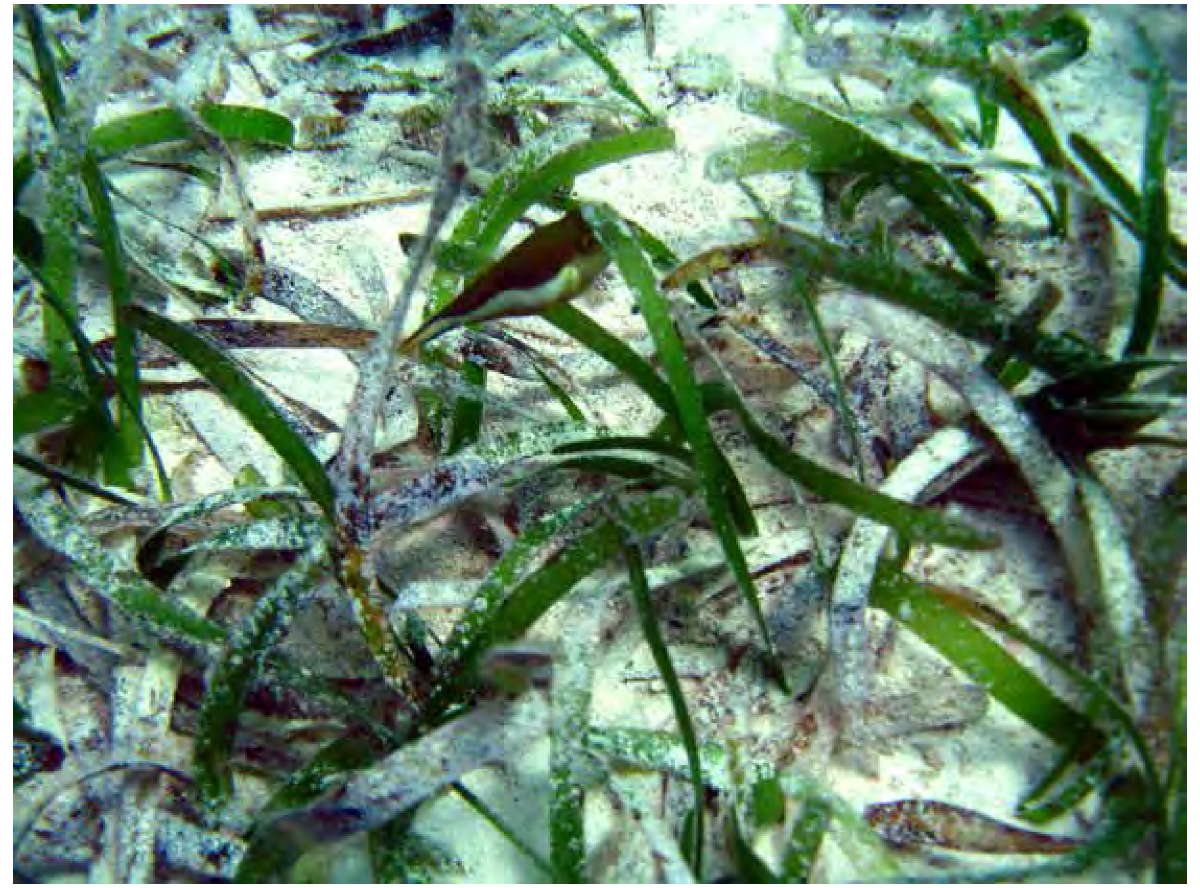
Many different species of algae grow amongst the seagrass, including Neptune's shaving brush (*Penicillus* sp.), Mermaid's wine glass (*Acetabularia crenulata*), Laurencia (*Laurencia obtusa*), Green feather alga (*Caulerpa sertularioides*), *Halimeda*, and *Dictyota*.

Common green macroalgae found in seagrass beds. Neptune's shaving brush *Penicillus* sp. (above left) and *Udotea* (above right). *Udotea* is heavily calcified. Flat-bladed *Thalassia* seagrass often becomes heavily colonized by epiphytes (bottom left). Stinker sponge, *Ircinia felix* from Cay Sal Bank (bottom right).



Distinguishing features of seagrasses

Of the 52 species reported world-wide, five species occur in the Bahamas:



Turtle grass, *Thalassia testudinum* (top left) has flat and ribbon-like grass blades, growing to 14 inches (35.5 cm) long and ½ inch (10 mm) wide. These blades have 9-15 parallel veins each, and are densely colonized by epiphytes. These long, broad blades distinguish it from other species of seagrasses. There are two to five blades per rhizome node. These rhizomes may be as deep as 10 inches (25 cm) below the substrate surface. Turtle grass grows in extensive meadows throughout its range.

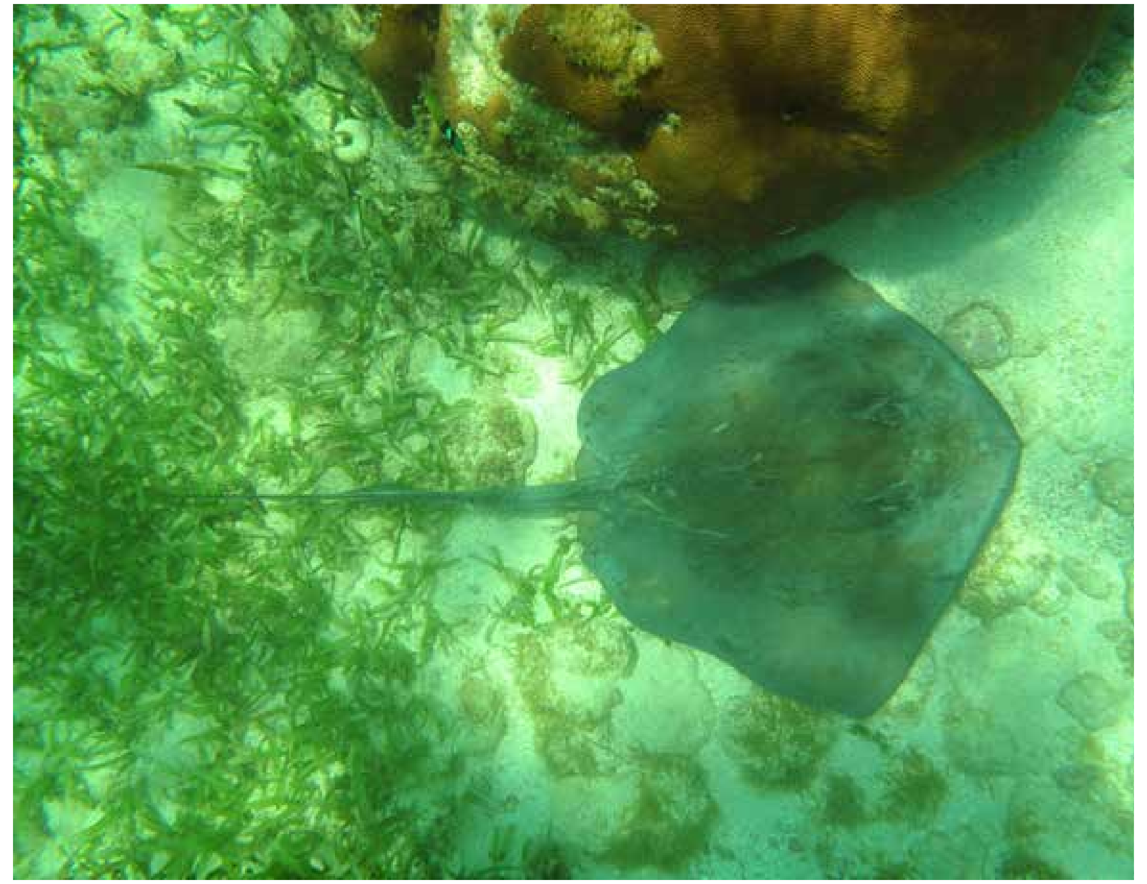
Shoal grass, *Halodule wrightii* (top right) The blades are clustered from a single node on the rhizome, with notched blade tips. The flat, narrow blades grow to maximum lengths of 4-6 inches (10-15 cm) and widths of only 0.08-0.11 inches (2-3 mm).

Manatee grass, *Syringodium filiforme* (bottom left), has cylindrical blades with two to four blades arising from each rhizome node. These blades can reach lengths of 20 inches (50 cm). Roots of this seagrass barely go below the substrate surface.

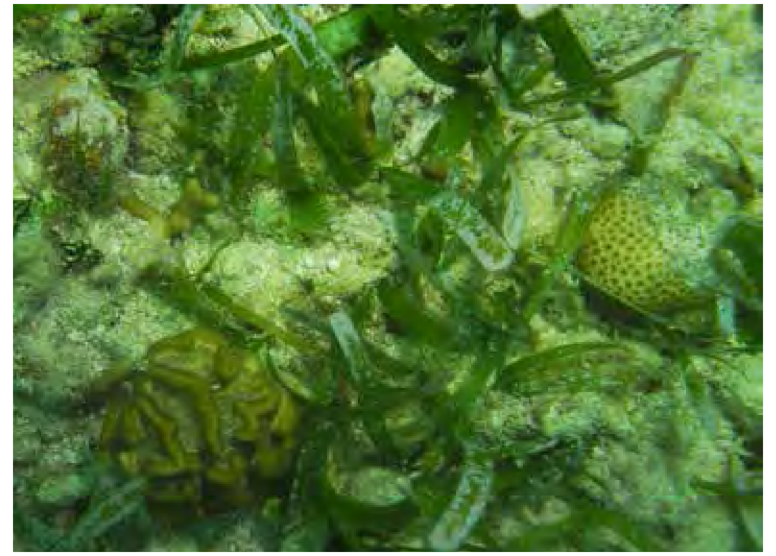
Paddle Grass, *Halophila decipiens* (bottom right) is distinguishable by a finely serrated leaf margin and a paddle-shaped green blade terminating with a rounded tip. The two, opposite, blades measure 0.5-1.0 inches (10-25 mm) long and 0.12-0.23 inches (3-6 mm) wide, extending directly from nodes on the rhizome.

Organisms found in seagrass beds

Habitat functions of seagrass beds. A lizardfish perches on the sediment waiting to ambush its prey (top left). Skates and rays often feed in grassbed habitats, searching for molluscs such as queen conch (bottom left).



Seagrass beds generally occur in calm shallow environments such as back reef and lagoonal habitats. Historically, a prominent halo was seen between the back reef and grassbed due to intense grazing pressure by *Diadema* and other herbivores. This halo disappeared from most reefs following the die-off of *Diadema*, and today seagrasses can be found growing adjacent to corals, such as the *Montastraea annularis* colony seen below.



***Montastraea annularis* colony within a turtle grassbed (top center). Three free living corals, *Porites furcata* (finger coral), *Manicina areolata* (rose coral) and *Siderastrea radians* (golfball coral) in a grassbed (bottom center). Grunts form a resting school within a bed of manatee grass on Cay Sal Bank (top right). A barracuda patrols a manatee seagrass bed (bottom right).**

Invertebrates found in seagrass beds. *Cassiopea* (upside down jellyfish) occur in calm, protected soft bottom habitats including mudflats, sandflats, grassbeds and mangroves (top left). *Oreaster reticulatus*, the West Indian red cushion sea star (left center) are found on sand flats, rubble fields and grassbeds. Sea cucumbers, such as *Holothuria mexicana* (bottom left) are important detritivores found in seagrass beds and sandflats. Juvenile conch (*Strombus gigas*) can be locally abundant in turtle grass beds (top center). Some free-living corals, such as branches of *Porites porites*, may occur within sparse seagrass meadows (bottom center). Herbivorous sea urchins such as the white sea egg (*Tripneustes ventricosus*) feed on grass blades and the attached epiphytes (top right). Many sponges, such as the purple rope sponge (right center) occur in seagrass beds. Motile predators such as the box crab (*Calappa flammea*) patrol grassbeds for prey (bottom right).

Mangroves

Mangroves are typically defined as trees and shrubs which grow in or adjacent to the intertidal zone. They are a diverse group of halophytic trees with little taxonomic relationship to each other, sharing only the ability to live in salt water. Mangroves are restricted to tropics and subtropics, found in association with coral reefs and also in areas where reefs are absent (coast off West Africa and Bay of Bengal). They are most common in coastal areas, but may also occur on offshore reefs. The highest diversity occurs in the coral triangle around Indonesia, the Philippines, the Solomon Islands, and Papua New Guinea. Mangroves are absent from much of central and Western Pacific where reefs thrive, and very sparsely distributed in arid regions of the northern Red Sea and Arabian Gulf; also absent from most oceanic atolls.

Mangroves vary in their ecological development, from scrub vegetation found as coastal fringe, to well developed stands with heights of up to 25 m found at river mouths. This variation depends on levels of rainfall and freshwater input from riverine and groundwater systems, the tidal range, salinity levels, degree of shoreline protection from high wave energy, the accumulation of fine-grained sediments, and localized conditions in the various parts of these islands. Mangroves occur in both terrestrial and marine habitats such as wetland forests and marshes, peatlands, sedge marshes, riparian swale, swamp and riparian forests; aquatic vegetation and coastal dunes, as well as seagrass beds and coral reefs. Mangrove communities found in large wetland areas may be in basins isolated from the sea by sand barriers, and are usually associated with various forms of swamp vegetation. Those found along rocky coasts are typically associated with coral reefs and seagrass beds.

Mangroves have developed unique adaptations to withstand extreme environmental conditions, including tolerance to wide variations in water temperature, salinity and dissolved oxygen. Mangroves are designed to live in sediments which are easily shifted and which often become highly anaerobic. Mangroves develop extensive root systems such as the prop roots of the red mangrove to remain stable in shifting sediments. Some species, such as the black mangrove, develop pneumatophores (elaborate systems of vertical shoots from the roots) that function in transporting oxygen to the roots. Several species also develop salt glands to excrete salts as they take up seawater.

Distribution and structure of Bahamian mangroves

Mangrove habitats in the Bahamas cover over 2100 sq km (estimates range from 2114 sq km to 2332 sq km), with the largest stands on Great Inagua, between Crooked Island and Aklins Island, western shores of Andros and Great Abaco and the north shore of Grand Bahama.

Although six functional types of mangroves are described in the western Atlantic (fringe, riverine, basin overwash, scrub and hammock), most mangroves in the Bahamas consist of fringe and coastal scrub. Abundance of mangroves are controlled by a number of factors, especially levels of rainfall and freshwater input from riverine and groundwater systems, the tidal range, salinity levels, degree of shoreline protection from high wave energy, the accumulation of fine-grained sediments, and localized conditions in the various parts of these islands. In the Bahamas, low freshwater inputs, as well as the exposure to low temperatures and frequent hurricane disturbances, limits the distribution and development of mangroves such that they typically only achieve an average height of 4 m. Mangroves are found predominantly in sheltered bays, marshes, lagoons, and tidal mudflats, where they play an important role in shoreline stabilization, by trapping sediments and building up land areas. Turtle grass (*Thalassia testudinum*) is often found in association with mangroves. Although they tend to be found where fine grained sediments have accumulated, mangroves are also found growing on limestone substrates at the edge of the water on the leeward sides of limestone islands.

There are four species of mangroves in the Bahamas, with species showing a clear zonation arranged according to elevation within the intertidal zone and along a salinity gradient from salt water to fresh water. Species that have a freshwater preference are found further inland such as the white mangrove (*Laguncularia racemosa*) and the buttonwood mangrove (*Conocarpus erectus*) progressing to red mangrove (*Rhizophora mangle*) at the seaward fringe and in the margins of creeks and lagoons. The black mangrove (*Avicennia germinans*) is usually found behind *R. mangle*, but it also occurs in areas with the highest salinity. Dwarf *R. mangle* can also be found far from the coast in association with *C. erectus*.

Unique features of mangroves found in the Bahamas. Pneumatophores of a black mangrove (bottom center). Reproductive structures (sea pencils, propagules) of the red mangrove (top right). Sea pencils that have become stabilized in the intertidal and are developing leaves and branches (bottom right).

Features of mangroves

Rhizophora mangle (red mangrove) trees have thick, waxy leaves that are smooth-edged and elliptical with shiny, dark green uppersides and pale green undersides. The leaves occur opposite from each other along the branches. Trunks and limbs are covered with gray bark, over a dark red wood. Clusters of white to pale yellow flowers bloom during the spring and early summer months. Aerial and submerged prop roots anchor the tree in soft sediments. Red mangroves produce seeds that germinate and grow while attached to the tree (viviparous seeds). The seeds grow 15-30 cm before dropping off the tree. These seedlings are basically a long tap root topped by a small bud. If the sea pencil falls off at low tide the tap root will spear itself in the mud and grow there; if the sea pencil falls off at high tide it floats, the root tip absorbs water, and the propagule turns upright. Red mangroves have a special mechanism to transport oxygen from the aerial roots to the roots submerged in anaerobic sediments. Red mangroves are salt extruders, getting rid of excess salts through their roots via reverse osmosis. Red mangrove trees can achieve a height of 40-50 m and a diameter of 1m with a biomass of 280-300 ton/hectare. Their ability to settle and survive in a mudflat is related to the amount of hydrogen sulfide in the soil. They can settle and survive in areas with higher concentrations of hydrogen sulfide than the black mangrove.

Black mangroves (*Avicennia germinans*) are characterized by long horizontal roots and root-like projections known as pneumatophores. They grow at elevations slightly higher than the red mangrove where tidal change exposes the roots to air. The pencil-shaped pneumatophores originate from underground horizontal roots projecting from the soil around the tree's trunk, providing oxygen to the underwater root systems. Leaves occur opposite of each other along the branches, with upper sides that are shiny and undersides densely covered with hairs. Balck mangroves are salt excreters, getting rid of excess salts through their leaves. The bark of this mangrove is dark and scaly. Black mangroves blossom in spring and early summer, producing white flowers. Black mangroves are slightly smaller than the red mangrove, reaching a maximum of 30 m height. Black mangroves have the widest distribution, occurring into the subtropics to about 30° N latitude. Black mangroves also tolerate lower temperatures than other species, occurring in areas with a minimum temperature of 10°C

The white mangrove (*Laguncularia racemosa*) occurs landward of the red and black mangrove. White mangroves have no visible aerial roots. However, when trees are found in oxygen-depleted sediments or flooded for extended periods of time, they often develops peg roots. White mangroves have light yellow-green leaves that are broad and noptched at the leaf tip with two bumps (extra-floral nectaries) located at the base of the leaf where the stem originates. White mangroves produce greenish-white flowers in spikes, blooming from spring to early summer. White mangroves are the least cold-tolerant of the three mangrove species.

Conocarpus erectus (buttonwood) are mangrove associates that have leaves that alternate. The leaves are leathery with pointed tips and smooth edges. Flowers appear in cone-like heads that grow in branched clusters and are greenish in color. It produces dense flower heads. This plant produces cone-like seed cases.

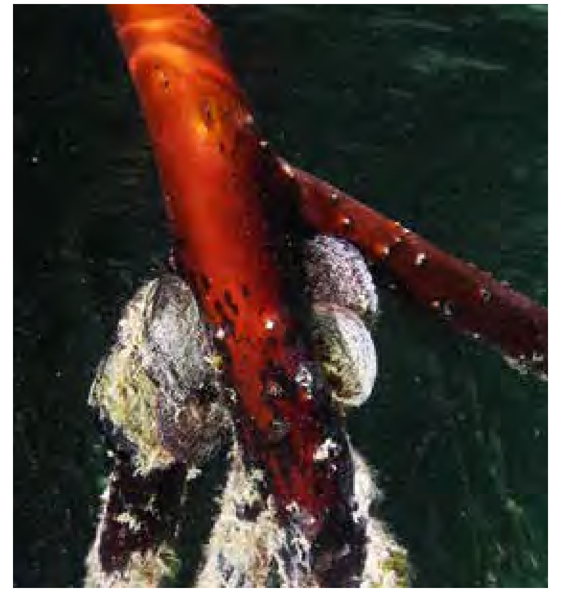
Buttonwood (*Conocarpus*; top left) along a rocky coastline in the Bahamas. The tree is covered with "buttons" (flowers). Propagules on a black mangrove (*Avicennia germinans*; lower left). A channel in a protected lagoonal habitat in southern Abaco lined with red mangroves (top right). A large red mangrove tree with long prop roots anchoring the tree into the sediment (bottom right)

Key importance

Like seagrasses, mangroves are capable of binding sediment and silt, reducing siltation to offshore areas and enabling reefs to flourish. Mangrove sediments are characterized by high organic matter, providing important organic substrates for microbial communities and potential nutrient regeneration. Mangrove prop roots support an abundant epibiont community that recycle water column nutrients and attract high-level consumers that can make additional nutrients available via excretion. Because of the large areal extent of fringing mangroves associated with seagrasses in tropical carbonate lagoons, mangroves may provide an important source of nutrients to adjacent seagrass beds, either directly through detrital mineralization or indirectly through excretion by associated fauna.

Mangroves are critical to marine life throughout the Bahamas. Fish feed among the props roots and the abundant leaf litter and use these as shelter. Many larvalfish and invertebrates also settle in the mangroves, using these as juvenile habitats before moving out to the coral reefs. Important fish species found in Bahamian mangroves are snappers (*Lutjanus* spp.), grunts (*Haemulon* spp.), parrotfishes (*Scarus* spp. and *Sparisoma viride*), and mojarra (*Gerres* spp. and *Eucinostomus* spp.), Nassau grouper (*Epinephelus striatus*), bonefish (*Albula vulpes*), tarpon (*Megalops atlanticus*) and barracuda (*Sphyraena barracuda*).

Examples of organisms associated with mangrove prop roots in the Bahamas. Colonial tunicates attached to the prop roots (top left). A high diversity of sponges attach to prop roots and compete for space with tunicates, bryozoans, cnidarians and algae (bottom left). Seagrasses often occur adjacent to red mangroves, benefiting from nutrients provided by mangrove leaf litter (center). Many species of fish, including grunts and snappers shelter and feed among the prop roots (top right and bottom right).



Mangrove oyster (above)

Human stressors

Most mangroves are subjected to human induced environmental stressors associated with land reclamation, dredging, discharge of sewage, clearing of mangrove areas for development of resorts, marinas and residential areas, and in general, for access to waterfront. Trees are often cut down for timber and fuel wood and charcoal and mangrove bark is in demand for leather tanning. Mangroves are also cleared to make fish and prawn ponds and for purposes of mosquito control. Once removed, impacts to coral reefs through scouring and increased siltation becomes evident during heavy rainfall. Replanting is possible, but challenging due to the difficulty in stabilizing the sediments sufficiently for mangrove seedlings to take root.

Vertebrates inhabiting Bahamaian mangrove ecosystems

There are four bird species endemic to the Bahamas islands which utilize mangrove habitats including the Bahama woodstar (*Calliphlox evelynae*), white-cheeked pintail (*Anas bahamensis*), Bahamas swallow (*Tachycineta cyaneoviridis*) and Bahama yellowthroat (*Geothlypis rostrata*). Other birds associated with mangroves include spotted sandpiper (*Actitis macularia*), roseate spoonbill (*Ajaia ajaja*), green heron (*Butorides virescens*), belted kingfisher (*Ceryle alcyon*), mangrove cuckoo (*Coccyzus minor*), mangrove warbler (*Dendroica petechia*), and reddish egret (*Egretta rufescens).*

Sea turtles found throughout Bahamas islands include the loggerhead (*Caretta caretta*) (top left), green turtle (*Chelonia mydas*) (bottom left), hawksbill (*Eretmochelys imbricata*) (top right), and leatherback (*Dermochelys coriacea*). These can be found in mangrove, seagrass beds and reef habitats.

The Inagua National Park in the Bahamas contains dense swamps of *Avicennia germinans* and *Conocarpus erectus*. These mangroves form a mosaic of diverse habitats that include seasonal marshes, swamps, pools and open water. These swamps support an endemic turtle, *Chrysemys malonei*, an endemic subspecies of the threatened parrot, *Amazona leucocephala bahamensis* and a breeding colony of the flamingo, *Phoenicopterus ruber*.

A single West Indian flamingo, *Phoenicopterus ruber*, wading in Lake Rosa (bottom center). Roseate spoonbills, *Ajaja ajaja*, feeding in in a shallow lagoon (bottom right).

Important Reef-Building Corals

Stony corals, belonging to the order Scleractinia are the major reef builders in the Caribbean. There are approximately 65 species, most of which are colonial. The colonial species lay down skeletons of calcium carbonate (limestone), building large structures. Some of the important massive species, such as the *Montastraea* group can build skeletons that are 5-15 m in diameter and height, deposited very slowly (1 cm per year) over centuries. Faster growing corals, such as the acroporids, produce complex branching and tree-like skeletons that are 1-2 m in height. Their skeletons are deposited much faster, with linear branch extensions of 5-15 cm per year.

Massive dome or boulder-shaped corals can live for hundreds of years, growing very slowly. The unit of the coral is a polyp, which is similar to an anemone. The fleshy polyps have a mouth and a ring of tentacles that usually emerge only at night, while in the day they are retracted. Each polyp is connected to its neighbor via a thin tissue (coenosarc). The polyp's tissue deposits calcium carbonate beneath themselves, forming a cup, or corallite. At specific intervals each polyp divides into two or more identical daughter polyps that continue to grow upward and outward, developing over time into colonies consisting of thousands to millions of polyps. There are many variations in the budding pattern - the polyp may divide into two within the ring of tentacles (intra-tentacular budding), a daughter polyp may develop outside the ring of tentacles, or a new polyp may bud from the stem of the parent polyp. The type of budding contributes to the vast range of colony shapes, sizes and growth forms. On a Caribbean reef growth forms range from branching, mounding, boulder, encrusting, and sheeting, leafy, to plate-like, and it can vary within a single species depending on exposure and depth.

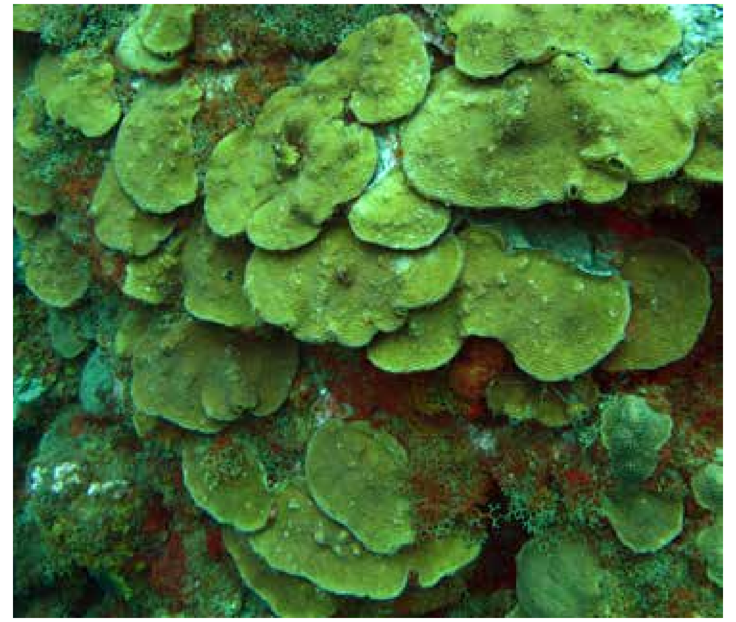
Elkhorn coral (*Acropora palmata*) usually thrives on the shallowest part of the fore reef unless wave action is too strong (above). This species once formed the characteristic "palmata zone", occurring as dense monospecific thickets from about 0-5 m depth. Colonies also occur in some shallow back reef areas and on reef flats in areas with moderate wave action. In areas with strong currents, this species can be found to depths of 15-18 m.

A single polyp of *Eusmilia fastigiata* (top center) with its tentacles extended at night. The white spots are batteries of nematocysts (stinging cells).

Acropora cervicornis (staghorn coral, middle center) is a branching coral that grows quickly and can form large monospecific stands in the back reef and fore reef at intermediate depths (5-30 m). This coral once formed the characteristic "cervicornis" zone, but it has been virtually eliminated from the Caribbean due to disease, predation by snails and fireworms, bleaching and other factors.

The *Montastraea annularis* complex (now placed in the genus *Orbicella*) includes three closely related boulder coral or star coral species, *M. annularis* (top right), *M. faveolata* (center right) and *M. franksi* (bottom right). These are the most important reef building corals in the Caribbean and once were the dominant massive corals found here. They occur throughout all reef environments, with *M. annularis* and *M. faveolata* occurring in back reef environments, *M. faveolata* on shallow fore reef environments and *M. franksi* found on the deep fore reef. These corals can reach immense sizes (over 10 m height/diameter) and live for centuries, but in recent years have succumbed to coral diseases (white plague and yellow band disease) and bleaching.

Montastraea cavernosa (center bottom) has larger polyps than *M. annularis*. This coral tends to be more common in turbid water and it is less susceptible to diseases, sediment, and other stressors.



Massive reef building corals

The brain corals include three closely related species in the genus *Diploria, D. strigosa* (top left), *D. labyrinthiformis* (center left) and *D. clivosa* (bottom left). *D. strigosa* is the most common brain coral occurring in both back reef and fore reef locations at all depths. *D. clivosa* is only found in shallow water.

A number of other corals with meandering rows of corallites are found in the Bahamas including *Colpophyllia natans* (above), *Meandrina meandrites* (below), *Mycetophyllia lamarckiana* (bottom center left) and *Manacina areolata* (bottom center right).

Massive boulder corals in the Bahamas include starlet coral, *Siderastrea siderea* (above), elliptical star coral (*Dichocoenia stokesi,* top right), *Solenastrea bournoni* (right center), and blushing star coral (*Stephanocoenia intersepta,* below).

Solenastrea occurs in sandy areas adjacent to the reef (right center).

Mycetophyllia forms saucer-like colonies, small massive boulders, and submassive colonies (left).

Manicina areolata is usually attached when young, but breaks off and is free living in soft bottom areas including grassbeds (right).

Dendrogyra cylindrus (pillar coral) is an unusual coral that forms large pillars and has its tentacles extended during the day (bottom right).

Two of the more unusual corals inlude flower coral, *Eusmilia fastigiata* (top left) and spiny flower coral, *Mussa angulosa* (bottom left). *Eusmilia* have large polyps (up to 4 cm diameter) that become completely separated from their daughter polyps forming short phaceloid branches. *Mussa* also have large polyps (up to 7 cm diameter), but these divide intratentaculary forming large clumps consisting of 1-4 polyps. These corals have a fleshy, colorful margin that may be red, green or purple.

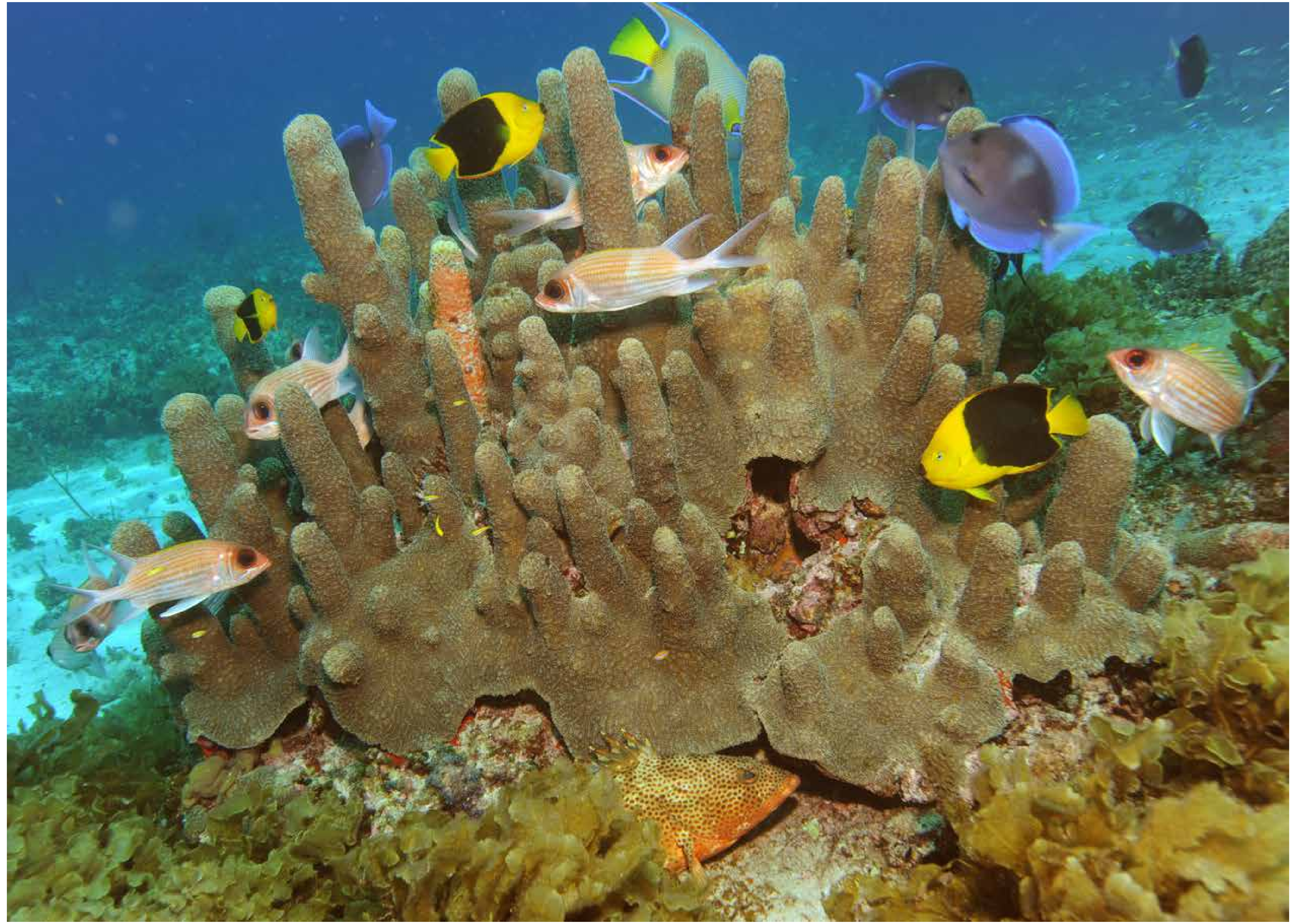
Agaricia agaricites, lettuce coral (bottom center) has many growth forms including thick upright bifacial plates (shown here). This coral has been renamed "Undaria". It is perhaps the most common coral on Caribbean reefs today.

Yellow pencil coral, *Madracis mirabilis* has short (2-5 cm) thin (1 cm) branches that can form mounds several meters in diameter (top center). Its closely related cousin, *M. decactis* (cactus coral) has shorter fat branches or knobs, and forms much smaller colonies (middle center). Also in this image is another growth form of *Agaricia agaricites.*

Leptoseris cucullata (below) is a thin plating coral similar to *Agaricia.* It can be distinguished by the prominent ridges between the pore-like corallites and presence of polyps on one face only.

The genus *Porites* includes the common mustard hill coral (*Porites astreoides*, top left) and finger coral *Porites porites. P. astreoides* forms small colonies (up to 50-70 cm diameter) that may be thick plates, submassive encrustations or small massive boulders. These tend to be early colonizers, becoming dominant on disturbed reefs. Like A*garicia agaricties, P. astreoides* can make up most of the live coral cover on a reef. *Porites porites* can form very large colonies, meters in diameter, and over several decades may form accumulations 4-5 m thick, such as those seen at the seaward edge of the lagoon on Hogsty reef.

On deeper fore reef locations several species of *Agaricia* form large plates, such as the *Agaricia lamarcki* colony from Little Inagua shown on the left.



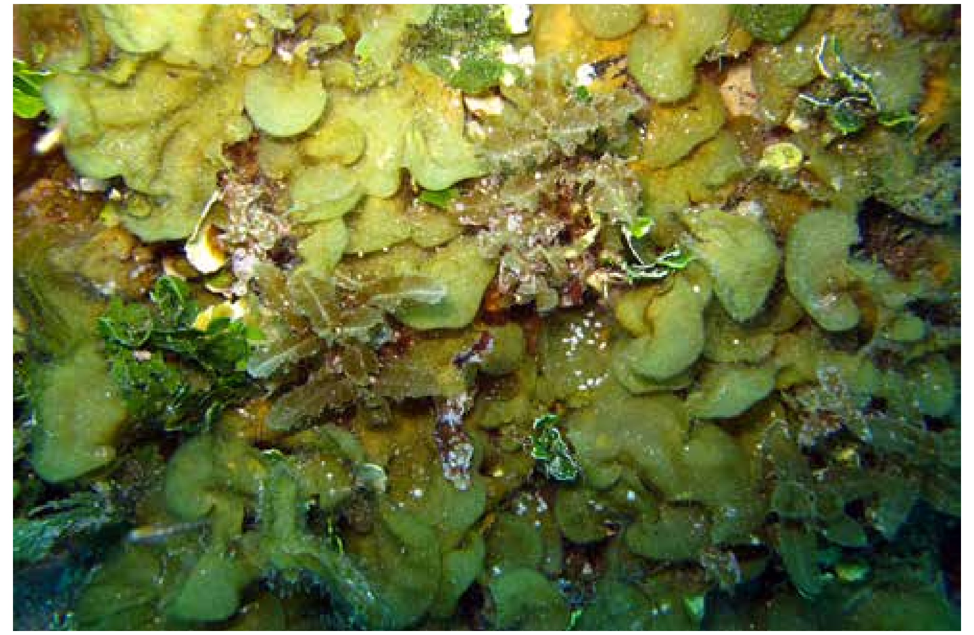
Corals play a critical role in the health and persistence of coral reefs. They are the major structure forming organisms that build reefs, but also produce high relief habitat that is used by fish and motile invertebrates as shelter, nursery areas and resting areas. Corals are important primary producers, sequester CO_2 and provide food for many species. This colony of pillar coral (*Dendrogyra cylindrus*) is a good example of fish habitat, with rock beauty, blue tang, red hind, squirrellfishes, blue angel (right, top to bottom, respectively) and smaller wrasses living among the pillars.

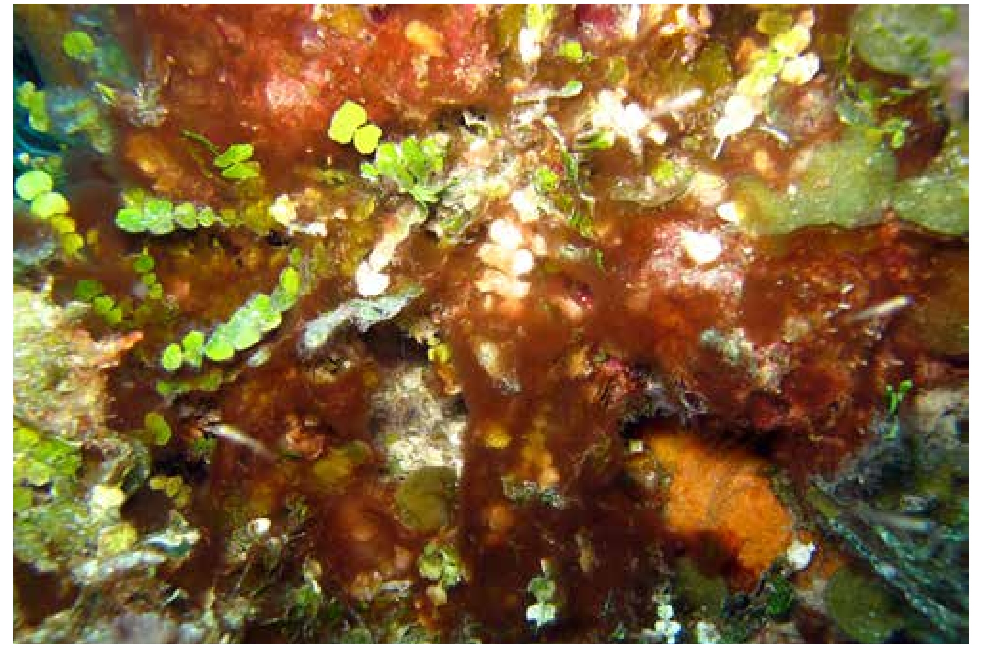
Macroalgae

Algae are species-rich, productive and functionally important members of coral reef ecosystems. Of more than 10,000 described species, nearly 3,000 have been described from coral reefs. Benthic coral reef algae include three families: chlorophyta or green algae, phaeophyta or brown algae and rhodophyta or red algae. Other algae found in reef environments are diatoms, dinoflagellates and cyanobacteria, of which only filamentous cyanobacteria form large mats easily observed by a diver.

The three algal families can be divided into four functional groups, fleshy macroalgae, turf algae, crustose coralline algae (CCA), and erect coralline algae. These play different roles. Some are reef constructors and stabilizers that bind sediment and help consolidate the reef (CCA). Others are major sand producers (some erect coralline algae such as *Halimeda*), and important primary producers and food for herbivores (turf algae). A small number of species of macroalgae are an important food source for some fish, sea urchins and other herbivores. Other types of macroalgae are avoided by herbivores, due to the presence of chemical compounds, calcified structures and other deterents. These taxa often occupy substantial areas of reef. Certain taxa, such as *Microdictyon, Caulerpa, Lobophora* and *Dictyota*, are opportunists, thriving on reefs that have been physically damaged and reefs exposed to elevated concentrations of nutrients. In many cases, macroalgae overgrow and outcompete corals and may prevent settlement and survival of coral recruits. Examples of pest species of macroalgae that have proliferated in the Bahamas, along with cyanobacteria are shown here.

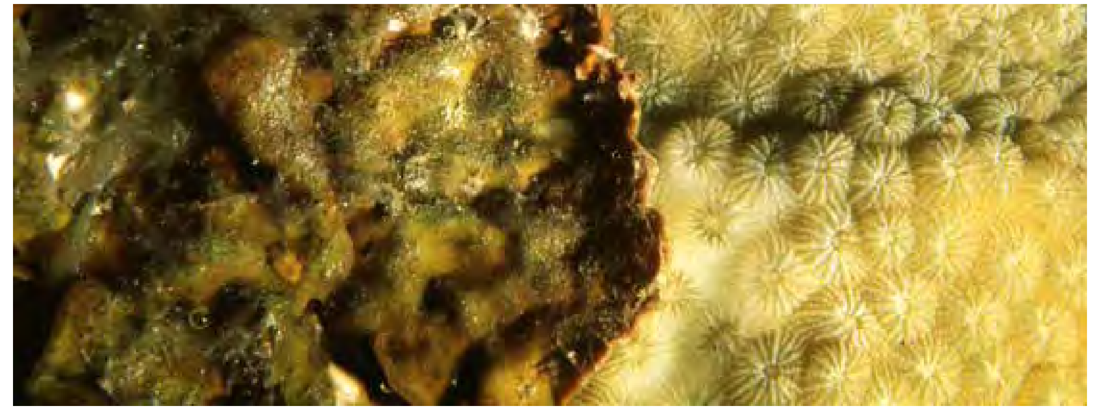
Abundant macroalgae in the Bahamas including *Stypopodium* (top center), *Halimeda* (top right), *Lobophora variegata* (middle center), *Dictyota* (right center), *Microdictyon* (bottom centert) and cyanobacteria in the genus *Lyngbya* (with *Halimeda*, bottom right). A colony of *M. annularis* that is being overgrown by *Microdictyon marinum* is shown in the bottom left.Eveles idipsaperit que comnihit





Red algae and brown algae

Rhodophyta (red algae) is a diverse group containing many species of filamentous turf algae, erect coralline algae (top left), crustose coralline algae (bottom left) and fleshy macroalgae such as *Asperagopsis* (top center). Although it appears red, filamentous cyanobacteria is not a red algae. Shown in the center is a colony of *Siderastrea* being overgrown by *Lyngbya*. A colony of *Montastraea annularis* being overgrown by *Peyssonnelia*, a calcified encrusting red algae (bottom center). A number of fleshy brown macroalgae are seen in the Bahamas, such as *Sargassum* (top right) and *Turbinaria* (bottom right) and which both occur on shallow reefs and in the reef crest in exposed areas. *Padina* is an unusual brown algae that incorporates calcium carbonate in its blades to deter predators (right center).



Reef Fishes

Reef fishes are often placed into broad functional groups or trophic levels based on what they eat as adults. The interactions between the different trophic levels define the food chain on a coral reef. Impacts to the reef can cause dramatic changes in the trophic levels, and hence the food chain, which can lead to trophic cascades and habitat impacts. For instance, a mass mortality of corals frees up space that can be colonized by algae. If herbivores populations decline this algae can proliferate at the expense of other benthic organisms, leading to a phase shift that may persist indefinitely.

Many fish change their diet as they grow. Most larvae begin life as planktivores feeding on fish eggs and zooplankton in the water column. After settling in shallow water they forage for small crustaceans and other invertebrates, before switching to their adult diet. Adult fish may predominantly feed on a single organism or group of organisms, while others are generalists consuming a wide range of prey. Often, adults will abandon their normal food to take advantage of prey items that become temporary abundant. For instance, blue tangs are herbivores that will feed on small jellyfish in early summer during their annual bloom.

The trophic groups found on a coral reef include planktivores, detritivores, herbivores, omnivores and carnivores. Most herbivores also ingest small invertebrates that attach to algae and seagrass blades and some (e.g. certain parrotfish) also consume coral. Carnivores include species that feed only on specific invertebrates (invertivores) as well as species that are primarily piscivores.

A total of 350 species of reef fish have been reported from the Bahamas, with the highest diversity around the Exumas. During KSLOF surveys, a total of 243 species were noted from Cay Sal Bank, while Great Inagua (150), Little Inagua (124) and Hogsty (118) had many fewer species.

Acanthurids, including the doctorfish, surgeonfish and blue tang (bottom left) are browsers, feeding on tufts of filamentous algae.

Parrotfishes include two genera, *Scarus* and *Sparisoma*. *Scarus* are usually scrapers, removing algae and a small amount of the reef substrate. One example is the initial phase queen parrotfish (*Scarus vetula*, top center) *Sparisoma viride* (stoplight parrotfish) are excavators, removing algae and a substantial amount of the reef substrate. This species also frequently bites corals, creating spot bites and large focal lesions (especially on *Montastraea* and *Colpophyllia*) . These fish occur as juveniles, initial phase (females and males; middle center) and terminal phase (large males; bottom center).

Damselfish are among the most common benthic herbivores in the Bahamas. The yellowtail damsel (top right) is usually found in shallow water around *Acropora* and *Millepora* colonies. The three spot damselfish (*Stegastes planifrons*) is an aggressive damselfish, establishing small territories that are vigorously defended. These fish kill patches on live corals to farm algae, cultivating a lawn of delectable species and weeding out the less preferred species. In staghorn coral, the coral produces chimneys to contain the algae (lower right). These damselfish used to occur primarily among staghorn coral (right center) and elkhorn coral. Damselfish abundance in many places has exploded and *Acropora* habitat has declined, so these fish are now found among massive corals where they can cause substantial coral mortality.

Carnivorous reef fish

Queen angelfish, ***Holacanthus ciliaris*** (top left) feeds mostly on sponges and algae; also eat tunicates, soft corals and jellyfish,
The **queen triggerfish**, ***Balistes vetula*** (bottom left) specializes on feeding on the long spined black sea urchin (*Diadema antillarium*). It blows water under the sea urchin to overturn it, exposing the part of the sea urchin where the spines are shortest. Because these urchins are still rare, it also feeds on other echinoderms, molluscs and crustaceans.
Spanish hogfish, ***Bodianus rufus*** (top center) feeds on molluscs, crustaceans, brittle stars and sea urchins as an adult. Juveniles often are cleaner fishes, feeding on parasites removed from other fishes.
Yellowhead wrasse, *Halichoeres garnoti* (center) feeds on small crabs, polychaetes and brittlestars that are found in crevices and under rocks. It is a favorite prey item of groupers. Like most other wrasses, this species changes sex, from a juvenile to an initial phase female or male, and finally to a terminal phase male (shown here).
Sheepshead porgy, ***Calamus penna*** (lower center) feeds on molluscs, worms, brittle stars, hermit crabs, crabs, and sea urchins. It occurs in grassbeds, reefs and rocky areas.

French grunt, ***Haemulon flavolineatum*** (bottom center) is one of 16 species of grunts found in the Bahamas. This species forms resting schools in the day on the reef, rocky areas and in grassbeds, and moves out to the reef to feed as solitary individuals on crustaceans.
Four eye butterflyfish, ***Chaetodon capistratus*** (top right) feed mainly on zoantharians, polychaete worms, gorgonians and tunicates.
Glasseye snapper, ***Priacanthus cruentatus*** (right center) is nocturnal, feeding mainly on octopuses, pelagic shrimps, stomatopods, crabs, small fish and polychaetes. During the day it is found under or near ledges.
Orangespotted filefish, ***Cantherhines pullus*** (lower right) feeds on sponge and algae, and occasionally tunicates, bryozoans and other sessile benthic invertebrates.
Blackbar soldierfish, ***Myripristis jacobus*** (bottom right) is a nocturnal species that forms large resting schools near ledges and large coral heads during the day and feeds on plankton at night.
Yellow stingray, ***Urobatis jamaicensis*** (below) feed on sandy bottoms near coral reefs on shrimp, small fish, clams, and worms.

Carnivores and top predators

Adult **yellowtail snapper**, ***Ocyrus chrysurus***(top left) are nocturnal predators. They feed on crabs, shrimp, cephalopods, worms, and fish. Juveniles are found in seagrass beds and feed on plankton.

Blackfin snapper, ***Lutjanus buccanella*** (bottom left) feeds mostly on small fish.

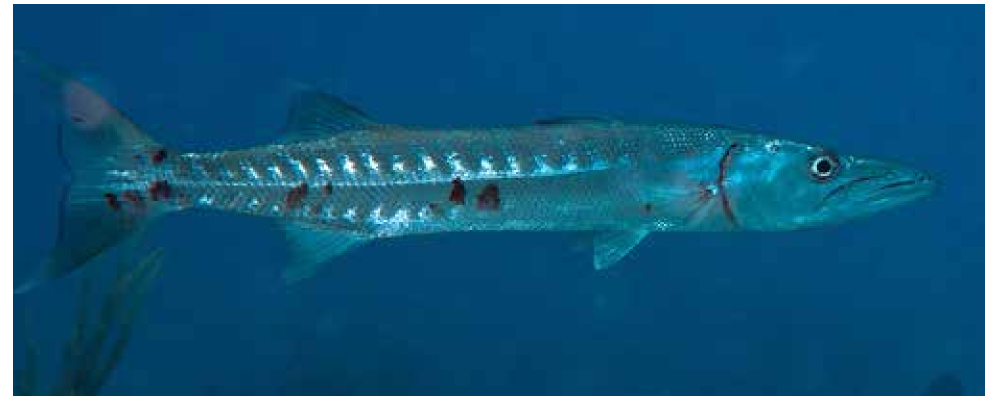
Red hind, ***Epinephelus guttatus*** feeds mainly on crabs, lobster, octopus, and small fish (top center).

The **coney *Cephalopholis fulva*** is a small grouper that feeds primarily on small fishes, crabs and shrimps. Adults have three color phases, red (found only in deepwater), orange-brown or bicolored with a dark upper portion and pale lower part, and a less common yellow phase (middle center).

Spotted moray, ***Gymnothorax moringa*** (bottom center) is nocturnal, foraging mainly in open seagrass beds away from patch reefs, rubble, or other shelter on fishes, crabs, and octopods.

Nassau grouper *Epinephelus striatus* (top right) change their habitats and diet throughout their life. Larvae, which hatch from pelagic eggs spend 30-50 days in the plankton. Small juveniles leave the water column, and settle in inshore benthic nursery areas including algal beds, seagrass, and shallow reefs. As the fish grow, they move to deeper reef environments. Their diet also changes as they grow, with juveniles feeding mainly on crustaceans, and adults feeding on both invertebrates and fishes.

Apex predators on coral reefs include pelagic species such as the bar jack, *Caranx ruber* (top right), the great barracuda (middle right), and the Caribbean reef shark, *Carcharhinus perezi* (bottom right). These all feed mostly on fish, along with large crustaceans and cephalopods.



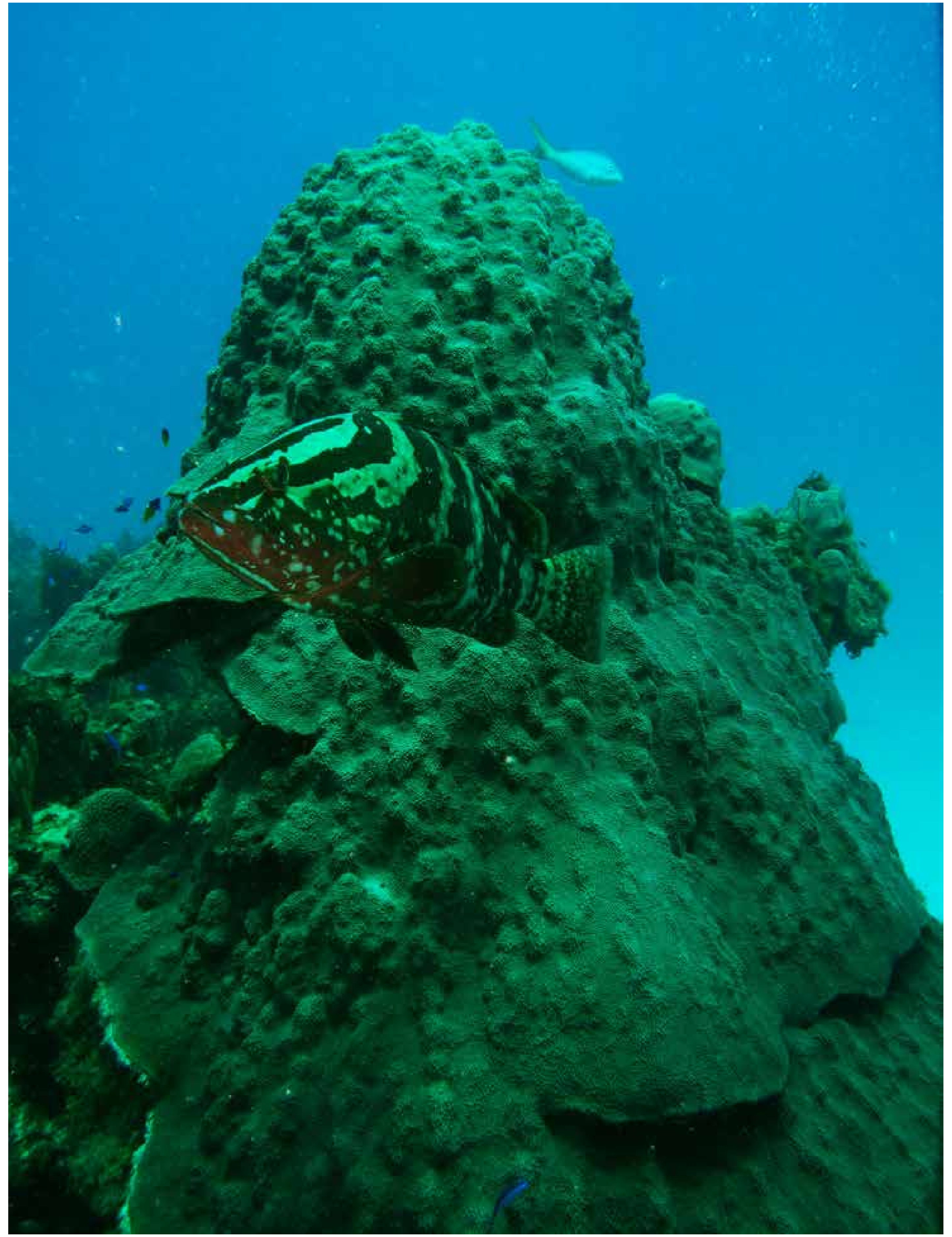
Threats to Bahamas Coral Reefs

Coral reefs throughout the western Atlantic have undergone major changes since the late 1970s in response to a host of human-induced and natural stressors. Most notable have been region-wide decline of several of the most important reef-building corals, dramatic increases in the cover and biomass of fleshy algae, and depletion of commercially important reef fishes and invertebrates. The Bahamas are no exception, where living coral cover in most locations now hovers around 5-10% and macroalgae cover exceeds 50%. Fortunately, for the Bahamas there are still areas with healthy populations of Nassau grouper, lobsters and conch. Some reefs still have large, completely live boulder star corals (*Montastraea faveolata*) and populations of elkhorn coral (*Acropora palmata*) have begun to rebound.

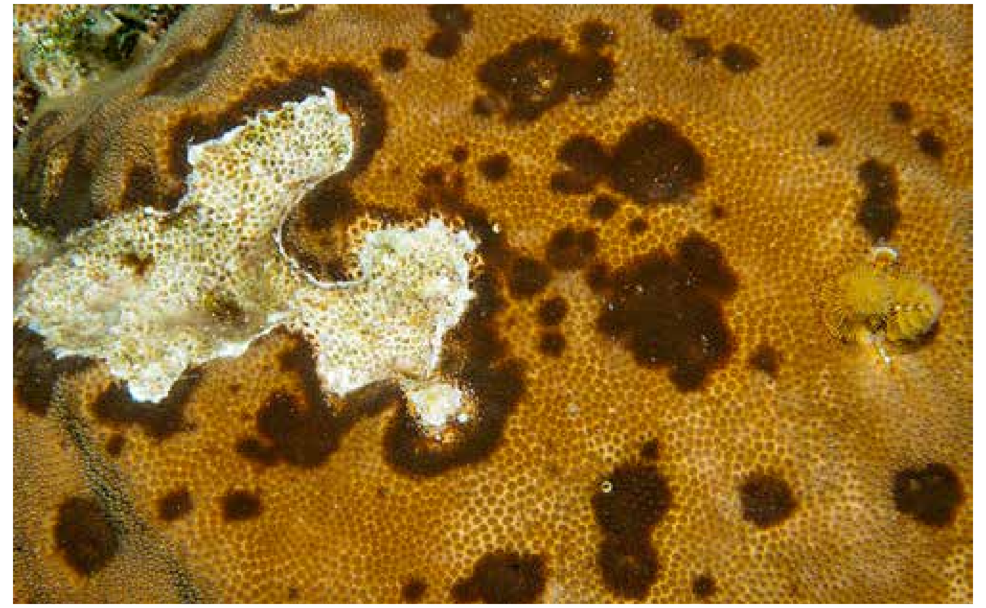
These reefs are at a critical stage, however, as stressors associated with climate change continue to worsen, and human pressures on reefs continues to expand. Conservation meansures, such as the establishment of no-take areas, more sustainable fishing practices and environemntally friendly coastal devleopment are imperative.

Many iconic coral reef species can still be found in the Bahamas, such as unusually large colonies of *Montastraea faveolata*, high numbers of the endangered Nassau grouper (right), as well as dense populations of queen conch (*Strombus gigas,* left center) and Caribbean spiny lobsters (*Panulirus argus*, bottom left). In contrast, *Diadema antillarum* were rarely observed and do not appear to have shown much recovery in Cay Sal or the Inagua region. The urchin shown above was photographed in the Exumas.

Nassau grouper (***Epinephelus striatus***) grow slowly and have delayed reproduction, reaching sexual maturity at 4-8 years of age when they reach 40-50 cm in length. These groupers are long-lived, capable of surviving over 20 years in the wild, and have naturally low adult mortality. In the Bahamas, adults undergo breeding migrations to specific offshore areas between November to February. These ephemeral spawning aggregations can be hundreds of kilometers away from their resident habitat an may contain thousands of fish. All of these characteristics enhance their vulnerability to overfishing.



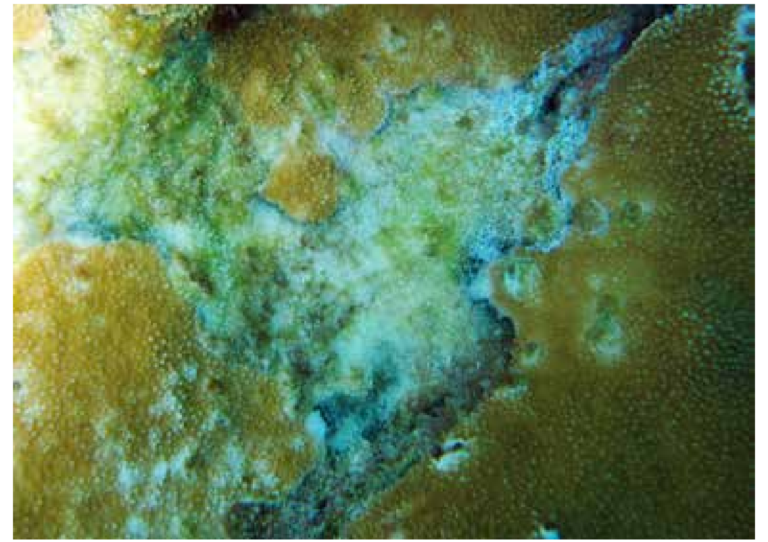
Coral diseases



All of the common diseases reported from the Caribbean were observed in the Bahamas during these surveys, although no outbreaks were noted. Of particular concern, dark spots disease was observed on multiple species including several species of *Agaricia, Madracis, Montastraea, Siderastrea* and *Stephanocoenia*. White band was rare, likely because both staghorn and elkhorn coral were uncommon. White plague caused the most severe lesions, especially when seen on large *Montastraea faveolata* colonies. Other diseases, including Caribbean ciliate infection (see next page) and red band disease were also found.

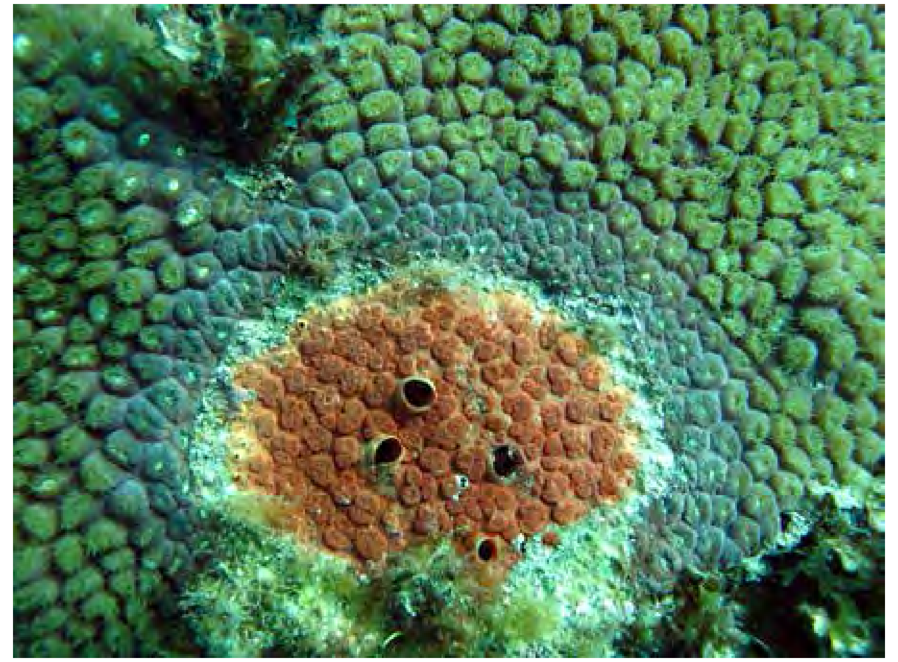
***Acropora cervicornis* with white band disease, Great Inagua (top left). *Montastraea annularis* with black band disease, Little Inagua (top center). White plague on *Montastraea annularis*, Cay Sal Bank (bottom center). Dark spots disease on *Stephanocoenia intersepta* (top right), *Madracis mirabilis* (right center) and *Siderastrea siderea* (bottom right). All images are from Great Inagua. *Montastraea faveolata* with yellow band disease on Cay Sal Bank (bottom left).**

Biotic stressors



Caribbean ciliate infection on elkhorn coral, *Acropora palmata* (top left).

Stressors include diseases, bleaching, and overgrowth by sponges and tunicates. Isolated cases of bleaching were observed during the surveys of Cay Sal Bank and the Inaguas, but severe bleaching events have been observed in previous years (2010, 2005, 1998 and 1995). Both encrusting and bioeroding sponges were common in the Bahamas, as was a colonial tunicate, *Trididemnum*.



Ring bleaching in *Agaricia* (center). There is some evidence that this is caused by fish bites (center). Corals that are white may be bleached or recently dead. A *Montastraea cavernosa* colony died within the last 3-4 days and is being overgrown by *Microdictyon* algae (bottom center). The white color on this coral will remain for only a few days until filamentous algae colonizes the skeleton. A number of organisms also overgrow corals. A black sponge was unusually abundant on Great Inagua. Here it is overgrowing *Porites astreoides* (top center). A boring, bioeroding sponge (*Cliona delitrix*) killing a colony of *Montastraea cavernosa* (top right). This sponge was abnormally abundant at Cay Sal and affected many species of corals, especially *Siderastrea*. The colonial tunicate, *Trididemnum* on *Montastraea* (middle right) and the encrusting sponge *Anthosigmella* was overgrowing *Siderastrea* (bottom right).

A bleached Montastraea faveolata colony from the Lee Stocking Island, Exumas during a bleaching event in 2005 (bottom left). The colony was pale, but retained some of its pigmentation.

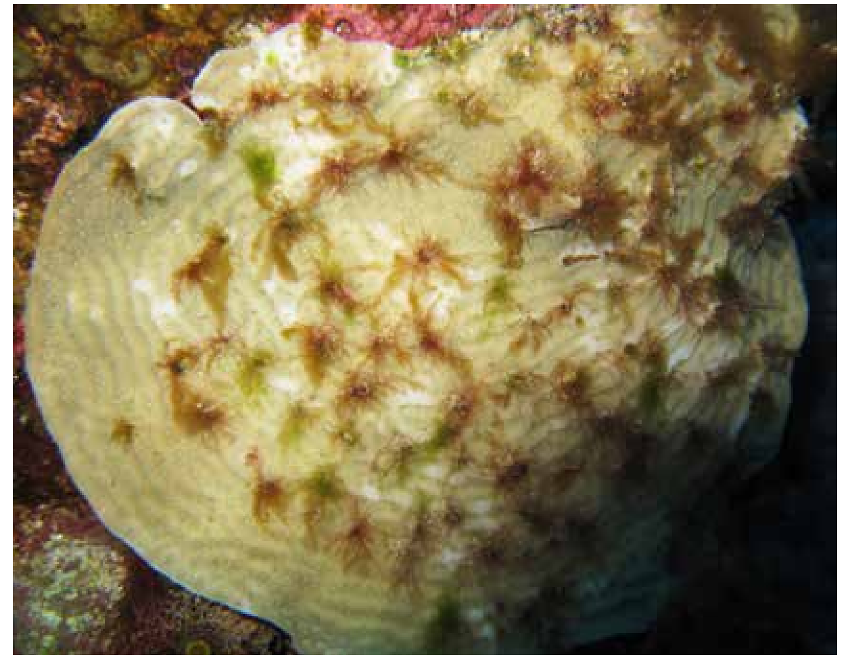
***Siderastrea* colonies that bleach may retain a blue coloration due to fluorescent pigments in their tissue (bottom middle).**

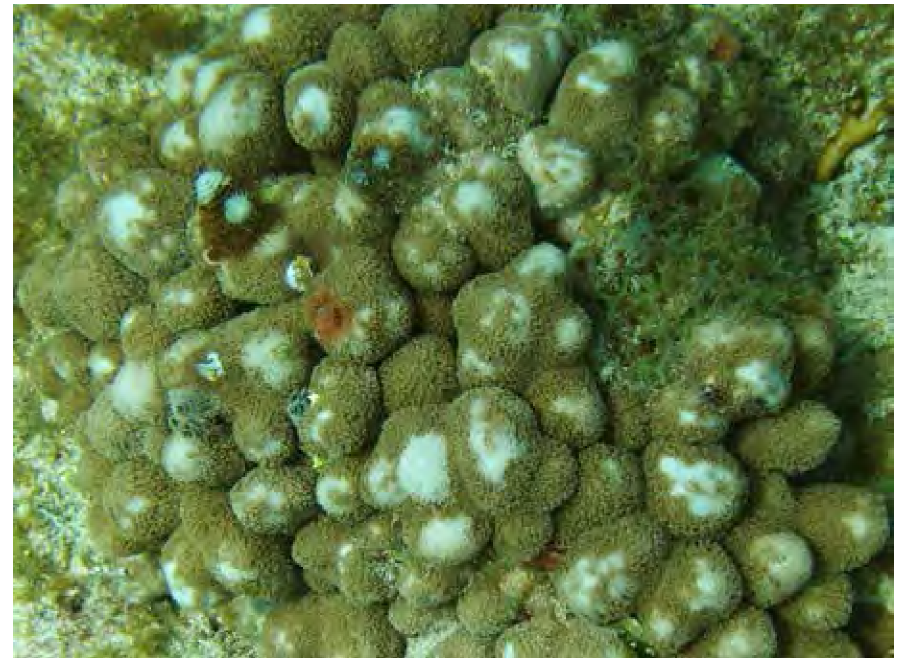
Corallivores

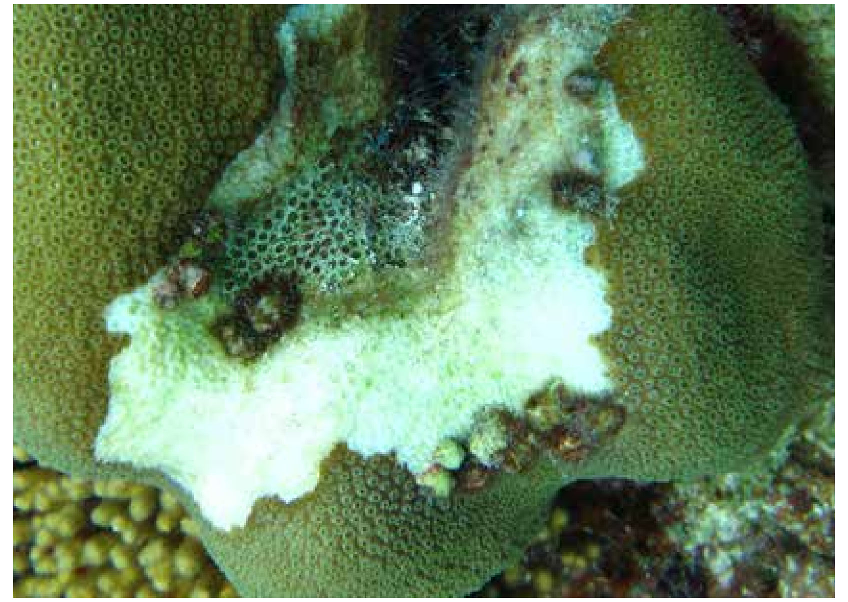
There are many organisms found on Bahamian reefs that eat coral or damage coral through their feeding. Organisms that feed on coral are called corallivores. One example of a fish that bites coral, killing tissue to open up substrate is the damselfish. **A damselfish algal lawn on *Acropora cervicornis*. A juvenile damselfish (*Stegastes planifrons*) has killed parts of the coral (white areas) through repeated biting and filamentous algae is settling on the skeleton (top left). A damselfish established a territory on a colony of *Agaricia*, taking individual bites over the entire coral surface which have been colonized by green and brown filamentous algae (top center).**

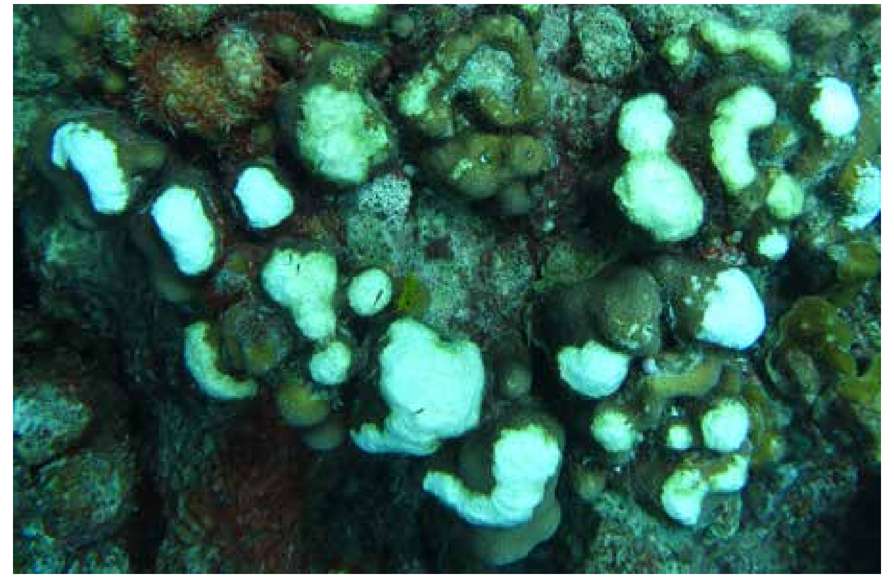
Several species of excavating parrotfish in the genus *Sparisoma* feed mostly on algae but will also bite live coral. Many species will create small lesions on a coral that are equal in size to their jaws, and often manifest in pairs. This type of biting is called spot biting. The stoplight parrotfish, will also repeatedly bite the same coral within its territory, excavating a large portion of the skeleton. This is called focused biting.

Colpophyllia natans (bottom left) and _M. annularis_ (bottom center) with focused biting are shown. Fireworms (_Hermodice carunculata_) feed on branching corals, fire coral and gorgonians. The worm here is eating _Madracis decactis_ (center). Coral eating snails in the genus Coralliophila feed on massive and branching corals. These snails are usually smaller than a dime when feeding on massive corals like _Montastraea annularis_ (left), but can get quite large when feeding on _Acropora palmata_ elkhorn coral, (bottom center). The colorful flamingo tongue snail (_Cyphoma gibbosum_) feeds on sea fans and other gorgonians and soft corals. The spots on the snail are from its mantle (bottom right).









Invasive Species

The lionfish *Pterois volitans* represents the first marine reef fish invasive species in the western Atlantic, and it is proving to be one of the greatest threats to the region. From an initial confirmed siting off Dania Beach, Florida, in 1985 and reports from offshore waters of North Carolina, South Carolina and Georgia, USA by 2000, lionfish quickly spread throughout the region occurring throughout the southeastern USA, Bahamas, Caribbean and Gulf of Mexico. As of 2014, they have been observed from the surface of the sea to depths of 300 m, across a variety of habitats including coral reefs, mangroves, seagrass beds, estuaries, hard bottom and artificial reefs. Lionfish have produced a marine predator invasion of unparalleled speed and magnitude.

There is growing evidence that lionfish are causing abrupt changes to the biodiversity and community structure of reef fishes because of their broad diet and general habitat preferences. These ambush predators consume a wide variety of native fish and invertebrate species at high rates, and are well defended from predation by venomous fin spines. Lionfish may trigger cascading impacts on reef ecosystems by disrupting the food web, and they compete for food and habitat with other species, especially commercially important predators such as groupers and snappers. The lionfish is already known to have a marked effect on populations of coral reef fish, decreasing both recruitment and abundance of numerous species, including ecologically important herbivorous reef fishes such as parrotfishes. Equally disconcerting, the interaction of the lionfish invasion with existing stressors such as bleaching events, ocean acidification, disease outbreaks, overfishing and pollution may accelerate the degradation of western Atlantic reefs.

The lionfish's venomous spines, in combination with their cryptic coloration and slow movement is thought to have released the species from significant top-down control by native predators. This problem is further exacerbated by the fact that large predatory fishes have been extensively overfished throughout much of the Caribbean.

Now common throughout the Bahamas and the Caribbean, the colorful, venomous red lionfish *(Pterois volitans)* is a menace to coral reefs. With poison glands at the base of its dorsal spines, a voracious diet consisting of a wide variety of reef fish and crustaceans, and a hunting strategy that is unique among Caribbean predators, they have become one of the most common and successful predator in the region. Their densities often exceed that recorded within their native distribution. In some parts of the Bahamas 30-50 individuals may be recorded in a single dive. The fish above was documented on Cay Sal Bank, where densities are still fairly low.

Lionfish are generalists, consuming most species of reef fish and crustaceans at unusually high rates, mostly during dawn and dusk, while sheltering under ledges and overhangs during daylight. These crepuscular predators exhibit a hunting strategy that is unique among Caribbean predators. Lionfish hover motionless over their prey, with their large pectoral fins extended. Sometimes, lionfish expel jets of water at the prey to orient the prey towards their mouth. Lionfish tend to eat similar prey to other predatory fishes such as certain groupers and snapper, yet prey consumption rates far exceed native predators, and growth is much faster. This suggests they may outcompete native predators for both food resources and habitats. Of grave concern, they also reproduce more frequently. In some cases, lionfish spawn throughout the year, every 3-4 days, producing eggs and larvae that are capable of dispersing great distances.

The red lionfish (*P. volitans*) is reported to be the most common species seen in the Atlantic, but populations may be intermixed with the devil firefish, *Pterois miles*. These two species are difficult to distinguish. The body of *P. volitans* is white or cream colored with red to reddish-brown vertical stripes. The vertical stripes alternate from wide to very thin, and sometimes merge along the flank to form a "V". Coastal populations of *P. volitans* tend to be darker, sometimes almost black. The red lionfish is also characterized by its greatly elongated fin spines. The red lionfish has 13 dorsal spines, 10 dorsal-fin rays, 3 anal spines, and 7 anal-fin rays. *Pterois miles* has 10 dorsal-fin rays and 6 anal-fin rays (bottom right).

Eradicating the lionfish

The lionfish provide a concrete example of the impacts of an intentional/accidental release of a non-native species. With growing information on the detrimental impacts of lionfish to western Atlantic reefs, many countries have established local control efforts.

First and foremost, it is critical that aquarium hobbyists do not release lionfish or other species from their fish tanks into the sea. Release from aquaria are known to have occurred following Hurricane Andrew in Florida (1992) and hobbyists have reported releases of their "pets" once they grew too large to maintain.

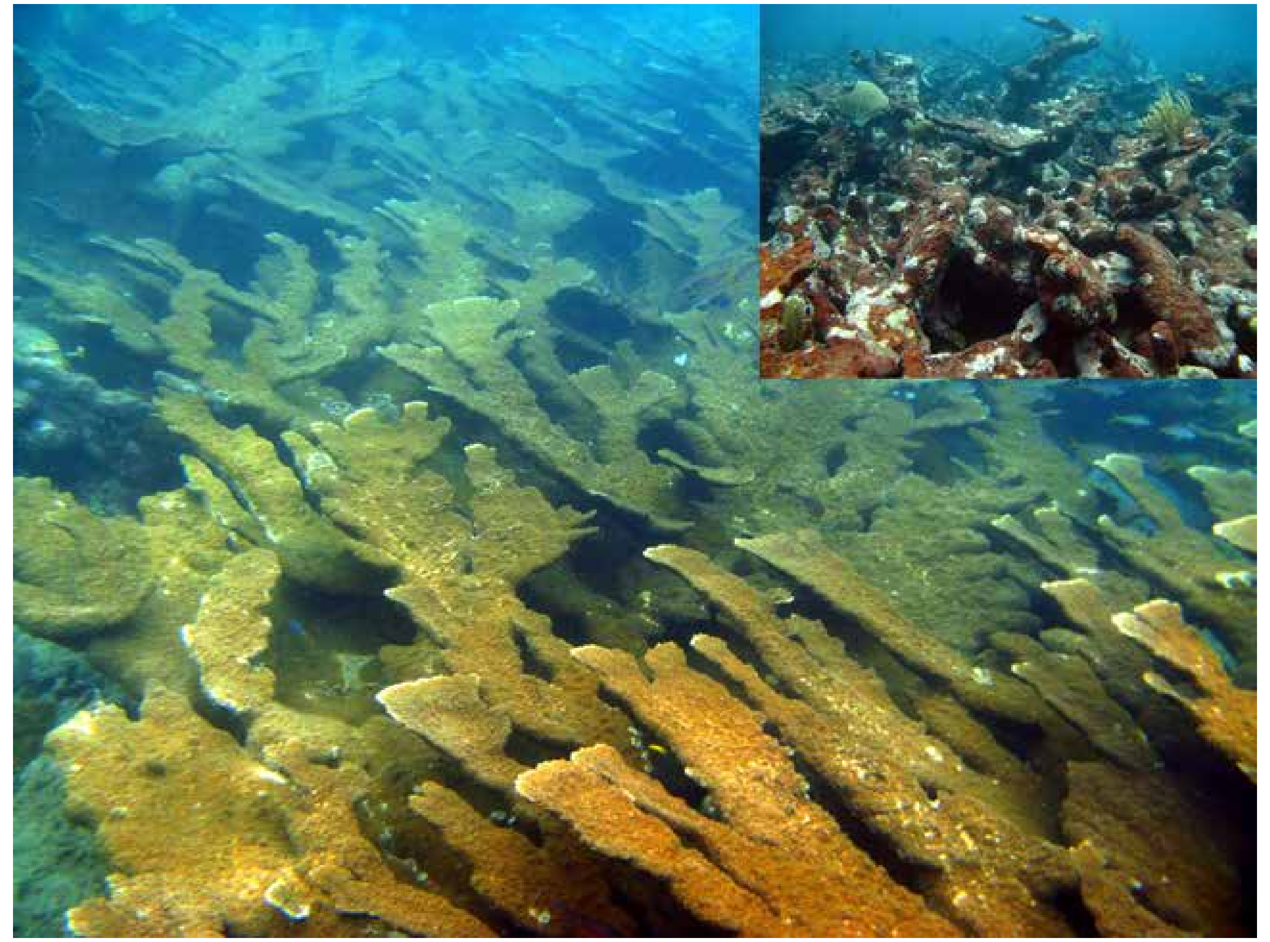
Local efforts include adopt-a-reef programs, removal efforts, and development of food-fish markets for these species. In their native range, lionfish are considered a delicacy. Although the spines are venomous, the toxin is not in the flesh. There have been a few reports of human health concerns associated with ciguatera and mercury, but this is rare. We know that complete eradication is not possible given existing technologies, but removal efforts can be successful in managing densities and mitigating impacts. There are a growing numbers of derbies and fishing and spearfishing tournaments, as well as lionfish cook-offs. These efforts can help promote tourism, provide an alternate species of fish for subsistence and take pressure off other resources such as lobster and grouper. These type of efforts have an important social aspect, engaging stakeholders, allowing opportunities for training and increased awareness, and providing an alternate, potentially less destructive activity for SCUBA divers.

Habitat classes

Habitat maps created for the Bahamas extend from the shoreline, at mean low water, to 25-30 m depth. The habitats include reef and associated communities that fringe islands, submerged and offshore reef communities, hardground habitats and soft bottom communities. Soft ground habitats identified in the Bahamas range from shallow, mudflats to subtidal sandy environments and soft bottom habitats colonized by seagrasses, turf algae, macroalgae and cyanobacteria, and mangroves. Hardground communities may be barren, scoured hardgrounds, or they may have a thin covering of sediment, turf algae or macroalgae, or various benthic invertebrates including gorgonians and stony corals.

Western Atlantic coral reefs include fringing reefs, barrier reefs, patch reefs, and bank-barrier reefs, defined partially based on their location relative to land. Historically these reefs have been further subdivided into specific zones, primarily based on the dominant coral found in that zone, the depth, and the degree of wave exposure. The zones of the reef include the back reef, reef crest or reef flat, and fore reef. The fore reef was further subdivided into the *palmata zone, cervicornis zone, mixed coral zone* and *plating coral zone*, extending from shallow to deep water respectively. In most locations these distinctive zones have disappeared, due to the decline of acroporids, losses of other long-lived massive corals, increases in macroalgae, and replacement of the formerly dominant corals with macroalgae, gorgonians, zoanthids, sponges, and early colonizing brooding corals such as *Porites* and *Agaricia*.

In the classification scheme used in this Atlas, biological cover types and geomorphological structural types were merged to identify the specific habitat. A 'habitat' was defined as a "unique combination of gross topographic structure, biotic community, and sediment/hardground composition occurring across the scale of at least one image pixel (2.4 m^2). Fourteen distinct habitat classes were used to create the benthic habitat maps of Cay Sal, Hogsty Reef, Great Inagua and Little Inagua. Maps were generated from WorldView-2 multispectral satellite imagery with a Projection of WGS 84 and UTM Zone 18N. Data are suitable for resource assessment, spatial analyses and the development of GIS database for planning and environmental management type applications. These habitat maps are not suitable for precise navigation use.



Classic Caribbean reef zonation included the "palmata zone" in the shallow fore reef (top left) which has been largely replaced by dead elkhorn coral skeletons in growth position (inset) or hardground areas with algae, *Palythoa*, gorgonians, and fire coral. Below this was a "cervicornis zone" (bottom left), a "mixed coral zone" (bottom center) and a "plating coral zone" (bottom right).

Benthic habitat classes of the Bahamas

Shallow coral framework

Biology: Coral framework with sparse live coral cover (generally <15%)
Hydrography: High-energy setting. Water motion is driven by wind, oceanic waves and alongshore currents. Wave influence on the habitat abates with increasing depth
Sedimentology: Coral dominated with substantial contributions from *Halimeda*. Terraces may serve to capture patches of sand and coral rubble
Topography: Gently sloping with some elevated mounds and spur-like structures formed through recent coral reef build-up
Depth range: Shallower than -5 m

Shallow coral framework at the western end of Hogsty Reef, 1.5 m depth. The framework is constructed of *Agaricia* colonies (top left). Shallow reef crest environment on Hogsty Reef. A large boulder has a single live elkhorn colony and *Millepora* (bottom left). A pile of *Acropora* rubble within shallow water at Fowl Cay, Abaco. Much of the *Acropora palmata* has died and the structure is beginning to break down (top center). Shallow fore reef within the *Acropora* zone at Great Inagua. The corals have all died, but their structure still remains (bottom center). A reef on Great Inagua with live *Acropora* (top right). *Acropora* framework (mostly dead) on Hogsty Reef (bottom right).

Acropora palmata framework

Biology: Coral framework composed primarily of *Acropora palmata*, typically building to within a meter of sea level. Live coral cover usually sparse (<10%), but may include patchy or continuous coral thickets with up to 50-80%.
Hydrography: High-energy setting
Sedimentology: Little to no sediment accumulation but abundant coral rubble
Topography: High relief, high rugosity
Depth range: Shallower than -10 m.

Platform-top coral framework

Biology: Poorly aggraded coral framework primarily composed of massive and sub-massive coral species located on the platform-top or shelf environment. This class preferentially occurs on the leeward side of blue holes. In most cases, this class is embedded within the sand class. Live coral sparse (generally <15%)

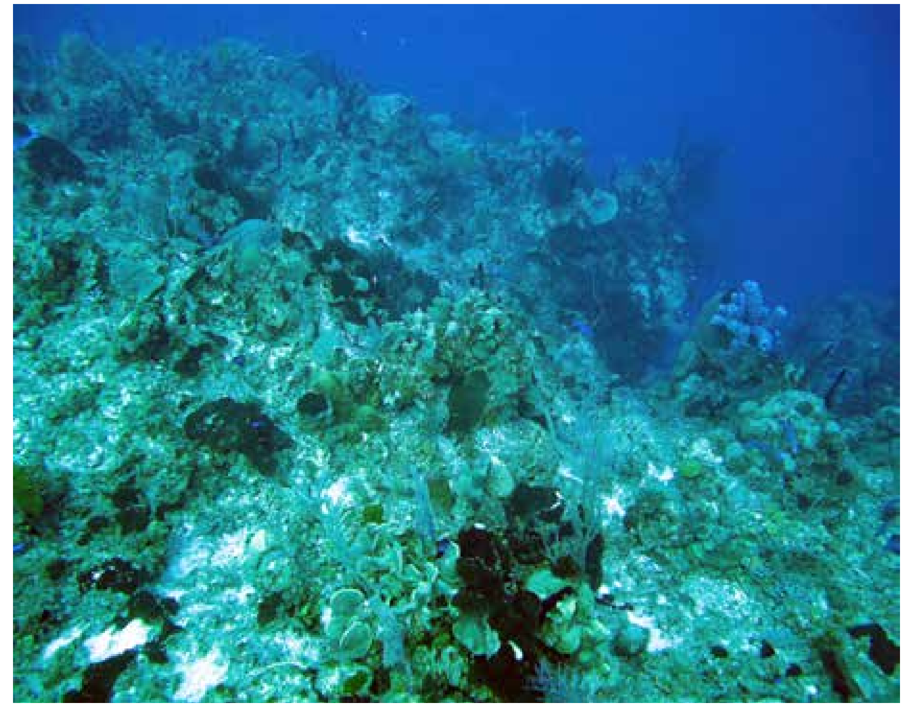
Hydrography: Low-energy platform-interior setting. Tides and wind-driven currents are the dominant drivers of water motion

Sedimentology: Coral dominated with substantial contributions from *Halimeda*. Terraces may serve to capture patches of sand and coral rubble

Topography: Moderate relief. Reef framework forms the highs; lows are sediment-filled

Depth range: Shallower than -10 m

Coral framework at the perimeter of a blue hole on the east side of Cay Sal Bank, 8 m depth. A hardground with sparse corals borders a sand flat (top right). *Montastraea cavernosa* at the edge of the blue hole (bottom left). Pillar coral at the edge of the blue hole (top center). *Montastraea* dominated Shelf edge on the east side of Hogsty Reef, 12 m depth (bottom center). Shelf edge off the south coast of Cay Sal Bank, 30 m depth (top left). High relief shelf edge community at Hogsty Reef, 20 m depth.



Shelf-edge coral framework

Biology: Coral framework primarily composed of massive coral species and sub-massive species located near the platform-margin. Live coral cover sparse to patchy (generally <20% with patches up to 50-60%)

Hydrography: Low energy setting. Lies below fair-weather wave base though episodically exposed to high energy during severe storm events. Likely also influenced by alongshore currents

Sedimentology: Coral dominated with substantial contributions from *Halimeda*. Terraces may serve to capture patches of sand and coral rubble.

Topography: Gently sloping in the shallower areas before steepening down-slope to the base of the zone of carbonate production (typically 40m)

Depth range: Deeper than -10 m

Patch reefs

Biology: Patches of coral framework within lagoons, or in the case of a poorly developed reef rim, leeward of the platform margin. Scleractinians, hydrocorals, and gorgonians are the primary benthic community constituents. Patch reef diameters vary from a few meters to tens of meters and may occur individually or in clusters. Live coral cover sparse (generally <15%)

Hydrography: Low-energy platform-interior setting. When platform-edge reefs are well developed, water movement is especially restricted

Sedimentology: Upper reaches of the patches are coral dominated. Flanks are composed of coral-derived debris in the sand and rubble size fractions

Topography: Isolated coral reef patches rising from the lagoon-floor to within a meter of sea level. Patches typically circular to elliptical in shape

Depth range: Shallower than -10 m

Shallow (5 m) patch reef within the lagoon at Hogsty Reef (top left). The community is dominated by large mounds of finger coral (*Porites porites*) and gorgonians (bottom left). Shallow patch reef in the center of Cay Sal Bank. The community is dominated by *Porites astreoides* corals, with scattered *Montastraea faveolata* and other species intermixed with gorgonians, 11 m depth (bottom center). Spur and groove reef system off the southwest end of Cay Sal Bank, 20 m (top center). Deep spur and groove fore reef off the west end of Cay Sal Bank, 25 m depth (top right). Low relief spur and groove habitat off Hogsty Reef, 20 m depth (bottom right).

Deep spur and groove formations

Biology: Spur morphology orientated normal to the platform-margin that are reminiscent of the spur-and-groove morphology that occur in high-energy shallow waters, but in this case, found at considerable depth and therefore interpreted to be palaeo-features formed during lowered sea level. These eroded carbonate surfaces retain some topography and are therefore sufficiently free from sand cover to allow development of a sparse coral community. Live coral cover sparse (<10%)

Hydrography: Low energy setting. Lies below fair-weather wave base though episodically exposed to high energy during severe storm events. Likely also influenced by alongshore currents and off-platform water transport.

Sedimentology: No sediment accumulated on spurs due to topography. Coral-derived rubble and sand accumulates in the grooves

Topography: Lateral changes in platform-normal topography occur at 10s of meters. Spurs have a vertical relief of up to 5 m

Depth range: From -15 m to >-40 m

Rubble fields

Biology: Areas of coral rubble with sparse coral growth. Rubble is fused or unattached. Macroalgae, turf algae and cyanobacteria often colonize the rubble. Few corals occur unless the rubble has been cemented to the substrate.

Hydrography: High energy

Sedimentology: Little sediment accumulated due to water motion. Dominated by coral-derived rubble and sand. May consist of hurricane or storm generated accumulations of broken corals, or areas formerly dominated by thickets of staghorn coral and finger corals (*Porites*) that died from disease or bleaching events.

Topography: Low

Depth range: Shallower than -4 m

Rubble field on Cay Sal bank, 8 m depth with a low abundance of *Porites astreoides* corals and patches of macroalgae (top left) and close-up of a rubble filed with cyanobacteria colonization, Cay Sal Bank 12 m depth (bottom left). Sub-tidal erosional surface at the northern end of Cay Sal Bank, 2 m depth (top center) and on the fore reef at Hogsty Reef at 2-3 m depth (top and bottom right). The substrate is colonized by turf algae and macroalgae with sparse colonization of encrusting and branching *Millepora* (bottom center). In high energy environments a high biomass of *Sargassum*, *Turbinaria* and other brown algae may occur.

Sub-tidal erosional surface

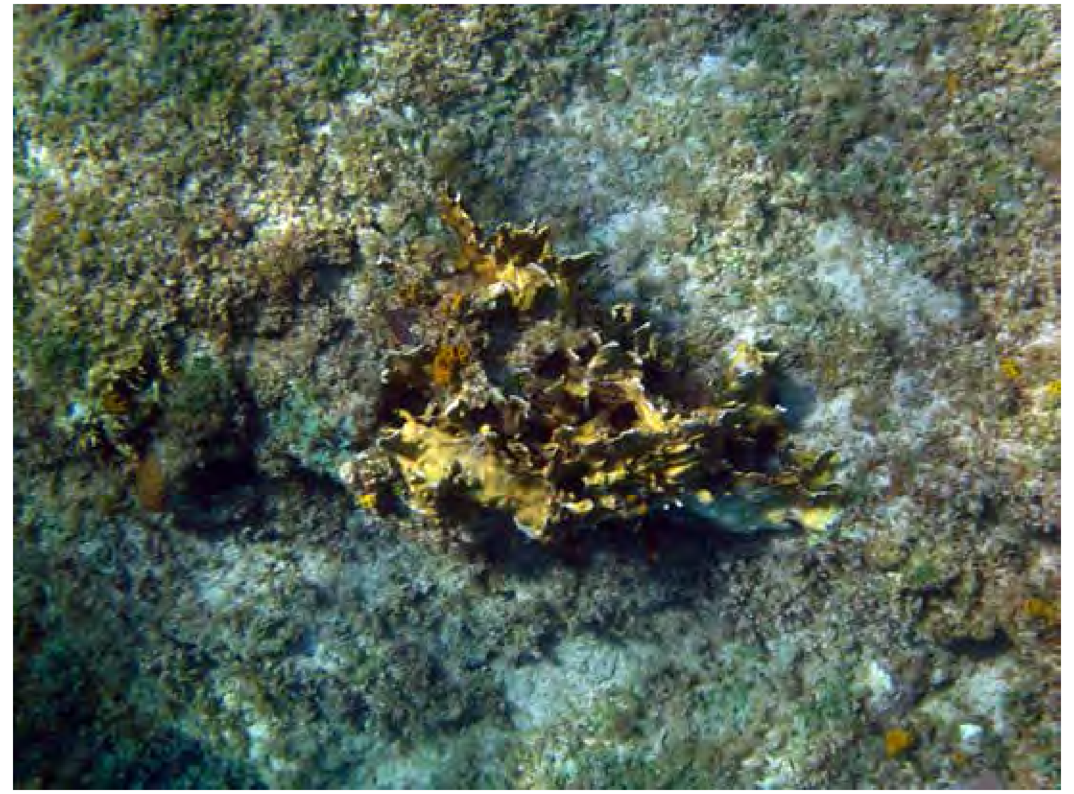
Biology: Low-relief erosional surface with depauperate coral cover but veneered by abundant turf-algae or brown macroalgae and *Millepora*. Coral cover <1%

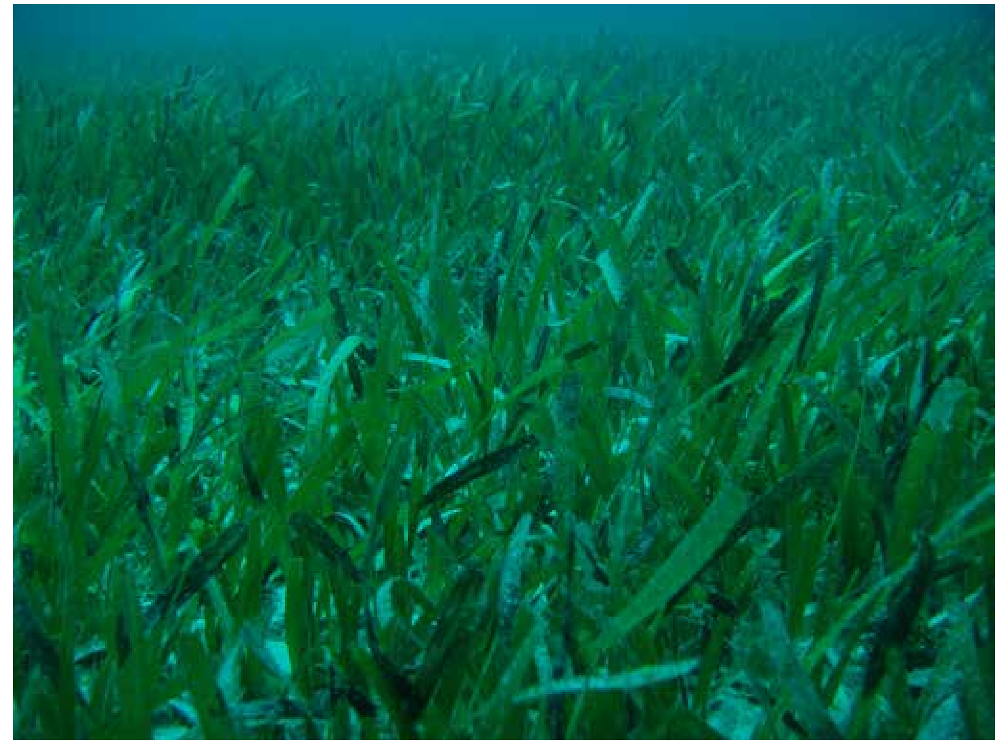
Hydrography: High energy setting, unless located leeward of a sheltering island

Sedimentology: Sediment-lean as detritus efficiently exported out of this high-energy environment

Topography: Low relief and low rugosity

Depth range: Shallower than -5 m





Moderately dense to dense seagrass

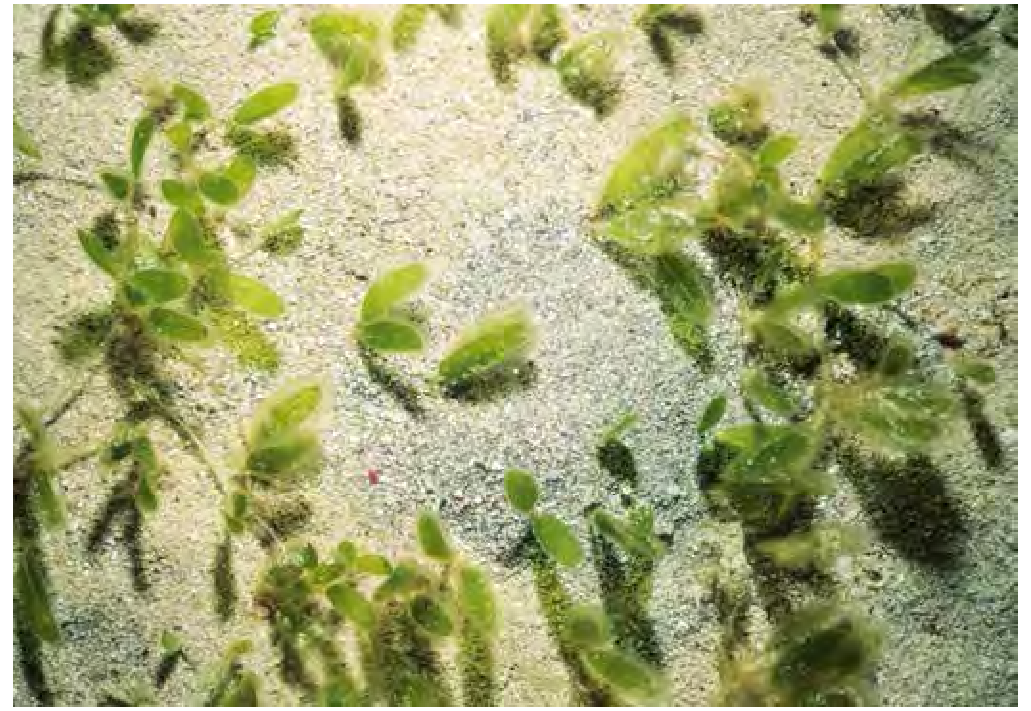
Biology: Luxuriant meadows of seagrass (>60% cover) dominated by *Thalassia testudinum*. Other seagrasses (e.g., *Syringodium filiforme*) and macroalgae are typically present, but at low density.

Hydrography: Low-energy platform-interior or shelf setting. Water motion driven by tides and wind-driven waves

Sedimentology: Seagrass serves to baffle current flow and trap fine-grained, organic rich, sands and muds

Topography: None, except in areas with blowouts

Depth range: Shallower than -15 m



Seagrass images. Dense *Thalassia testudinum* (top left). Dense *Syringodium filiforme* (bottom left). Sparse *Halophila decipiens* (top center). Sparse *Thalassia testudinum* (middle center). All photos are from Cay Sal.

Sparse to moderately dense seagrass

Biology: Sand with <60% seagrass cover. Dominant species are *Thalassia testudinum* and *Syringodium filiforme*.

Hydrography: Low-energy platform-interior or shelf setting. Water motion driven by tides and wind-driven waves

Sedimentology: Seagrass serves to baffle current flow and trap fine-grained, organic rich, sands and muds

Topography: None

Depth range: Shallower than -25 m

Mangroves/Mangles

Biology: Expanses of mangroves. Occurs primarily along shorelines. Acts as nursery for reef fishes. Live invertebrate cover is sparse, but the species present can differ from those found on nearby reefs.

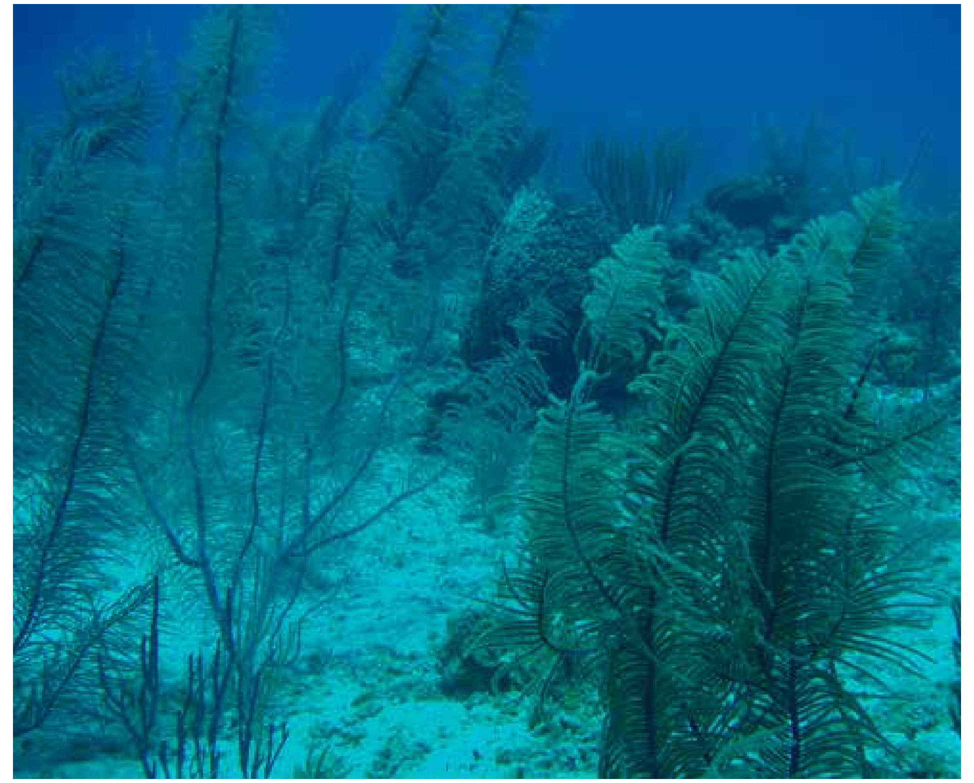
Hydrography: Low energy, primarily driven by tidal pumping and run-off

Sedimentology: High sedimentation rates dominated by mud

Topography: Variable with root density

Depth range: Shallower than -2 m

Mangrove communities near Andros. A dense forest of *Rhizophora mangle* (red mangrove) with larger mangroves in the background. An old mangrove in a shallow lagoon. The prop roots are anchoring the tree into the mud.



Gorgonian-dominated hardground

Biology: Low rugosity hardground that may have a thin sediment layer hosting high densities of gorgonians (>10 m^{-2})

Hydrography: Moderate energy setting. Affected by tidal motion, waves, and currents

Sedimentology: Low sediment production combined with high export rates delivers a sediment-lean environment

Topography: Low relief

Depth range: From -5 m to -15 m.

Turf-algal-dominated hardground

Biology: Low rugosity hardground dominated by turf algae with invertebrate <5% cover (scleractinians, gorgonians, poriferans)

Hydrography: High energy environment. Affected by tidal motion and wave action

Sedimentology: Very little sediment production combined with high export rates delivers a sediment-lean environment

Topography: Very low relief

Depth range: Shallower than -15 m.

Gorgonian dominated hardground on the fore reef at Hogsty Reef, 20 m depth (top left) and a gorgonian hardground at Great Inagua, 12 m depth (bottom left). In both environments a thin layer of sediment covers the pavement. Very few live corals occur and communities are dominated by branching *Psuedoterigorgia* with a mix of other species of soft corals. A spotted snake eel cruises over pavement with turf algae (top center). Hardground with turf algae and low densities of gorgonians, corals and sponges (bottom center).

Macroalgal-dominated hardground

Biology: Low rugosity hardground dominated by macroalgae with <5% cover of invertebrates (scleractinians, gorgonians, poriferans)

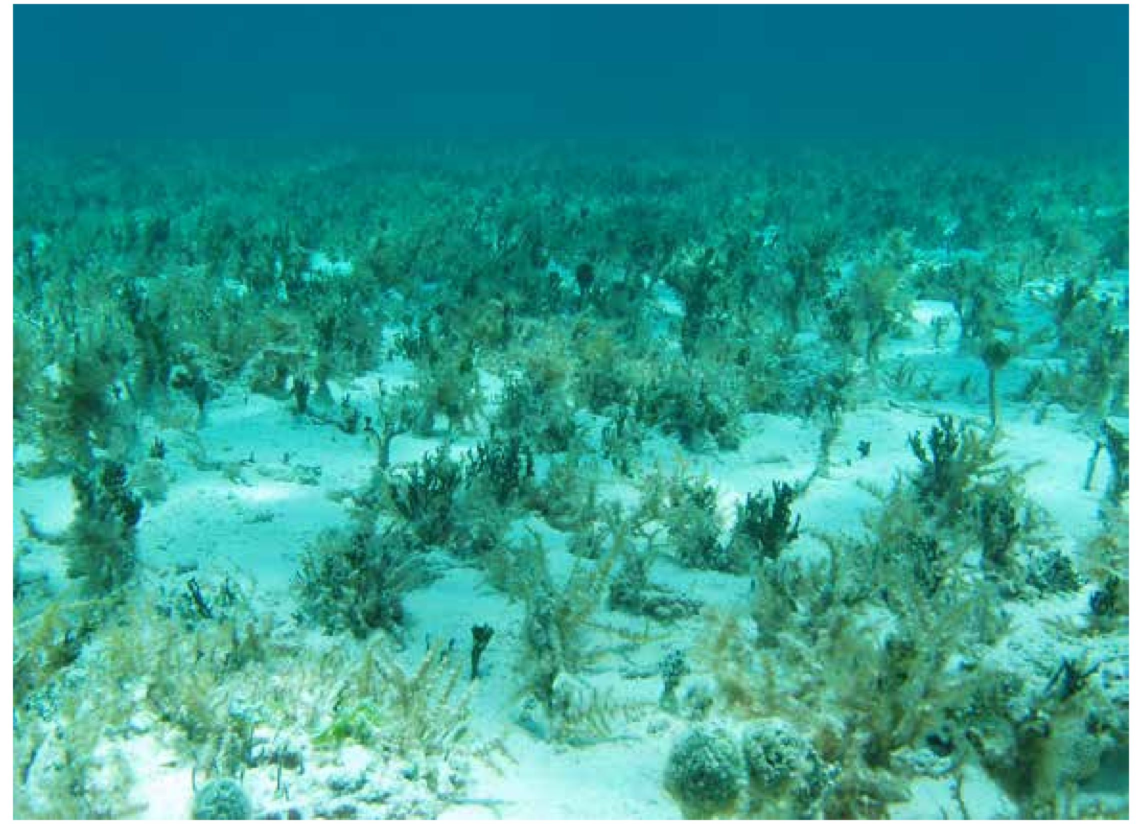
Hydrography: High energy environment. Affected by tidal motion and wave action

Sedimentology: Very little sediment production combined with high export rates delivers a sediment-lean environment

Topography: Low relief

Depth range: From -5 m to -15 m

Hardground with high biomass of macroalgae and scattered *Siderastrea* corals on Hogsty Reef, 10 m depth (top right). Hardground with small boulders, a sediment layer and macroalgae on Hogsty reef, 6 m depth (bottom right).



Moderate to dense macroalgae in sand

Biology: Areas of unconsolidated sand with <5% seagrass cover and high, typically erect calcareous, green macroalgae cover (>60%)

Hydrography: Low-energy platform-interior or shelf setting. Water motion driven by tides and wind-driven waves

Sedimentology: This environment hosts a diverse mollusk and echinoderm fauna which, along with debris from the breakdown of calcareous algae, deliver thick accumulations of skeletal carbonate sands and muds

Topography: None

Depth range: Shallower than -15 m

Dense macroalgae including *Halimeda, Dicyota* and *Penicillus* at 8 m depth, Cay Sal Bank (top left). Sandflat with algae in the lagoon of Hogsty reef, 7 m depth (top center). Deep sand flat on the fore reef slope of Hogsty reef, 15 m depth (top right). Aerial view of a sand flat with cyanobacteria off Cay Sal Island (center). Mudflat on inland lagoon on Great Inagua (lower left). Sandflat with no algal colonization on Cay Sal Bank (lower right).

Mud flats

Biology: Expanses of fine sediments.

Hydrography: Low energy

Sedimentology: High sedimentation rates dominated by mud

Topography: Low

Depth range: Shallower than -3 m

Sand

Biology: Unconsolidated rippled sand sheets with little to no growth of benthic invertebrates, seagrasses, or algae. Well-developed mollusk and echinoderm fauna

Hydrography: Low to high energy platform-interior, shelf, or off-shelf setting. Water motion driven by tides and waves

Sedimentology: These areas hold sediments produced in different environments superimposed and mixed. Degree of water movement controls grain-size and sorting

Topography: None, unless sand shoals develop

Depth range: At all mapped depths (0 to -40 m)

Blue holes

Biology: Karst depressions with >10 m diameter throats located in platform-interior and shelf environments. The depression have vertical to near-vertical walls. In some cases, scleractinian corals colonize the upper margins and perimeter, and rich *Halimeda* assemblages colonize the vertical surfaces. Rich mollusk and echinoderm fauna develop in the sediment filled depressions as the organisms become trapped. Depending on rates of sediment in-fill, these depressions have depths varying from >100 m, to completely sediment filled.

Hydrography: A low-energy platform-interior or shelf setting. Water motion driven by tides, waves, and currents.

Sedimentology: Blue holes are typically infilled by muddy sediment

Topography: Variable relief depending on degree of in-fill of depressions

Depth range: From -10 m to -200 m

Images of blue holes and coastal environments. A large blue hole at the northeastern end of Cay Sal Bank that is over 100 m deep. The rim was densely colonized by coral and surrounded by sand and sparse seagrass (top left). The blue hole had a near vertical slope that plummeted below diving depths. In shallow water the sides had extensive colonization of macroalgae (lower left). Numerous blue holes on Cay Sal Bank that have been infilled with sediment and colonized by seagrass can be seen from the air (top center). An eolionite dune on Great Inagua at low tide. The white, black and yellow zones are visible (center). A low-lying limestone island at the northern end of Cay Sal Bank (top right). A sandy beach at Great Inagua (lower right).

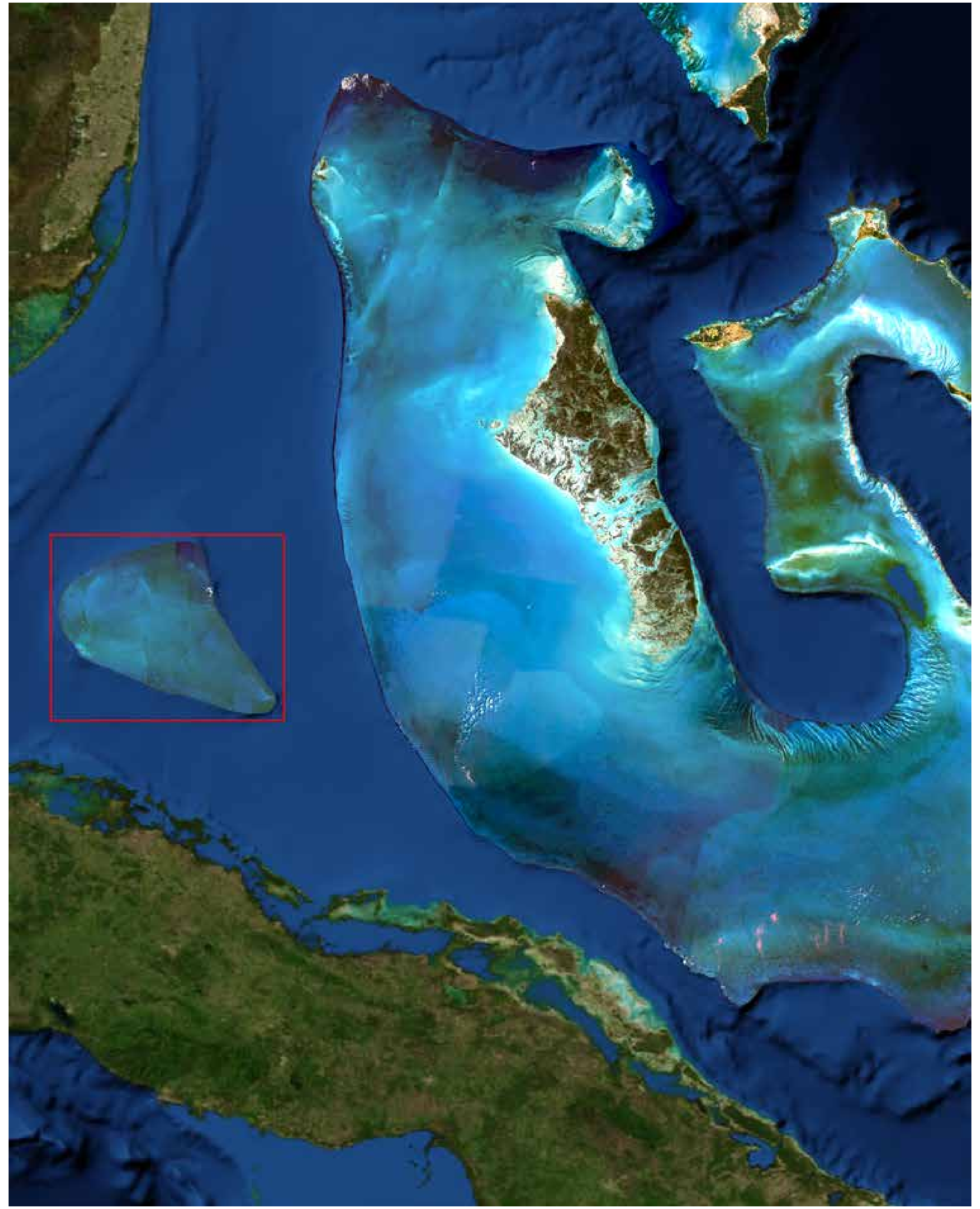
Land

Biology: All areas above the intertidal. Includes sandy beaches, rocky coastlines, mangroves, uplifted reef, shoreline vegetation, lowland scrub forests and conifer forests.

Hydrography: High energy shorelines in coastal areas on windward (east) sides of islands; lower energy on leeward (western) sides.

Sedimentology: Includes both fine sands to muds and karst limestone.

Topography: Variable relief, depending on location, extending from high water to 62 m above sea level.



Cay Sal Bank, Bahamas

Above: Anguilla Cays are located at the southeast end of Cay Sal Bank. They consist of several elongated, scrub-covered, sandy islands with small pocket beaches. The northern end of Anguilla Cays is marked by a beacon, 5 m high. There is a well established population of stunted palm trees and the islands are swampy near their southern end.

Opposite page, top right: Double Headed Shot Cays consist of a group of elongated eolianite islets on the northwest side of Cay Sal Bank. They extend from South Elbow Cay in the southwest to Water Cays in the northeast.

Opposite page, bottom right: Cay Sal Island, in the southwest portion of the Bank, is low-lying, roughly circular in shape and about 1.6 km in diameter. It has a large, shallow hypersaline lake and a series of sand hills and karstified dunes that form a 10 m tall ridge on its northeast side. The island is covered in stunted palm trees. A beach, from 1-15 m in width, fringes most of the island.

Several islands, including Cay Sal (above) have a prominent Pleistocene-Holocene Eolianite ridge along the shoreline.

Cay Sal Bank

Cay Sal Bank, the third largest bank in the Bahamas, is an isolated, submerged carbonate platform surrounded by deep water. It is located between 23º27'N - 24º10'N and 079º25'W – 080º35'W. It is approximately 50 km from Cuba; the Nicholas Channel separates Cuba from Cay Sal Bank. The western rim of the Great Bahamas Bank, which is about 50 km away, is separated from Cay Sal Bank by the Santaren Channel. To the north, the Straits of Florida lie between Cay Sal Bank and the Florida Keys (USA). Key Largo is the closest United States land mass, located approximately 100 km from the northern tip of Cay Sal Bank.

Cay Sal Bank is roughly triangular in shape, with a length along the south rim of 105 km and a width of 66 km north-south. The Bank occupies a total area of over 6000 km^2 Cay Sal Bank, yet the land area measures only 14.87 km^2 (Goldberg 1983). Over 99% of the bank is submerged, ranging in depths from 5-16 m. There is a narrow fringe of emergent land that forms a rim around much of the perimeter, and surrounds a central lagoon. Land masses are comprised of small sandy vegetated islands, rocky outcrops, and lithified sand dunes. Numerous channels are found between the cays; these vary in width and depth but allow tidal exchange between the central lagoon and the oceanic waters of the outer bank margin. The outer margin is rimmed by a number of small cays consisting of cemented sand and coral rubble dunes and cliffs (karstified eolianite) which are colonized in places by vegetation (primarily *Sesuvium* and *Tournefortia*).

The largest islands include Anguilla Cay, Cay Sal, and Double Headed Shot Cays. The emergent cays on the platform-top are built from a semi-continuous eolianite ridge that rims the north and east platform-margins. The ridge can be traced between the numerous emergent cays as a narrow marine topographic high with several meters of vertical relief and width of ~100 m (Purkis et al. 2014).

Cay Sal Bank has been referred to as a drowned atoll (Agassiz 1894), although it is of a different geologic origin and is not formed around a submerged volcano. The structure of the bank is largely controlled by wind and periodic storms that resuspend and transport sediments. The combination of wave stress and current-induced sediment stress appear to have limited coral development on much of the bank interior.

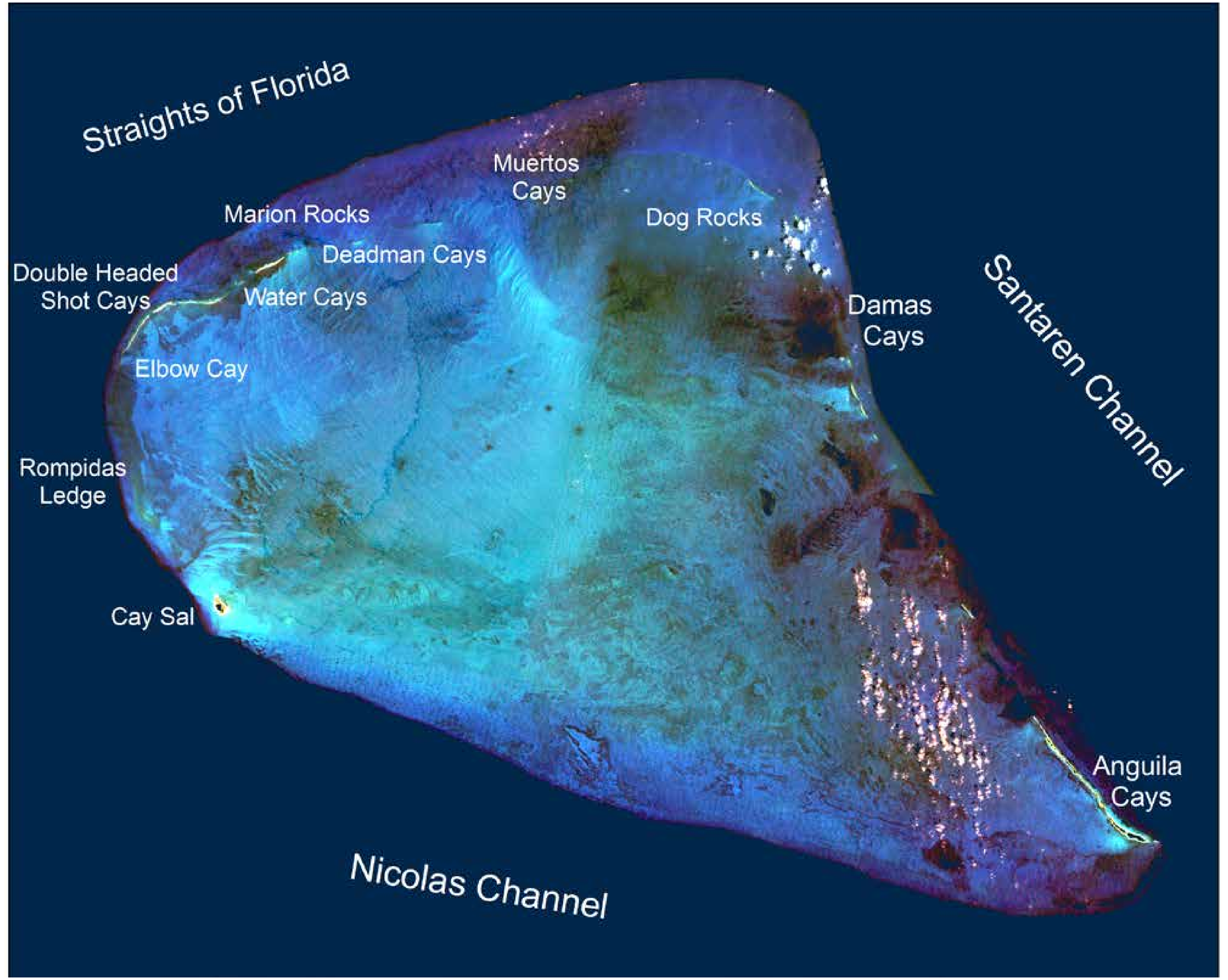
The platform-interior is mostly sandy, with vast meadows of sparse to medium density seagrass. Platform-top coral frameworks are confined to the eastern-half of the platform and are small in size (<500 m diameter). Hardgrounds, dominated by gorgonians and macroalgae, become more prevalent closest to the platform-margin. Karst depressions are frequent atop the platform and attain widths of many hundred meters. The Bank lacks an actively accreting coral-reefal rim and live coral cover on the platform margins is <20%.

The platform-top is exposed to substantial wave and current energy which serves to export much of the sediment off the platform (Purkis et al. 2014).

Double Headed Shot Cays consist of a group of elongated islets on the northwest side of Cay Sal Bank (top right). They extend from South Elbow Cay in the southwest to Water Cays in the northeast. Like the other rocky Cays, these all are eolianites that were deposited during sea-level highstands stretching from the Pleistocene into the Holocene. North Elbow Cay, the highest of the islets making up Double Headed Shot Cays, has a conical stone lighthouse at an elevation of 17.7m (bottom right). The lighthouse was built in 1839 during the long period of British rule in the Bahamas.

Diverse geologic features of the bank and unique habitats were shaped by underlying Pleistocene (limestone) structures. Cay Sal lacks an actively accreting coral-reefal rim and, for this reason, the platform-top is exposed to substantial wave and current energy. Sediment distribution on Cay Sal, including infill patterns of karst depressions, suggest that easterly trade winds drive the hydrodynamics of the platform-top (Purkis et al. 2014). Cay Sal Bank flooded earlier and at relatively higher rates of Holocene sea-level rise than other platforms in the Bahamas. Unusual features include blue holes which may be over a 100 m deep (top left). These are distributed across the top of the bank and in many locations have been infilled with sediment. Presumably, high concentrations of nutrients associated with the debris that accumulates in the blue hole, supports the growth of seagrasses that often form a nearly perfect circular meadows atop these infilled blue holes. Several of the islands at the margin of the platform on the north and east sides are lithified sand dunes (eolianite outcrops), 3-5 m in height, deposited over the last 500,000 years (bottom left). The islands are important nesting areas for sea turtles and sea birds (top right).

Middle Cay, between Anguilla Cay and Cotton Cay contains a wide, several hundred meter long beach that faces Santaren Channel (bottom right). This cay has relatively high relief and is backed by low-growing vegetation. The southwest shore of Cotton Cay also contains small sandy beaches backed by vegetated sandy ridges that reach elevations of up to 20 m.



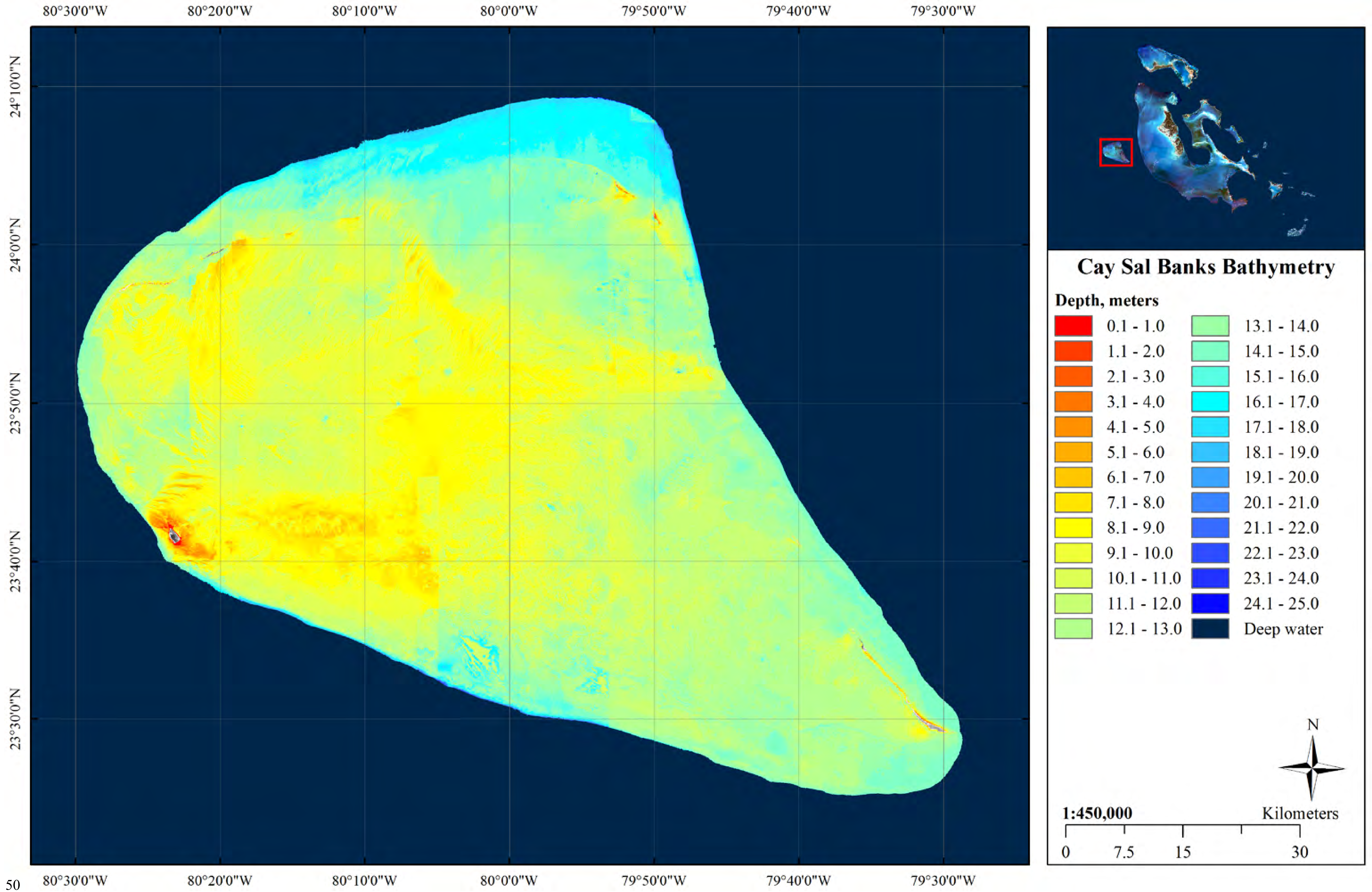
Cay Sal Bank is unusual in that it is only slightly deeper than the Grand Bahama Bank, yet it is devoid of central islands, lacks platform-margin coral reefs, and holds little sediment on the platform-top. The platform is incipiently drowned, yet it is conspicuously larger (6,000 sq. km) than other incipiently drowned platforms in the region, such as Serranilla Bank (1,100 sq. km) and the Cat Island platform (1,500 sq. km). Satellite image of Cay Sal Bank is shown above. The bank is separated from Cuba by the Nicolas Channel, from Florida by the Florida Straits, and from the Great Bahama Bank by the Santaran Channel. The water temperatures at the surface range from about 24.4°C to 30°C and the salinity is approximately 36 ppt. Currents passing by Cay Sal Bank include the Florida current, with a speed of 0.53-1.6 m/sec, and the Antilles Current with a velocity of 0.17-0.35 m/sec.

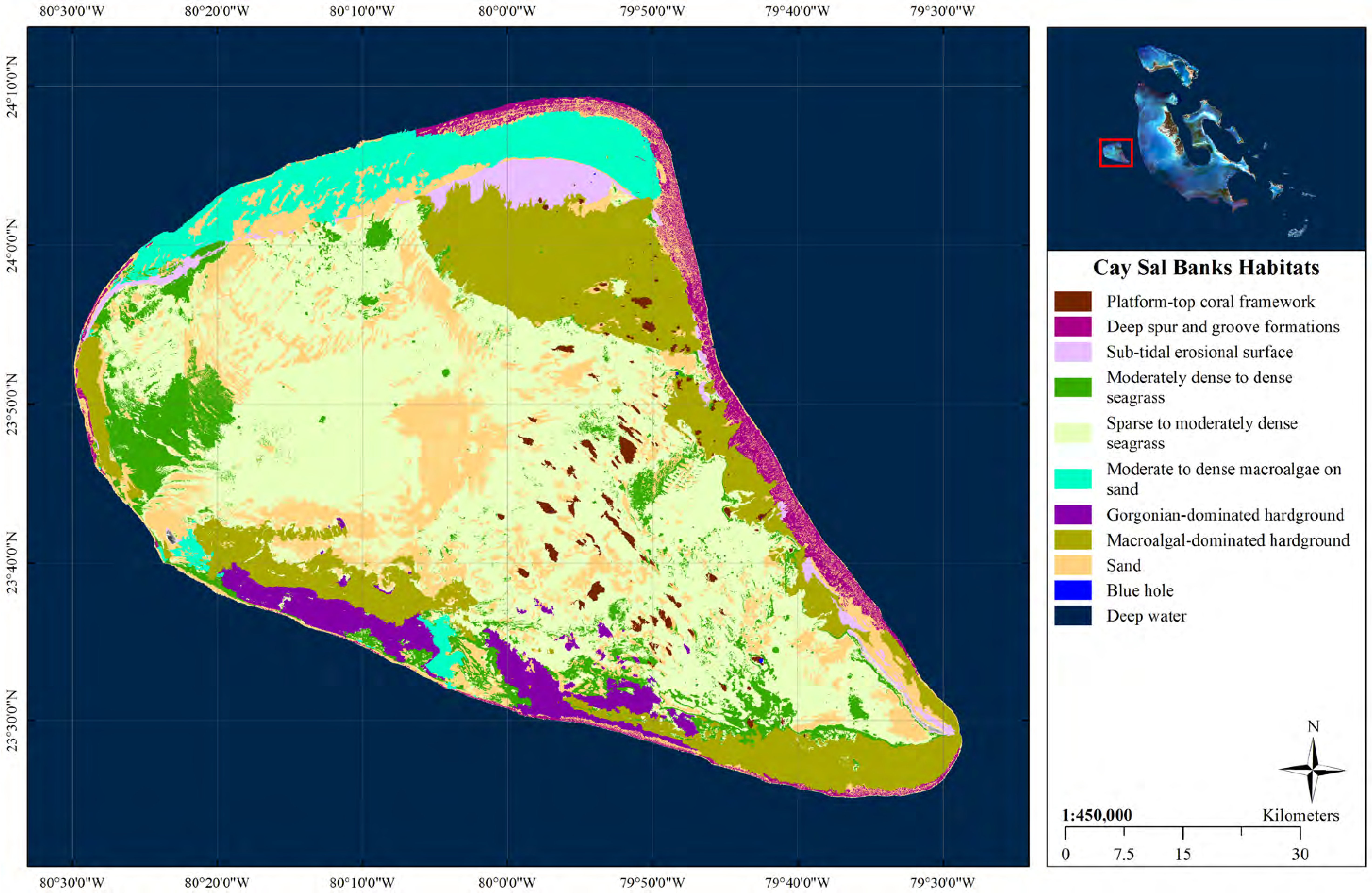
Cay Sal Bank Imagery and Habitat Maps

Satellite imagery, bathymetry and habitat maps for Cay Sal Bank are illustrated on pages 48-192. WorldView-2 multispectral satellite imagery of Cay Sal Bank (left), bathymetry (page 49) and a resulting habitat map for the same area (page 50) are shown at a scale of 1:450,000. A regional locator map, bathymetric map and habitat map, at a scale of 1:200,000, are shown for the north on pages 52-54, southeast on pages 84-86, south on pages 136-138, and west on pages 160-162. Higher resolution habitat maps (1:24,000) and bathymetric maps for representative areas within Cay Sal Bank are shown on subsequent pages. Each of the 1:24,000 scale habitat maps included in this section is on the left (odd numbered) page and the bathymetric map for the same area is shown on the right (even numbered page). Habitat maps start in the north and work progressively southward. Source of terrestrial basemap imagery used in all habitat maps and bathymetric maps is: ESRI, i-cubed, USFSA, USGS, AEX, GeoEye, AeroGRID, Getmapping, IGP.

A total of 5982 sq km were mapped and subdivided into 10 habitat classes with areas below 25 m depth (deepwater) depicted in dark blue. The aerial coverage of each habitat is presented in the table. The most extensive habitat types were sparse to moderately dense seagrass followed by macroalgal-dominated hardground and sand which together made up over 75% of all marine habitats. Corals were found in five habitat types, although they were a major component in only two, covering an area of about 245 sq. km. Hardground areas with isolated corals constitute an additional 1375 sq. km of the bank, while soft bottom habitats with seagrass, algae, and cyanobacteria occupied 3330 sq km. Mangrove communities were absent. Emergent land occurs at the perimeter of the Bank and is made up of numerous small low-lying islands, some with sandy beaches, scrub vegetation, and saline ponds, and others consisting of karstified eolianite sand dunes.

Cay Sal Bank Habitats	Total Area (sq km)	% region total
Platform-top coral framework	59.69	1.00
Deep spur and groove formations	186.93	3.12
Sub-tidal erosional surface	141.49	2.37
Moderately dense to dense seagrass	479.26	8.01
Sparse to moderately dense seagrass	2453.92	41.02
Moderate to dense macroalgae in sand	405.54	6.78
Gorgonian-dominated hardground	203.13	3.40
Macroalgal-dominated hardground	1031.94	17.25
Sand	1019.83	17.05
Blue hole	0.46	0.01
Land	7.15	
TOTAL AREA MAPPED	5982.18	100.00


80°30'0"W
80°20'0"W
80°10'0"W
80°0'0"W
79°50'0"W
79°40'0"W
79°30'0"W
24°10'0"N
24°0'0"N
23°50'0"N
23°40'0"N
23°30'0"N
Cay Sal Banks Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:450,000
Kilometers
0
7.5
15
30

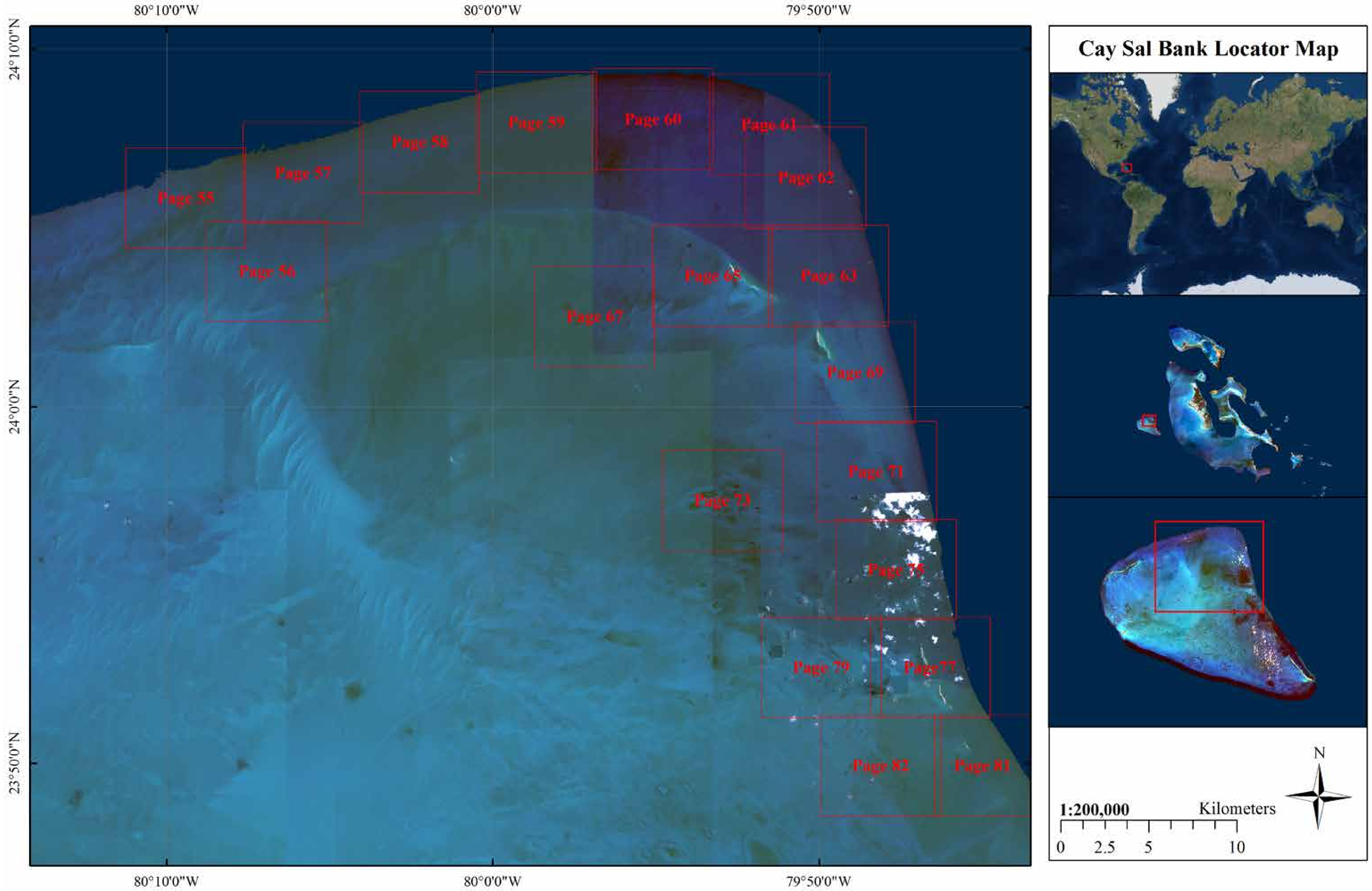

80°30'0"W
80°20'0"W
80°10'0"W
80°0'0"W
79°50'0"W
79°40'0"W
79°30'0"W
24°10'0"N
24°0'0"N
23°50'0"N
23°40'0"N
23°30'0"N
Cay Sal Banks Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:450,000
Kilometers
0
7.5
15
30

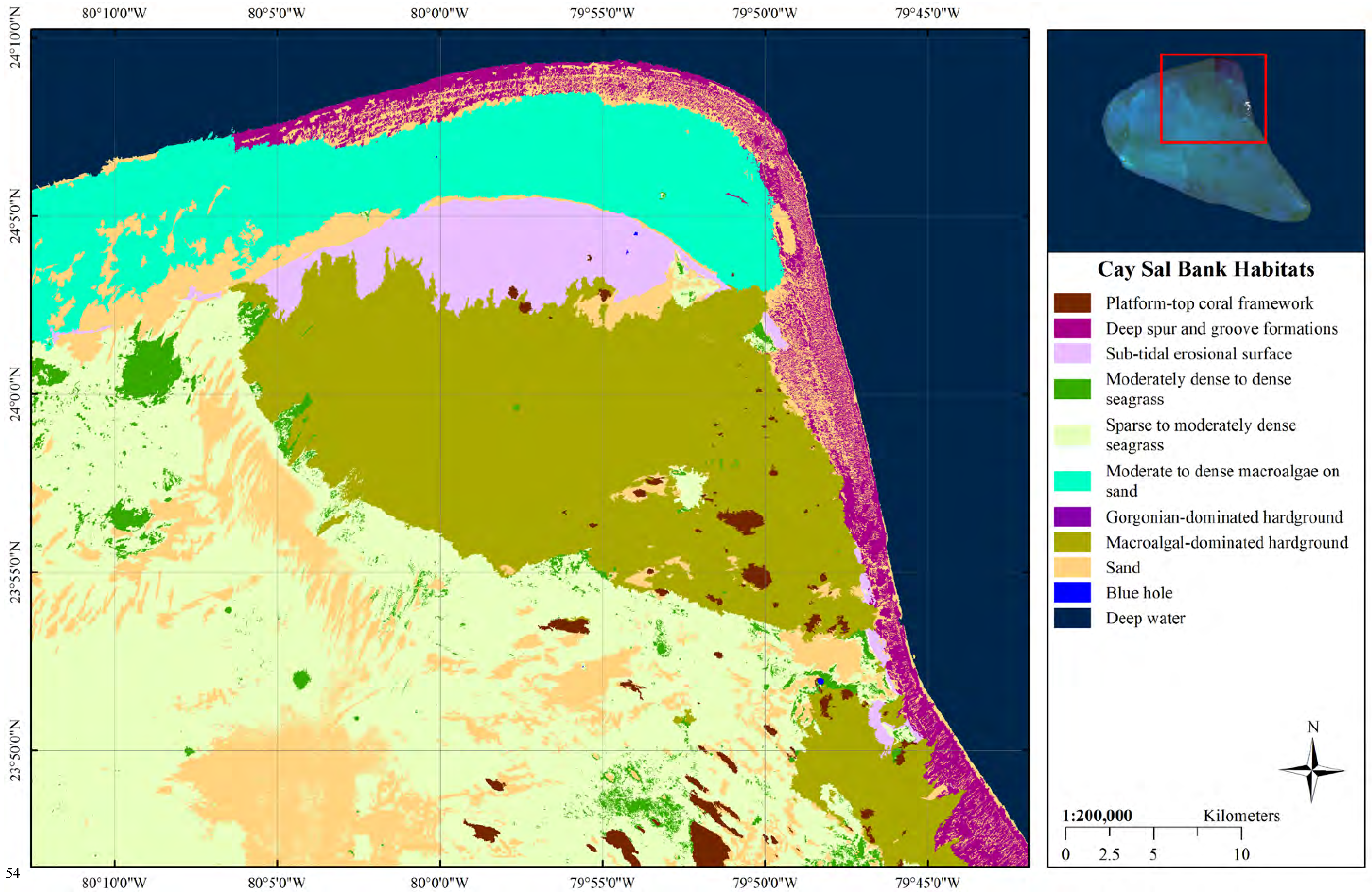
Many of the shallow coral habitats on the bank appeared to be biologically impoverished, with little living coral and proliferant growth of fleshy seaweeds, gorgonians and sponges.

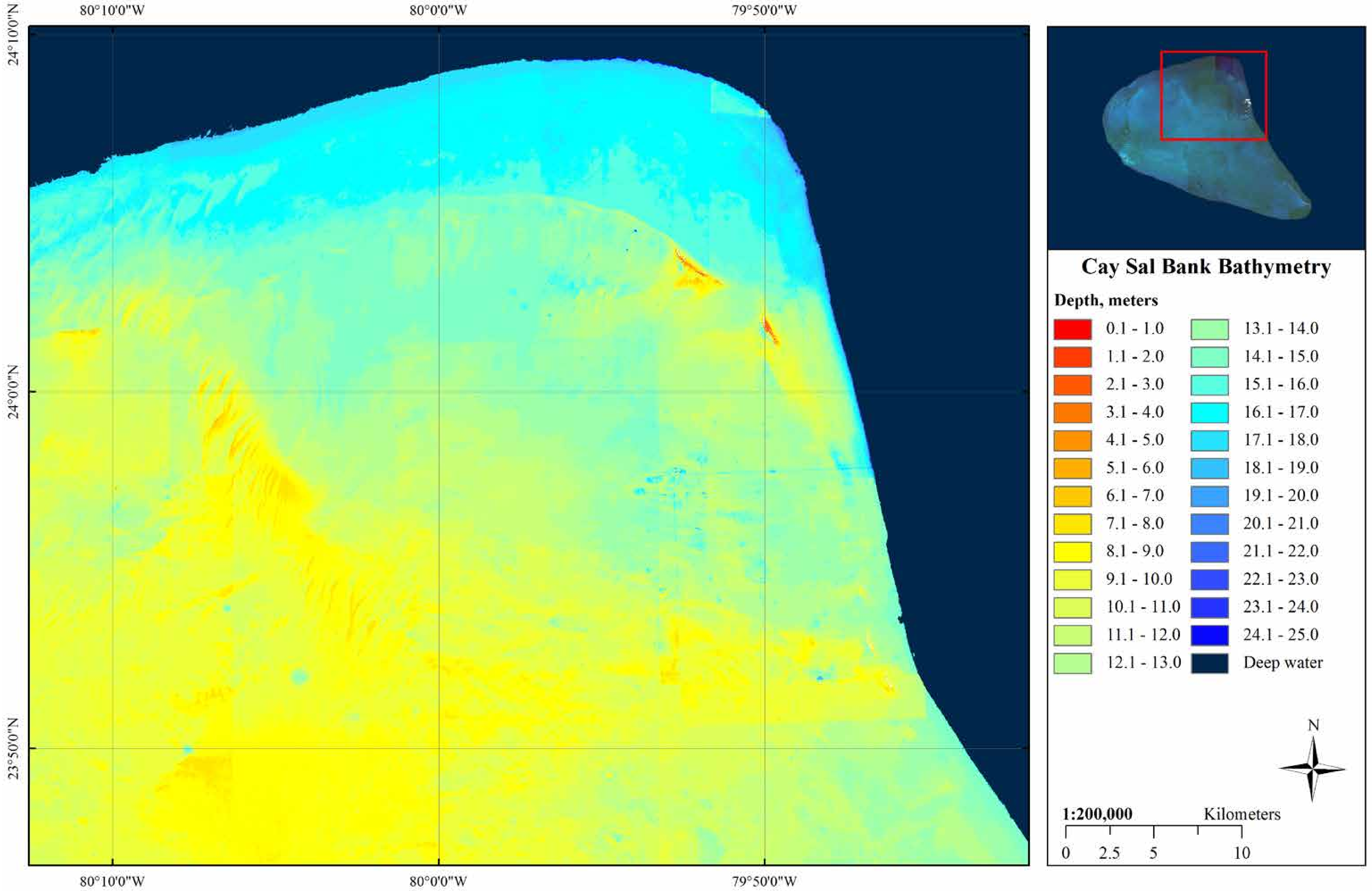
Cay Sal Bank contains important seagrass beds, but mangrove communities are absent. The seagrass habitats are important feeding grounds and nursery areas for many species. However, because of the lack of mangrove nursery habitats, and a great distance and deep water separating Cay Sal Bank from other shallow areas in the Bahamas, groupers, snappers, grunts and other species that migrate between habitats were rare and fish biomass in general was low.

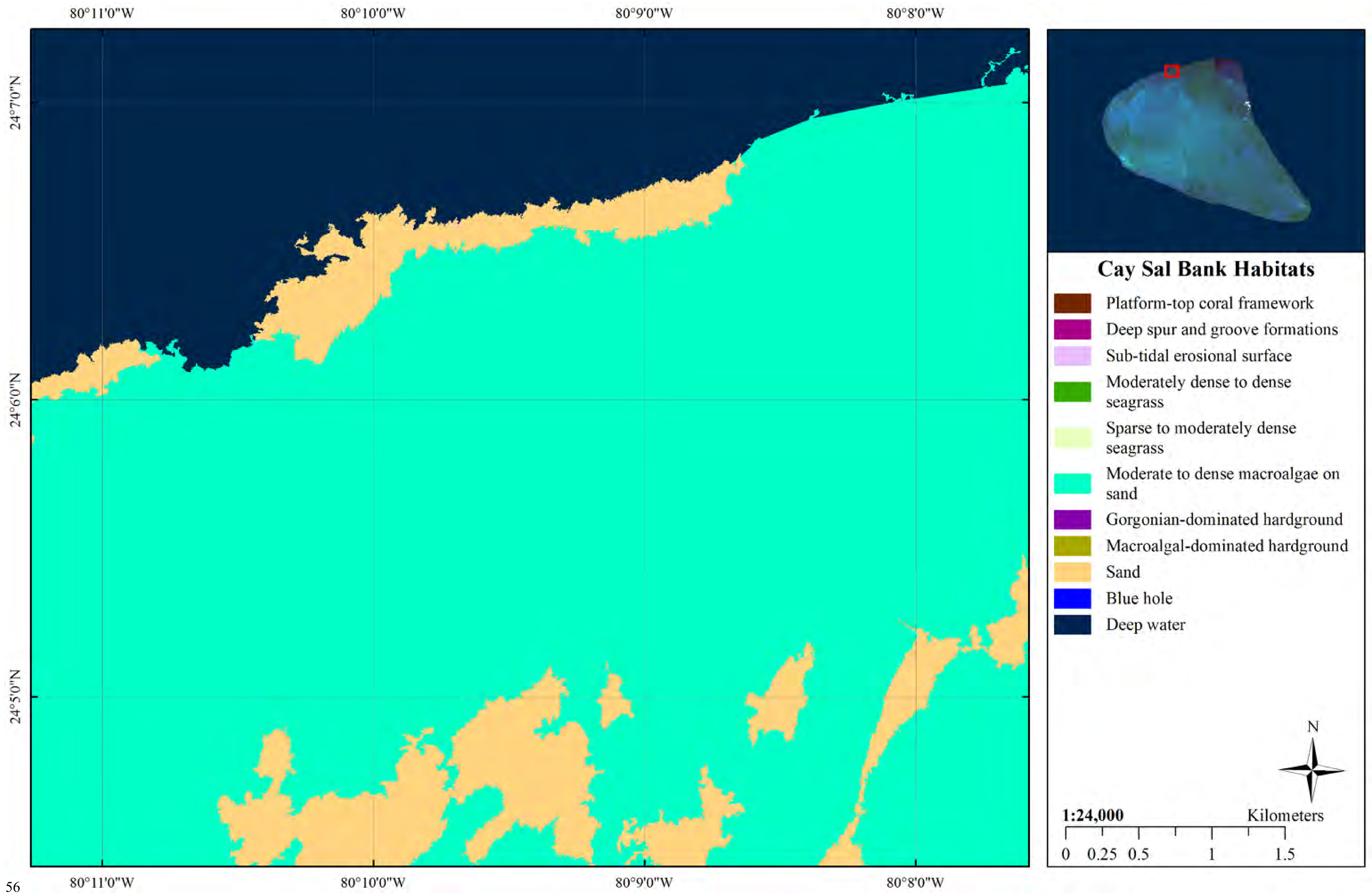
A barracuda patrols a seagrass bed on the southern end of Cay Sal Bank.

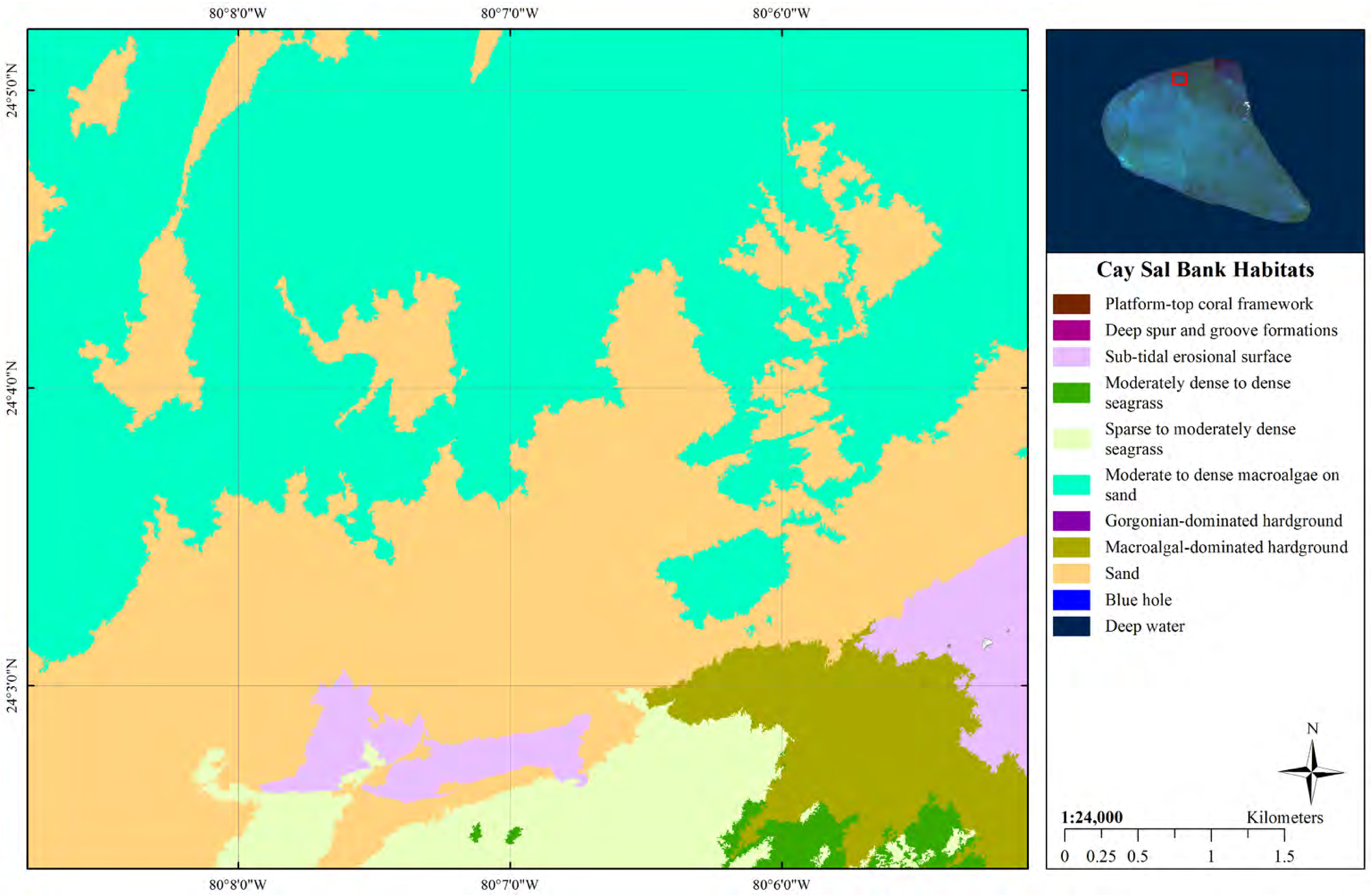
Much of the top of the bank is hardground with a fine layer of sediment. Sand shoals and moving sand waves are also found, especially at the northwestern margin. Unusual coral and sponge patches were observed within the bank. These exhibited highly variable structure and species assemblages (center). The extensive seagrass communities and sand flats on the bank supported very large queen conch (*Strombus gigas*) populations (bottom center). Well-developed spur-and-groove reef systems exist on the outer portions of the bank in the east, west (top right) and south (center right). Shallow-water had very low relief with high cover of macroalgae and scattered gorgonians. Schools of grunts, snapper and other small carnivorous fish typically schooled around small coral heads, ledges and other areas with relief (bottom right).

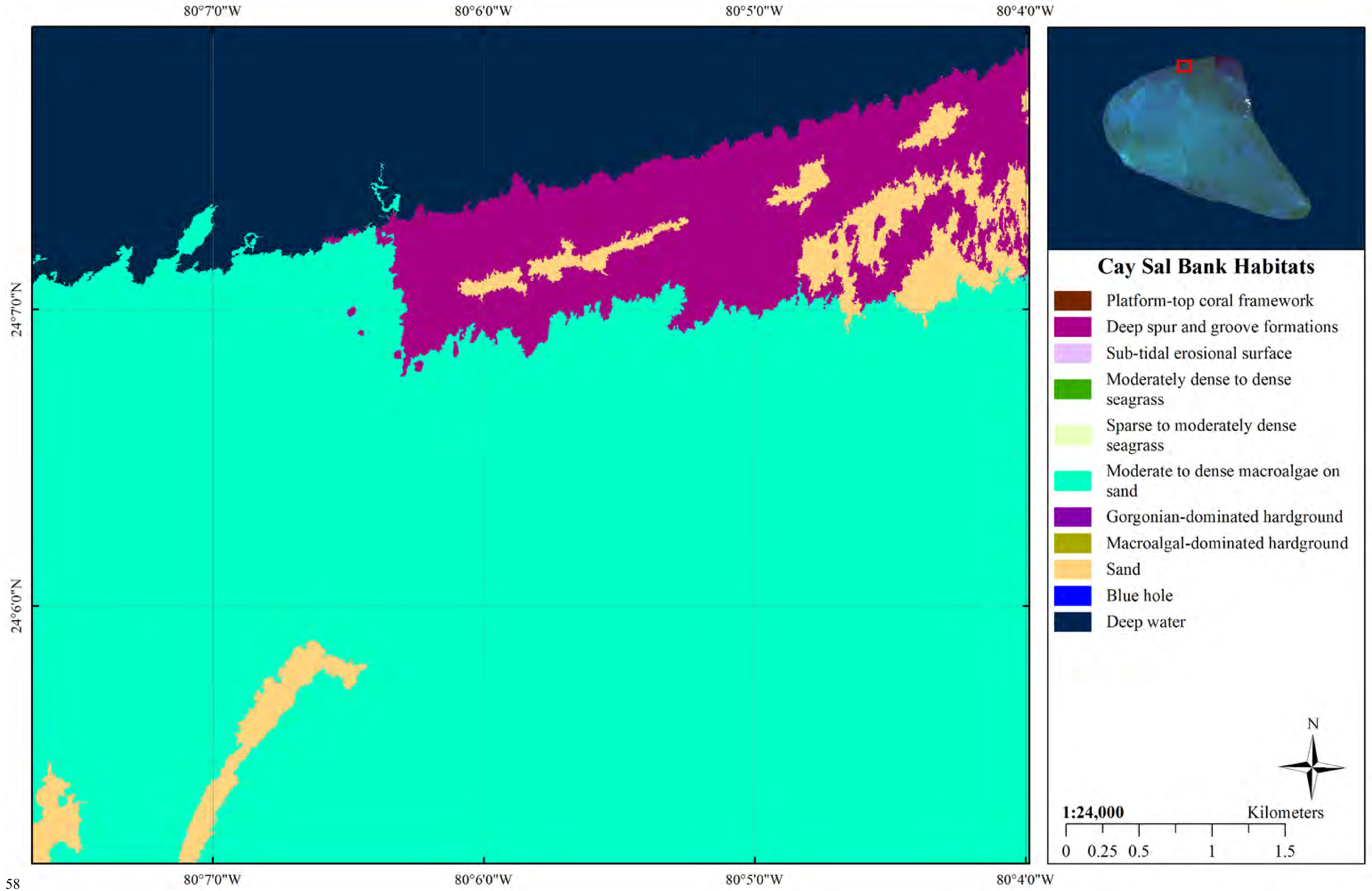



80°10'0"W
80°5'0"W
80°0'0"W
79°55'0"W
79°50'0"W
79°45'0"W
24°10'0"N
24°5'0"N
24°0'0"N
23°55'0"N
23°50'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:200,000
Kilometers
0
2.5
5
10

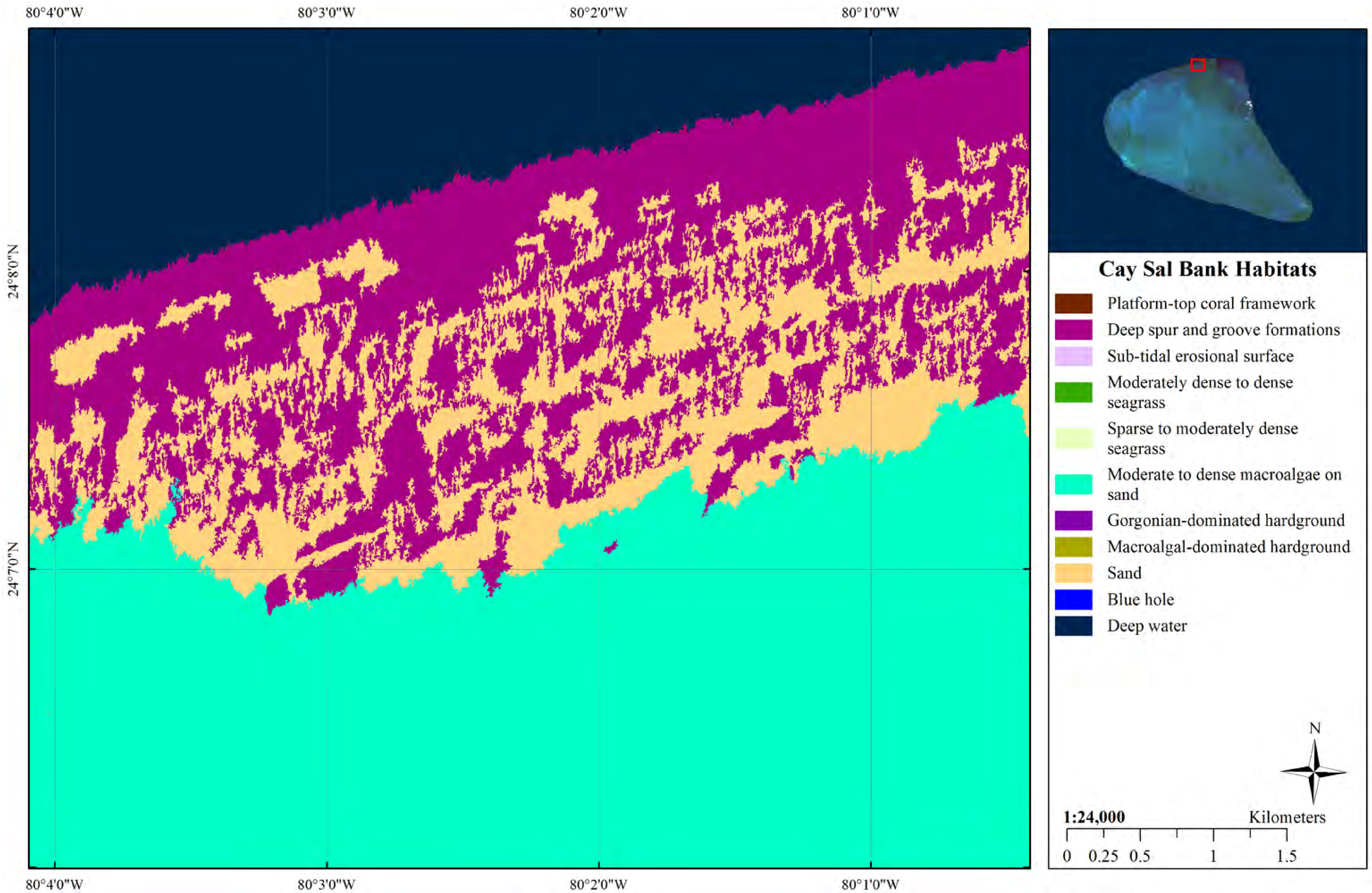

80°10'0"W
80°0'0"W
79°50'0"W
24°10'0"N
24°0'0"N
23°50'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:200,000
Kilometers
0
2.5
5
10


80°11'0"W
80°10'0"W
80°9'0"W
80°8'0"W
24°7'0"N
24°6'0"N
24°5'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

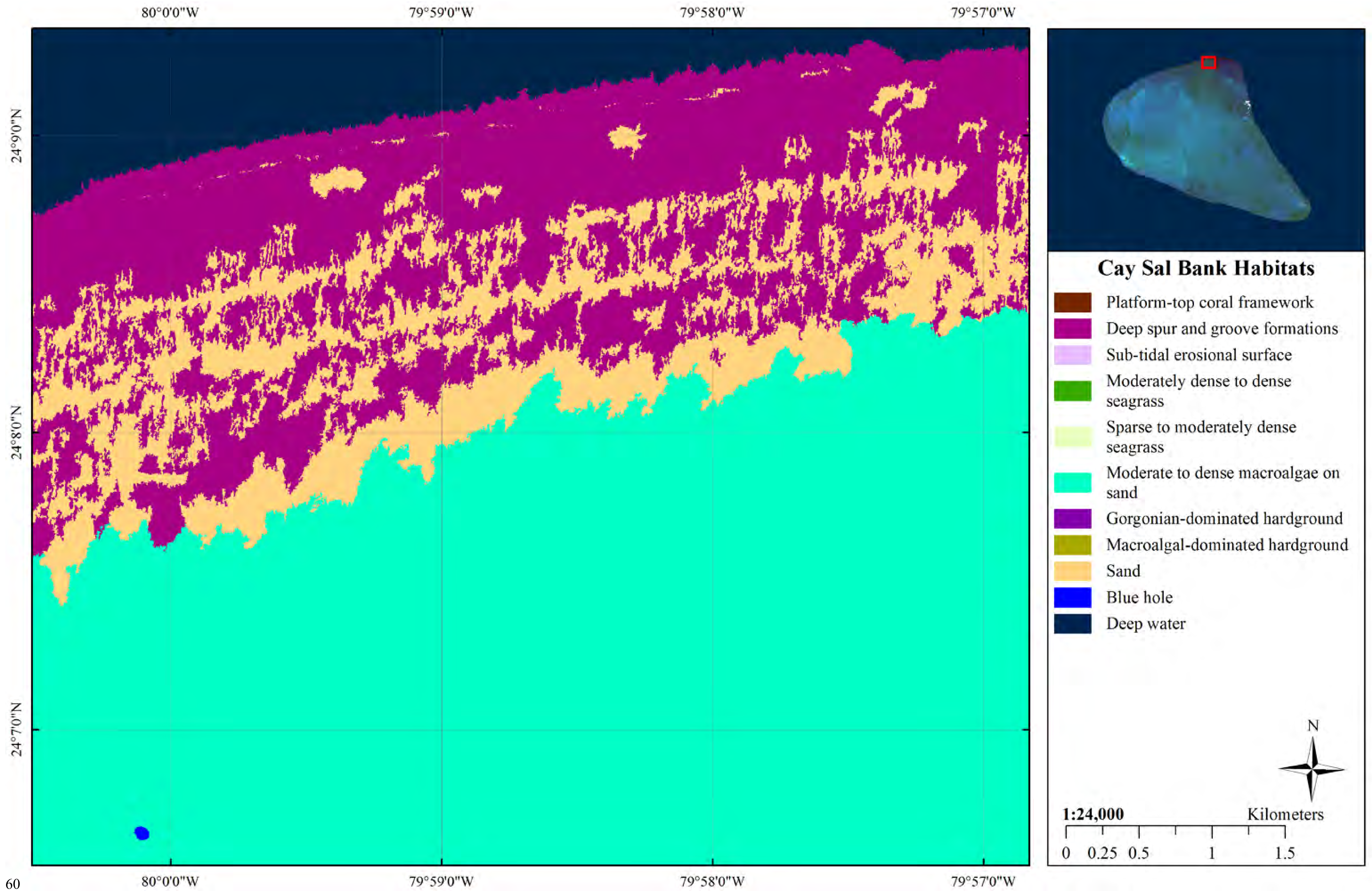

80°8'0"W
80°7'0"W
80°6'0"W
24°5'0"N
24°4'0"N
24°3'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

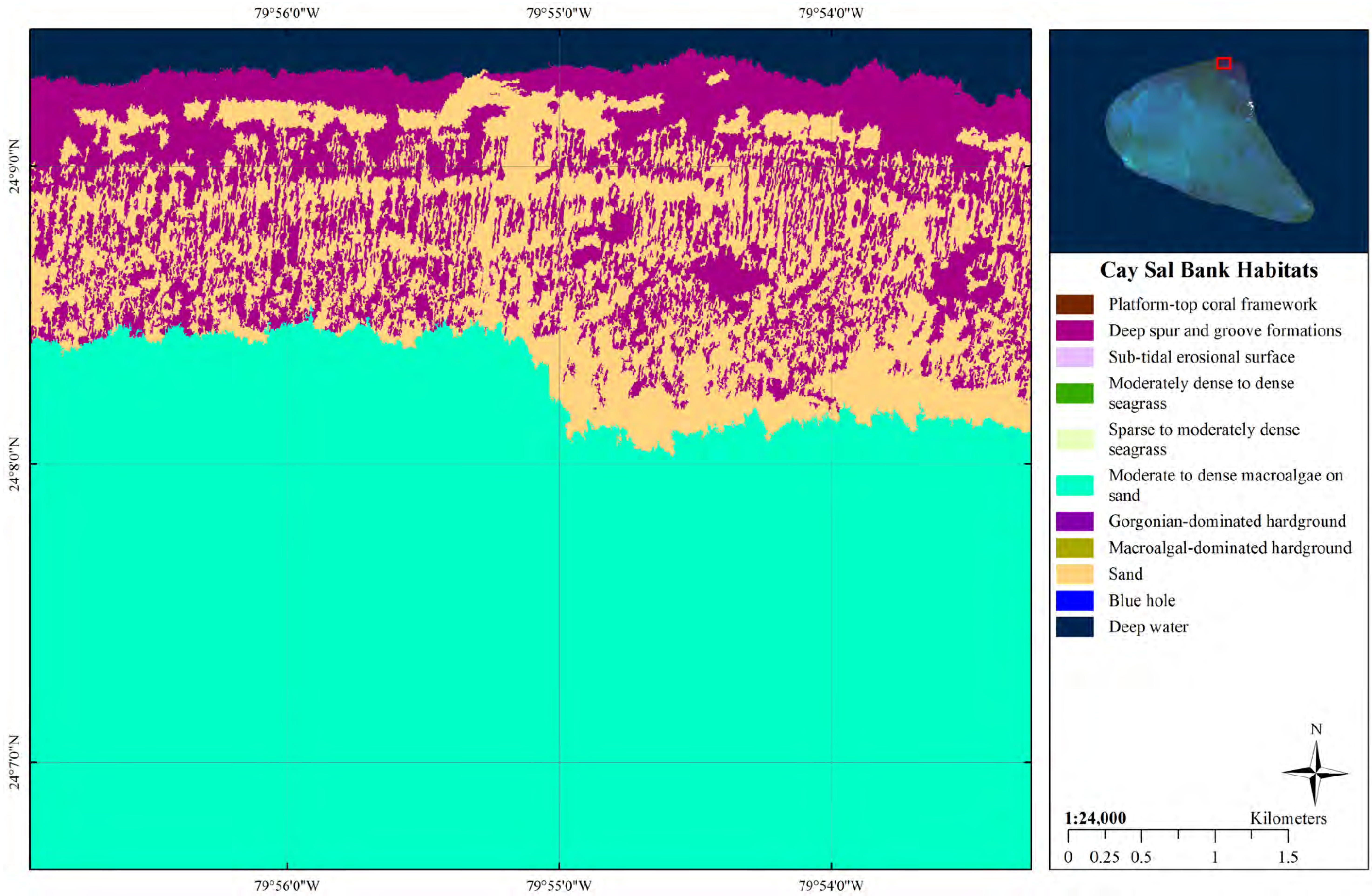


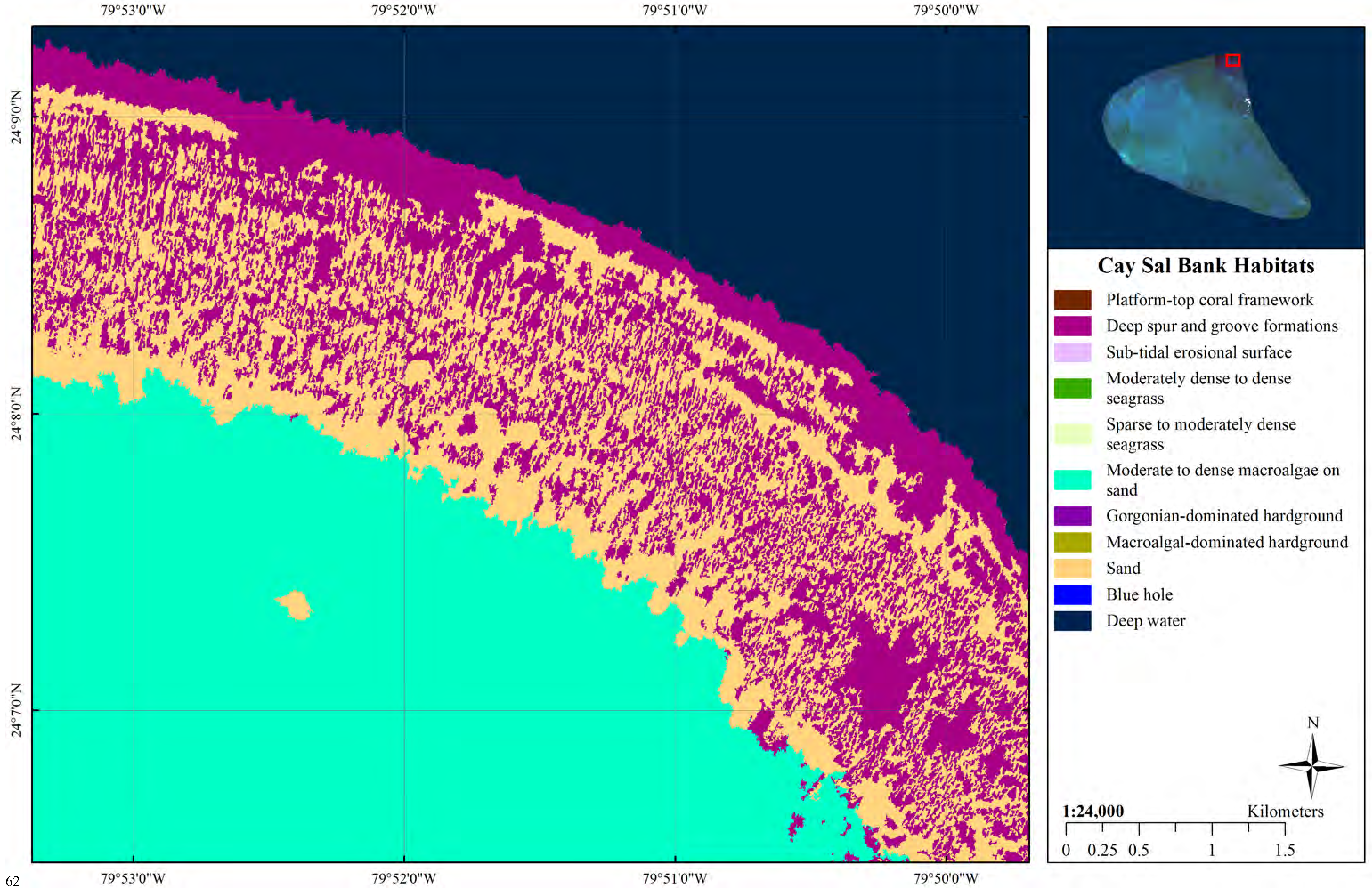
80°7'0"W
80°6'0"W
80°5'0"W
80°4'0"W
24°7'0"N
24°6'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5



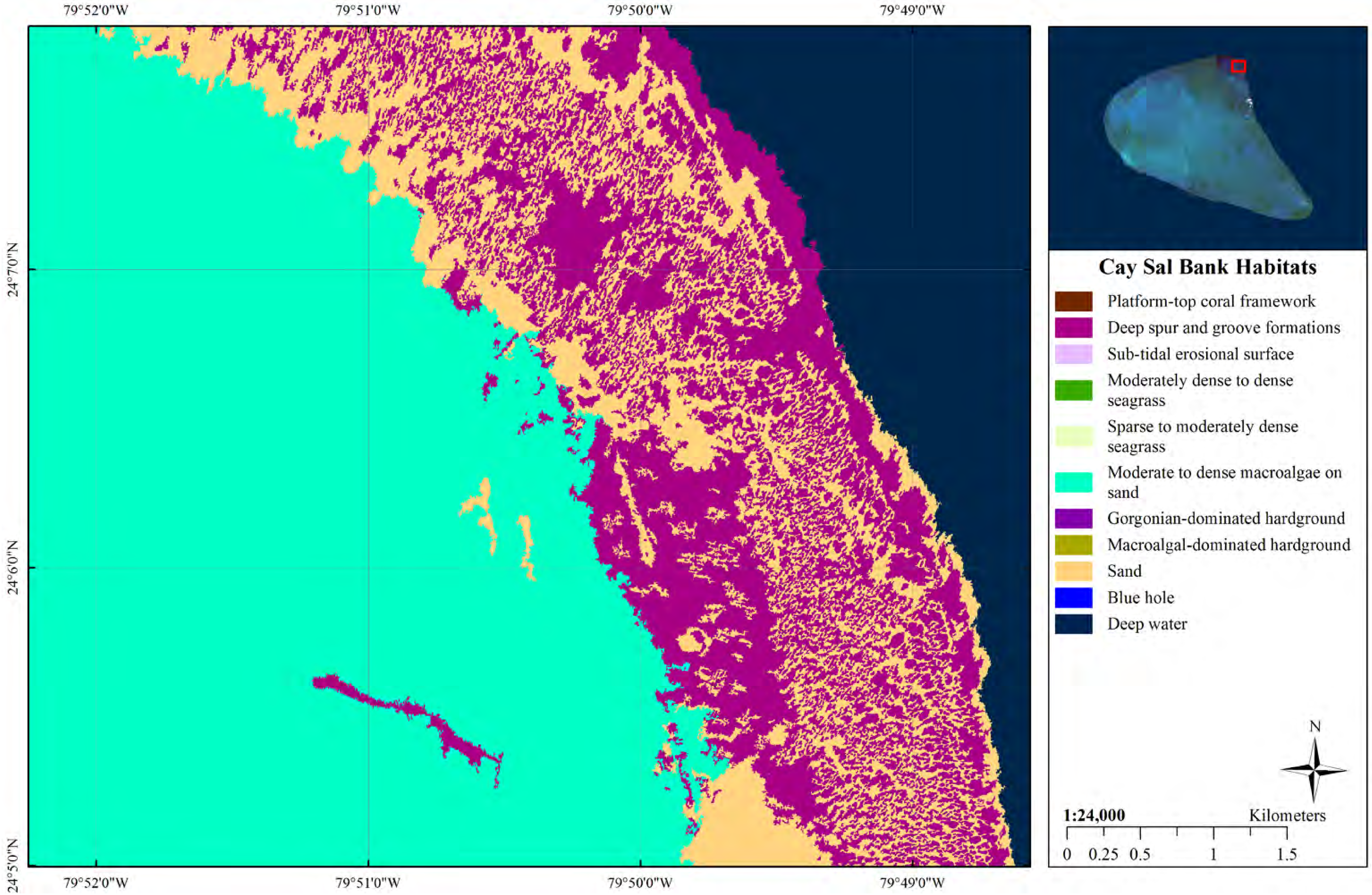
80°4'0"W
80°3'0"W
80°2'0"W
80°1'0"W
24°8'0"N
24°7'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


80°0'0"W
79°59'0"W
79°58'0"W
79°57'0"W
24°9'0"N
24°8'0"N
24°7'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

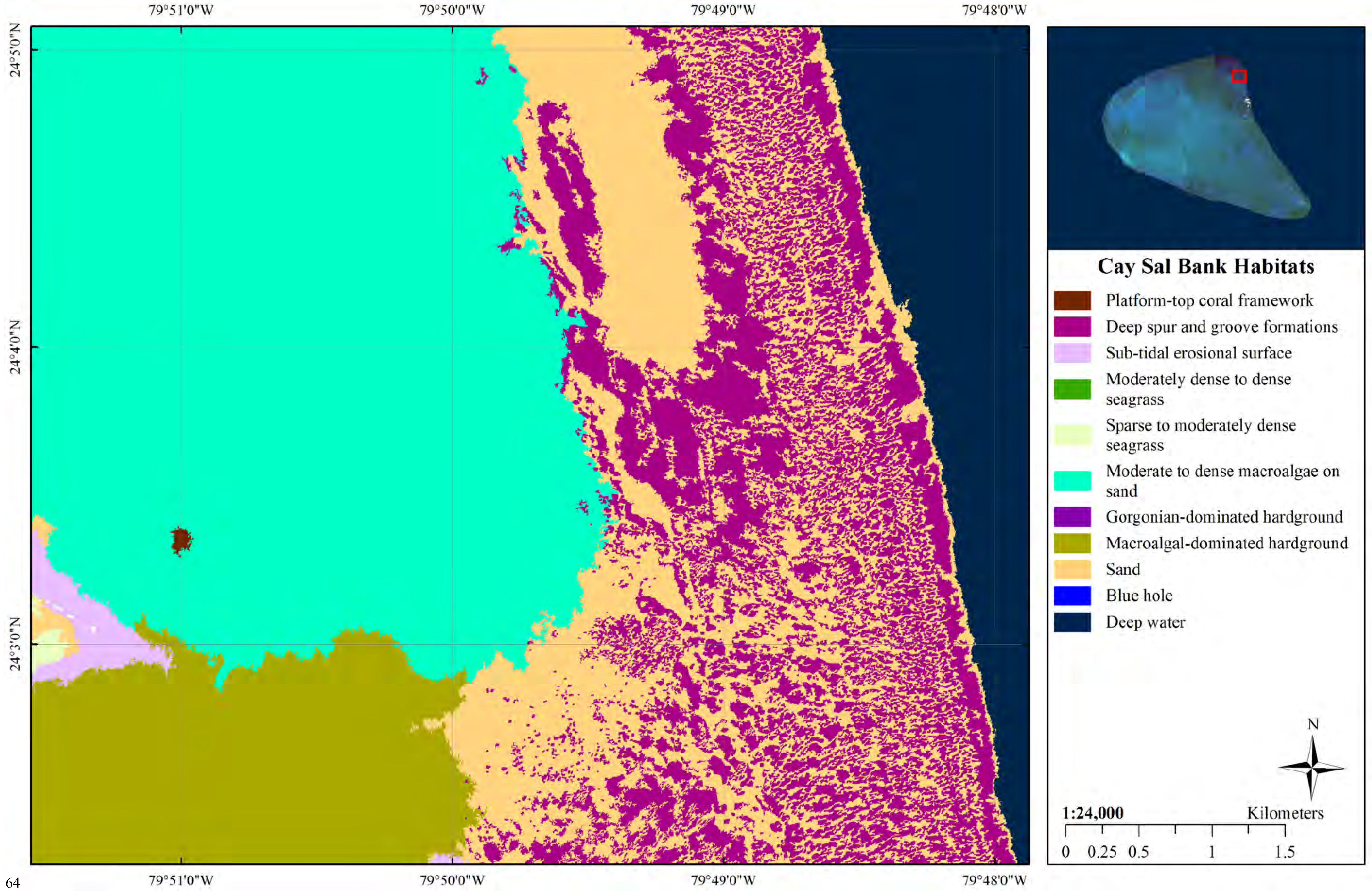

79°56'0"W
79°55'0"W
79°54'0"W
24°9'0"N
24°8'0"N
24°7'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

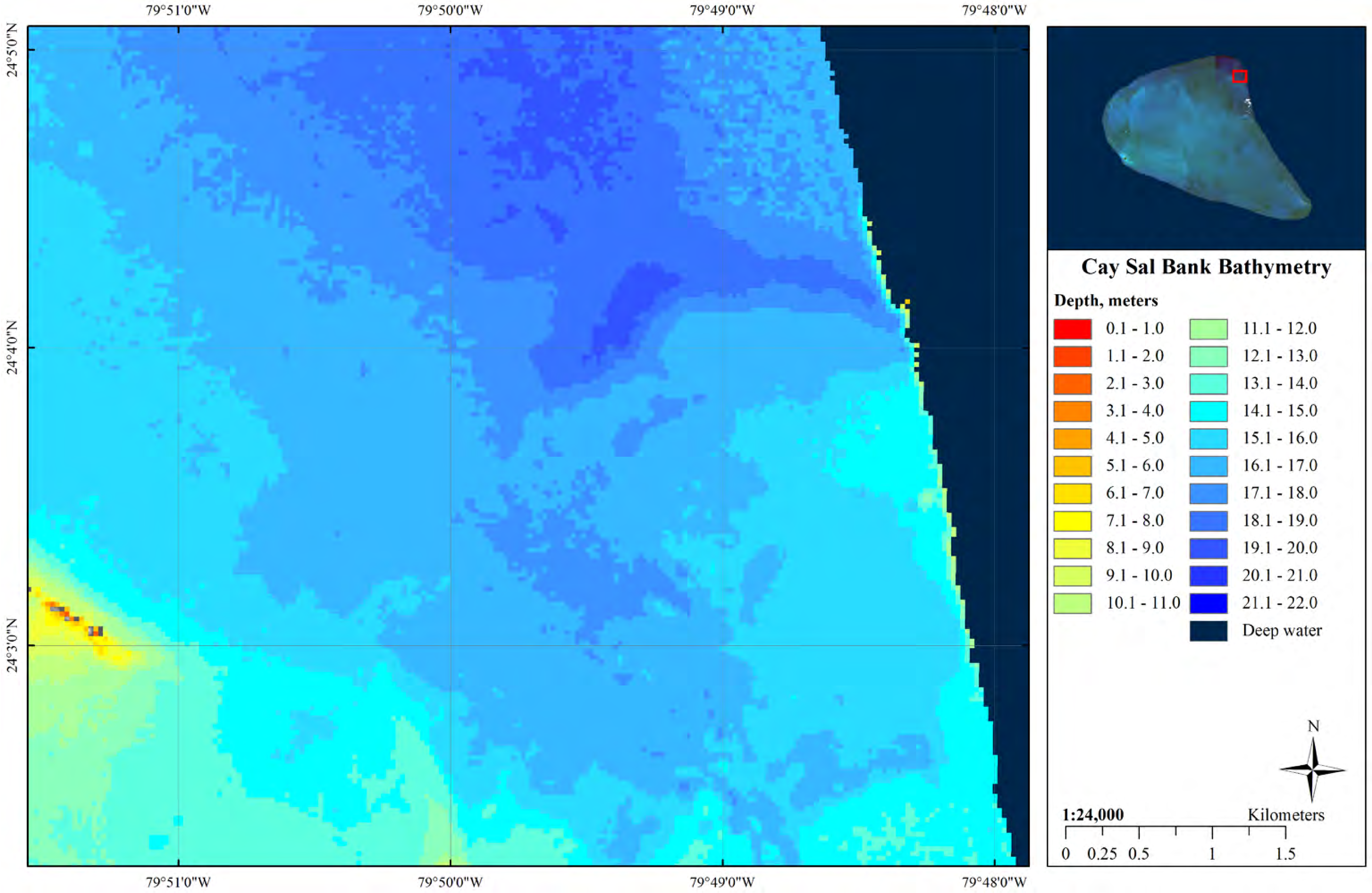


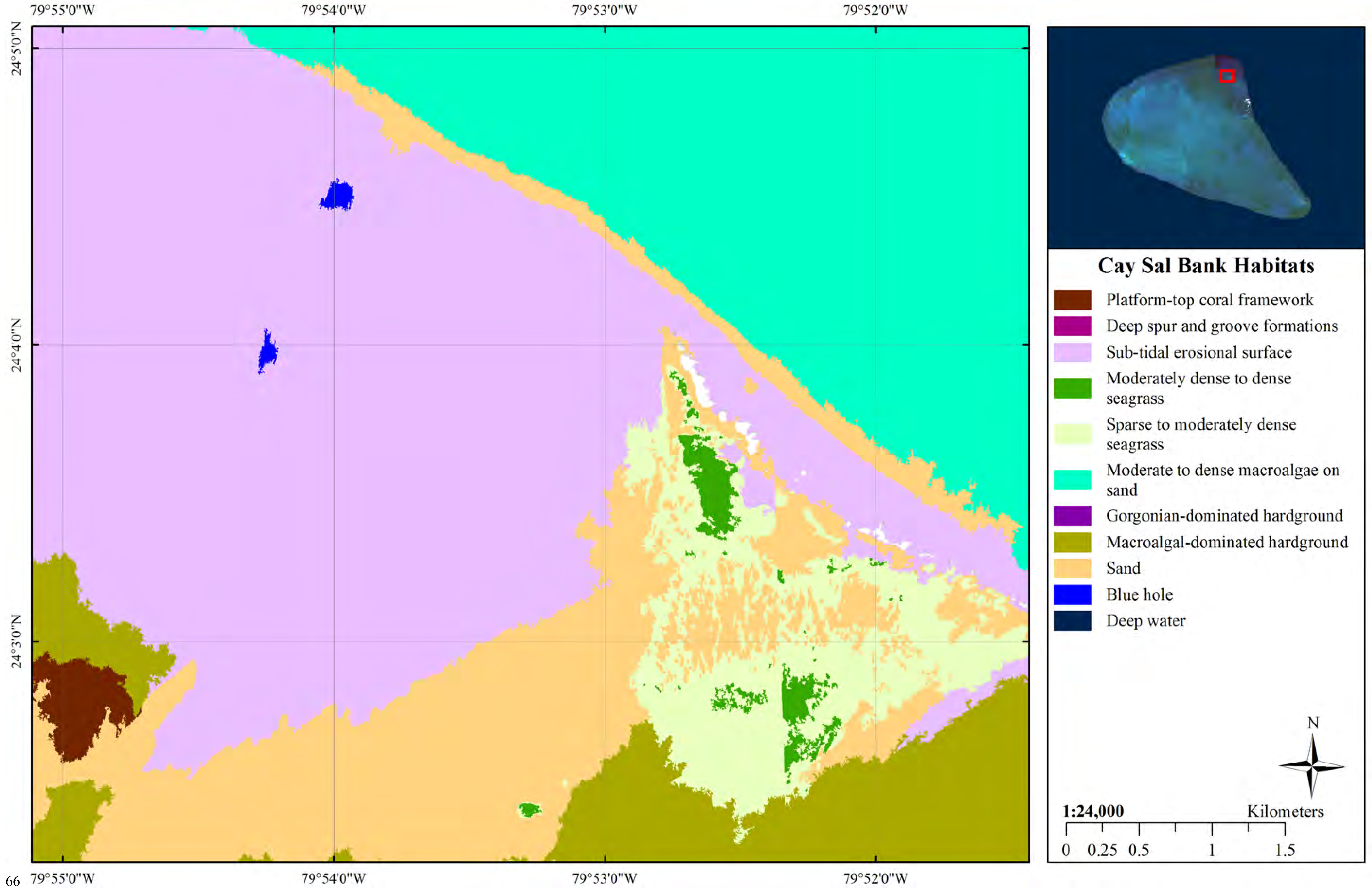
79°53'0"W
79°52'0"W
79°51'0"W
79°50'0"W
24°9'0"N
24°8'0"N
24°7'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

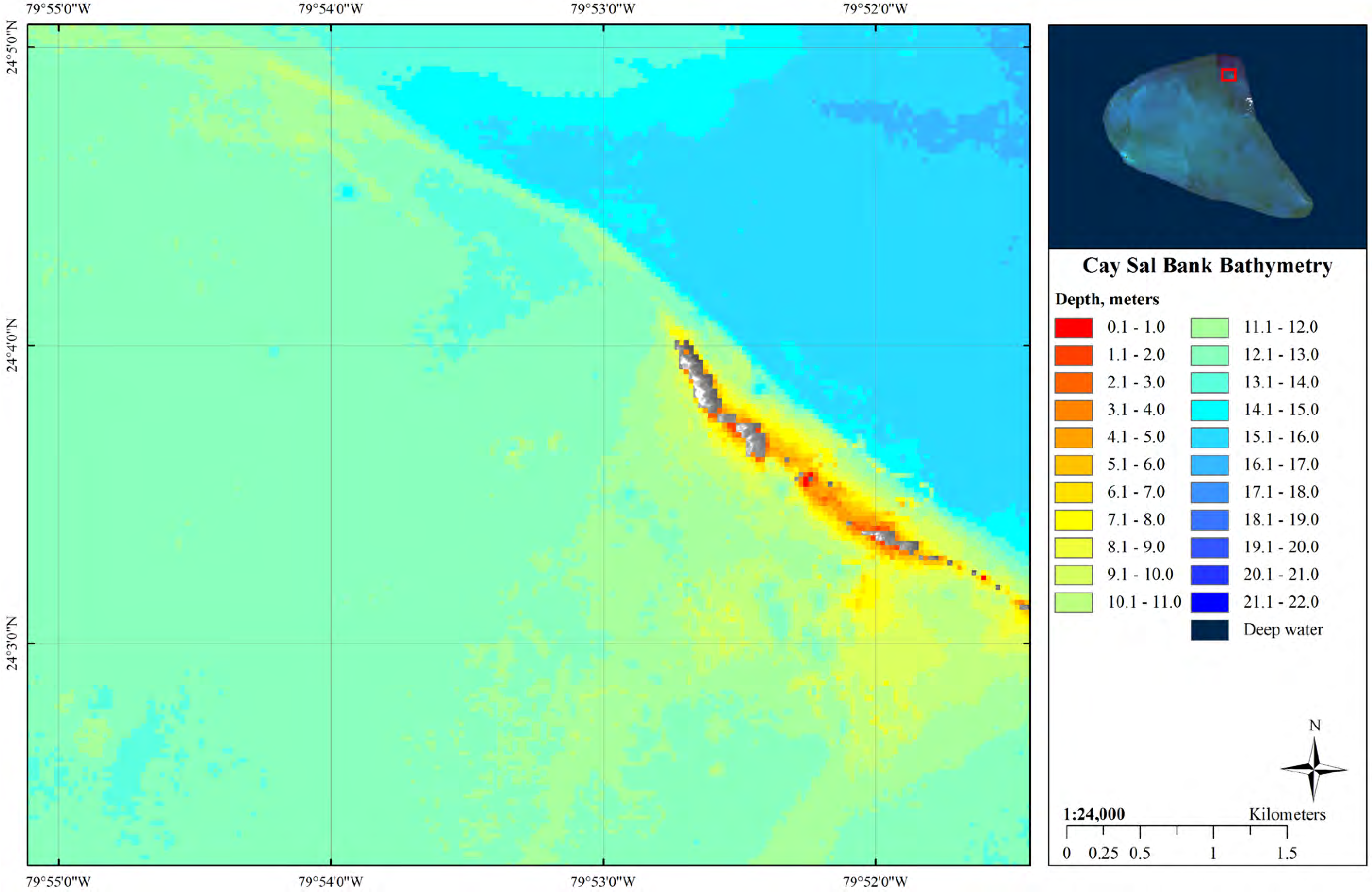


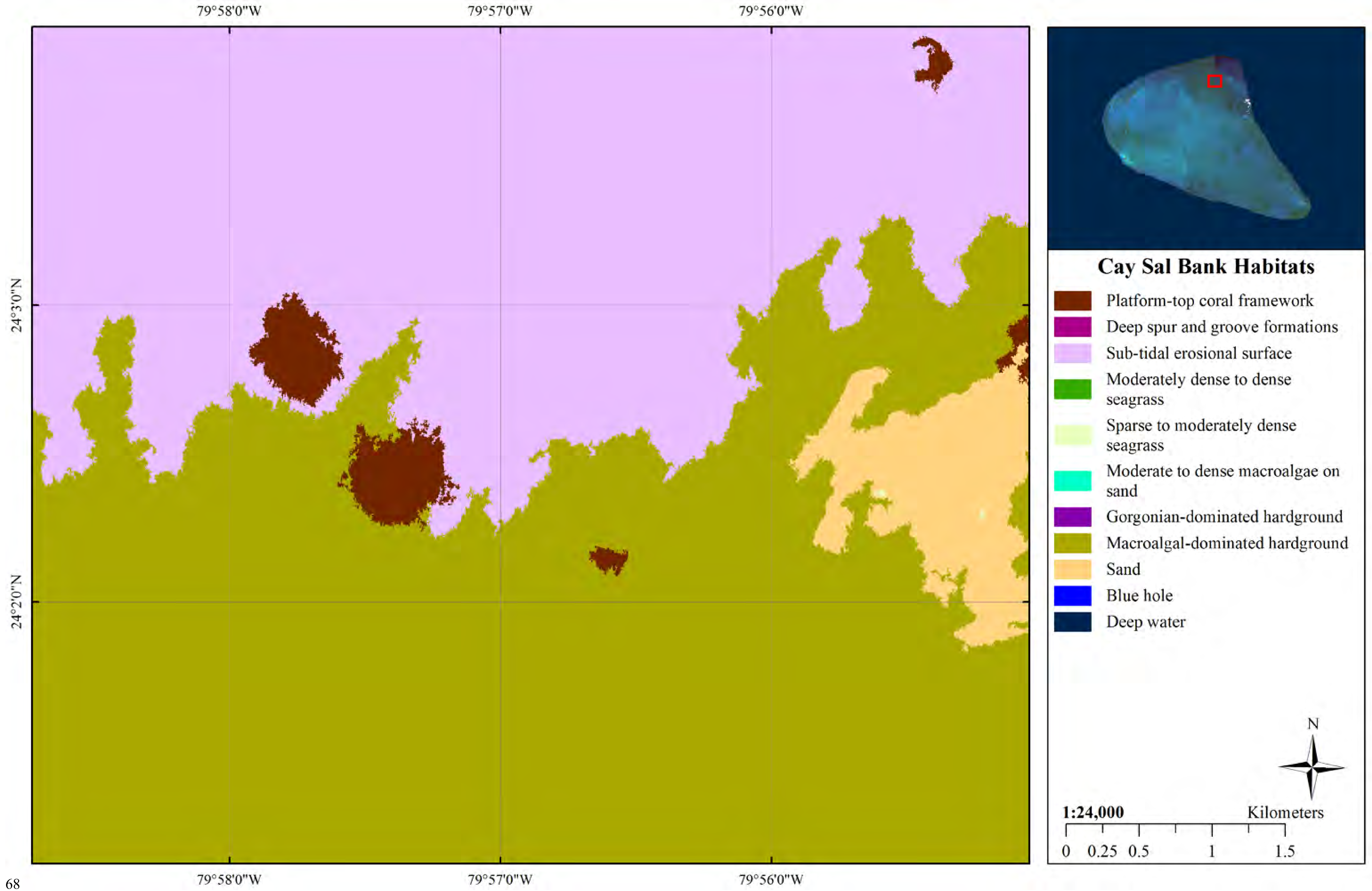
79°52'0"W
79°51'0"W
79°50'0"W
79°49'0"W
24°7'0"N
24°6'0"N
24°5'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


79°51'0"W
79°50'0"W
79°49'0"W
79°48'0"W
24°5'0"N
24°4'0"N
24°3'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

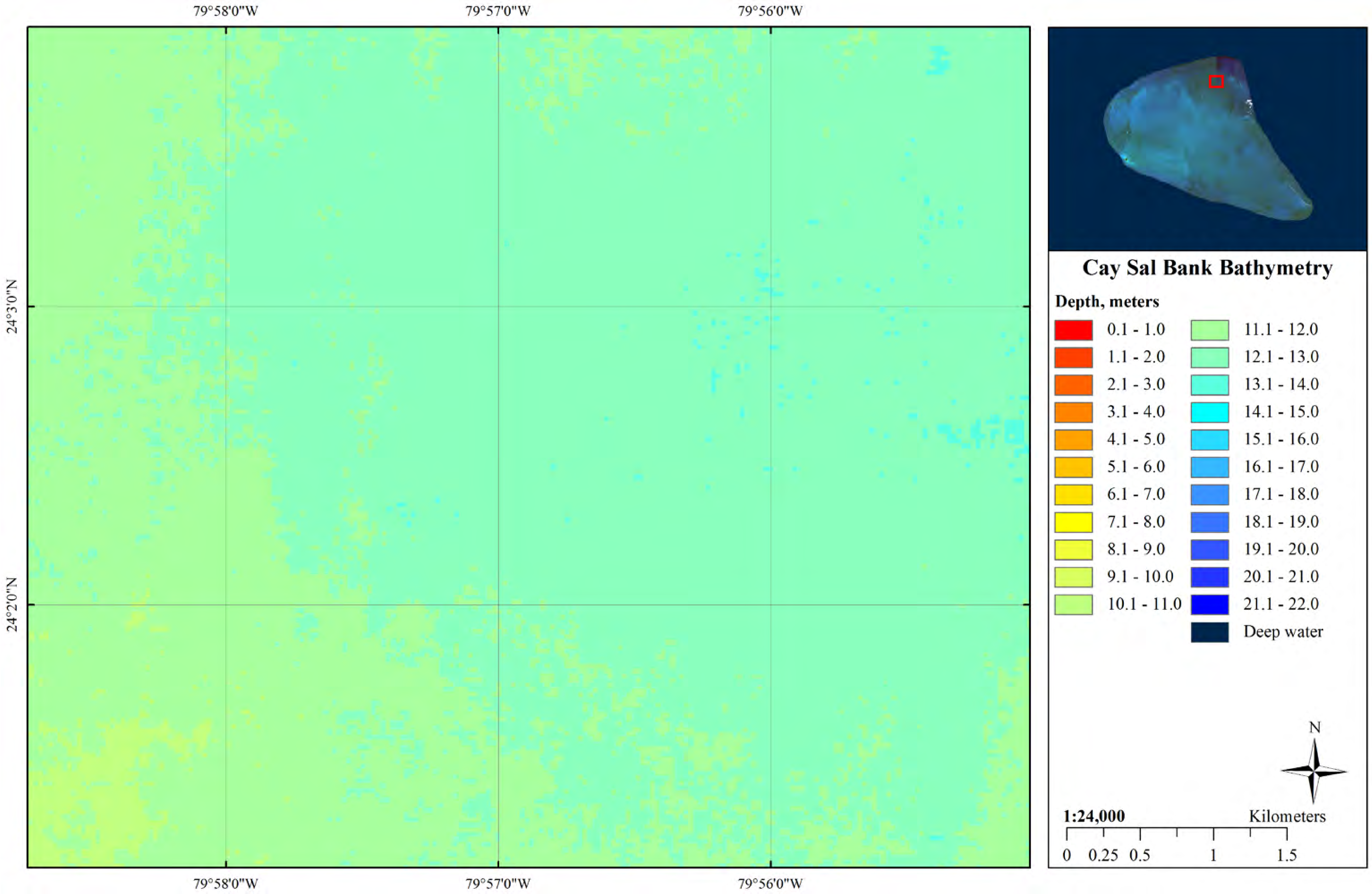

79°51'0"W
79°50'0"W
79°49'0"W
79°48'0"W
24°5'0"N
24°4'0"N
24°3'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


79°55'0"W
79°54'0"W
79°53'0"W
79°52'0"W
24°5'0"N
24°4'0"N
24°3'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

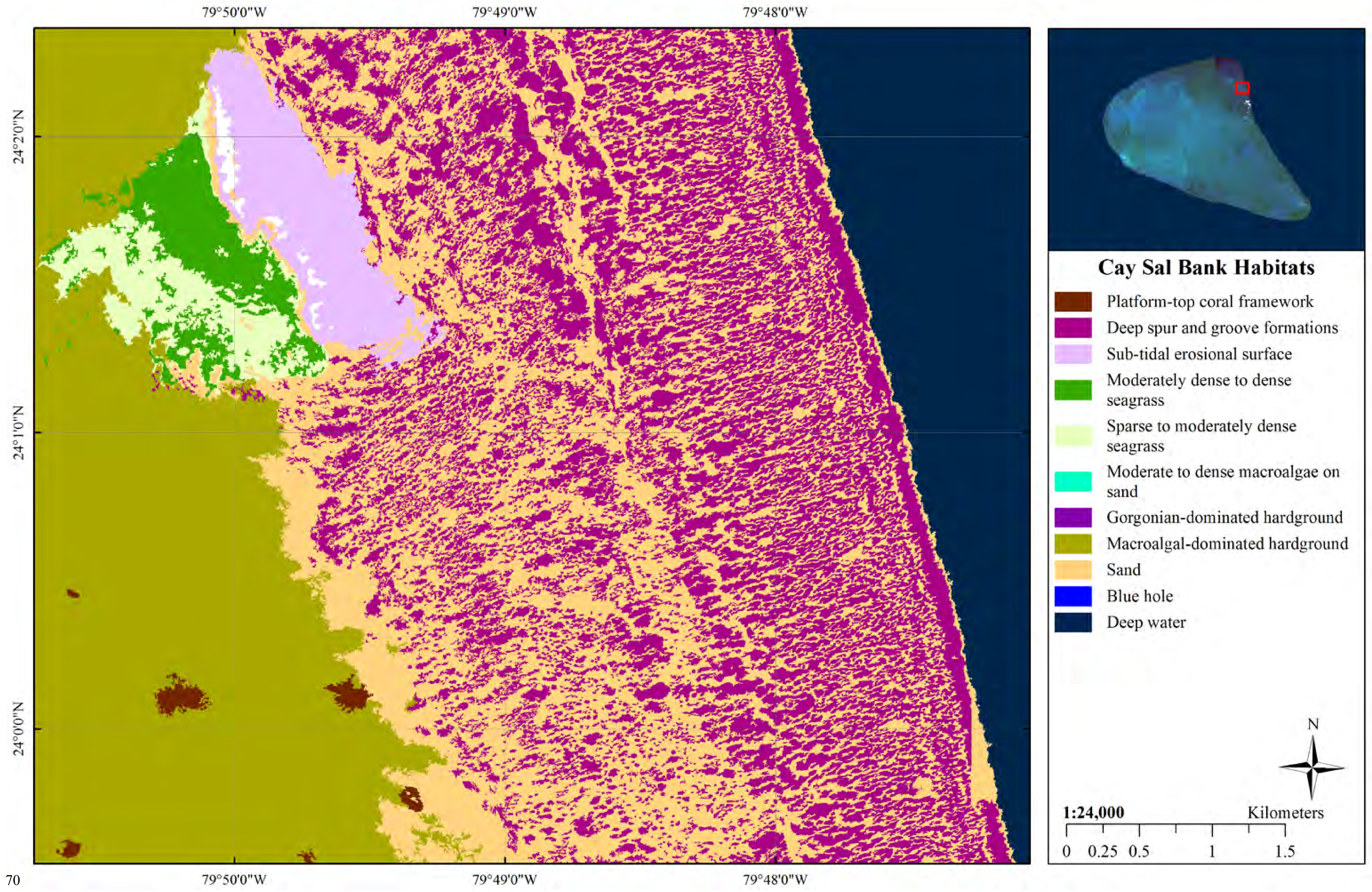

79°55'0"W
79°54'0"W
79°53'0"W
79°52'0"W
24°5'0"N
24°4'0"N
24°3'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

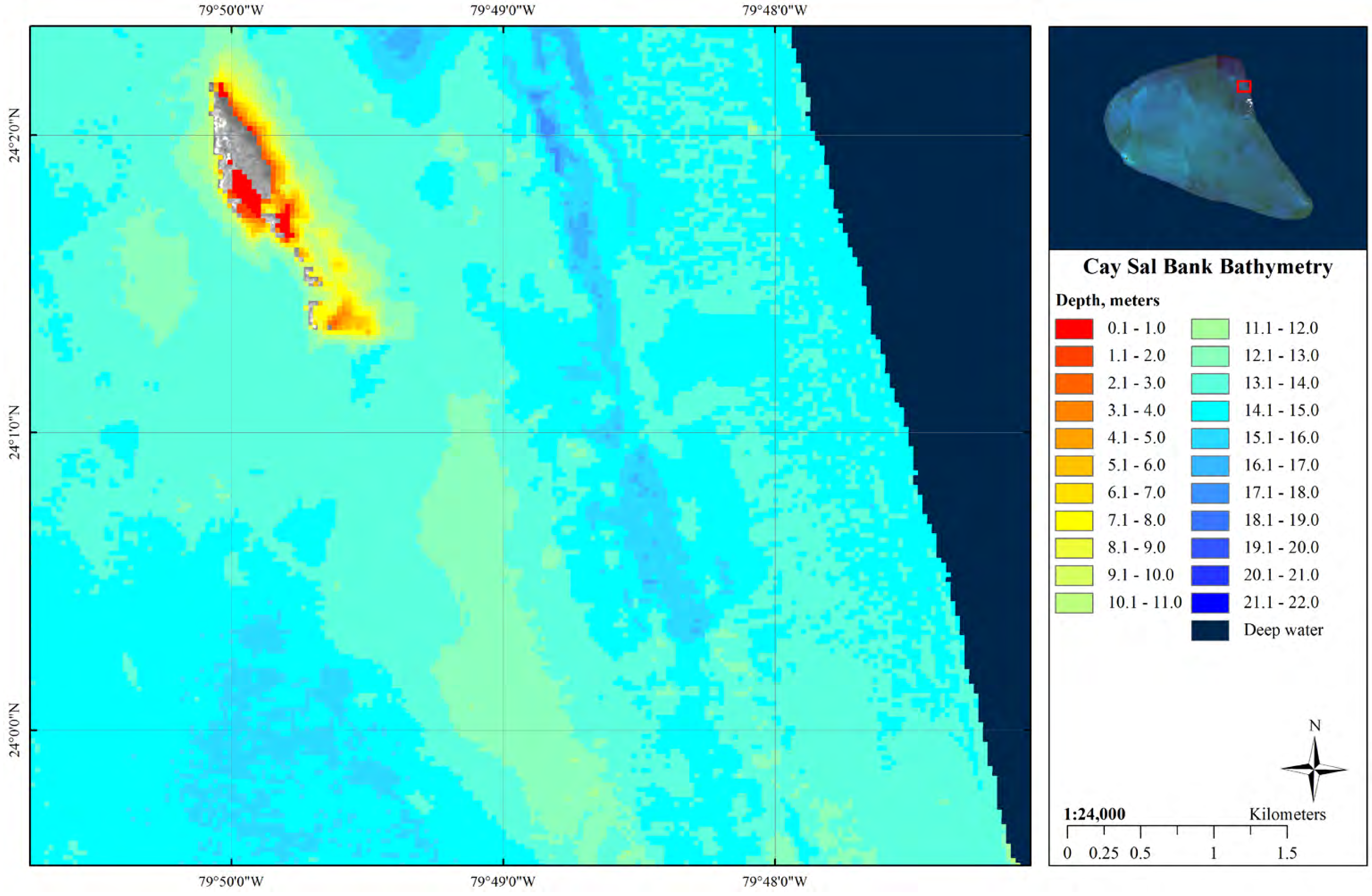


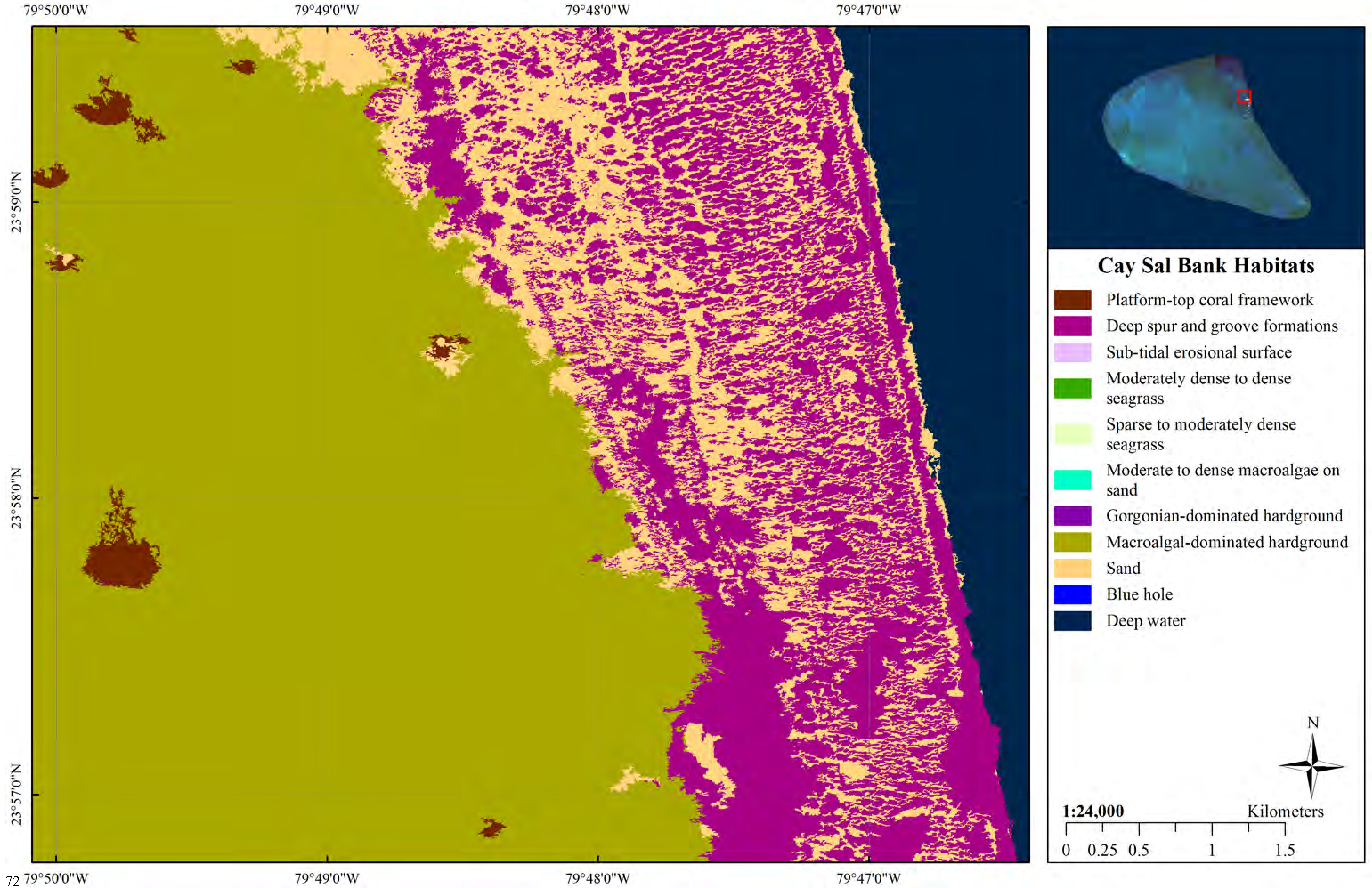
79°58'0"W
79°57'0"W
79°56'0"W
24°3'0"N
24°2'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5



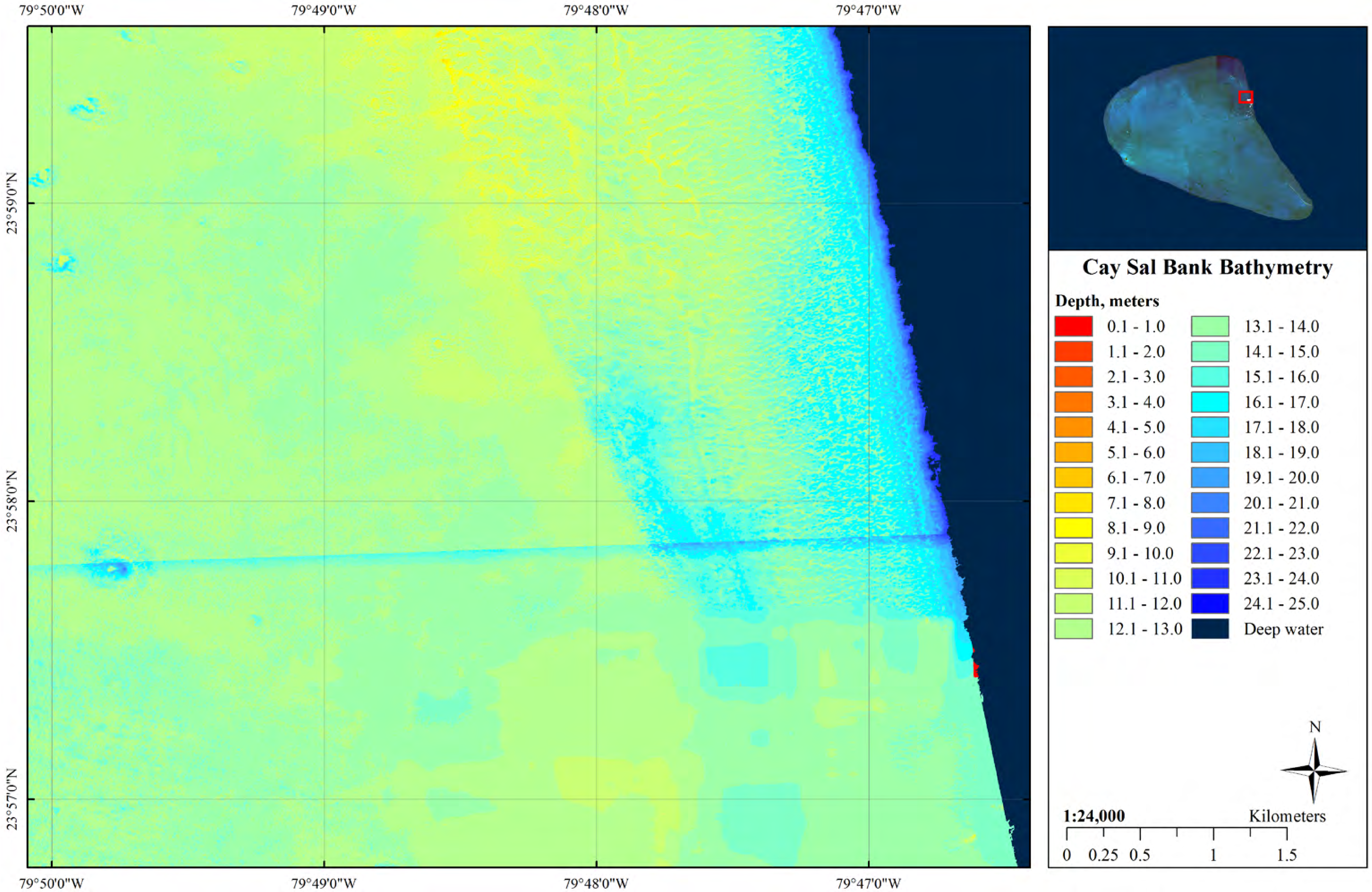
79°58'0"W
79°57'0"W
79°56'0"W
24°3'0"N
24°2'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


79°50'0"W
79°49'0"W
79°48'0"W
24°2'0"N
24°1'0"N
24°0'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

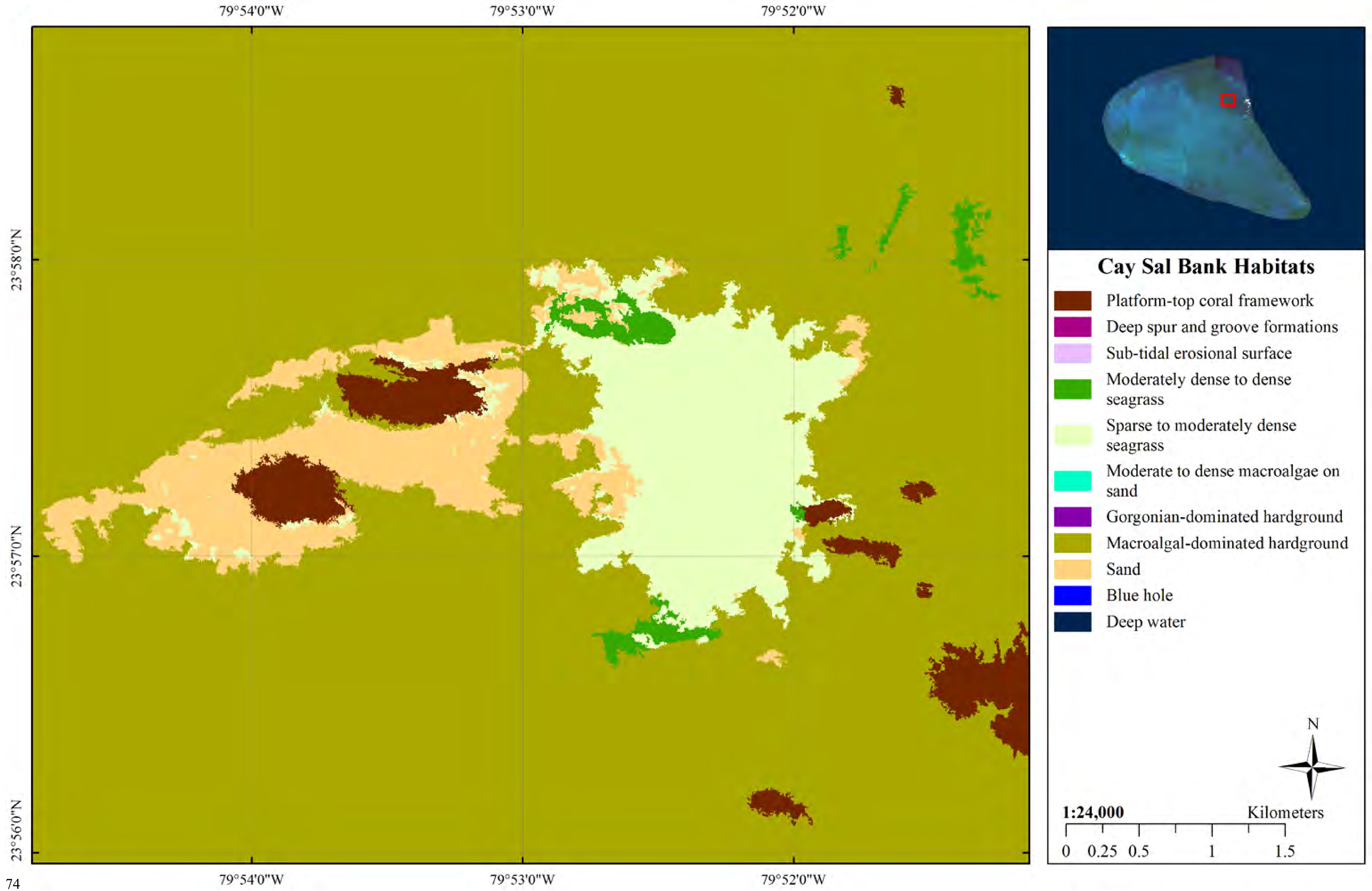

79°50'0"W
79°49'0"W
79°48'0"W
24°2'0"N
24°1'0"N
24°0'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

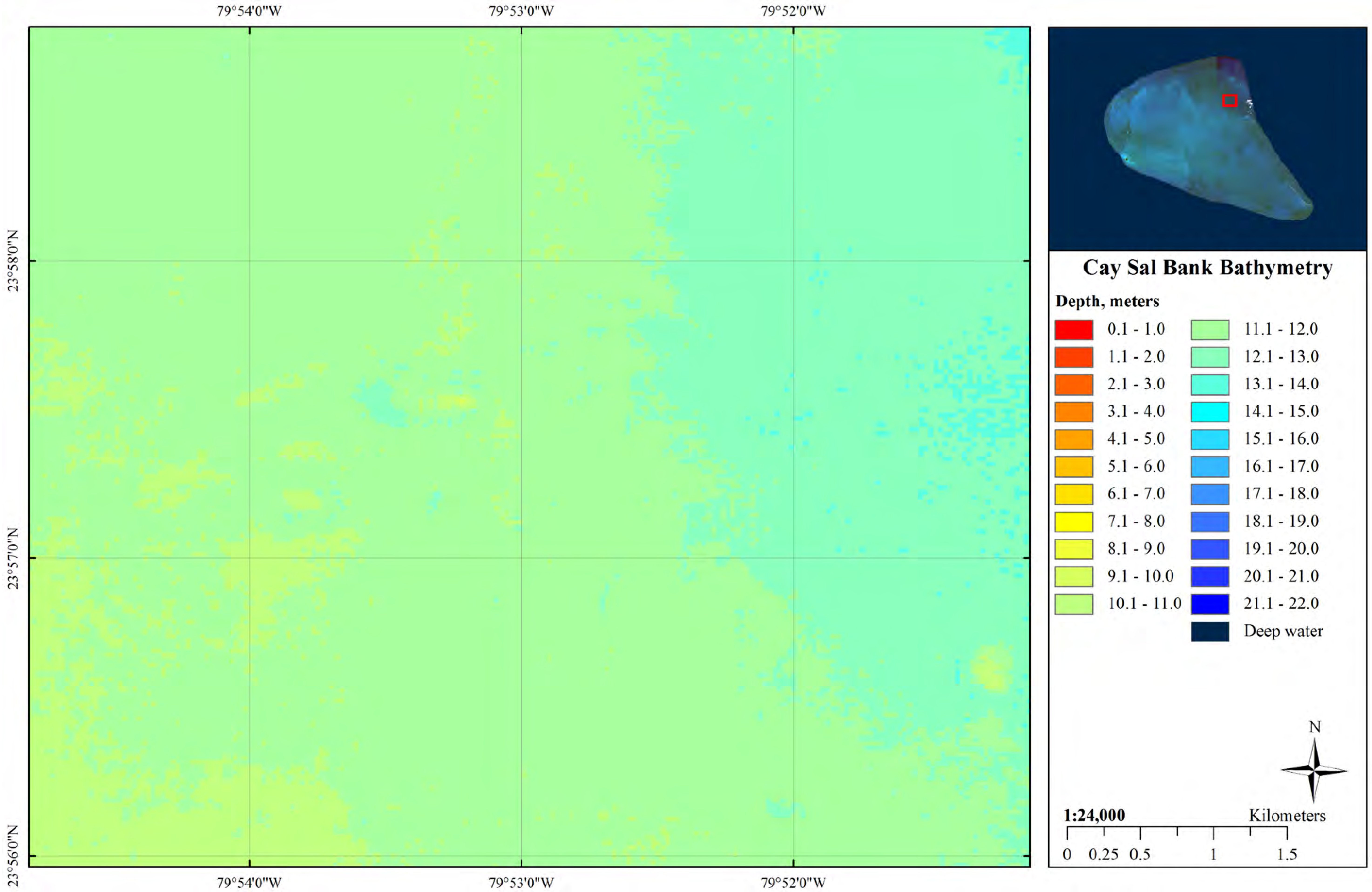


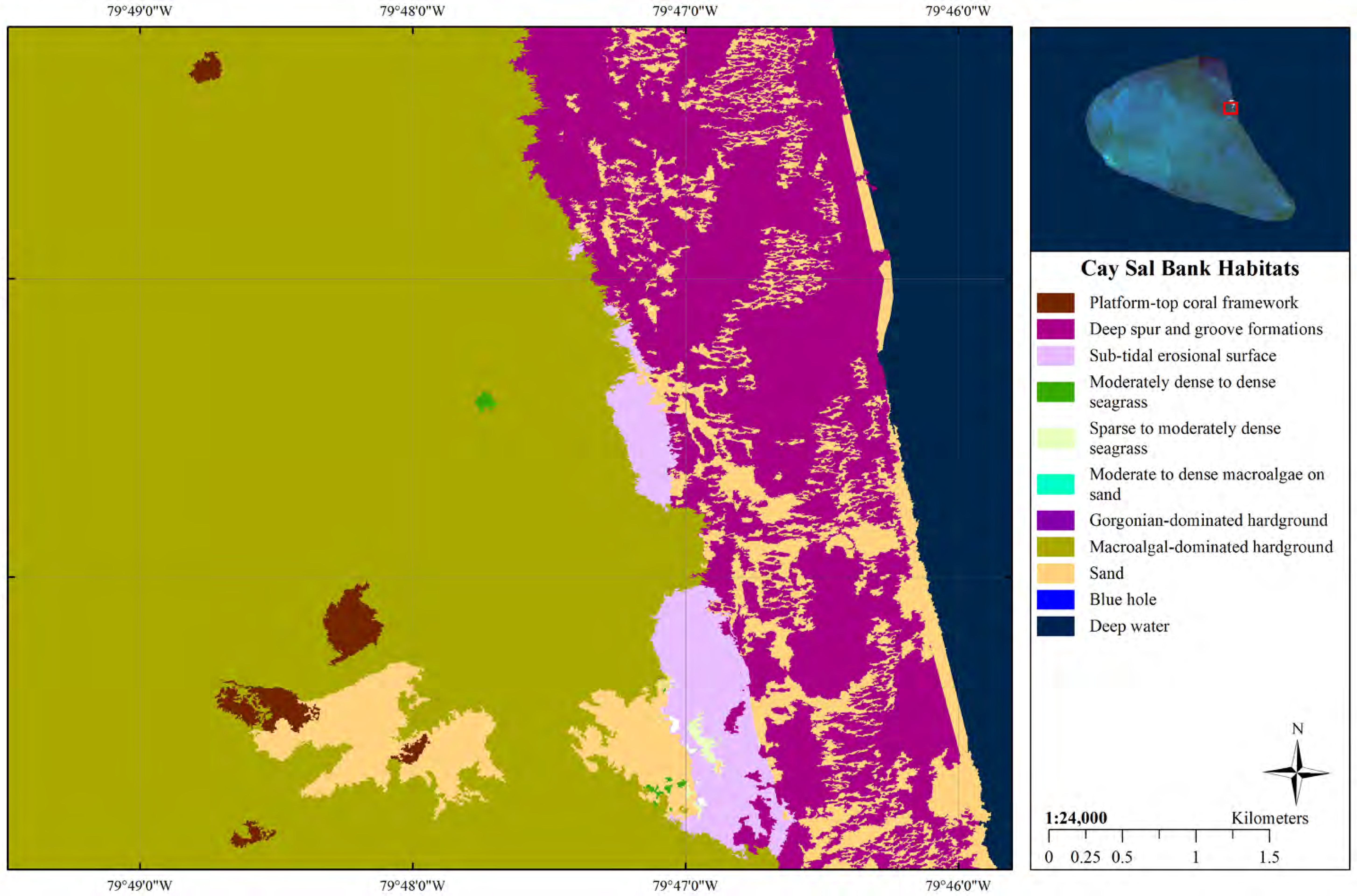
79°50'0"W
79°49'0"W
79°48'0"W
79°47'0"W
23°59'0"N
23°58'0"N
23°57'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

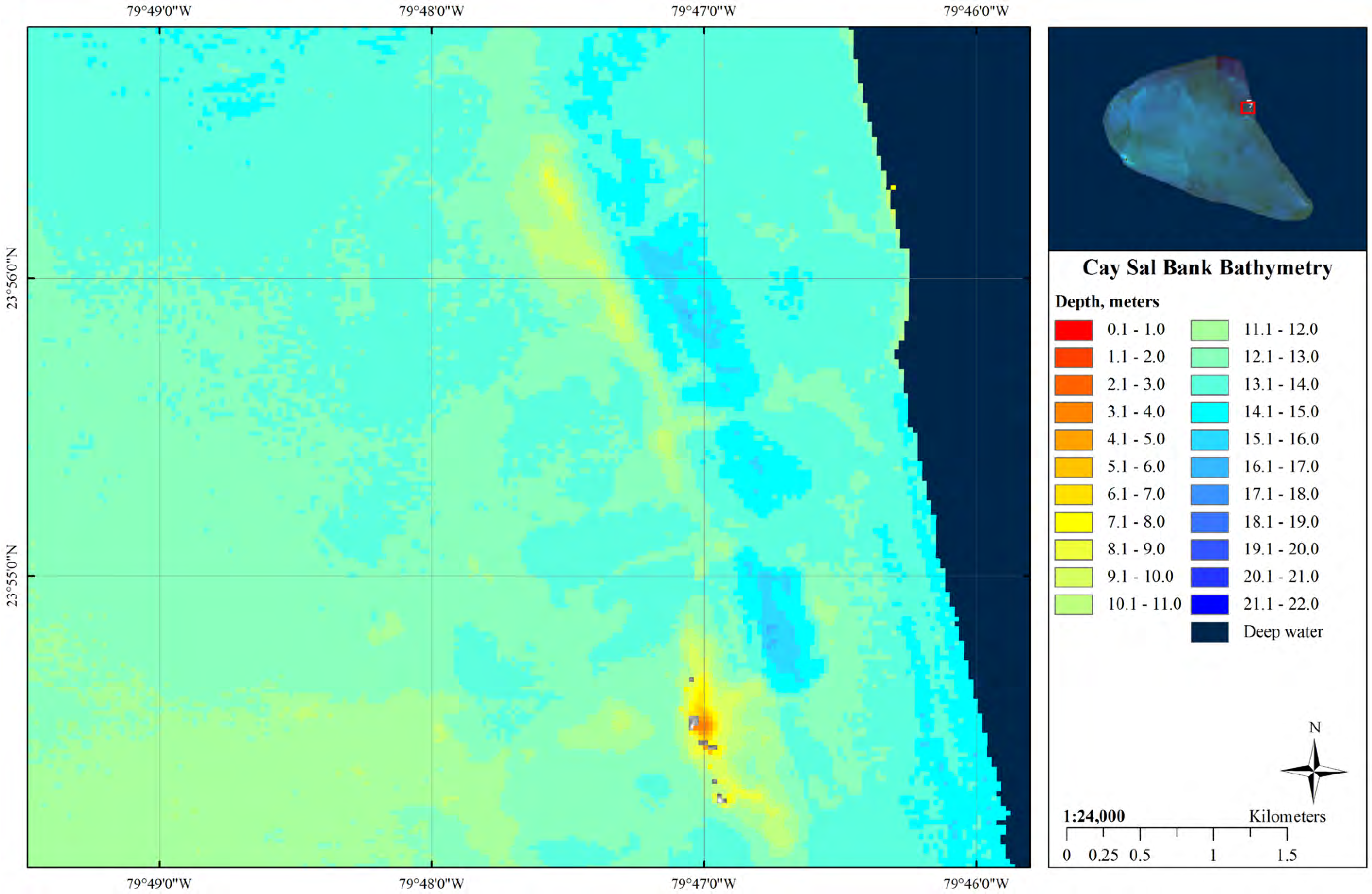


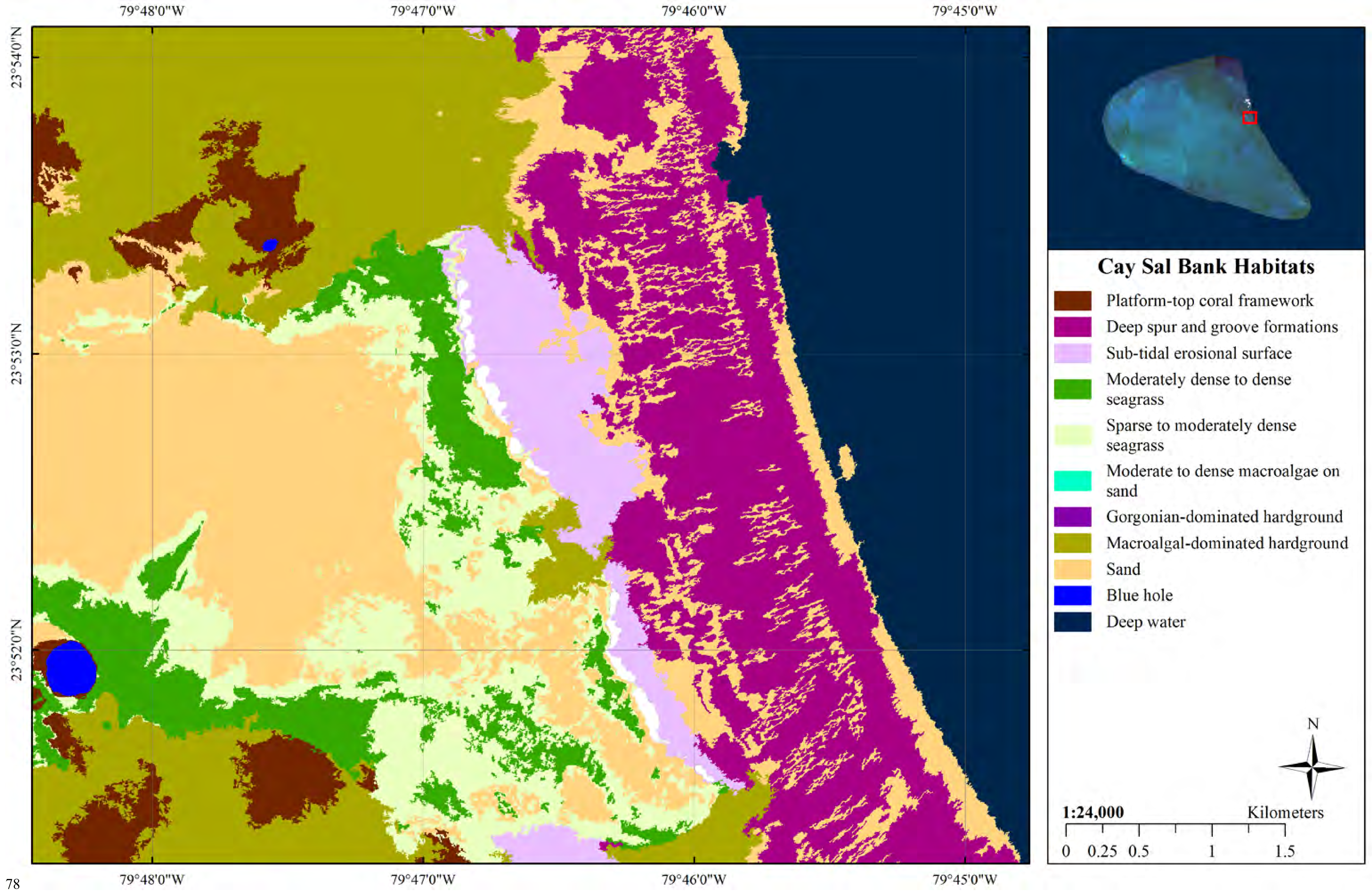
79°50'0"W
79°49'0"W
79°48'0"W
79°47'0"W
23°59'0"N
23°58'0"N
23°57'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

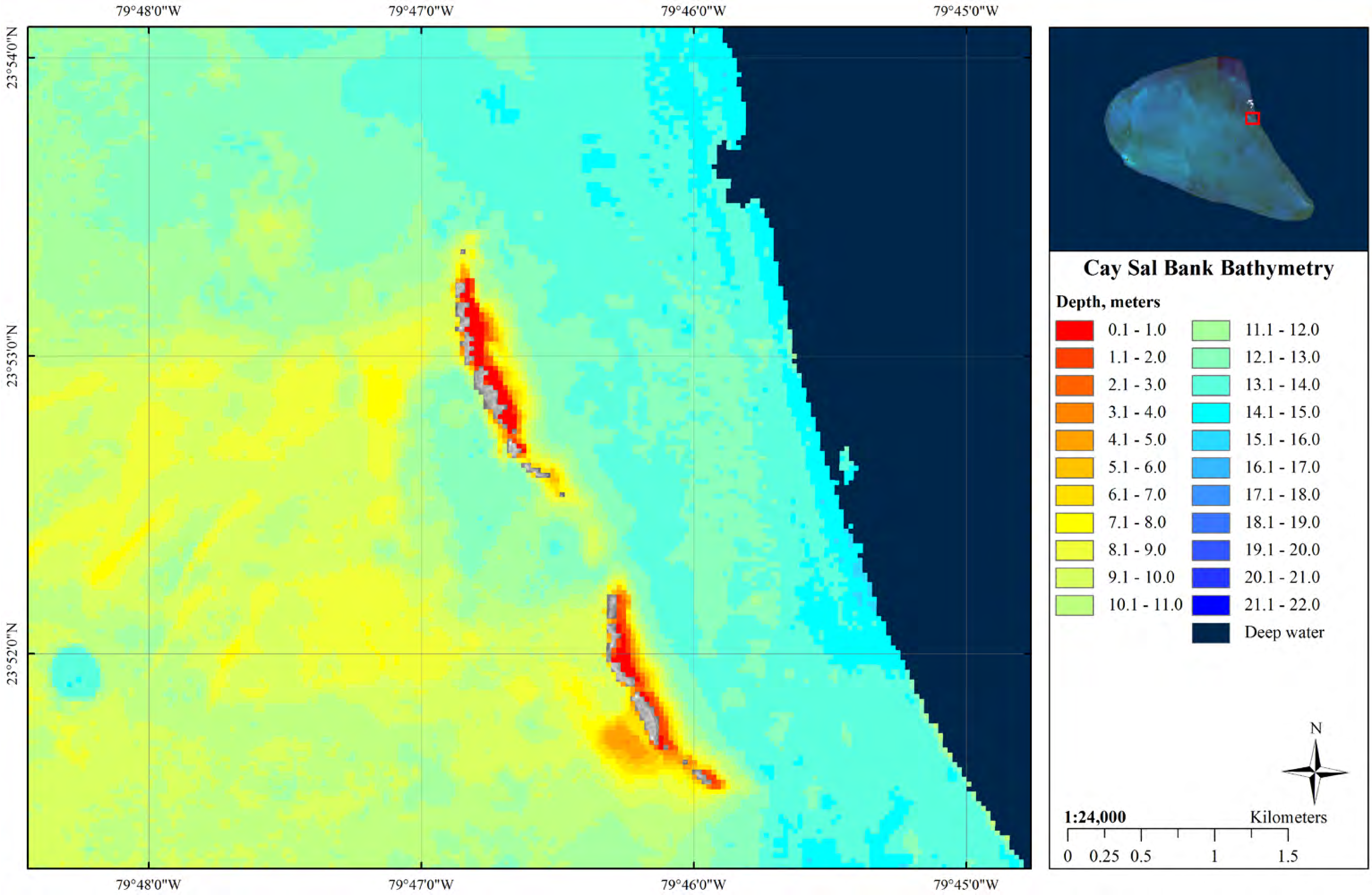

79°54'0"W
79°53'0"W
79°52'0"W
23°58'0"N
23°57'0"N
23°56'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

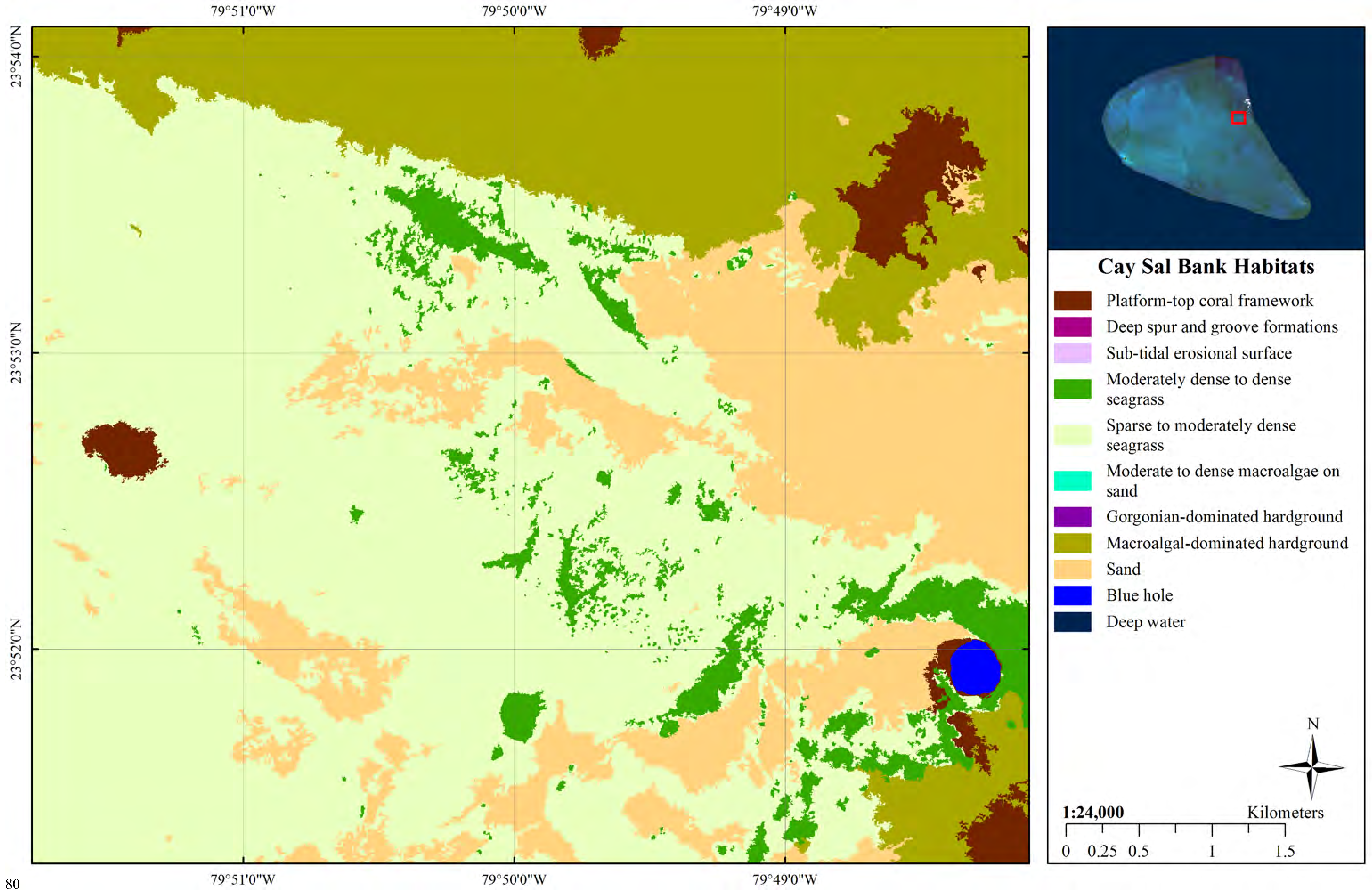

79°54'0"W
79°53'0"W
79°52'0"W
23°58'0"N
23°57'0"N
23°56'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

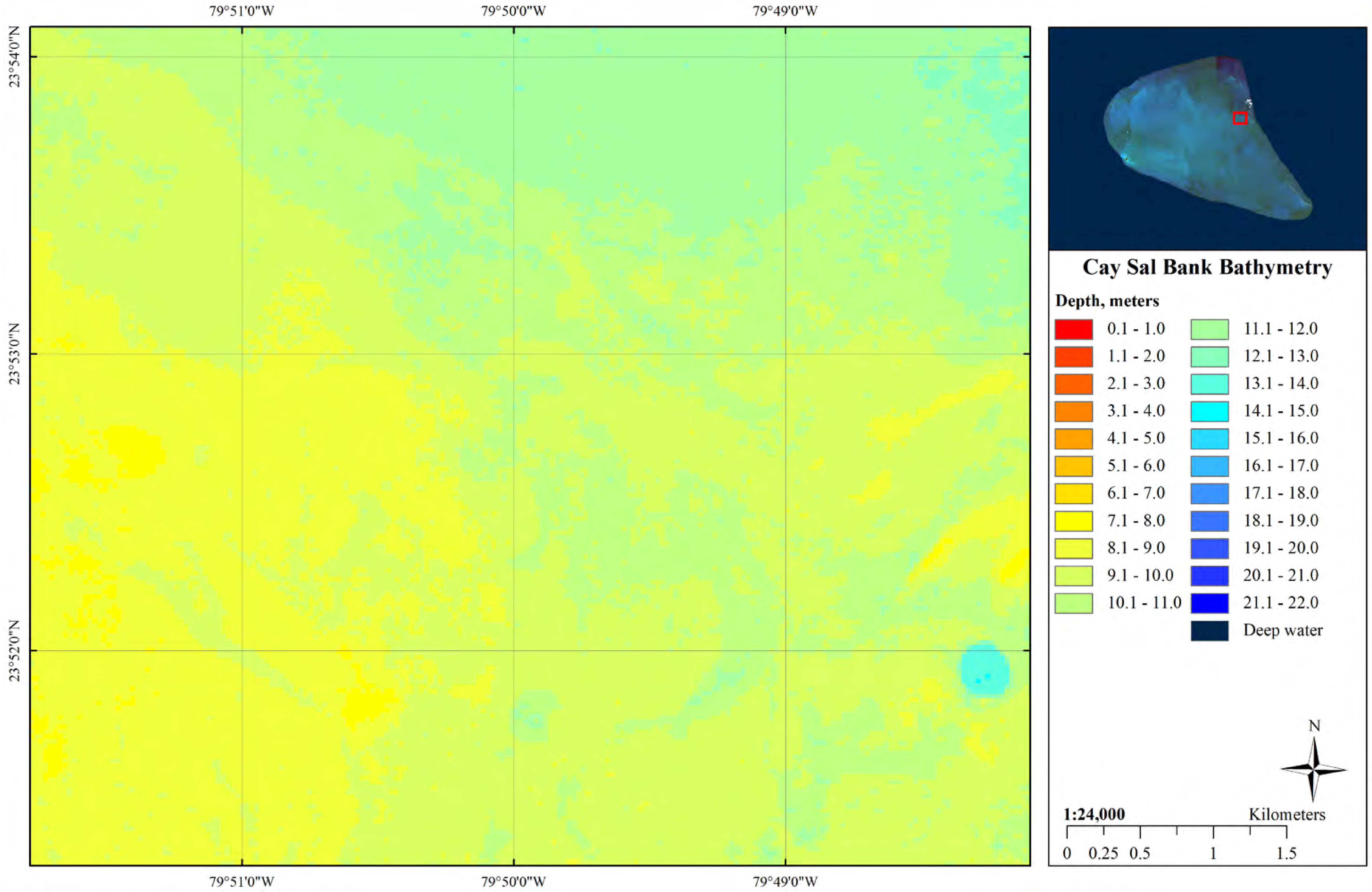

79°49'0"W
79°48'0"W
79°47'0"W
79°46'0"W
23°56'0"N
23°55'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

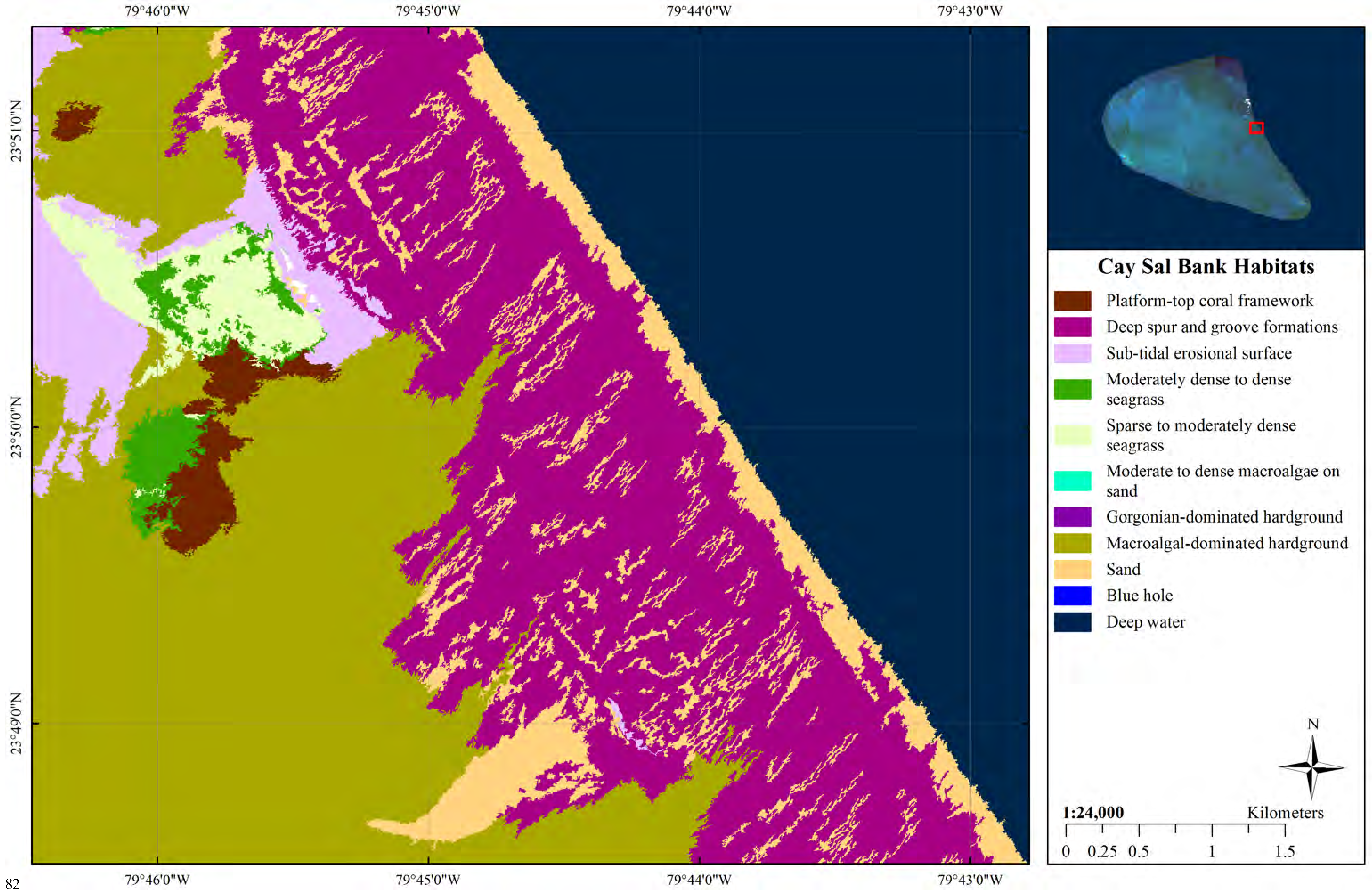

79°49'0"W
79°48'0"W
79°47'0"W
79°46'0"W
23°56'0"N
23°55'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

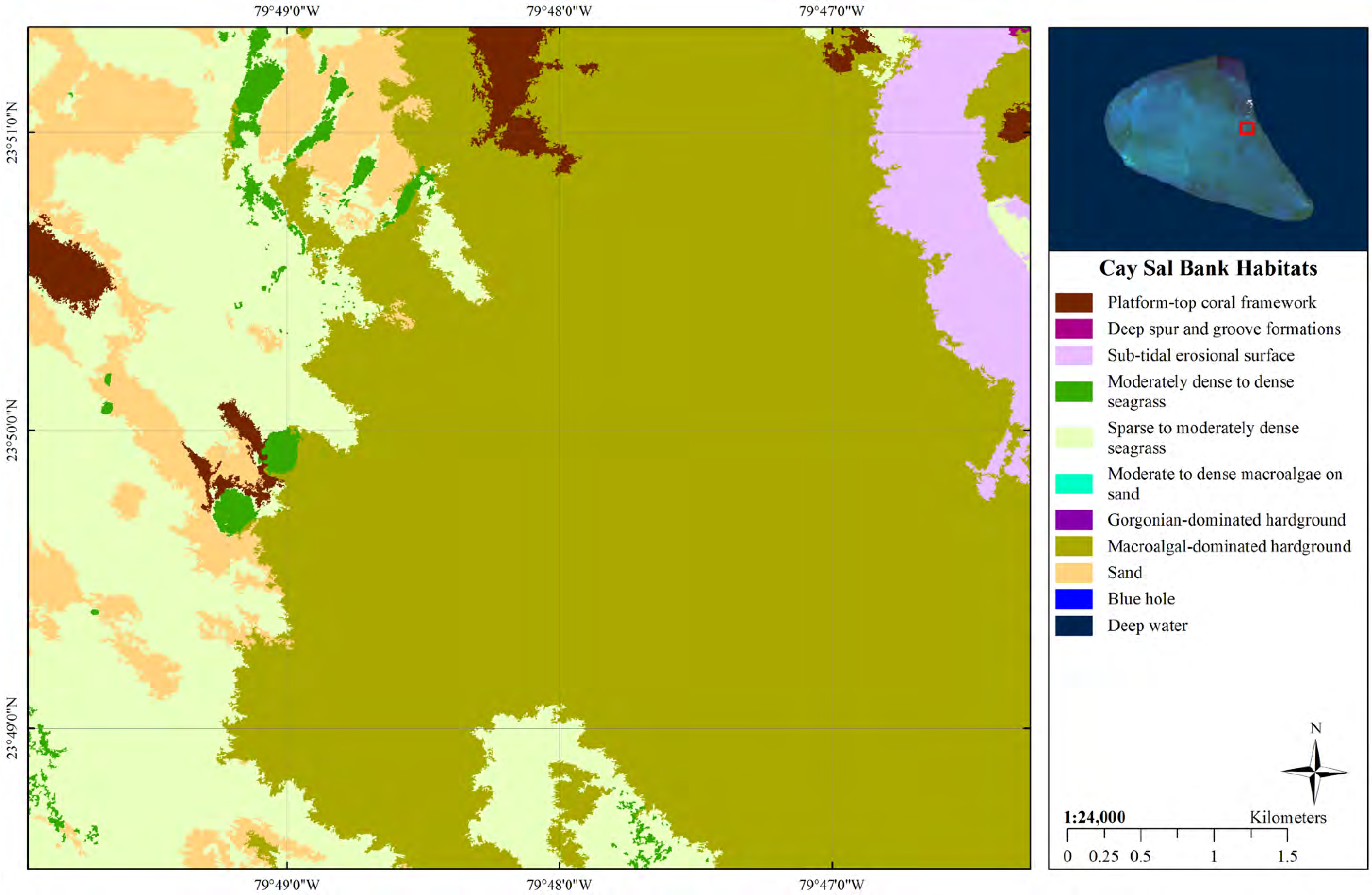

79°48'0"W
79°47'0"W
79°46'0"W
79°45'0"W
23°54'0"N
23°53'0"N
23°52'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


79°48'0"W
79°47'0"W
79°46'0"W
79°45'0"W
23°54'0"N
23°53'0"N
23°52'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


79°51'0"W
79°50'0"W
79°49'0"W
23°54'0"N
23°53'0"N
23°52'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


79°51'0"W
79°50'0"W
79°49'0"W
23°54'0"N
23°53'0"N
23°52'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


79°46'0"W
79°45'0"W
79°44'0"W
79°43'0"W
23°51'0"N
23°50'0"N
23°49'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

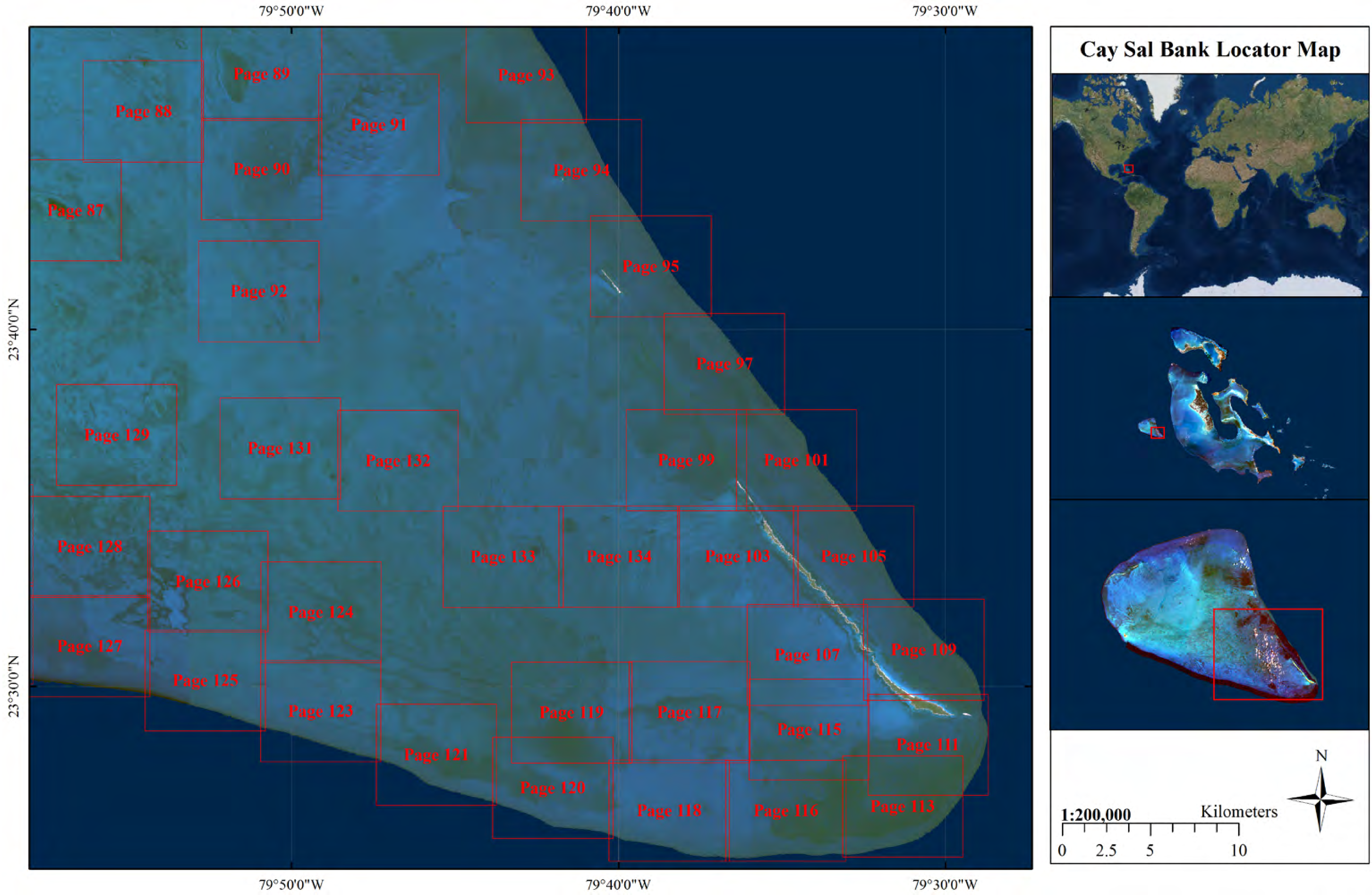

79°49'0"W
79°48'0"W
79°47'0"W
23°51'0"N
23°50'0"N
23°49'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

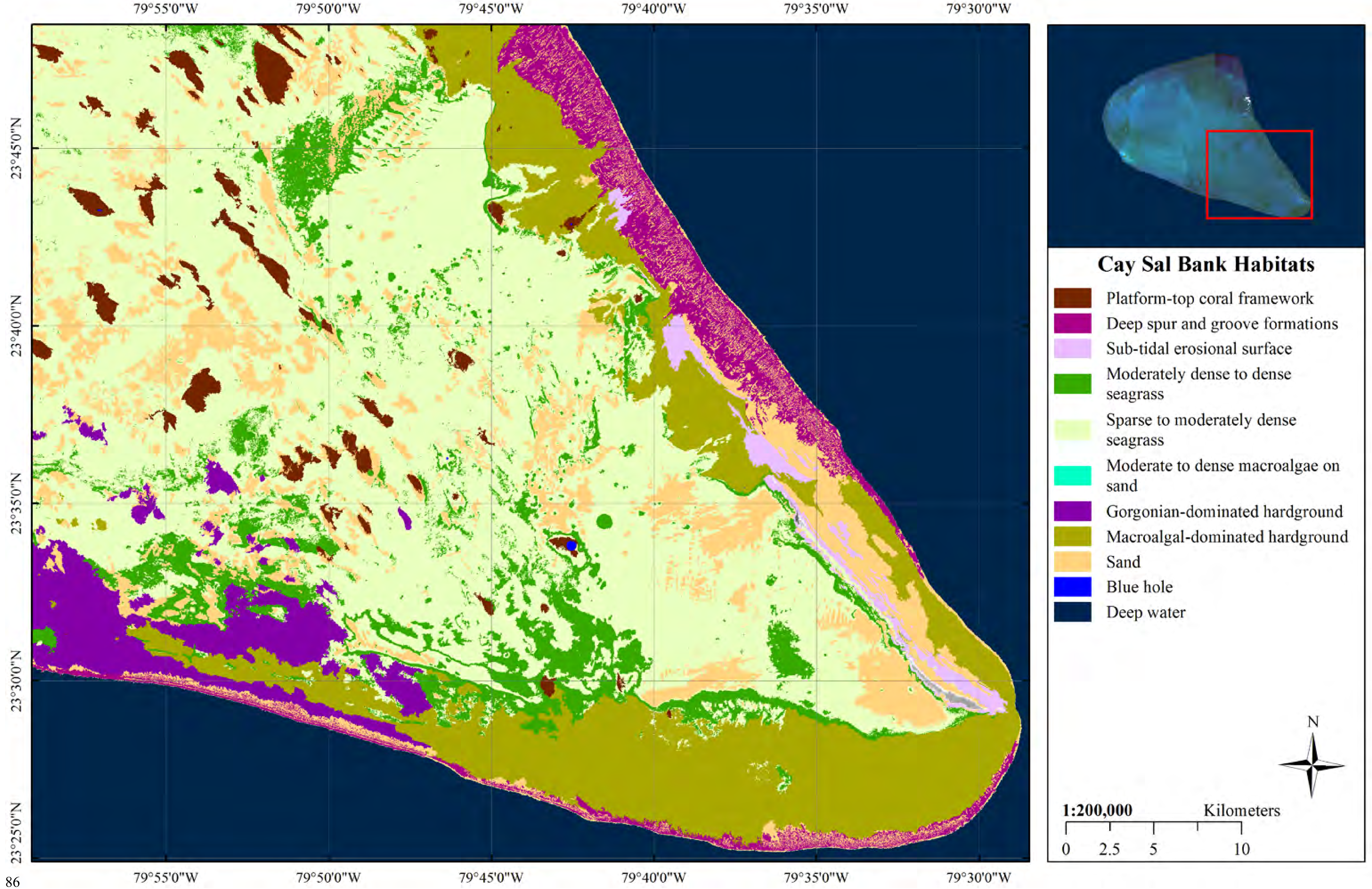
Examples of different reef communities identified on Cay Sal Bank. Many of the hardground areas on the bank were dominated by branching gorgonians with a dense cover of macroalgae (top left).

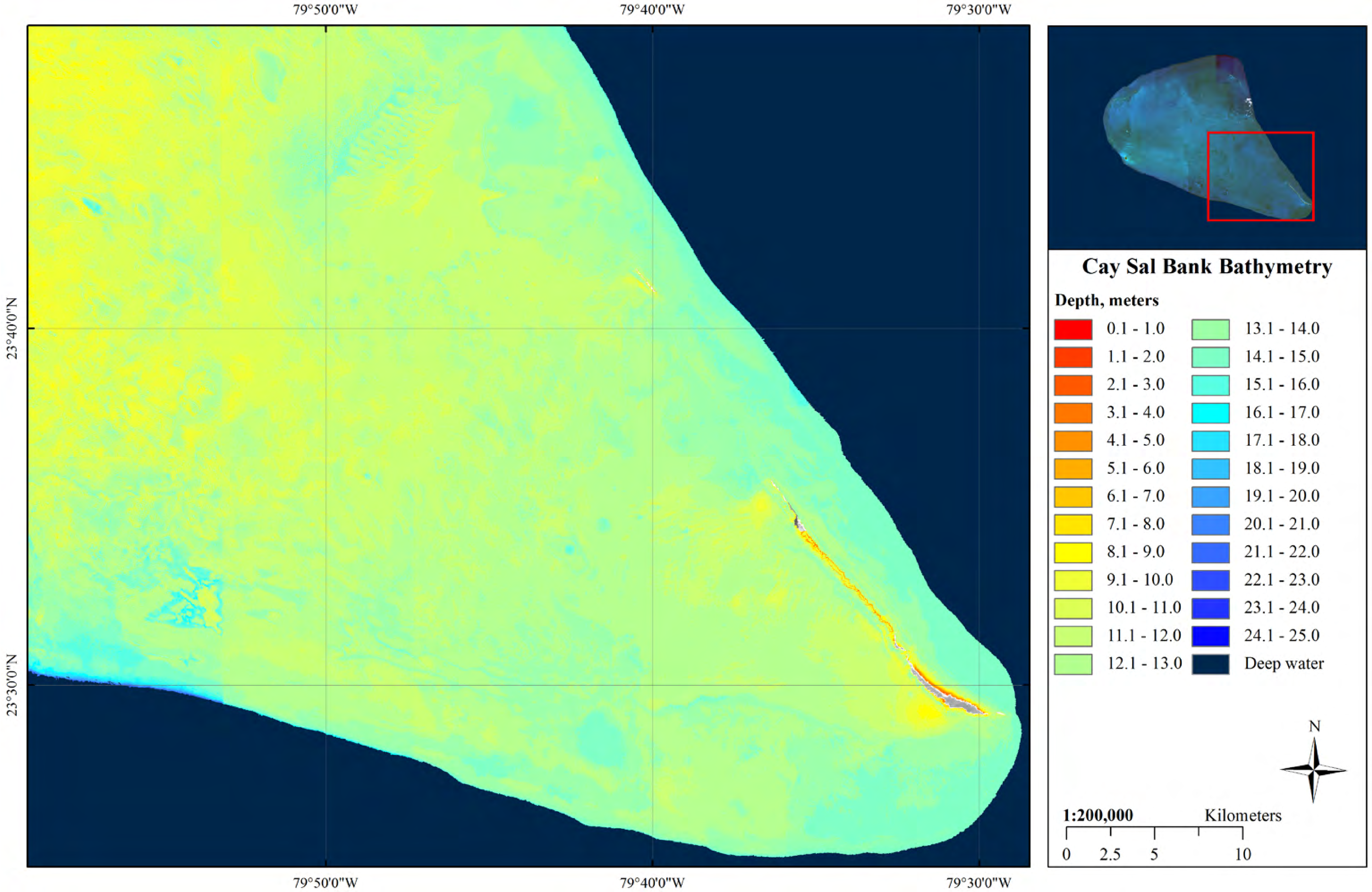
An extensive patch reef was found in the southeast dominated by *Porites astreoides* with a large number of massive and plating corals (bottom left). Adjacent to this was a former *Acropora cervicornis* community that had died in its entirety. All that remained were piles of fused staghorn coral rubble.

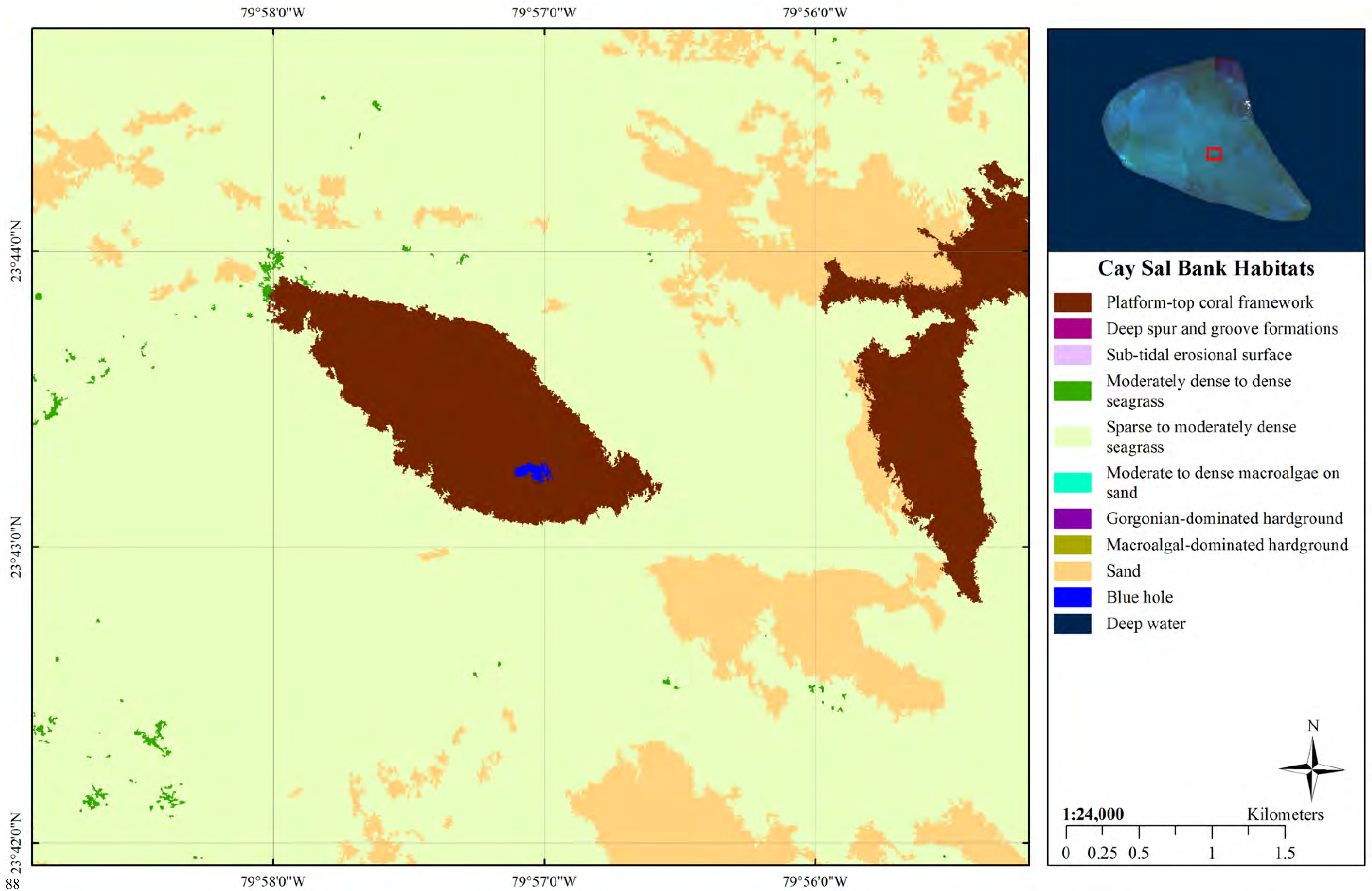
Very few reefs had large colonies of *Montastraea faveolata*. Some of the healthiest examples were found on the shallow shelf edge off the southern platform margin (top right).

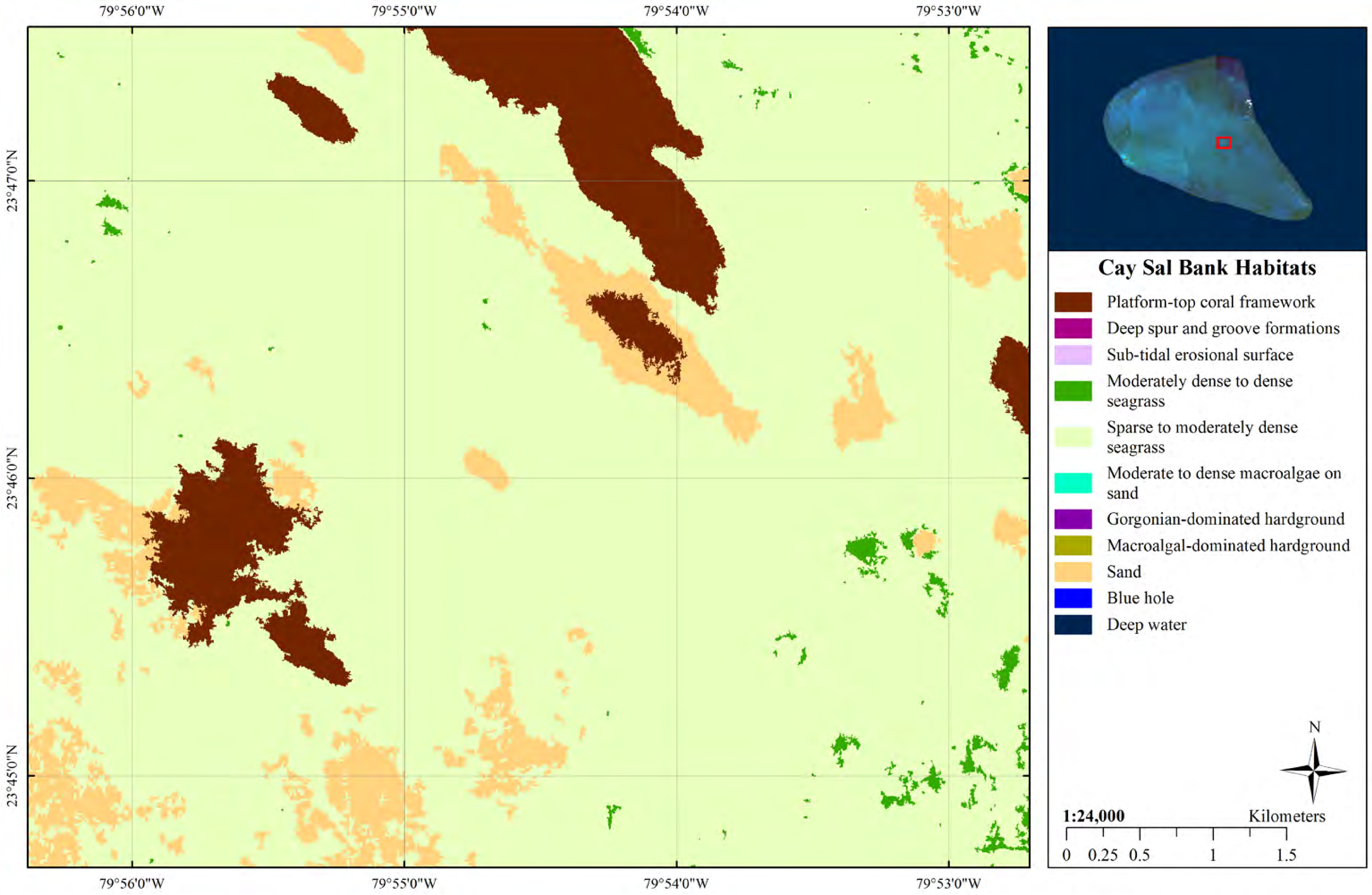
The shelf edge on the west side of Cay Sal Bank had prominent spur and groove features with large massive corals on the tops of spurs and a well developed plating community on the wall. The photo on the lower right is from 30 m depth.

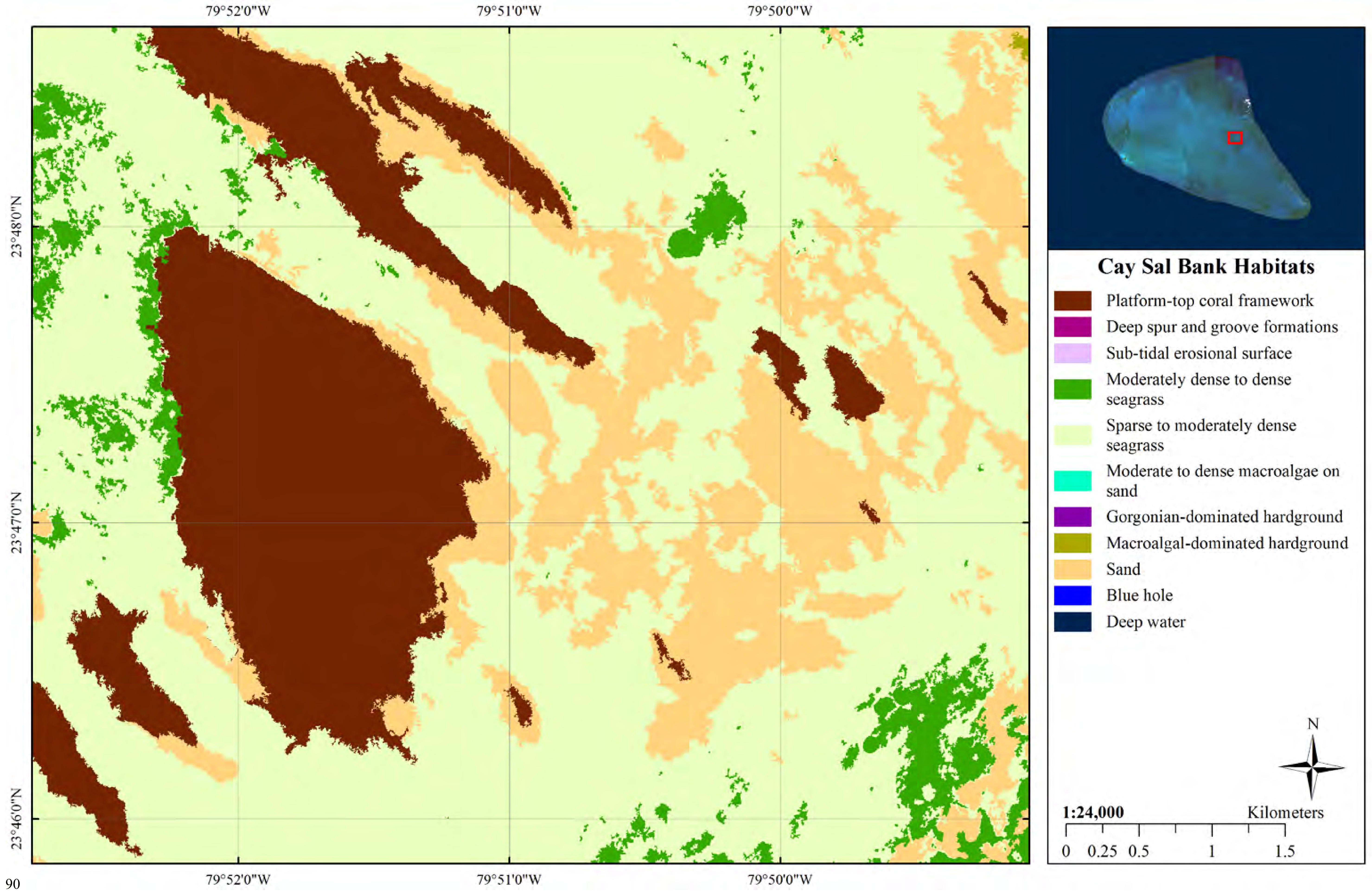


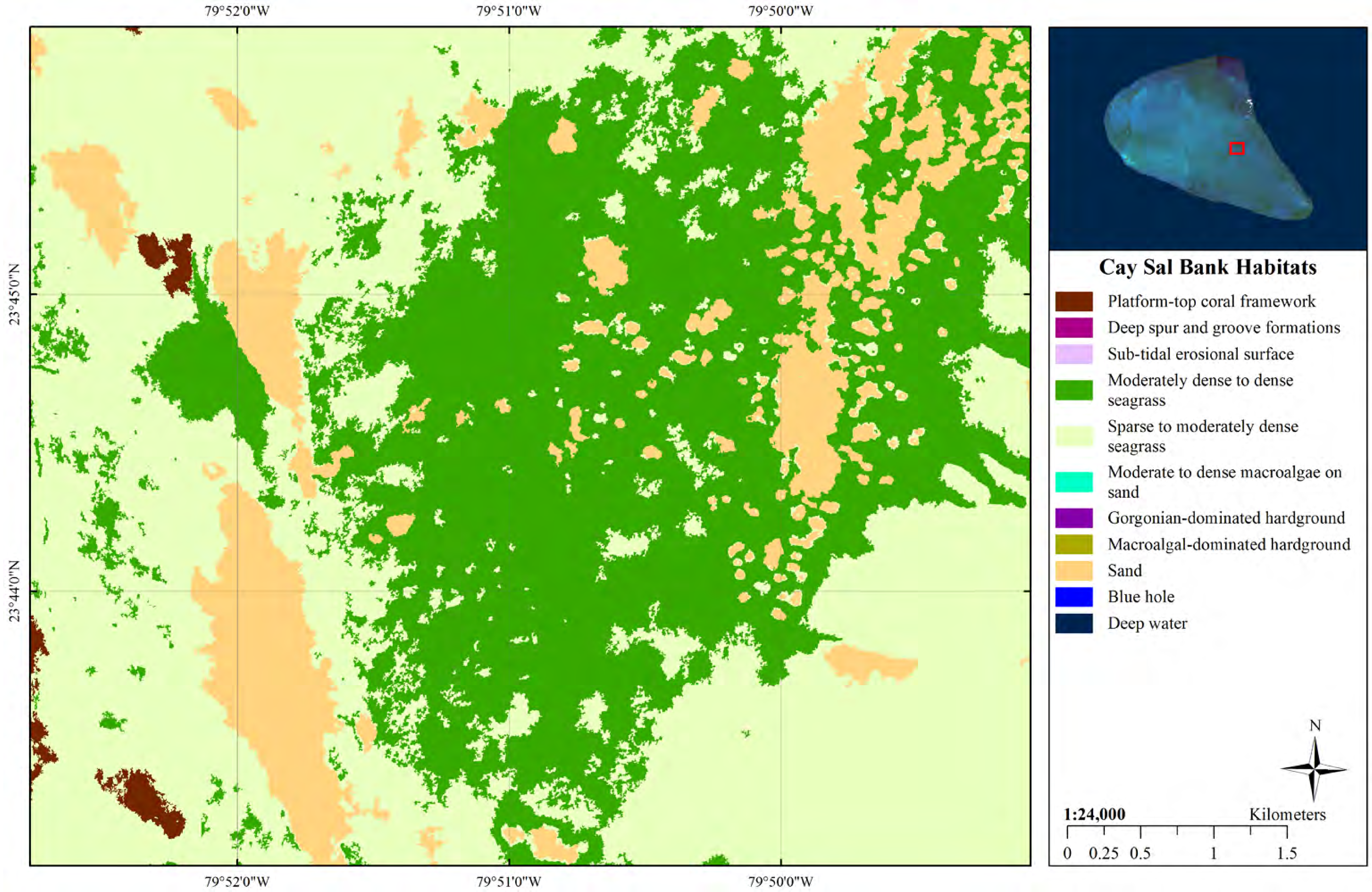

79°55'0"W
79°50'0"W
79°45'0"W
79°40'0"W
79°35'0"W
79°30'0"W
23°45'0"N
23°40'0"N
23°35'0"N
23°30'0"N
23°25'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:200,000
Kilometers
0
2.5
5
10

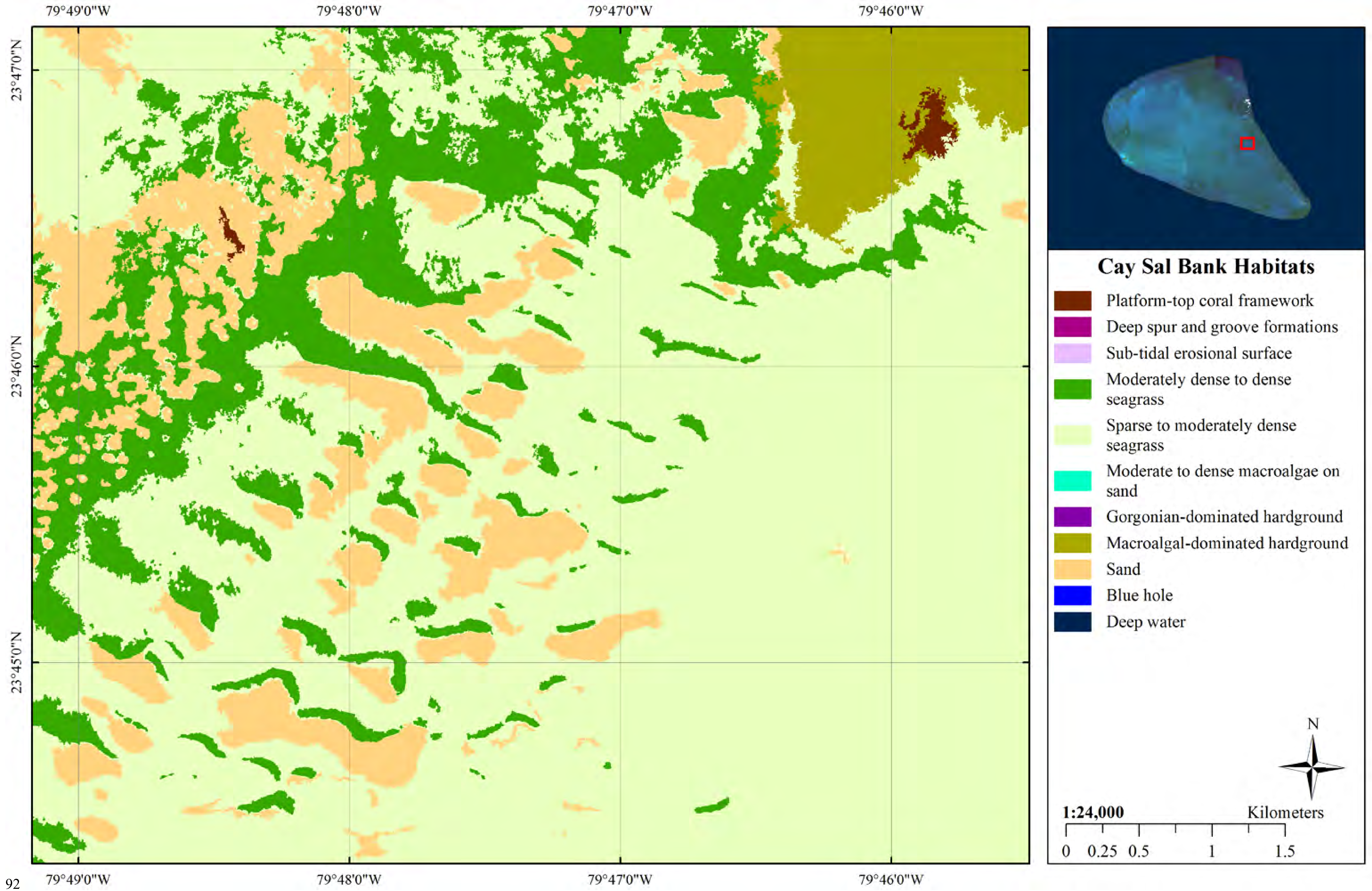

79°50'0"W
79°40'0"W
79°30'0"W
23°40'0"N
23°30'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:200,000
Kilometers
0
2.5
5
10

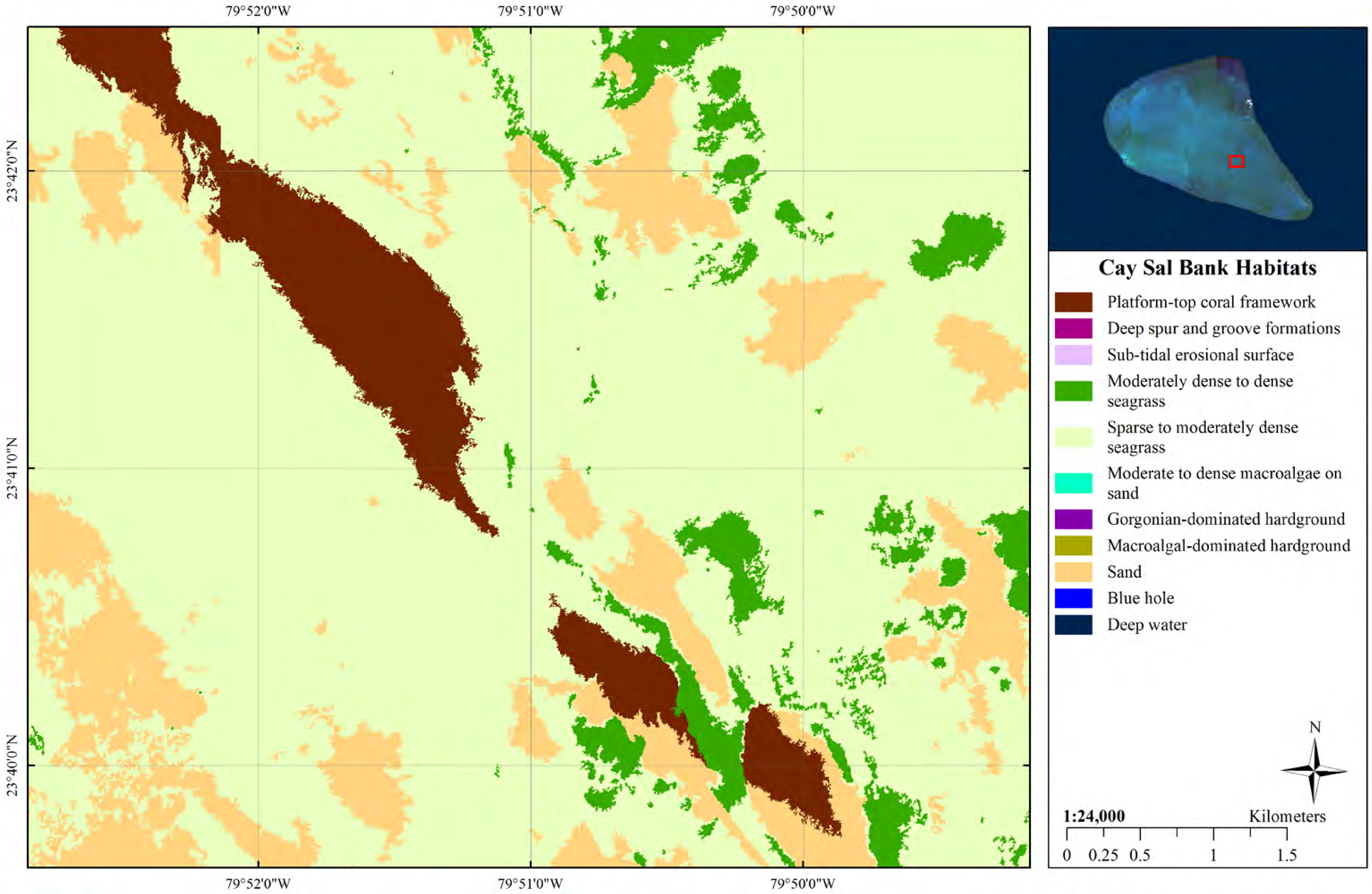

79°58'0"W
79°57'0"W
79°56'0"W
23°44'0"N
23°43'0"N
23°42'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

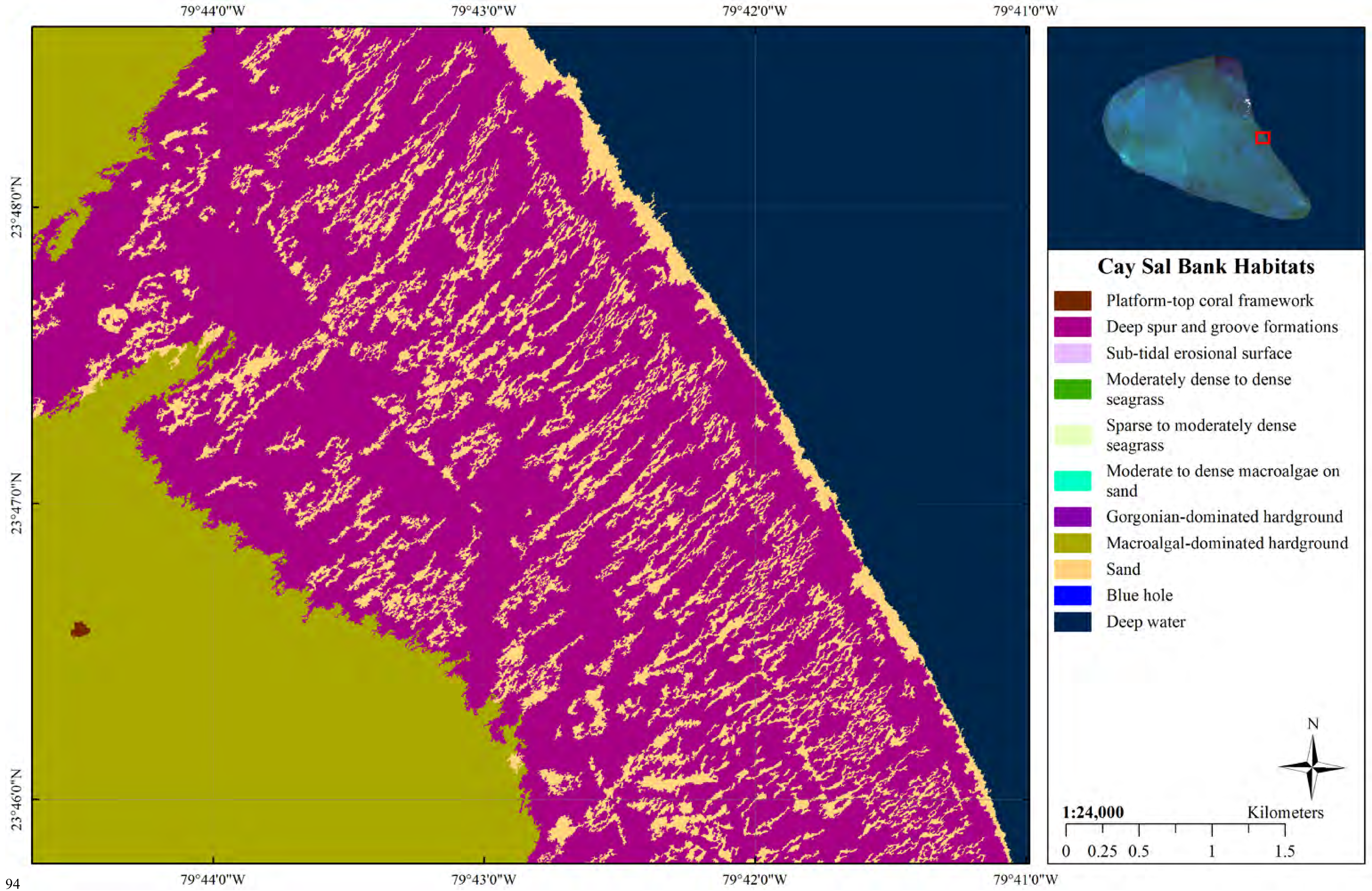

79°56'0"W
79°55'0"W
79°54'0"W
79°53'0"W
23°47'0"N
23°46'0"N
23°45'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

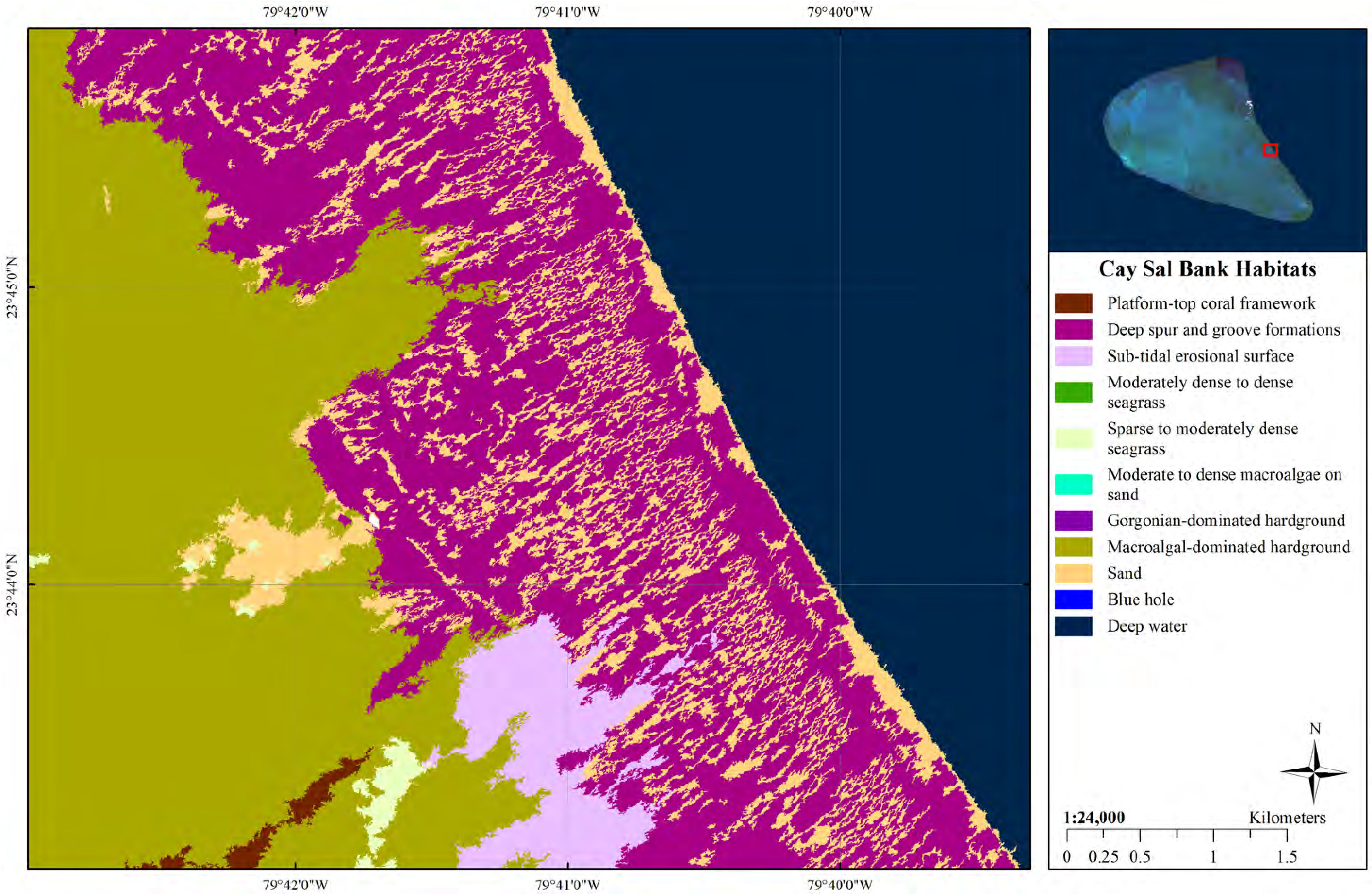

79°52'0"W
79°51'0"W
79°50'0"W
23°48'0"N
23°47'0"N
23°46'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

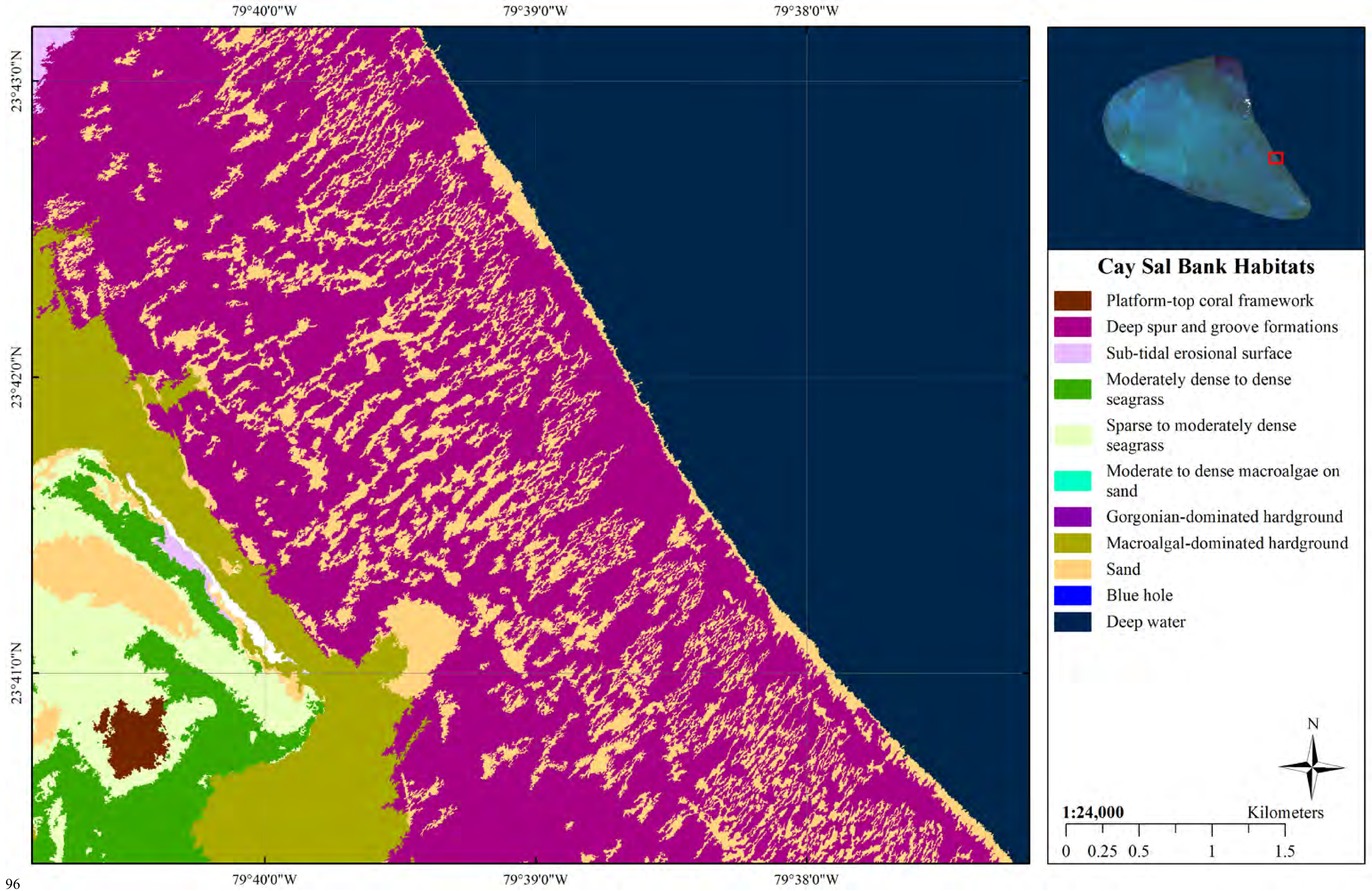

79°52'0"W
79°51'0"W
79°50'0"W
23°45'0"N
23°44'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

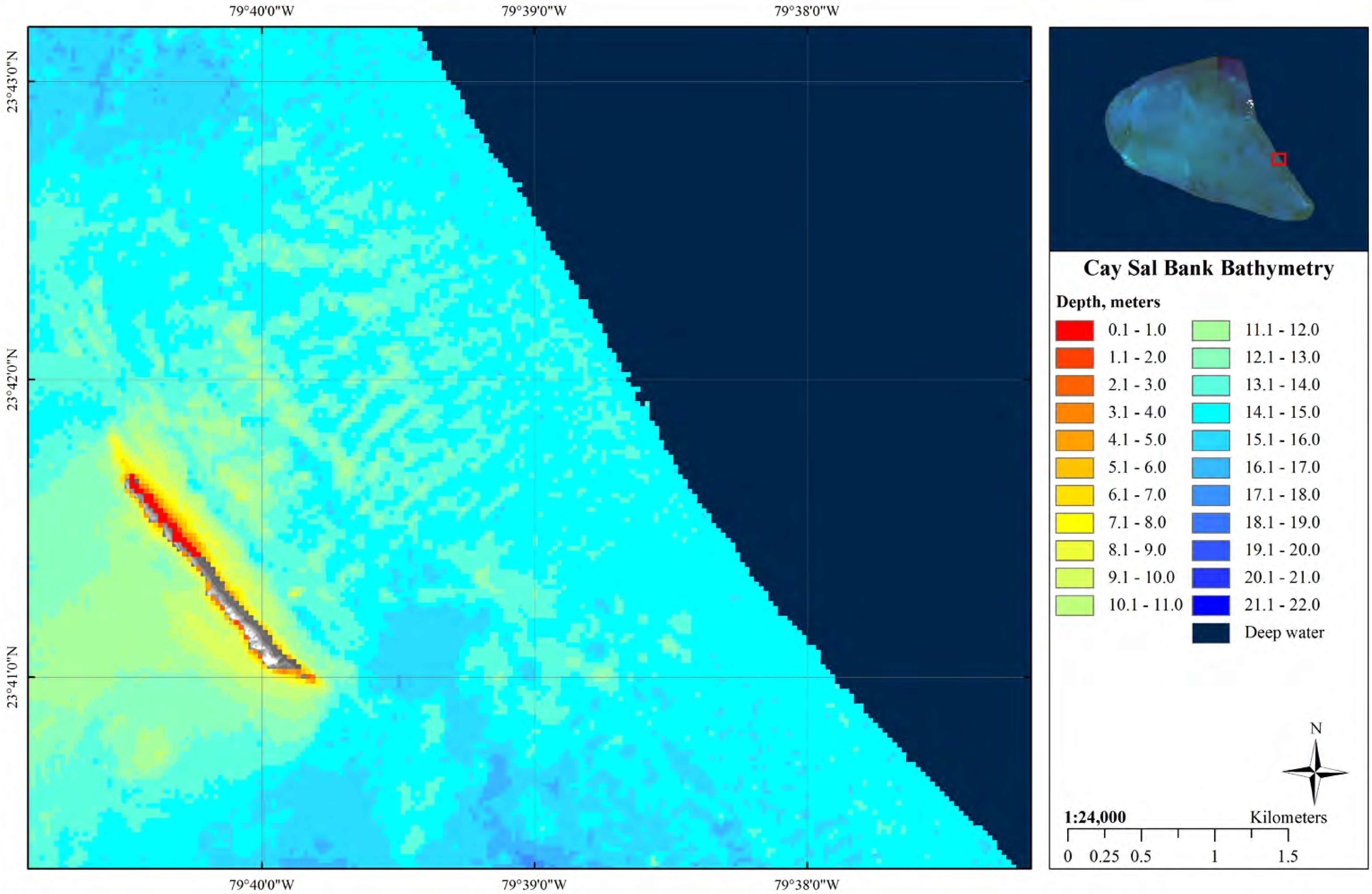

79°49'0"W
79°48'0"W
79°47'0"W
79°46'0"W
23°47'0"N
23°46'0"N
23°45'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

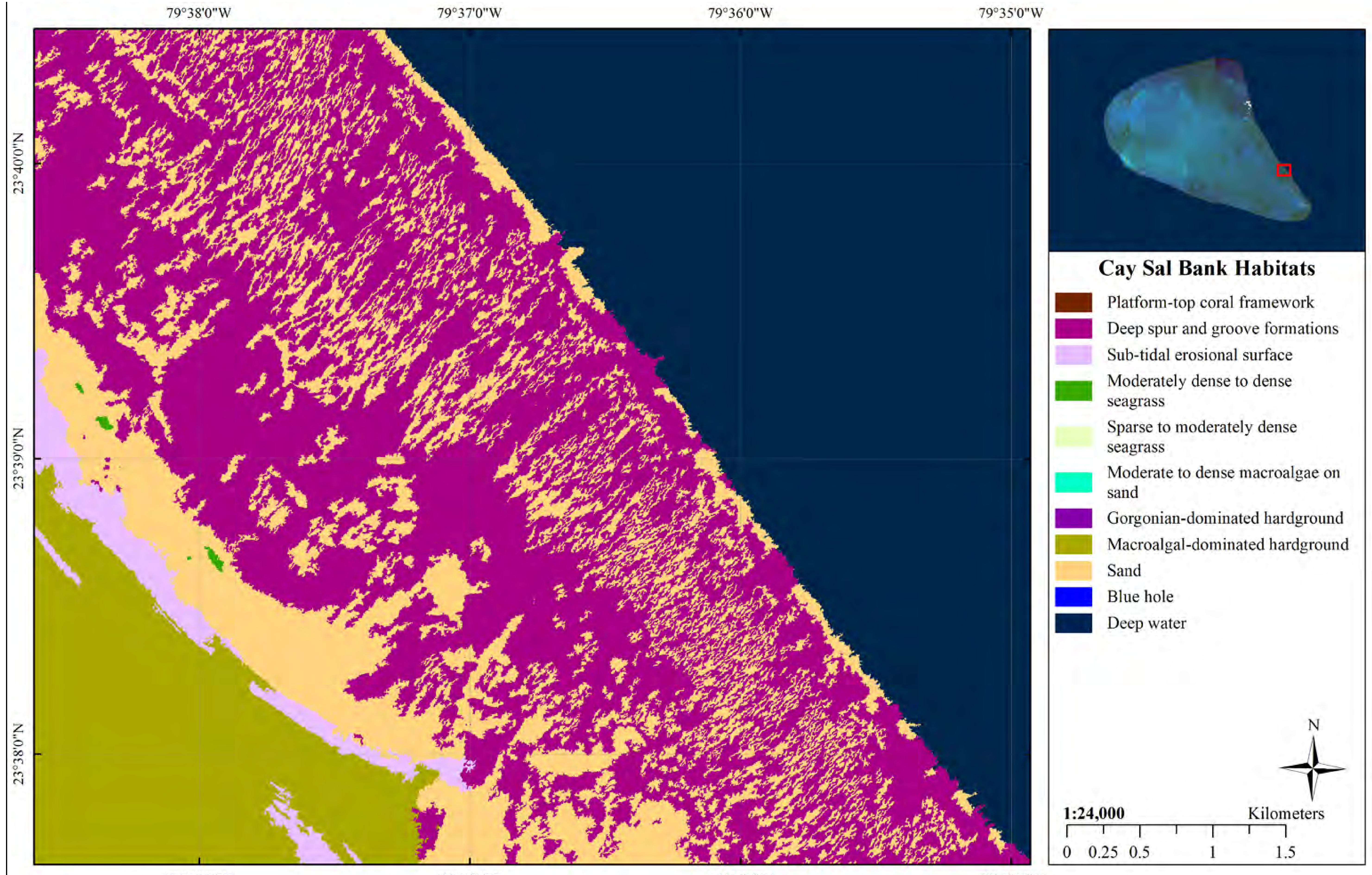

79°52'0"W
79°51'0"W
79°50'0"W
23°42'0"N
23°41'0"N
23°40'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

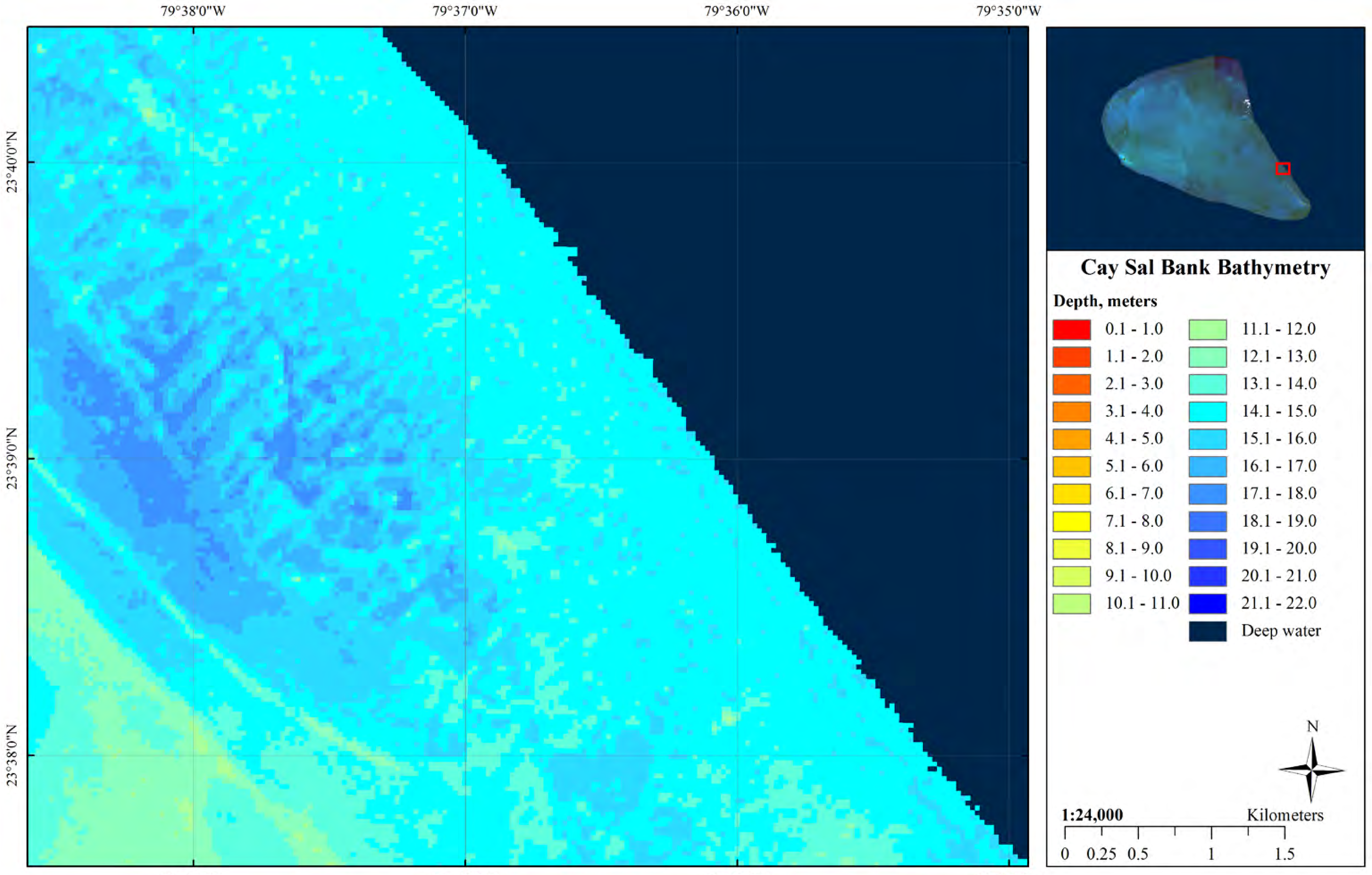

79°44'0"W
79°43'0"W
79°42'0"W
79°41'0"W
23°48'0"N
23°47'0"N
23°46'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

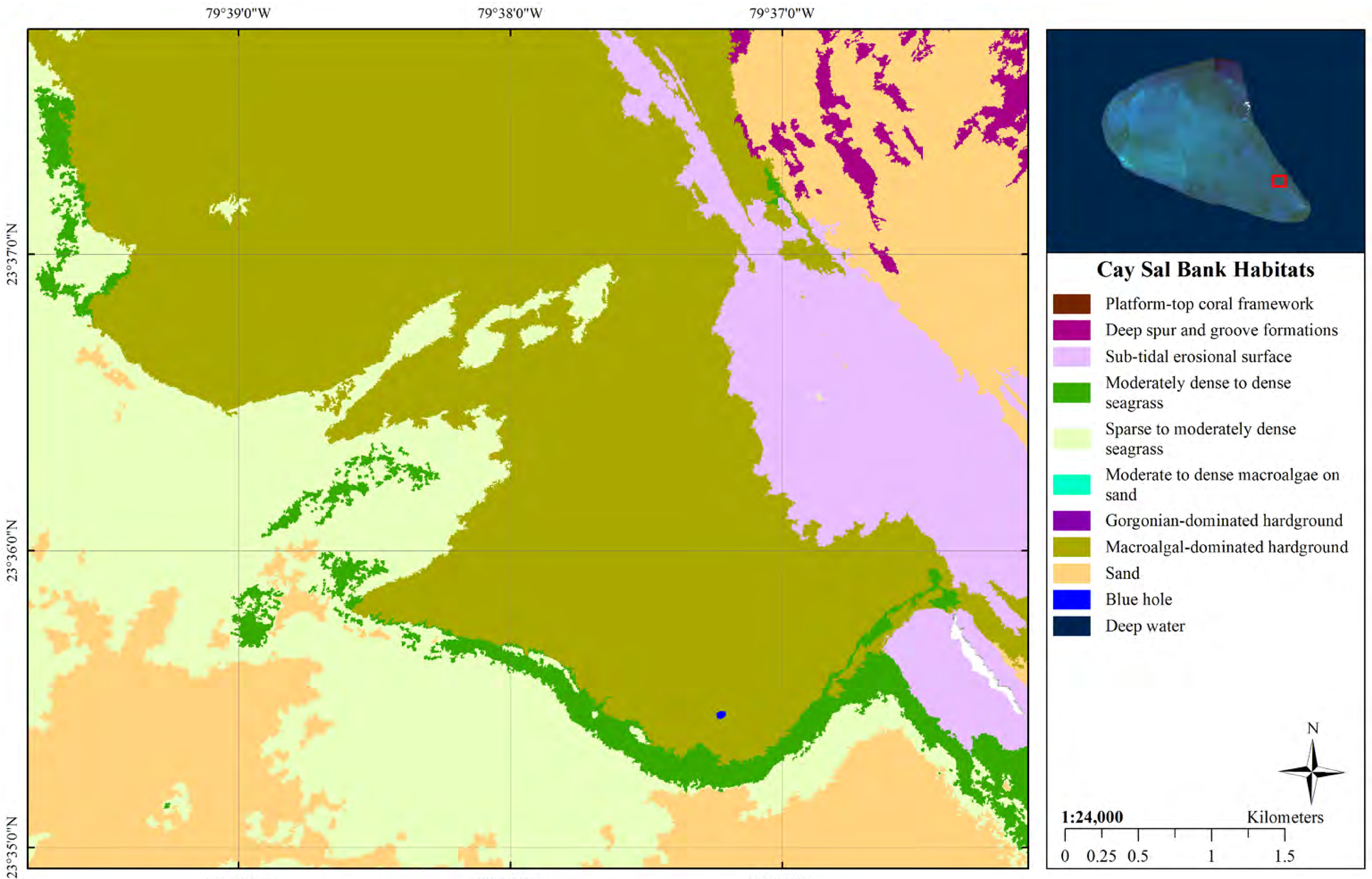

79°42'0"W
79°41'0"W
79°40'0"W
23°45'0"N
23°44'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


79°40'0"W
79°39'0"W
79°38'0"W
23°43'0"N
23°42'0"N
23°41'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

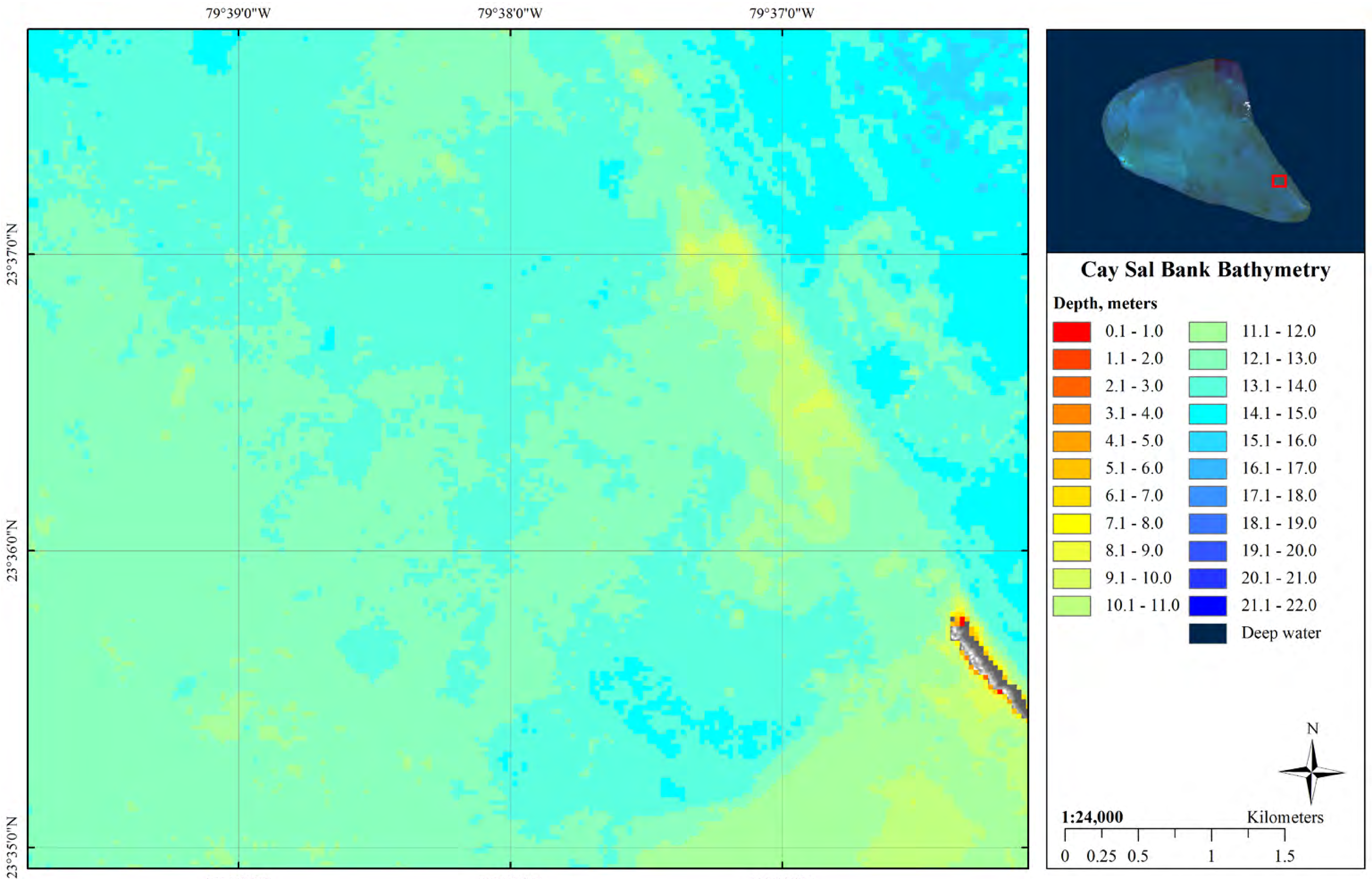

79°40'0"W
79°39'0"W
79°38'0"W
23°43'0"N
23°42'0"N
23°41'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


79°38'0"W
79°37'0"W
79°36'0"W
79°35'0"W
23°40'0"N
23°39'0"N
23°38'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

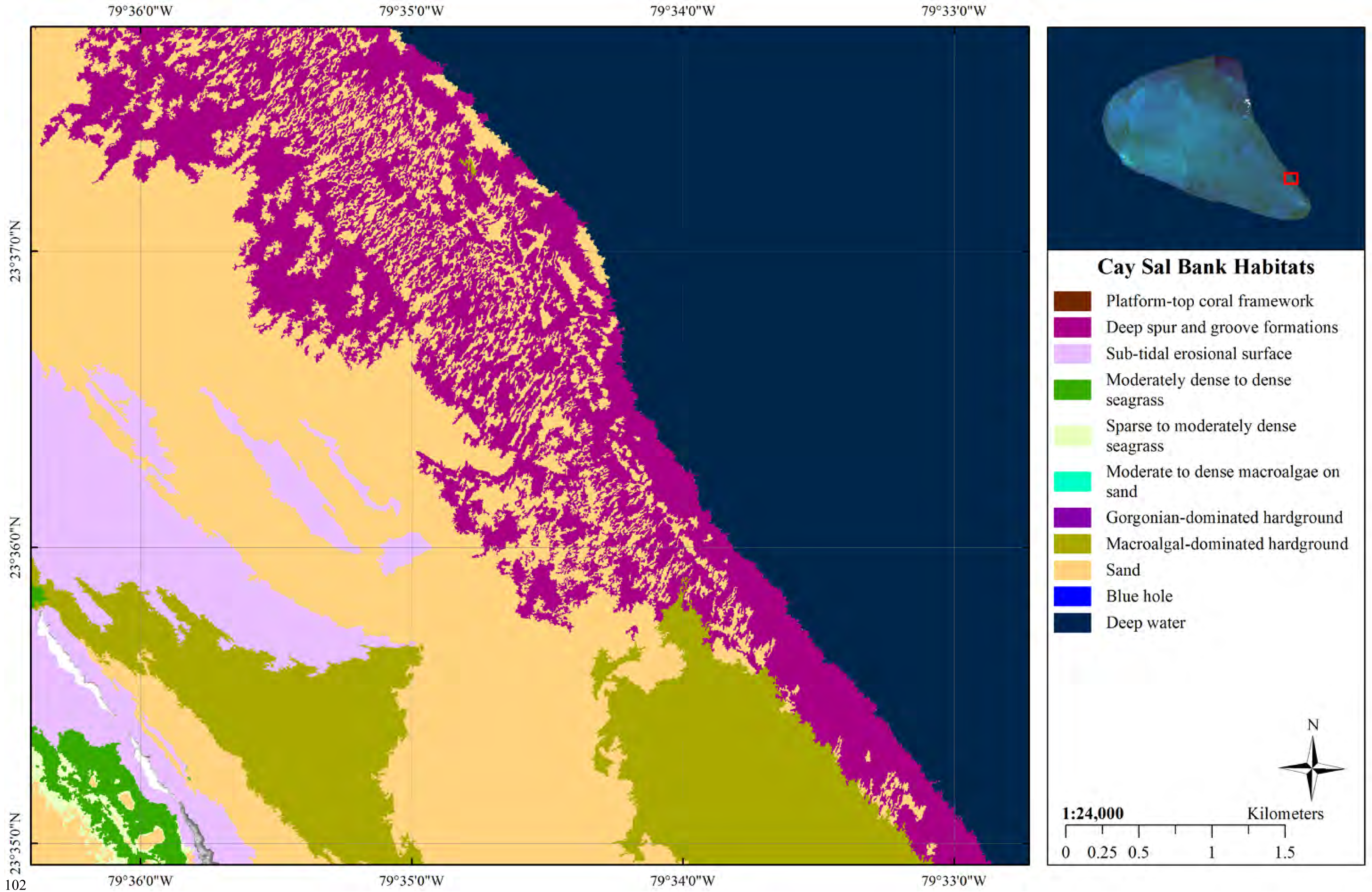

79°38'0"W
79°37'0"W
79°36'0"W
79°35'0"W
23°40'0"N
23°39'0"N
23°38'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

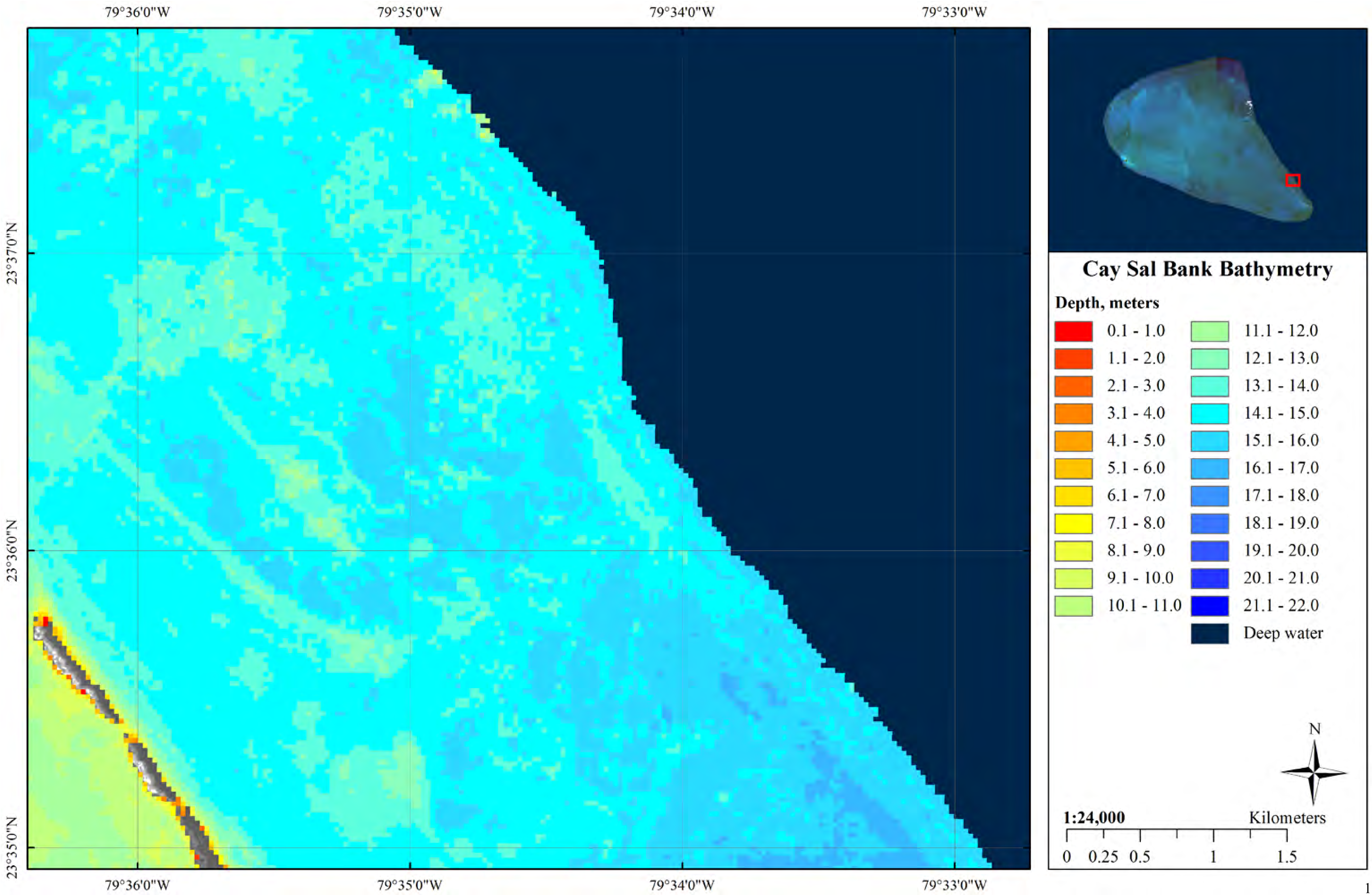


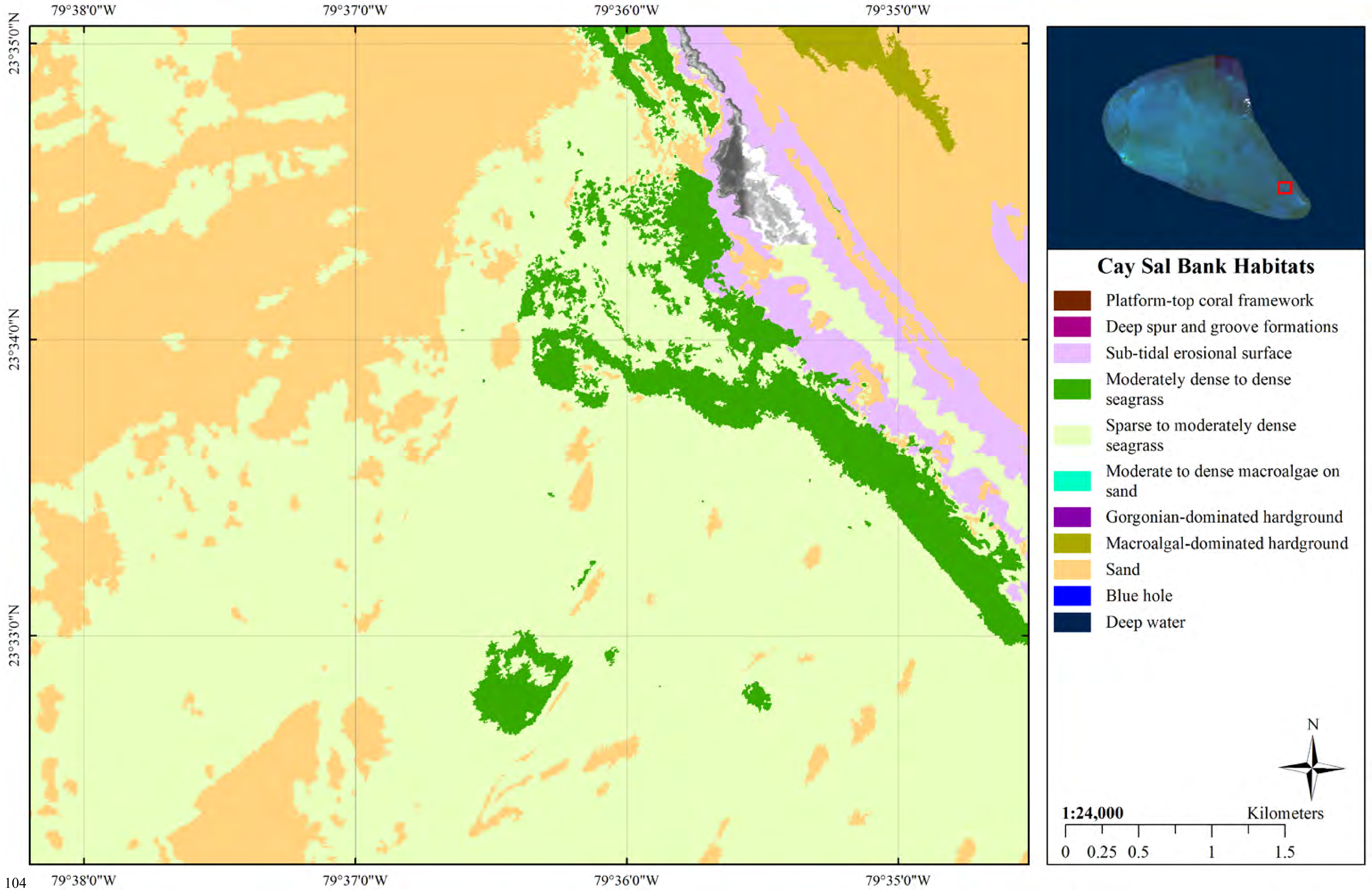
79°39'0"W
79°38'0"W
79°37'0"W
23°37'0"N
23°36'0"N
23°35'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

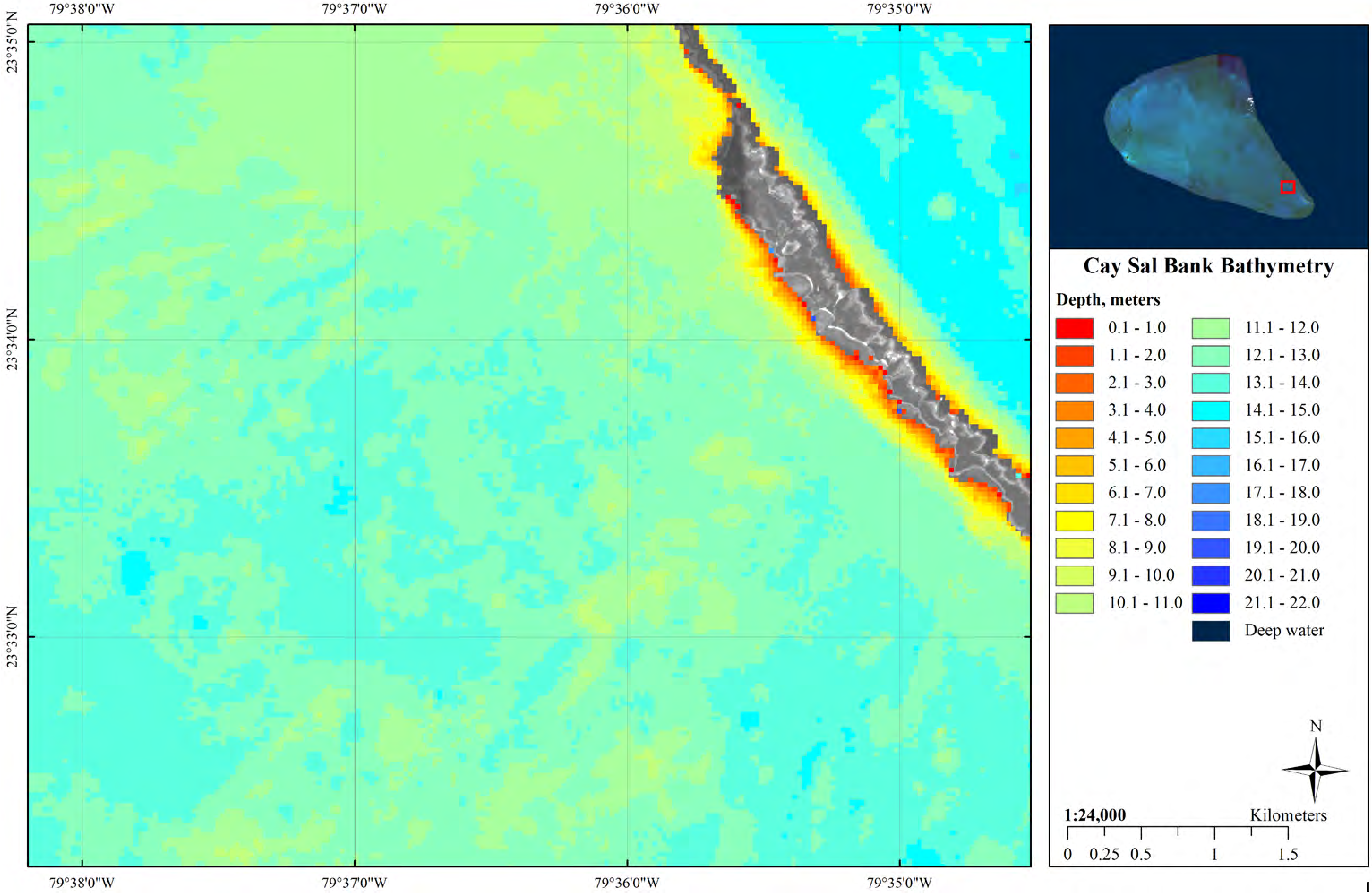


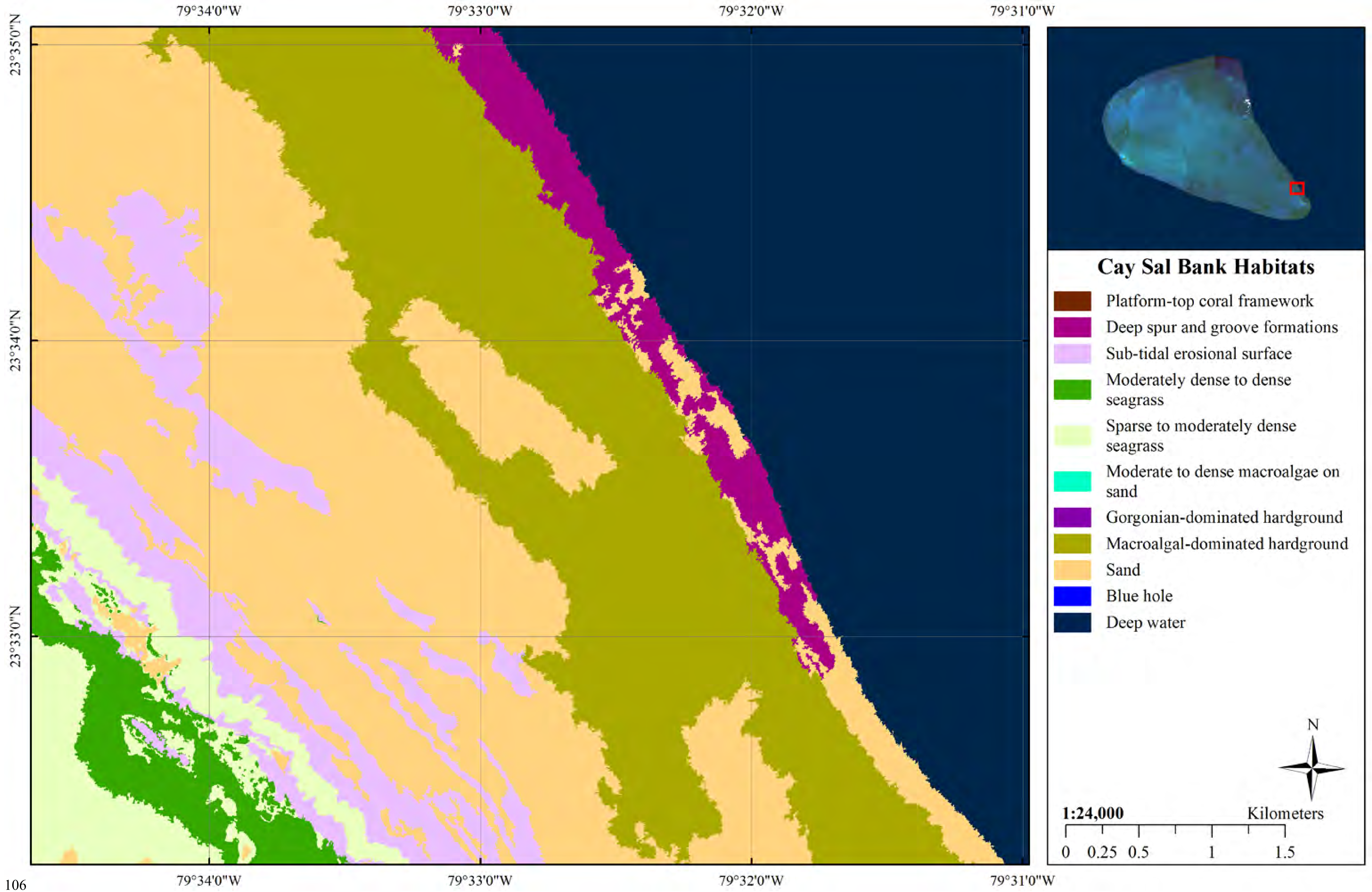
79°39'0"W
79°38'0"W
79°37'0"W
23°37'0"N
23°36'0"N
23°35'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

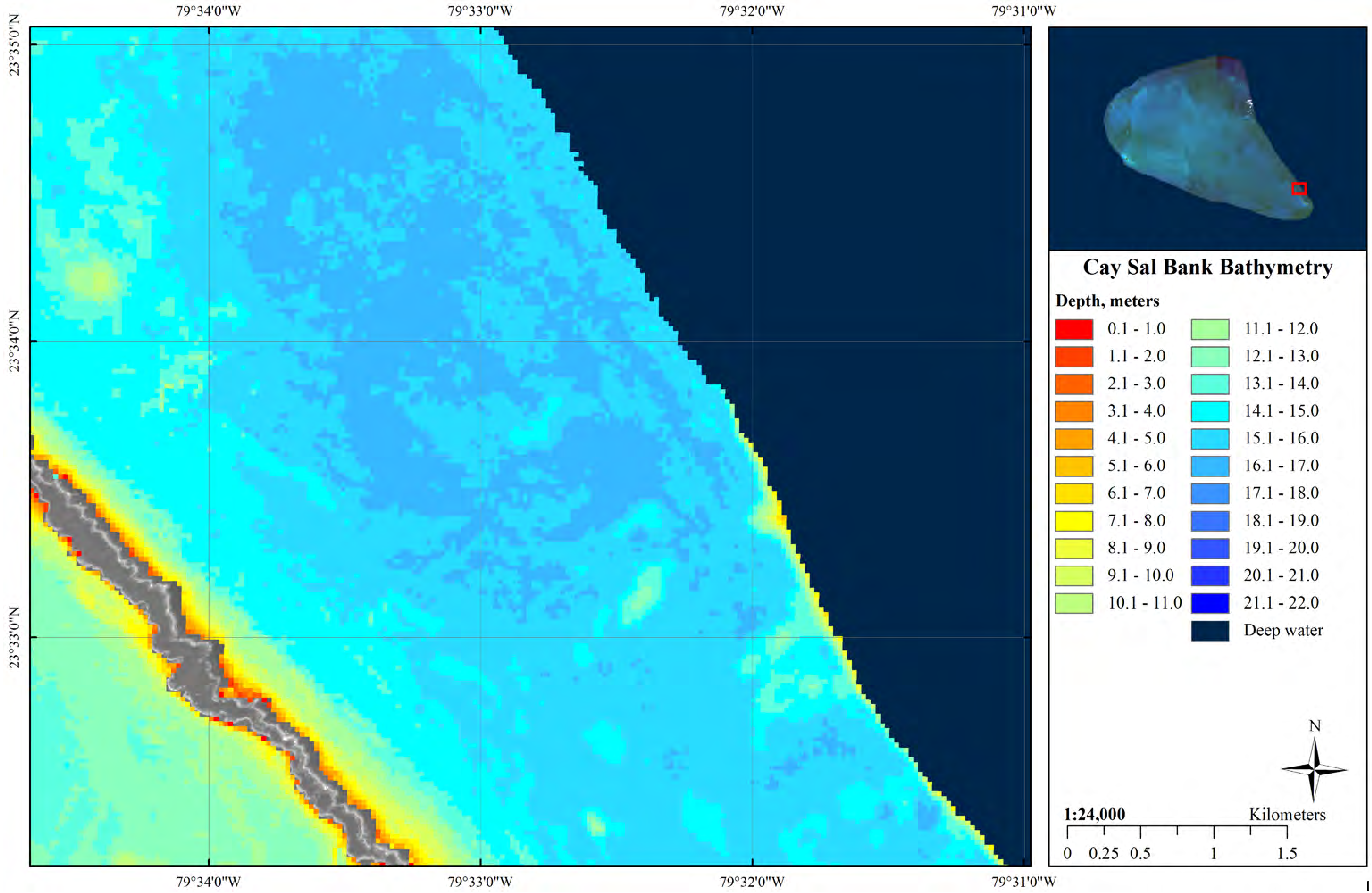

79°36'0"W
79°35'0"W
79°34'0"W
79°33'0"W
23°37'0"N
23°36'0"N
23°35'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

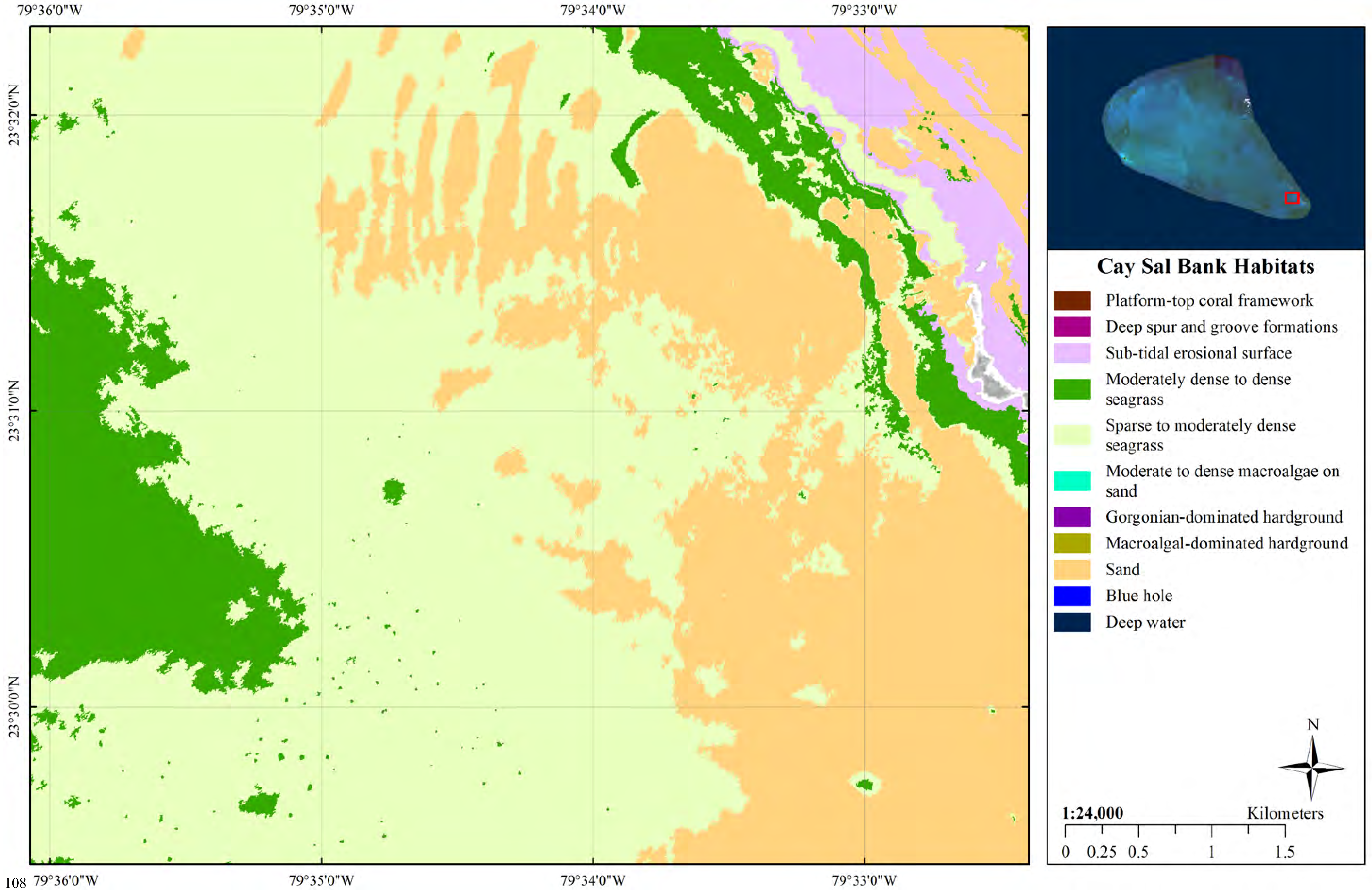

79°36'0"W
79°35'0"W
79°34'0"W
79°33'0"W
23°37'0"N
23°36'0"N
23°35'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

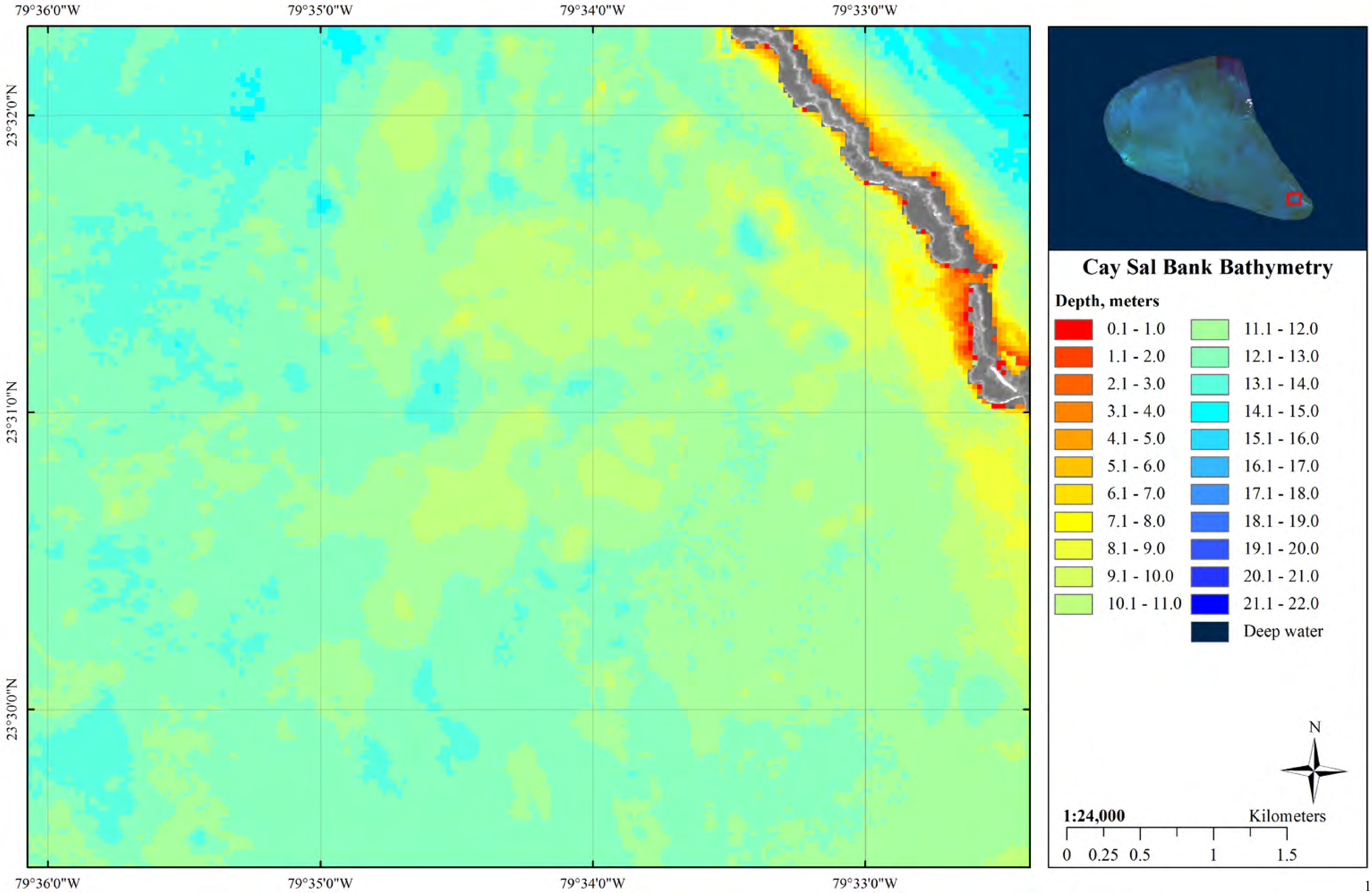

79°38'0"W
79°37'0"W
79°36'0"W
79°35'0"W
23°35'0"N
23°34'0"N
23°33'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

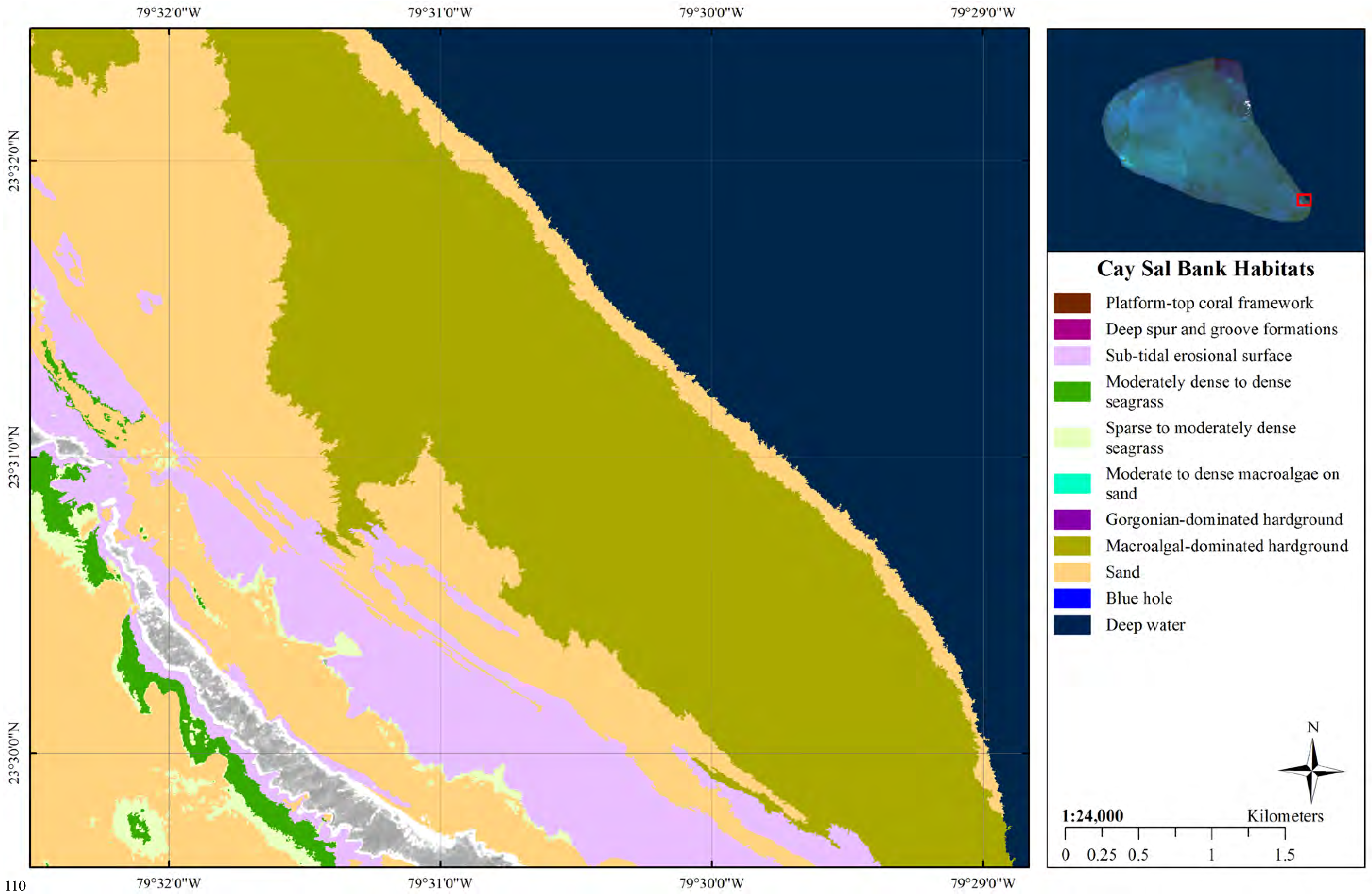

79°38'0"W
79°37'0"W
79°36'0"W
79°35'0"W
23°35'0"N
23°34'0"N
23°33'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

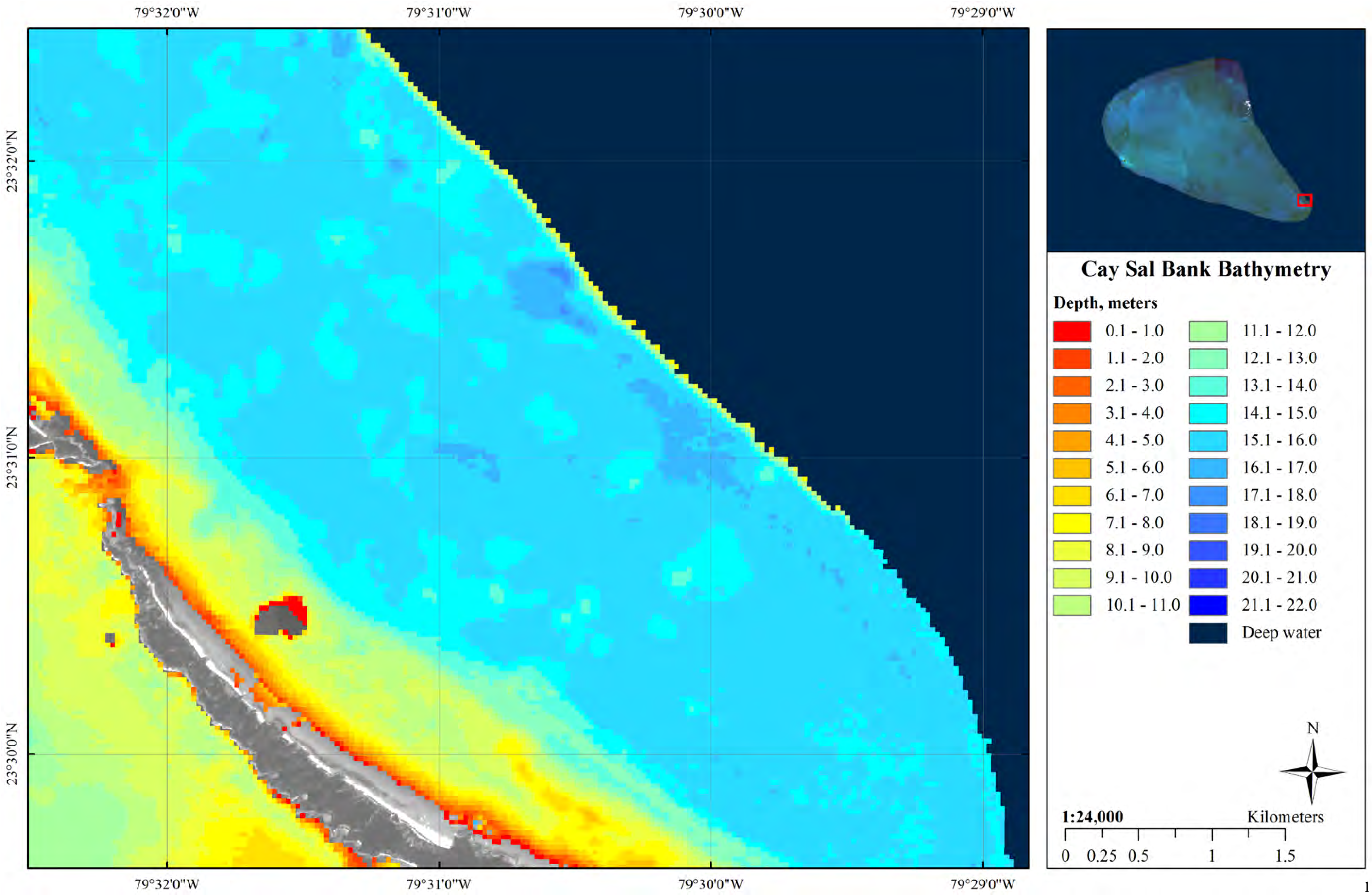

79°34'0"W
79°33'0"W
79°32'0"W
79°31'0"W
23°35'0"N
23°34'0"N
23°33'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

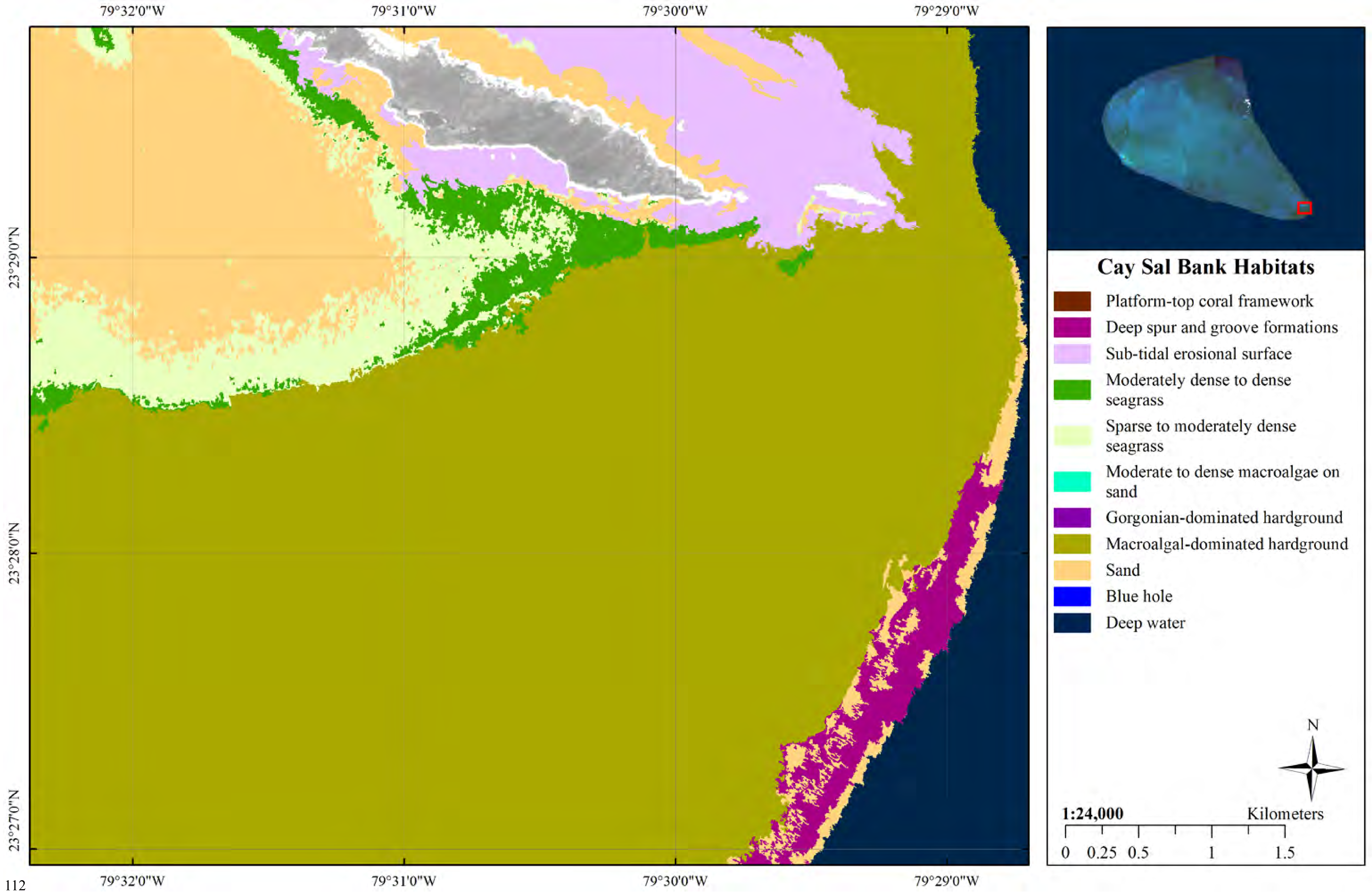

79°34'0"W
79°33'0"W
79°32'0"W
79°31'0"W
23°35'0"N
23°34'0"N
23°33'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


79°36'0"W
79°35'0"W
79°34'0"W
79°33'0"W
23°32'0"N
23°31'0"N
23°30'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

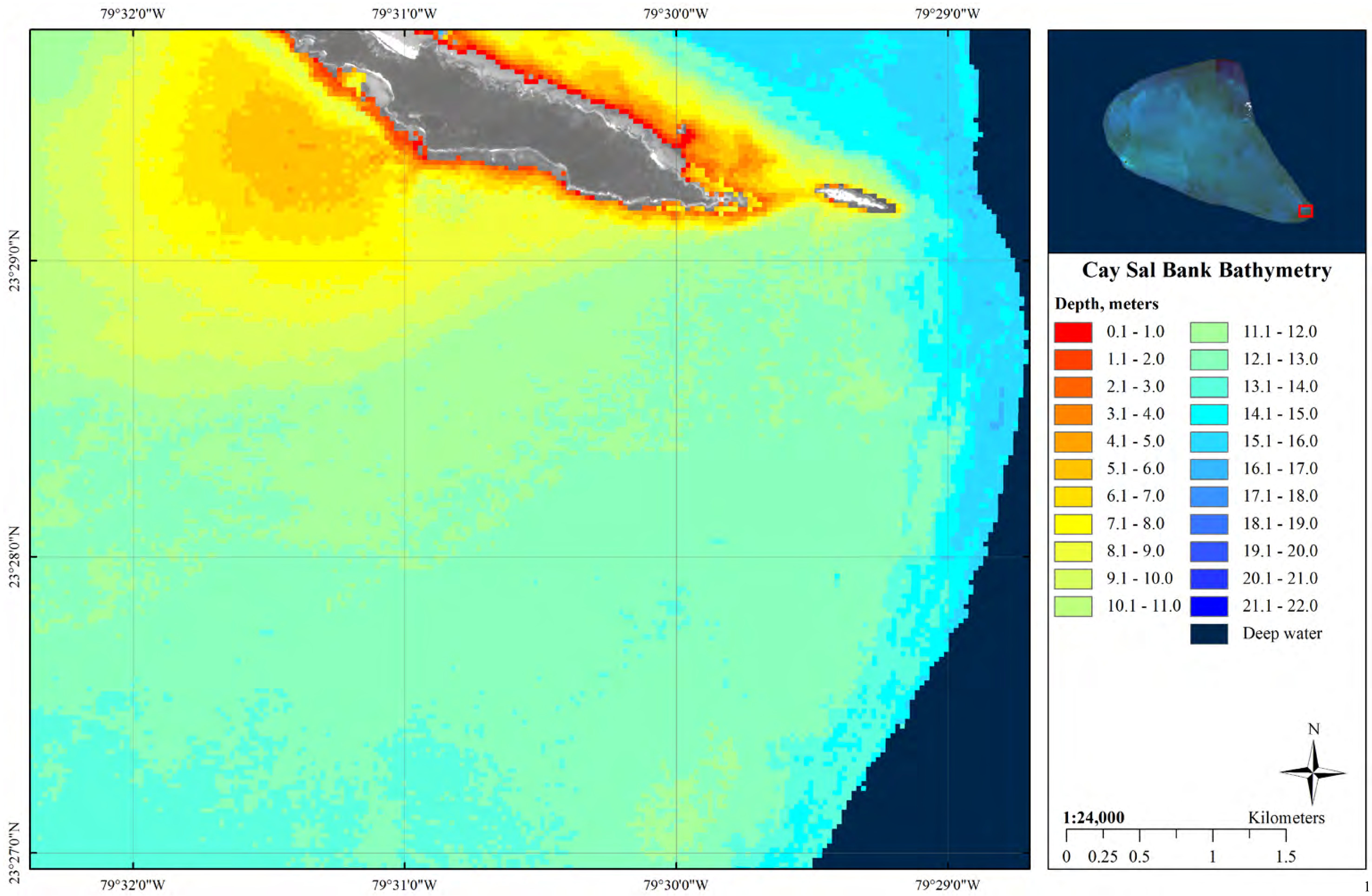

79°36'0"W
79°35'0"W
79°34'0"W
79°33'0"W
23°32'0"N
23°31'0"N
23°30'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


79°32'0"W
79°31'0"W
79°30'0"W
79°29'0"W
23°32'0"N
23°31'0"N
23°30'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

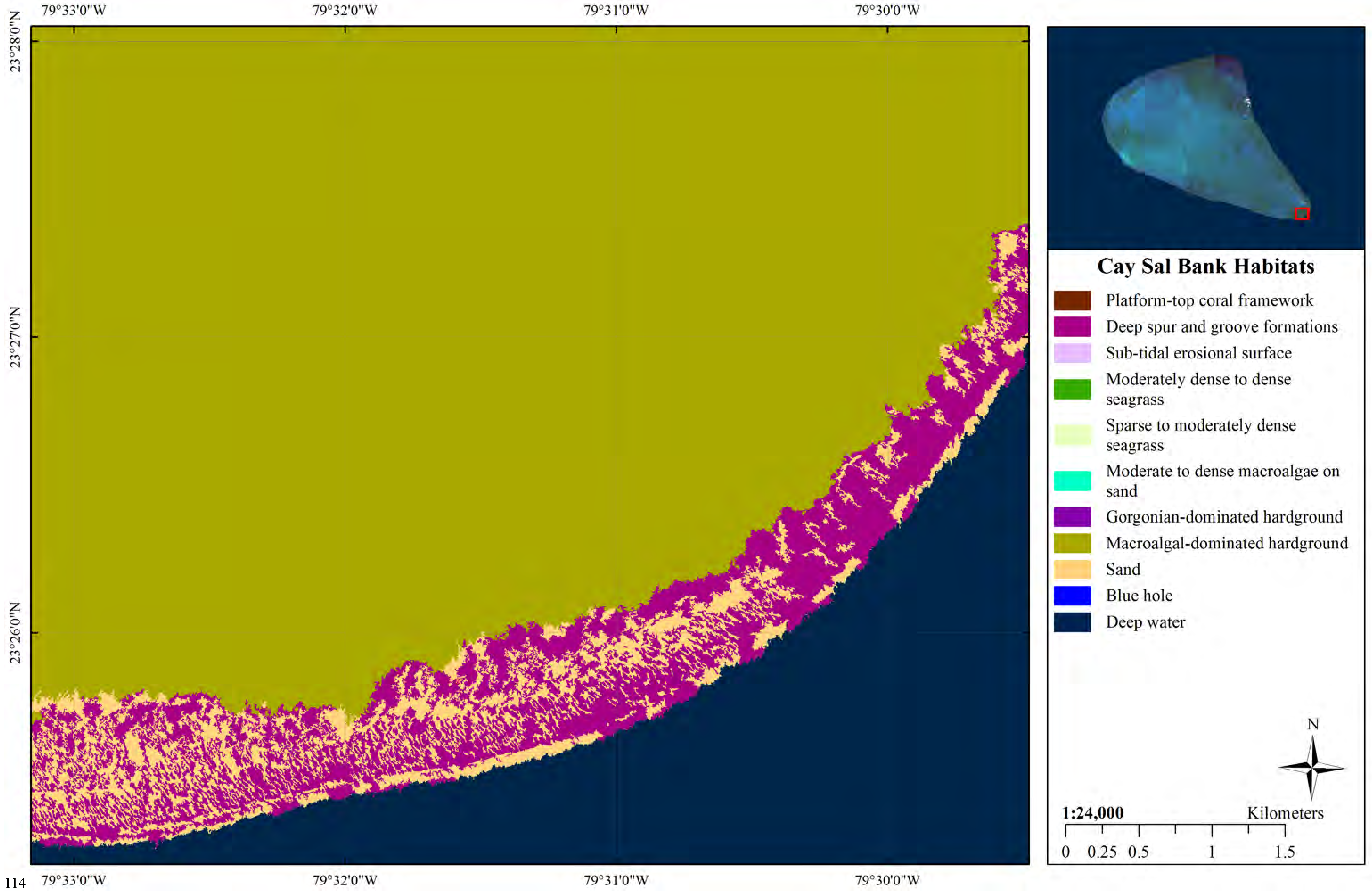

79°32'0"W
79°31'0"W
79°30'0"W
79°29'0"W
23°32'0"N
23°31'0"N
23°30'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

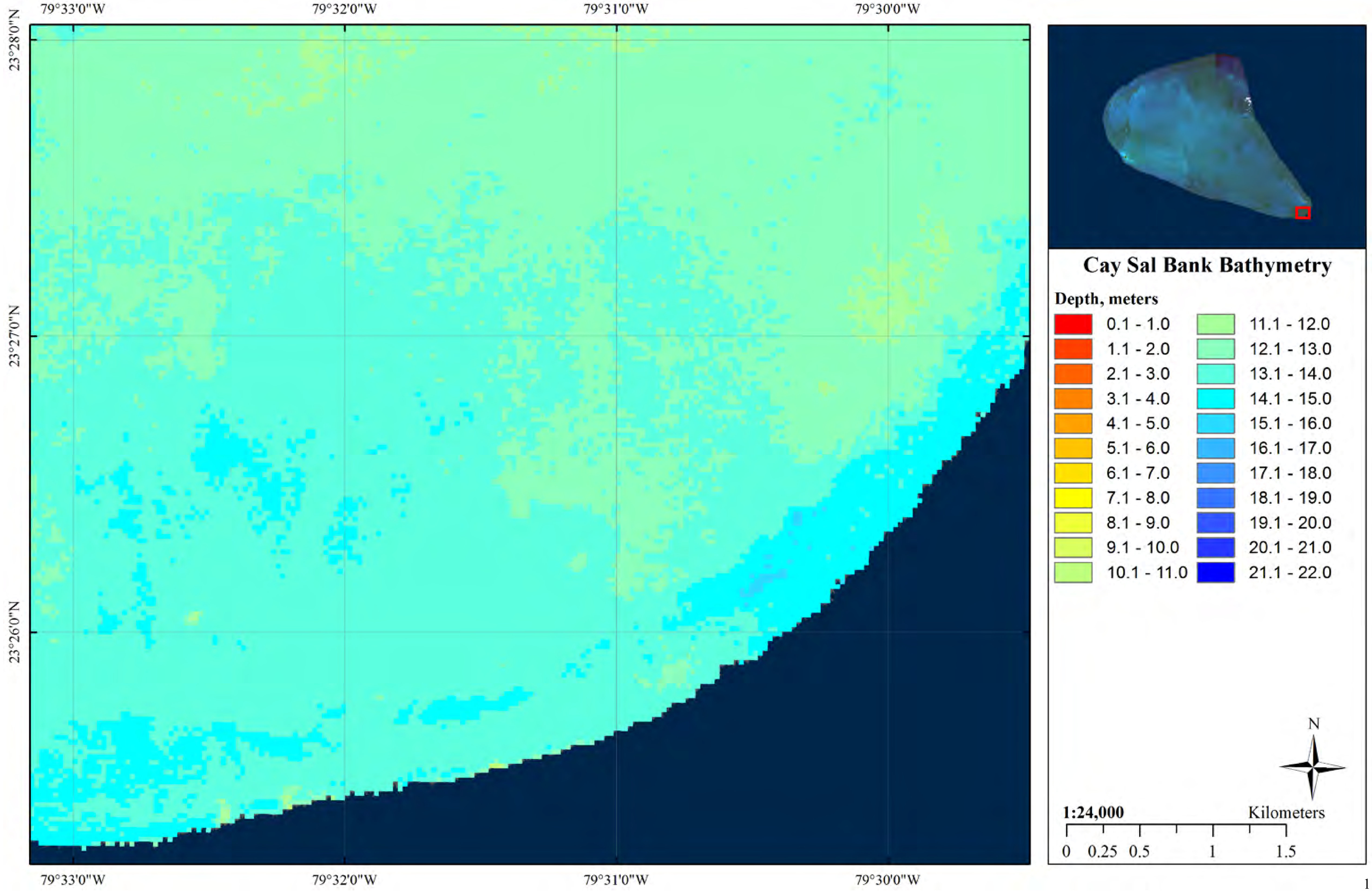


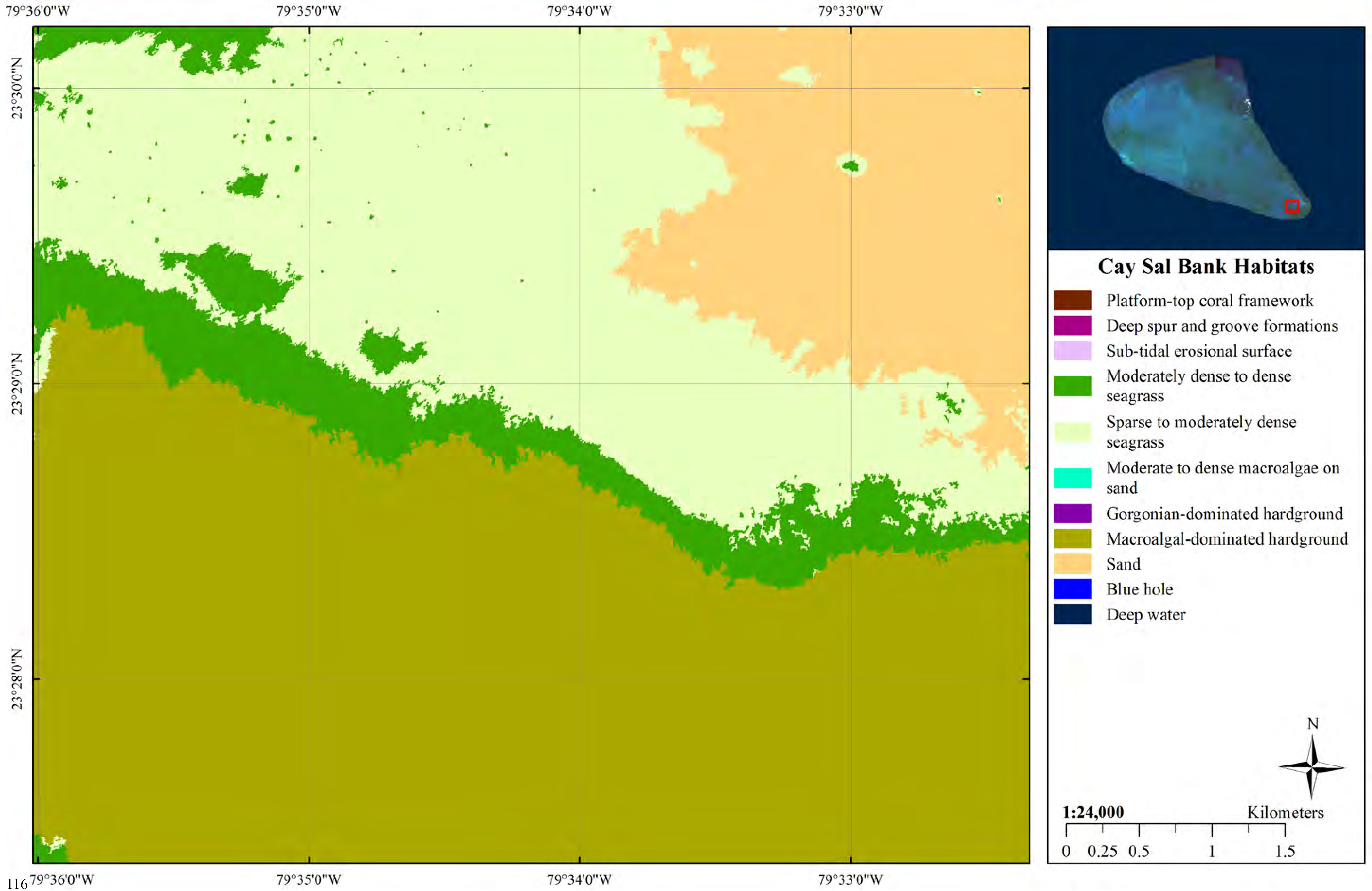
79°32'0"W
79°31'0"W
79°30'0"W
79°29'0"W
23°29'0"N
23°28'0"N
23°27'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5



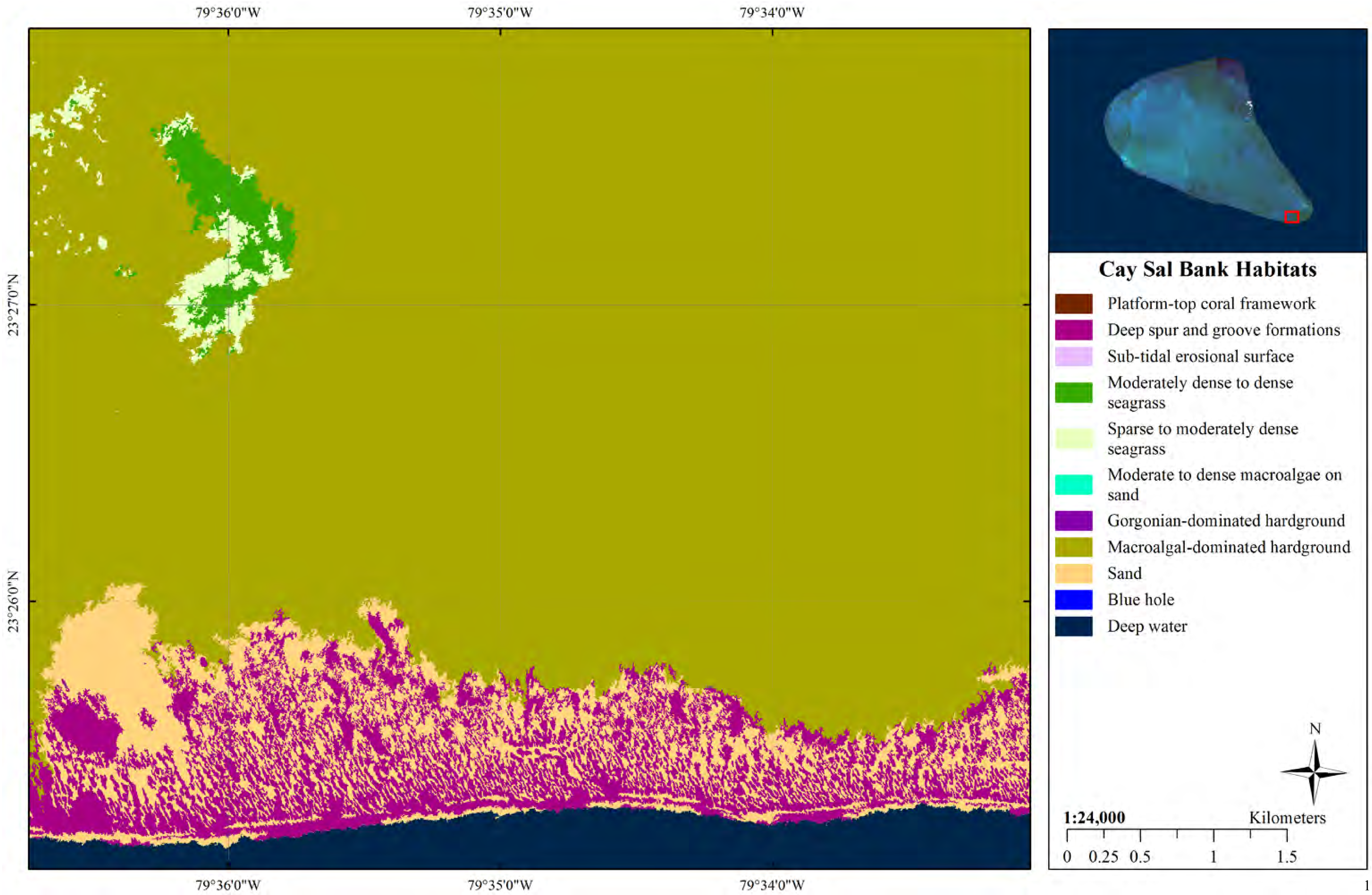
79°32'0"W
79°31'0"W
79°30'0"W
79°29'0"W
23°29'0"N
23°28'0"N
23°27'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


79°33'0"W
79°32'0"W
79°31'0"W
79°30'0"W
23°28'0"N
23°27'0"N
23°26'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

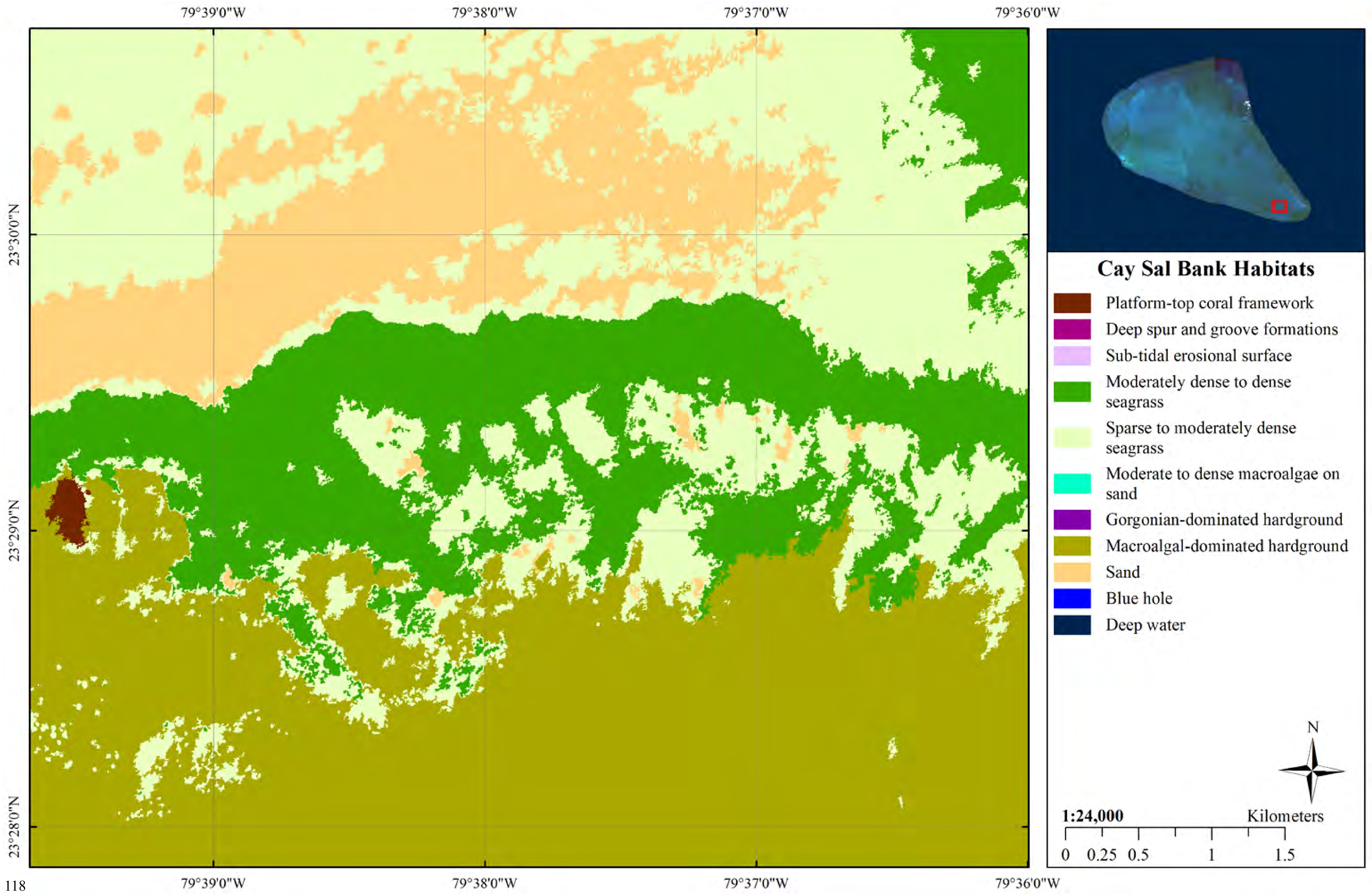

79°33'0"W
79°32'0"W
79°31'0"W
79°30'0"W
23°28'0"N
23°27'0"N
23°26'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

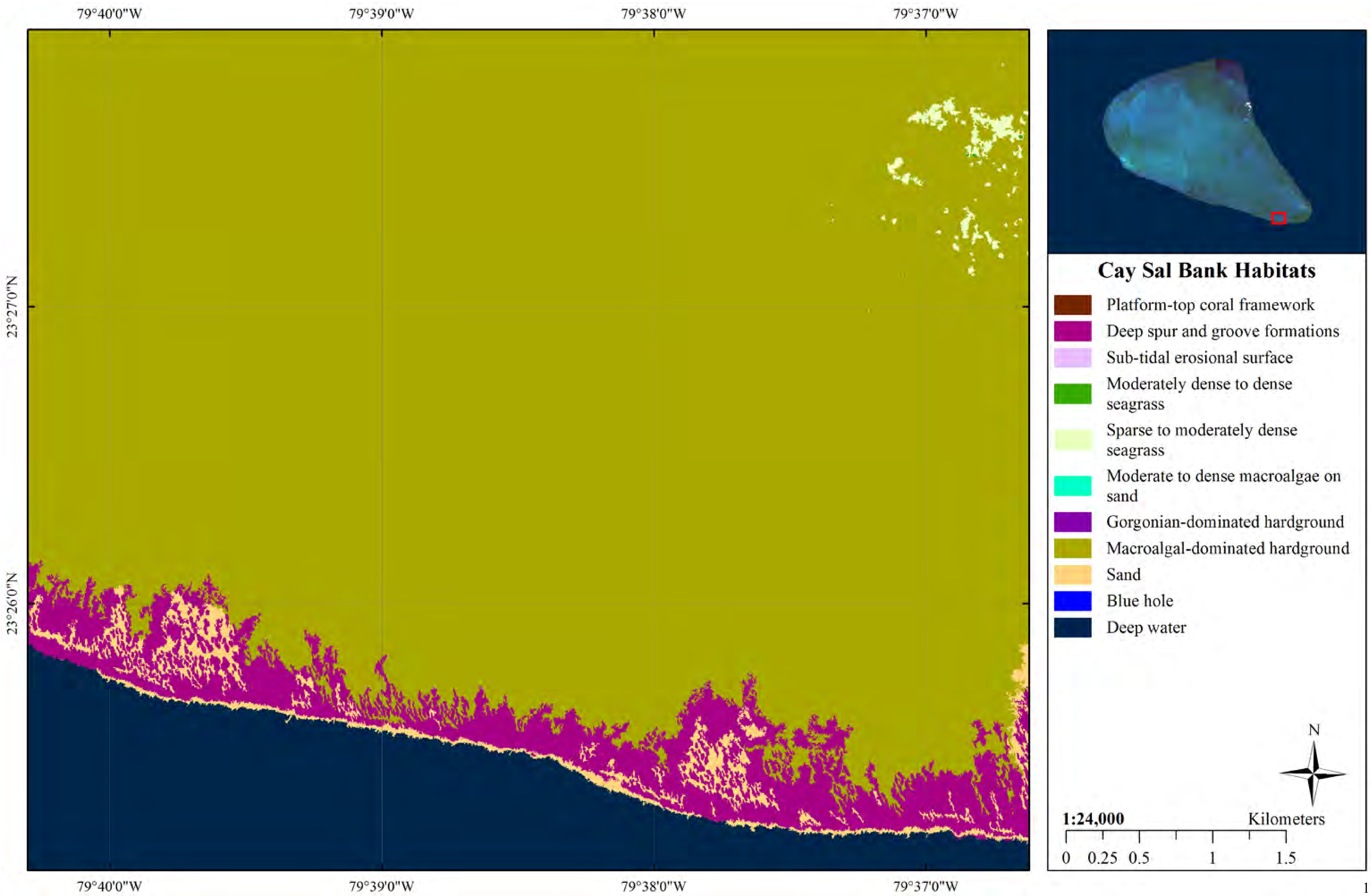


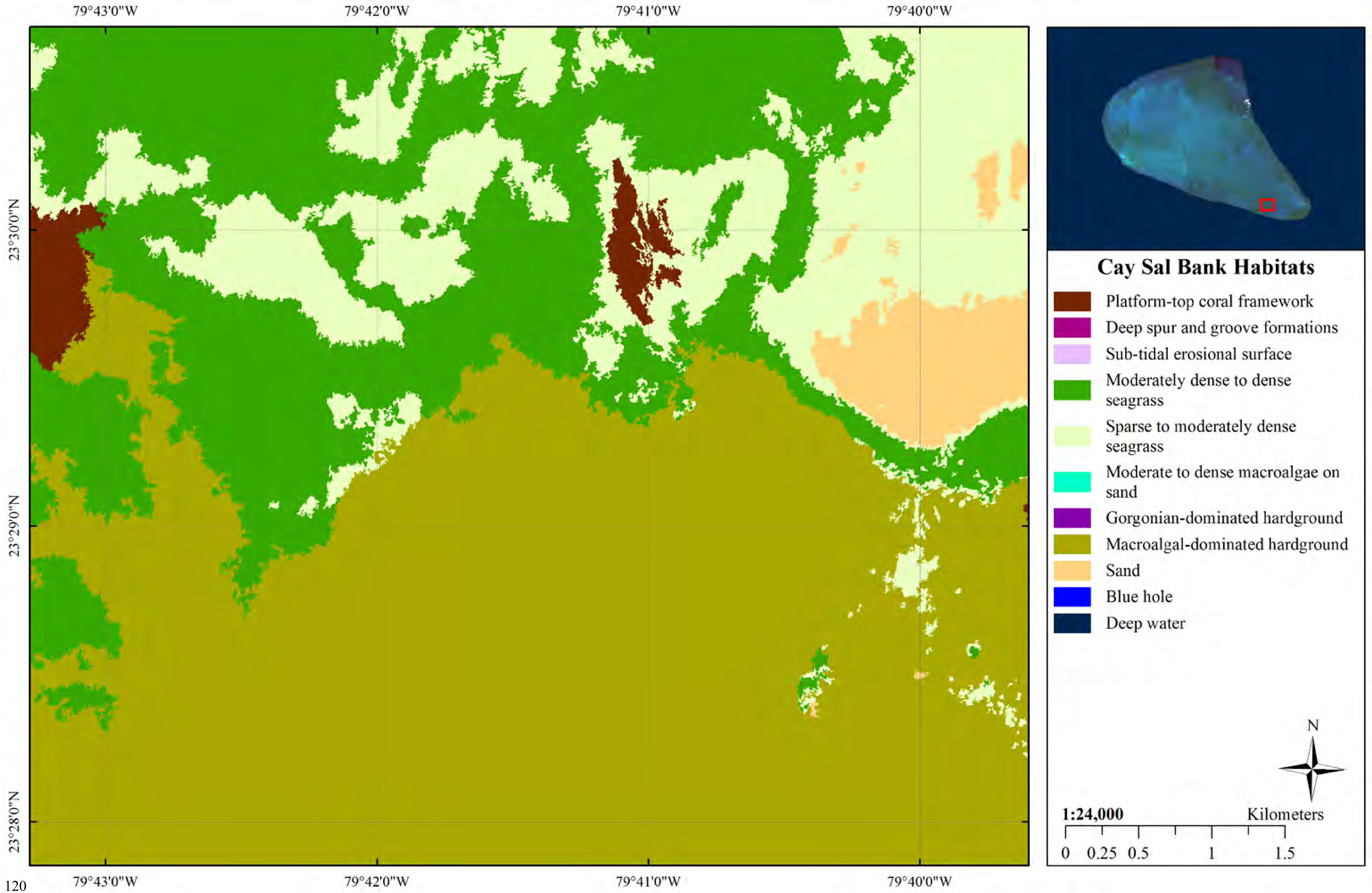
79°36'0"W
79°35'0"W
79°34'0"W
79°33'0"W
23°30'0"N
23°29'0"N
23°28'0"N
Cay Sal Bank Habitats
🟫 Platform-top coral framework
🟪 Deep spur and groove formations
🟪 Sub-tidal erosional surface
🟩 Moderately dense to dense seagrass
🟩 Sparse to moderately dense seagrass
🟦 Moderate to dense macroalgae on sand
🟪 Gorgonian-dominated hardground
🟫 Macroalgal-dominated hardground
🟧 Sand
🟦 Blue hole
🟦 Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

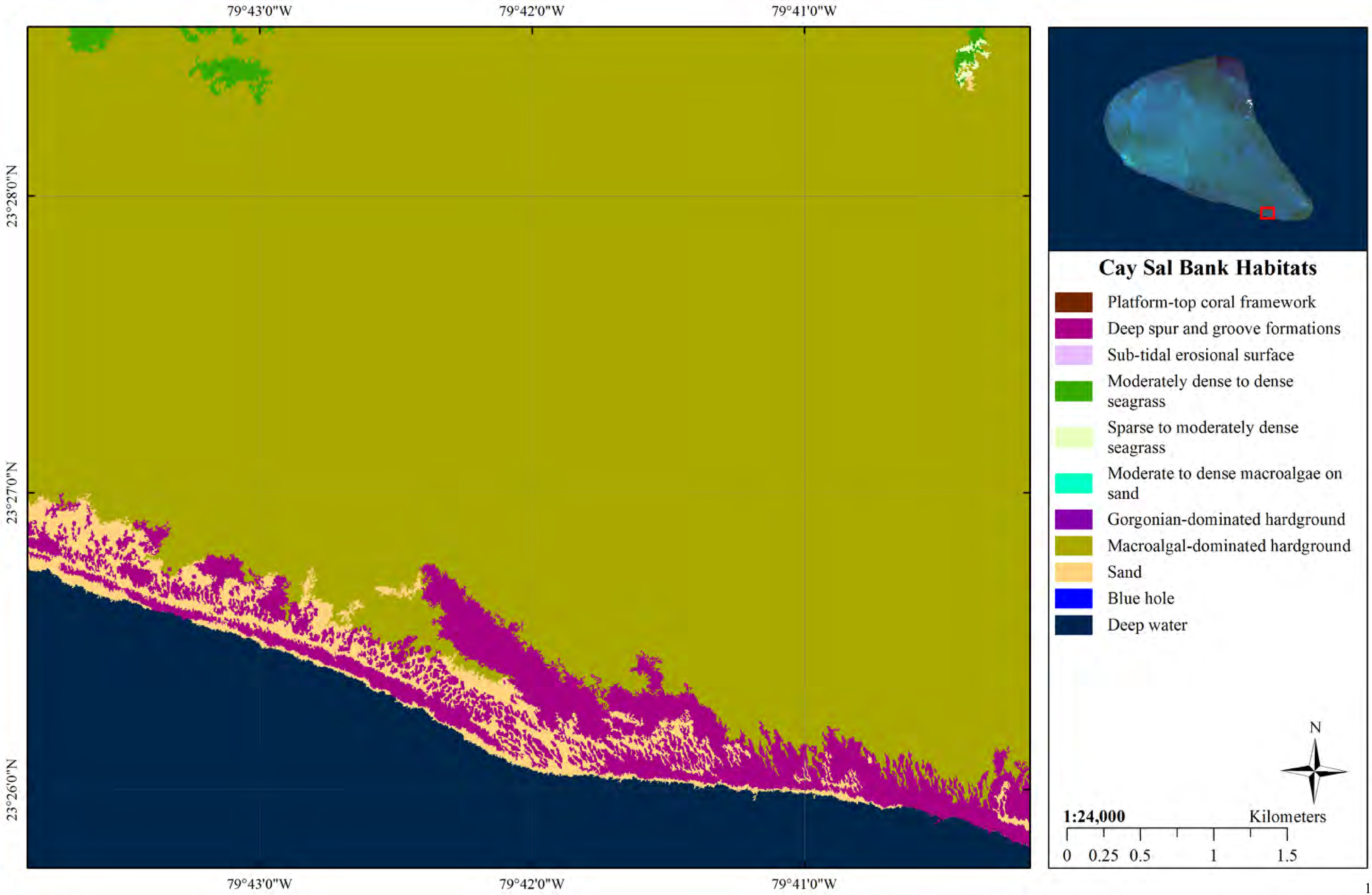


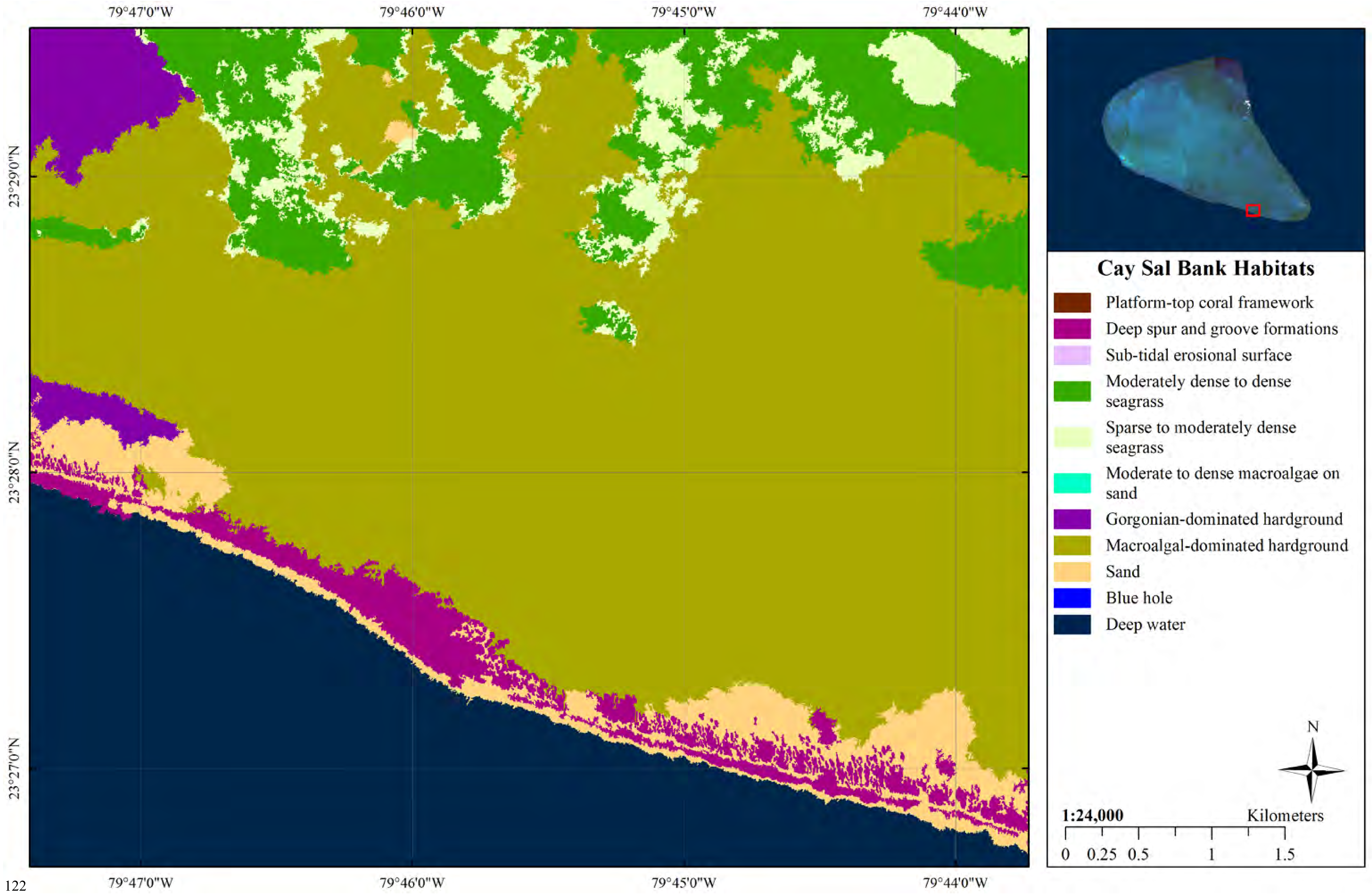
79°36'0"W
79°35'0"W
79°34'0"W
23°27'0"N
23°26'0"N
Cay Sal Bank Habitats
🟫 Platform-top coral framework
🟪 Deep spur and groove formations
🟪 Sub-tidal erosional surface
🟩 Moderately dense to dense seagrass
🟩 Sparse to moderately dense seagrass
🟦 Moderate to dense macroalgae on sand
🟪 Gorgonian-dominated hardground
🟫 Macroalgal-dominated hardground
🟧 Sand
🟦 Blue hole
🟦 Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

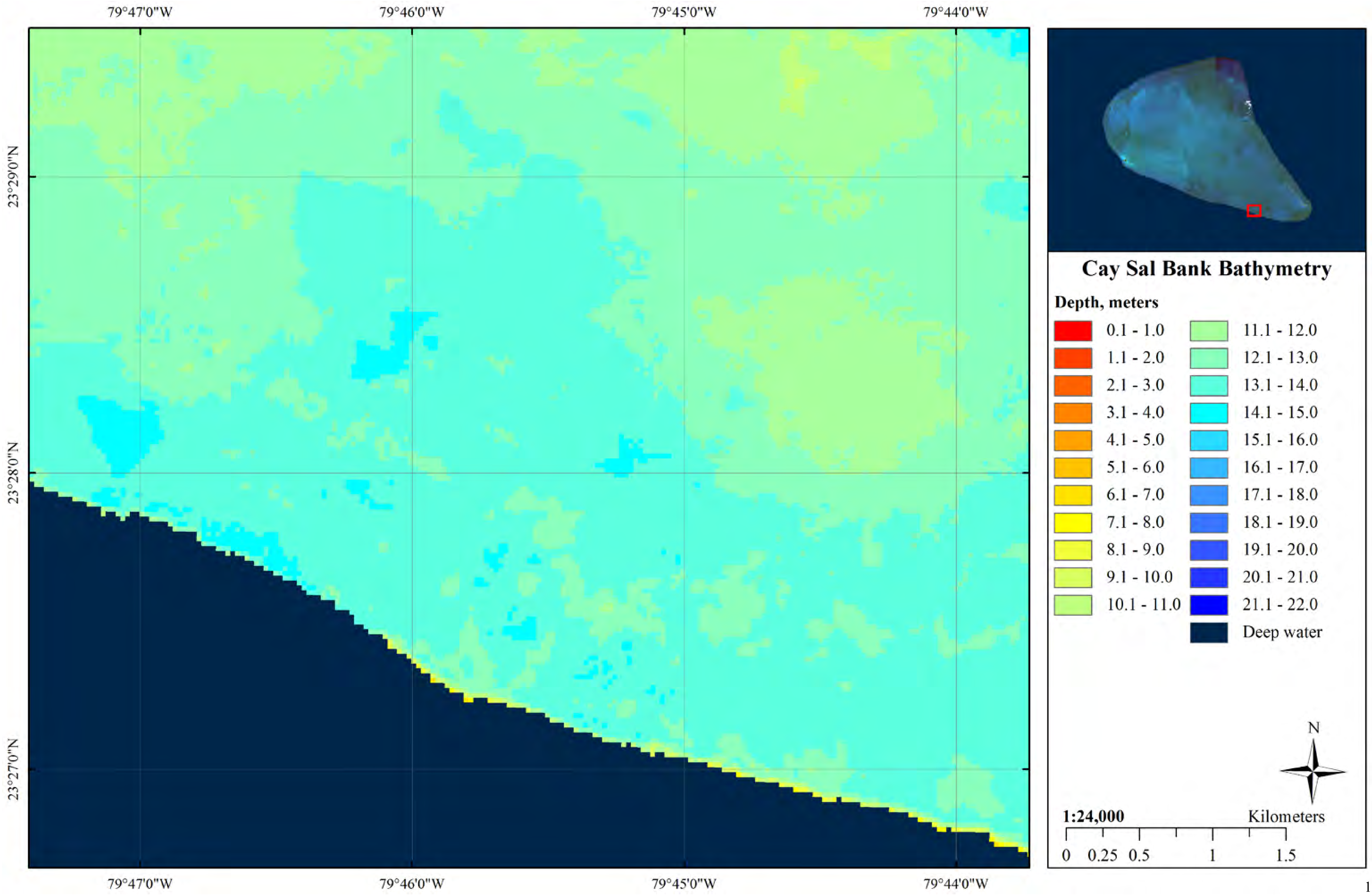

79°39'0"W
79°38'0"W
79°37'0"W
79°36'0"W
23°30'0"N
23°29'0"N
23°28'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

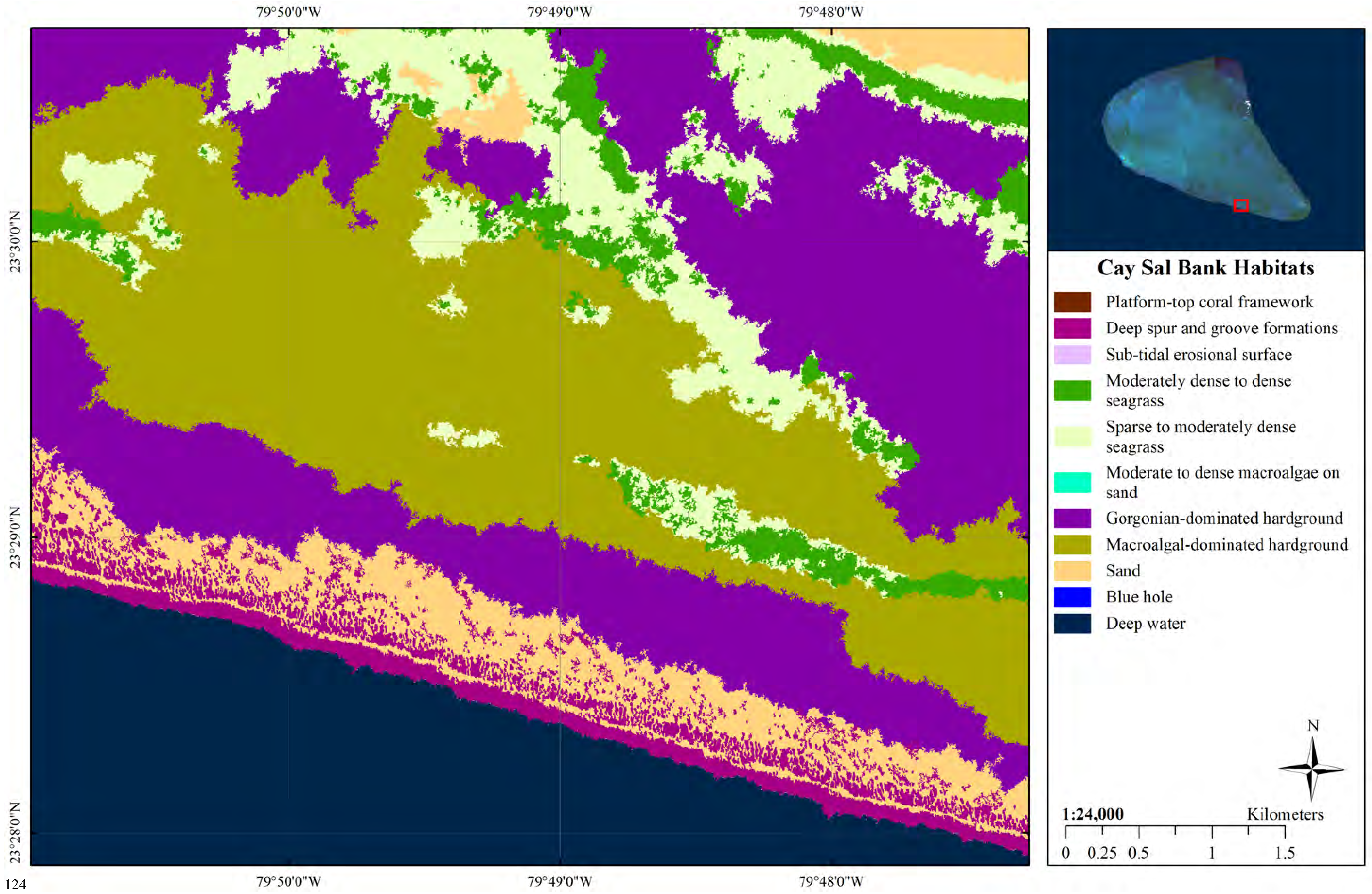

79°40'0"W
79°39'0"W
79°38'0"W
79°37'0"W
23°27'0"N
23°26'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

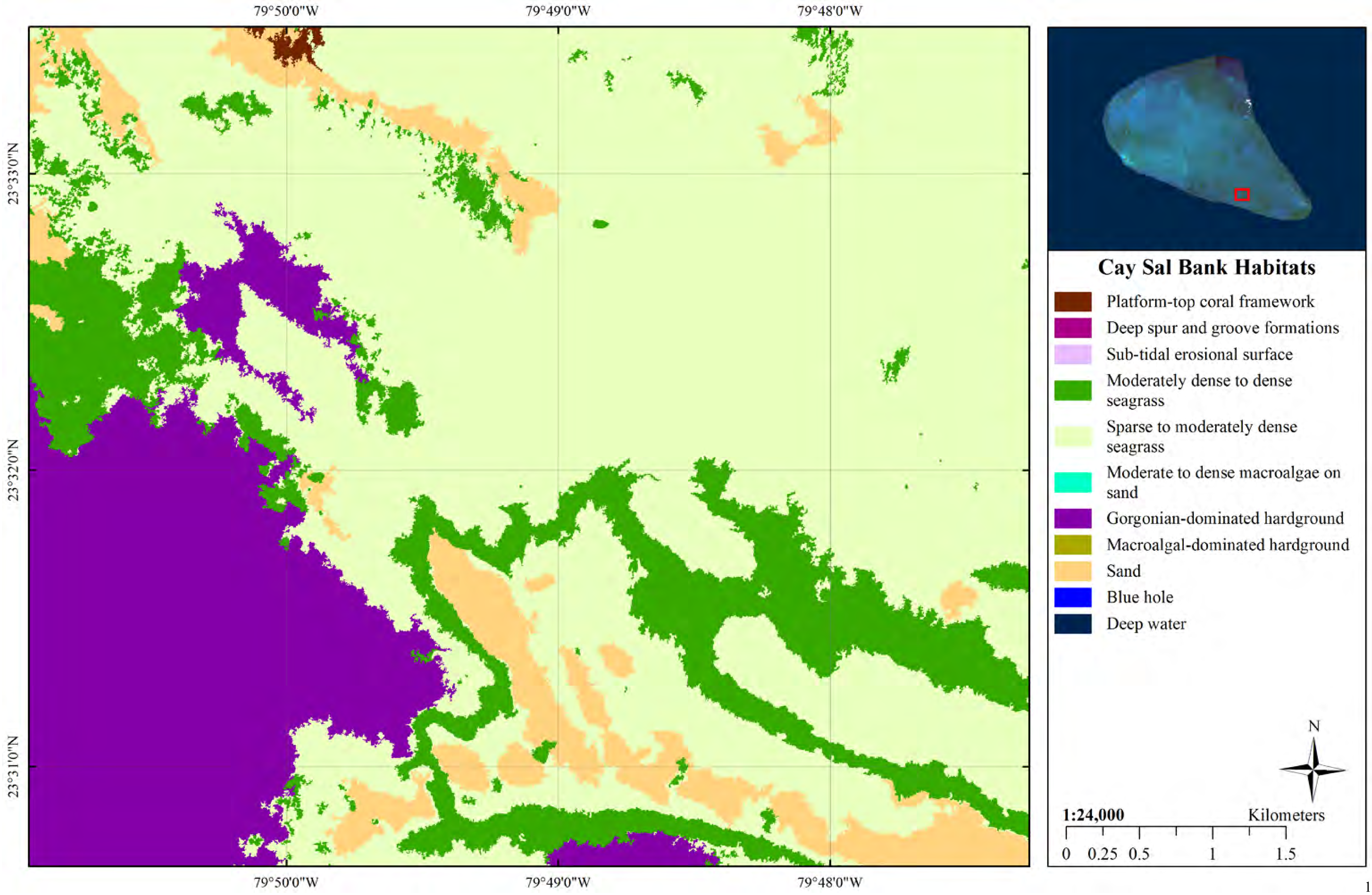

79°43'0"W
79°42'0"W
79°41'0"W
79°40'0"W
23°30'0"N
23°29'0"N
23°28'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

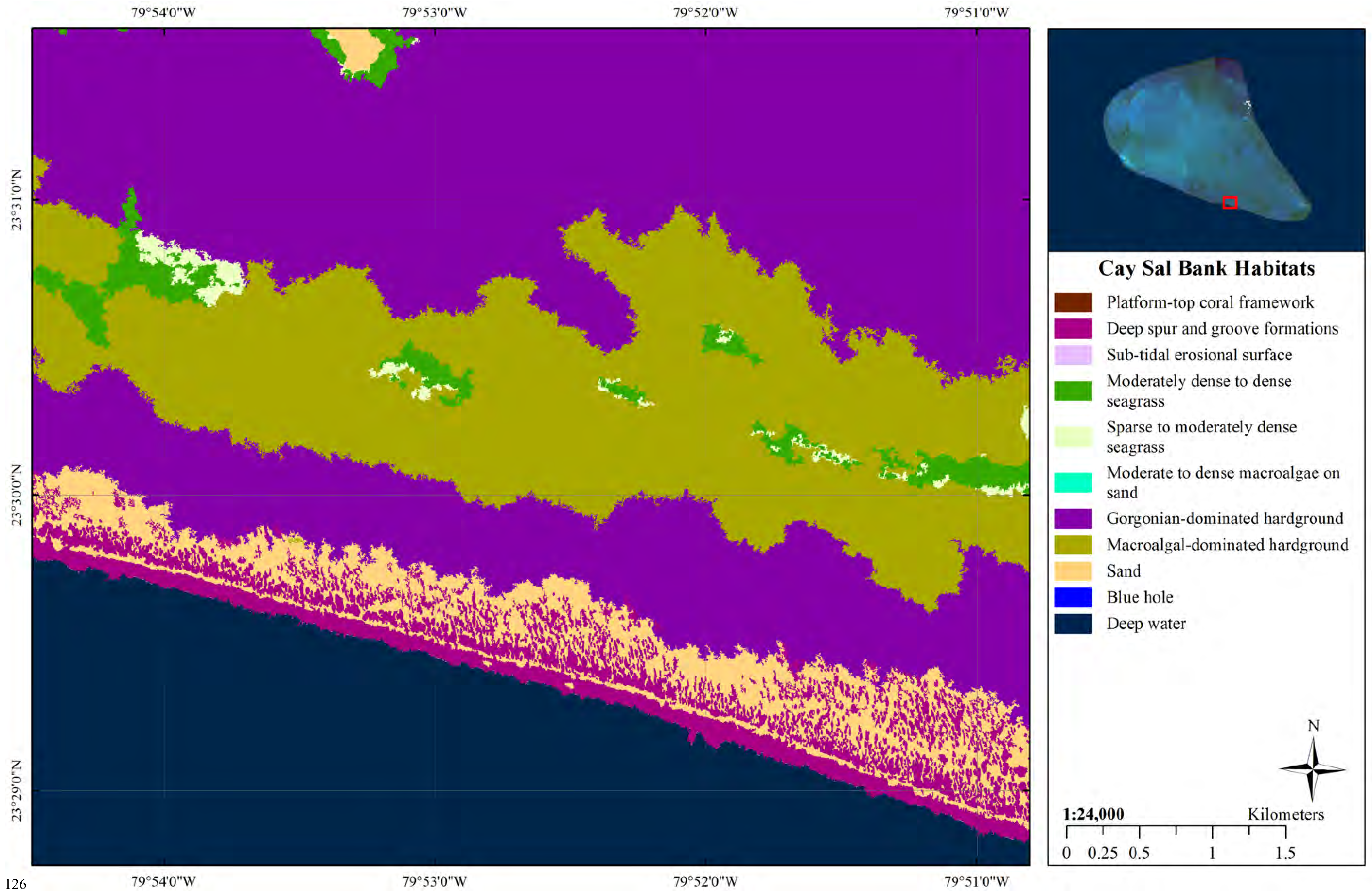

79°43'0"W
79°42'0"W
79°41'0"W
23°28'0"N
23°27'0"N
23°26'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

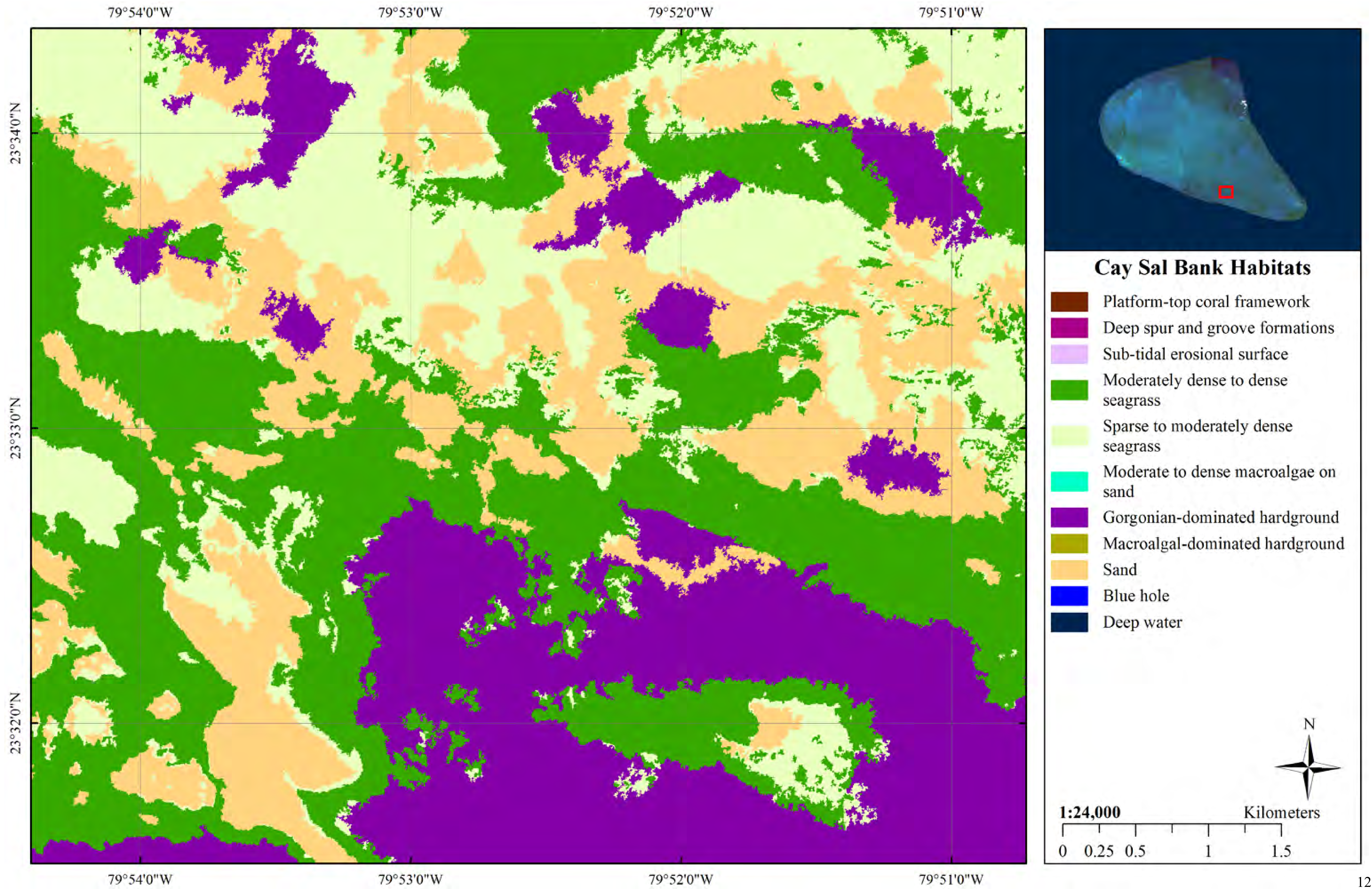

79°47'0"W
79°46'0"W
79°45'0"W
79°44'0"W
23°29'0"N
23°28'0"N
23°27'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

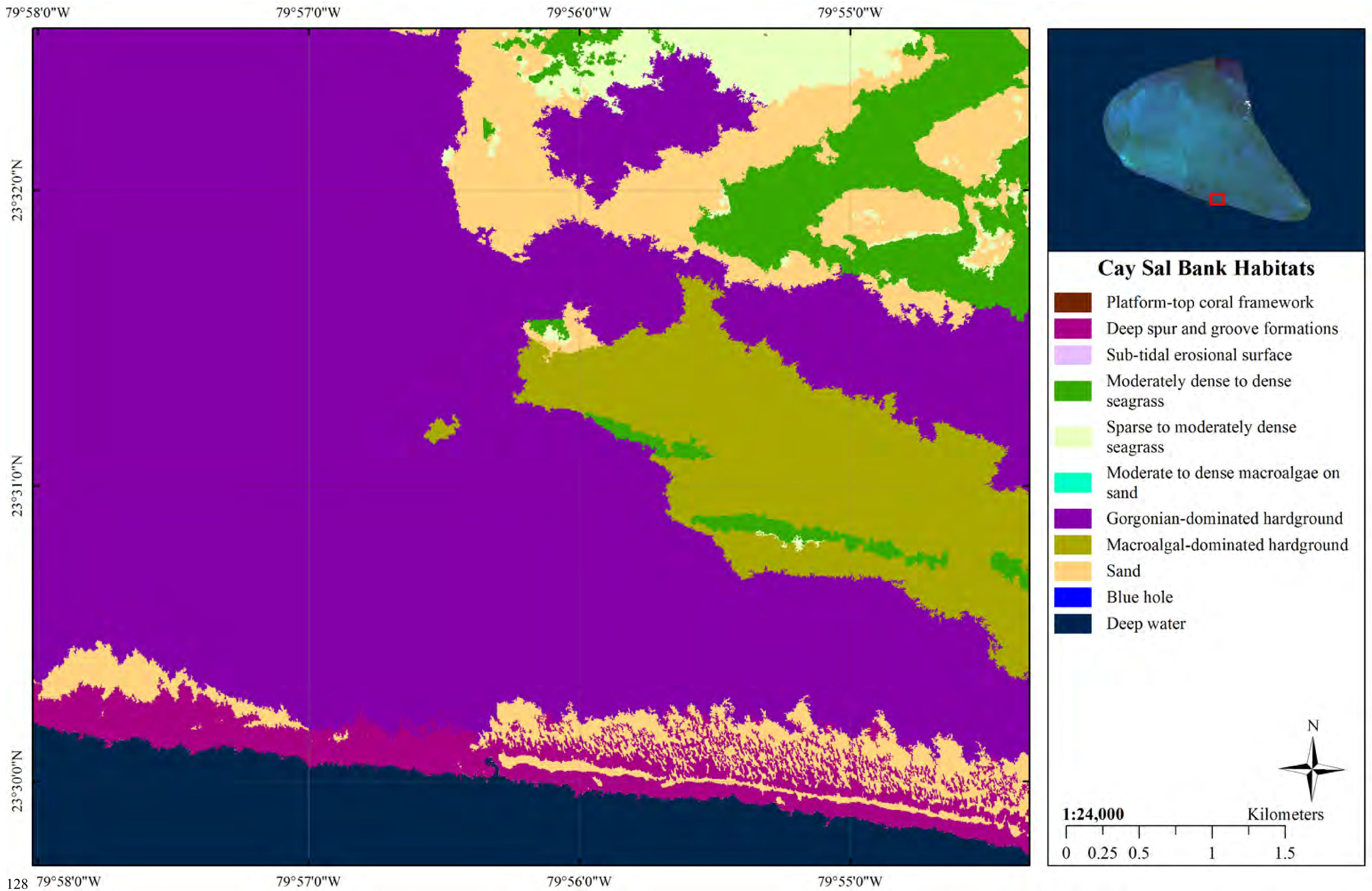

79°47'0"W
79°46'0"W
79°45'0"W
79°44'0"W
23°29'0"N
23°28'0"N
23°27'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

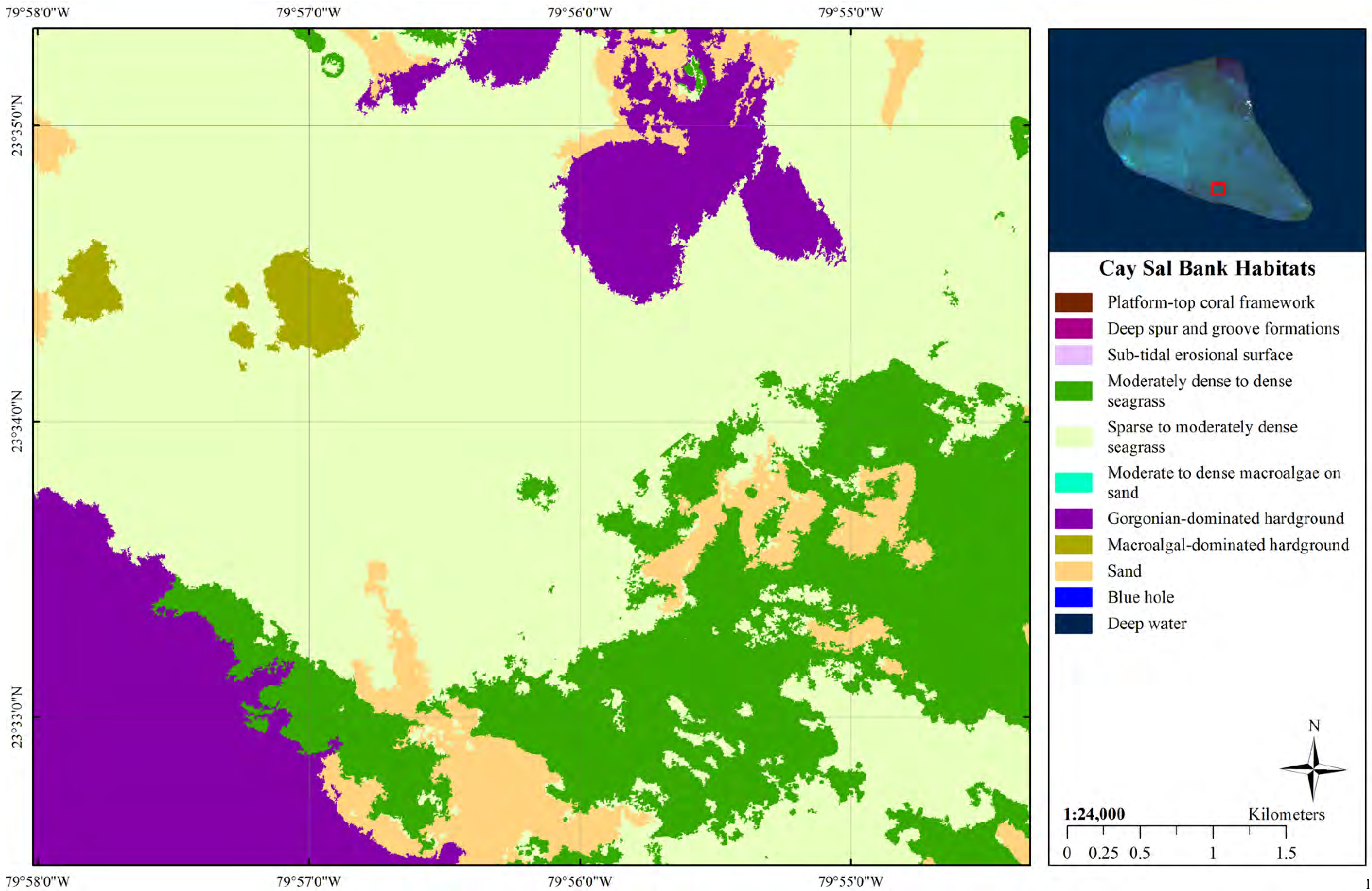

79°50'0"W
79°49'0"W
79°48'0"W
23°30'0"N
23°29'0"N
23°28'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

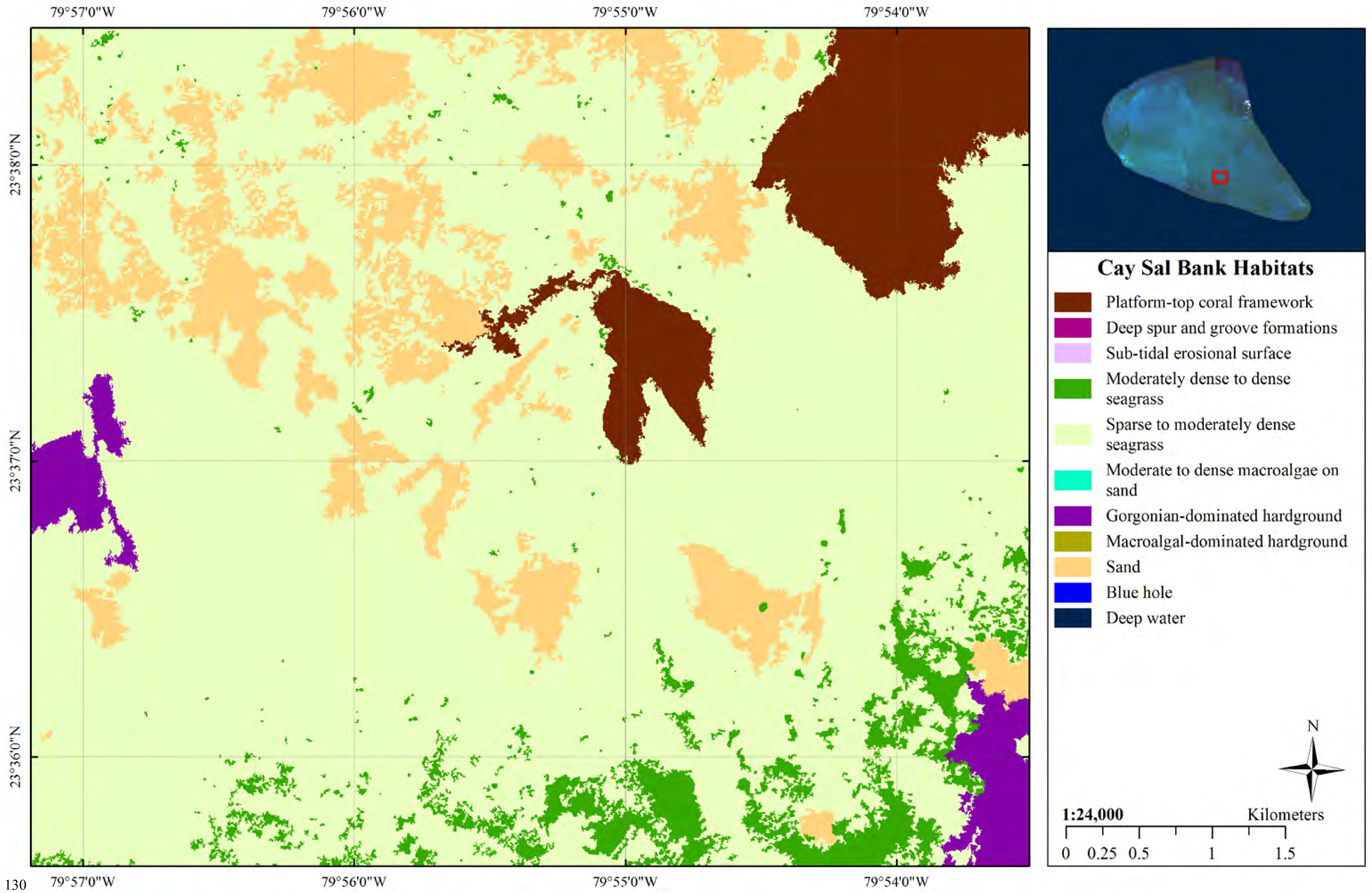

79°50'0"W
79°49'0"W
79°48'0"W
23°33'0"N
23°32'0"N
23°31'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

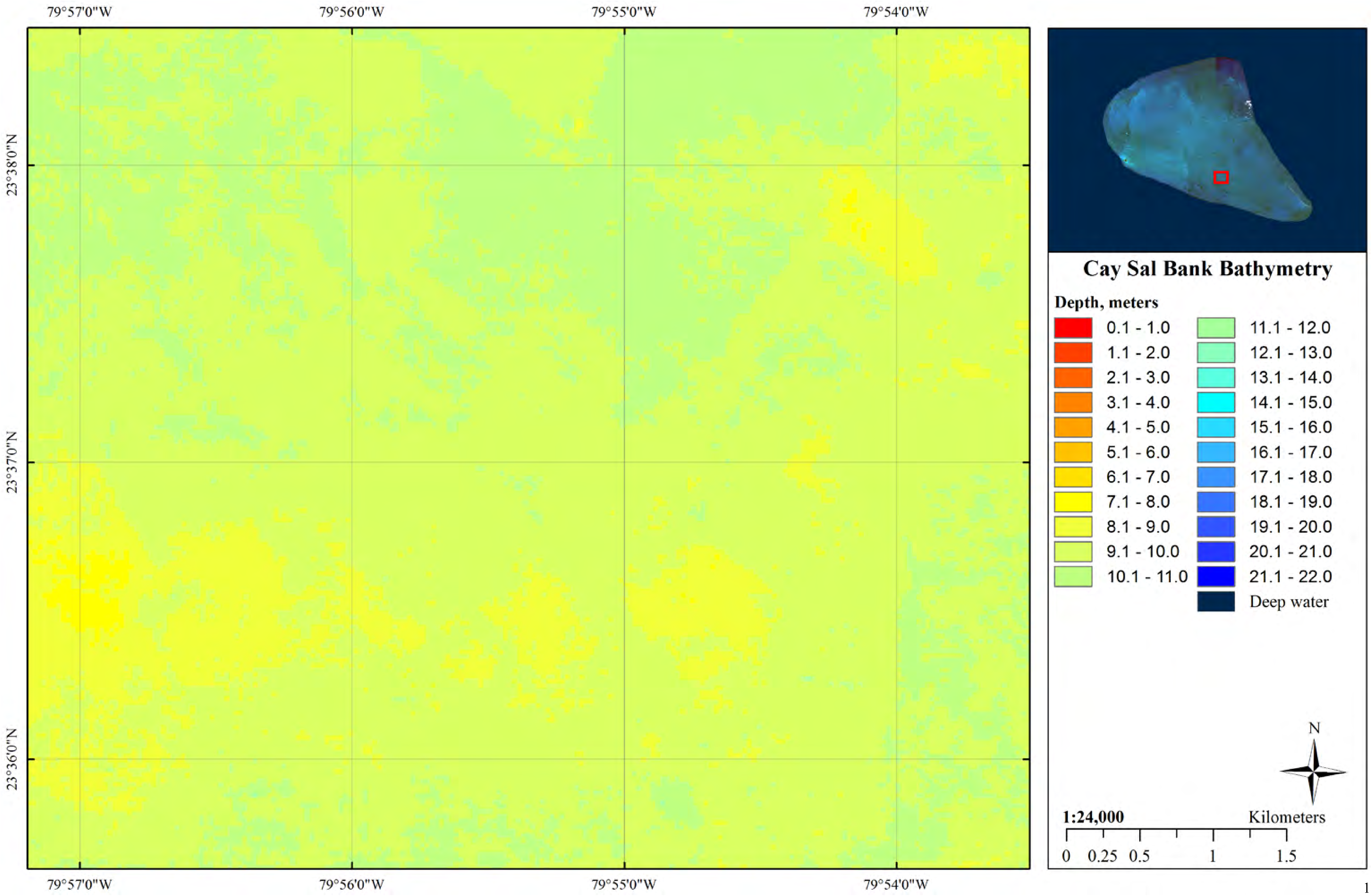

79°54'0"W
79°53'0"W
79°52'0"W
79°51'0"W
23°31'0"N
23°30'0"N
23°29'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

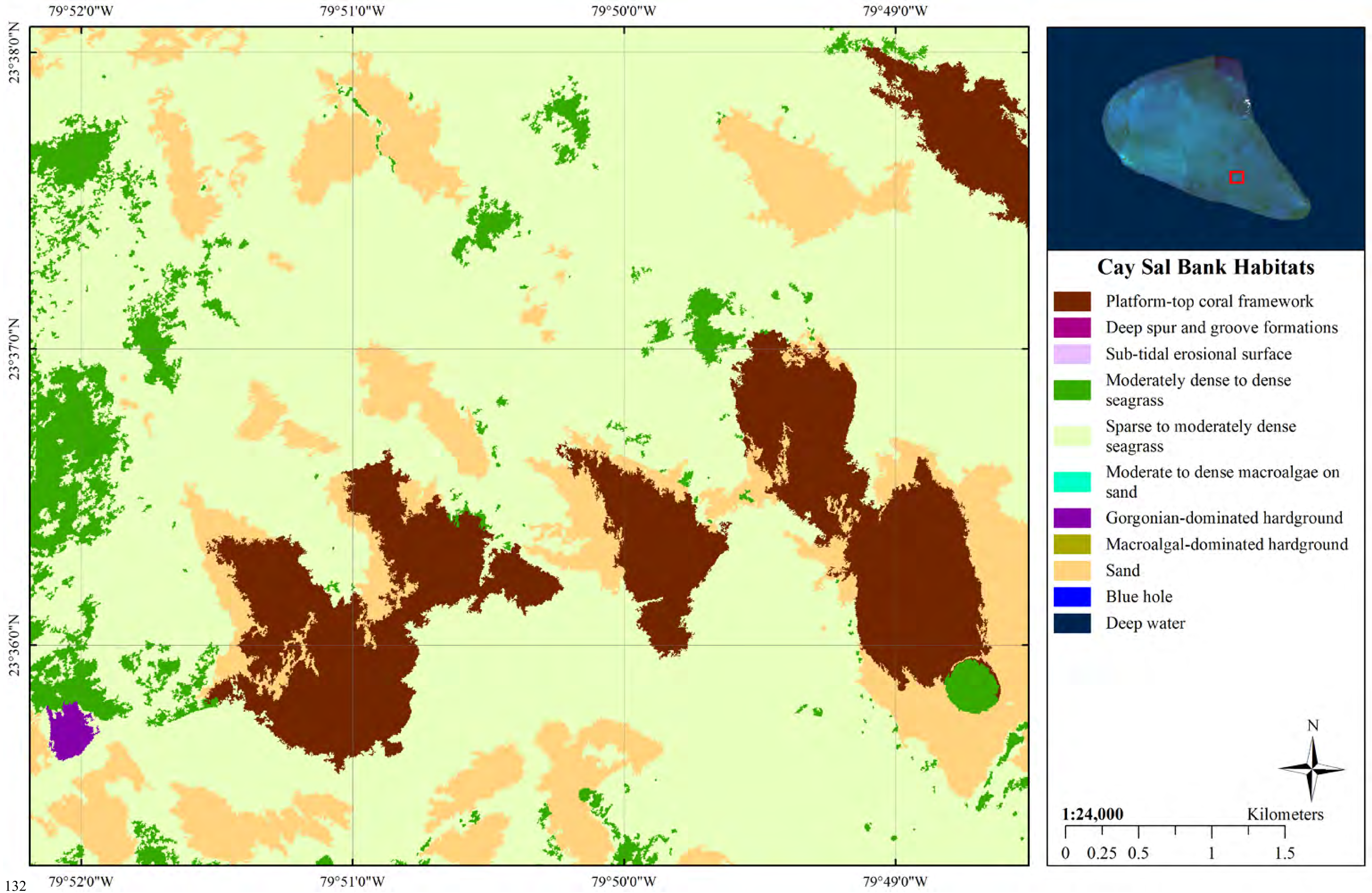

79°54'0"W
79°53'0"W
79°52'0"W
79°51'0"W
23°34'0"N
23°33'0"N
23°32'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

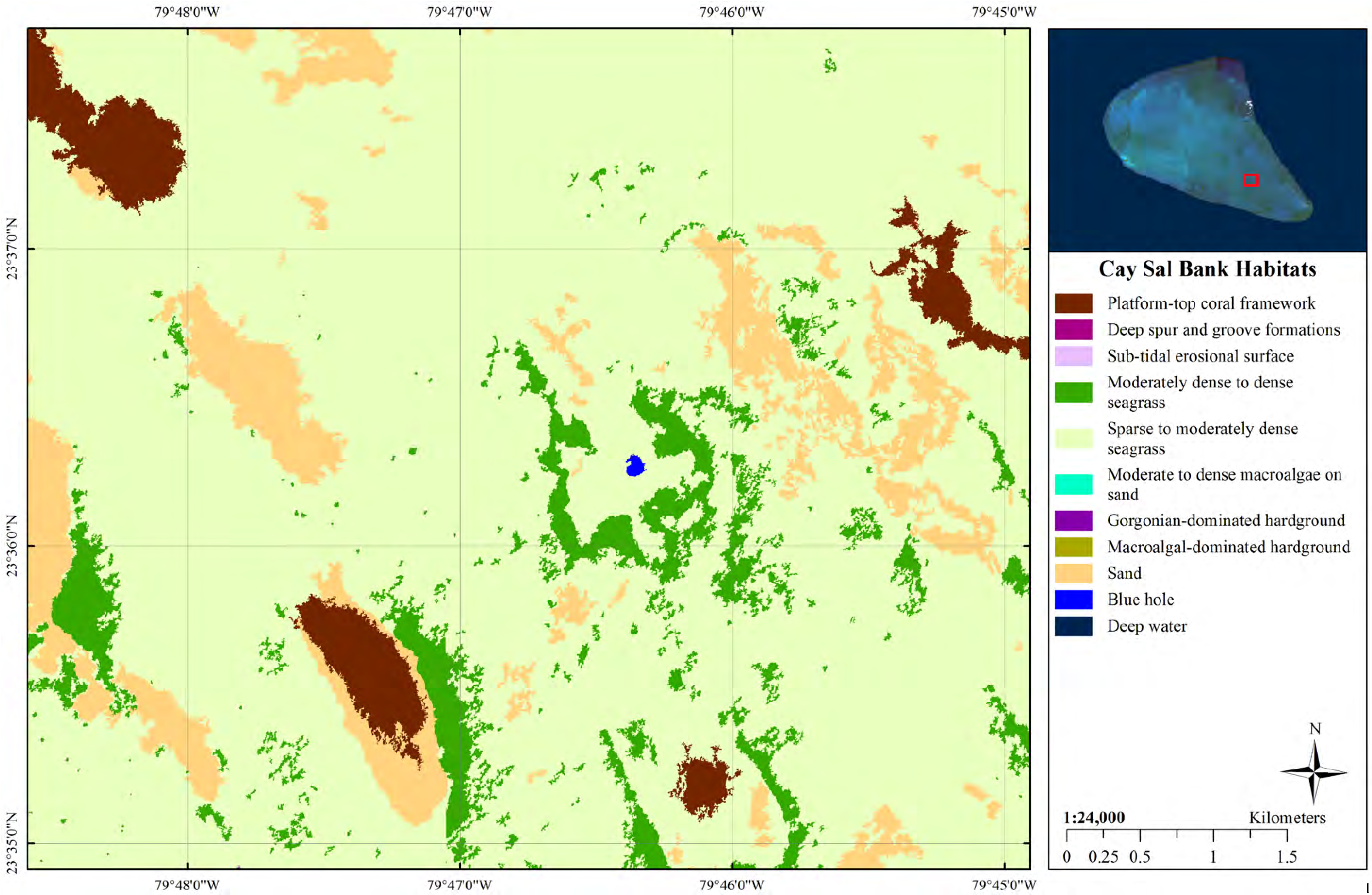

79°58'0"W
79°57'0"W
79°56'0"W
79°55'0"W
23°32'0"N
23°31'0"N
23°30'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

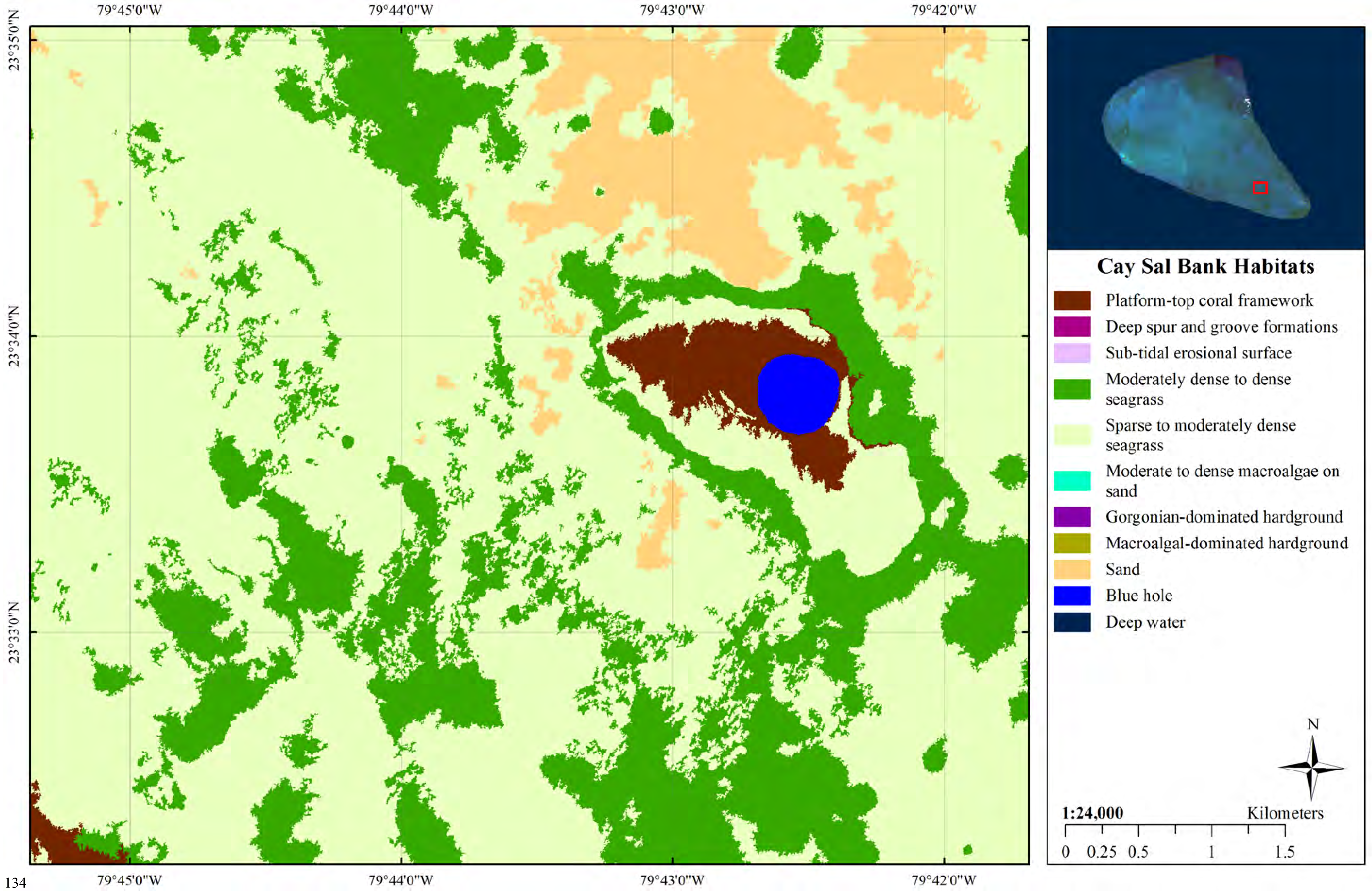

79°58'0"W
79°57'0"W
79°56'0"W
79°55'0"W
23°35'0"N
23°34'0"N
23°33'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

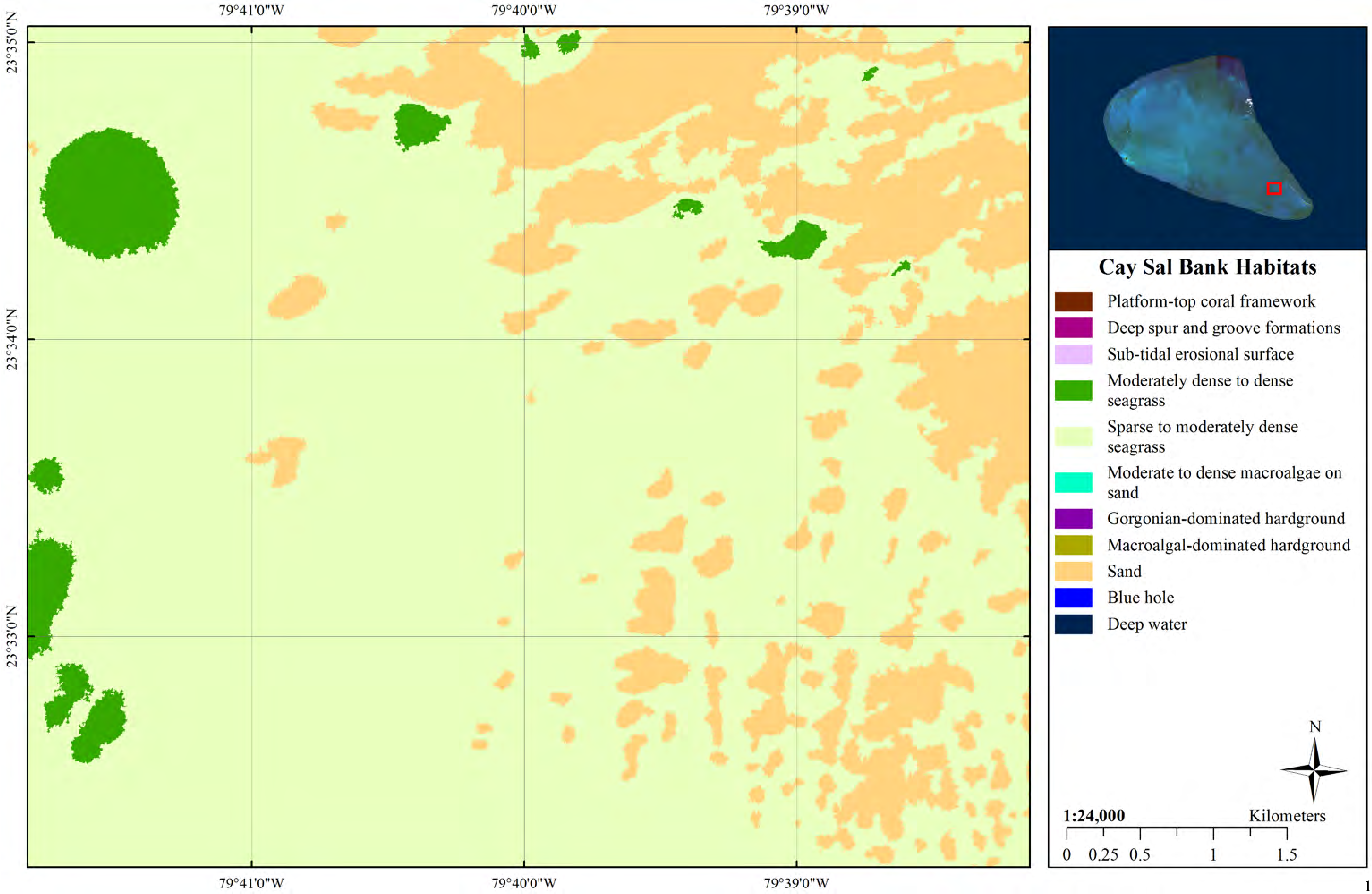

79°57'0"W
79°56'0"W
79°55'0"W
79°54'0"W
23°38'0"N
23°37'0"N
23°36'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


79°57'0"W
79°56'0"W
79°55'0"W
79°54'0"W
23°38'0"N
23°37'0"N
23°36'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


79°52'0"W
79°51'0"W
79°50'0"W
79°49'0"W
23°38'0"N
23°37'0"N
23°36'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


79°48'0"W
79°47'0"W
79°46'0"W
79°45'0"W
23°37'0"N
23°36'0"N
23°35'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


79°45'0"W
79°44'0"W
79°43'0"W
79°42'0"W
23°35'0"N
23°34'0"N
23°33'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


79°41'0"W
79°40'0"W
79°39'0"W
23°35'0"N
23°34'0"N
23°33'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5







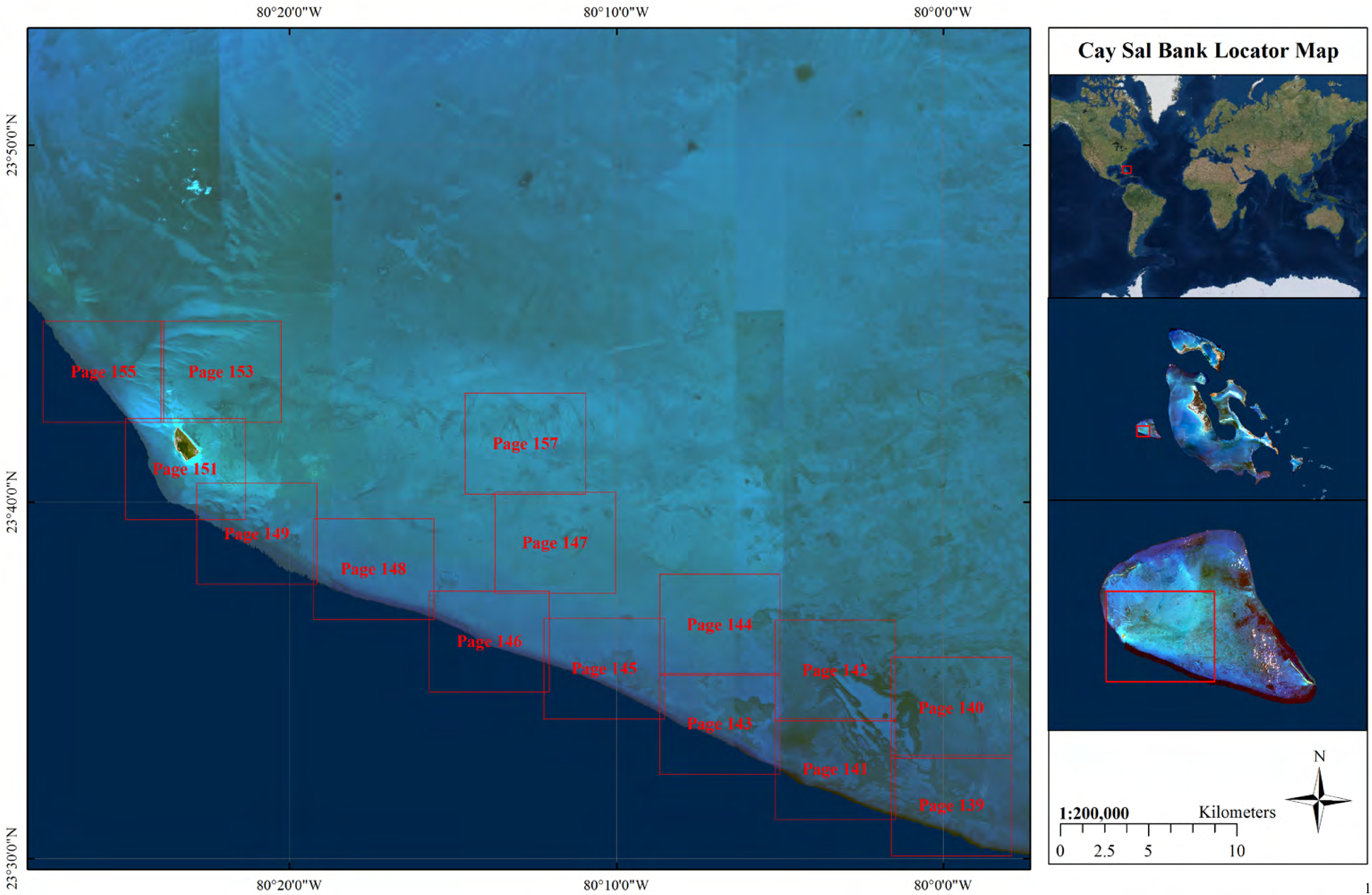

Coral reef scenes on Cay Sal Bank. One of the dominant frame-builders, *Montastraea faveolata*, had been greatly reduced in abundance and health, Very few completely live colonies were seen. The coral shown in the top left was from a shallow patch reef in the southern part of the bank. In most cases, the structure of the skeletons of these corals was still visible, but they had been completely colonized by algae, sponges and soft corals (left center). Frequently, small remnants of living coral remained on the skeletons (bottom left). Over time, these could resheet over the original skeleton, or they can continue growing up and outward.

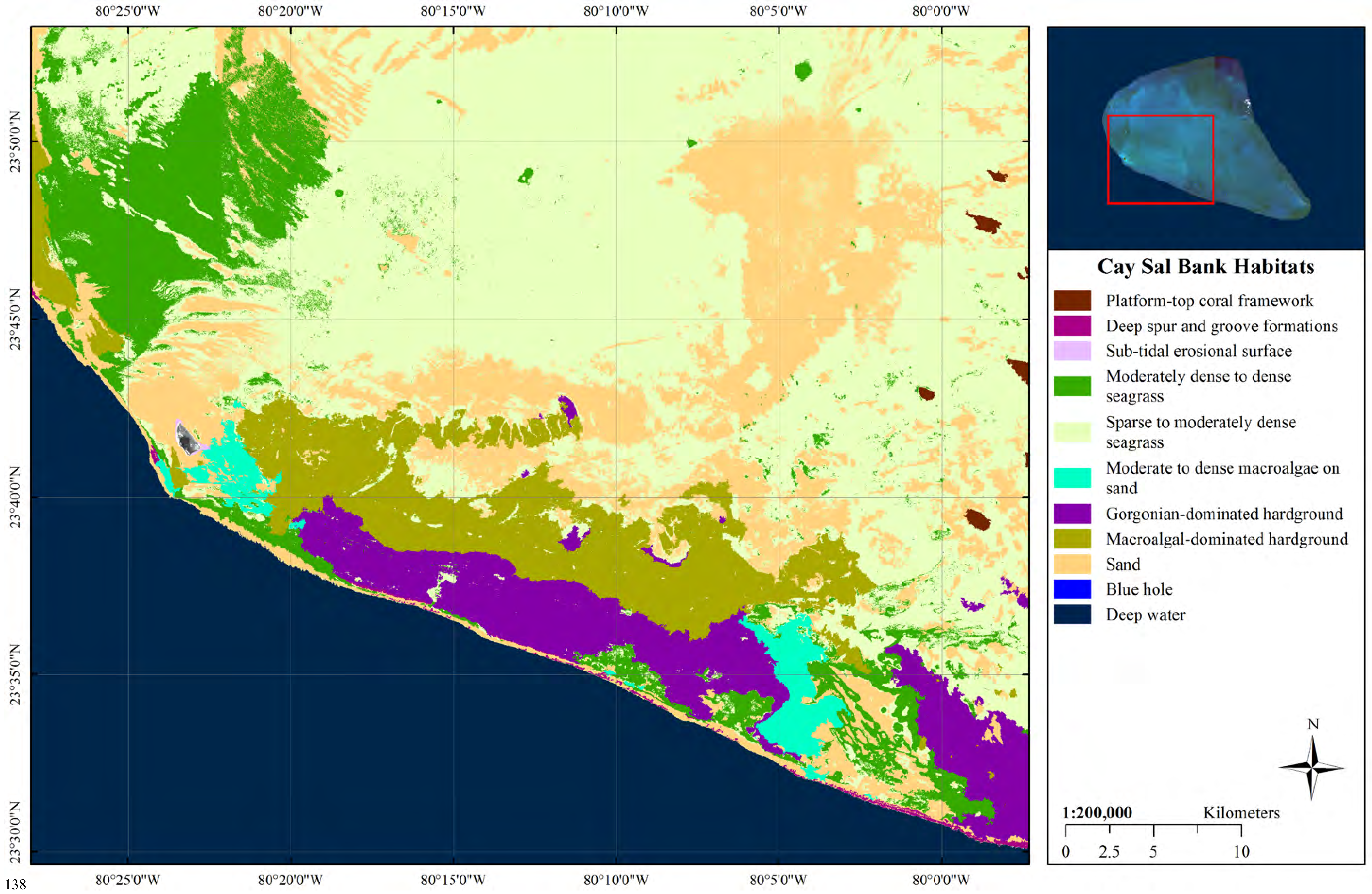
One of the most common corals now seen on Cay Sal Bank is an early colonizer or "weedy species" of coral known as *Porites astreoides* (top center).

Elkhorn coral was found on a single shallow fore reef location. The population consisted of very few completely live larger corals (center). Often, small remnants of live tissue were seen on larger skeletons (bottom center). These appeared healthy and may serve to restore populations of this coral.

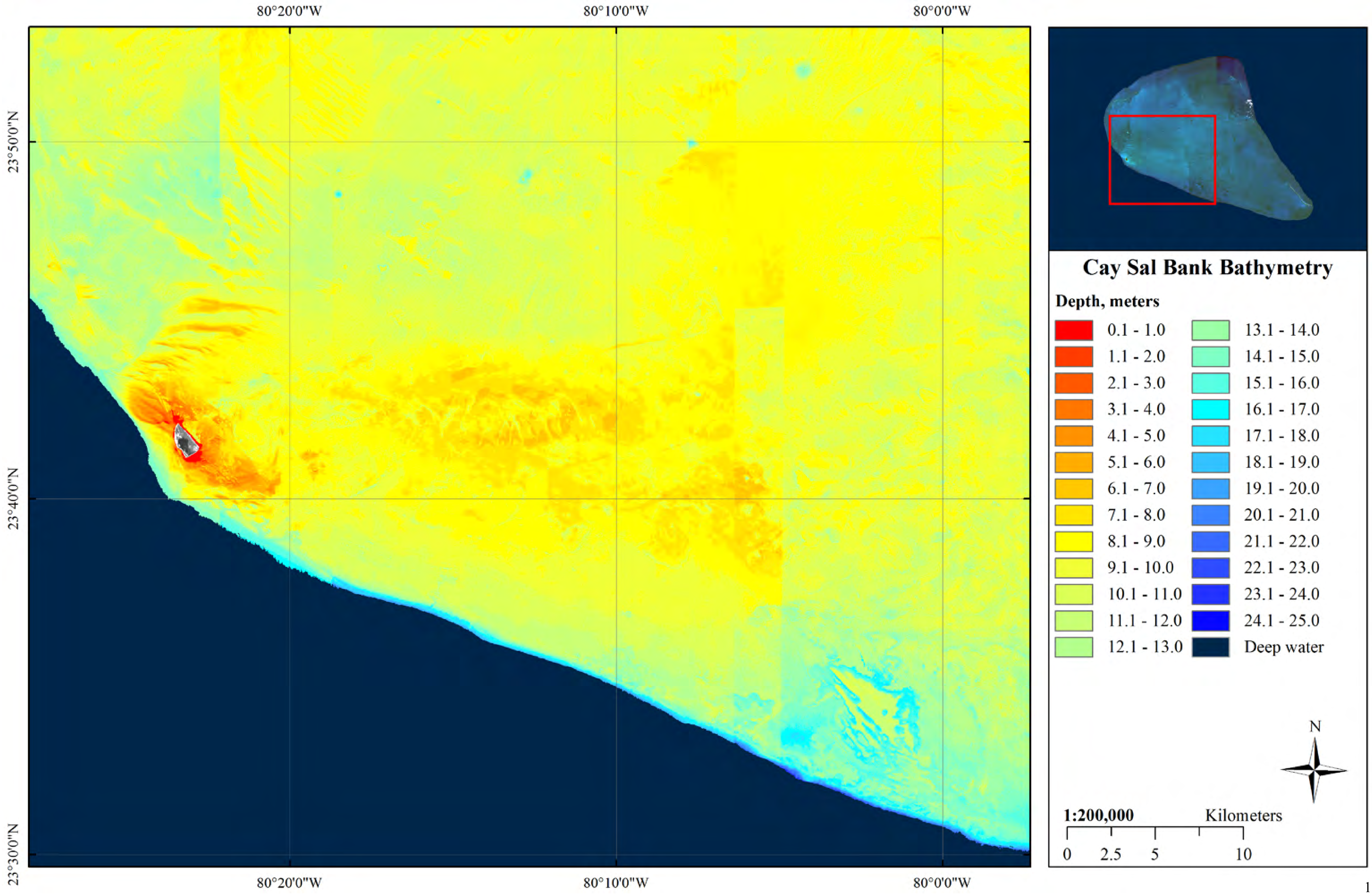
Unusual corals were found in seagrass beds such as the *Meandrina* brain coral shown in the top right.

Cay Sal Bank had many ridges and undercut ledges that provided important habitat for lobsters (bottom right).

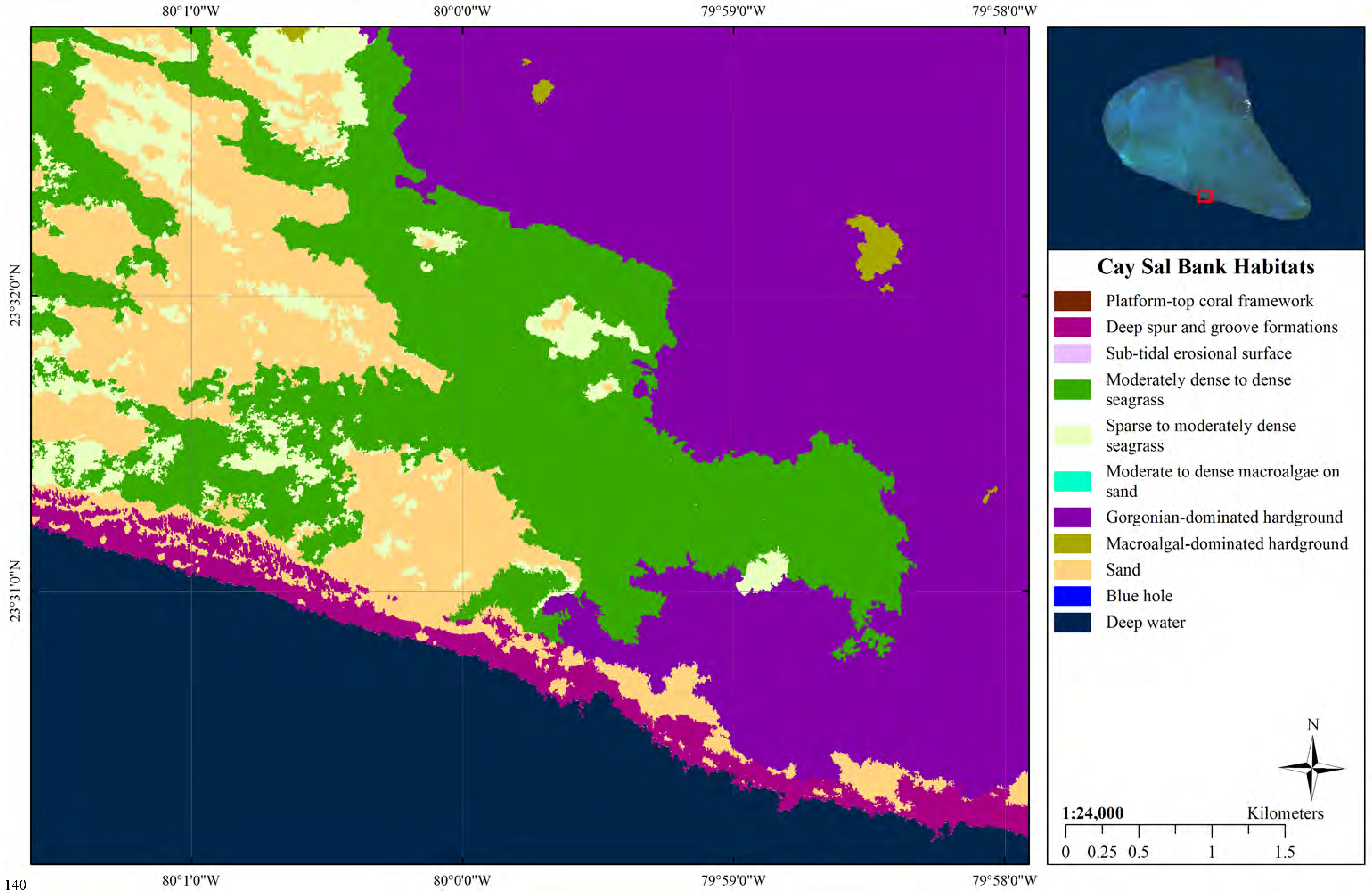


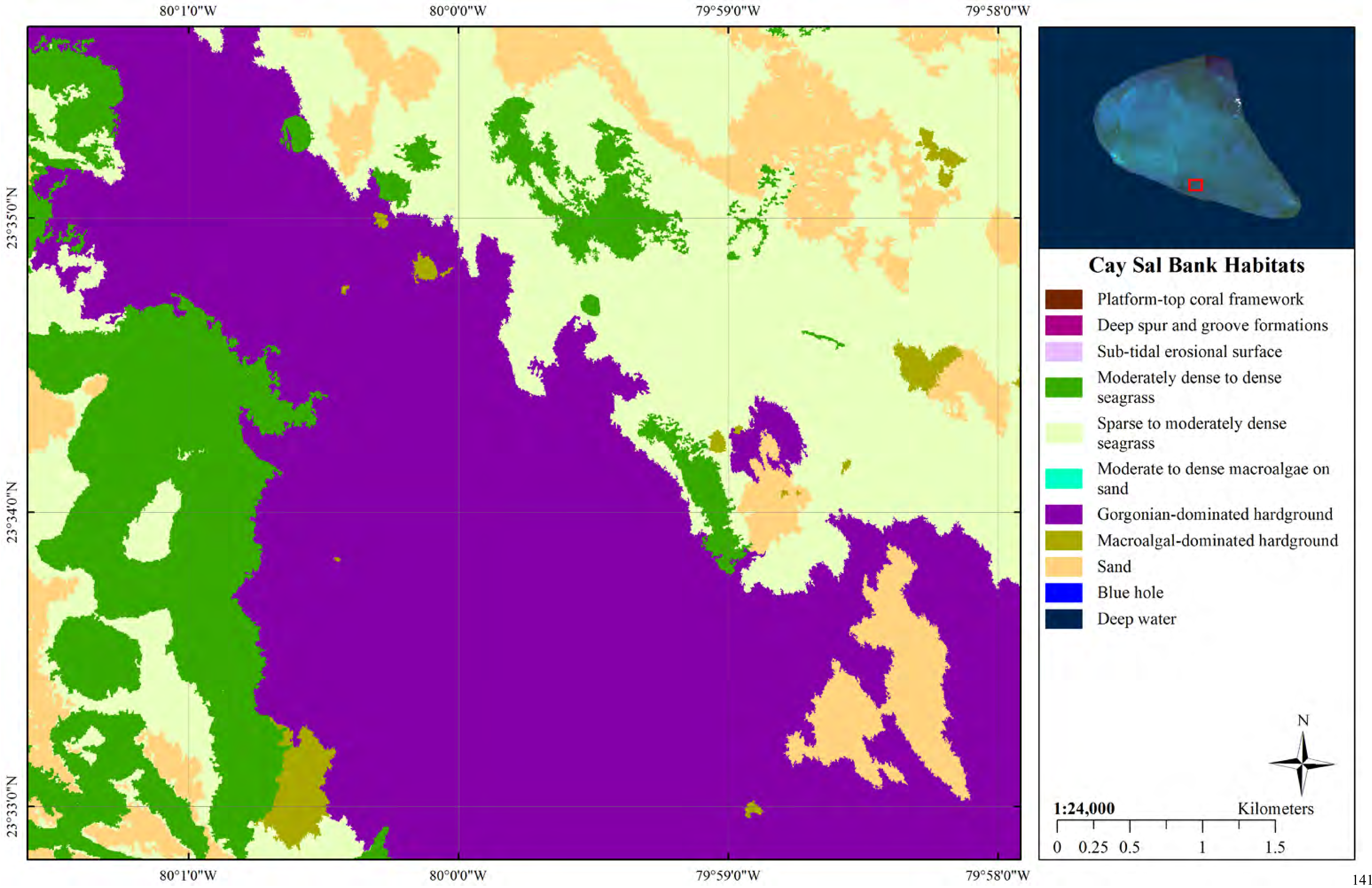


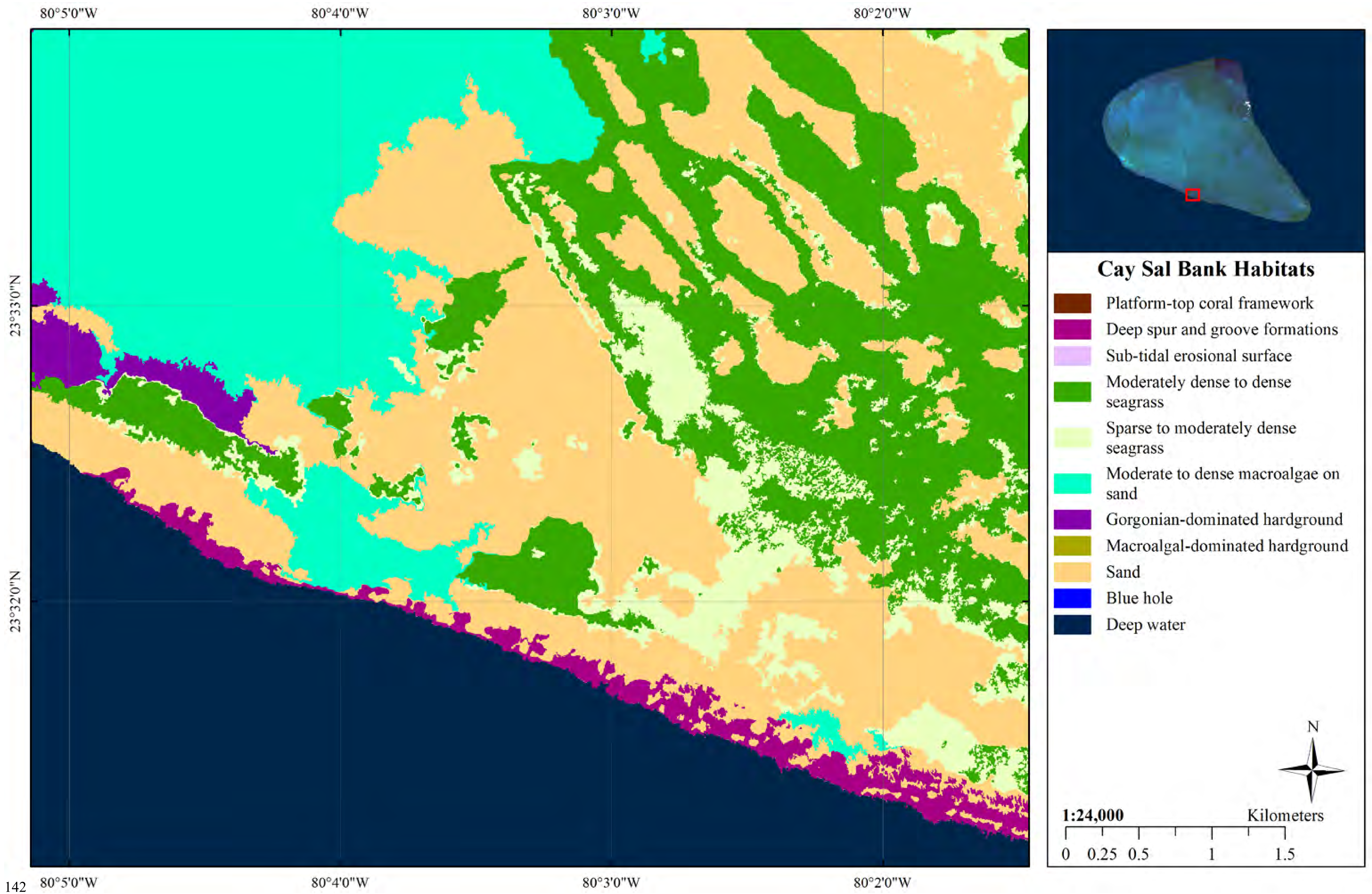
80°25'0"W
80°20'0"W
80°15'0"W
80°10'0"W
80°5'0"W
80°0'0"W
23°50'0"N
23°45'0"N
23°40'0"N
23°35'0"N
23°30'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:200,000
Kilometers
0
2.5
5
10

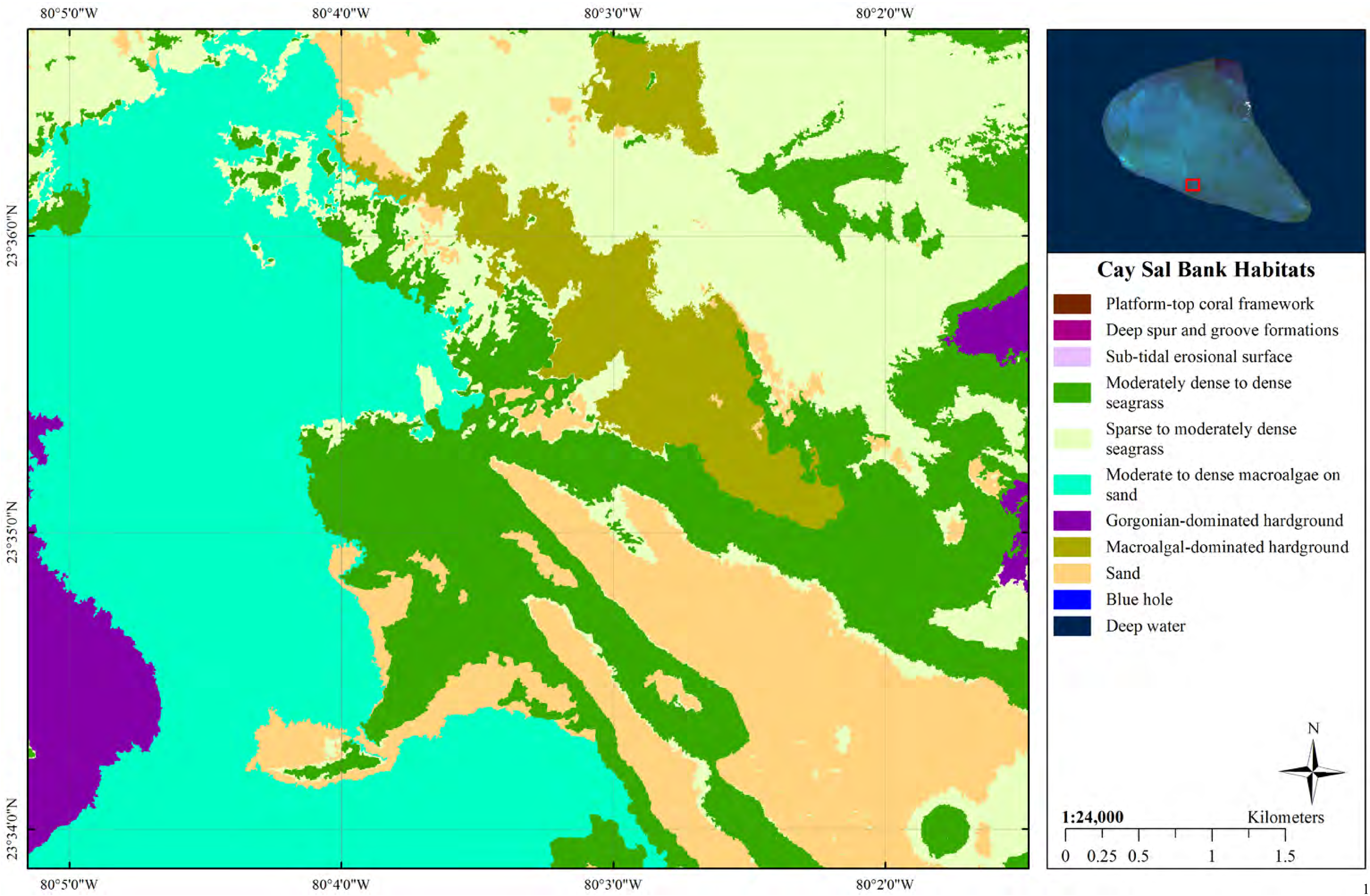


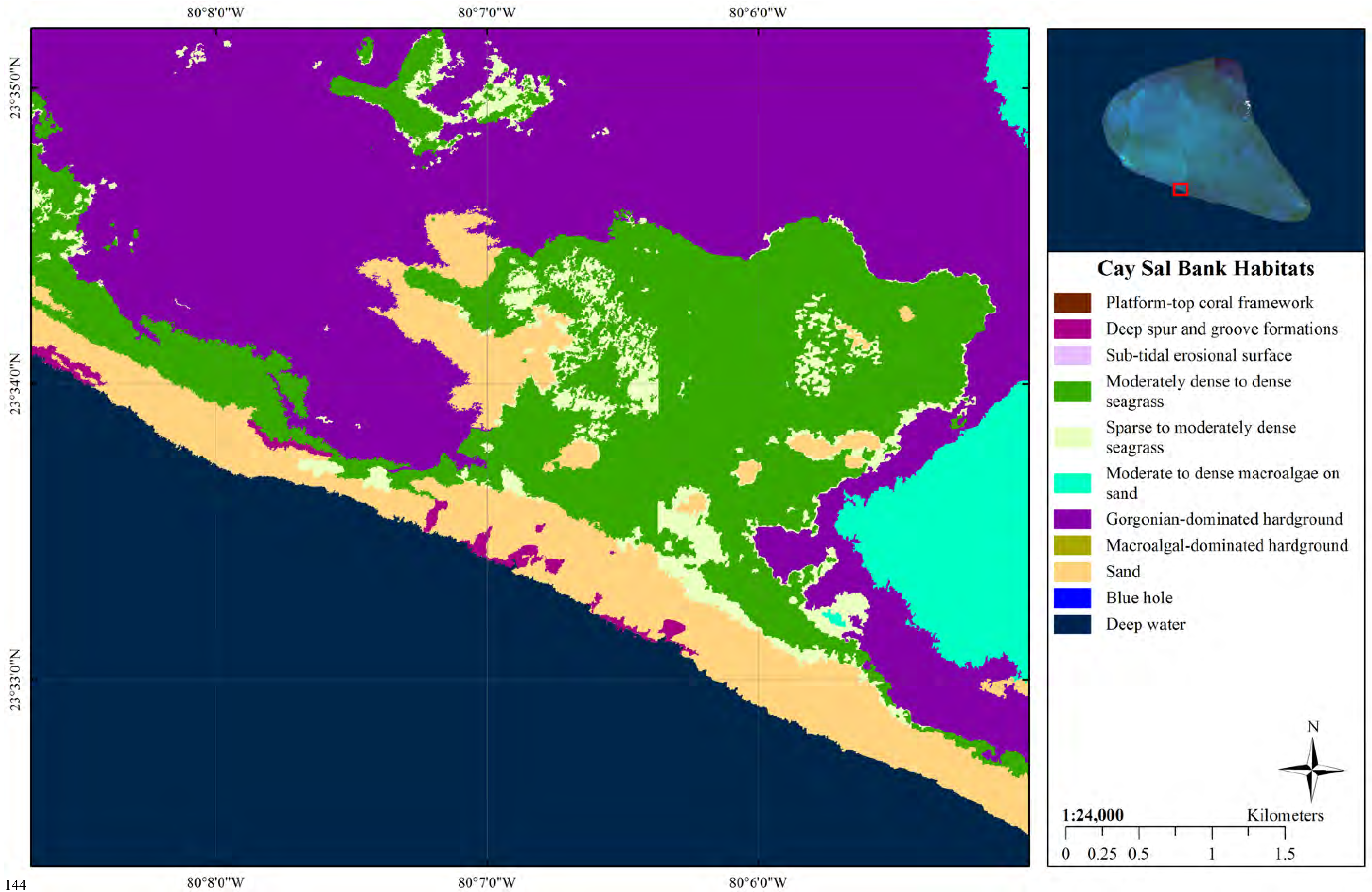
80°20'0"W
80°10'0"W
80°0'0"W
23°50'0"N
23°40'0"N
23°30'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:200,000
Kilometers
0
2.5
5
10

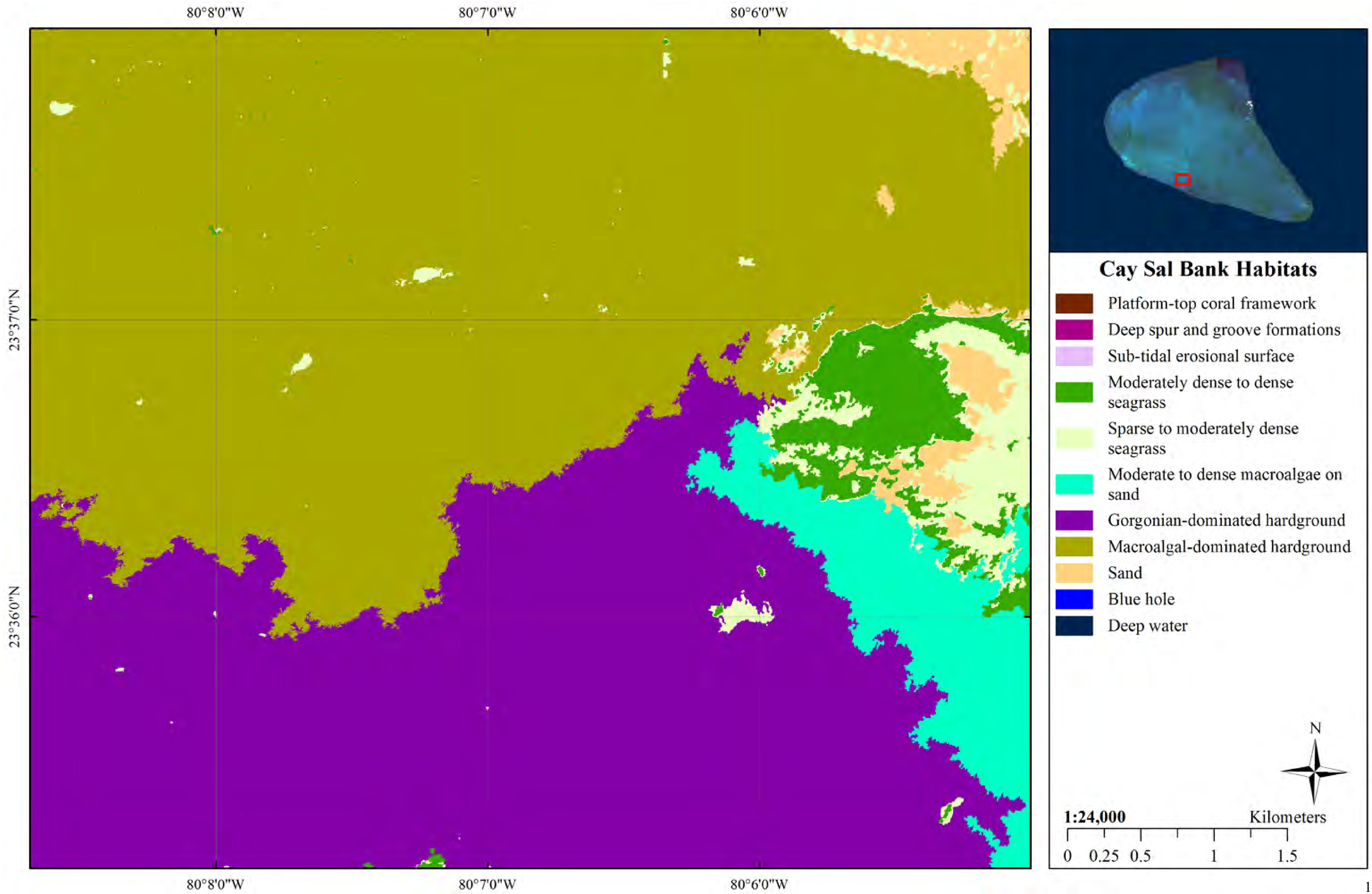

80°1'0"W
80°0'0"W
79°59'0"W
79°58'0"W
23°32'0"N
23°31'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

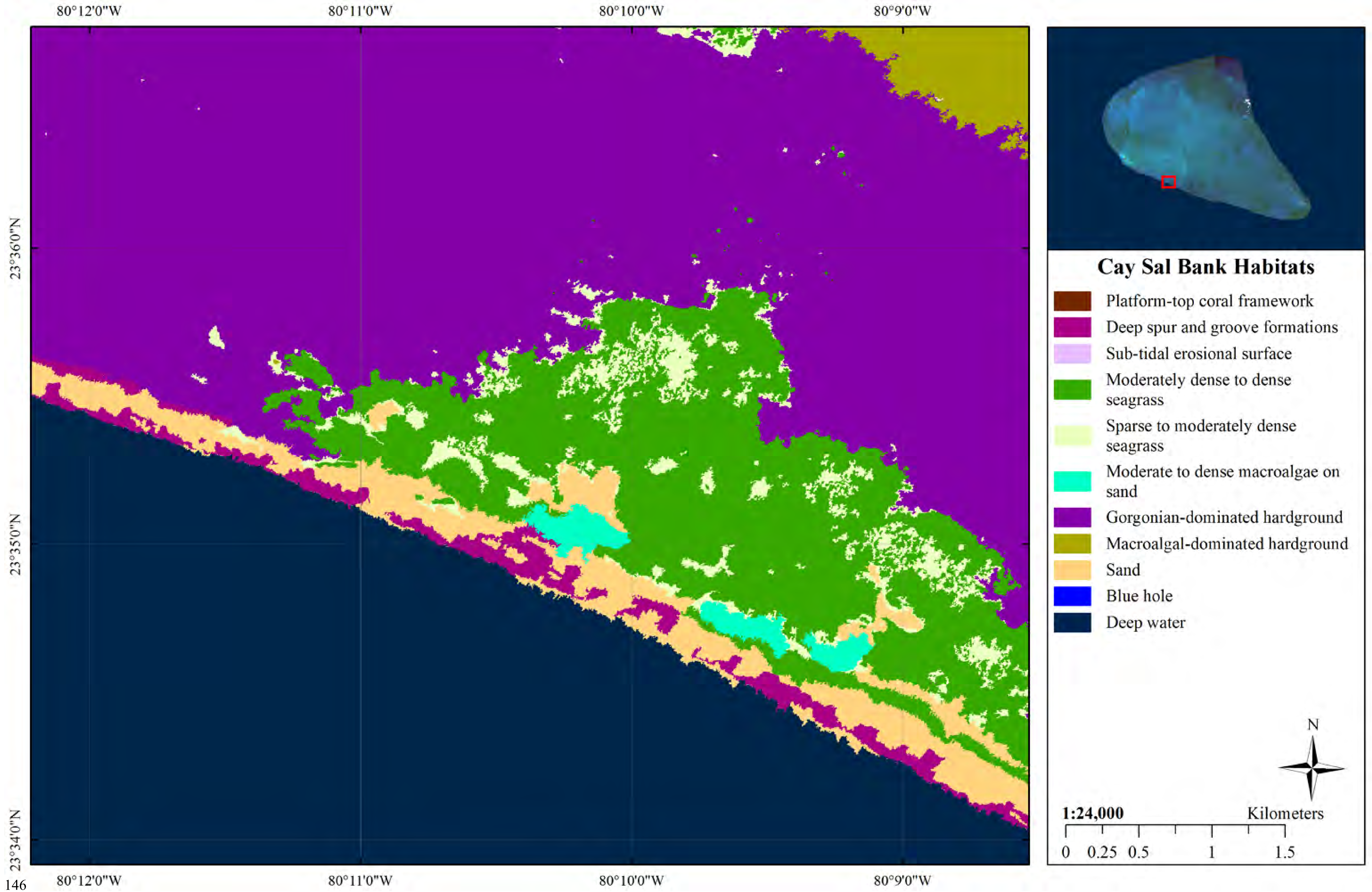

80°1'0"W
80°0'0"W
79°59'0"W
79°58'0"W
23°35'0"N
23°34'0"N
23°33'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


80°5'0"W
80°4'0"W
80°3'0"W
80°2'0"W
23°33'0"N
23°32'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

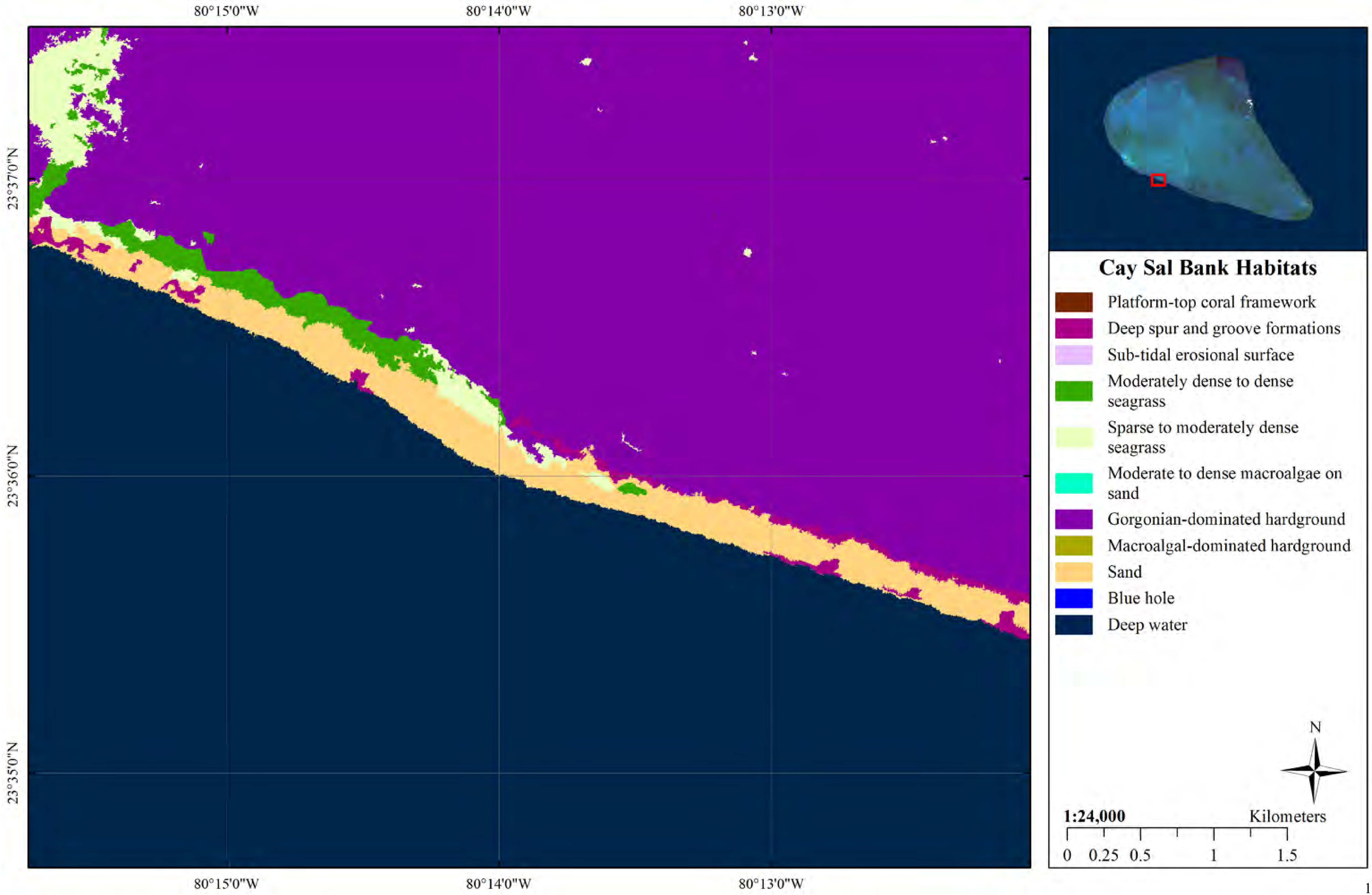

80°5'0"W
80°4'0"W
80°3'0"W
80°2'0"W
23°36'0"N
23°35'0"N
23°34'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


80°8'0"W
80°7'0"W
80°6'0"W
23°35'0"N
23°34'0"N
23°33'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

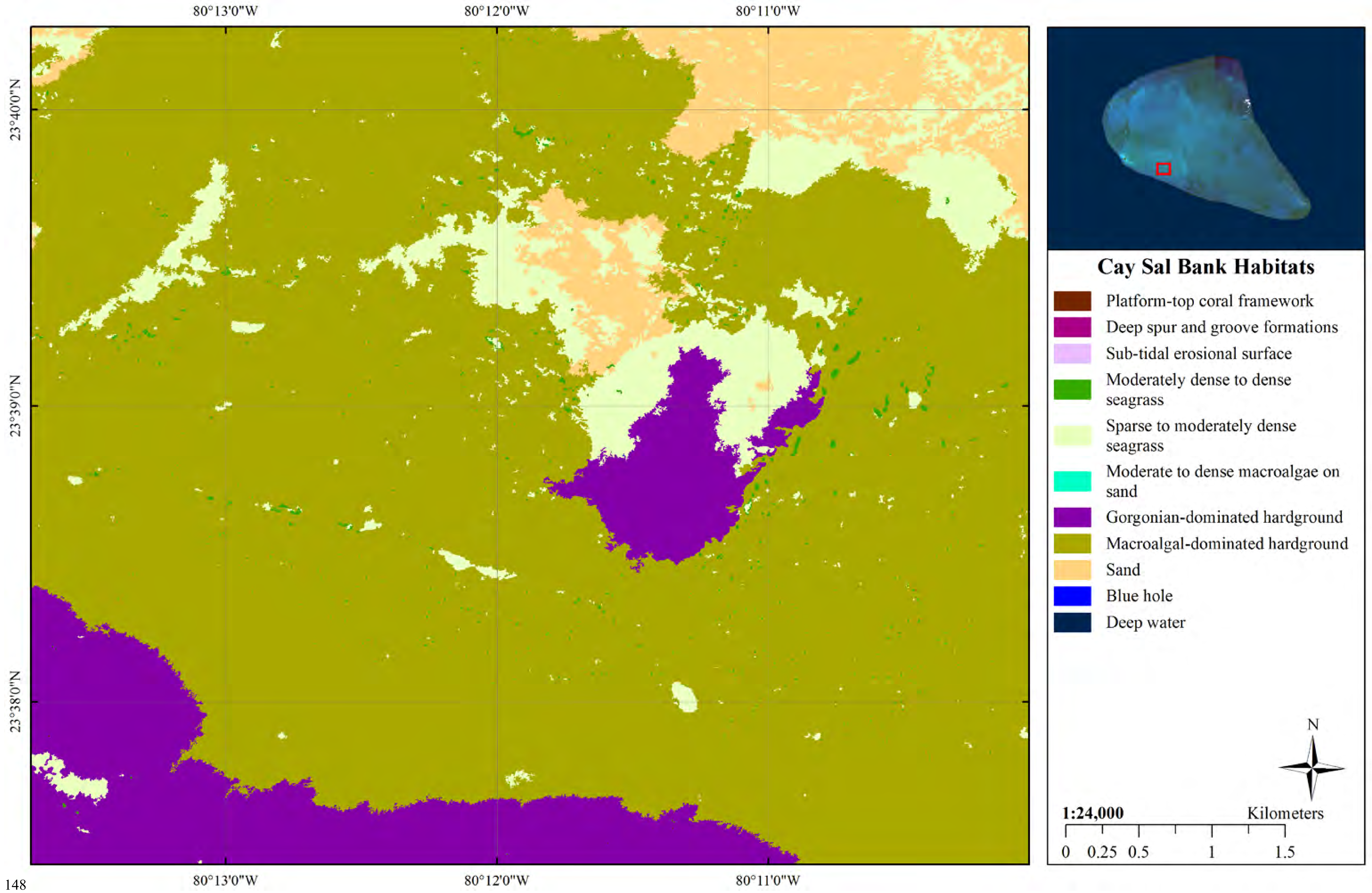

80°8'0"W
80°7'0"W
80°6'0"W
23°37'0"N
23°36'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

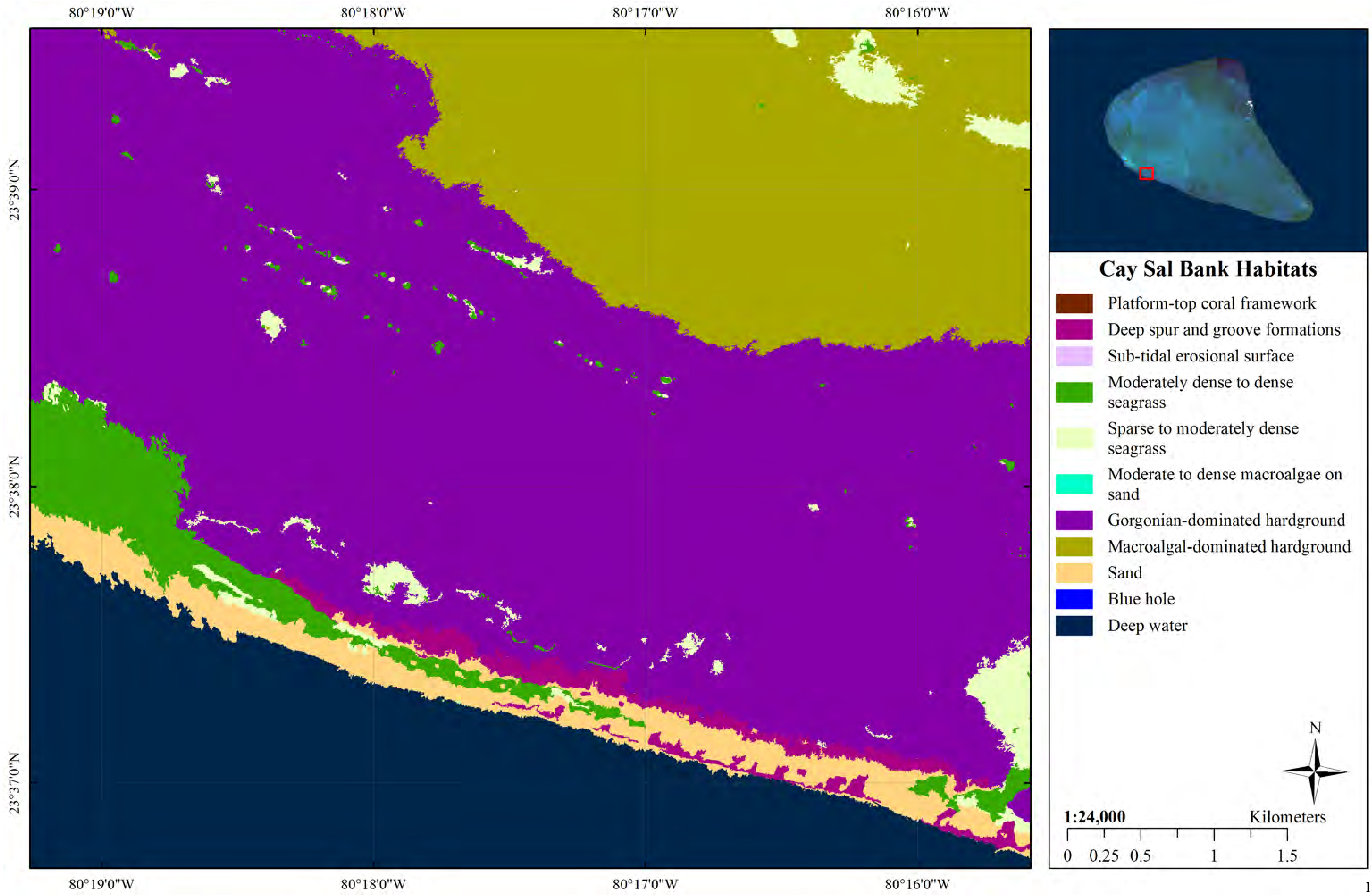


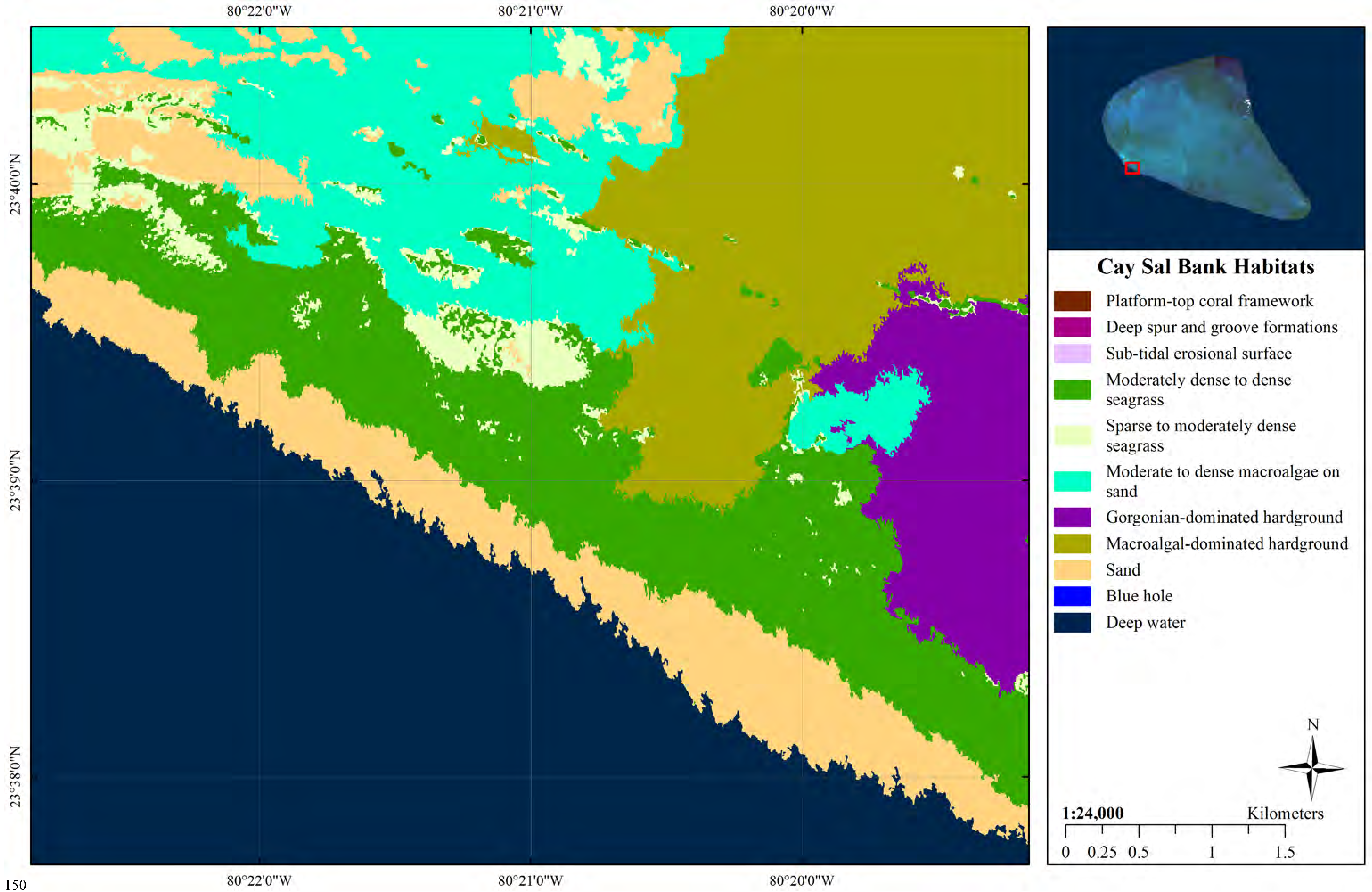
80°12'0"W
80°11'0"W
80°10'0"W
80°9'0"W
23°36'0"N
23°35'0"N
23°34'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

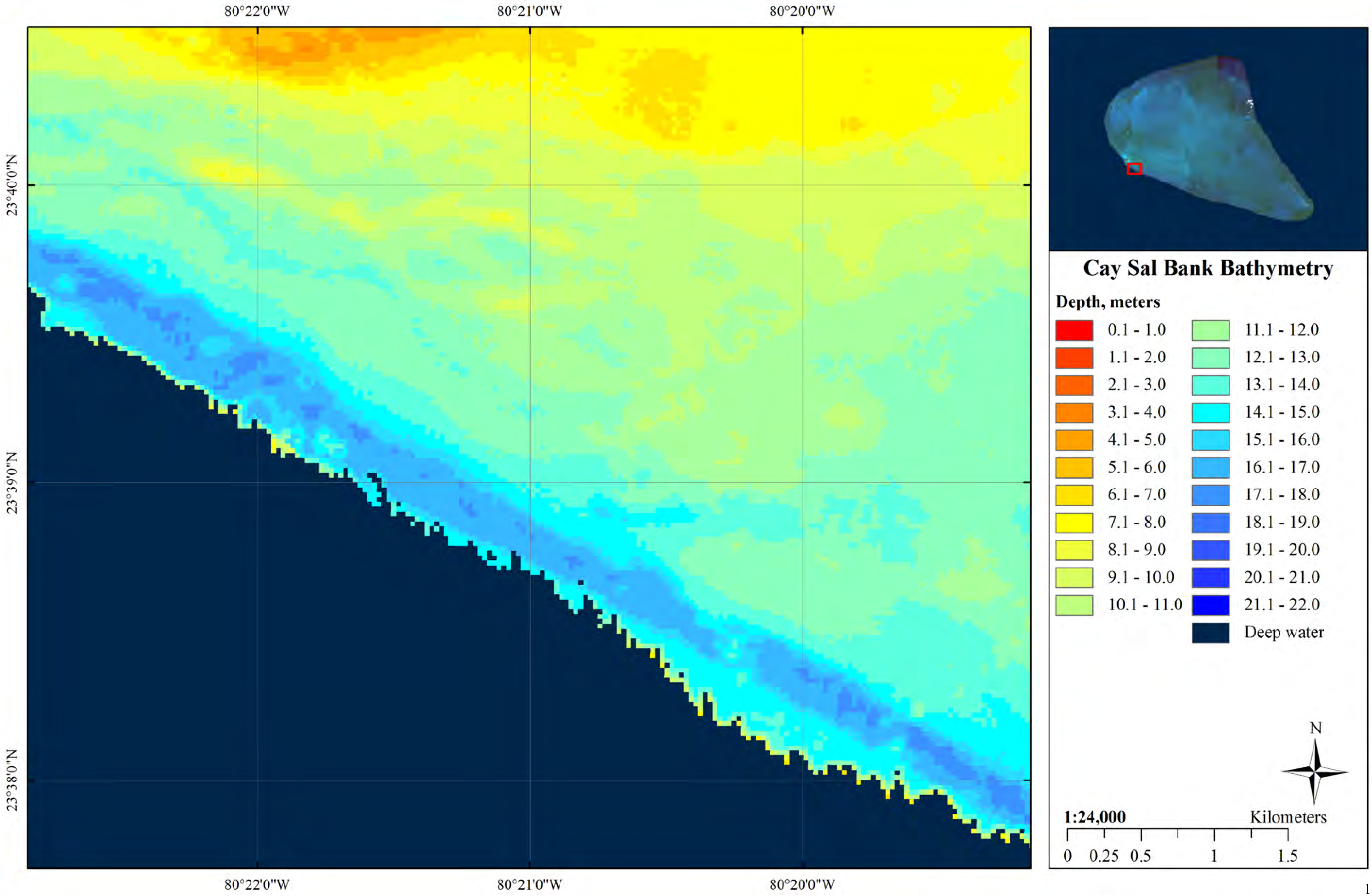


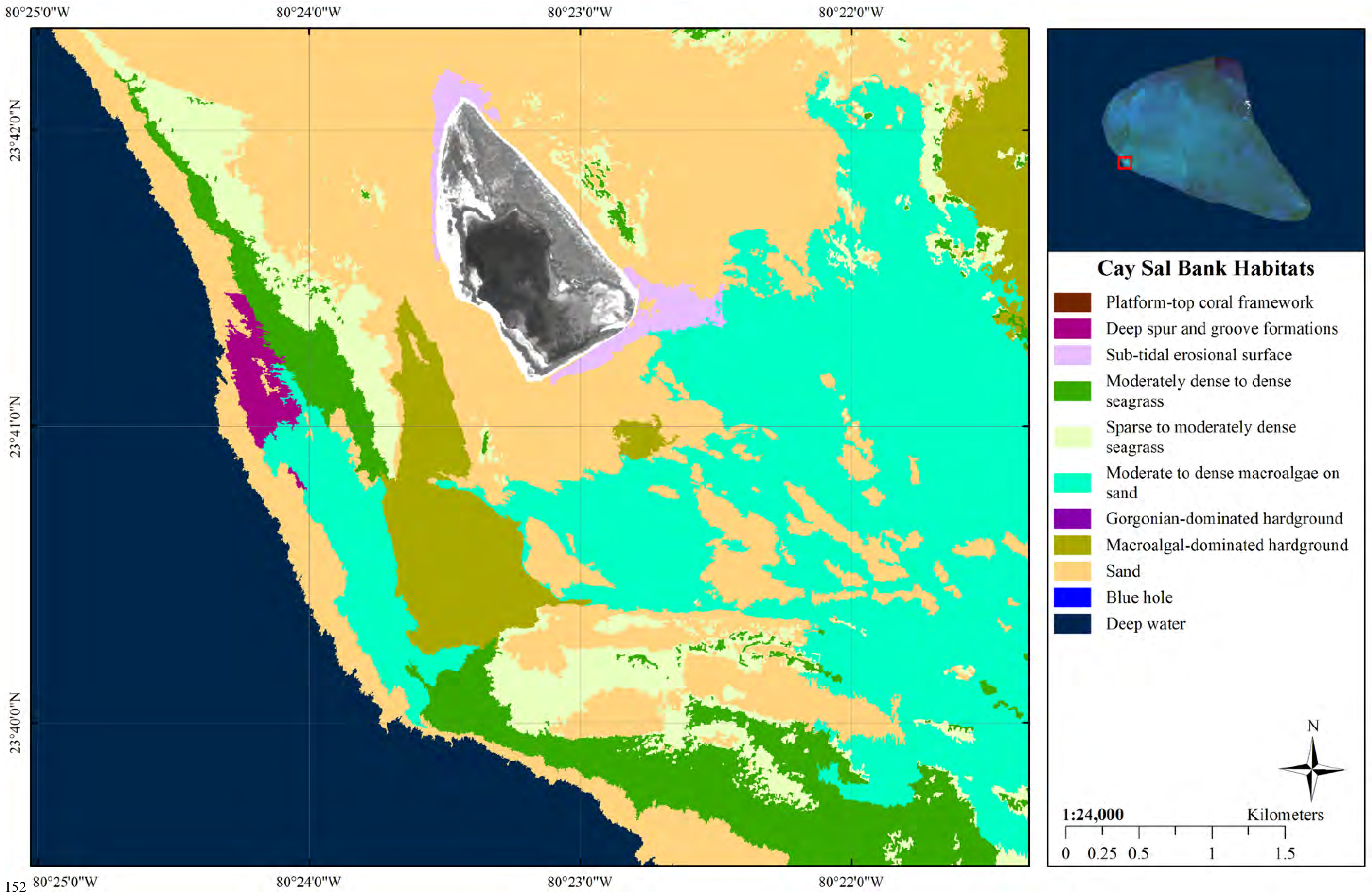
80°15'0"W
80°14'0"W
80°13'0"W
23°37'0"N
23°36'0"N
23°35'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

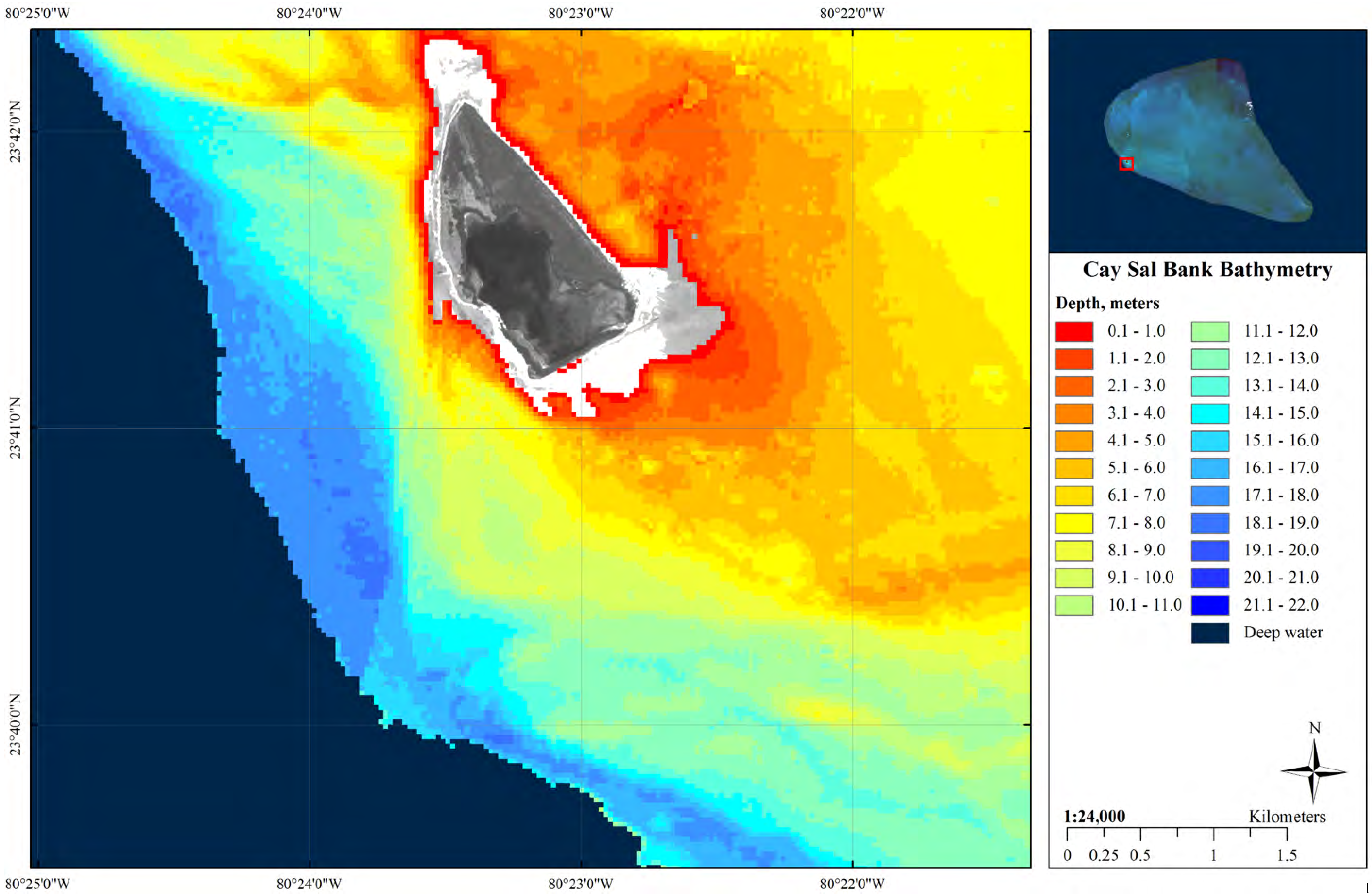

80°13'0"W
80°12'0"W
80°11'0"W
23°40'0"N
23°39'0"N
23°38'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

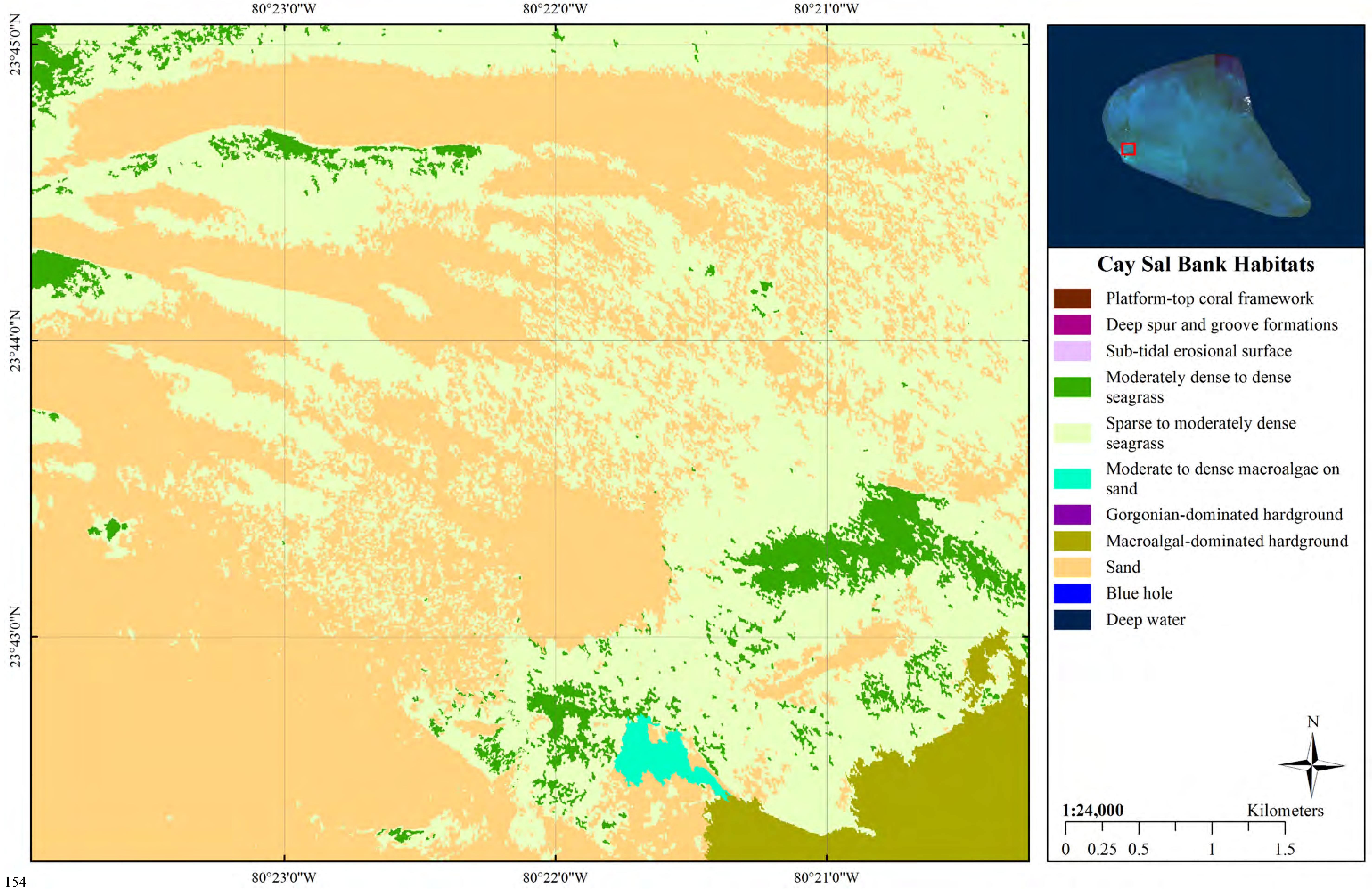

80°19'0"W
80°18'0"W
80°17'0"W
80°16'0"W
23°39'0"N
23°38'0"N
23°37'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

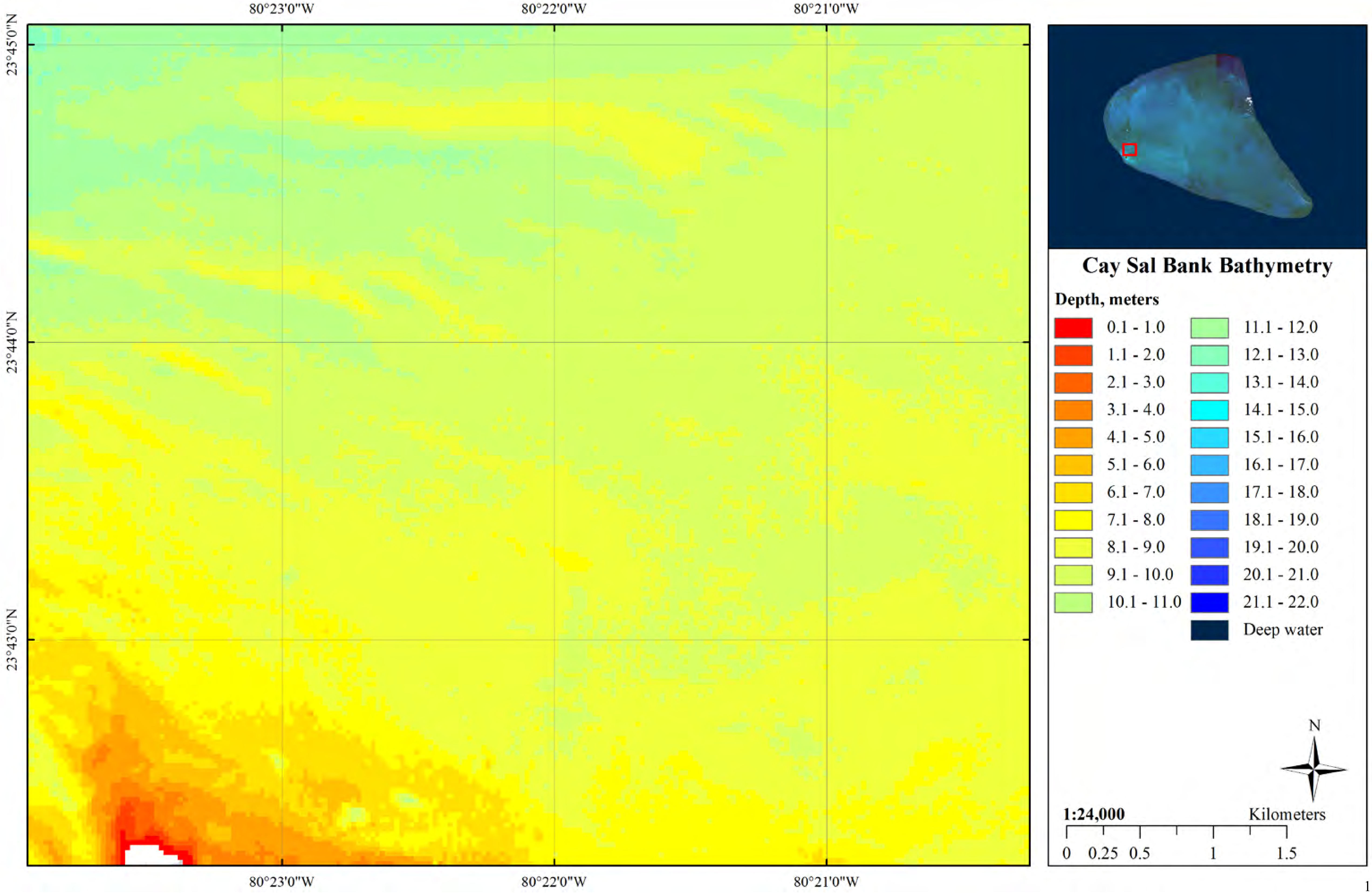

80°22'0"W
80°21'0"W
80°20'0"W
23°40'0"N
23°39'0"N
23°38'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

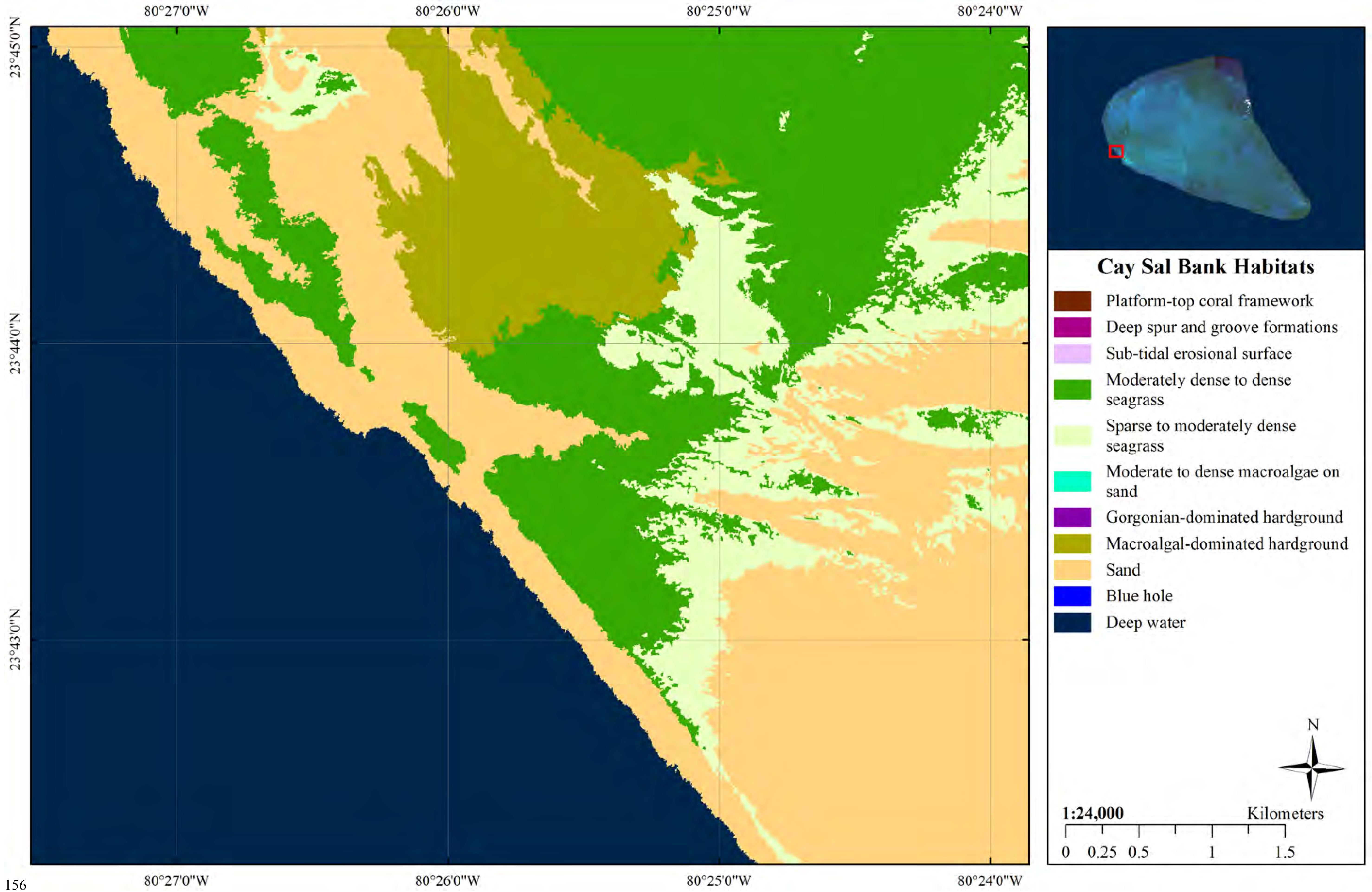

80°22'0"W
80°21'0"W
80°20'0"W
23°40'0"N
23°39'0"N
23°38'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

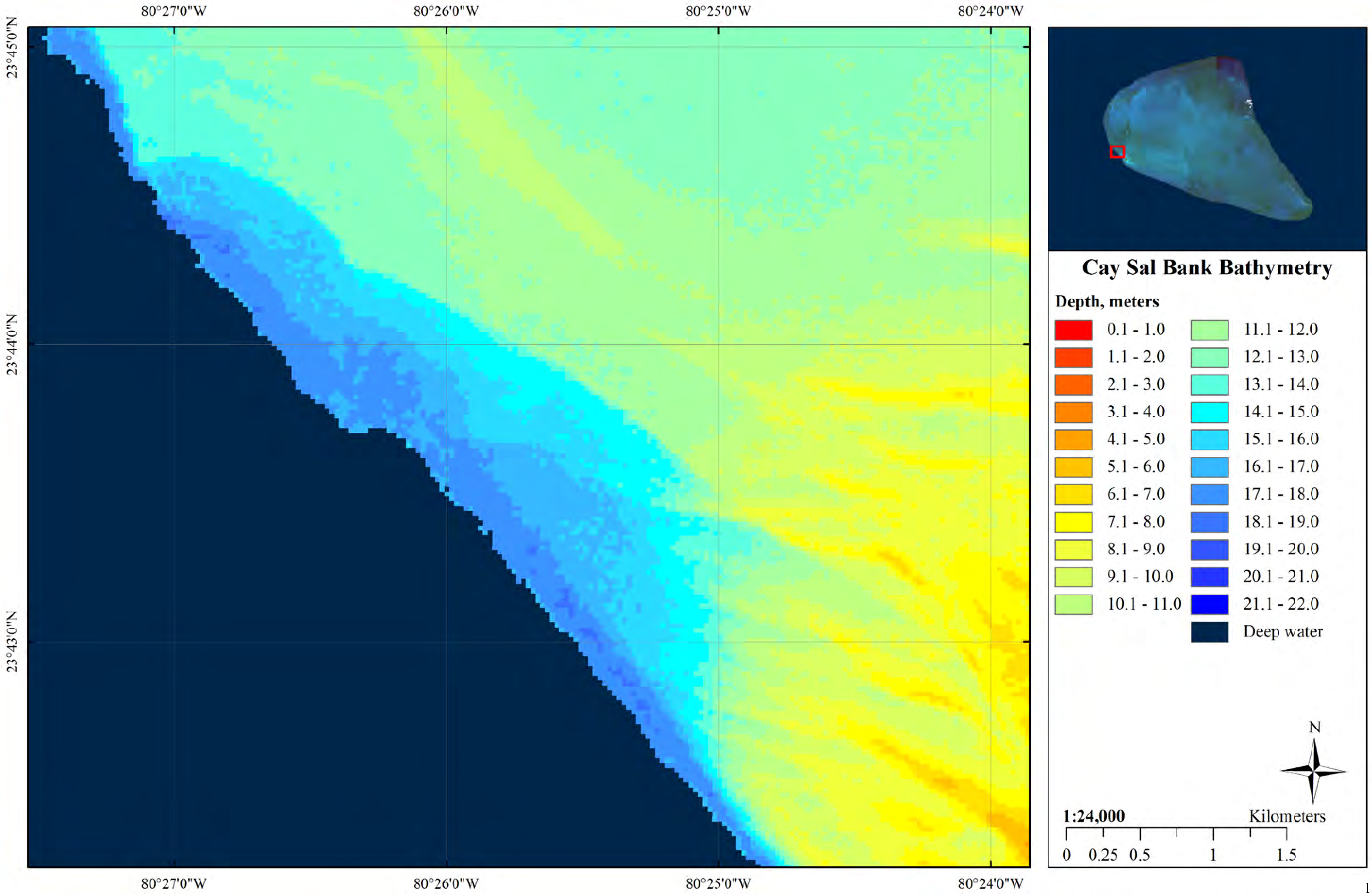

Cay Sal Bank Habitats

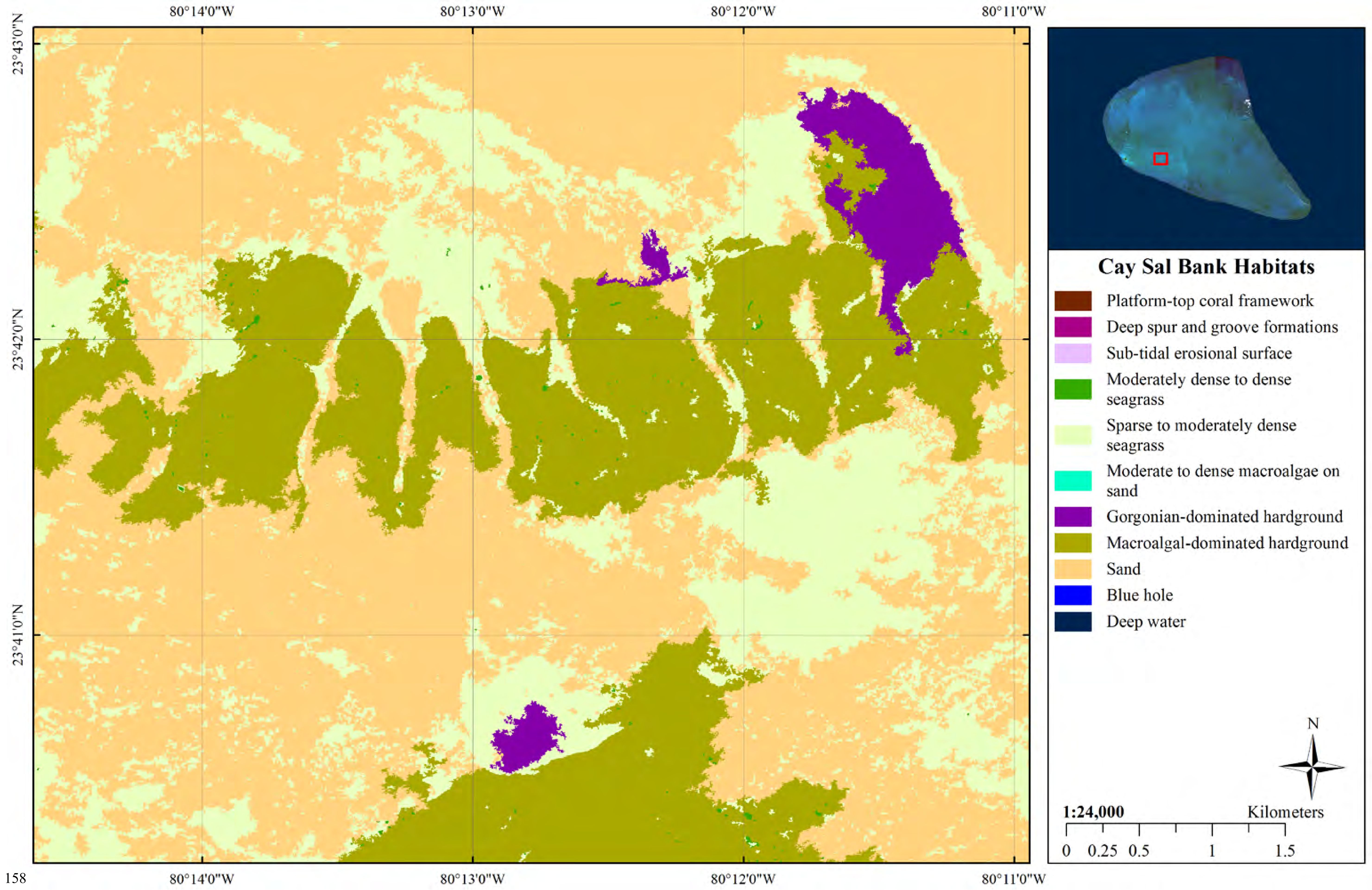

Cay Sal Bank Bathymetry


80°23'0"W
80°22'0"W
80°21'0"W
23°45'0"N
23°44'0"N
23°43'0"N
Cay Sal Bank Habitats
🟫 Platform-top coral framework
🟪 Deep spur and groove formations
🟪 Sub-tidal erosional surface
🟩 Moderately dense to dense seagrass
🟩 Sparse to moderately dense seagrass
🟦 Moderate to dense macroalgae on sand
🟪 Gorgonian-dominated hardground
🟨 Macroalgal-dominated hardground
🟧 Sand
🟦 Blue hole
⬛ Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


80°23'0"W
80°22'0"W
80°21'0"W
23°45'0"N
23°44'0"N
23°43'0"N
Cay Sal Bank Bathymetry
Depth, meters
🟥 0.1 - 1.0
🟥 1.1 - 2.0
🟧 2.1 - 3.0
🟧 3.1 - 4.0
🟧 4.1 - 5.0
🟨 5.1 - 6.0
🟨 6.1 - 7.0
🟨 7.1 - 8.0
🟨 8.1 - 9.0
🟩 9.1 - 10.0
🟩 10.1 - 11.0
🟩 11.1 - 12.0
🟩 12.1 - 13.0
🟦 13.1 - 14.0
🟦 14.1 - 15.0
🟦 15.1 - 16.0
🟦 16.1 - 17.0
🟦 17.1 - 18.0
🟦 18.1 - 19.0
🟦 19.1 - 20.0
🟦 20.1 - 21.0
🟦 21.1 - 22.0
⬛ Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

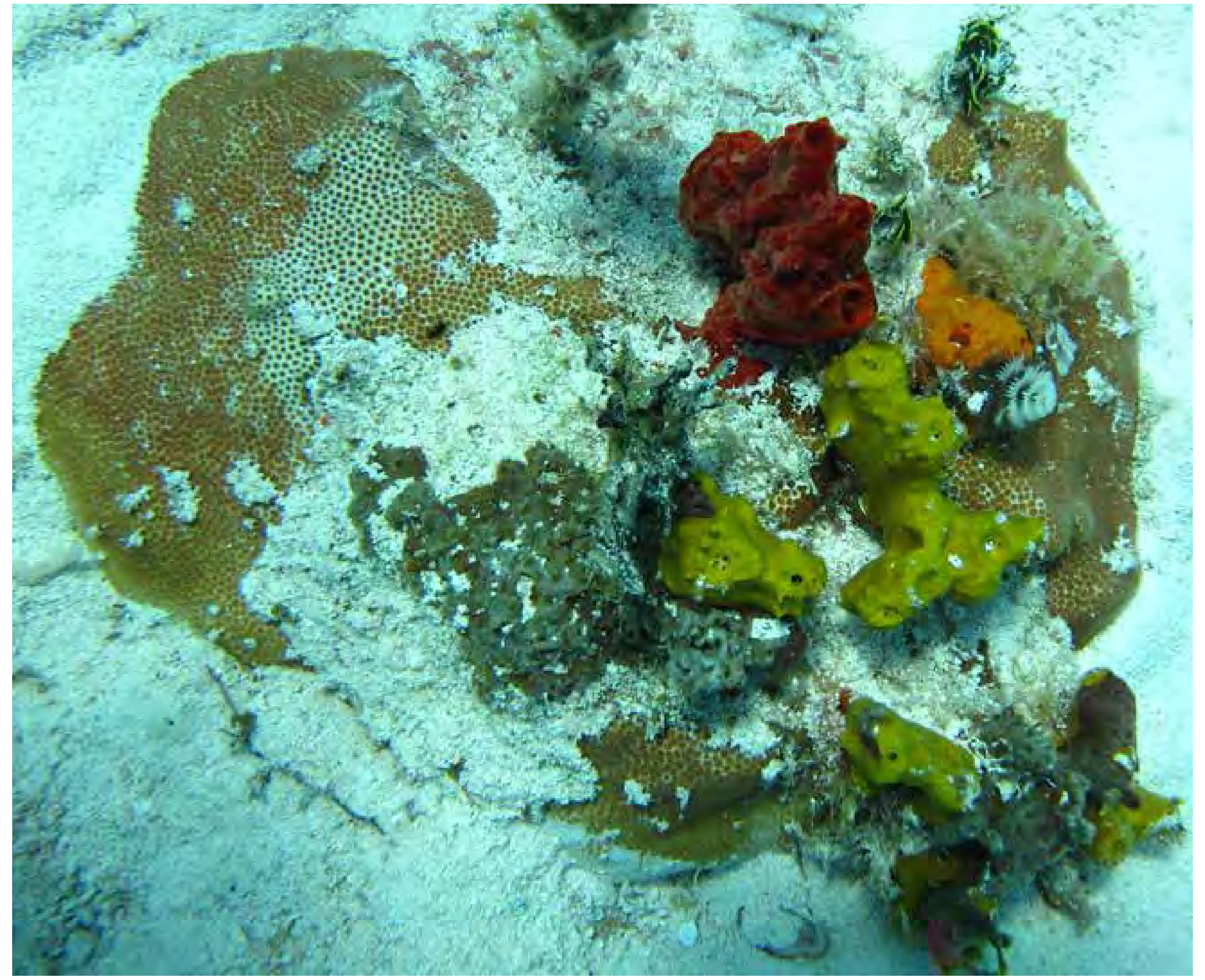

80°27'0"W
80°26'0"W
80°25'0"W
80°24'0"W
23°45'0"N
23°44'0"N
23°43'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


80°27'0"W
80°26'0"W
80°25'0"W
80°24'0"W
23°45'0"N
23°44'0"N
23°43'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5



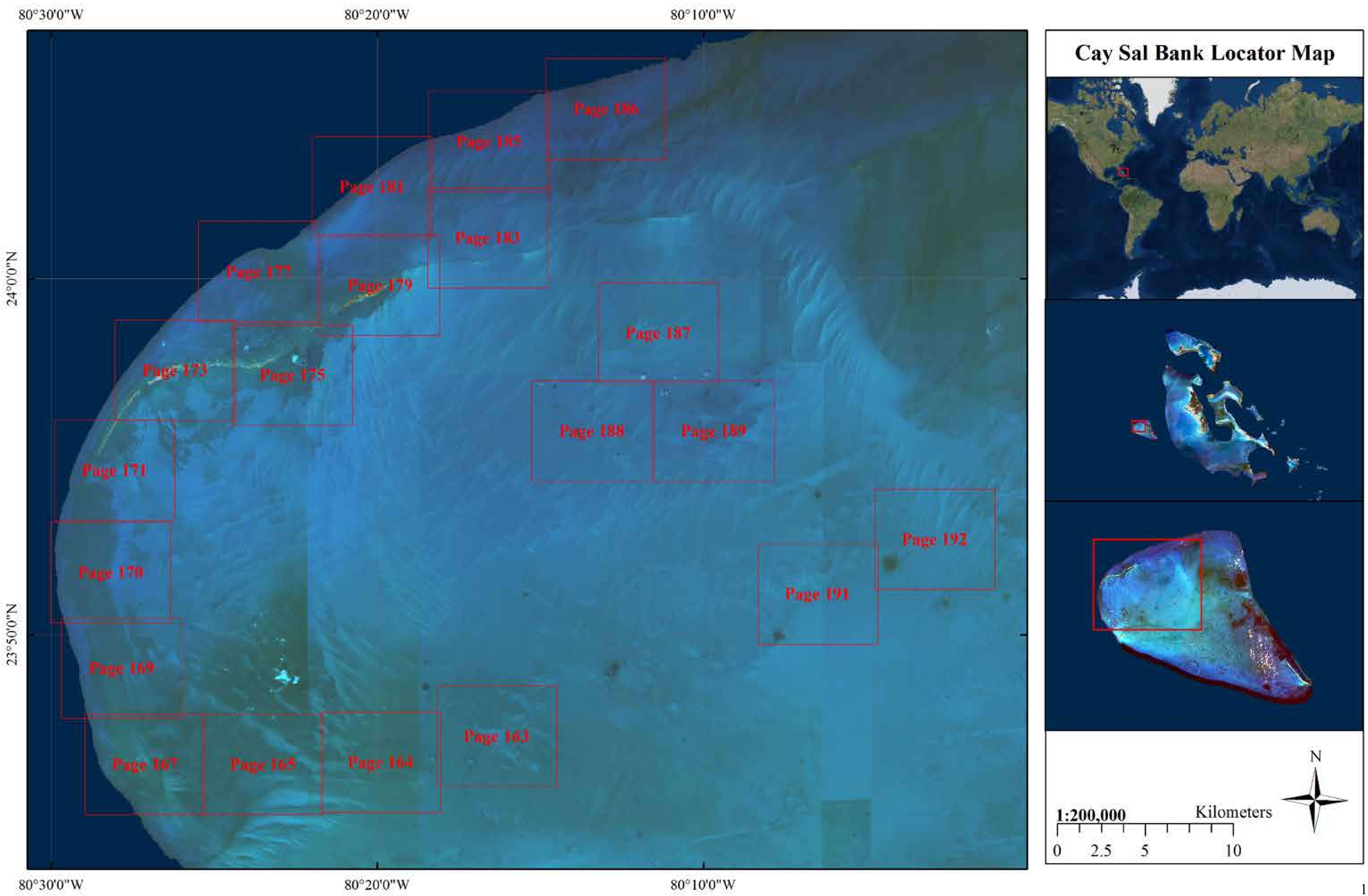


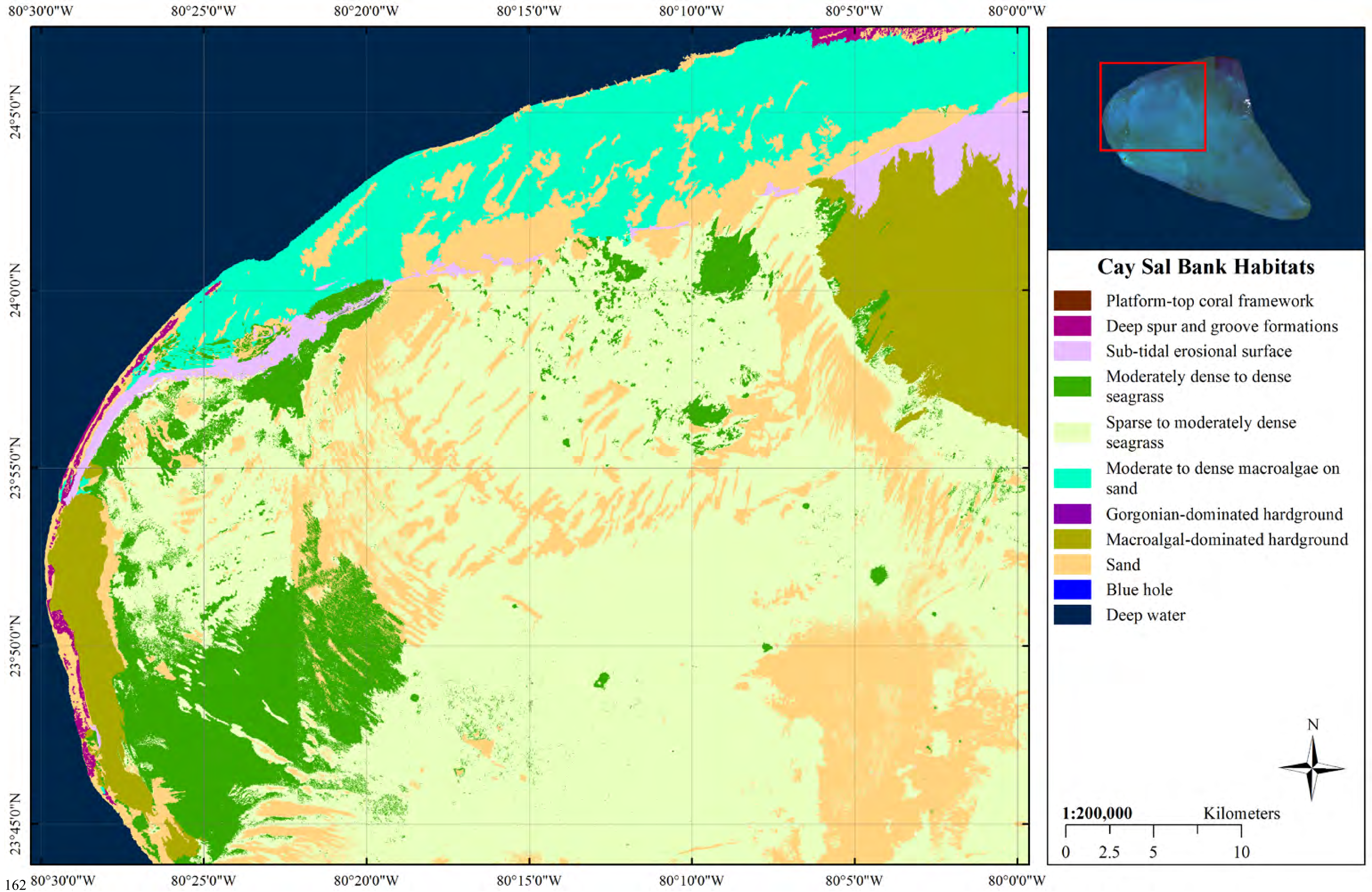


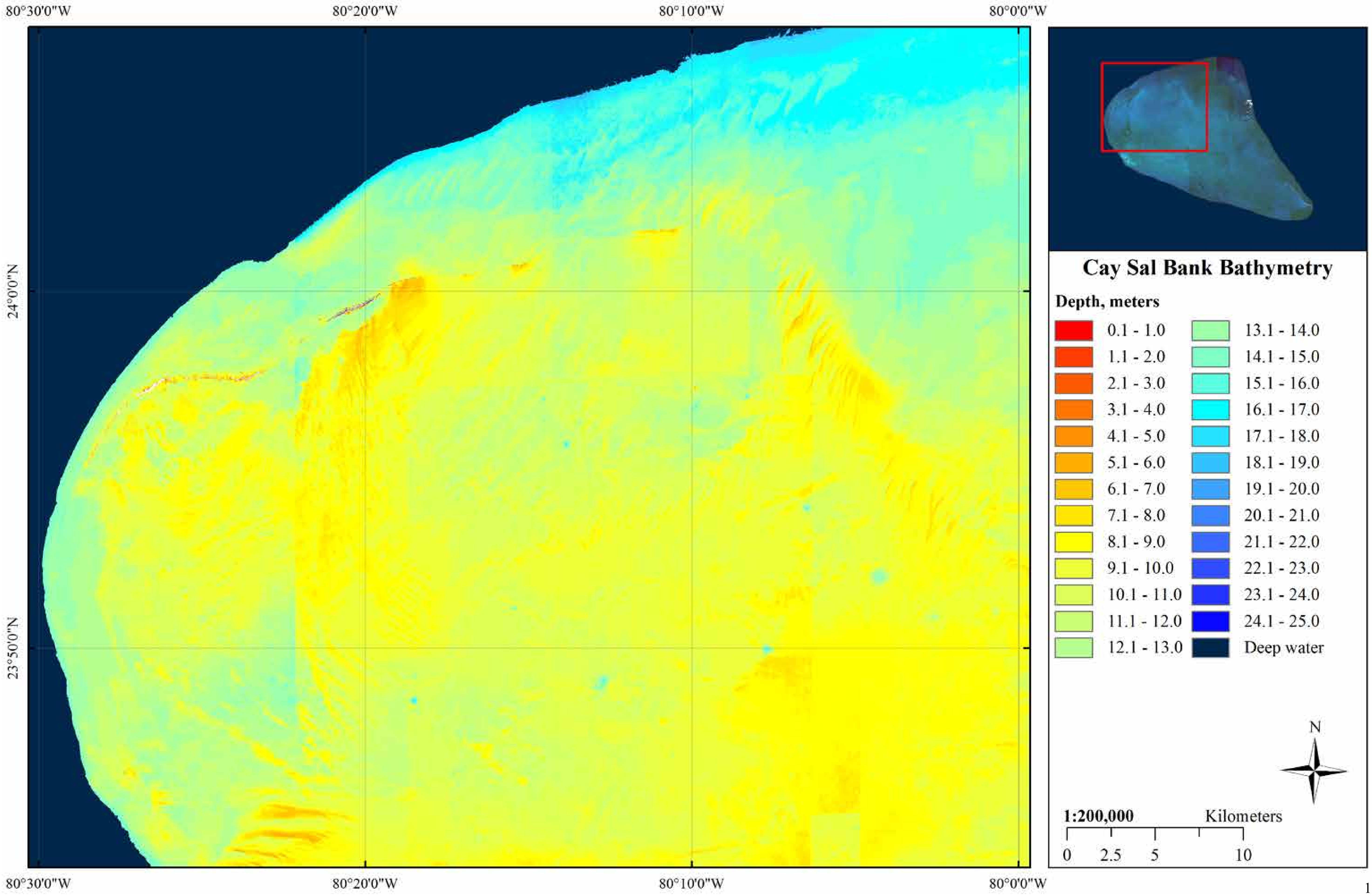


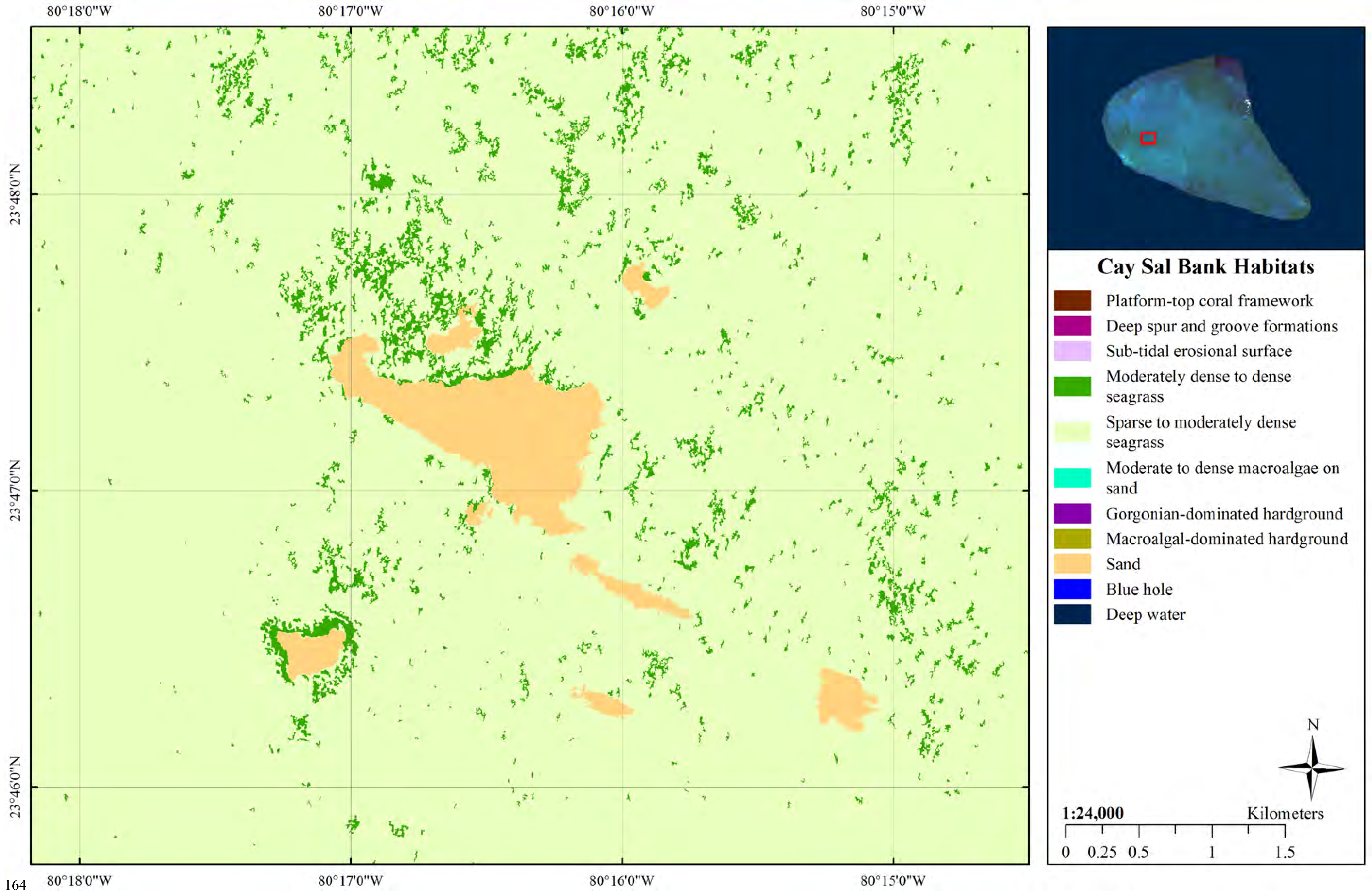
Coral reef images on top of the platform of Cay Sal Bank. Large *Montastraea faveolata* colonies are intermixed with *Porites astreoides* (top left) and other corals on a shallow patch reef in the south central part of the bank. Extensive seagrass habitats are found from 5-12 m depth. These have large populations of *Strombus gigas* (bottom left). An unusual pillar-like growth form of *Meandrina jacksoni* (top center). Much of the bank is hardground with a thin veneer of sediment and small coral heads and patches of gorgonians (top right). A very unusual patch reef in the southwest with small coral bommies that contained a high diversity of corals, sponges and other invertebrates, interspersed with sediment covered pavement. A *Stephanocoenia intersepta* with several colorful submassive sponges are shown (bottom right).

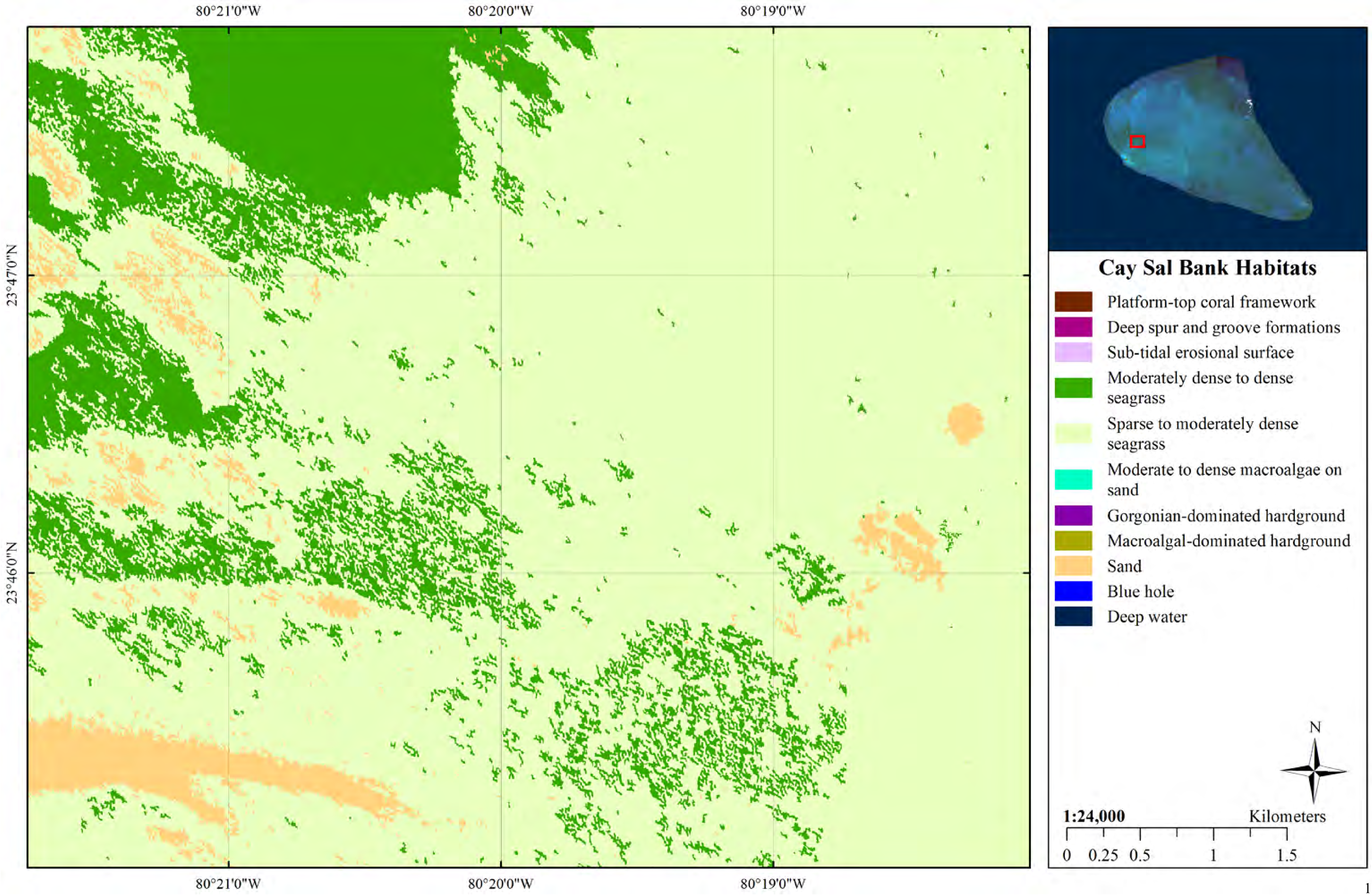
Evidence of human activity is found throughout Cay Sal Bank. Shallow water habitats were littered with ballast, remains of gear from former oil exploration efforts, rigging, nets and other fishing gear, anchors, carronade cannons, and small vessels, cargo ships, and aircraft. Often these provide the only high relief habitat and serve as fish aggregation devices. Aerial photograph of a wreck of a barge, laying on its side, lies in 6 m depth (top left). The remains of *Mystic Wreck* are scattered over the bottom in about 7 m depth (bottom left). A twin-engine Beechcraft crashed to the east of Cay Sal Island in 1987 (top right). The cargo ship M/V *Cork* ran aground on Rompidas Ledge, a submerged coral head 3 km northwest of Cay Sal, in 1983. Its remains are scattered over about a 100 m sq area. Gorgonians have settled on the structure (bottom right).

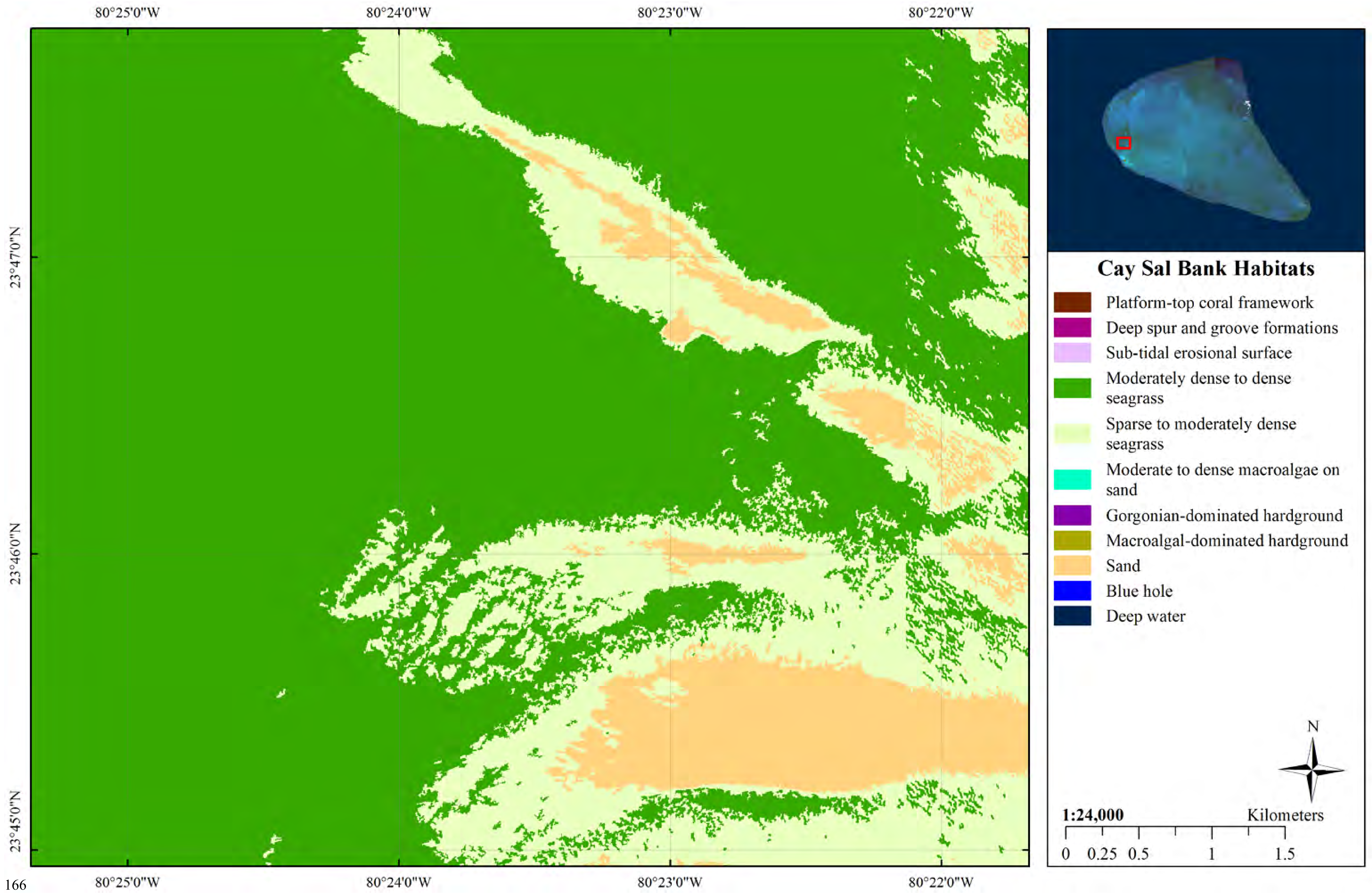


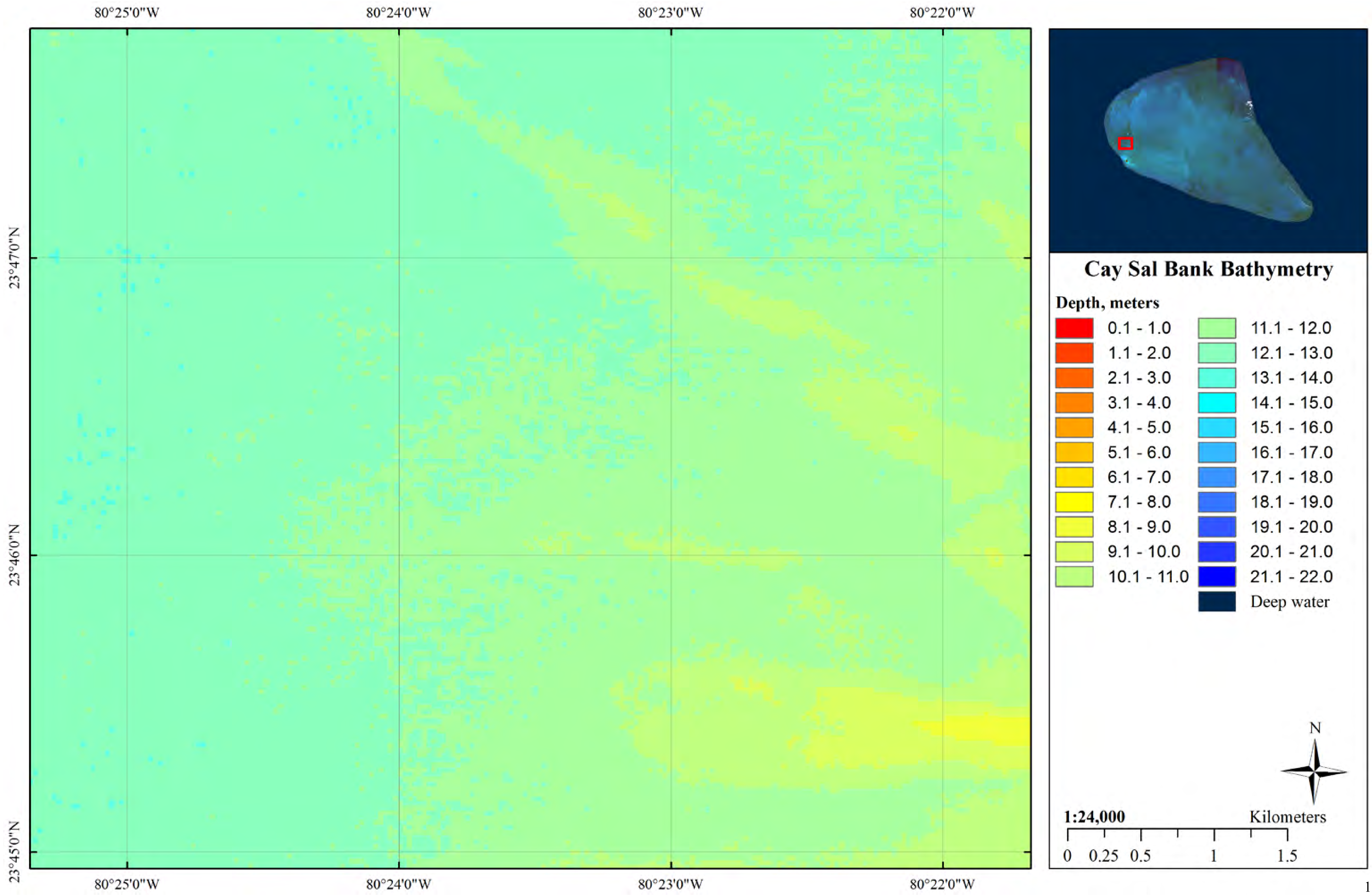

80°30'0"W
80°25'0"W
80°20'0"W
80°15'0"W
80°10'0"W
80°5'0"W
80°0'0"W
24°5'0"N
24°0'0"N
23°55'0"N
23°50'0"N
23°45'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:200,000
Kilometers
0
2.5
5
10

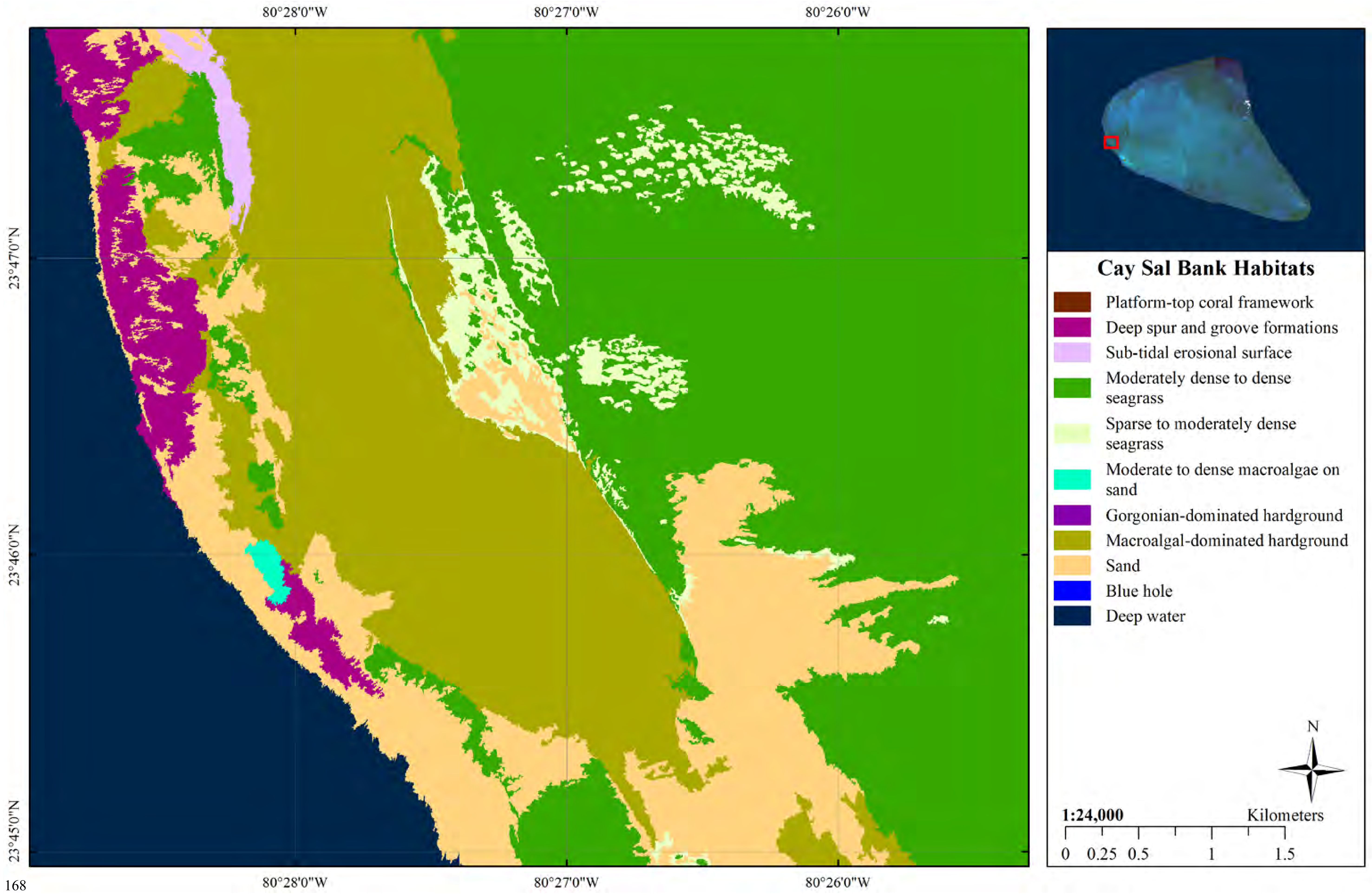

80°30'0"W
80°20'0"W
80°10'0"W
80°0'0"W
24°0'0"N
23°50'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:200,000
Kilometers
0
2.5
5
10

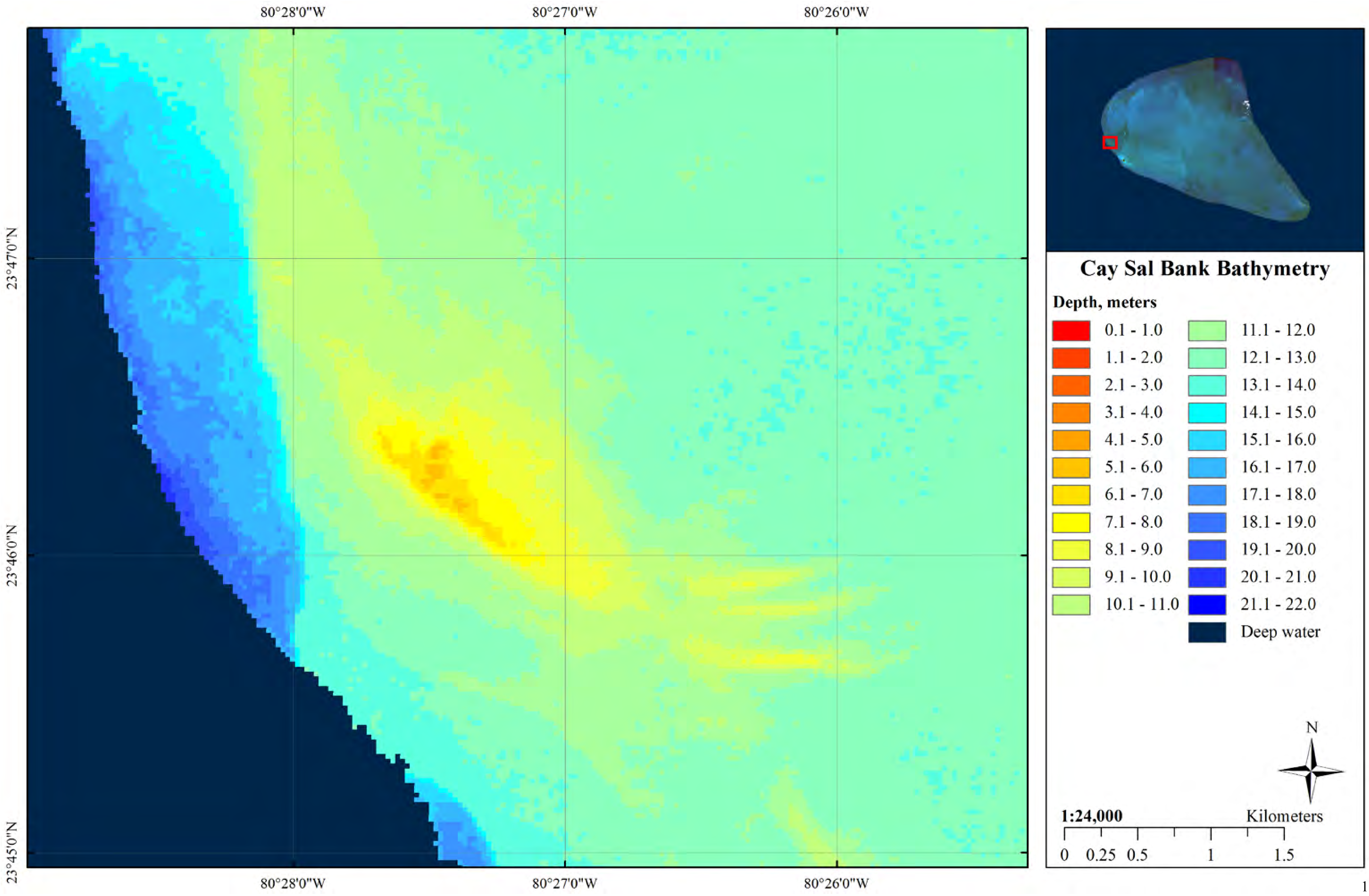

80°18'0"W
80°17'0"W
80°16'0"W
80°15'0"W
23°48'0"N
23°47'0"N
23°46'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

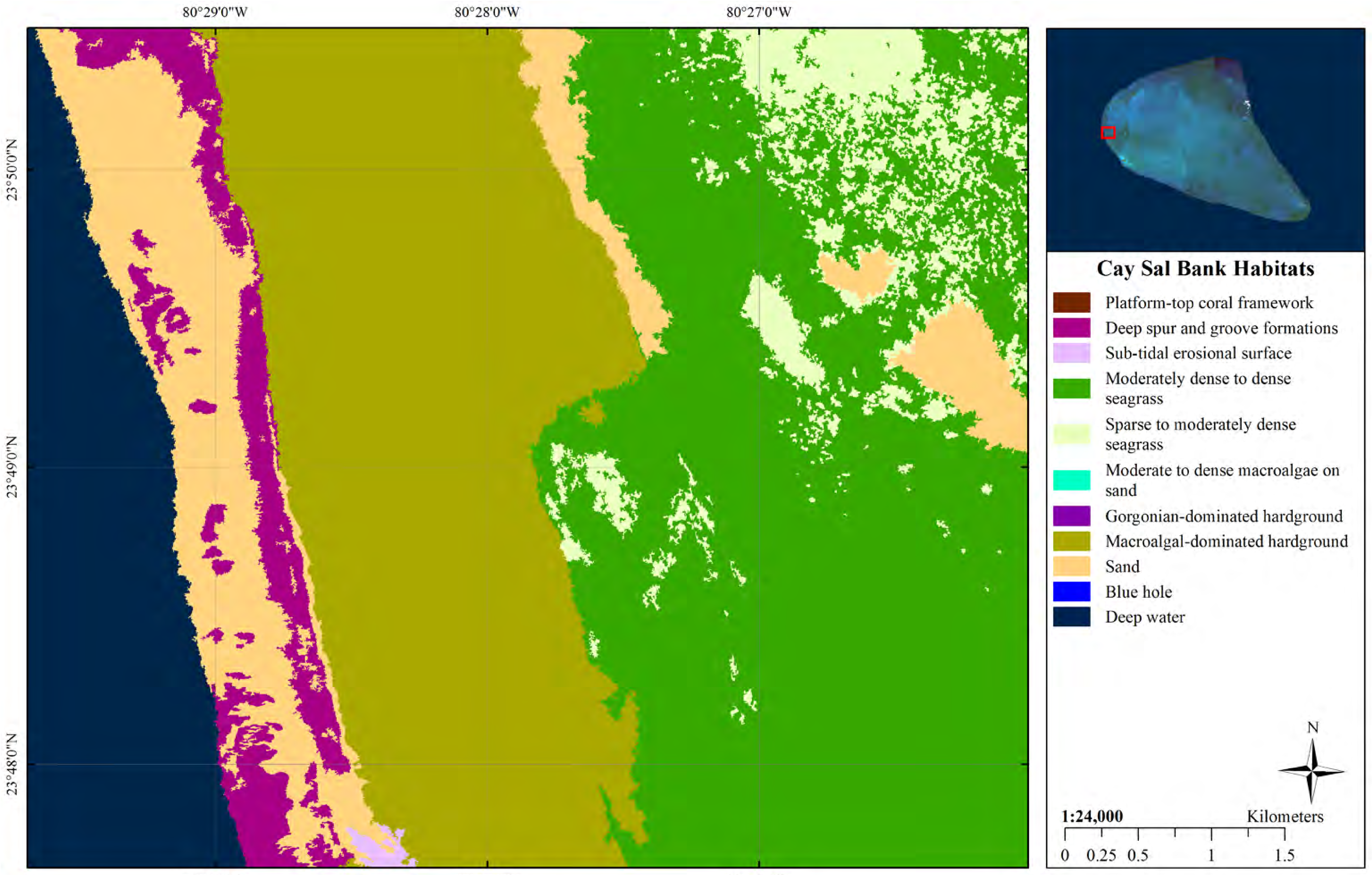

80°21'0"W
80°20'0"W
80°19'0"W
23°47'0"N
23°46'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


80°25'0"W
80°24'0"W
80°23'0"W
80°22'0"W
23°47'0"N
23°46'0"N
23°45'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

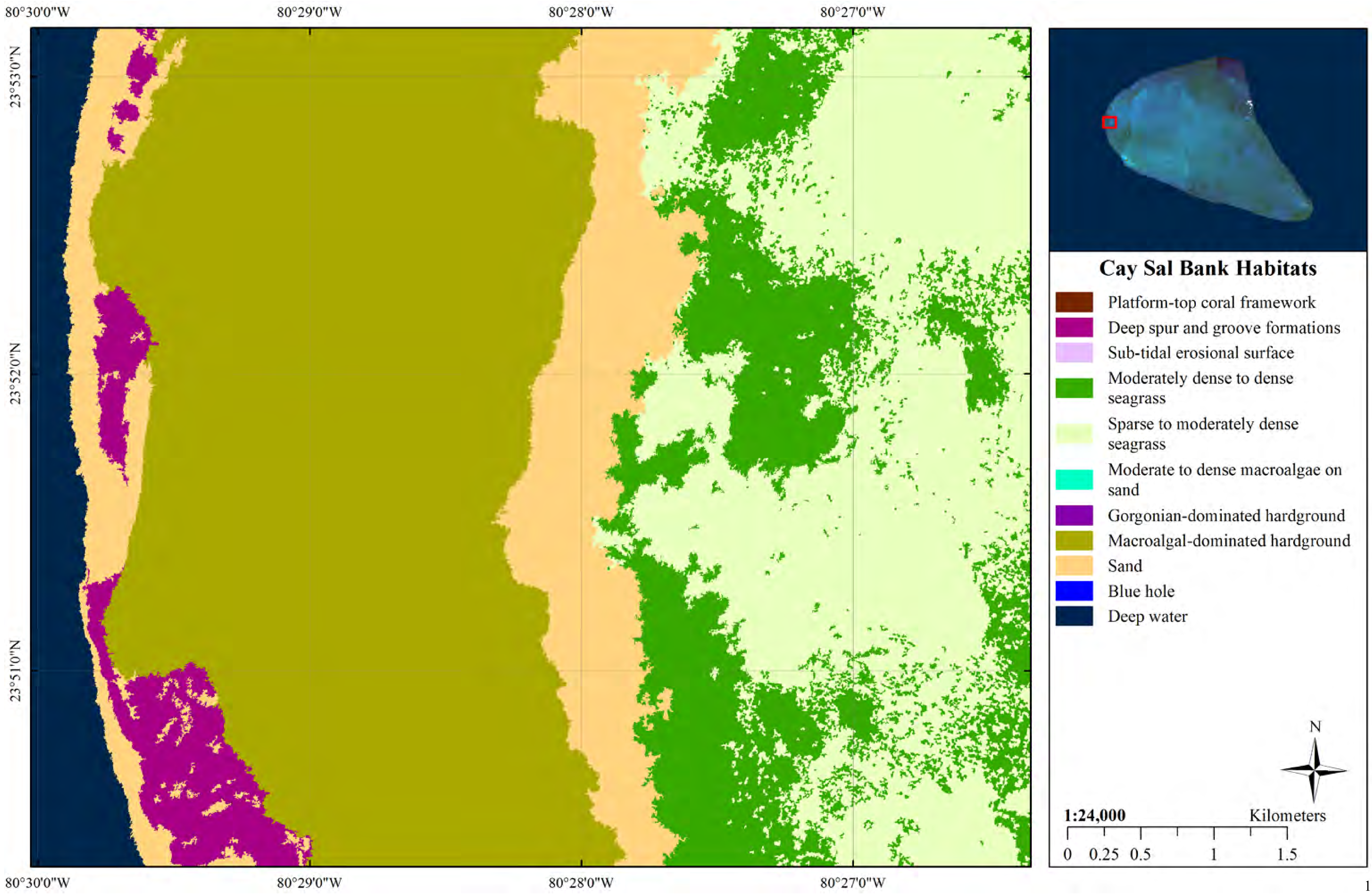

80°25'0"W
80°24'0"W
80°23'0"W
80°22'0"W
23°47'0"N
23°46'0"N
23°45'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


80°28'0"W
80°27'0"W
80°26'0"W
23°47'0"N
23°46'0"N
23°45'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

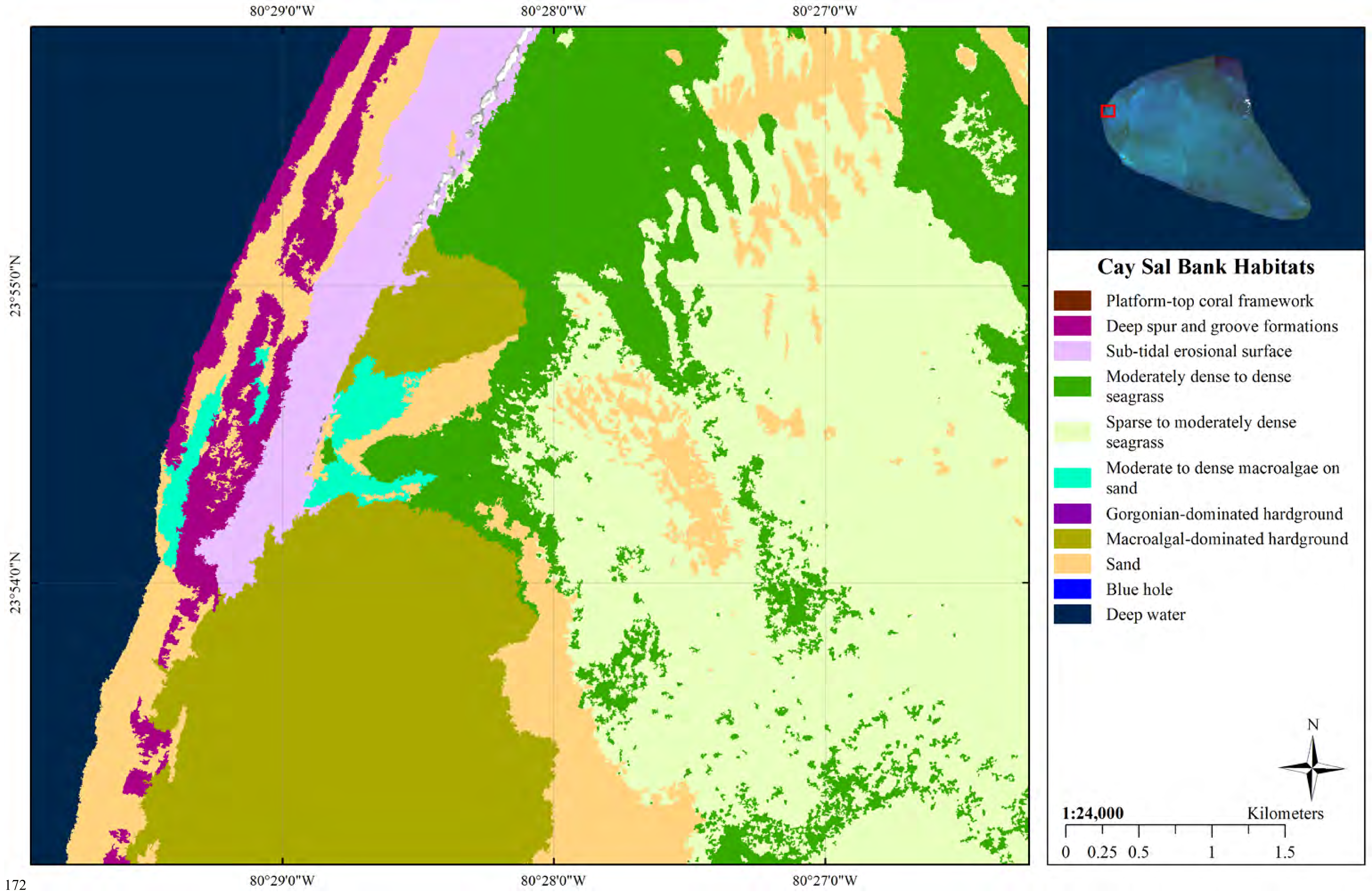

80°28'0"W
80°27'0"W
80°26'0"W
23°47'0"N
23°46'0"N
23°45'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

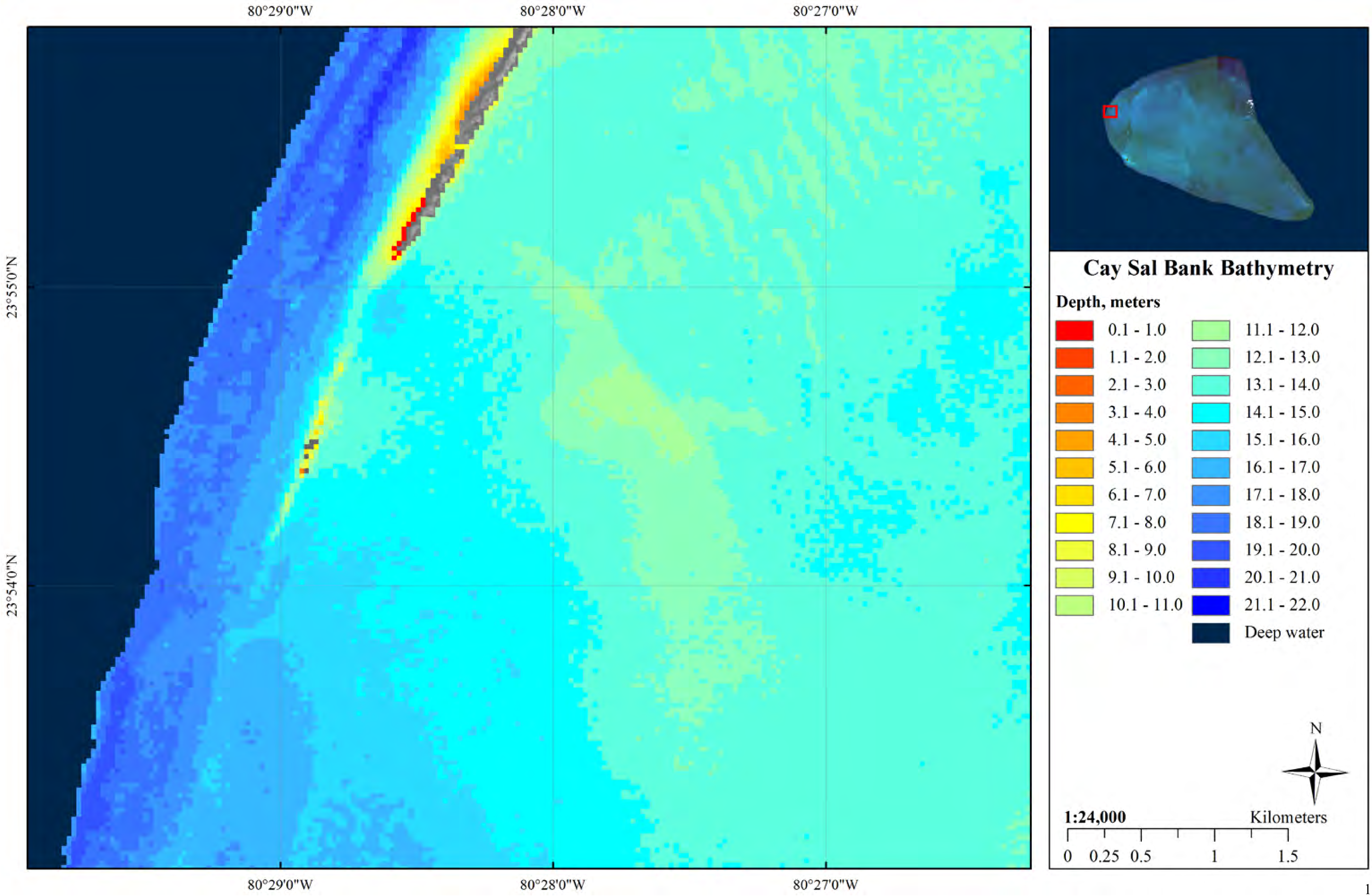


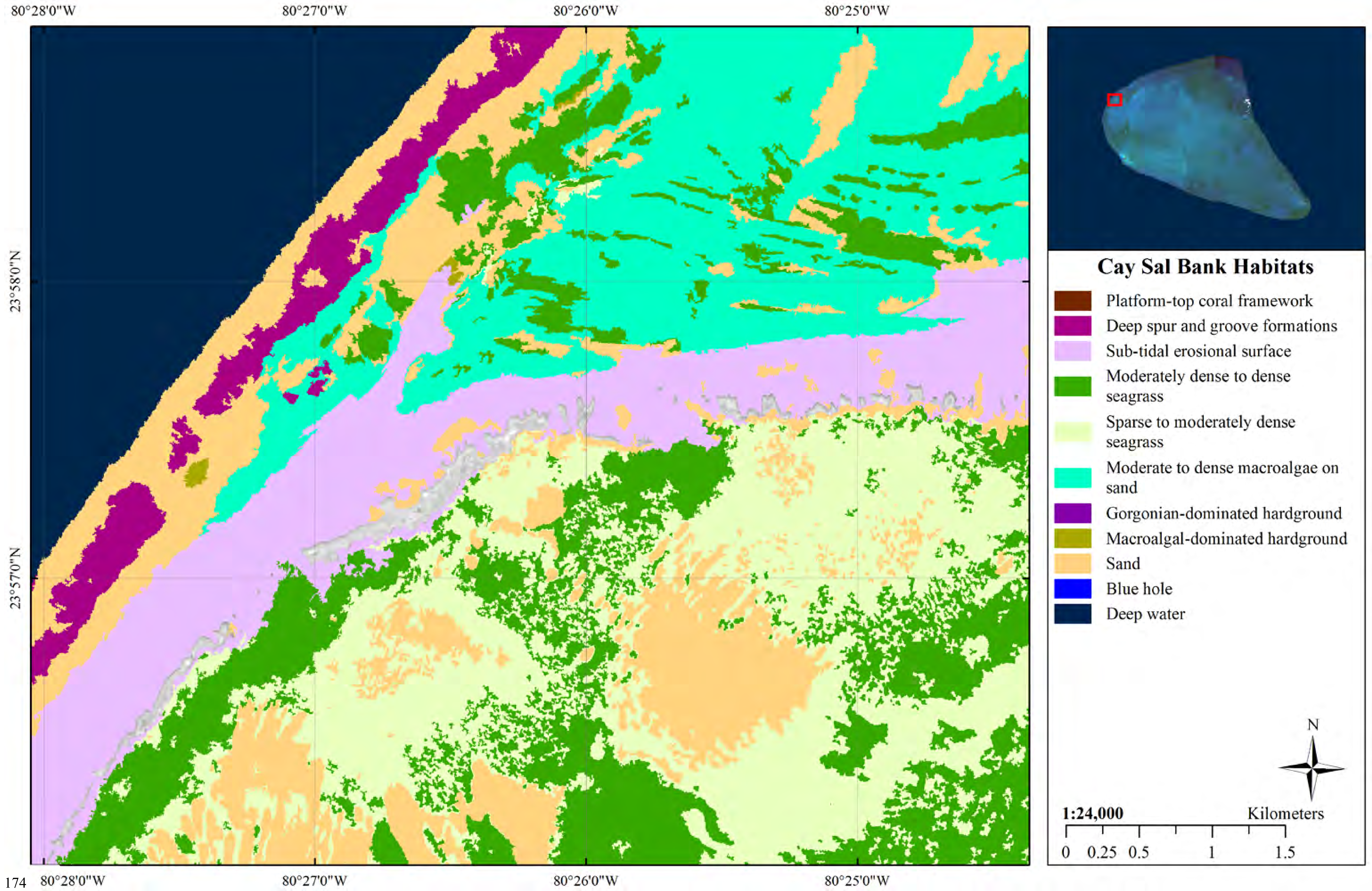
80°29'0"W
80°28'0"W
80°27'0"W
23°50'0"N
23°49'0"N
23°48'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5
80°29'0"W
80°28'0"W
80°27'0"W

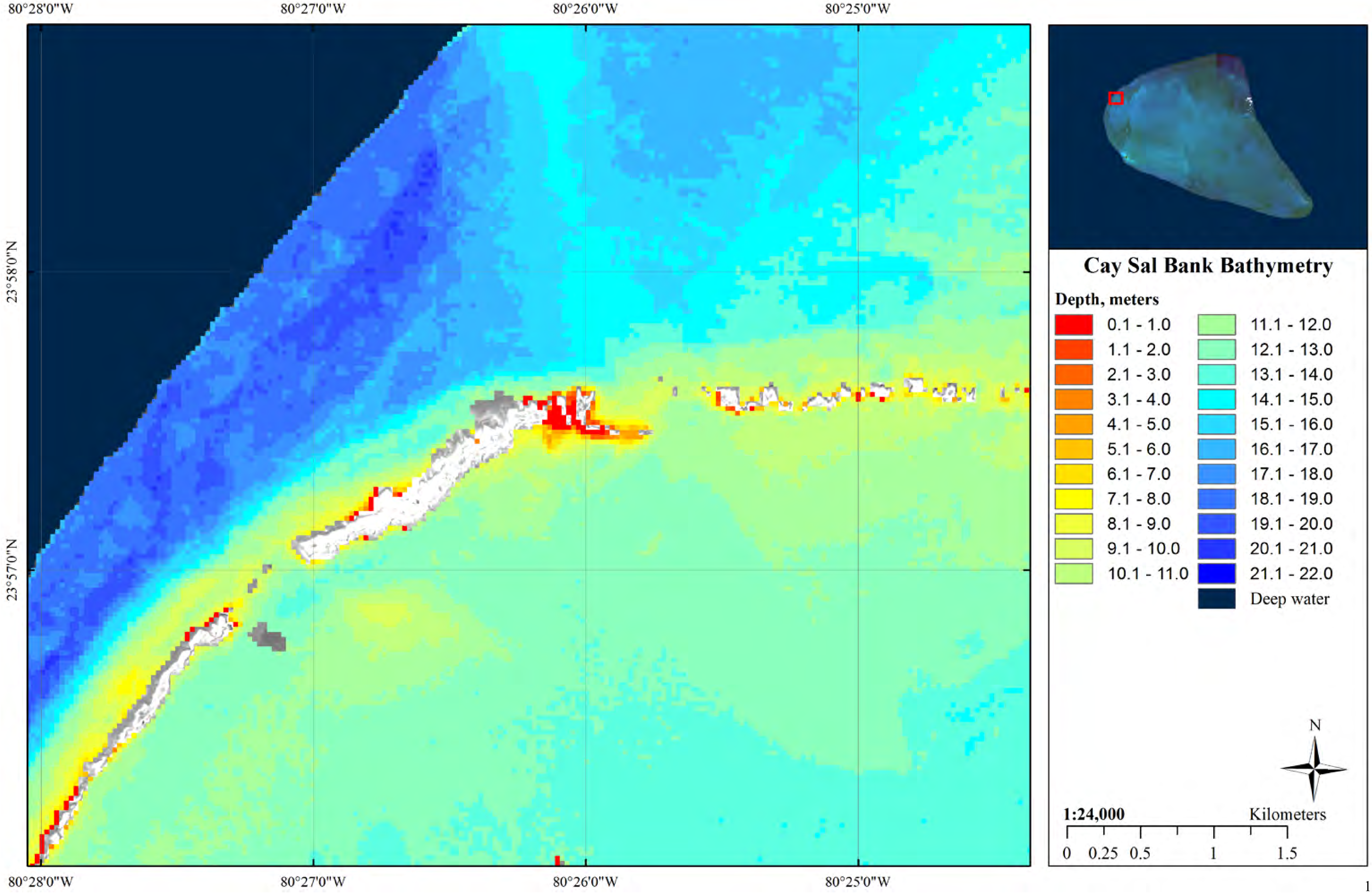


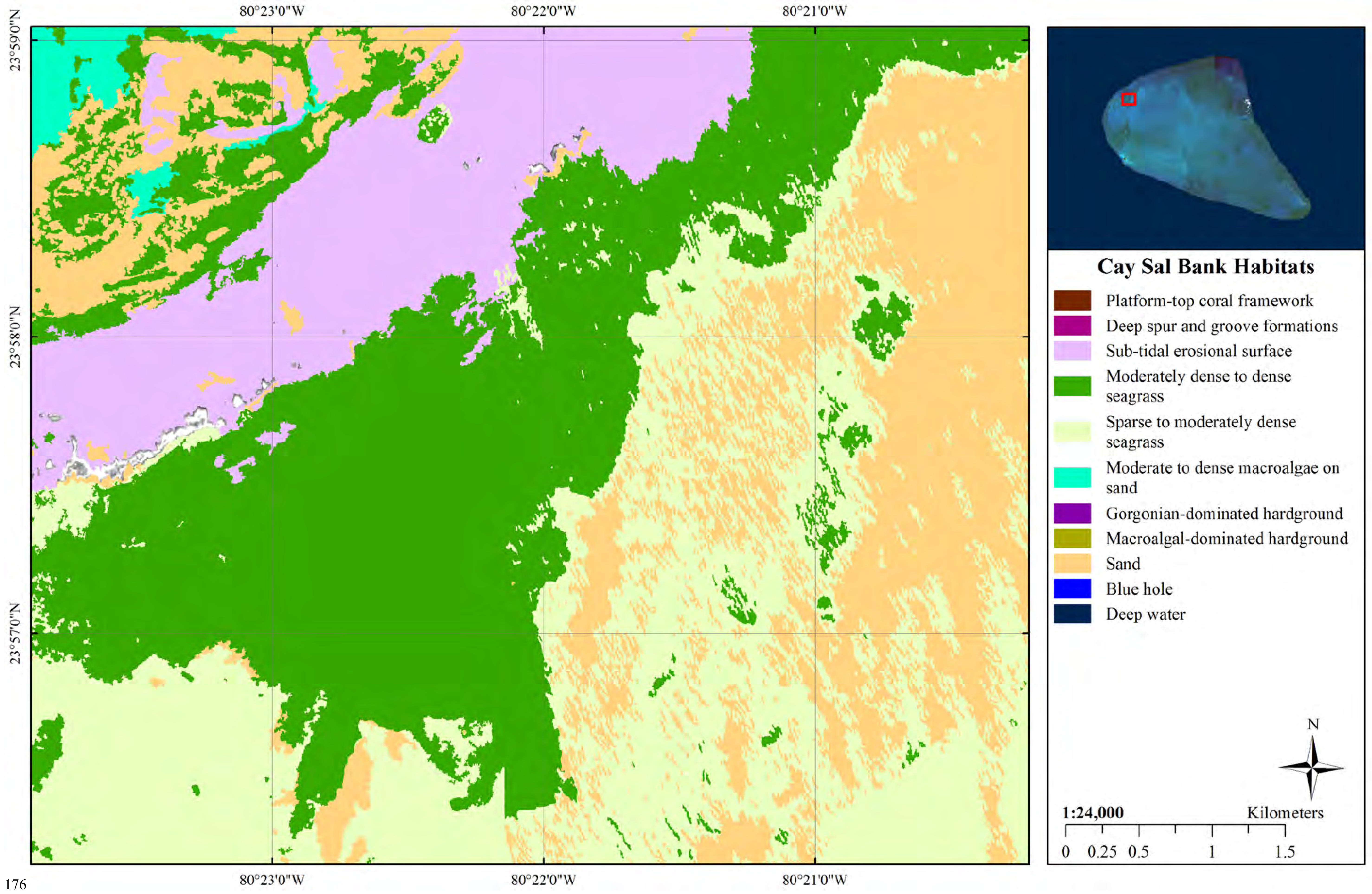
80°30'0"W
80°29'0"W
80°28'0"W
80°27'0"W
23°53'0"N
23°52'0"N
23°51'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5
80°30'0"W
80°29'0"W
80°28'0"W
80°27'0"W

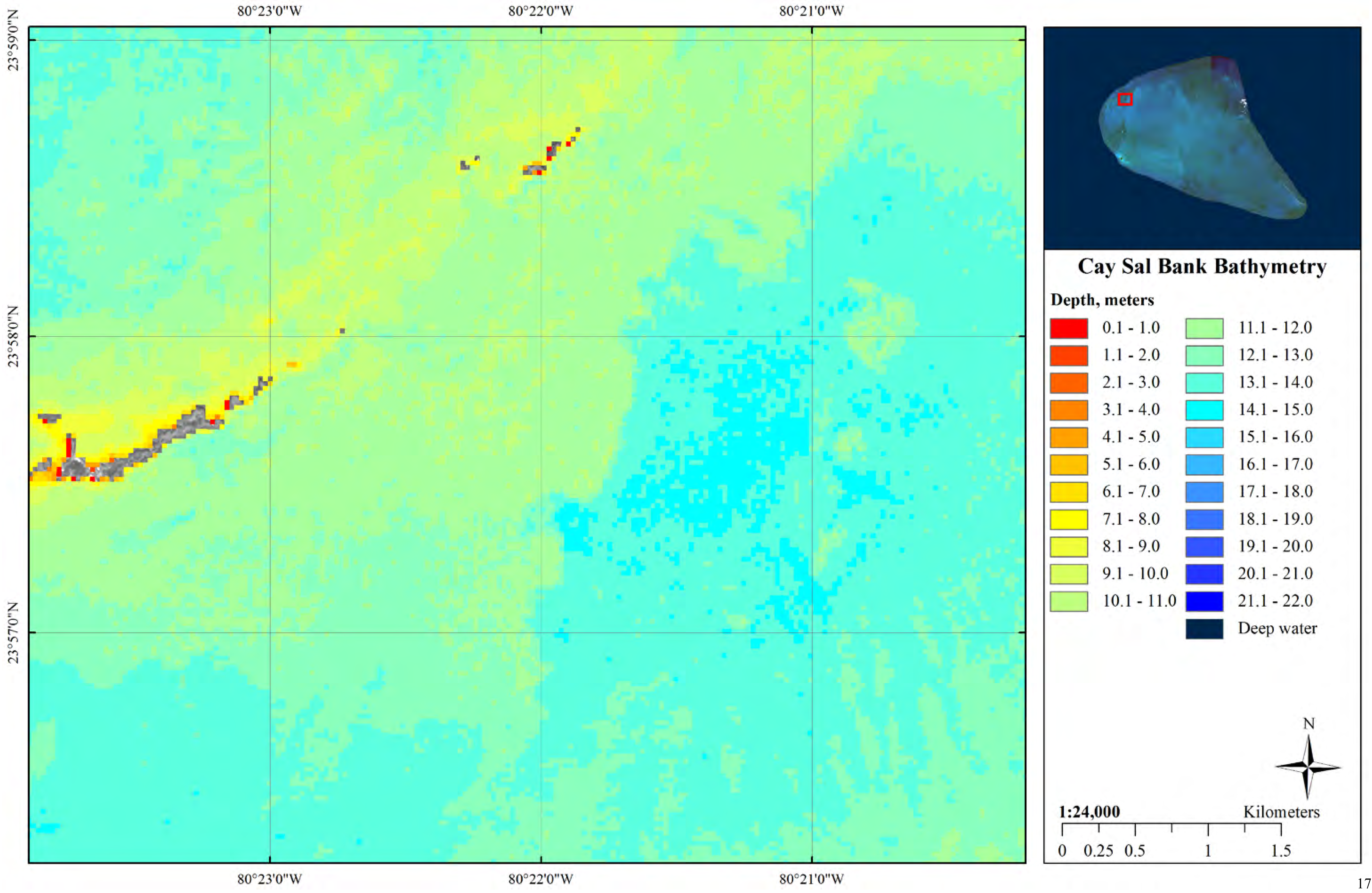

80°29'0"W
80°28'0"W
80°27'0"W
23°55'0"N
23°54'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

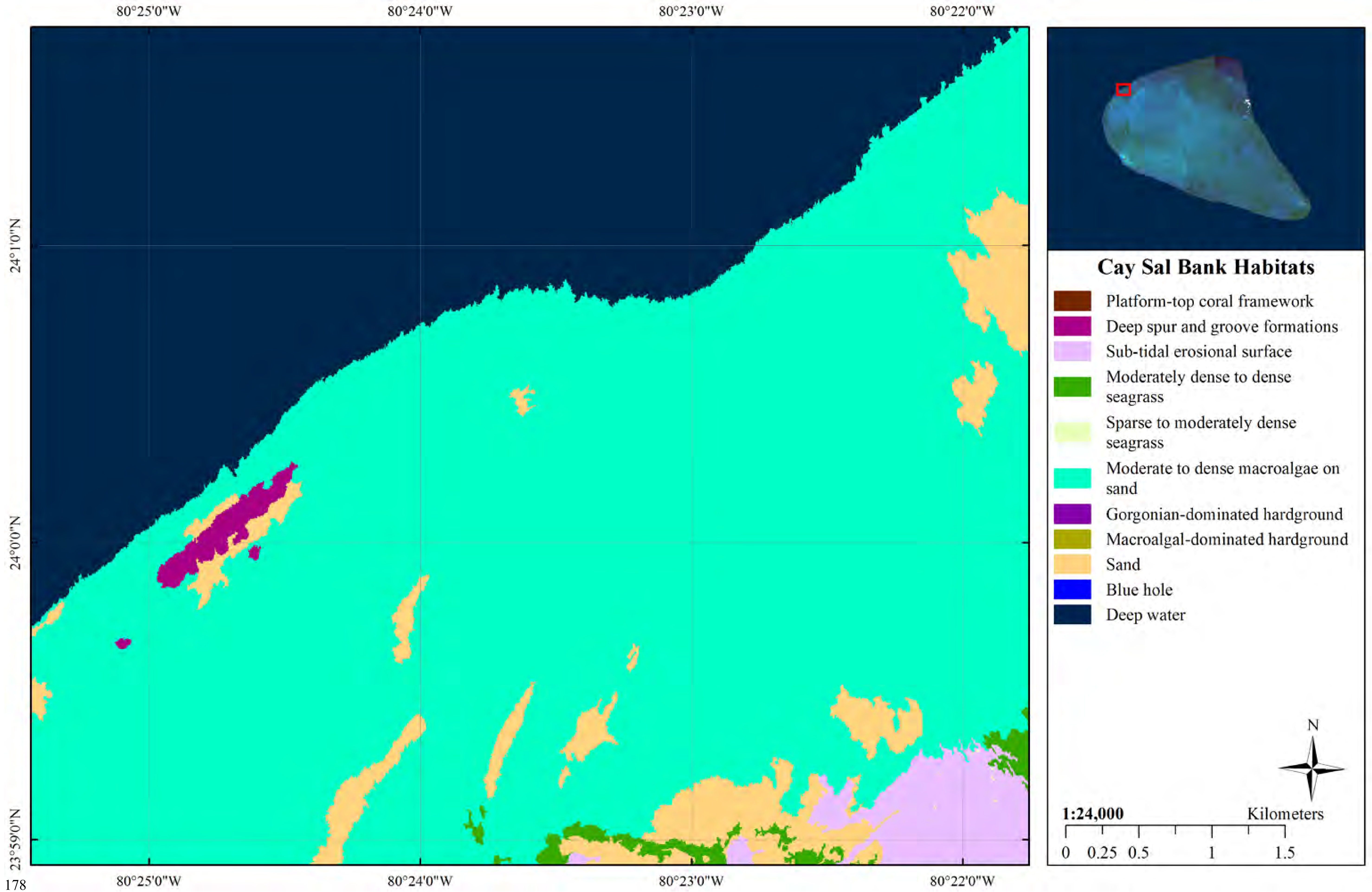

80°29'0"W
80°28'0"W
80°27'0"W
23°55'0"N
23°54'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

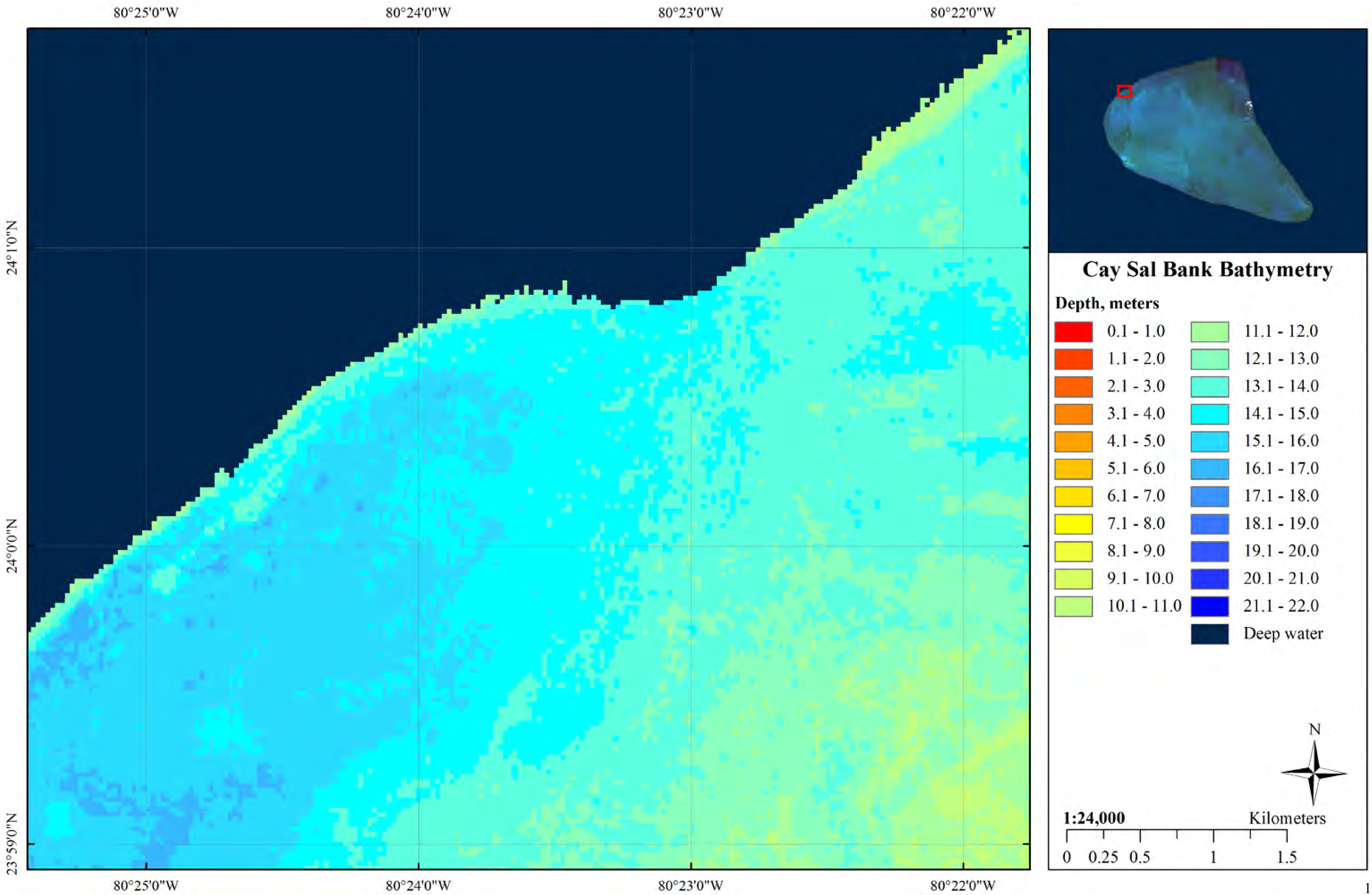

80°28'0"W
80°27'0"W
80°26'0"W
80°25'0"W
23°58'0"N
23°57'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

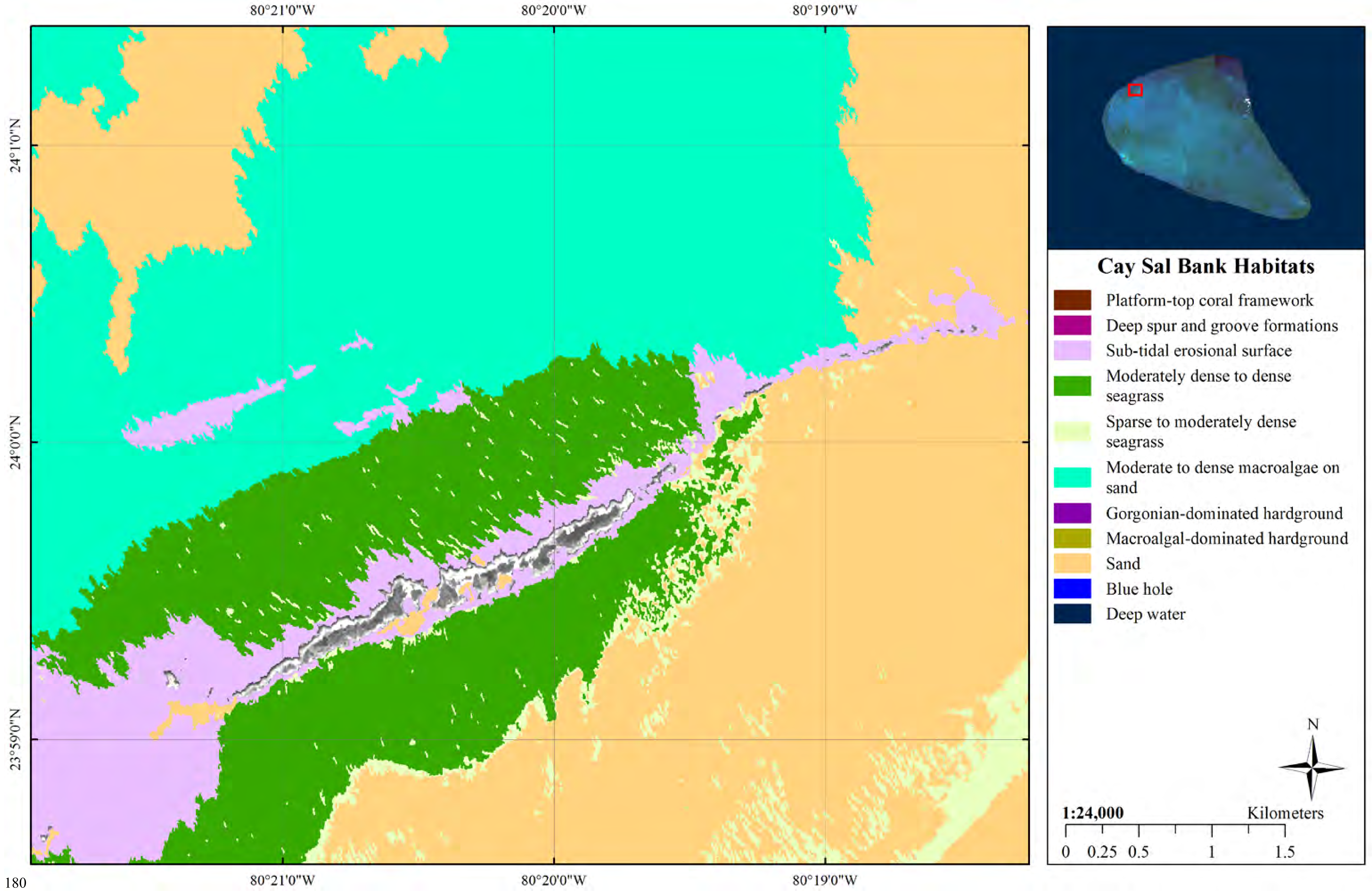

80°28'0"W
80°27'0"W
80°26'0"W
80°25'0"W
23°58'0"N
23°57'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

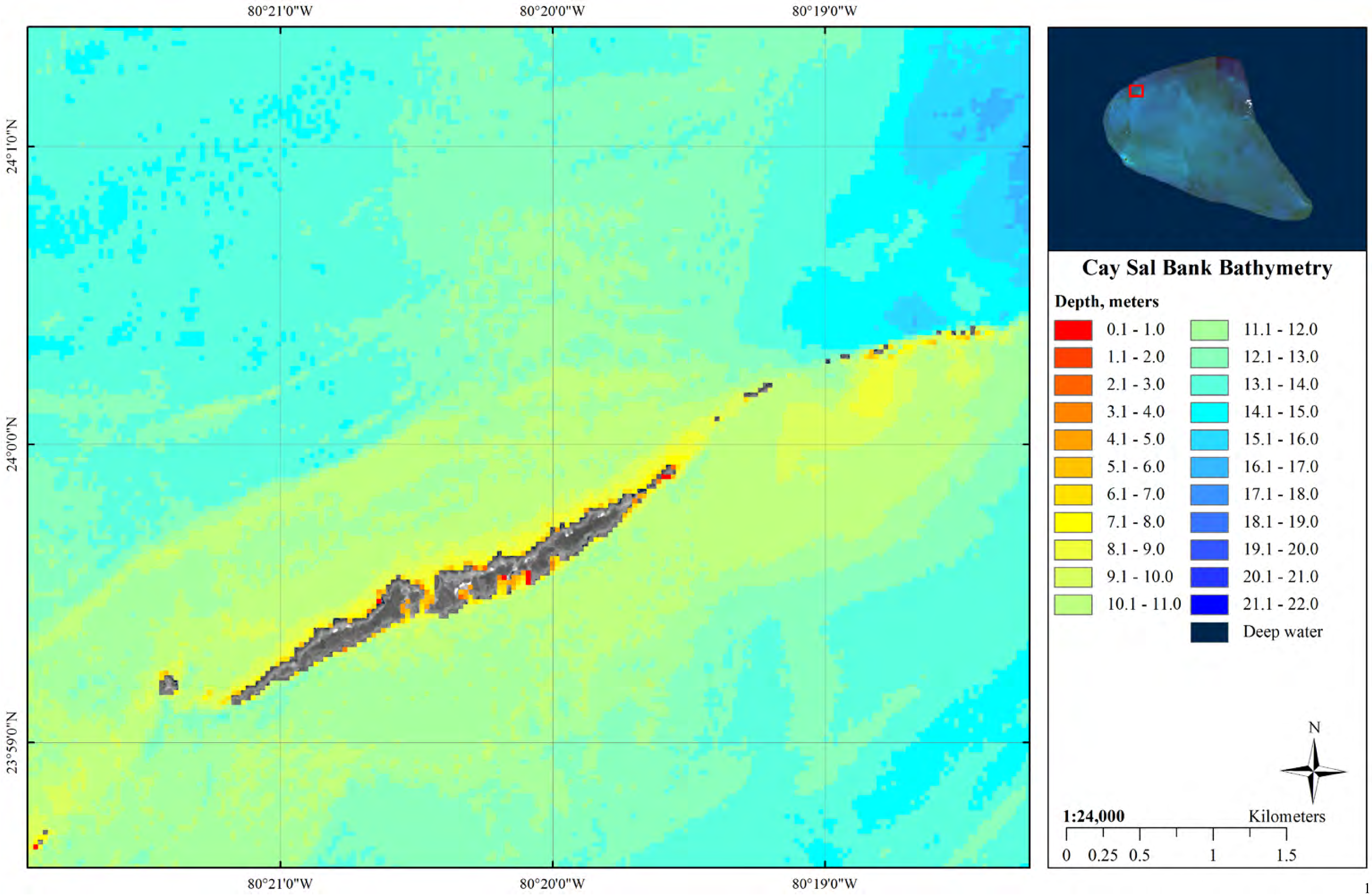

80°23'0"W
80°22'0"W
80°21'0"W
23°59'0"N
23°58'0"N
23°57'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

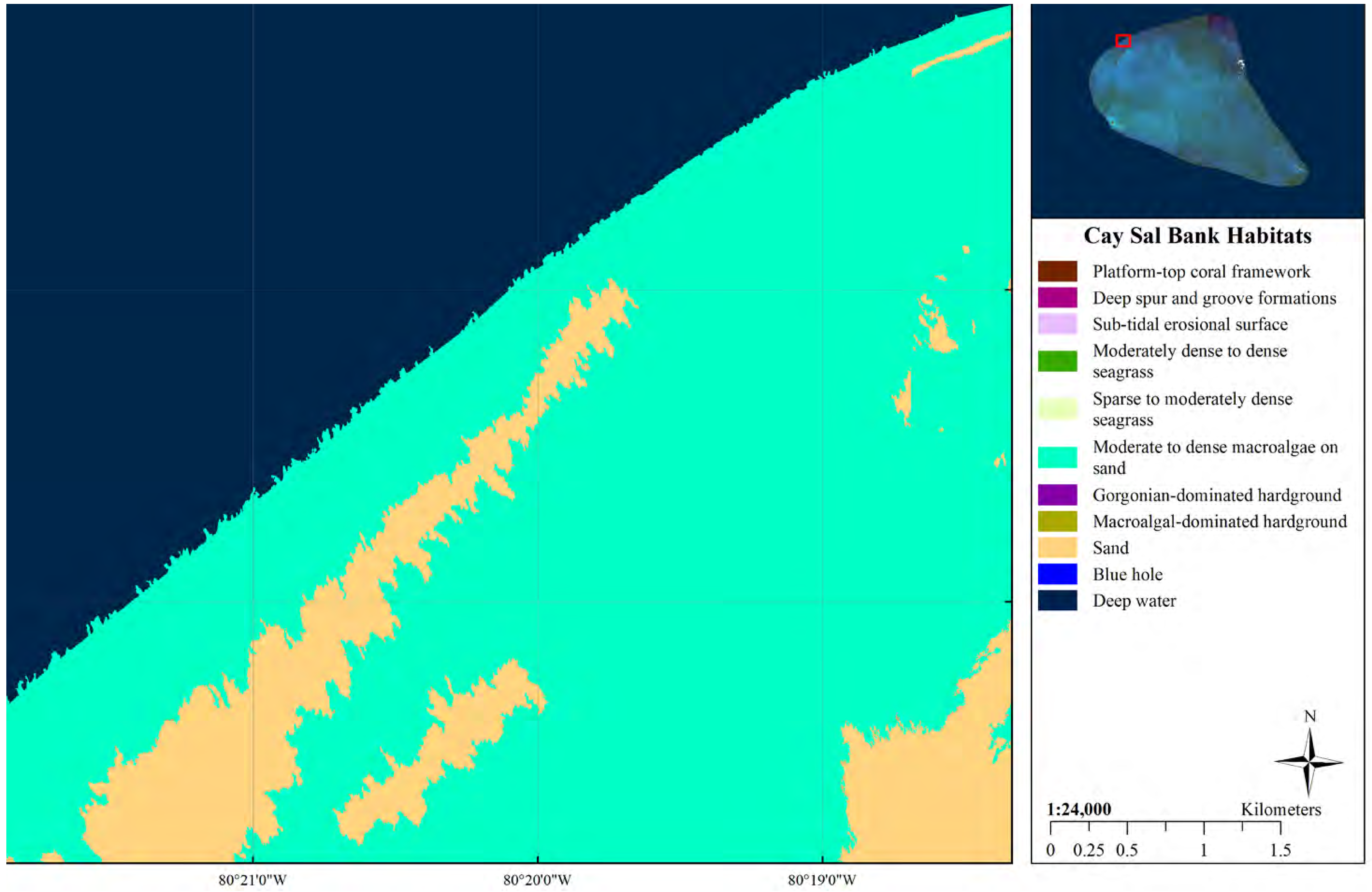

80°23'0"W
80°22'0"W
80°21'0"W
23°59'0"N
23°58'0"N
23°57'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

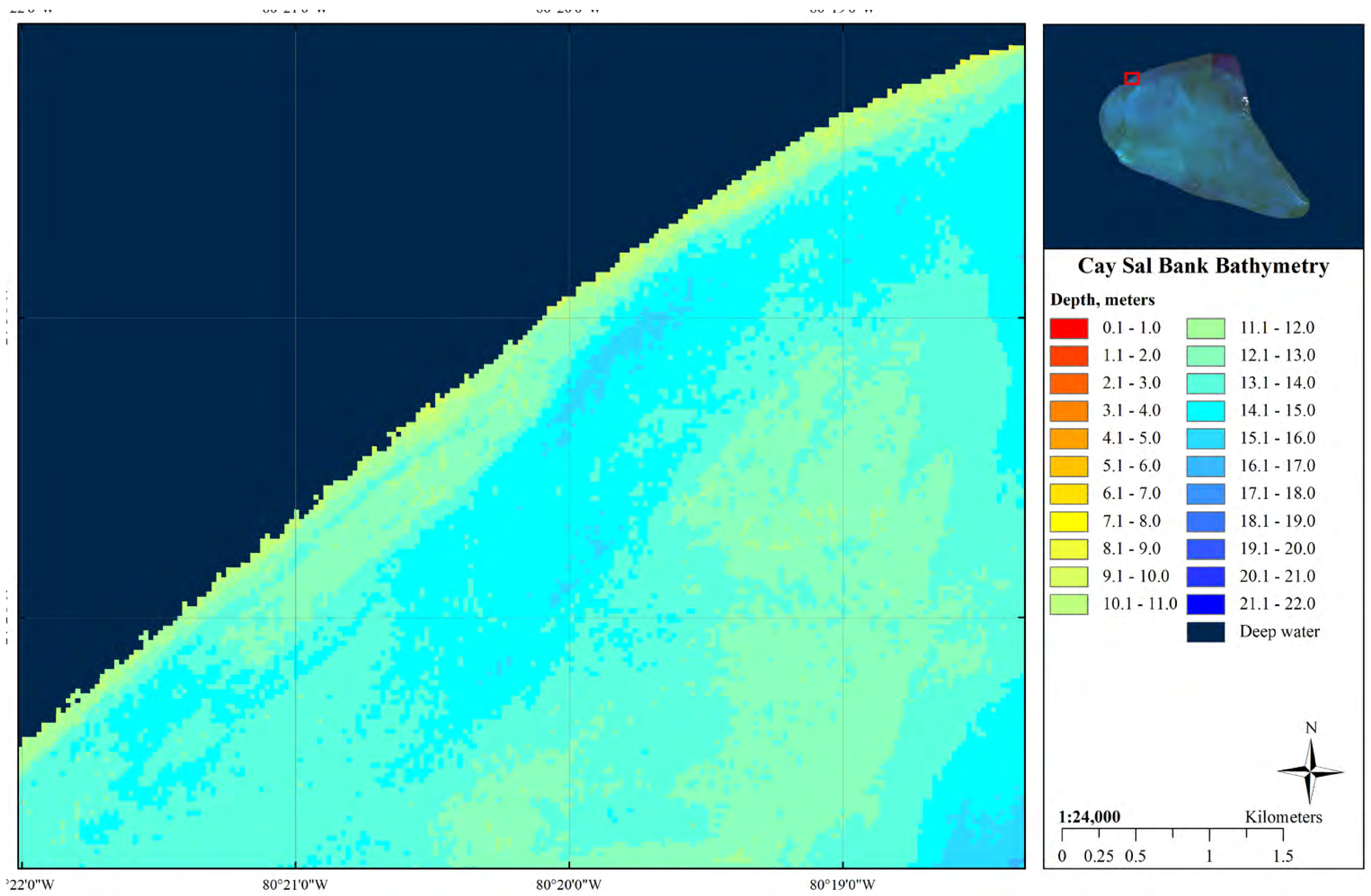

80°25'0"W
80°24'0"W
80°23'0"W
80°22'0"W
24°1'0"N
24°0'0"N
23°59'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

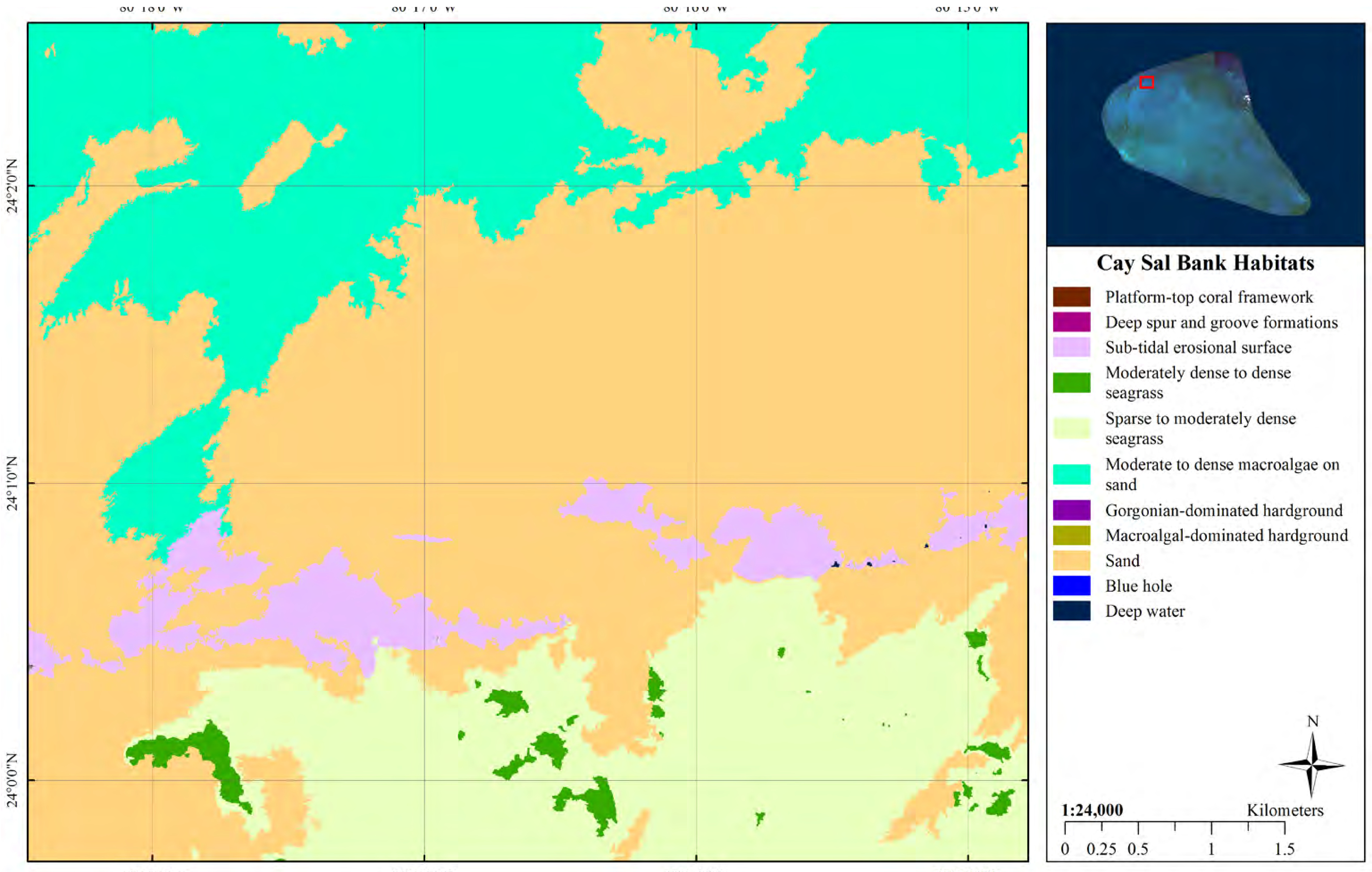

80°25'0"W
80°24'0"W
80°23'0"W
80°22'0"W
24°1'0"N
24°0'0"N
23°59'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

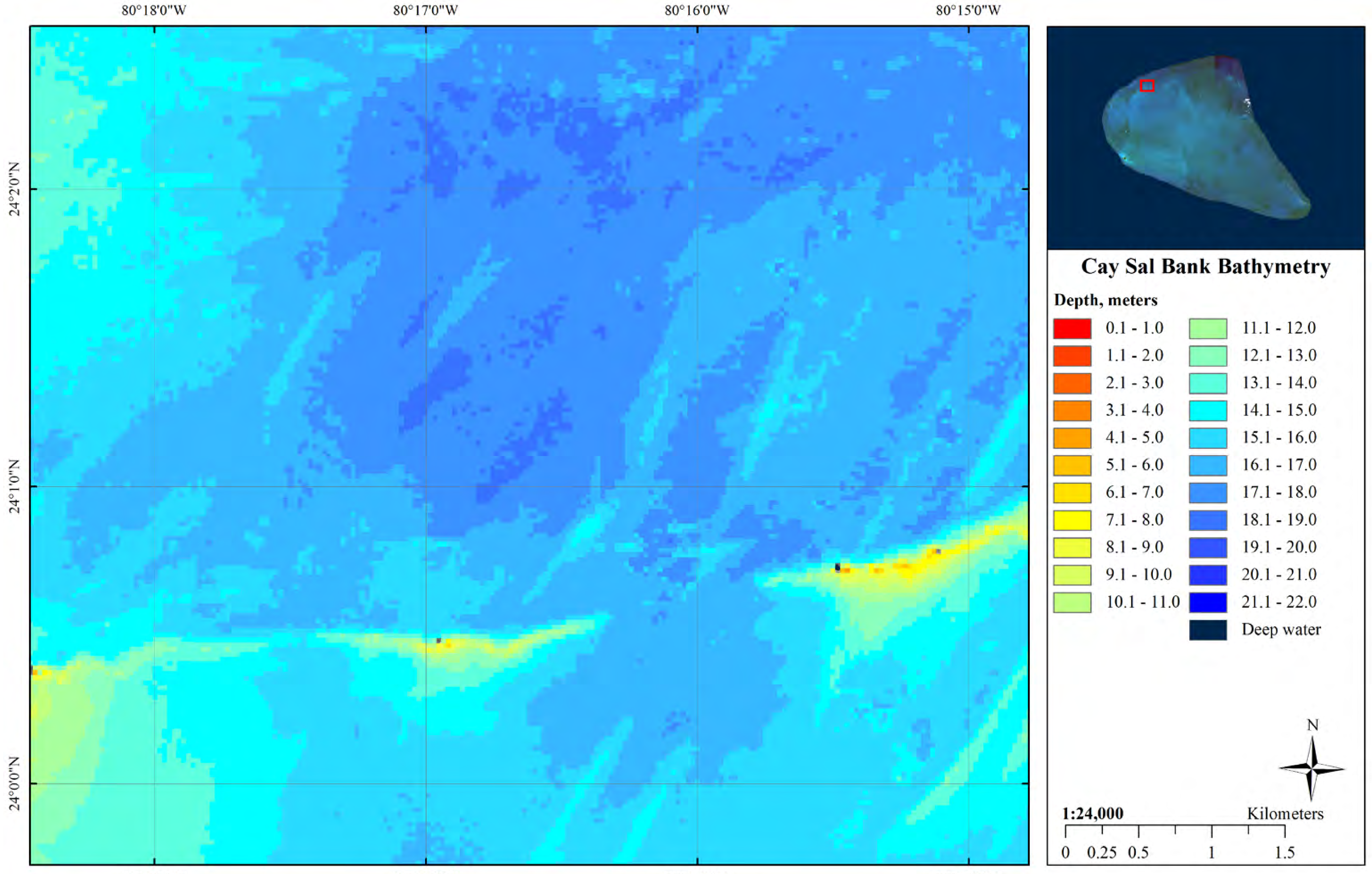

80°21'0"W
80°20'0"W
80°19'0"W
24°1'0"N
24°0'0"N
23°59'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

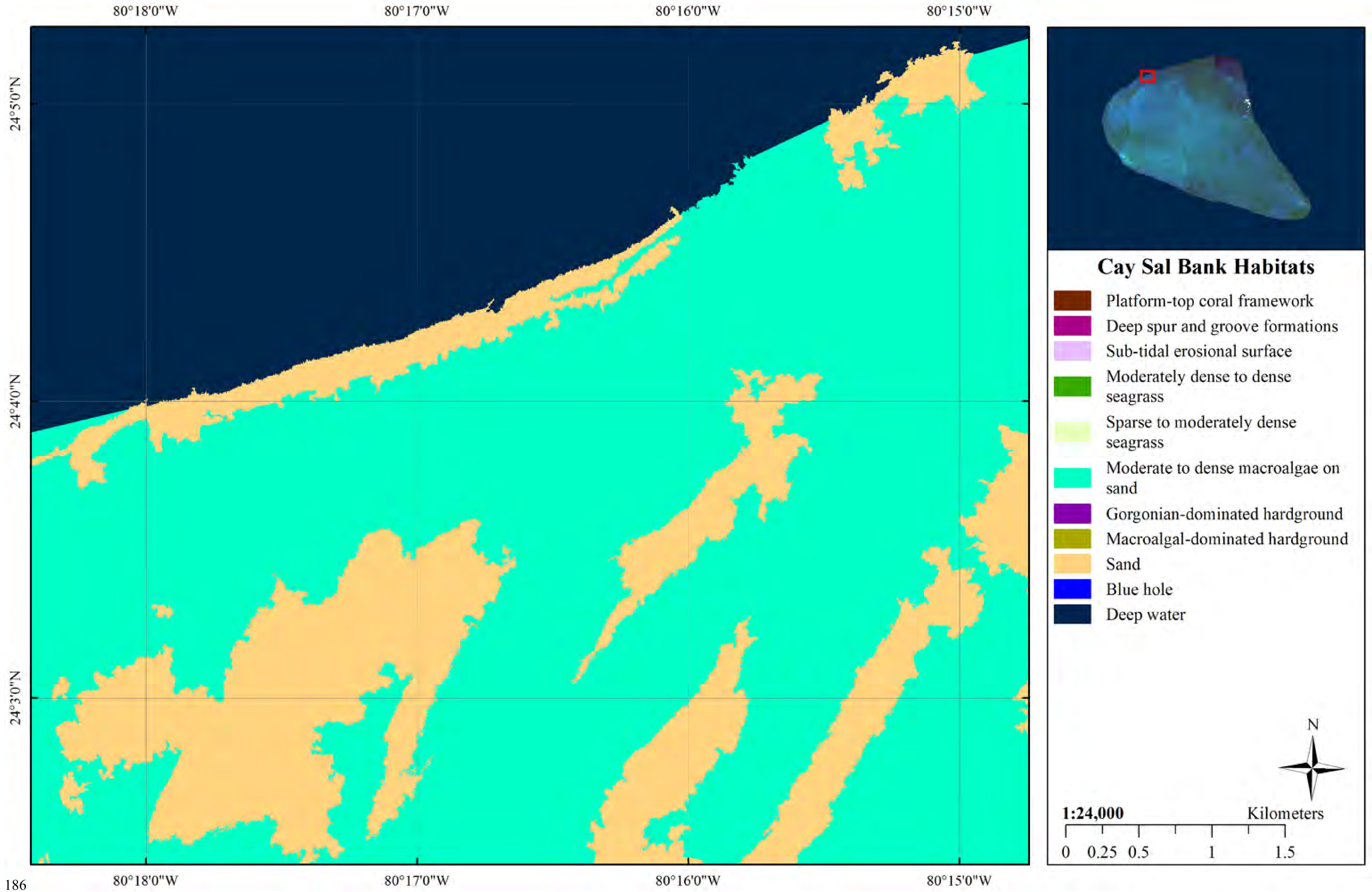

80°21'0"W
80°20'0"W
80°19'0"W
24°1'0"N
24°0'0"N
23°59'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

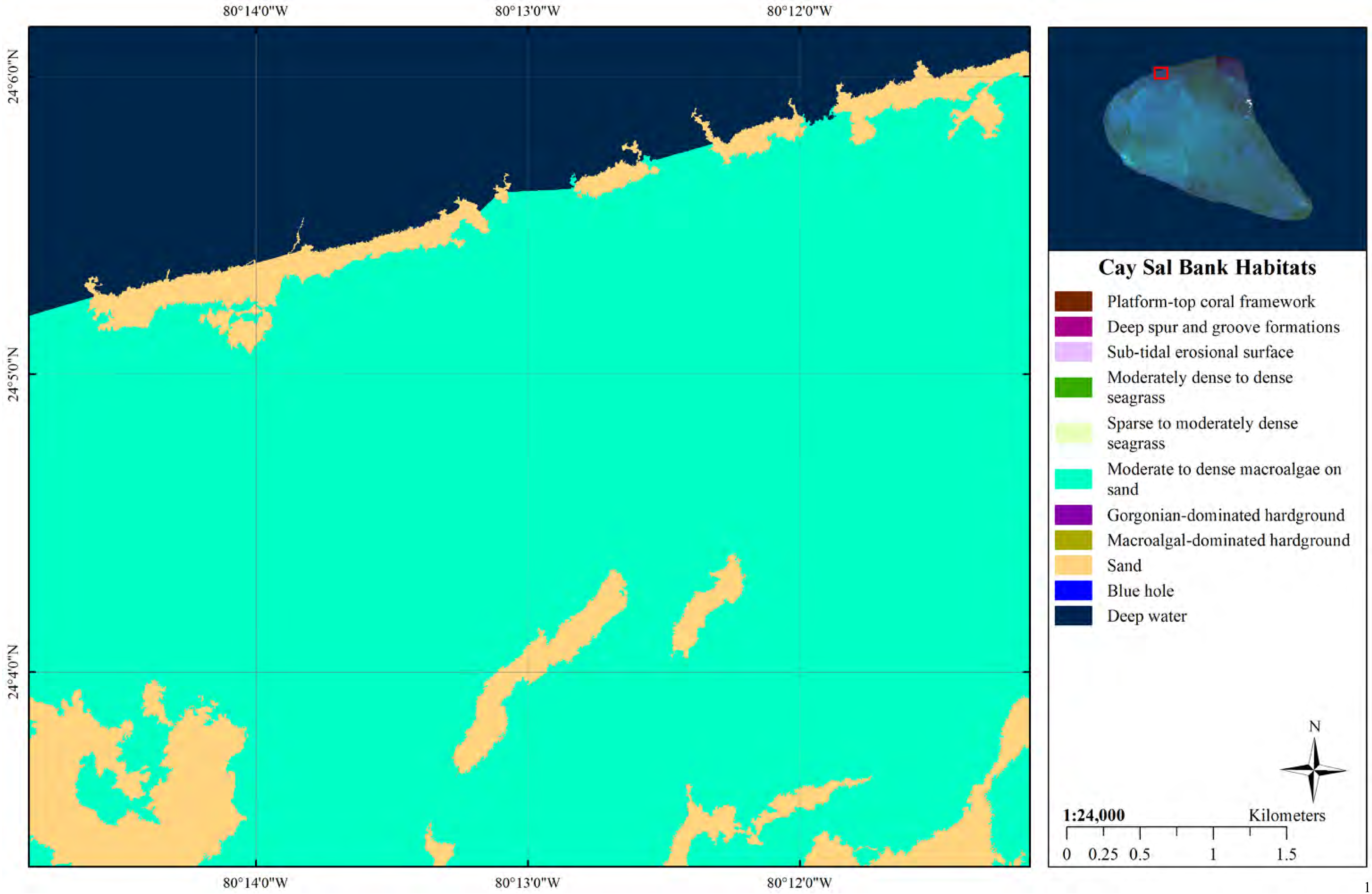

Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5
80°21'0"W
80°20'0"W
80°19'0"W

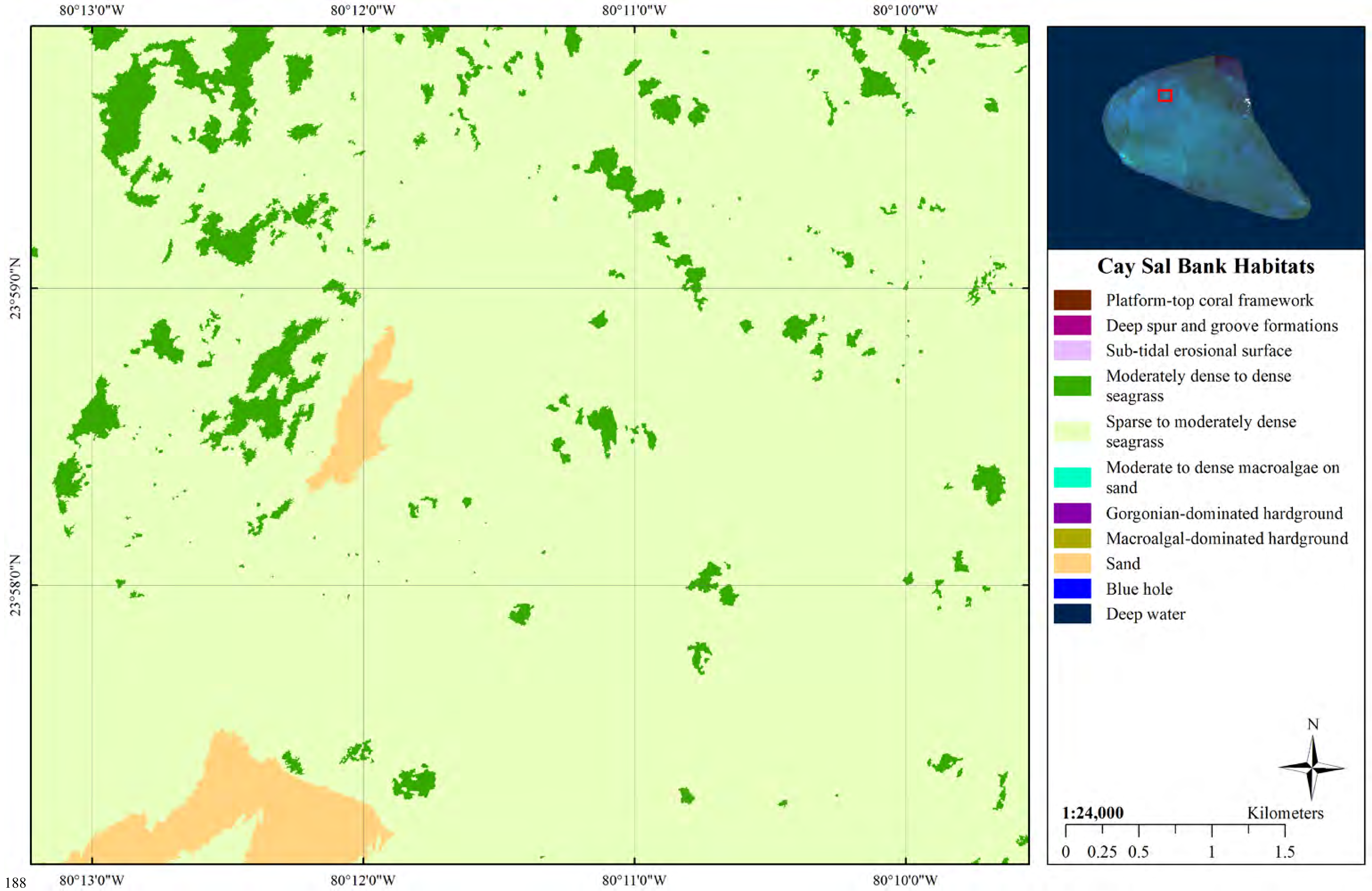

Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5
22'0"W
80°21'0"W
80°20'0"W
80°19'0"W

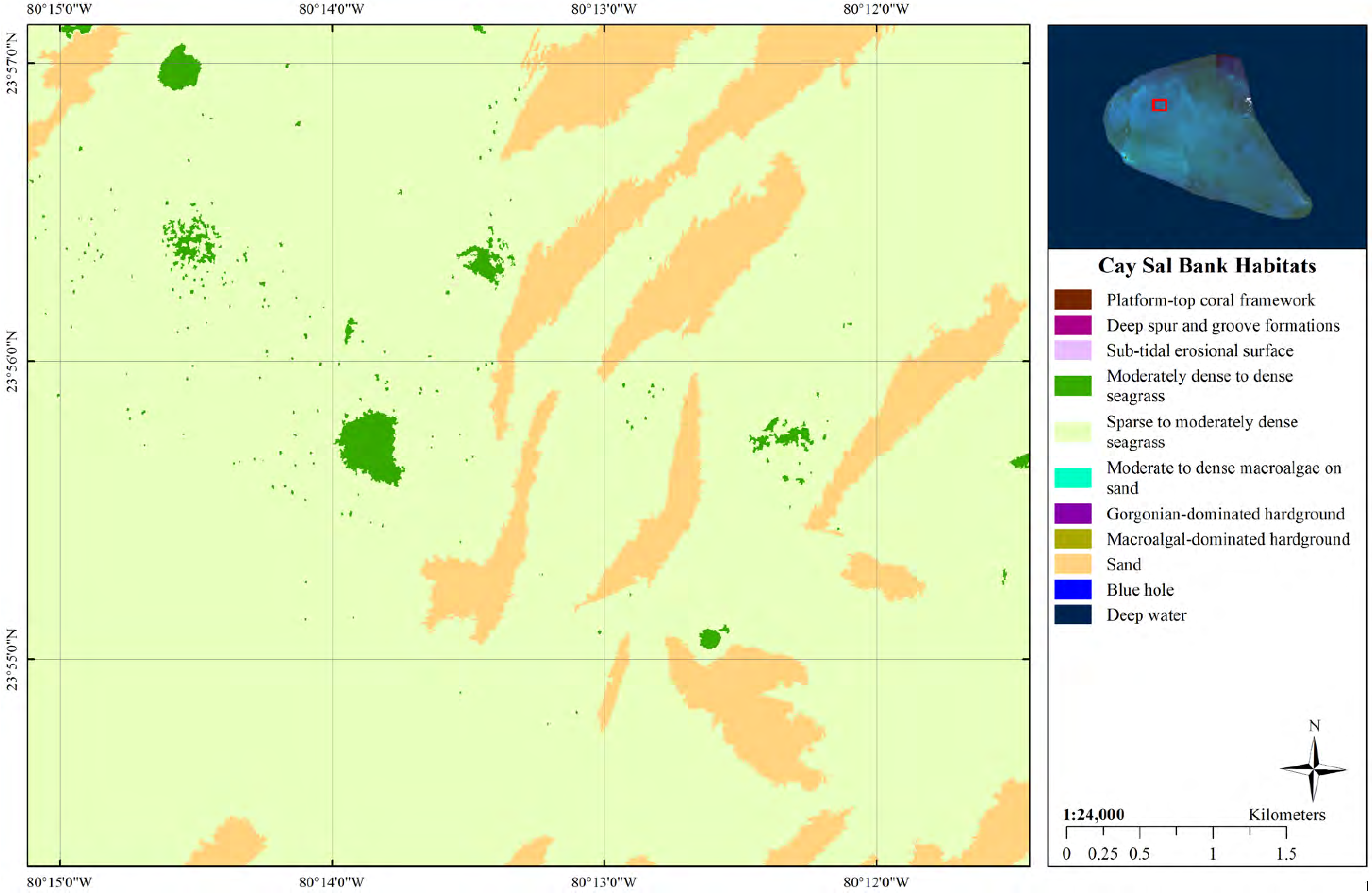

Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5
24°2'0"N
24°1'0"N
24°0'0"N
80°18'0"W
80°17'0"W
80°16'0"W
80°15'0"W

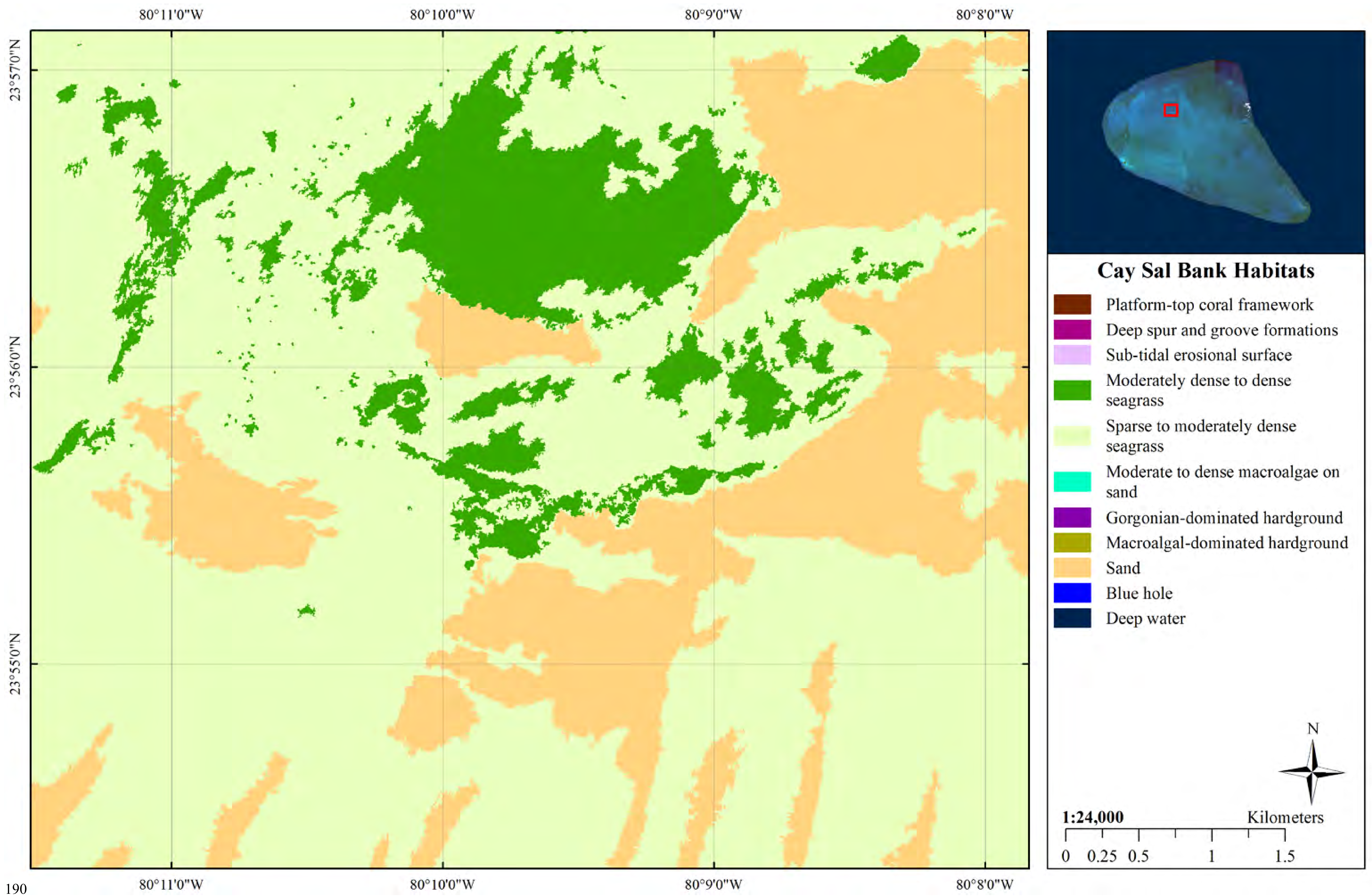

80°18'0"W
80°17'0"W
80°16'0"W
80°15'0"W
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5
24°2'0"N
24°1'0"N
24°0'0"N

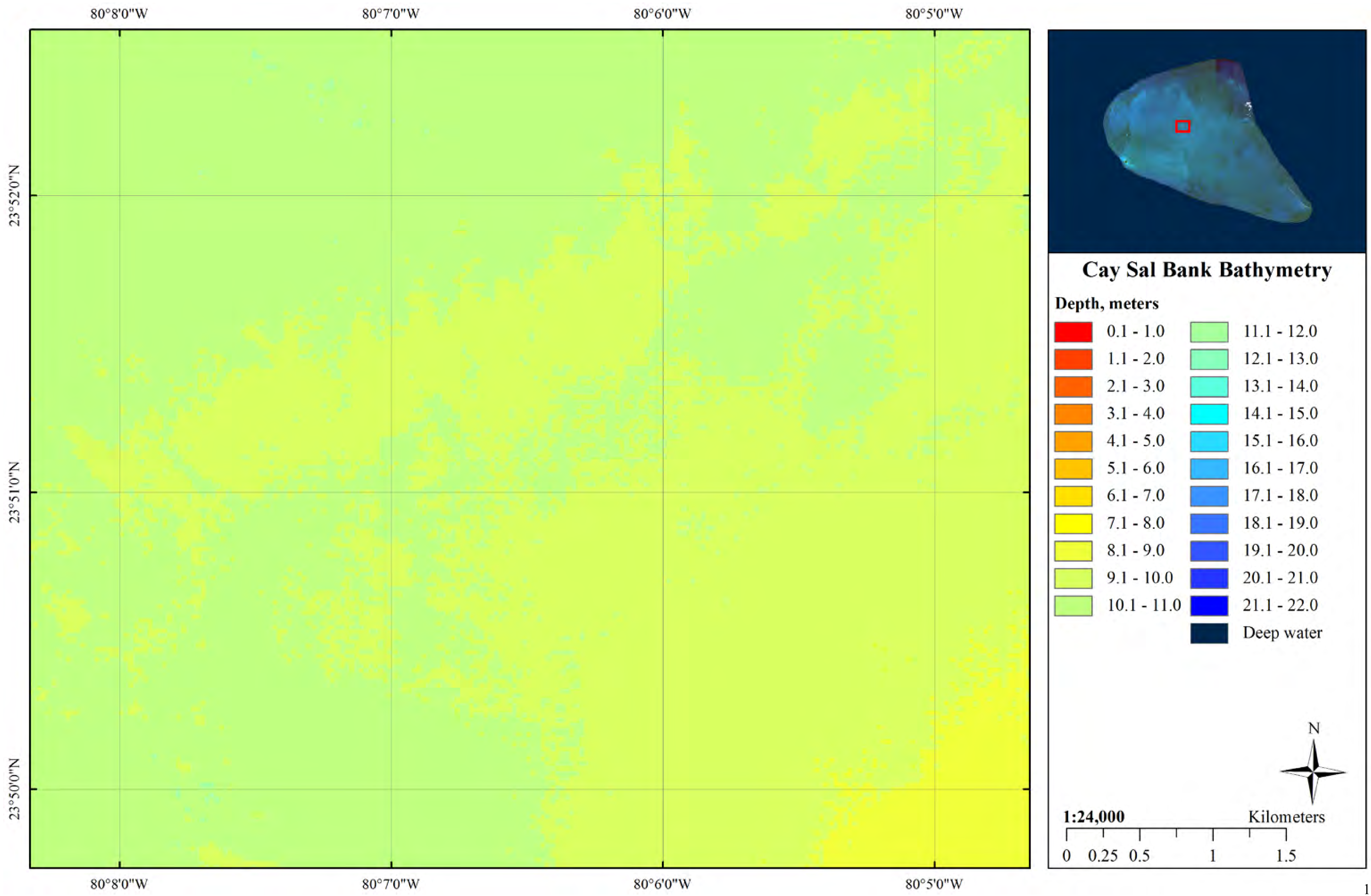

80°18'0"W
80°17'0"W
80°16'0"W
80°15'0"W
24°5'0"N
24°4'0"N
24°3'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

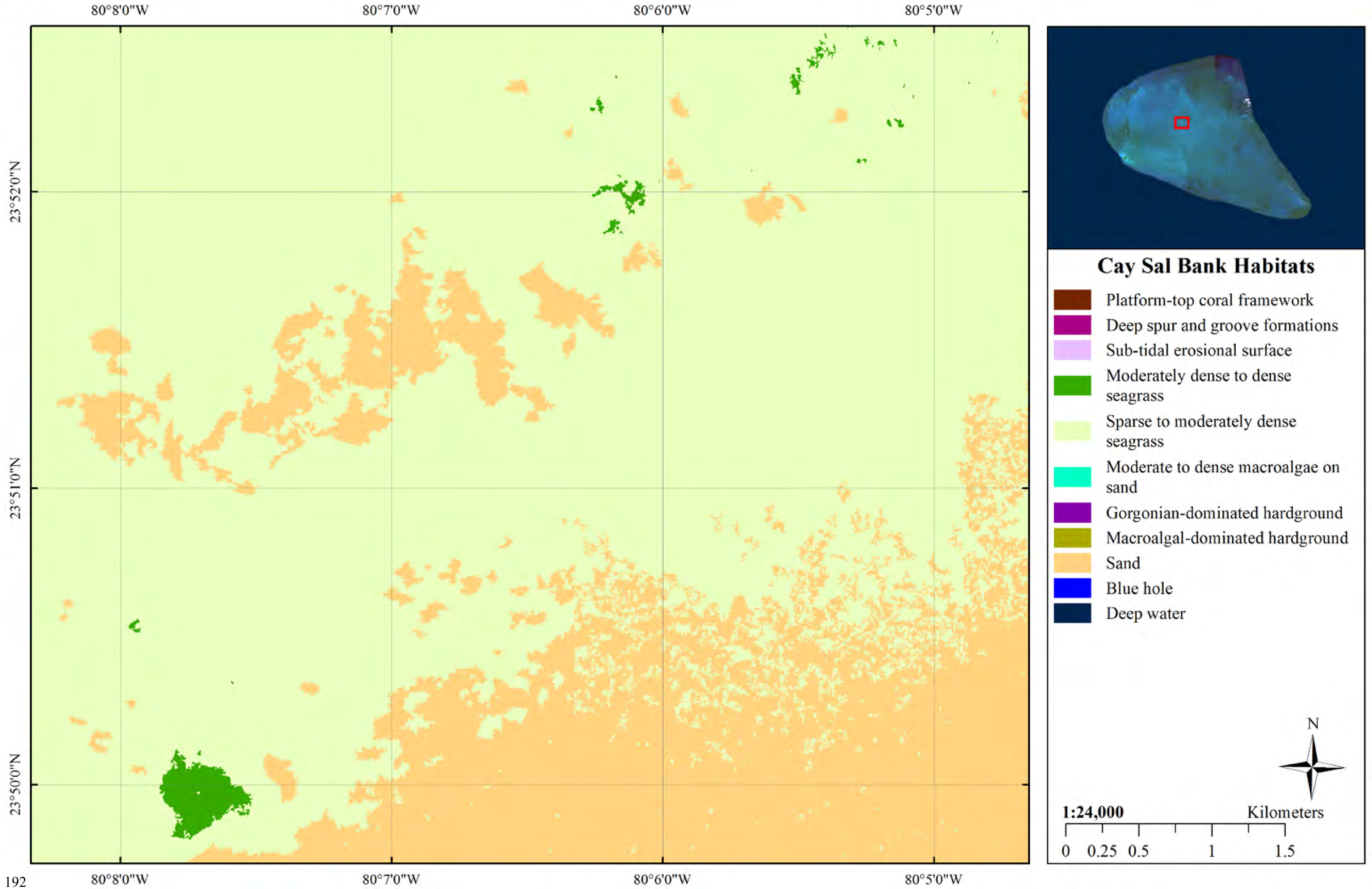

80°14'0"W
80°13'0"W
80°12'0"W
24°6'0"N
24°5'0"N
24°4'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

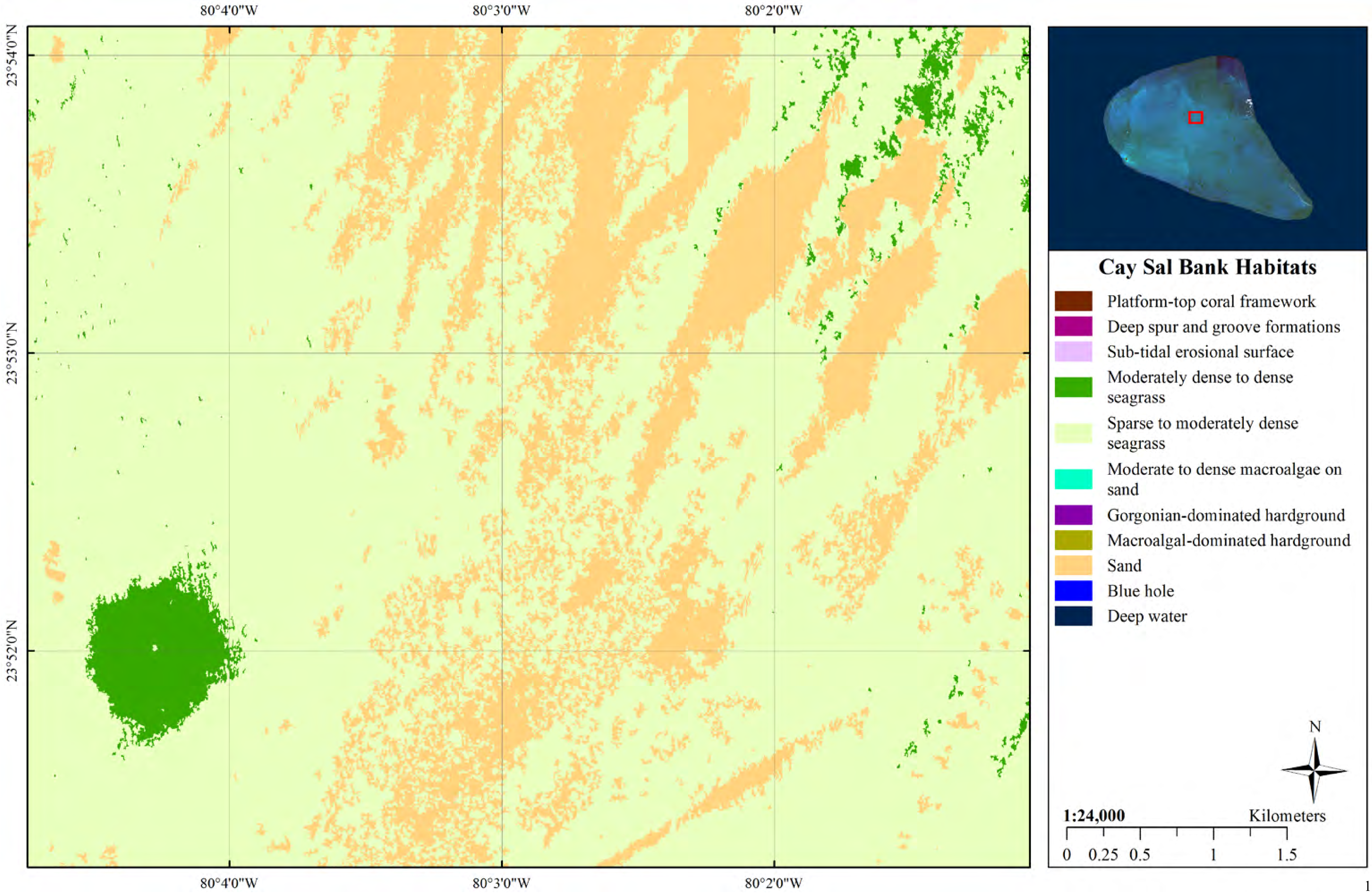

80°13'0"W
80°12'0"W
80°11'0"W
80°10'0"W
23°59'0"N
23°58'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

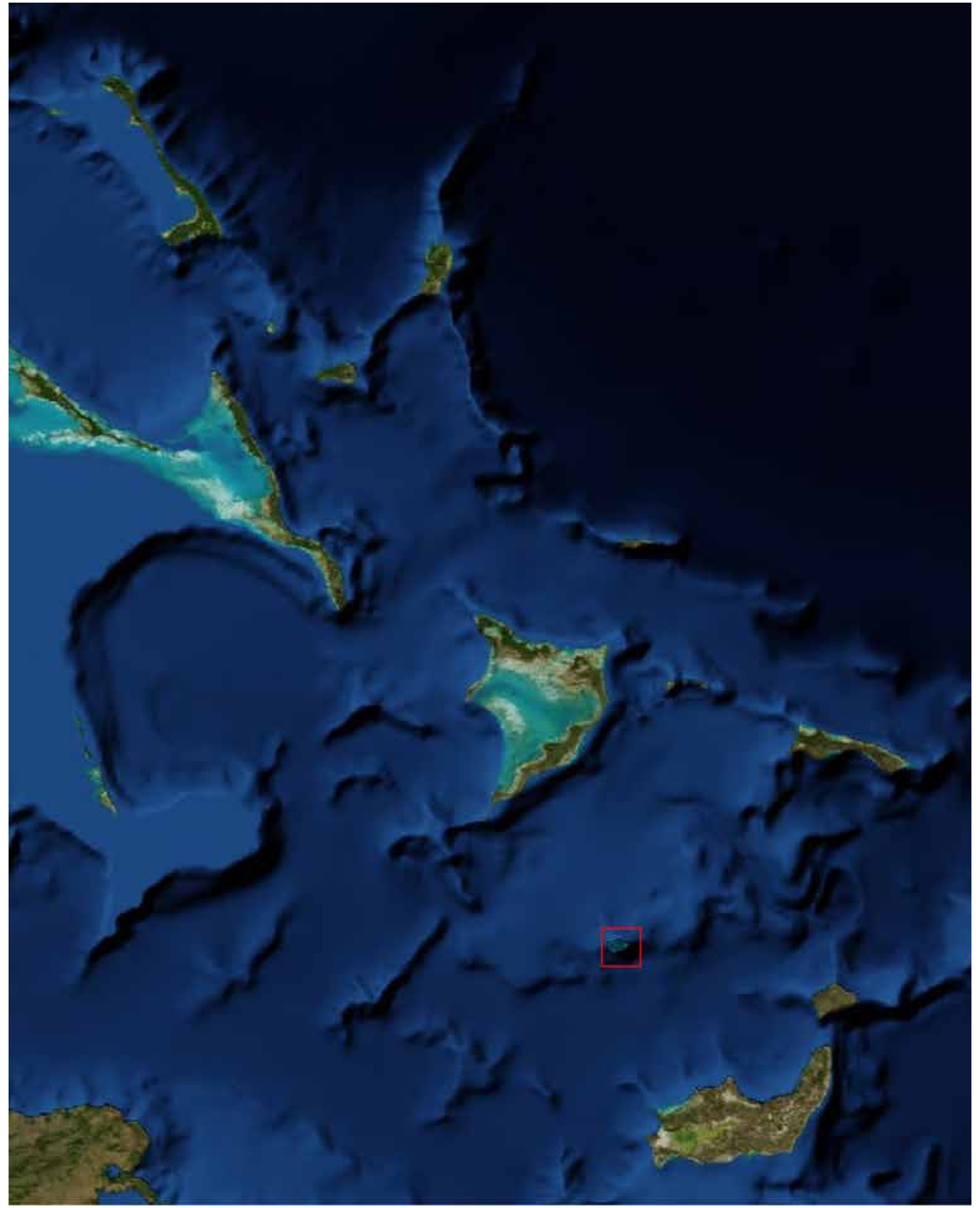

80°15'0"W
80°14'0"W
80°13'0"W
80°12'0"W
23°57'0"N
23°56'0"N
23°55'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


80°11'0"W
80°10'0"W
80°9'0"W
80°8'0"W
23°57'0"N
23°56'0"N
23°55'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


80°8'0"W
80°7'0"W
80°6'0"W
80°5'0"W
23°52'0"N
23°51'0"N
23°50'0"N
Cay Sal Bank Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


80°8'0"W
80°7'0"W
80°6'0"W
80°5'0"W
23°52'0"N
23°51'0"N
23°50'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


80°4'0"W
80°3'0"W
80°2'0"W
23°54'0"N
23°53'0"N
23°52'0"N
Cay Sal Bank Habitats
Platform-top coral framework
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5



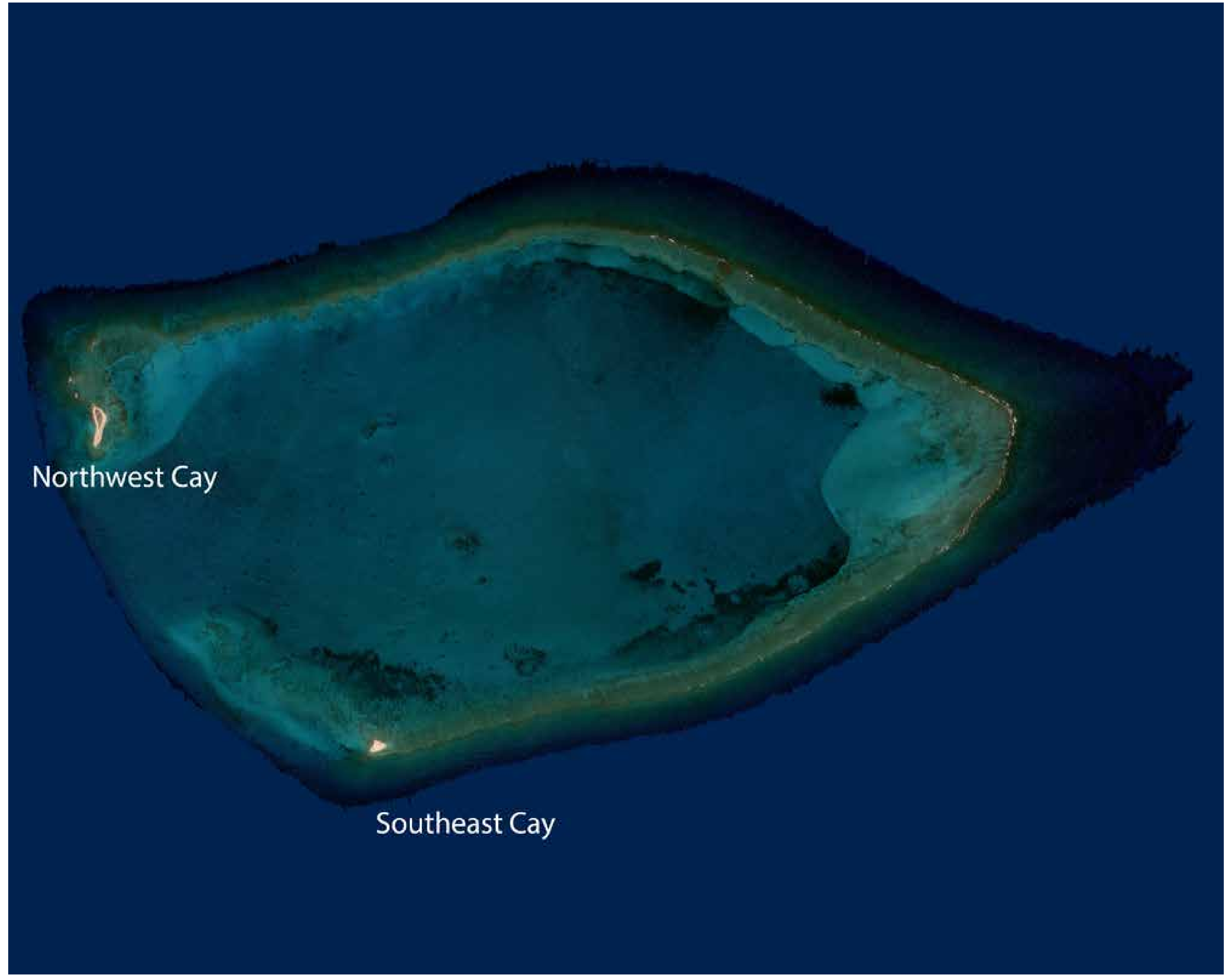
Hogsty Reef, Bahamas

Hogsty Reef is a small (9 × 5 km) atoll located nearly equidistant from the Acklins Island, Great Inagua and Little Inagua. Hogsty reef contains two small sand islands, a distinct peripheral reef, a shallow (6-8 m depth) lagoon, and a pronounced leeward pass (Milliman 1967a). The bottom depths surrounding the atoll range from 1,800-2,600 m. Hogsty Reef has been considered a classic Atlantic atoll as defined by its geomorphology. It has steep upper slopes, a reef flat, lagoonal patch reefs, and a lagoonal pass connecting it to deep water. It is unlike most Pacific atolls, in that it is not formed through the subsidence of a volcano and build-up of coral reefs. Furthermore, present day reef communities form a thin veneer atop a pre-existing structure. The reef flat is believed to be non-coralline in origin, but rather a lithified Pleistocene aeolian dune. Corals and other organisms appear to have only recently colonized the margin, forming a thin veneer on a pre-existing platform. In addition, the lagoon has extensive accumulations of sediments that are up to approximately 800 m in thickness (Milliman 1967b). The lagoonal sediments consist of reef material (mollusk shells, coral, coralline algae) as well as non-skeletal fragments that were inorganically precipitated (Milliman 1967a). Hogsty Reef is separated from Great and Little Inagua by extremely deep (1800-2200 m) water.

The fore reef slope is mostly a hardground with thick accumulations of macroalgae, scattered branching gorgonians and isolated reef building corals (below). Coral cover is very low in most locations, although there are some areas at 25-30 m depth, on the steeper part of the slope, with well developed communities of plating corals. One of the islands has a sandy beach, accumulations of coral rubble and some small dunes that are important nesting habitat for sea birds (top right). The Trebisnjica, a Liberty ship (cargo ship built in the U.S. during World War II), grounded on the northern part of the reef on July 17, 1963 (bottom right).

The fore reef community around Hogsty included shallow hardground habitats with relatively low relief and only isolated larger corals, such as the pillar coral, *Dendrogyra cylindrus* (top left). This is an unusual coral in that it has separate sexes and is often found on reefs as individual corals. Occasionally, in exposed shallow locations, groups of colonies may occur. When found in groups, the corals tend to be fairly close together and they are all genetically identical, resulting from fragmentation. During storms, pillars often break off a colony, fuse to the bottom, and then send up new projections (bottom left). This mechanism increases overall rates of growth and can quickly generate a colony with multiple large pillars. Pillar corals were very common on Hogsty Reef.

In addition to an abundance of branching gorgonians, one of the most common corals found on the fore reef of Hogsty Reef was the genus *Montastraea*, including *M. annularis* and *M. faveolata*. The two species were found next to each other on a shallow reef (10 m depth) off the south coast (bottom center). These corals often formed large hemispherical mounds up to 1.5 m in height and diameter (top right). They were present on all reefs, but their abundance was fairly low, and typically only a single colony occurred in one area as seen above. In many cases, these had experienced extensive partial mortality and several hundred year old corals had been reduced to tiny remnants of living tissue with most of their skeleton colonized by algae and other corals (bottom right).



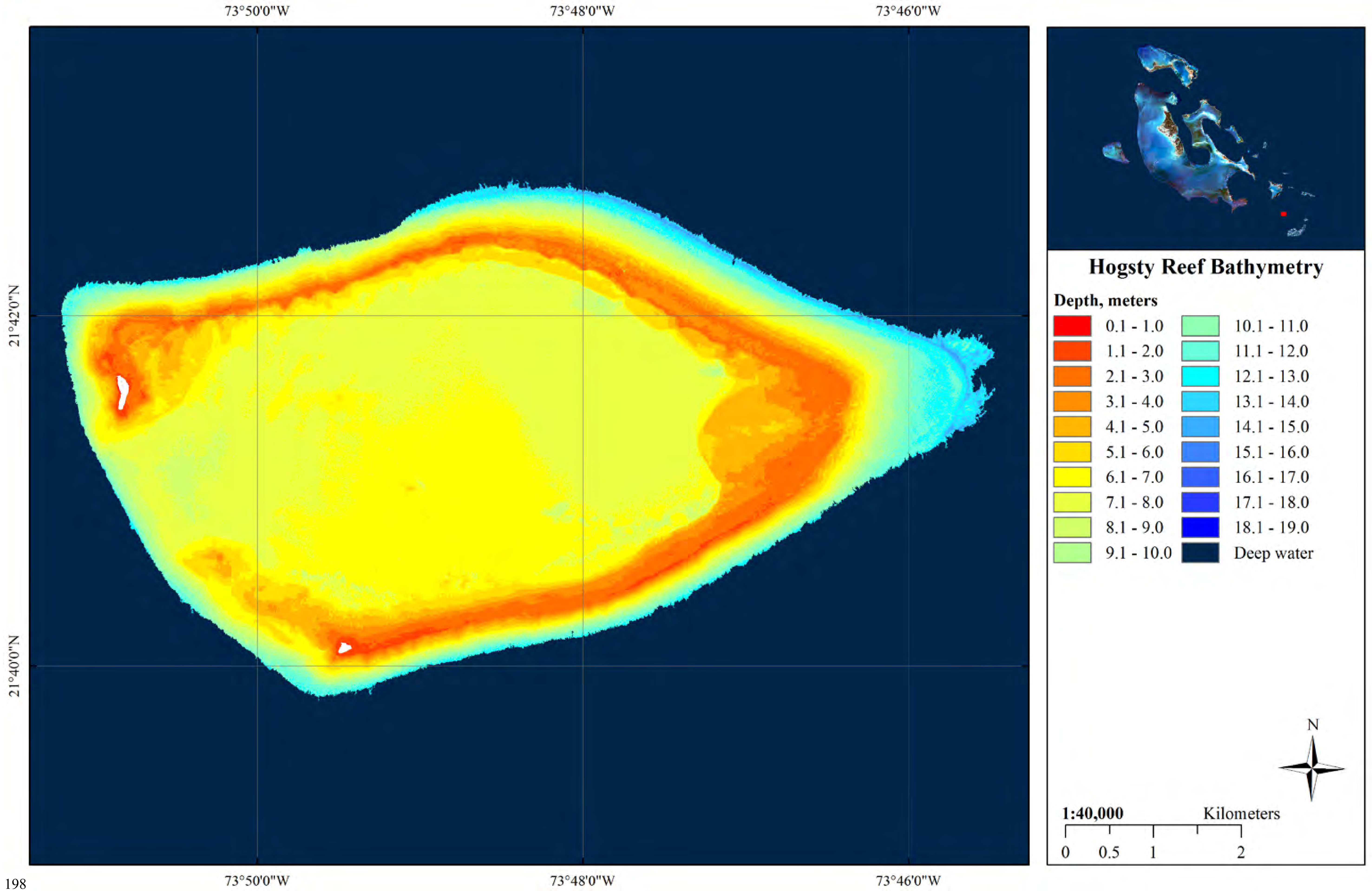
High resolution satellite image of Hogsty Reef at a scale of 1:40,000 taken in April, 2011. Northwest Cay (270 m x 65 m) and Southeast Cay (150 m x 50 m) are the only emergent land. Both islands are surrounded by beach rock and have some vegetation including creepers and low-lying shrubs; Northwest Cay also has a few coconut palm trees and Australian Pine.

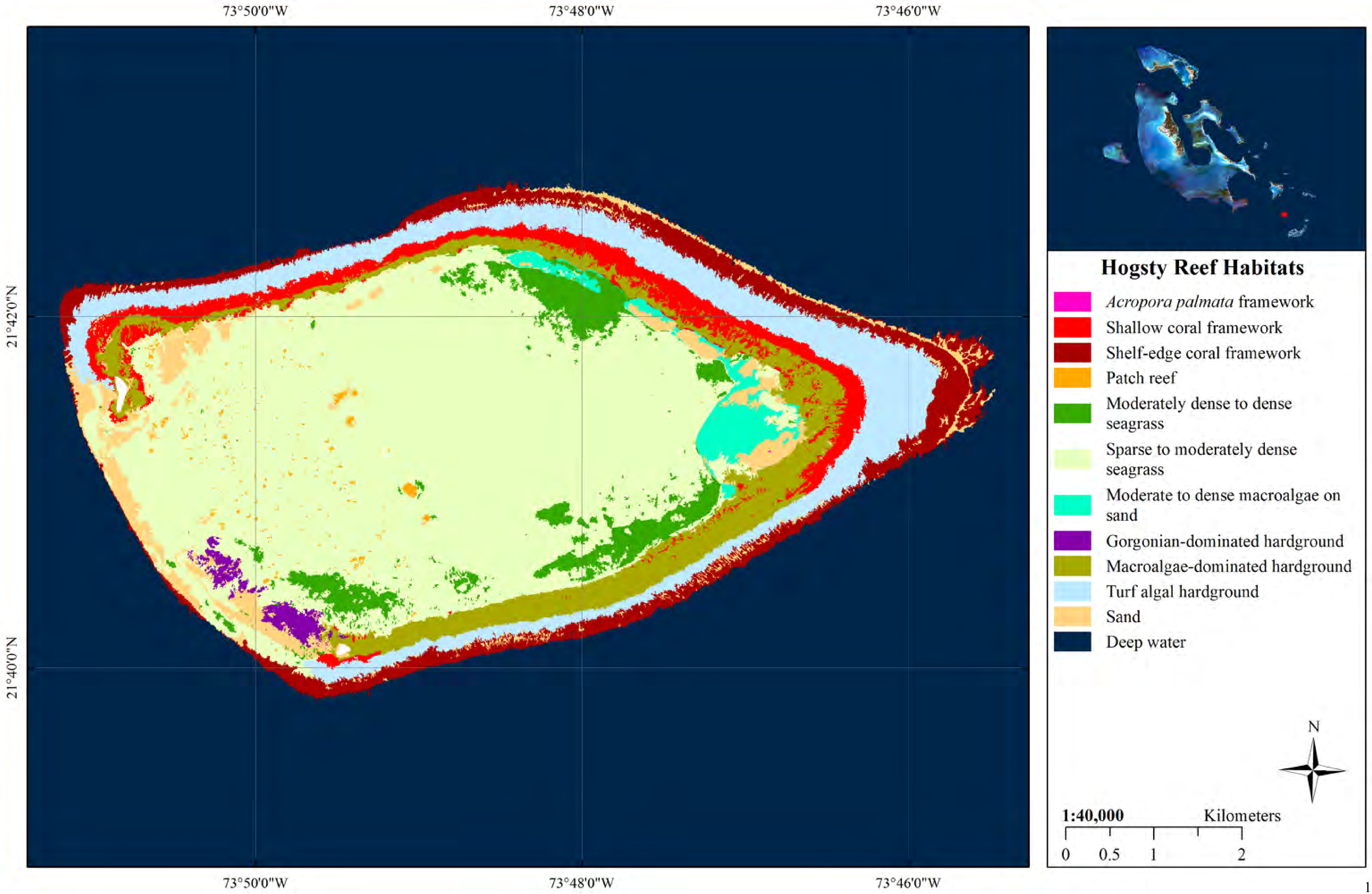
Hogsty Reef Imagery and Habitat Maps

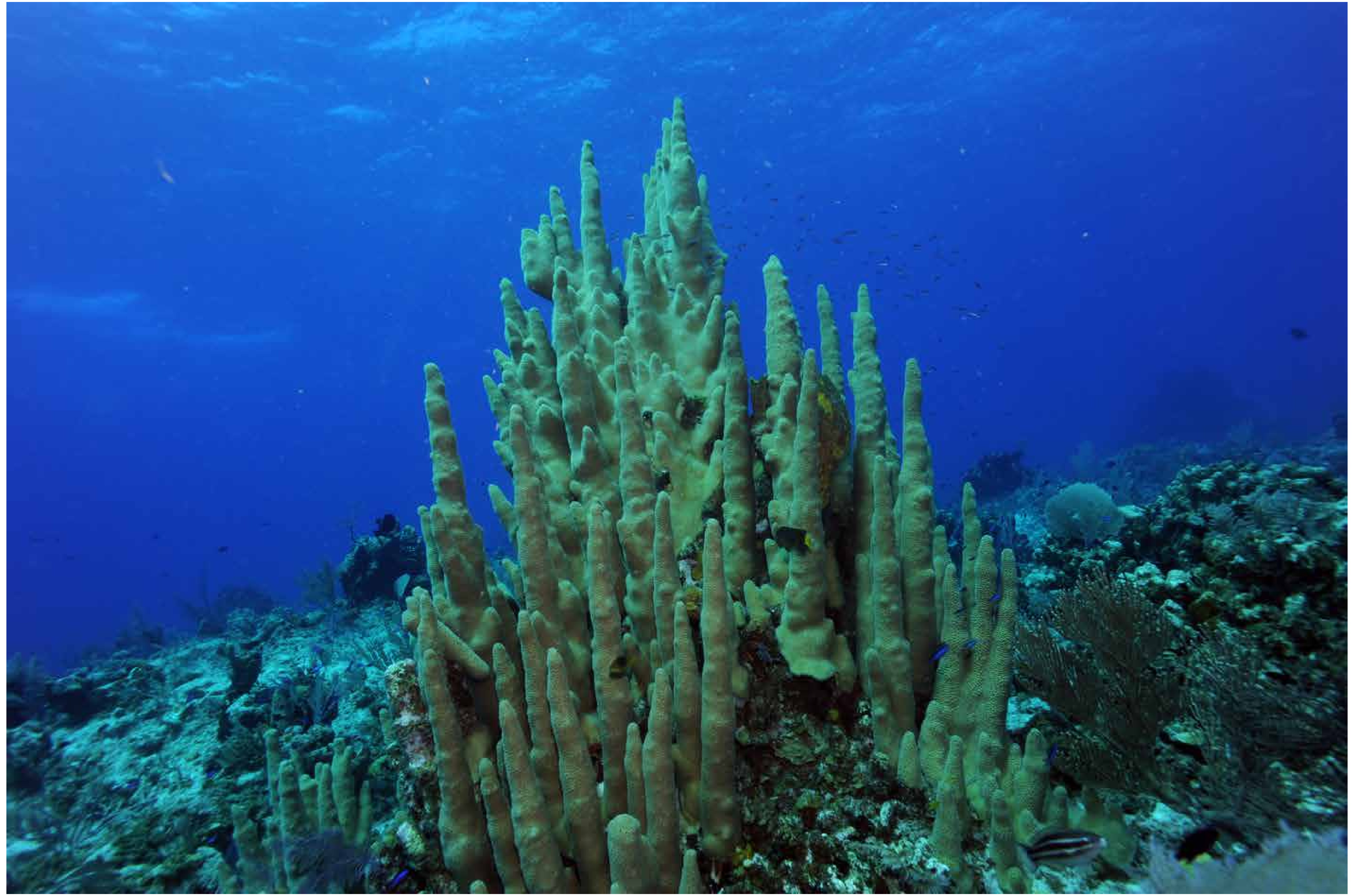
Satellite imagery, bathymetry and habitat maps for Hogsty Reef are illustrated on pages 196-204. WorldView-2 multispectral satellite imagery of Hogsty Reef (left), and a resulting habitat map for the same area (page 197) are shown at a scale of 1:40,000. Higher resolution habitat maps (1:24,000) and bathymetric maps for each section within Hogsty Reef are shown after the 1:40,000 scale habitat maps. Habitat maps (1:24,000 scale) are shown on pages 201 and 203 with bathymetric maps for the same area illustrated on the right (even numbered page). These maps illustrate habitats associated with the shallow coral reef framework, hardground areas, deep shelf-edge reefs and patch reefs, sand flats, seagrass beds within the lagoon. Source of terrestrial basemap imagery used in all habitat maps and bathymetric maps is: ESRI, i-cubed, USFSA, USGS, AEX, GeoEye, AeroGRID, Getmapping, IGP.

A total of 39.35 sq km were mapped and subdivided into 11 habitat classes with areas below 25 m depth (deepwater) depicted in dark blue. The aerial coverage of each habitat is presented in the table. The most extensive habitat type was sparse to moderately dense seagrass, which made up over 50% of all marine habitats. Corals were found primarily in four habitat types, covering an area of approximately 6 sq km. Additional areas with very low coral cover included gorgonian, macroalgal and turf hardgrounds which constituted about 8 sq km of the mapped area. Other soft bottom habitats, including sand, macroalgae on sand, and moderately dense to dense seagrass beds occupied over 5 sq km.

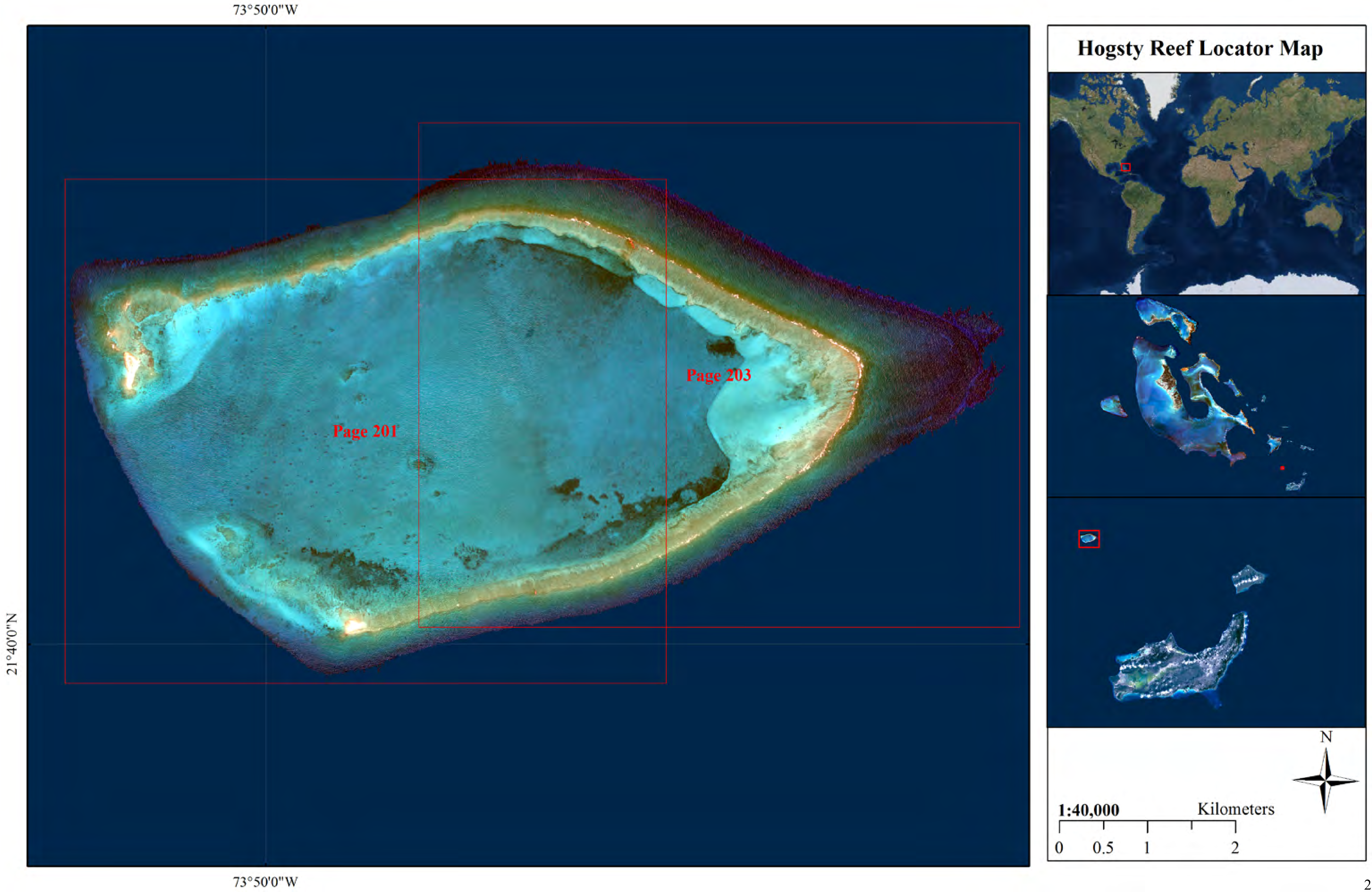
Hogsty Reef Habitats	Total Area (sq km)	% region total
Acropora palmata framework	0.00	0.00
Shallow coral framework	2.21	5.61
Shelf-edge coral framework	3.29	8.37
Patch reefs	0.18	0.45
Moderately dense to dense seagrass	2.04	5.18
Sparse to moderately dense seagrass	20.14	51.18
Moderate to dense macroalgae on sand	0.79	2.01
Gorgonian-dominated hardground	0.33	0.83
Macroalgal-dominated hardground	3.41	8.66
Turf-algal-dominated hardground	4.68	11.90
Sand	2.29	5.81
Land	0.04	
Total Area Mapped	39.35	100.00

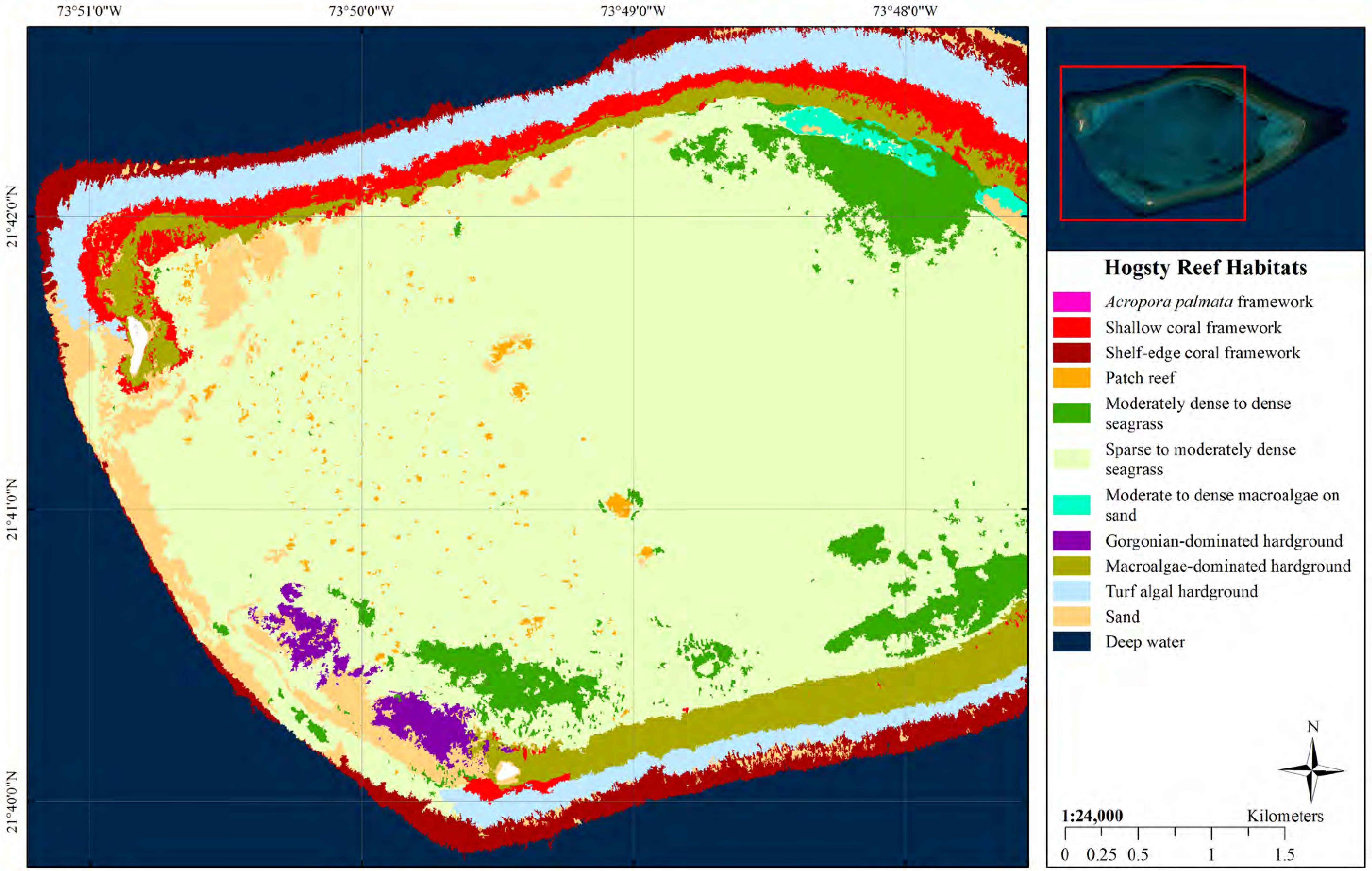

73°50'0"W
73°48'0"W
73°46'0"W
21°42'0"N
21°40'0"N
Hogsty Reef Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
Deep water
N
1:40,000
Kilometers
0 0.5 1 2

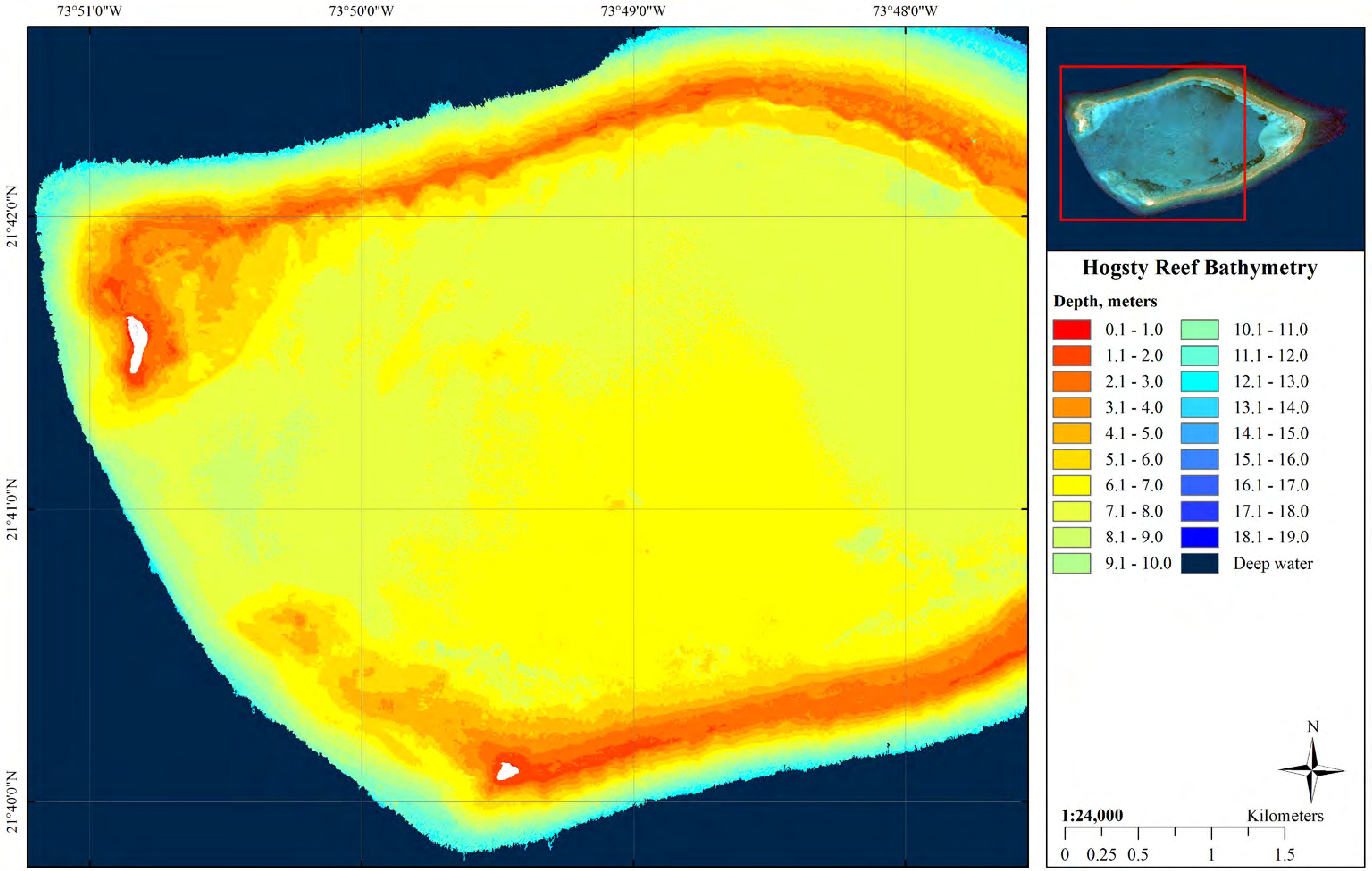

73°50'0"W
73°48'0"W
73°46'0"W
21°42'0"N
21°40'0"N
Hogsty Reef Habitats
Acropora palmata framework
Shallow coral framework
Shelf-edge coral framework
Patch reef
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf algal hardground
Sand
Deep water
N
1:40,000
Kilometers
0 0.5 1 2

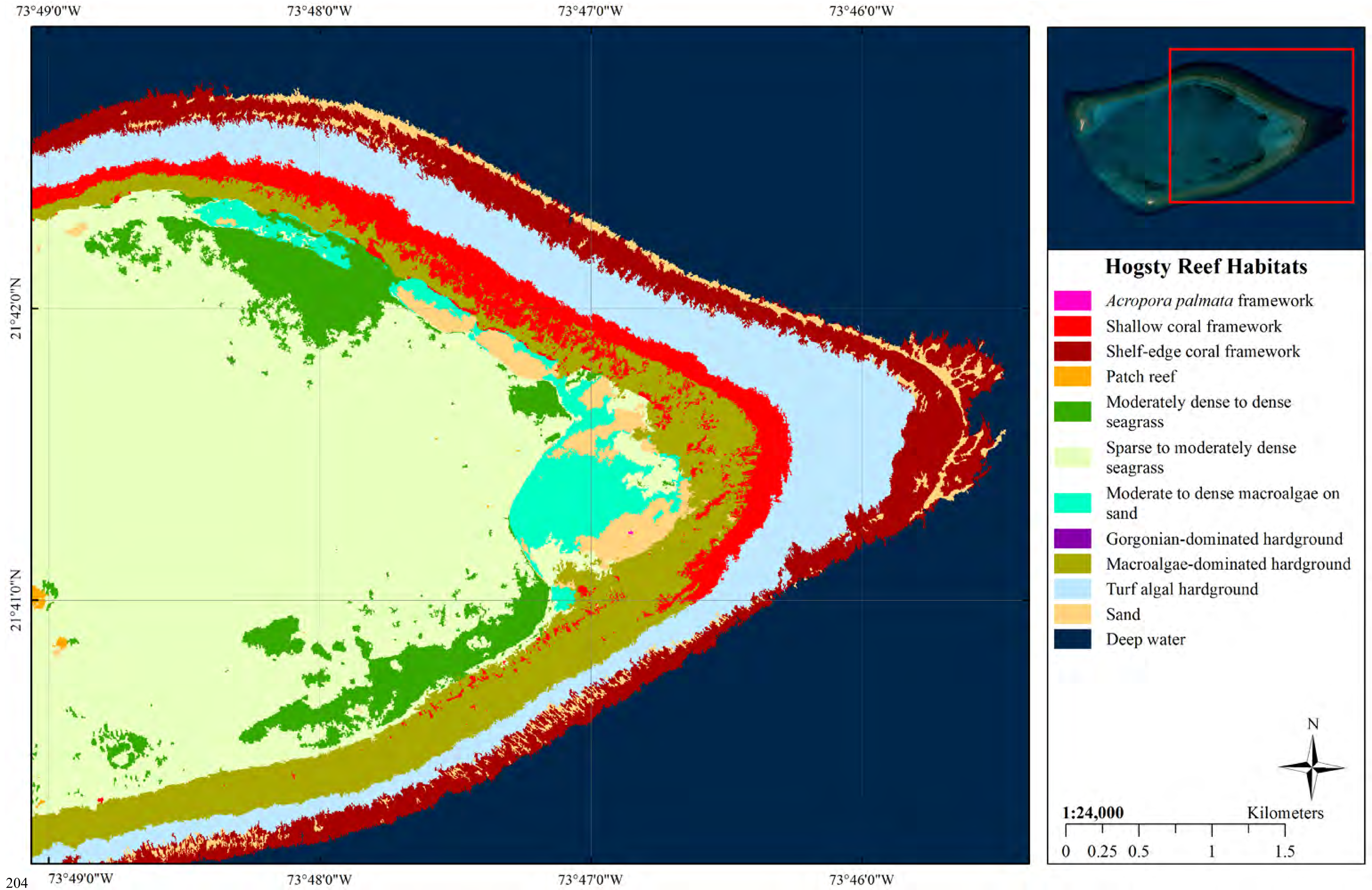


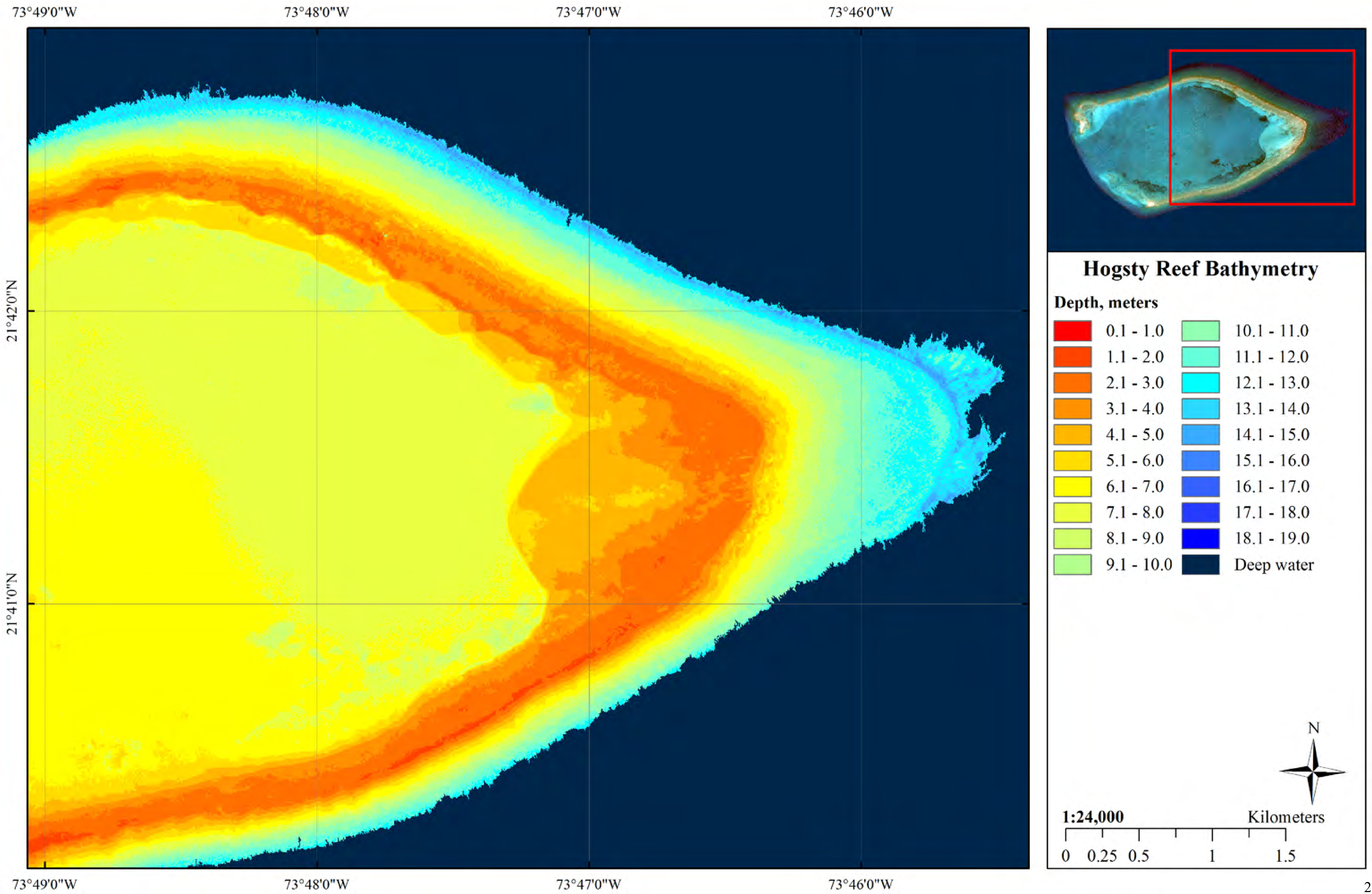
A very large colony of pillar coral, *Dendrogyra cylindrus* on the fore reef slope of Hogsty Reef.

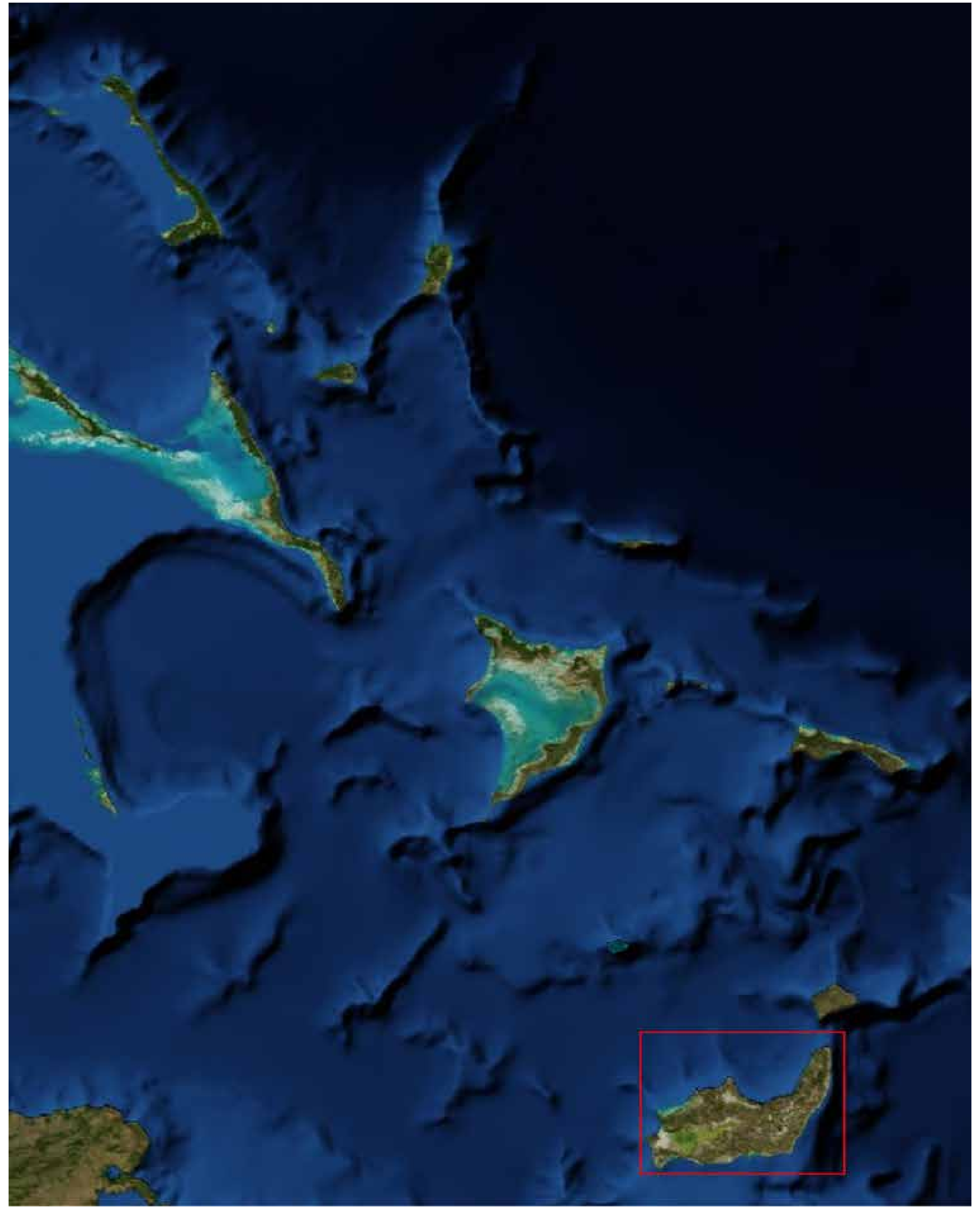



73°51'0"W
73°50'0"W
73°49'0"W
73°48'0"W
21°42'0"N
21°41'0"N
21°40'0"N
Hogsty Reef Habitats
Acropora palmata framework
Shallow coral framework
Shelf-edge coral framework
Patch reef
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf algal hardground
Sand
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


73°51'0"W
73°50'0"W
73°49'0"W
73°48'0"W
21°42'0"N
21°41'0"N
21°40'0"N
Hogsty Reef Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


73°49'0"W
73°48'0"W
73°47'0"W
73°46'0"W
21°42'0"N
21°41'0"N
Hogsty Reef Habitats
Acropora palmata framework
Shallow coral framework
Shelf-edge coral framework
Patch reef
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf algal hardground
Sand
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


73°49'0"W
73°48'0"W
73°47'0"W
73°46'0"W
21°42'0"N
21°41'0"N
Hogsty Reef Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5



Great Inagua, Bahamas

Aerial photo of Morton Salt Company (opposite page, top right). Aerial photo of Matthew Town (top left). A large lagoonal habitat enclosed within the reef system on the south coast and a shallow hypersaline lake (bottom left).

Great Inagua is the third largest island in the Bahamas (1544 km²). It lies about 520 km from Nassau and 90 km from the eastern tip of Cuba. The island is about 90 x 30 km in extent, with a maximum elevation of 33 m on East Hill. There is one small town (Matthew Town), with a population of approximately 1,200. The interior has several lakes, most notably Lake Windsor (also called Lake Rosa) which occupies close to 25% of the island. Lake Rosa is a permanent, shallow (<1.5 m), brackish lake, 19 km in length. It is surrounded by open scrub habitat and seasonal marshes, and has several mangrove islands. Both black mangrove (*Avicennia germinans*) and buttonwood (*Conocarpus erectus*) are found around Lake Rosa.

The island has the second largest solar-powered saline plant in North America, the Morton Salt Crystal Company. Known locally as the Salinas of Inagua, it has over 80 salt ponds covering 4,856 hectares. It was first established here in the 1800s, and now produces nearly 450,000 kg of salt a each year.

The island is home to the world's largest breeding colony of West Indian flamingos, with an estimed 60,000 birds. The flamingos primarily inhabit the Great Inagua National Park, within an area covering about half of the island (744 km^2). Other bird life includes Tri-colored Herons, Great Egrets, Reddish Egrets, Roseate Spoonbills, Brown Pelicans, White Cheeked Pintails, West Indian Whistling Ducks and Burrowing Owls. Another protected area, Union Creek Reserve is a small (18 km^2) tidal creek used by green turtles.

Great Inagua is known for the large bank-barrier reefs that developed in two stages over the last interglacial period. Their growth was interrupted by one major cycle of sea level transgression and regression, resulting in a wave cut platform visible at Devil's Point, off the west coast (White et al. 1997). This region is also known to have undergone tectonic uplift and tilting during the last 100,000 years; the island is less than 100 km away from the oblique convergence zone between the North American and the Caribbean plates (Kindler et al. 2007).

Beach rock, formed from carbonate sands in the intertidal, fringes much of the coastline (top right). A small herd of ferel donkeys along the shoreline (bottom right).

Aerial photographs of coral reef habitats (left). Lagoonal habitat with coral bommies and a well-developed back reef environment (top left). Shallow and deep spur and groove fore reef habitats (left center). Offshore submerged patch reef off the southeast tip of Great Inagua (bottom left).

On exposed shorelines, piles of coral rubble accumulate following tropical storms and hurricanes (top center).

The photos on the right show cross sections through large eolianite dunes. Fossil eolianite (wind blown) sand dunes are composed of carbonate sand which was blown landward from marine beaches by onshore winds. These large outcrops typically straddle multiple episodes of dune formation spanning the Pleistocene through the Early Holocene. The eolianites form when sea level is sufficiently high to facilitate beach formation - from which the wind blown marine grains originate. The dark strata in the foreground, at the base of the dune, is a beach rock forming through cementation of carbonate sands in the inter-tidal (top right). The dark color comes from the bacteria that inhabit this zone and probably mediate the lithification through the precipitation of carbonate cements (top right). The characteristic criteria for the eolianite are the large-scale steeply-dipping cross beds with a herring-bone bedding pattern (right center). Lantern Head on the south coast (bottom right). This structure is a fossilized (Pleistocene) coralline limestone composed of coral heads encased in a calcarenitic matrix, with an absence of siliciclastic sediment.

High resolution satellite image of Great Inagua. Most of the island is uninhabited except for the east side near Matthew Town. The largest industry in Great Inagua is the Morton Salt Company, with 80 salt ponds and a large dock extending into the sea. About 25% of the island is occupied by Lake Windsor, and a smaller watershed associated with Union Creek is at the northwestern end of the island. An extensive reefal terrace is exposed on the southwest end of the island near Devil's Point.

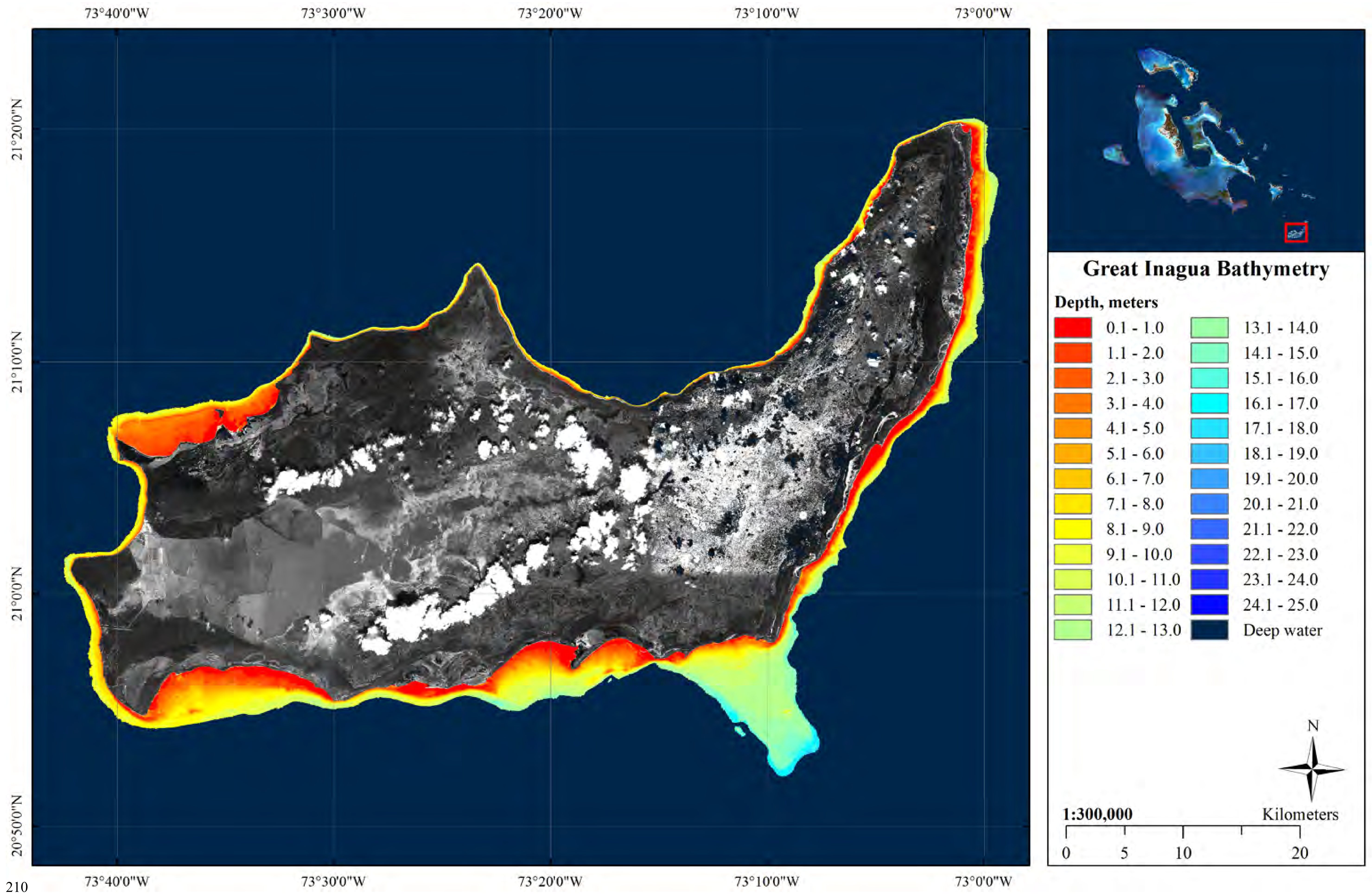
Great Inagua Imagery and Habitat Maps

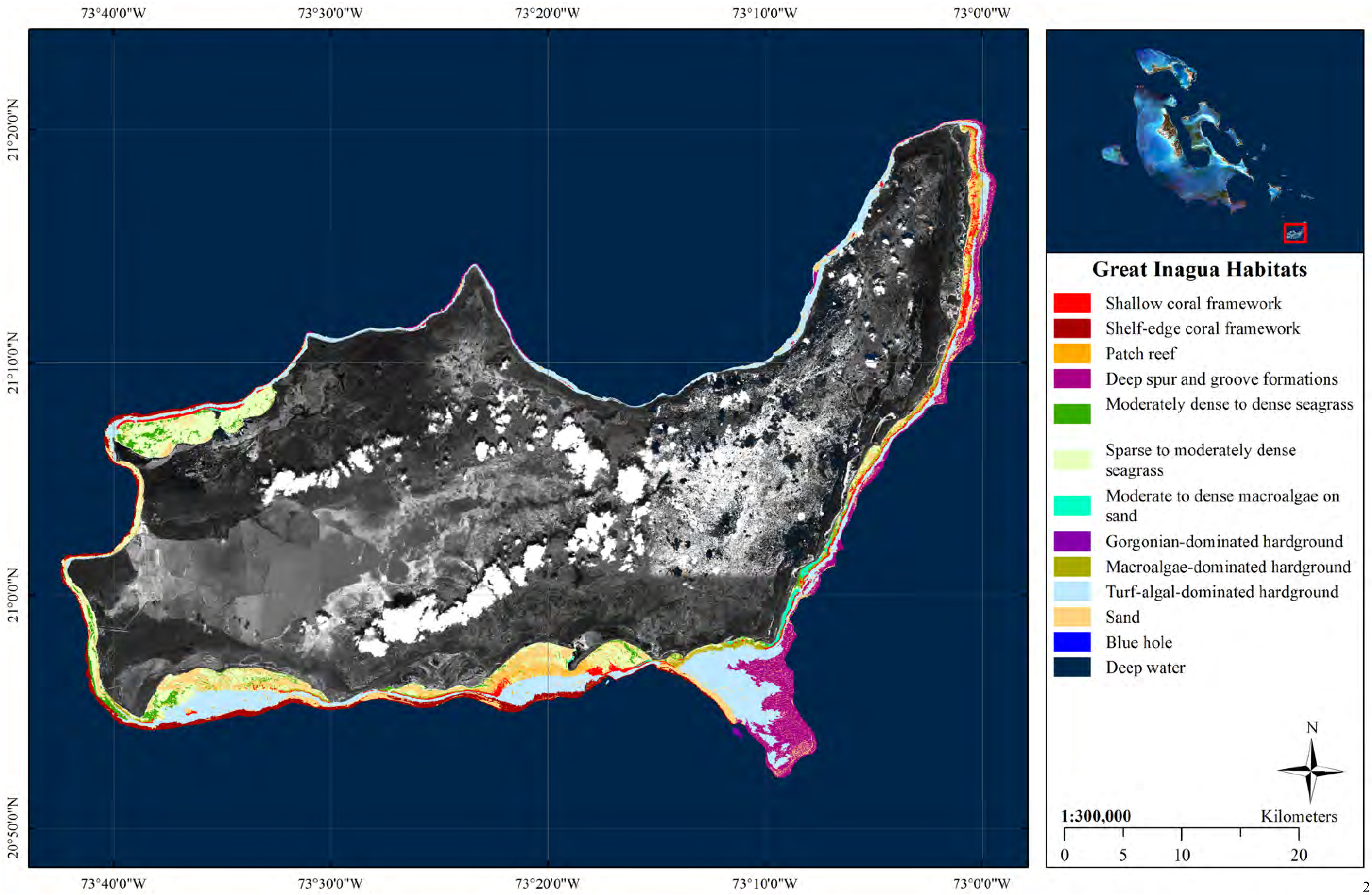
Satellite imagery, bathymetry and habitat maps for Great Inagua are illustrated on pages 208-279. A total of 290.6 sq km was mapped and subdivided into 12 shallow marine habitat classes. Deepwater, depicted in dark blue, includes areas below 25 m depth.

WorldView-2 multispectral satellite imagery of Great Inagua (left), bathymetry (page 209) and a resulting habitat map for the same area (page 210) are shown at a scale of 1:300,000. A regional locator map, habitat map and bathymetric map at a scale of 1:180,000, are shown for the north on pages 212-214 respectively, south on pages 238-240, and west on pages 258-260. Detailed habitat maps (1:24,000) and bathymetric maps for representative areas within the Great Inagua region are on subsequent pages. Each of the twenty one 1:24,000 scale bathymetric maps included in this section is on the right (even numbered) page and the habitat map for the same area is shown on the left (odd numbered pages). Source of terrestrial basemap imagery used in all habitat maps and bathymetric maps is: ESRI, i-cubed, USFSA, USGS, AEX, GeoEye, AeroGRID, Getmapping, IGP.

A total of 356 sq km of shallow marine habitats was mapped and subdivided into ten different habitat types, four of which contain coral. The aerial coverage of each habitat is presented in the table. Coral reef habitats made up over 96 sq km, which is about 27% of the total area mapped. The majority of the shallow marine habitats were hardground areas colonized by turf algae, macroalgae and gorgonians. These occupied 119 sq km which represents 33% of the mapped area. Seagrass beds were the third most common habitat type, covering over 72 sq km (20% of the mapped area). A large area (66 sq. km; 18% of the mapped area) of uncolonized sand also occurred off Great Inagua.

Great Inagua Habitats	Total Area (sq km)	% region total
Shallow coral framework	14.96	4.20
Shelf-edge coral framework	26.26	7.37
Patch reefs	7.92	2.22
Deep spur and groove formations	46.70	13.11
Moderately dense to dense seagrass	14.58	4.09
Sparse to moderately dense seagrass	58.02	16.29
Moderate to dense macroalgae on sand	3.11	0.87
Gorgonian-dominated hardground	0.42	0.12
Macroalgal-dominated hardground	9.11	2.56
Turf-algal-dominated hardground	109.50	30.74
Sand	65.68	18.43
Land	1776.28	
Total Area Mapped	356.27	100.00

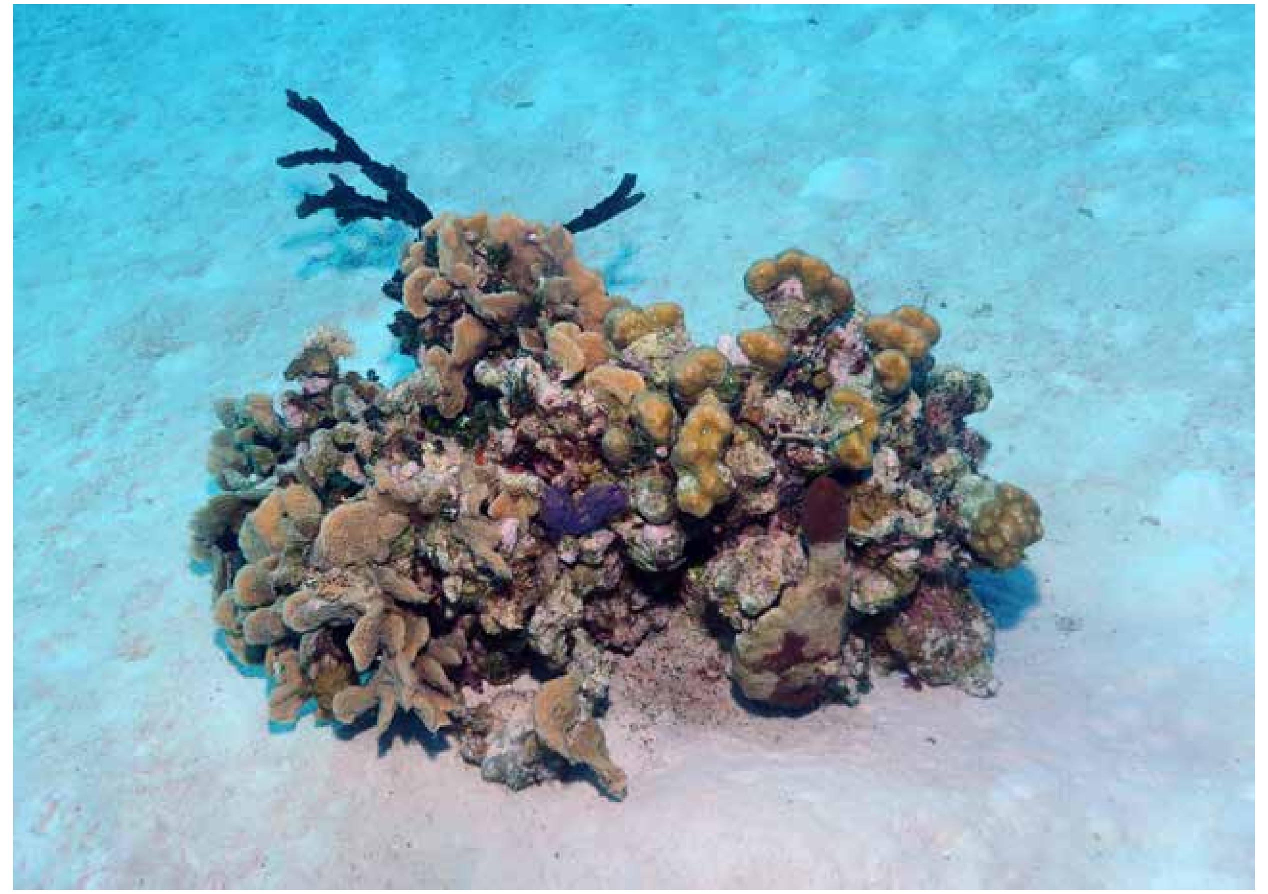

73°40'0"W
73°30'0"W
73°20'0"W
73°10'0"W
73°0'0"W
21°20'0"N
21°10'0"N
21°0'0"N
20°50'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:300,000
Kilometers
0
5
10
20

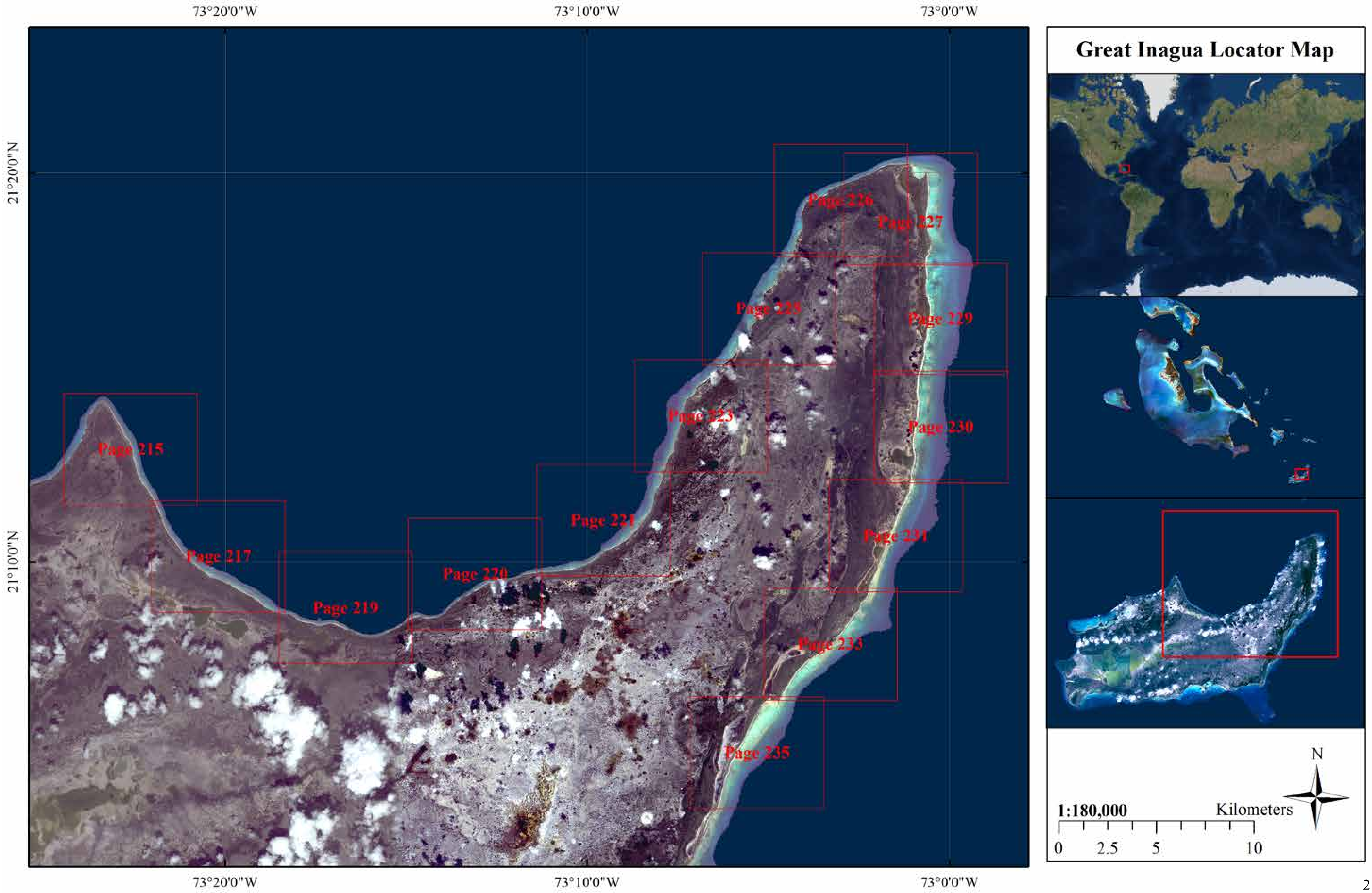

73°40'0"W
73°30'0"W
73°20'0"W
73°10'0"W
73°0'0"W
21°20'0"N
21°10'0"N
21°0'0"N
20°50'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:300,000
Kilometers
0
5
10
20

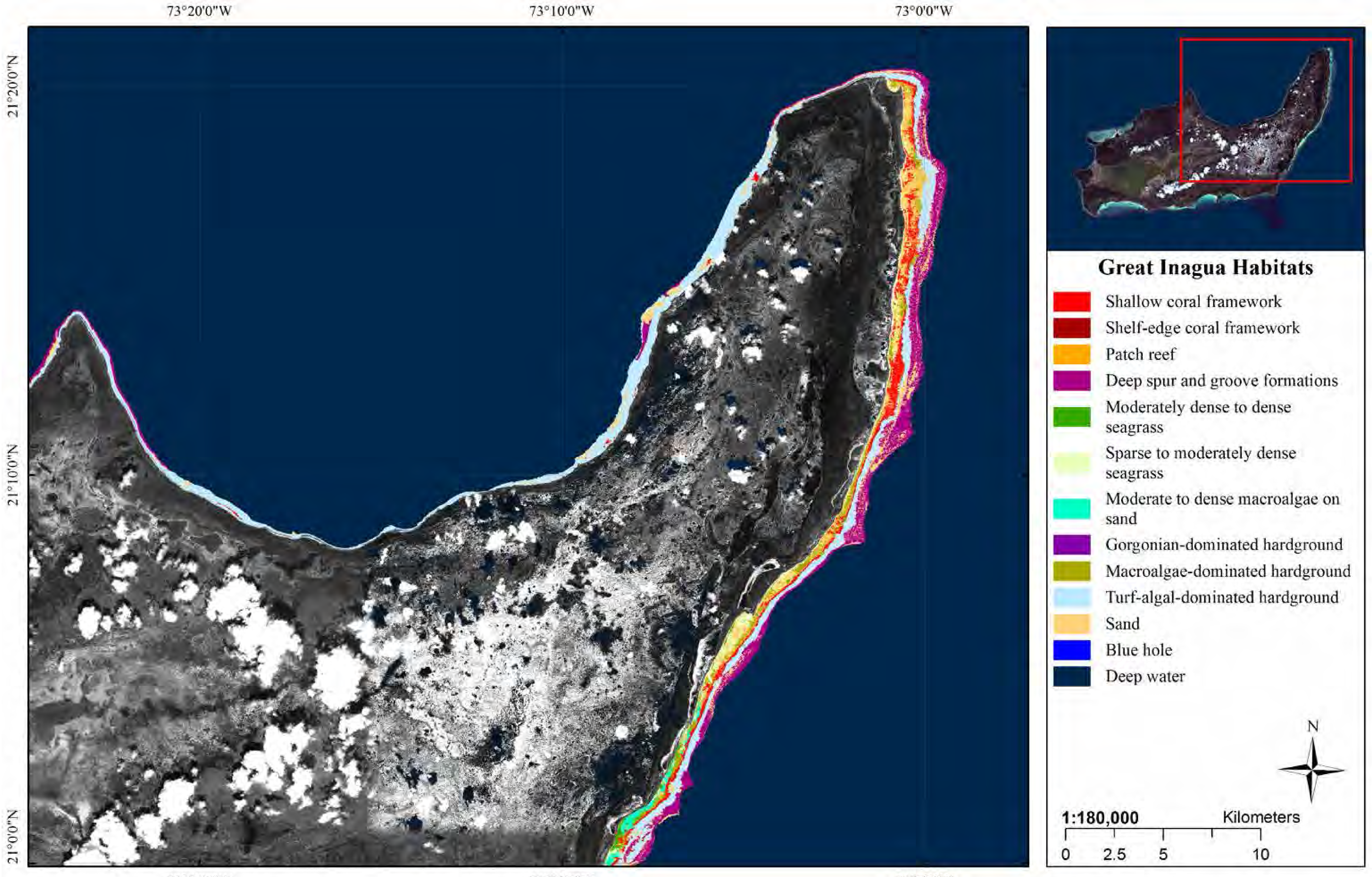
Acropora palmata reef framework is present in shallow water on the northwest end of Great Inagua. This reef has a high number of living elkhorn coral colonies, including many remnants and fragments (top left).

Fore reef communities at 15-20 m depth often had moderately high cover of living corals consisting of a mix of branching, foliose, plating, massive and submassive corals with gorgonians and sea fans, sponges, and macroalgae and turf algae. Large *Montastraea faveolata* and *M. franksi* colonies were still very common (bottom left). On one shallow reef (10 m depth) on the east side of Great Inagua a very high-relief *Montastraea annularis* community intermixed with staghorn coral (*Acropora cervicornis)* and other species was identified (top right).

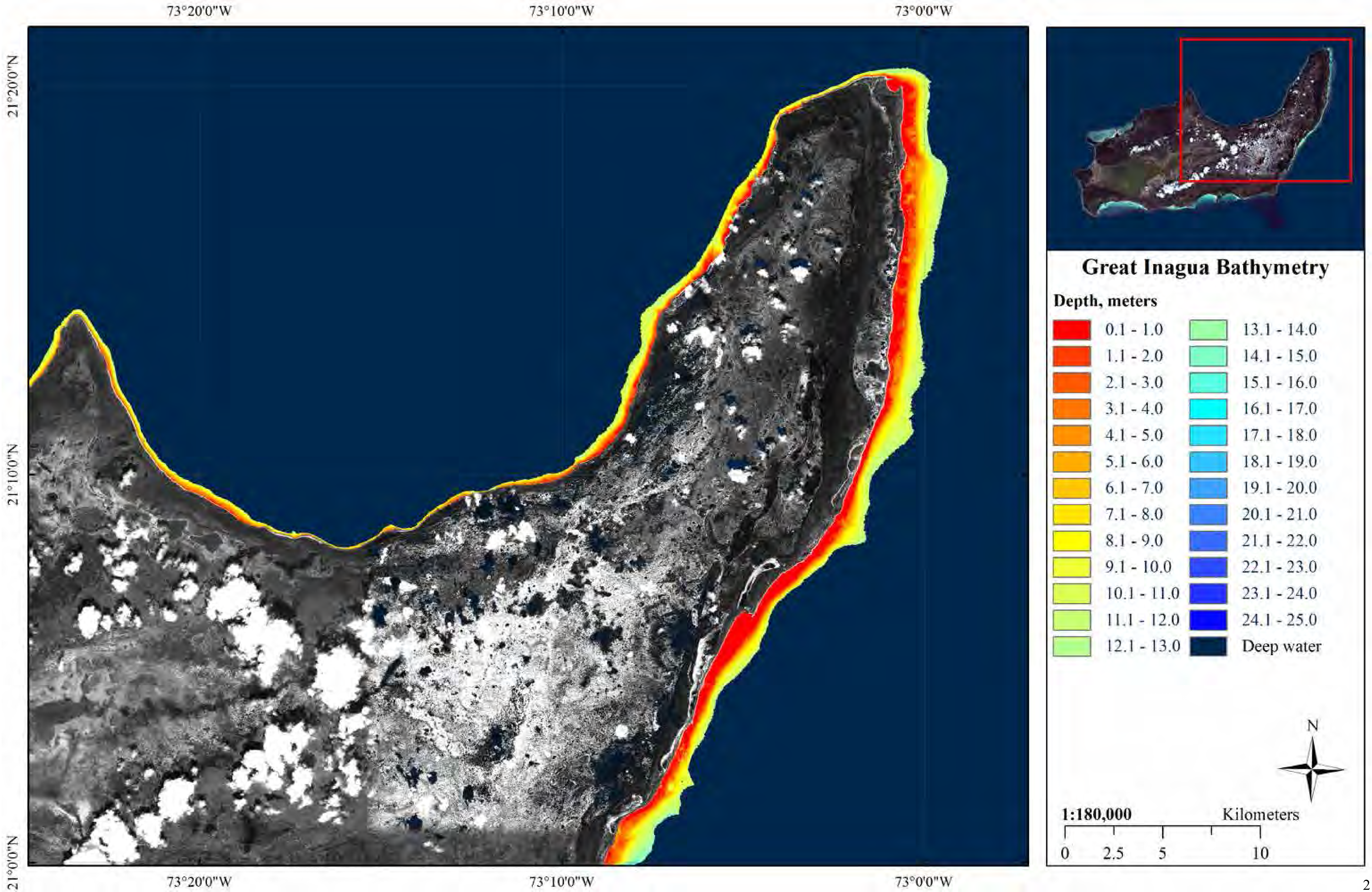
In deeper water, at the base of the reef, sandflats often contained coral bommies such as the one shown in the bottom right. This coral head is constructed primarily of massive *M. annularis* (star coral) and plates of *Agaricia agaricites* (lettuce coral).



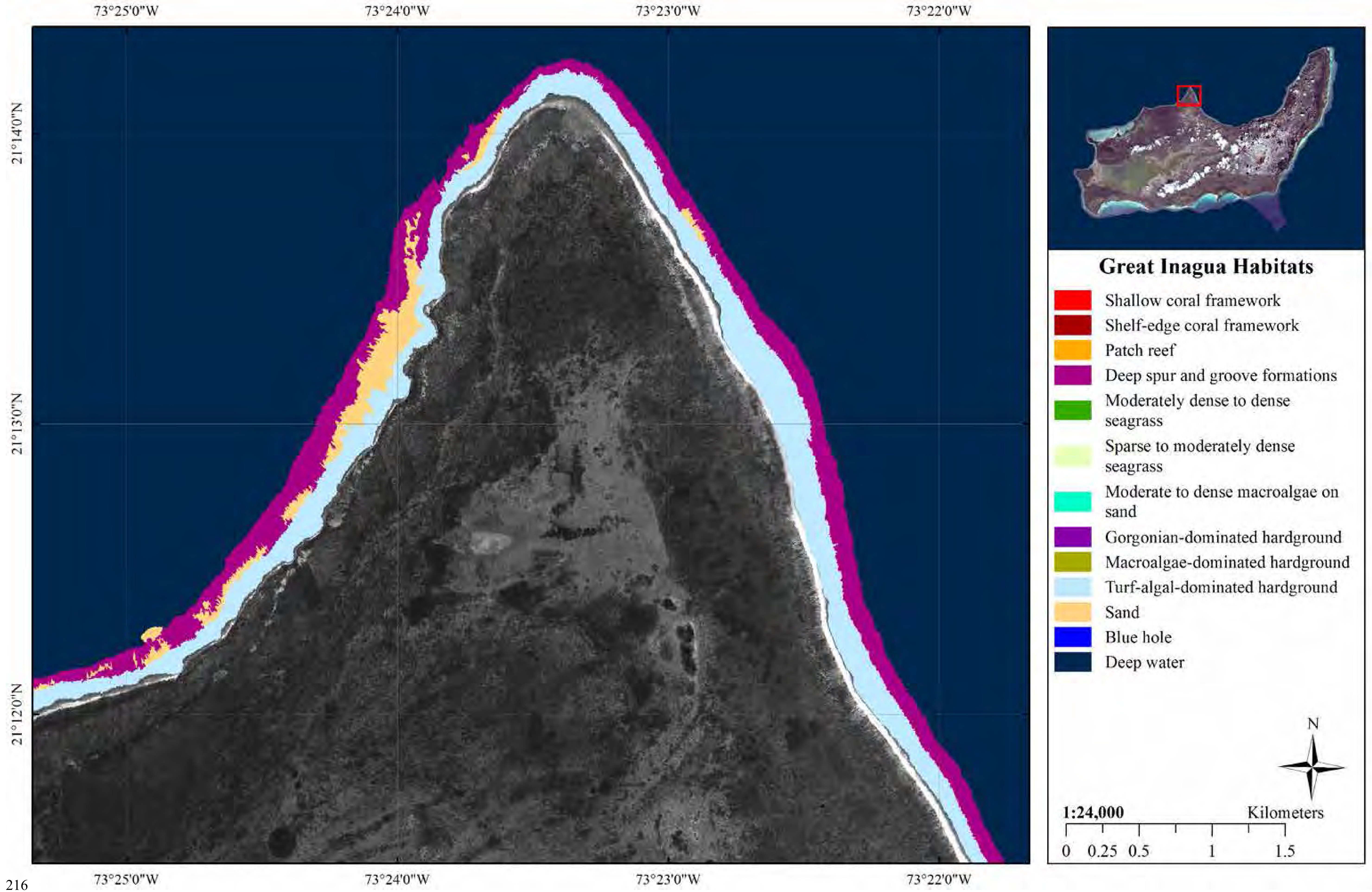


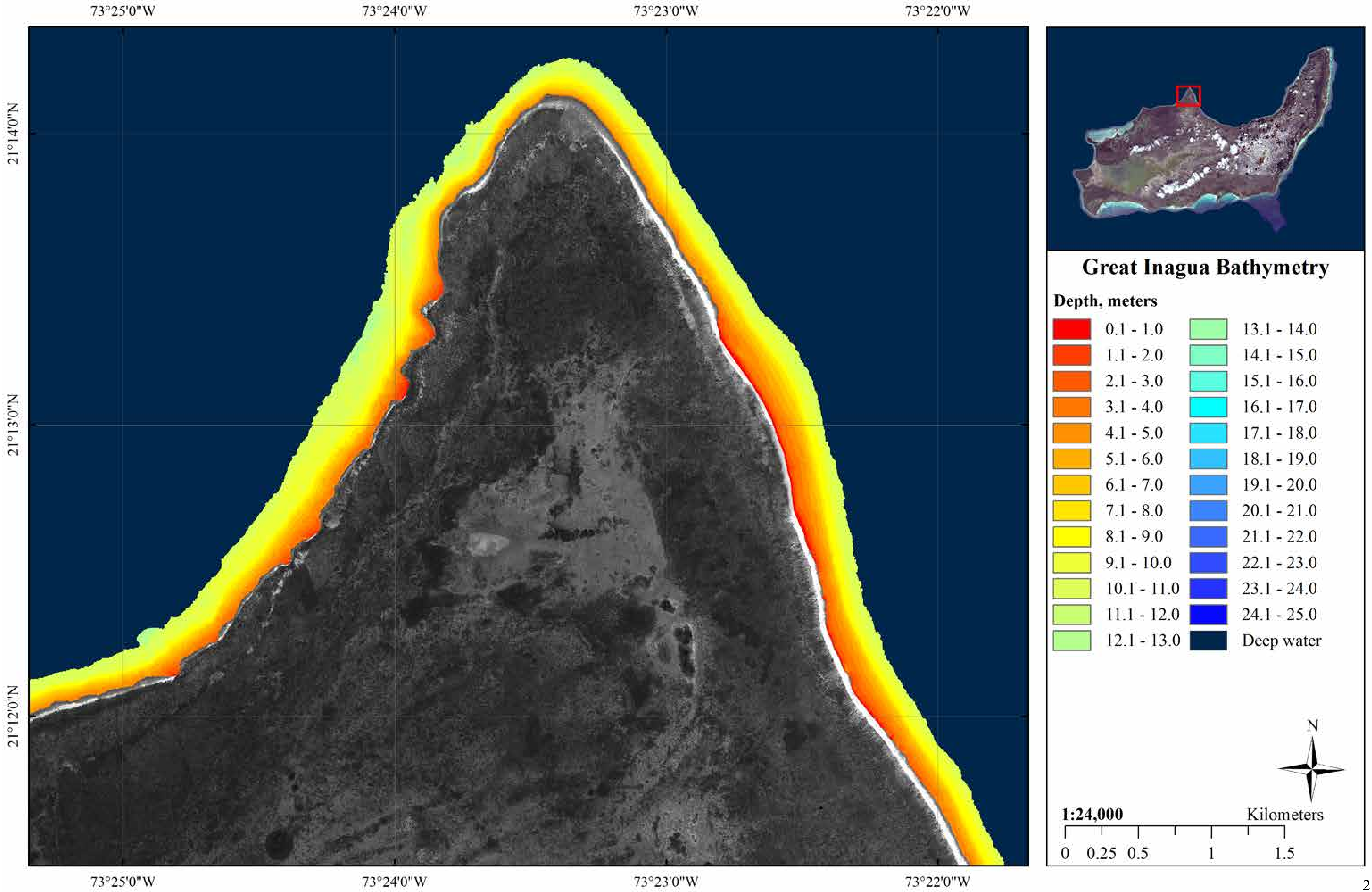


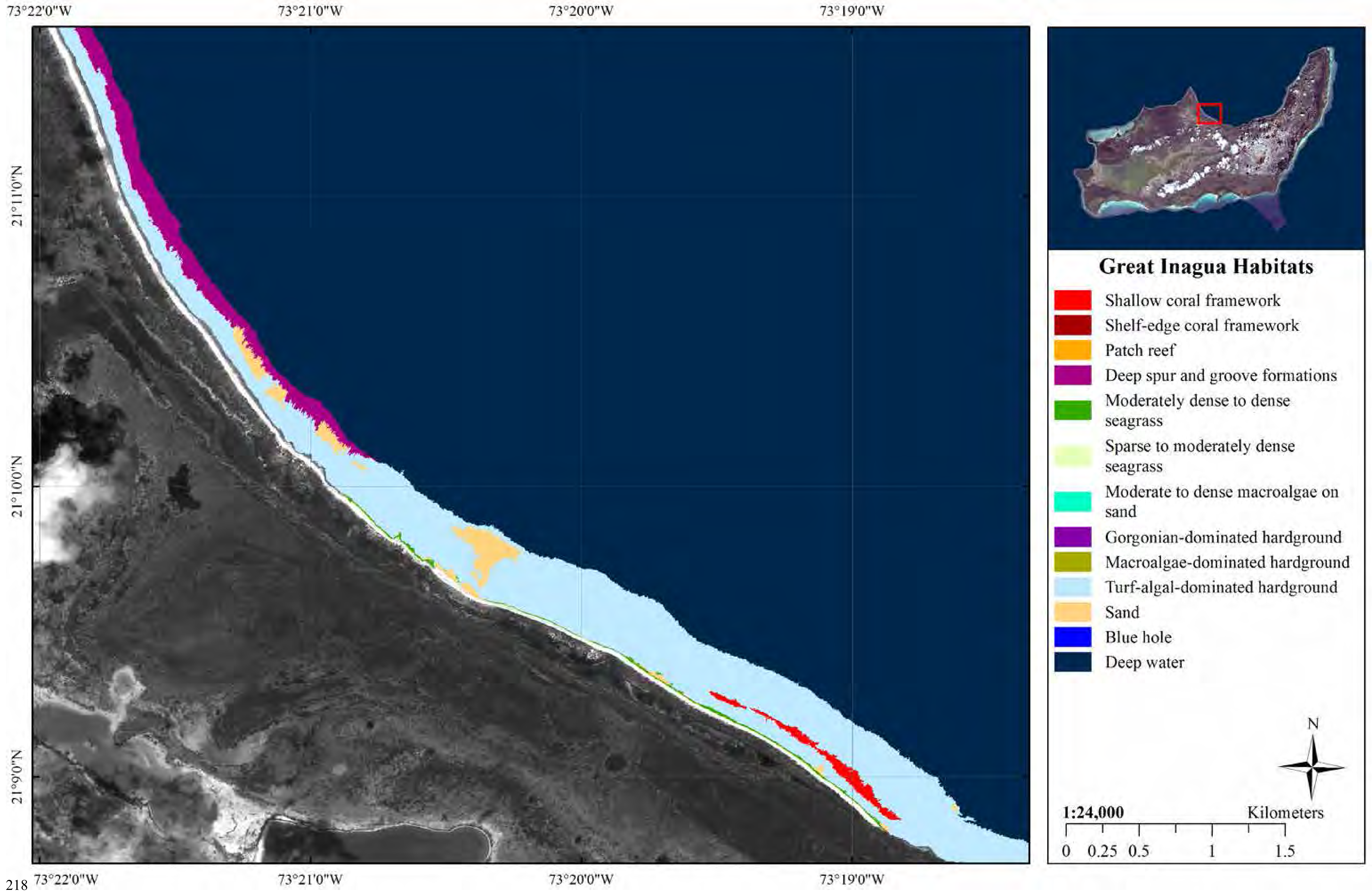
73°20'0"W
73°10'0"W
73°0'0"W
21°20'0"N
21°10'0"N
21°0'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:180,000
Kilometers
0
2.5
5
10
73°20'0"W
73°10'0"W
73°0'0"W

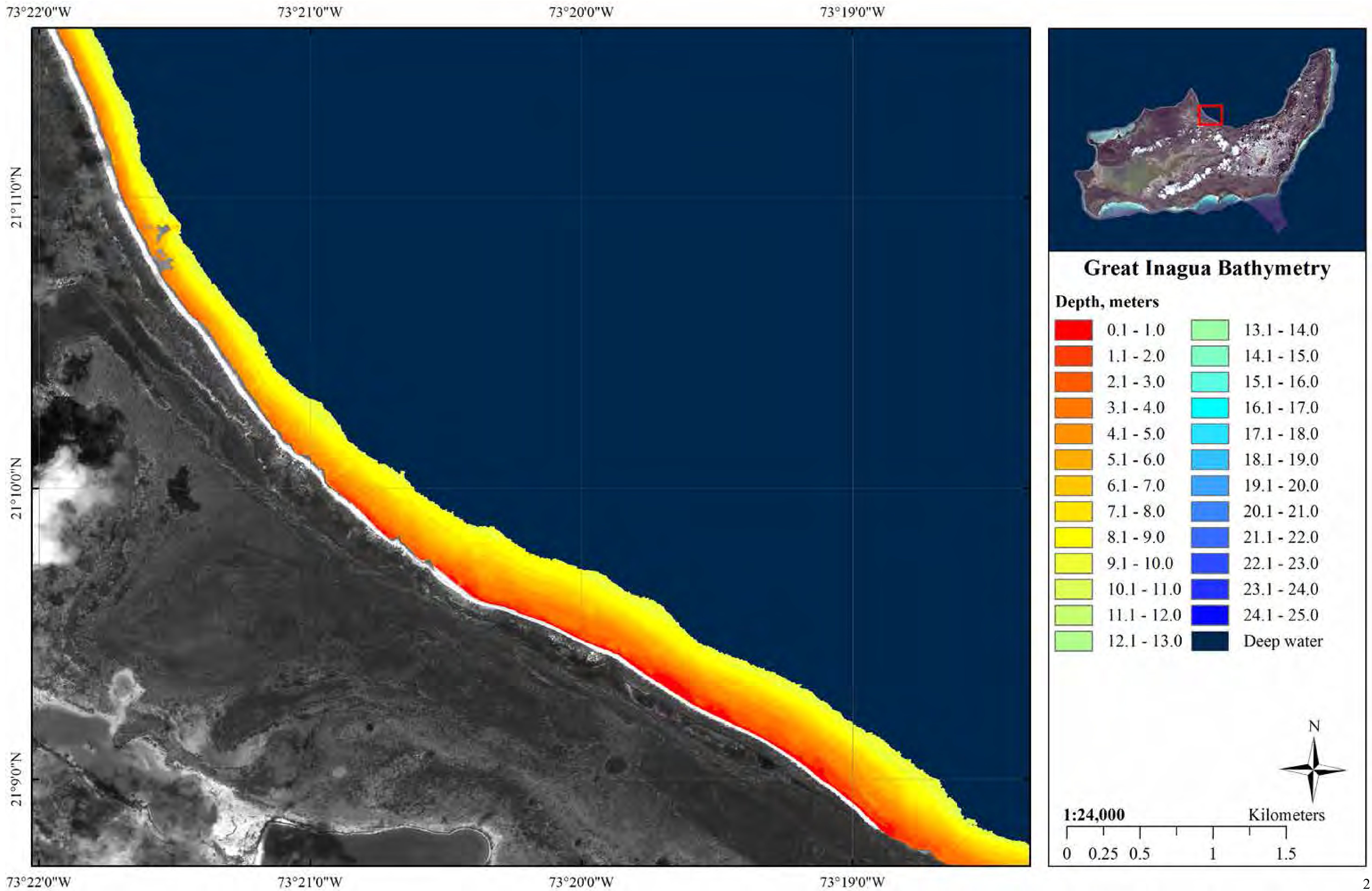


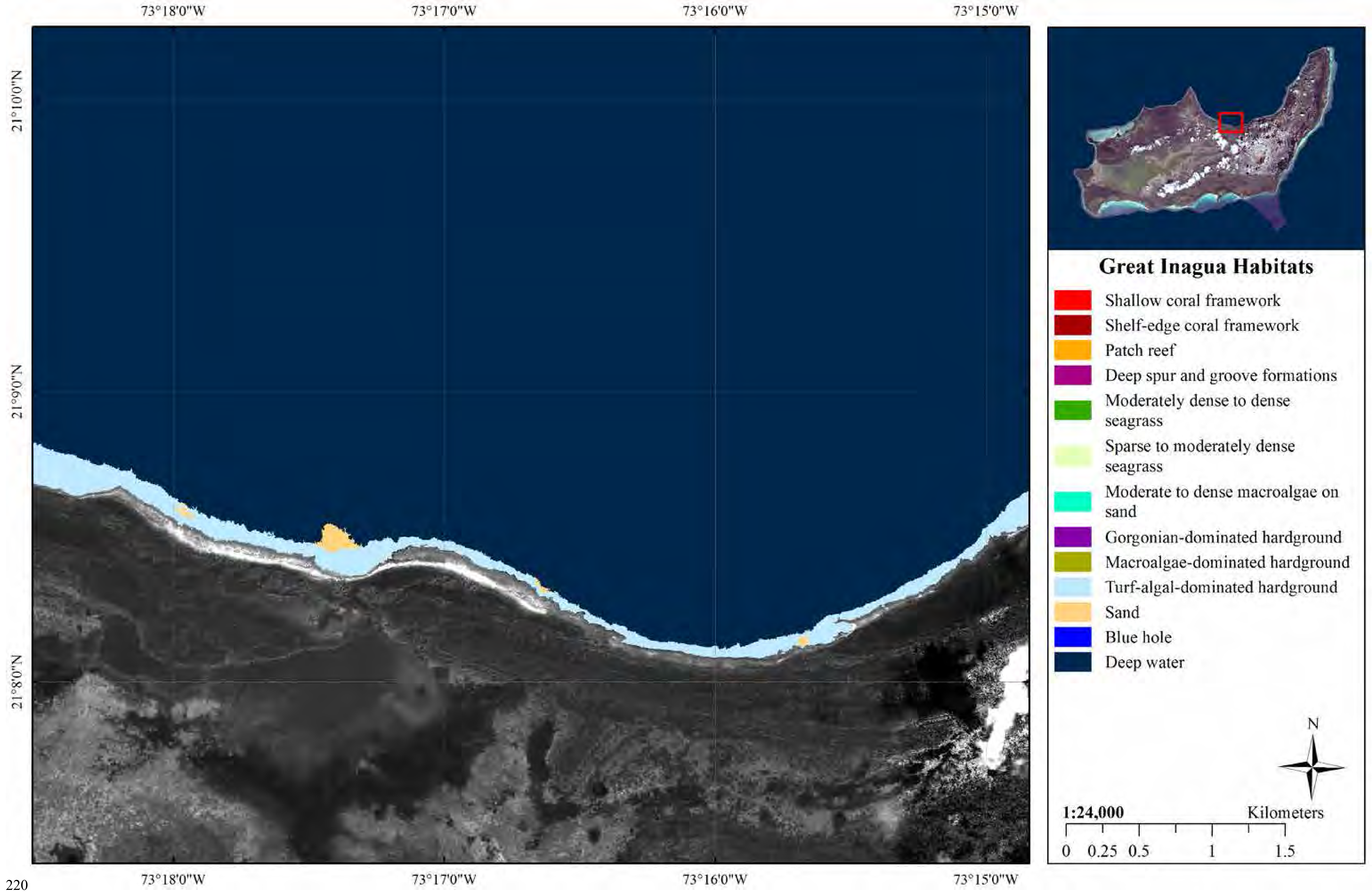
73°20'0"W
73°10'0"W
73°0'0"W
21°20'0"N
21°10'0"N
21°0'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:180,000
Kilometers
0
2.5
5
10
73°20'0"W
73°10'0"W
73°0'0"W

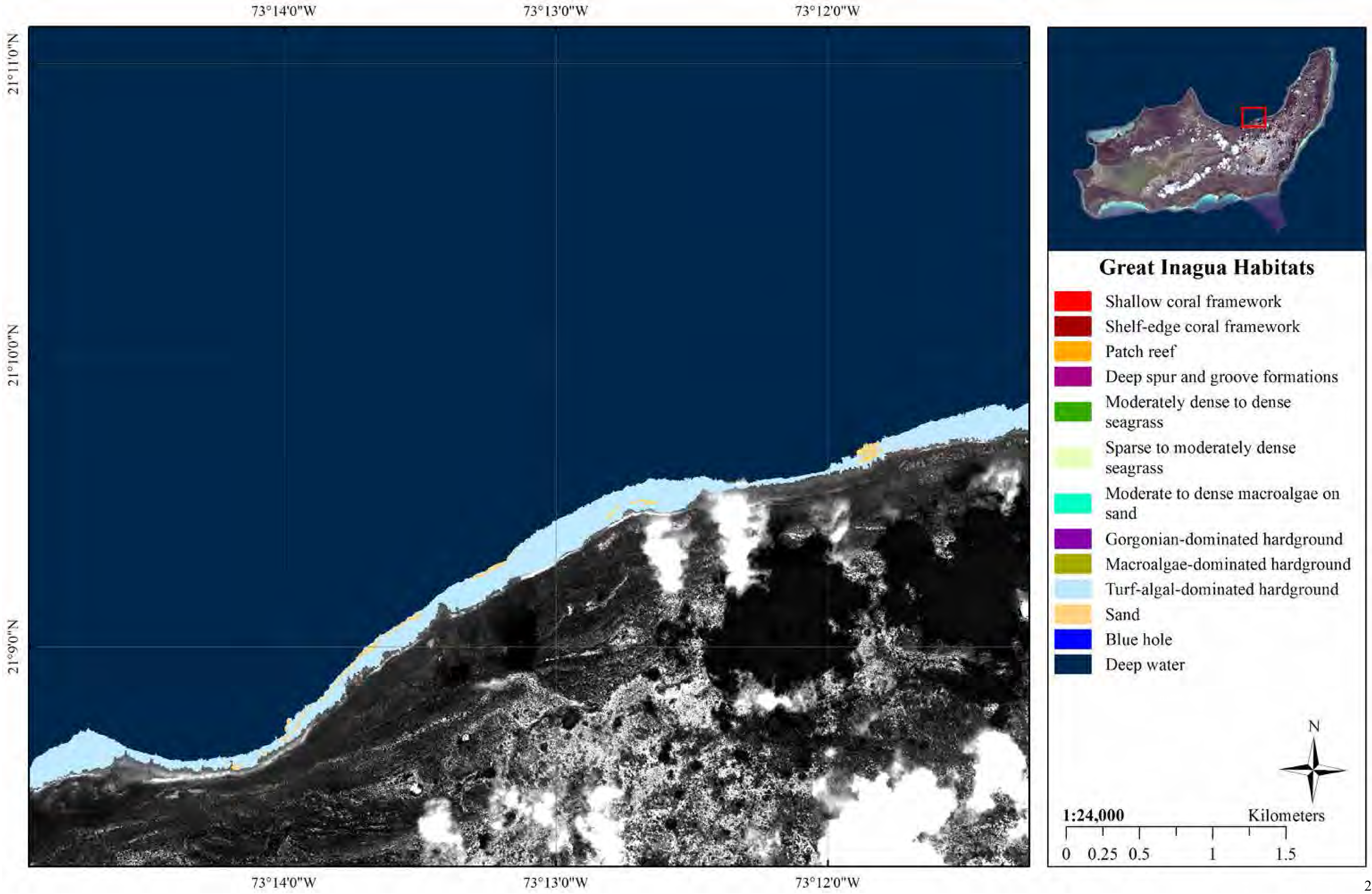

73°25'0"W
73°24'0"W
73°23'0"W
73°22'0"W
21°14'0"N
21°13'0"N
21°12'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

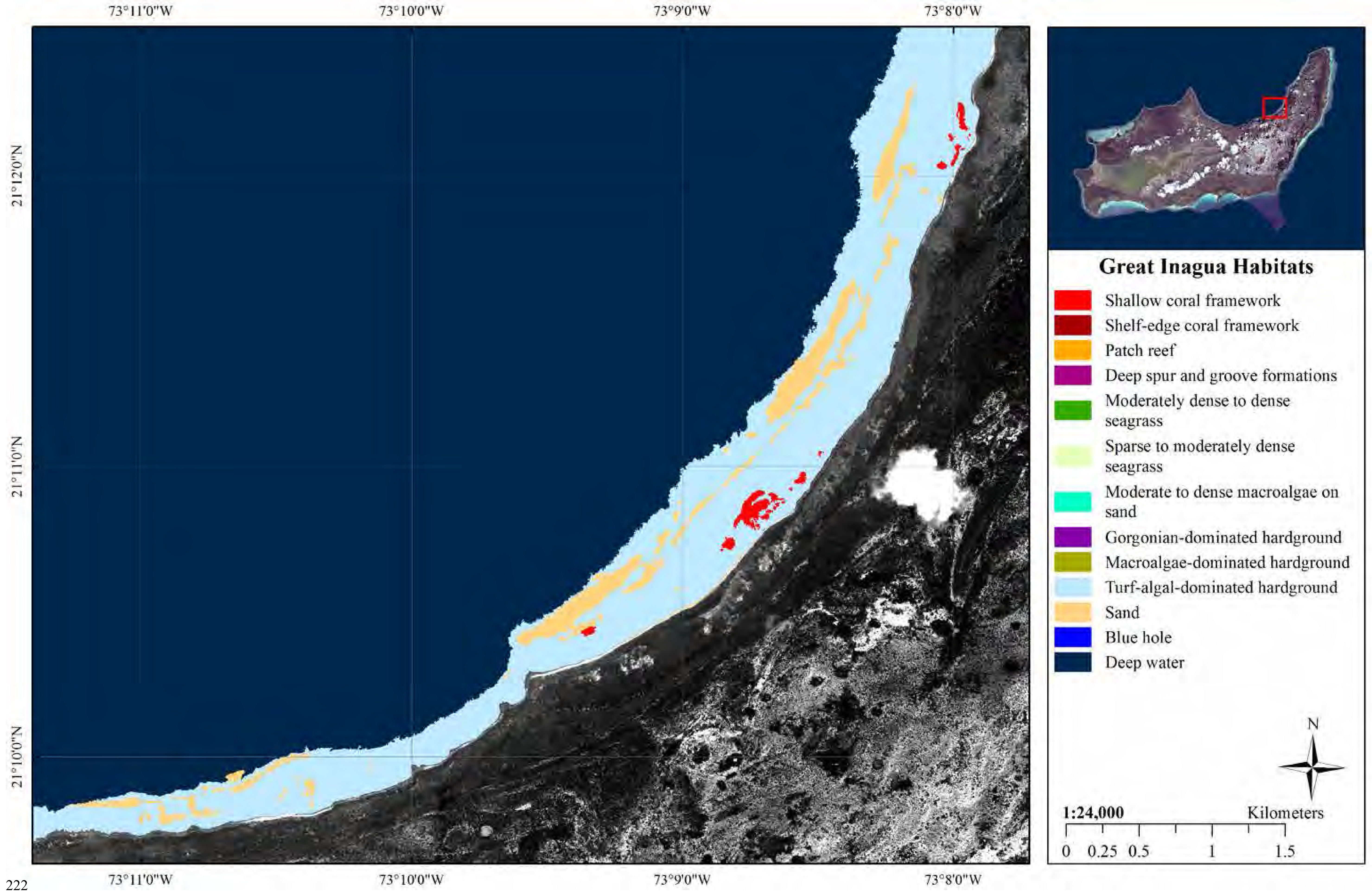

73°25'0"W
73°24'0"W
73°23'0"W
73°22'0"W
21°14'0"N
21°13'0"N
21°12'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

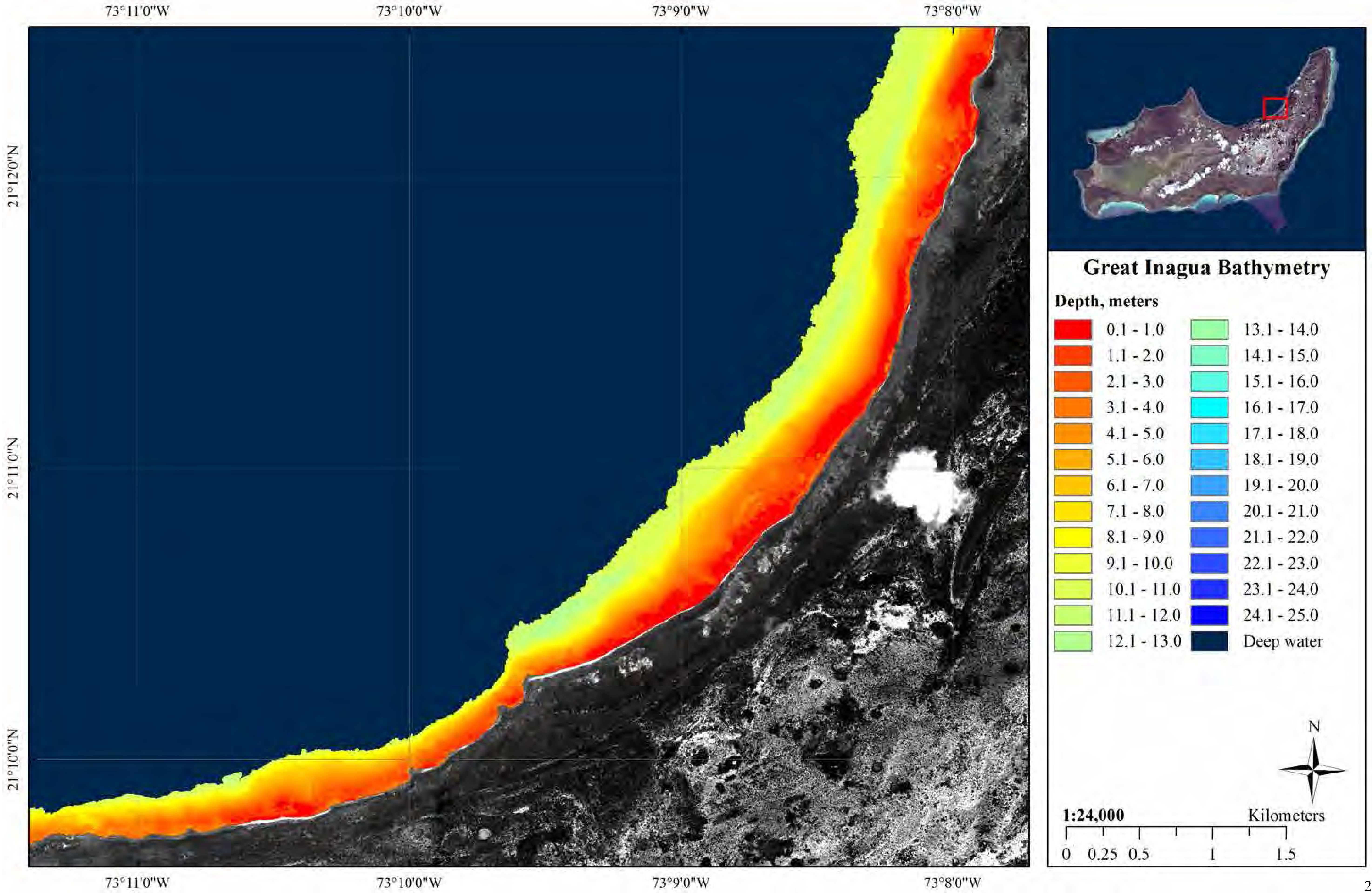

73°22'0"W
73°21'0"W
73°20'0"W
73°19'0"W
21°11'0"N
21°10'0"N
21°9'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

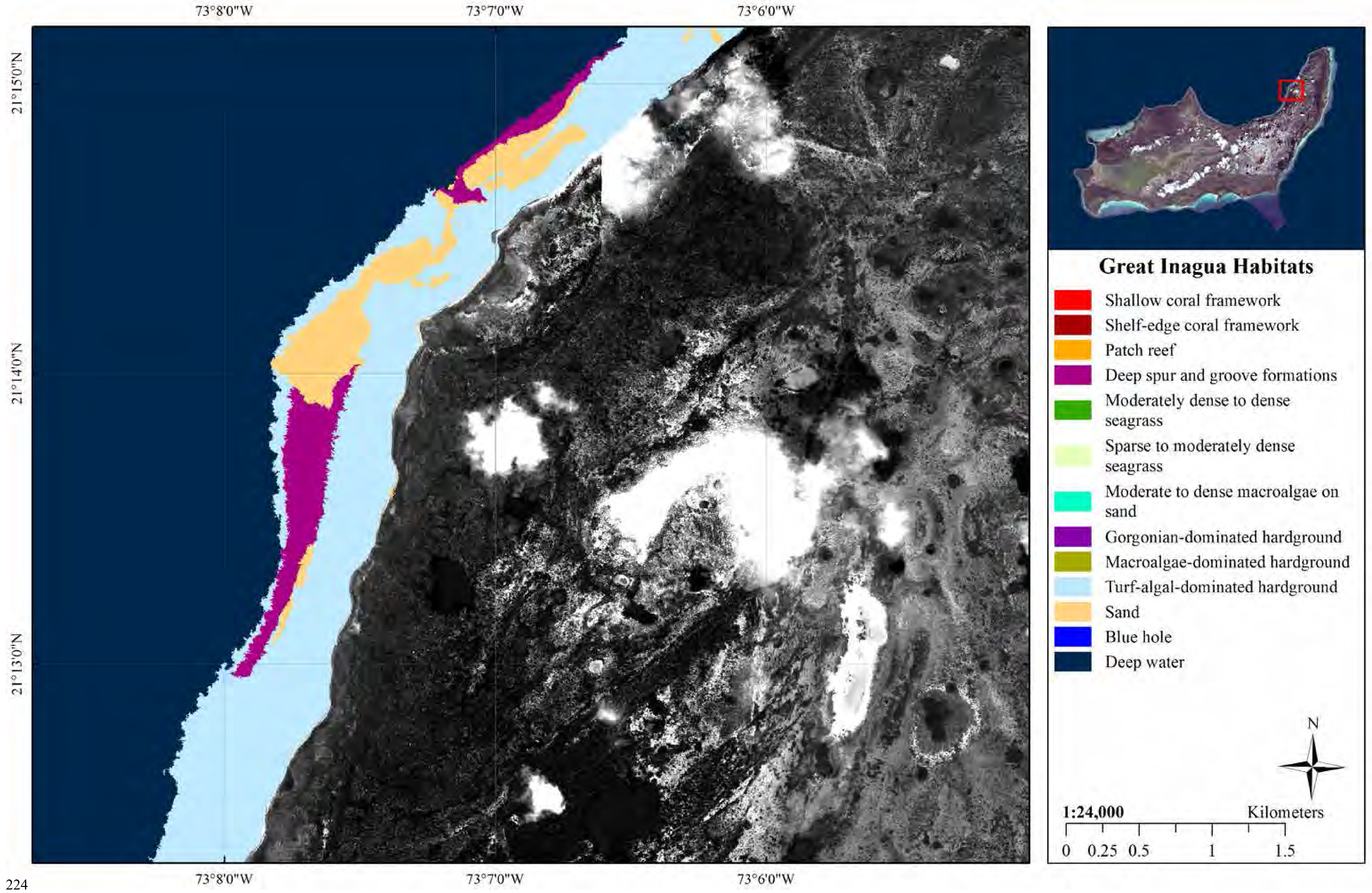

73°22'0"W
73°21'0"W
73°20'0"W
73°19'0"W
21°11'0"N
21°10'0"N
21°9'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

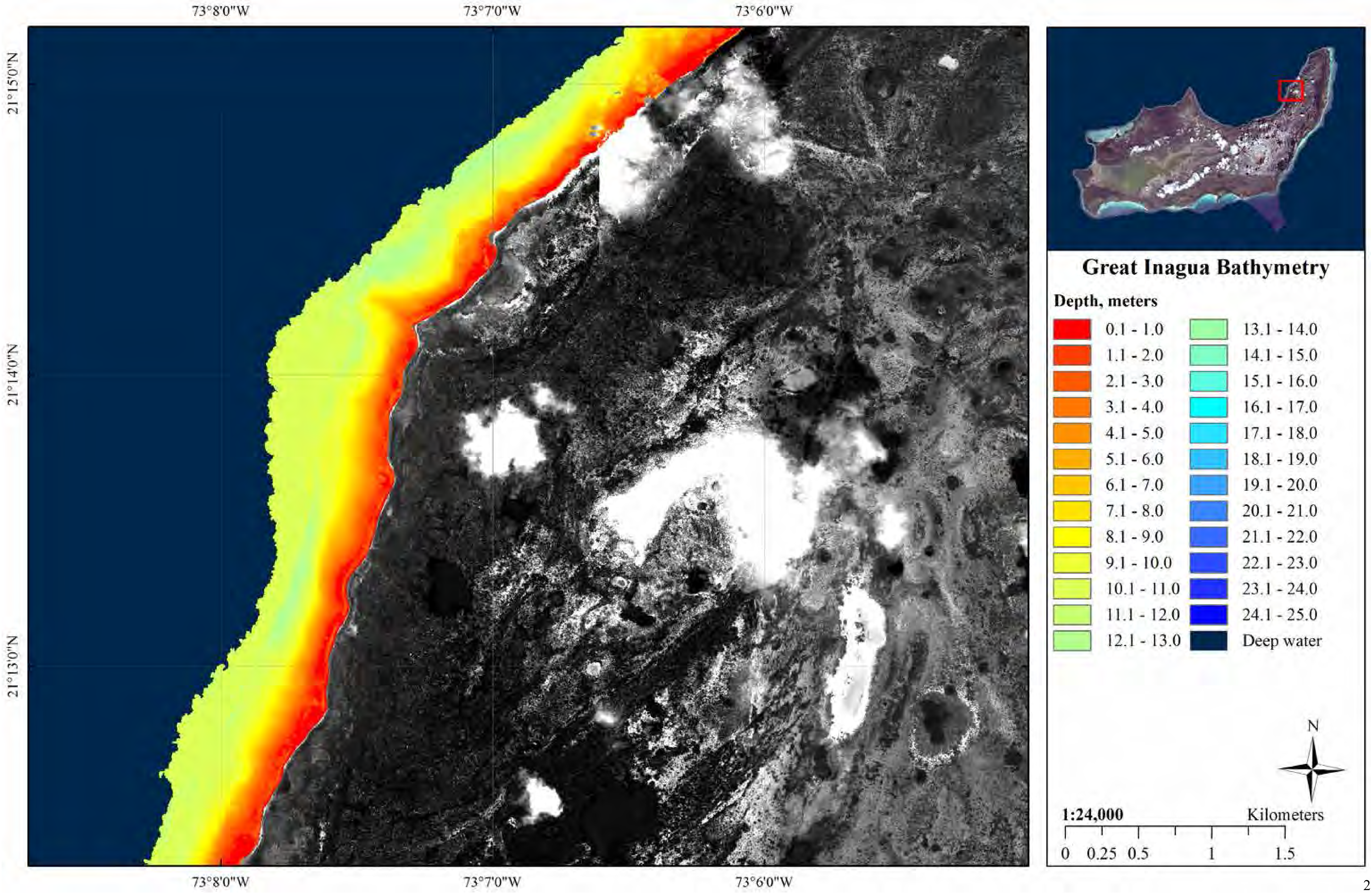

73°18'0"W
73°17'0"W
73°16'0"W
73°15'0"W
21°10'0"N
21°9'0"N
21°8'0"N
Great Inagua Habitats
🟥 Shallow coral framework
🟥 Shelf-edge coral framework
🟧 Patch reef
🟪 Deep spur and groove formations
🟩 Moderately dense to dense seagrass
🟩 Sparse to moderately dense seagrass
🟦 Moderate to dense macroalgae on sand
🟪 Gorgonian-dominated hardground
🟩 Macroalgae-dominated hardground
🟦 Turf-algal-dominated hardground
🟨 Sand
🟦 Blue hole
🟦 Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

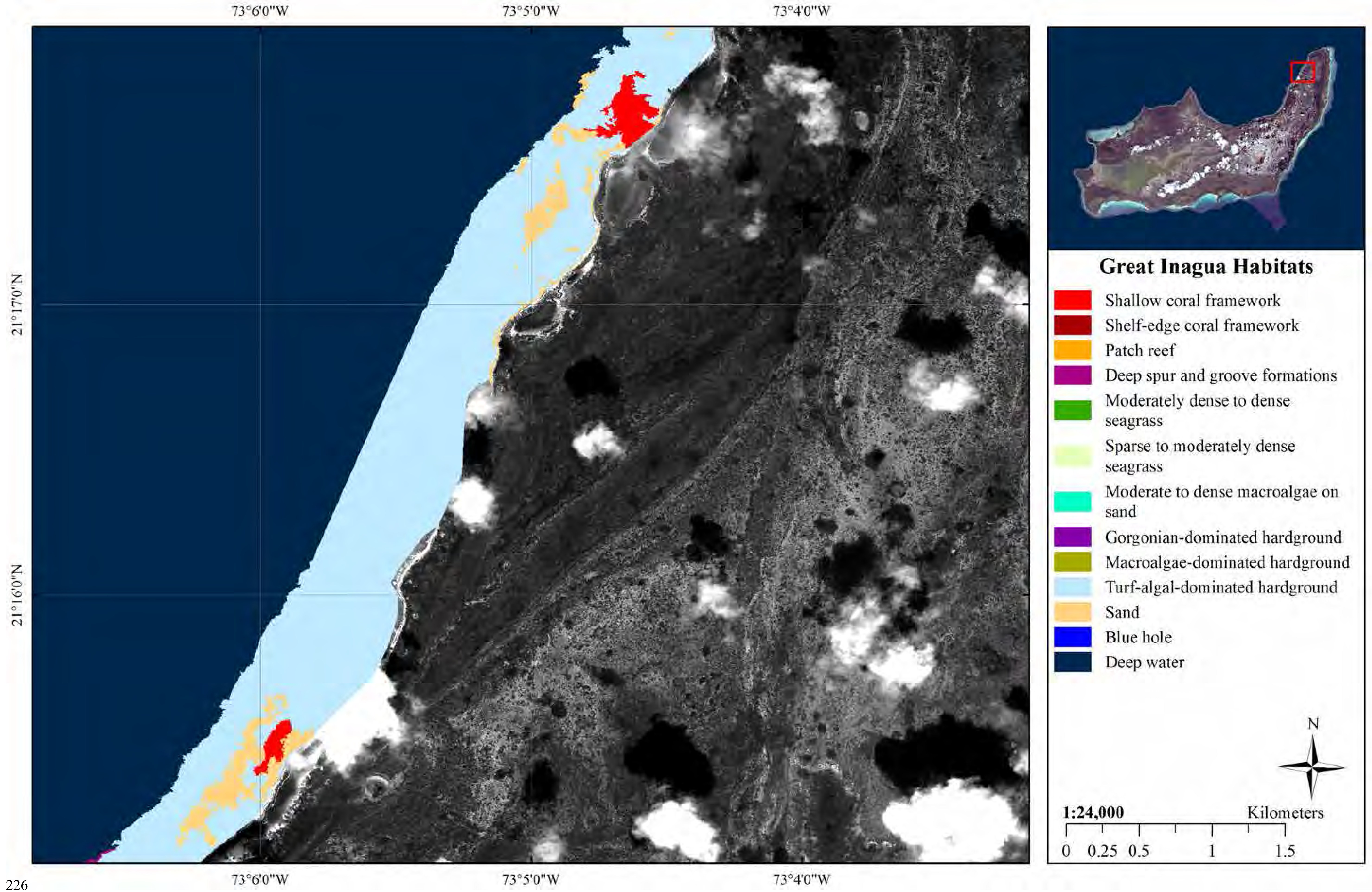

73°14'0"W
73°13'0"W
73°12'0"W
21°11'0"N
21°10'0"N
21°9'0"N
Great Inagua Habitats
🟥 Shallow coral framework
🟥 Shelf-edge coral framework
🟧 Patch reef
🟪 Deep spur and groove formations
🟩 Moderately dense to dense seagrass
🟩 Sparse to moderately dense seagrass
🟦 Moderate to dense macroalgae on sand
🟪 Gorgonian-dominated hardground
🟩 Macroalgae-dominated hardground
🟦 Turf-algal-dominated hardground
🟨 Sand
🟦 Blue hole
🟦 Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

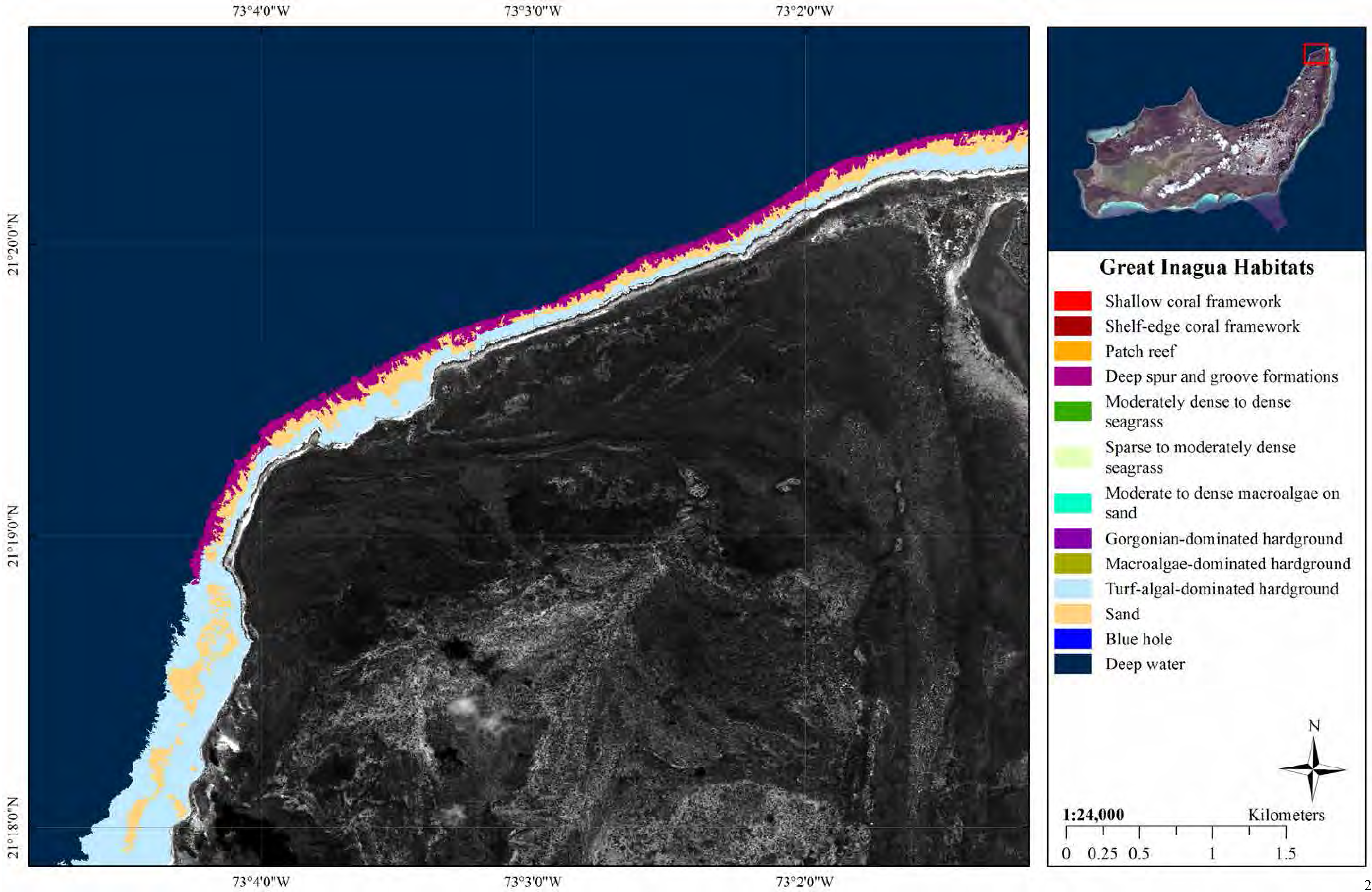

73°11'0"W
73°10'0"W
73°9'0"W
73°8'0"W
21°12'0"N
21°11'0"N
21°10'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

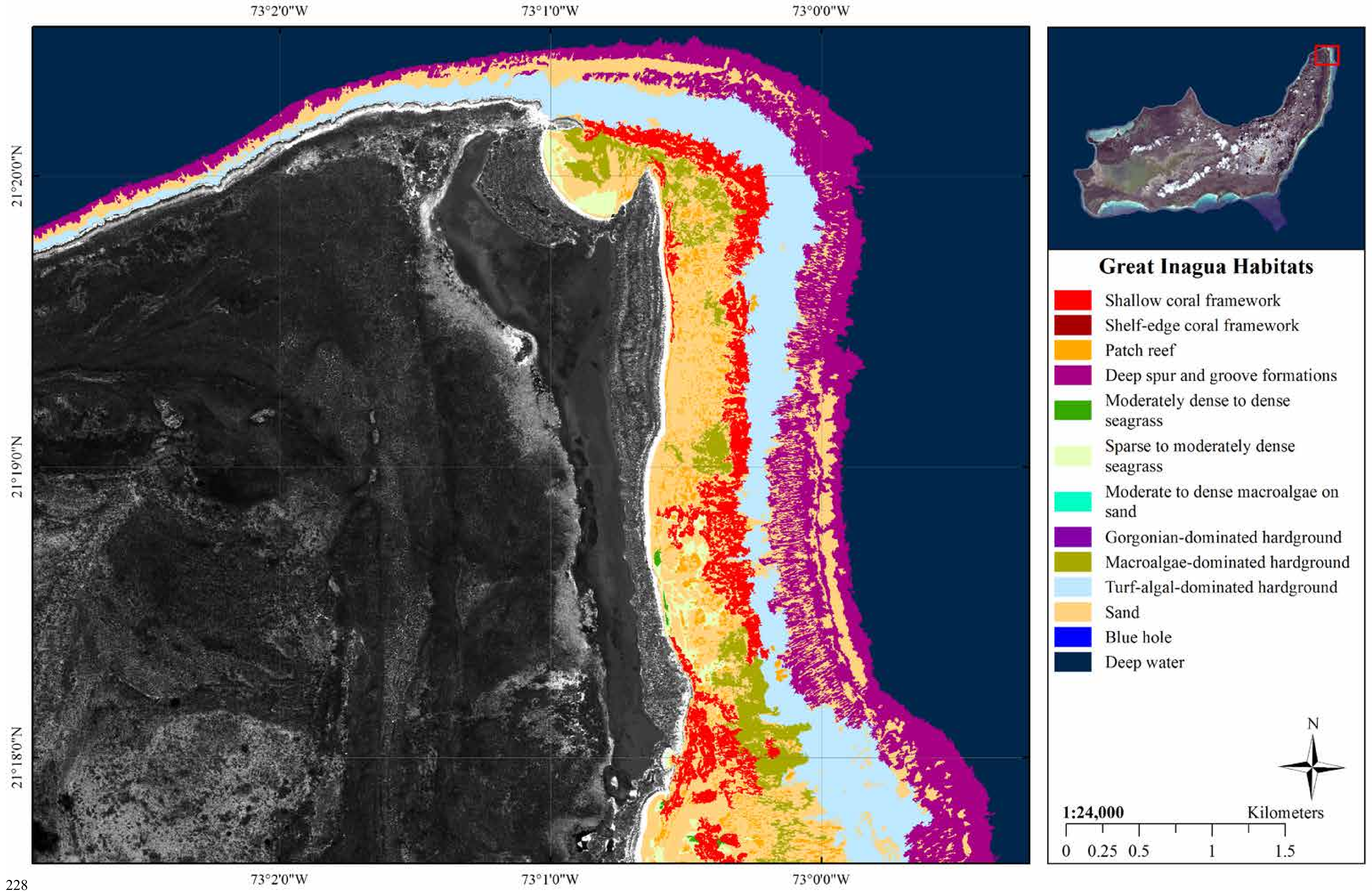

73°11'0"W
73°10'0"W
73°9'0"W
73°8'0"W
21°12'0"N
21°11'0"N
21°10'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

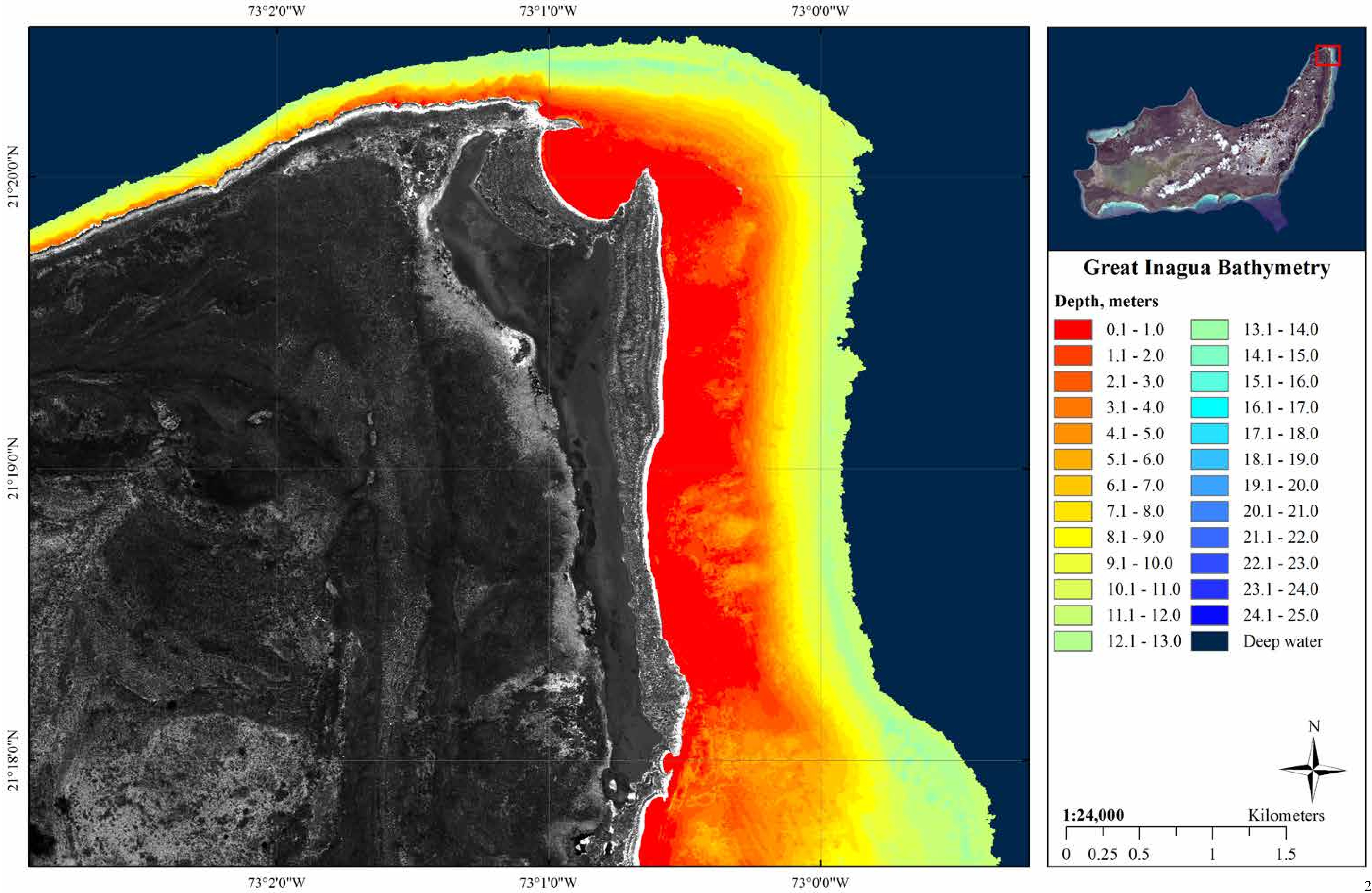

73°8'0"W
73°7'0"W
73°6'0"W
21°15'0"N
21°14'0"N
21°13'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

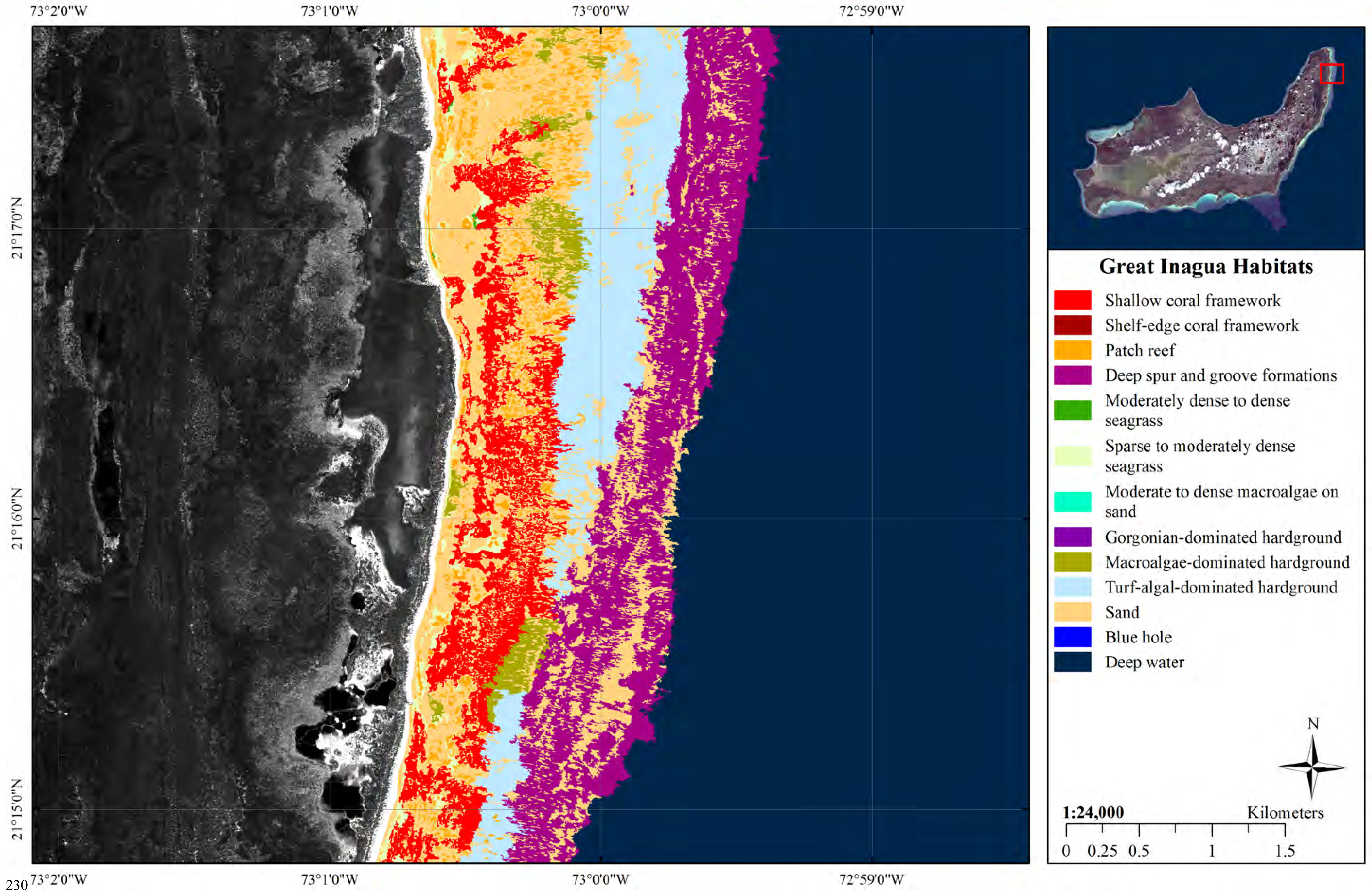

73°8'0"W
73°7'0"W
73°6'0"W
21°15'0"N
21°14'0"N
21°13'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


73°6'0"W
73°5'0"W
73°4'0"W
21°17'0"N
21°16'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

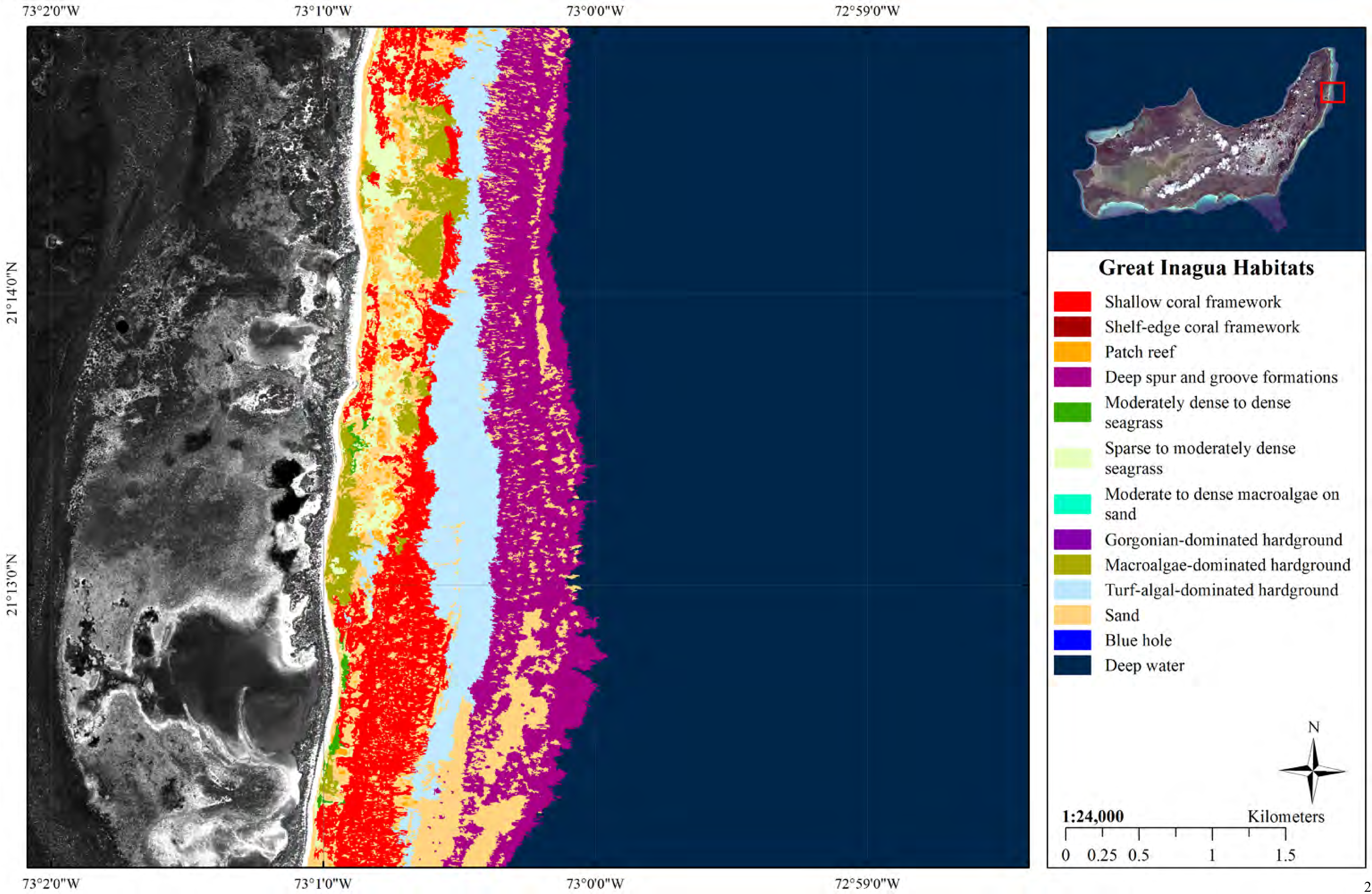

73°4'0"W
73°3'0"W
73°2'0"W
21°20'0"N
21°19'0"N
21°18'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


73°2'0"W
73°1'0"W
73°0'0"W
21°20'0"N
21°19'0"N
21°18'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

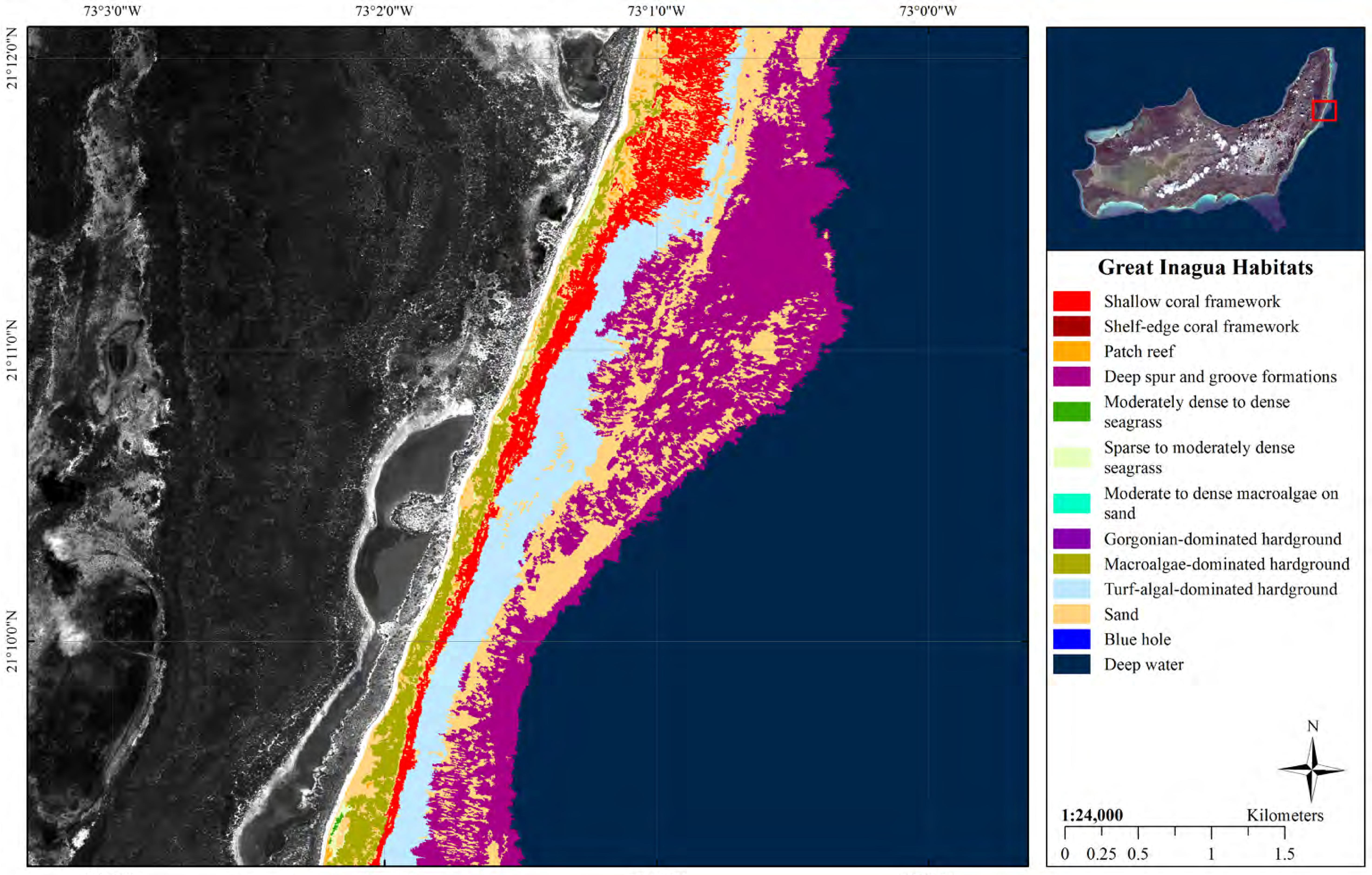

73°2'0"W
73°1'0"W
73°0'0"W
21°20'0"N
21°19'0"N
21°18'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

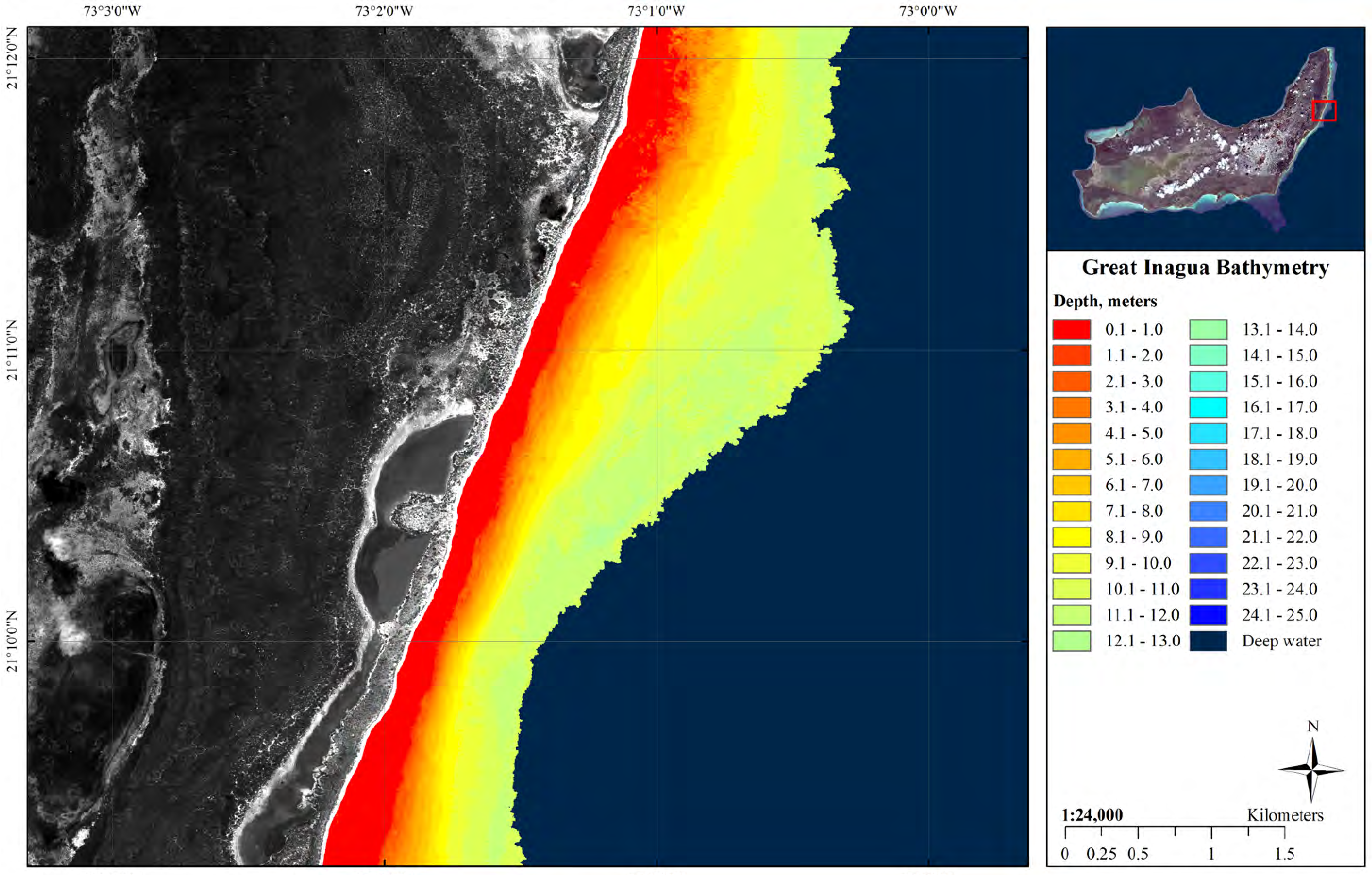


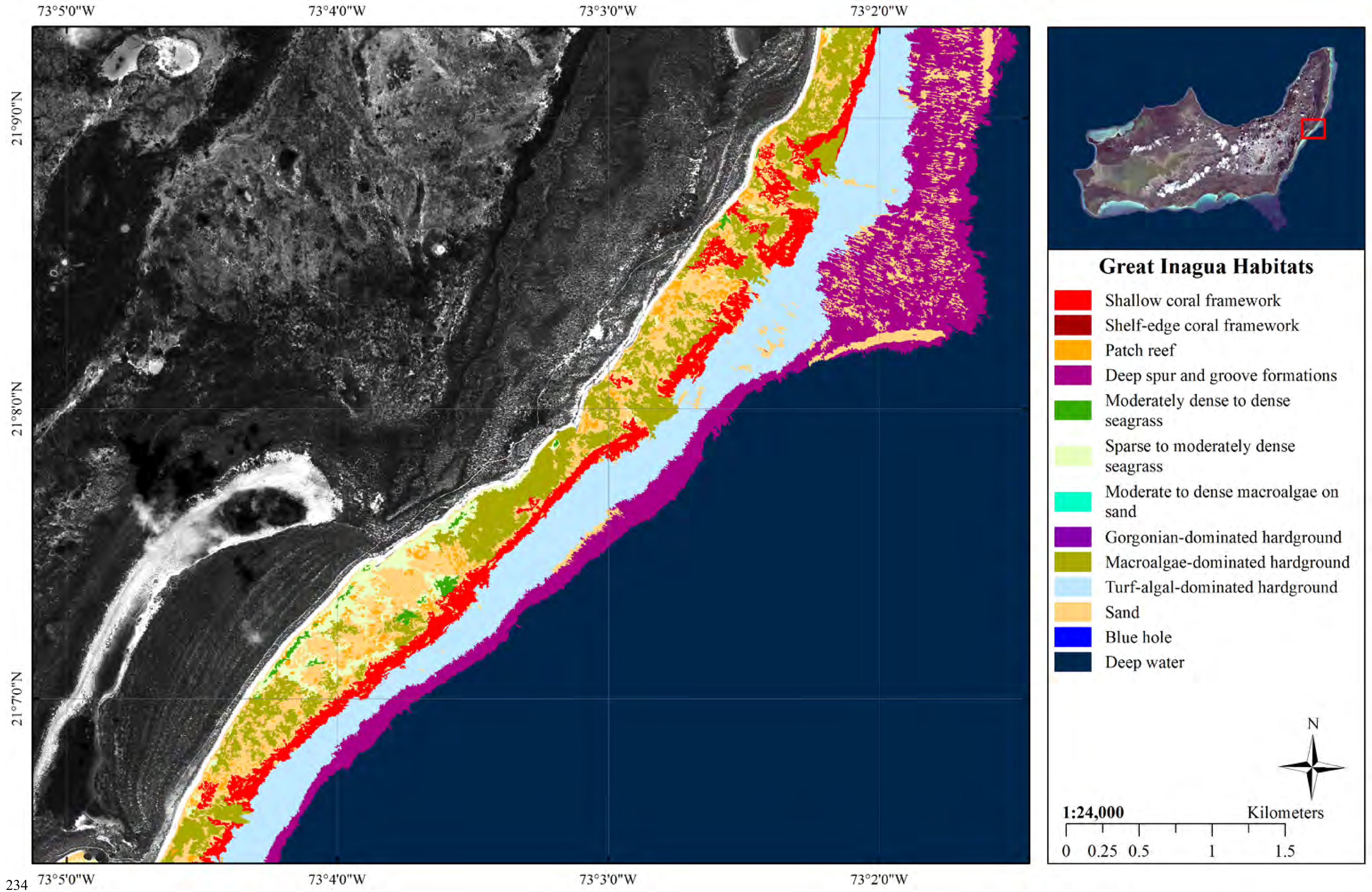
73°2'0"W
73°1'0"W
73°0'0"W
72°59'0"W
21°17'0"N
21°16'0"N
21°15'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5



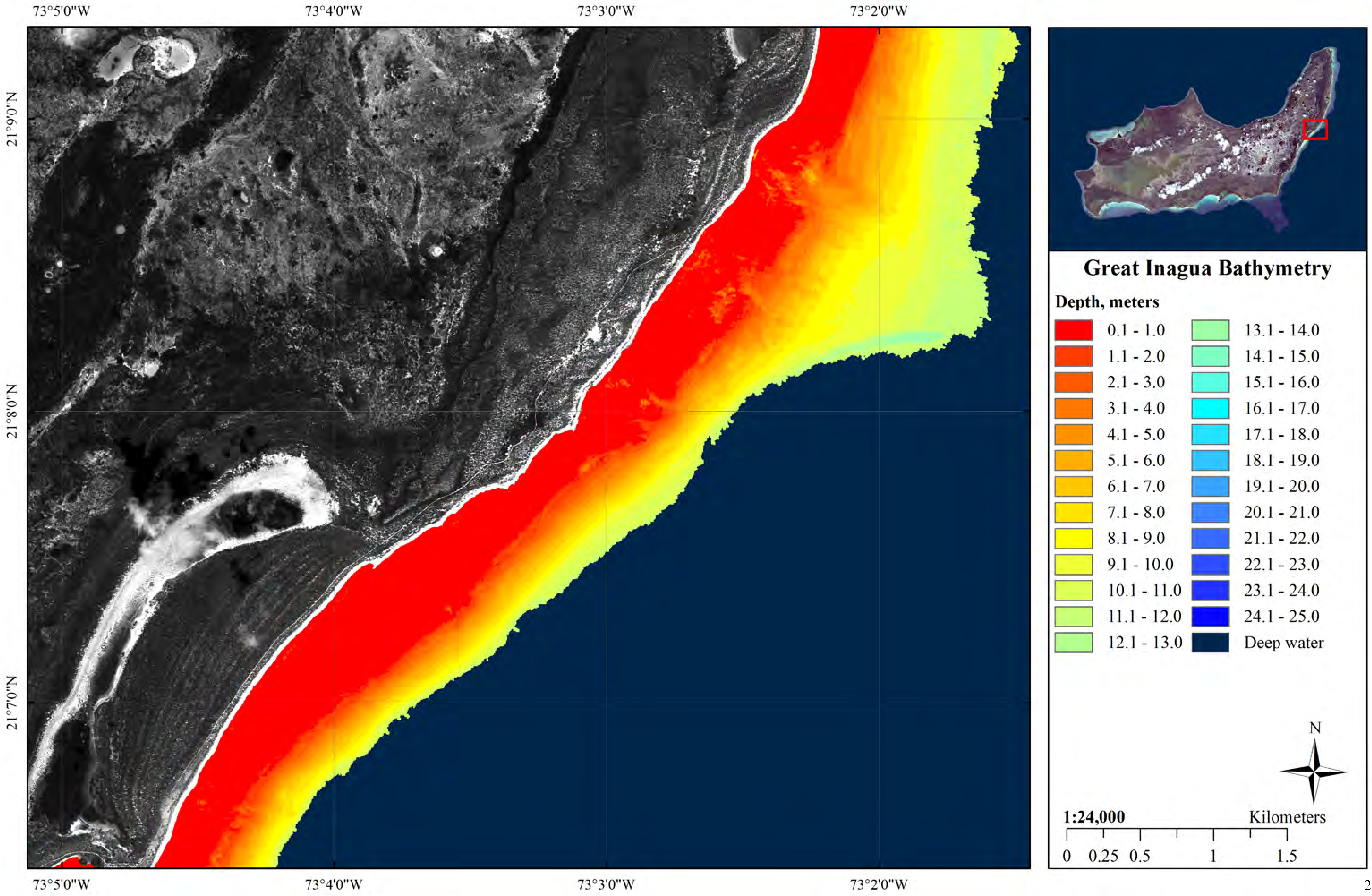
73°2'0"W
73°1'0"W
73°0'0"W
72°59'0"W
21°14'0"N
21°13'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


73°3'0"W
73°2'0"W
73°1'0"W
73°0'0"W
21°12'0"N
21°11'0"N
21°10'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

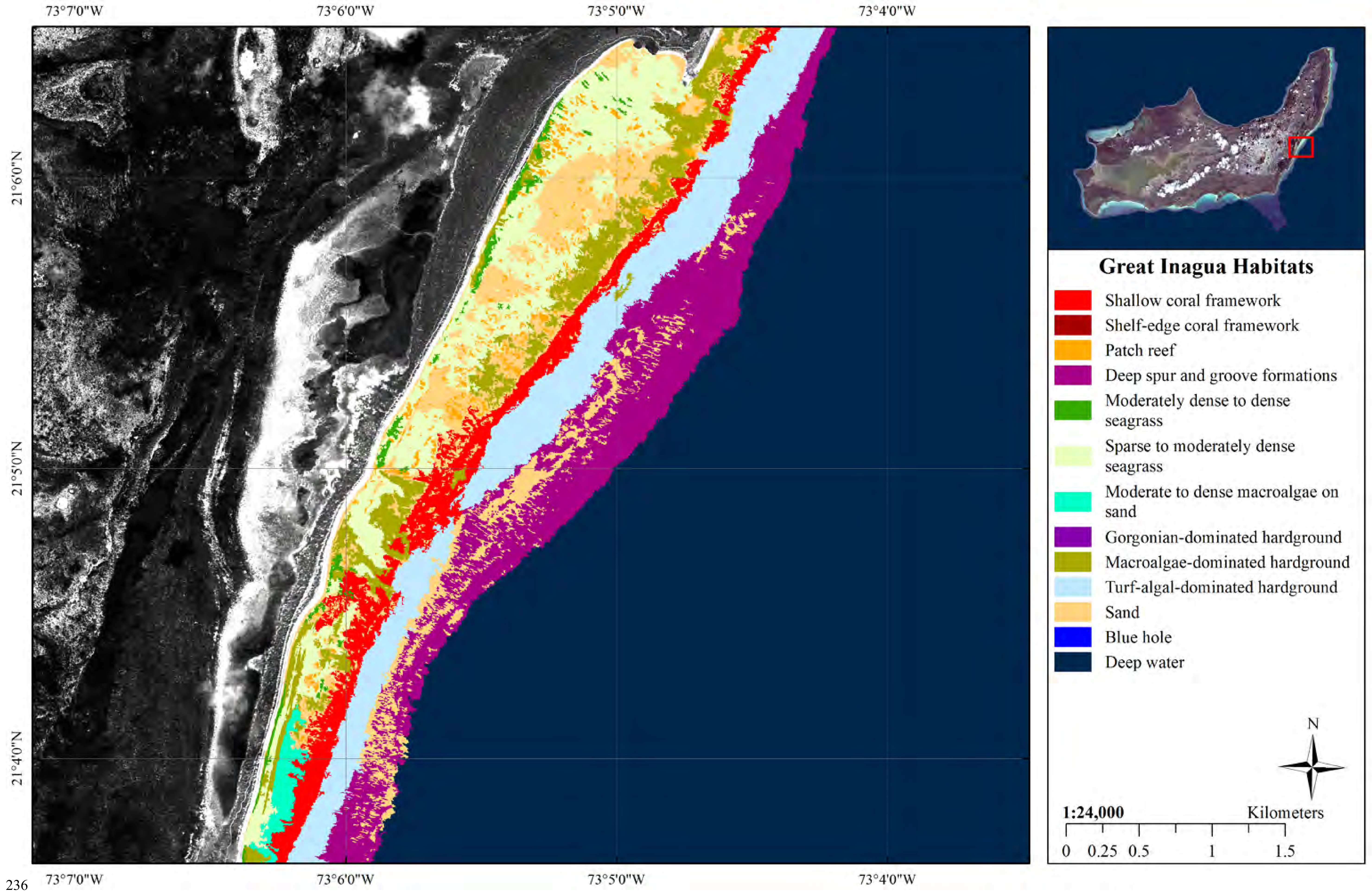

73°3'0"W
73°2'0"W
73°1'0"W
73°0'0"W
21°12'0"N
21°11'0"N
21°10'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

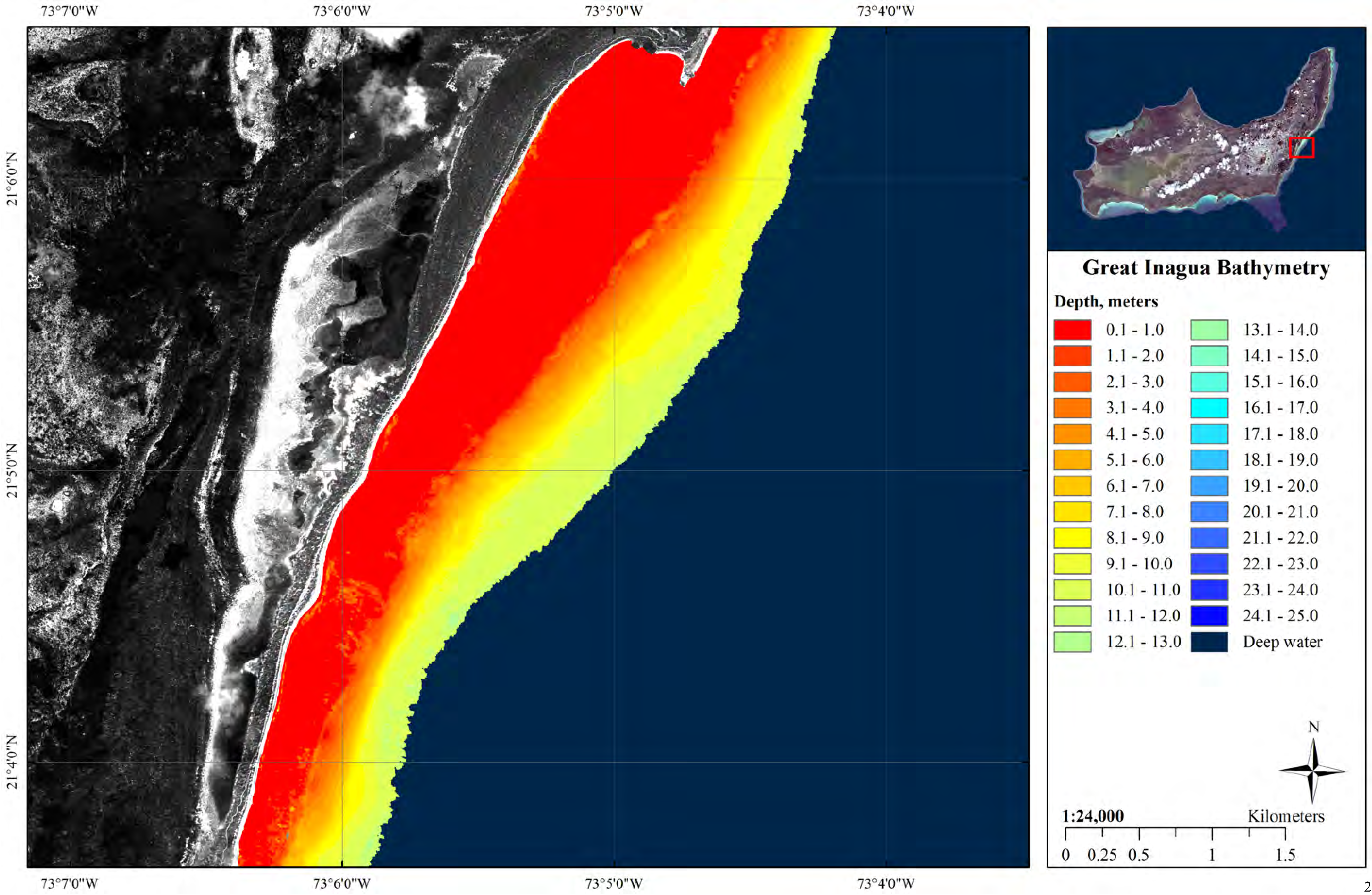


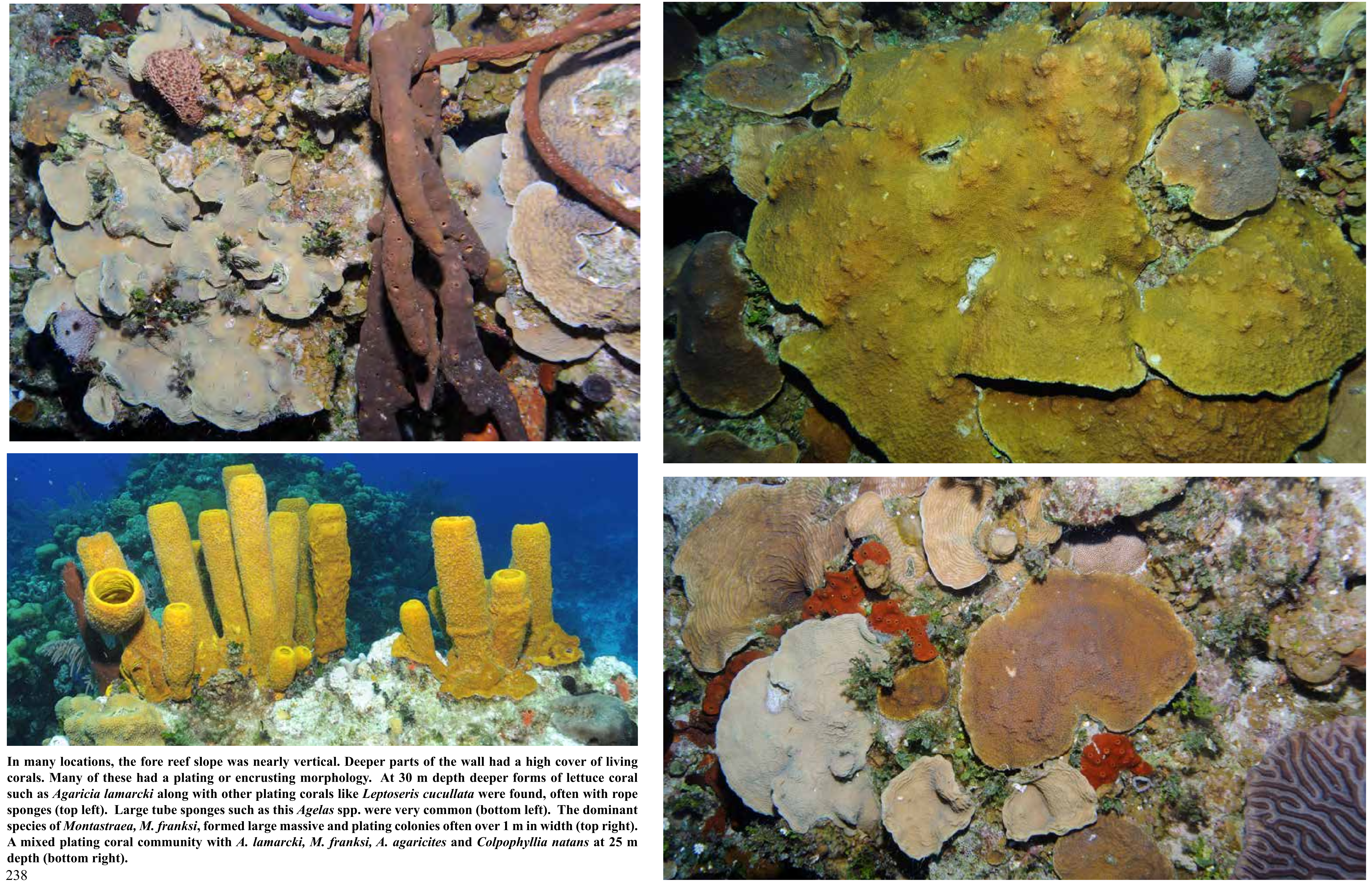
73°5'0"W
73°4'0"W
73°3'0"W
73°2'0"W
21°9'0"N
21°8'0"N
21°7'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5



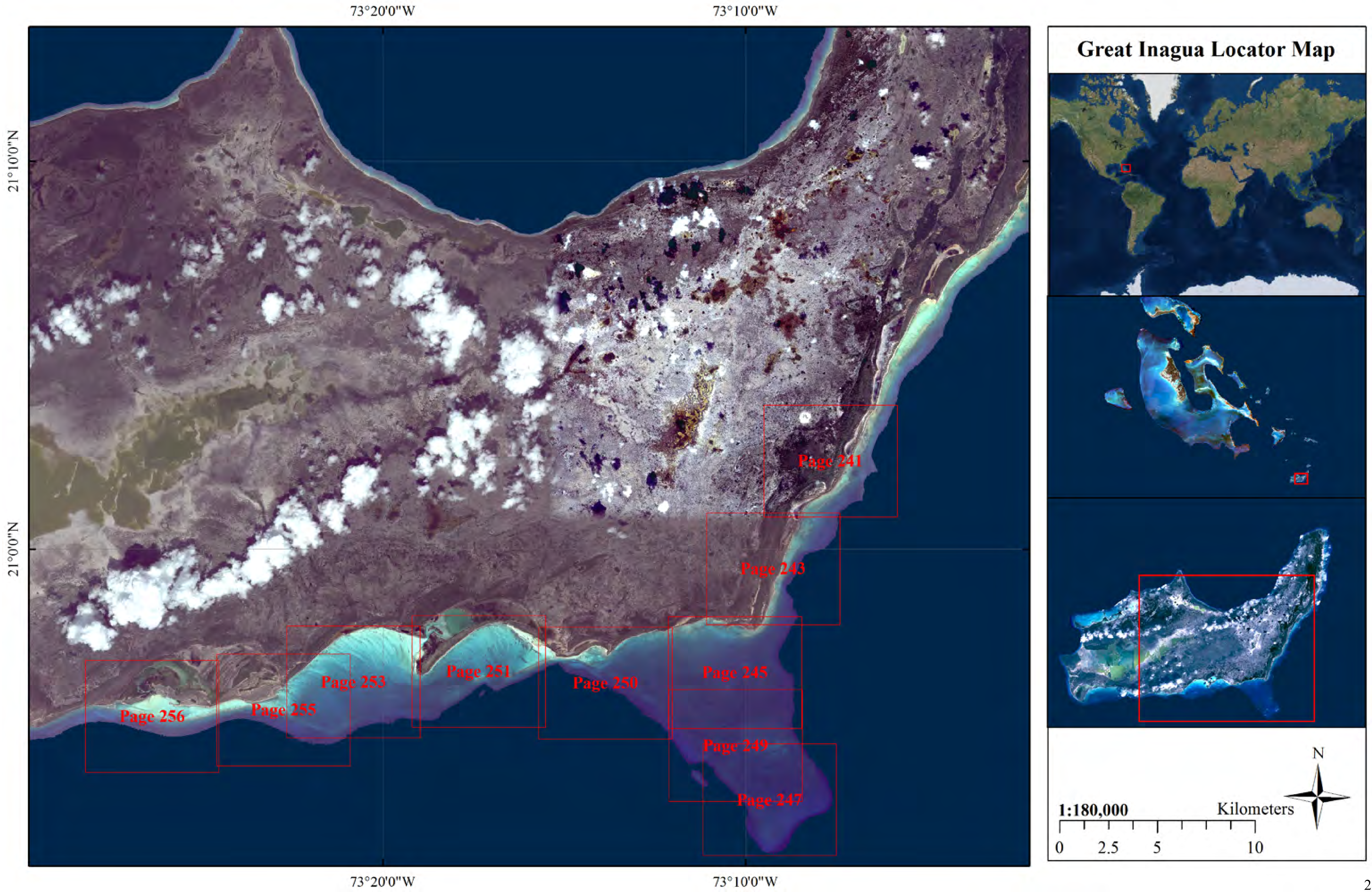
73°5'0"W
73°4'0"W
73°3'0"W
73°2'0"W
21°9'0"N
21°8'0"N
21°7'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

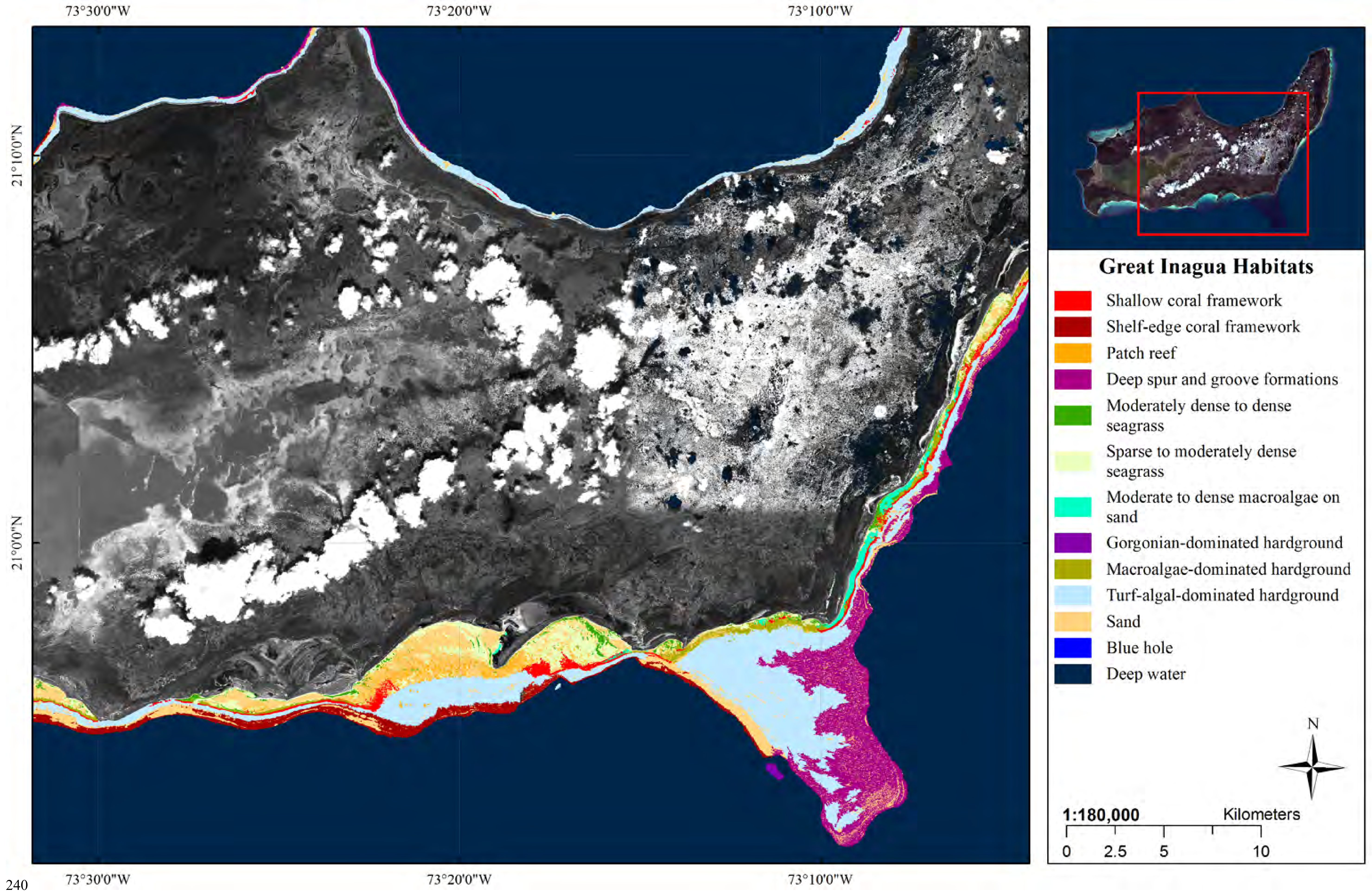

73°7'0"W
73°6'0"W
73°5'0"W
73°4'0"W
21°6'0"N
21°5'0"N
21°4'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

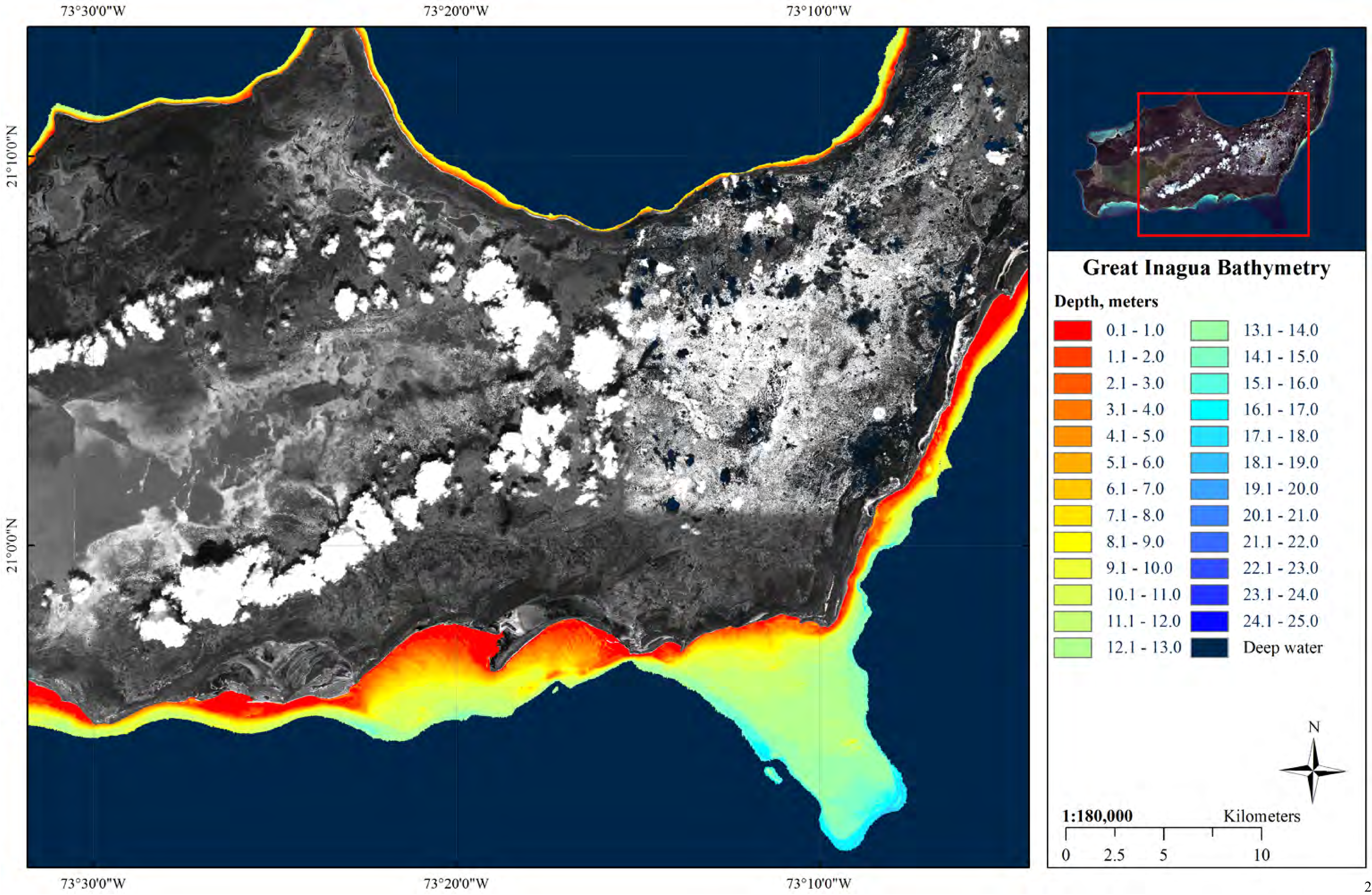

73°7'0"W
73°6'0"W
73°5'0"W
73°4'0"W
21°6'0"N
21°5'0"N
21°4'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

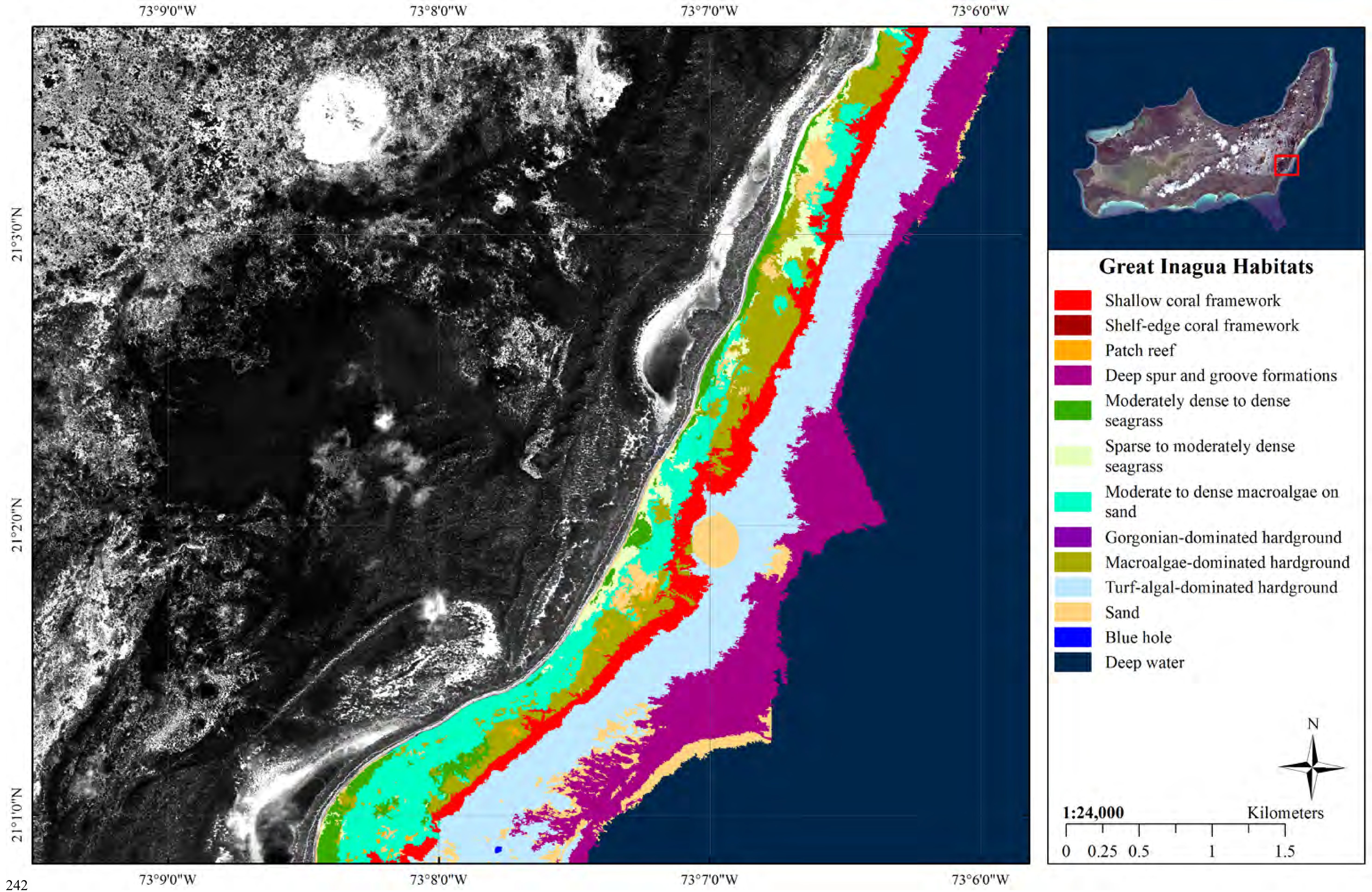


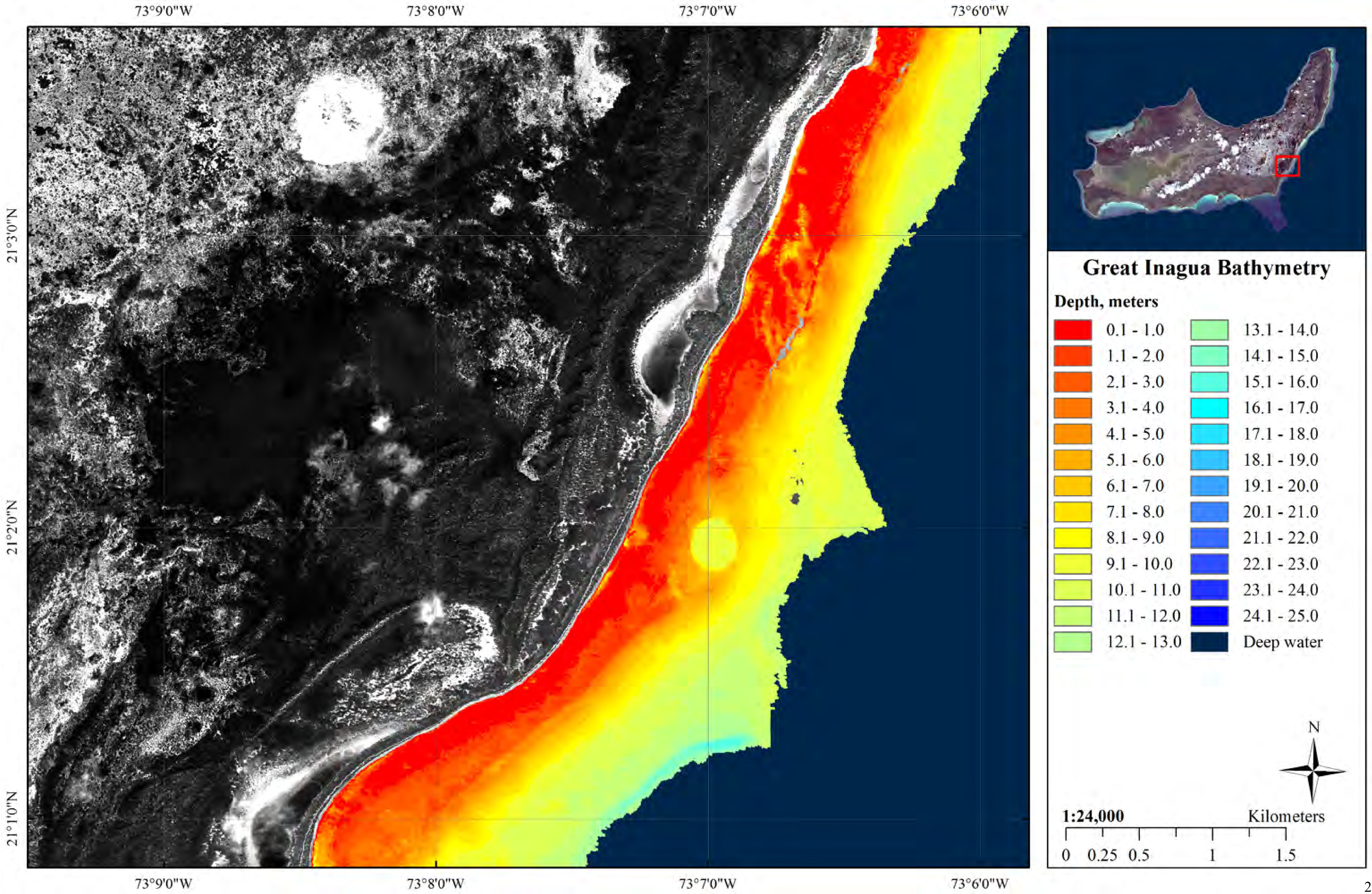
In many locations, the fore reef slope was nearly vertical. Deeper parts of the wall had a high cover of living corals. Many of these had a plating or encrusting morphology. At 30 m depth deeper forms of lettuce coral such as *Agaricia lamarcki* along with other plating corals like *Leptoseris cucullata* were found, often with rope sponges (top left). Large tube sponges such as this *Agelas* spp. were very common (bottom left). The dominant species of *Montastraea, M. franksi*, formed large massive and plating colonies often over 1 m in width (top right). A mixed plating coral community with *A. lamarcki, M. franksi, A. agaricites* and *Colpophyllia natans* at 25 m depth (bottom right).

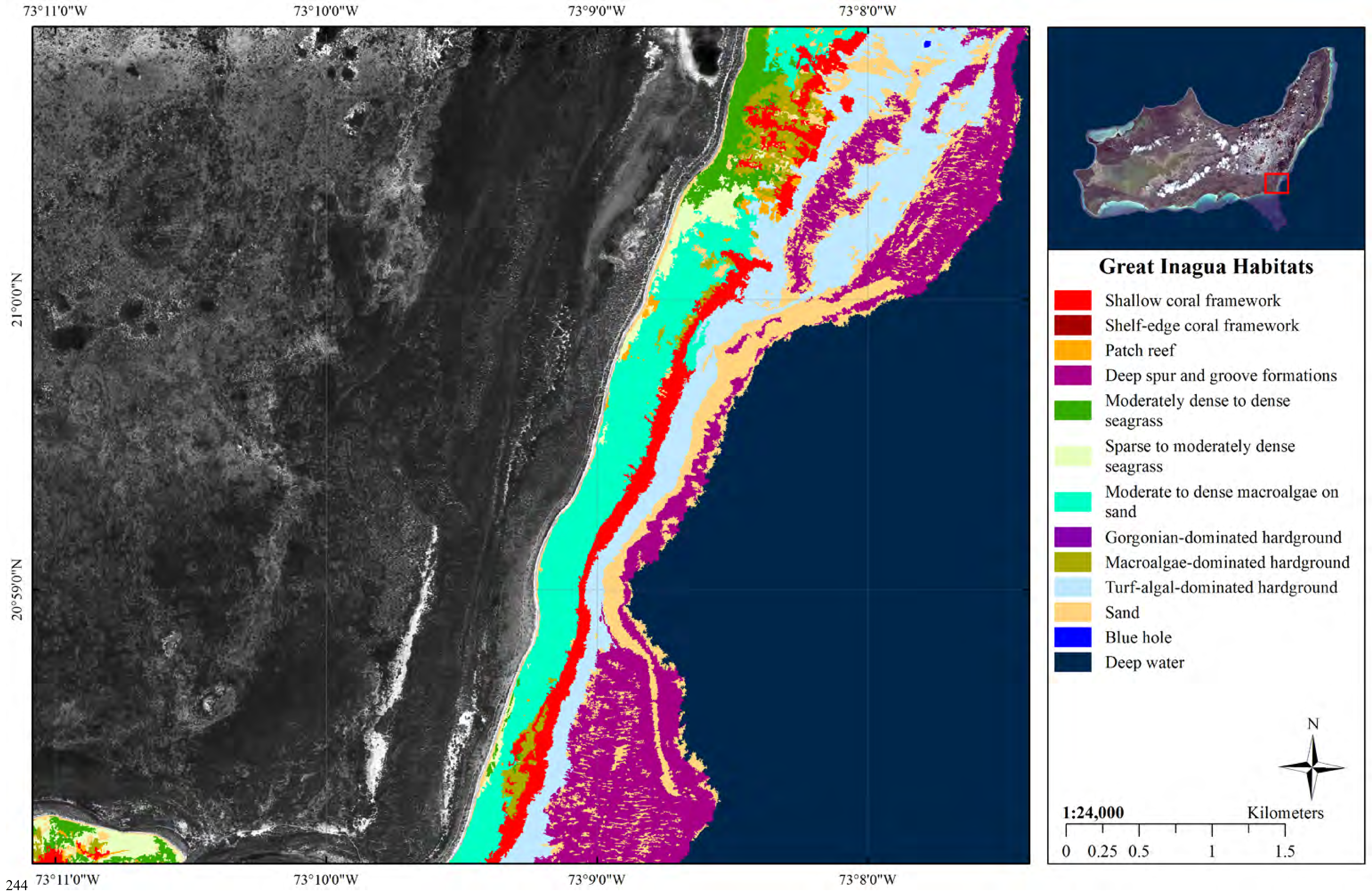


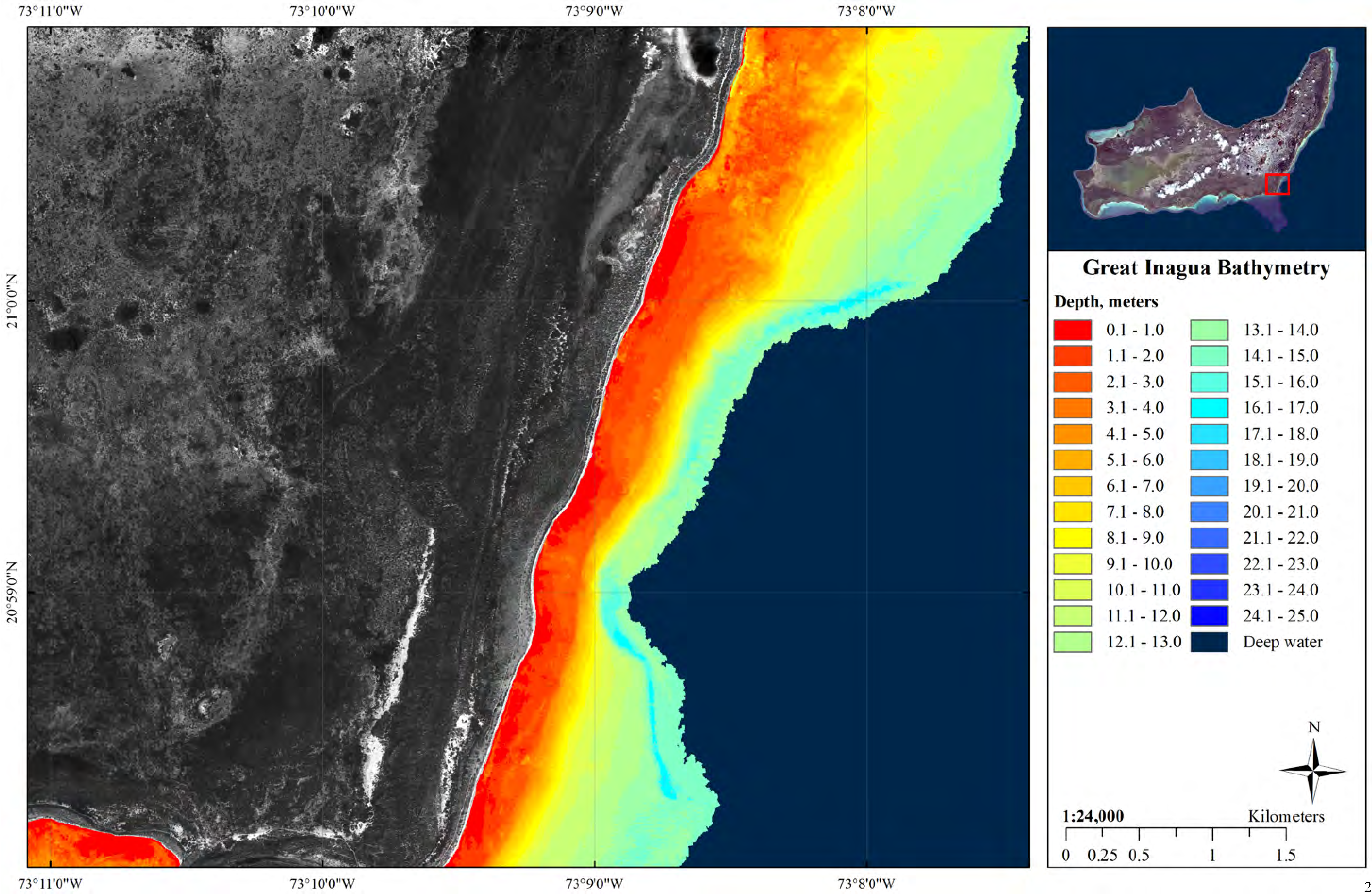

73°30'0"W
73°20'0"W
73°10'0"W
21°10'0"N
21°0'0"N
Great Inagua Habitats
🟥 Shallow coral framework
🟥 Shelf-edge coral framework
🟧 Patch reef
🟪 Deep spur and groove formations
🟩 Moderately dense to dense seagrass
🟩 Sparse to moderately dense seagrass
🟦 Moderate to dense macroalgae on sand
🟪 Gorgonian-dominated hardground
🟩 Macroalgae-dominated hardground
🟦 Turf-algal-dominated hardground
🟧 Sand
🟦 Blue hole
⬛ Deep water
N
1:180,000
Kilometers
0
2.5
5
10

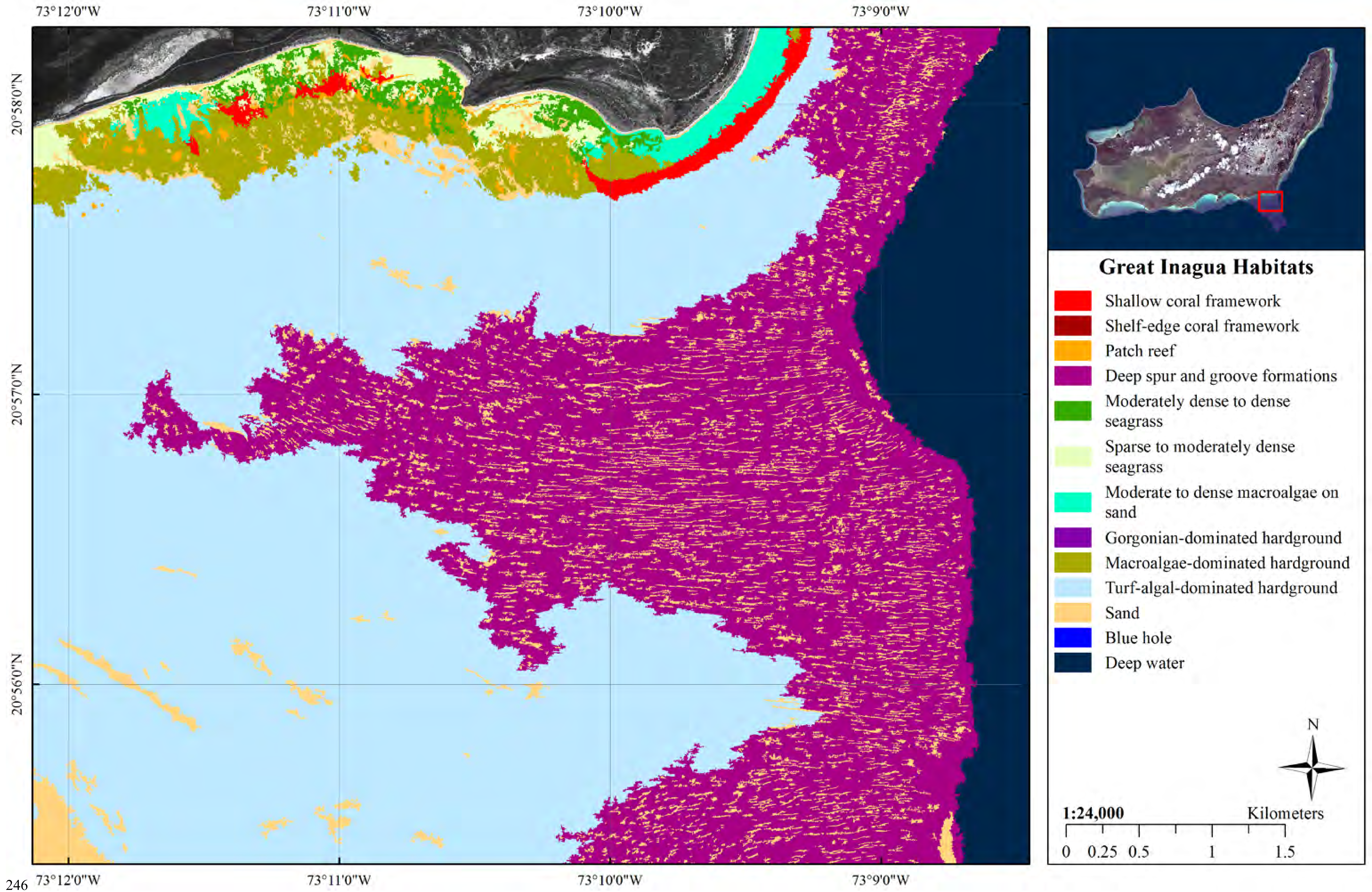

73°30'0"W
73°20'0"W
73°10'0"W
21°10'0"N
21°0'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:180,000
Kilometers
0
2.5
5
10

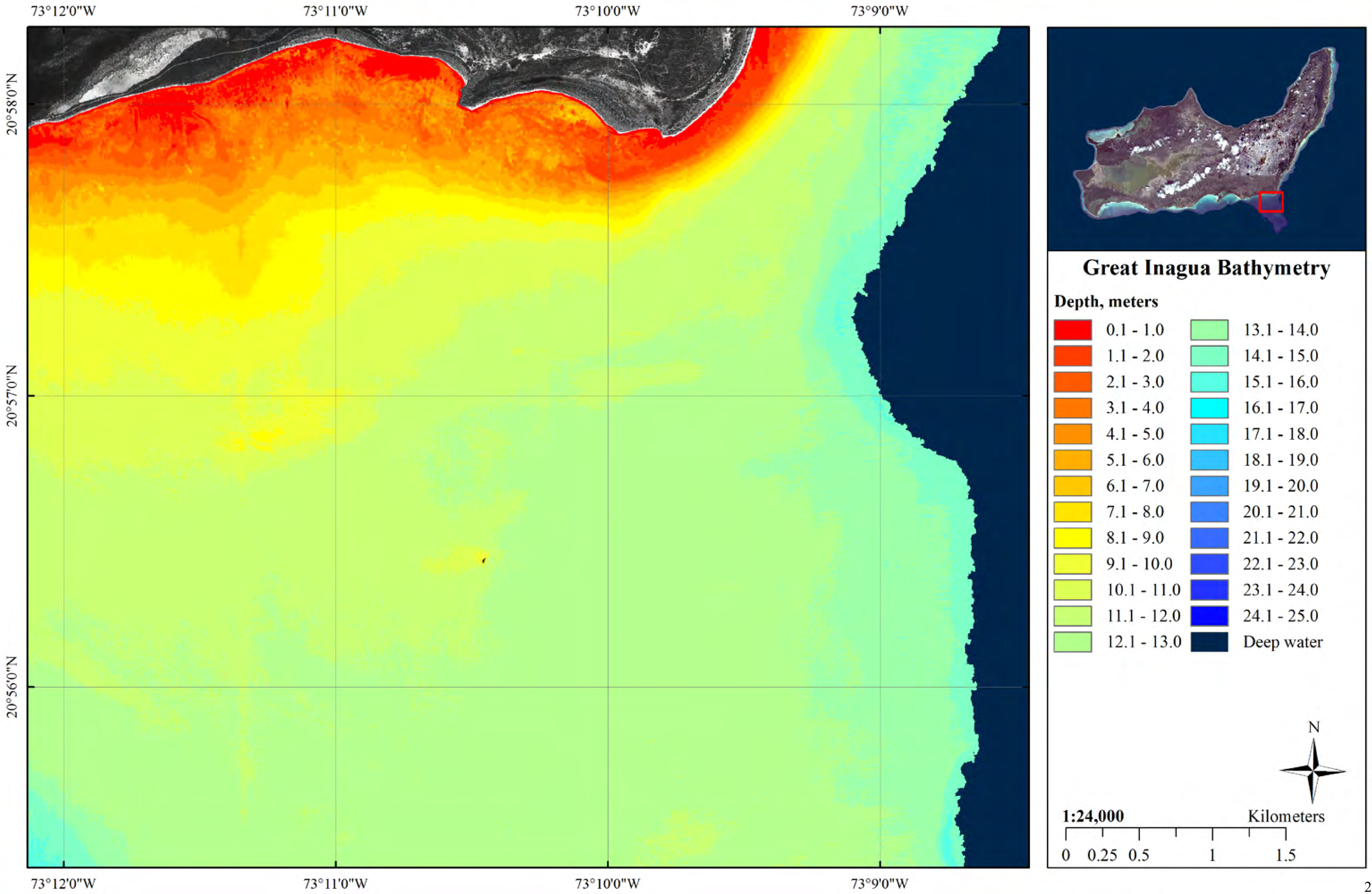

73°9'0"W
73°8'0"W
73°7'0"W
73°6'0"W
21°3'0"N
21°2'0"N
21°1'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

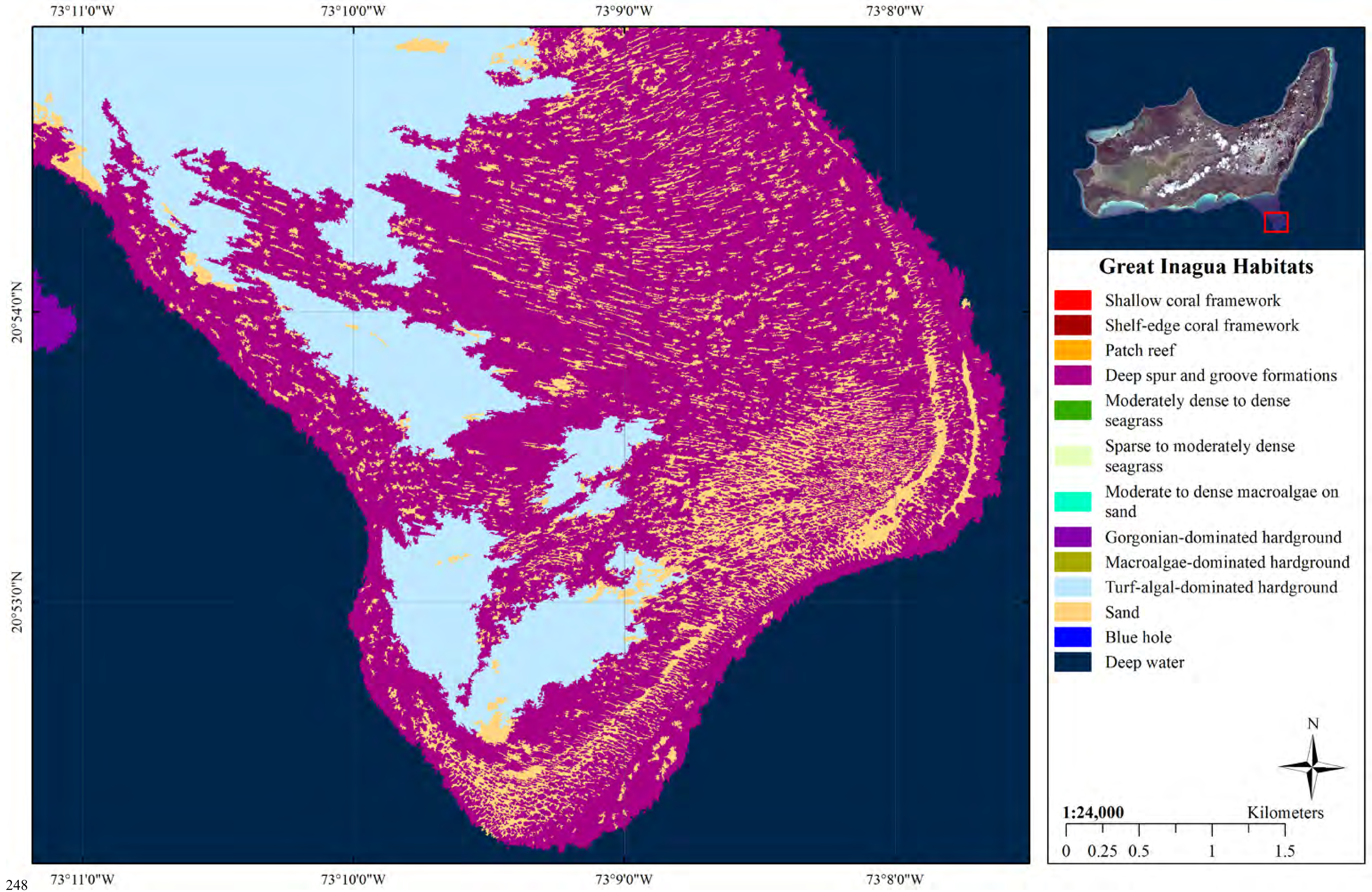

73°9'0"W
73°8'0"W
73°7'0"W
73°6'0"W
21°3'0"N
21°2'0"N
21°1'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

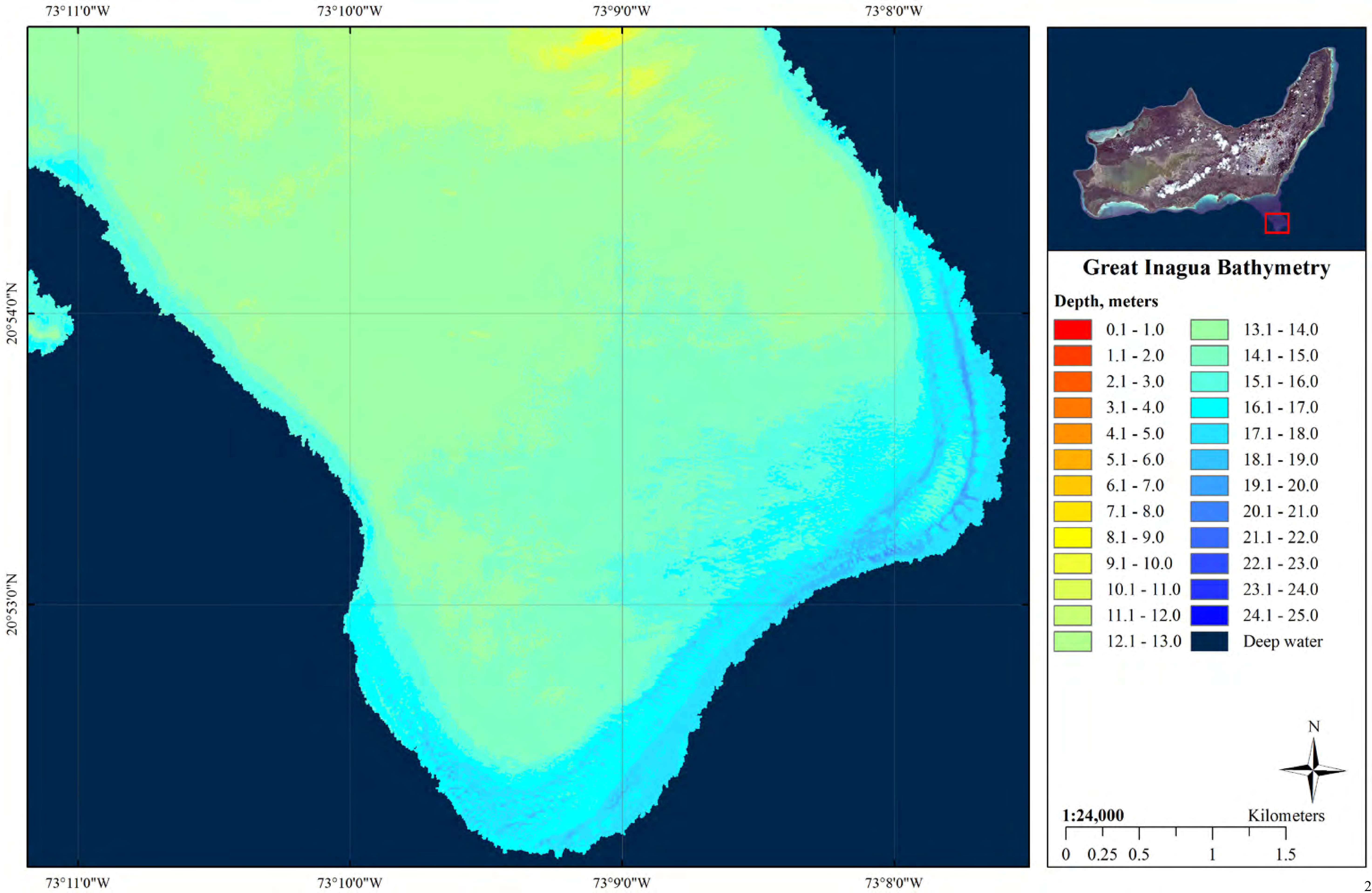

73°11'0"W
73°10'0"W
73°9'0"W
73°8'0"W
21°0'0"N
20°59'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

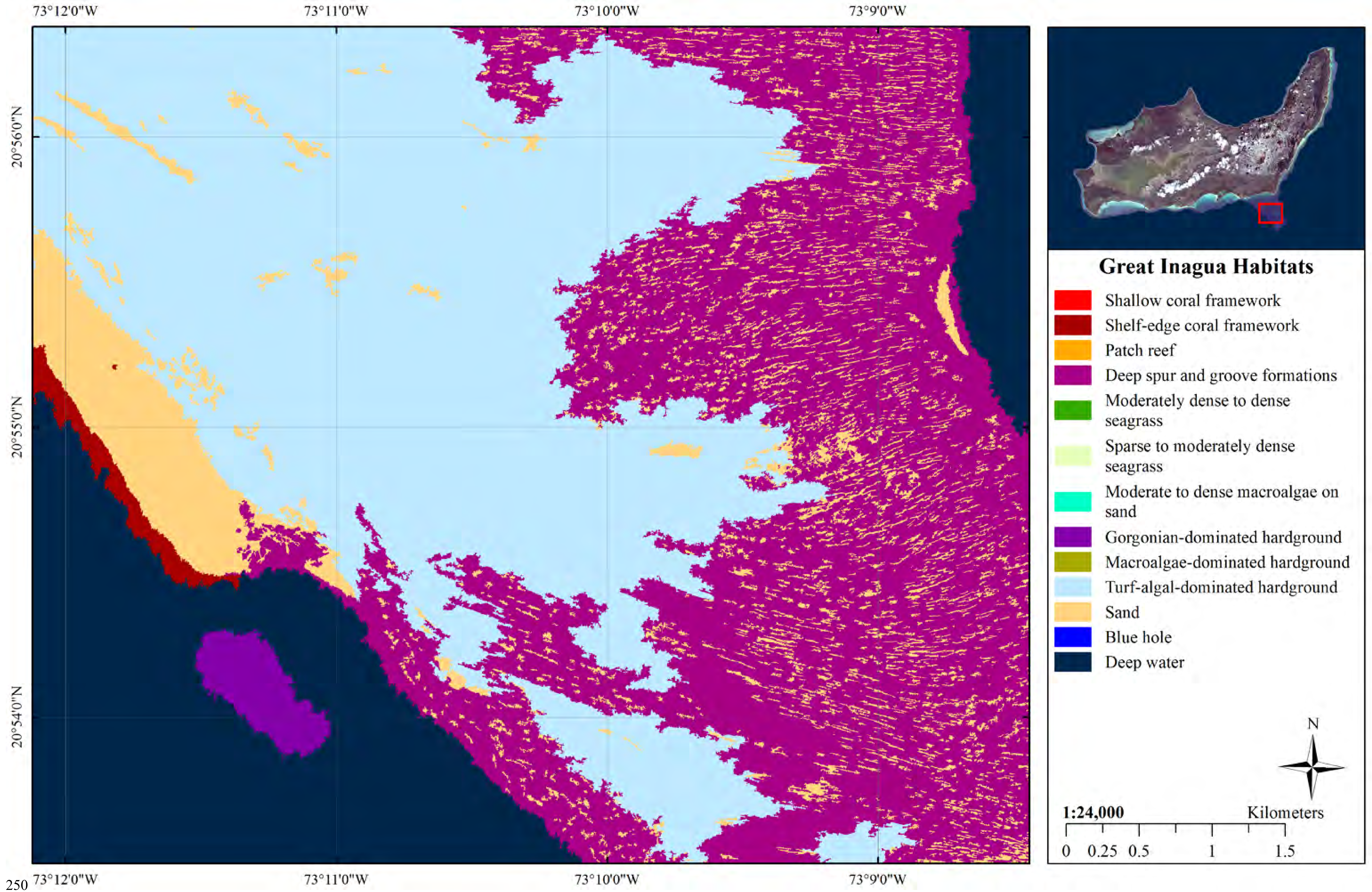

73°11'0"W
73°10'0"W
73°9'0"W
73°8'0"W
21°0'0"N
20°59'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

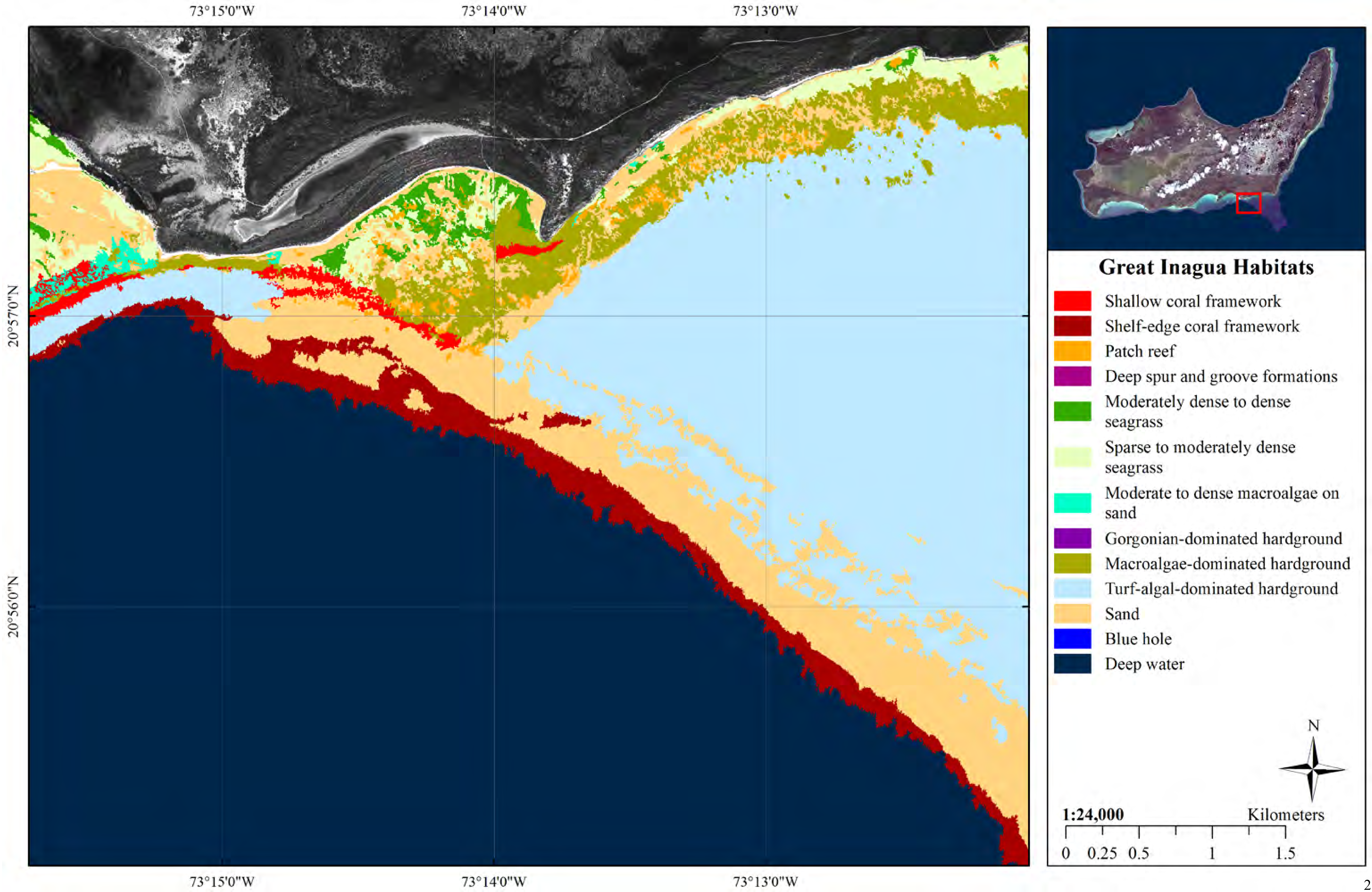

73°12'0"W
73°11'0"W
73°10'0"W
73°9'0"W
20°58'0"N
20°57'0"N
20°56'0"N
Great Inagua Habitats
🟥 Shallow coral framework
🟥 Shelf-edge coral framework
🟧 Patch reef
🟪 Deep spur and groove formations
🟩 Moderately dense to dense seagrass
🟩 Sparse to moderately dense seagrass
🟩 Moderate to dense macroalgae on sand
🟪 Gorgonian-dominated hardground
🟩 Macroalgae-dominated hardground
🟦 Turf-algal-dominated hardground
🟧 Sand
🟦 Blue hole
🟦 Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

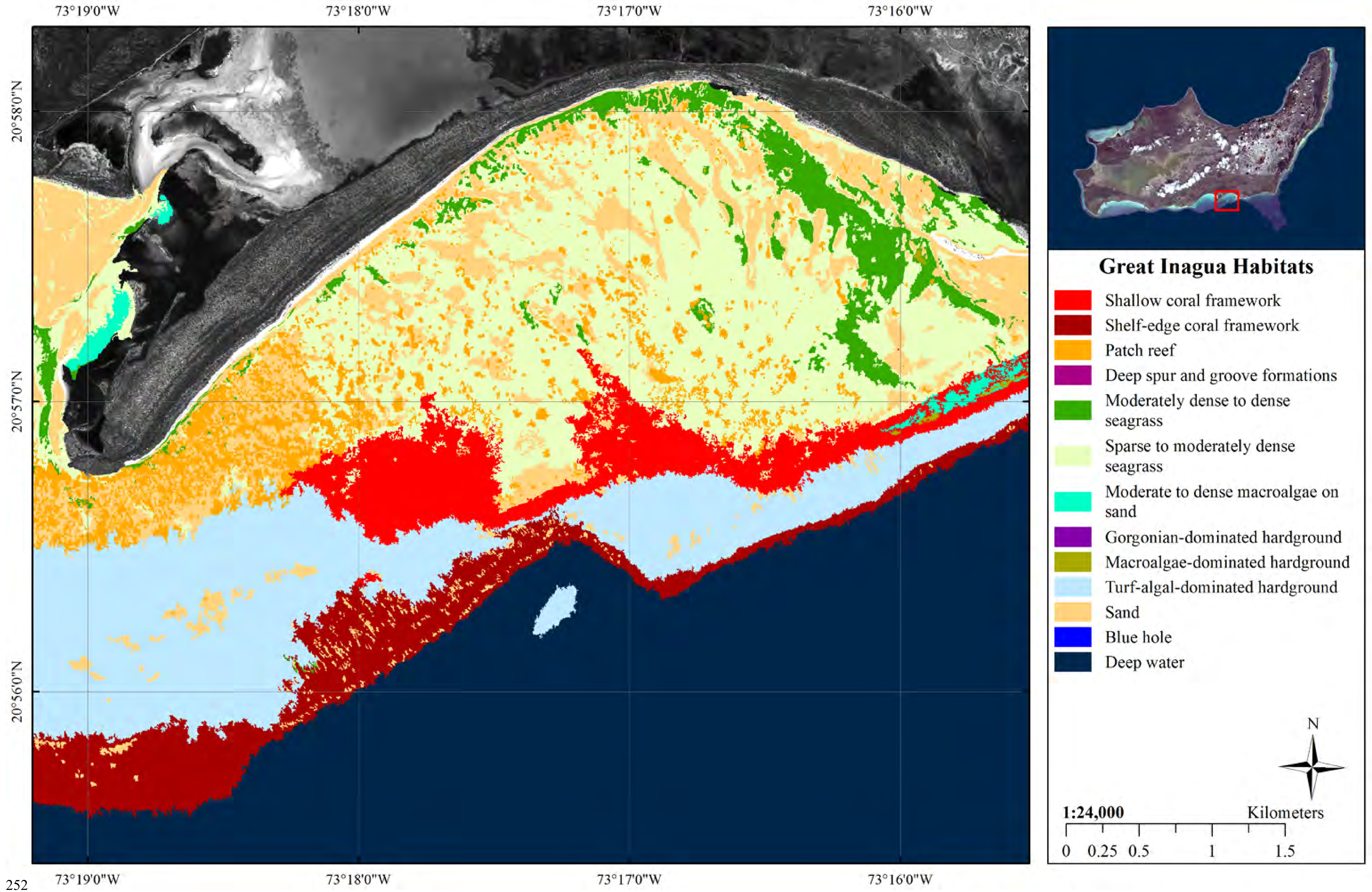

73°12'0"W
73°11'0"W
73°10'0"W
73°9'0"W
20°58'0"N
20°57'0"N
20°56'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

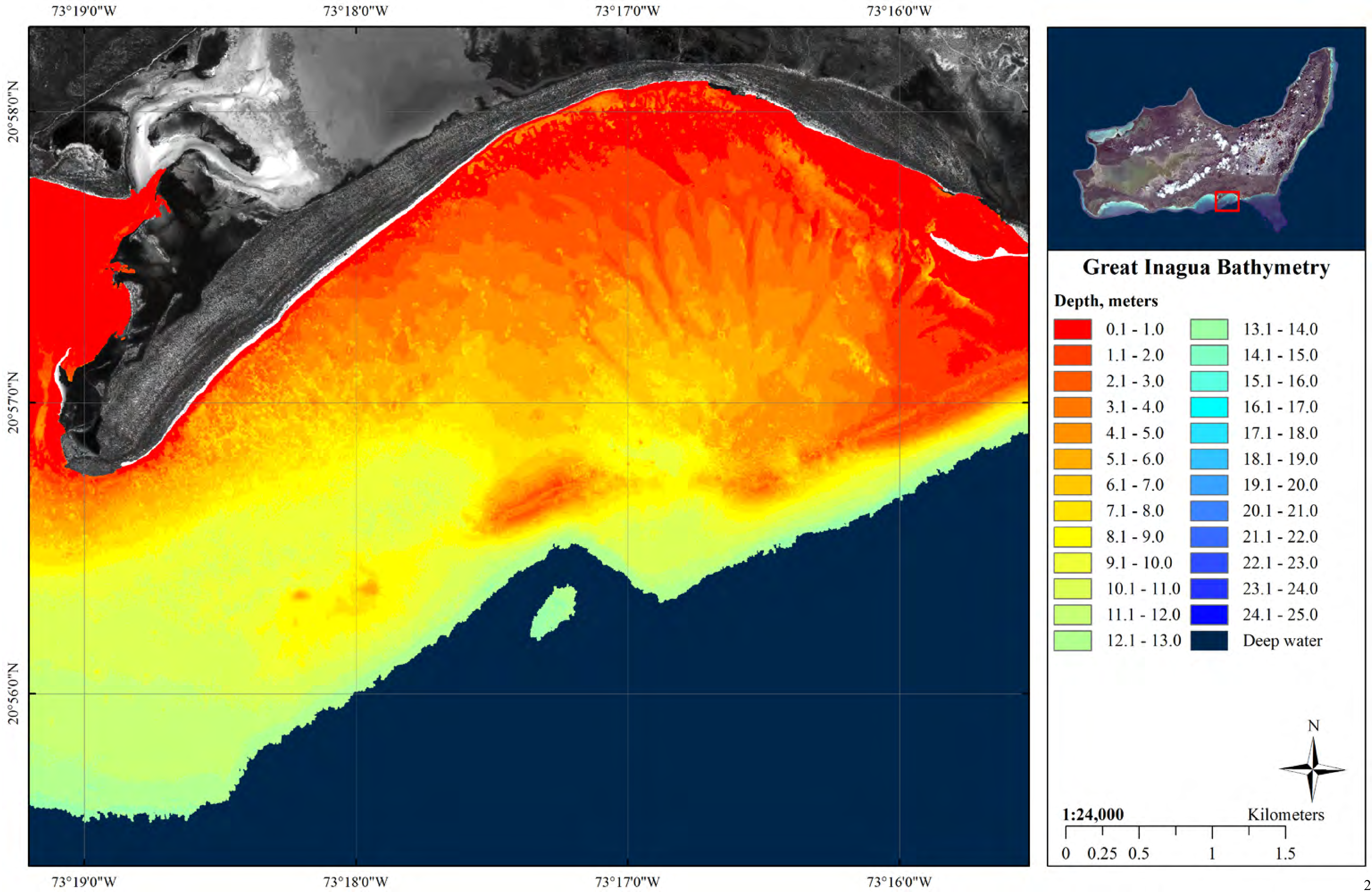

73°11'0"W
73°10'0"W
73°9'0"W
73°8'0"W
20°54'0"N
20°53'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

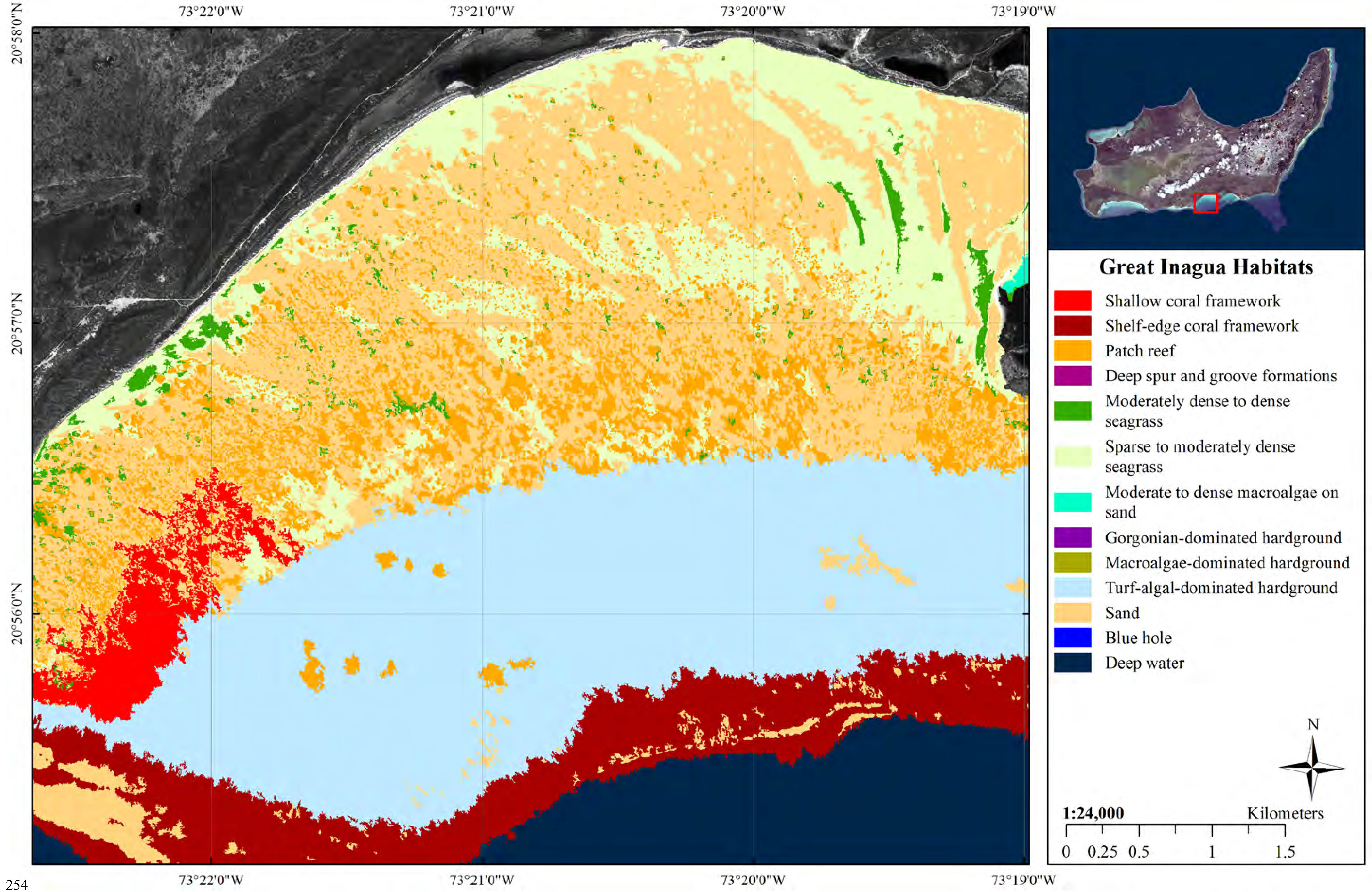

73°11'0"W
73°10'0"W
73°9'0"W
73°8'0"W
20°54'0"N
20°53'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

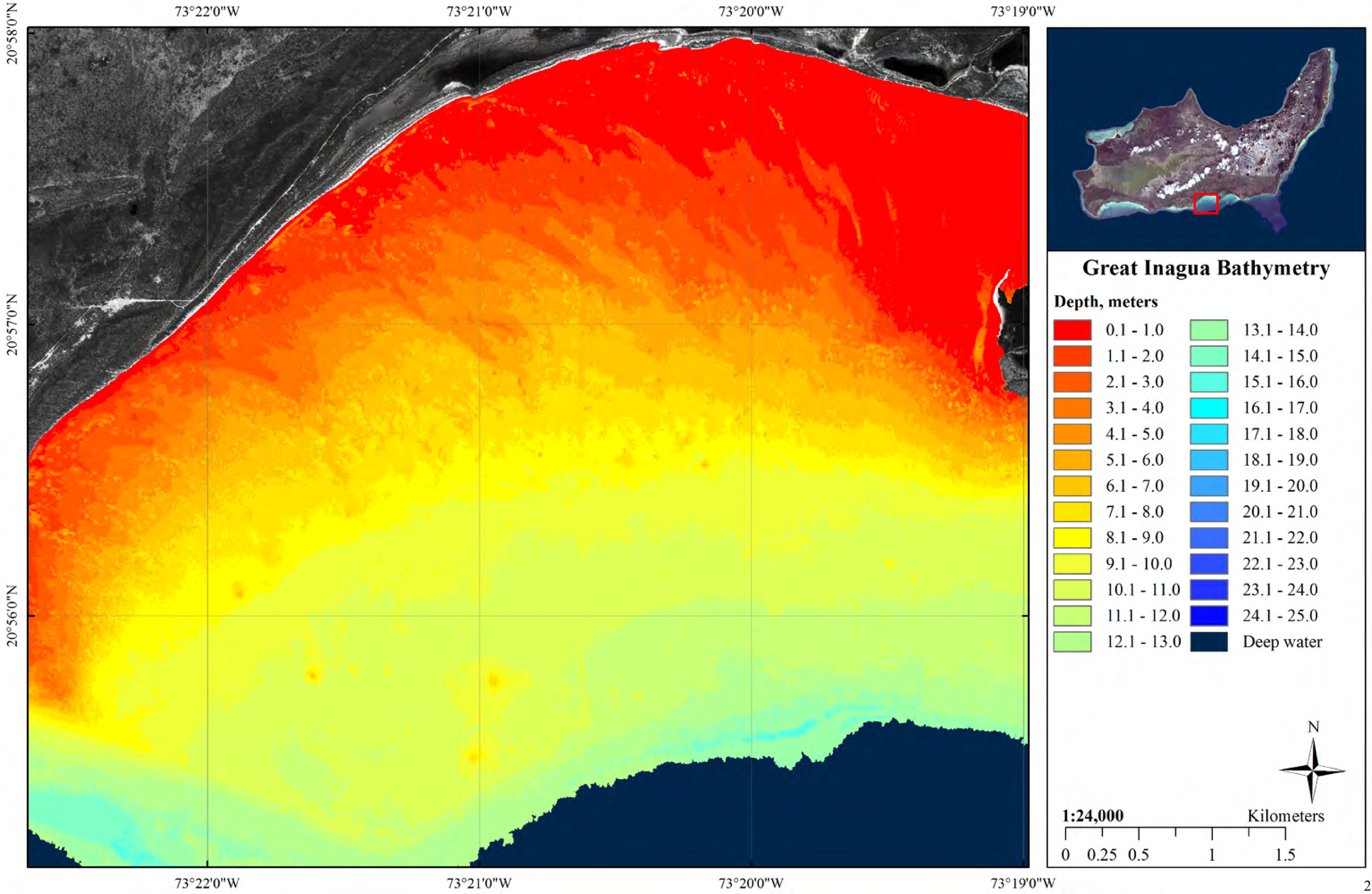

73°12'0"W
73°11'0"W
73°10'0"W
73°9'0"W
20°56'0"N
20°55'0"N
20°54'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

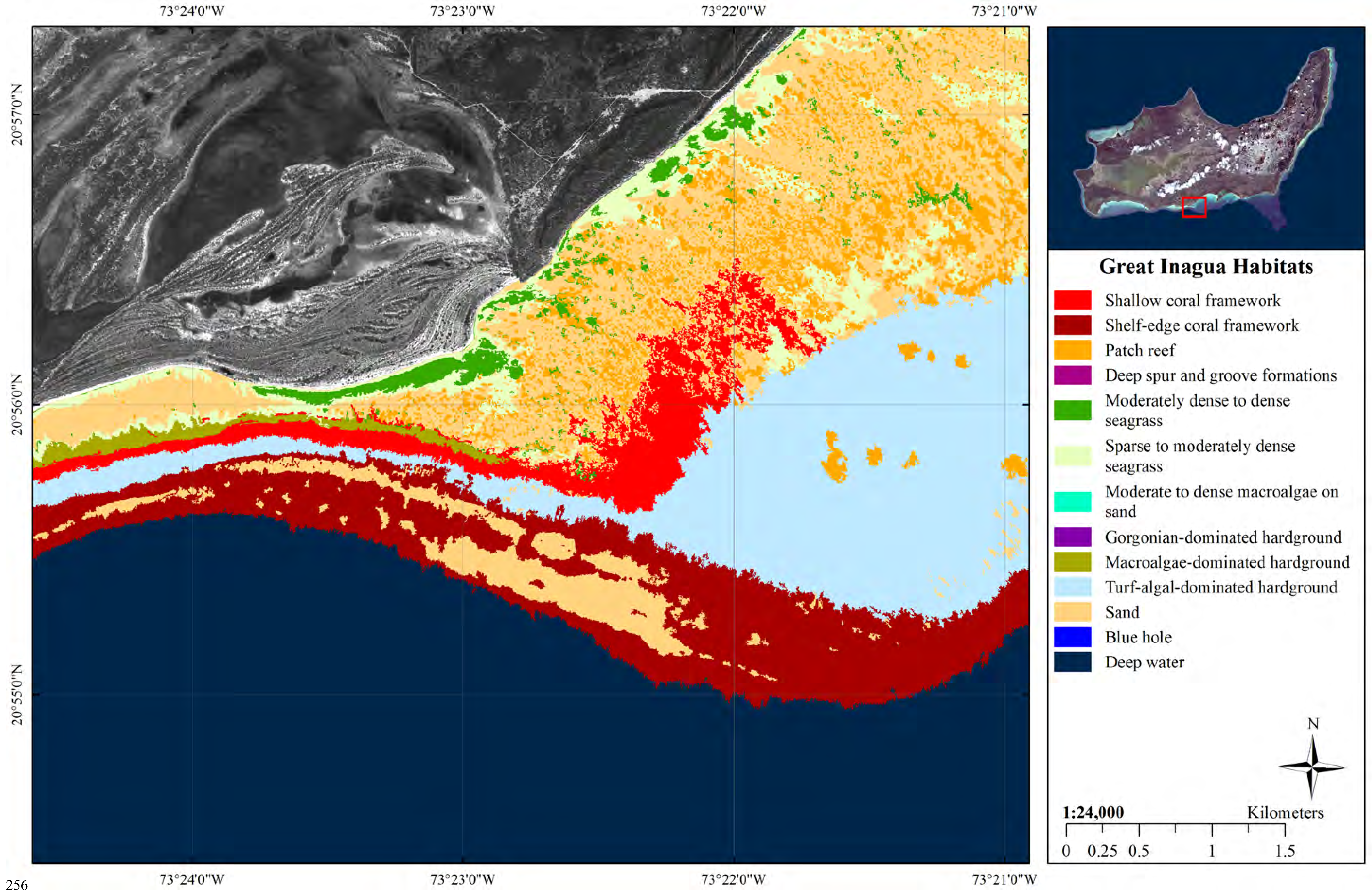

73°15'0"W
73°14'0"W
73°13'0"W
20°57'0"N
20°56'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

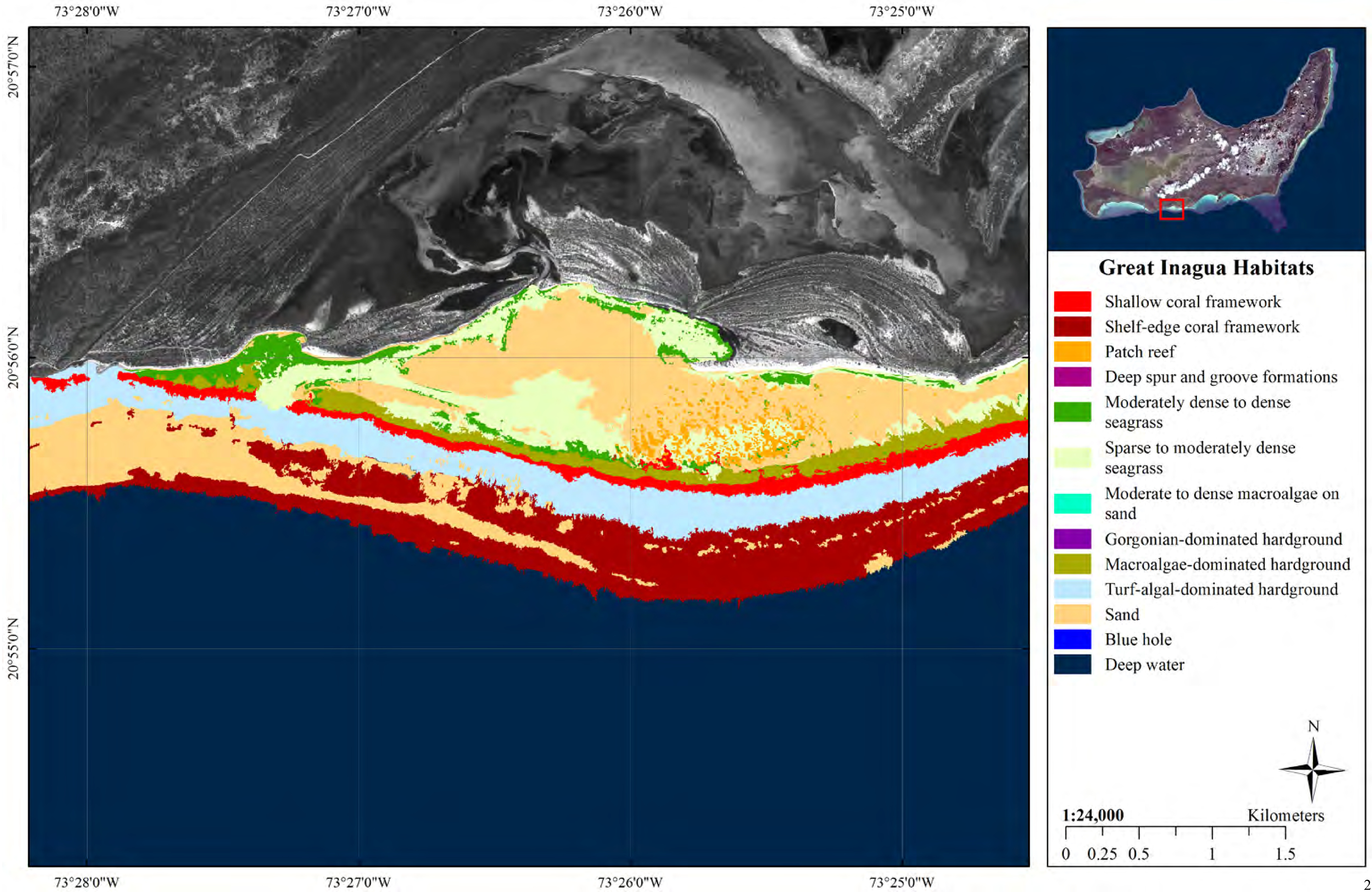

73°19'0"W
73°18'0"W
73°17'0"W
73°16'0"W
20°58'0"N
20°57'0"N
20°56'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

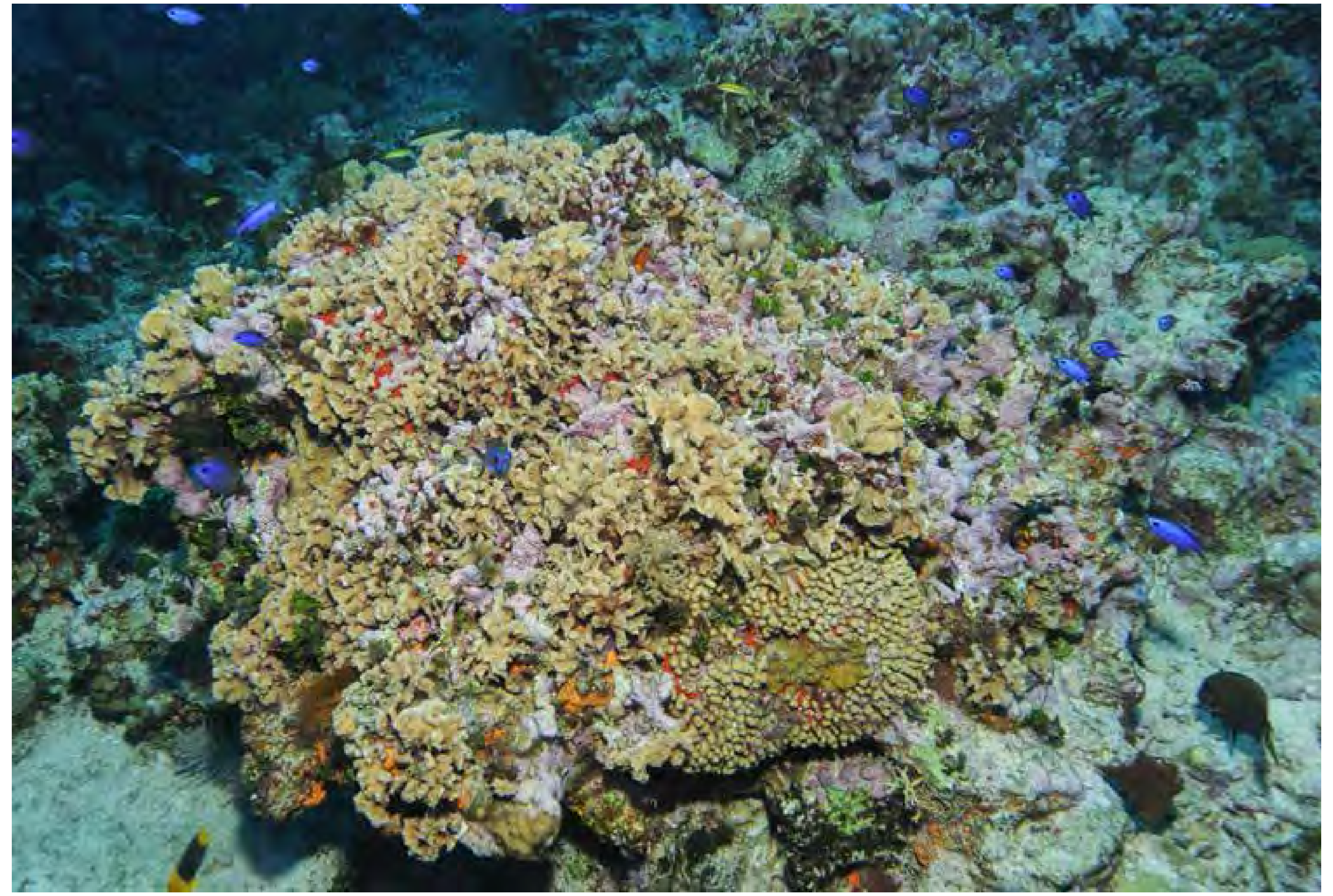

73°19'0"W
73°18'0"W
73°17'0"W
73°16'0"W
20°58'0"N
20°57'0"N
20°56'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


73°22'0"W
73°21'0"W
73°20'0"W
73°19'0"W
20°58'0"N
20°57'0"N
20°56'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

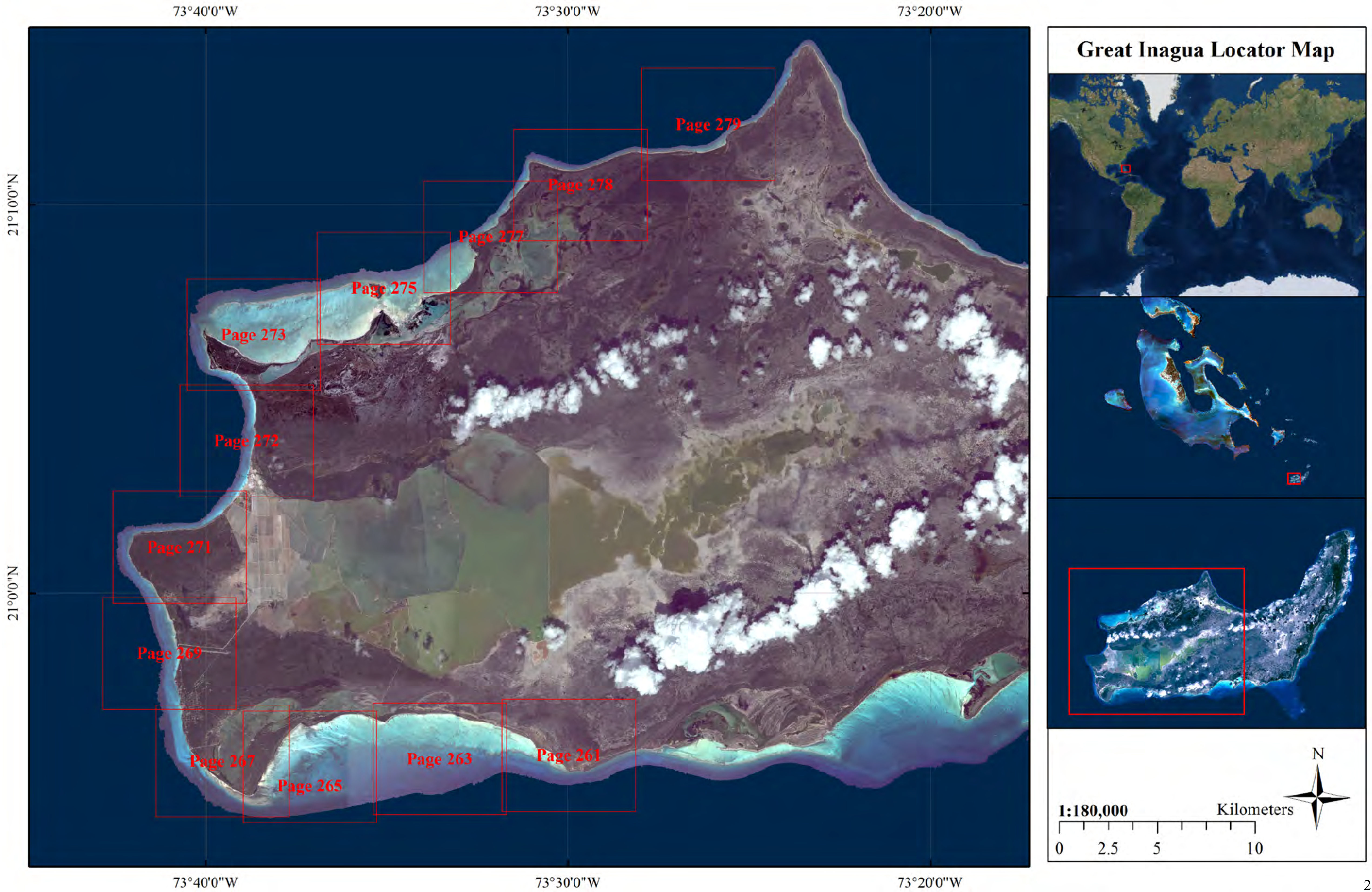

73°22'0"W
73°21'0"W
73°20'0"W
73°19'0"W
20°58'0"N
20°57'0"N
20°56'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

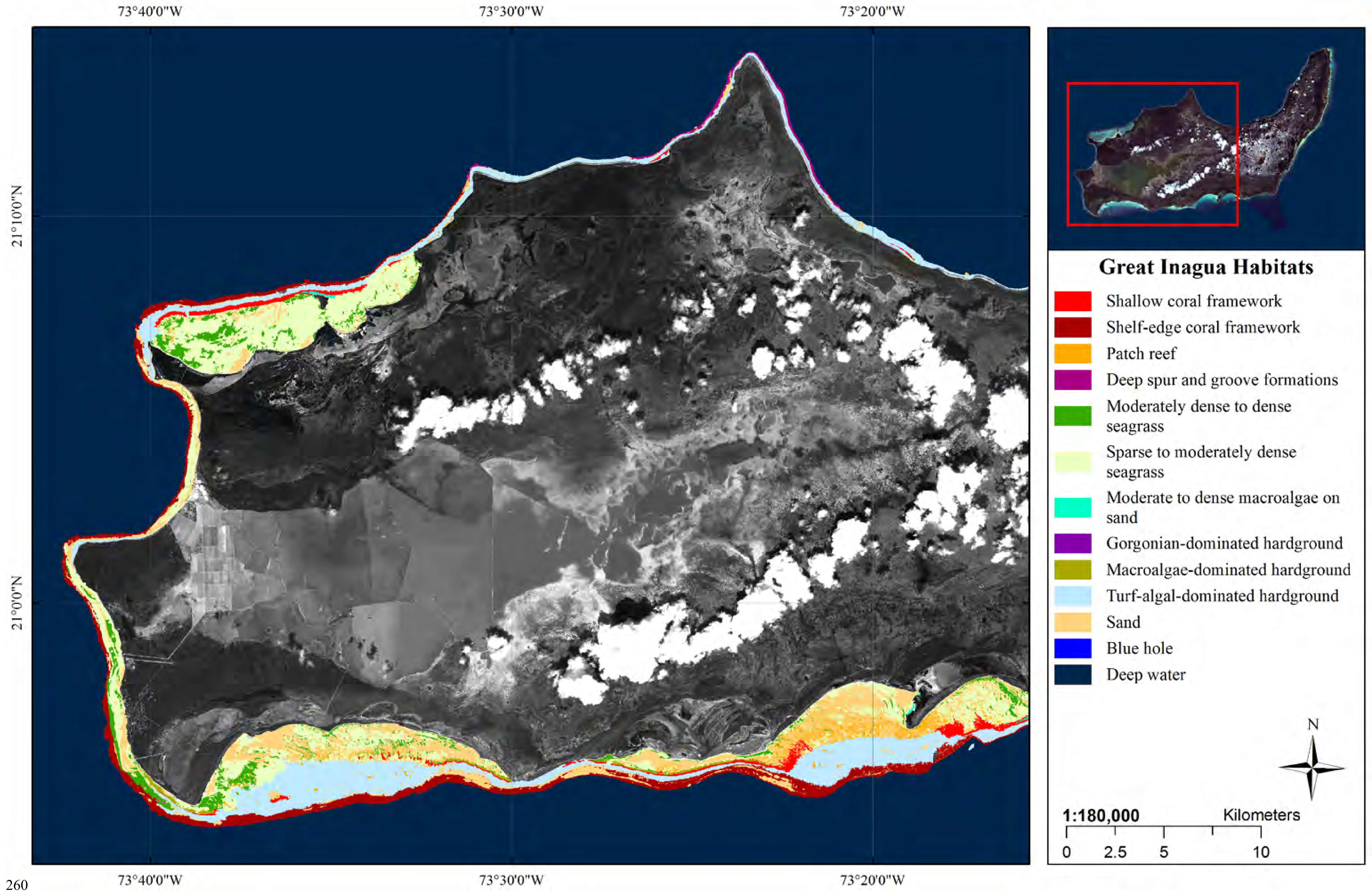

73°24'0"W
73°23'0"W
73°22'0"W
73°21'0"W
20°57'0"N
20°56'0"N
20°55'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


73°28'0"W
73°27'0"W
73°26'0"W
73°25'0"W
20°57'0"N
20°56'0"N
20°55'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

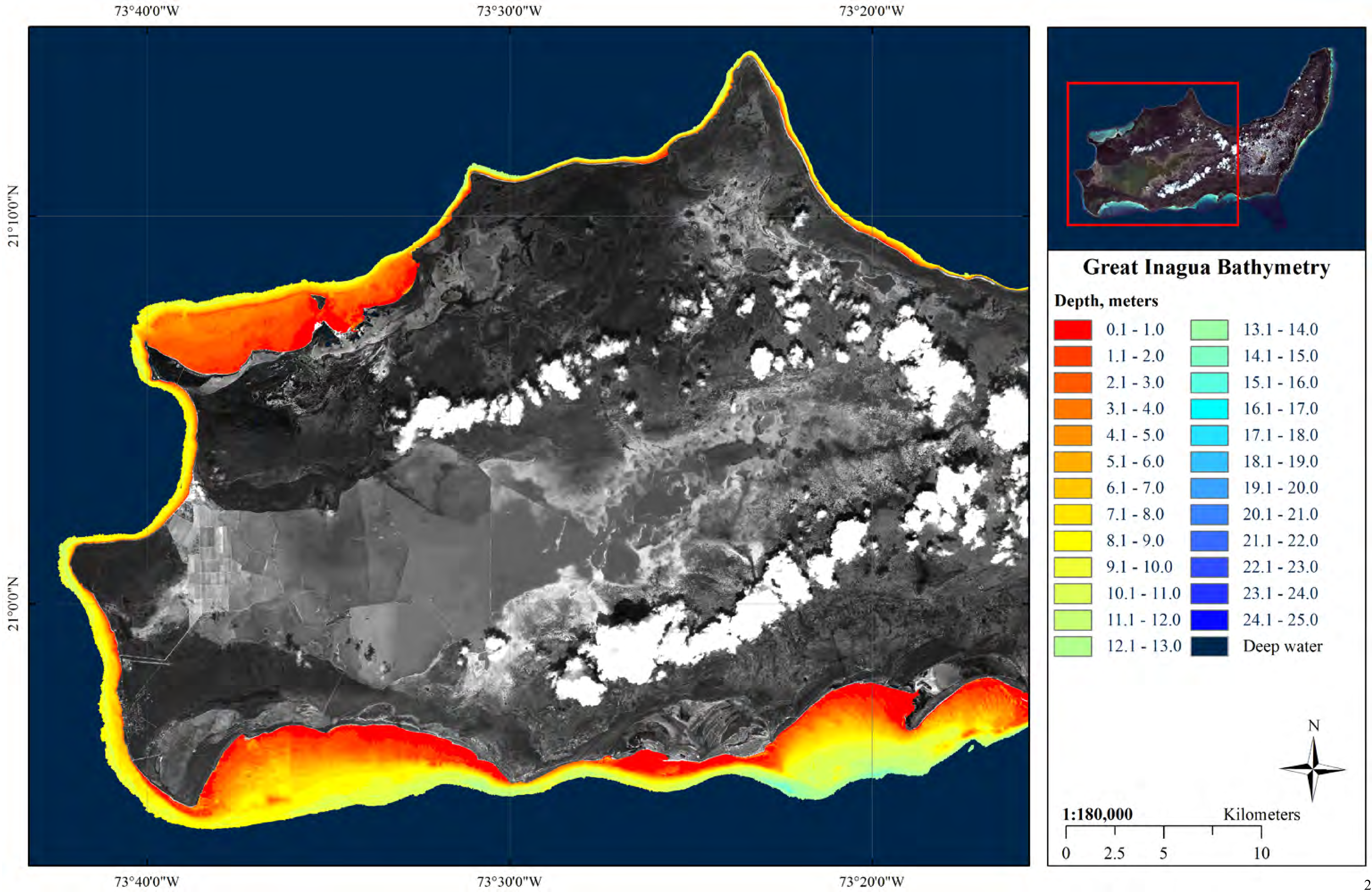


Reef scenes off Great Inagua. Divers surveying a *Montastraea* reef (top left). Shallow reef framework (5 m) with *Agaricia* and *Eusmilia* (bottom left). A *Montastraea* reef with a high number of soft corals at 15 m depth (top right). A high relief coral community with sea fans, branching gorgonians and massive corals (bottom right).

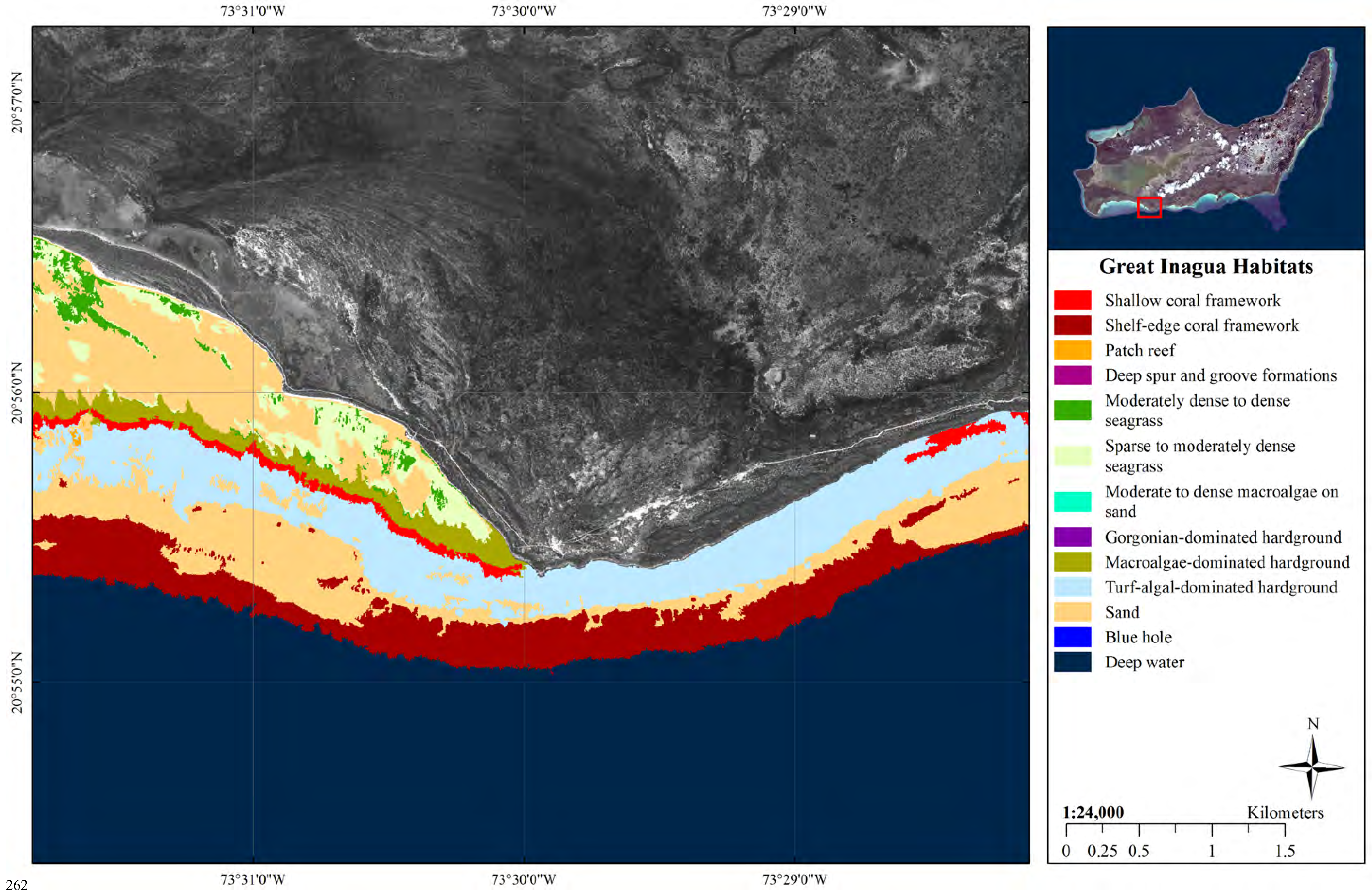


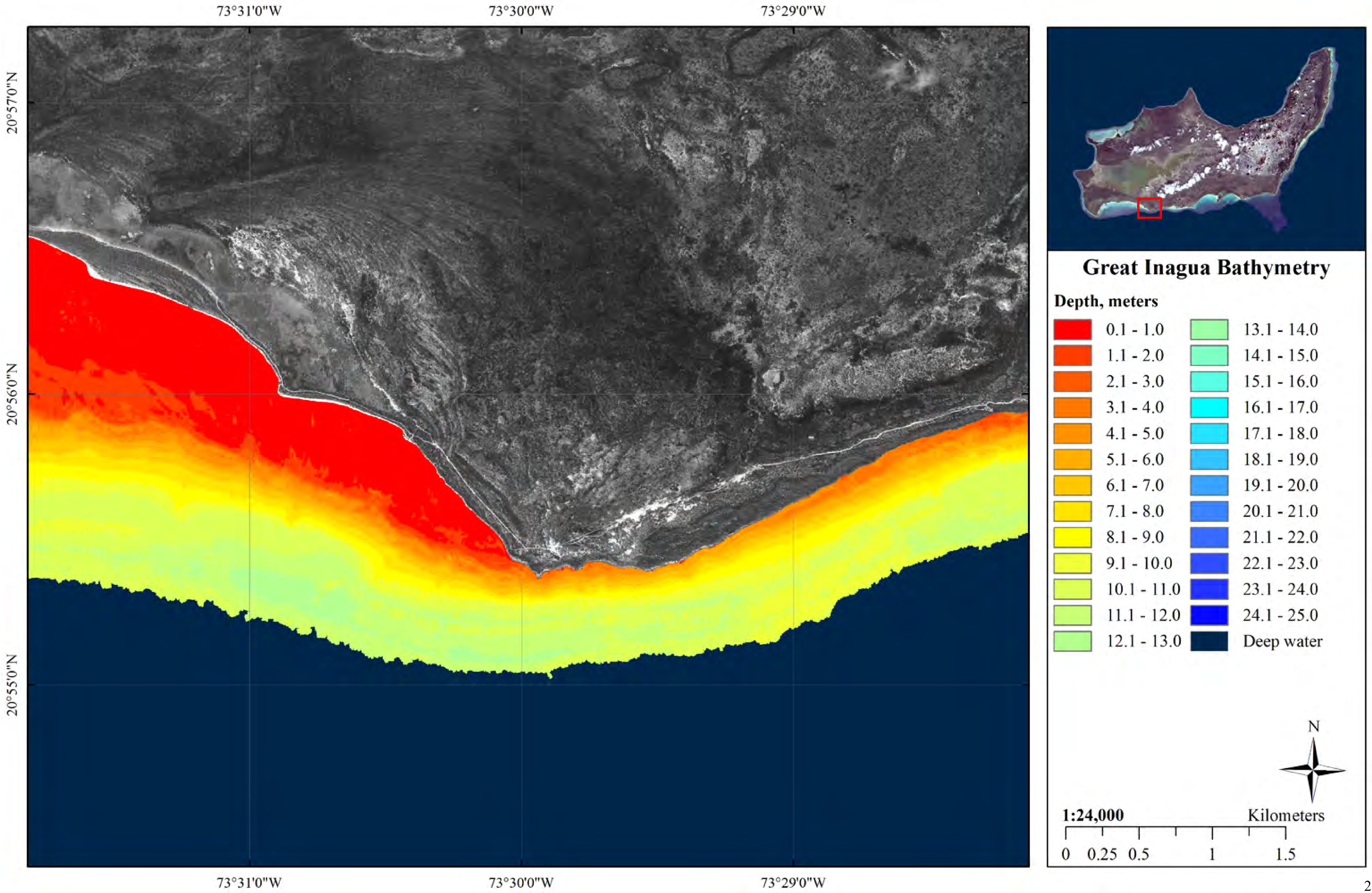


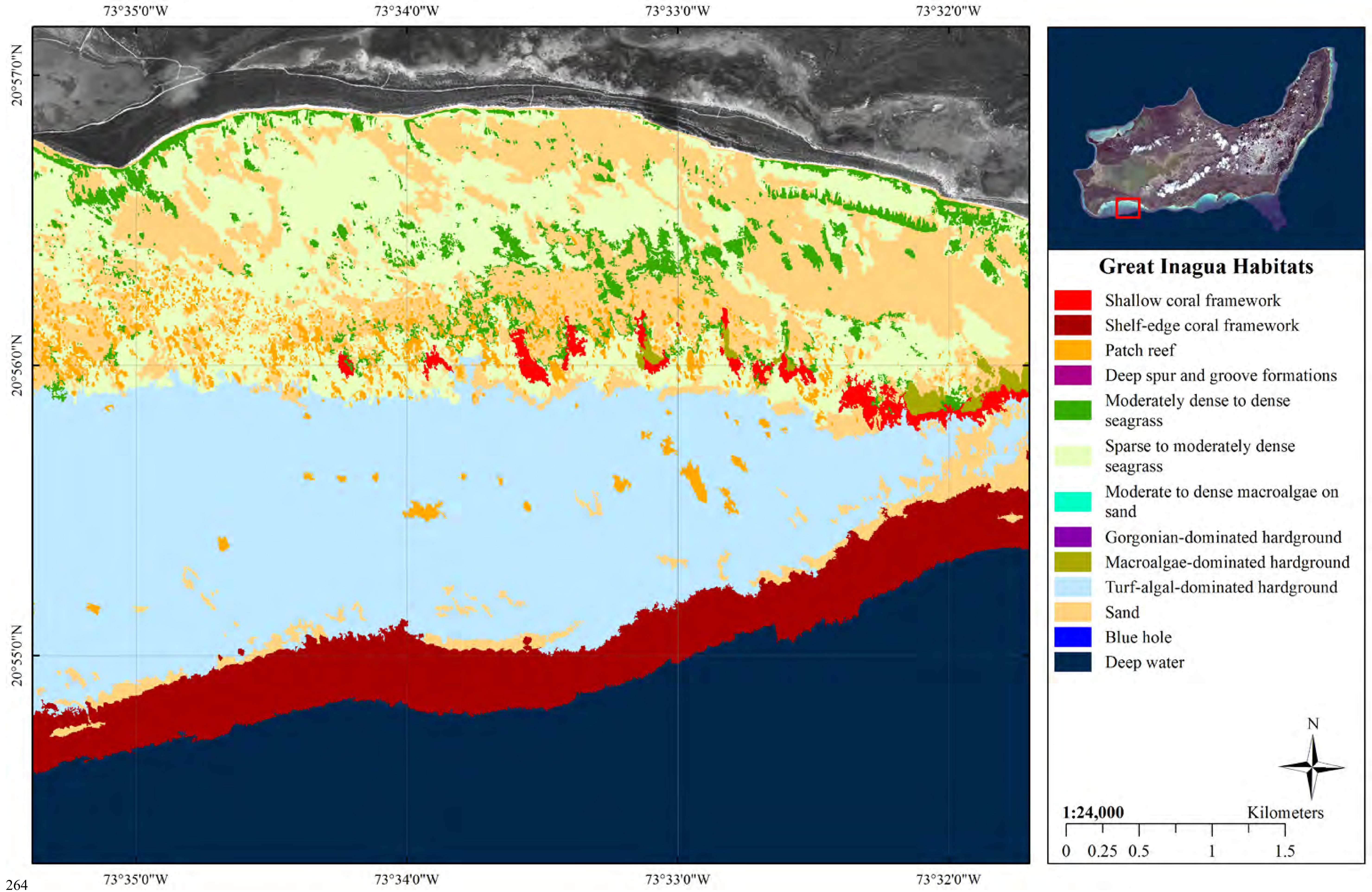
73°40'0"W
73°30'0"W
73°20'0"W
21°10'0"N
21°0'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:180,000
Kilometers
0
2.5
5
10

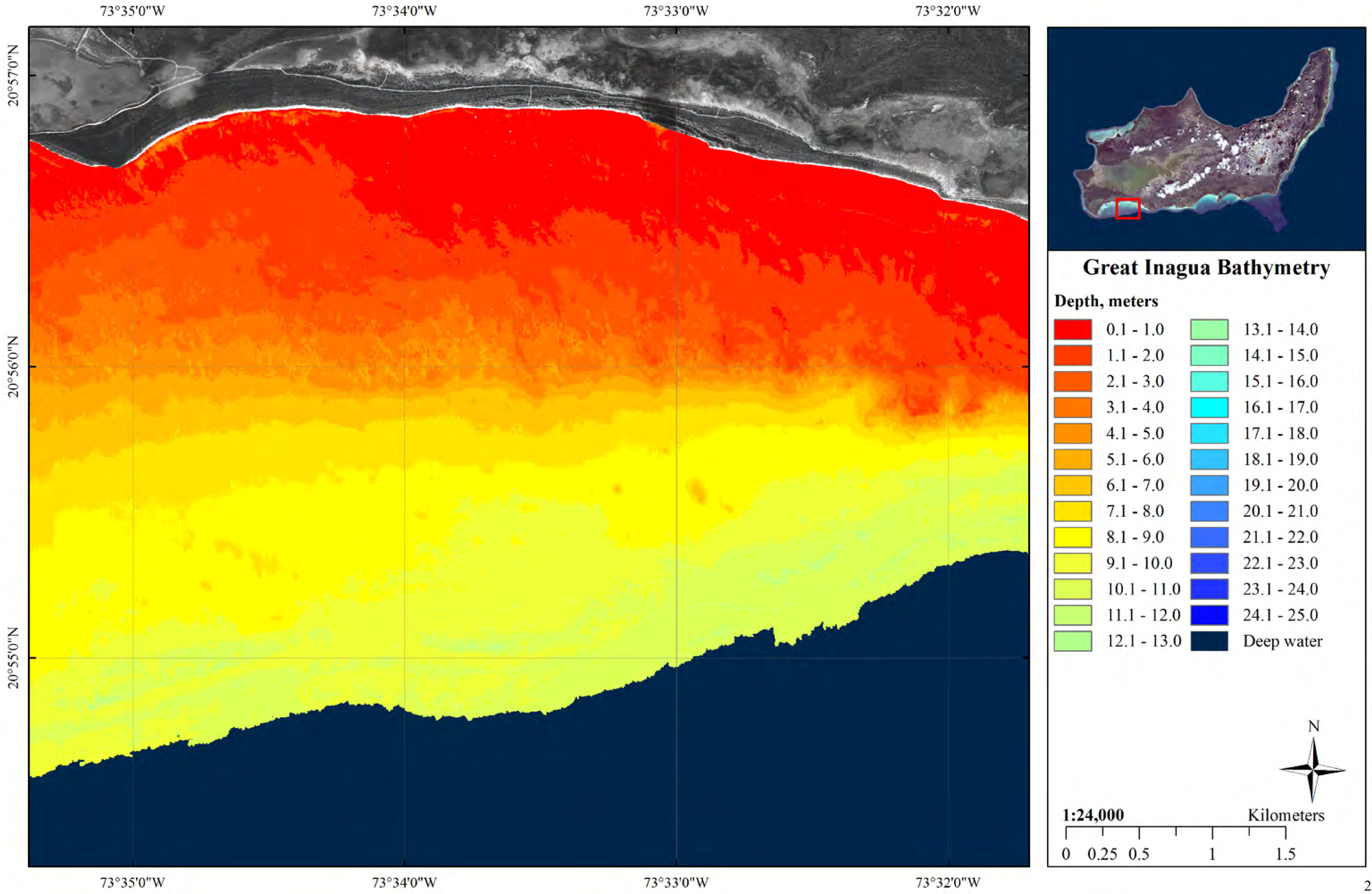


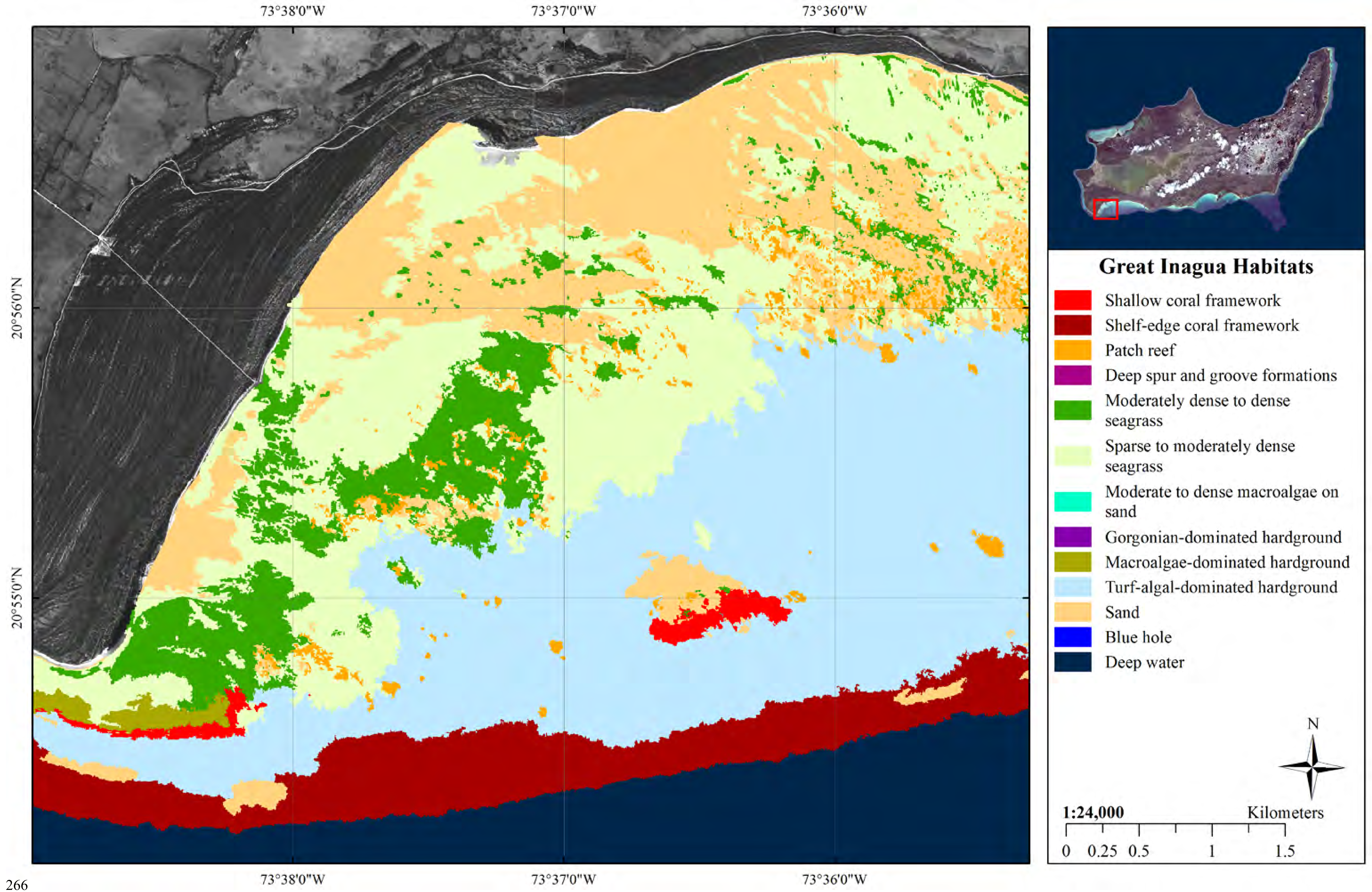
73°40'0"W
73°30'0"W
73°20'0"W
21°10'0"N
21°0'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:180,000
Kilometers
0
2.5
5
10

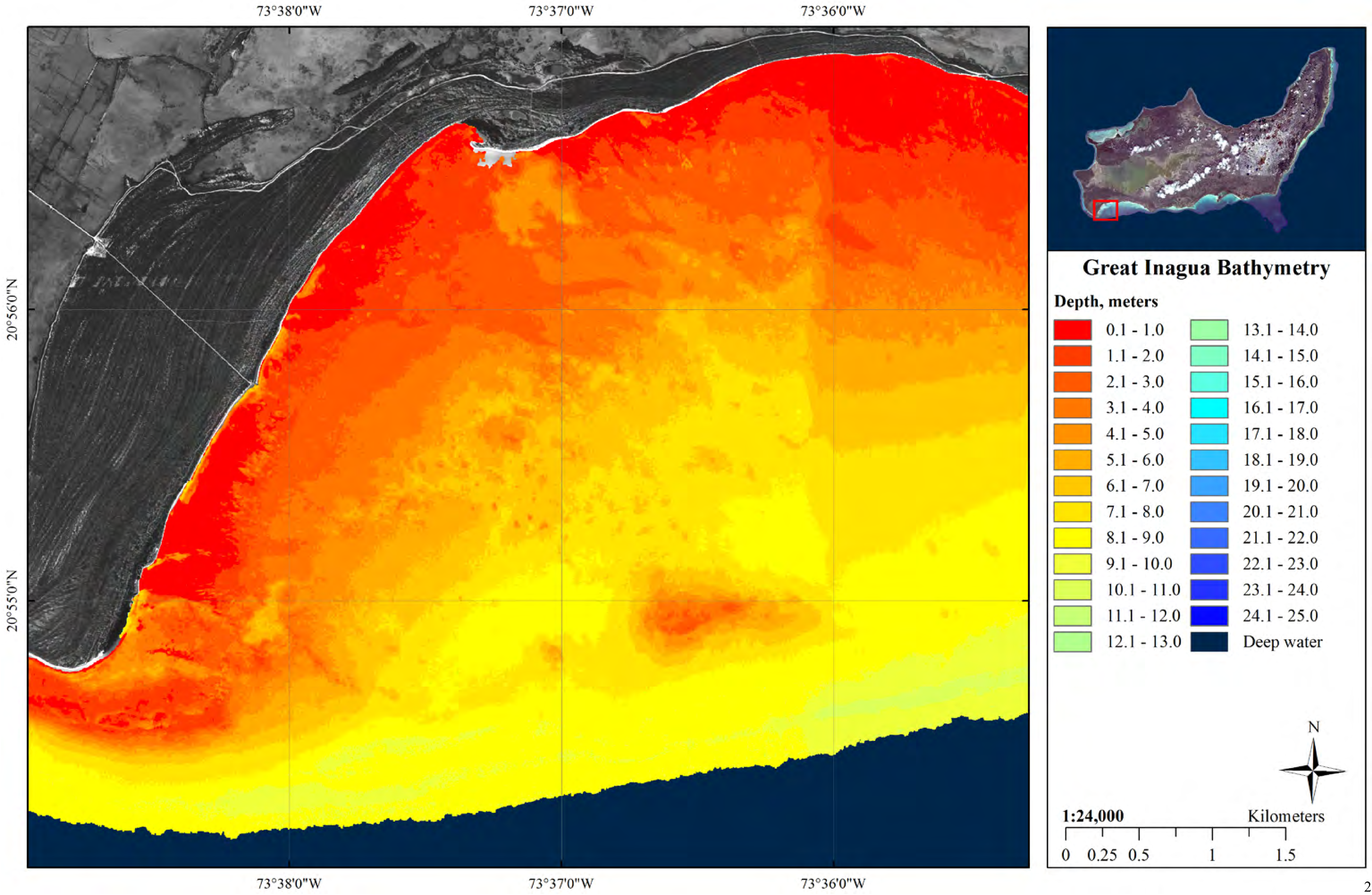

73°31'0"W
73°30'0"W
73°29'0"W
20°57'0"N
20°56'0"N
20°55'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

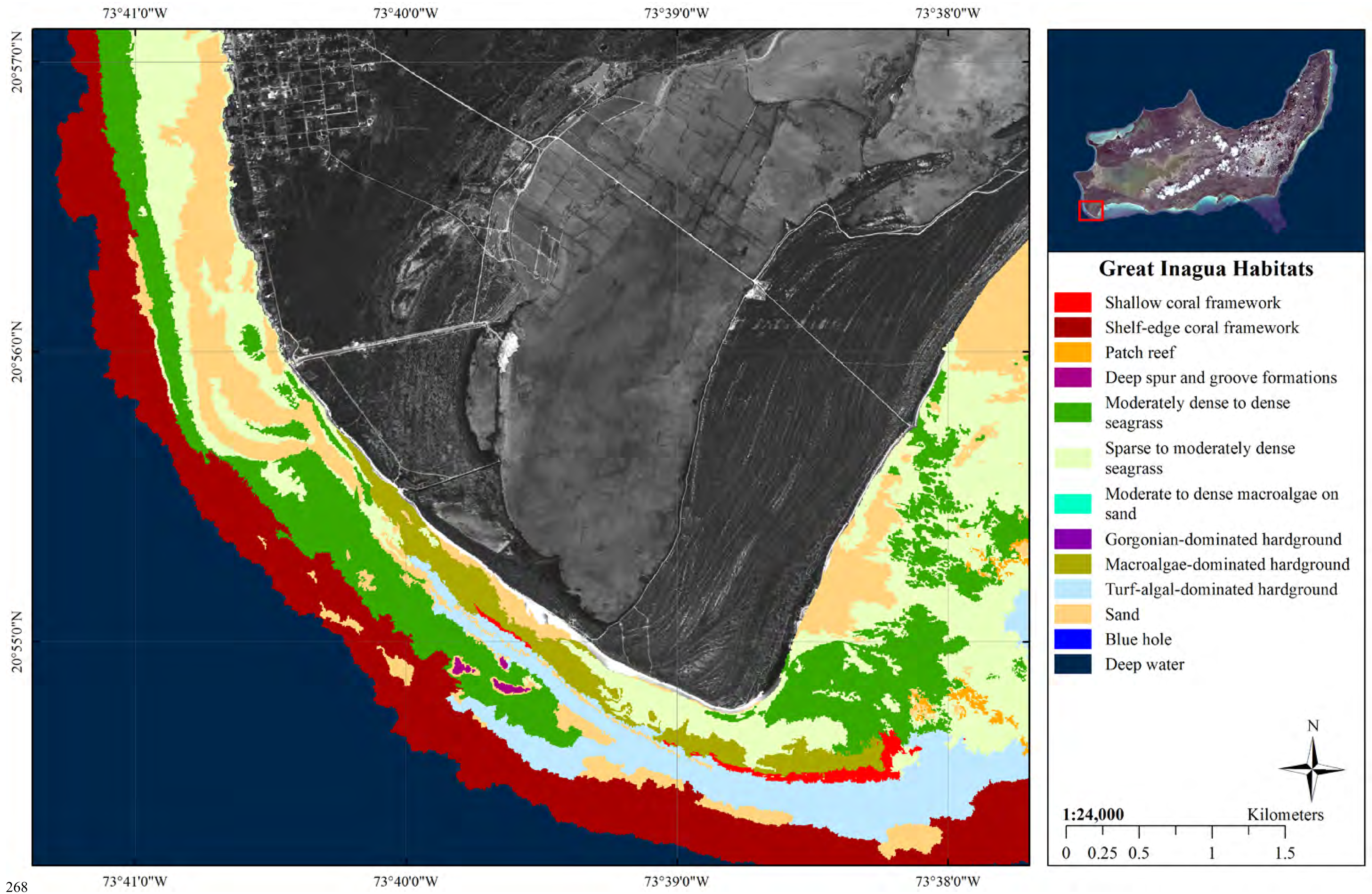

73°31'0"W
73°30'0"W
73°29'0"W
20°57'0"N
20°56'0"N
20°55'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

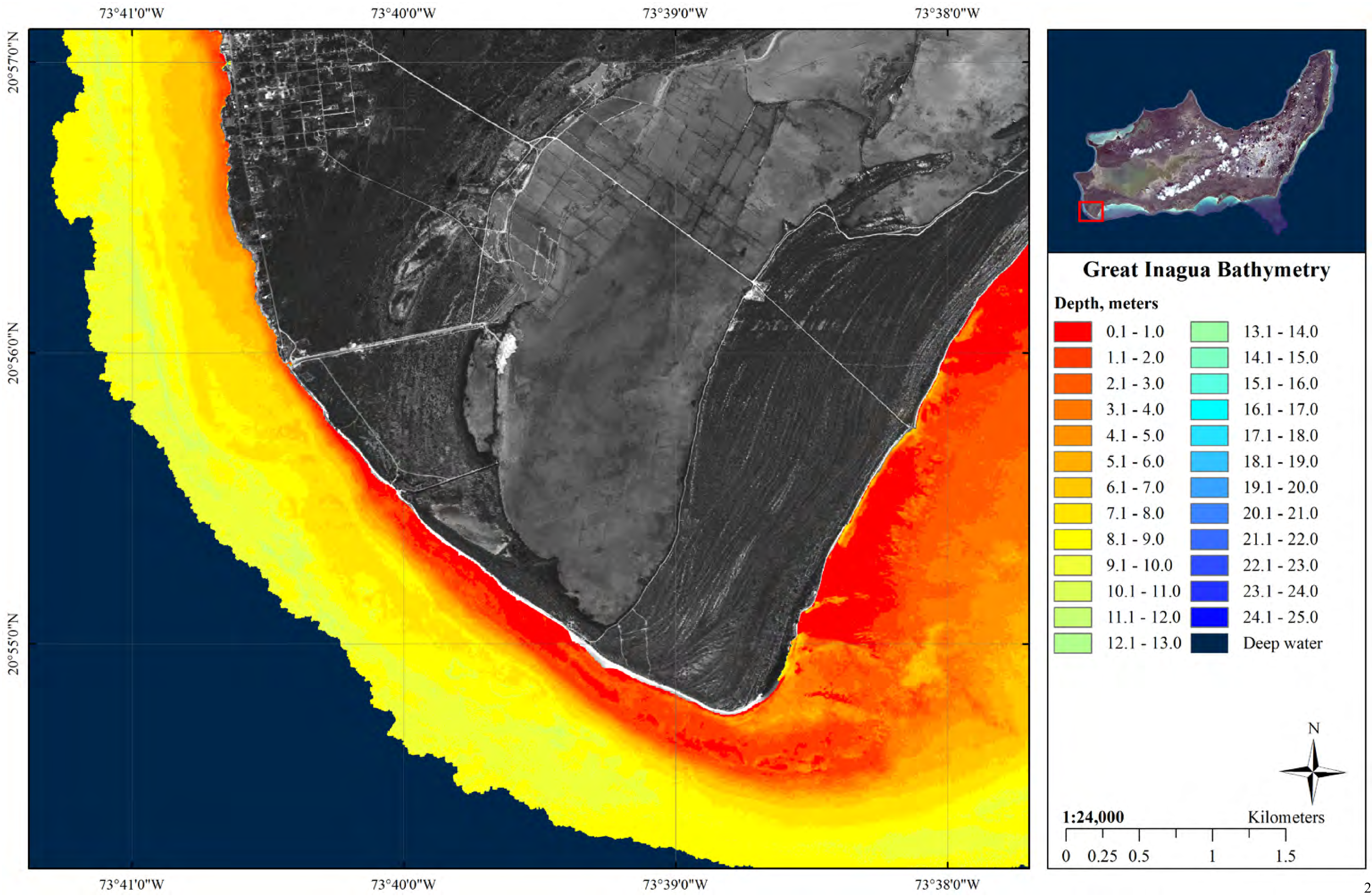

73°35'0"W
73°34'0"W
73°33'0"W
73°32'0"W
20°57'0"N
20°56'0"N
20°55'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

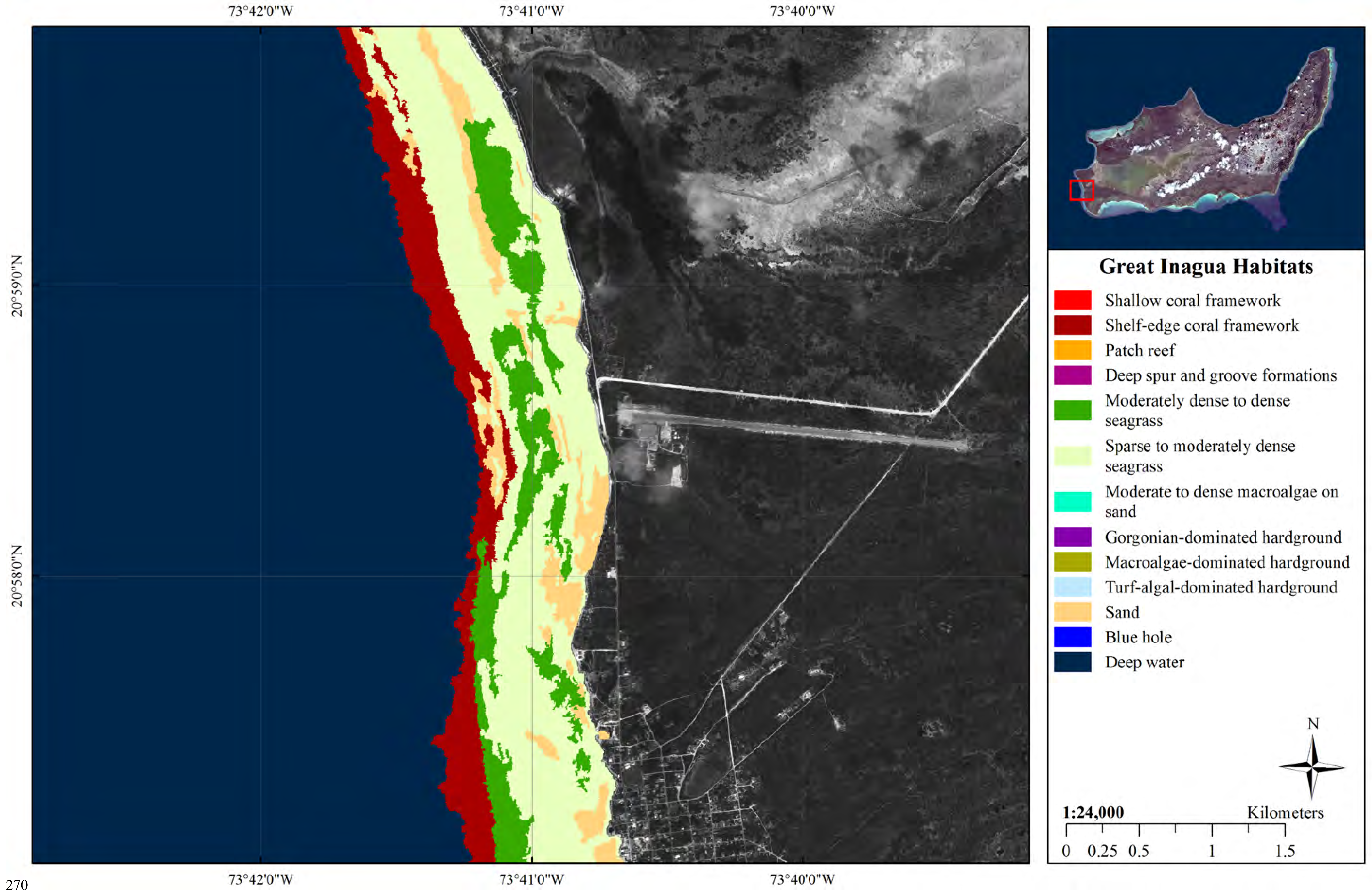

73°35'0"W
73°34'0"W
73°33'0"W
73°32'0"W
20°57'0"N
20°56'0"N
20°55'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

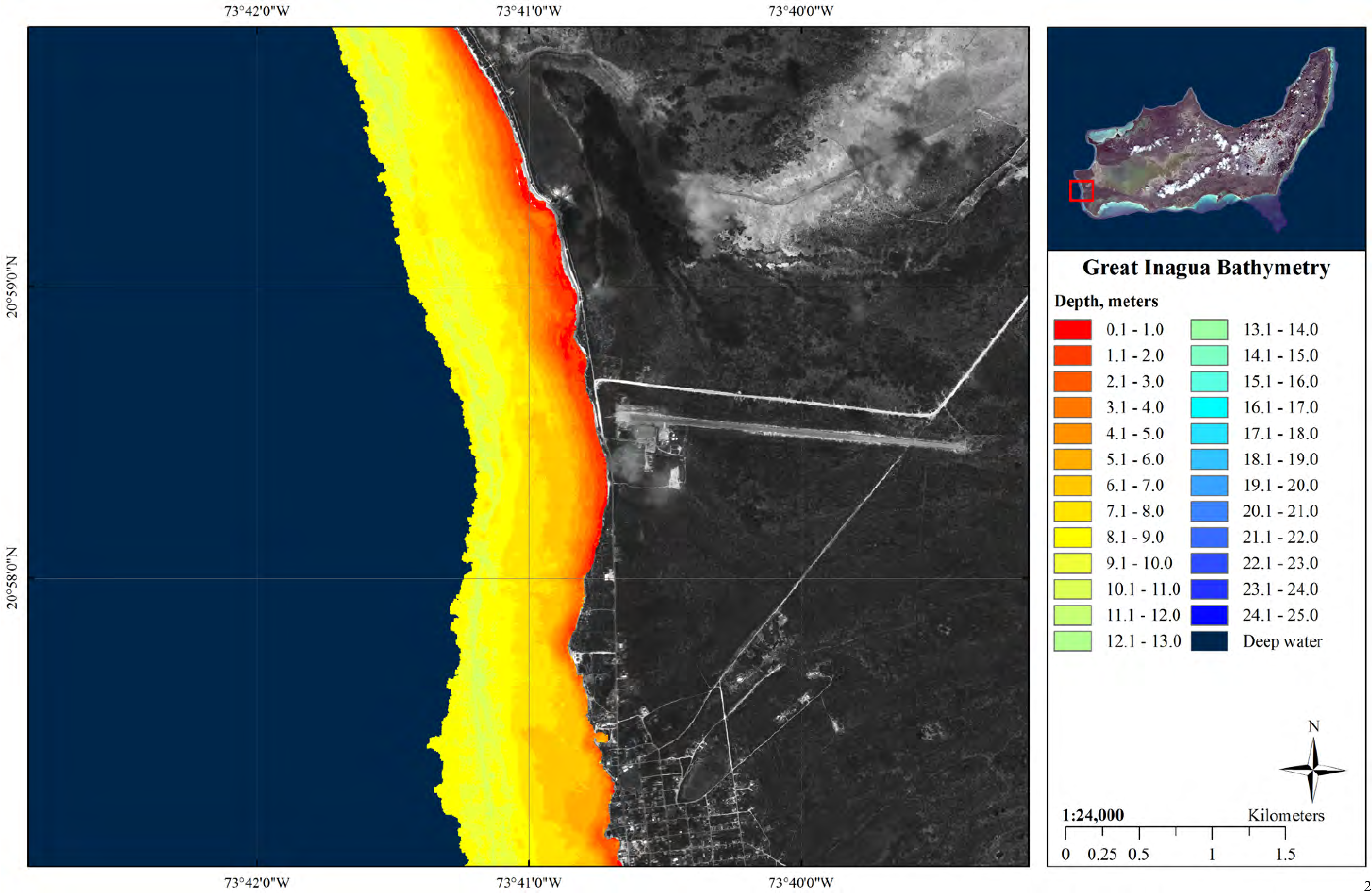

73°38'0"W
73°37'0"W
73°36'0"W
20°56'0"N
20°55'0"N
Great Inagua Habitats
🟥 Shallow coral framework
🟥 Shelf-edge coral framework
🟧 Patch reef
🟪 Deep spur and groove formations
🟩 Moderately dense to dense seagrass
🟩 Sparse to moderately dense seagrass
🟦 Moderate to dense macroalgae on sand
🟪 Gorgonian-dominated hardground
🟨 Macroalgae-dominated hardground
🟦 Turf-algal-dominated hardground
🟧 Sand
🟦 Blue hole
🟦 Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

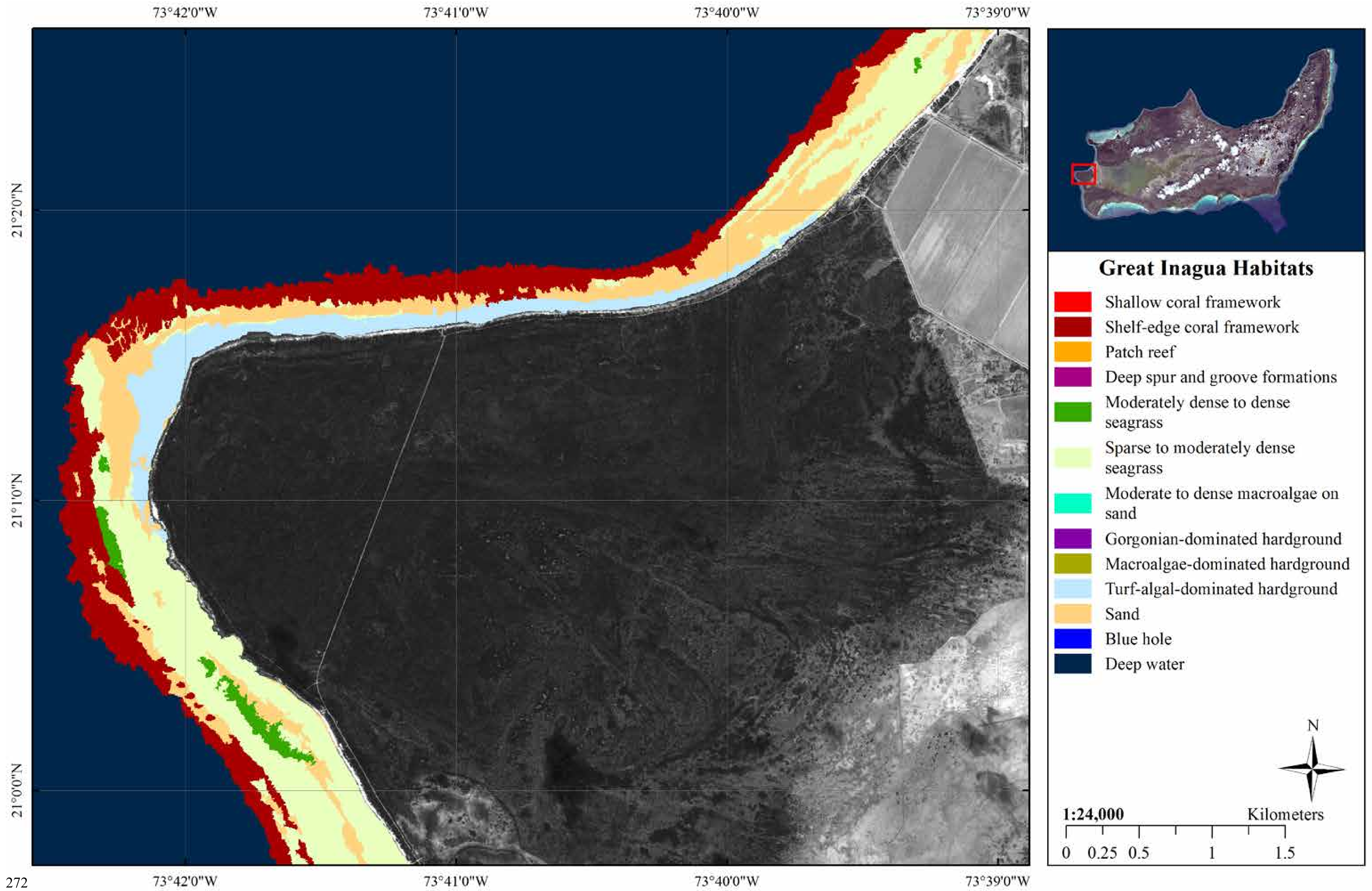

73°38'0"W
73°37'0"W
73°36'0"W
20°56'0"N
20°55'0"N
Great Inagua Bathymetry
Depth, meters
🟥 0.1 - 1.0
🟥 1.1 - 2.0
🟧 2.1 - 3.0
🟧 3.1 - 4.0
🟧 4.1 - 5.0
🟧 5.1 - 6.0
🟨 6.1 - 7.0
🟨 7.1 - 8.0
🟨 8.1 - 9.0
🟨 9.1 - 10.0
🟩 10.1 - 11.0
🟩 11.1 - 12.0
🟩 12.1 - 13.0
🟩 13.1 - 14.0
🟩 14.1 - 15.0
🟦 15.1 - 16.0
🟦 16.1 - 17.0
🟦 17.1 - 18.0
🟦 18.1 - 19.0
🟦 19.1 - 20.0
🟦 20.1 - 21.0
🟦 21.1 - 22.0
🟦 22.1 - 23.0
🟦 23.1 - 24.0
🟦 24.1 - 25.0
🟦 Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

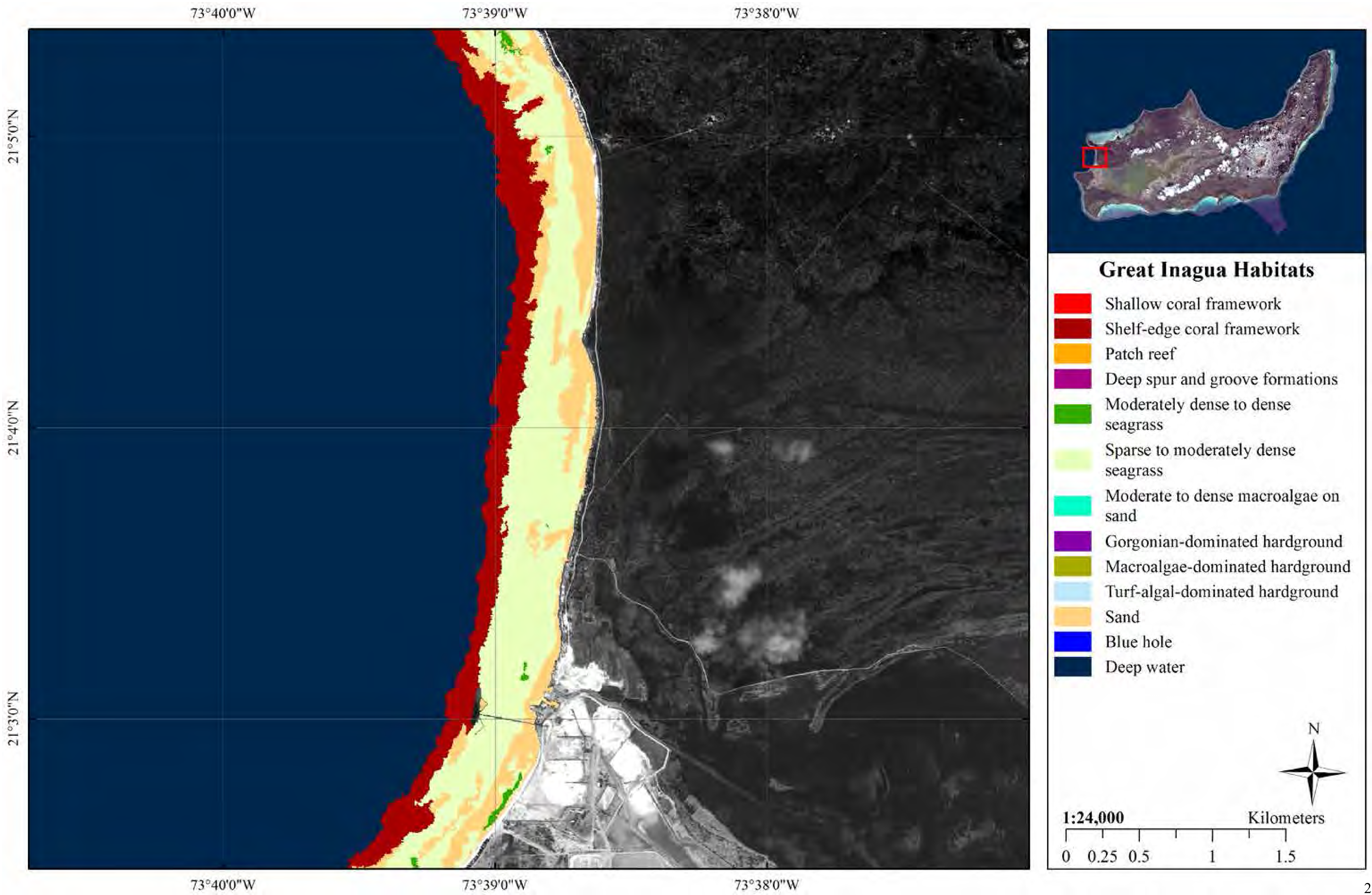

73°41'0"W
73°40'0"W
73°39'0"W
73°38'0"W
20°57'0"N
20°56'0"N
20°55'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

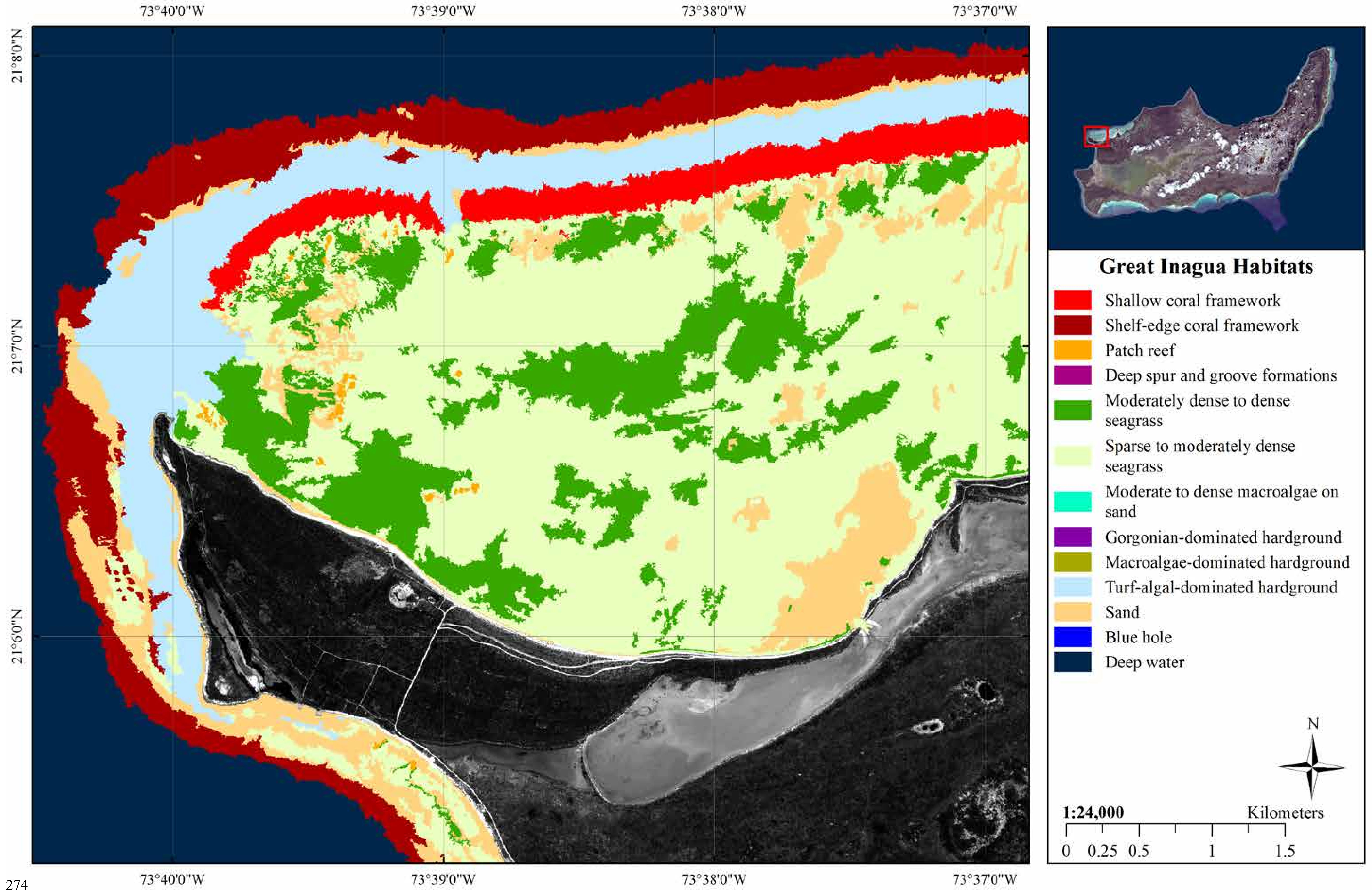

73°41'0"W
73°40'0"W
73°39'0"W
73°38'0"W
20°57'0"N
20°56'0"N
20°55'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

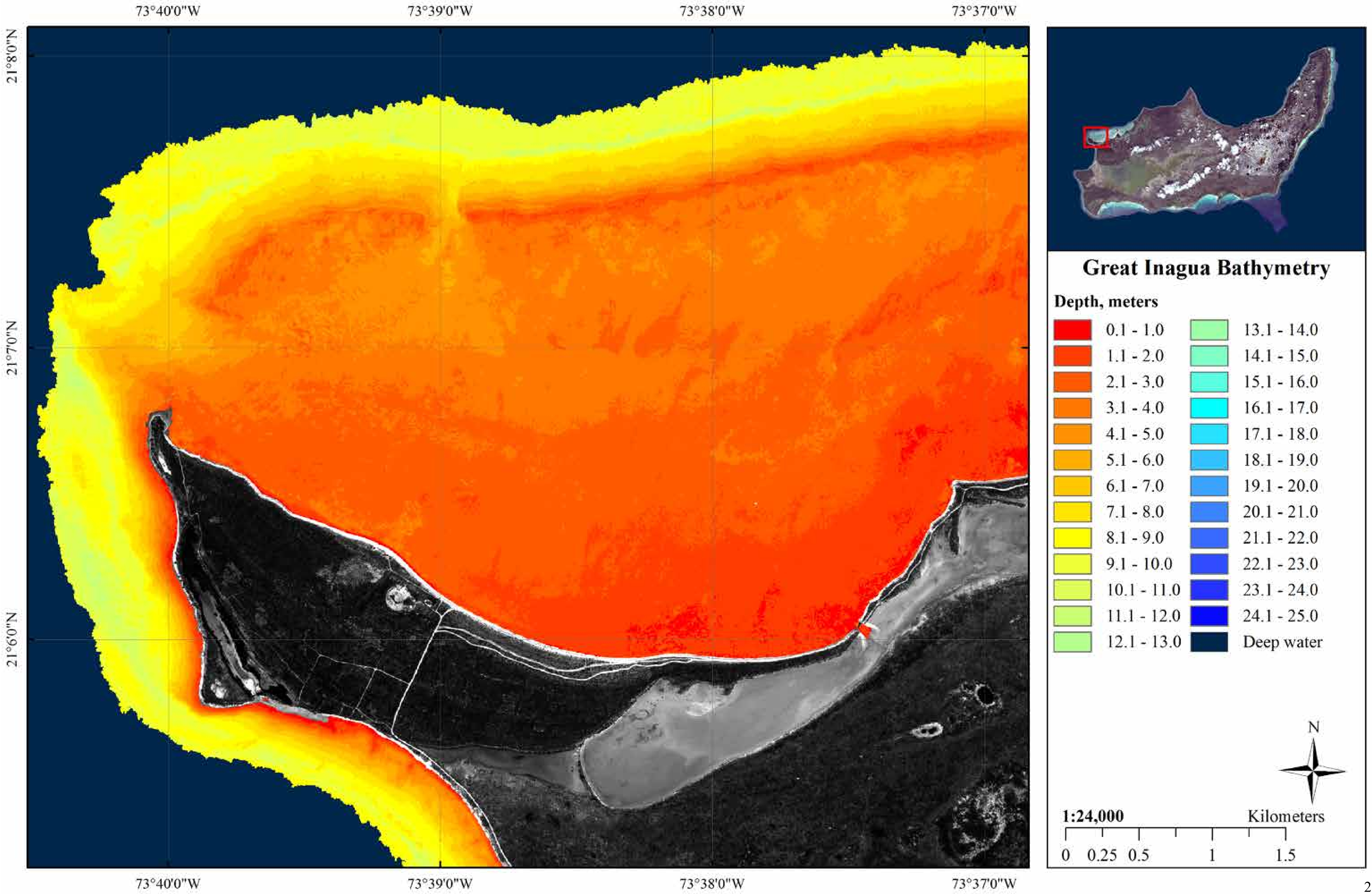

73°42'0"W
73°41'0"W
73°40'0"W
20°59'0"N
20°58'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

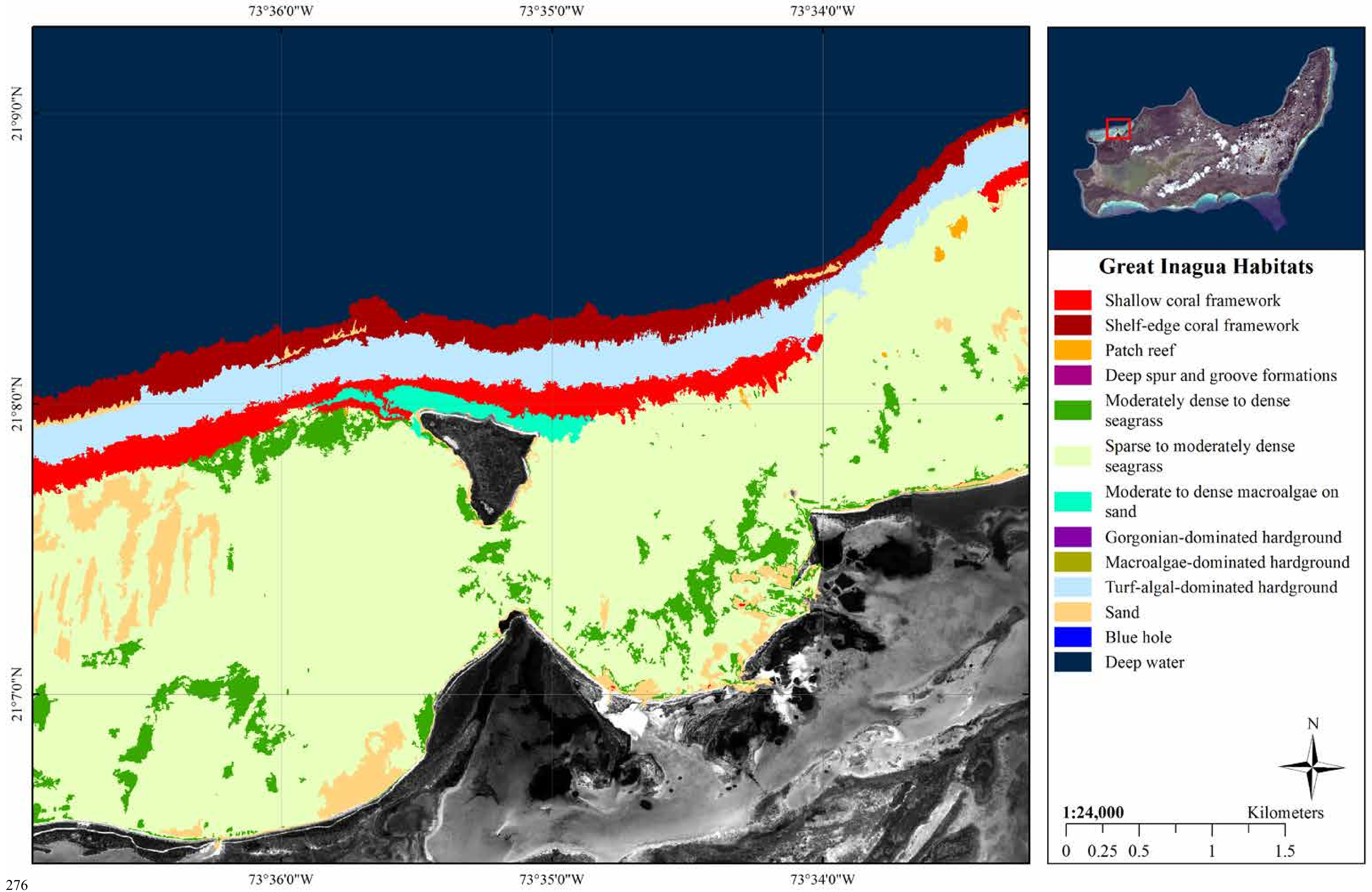

73°42'0"W
73°41'0"W
73°40'0"W
20°59'0"N
20°58'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

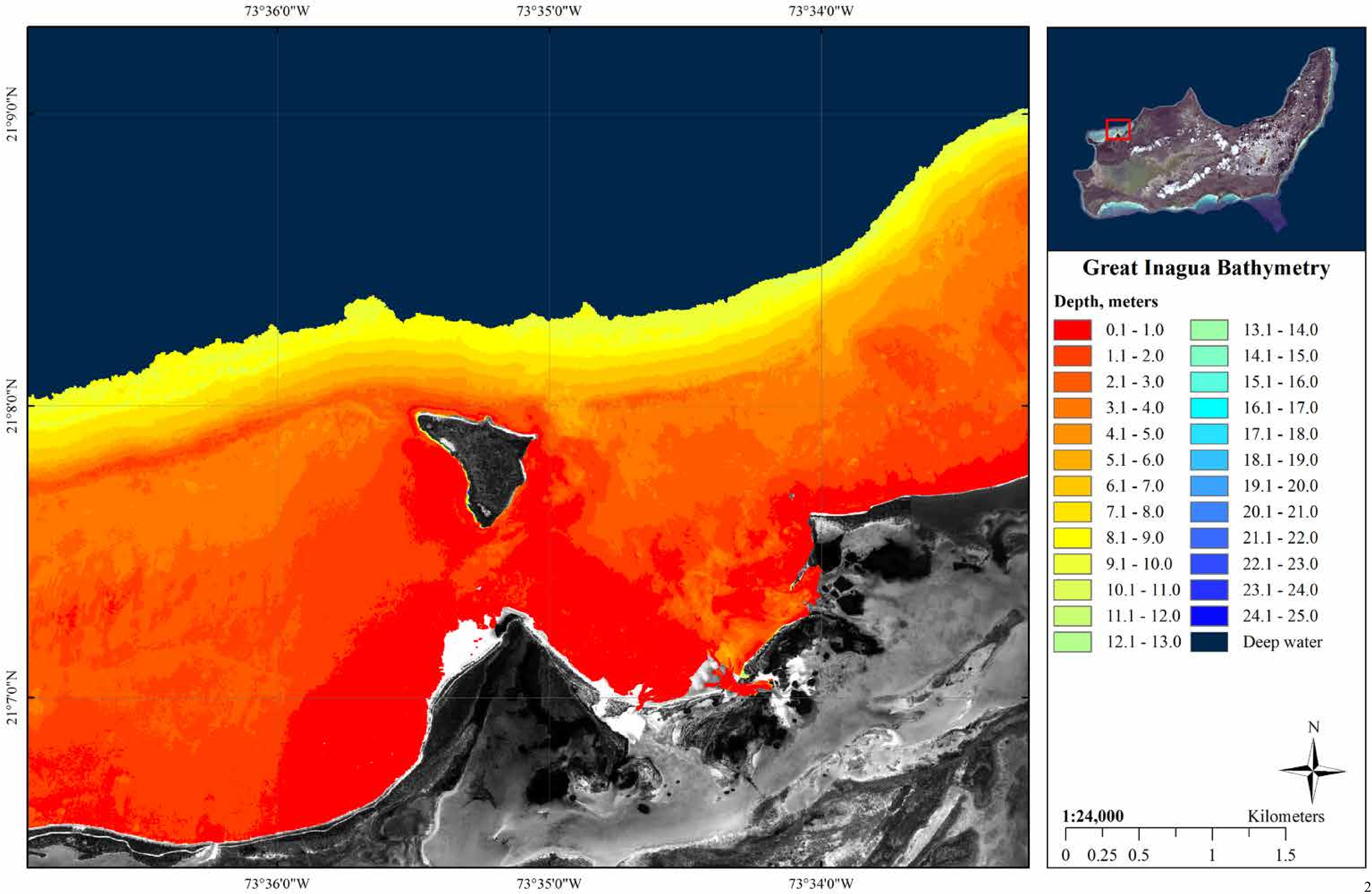

73°42'0"W
73°41'0"W
73°40'0"W
73°39'0"W
21°2'0"N
21°1'0"N
21°0'0"N
Great Inagua Habitats
🟥 Shallow coral framework
🟥 Shelf-edge coral framework
🟧 Patch reef
🟪 Deep spur and groove formations
🟩 Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
🟪 Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
🟦 Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

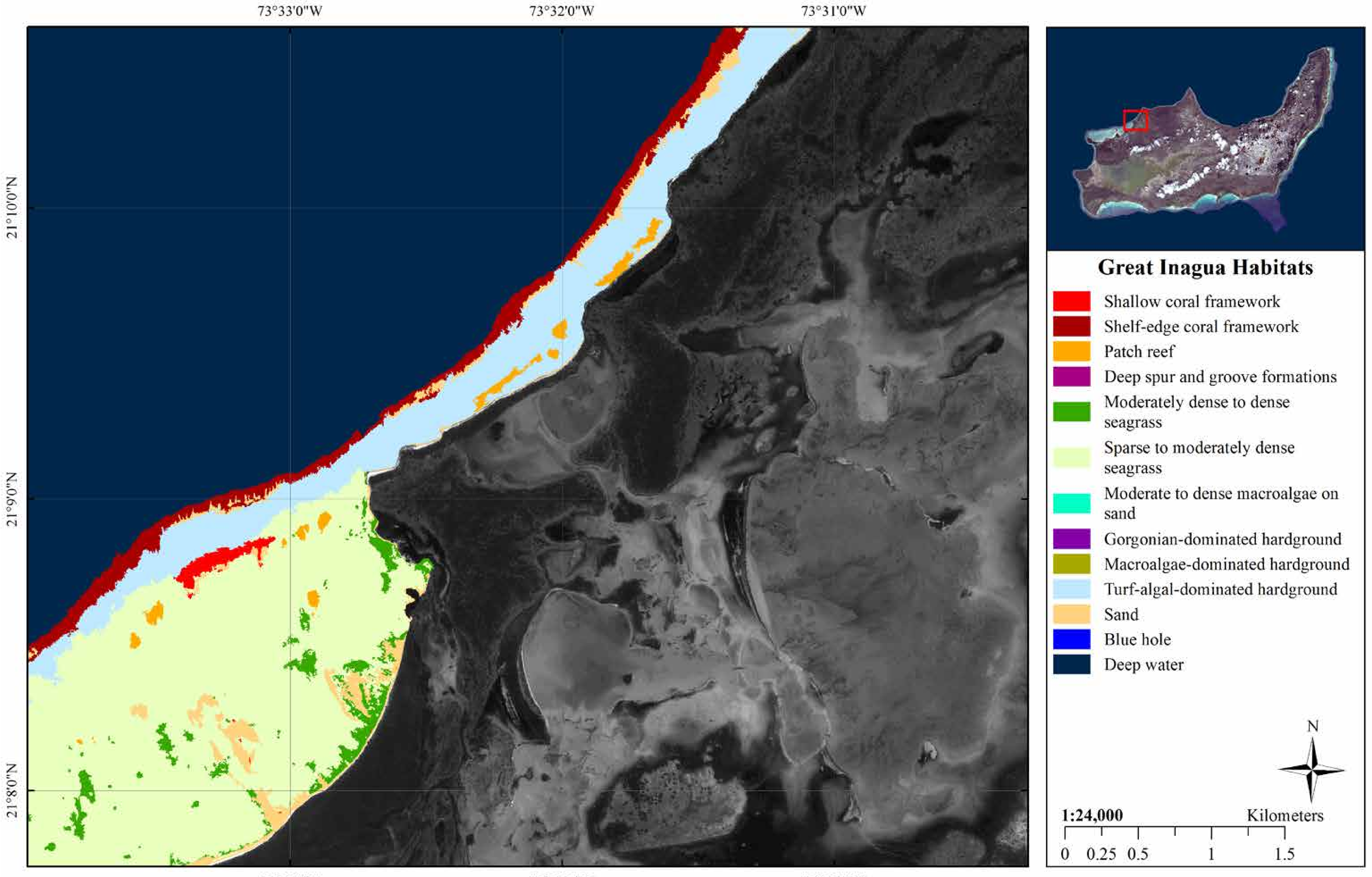

73°40'0"W
73°39'0"W
73°38'0"W
21°5'0"N
21°4'0"N
21°3'0"N
Great Inagua Habitats
🟥 Shallow coral framework
🟥 Shelf-edge coral framework
🟧 Patch reef
🟪 Deep spur and groove formations
🟩 Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
🟪 Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
🟦 Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

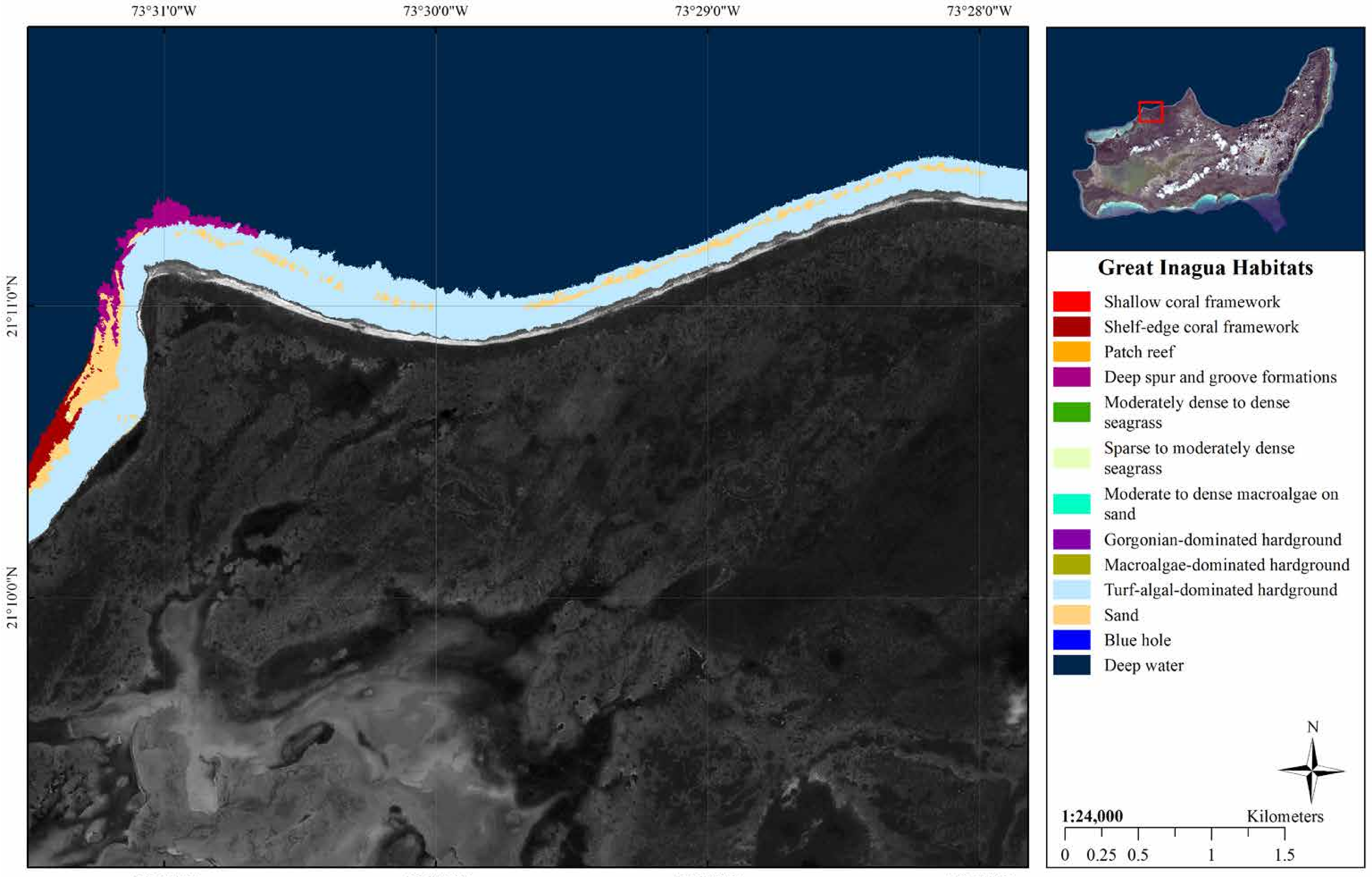

73°40'0"W
73°39'0"W
73°38'0"W
73°37'0"W
21°8'0"N
21°7'0"N
21°6'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5

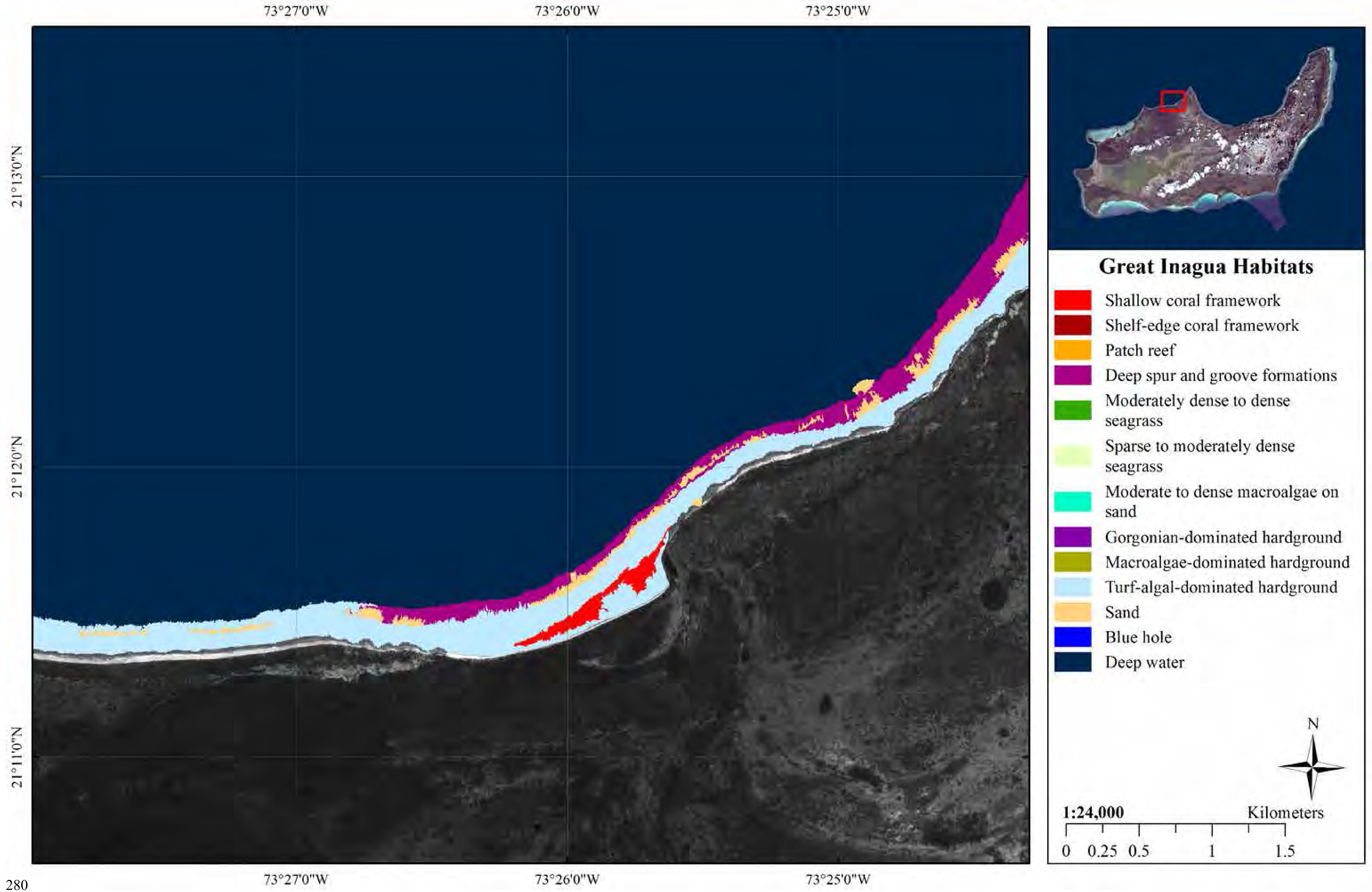

73°40'0"W
73°39'0"W
73°38'0"W
73°37'0"W
21°8'0"N
21°7'0"N
21°6'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


73°36'0"W
73°35'0"W
73°34'0"W
21°9'0"N
21°8'0"N
21°7'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


73°36'0"W
73°35'0"W
73°34'0"W
21°9'0"N
21°8'0"N
21°7'0"N
Great Inagua Bathymetry
Depth, meters
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
24.1 - 25.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


73°33'0"W
73°32'0"W
73°31'0"W
21°10'0"N
21°9'0"N
21°8'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5
73°33'0"W
73°32'0"W
73°31'0"W

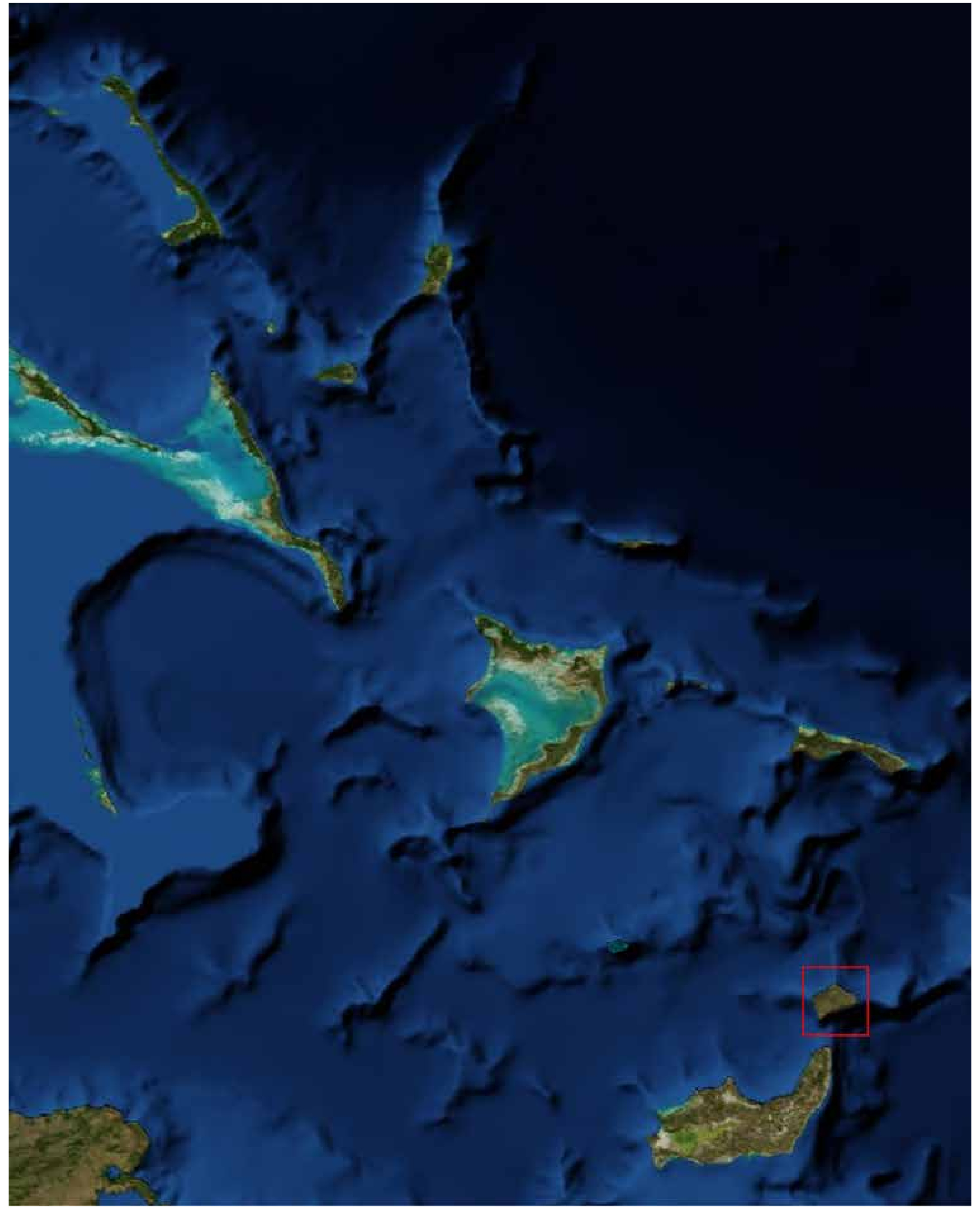

73°31'0"W
73°30'0"W
73°29'0"W
73°28'0"W
21°11'0"N
21°10'0"N
Great Inagua Habitats
Shallow coral framework
Shelf-edge coral framework
Patch reef
Deep spur and groove formations
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Moderate to dense macroalgae on sand
Gorgonian-dominated hardground
Macroalgae-dominated hardground
Turf-algal-dominated hardground
Sand
Blue hole
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5
73°31'0"W
73°30'0"W
73°29'0"W
73°28'0"W



Shallow areas around Great Inagua contained large colonies of *Montastraea annularis*. These were often scattered over a sandy bottom (top left), but also formed dense communities intermixed with *Acropora cervicornis*. Diverse fish communities seen on reefs included sharks (left middle), cherubfish *Centropyge argi* (bottom left), moray eels *Gymnothorax funebris*, jawfish *Opistognathus aurifrons*, porcupinefish *Diodon hystrix* (middle center) and Nassau grouper *Epinephelus striatus* (bottom center). The Inaguas region also had healthy populations of herbivorous parrotfish including the stoplight parrotfish, *Sparisoma viride*. A terminal phase male (top center) and initial phase fish (middle center) are shown.

A *Montastraea* reef at the edge of the drop-off (top right). Living colonies often had partial mortality, with dead areas colonized by macroalgae. The shallow (1-3 m) reef substrate often consisted of dead framework with algae, scattered brain corals and high numbers of sea fans (*Gorgonia ventalina*) (bottom right).

Little Inagua, Bahamas

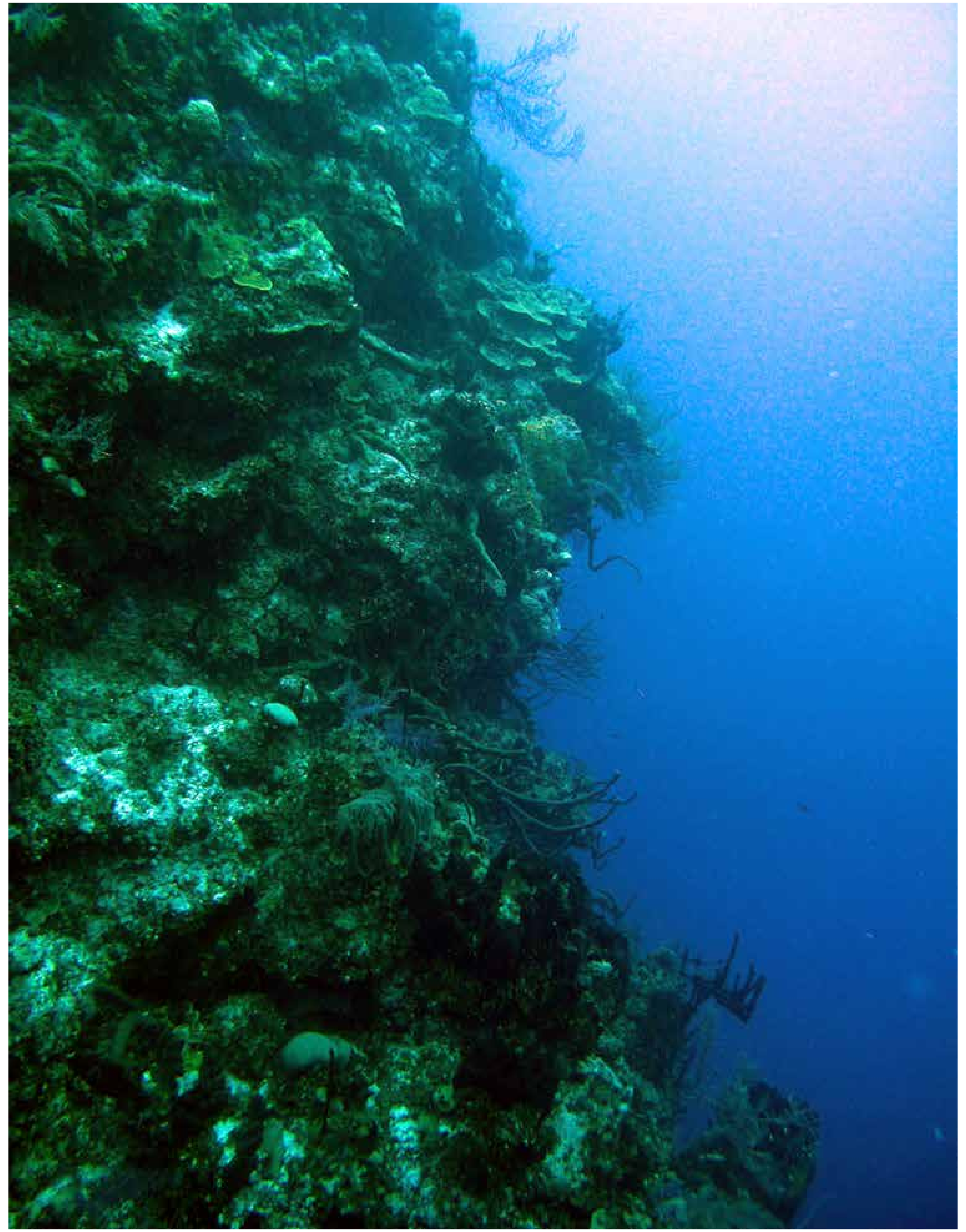


Little Inagua is located 8 km to the northeast of Great Inagua. It sits on its own platform, separated from Great Inagua by a 1000 m deep channel (Inagua Passage). It is the largest uninhabited island in the Bahamas. The island and the surrounding waters (to a depth of 180 meters) were declared a reserve in 2002. The Land and Sea Park occupies an area of about 78 km^2.

Wildlife found here include flamingos, West Indian tree ducks and other rare birds. The snake *Hypsirhynchus parvifron*s is found here. It also occurs in Haiti and the Dominican Republic. There are also herds of feral goats and donkeys that were introduced by the French.

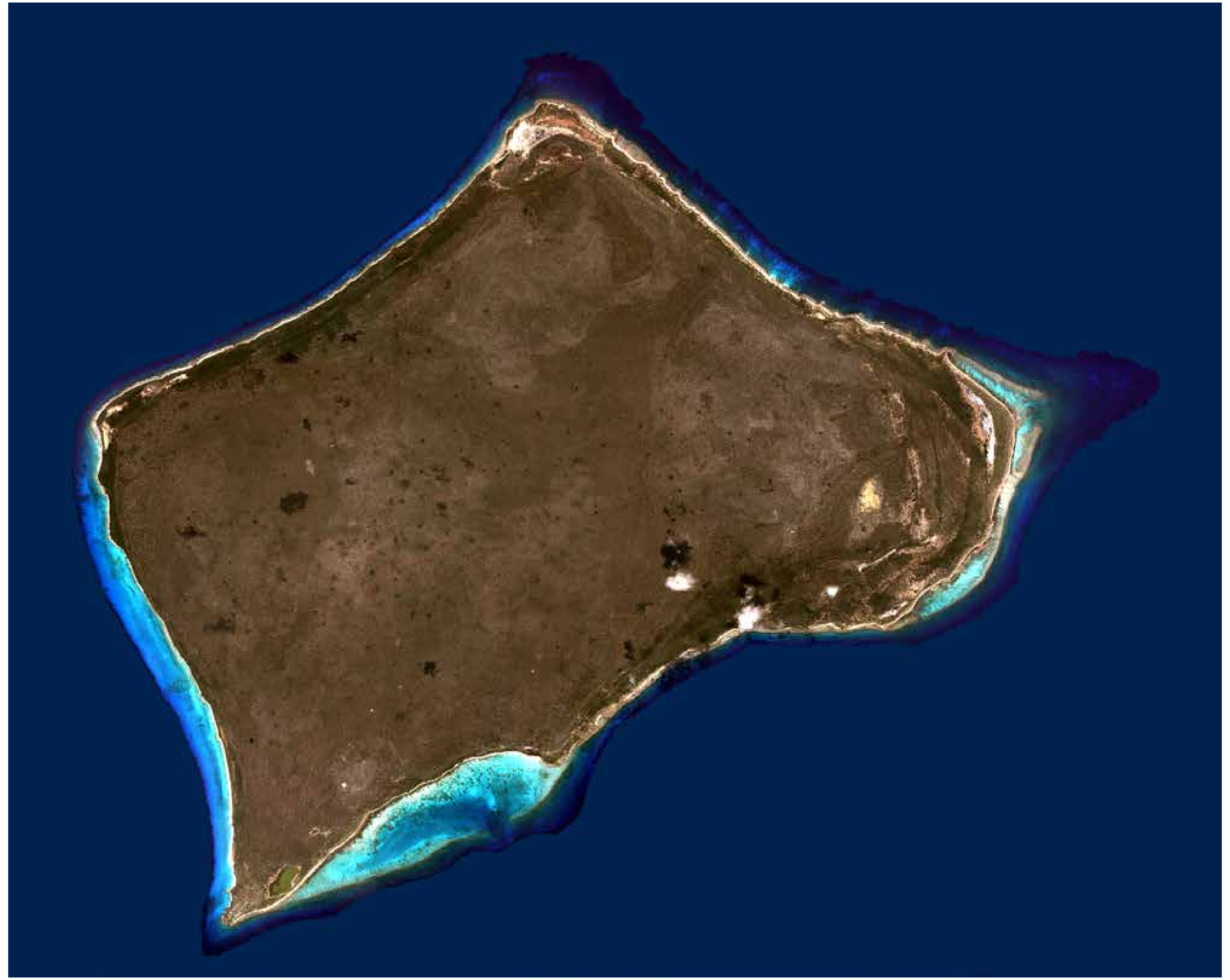
The east side of Little Inagua has a Pleistocene/Holocene eolianite ridge, 5-6 m in height, adjacent to the coastline (opposite page, top right). In many locations, a sandy terrace extended from shore about 30-50 m. Closer to the edge of the drop-off a well developed spur and groove reef system was found (opposite page, bottom right). The interior of the island had low-lying scrub forest. Numerous blue holes occurred within its interior (top left). Parts of the south and west coast had a prominent shallow lagoon, well developed reef crest and a steep fore reef slope. The most extensive lagoonal habitat and a large hypersaline pond is shown in the bottom left. The eastern tip of Little Inagua, facing south, has a large reef system extending offshore (top right).

Coral reef outcrops dating from ~125,000 yrs BP. A large *Montastraea* skeleton is visible in the center of the photo (bottom right).



Little Inagua is fringed by coral reefs, with extensive spur and groove structures located on the windward margins. Shallow (2-3 m deep) lagoonal habitats are confined mostly to the leeward southwestern side and the south. Extensive reef structure and a shallow lagoon also exists on the eastern tip. On the western side there is a seven-mile beach lined with tropical palms.

The fore reef off Little Inagua was characterized by steep walls with well developed coral, sponge and gorgonian communities. In some areas the wall plummeted, near vertically to the abyss (left). In other locations it sloped steeply from 5-6 m to 20 m, with a deeper terrace and then a second slope (top right). Many of the corals had a plating morphology. Colonies of *M. faveolata* were much more common and in better condition than both Hogsty Reef and Great Inagua. There was also a lower cover of macroalgae. Large pelagic predators were common (bottom right).



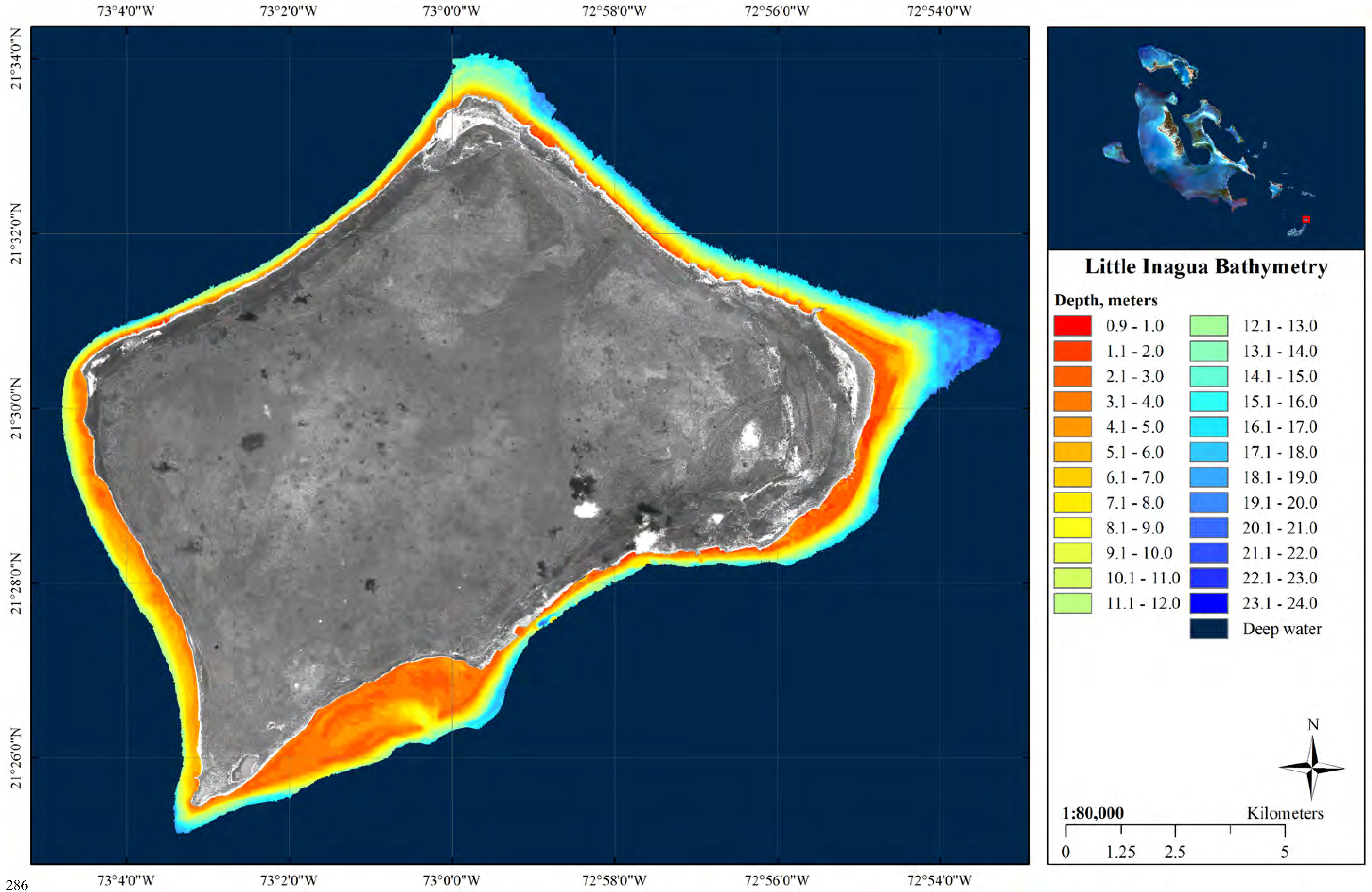
High resolution WorldView-2 satellite image of Little Inagua at a scale of 1:80,000.

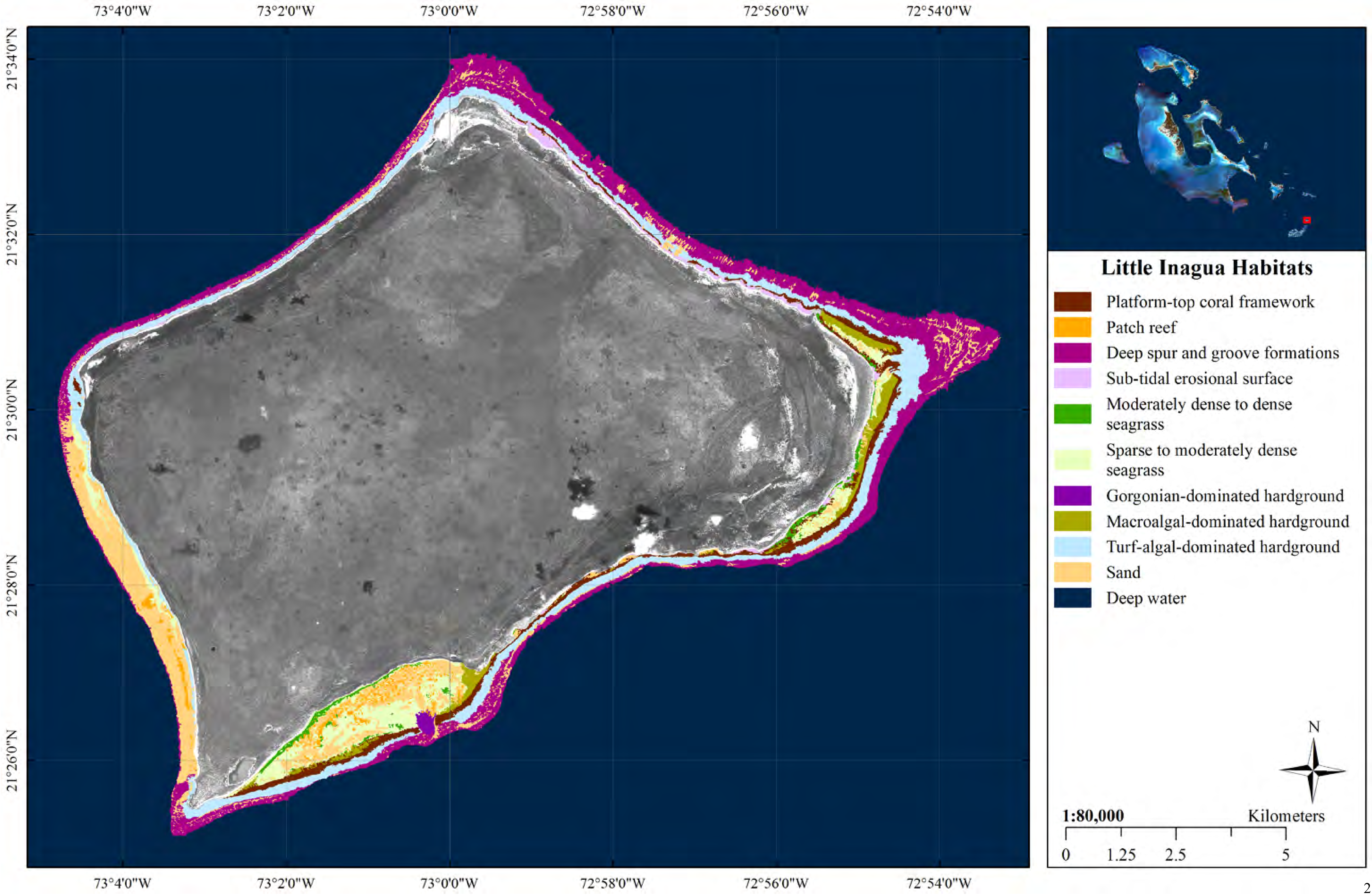
Little Inagua Imagery and Habitat Maps

Satellite imagery, bathymetry and habitat maps for Little Inagua are illustrated on pages 284-304. WorldView-2 multispectral satellite imagery of Little Inagua (left), bathymetry (page 285) and a resulting habitat map for the same area (page 286) are shown at a scale of 1:80,000. A locator map is shown on page 288 at a scale of 1:80,000. High resolution habitat maps (1:24,000) and bathymetric maps for representative areas within Little Inagua are shown on subsequent pages. Each of the six 1:24,000 scale habitat maps included in this section is on the left (odd numbered) page and the bathymetric map for the same area is shown on the right (even numbered page). Habitat maps start in the north and are arranged in a clockwise manner. These include habitats associated with the shallow coral framework, lagoonal environments and hardground habitats. Source of terrestrial basemap imagery used in all habitat maps and bathymetric maps is: ESRI, i-cubed, USFSA, USGS, AEX, GeoEye, AeroGRID, Getmapping, IGP.

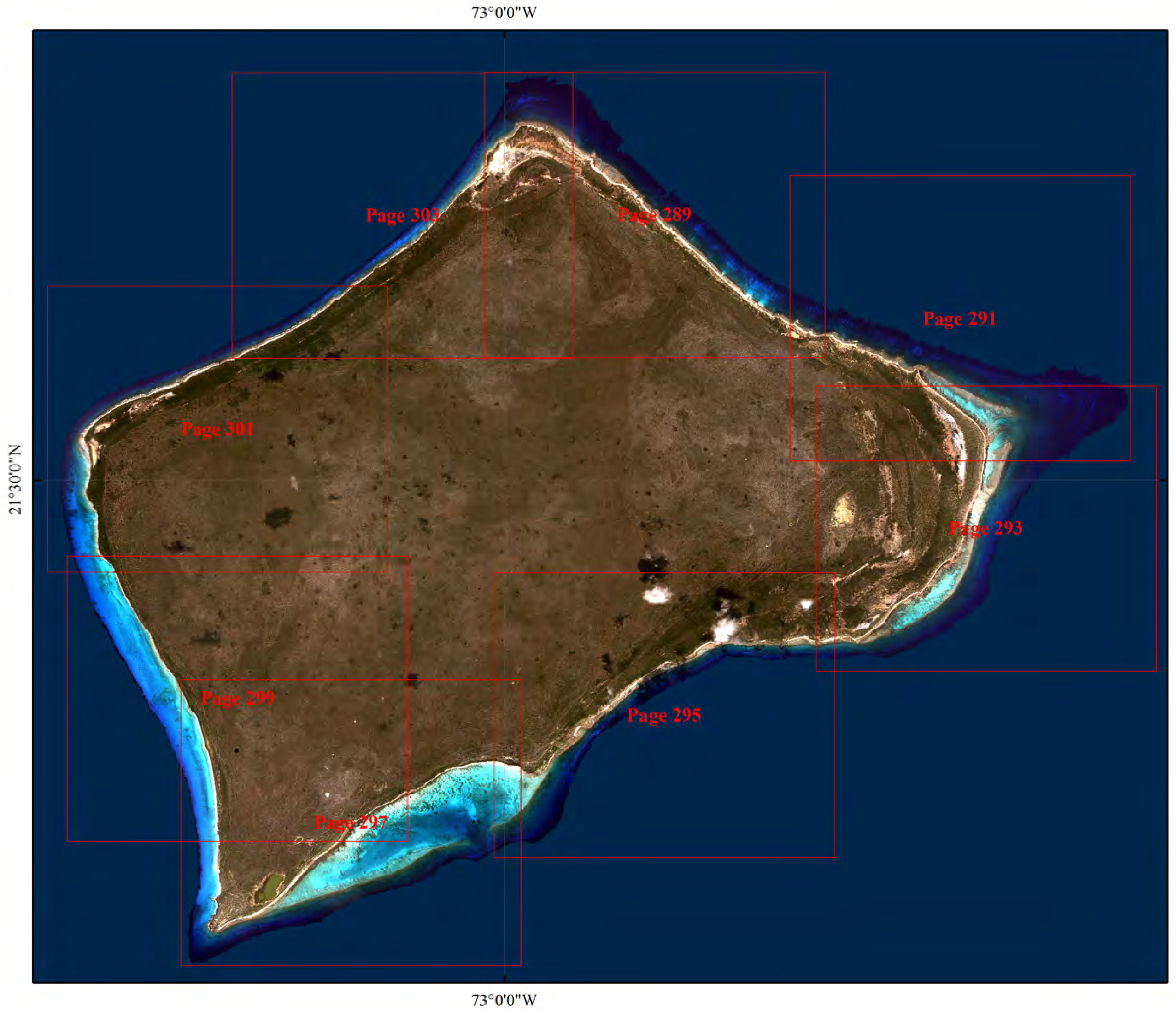
A total of 37.31 sq km of shallow marine habitats were mapped and subdivided into 10 habitat classes with sites below 25 m depth (deepwater) depicted in dark blue. The aerial coverage of each habitat is presented in the table. The most extensive habitat types were deep spur and groove formations, which made up over 32% of all marine habitats. Corals were found in three habitat types, covering an area of about 16 sq km. Hardground areas with macroalgae, turf algae, gorgonians and scattered corals constitute an additional 9 sq km of the bank, while other soft bottom habitats with seagrass and sand occupied 12 sq km.

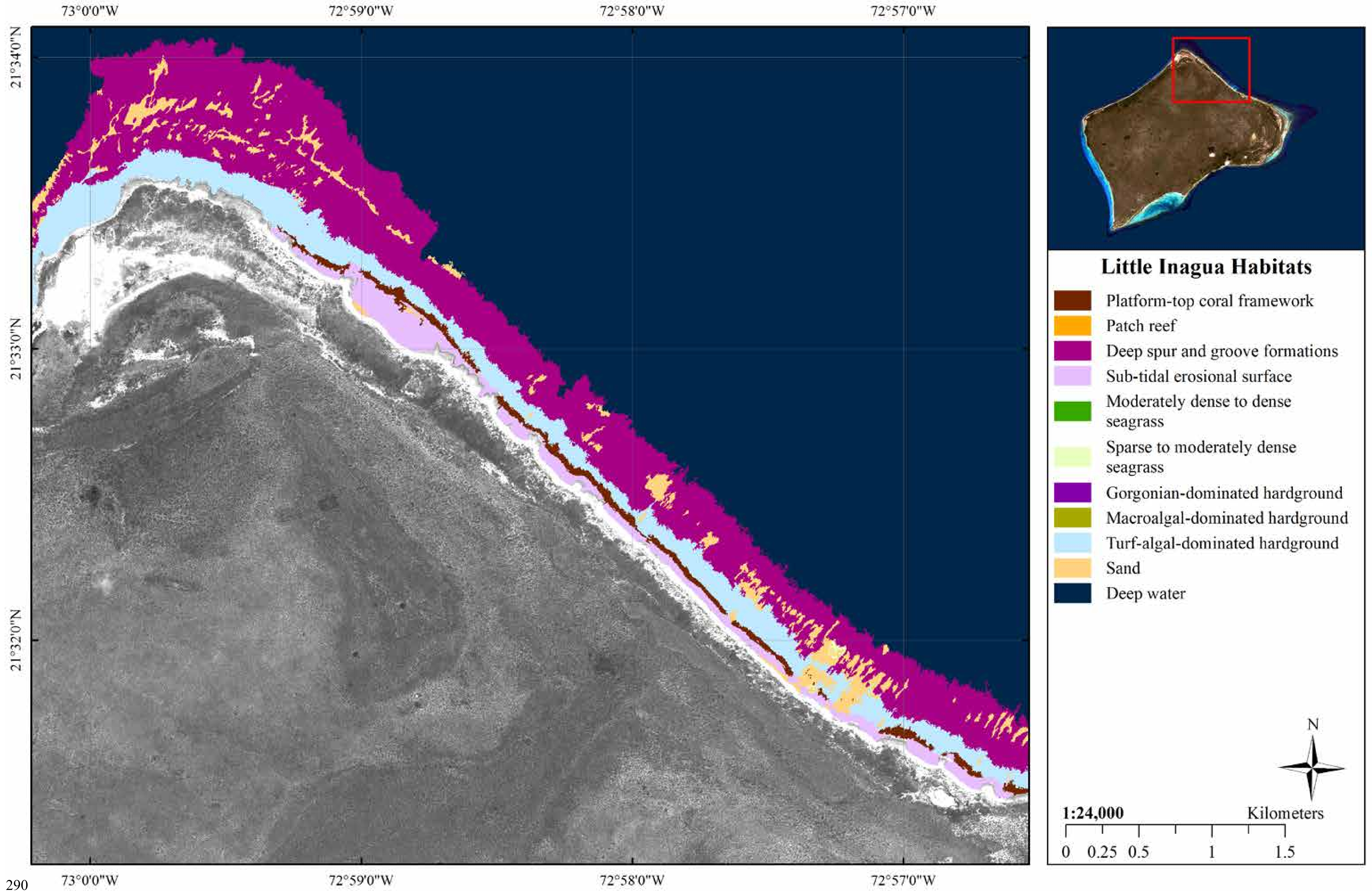
Little Inagua Habitats	Total Area (sq km)	% region total
Shallow coral framework	2.80	7.51
Patch reefs	0.98	2.64
Deep spur and groove formations	11.96	32.05
Sub-tidal erosional surface	0.76	2.04
Moderately dense to dense seagrass	0.66	1.76
Sparse to moderate density seagrass	3.65	9.78
Gorgonian-dominated hardground	0.17	0.45
Macroalgal-dominated hardground	1.35	3.63
Turf-algal-dominated hardground	7.27	19.50
Sand	7.70	20.64
Land	151.95	
Total Area Mapped	37.31	100.00


73°4'0"W
73°2'0"W
73°0'0"W
72°58'0"W
72°56'0"W
72°54'0"W
21°34'0"N
21°32'0"N
21°30'0"N
21°28'0"N
21°26'0"N
Little Inagua Bathymetry
Depth, meters
0.9 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
Deep water
N
1:80,000
Kilometers
0
1.25
2.5
5

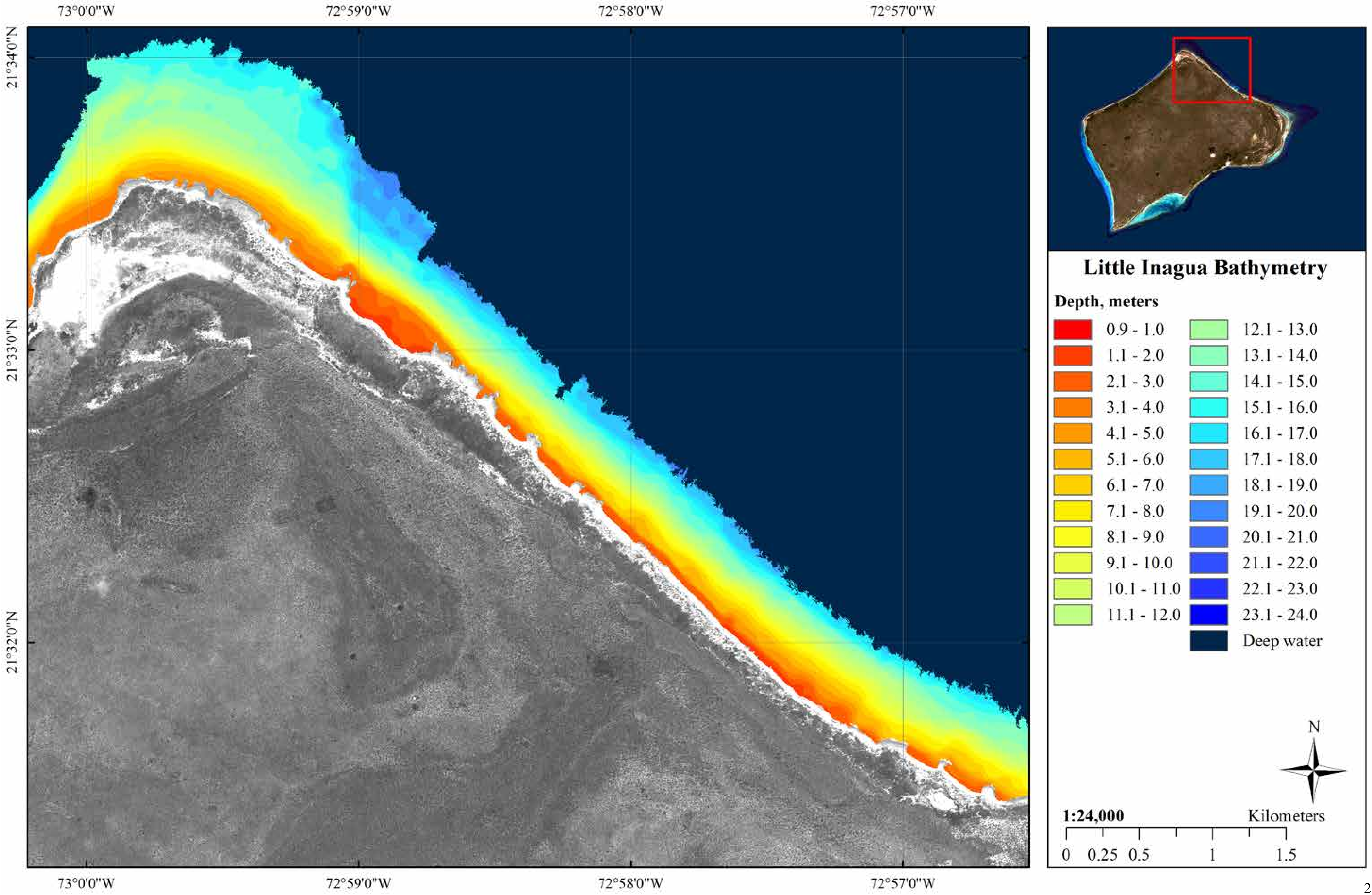

73°4'0"W
73°2'0"W
73°0'0"W
72°58'0"W
72°56'0"W
72°54'0"W
21°34'0"N
21°32'0"N
21°30'0"N
21°28'0"N
21°26'0"N
Little Inagua Habitats
Platform-top coral framework
Patch reef
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Turf-algal-dominated hardground
Sand
Deep water
N
1:80,000
Kilometers
0
1.25
2.5
5

Reef scenes on Little Inagua. Fore reef slope (top left). Base of the fore reef, 25 m (bottom left). Large *Colpophyllia natans* colony (top right). *Montastraea* reef with a tiger grouper (bottom right).

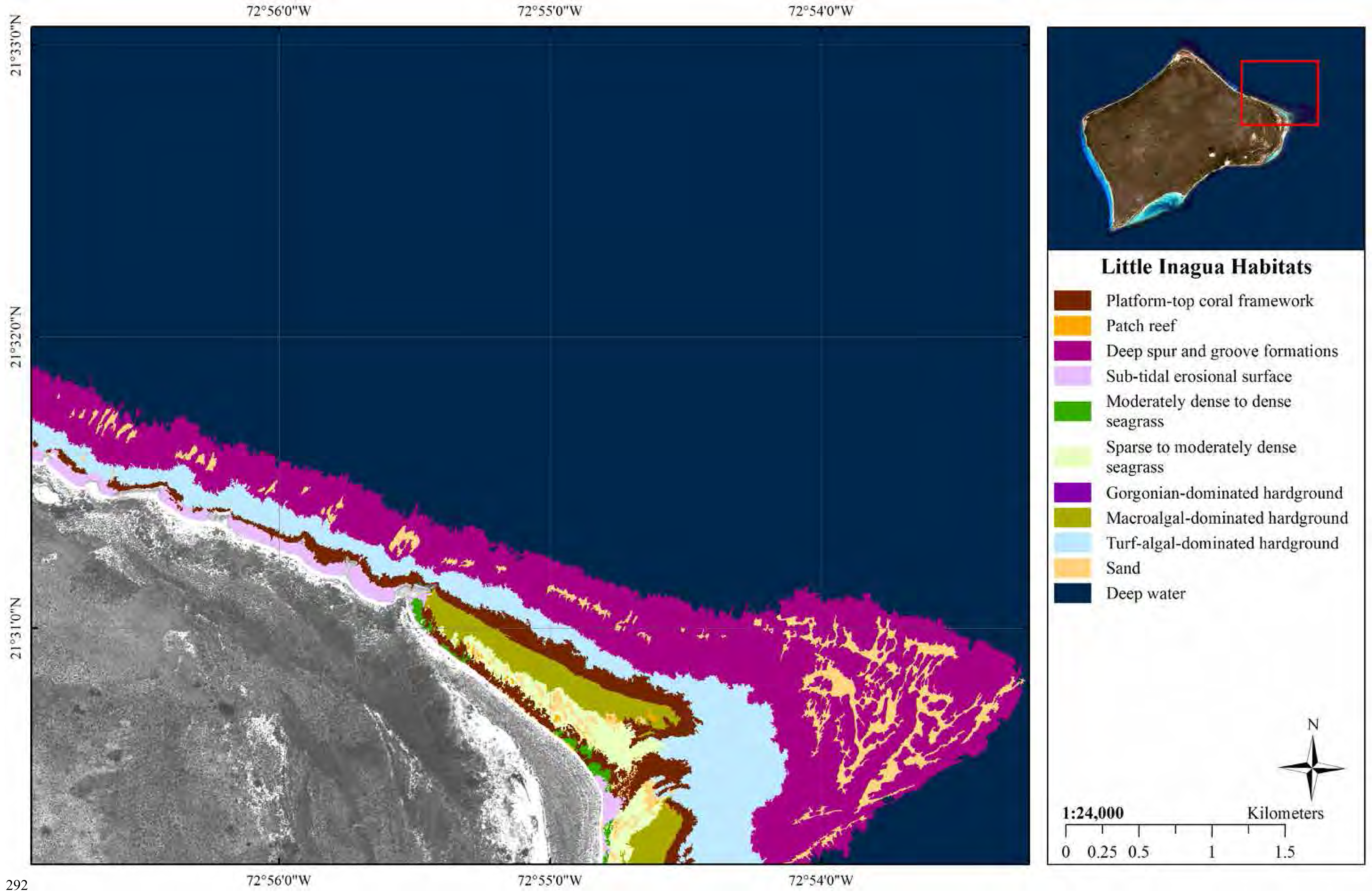


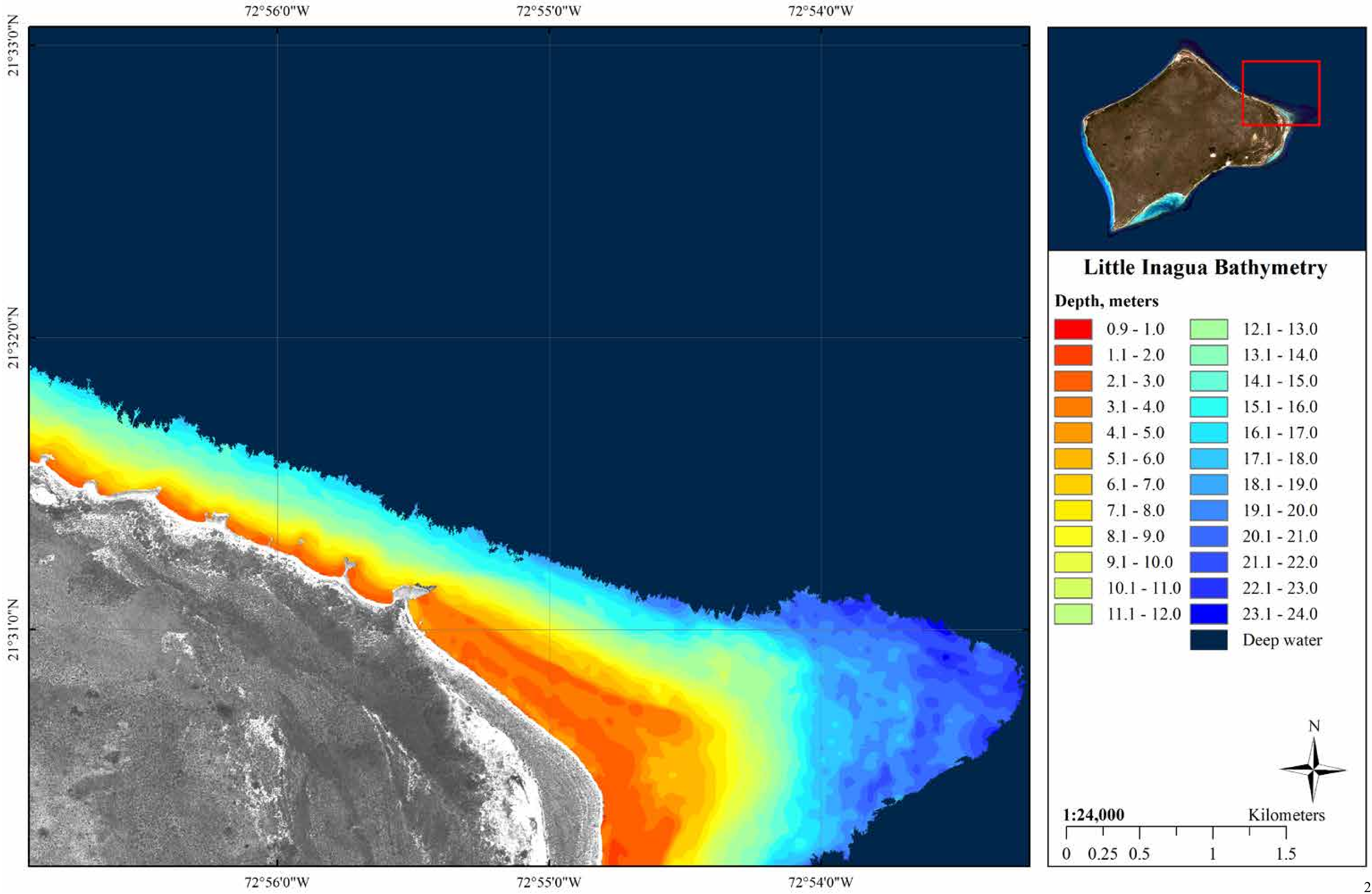


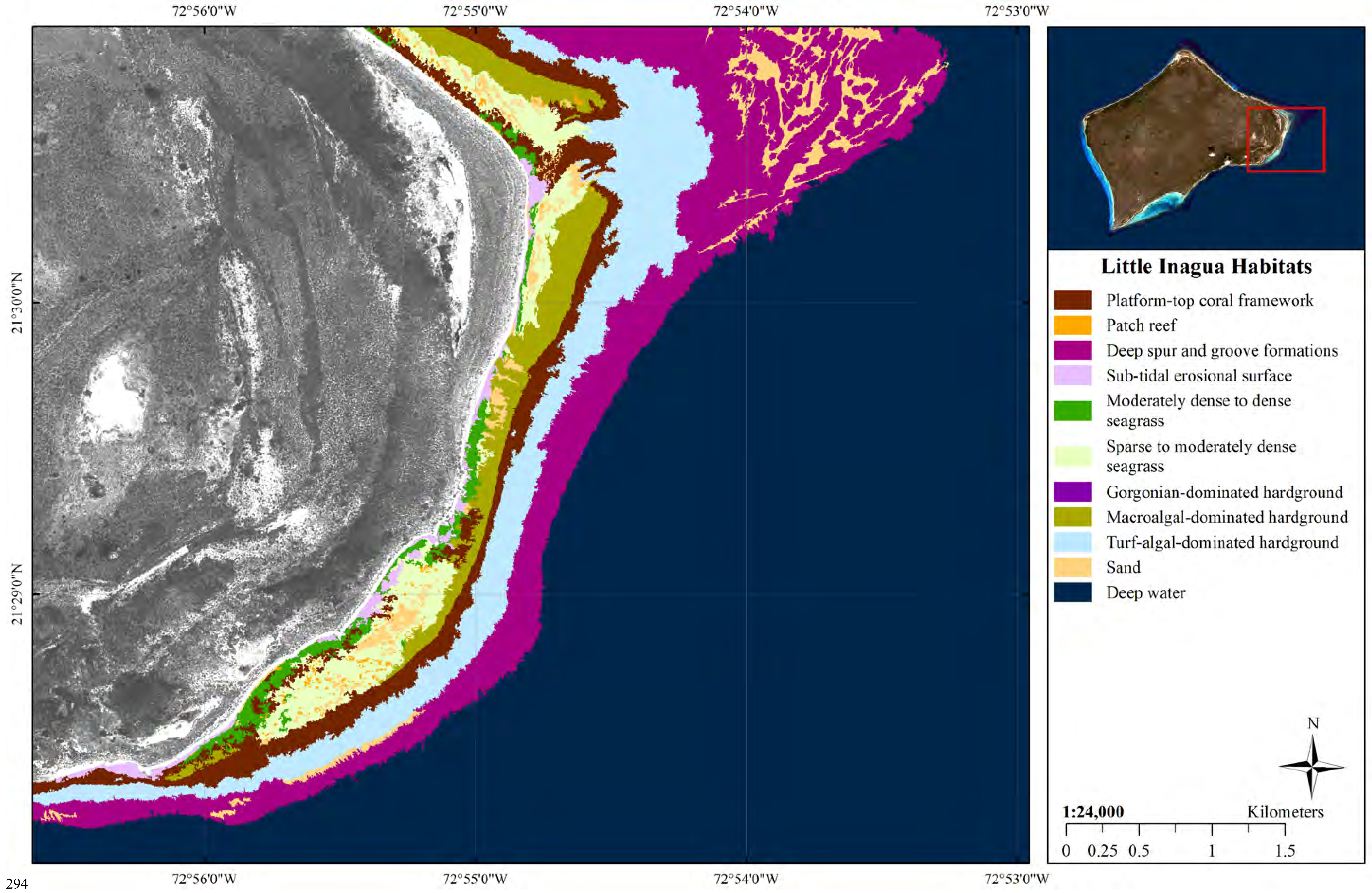
73°0'0"W
72°59'0"W
72°58'0"W
72°57'0"W
21°34'0"N
21°33'0"N
21°32'0"N
Little Inagua Habitats
Platform-top coral framework
Patch reef
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Turf-algal-dominated hardground
Sand
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

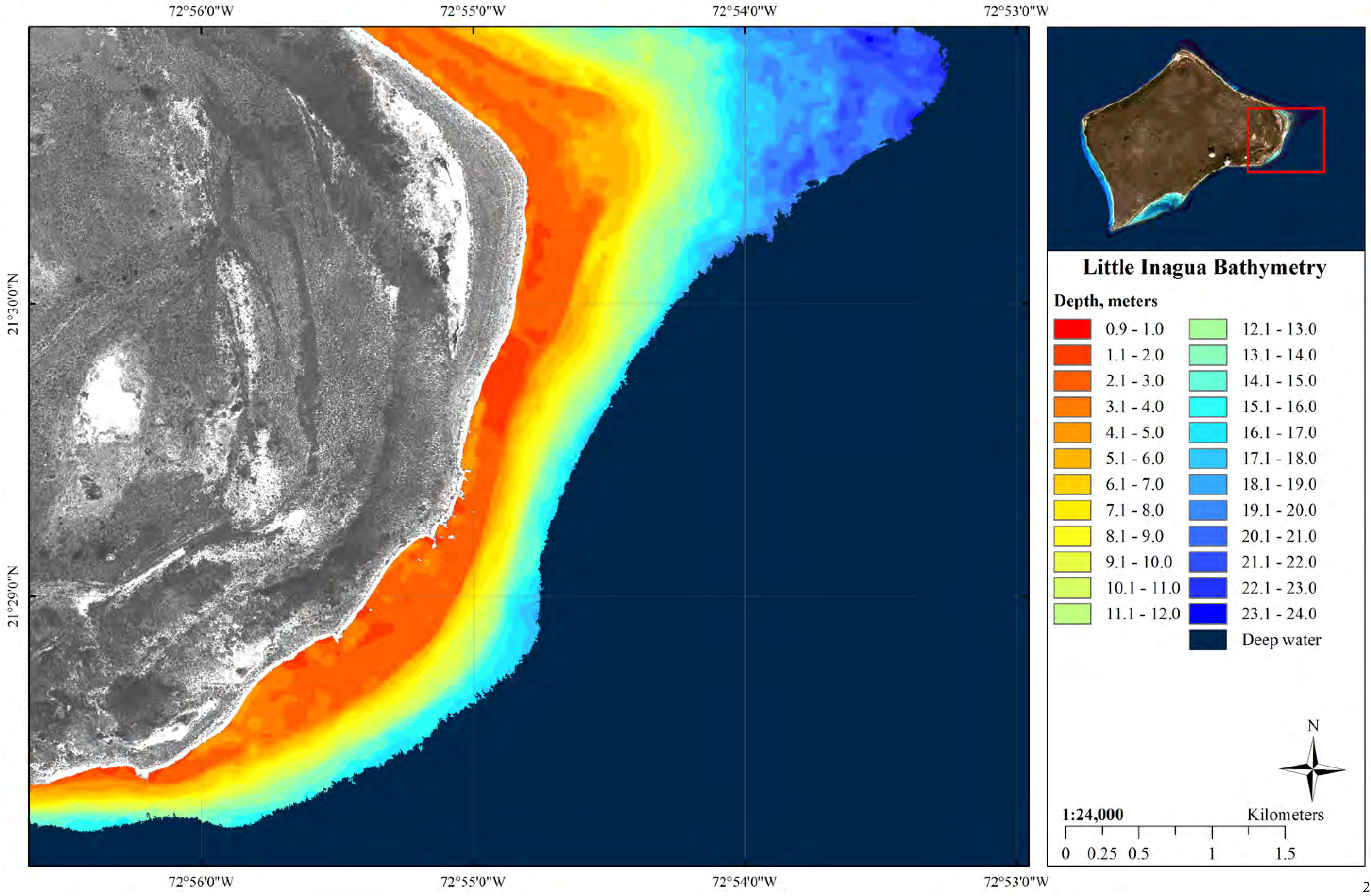


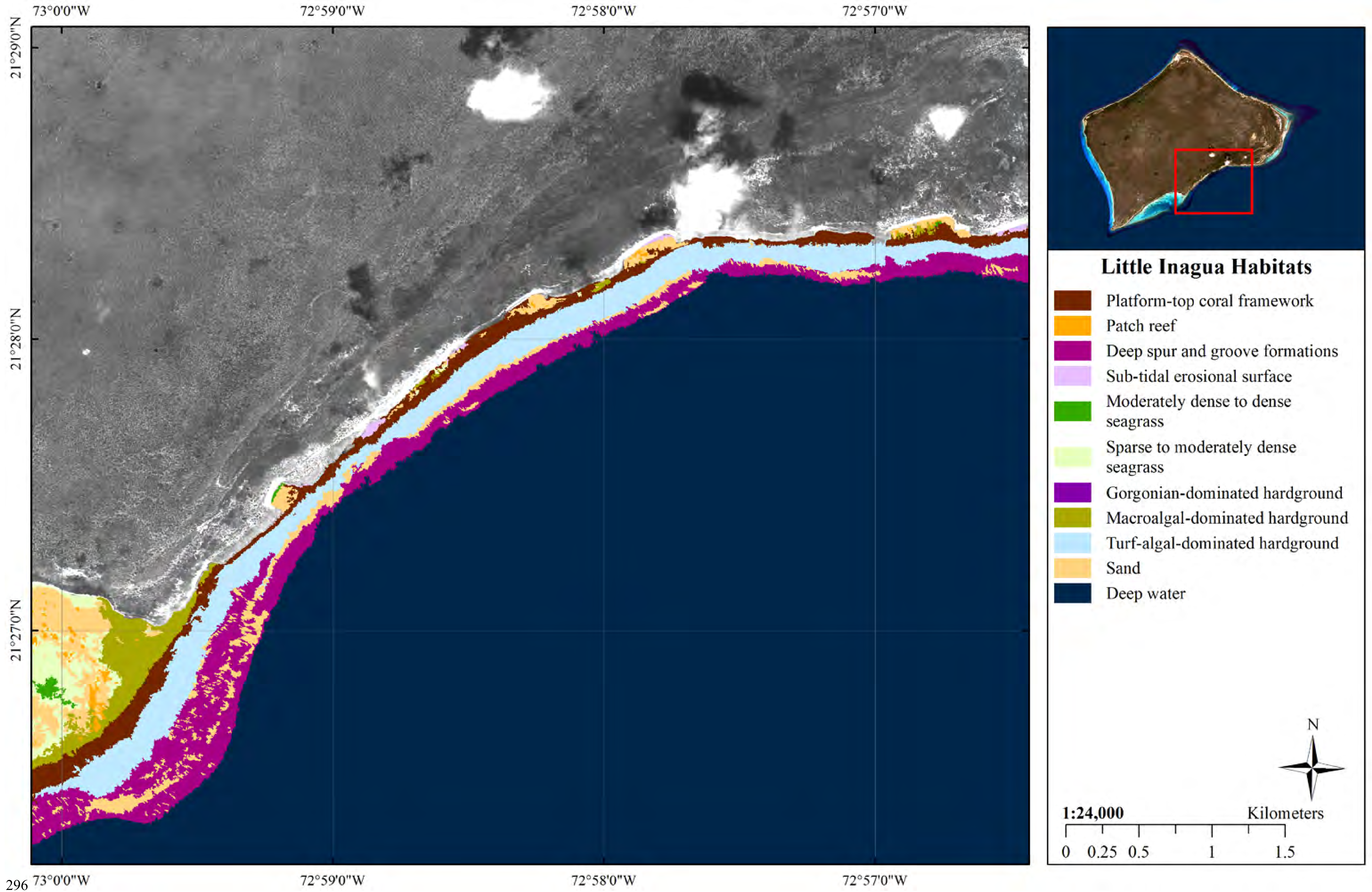
73°0'0"W
72°59'0"W
72°58'0"W
72°57'0"W
21°34'0"N
21°33'0"N
21°32'0"N
Little Inagua Bathymetry
Depth, meters
0.9 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


72°56'0"W
72°55'0"W
72°54'0"W
21°33'0"N
21°32'0"N
21°31'0"N
Little Inagua Habitats
Platform-top coral framework
Patch reef
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Turf-algal-dominated hardground
Sand
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

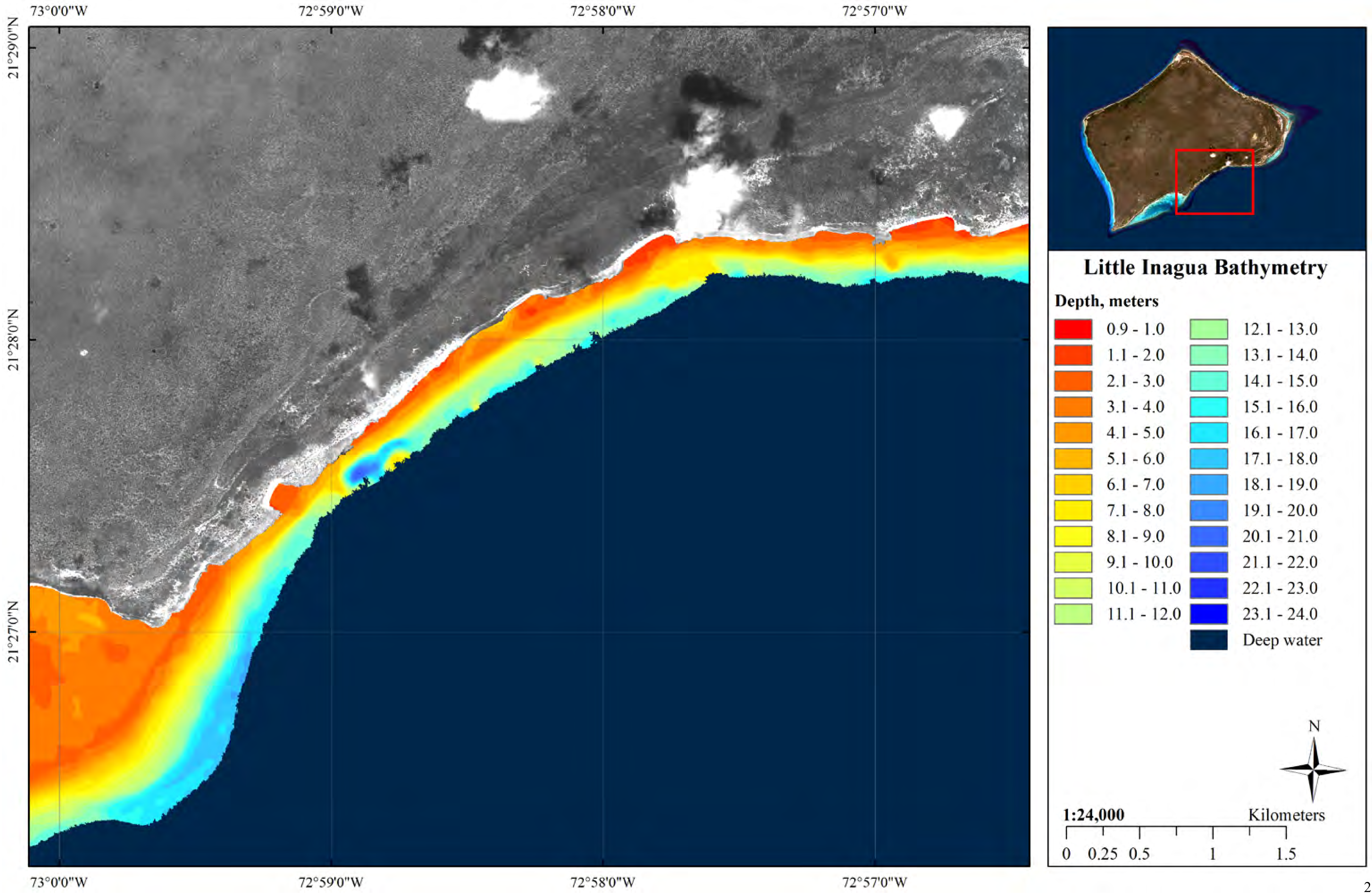

72°56'0"W
72°55'0"W
72°54'0"W
21°33'0"N
21°32'0"N
21°31'0"N
Little Inagua Bathymetry
Depth, meters
0.9 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


72°56'0"W
72°55'0"W
72°54'0"W
72°53'0"W
21°30'0"N
21°29'0"N
Little Inagua Habitats
Platform-top coral framework
Patch reef
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Turf-algal-dominated hardground
Sand
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

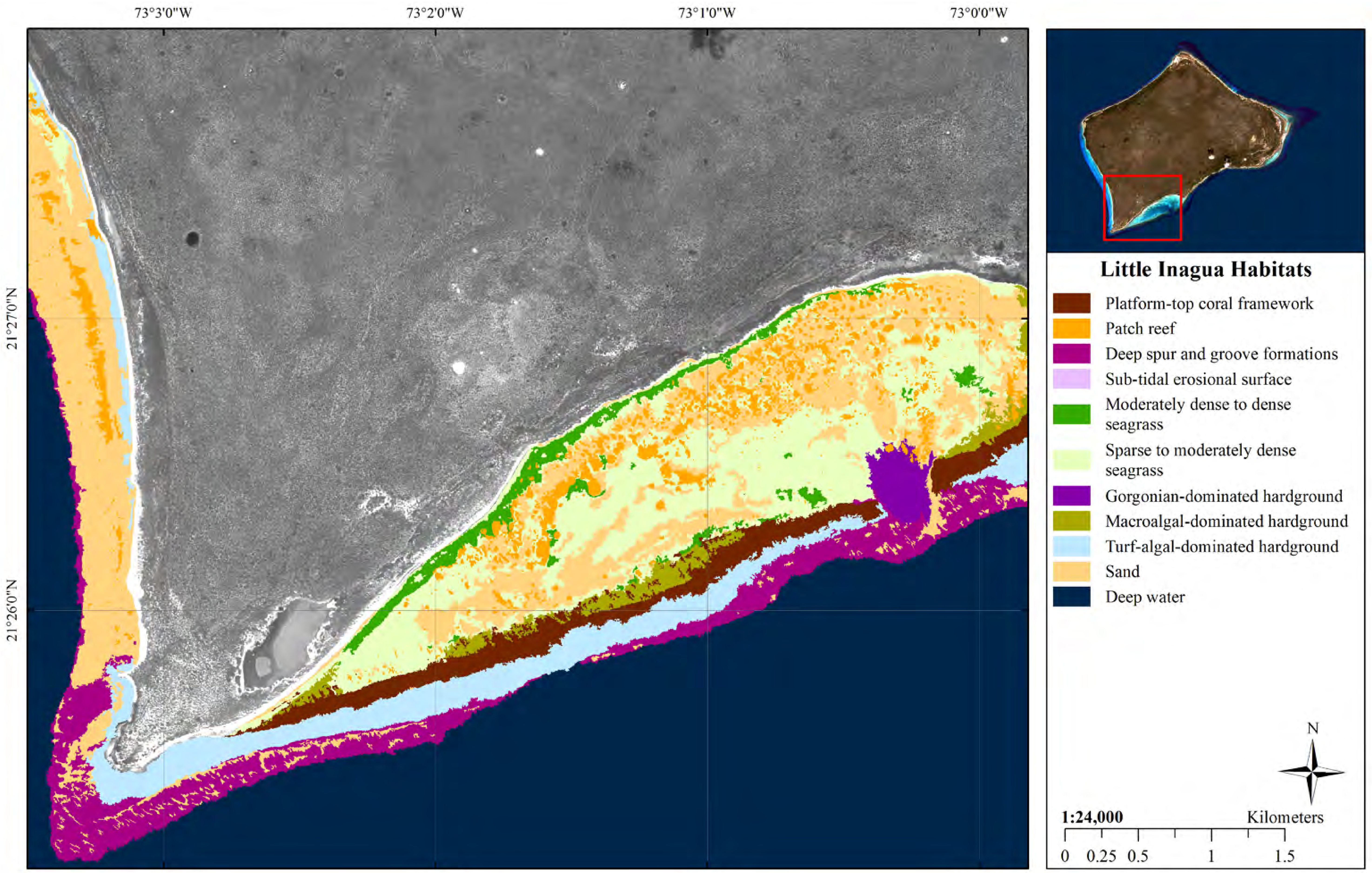

72°56'0"W
72°55'0"W
72°54'0"W
72°53'0"W
21°30'0"N
21°29'0"N
Little Inagua Bathymetry
Depth, meters
0.9 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

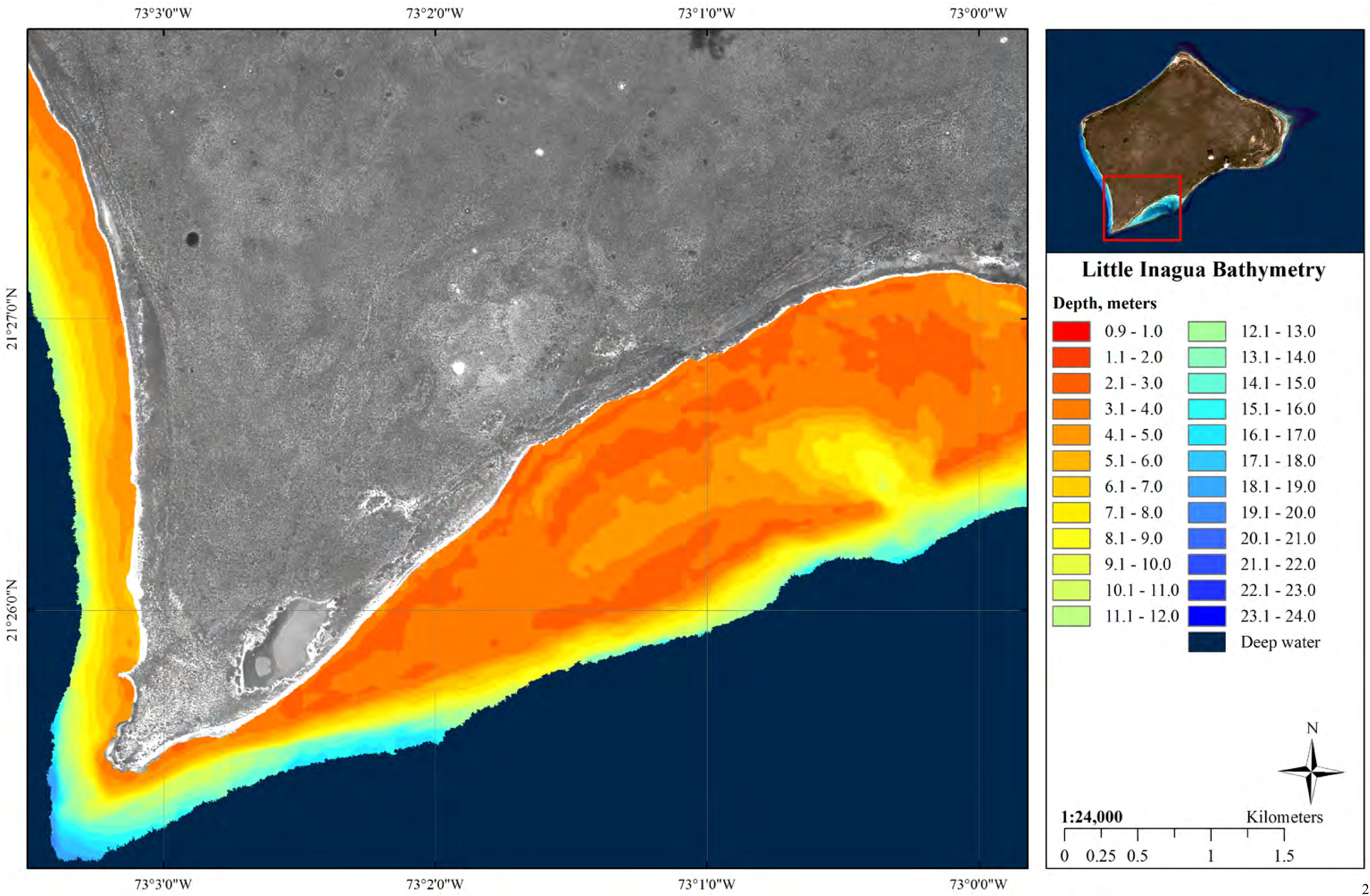


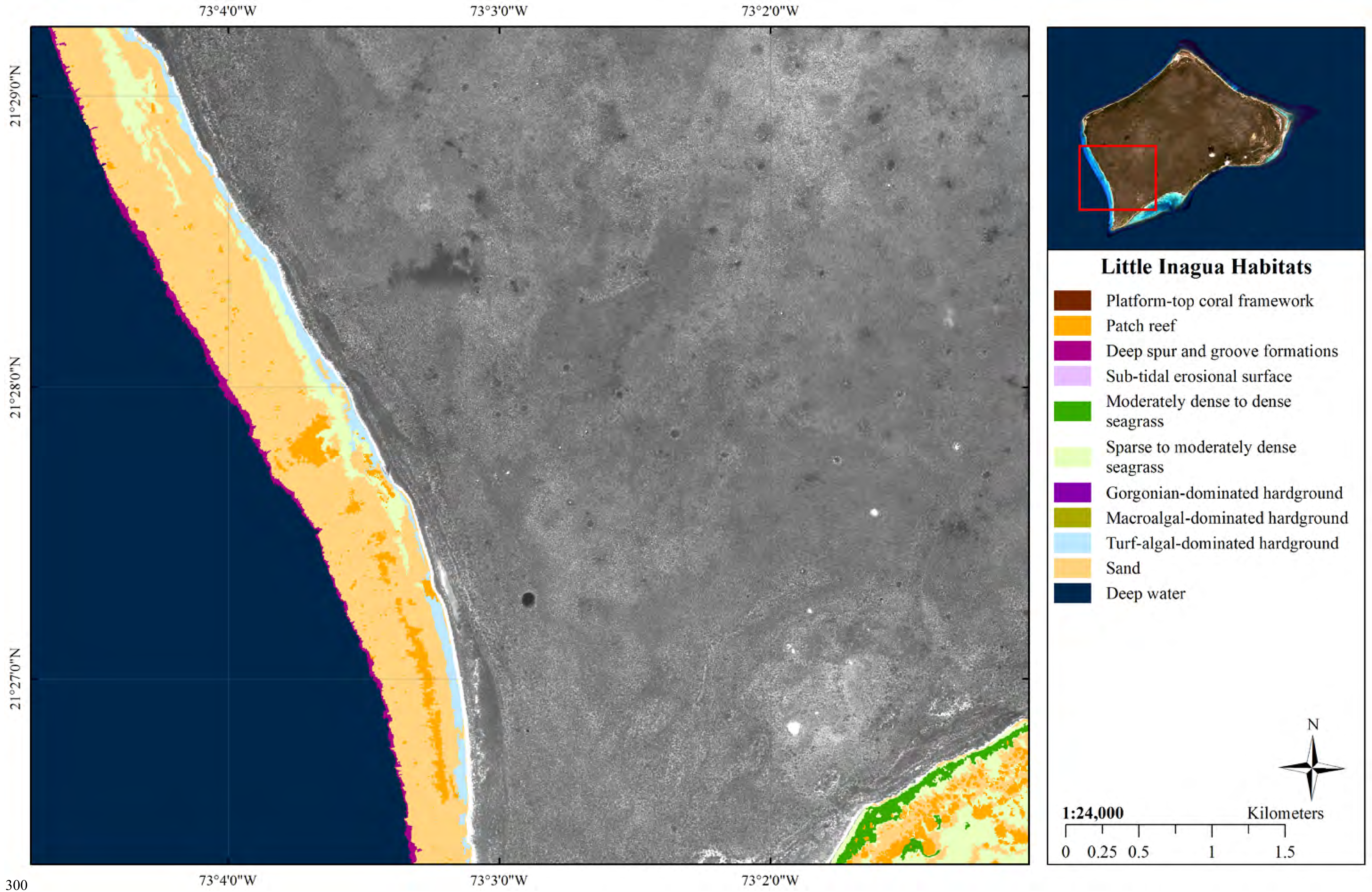
73°0'0"W
72°59'0"W
72°58'0"W
72°57'0"W
21°29'0"N
21°28'0"N
21°27'0"N
Little Inagua Habitats
Platform-top coral framework
Patch reef
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Turf-algal-dominated hardground
Sand
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

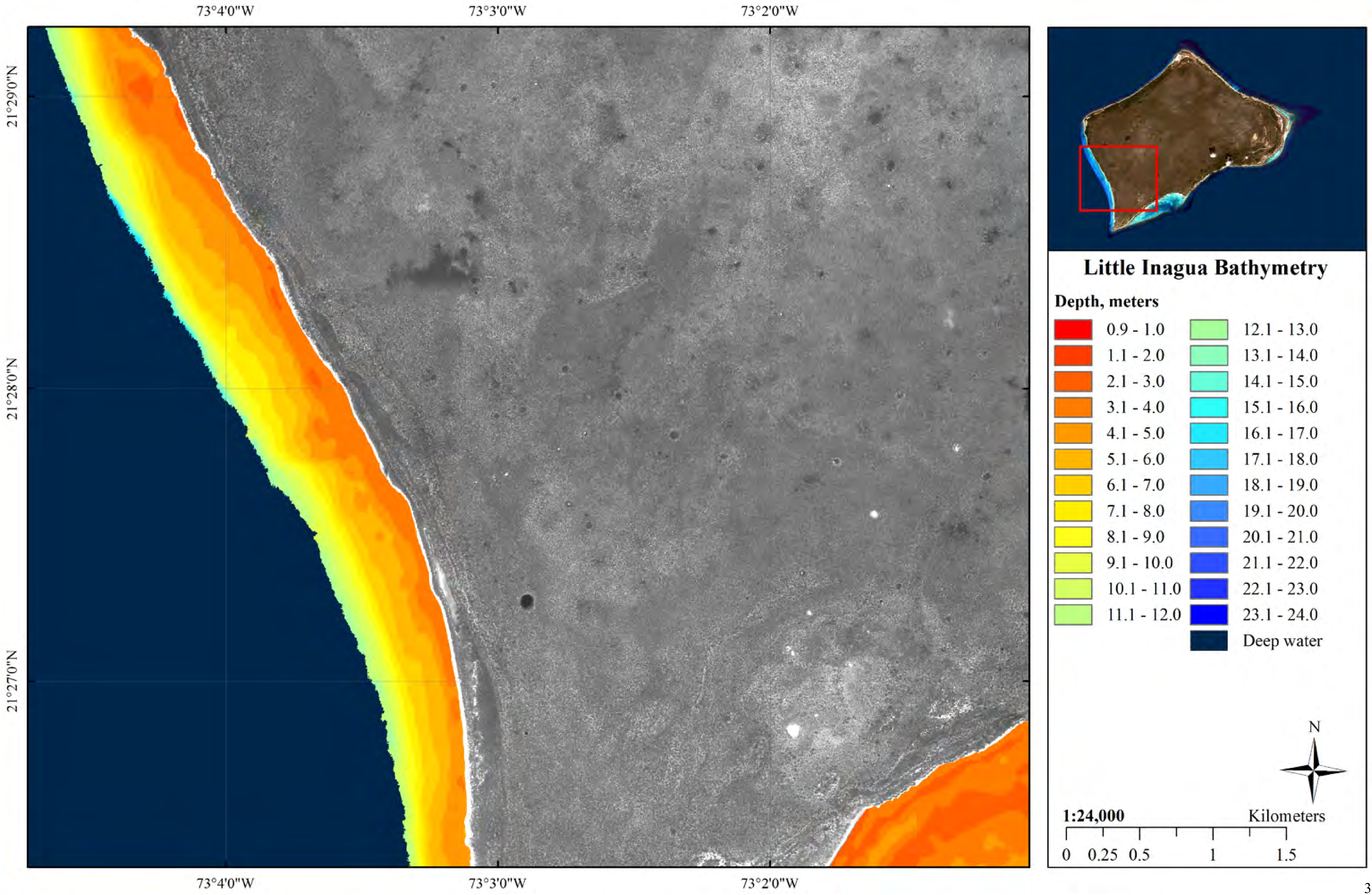


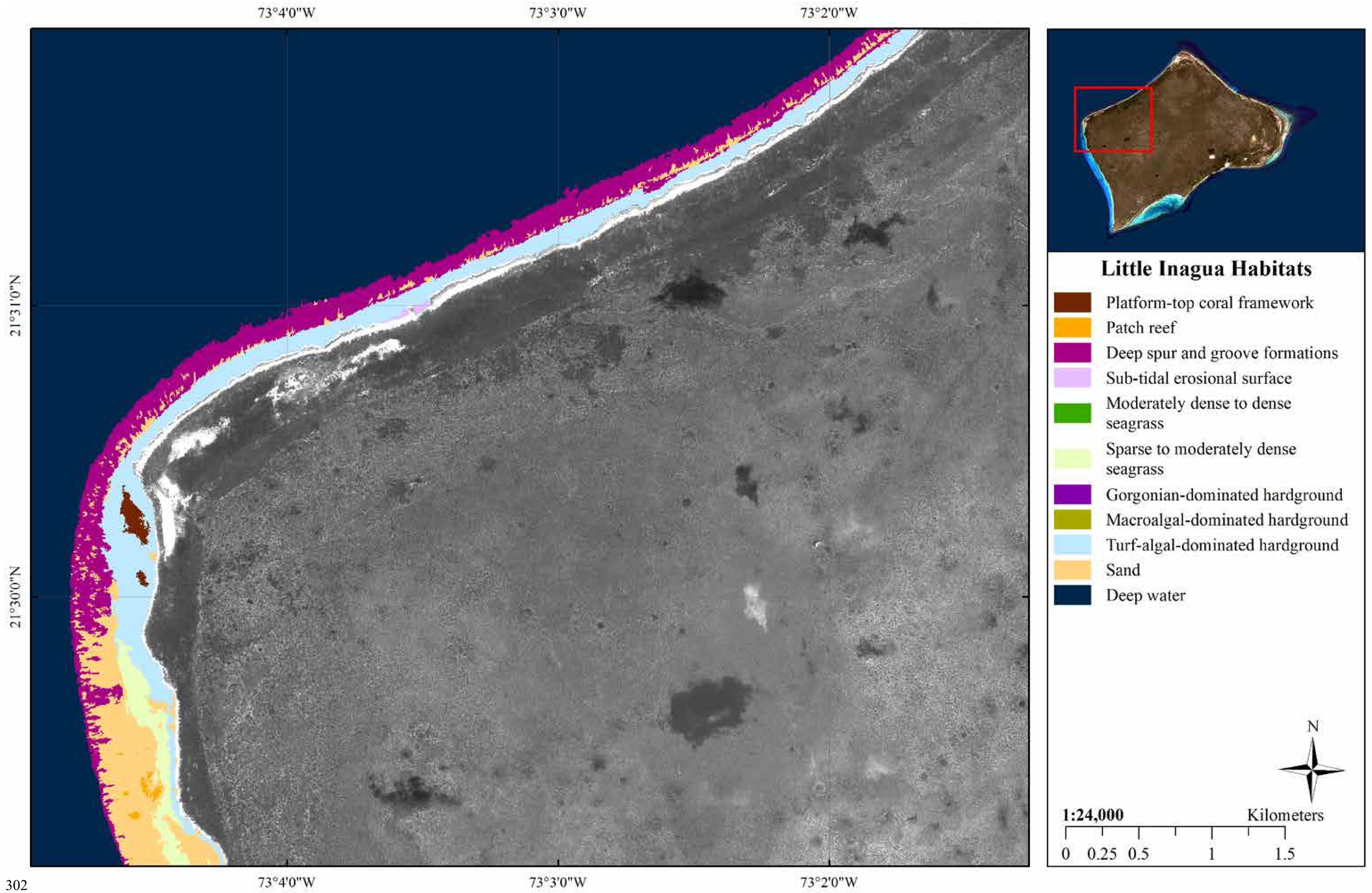
73°0'0"W
72°59'0"W
72°58'0"W
72°57'0"W
21°29'0"N
21°28'0"N
21°27'0"N
Little Inagua Bathymetry
Depth, meters
0.9 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

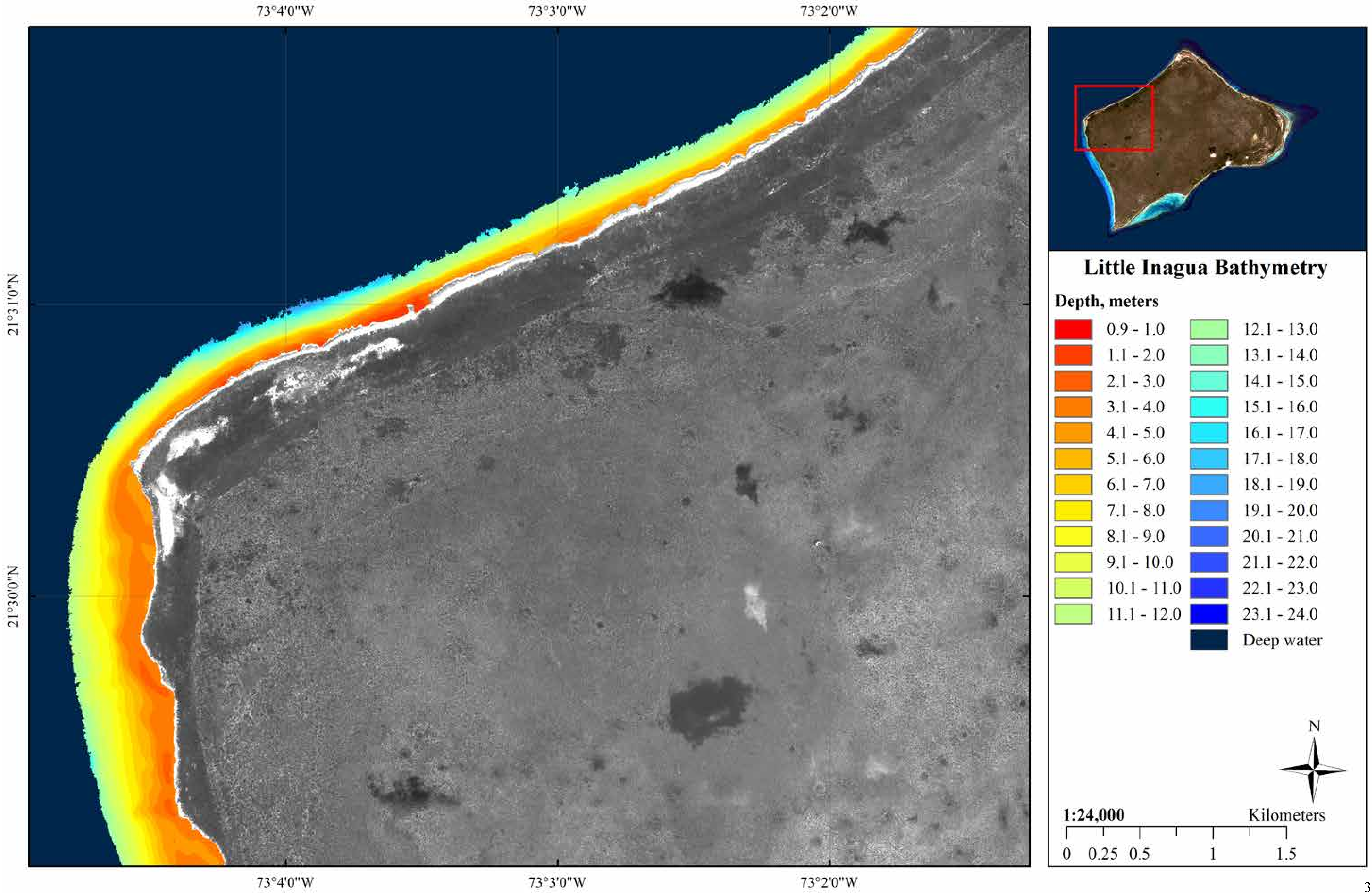

73°3'0"W
73°2'0"W
73°1'0"W
73°0'0"W
21°27'0"N
21°26'0"N
Little Inagua Habitats
Platform-top coral framework
Patch reef
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Turf-algal-dominated hardground
Sand
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5
73°3'0"W
73°2'0"W
73°1'0"W
73°0'0"W

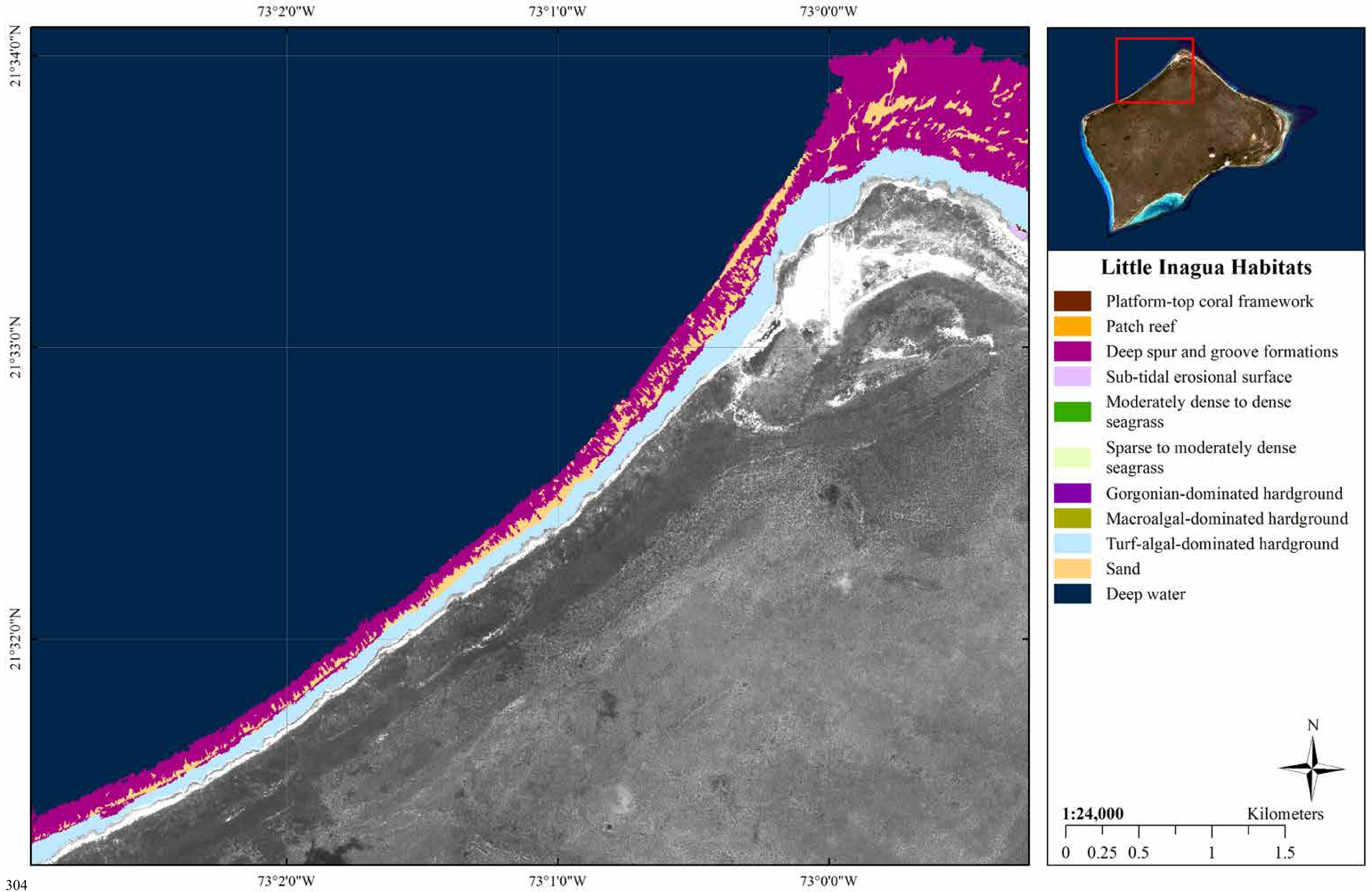

73°3'0"W
73°2'0"W
73°1'0"W
73°0'0"W
21°27'0"N
21°26'0"N
Little Inagua Bathymetry
Depth, meters
0.9 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5
73°3'0"W
73°2'0"W
73°1'0"W
73°0'0"W

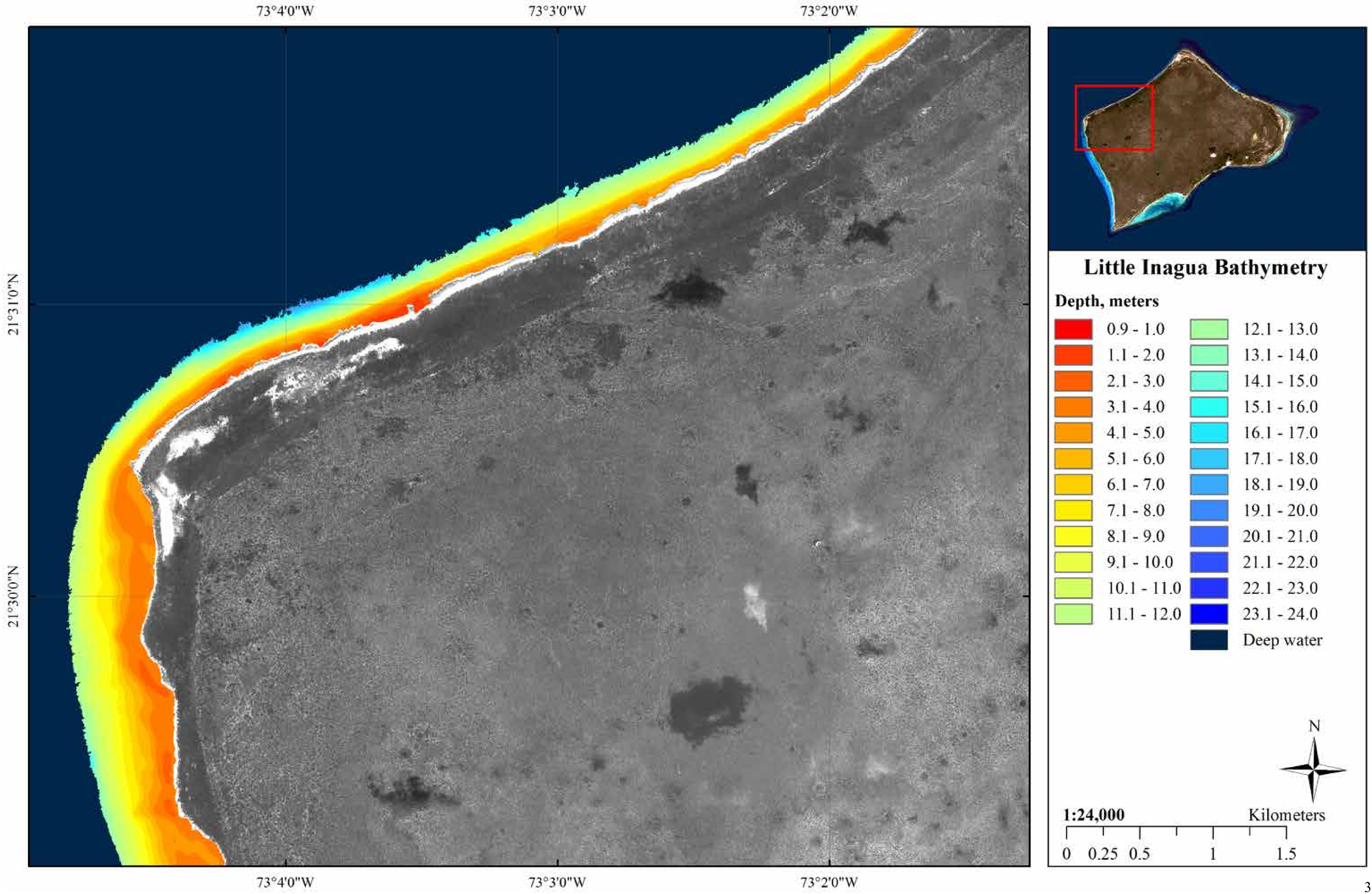

73°4'0"W
73°3'0"W
73°2'0"W
21°29'0"N
21°28'0"N
21°27'0"N
Little Inagua Habitats
Platform-top coral framework
Patch reef
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Turf-algal-dominated hardground
Sand
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


73°4'0"W
73°3'0"W
73°2'0"W
21°29'0"N
21°28'0"N
21°27'0"N
Little Inagua Bathymetry
Depth, meters
0.9 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
Deep water
N
1:24,000
Kilometers
0
0.25
0.5
1
1.5


73°4'0"W
73°3'0"W
73°2'0"W
21°31'0"N
21°30'0"N
Little Inagua Habitats
Platform-top coral framework
Patch reef
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Turf-algal-dominated hardground
Sand
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


73°4'0"W
73°3'0"W
73°2'0"W
21°31'0"N
21°30'0"N
Little Inagua Bathymetry
Depth, meters
0.9 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


73°2'0"W
73°1'0"W
73°0'0"W
21°34'0"N
21°33'0"N
21°32'0"N
Little Inagua Habitats
Platform-top coral framework
Patch reef
Deep spur and groove formations
Sub-tidal erosional surface
Moderately dense to dense seagrass
Sparse to moderately dense seagrass
Gorgonian-dominated hardground
Macroalgal-dominated hardground
Turf-algal-dominated hardground
Sand
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5


73°4'0"W
73°3'0"W
73°2'0"W
21°31'0"N
21°30'0"N
Little Inagua Bathymetry
Depth, meters
0.9 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
14.1 - 15.0
15.1 - 16.0
16.1 - 17.0
17.1 - 18.0
18.1 - 19.0
19.1 - 20.0
20.1 - 21.0
21.1 - 22.0
22.1 - 23.0
23.1 - 24.0
Deep water
N
1:24,000
Kilometers
0 0.25 0.5 1 1.5

REFERENCES

Agassiz, A. 1894. Reconnaissance of the Bahamas and the elevated reefs of Cuba in the steam yacht "Wild Duck"January to April, 1893. Bull. Mus. Comp. Zool. Harvard. 26:81-84.

Banks, K.W. 1999. Analysis of Modern Carbonate Sediments: Lubber's Bank, Abaco, Bahamas. M.S. Thesis. Florida Atlantic University, Boca Raton, Florida, USA. 104 p.

Broecker, W. S. and Takahashi, T. 1966, Calcium carbonate precipitation on Bahama Banks: Journal of Geophysical Research. 71:1575-1602.

Carew, J.L. and Mylroie, J.E. 1997. Geology of the Bahamas, in Vacher, H.L., and Quinn, T.M., eds., Geology and hydrogeology of carbonate islands: Developments in Sedimentology. 54: 91–139.

Cloud, P. E. 1962. Environment of calcium carbonate deposition west of Andros Island, Bahamas,Washington DC, U.S. Geological Survey Professional Papers, 138 p.

Goldberg, W.M. 1983. Cay Sal Bank, Bahamas: A biologically impoverished, physically controlled environment. Atoll Research Bulletin. 273:1-23.

Gordon, H.R. 1993. Radiative transfer in the atmosphere for correction of ocean color remote sensors. In: Ocean color: theory and applications in a decade CZCS experience. Springer, Netherlands, pp 33-77.

Kindler, P., Reyss J.L., Cazala, C. and Plagnes, V. 2007. Discovery of a composite reefal terrace of middle and late Pleistocene age in Great Inagua Island, Bahamas. Implications for regional tectonics and sea-level history Sedimentary Geology. 194:141-147.

Kindler, P., Godefroid, F., Chiaradia, M., Ehlert, C., Eisenhauer, A., Frank, M., Hasler, C.-A., and Samankassou, E. 2011. Discovery of Miocene to early Pleistocene deposits on Mayaguana, Bahamas: Evidence for recent active tectonism on the North American margin: Geology. 39:523–526. doi:10.1130/G32011.1.

Hine, A.C. and Steinmetz, J.C. 1984. Cay Sal Bank, Bahamas -- A partially drowned carbonate platform, Marine Geology. 59: 135-164. DOI: 10.1016/0025-3227(84)90091-4.

Meyerhoff, A.A. and Hatten, C.W. 1974. Bahamas salient of North America: Tectonic framework, stratigraphy and petroleum potential: American Association of Petroleum Geologists Bulletin.58:1201-1239.

Milliman, J.D. 1967a. Carbonate sedimentation on Hogsty Reef, a Bahamian atoll. Journal of Sedimentary Petrology. 37:658-676.

Milliman, J.D. 1967b. The geomorphology and history of Hogsty Reef, a Bahamian atoll. Bull.Mar. Sci. 17:519-543.

Morse, J. W., Gledhill, D. K. and Millero, F. J. 2003. CaCO3 precipitation kinetics in waters from the Great Bahama Bank: Implications for the relationship between Bank hydrochemistry and whitings: Geochimica et Cosmochimica Acta. 67:2819-2826.

Morse, J. W., Millero, F. J., Thurmond, V., Brown, E. and Ostlund, H. G. 1984. The carbonate chemistry of Grand Bahama Bank waters - After 18 years another look. Journal of Geophysical Research- Oceans. 89:3604-3614.

Mullins, H. T. and Lynts, G. W. 1975. Plate tectonic origin for the northwestern Bahama Platform. Geol. Soc. America. 7:1207.

Mullins, H. T. and Lynts, G. W. 1976. Stratigraphy and structure of Northeast Providence Channel, Bahamas: Am.Assoc. Petroleum Geologists Bull. 60:1037-1053.

Pitman, W. C., III and Talwani, M. 1972. Seafloor spreading in the North Atlantic: Geol.Soc. America Bull. 83:619-646.

Pitts, P .A. and Smith, N.P.. 1993. Annotated summary of temperature and salinity data from the vicinity of Lee Stocking Island, Exuma Cays, Bahamas . CMRC Tech. Rept. No. 93-3, Vero Beach, FL.

Purdy, E. 1963. Recent calcium carbonate facies of the Great Bahama Bank.2. Sedimentary facies: Journal of Geology. 71:472-497.

Purkis, S.J. and Klemas, V. 2011. Remote Sensing and Global Environmental Change. Wiley-Blackwell, Oxford, 368pp, ISBN 978-1-4051-8225-6 (pbk.)

Purkis, S., Kerr, J, Dempsey, A., Calhoun, A., Metsamaa, L., Riegl, B., Kourafalou, V., Bruckner, A. and Renaud, P. 2014. Large-scale carbonate platform development of Cay Sal Bank, Bahamas, and implications for associated reef geomorphology. Geomorphology. 222:25-38.

Shinn, E. A., Steinen, R. P., Lidz, B. H. and Swart, P. K. 1989. Whitings, a sedimentologic dilemma: Journal of Sedimentary Petrology. 59:147-161.

Sullivan Sealey, K. and Bustamante, G. 1999. Setting geographic priorities for marine conservation in Latin America and the Caribbean. The Nature Conservancy, Arlington, Virginia.146 p.

Traverse, A. and Ginsburg, R. N. 1966. Palynology of the surface sediments of Great Bahama Bank, as related to water movement and sedimentation.: Marine Geology. 4:417-459.

Trumbull, W.J. 1988. Depositional History of a Windward, Open Marginal Lagoon: Northern Great Bahama Bank. M.S. Thesis, University of North Carolina at Chapel Hill, 122 p.

White, B., Curran H.A. and Wilson, M.A. 1997. Bahamian Sangamonium coral reefs and sea level change. Proc 8th Symp on the Geology of the Bahamas and Other Carbonate Regions. 196-213.