Workshop on Telepresence-enabled Exploration of the Caribbean Region
White Paper Submissions

Ocean Exploration Trust

October 5, 2012

Contents

1 Overview **4**

2 Region 1: Yucatán to Bahamas **6**
2.1 Yucatán continental slope and Yucatán basin 6
2.2 Relict Reefs 8
2.3 Campeche and Yucatán Escarpments 9
2.4 Escarpment biodiversity along the Campeche Bank 11
2.5 Offshore sinkholes and caves Yucatán Mexico 13
2.6 Yucatán Strait 14
2.7 Chinchorro Bank Biosphere Reserve 16
2.8 Shipwrecks of the Belizean Cayes & coastal deep waters 18
2.9 Belize Barrier Reef and the Gulf of Honduras 19
2.10 Oil & gas cold seep benthic communities 22
2.11 Exploring hidden ecosystems in the Straits of Florida 23
2.12 The Exuma Sound 26
2.13 North Bahamas to Dominican Republic 29
2.14 Using ROVs to explore Bahamas Blue Holes 31
2.15 Mesophotic coral ecosystem 32

3 Region 2: Cayman Rise to Greater Antilles **35**
3.1 Mid Cayman Rise 36
3.2 Cayman Trough 37
3.3 Gonave Bay, Haiti 37
3.4 Bobadilla's Fleet 39
3.5 Mona Passage, Puerto Rico 40
3.6 Mona Channel 42
3.7 Puerto Rico Trench and Muertos Trough 44
3.8 Glacial Shorelines and Reefs on Insular Slopes 46
3.9 Corals as an indicator of SST Variation 48
3.10 Anegada-Jungfern Passage Complex 50

3.11 U.S. EEZ around Puerto Rico and the Virgin Islands . . . 52
3.12 Spawning aggregation of mutton snapper . . . 55
3.13 Exploration of deep water fauna off the Virgin Islands shelf . . . 57

4 Region 3: Caribbean Basin 59
4.1 Bay Islands, Honduras . . . 59
4.2 Chicxulub Ejecta Impacts . . . 62
4.3 Caribbean Margin of Nicaragua . . . 63
4.4 Oil Exploration . . . 64
4.5 Regional tectonics, Geophysics . . . 65
4.6 Colombian Caribbean deep water coral communities . . . 67
4.7 Islas del Rosario y San Bernardo . . . 69
4.8 Sinú Belt, Columbian Basin, S. Caribbean . . . 72
4.9 Bonaire, Mesophotic reefs and tsunami deposits . . . 75
4.10 Trinidad & Tobago Fish and Oil . . . 78

5 Region 4: Lesser Antilles 80
5.1 Submarine slopes of Soufriere Hills volcano, Montserrat, Lesser Antilles . . . 81
5.2 ROV Exploration of submarine debris avalanche deposits . . . 83
5.3 The Eastern Caribbean . . . 87
5.4 Aves Ridge . . . 92
5.5 Qualibou Caldera, Saint Lucia, Lesser Antilles . . . 93
5.6 Grenada undersea volcanoes and adjacent island slopes . . . 95
5.7 Kick'em Jenny submarine volcanic field, Grenada, Lesser Antilles . . . 97
5.8 Trinidad Barbados seep province . . . 100

6 Caribbean-wide 103
6.1 Steep slopes of Cayman and Puerto Rico . . . 104
6.2 Benthic-pelagic coupling . . . 106
6.3 Caribbean Seamounts . . . 108
6.4 Naval Craft in the Caribbean . . . 110
6.5 Deep sea corals . . . 112
6.6 Deep water sponges and gorgonians . . . 116
6.7 Biofluorescence/Bioluminescence . . . 118
6.8 Former CARICOMP marine laboratory network sites . . . 120
6.9 Ciguatera Fish Poisoning in the Caribbean . . . 122
6.10 Ciguatera Fish Poisoning . . . 123
6.11 Deep reefs . . . 124
6.12 Marine Mammals . . . 126
6.13 Fish Kills and Coral Bleaching . . . 127
6.14 Burrow morphology and ichnofacies . . . 128

7 Technology **130**
7.1 Caribbean Sea 130
7.2 Technology development 131

8 Terrestrial/Shallow **133**
8.1 Novel Antibiotics and Anticancer Drugs 133
8.2 Lost pre-Columbian landscapes of the Caribbean 134
8.3 Historical Ecology 136

List of Figures

1.1 Map of target areas in the Caribbean Region. Yellow: Region 1. Red: Region 2. Blue: Region 3. Green: Region 4. 5

2.1 Map of target areas in Region 1: Yucatán to Bahamas 6

3.1 Map of target areas in Region 2: Cayman Rise to Greater Antilles 35

4.1 Map of target areas in the Bahamas 59

5.1 Map of target areas in the Lesser Antilles Region 80

6.1 Map of target areas that span several regions of the Caribbean 103

Chapter 1

Overview

The Ocean Exploration Trust is pleased to announce a regional conference in October 2012 to enable stakeholders interested in exploration of the Caribbean region to discuss which specific areas are the most promising for making new discoveries and for developing collaborative region-wide research programs based upon these discoveries.

The workshop builds upon a workshop hosted by the National Oceanic and Atmospheric Administration (NOAA) Office of Ocean Exploration and Research (OER) in May 2011, at the University of Rhode Island Graduate School of Oceanography. That workshop focused on the Atlantic Ocean, Caribbean Sea and Gulf of Mexico. Fifty scientists, archaeologists, and agency representatives reviewed a series of white papers that had been solicited to define the biggest priorities for exploration in these regions, with 12 papers submitted for work in the Gulf of Mexico and 11 in the Caribbean Sea. Some of the papers extended or built upon existing primary research, and some of the papers laid out a more general program to survey unexplored terrain.

The 2012 workshop and resulting plan will support the mandate to strengthen our understanding of the Caribbean Sea through the use of mapping, deep submergence, and telepresence technology. The document will be used by the Nautilus Exploration Program to develop field programs during the 2013 field season period that *Nautilus* is operating in the region. The planning document will also provide valuable input to NOAA OER as it prepares for field programs on the NOAA Ship *Okeanos Explorer*, which will be operating in the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea for the foreseeable future. Operating two ships of exploration in the region will be key to successful implementation of the planning document but we also anticipate that other research platforms, perhaps from regional countries, can be enlisted to undertake exploration programs based on the plan.

In addition to identifying key priority areas for exploration, the planning process will include further development of the "Doctors on Call" model of engaging a broad range of scientific expertise through live satellite-based interaction with the ships of exploration. We also plan to include education and outreach programs in the plan for this region. This telepresence capability will enable us to work with partner countries to foster real-time interaction by their research communities and stakeholders, and open opportunities for engaging the next generation of regional scientists. Because of the possibility for live access to field programs, we expect that they will generate broader public support for and interest in exploration of the Caribbean Seas and ocean exploration in general.

For more information on the *Nautilus* and *Okeanos Explorer* exploration programs, please see our latest supplement to *Oceanography*, which can be found here:
http://www.tos.org/oceanography/archive/25-1_supplement.html

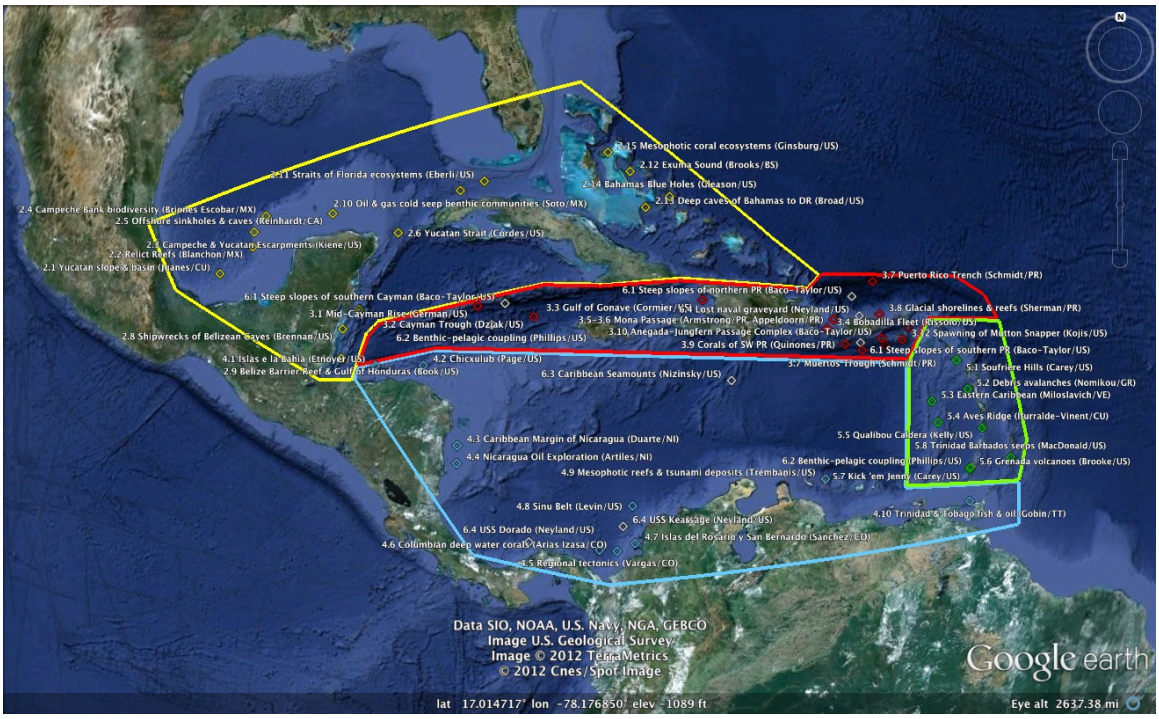

Figure 1.1: Map of target areas in the Caribbean Region. Yellow: Region 1. Red: Region 2. Blue: Region 3. Green: Region 4.

Chapter 2

Region 1: Yucatán to Bahamas

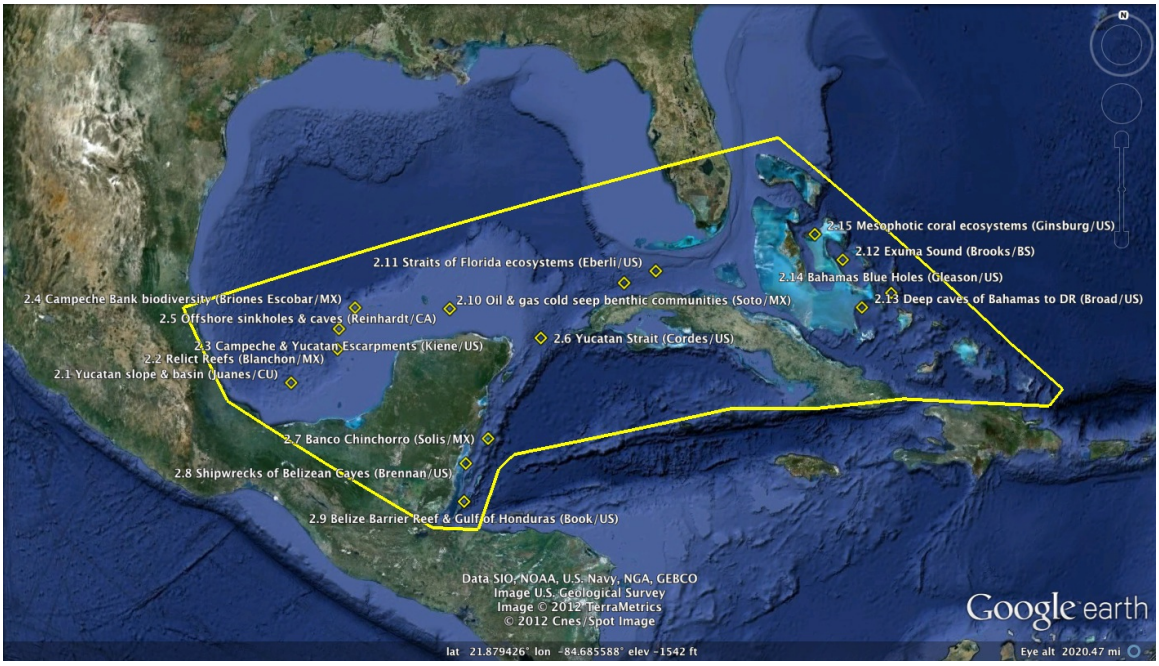

Figure 2.1: Map of target areas in Region 1: Yucatán to Bahamas

2.1 Yucatán continental slope and Yucatán basin

Author and collaborators

Jose Luis Juanes juanes@oceano.inf.cu
Institute of Oceanology. Ministry of Science, Technology and Environment. Cuba

Manuel Iturralde-Vinent iturralde@ama.cu
Sociedad Cubana de Geología

Why this area may be of interest

Biology The discovery of new species of fishes, benthic organisms and microorganisms contributes to marine biodiversity knowledge on the continental slope and basin. Marine macro and microorganisms are also a potential source for the production of biologically actives substance that would not be observed from terrestrial organisms.

Geology The study of geological structures and sediments on the continental slope contribute to understanding the shelf origin. The information obtained may be useful to explore mineral resources, gas, and oil. Knowledge of the area is essential to understand the geologic constitution of the basin and deep, a key aspect to the understanding of the origin of the Caribbean.

Chemistry The chemical characterization of water and sediments contribute to understanding the particularities of the environmental conditions on the continental slope and basin.

Physical oceanography The physical characterization of water and current measurements at different levels contribute to understanding the particularities of the environment conditions on the continental slope and basin.

Archaeology/history

Other

Rationale for exploration in the target area While the continental slope in the Gulf of Mexico has been explored from different disciplines and objectives, this target area has been much less studied despite its potential natural resources.

Knowledge of this area is essential to understanding the geological constitution of the basin and a key aspect to the understanding of the origin of the Caribbean. The location and characterization of geological structures like submarine canyons will contribute to understand the ways through which the sand erodes from beaches is carried out to continental slope. This result will be useful to elaborate a compressive scheme of sediment transport on the shelf.

Overview of target area The Peninsula of Yucatán is located in the southeast of Mexico and constitutes a wide territory projected northwest closing the Gulf of Mexico waters. North of Yucatán, the Gulf of Campeche constitutes a wide platform of shallow waters and relatively gentle continental slope while to the southeast the shelf is narrow and the continental slope becomes much steeper. The deep stretch of Yucatán floor is enclosed as part of this area where geological and oceanography processes influence over Gulf Stream.

Summary of what is known about the target area All around the deep ocean basins, separating them from the continents is the continental slope, the largest relief feature of the Earth. Due to its extension and inaccessible location the continental slope still holds many secrets to science. Particularly in the Caribbean, not many continental slopes have been studied and their detailed exploration is beginning in our days. The most common origin for the shelf and slope is that they result from the building out of sediment from the land, the forest beds of a vast deltaic-type of sedimentation. In the case of the Yucatán continental slope, where there are no important rivers, the contribution of sediment from coastal erosion constitutes an important source of sediment to continental slope. Yucatán basin is a wide area which has never been drilled and only few dredge samples have been recovered from its interface with the ridge and valley section along the western margin of the Yucatán peninsula. Some old Russian shallow seismic indicate the occurrence of acoustic basement highs in the Yucatán basin, which may be an interesting target for drilling. In fact, Rosencrantz and others have speculated that the basin yields a volcanic basement and the deep a young oceanic basement, but there are no samples or cores to test those views.

The characterization of sediments allow us to understand better the processes of formation of the continental slope and how take place these process in our days. Geological structures like submarine canyons become an important way through which the currents carry out sand off the shelf.

2.2 Relict Reefs

Author and collaborators

Paul Blanchon blanchon@cmarl.unam.mx
UNAM ICML. Puerto Morelos

Why this area may be of interest

Biology

Geology

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area

Overview of target area During the last 20 ka, sea-level has risen more than 120 m and coast and coastal environments have followed leaving a rich legacy of relict deposits. The relict remains of former coral reefs are particularly important archives because they record the rate and magnitude of that rise, as well as the change in environmental conditions. The exploration for relict reefs, however, is in its early stages, and has so far concentrated on tectonically active areas, or areas where modern subsidence is occurring, such as Barbados, Hawaii, and Tahiti (Blanchon 2011). Yet relict reefs should be present in all stable areas of the Caribbean where modern reef building presently occurs.

Two stable areas in particular are attractive targets for discovering more relict reef structures, including the Chinchorro and Campeche Banks. Both banks are isolated from terrestrial input and should have developed significant reef structures during the lowstand of sea level 14.5 ka ago and the subsequent rapid rise. Their records of environmental conditions and the sea-level rise rate should be unbiased by geothermal subsidence or neotectonic uplift and so provide a clear picture of how fast sea level rose in the past and, by analogy, how fast it might rise in the future.

Summary of what is known about the target area

2.3 Campeche and Yucatán Escarpments

Author and collaborators

William Kiene William.Kiene@noaa.gov
NOAA's Office of National Marine Sanctuaries, Galveston TX

Wes Tunnell Wes.Tunnell@tamucc.edu
Harte Research Institute in Corpus Christi

Elva G. Escobar-Briones escobri@cmarl.unam.mx
Universidad Nacional Autonoma de Mexico

Pedro Alcolado alcolado@ama.cu

Jose Espinosa espinosa@oceano.inf.cu

Manuel Ortiz ortiztouzet@yahoo.com

Rodolfo Claro rodolfo_claro@yahoo.es

Julio Baisre baisre@fishnavy.inf.cu

Porfirio Alvarez-Torres alvarez.porfirio@gmail.com
Gulf of Mexico Large Marine Ecosystem, United Nations Industrial Development Organization (UNIDO)

Why this area may be of interest

Biology Biological community exploration, habitat affinities and connectivity to Gulf of Mexico and Caribbean

Geology Escarpment lithology and potential for seeps that support chemosynthetic communities

Chemistry Undetermined at this time

Physical oceanography Deep Loop Current conditions

Archaeology/history Early Mayan and other peoples of the Yucatán were known to navigate this region between Yucatán and Cuba.

Other Building tri-national collaboration with Mexico and Cuba to better understand our shared ocean environment

Rationale for exploration in the target area I see this as a great opportunity to use the OET's technology and telepresence abilities to collaborate with Mexican and Cuban colleagues and explore some unvisited and potentially very interesting parts of the Gulf of Mexico and Yucatán Channel. The biological communities in deep and shallow water in the area are essentially linked to Gulf of Mexico ecosystem through the Loop Current and to the rest of the Caribbean.

I was closely engaged with the recent Gulf of Mexico *Okeanos Explorer* expedition. The ability for Internet access to the live feeds and the collaboration tools is exceptional. I envision a unique opportunity to engage researchers and students throughout all three countries for a high-profile combined science and education mission.

Overview of target area The Campeche and Yucatán escarpments straddle and cross the Mexico and Cuba EEZs through the Yucatán Channel and Gulf of Mexico. This could include areas north and northeast of the Yucatán Peninsula and features along a transect from near Banco Chinchorro off southeast Yucatán to eastern tip of Cuba. Several knolls and pinnacles could also be explored for their biological and geological characteristics. Also of interest, and an area for tri-national exploration is the "Eastern Gap" of international waters adjacent to the Mexico, US, and Cuba EEZs. This area north of the Yucatán Escarpment is deep sea floor with few known topographic features. The opportunity to map and jointly explore this area would be unprecedented.

Summary of what is known about the target area Unexplored biologically. Some sub-seafloor geological studies as part of Deep Sea Drilling Program and for oil exploration.

2.4 Escarpment biodiversity along the Campeche Bank

Author and collaborators

Elva G. Escobar Briones escobri@cmarl.unam.mx
Universidad Nacional Autónoma de México

Ian R. Mac Donald imacdonald@fsu.edu
Florida State University

Darryl Felder lf4517@louisiana.edu
University of Louisiana at Lafayette

Adolfo Gracia Gasca gracia@unam.mx
UNAM ICML

Francisco Solís fasolis@cmarl.unam.mx
UNAM ICML

Paul Blanchon blanchon@cmarl.unam.mx
UNAM ICML. Puerto Morelos

Manuel Ortiz Touzet ortiztouzet@yahoo.com
FES Iztacala UNAM

Why this area may be of interest

Biology

Geology The origin of the escarpment and the variability from an escarpment with (Northern Caribbean) and without borderland (Gulf of Mexico) along the Campeche Bank.

Chemistry That defined by depth, geographic variability, and influx of organic carbon

Physical oceanography Hydrographic control of the primary productivity derived carbon and the hydrodynamic forcing factors defining zonation patterns in the community along the escarpment in the Campeche Bank.

Archaeology/history None

Other Generate baseline data for better management of potential energy resource extraction.

Rationale for exploration in the target area Escarpments are subject to sediment slumping in the immediate abyssal plain affecting benthic soft sediment communities and most probably habitats along the escarpment.

Overview of target area The Bank of Campeche is a well defined-physiographic structure extending from 19° to 23°N and from 89° to 93° W (Gore 1992), which expands off Laguna de Términos in the Gulf of Mexico to Chinchorro Bank and is characterized by a pronounced slope, with exception of the Campeche Canyon. The Escarpment of Campeche delimits the Bank to the north along the 400 km wide continental shelf off Yucatán, to the south the narrow shelf off the states of Yucatán and Quintana Roo, to the east by the Yucatán Channel. The escarpment benefits from the upwelling from the Yucatán current. The Bank is a carbonate basement of biogenic origin and anhidrates from the Yucatán group with a slope that varies from 2° to over 45°.

Summary of what is known about the target area The Biodiversity and Macroecology Laboratory lead by Prof. Escobar has assessed the diversity patterns and variability in the Gulf of Mexico and northern Caribbean Sea including hypotheses related to evaluate the effects of escarpments on the biodiversity.

The first collections along the Bank of Campeche and the borderland escarpments along the northern Caribbean Sea were made in joint collaboration by UNAM and Harbor Branch Oceanographic Institute (HBOI) with Dr. R. Grant Gilmore in 1991 that included 33 dives using the Johnson Sea Link.

The ongoing Sigsbee cruises from ICML UNAM have allowed us to study the biological diversity of the megafauna occurring on the Escarpment ledges along the Campeche Es-

carpment, as well as the effect slumping of sediment accumulated along the margin on the abyssal infaunal communities of the Campeche Bank.

Other efforts on escarpment communities carried out in the region include the DGoMB Study conducted from 2000-2002, those by Drs. I.R. MacDonald (formerly at GERG) and W. Bryant (TAMU, Oceanography), investigating the fauna and geology of the lower Sigsbee and Florida Escarpment using the deep submergence vehicle (DSV) Alvin. Studying the escarpment biological diversity and its variability along the depth and geographical gradients has been a real challenge when retrieving samples from the sea surface with conventional samplers, the exception being our collaborative work with HBOI.

The use of an integral, manned-submersible component with unique deep sampling and observational capabilities such as those from an ROV or a DSV could be of great benefit for acquiring new knowledge. Escarpment biota will contribute to knowledge of biodiversity hotspots, its understanding to dispersion processes of the species in the western tropical Atlantic.

2.5 Offshore sinkholes and caves Yucatán Mexico

Author and collaborators

Eduard Reinhardt ereinhar@mcmaster.ca
McMaster University

Dominique Rissolo dominique@waittinstitute.org
Waitt Institute

Patricia Beddows patricia@earth.northwestern.edu
Northwestern University

Why this area may be of interest

Biology Cave dwelling organisms

Geology Submerged shorelines and the coastal environment

Chemistry Groundwater hydrology and the shelf environment

Physical oceanography Cave formation

Archaeology/history Early evidence of peopling of North America

Other

Rationale for exploration in the target area Exploration would utilize sidescan sonar, multibeam bathymetry, and seismic surveys to find submerged sinkholes and cave systems offshore the Tulum area where the other Paleo-Indian remains were found. The sinkholes would be cored to determine sea-level rise and reconstruct the coastal environment while the caves would be explored using ROV's and diver surveys. The caves could potentially contain human and faunal remains that are older than previously discovered. ROVs could provide initial survey results but deep diving would be needed for any extensive exploration (penetrations). I have been working in the area for many years, and have a group of divers that have explored and mapped the caves on land, but who have also explored offshore areas. In order to cover any meaningful survey, we need extensive mapping of the target area to focus our efforts.

Overview of target area The Yucatán Peninsula is a karstic platform with extensive cave systems that formed during Quaternary sea-level low-stands which have now been flooded with rising Holocene sea-level. Over the past 20-30 years, exploration on the eastern margin of the Yucatán has shown that these caves are extensive networks often 10-100s kms long which likely continue into the offshore area. The Yucatán shelf is relatively narrow on the eastern side and covered with reef systems, but cave conduits should be present and free of sediment on the platform wall to allow access for exploration.

Summary of what is known about the target area In the past few years, Yucatán caves have yielded several well-preserved articulated Paleo-Indian skeletons with a recent discovery near Tulum of a young girl 18-19 years old (Hoyo Negro). She was found in a deep submerged cave (160 ft deep) along with an extensive array of other faunal remains (mastodon, sloths, jaguars, etc.). Radiocarbon dates are still pending but she could be similar in age (estimate approx. 10,000 years BP) to other skeletons found in the area (Young Man of Chan Hol; this skeleton was recently stolen). The Yucatán cave systems represent repositories for human and faunal remains that have no preservation potential in the weathered soils on the surface. Many early human habitations sites were coastal but are now submerged; we have little information on the coastal paleogeography during the last glacial lowstand and how these individuals interacted with the landscape.

2.6 Yucatán Strait

Author and collaborators

Erik Cordes ecordes@temple.edu
Temple University

Andrea Quattrini andrea.quattrini@temple.edu
Temple University

Why this area may be of interest

Biology Deep-water corals

Geology Mapping of sill depth and high relief topographic features

Chemistry Carbonate system, including alkalinity/pH

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area The species composition of the coral communities in the deep Yucatán Strait will contribute a significant piece of the biogeographic puzzle of the region. We are learning more and more about the deep coral communities of the Gulf of Mexico, and also the Caribbean Sea, but the knowledge of the connectivity between these two basins remains poorly understood. A key first step will be to augment our oceanographic knowledge of the strait and to conduct the first biological surveys of this area.

Overview of target area The Yucatán Strait provides the connection between the Caribbean Sea and the Gulf of Mexico. It consists of very steep walls rising from a sill depth of approximately 2,000 m. Flow through the strait is primarily to the north, but bidirectional flow has been reported in the deeper parts of the feature. This flow pattern represents the only deep-water connection of the Gulf of Mexico since the primary outlet for Gulf waters is through the relatively shallow (700 m) Florida Straits.

Summary of what is known about the target area There is decent literature on the physical oceanography of this region, with studies of the current patterns and the development of internal waves in the strait. However, even the absolute sill depth of the strait remains a matter of some debate. There are no studies of the biology of this key area that connects two marginal basins and two different faunas.

2.7 Chinchorro Bank Biosphere Reserve, Mexican Caribbean

Author and collaborators

Francisco Solís fasolis@cmarl.unam.mx
UNAM ICML

Why this area may be of interest

Biology Because of its unique marine habitat quality, conservation and architectural complexity it is expected to hold high concentrations of endemic species of invertebrates and fish. A total of 95 coral species have been reported in the area, together with 35 sponges, 78 gastropods, 26 bivalves, and six crustaceans. There are approximately 213 species of marine vertebrate species recorded. 135 species of algae and other aquatic flora have been reported so far. Research has increased in the Banco Chinchorro reef complex of Mexico at a very slowly rate (Jordan and Martin, 1989; Novak et al., 1992; Torruco and Gonzalez, 1992, 2000a,b; Torruco et al 2003), though much of it has concentrated on only a few of the species groups within the reef communities. Very few studies integrate species interrelations with their environmental framework, even though environmental parameters are of vital significance. A more detailed exploration needs to be done specially on the deepest areas of the area.

Geology None

Chemistry None

Physical oceanography None

Archaeology/history Most of the reef lies just beneath the surface, and during the squalls in the area, is scarcely visible and has claimed over 20 known ships, from the 17th through the 20th centuries. Close to the last one, is located a wreck from the 18th century called The Forty Cannon Wreck. This wreck lies at a depth of 8 m inside the reef on a large patch of coral sand. The site is marked by the presence of 40 cast-iron cannon resting on the sea-bed and a large ballast spill 40 m in diameter (Irion 1978).

Other Coastal development in the Caribbean poses a major threat to coral reef ecosystems and mangroves. Coastal areas of the Mexican Caribbean are no exception and to avoid coral reef degradation by massive tourism and overfishing, Mexican federal and state governments have been working to establish marine protected areas in the Caribbean to protect mangroves and coral ecosystems. Chinchorro Bank Biosphere Reserve (CHBBR) is considered to be a priority conservation area. Coral reef systems of CHBBR support many different species, which are the main component of fisheries

in the area. These fisheries are generally small scale, artisanal and multi-specific; however, economic progress, growing coastal tourism and increased population have led to greater competition for fishery resources and possible overfishing.

Rationale for exploration in the target area

Overview of target area The coral reefs of the Caribbean are highly diverse ecosystems, with high relative species number and abundance (Reichelt 1988). The remote, pristine reefs of the Chinchorro Bank, a threatened Mexican Caribbean atoll, featuring beautiful swim troughs, more than 250 wrecks, and a huge diversity of flora and fauna, are an often mentioned but seldom explored by the scientist in the Mexican Caribbean, just north of Belize. Chinchorro Bank is one of the largest atoll-like reefs in the Caribbean Sea (Jordan and Martin 1987), is an elliptical reef (40 km in length and 18 km wide) located to 30.8 km off the southeastern Yucatán Peninsula (Jordan and Martin 1987). Is has an extensive, shallow reef lagoon, and a marked bathymetric gradient running from south to north (deep to shallow). Chinchorro has three sandy cays (Cayo Norte, Cayo Centro and Cayo Lobos) located on the north, central, and south sides, respectively. At least three sections (reef areas) are recognized according to the degree of current and wave exposure: a) Windward, having a platform with 3-8 inclination degrees reaching 60 m in depth and comprising a well developed reef crest; b) Reef Lagoon, having an open and shallow lagoon, varying from 7 to 9 m in depth at southern areas and 2 to 3 m in depth towards northern areas, with patch reefs and coral knolls gradually decreasing in number and size from South to North; and c) Leeward, without a developed reef crest with reef structures less prominent than those in the windward.

Since 1966, Chinchorro Bank has been an important zone for the exploitation of spiny lobster (*Panulirus argus*) and queen conch (*Strombus gigas*), which are the most important fisheries on this atoll (Sosa-Cordero et al. 1993). The depletion of populations of both *P. argus* and *S. gigas* is evident (Sosa-Cordero 1994). Ch/'avez and Hidalgo (1988) concluded that fisheries are the only antrophogenic impact in Chinchorro Bank, and qualified the effect as chronic. In 1996 Chinchorro Bank was decreed by the Mexican Government as a Biosphere Reserve, one of the categories of marine areas protected in Mexican legislation. However, there is no management plan to date. The southern portion of the Mexican Caribbean is scarcely impacted by human activities. However, there are plans for tourist development. These plans include Chinchorro Bank, which will most likely be a favoured destination for domestic and international tourists after the construction of an hotel on Cayo Centro, a mangrove island in the middle of the reef lagoon. Cayo Centro is a hawskbill sea turtle (*Eretmochelys imbricata*) nesting area, and also has a significant population of crocodiles (*Crocodylus acutus*). Since it is clear that the impact of human activities will increase at Chinchorro Bank (anchoring, sewage, collection of specimens, etc.), an

appropriate management plan is needed for the atoll.

The protection provided reefs in protected marine areas in Mexico is essentially ineffective. The Mexican Government and its citizens need to recognize the importance of this natural resource and protect it for future generations.

Summary of what is known about the target area

2.8 Shipwrecks of the Belizean Cayes & coastal deep waters

Author and collaborators

Michael Brennan mlbrennan@gso.uri.edu
University of Rhode Island

Dr. Leslie Shaw lshaw@bowdoin.edu
Bowdoin College

Dr. Eleanor King emking@howard.edu
Howard University

Dr. Jaime Awe jaimejawe@gmail.com
Institute of Archaeology, Belize

Why this area may be of interest

Biology Exploration of deeper areas of coral reefs

Geology Seafloor mapping

Chemistry

Physical oceanography

Archaeology/history Search for deep water shipwrecks off Belize Cayes

Other

Rationale for exploration in the target area The eastern coast of the cayes drop off quickly into waters deeper than 100 m off the edge of the barrier reef. Between here and some of the offshore reefs are large areas of seafloor in the depth range of 100-800 m, and also in close proximity to Ambergris and St. George's Cayes, where naval battles are

reported to have taken place. As little exploration of this coastline has been done in deep water, large-scale multibeam sonar mapping and finer-scale side-scan sonar mapping is important for not only locating and identifying archaeological sites, but also documenting the seabed in general. The targeted region for exploration is also close to the edge of the barrier reefs, so ROV operations could conduct transects upslope to explore the biology and conditions of the reefs.

Overview of target area The coast of Belize consists of an inner lagoon segregated from the Bay of Honduras by a series of barrier reefs in the form of cayes. These islands were a common hiding ground for pirates in the 18th century, as this region of the Caribbean was outside the more heavily trafficked routes and also provided shelter from winds and storms. Colonies in British Honduras are in fact thought to have been originally founded by pirate crews who settled on shore to begin logwood cutting. Belize, formerly British Honduras, was also a heavily contested area between the Spanish and British, who fought for wood resources between Campeche in the Yucatan and Honduras. Sea battles took place between them over the territory, one in particular of note off St. George's Caye in 1798. The culmination of storms, low-lying reefs, and altercations along a disputed coastline, in addition to a lack of exploration here, leads to a great potential for significant cultural finds off the Belizean coast.

Summary of what is known about the target area Underwater archaeology is still in its early stages in Belize, with much of the focus on submerged shorelines along the cayes and in caves. No exploration has been done in deep water. A large number of shipwrecks are well known throughout the coast and cayes and are popular dive sites, particularly those near Ambergris Caye and St. George's Caye, northeast of Belize city. The few wrecks that have been located consist of anchors and cannon from ships that sank on the reefs and are within recreational diving depth.

2.9 Belize Barrier Reef and the Gulf of Honduras

Author and collaborators

Jeffrey Book book@nrlssc.navy.mil
Naval Research Laboratory

Dr. Leandra Cho-Ricketts lricketts@ub.edu.bz
Environmental Research Institute, University of Belize

Dr. Derek Burrage derek.burrage@nrlssc.navy.mil
Naval Research Laboratory

Dr. Ana Rice ana.rice.ctr.es@nrlssc.navy.mil
National Research Council Postdoctoral Research Associate

Dr. Richard Gould gould@nrlssc.navy.mil
Naval Research Laboratory

Why this area may be of interest

Biology The Belize Barrier Reef has great ecological diversity and importance and is part of the Mesoamerican Barrier Reef System, the largest barrier reef in the Western Hemisphere.

Geology Cayman Trench

Chemistry

Physical oceanography This region is characterized by complex circulation patterns influenced by the Caribbean Current offshore, a general cyclonic circulation pattern, high levels of fresh water input, mesoscale eddies and filaments, and topographically influenced local flows.

Archaeology/history

Other The Belize Barrier Reef Reserve System is a World Heritage Site and has been included on the UNESCO List of World Heritage in Danger

Rationale for exploration in the target area Despite the ecological importance of the area and the important role that ocean currents play in its ecology, there has been no in situ program to map the general circulation. Current knowledge is based upon numerical models without data in the coastal regions for validation and assimilation, altimetry which is limited to mapping larger offshore circulation features, remote sensing of sea surface temperature and color which is often limited by cloud cover and unable to map the general coastal circulation, and very limited direct ocean measurements (e.g., 2 WOCE drifters in 2000 and the single mooring done by Ezer et al. in 2009). Basic knowledge is lacking on the currents connecting Honduras Gulf to Glover's Reef to the Turneffe Islands and to the central barrier reef, and on the currents between the Turneffe Islands and the Lighthouse Reef Atoll further offshore.

Establishing a series of basic transect lines instrumented by current moorings from the continental shelf to the offshore regions and atolls would comprise basic exploration of the unknown circulation patterns and would provide a baseline for understanding larval and nutrient transport vital to the reefs. Investigating the oceanographic and bathymetric patterns of Belize's coastal and marine environment was designated as a priority area in

the Belize National Environmental and Natural Resources Management Research Agenda. Furthermore the capability exists to provide the first maps of the river discharge and fate of low saline waters for the region through use of NRL's high-resolution (1 km) airborne Salinity, Temperature and Roughness Remote Scanner (STARRS) which could be deployed in the region. Also, the Hyperspectral Imager for the Coastal Ocean, currently flying on the International Space Station and operated by NRL could be used to derive optical properties and suspended sediment loads and map coastal eddies and filaments in very high resolution (100m). Together these remote sensing capabilities could be very useful in combination with a basic program to map the physical oceanography of the region. Any such exploration study should naturally include and engage the scientists of the region and their students and promote future exploration and environmental monitoring of the Western Caribbean.

Overview of target area The Belize Barrier Reef System comprises roughly one third of the Mesoamerican Barrier Reef System and includes a large lagoon, fringing coral reef, barrier reef, and three major coral reef atolls. The Gulf of Honduras is formed by a 90 degree turn in the Western Caribbean coastline from Honduras to Guatemala to Belize. It is a dilution basin in which river and terrestrial runoff is mixed and distributed into the surrounding oceanic waters.

Summary of what is known about the target area A limited number of studies based mainly on numerical modeling results and satellite observations all indicate that the circulation of the region is complex with mesoscale and sub-mesoscale variability superimposed on the general circulation. This circulation includes the Caribbean Current offshore of coast and the region cyclonic circulation of the Gulf of Honduras and Belize coastal region. Ezer et al. (Ocean Dyn. 2005) use a numerical model to show how eddies and changes in the position of the Caribbean Current can act to reverse the flow between the barrier reef and offshore atolls for particular events. Chérubin et al. (report to the World Resources Institute, 2006) used remote sensing data to demonstrate that river discharging locally from Belize and regionally from Honduras both have a strong impact on the Belize coral reefs. Additionally, Ezer et al. (Ocean Dyn. 2011) who studied the southern Belize reef promontory of Gladden Spit, show a strong tendency for excitation of internal waves and high frequency flow variations by tides and remote eddies. Although there has been a significant amount of mapping done on individual coral reef habitats, the effects of the regional circulation on larval and nutrient transport and the ecological health of the coral reef systems are unknown.

2.10 Oil & gas cold seep benthic communities

Author and collaborators

Luis Soto lasg@cmarl.unam.mx
Instituto de Ciencias del Mar y Limnología, UNAM

Aldo Croquer croquereef@gmail.com
University of Venezuela

Arsenio Areces areces@oceano.inf.cu
Instituto Oceanologico

Diego López Veneroni dglopez@imp.mx
Mexican Petroleum Institute

Why this area may be of interest

Biology

Geology Southern Straits of Florida

Chemistry

Physical oceanography

Archaeology/history

Other Biogeochemical of deep sediments

Rationale for exploration in the target area The insular slope of the target area has the characteristics of an erosional slope without significant deposition. Unfortunately, no sedimentation rate has been estimated in the Straits. Future research in this interesting region must seriously consider conducting direct submersible observations to further examine local fluid chemistry and seep community composition in one of the deepest seep sites near the Gulf of Mexico.

Overview of target area The southern Straits of Florida lie under the influence of the Florida Current, the Yucatan Current and the southerly-flowing surface Cuban Counter-Current. In the water column at least four water masses can be recognized. The area of study includes the insular slope seabead of the southwestern channel of the Florida Straits between 23°23' 57" N, 83°06' 47" W and 23°27' 39" N, 81°44' 37" W off Bahía Honda and Puerto Escondido, Cuba.

The deep sea floor in the proposed studied area has remained unexplored for several decades and there are perhaps good evidence of finding cold seep habitats similar as those found in the Florida Scarpment.

What is known about the target area Recent initiatives of searching for fossil fuels in the seabed have renewed interest in studying the deep sea processes such as erosion of surficial sediments, new sedimentological depositional models, organic particle fluxes, and benthic biodiversity (Gaumet and Letouzey 2002; Chambers et al.2003; Magnier et al.2004; Piñón 2006).

Previous geophysical survey of the area of study (Soto, et al. 2011 submitted) indicated the presence of topographic features on the northwestern coast of Cuba such as sediment mounds, numerous sink holes, and a complex of knolls on the slope associated perhaps to collapsed karstic structures that may be indicative of a seeping oil and gas province. Cold seeps are associated with carbonate mounds, coral reefs, pockmarks, mud volcanoes, and seamounts (Mazzini et al. 2003). According to these authors, in conventional cold seeps fluids escape through permeable fractures and faults which act as conduits for seepage. These types of systems have been documented with different approaches at numerous sites at passive and active margins in the Atlantic ocean, Eastern and Western Pacific oceans, and in the Mediterranean Sea (Paull et al. 1984 and 1985; Kennicutt et al. 1985; Kulm et al. 1986; Sibuet and Olu 1998; León et al. 2007).

2.11 Exploring hidden ecosystems in the Straits of Florida

Author and collaborators

Gregor Eberli geberli@rsmas.miami.edu
RSMAS - University of Miami

Donald F. McNeill dmcneill@rsmas.miami.edu
RSMAS - University of Miami

Mark Grasmueck mgrasmueck@rsmas.miami.edu
RSMAS - University of Miami

Sam Purkis purkis@nova.edu
Nova Southeastern University

Charles G. Messing messingc@nova.edu
Nova Southeastern University

John Reed jreed12@hboi.fau.edu
Harbor Branch Oceanographic Institute - Florida Atlantic University

Why this area may be of interest

Biology Deep-water ecosystem diversity and provenances

Geology Slope instability with potential tsunami threat from mass wasting. Drift deposits from ocean currents.

Chemistry Water mass differences in relation to benthic current pattern. Methane gas escape from sea floor

Physical oceanography In particular the benthic currents in the Straits of Florida that are characterized by countercurrents and eddies.

Archaeology/history Supposedly the Straits of Florida (off Bimini) is the site of Atlantis

Other

Rationale for exploration in the target area The deep portion of the Straits of Florida includes a broad underexplored cold-water coral province that appears to be more diverse than other known cold-water areas. In some ways this ecosystem can be compared to the tropical rainforest. The working hypothesis is that this abundance and diversity is possible because of the favorable interplay between geological, chemical, and oceanographic processes.

The tasks to test this hypothesis in the target area are to: 1) describe and quantify the faunal diversity; 2) assess the sedimentologic processes and it products that aid in creating the habitat for this lush ecosystem; 3) assess the current pattern and relate it to the sediment distribution and larvae transport and evaluate if the current pattern is responsible for creating the observed faunal provinces; and, 4) capture the chemical differences in the water masses transported by the various bottom currents and relate them to the faunal assemblages in each area.

A second reason for exploration in the target area is the potential hazard from the slope failure. These slope failures create slump scars of up to 100 m in height over distances of 10-15 km. The one slope failure documented so far released slope material that travelled over 20 km into the basin. Such catastrophic slope failures create tsunamis. Incipient slope failures have been observed on seismic data but their lateral extents have not been documented. Documenting and measuring these incipient slope failures, which are expressed as small displacements on the sea floor, will help evaluate their risk by modeling the potential volume of failure.

A third reason for exploration is the documented pockmarks in the Straits of Florida. These methane-releasing sites might harbor another biological community that receives its energy from methane. Methanogenic communities have not been documented yet, because no concentrated effort has been made to dive into these holes, which reach 10 m deep and 500 m wide.

Although the entire deep Straits of Florida is a possible target area, the site where the currents, sedimentologic, and biologic processes are thought to interact most intensively is the cross-section between Cay Sal Bank, a triangular outlier of the Bahama Platform, and the Pourtalès Terrace. Here, the entire mass transport of the Florida Current, a mean of 30 million cubic meters of water per second, flows through a channel only 42 km across.

Overview of target area The Strait of Florida is a reversed L-shaped trough that separates the Florida Peninsula from the Bahama Platform and Cuba. This small channel on the edge of the Atlantic Ocean serves as both conduit and barrier, and so forms an important biodiversity hotspot. The Strait's primary hydrographic feature, the Florida Current, creates the conduit. Hidden below this warm surface current is an underexplored seascape of steep slopes, thick current drift deposits and a luxurious ecosystem of cold-water corals and associated fauna in water depths below 300 m.

Geologically, the Straits are characterized by steep marginal slopes that form a deep seaway between Cuba and the Florida Keys and to the north between Florida and the carbonate platforms of the Bahamas. On the Florida flank lie the broad karstic carbonate Miami and Pourtalés Terraces. Along both margins of this seaway, slope instabilities can generate large mass gravity flow deposits that pose a tsunami threat to adjacent islands. Today, large flows and blocks form habitats for deep-water fauna, especially cold-water corals. In addition, the seaway floor is, in places, dotted with pockmarks generated by catastrophic release of methane gas. Ocean currents influence both sedimentation and biological activities. They are important for the distribution of sediment but also for separating the ecosystems into faunal provinces. The combination of water mass properties within the Straits and the features of its margins create an important biogeographic boundary where different deep faunas meet to contribute to the greatest known species richness in the western Atlantic Ocean; the Straits also houses more endemic marine fish species than anywhere else in the region. As such, the deep portions of the Straits of Florida provide the unique opportunity to study the interaction of the geological, chemical, and physical oceanographic processes on the teeming ecosystem below the Florida Current as it joins the Gulf Stream.

What is known about the target area The current knowledge of the deep portion of the Straits of Florida is largely based on geophysical data (seismic, and new multibeam echosounder data), older trawl and dredge data, and a limited number of submersible dives.

AUV and shipboard multibeam data reveal highly variable slope and basin morphologies that are sculptured by geologic and biological processes. The geologic processes include off-bank transport of sediments that are partly redistributed by currents to form large-scale drift deposits. These perennial processes are interrupted by large-scale (10's of km) slope failures, which produce spectacular escarpments up to 100 m high and widespread debris fields at the toe of the slope. Cold-water corals settle on the debris and in some places build reef mounds over 100 m high on this antecedent topography. In other places the cold-water ecosystem builds ridges and mounds in response to the currents. For example, at the base of the Miami Terrace at depths of 630-870 m, deep-water corals have constructed a field of ridges up to 20 m high and covering more than 20 km^2. In the middle of the Straits, knobby chevron-shaped, bioconstructed mounds (up to 30 m high) cover 70% of the seafloor. Sampling and video footage from submersible dives indicate different faunal assemblages across the Straits, e.g., fields of stylasterid lace corals, sponges and gorgonians on the Pourtalès Terrace south of the Florida Keys; stalked crinoid meadows in the northeastern Straits, and a swath of deep coral pinnacles in the central northern Straits. These faunal provinces are likely controlled by a combination of water mass properties, steep isothermal slopes associated with geostrophic flow of the Florida Current, and the benthic currents characterized opposing undercurrents and internal tides.

2.12 The Exuma Sound

Author and collaborators

Edward Brooks eddbrooks@ceibahamas.org
Cape Eleuthera Institute

Why this area may be of interest

Biology An undisturbed diverse and abundant deep water community.

Geology Carbonate dominated sediments

Chemistry Complex shallow/deep water interactions.

Physical oceanography Steep sided oceanic trough surrounded by shallow carbonate banks.

Archaeology/history Busy transport route dating from the early settlement of The Bahamas

Other Extensive education and outreach opportunities

Rationale for exploration in the target area The oceanographic structure of the Exuma Sound has begun to facilitate a paradigm shift in the way deep water research is approached. The ease of access to deep water facilitates the repetitive sampling of deep sea communities via any number of survey techniques at a high resolution, and over wide temporal scale. Furthermore, these surveys can be conducted from small, shore based vessels at a fraction of the cost of traditional oceangoing research vessels.

The last two years of work conducted by the Cape Eleuthera Institute (CEI) has just begun to document the wealth of deep sea biological information available in the undisturbed deep-water ecosystem of the Exuma Sound. Two years of deep water longline surveys have now been supplemented by a pilot deep water baited video study, more of which are planned for the end of the year. Past and future survey data would benefit greatly from high resolution bathymetric and chemical oceanographic data to both supplement biological conclusions, and guide future research hypotheses. At present, CEI does not have the capacity to acquire this type of data with the speed and accuracy available onboard E/V *Nautilus* and NOAA Ship *Okeanos Explorer*. Furthermore, the deep exploration capacity of the vessels via ROVs will be able to supplement the biological surveying regime in areas where the current surveys cannot function. In particular, the rocky substrate and steep slopes of the Exuma Sound margins and isolated sea mounts carry a high risk of gear loss for surveys deployed directly on the seabed and would be better surveyed by a manoeuvrable vehicle. By combining the ongoing biological surveying currently underway, with the advanced data acquisition and exploration capabilities of the exploration vessels, a holistic profile of deep ocean communities and be generated at a resolution that has never before been undertaken.

An additional benefit of conducting research in the Exuma Sound are the educational opportunities available through CEI's sister organizations, The Island School (www.islandschool.org) and the Deep Creek Middle School (www.dcmsbahamas.org). The Island School is a 14 week placed-based, semester abroad program for students from all over the world. A large portion of The Island School experience involves participation in real-world research projects underway at CEI, and every semester a group of six students take part in the on-going deep water research program. Students are guided through the entire research process from designing a study, gathering and analysing data, and forming conclusions. They communicate their findings via scientific posters and presentations, which are presented at a student-led research symposium attended by local community members, collaborating scientists, and government officials. The integration of Island School research with the on-going biological sampling conducted at CEI and the advanced data gathering capabilities of E/V *Nautilus* and NOAA Ship *Okeanos Explorer* will offer a truly unique educational experience for these young biologists. In addition, students from Deep Creek Middle School regularly take part in the on-going research at CEI. These hands on field experiences help foster a sense of stewardship over the marine environment and hopefully inspire students to pursue careers in marine science and conservation. The deep water research program at

CEI has begun to communicate to young Bahamians the marvels that inhabit the Exuma Sound, however, the telepresence enabled capabilities of the OER vessels will allow this to be done far more effectively, both at Deep Creek Middle School and at other middle and secondary schools throughout Eleuthera and the Bahamas.

The Cape Eleuthera Institute and The Island School maintain strong ties with governmental and non-governmental organisations, including the Department of Marine Resources, the Bahamas National Trust (BNT), the Bahamas Reef Environment Education Foundation (BREEF), the Caribbean Regional Fisheries Mechanism (CRFM) and local United Nations FAO offices. Results from all ongoing research at CEI and The Island School, including the deep water research project, are shared with all of these organisations, and as such, the findings of the proposed research can be effectively disseminated to policymakers on a national and regional level.

Establishing an exploration program in the Exuma Sound, in collaboration with the Cape Eleuthera Institute and The Island School, will facilitate the holistic investigation of an unexploited and previously unexplored deep water community; promote the scientific education of local communities and young students; and provide local and regional policymakers with information pertinent to the effective management of these sensitive ecosystems. This collaborative research, education, and outreach opportunity makes the Exuma Sound an excellent candidate for a 2013 ocean exploration expedition.

Overview of target area The Exuma Sound is a virtually unexplored deep water inlet of the Atlantic Ocean surrounded on all margins by the shallow waters of the Great Bahamas Bank. It is approximately 160 km long by 55 km at the widest point and the margins are characterized by steep walls dropping from 30 m to over 500 m, attaining a maximum depth of ∼2200 m. The sound has two entrances to the Atlantic Ocean, one ∼1500 m deep and 50 km wide, located in the south, and a second shallow water entrance 15-30 m deep and 27 km wide half way along the eastern part of the long axis. The margins and epipelagic areas of the Exuma sound are known as areas of critical habitat for a number of marine species, however, biological communities on the floor of the sound and on isolated sea mounts have yet to be explored. The limited research that has been conducted suggests a diverse and abundant community, shaped by complex interactions between the shallow and deep water.

Summary of what is known about the target area There has been virtually no exploration of the Exuma Sound to date. The largest body of scientific literature relates to the sedimentary geology of deep water carbonate deposits from the bottom of the Exuma Sound, however, there have been no publications in this field since the 1980s. More recent research in 1995 concluded that prevailing currents are north-west in direction, originating

in the deep water entrance in the south of the sound. This current, and the resulting upwelling it generates, propagates oolitic shoals found in the shallow water on the northern margin which have been studied extensively by contemporary marine geologists. Furthermore, these currents are known to be important for the larval transport of a number of species (e.g. Blue Marlin *Makaira nigricans*, Queen Conch *Strombus gigas* and Caribbean spiny lobster *Panulirus argus*).

The only sustained investigation into the deep water of the Exuma Sound has been conducted in recent years by the Cape Eleuthera Institute (www.ceibahamas.org). Situated on the south west tip of the island of Eleuthera, less than two miles from the wall of the sound, the Cape Eleuthera Institute (CEI) has utilised deep water longline surveys and more recently deep water baited video surveys to start to describe the deep water fauna of the sound. In 2010 and 2011 a total of 69 deep water longline surveys were conducted aimed at quantifying the diversity and abundance of deep water elasmobranchs, the results of which were presented at the OER session at the 2012 Ocean Sciences conference. These surveys captured 144 sharks from 9 different species, in addition to seven teleost species and one eel. In spring of 2012 a pilot study using deep water baited video lander known as the Medusa, recorded one more elasmobranch species, two teleost species, and a wealth of crustaceans from only five surveys. All of these surveys, both longline and video, were conducted within and area less than 11 km^2 suggesting that the Exuma Sound supports a diverse and abundant deep water community.

At present, this diverse deep water community, and the complex physical and chemical processes that support and shape it, are very poorly understood. The ongoing research at CEI, if coupled with the advanced data acquisition capacity of the ocean exploration vessels, represents a unique opportunity to generate an in-depth understanding of this poorly understood ecosystem.

2.13 North Bahamas to Dominican Republic

Author and collaborators

Kenneth Broad kbroad@rsmas.miami.edu
University of Miami, RSMAS

Dr. Peter Swart pswart@rsmas.miami.edu
University of Miami

Dr. Keene Haywood khaywood@gmail.com
University of Miami

Brian Kakuk bahamacave@aol.com

Bahamas Cave Research Foundation

Why this area may be of interest

Biology

Geology Speleothem and Sediment Samples

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area ANY samples from the Caribbean chain will help characterize the extent of regional variability in climate and thus allow reconstructions to be properly interpreted and data incorporated into the climate and dust models (NCAR). We have funding for 3 years from NSF for the analysis but not for fieldwork which includes extensive cave diving. We envision a strong citizen science component - i.e., experiencing and learning via virtual expedition to these difficult to explore areas. Logistically, we envision being dropped off nearshore as the ship does offshore work, thus increasing the bang for the buck of a multi-team, multi-disciplinary expedition. We note that other proposals from UM for offshore work using multibeam, AUVs, and ROVs in the same area make the plan feasible.

Overview of target area The north Atlantic plays a critical role in the global climate system, yet little is known about the environmental history of this area. The Bahamas down to the Dominican Republic contain inland and offshore submerged and dry caves that are repositories of information about past climate yet are barely explored.

Summary of what is known about the target area Speleothem and sediment samples from Bahamas and one sample from Dominican Republic have been retrieved. The Bahamian samples, after isotopic analysis, reveal new evidence regarding abrupt climate change, including confirmation of some Heinrich and D-O event, identification of new Heinrich events, and correlation with Saharan Dust events previously unidentified. The 'dust story' has significant implications for understanding current climate processes and for the potential forcing implications of land use change in Africa and other parts of the world.

2.14 Using ROVs to explore Bahamas Blue Holes

Author and collaborators

Mark Gleason, PhD gleason@mtu.edu
USS Silversides Museum and Grand Valley State University

Why this area may be of interest

Biology Bacteria sample from different levels within Blue holes. Using small ROVs to collect the samples will provide a demonstration of collection techniques that can work in any environment on the planet.

Geology Demonstrate the usefulness of small ROVs to document mineral formations with in Blue Holes that are very sensitive to exploration by divers.

Chemistry Demonstrate the usefulness of small ROVs to measure and collect water samples in several Blue Holes. In particular, samples of layers of water from the oxygen free zones.

Physical oceanography Demonstrate the usefulness of filming Stalagmites and not damaging them.

Archaeology/history Explore and search for any sites using ROVs

Other Demonstrate live programing from a Blue hole to USA and Bahama public schools.

Rationale for exploration in the target area I would like to create a mobile research team that demonstrates the usefulness of small ROVs to studying remote sites that have significant features that are sensitive to being disturbed. Team members would be representative of several research areas but mostly would include new researchers and students from both USA and the Bahamas. I have experience in this type of project including using small ROVs to study Moose while they are feeding underwater and Manatee without disturbing their behavior. Small ROVs are easy to use by researchers but need trained technicians to maintain them. Yet these small tools could open up much of the underwater world to non divers and the general public. This project would demonstrate that ROVs can be used by researchers in remote areas supported by students to undertake a studied of these sensitive sites.

Overview of target area Bahamas Blue Holes: These numerous and unique geological features are rarely studied due to location along with their difficulty and sensitivity to disturbances. There have been research efforts to them in the last few years and those

efforts have documented the unusual features and confirm the believe that they are threaten by the change in ocean levels. These are among the types of environments that should be documented before they change that is coming occurs

Summary of what is known about the target area Brief? There is enough known on Bahama Blue Holes to show they are truly worth studying using a technology that researchers around the world could use to open up new sites. These site have a wide range of worth while research areas to interest a diverse team.

2.15 Mesophotic coral ecosystem

Author and collaborators

Robert Ginsburg rginsburg@rsmas.miami.edu
Ocean Research and Education Foundation

Joaquin R. Garza Perez wetsuit@mac.com
UMDI-Sisal, F. Ciencias, Universidad Nacional Autonoma de Mexico

Paul Blanchon blanchon@gmail.com
Inst. de Ciencias del Mar y Limnologia, Universidad nacional Autonoma de Mexico

John Reed n/a
n/a

Dennis Hubbard n/a
Oberlin College

Why this area may be of interest

Biology

Geology

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area My proposed exploration is to examine the ocean-facing slopes of selected sites around Great and Little Bahama banks for the mesophotic coral ecosystem in depths of 30-100 meters. The mesophotic coral community represents a major expansion of the range of the familiar corals of shallow depths. As a result it presents new aspects of biology of corals, fish and new habitats for invertebrates. For example the major framework builder of mesophotic communities is a platy form of Montastrea that produces an unusually cavernous structure that is quite different from that of shallow reefs. How does this difference influence the myriad of invertebrate and fish that live in this habitat?

Principal coral builders. The major structure-forming corals of these mesophotic communities are familiar shallow-water species, Montastrea spp. and Agaricia spp. In addition structure-forming sclerosponges are present. The skeletons of both taxa can provide critical information about historical water properties, such as temperature and salinity. The high complexity of mesophotic communities provides habitat for exploitable fish and shellfish, refuge for settling juvenile fish, spawning sites for commercial reef fish, potentially useful bio-active compounds and they are the focus of much scuba diving. Furthermore, these reefs, by virtue of their insulation from natural and anthropogenic near-surface impacts, may serve as refugia for fish, corals and invertebrates that could repopulate degraded shallow reefs.

Assessment of corals. Mesophotic community have significant resources of fish and shellfish that are already being exploited and fishing pressure will surely increase as shallower areas are fished out. Our main objective is to determine if the mesophotic community is present, and if so at what depths, to determine the main coral species And estimate their condition. Using the well-established AGRRA Protocol. In addition we will have an opportunity to assess the fishes and compare their variety and with the results from shallow reefs.

Model for fossil reefs. Paleontologists use living reefs to understand fossil examples. It is possible that still-living mesophotic coral communities may provide additional new models of reef building and of the variety and abundance of associate invertebrates that will help to understand fossil examples.

Overview of target area See attached Figure 1 chart of region and Figure 2 Great and Little Bahama banks showing area outline, locations visited, sampled and depth profiles. Flat-topped carbonate platforms less than 10 meters below sea level. Islands of Pleistocene limestone preferentially occur on the east, ocean-facing margins. Figure 2 also reveals varied orientation of different platform margins and exposure to sea and swells.

Summary of what is known about the target area Topography and bathymetry are well established. All sediments and rocks are calcium carbonate sand sizes or mud sized.

Mesophotic zone less than ten meters thick. Coral reef community alive on windward Bank margins.

Chapter 3

Region 2: Cayman Rise to Greater Antilles

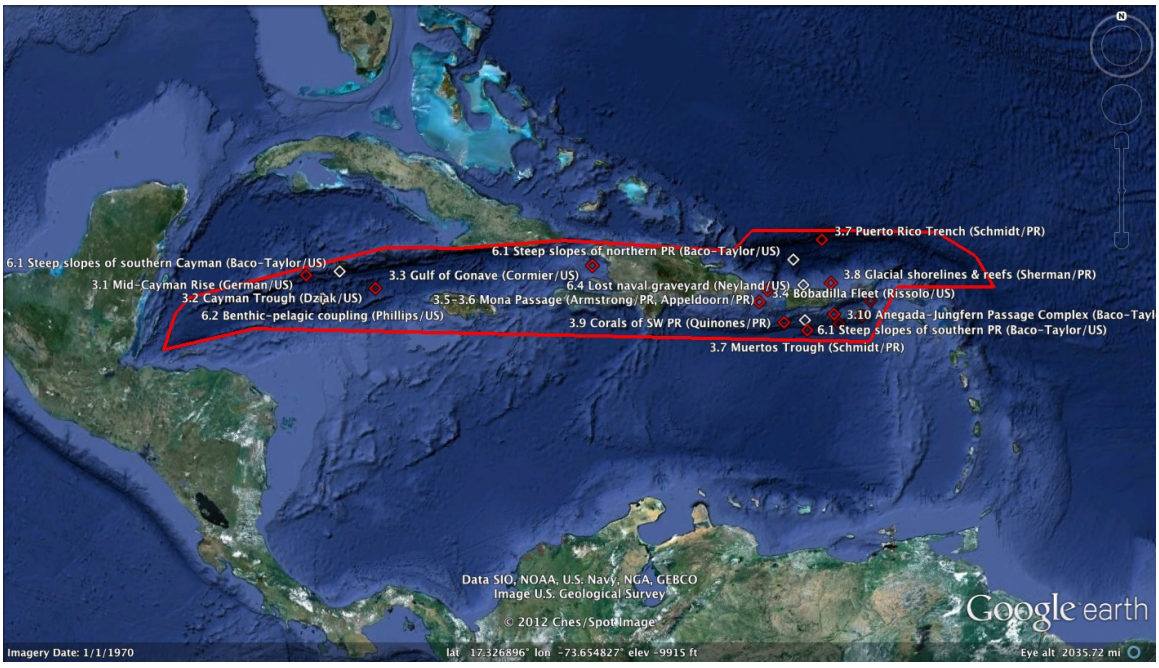

Figure 3.1: Map of target areas in Region 2: Cayman Rise to Greater Antilles

3.1 Mid Cayman Rise

Author and collaborators

Christopher German cgerman@whoi.edu
WHOI

Why this area may be of interest

Biology Vent fauna

Geology Ultra slow spreading center

Chemistry Hydrothermal vents

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area The first two vent-sites located on the MCR (Von Damm, Piccard) have revealed interesting results in terms of how geologic processes could have generated conditions conducive to the origins of life on early Earth and also in terms of how planet-scale tectonics can influence biological evolution. To be able to pursue these compelling science themes in future we need to track the missing link vent-sites to source - otherwise there are just too many variables in play to say anything definitive based on the two sites already visited by ROV.

Overview of target area The Mid Cayman Rise is one of the world's slowest-spreading and deepest Mid Ocean Ridges and much more readily accessible to the US than its more remote counterparts in the Arctic and SW Indian Ocean. It has potential to serve as a fascinating natural laboratory for US research in the future - but before that can be achieved, it needs some first-order exploration to be completed.

Summary of what is known about the target area The bathymetry of the seafloor of the MCR has been re-mapped in recent years not least by EX11-04 in 2011 to reveal that the majority of spreading along axis is via Oceanic Core Complexes - a just recognised phenomenon, yet one that explains how tectonic plates separate along 25% of the global mid ocean ridge axis! Preliminary exploration that I have helped lead, starting in 2009, has revealed evidence for at least four distinct hydrothermal systems on the MCR but only two have been tracked to source.

3.2 Cayman Trough

Author and collaborators

Robert Dziak robert.p.dziak@noaa.gov
Oregon State University/NOAA

Why this area may be of interest

Biology Marine animal sounds

Geology Earthquakes from transform fault, volcanoes

Chemistry

Physical oceanography Deepest point in Caribbean Sea

Archaeology/history

Other

Rationale for exploration in the target area Very little is known about the physical environment and what life exists at the bottom of the Cayman Trough. My group has developed a deep-ocean, broad-band, hydrophone that can withstand the pressures at this location. We would be interested in making the first records of ambient sounds and marine animals that live in this extreme environment.

Overview of target area The Cayman Trough is a pull-apart basin formed within the Oriente Transform Fault Zone that runs east-west along southern Cuba.

Summary of what is known about the target area The trough is a narrow feature, but at 7,686 m deep is is the deepest point in the Caribbean Sea and one of the deepest places on Earth.

3.3 Gonave Bay, Haiti

Author and collaborators

Marie-Helene Cormier cormierm@missouri.edu
University of Missouri

Why this area may be of interest

Biology corals, deep water corals may be present judging from available seismic data.

Geology active plate boundary, seismic hazard

Chemistry Windward Passage may be key gateway between Atlantic and Caribbean, but little is known about its local impact on ocean circulation, salinity, etc.

Physical oceanography Strong currents through the Windward Passage may be key connection between Atlantic to Caribbean

Archaeology/history Hispañiola was the first European colony in the new world; shipwrecks as old as 16th century are expected in area.

Other drowned coral reefs have been recently mapped, with spectacular karstic features; impact of hurricanes, earthquakes, deforestation, and overfishing on live coral reefs need to be understood.

Rationale for exploration in the target area Gonave Bay is a fascinating area to investigate the interplay between tectonics, sedimentation, bottom water circulation, climate change, and coral growth. To our knowledge, Gonave Bay has yet to be explored with deep-submergence technology. A comprehensive multibeam bathymetric coverage combined with the simultaneous acquisition of CHIRP seismic profiles would highlight the plan-view geometry of active faults, folds, and landslides, much-needed information for the assessment of seismic and tsunami hazards in Haiti. Seismic profiles show erosional surfaces near the crest of anticlines that are now in several 100s m-water depth, suggesting that the floor of Gonave Bay is regionally subsiding. High-resolution bathymetric mapping, sampling and dating of drowned reefs or shorelines would quantify rates of vertical deformation and provide insights into competing models for the 2010 earthquake rupture. The Windward Passage may be a key gateway for bottom waters from the Atlantic to the Caribbean, but little is known about its local impact. For example, if the deep-water mounds imaged with industry seismic are live cold-water corals, their occurrence are likely controlled by bottom currents. Various US scientists are collaborating with Haitian scientists and seek to invigorate this emerging collaboration.

Overview of target area Gonave Bay is bracketed by Haiti's northern and southern peninsulas, and terminates eastward at Port-au-Prince. To the west, it opens up to the Windward Passage, a deep (1,680 m) gateway between the Atlantic and the Caribbean. It covers ∼15,000 km2 and comprises basins, some as deep as 3,700 m, separated by shallow ridges. One ridge emerges as the 58 km-long Gonave Island. A shallow depression offshore Port-au-Prince is surrounded by a 35 m-deep platform. Coral reefs fringe most

of the shorelines, and barrier reefs also occur. The devastating 2010 Haiti earthquake dramatically demonstrated that the Gonave microplate (a narrow plate wedged between the N. American and Caribbean plates that includes Gonave Bay) is tectonically active. This complex plate boundary controls the shoaling and deepening of northern Caribbean gateways and the growth or demise of coral reefs.

Summary of what is known about the target area Industry seismic reflection data collected in the 1980's in Gonave Bay image a system of fold-and-thrust belts and strike-slip faults that appear to be active. They also reveal some intriguing seafloor mounds as deep as 1,200 m. These have dimensions compatible with cold-water coral mounds, mud volcanoes, or drowned coral reefs. Gonave Bay had not been explored with modern geophysical method until 2010. A French team acquired a few bathymetric swaths through deep portions of the Bay immediately after the 2010 earthquake. A short cruise conducted in 2010 to investigate the underwater extension of the fault responsible for the earthquake mapped that fault close to shore and sampled fresh turbidites. It also mapped portions of the platform surrounding the shallow basin off Port-au-Prince, revealing spectacular dissolution structures 1-2 km across and ∼80 m deep. These are interpreted to be antecedent karst topography that developed during previous eustatic lowstands.

3.4 Bobadilla's Fleet

Author and collaborators

Dominique Rissolo dominique@waittinstitute.org
Waitt Institute

Why this area may be of interest

Biology

Geology The seismically active Mona Passage rift zone

Chemistry

Physical oceanography

Archaeology/history 1502 Spanish Treasure Fleet

Other

Rationale for exploration in the target area The story of the doomed fleet involves the arrest of Christopher Columbus, who was detained by Bobadilla (by order of Ferdinand and Isabella). After he was exonerated by the Crown, Columbus was to return to Spain with Bobadilla. Concerned about the approaching storm, Columbus decided not to join the fleet, which sailed headstrong into a hurricane. Lost among the 24 caravels and naos was the treasure-laden flagship "El Dorado" – the remains of which lie beneath the deep waters of the Mona Passage.

Overview of target area The Mona Passage, which separates the islands of Hispanola and Puerto Rico, was heavily trafficked by Spanish and French fleets until about 1550, when the principal port for the region shifted from Santo Domingo to Havana. The passage is notorious for its treacherous currents and, during a storm in 1502, claimed 24 ships bound for Spain with former governor Francisco de Bobadilla on board.

Summary of what is known about the target area The Mona Passage has been the focus of numerous geological studies. No large-scale, systematic survey (using underwater remote sensing techniques) has been conducted for the purpose of locating and identifying submerged cultural resources in the passage.

3.5 Mona Passage, Puerto Rico

Author and collaborators

Roy Armstrong roy.armstrong@upr.edu
University of Puerto Rico

Graciela Garcia-Moliner graciela_cfmc@yahoo.com
NOAA-CFMC

Hanumant Singh hsingh@whoi.edu
Woods Hole Oceanographic Institution

Reni Garcia goingdeep49@gmail.com
University of Puerto Rico

Uri Ten Brink utenbrink@usgs.gov
USGS

Dwight Coleman dcoleman@gso.uri.edu
University of Rhode Island

Why this area may be of interest

Biology Deep coral ecosystems

Geology

Chemistry

Physical oceanography

Archaeology/history

Other Fishery resources

Rationale for exploration in the target area Although the U.S. Caribbean and the wider Caribbean region contain a huge diversity of deep water corals, there are no conservation or management efforts specifically targeting deep-water corals (Lutz and Ginsburg 2007). The available information on benthic communities associated with deep coral ecosystems in Puerto Rico and the U.S. Virgin Islands is scarce and mostly limited to taxonomic listings from incidental collections by fish traps, shrimp trawls and coral entanglement devices. To this day, quantitative characterizations of sessile-benthic populations as well as relative abundance of motile-megabenthic invertebrates and fishes in these deep reef habitats are lacking.

Overview of target area Deep coral ecosystems are distributed throughout the poorly known platform of the Puerto Rico fault zone, a submerged section of the Antillean Ridge that extends across the entire Mona Passage, connecting Puerto Rico with Hispañiola (Garcia-Sais, 2005). The deep reefs of Mona Passage are of particular interest because they are the main habitats of the queen snapper (*Etelis oculatus*) and the silk snapper (*Lutjanus vivanus*), two commercially important fish species in Puerto Rico. The depth ranges of these species are 250-500 m and 146-329 m, respectively. The location and distribution of deep coral habitats in the US Caribbean is presently unknown.

Summary of what is known about the target area Preliminary surveys of deep coral ecosystems were conducted by the Seabed AUV in 2008 (Armstrong et al. in review). Two 0.5 km long photo transects were obtained at depths ranging from 198 to 280 m in the Mona Passage west of Puerto Rico. Silk snappers were observed during the descent of the AUV at 21 m from the bottom (total depth 198 m) and near the bottom at a depth of 219 m . Abundant coral and sponge communities were also present including large, unidentified sponges and numerous colonies of ahermatypic corals at a depth of 206 m.

3.6 Mona Channel

Author and collaborators

Richard Appeldoorn richard.appeldoorn@upr.edu
Department of Marine Sciences, University of Puerto Rico

Nikoloas Schizas nschizas@gmail.com
University of Puerto Rico

Clark Sherman clark.sherman@upr.edu
University of Puerto Rico

Ernesto Weil eweil@caribe.net
University of Puerto Rico

Graciela Garcia-Moliner graciela_cfmc@yahoo.com
Caribbean Fishery Management Council

Jesus Vega-Fernandez drjesusvega@yahoo.com
Consultat

Why this area may be of interest

Biology Deep corals, fishes, diversity, connectivity

Geology Geomorphology relative to plate techtonics and biological habitats

Chemistry

Physical oceanography Interchange between Atlantic and Caribbean

Archaeology/history Ship wrecks

Other

Rationale for exploration in the target area The Mona Channel remains one of the least studied areas in the US Caribbean. Geologically, the observed morphology is highly rugose, which is unique compared to the areas known off the deep slope of Puerto Rico and the US Virgin Islands. This may result from the fact that the channel represents the border between portions of the Caribbean plate, which to the east is moving faster and further north than to the west. The area is also unique in that it forms a vast area at depths of several hundred meters. The combination of this depth range, a highly rugose bottom, and strong currents flowing between the Atlantic and Caribbean may be what is supporting the current deep snapper fishery from the west coast of Puerto Rico. Encounters

with stylasterine corals by fishing gear have led fishers to assume that there occur broad areas of coral cover, which they avoid. While such corals were observed in isolation in both limited submersible and AUV dives, the extent of this habitat, its importance and the threat posed by fishing activities are unknown. The crude classification by fishers also suggests that bathymetry and geomorphology have a strong control on the fish community composition as well. In general, the faunal composition is poorly known, and a new fish species (caught by fishermen) was recently published. Based on findings from shallower mesophotic areas, it is expected that many new species may be present. Genetic studies could help extend our knowledge of connectivity across the channel to deeper depths where a continuum of habitat may allow gene flow not seen at shallower depths.

Overview of target area The Mona Channel lies between the islands of Puerto Rico and Hispañiola. The insular shelf off the west coast of Puerto Rico reaches it largest extent, about 27 km before dropping to depths of over 200 m at the edge of the platform. Another 45 km to the west are islands of Mona and Monito, which rise from depths of 400 m. In between Mona and Puerto Rico is a unique and extensive area that ranges in depth from 300 m to 1,000 m, with even greater depths to the north and south as the bottom falls into the Caribbean Basin and Puerto Rico Trench, respectively. To the north of Mona is a seamount (Pichincho) that rises to depths of only 50 m. Bajo de Sico is another seamount located just off the western Puerto Rico platform. The area is important commercially as it supports an active fishery for deep snappers, with Pichincho also noted as an important recreational site for highly migratory pelagic fishes. Studies on shallow fauna have identified the Mona Channel as a partial biogeographic barrier, especially for summer-spawning organisms or those with short larval durations. Historically, the Mona Passage has been an important area for trade (and piracy), and there are documented shipwrecks along the coast of Puerto Rico and Mona Island.

Summary of what is known about the target area Very little information is available for the Mona Channel. The USGS has developed coarse-scale (100 m) bathymetry maps of the northern portion to the Mona Passage, while NOAA has developed high-resolution (6 m) bathymetry for small targeted areas around Mona Island and along the PR shelf break of managed areas of the Caribbean Fishery Management Council. In 1985, NOAA and UPR-Sea Grant conducted submersible dives at several locations: two along the western insular slope, one off of Desacheo (off northwest PR) and one out in the Mona Passage proper. These collected data on commercial fish abundance and video documenting some biota (with variations with depth) and the general geomorphology. The site within the Channel proper was unique, both in the geomorphology and in the diversity of organisms. In 2008, two 0.5-km photo transects were conducted at 200-280 m using the Seabed AUV. Fishers working depths >300 m have classified sites into three types based

on catch: 1) those with high catch of commercially important snappers, 2) those with catch of a high diversity of fishes, and 3) those where gear gets tangled in stylasterine corals. Fishermen avoid the latter two sites. Some detailed studies have been conducted by the University of Puerto Rico at mesophotic depths (40-100 m) on the slopes of the western PR platform, Mona, Deseacheo, and Bajo de Sico; the latter is a hotspot for mesophotic corals. Samples of corals and other mesophotic invertebrates have been collected for ongoing genetic analyses to study connectivity across the channel and between shallow and deep reefs. NOAA has similarly conducted deeper ROV and drop camera surveys at similar locations. Perhaps the most intriguing shipwreck in the area is one off the coast of northwest PR located in 35-60 m. Discovered in 1991, but whose exact location has been kept secret, it has been to be the remains of one of Francis Drake's ships that was known to have sank in the area following his unsuccessful attack on San Juan in 1595.

3.7 Puerto Rico Trench and Muertos Trough below 5,000 m

Author and collaborators

Wilford Schmidt wilford.schmidt@upr.edu
University of Puerto Rico, Mayaguez

Dr. Manuel Jimenez mjimenez@ece.uprm.edu
UPRM

Dr. Nikolas Schizas nikolaos.schizas@upr.edu
UPRM

Dr. Pedro Quintero Pedro O Quintepedro.quintero@upr.edu
UPRM

Dr. Uri ten Brink utenbrink@usgs.gov
USGS

Andrew Bowen abowen@whoi.edu
WHOI

Why this area may be of interest

Biology Hadal and abyssal faunal assemblages

Geology Plate boundary tectonics and hazards

Chemistry Establish water property baselines below 6000 m

Physical oceanography Water mass contacts below 6000 m and hadal/deep-abyssal physical processes

Archaeology/history Ocean dumping impacts

Other Developing low-cost hadal research techniques

Rationale for exploration in the target area Although twelve people have walked on the Moon and numerous spacecraft are now exploring our solar system and beyond, very little in situ sampling of the Earth's oceanic trenches has occurred. Their general geographic remoteness and extreme bottom-pressures (>600 atmospheres) have made all sampling techniques difficult. Cable lengths needed (>6.5 km) make tethered sampling cost-prohibitive, and problematic in terms of successful data acquisition. Recent autonomous (AUV), remotely-operated (ROV), and free-vehicle sampling attempts have proved equally technically difficult and expensive (cf., Nereus, Kaiko, Big Alfie, and Deepsea Challenger). However, developments in the manufacture of glass housings offer scientific investigators and engineers the opportunity to sample the Earth's deepest trenches at a fraction of the cost of previous methods using untethered free vehicles (cf., Schmidt and Siegel, 2011). These devices can be thought of as oceanographic analogs to small-satellite space missions, which have been shown (Baker and Worden, 2008) to:

1) Be a cost effective method for addressing key scientific questions, 2) Have the capability for quick response to targets of opportunity, 3) Be a means for the development and demonstration of new technology and design concepts, and 4) Facilitate opportunity for multi-disciplinary and international collaborations

The PRT and MT, though potentially hazardous to the region, represent a logistically-favorable opportunity for hadal and deep-abyssal research of all disciplines.

Overview of target area The Puerto Rico Trench (PRT) and Muertos Trough (MT) represent the closest active plate boundary to the U. S. Atlantic and Gulf of Mexico seaboards, and of course to Puerto Rico, the U. S. Virgin Islands, and the greater Caribbean. Significant seismic and tsunami hazards to U.S. and regional interests are thought to exist, but recurrence rate estimates are largely limited to the spotty historical record. Hadal and deep-abyssal faunal assemblages are largely undescribed, and the PRT and MT are ideal areas to focus sampling efforts and develop techniques. The PRT is isolated form other trenches and uniquely situated midway between North Atlantic Deep Water and Antarctic Bottom Water sources.

Summary of what is known about the target area The French bathyscaphe Archimede made a number of dives in the early 1960s, but publications from this campaign were few

(Peres, 1995). Studies targeting hadal/abyssal fauna in the PRT/MT are restricted to 1980s and 1990s species descriptions and enumerations, based primarily on nematodes (Tietjen, 1989) and quantitative studies of the fauna (Richardson et al., 1995). Deep sediment samples obtained from box core were described in 1995 (Richardson et al., 1995). USGS bathymetry was published in 2002 (ten Brink et al., 2002). Recent efforts (3 Niskin casts, 1 camera deployment, and 1 ADV deployment), made in 2006 and 2008 utilized low-cost untethered free vehicles (Schmidt and Siegel, 2011; Eloe et al., 2011).

3.8 Glacial Shorelines and Reefs on Insular Slopes in Puerto Rico and US Virgin Islands

Author and collaborators

Clark Sherman clark.sherman@upr.edu
University of Puerto Rico-Mayaguez

Richard Appeldoorn richard.appeldoorn@upr.edu
University of Puerto Rico-Mayaguez

Ernesto Weil eweil@caribe.net
University of Puerto Rico-Mayaguez

Why this area may be of interest

Biology Lower limit of mesophotic coral ecosystems

Geology Record of glacial sea level positions and biologic and geologic responses to rapid sea-level and climate changes during the last deglaciation

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area Slope settings in the target depth range of 90-160 m have been explored in only a few locations in the Caribbean such as Belize, Jamaica, Barbados and the Bahamas, much of this work occurring several decades ago. There have been no systematic explorations of this zone in Puerto Rico and US Virgin

Islands (PR/USVI). This depth range is significant in that it encompasses estimated positions of sea level (∼120-130 m below present) during the last glacial maximum (LGM), ∼21,000 years ago. Exploration of insular slopes in the target depth range of 90-160 m in PR/USVI has the potential to identify geomorphic features, such as relict reefs and erosional shoreline notches, indicative of LGM sea level position. Because the insular slope is often a steep wall at these depths, erosional shoreline notches may be expected to be the more likely LGM sea-level record rather than reefs. Significant reef development would not be expected on a vertical wall. Importantly, erosional notches cannot be identified by bathymetric techniques. Visual observations are required (e.g., ROV) to identify and catalog these features. The identification of an extensive and consistent LGM shoreline notch would be unprecedented. Alternatively, if relict reefs are found, there is some potential for sampling relict shallow-water corals dating to the LGM. LGM corals have only been recovered (in drill cores) from two locations globally, Barbados and, recently, Great Barrier Reef, Australia. Paleo-data of sea-level and climate change are crucial to accurate models of future anthropogenically induced global change. Identifying the position of LGM sea level is of critical importance in order to test the few global records of sea level positions at this time. Understanding the full range of sea-level change from the LGM to the present is particularly important as this period represents the most recent episode of major global climate change under natural conditions.

In addition to LGM geological archives, the target area also encompasses the lower limit of scleractinean coral growth. Ongoing work at the University of Puerto Rico has described mesophotic coral ecosystems in the region extending to depths of ∼80-90 m. However, there has been only limited observations made beyond these depths. A systematic exploration of slope settings in the target depth range of 90-160 m would almost certainly extend the reported ranges of mesophotic corals and potentially reveal new and undescribed types of mesophotic coral ecosystems.

Overview of target area Upper insular slopes in Puerto Rico, US Virgin Islands and throughout the Caribbean represent unique areas for study and exploration. They are prime habitats for mesophotic coral ecosystems and contain relict topographic features that represent important geological archives of late Quaternary sea-level and climate change. Of particular importance is the depth range of ∼90-160 m as this is a zone that has not been adequately explored and has potential for containing records of sea-level position during glacial periods.

Summary of what is known about the target area NOAA multibeam bathymetry of insular slopes in Puerto Rico and US Virgin Islands reveals relict features formed during preexisting sea levels lower than present. The most prominent of these are a system of deep buttresses at depths of ∼45-65 m and a pronounced terrace at a depth of ∼80 m. These

features are thought to have been formed during the last deglaciation ∼12 and 15 thousand years ago, respectively. There are ongoing investigations at the University of Puero Rico examimg the biology, ecology and geology of these settings. At depths of ∼90 m there is typically a sharp break in slope gradient where a steep wall begins that drops to depths of ∼160 m and beyond. This depth range from ∼90-160 m has not been adequately explored and has the potential to contain an important record of sea-level positions during the last glacial maximum (∼21,000 years ago) as well as the deepest occurrences of mesophotic coral ecosystesm in the region.

3.9 Using Corals from Southwest Puerto Rico to Determine Variations in Sea Surface Temperature during the Last Millennium

Author and collaborators

Edgardo Quinones ejqc_15@hotmail.com
University of Puerto Rico at Mayaguez

Dr. Wilson Ramirez wilson.ramirez1@upr.edu
University of Puerto Rico at Mayaguez

Dr. Clark Sherman clark.sherman@upr.edu
University of Puerto Rico at Mayaguez

Why this area may be of interest

Biology

Geology The understanding of future tropical climate variations depends on our ability to find information about the past climate using methods that can reach long before the available short term instrumental records. This led to the development of paleoclimatic reconstructions using proxies for temperature records contained in the skeleton of scleractinean banded corals.

Chemistry Because in sea water, coral builds a skeleton made from calcium carbonate (Aragonite, CaCO3) that is in equilibrium whit the marine environment. The trace of elements (Sr, Mg, B, F, etc.) that substitute for Ca+ in the crystal structure as well as the oxygen isotopes incorporated as part of the chemical composition are directly influenced by the conditions in the marine environment the skeleton precipitates from.

Physical oceanography

Archaeology/history

Other Also important on the perspective of the global warming and also will permit comparisons of the Puerto Rico La Parguera with other places around the world (especially in the Caribbean).

Rationale for exploration in the target area Corals will be studied using trace elemental and isotopic analysis that will reveal paleotemperature records for the time span available. The data to be obtained is very important on the perspective of the global warming and also will permit comparisons of the PR with other places around the world (especially in the Caribbean) for the same interval of time.

Overview of target area This project will conduct a sclerochronology analysis in corals that lived approximately from 460 to 1160 (14C) years ago (Dr. Clark Sherman personal communication) on the southwestern Puerto Rico Shelf at Parguera. The anomalies present in the corals growth bands, detected during the sclerochronology study, will be carefully documented to determine the times when the coral growth was hindered. In addition stable isotopes (oxygen) and trace elemental concentrations (Sr/Ca) will be measured in the coral growth bands (measured and documented by sclerochronology) to reconstruct and establish a sea surface temperature-record (SST) for the time span available. The work will provide approximately 720 years of SST records during the last millennium. The record will be compared with today's values and to other places in the Caribbean. The climate variation trends obtained will also be compared with modern and other time equivalent trends.

Summary of what is known about the target area Sixty years have passed since the first description of the thermodynamics that explained isotopic fractionation in natural systems (Swart and Grottoli, 2003). Years later Keith and Weber (1965) reveal that corals are able to form their skeleton in isotopic equilibrium with their environment (Swart and Grottoli, 2003). This discovery provides the opportunity to compare the oxygen isotopic fractionation (18O/16O) present in the aragonite deposited by coral with the temperature at the time of skeletization (Weber et al., 1970). The results obtained of isotopic fractionation (18O/16O) as a function of temperature (Weber et al., 1970). Later Adkins et al., (2003) established other factors that affect ?18O (Swart et al., 2003). The first one related to sea surface salinity (SSS) and the second one to potential kinetic effect, showing that ?18O depends on more than one environmental factor (Swart and Grottoli, 2003). Today many scientists are conducting successful research with stable isotopes (oxygen) as a proxy for temperature in a variety of skeletons from different organisms (corals, sclerosponges, oysters, foraminifera, etc.) because δ18O reflects in some way the SST and SSS present in

the environment during skeletization (Swart and Grottoli, 2003; Swart et al., 2002; Grottoli A., 2001).

3.10 Anegada-Jungfern Passage Complex, southern slopes of Puerto Rico and the Virgin Islands

Author and collaborators

Amy Baco-Taylor abacotaylor@fsu.edu
Florida State University

Sandra Brooke Sandra.Brooke@marine-conservation.org
Marine Conservation Institute

Shirley Pomponi SPomponi@hboi.fau.edu
Harbor Branch Oceanographic

Why this area may be of interest

Biology High through-flow, steep topographic series of channels. Two factors that provide prime habitat for a dense and diverse array of suspension-feeding organisms, including deep-sea corals and sponges

Geology This site has steep slopes with a maximum sill depth of ∼1915 m

Chemistry This series of channels provides the only source of deep-water for the entire eastern Caribbean basin

Physical oceanography This series of channels provides the only source of deep-water for the entire eastern Caribbean series of basins. This leads to relatively high but seemingly poorly studied flow rates. Particularly in deep-water, there may be interest in deploying deep-water drifters or current meters to further quantify the flow and its pathways.

Archaeology/history

Other

Rationale for exploration in the target area The deep Caribbean is vastly unexplored and it can be challenging to select a single location for study. In particular at depths below 1000 m, almost no sampling has been undertaken in hard substrate habitats. Explorations throughout the world's oceans indicate that deep-sea corals and sponges can

be very abundant well beyond depths of 1000 m. Thus we predict there may be a rich world of deep-sea corals and sponges in the Caribbean at these depths just waiting for discovery. Of course with exploration comes risk, so it makes sense to choose a target with a high likelihood of success. The high through-flow of the Anegada-Jungfern Passage and the steep slopes of these canyons (and the Islands just to the west of the canyons), provide the highest likelihood of success, of any location in the eastern Caribbean Basin, for finding rich communities at depths >1000 m.

Overview of target area The deep seafloor of the Caribbean is divided into the eastern and western basins which are further subdivided into a total of 5 smaller basins. The Columbia Basin, The Venezuela Basin and the Grenada Basin are considered to be a part of the larger eastern Caribbean basin. The deep waters of these basins are isolated from the western basin by the Jamaica Rise, which essentially acts as a sill with a maximum depth of about 1500 m. The only source of deep-water from the Atlantic into this basin is through a complex of deep channels running approximately northeast to southwest between the Virgin Islands and Anguilla known as the Anegada-Jungfern Passage complex. The 2 largest channels in this complex are the Anegada with a sill depth of 1915 m and Jungfern with a sill depth of 1815 m. The slightly shallower Grappler Channel with a sill depth of 1710 m also contributes significantly to the total flow. The steep southern slopes of Puerto Rico and the Virgin Islands are a part of and just west of this channel complex.

Summary of what is known about the target area There are a handful of records of deep-sea corals, including scleractinians, antipatharians and octocorals, in the vicinity of these channels and on the southern slopes of the Virgin Islands and Puerto Rico, however, most of the records are from fairly shallow depths, generally < 1000 m. In fact for the overall Caribbean, almost no sampling or exploration has been done of hard susbtrate habitats below 1000 m, with only a handful of records of deep-sea corals below this depth.

In general in the deep-sea, steep topography and high flow help to keep the substrate free from sediment, and high flow provides a higher food particle encounter rate for suspension feeders, as well as higher numbers of recruiting larvae. Locations with these factors in combination have been shown to coincide with occurrences of deep coral and sponge communities. Thus although there is not a lot of data for the Anegada-Jungfern Channel, it is easy to deduce that it will be home to lush communities of deep-sea corals and sponges as well as other suspension feeders.

3.11 U.S. Exclusive Economic Zone around Puerto Rico and the Virgin Islands

Author and collaborators

Uri ten Brink utenbrink@usgs.gov
United States Geological Survey, Woods Hole

Dwight F. Coleman dcoleman@gso.uri.edu
University of Rhode Island Graduate School of Oceanography

Roy A. Armstrong roy.armstrong@upr.edu
University of Puerto Rico at Mayaguez, Department of Marine Science

Alberto M. López alberto.lopez3@upr.edu
University of Puerto Rico at Mayaguez, Department of Geology

I. Roderick Mather roderick@uri.edu
University of Rhode Island Department of History

Why this area may be of interest

Biology Deep Coral Ecosystems and other Deep Benthic Habitats

Geology Plate Boundary Faults, Structure of the Continental Margin, Submarine Landslide Features, Possible Fluid/Gas Seeps

Chemistry N/A

Physical oceanography Surface and Deep Water flow of Atlantic Waters through the Mona and Anegada Passages

Archaeology/history Potential for Shipwrecks from the Spanish, English, French, and Dutch Colonial Periods and later

Other N/A

Rationale for exploration in the target area The M7.2 1918 earthquake offshore northwestern Puerto Rico produced a large tsunami in the area of Aquadilla, Rincon, and Mayaguez, now major urban and tourist areas. 140 people died due to the earthquake and tsunami. USGS multibeam bathymetry data and additional seismic profiles have identified a 10x10 km landslide in that area and hydrodynamic models suggest that it could have been the source of the tsunami. The landslide is at water depths of 1000-3000 m and the

debris field could be visited and dated. This target could be combined with a vertical transect(s) along the vertical walls of Mona Rift (5500 to 1500 m).

To the north of Puerto Rico, the Septentrional fault is the major strike-slip fault taking the oblique motion between the Caribbean and North American plate. Its offshore extension at depths of 1000-2000 m is clearly observed on multibeam bathymetry. The fault ends in an unusual circular depression, not seen in any major strike-slip fault system around the world. Fluid flow is highly likely along this fault and with it biological communities. Another major strike-slip fault is located much closer to the Puerto Rico trench at depths of 7000-8000 m. The fault is likely a conduit for fluid flow and diverse biological communities, but the depth of the fault may preclude direct dive on this target. However, mapping the fault in water depths greater than 4000 m will substantially improve the resolution of the fault structure and will identify targets for dives with suitable vehicles in the future. There also appears to be a mud volcano along the fault but the resolution of the derived side-scan image at this water depth is coarse.

A transect along the tilted carbonate platform north of Puerto Rico will provide evidence for slope failure and fissure development within the platform, which are probably induced by fresh water seepage. The platform was horizontal near sea level until 3 m.y. ago, but its northern edge is now at depths of 2500-4000 m. The transect can be extended to the north deeper down the 1-1.5 km thick cliff-like edge of the carbonate platform, which will provide a geological cross-section as well as likely fresh water seepages.

The 1867 Virgin Islands earthquake and tsunami devastated both St. Thomas and St. Croix. The source of the earthquake is unknown, despite the large event and the spectacular underwater topography of the area. Using multibeam bathymetry and tsunami modeling, the USGS work located the fault at the same place along a scarp crossing the wall diagonally. It is difficult to verify the location and orientation of this fault without direct seafloor observations, because the wall is almost devoid of sediment. This target could be combined with a vertical transect across the northern wall of the Virgin Islands basin, where depth varies between 4500 m and 50 m over 10 km. Additionally, there are some faults and mounds on the floor of the Virgin Islands Basin that could focus fluid flow.

Although the U.S. Caribbean and the wider Caribbean region contain a huge diversity of deep-water corals, there are no conservation or management efforts specifically targeting deep coral ecosystems. The available information on benthic communities associated with deep coral ecosystems in Puerto Rico and the U.S. Virgin Islands is scarce and mostly limited to taxonomic listings from incidental collections by fish traps, shrimp trawls and coral entanglement devices. To this day, quantitative characterizations of sessile-benthic populations as well as relative abundance of motile-megabenthic invertebrates and fishes in these deep reef habitats are lacking. Therefore, from a biological perspective, this region should be explored in detail.

Overview of target area Portions of the deep basins and continental margins between and surrounding the Greater Antilles islands of Hispañiola, Puerto Rico, and the U.S. and British Virgin Islands are contained within the Exclusive Economic Zone (EEZ) of the United States of America and represent an ideal setting for a major ocean exploration program. The Ocean Exploration Trust's E/V *Nautilus* and NOAA Ship *Okeanos Explorer* are well equipped to carry out deep-sea investigations of the biological, geological, and physical oceanographic characteristics of this region of US territory. The region also has the potential to contain historical shipwrecks from colonial times and the age of early Atlantic exploration.

This unexplored region contains some extreme depths, including the deepest location in the Atlantic basin at the Puerto Rico Trench – too deep for either ships' remotely operated vehicle systems – but ideally suited for short distance deep-to-shallow biological and geological transects to document and sample the depth-varying geological structure and biological habitat around Puerto Rico and the Virgin Islands

The Mona and Anegada passages represent conduits for the flow of Atlantic waters into the Caribbean Basin. This process is poorly understood and worthy of exploration, especially where intermediate and deep waters flow through the Anegada Basin. Mona Passage is one of the entry points for surface Atlantic waters into the Caribbean. These waters become warmer and saltier in the Caribbean and returns back to the Atlantic via the Gulf of Mexico as the Gulf Stream. USGS multibeam bathymetry data clearly show flow marks on the seafloor across the shallowest parts of the Mona Passage. At some locations strong turbulence was noticed when imaging with multibeam sonar.

Deep coral ecosystems are distributed throughout the poorly known platform of the Puerto Rico fault zone, a submerged section of the Antillean Ridge that extends across the entire Mona Passage, connecting Puerto Rico with Hispañiola. The deep reefs of Mona Passage are of particular interest because they are the main habitats of the queen snapper (Etelis oculatus) and the silk snapper (Lutjanus vivanus), two commercially important fish species in Puerto Rico. The depth ranges of these species are 250-500 m and 146-329 m, respectively. The location and distribution of deep coral ecosystems in the US Caribbean is presently unknown and worthy of exploration.

Summary of what is known about the target area The USGS has been engaged in Caribbean exploration and research during the past decade. The foundation for this work was established with funding by the NOAA Office of Ocean Exploration and Research to map the Puerto Rico trench using the multibeam sonar system aboard the NOAA Ship Ronald H. Brown in 2002 and 2003. The work got additional boost from Congress following the 2004 Sumatra earthquake and tsunami. The work has since expanded to include diverse exploration methods such as multichannel seismic reflection profiling, sediment coring, deployment of ocean bottom seismometers to record earthquakes, paleo-tsunami

studies, installation of GPS stations, as well as additional multibeam bathymetry mapping. More than 200,000 km2 of the ocean floor around Puerto Rico and the Virgin Islands has been mapped with resolution varying from 150 m to 5 m depending on water depth. Analysis and modeling of various data sets, the assembly of an historical earthquake catalog, and geophysical modeling followed the mapping. The work led to a detailed view of the Caribbean in scales ranging from several hundred kilometer deep upper mantle to a few centimeter thick storm and tsunami deposits. It led to an understanding of many (but not all!) of the geological processes that shaped this part of the world and their associated natural hazards. The work was accomplished in cooperation with other government and academic institutions both within and outside the U.S., including NOAA - PMEL and the NOAA Biogeography program.

The Mona Passage is crossed by many normal faults that are probably active, but because of current erosion the surface is cleared of recent sediments. Targeted dives to find pockets of sediment offset by the faults could be sampled and dated. The Anegada Passage, which is mostly in British Virgin Islands EEZ, is the only conduit for Atlantic intermediate water into the Caribbean Sea. All other waters entering the Caribbean Sea from the central Atlantic are surface waters because the other sills are only a few hundreds of meters deep. Most of the intermediate waters are thought to run along the northern wall of the passage but bathymetry and seismic stratigraphy data suggest another route and a spillway for the waters farther south. This spillway is bounded by Barracuda bank, a narrow bank, which rises from a depth of 2000 m to 40 m over 3 km. The top of the bank is only 1 km wide and is flat. Nothing is known about the formation of the bank and the possible biological activity on its crest.

Preliminary surveys of deep coral habitats were conducted by the Seabed AUV in 2008. Two 0.5 km long photo transects were obtained at depths ranging from 198 to 280 m in the Mona Passage west of Puerto Rico. Silk snappers were observed during the descent of the AUV at 21 m from the bottom (total depth 198 m) and near the bottom at a depth of 219 m. Abundant coral and sponge communities were also present including large, unidentified sponges and numerous colonies of ahermatypic corals, at a depth of 206 m. The Hercules-Argus ROV system onboard the E/V *Nautilus* will allow us to sample corals and other macro invertebrates for taxonomic purposes as well as provide high-resolution imaging for benthic characterization.

3.12 The spawning aggregation of mutton snapper (*Lutjanus analis*) on the south coast of St. Croix, USVI

Author and collaborators

Barbara Kojis bkojis@hotmail.com
Barbara Kojis LLC

Norman Quinn norman_q@hotmail.com
Tropical Discoveries

Nicky Martinez n/a
Local fisherman

Why this area may be of interest

Biology Fisheries management

Geology

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area No spawning was observed, nor was any increase in L. analis abundance either near the bottom or in the water column observed in our previous work. Considering that the observations were made as unobtrusively as possible with only 2-3 divers in the water and with dives commencing just before dusk and until darkness made further observations impossible, it is difficult to explain why less than 30 minutes after dives were completed that L. analis was easily caught. Possibly, the fish are in water >35 m and the chumming and light on the boat drew them to shallower waters where they were caught. Increased numbers of snappers were observed at a site adjacent to the MPA, but limitations on funding prevented further efforts during to actually sight a spawning aggregation. Further work is needed in this poorly known area of fish spawning aggregations and associated behavior.

Overview of target area In 1993, the US Department of Commerce, based on the recommendation of the Caribbean Fishery Management Council, established a seasonal closed area to protect the spawning aggregation of Lutjanus analis in the southwest corner of St. Croix. Because only a portion of the spawning area occurred in federal waters, joint territorial and federal protection was essential to protect the spawning aggregation. In 1994, the US Virgin Islands (USVI) government established compatible regulations within their area of jurisdiction to establish a seasonally closed area deemed adequately sized to

protect the mutton snapper spawning aggregation. The joint efforts of the two governments established an annual seasonal closed area for L. analis from March 1 to June 30.

Summary of what is known about the target area The mutton snapper aggregation within the seasonally closed area was targeted by St. Croix fishers for many years, even after the implementation of the seasonal closed area. Because fishers often targeted the aggregation at night, enforcement had been problematic. In order to increase compliance and improve enforcement, the U.S Department of Commerce in 2005 and USVI Government in 2006 implemented regulations to prohibit possession of mutton snapper during the presumed peak spawning months, April 1 to June 30, each year in federal and territorial waters respectively.

USVI fishers have often expressed dissatisfaction with the lack of monitoring of the status of spawning aggregations after seasonal closures have been put in place. Management of species by seasonal closing spawning areas to all fishing and prohibiting possession of a species during spawning periods can have profound socio-economic effects, especially in the short term, because of the high CPUE of high value fish that occurs when spawning aggregations are fished. Monitoring the effectiveness of regulations protecting spawning aggregations is needed. Prior to the establishment of regulations protecting the mutton snapper spawning aggregation, biostatistical data obtained from individual commercial fisher catches indicated a decline in landings and size of fish caught from the spawning aggregation.

3.13 Exploration of deep water fauna off the Virgin Islands shelf

Author and collaborators

Norman Quinn norman_q@hotmail.com
Tropical Discoveries

Barbara Kojis bkojis@hotmail.com
Barbara Kojis LLC

Why this area may be of interest

Biology Fish and invertebrate populations

Geology

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area To discover the unknown and map the distribution and abundance of these benthic communities.

Overview of target area The Virgin Islands of the United States (commonly called the United States Virgin Islands, U.S. Virgin Islands or USVI) are a group of islands in the Caribbean that are an insular area of the United States. The islands are geographically part of the Virgin Islands archipelago and are located in the Leeward Islands of the Lesser Antilles. Over 90% of the EEZ in the US Virgin Islands is has depths >200 m and is virtually unexplored.

Summary of what is known about the target area There are virtually no scientific publications of the biological benthic fauna and associated benthic fish populations in waters >100 m in the EEZ of the US Virgin Islands.

Chapter 4

Region 3: Caribbean Basin

Figure 4.1: Map of target areas in the Bahamas

4.1 Bay Islands, Honduras

Author and collaborators

Peter Etnoyer peter.etnoyer@noaa.gov
NOAA

Tom Shirley thomas.shirley@tamucc.edu
Harte Research Institute

Dwight Coleman dcoleman@gso.uri.edu
URI

Brendan Roark broark@geos.tamu.edu
Texas A&M University

Cheryl Morrison cmorrison@usgs.gov
USGS

Tim Shank tshank@whoi.edu
WHOI

Why this area may be of interest

Biology Recently discovered deep-sea coral communities

Geology Large, unmapped vertical escarpment

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area The primary rationale for exploration of the Bay Islands deep-coral reefs is to enhance understanding of population connectivity between deep-coral assemblages of the Gulf of Mexico and the Caribbean Sea. Biogeographic studies indicate that most deep-coral species in the West Atlantic are widely distributed throughout the Gulf of Mexico, South Atlantic Bight, and the Caribbean Sea. Few deep-corals are truly endemic. However, the pathways and means of connectivity between metapopulations are completely unknown. *Lophelia pertusa* is one notable exception, but even then, *Lophelia* studies are largely focused on US waters, lacking samples from other regions for comparison.

Deep-sea corals provide habitat structure for an array of organisms that have developed diverse symbiotic relationships with relative specificities to their host corals. With the established impact to deepwater corals and their associates from 10 to 200+ miles from the

Deepwater Horizon incident, it is now critical to explore for, locate, and characterize deep coral ecosystems outside of the Gulf to not only determine the bioegeographic character of deep Caribbean coral communities, but also populations that may serve as sources of larvae and connectivity to the Gulf and Atlantic (likely via the Loop Current dynamics and Gulf Stream flow). First order exploration, sampling, and characterization of these ecosystems is critical to assess levels of coral and symbiont associate connectivity across hosts and locations inside and outside the Gulf – the Caribbean is the key.

Exploration of the Bay Islands provides a high confidence, low risk opportunity for biological sampling to support connectivity studies, but also provides good opportunities for interdisciplinary research. High-resolution multibeam mapping of the escarpment feature would support geological investigations, protected area management initiatives, and predictive modeling of deep-coral and seep habitat. Water chemistry research would help understand the vulnerability of deep-sea scleractinian corals to low aragonite saturation. Preliminary evidence indicates some corals are growing in undersaturated conditions, but more comprehensive sampling using a CTD-rosette is necessary.

Further rationale for exploration of Bay Islands is the ample opportunity for public outreach and education using telepresence technology in combination with new social media tools and modern biological sampling protocols to help create a new gold standard for bio-informatics technology. More information on this topic can be provided at the workshop.

Overview of target area The Bay Islands of Honduras consist of three islands (Isla Utila, Isla Roatan, and Isla Guanaja) located in the western Caribbean Sea at the southern extent of the Mesoamerican Reef (MAR), approximately 40 km north of mainland Honduras. Recent visual reconnaissance surveys working off Roatan 300-800 meters deep identified several rich assemblages of hard and soft corals with numerous associated epifauna bearing strong resemblance to corals and associates in the Gulf of Mexico and South Atlantic Bight. The assemblages offer a good opportunity for biological sampling to support population connectivity studies, as well as the opportunity to map and survey promising unexplored habitat down to 3,000 meters and more. The Bay Islands are situated upstream from the US EEZ at the western edge of the Caribbean Current, so these and others sites along the MAR may be an important source of larvae to the Gulf of Mexico and Straits of Florida.

Summary of what is known about the target area Visual surveys off Roatan were conducted in 2010 and 2011 using a private submersible to 800 meters depth. The surveys identified six sites along a five kilometer escarpment with substantial aggregations of deep-sea corals including stony corals *Lophelia pertusa* and *Madrepora oculata*, and large

soft corals in the families Corallidae, Primnoidae, and Plexauridae. Only a few of ∼50 morphospecies present could be sampled, 4 stony corals, one sea fan, no black corals, no sponges. Sea fans are large (>1 m) and presumably very old. Large colonies have many ophiuroids and crabs. No associates have been sampled. The coral colonies are colorful and photogenic, which is good for public outreach. Some shipwrecks are in the area. The vertical escarpment is 10-20 kilometers in length and descends to 3,000 m or more, with highest known coral diversity between 500-700 meters depth. The escarpment had extensive basaltic rock with intermittent sand channels, punctuated by large carbonate blocks broken off from the shallow coral reef above.

4.2 Chicxulub Ejecta Impacts

Author and collaborators

Robert/Bob Page bob2yacht@gmail.com
Kansas State University

Why this area may be of interest

Biology

Geology Offshore oil development is increasing in the Gulf of Mexico and may encroach on the sites

Chemistry Material from the Chicxulub Asteroid may be identified from the terminal impact area

Physical oceanography The findings would be of international interest

Archaeology/history Exploration and confirmation that the trenches and terminal impact are related to Chicxulub

Other NASA, Astronomers, Geologists, Oceanographers

Rationale for exploration in the target area The Chicxulub Asteroid impact is thought to have caused the extinction of the dinosaurs about 65 million years ago. The relationship of the trenches to the Chicxulub impact seem confirmed by extending their central axis which impacts at the Chicxulub impact. Few oceanic Asteroid impact sites have been identified or explored. What appears to be the terminal impact field of the object that created the trenches may reveal original material from the impactor and contribute to the understanding of large Asteroids

Exploration of the trenches and the impact field will contribute to the knowledge of the Chicxulub Impact and potential identification of its composition.

Research of the trenches will identify areas of future exploration and research by the international scientific community.

Overview of target area What is believed to be impact trenches created by ejecta from the Chicxulub Asteroid (21°20'N 89°30'W) were discovered while preparing for and review of data for a 11,000 mile voyage on a small research vessel from the East coast of Australia to the Strait of Juan De Fuca. The trenches are on a bearing of 131.82 degrees 705 K from the Chicxulub impact. The ejecta appears to have created two trenches. The two trenches begin at approximately 705 K down range, 17°21'54.584"N 85°4'13.794"W at a depth of 5,000 m. On NOAA chart 28004 this is on a straight line from the Guanaja Island, Honduras Light to the Light on Santanilla or Swan Island. This line is on a bearing of 244 and the impact is 58 miles SW of the light on Santanilla Island. The object that created the trenches appears to have carried on another 358 km to its breakup and terminal impact approximately 1,116 km from the Chicxulub impact. The terminal impact field is in the area of the Miskito Cays which have boulders more than 10 meters high embedded in the shallow seas. These boulders may be part of the Asteroid or ejecta from the impact.

Summary of what is known about the target area The target trench area is about 100 km north of the Honduras coast.

The target terminal impact area is about 55 km east of the border between Honduras and Nicaragua. The trenches can be viewed in Google Earth and are first visible from about 1,000 mile attitude. Barry Eakins, NOAA, referenced a single-beam profile, KA9322008, that appears to cross the trenches identified and suggested that we download the data and look at it. We have done that and have prepared preliminary bathymetric data on the trenches. We have also prepared a conceptual section of the Asteroid impact and ejecta ballistics that created the trenches and its impact field.

Camargo and Juarez Abstract 2004AGUSMGP31A..08C ...suggests that 'multiple impacts at sea....' would be related to the Chicxulub impact. The trenches are in an area of the Western Caribbean that has a current towards the Gulf of Mexico that would have prevented the trenches from being silted in. They are in the area of the Caribbean Oceanic Transform Fault that is moving approximately 10mm/year to the NW.

4.3 Caribbean Margin of Nicaragua

Author and collaborators

Manuel Duarte mduarte@ine.gob.ni
Nicaraguan Institute of Energy

Why this area may be of interest

Biology

Geology Geological history

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area The above mentioned is based upon geological and geophysical studies and surveys conducted in the Caribbean Margin. Recent seismic studies have confirmed the presence of important structures which contribute to the history of the basin, as well as the petroleum potential.

Overview of target area Miskito basin located in the Caribbean Margin of Nicaragua is composed by two blocks nominated Chortis and Chorotega. Seismic studies conducted offshore and addressed to petroleum potential have also shown the geological structures of the area,the faulting location and the geological development of the basin.

It is very important to find out how the joint of these two blocks occurred and how they are connected.

Summary of what is known about the target area The geological and structural development of the Miskito Basin and other sub-basins have complex faulting systems. These characteristics allow the historical knowledge of the basin since Jurassic to recent times.

4.4 Oil Exploration

Author and collaborators

Veronica Artiles veronica.artiles@mem.gob.ni
Ministry for Energy and Mines

Why this area may be of interest

Biology

Geology

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area Petroleum exploration started in 1960 in Nicaragua including the drilling of 24 wells during exploration campaigns carried out in 1960-1978. Several wells gave hydrocarbon evidences considering out-of-date technology. The last exploration campaign in Nicaragua started in 2008 and is currently active.

Oil exploration is based on evaluation studies, geophysical surveys, and drilling that have confirmed the sedimentary basin and the existence of geological structures to accumulate hydrocarbons.

Overview of target area Petroleum Exploration is active in the Offshore Caribbean Margin of Nicaragua and new exploration drilling will be conducted soon. Exploration is conducted by private oil companies.

Summary of what is known about the target area The Nicaraguan Caribbean platform is a sedimentary basin where good structures for hydrocarbon accumulation have been identified. Sedimentary thickness of the Miskito basin varies from 2,000 meters in the South to 10,000 meters in the North. These sedimentary succession was deposited during the Tertiary to Recent Times. Carbonate with good porosity has been identified in the central part of the basin.

4.5 Regional tectonics, Geophysics

Author and collaborators

Carlos A. Vargas cavargasj@unal.edu.co
Universidad Nacional de Colombia

Paul Mann pmann@uh.edu
University of Houston

Lorena Moscardelli lorena.moscardelli@beg.utexas.edu
University of Texas

Why this area may be of interest

Biology

Geology Seismotectonic regime

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area The deployment of several Ocean-Bottom Seismometers (OBS) on the Colombia Basin and on the continental shelves of Colombia and Panama, will improve the seismotectonic knowledge of the Southern Caribbean and to promote new images of the oceanic lithosphere geometry, as well as the interaction between the Panama - Costa Rica and northern South America. In addition, the installation of at least 15 OBS stations in this area will provide an improvement of the velocity models used by different agencies in charge of hypocentral solutions, and strengthen the knowledge of the stress regime generated by the processes of tectonic convergence. Although it is desirable a medium to long term campaign (e.g. 2 years), a temporary deployment could substantially contribute to a better understanding of this region.

Overview of target area The SW Caribbean Sea is a large deformation zone that dissipates the relative motion of the Caribbean plate against South America. Despite the high activity of mud volcanoes, many other evidences of active tectonics in the area are quickly covered by recent sediments from the rivers that flow through this region. From northern Panama to the border between Colombia and Venezuela, a varied structural behavior highlights its tectonic complexity. For example, the presence of large areas crossed by dextral fault systems at the northern region (Oca-Ancon Fault System); the presence of an isolated pyramidal orogenic structure of approx. 5600 masl, gives to the Sierra Nevada de Santa Marta and its continuity into the offshore, an isostatic imbalance that could reactivate fault zones and mobility in onshore of several tributary streams of the Caribbean Sea (Magdalena, San Jorge , Sinu, Atrato rivers etc.); and a zone of thrust- folds related to

the South Caribbean Deformed Belt, which envelops the continental shelves of Colombia and Panama.

Summary of what is known about the target area The SW Caribbean basin is a complex zone of tectonic interaction, key for understanding the geological evolution of America and the Caribbean Sea. The interaction between tectonic blocks (e.g. Panama - Costa Rica block and South America continent) introduces potential natural hazards to a densely populated area, but little studied to date due to socio-cultural patterns, and important technological constraints related to seismic monitoring on the seabed. Energetic seismic events in the northern Caribbean Sea, contrast with sparse seismicity and apparently rare in the South, which does not permit to get clear images of subduction or collision processes (e.g. into Block 6, Figure 4, Workshop Summary, 2011).

4.6 Colombian Caribbean deep water coral communities

Author and collaborators

Francisco Arias Izasa fariasis@invemar.org.co
Marine and Coastal Research Institute INVEMAR

Paola Flórez paola.florez@invemar.org.co
INVEMAR

Andrea Polanco anpolanco@invemar.org.co
INVEMAR

Giomar Borrero giomar_borrero@invemar.org.co
INVEMAR

David Alonso dalonso@invemar.org.co
INVEMAR

Nadiezhda Santodomingo nsantodomingo@gmail.com
Natural History Museum

Why this area may be of interest

Biology Determination of position and extent of deep water corals communities, the structural species and their associated fauna in the Colombian Caribbean.

Geology Identification of geoforms that can affect the spatial distribution of deep water corals communities in the Colombian Caribbean.

Chemistry Identification of key chemical factors that drive the spatial distribution of deep water coral communities in the Colombian Caribbean.

Physical oceanography Identification of key physical factors that drive the spatial distribution of deep water coral communities in the Colombian Caribbean.

Archaeology/history

Other

Rationale for exploration in the target area Due to the depletion of fossil fuel reserves worldwide, Colombia in its development policies has increased the interest of exploration and exploitation of fossil hydrocarbon resources offshore. This exploration needs the correct and accurate knowledge of the ecosystems present on the deep sea. The evidence of coralline banks constructed by different azooxanthellate corals species indicate the priority of studying these deep coral communities in Colombia, in order to prioritize areas for conservation, and avoid human activities that affect those communities.

The three points of the Colombian Caribbean where evidence of deep communities were found, were already declared as an object of study and are considered an Ecologically or Biologically Significant Marine Area (EBSA) under the Convention on Biological Diversity. Add to this, with overexploitation and overfishing of coastal waters, attention has turned to the deep water biodiversity on the deep sea. Research projects have been conducted recently with the aim of establish new fishing grounds in deeper waters. Moreover, despite the value of information found in Colombian deep waters and the new research questions generated by recent discoveries, funding resources and infrastructure technology available in the country is limited. That situation leads the research team to use methodologies that limit the study, and restrict areas and scope, because the use of appropriate technologies (ROV among others) and generation of more detailed information have a high cost.

Overview of target area The Colombian Caribbean has an area extent of 540,876 km^2, a coastline of 1,642 km. The target area belongs to the oceanic bottom ranging from 200 m to 3,000 m. The submarine morphology of the area is very complex, with a sharp slope and the presence of canyons, steeps, domes, depressions, submarine hills, channels up to a 2,000 m depth and deltaic valleys. The region also shows special environmental features as a seasonal upwelling event, which promotes productivity. These morphological and oceanographic conditions provide the adequate habitats to the settlement of different kind of deep water ecosystems, allowing the presence of unique, fragile, and important biological deep water corals communities, which host a high biodiversity associated to them.

Summary of what is known about the target area During previous studies on the continental shelf and upper slope of the Colombian Caribbean between 70 and 1,000 m depth, evidence of three locations with the presence of communities supported by azooxanthellate corals was found. The results of this study represent new evidence of coralline banks constructed by different azooxanthellate corals species than those already reported for the area. The associated faunas were quite different in each one of the three coral settings, represented primarily by anthozoans, crustaceans, mollusks, echinoderms and fishes. In this way, these three unique azooxanthellate coral communities sustain one of the highest species diversities found along the Colombian continental shelf. These points were observed between 70 and 250 m depth and have been identified as key framework species to *Cladocora debilis* and *Madracis myriaster*. Add to those species, the isolated presence of other important species in the deep habitat structural consolidation was detected, as the case of *Lophelia pertusa*, *Madracis spp.* and *Madrepora spp.* as well as the presence of some antipatharians and alcyonaceans as a potential structural habitat-forming species. Three new species were discovered for science associated to these points of interest – *Tethocyatus prahli* (Lattig and Cairns 2000); *Stephanocyathus isabellae Reyes* (Santodomingo and Cairns 2009); and *Heterocyathus antoniae Reyes* (Santodomingo and Cairns 2009). However there are still unknown the spatial distribution and extent of these communities.

4.7 Islas del Rosario y San Bernardo (Rosario and San Bernardo Archipelago)

Author and collaborators

Juan Sanchez juansanc@uniandes.edu.co
Universidad de los Andes

Luisa Dueñas lf.duenas161@uniandes.edu.co
Universidad de los Andes

Why this area may be of interest

Biology Our main biological interest is deep-sea coral reefs, including both hard (scleractinians) and soft (octocorals) corals and their associated organisms. For the target area, Florez & Santodomingo (2010) found a deep-sea coral reef on the continental platform at 150 m of depth. The reef was dominated by the hard coral *Madracis myriaster* accompanied by 19 species of scleractinians, and a total of 135 associated species. It is believed that the continental slope down to 4000 m harbors additional deep-sea fauna (Carvajal et al. 2010).

Geology Islas del Rosario and San Bernardo are less than 5,000 years old. They arose by the activity of mud diapirism that lifted the seabed and created optimal conditions for coral reef formation. During the last glaciation period, sea level decreased, and the islands emerged (Cubillos 2007). The mud volcanoes that gave origin to the archipelago were part of a volcanism chain that still runs from Barranquilla, going through Cartageña and the archipelago, all the way down to the Uraba Gulf. Both terrestrial and submarine mud volcanoes, many of which are still active, characterize the volcanisms chain. Deep-sea research will enable the exploration of volcanism activity around the target area.

Chemistry See Geological interest.

Physical oceanography See Geological interest.

Archaeology/history The area of interest lays a few miles southwest of the city of Cartageña de Indias. This city was established in 1533, and since then it has been one of the largest ports in the Caribbean. During the colonial period, around Cartageña and Islas del Rosario many battles between English and Spanish-French ships took place. The major historical evidence of those battles is the San José shipwreck, sunken in 1708 by English ships. Because no deep-sea exploration has been done in the area, additional evidence of the colonial period could be found.

Other

Rationale for exploration in the target area Islas del Rosario and San Bernardo harbor a great diversity of conditions that could be of great interest for geologists (e.g. mud volcanoes, canyons), biologists (e.g. deep-sea coral formations), and oceanographers (e.g. deep water and sediment flow). Additionally, it has a prerogative location given that the archipelago is positioned in an area under the direct influence of two of the largest rivers that flow into the Caribbean. This characteristic gives the area particular physical and chemical conditions not found elsewhere in the region. It is then possible to evaluate the effect of the rivers discharge on the underwater topography, volcanic activity and growth of soft- and hard-bottom fauna.

Overview of target area In general, the Colombian continental slope varies in width from 25 to 80 km, and falls to a maximum depth of 3,500-4,000m (Vinnels et al. 2010). It is characterized by a great bathymetrical, sedimentological, and topographical heterogeneity with hills, valleys, seamounts and canyons (both parallel and perpendicular to the coast line), and slope drops from 2-30° (INVEMAR 2010).

The area of interest, Islas del Rosario, is a small archipelago located at 30 km southwest of the city of Cartageña. It belongs, along with the San Bernardo archipelago, to the National

Natural Park Rosario and San Bernardo Corals (NNP-RSBC; 10°15 and 9°35N, 75°47 and 75°50W), established in 1977. The Marine Protected Area (MPA) has an extension of 1,200 km^2 and represents the most diverse and developed shallow-coral reefs in the Colombian continental platform. About 40 islands and cays form both archipelagos, whose geological origins were mud diapirism (Vernette et al. 1992).

The archipelagos are near the Sinú Accretionary Prism that is an arched submarine feature that goes from the shelf-slope break to the basin floor (Colombian Basin) with depths greater than 3,500 m. This submarine structure exhibits the typical features (e.g. thrusts and folds) seen in an accretion process, and around 250 m of depth there is an evident shelf-slope break with slope drops from 9-30°. Tributary gullies and canyon networks are also present. They are thought to play an important role in the sediment dispersal from rivers mouths and deltas down to the Colombian basin, mainly from the Sinú River and in a small proportion from the Magdalena River (Vinnels et al. 2010).

Summary of what is known about the target area For the whole Colombian continental platform, most of our deep-sea knowledge comes from geological surveys. Data from multibeam echosounder bathymetry surveys and 2D seismic reflection profiles has been obtained over the years mainly for oil and gas exploration purposes. However, the same data has helped to understand the diapirism activity, submarine channel architecture, flow behavior, and sediment dispersal pathways from the Colombian Continental Shelf to the Colombian Basin floor (Estrada et al. 2005, Vinnels et al. 2010). So we can say we know more about the geomorphological complexity of our continental platform, slope and basin than its biodiversity.

Biological deep-sea exploration in Colombia is relatively recent and restricted. Since 1995, several expeditions have been conducted along the Caribbean Colombian coast, particularly on the continental shelf and upper slope, from 50 to 900 m depth (INVEMAR 2010). These explorations have been done using trawling nets and bottom dredging along transects at different depths. Different kinds of organisms have been found in both soft and hard bottoms, from where new species have been described (e.g. *Stephanocyathus isabellae* - Cnidaria, *Armina juliana* - Mollusca, *Nancyplax vossi* - Crustacea, *Ctenantedon kinziei* - Echinodermata, *Paramyxine wayuu* - demersal fish, among others) and new distributions have been registered (INVEMAR 2010). Particularly, for Islas del Rosario and San Bernardo, a deep-sea coral formation dominated by *Madracis myriaster* was found between 150 and 160 m. According to a pioneer seismic survey, Vernette (1985, see also Vernette et al. 1991) argued that there was an older barrier reef off Islas del Rosario and San Bernardo that drifted with the continental shelf towards the slope. This suggested that the upper slope near this area contains remarkable limestone formations, which are likely substrates for deep-sea corals in general.

References Carvajal, et al. 2010. areas significativas para la biodiversidad. Pp 393-423. En INVEMAR (Eds.). 2010. Biodiversidad del margen continental del Caribe colombiano. Serie de Publicaciones Especiales, Invemar No. 20 p. 4588.

Cubillos, C. et al. (Eds.). 2007. Estudios e investigaciones de las obras de restauración ambiental y de navegación del Canal del Dique. Informe CM-CD-5. Pp 96.

Estrada, F. et al. 2005. Quantitative study of a Magdalena submarine channel (Caribbean Sea): implications for sedimentary dynamics. Marine and Petroleum Geology 22: 623–635.

Flórez, P. & N. Santodomingo. 2010. Cnidaria: corales escleractinios, antipatarios, anémonas, zoantídeos, octocorales e hidroides. Pp 151-178. En INVEMAR (Eds.). 2010. Biodiversidad del margen continental del Caribe colombiano. Serie de Publicaciones Especiales, Invemar No. 20 p. 4588.

Gracia, A. & N. Ardila. 2010. Moluscos de la plataforma y talud superior del Caribe colombiano (20-940 m): 12 años de investigación. Pp 182-227. En INVEMAR (Eds.). 2010. Biodiversidad del margen continental del Caribe colombiano. Serie de Publicaciones Especiales, Invemar No. 20 p. 4588.

INVEMAR (Eds.). 2010. Biodiversidad del margen continental del Caribe colombiano. Serie de Publicaciones Especiales, Invemar No. 20 p. 458.

Vernette, G. 1985. La plateforme continetal caraibe de Colombie (du deboche du Magdalena au Golfe de Morrosquillo) Importance du diapirisme argileux sur la morphologie et la sedimentation. Tesis de Doctorado

Vernette, G. et al. 1991. Mud diapirism, fan sedimentation and strike-slip faulting, Caribbean Colombian Margin. Tectonophysics 202.

Vernette, G. et al. 1992. Mud diapirism, fan sedimentation and strike-slip faulting, Caribbean Colombian Margin. Tectonophysics 202 (2–4):335–349.

Vinnels, J. et al. 2010. Depositional processes across the Sinu Accretionary Prism, offshore Colombia. Marine and Petroleum Geology 27:794–809.

4.8 Sinú Belt, Columbian Basin, S. Caribbean

Author and collaborators

Lisa Levin llevin@ucsd.edu
Scripps Institution of Oceanography

Adriana Gracia adriana.gracia@invemar.org.co
INVEMAR, Columbia

Why this area may be of interest

Biology Methane seep biota, slope biota

Geology South Caribbean Deformation Front

Chemistry Methane seepage

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area The southwestern Caribbean could be cataloged as one of the regions of high priority due to limited biologic, geological, and oceanographic knowledge and because this area may be a region of significant transition or 'passages' (NOAA Workshop Summary May 2011). This region reflects physical transitions and potential historical pathways of larval exchange between what is now the Pacific and the Caribbean. The chemosynthetic ecosystems of the Colombian slope may hold key information that will help explain unusual species distributions and genetic linkages between seeps of the Gulf of Mexico, the Gulf of California, and the Costa Rica Margin, and even the eastern Atlantic.

Interdisciplinary and multinational collaboration is required on a large scale to explore these areas and to advance in the global understanding of chemosynthetic ecosystems. Researchers at the Instituto de Investigaciones Marinas y Costeras - Invemar and the Museo de Historia Natural Marina de Colombia stand ready to collaborate. Key goals would be exploration and basic characterization of local environments, to understand physical and geological structure and biotic interactions with other ecosystems. The available data indicate that at least the southern area off Colombia (Sinú area - near the border with Panama approx 10°N 76°W) where most of the records of chemosymbiotic species occur (500 - 700 m), should be considered as a priority for the study of seep environments. The scarcity of direct observations of seep communities for the Colombian Caribbean highlights a challenge that should be tackled in the short and medium term in order to gain sufficient information for assessing the current conservation status of these fragile communities.

Ultimately, there is need of a follow up expedition to provide complementary information about taxonomically enigmatic species, carry out DNA sequencing (to establish species identities and determine whether there is gene-flow between regions), describe the ecology of the autotrophic and heterotrophic fauna and describe the geology and geochemistry of the habitats. The characterization of communities in this region provide key information to understand the biodiversity, ecology, and evolution of the fauna based on chemosynthetic processes in the Atlantic and will allow direct comparison with other areas in the same

region and with the East Pacific Ocean at similar latitudes. Studies of deeper sites (800 - 4,000 m) will to continue filling gaps in our knowledge about biogeographical patterns of seep communities at a regional and global scale.

Overview of target area The Caribbean basin is divided into four smaller basins: the Yucatan, Colombian, Venezuelan, and Granada basins. The deep-sea Colombian basin is one of the less explored areas along the Caribbean. This exhibits morphologic features such as submerged hills, escarpments, canyons, channels, levees, mass-flow deposits, and domes related to mud diapirism. The Colombian Caribbean Sea exhibits different morphological sectors which are characterized by a wide continental shelf (with maximum values of 50 km at the Morrosquillo gulf) or a very narrow one (off Sierra Nevada de Santa Marta area). Their morphology is complex and is controlled by the Magdalena River delta and the Sinú accretionary complex. Previous studies in the area came from biological records of few stations carried out by regional deep-sea expeditions. The most relevant include the R/V *Oregon* in the 70's made by the U.S. Bureau of Commercial Fisheries, R/V *Pillsbury* in 1972 made by Rosenstiel School of Marine and Atmospheric Science, Miami, and CIOH-Invemar-Smithsonian in 1995 on the R/V *Ancon*. In 2011, along the southernmost part of the Colombian Caribbean (continental shelf and slope areas belong to the Sinú belt) new biological and geological evidence emerged supporting the presence of chemosynthesis-based environments, previously unknown in Colombian waters.

Summary of what is known about the target area Recently and based on previous results, the Marine and Coastal Research Institute of Colombia (INVEMAR) carried out a series of cruises (1998-2009), whose primary aim was to fill the information gaps in the inventories of the Colombian soft-bottom epibenthic macrofauna inhabiting depths of 20 to 900 m. These biodiversity inventories for the Caribbean coast of Colombia offered a first glimpse of this sea floor and also provided the the first evidence of environments based on chemosynthesis processes (cold seeps), around 500-700 m depth. Biological and geological evidence include: (i) key species such as bivalves and gastropods (ii) empty tubes of siboglinid (vestimentiferan) polychaetes and (iii) authigenic carbonate rocks. This information is preliminary since the presence of some of chemosynthetic bivalves is sparsely reported and we are lacking any ecological information. There is no knowledge of the extent of such habitats, how they are structured, species composition, and their relationships with other slope faunas. Only a small fraction of the Colombian Caribbean, which reaches almost 4,000 m depth, has been explored.

4.9 Bonaire, Mesophotic reefs and tsunami deposits

Author and collaborators

Arthur Trembanis art@udel.edu
University of Delaware

Dr. Mark Patterson mrp@vims.edu
College of William and Mary

Dr. Alex Forrest alforrest@ucdavis.edu
UC Davis- Tahoe Environmental Research Center

Dr. Jim Leichter jleichter@ucsd.edu
UC San Diego

Dr. Dale Stokes dstokes@ucsd.edu
UC San Diego

Why this area may be of interest

Biology some of the most pristine reef in the Caribbean, yet signs of distress in shallow reef and the discovery of new deep unexplored mesophotic reefs

Geology discovery in 2008 of distinct downslope slump features possibly either tsunamigenic or hurricane deposits (there is a big debate in the geologic community about these) mesophotic (pale?) reefs >100 m depth and also occurrences of distinct

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area In a precursor exploration expedition in 2008 we (the collaborators listed below) conducted a 3 week investigation of the leeward reef and insular shelf of Bonaire and Klein Bonaire utilizing autonomous underwater vehicles (AUVs) exploring sites from depths of 10-240 m. Our subsequent analysis of the swath bathymetry, side-scan, and color still camera images collected over the reef system identified many previously unknown and uncharted deep mesophotic reef structures and other unique geologic deposits that may be the remains of tsunami or hurricane storm damage. At the time of our previous expedition we had neither the deep ROV capability nor analyzed mapping results to be able to target these newly discovered sites adequately. We were

contacted shortly after the expedition by Vulcan Enterprises and the operators of the M/V Octopus seeking guidance on sites for them to take their ROV and submarine system to targets around Bonaire but we were unable to work out the logistics on an expedition at that time and we were still very early on in our analysis of the AUV mapping data. We now have the detailed high resolution (20 cm to 1 m gridded) map datasets to be able to target these sites along the leeward coast that would be excellent locations for exploration by the E/V Nautilus and it's available assets.

Exploration of these recently discovered sites would be extremely valuable and telling both in terms of assessing the condition of these mesophotic reef systems, are they relict and moribund or still active sites of deep reef growth and thus a potential refuge and recovery resource for shallower portions of the reef. Furthermore, exploration of the distinct down slope slump features could provide critical in addressing the debate in the geologic community regarding the interpretation of onshore boulder deposits that have been interpreted by some as tsunamigenic (Scheffers and Kelletat) and as less catastrophic in origin paleotempestites (Morton et al). The marine record of these processes which we believe to be found in these insular shelf sites that we have located may hold the key to this debate and has valuable implications for human risk assessment from these geologic hazards for the people of the Caribbean region.

Overview of target area Coral reefs surrounding the island municipality of Bonaire, Netherlands, are arguably some of the most pristine in the Caribbean even though there is now evidence of coral mortality, decline in cover and changing population dynamics as compared to previous decades (Bak et al. 2005). Ecosystem research in Bonaire has been focused along the shallow (< 12 m water depth), near-shore reef communities. For example, van Duyl (1985) mapped out bottom types and benthic community structure around the entire shoreline of the island. Little to no work has been done to date in the mesophotic coral ecosystems (MCEs) that have only recently been shown to exist (Keller and Trembanis, 2010; Keller, 2011) in this region at water depths greater than 75-100 m.

Shown to exist at multiple locations around the world (e.g. Bridge et al. 2010; Fricke and Meischner 1985), MCEs deep-water communities are: (1) generally extending from the shallow reefs ($10 - 30$ m deep) to the bottom of the photic zone (> 75 m depending on the light penetration through the water column; Bridge et al. 2010); (2) potentially important refugia for deep and shallow water fish and coral species (Lesser et al. 2009); (3) important sources and sinks of shallow coral larvae important for the recovery of damaged coral reefs (Bongaerts et al. 2010); (4) comprised mainly of zooxanthellate octocorals (Kahang et al. 2010); and, (5) sources of biological and physical mixing at depth in the water column (Leichter et al. 1998).

Advances in recent years in field robotics (Remotely Operated Vehicles, ROVs), and sur-

vey techniques (sonar and benthic imagery techniques) allow MCEs to be explored in an unprecedented way (Bridge et al. 2010). We previously used an AUV as a data collection platform to survey the reef system broadly but without a large capable ROV we have been unable to get close up direct video and sampling of the new sites we have identified.

Summary of what is known about the target area Bonaire, Netherlands is in the Caribbean Sea immediately north of Venezuela (12°10'N, 68°17' W). The island municipality of Bonaire is comprised of the main island of Bonaire itself and then the smaller island of Klein Bonaire, which is located in the leeward, eastern side of the main island. While the western side of the island is subject to relatively frequent hurricane, the eastern side sees infrequent events (Bries et al. 2004). The eastern side of the island is also exposed to smaller wave energy environments (van Duyl, 1985). As wave heights along the eastern side of the island are lower than the western, the shallow reefs are better preserved (Steneck and McClanahan 2004). Slopes at almost all the locations are relatively shallow ($<5°$) until the reef break $\sim$ 100 m from shore and then dropped quite steeply ($>20°$) as evidenced by the steep isobaths in all directions around the island.

Due to its long history of conservation, Bonaire is an ideal place for scientists to conduct research programs in a more pristine environment than would be available in other locations. One of the most famous works of research done in Bonaire was the Atlas of the Living Reefs of Curaçao and Bonaire (Netherlands Antilles) by Dr. Fleur van Duyl in 1985. This atlas maps the bottom type and benthic community from the shoreline to a depth of 10-12 m. Even though this atlas has become somewhat dated, it is still relevant as a benchmark for present day research and comparisons.

Percent coral cover is the highest and percent algal cover the lowest compared to other Caribbean reefs and thus its reef environment represents a baseline sensu Jackson (2001). Bonaire's economy depends heavily on diving tourism, with over 70,000 SCUBA divers entering its waters annually. Bonaire's reefs are among the most well protected in the Caribbean with no collections of any kind allowed, with the exception of a hook and line fishery. The Bonaire Marine Park Authority oversees the administration and protection of this unique underwater resource with help from STINAPA, a management advisory body. Although the shallow environment near Bonaire has been extensively visited, little to no survey work has been conducted on the deeper reef (60-100 m) on into deeper water (100-300 m).

Despite Bonaire's position outside the hurricane belt, hurricanes, though uncommon, do occur. The Metrological Service of the Netherlands Antilles and Aruba lists 37 tropical cyclones passing within 100 nautical miles of 12.5N 69.0W from 1605 through 2008. One particularly notable storm, Hurricane Lenny, passed to the north of the Netherlands Antilles, in a west to east direction in November 1999 (Scheffers, 2004). Even though the closest distance from the storm to the islands was over 350 km (188 nautical miles), the

wave damage inflicted on the leeward reefs was the most severe ever recorded. (Meyer, Bries, Greenstein, & Debrot, 2003). Another storm of interest, Tropical Storm Omar, passed within 200 km of Bonaire in October 2008. After the storm, surveyors claimed that 75% of the coral deeper than 20m was covered with silt, though negligible mechanical damage was observed. The shallow reefs, however, lost a significant part of their adult coral population (de Leon, 2008).

Although tsunamis are extremely rare in this area, particularly in recent history, they do occur, with the most recent major occurrence taking place sometime during the sixteenth century (Scheffers, Scheffers, & Kelletat, 2005). There have been 91 reported wave events, since 1530, which are considered to be possible tsunamis. Of these reports, 27 are considered to be reliable and an additional nine are classified as true tsunamis (Lander, Whiteside, & Lockridge, 2002).

4.10 Trinidad & Tobago Fish and Oil

Author and collaborators

Judith Gobin Judith.Gobin@sta.uwi.edu
University of the West Indies, St. Augustine

Prof. John Agard John.Agard@sta.uwi.edu
University of the West Indies, St. Augustine

Dr. Patricia Miloslavich patricia.miloslavich@gmail.com
Universidad Simón Bolívar

Dr. Eduardo Klein eklein@usb.ve
Universidad Simón Bolívar

Why this area may be of interest

Biology yes

Geology yes

Chemistry yes

Physical oceanography yes

Archaeology/history yes

Other

Rationale for exploration in the target area Relatively little is known about the deep sea/shelf areas on the east coast of Trinidad as well as the Oil seep areas (Gulf of Paria, west coast). The ultimate goal of this exploration would be to provide critical data such as: Marine geological data and sediment benthic faunal data, Geophysical, geological and data on the seabed character and distribution of sediments, and Biodiversity (fauna and flora) and distribution data . Such data can be integrated to map biotopes using seabed faunal assemblages, overlaid with sea bed types- habitats, sediments etc. Such characterisation of the seabed and resources, the unique interactions and ecosystem functions will be useful in order to guide future coastal/marine management decisions for Trinidad and Tobago.

Overview of target area The twin island state of Trinidad and Tobago (T&T) is archipelagic and located in the continental shelf area of South America. This uniqueness is compounded by the fact that T&T sits in the proximal area of two of the world's largest river systems- the Amazon and the Orinoco, which together account for approx. 20% of fresh water discharges into the world's oceans. The gradient of oceanographic conditions surrounding the islands of the lesser Antilles constitutes the major overall environmental determinants of environmental conditions which include estuarine (dark green/brown waters), intermediate (aquamarine waters) and oceanic (blue waters) areas. Trinidad and Tobago's marine production is expectedly greater than the rest of the Lesser Antilles, because of its location on the estuary and additionally, it's location on the continental shelf.

Summary of what is known about the target area The shelf area is responsible for Trinidad and Tobago's (T&T) rich resources of commercial fisheries and oil and gas fields (east and north-east coast). T&T has an extensive offshore production of oil and natural gas which is presently being exploited by mainly multinational energy companies. Along the Gulf of Paria coast (west) of Trinidad there are several world scale petrochemical plants (includes iron and steel, methanol, urea, ammonia etc.) which are fuelled by these natural gas resources. Of additional interest is the La Brea oil seep, located between Point Courbarill and Point Rouge west of the Trinidad Pitch Lake is the world's largest natural deposit (over 100 acres and approx. 250 ft deep) of asphalt. A steady stream of oil globules can be seen emerging at the surface of the water over an area of approximately 70-100 m2. The La Brea seep has one of the highest seepage rates in the world with an estimated volume of 100 barrels per day per 1000 sq. miles metric (Johnson 1970; Wilson et al. 1979; Agard et al. 1993). Within hydrocarbon-rich environments such as seeps, numerous oil-degrading bacteria have been identified which may utilize the hydrocarbons as a source of energy, and serves as a supplementary food source for meio- and macro-benthic organisms in shallow water (Spies and DesMarais 1983; Bauer et al. 1990).

Chapter 5

Region 4: Lesser Antilles

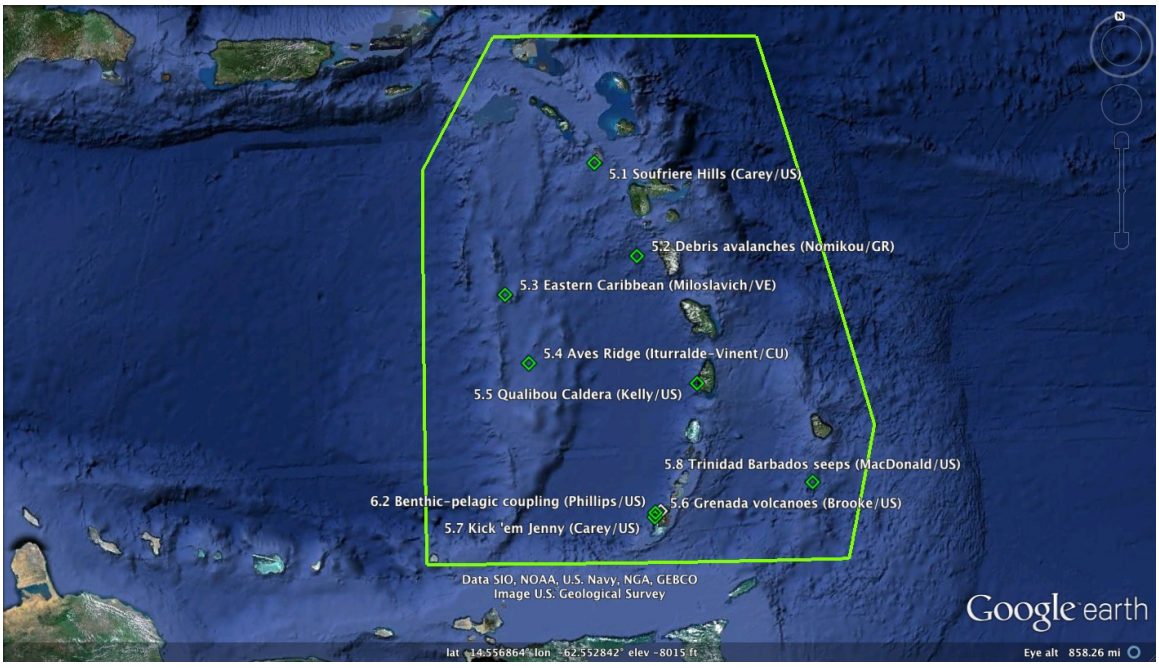

Figure 5.1: Map of target areas in the Lesser Antilles Region

5.1 Submarine slopes of Soufriere Hills volcano, Montserrat, Lesser Antilles

Author and collaborators

Steven Carey scarey@gso.uri.edu
Graduate School of Oceanography, University of Rhode Island

Dr. R.S.J. Sparks Steve.Sparks@bristol.ac.uk
Bristol University, UK

Dr. Katy Croff Bell katy@oceanexplorationtrust.org
Graduate School of Oceanography, University of Rhode Island

Dr. Pareskevi Nomikou evi@hcmr.gr
University of Athens, Greece

Why this area may be of interest

Biology Impact of eruption-derived volcanic ash on the local biological communities

Geology Turbidity currents, entrance of pyroclastic flows into the sea, submarine debris avalanches, generation of tsunamis, new submarine volcanic centers

Chemistry possible hydrothermal venting

Physical oceanography Production of tsunamis

Archaeology/history Fate of a coastal town destroyed by a 1997 eruption of Soufriere Hills volcano

Other

Rationale for exploration in the target area Pyroclastic flows are one of the most deadly of volcanic hazards. A violent type of pyroclastic flow, sometimes called a volcanic blast from Mont Pelée volcano killed 29,000 citizens of the town of St Pierre in 1902 on the island of Martinique in the eastern Caribbean, and buried Pompei in the AD79 eruption of Vesuvius. They are also one of the most important mechanisms of transport volcanic materials into the ocean basins around volcanic arcs. The eruption of the Soufrière Hills volcano, Montserrat provides an unprecedented opportunity to study these phenomena, especially what happens to the flows when they enter the sea. In particular, the identification of man-made objects in the submarine deposits by exploration techniques will enable an analysis of the dynamics and transport mechanism of large sediment gravity flows in the marine environment. Additionally, the rapid influx of large volumes of volcanic ash can

have significant impacts on the benthic biological communities and new surveys will allow for documentation of such effects on biologically sensitive communities such as shallow and deep-water corals. Finally the presence of unexplored submarine volcanoes in close proximity to the highly active island of Montserrat provide intriguing target of exploration from the perspective of potential hydrothermal venting and recent submarine volcanism.

Overview of target area The Soufriere Hills volcano is located on the island of Montserrat in the northern part of the Lesser Antilles volcanic arc. It has been erupting since 1995 leading to evacuation of most of the southern part of the island. About 1 km3 of andesite magma has been erupted and much of this material has ended up in the ocean in the form of volcanic ash and debris, mostly through the mechanism of large collapses of the lava dome often accompanied by explosions. The collapses include the largest known volcanic dome collapse in history on 12 July 2003. The submarine emplacement of these flows has been documented by repeated bathymetric surveys and coring of the new deposits. The volcanic events also included a devastating volcanic blast on 26th December 1997 that affected the west flanks of the volcano and razed two villages to the ground, sweeping the houses, their contents, and other objects such as trucks and tractors, into the sea. Theses events provide a remarkable opportunity for the application of state-of-the-art ocean exploration techniques to understand the dynamics of pyroclastic flows that are discharged into the ocean and their effects on the marine environment. The area around Montserrat is characterized by hummocky bathymetry indicative of the emplacement of large scale debris avalanches and other types of sediment gravity flows. In addition, to the southeast of Montserrat island there are two submarine volcanic complexes ($\sim$700 meters water depth) that have been identified by SEABEAM mapping but have not yet been explored.

Summary of what is known about the target area There have been numerous collapses of the andesite lava dome at the Soufriere Hills volcano since 1995 and the build-up of submarine pyroclastic flow fans and associated more distal turbidites has been documented in considerable detail through bathymetric surveys with depth resolution of 3 to 10 m and coring. Major collapses of 12 July 2003 (210 x 106 m3) and 20 May 2006 (115 x 106 m3) have been studied, along with data on the distribution of the submarine deposits. However, of great interest is an event that occurred in December of 1997. In October 1996 the western flanks of the Soufrière Hills volcano showed signs of instability and the villages of Morris's, Kinsale and St Patricks were evacuated, as the scientists at the Montserrat Volcano Observatory feared that conditions were right for a violent volcanic blast like that which destroyed St. Pierre, Martinique in 1902 and devastated the landscape around Mount St Helens in 1980. After 14 months the blast occurred on 26th December 1997 at 3 am. In total the event lasted about 10 minutes, but the peak lateral explosion probably lasted less than a couple of minutes with a peak velocity of 300 kph.

The devastation was total at St. Patricks village with only the foundations of the buildings remaining. All structures and objects were destroyed and transported into the sea. A mangled truck and bulldozer were transported 200 metres to the beach in an area where the blast had less energy (< 200 kph) and illustrate their phenomenal energy, which can be likened to a nuclear blast. Given that all the buildings, vehicles and household objects were transported into the sea a key question is how were these materials dispersed on the seafloor? Blast deposits are typically very thin, partly because the material is spread out by the intense dynamics. Thus it should be possible to identify large objects from the village of St. Patricks on the sea floor and map out their distribution. The study suits the methodologies of marine archaeology and the tools that are available on the E/V Nautilus. In addition, there is a cluster of unexplored submarine volcanoes southeast of the island that have been identified by high-resolution bathymetric mapping. Given the highly active nature of the Montserrat area it would interesting to investigate these volcanoes for signs of recent activity or hydrothermal venting.

5.2 ROV Exploration of submarine debris avalanche deposits on the slopes of Montserrat, Dominica, and Martinique volcanic islands.

Author and collaborators

Paraskevi Nomikou evinom@geol.uoa.gr
University of Athens, Dept of Geology and Geoenvironment

Prof. Dimitris Papanikolaou dpapan@geol.uoa.gr
University of Athens

Dr. Vassilis Lykousis vlikou@ath.hcmr.gr
HCMR (Hellenic Centre for Marine Research)

Prof. Alessandro Tibaldi alessandro.tibaldi@unimib.it
University of Milan

Prof. Steve Carey scarey@gso.uri.edu
Graduate School of Oceanography, URI

Dr. Katherine Croff Bell katy@oceanexplorationtrust.org
Ocean Exploration Trust

Why this area may be of interest

Biology

Geology Volcanic Debris Avalanches along the Lesser Antilles arc.

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area The frequency of flank collapses in the Lesser Antilles is at least an order of magnitude larger than at other regions like in Hawaii and in Canary islands. Le Friant et al. (2009, 2010) have shown that as much as 70 vol% of the erupted products along the arc are finally deposited in the surrounding marine environment, emphasizing the need for further submarine studies in this tectonic environment to retrieve a complete picture of the constructive and destructive processes associated with arc volcanism. Furthermore, the constructive as well as the destructive processes along island arcs are often associated with large geohazards. For example, (1) arc volcanoes could erupt explosively, producing large eruption clouds, and (2) flank collapses in these areas can be accompanied by large tsunamis.

Different morphologies and deposit geometries of debris avalanche deposits have been observed along the Lesser Antilles. Large hummocks (as large as 2 km) characterize the debris avalanches off Dominica, whereas the morphology of the debris avalanches off Martinique is smooth. These differences are probably related to contrasted lithologies of the volcanic products (Boudon et al., 2007). Northern island volcanoes collapsed repeatedly and contrast with southern island volcanoes where collapses are infrequent. Such size and frequency variations along a volcanic arc have not been documented previously for any other arc.

Rov Exploration will document the external architecture and stratigraphy of debris avalanche deposits and reveal the degree to which given debris avalanche deposit volumes result from erosion and entrainment during emplacement. Integration of ROV observations and onshore geologic studies are thus the principal way to investigate the morphology of the whole volcanic edifices.

Samples of the hummocks will be collected by grabbing pieces with the ROV manipulator arm or by the rotary coring device and by suction sampling. These samples will be used to assess the bulk composition of the blocks in conjunction with an analysis of the previous sediment piston cores and dredge samples.In addition to the ROV exploration and sampling of the possible debris avalanche blocks a detailed side-scan survey will be undertaken in the debris avalanches deposits. Results of the side-scan survey will be used to evaluate the surface morphology of avalanche field and compare it with more recent examples of known

debris avalanche deposits. Part of this work will include a quantitative of block dimensions and distribution.

The proposed targets for ROV exploration are the following: i) at the NE slope of Montserrat volcano, (where the Soufrière Hills volcano has been erupting and resulting in serious hazards and social disruption since 1995) in water depths of 600-1000 m, ii) at the SW slope of Dominica volcano (where several large silicic eruptive centers are considered active and pose serious potential regional hazards because of the occurrence of large-magnitude ignimbrite-forming eruptions=Soufriere Volcanic complex) in water depths of 2000-3000m and iii) at the NW slope of Martinique volcano (with the sadly famous Montagne Pelée volcano), in water depths of 2100-3000m. The hummocks are similar in morphology to debris avalanche deposits found in other volcanic arc environments, such as Santorini and Nisyros Volcano in the Aegean Sea that have further mapped with sidescan sonar and observed with remotely operated vehicles (ROVs) aboard E/V Nautilus in 2010 (NA007 and NA010). Exploring the volcanic debris avalanches in the Laser Antilles arc could be compared with the similar ones along the Hellenic volcanic arc.

Overview of target area Volcano flank collapses are increasingly recognized as a normal process in the construction and destruction of volcanic edifices (Ida and Voight, 1995; McGuire, 1996; Voight, 2000). Thus, they play a significant role in the evolution of volcanic edifices and on the dynamics of subsequent eruptions and are a significant potential geohazard. The recognition of flank-collapse events is based on mapping debris avalanche deposits that can be traced to a generally horseshoe-shaped collapse depression (Voight, 1981). The most voluminous events (volumes from tens to hundreds or even thousands of cubic kilometers) have been recognized on oceanic islands: Hawaii (Lipman et al., 1988; Moore et al., 1989), La Réunion (Labazuy, 1996; Oehler et al., 2004, 2008), and in the Canary archipelago (Holcomb and Searle, 1991; Watts and Masson, 1995; Urgeles et al., 1997; Krastel et al., 2001).

On volcanoes of the Lesser Antilles arc, at least 52 flank-collapse events have been identified (Deplus et al., 2001; Le Friant, 2001; Le Friant et al., 2002, 2003a, 2003b, 2004; Lebas et al., 2011; Boudon et al., 2007). The Lesser Antilles more or less coincide with the outer edge of the Caribbean Plate. Many of the islands were formed as a result of the subduction of oceanic crust of the North American Plate under the Caribbean Plate in the Lesser Antilles subduction zone.

In the northern part of the arc, flank collapses are repetitive, do not exceed 1 km3 in volume, can occur in all directions, and are promoted by intense hydrothermal alteration and well-developed fracturing of the summit part of the edifices. For example, several prehistoric flank collapses have been recognized on the Soufrière Hills volcano, Montserrat (Le Friant et al., 2004; Lebas et al., 2011). The English's crater event occurred ∼2000 y ago, producing debris avalanche (volume = ∼1.5 km3). Debris avalanche probably resulted

from a combined submarine and subaerial flank collapse of the eastern flank of the volcano dated between 130 and 112 ka (Le Friant et al., 2004). In the southern part of the arc, flank collapses are larger (with volumes up to tens of km3), always directed to the west, and related to the higher overall slopes of the leeward side of the islands. For example, the evolution of the active Montagne Pelée volcano, Martinique, has been marked by three major flank collapses (∼0.1 Ma, ∼25,000 y ago, and ∼9000 y ago) that systematically destroyed the western flank of the volcano (Le Friant et al., 2003a, 2003b; Boudon et al., 2005, 2007). Collapse volumes varied from 2 to 25 km3, and debris avalanches flowed down to the Grenada Basin. In addition, marine and terrestrial evidence indicate a succession of at least three flank collapses on Dominica (Le Friant et al., 2002). Dominica was also the site of the generation of the most voluminous debris avalanches in this area, with submarine deposits that cover 3500 km2. The proximal debris avalanche deposit consists of megablocks (as long as 2.8 km and as high as 240 m) that reflect the predominance of lava flows and lava domes as observed in the source Plat Pays volcanic complex and in terrestrial relict debris avalanche material.

Summary of what is known about the target area Previous work has involved on-land geological, geochemical, petrological, geochronological, and geophysical studies and offshore marine studies:

1. The Endeavour cruise of 1979 gathered a regional collection of piston cores allowing assessments of rates of volcanism and sedimentation, dating of major explosive eruptions, recognition of submarine pyroclastic flow deposits, and establishment of a biostratigraphic framework for the eastern Caribbean (Sigurdsson et al., 1980; Sparks et al., 1980a, 1980b; Reid et al., 1996).

2. Deep Sea Drilling Project (DSDP) in 1969 was drilled to investigate the geologic history of the Aves Ridge (west of the Grenada Basin).

3. During the Aguadomar (December 1998–January 1999) and Caraval (March 2002) cruises of the RV L'Atalante, Simrad EM12D swath bathymetry and backscatter data, 3.5 kHz echosounder, gravity, magnetic, and six-channel seismic reflection data were collected from Montserrat to St. Vincent (Deplus et al., 2001). During Caraval, seismic profiles using a 24-channel streamer (Deplus et al., 2002), sediment piston cores, and dredge samples were also collected.

4. During the JCR123 cruise of the RRS James Clark Ross in May 2005, sediment cores were collected from around Montserrat to study the submarine pyroclastic deposits from the recent eruption (Trofimovs et al., 2006).

5. Two Natural Environment Research Council (NERC)-funded cruises took place in December 2007. The first cruise collected box cores and shallow gravity cores at ∼34 sites

around Montserrat. The second cruise, a component of the SEA-CALIPSO seismic experiment sponsored by the US National Science Foundation (NSF), NERC, and collaborating agencies aimed at imaging the interior of Montserrat and the Soufrière Hills volcano, using source seismic techniques in combination with ∼240 onshore seismometers and offshore ocean borehole seismometers (OBS) (Voight et al., 2008; Sparks et al., 2008).

6. During the Gwadaseis cruise of the RV Suroit (February–March 2009), high-resolution seismic data were collected as well as piston cores.

7. During the JC45/46 cruise of the RRS James Cook in April–May 2010, high resolution 2D and 3D seismic data were collected around Montserrat.

8. Integrated Ocean Drilling Program Expedition 340, the "Lesser Antilles Volcanism and Landslides" project in 2012 (March-April) involved drilling, coring, and logging along: i)one transect with three sites southeast of Montserrat, ii) one site southwest of Montserrat, iii) one site southwest of Dominica, iv) one site northwest Martinique, as well as v) one transect with three sites southwest of Martinique. It was designed to give us a better understanding of the constructive and destructive processes related to volcanism along island arcs.

5.3 The Eastern Caribbean

Author and collaborators

Patricia Miloslavich pmilos@usb.ve
Universidad Simón Bolívar, Venezuela

Eduardo Klein eklein@usb.ve
Universidad Simón Bolívar, Venezuela

Angelique Brathwaite abrathwaite@coastal.gov.bb
Coastal Zone Management Unit, Barbados

Judith Gobin Coastal Zone Management Unit
University of West Indies at trinidad & Tobago

Pat Halpin phalpin@duke.edu
Duke University Marine Lab, USA

Why this area may be of interest

Biology Marine biodiversity, marine ecosystems

Geology Seamounts, trenches, Aves Ridge

Chemistry

Physical oceanography Upwelling system

Archaeology/history

Other

Rationale for exploration in the target area The potential for discovery in the target area is very high, not only in terms of coastal, oceanic and deep sea biodiversity, but also of deep sea ecosystems as well as geologically interesting habitats. In a recent workshop held by the Convention of Biological Diversity in Brazil (February 2012) to facilitate the description of Ecologically or Biologically Significant marine Areas (EBSAs) within the wider area of the Tropical Western Atlantic, the Eastern Caribbean was identified as an area meeting several of the EBSA criteria. The information compiled at this workshop included biological data such as (1) Distribution of coral reefs, seagrasses and mangroves, (2) Historical whale captures, (3) Catches on commercial pelagic species, (4) Turtle tagging data, (5) SWOT/WIDECAST nesting beaching, (6) OBIS data (all species, mammals, turtles, shallow species, deep species and IUCN Red List species), (7) Predictions of deep-sea corals, and (8) Important Bird Areas. Physical data included: (1) seamounts, (2) vents and seeps, (3) bathymetry (GEBCO), (4) distribution of large submarine canyons, (5) total sediment thickness of the world‘s oceans and marginal seas, (6) global seascapes, (7) physical ocean climatologies (temperature climatology, salinity climatology, oxygen climatology, nitrate climatology, silicate climatology, phosphate climatology, mixed layer depth climatology, sea surface height, VGPM global ocean productivity, SeaWiFS chlorophyll-a concentration, eddy kinetic energy, sea surface temperature front probability, and summary of currents). While some of this information was available for the Eastern Caribbean, much of it was not at the required detailed scale. Therefore, it is necessary to undertake research at a proper scale within a regional, multinational effort. Some of the EBSA criteria that this region met which speak in favor of an integrated exploration program are:

(1) Uniqueness or rarity: -Kick-Em-Jenny is the only active underwater volcano in the Caribbean -the Montserrat lava-covered reefs which resulted from recent and ongoing volcanic activity represent a potential habitat for coral-reef related species -the deep-water corals, hydrothermal vents, seamounts and cold-water seeps which occur along the Eastern Caribbean island chain -the cold-water upwelling in the west coast of Saint Lucia

(2) Special importance for life-history stages of species: -feeding and breeding sites for several bird species -nursery grounds for fishes and invertebrates within coral reefs, seagrasses, and mangroves

(3) Importance for threatened, endangered or declining species and/or habitats: -nesting and foraging zones for endangered sea turtles, hawksbill (Eretmochelys imbricate), green

(Chelonia mydas), and leatherback (Dermochelys coriacea) sea turtle species -highly productive and threatened coral reefs, seagrass beds, and mangroves

(4) Vulnerability, fragility, sensitivity, or slow recovery: -significant natural (e.g. hurricanes) and anthropogenic threats combined with low resilience of some ecosystems such as coral reefs

(5) Biological productivity: -highly productive ecosystems within areas of low primary productivity -significant influence of the Orinoco River

(6) Biological diversity: -besides highly diverse assemblages associated to coral reefs, seagrass beds and mangroves, the area has a high diversity of seabirds and cetacean species

(7) Naturalness: -despite the intense tourist activity, some parts of The Grenadines islands of St. Vincent and Anguilla are considered relatively pristine.

Overview of target area The target area is defined by Box 2 and Box 3 for the Caribbean Sea Region as defined by NOAA (2011) which corresponds to the Eastern Caribbean. The Eastern Caribbean consists of an arc of approximately 15 small islands separating the Caribbean Sea from the Atlantic Ocean located just north of the continental shelf off the northeast coast of South America. These islands extend from Anguilla in the north (at 18°12.80 N and 63°03.00 W), through Antigua, St. Kitts & Nevis, Guadeloupe, Saba, Martinique, Dominica, St. Lucia, Barbados, St. Vincent and the Grenadines, Grenada, to Trinidad and Tobago in the south (at 10°2' to 11°12' N and 60°30' to 61°56' W). Many of these islands are volcanic in origin, and some still have volcanic activity (MacDonald et al. 2000; Roman et al. 2008). There are also three known hydrothermal vents distributed along the arc, and a large underwater volcano, "Kick-em-Jenny", located 9 km off the north coast of Grenada (Devine and Sigurdsson, 1995). Between 200 and 250 km to the east, parallel to this arc, in Venezuelan waters, runs the underwater Aves Ridge, of which the only emerged territory is the island of Isla de Aves located at 15°40' 33"N and 63°36' 27"W. The Aves Ridge is also characterized by several seamounts and deep sea trenches. Similarly, the islands in the arc are often separated by deep water trenches/-submarine canyons (Harris and Whiteway, 2011). Primary productivity of the open ocean in the Eastern Caribbean is low (MODIS AQUA and SeaWIFS databases), however, high seasonal productivity may be observed due to (1) the intrusion of the Orinoco River during autumn which generates large concentrations of chlorophyll-a in this region reaching the island of Puerto Rico, and (2) strong trade winds during winter and spring which cause coastal upwelling along the eastern Venezuelan coast (Miloslavich et al., 2010). The main coastal ecosystems along this arc of islands are coral reefs, seagrass beds, and mangroves characterized by a high diversity of associated flora and fauna, which contribute to making the Caribbean a major global marine biodiversity hot spot (Miloslavich et al., 2010; Gollock

et al. 2011, CARSEA, 2007). These ecosystems are considered ecologically and economically important not only because of their high species diversity including commercially valuable fishes, mollusks and crustaceans, but also because they provide critical goods and services for human populations (CARSEA, 2007).

Summary of what is known about the target area A total of 12,046 marine species have been reported in the whole Caribbean region. A great majority of these species have been collected in shallow, nearshore waters, while offshore and deep environments have been less studied. As a result, there are numerous gaps in the information on deep sea benthic features and their associated flora and fauna (Miloslavich et al., 2010). Despite limitations in data (e.g. localized collecting efforts, limited taxonomic expertise for some groups), coastal species richness tends to concentrate along the Antillean arc (Cuba to the southernmost Antilles) and the northern coast of South America (Venezuela – Colombia). In the deep sea, no pattern can be observed with the available data. Specifically within the Antilles arc in the Eastern Caribbean, data submitted by ChEss Base and Deep Sea Research suggest that hydrothermal vents and seamounts exist in the area. In terms of information and knowledge on the Eastern Caribbean, there is data on some species inventories (mainly of the most conspicuous taxonomic groups), as well as some data on ecosystem structure and function especially for the coastal areas that are routinely monitored through government-supported programmes (e.g., CRFM, 2010, CRFM 2011). However, monitoring has had the tendency to be sporadic and inconsistent across many of the islands. Gaps in information and knowledge include biological connectivity among ecosystems at the island and sub-regional levels (Harlan et al. 2002), ecosystem resilience (Mohammed et al. 2008), and deep-sea ecosystems. Moreover, the deep sea environments in this region including the seamounts, trenches, and the Aves Ridge are completely unknown. At Isla de Aves, there are inventories of coastal corals, fish, mollusks, birds, and some knowledge on green turtle (Chelonia midas) nesting (see X CVE book of abstracts: Isla de Aves Symposium, 2011). In terms of pelagic species, the region supports both resident and migrant species (Mohammed et al., 2008) either of fish, birds, turtles and mammals (whales and dolphins) (Gomes et al. 1999; Agostini et al., 2010; Dow et al. 2007). Since many species of pelagic fishes are important food sources, many of them have been more intensively studied (e.g. the flyingfish, Hirundichthys affinis).

Specifically regarding birds, there are 52 BirdLife-designated Important Bird Areas (IBAs) included within the area, with seabirds as a qualifying feature. Thirty-six of these are globally important, while the other 16 are of Caribbean regional importance. Also, six sites meet the Ramsar criteria for presence of >20,000 waterbirds and nine sites hold >10,000 UNEP/CBD/SBSTTA/16/INF/7 individuals.

References Agostini V.N.,S.W.Margles, S. R. Schill, J. E. Knowles, and R. J. Blyther (2010). Marine Zoning in Saint Kitts and Nevis: A Path Towards Sustainable Management of Marine Resources. The Nature Conservancy.

CARSEA (2007). Caribbean Sea Ecosystem Assessment (CARSEA). A sub-global component of the Millennium Ecosystem Assessment (MA), J. Agard, A. Cropper, K. Garcia, eds., Caribbean Marine Studies, Special Edition, 2007. 106 pp.

CRFM (2010). Report of Sixth Annual Scientific Meeting – Kingstown, St. Vincent & the Grenadines, 07 - 16 June 2010 - National Reports. CRFM Fishery Report – 2010. Volume 1, Suppl. 1. 55p. CRFM (2011). Report of Seventh Annual Scientific Meeting – Kingstown, St. Vincent and the Grenadines, 16 - 24 June 2011 - National Reports. CRFM Fishery Report – 2011. Volume 1, Suppl. 1. 65 p.

Devine, J.D., and H. Sigurdsson, (1995). Petrology and eruption styles of Kick-em-Jenny submarine volcano, Lesser Antilles Island arc. Journal of Volcanology and Geothermal Research, 69, p 35-58.

Dow, Wendy, Karen Eckert, Michael Palmer and Philip Kramer. (2007). An Atlas of Sea Turtle Nesting Habitat for the Wider Caribbean Region. The Wider Caribbean Sea Turtle Conservation Network and The Nature Conservancy. WIDECAST Technical Report No. 6. Beaufort, North Carolina. 267 pages, plus electronic Appendices.

Gollock, M., D. Curnick, C. Head, H. Koldewey, E. Long, M. Taylor, B. Zimmerman (2011). A Biological and Socio-economic Assessment of the Coral reefs and Associated Fauna of the Tobgao Cays Marine Park and Canouan Island. A Publication of the Zoological Society of London and University of Oxford. 44 pp.

Gomes, C., H.A. Oxenford, and R.B.G. Dales. (1999). Mitochondrial DNA D-Loop Variation and Implications for Stock Structure of the Four-Wing Flyingfish, Hirundichthys Affinis, in the Central Western Atlantic. Bulletin of Marine Science, 64 (3), p. 485-500. Harlan, J.A., S.E. Swearer, R.R. Leben, and C.A. Fox (2002). Continental Shelf Research, 22, p 417-434.

Harris & Whiteway (2011). Global distribution of large submarine canyons. Geomorphic differences between active and passive continental margins. Marine Geology 285:6986.

MacDonald, R., C.J. Hawkesworth, and E. Heath (2000). The Lesser Antilles Volcanic Chain: a study in arc magmatism. Earth-Science Reviews, 49, p 1-76.

Miloslavich P, Díaz JM, Klein E, Alvarado JJ, Díaz C, et al. (2010) Marine Biodiversity in the Caribbean: Regional Estimates and Distribution Patterns. PLoS ONE 5(8): e11916. doi:10.1371/journal.pone.0011916.

Mohammed, E., M. Vasconcellos, S. Mackinson, P. Fanning, S. Heileman, and F. Carocci (2008). Scientific Basis For Ecosystem-Based Management In The Lesser Antilles Including

Interactions With Marine Mammals And Other Top Predators: A Trophic Model Of The Lesser Antilles Pelagic Ecosystem. FAO publication: FI:GCP/RLA/140/JPN. Technical Document No. 2, 168 pp.

NOAA (2011). Workshop Summary on Systematic Telepresence-Enabled Exploration in the Atlantic Basin, May 10-11, 2011, Coastal Institute Building, University of Rhode Island, Narragansett, Rhode Island. 24 p.

Roman, D.C., S. De Angelis, J.L. Latchman, and R. White. (2008). Patterns of Volcanotectonic seismicity and stress during the ongoing eruption of the Soufrière Hills Volcano, Montserrat (1995-2007). Journal of Volcanology and Geothermal Research, 173, p 230-244.

5.4 Aves Ridge

Author and collaborators

Manuel Antonio Iturralde-Vinent Iturralde@ama.cu, maiv_cu@yahoo.com
Cuban Geological Society

Jose Juanes juanes@oceano.inf.cu
Institute of Oceanology. Ministry of Science, Technology and Environment. Cuba

Why this area may be of interest

Biology The Aves ridge, allegedly a land bridge during the Eocene-Oligocene transition, is a golden spike to understand the overland dispersion and biogeography of terrestrial biota of the Greater Antilles (See summary in Iturralde-Vinent and MacPhee 1999, AMNH Bull. 238), a matter of great debate since early in the XX Century.

Geology Aves ridge is a key to understand the origin of the Caribbean Plate, as we have not direct information about its composition in deep.

Chemistry Along the Aves ridge flows eastward the Caribbean current, which originated in the Atlantic and merge with the Gulf loop current, feeding the Gulf Stream. Its composition and temperatures in deep along the column will be an important information to understand the distribution of water temperature and composition in the Colombian basin and elsewhere.

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area Knowledge of the stratigraphic section by drilling and and more dredge samples will provide a necessary base for further reconstruction of the origin and evolution of the Aves Ridge and the Caribbean plate. Also will provide oceanographic information in a location where all the waters arriving from the Atlantic merge into the Caribbean Sea.

Overview of target area The Aves ridge is generally a submarine promontory located in the eastern half of the Caribbean Sea, fringing by the Colombian basin and the Grenada trough. The only exposed area is the Aves Island.

Summary of what is known about the target area Aves Ridge has never been drilled. Some authors speculate it is a remnant arc of the Lesser Antilles arc based on limited seismic and dredge samples. According to Iturralde-Vinent and MacPhee 1999, Iturralde-Vinent 2006, International Geology Review no. 9) the element was probably an uplifted promontory during the Eocene-Oligocene transition, which connected South America and the Greater Antilles during this time. Later it was subsiding since the lower Oligocene to the Recent, with the exception of the emerged sector known as Aves Island.

5.5 Qualibou Caldera, Saint Lucia, Lesser Antilles

Author and collaborators

Joshua Kelly j_kelly@gso.uri.edu
URI Graduate School of Oceanography

Why this area may be of interest

Biology Hydrothermal Vent Biota

Geology Hydrothermal Venting - Implications for Volcanic Hazards

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area In 2002, the University of West Indies published a detailed volcanic hazard assessment report for the island of St. Lucia. The geologic fieldwork that contributed to this report was focused entirely on subaerial features such as sampling gases at fumaroles, installing a ground deformation network, and upgrading the seismic network. At the time of publishing, there were occurrences of swarms of shallow earthquakes along with hot vigorous hot spring activity in southern St. Lucia. This activity indicates that the volcano is still potentially active and poses a significant threat to the population of St. Lucia and the surrounding isles. The study did not assess any submarine evidence of increased activity, but there is a strong possibility of increased hydrothermal activity at the vent field discovered by Johnson and Cronan in 2001. It should be noted that volcanic eruptions have killed over 30,000 people in the Lesser Antilles during the last century.

With the availability of the ROV Hercules, analysis of flow rates from hydrothermal vents, temperature of the vent fluids, and sampling of the discharged hydrothermal fluids and precipitates for chemical composition analysis is possible. Work off Montserrat (Cronan et al., 1997), has shown that temporal variation in hydrothermal fluid chemical composition is in response to the activity of the associated volcano. Evidence of elevated concentrations of elemental hydrothermal signatures and increased fluid temperatures compared to pre-existing data (Johnson & Cronan, 2001), would be essential in contributing to the assessment of volcanic hazards for the island of St. Lucia. This study would also provide an opportunity to collaborate with the University of West Indies and the surrounding communities.

Overview of target area The target area is a hydrothermal vent field located at the northern end of Soufriere Bay within the Qualibou Caldera off the western coast of St. Lucia.

Summary of what is known about the target area In January 1995 and December 1996, researchers from Imperial College, London discovered and sampled the hydrothermal fields within the Soufriere Bay. In January 1995, they observed venting over an area of about 30m by 50m with vent fluid temperatures reaching 28°C. In December 1996, the nature of venting changed drastically with vents visibly more active and fluid temperatures reaching 35°C. The fluid samples collected in 1996 were enriched in B, Li, Si, Mn, Fe, and As as a result of hydrothermal activity. Additionally, sediment samples collected at the vent field were enriched in Fe, P, Mo, As, Sb, Hg, Cu, and Pb due to hydrothermal activity. (Johnson & Cronan, 2001)

5.6 Grenada undersea volcanoes and adjacent island slopes

Author and collaborators

Sandra Brooke sandra.brooke@marine-conservation.org
Marine Conservation Institute

Steve W Ross rosss@uncw.edu
University of North Carolina Wilmington

Amy Baco-Taylor abacotaylor@fsu.edu
Florida State University

Why this area may be of interest

Biology Hydrothermal vent fauna and abundant shallow and mesophotic benthic communities have been documented at this location, as well as deep sea corals, but there is almost no information on their composition, distribution or ecology. Areas below 200m are almost unknown.

Geology This site has the shallowest (250 m) active submarine volcano in the Caribbean with numerous venting sites and a dormant volcano 4km to the southeast. The site also has lava domes, lava and debris flows, and steep island slopes. The slopes of these islands and submarine volcanoes can drop to 1600 m or more, and exhibit a variety of rugged bottom.

Chemistry Hydrothermal vents of various thermal and chemical profiles. Chemosynthetic communities.

Physical oceanography The prevailing currents flow from the east through the Grenada passage and between the islands of the Lesser Antilles. Interactions between these accelerated currents and the complex topography of the target site, together with warm hydrothermal fluids make this a potentially interesting hydrodynamic and environmental regime.

Archaeology/history None known of in deep water, but the Island of Grenada has numerous shipwrecks in shallow water, some of historical interest. The island has been a center of commerce for hundreds of years.

Other This area represents part of the bridge between the islands of the Lesser Antilles and the mainland of South America.

Rationale for exploration in the target area This target has several factors that make it appropriate for exploration. There is sufficient information to indicate a high prob-

ability of finding interesting ecosystems to explore, but the area in general is very poorly known. Beyond descriptions of some of the vent fauna, there is almost no information on the biological communities inside or outside the volcano crater, or on adjacent slopes that drop sharply to depths of over 1600 m. The complex physical and geological environment provides many different habitat types (visible from existing multibeam maps), which may support numerous and varied biological assemblages. The acceleration of currents between the islands, and the interaction of currents with the topography of the area may facilitate the development of sessile benthic communities. Finally although there is very limited information on the fauna of the target area, documentation on deep corals of the Caribbean region indicate a high probability that they would occur on the slopes of Grenada and adjacent submarine slopes. Grenada also has diverse and abundant shallow and mesophotic sessile benthic communities.

Overview of target area The commonwealth of Grenada is located at the southern end of the Lesser Antilles island chain in the eastern Caribbean and is composed of the main island (Grenada) and six smaller islands. Approximately 8 km off the northern coast of Grenada lies the shallowest active volcano in the Caribbean, named Kick'em Jenny (KEJ). The rim of the crater is 180 m deep, but the crater itself is 250-260 m. This volcano is part of a complex of topographic features which includes a dormant volcano 4 km to the southeast, lava cones, debris slides and steep island slopes. The temperatures are warm-tropical on the surface, with a mixing layer at approximately 50 m depth. The prevailing currents come from the east, passing through the Grenada passage between the Lesser Antilles and the northern coast of South America. Constriction of water through the island passages elevates [accelerates?] currents, potentially creating appropriate environmental conditions for development of sessile benthic communities on the hard substrate of the island slopes and volcanoes. Ambient temperatures at the depth of the crater are 14-17°C, but venting fluids can reach 70°C, creating a very dynamic physical and chemical environment. Studies conducted in this region have been limited primarily to geological and geochemical research on the active volcano, with some very limited biological samples and observations.

Summary of what is known about the target area The active volcano (KEJ) and surrounding area has been mapped with multibeam sonar and the crater has been surveyed several times for geological and geochemical objectives; therefore, these aspects of the KEJ volcano are relatively well known. Understanding of the biology of the volcano and surroundings is much more limited; there are a few papers that document crustaceans and a polychaete found near vents in the crater (two were new species), but in general vent fauna was locally abundant but depauperate in species diversity. Observations of non-vent fauna include more diverse faunal assemblages, including urchins, crabs, sponges, corals, holothurians, and fishes on inactive vents, and abundant large suspension feeders and

fishes along the crater rim. But, most of these data are qualitative observations. There are also records of deep-sea structure forming stony corals, large gorgonians, and large antipatharians from the Lesser Antilles chain, including Grenada, but the distribution, abundance and species composition are not known. Grenada is located just northeast of Venezuela, where a research trawl in 1968 hauled in a large diverse assemblage of benthic fauna, including the deep-sea coral Lophelia pertusa.

5.7 Kick'em Jenny submarine volcanic field, Grenada, Lesser Antilles

Author and collaborators

Steven Carey scarey@gso.uri.edu
Graduate School of Oceanography, University of Rhode Island

Dr. Karen Wishner kwishner@gso.uri.edu
Graduate School of Oceanography, University of Rhode Island

Dr. Brad Seibel seibel@uri.edu
Graduate School of Oceanography, University of Rhode Island

Brennan Phillips brennan@ife.org
Graduate School of Oceanography, University of Rhode Island

Dr. Richard Robertson richie_robertson@uwiseismic.com
University of the West Indies, Seismic Research Unit

Why this area may be of interest

Biology Discovery of new vent fauna, interactions of local fauna with vent discharges especially topographic trapping of midwater fauna, effects of ocean acidification, possible effects on local fisheries

Geology Shallow water explosive volcanism, submarine debris avalanches, generation of tsunamis, hydrothermal vents, exotic biological communities

Chemistry Venting of hydrothermal fluids, second boiling of seawater, degassing of carbon dioxide, local ocean acidification

Physical oceanography Production of dense saline brines by second boiling of hydrothermal fluids

Archaeology/history

Other volcanic hazards

Rationale for exploration in the target area Kick'em is most active and dangerous submarine volcano in the Caribbean Sea. During the past century it has shown a history of progressive growth with explosive eruptions that pose hazards to the local island populations of the Lesser Antilles. Monitoring of this volcano has critical societal implications and the Nautilus possesses the necessary tools to carry out a complete assessment of the current state of the volcano. Preliminary exploration of the crater area of Kick'em Jenny has also shown the existence of an active hydrothermal system that is host to a unique biological community. The system may be discharging carbon dioxide in which case the possibility exists for the production of acidic waters that may have adverse impacts on the submarine biological community and can serve as an interesting analog to large-scale ocean acidification effects. A return to Kick'em Jenny and its vicinity will enable verification and explanation of the biological trapping phenomenon. We will be able to compare day versus night abundances on the seafloor and compare the situation at Kick'em Jenny with that at nearby submarine volcanoes (and topographic features without vents) at different depths. By collecting vent effluent for chemical analyses and animals for experiments onboard the ship, we can document physiological responses by these pelagic animals to the unique vent chemistry at these locations. This work will also be associated with the PhD project of Brennan Phillips, who is interested in examining benthic-pelagic coupling and the vertical extent of vent influence on the pelagic community. These studies will provide new perspectives on vent biology and, because these vents are so shallow and close to land, may also have implications for local fisheries. Finally, the discovery of at least five other submarine volcanoes in the general area of Kick'em Jenny raises important questions regarding the history and potential activity level of these centers. New explorations will shed light on the relative ages of these centers, the types of eruptive products, and whether other hydrothermal vent systems occur at these locations.

Overview of target area Kick'em Jenny is a submarine arc volcano located 7.5 km north of the island of Grenada in the Lesser Antilles volcanic arc. It has erupted at least 12 times since 1939 and is the most active volcano in the West Indies(Lesser Antilles). The most recent eruption took place in December, 2001. Although recognized as a hazard because of its explosive activity, recent multi-beam revealed evidence of a potentially more dangerous and widespread hazard from large-scale flank failure and debris avalanche generation. With a summit depth of only 180 meters, Kick'em Jenny provides a unique natural laboratory to study the activity and emergence of a young volcanic arc island. The volcano lies in a critical depth zone where eruptions can become more explosive in nature as it nears the surface. A summit crater at $\sim$250 m depth (2003 survey) contains an active hydrothermal system that is venting both high temperature fluids and gases. In addition

to Kick'em Jenny, new bathymetric mapping in the area carried out in 2003 revealed the existence of 5 other submarine volcanic centers in close proximity to Grenada. Studies of such submarine arc volcanoes are needed to better understand the evolution of volcanic systems at convergent plate boundaries. In particular, such studies can reveal the interrelationships between volcanic activity, biogeochemical processes, and mineralization in the marine environment.

Summary of what is known about the target area Kick'em Jenny submarine volcano is located on the western flank of the Lesser Antilles arc (approx. 12°18'N, 61°38.3'W). The volcano was discovered in 1939, when numerous earthquakes were felt, and tsunamis affected Grenada, the Grenadines, and reached as far as Barbados. An explosive eruption broke the surface and produced ash-laden columns that reached up to 300 m above the sea surface. There have been at least eleven eruptions since that event, and some of them have caused disturbances at the surface and minor tsunamis. A reconnaissance survey in 1962 showed that the depth to the crater rim was 223 to 232 m. The depth decreased as a result of each successive eruption, reaching a minimum of 160 m by 1978.

The first detailed survey of the volcano in 1972 revealed a 1300 m high conical structure, constructed on the western flank of the arc. The summit crater was found to be at a depth of 190 m and approximately 180 m in diameter. The first multi-beam survey of the volcano in 1985 confirmed the earlier findings, but showed that the region between the volcanic cone and the Grenada Basin to the west is one of rather irregular topography. Following an eruption in 2001 the volcano was surveyed again by the NOAA research vessel Ronald H. Brown. The survey yielded a high-resolution image of the volcano and surrounding region, revealing new details regarding its structure. The most striking feature is an arcuate west-facing scarp that surrounds much of the volcanic cone to the south, west and north. The new data shows that the Kick'em Jenny volcanic cone is located inside a major 5 km wide horse-shoe shaped and west-facing depression that most likely was formed by slope failure and associated debris avalanche. ROV explorations of the crater floor found high temperature (>250°C) venting of fluids and gases, along with the discovery of new species of vent specific worms.

SEABEAM mapping during the 2003 cruise of the R/V Brown also revealed the existence of five new volcanic centers that were previously unknown in the area. Three are conical in shape with well-defined craters, whereas two have a dome-like morphology. One of the cones, provisionally named Kick'em Jack, is similar in size to Kick'em Jenny and exhibits a horse-shoe shaped crater with an interior dome. The discovery of these new craters raises many questions about the magmatic system feeding this area. Are there multiple magma chambers and sources for these different centers or are they related to a central feeding system? From a hazards perspective it is important to know whether these centers have been recently active or are they mostly dormant?

An unusual biological phenomenon was discovered at Kick'em Jenny during the 2003 cruise, namely, the apparent topographical trapping of three species of midwater shrimp not typically associated with vents. These animals occurred in abundance on and near the seafloor of the central (venting) crater during three daytime surveys but were not seen in a nearby secondary crater lacking vents. The most likely explanation was that they were part of the normal midwater Caribbean fauna that became trapped in the crater during their daytime diel vertical migration to depth and were perhaps rendered comatose by constituents of the venting effluent. However, because of the limited sampling at the time, a number of questions remained. There were no ROV dives at night, so we do not know if shrimp rose from the seafloor at night as part of a normal diel vertical migration back to shallower water. It was also puzzling that, given the wide variety of known diel vertical migrators (fish, crustaceans, gelatinous taxa), shrimp were the only pelagic group observed on the seafloor. Furthermore, no chemical measurements were made of vent effluent composition.

5.8 Trinidad Barbados seep province

Author and collaborators

Ian MacDonald imacdonald.fsu@gmail.com
Florida State University

Amy Baco-Taylor abacotaylor@fsu.edu
Florida State University

Jim Brooks drjmbrooks@aol.com
TDI-Brooks International

Chuck Fisher cfisher@psu.edu
Penn State Univ.

Erik Cordes ecordes@temple.edu
Temple Univ

Albert Hine hine@marine.usf.edu
University South Florida

Why this area may be of interest

Biology seep chemosynthetic communities

Geology accretionary prism

Chemistry oil and gas seeps, gas hydrates

Physical oceanography Unknown

Archaeology/history Unknown

Other

Rationale for exploration in the target area The proposed study area sits astride a longitudinal gradient populated by diverse chemosynthetic fauna extending from the Gulf of Mexico cold seeps to the continental margin off Central Africa and including hydrothermal vents on the Mid-Atlantic Ridge (MAR), north and south of the Equatorial (Romanche and Chain) Fracture Zones. The so-called Equatorial Atlantic Belt has been identified as a critical biogeographic corridor by the Census of Marine Life and the ChEss program for chemosynthetic fauna. Prior to the closure of the Isthmus of Panama, ca. 5 Ma ago, the present-day Equatorial Atlantic Belt formed a major, low-latitude, deep-ocean corridor between the Indian, Atlantic, and Pacific Oceans. Systematic similarities are recognized over the western extent of the corridor. For example, fauna from cold seeps across the geologically modern Central America land-bridge, i.e. the Gulf of Mexico and Florida Escarpment clustered with the Oregon Margin seep communities in similarity studies. Also, the only seep-endemic genus of tube worms (Lamellibrachia spp.) is known from the Gulf of Mexico, the Oregon Margin, and the Nankai Trough offshore Japan. Thus, the limited data available to date suggest a dispersal pathway for seep species between the Pacific and Atlantic via the (now-closed) Panama Isthmus. The role played by natural hydrocarbon seeps or gas hydrates in this dispersal is not documented though hydrates are found in both the Gulf of Mexico and California slope. Very recent findings also document Lamellibrachia-like tube worms from gas hydrate deposits on the continental slope offshore Nigeria. Analysis of the cold seep communities from the Trinidad-Barbados Trough sites would provide data to test this hypothesis of gene flow between adjacent ocean basins, prior to closure. This region is potentially a mid-point in a gradient of hydrocarbon-associated fauna extending from West Africa to Oregon.

Overview of target area The structure of the Lesser Antilles volcanic arc, which includes eight active volcanoes, results from the subduction of Atlantic crust by the Caribbean plate. The accreted sediments of the Barbados Ridge complex, together with the Trinidad-Barbados Trough and several other basins to the west, form the forearc of the Lesser Antilles convergent margin. DSDP Leg 78A and ODP Leg 110 greatly contributed to establishing the biostratigraphy and sedimentary history of the area. The findings from these two expeditions indicate that the development of a décollement zone in the lower Miocene sediments of the Barbados accretionary complex separates the sedimentary section into an upper Miocene to Holocene sequence and a lower Campanian to Oligocene series of underthrusted sediments. The development of these distinctive tectonic struc-

tures greatly influences the hydrology of the area, producing focused fluid expulsion in a variety of geologic styles.

Summary of what is known about the target area Cold seep chemosynthetic communities are reported from 1000-2000 m depths on Barbados Accretionary Prism, where major groups in the seep community comprise mussels, vesicomyid clams, and vestimentiferans, but also include a large numbers of sponges, gorgonians, and corals. Mud volcanoes and their associated seep fauna—including sponges with methanotroph endosymbionts—also occur in the Barbados Trench at 5000 m depth. Neither of these communities was reported to be associated with HMW hydrocarbons or gas hydrates. Jollivet et al. completed a series of camera transects—some of them closely associated with recent geochemical discoveries. However, comparing the location of their effort with geochemical prospecting data, it appears that they were about 100 km away from a major concentration of hydrocarbon seeps.

The present proposal is a resubmission of a response to the 2004 Ocean Exploration announcement. That proposal received generally strong reviews, but was ultimately declined in part because the requested submersible was not available. With the availability of the OE and ROV, this work should be reconsidered.

Chapter 6

Caribbean-wide

Figure 6.1: Map of target areas that span several regions of the Caribbean

6.1 Steep Southern Slopes of the Cayman Islands and Puerto Rico and steep northern slope of Puerto Rico

Author and collaborators

Amy Baco-Taylor abacotaylor@fsu.edu
Florida State University

Sandra Brooke Sandra.Brooke@marine-conservation.org
Marine Conservation Institute

Shirley Pomponi SPomponi@hboi.fau.edu
Harbor Branch Oceanographic

Steve Ross rosss@uncw.edu
UNC Wilmington

Why this area may be of interest

Biology Steep topographic features that extend to significant depth allow for exploration for deep-sea coral and sponge communities at deeper depths than most work has been done in the Caribbean or even globally. Nature of deep-water masses of the Caribbean basins provides for potential evolutionary novelty and/or insights into distributions of fauna in relation to water mass.

Geology The Cayman Trough borders the southern slope of the Cayman Islands and was recently found to host fascinating new hydrothermal vent communities

Chemistry Potential insights into deep water masses in the Caribbean basins

Physical oceanography Potential insights into deep water masses and flow at depth in the Caribbean basins

Archaeology/history

Other

Rationale for exploration in the target area On a global basis, most in situ exploration in the deep-sea has still been concentrated at depths <1,000-2,000 m. Not surprisingly most records of deep-sea corals are concentrated at depths <2,000 m, and distributions likely reflect sampling effort. The Caribbean is no exception, with most records occurring shallower than 1,000 m. However, back at the global scale, deep-sea coral and sponge communities have been found to occur much deeper, with maximum depth records for corals of over 6,000 m. But these deeper records are sparse. Does the paucity of records

mean the corals are sparse? Or does it simply mean we haven't put enough effort into exploration? Most likely it's the latter. For example, explorations on Derickson Seamount off the Aleutian chain showed communities as diverse and abundant at 2,700-4,500 m as have been seen in other regions at 1,000 m. Like Derickson, the Caribbean provides an exciting opportunity to explore coral and sponge communities on the more extreme end of deep, over a short geographic distance. The steep southern slopes of the Cayman Islands and Puerto Rico extend from the surface rapidly to depths >5,000 m. These steep slopes provide a high likelihood of finding rich suspension feeding communities including corals and sponges, allowing us to address the question of whether corals exhibit significant abundances and diversities at depths >2,000 m. Of course the low degree of exploration at depths >2,000 m also provides the potential for discovery of many new species, e.g. almost every species found on the deep slopes of Derickson was new to science, and the depth record for several genera were extended from these discoveries.

Another exciting draw of these Caribbean locations is the nature of the deep-water masses. The source of the deepest waters in these basins is from fairly shallow water masses in the Atlantic, and there is also some separation by shallower sills of the eastern and western basins from each other. This raises two really fascinating possibilities. One is that the deep-water masses of the Caribbean basins are fairly isolated. This depends on the residence time of the deep water, but if isolation is indeed the case, there is potential for evolutionary novelty, and their isolation from each other provides the potential of independent evolutionary pathways in the eastern vs western basin. This provides enormous potential for the discovery of new species. The other possibility is that the basins are well flushed in deep water, but by shallower water masses. The distributions of species in the deep-sea often seem to be tightly coupled with the distribution of water masses. So we may e.g. find species typically found at <2,000 m, occurring at much greater depths. Either of these two possibilities provide for exciting discoveries at great depths in the Caribbean.

The steep northern slope of Puerto Rico also extends to great depth, but is on the Atlantic side of the Caribbean and therefore more well-connected with the broader Atlantic. This would make an excellent site for comparison of deep-slope fauna in the Caribbean basins and provide something of a control site for distinguishing between the two possibilities in the previous paragraph.

Overview of target area The deep seafloor of the Caribbean is divided into five basins. The Columbia Basin, the Venezuela Basin, and the Grenada Basin are considered to be a part of the larger eastern Caribbean basin. The Yucatán and Cayman Basins make up the western basin. The eastern and western basins are separated from each other by the Jamaica Rise, which essentially acts as a sill with a maximum depth of about 1,500 m. The deep waters of the western basins are connected to the Atlantic by the Windward Passage with a sill depth of <1,700 m. The only source of deep-water from the Atlantic into the

eastern basins is through Anegada-Jungfern Passage complex with a maximum sill depth of 1,915 m. Despite these comparatively shallow sills, both basins extend to considerable depth, 5,400 m in the eastern basins and nearly 7,700 m in the Cayman Trough in the western basin. The fairly restricted deep-water flow into the basins of the Caribbean Sea provides the potential for moderate isolation of deep water masses in these basins below 2,000 m, e.g. residence times of 800 years are estimated for the eastern basin.

Summary of what is known about the target area Although there are many records of deep-sea corals and sponges throughout the Caribbean, including scleractinians, antipatharians, and octocorals, most of the records are from fairly shallow depths, generally <1,000m. In fact for the overall Caribbean, almost no sampling or exploration have been done of hard substrate habitats below 1,000 m, with only a handful of records of deep-sea corals below this depth.

6.2 Benthic-pelagic coupling between vents and pelagic communities

Author and collaborators

Brennan Phillips brennan@ife.org
Institute for Exploration

Karen Wishner kwishner@gso.uri.edu
University of Rhode Island

Brad Seibel seibel@uri.edu
University of Rhode Island

Why this area may be of interest

Biology Benthic-pelagic coupling: comparing the midwater macrozooplankton and nekton community above active hydrothermal venting sites with non-active seafloor sites

Geology Active hydrothermal venting features, non-venting features at similar depths for comparison.

Chemistry Hydrothermal vent plume size and structure.

Physical oceanography Current structure and vertical mixing influence how midwater macrozooplankton and nekton interact with benthic features of study areas.

Archaeology/history None

Other None

Rationale for exploration in the target area Across all oceans, zooplankton biology is poorly understood at depths beneath the photic zone; new species are identified on a regular basis, and little is known about deep-sea food webs. Since the discovery of hydrothermal vents in 1977 it has been known that primary production occurs in deep lightless environments, but how far that energy extends spatially beyond the vent field is poorly known. Vent plumes have been traced and mapped to reach surface waters and extend hundreds of miles from their source; studies of larval dispersion between vent communities highlight the scale of their biological extent. Some data suggest that there is increased midwater biomass near mid-ocean ridges, seamounts and submarine volcanoes; in particular, years of work by fisheries researchers in Canada describe an 'epiplume' zone of increased zooplankton biomass that may be directly associated with vent energy sources. This proposed research will test the hypothesis that direct links exist between hydrothermally-driven production and the pelagic consumers living above them. A specific focus will be on large salps and other taxa easily visualized by a variety of camera systems and collectable in targeted sampling. Laboratory analyses of gut contents and possibly metabolism will be done with selected taxa onboard the ship. A better understanding of these relationships could affect broader scientific interests such as deep-sea carbon cycling and remineralization, as well as impact decisions on deepwater management policies related to mining, fisheries and climate change.

This research is proposed as part of B. Phillips' Ph.D. thesis research, which is scheduled to begin in the Spring semester of 2013. K. Wishner, B. Seibel, and C. Roman are expected to serve on his committee.

Overview of target area We propose to observe and sample opportunistically in several regions within 100m of the seafloor. This will include comparative features at different depths and locations and comparative sites within each area with and without venting. These include, but are not limited to:

- Kick'Em Jenny submarine volcano active vent field (∼200 m depth)
- Kick'Em Jenny surrounding active and dormant submarine volcanoes
- Montseratt region, unexplored volcanoes to the SE of the island (∼700 m depth)
- Mid-Cayman Spreading Center, Von Damm hydrothermal vent field (∼2300 m depth)
- Mid-Cayman Spreading Center, similar depth to Von Damm vent field but as far away from active vent site as possible

Summary of what is known about the target area Kick'Em Jenny: A biological study in 2003 by K. Wishner in association with Carey, Sigurdsson, Seibel and others,

revealed a large group of shrimp on the seafloor, possibly associated with the active vent field but taxonomically of midwater origin. They observed daytime aggregations of the shrimp, collected samples and examined gut contents. Nighttime behavior, however, was not observed (because of no night dives) These midwater shrimp were apparently topographically trapped within the venting crater during their diel vertical migration to depth and may have been affected by the vent effluent. However, if the shrimp return to shallow water at night, this vertical migration could be an energy pathway to higher trophic levels. Additional dives both at the vent field and away from it (dormant structures) and both day and night could better explain the relationship between the shrimp (and other pelagic fauna) and hydrothermal vent primary production. (see Carey et al. document for additional Kick'em Jenny project information). Montserrat: An active volcano above water, the submarine environment surrounding the island is relatively unknown. Furthermore there are several unexplored submarine volcanoes nearby, in water depths of ∼700m. If active hydrothermal venting is discovered in the region, it could be a comparative site to Kick'Em Jenny.

Mid-Cayman Spreading Center: Several expeditions have explored hydrothermal vent fields in this region; it is known for hosting the deepest vents in the world. The Von Damm vent field is of interest not only because it is at a depth that Hercules/Argus can reach, but also because it is off-axis and structured quite differently than a volcanic vent field. Clear, hot (>140°C) fluids dominantly produced by serpentinization host a dense community of vent-specific shrimp, as well as galatheid crabs and the occasional fish. Because of the number of vents in the region, any benthic-pelagic coupling could have major implications for understanding the midwater community in the Cayman Trough, and potentially vent sites around the world.

6.3 Caribbean Seamounts

Author and collaborators

Martha Nizinski Martha.Nizinski@noaa.gov
NOAA/NMFS/NEFSC/National Systematics Laboratory

Why this area may be of interest

Biology Deep-sea corals and associated fauna; endemism; connectivity

Geology

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area Deep-sea coral research in the Caribbean Region is virtually non-existent yet this region supports high diversity of deep-sea corals. Mapping with associated video would be a first step towards understanding coral distributions and habitat composition in the region.

Seamounts are known hotspots of biodiversity and deep-sea corals can be a numerically dominant component of the invertebrate fauna associated with seamounts. Seamounts within the Caribbean Region have not been explored extensively. It would be desirable to begin investigations in this region to first determine if deep-sea corals are present and then to assess the diversity, distribution, and abundance of the corals as well as the fauna associated with these corals. An extensive deepwater fishery, primarily for snapper, occurs around Puerto Rico. The association between deep-sea fishing and deep-sea coral habitat in this region is unknown. However, damages caused by gear used in this fishery can pose significant threats to deep-sea corals. Seamounts are often target areas for a variety of commercially and recreationally important species. Given the intensive fishing activity throughout the region and the potential for fisheries to move to deeper waters, it is important to investigate these seamount habitats to determine the extent of coral growth and the diversity and abundance of species utilizing the coral habitat. Only after this information is gathered can we begin to make sound management decisions for the region. Additionally, there are many unanswered questions regarding larval dispersal and the connectivity between deep-sea coral populations. These Caribbean seamount habitats may play a vital role in supplying larvae to both the Gulf of Mexico and the southeastern United States. Data collected from these seamounts would provide much needed comparative data for seamount habitats in general.

Overview of target area The Caribbean Sea is a semi-enclosed basin, approximately 2,640,000 square km (Lutz and Ginsburg 2007) and includes the U.S. territories of Puerto Rico, the Virgin Islands, and the uninhabited island of Navassa. Deep coral mounds and lithoherms, to depths of approximately 900 m, are reported throughout the region. Additionally, within the EEZ of Puerto Rico and the Virgin Islands, there are four seamounts: Grappler, Whiting, Mona, and Dos Ni'os Knoll. These seamounts are proposed as an area of exploration and investigation. Predicted bathymetric maps of three of these seamounts, available at Seamount Catalog (Earthref.org), indicate a depth range of approximately 500 to 2000 m. Grappler Seamount is approximately 500 m depth; Whiting Seamount 600 m at the top, 1300 m at the base; and Mona Seamount is approximately 1300 m at the top, 2000 m at the base. No information is currently available for Dos Ni'os Knoll. Two addi-

tional seamounts, Gibbs and Golondrina, occur further south, off the Lesser Antilles. These seamounts (approximately 500-2000 m relief) are also desirable areas for exploration.

Summary of what is known about the target area Lutz and Ginsberg (2007) summarized the state of knowledge of deep-sea corals in the Caribbean Region. These authors commented that the diversity of deep-sea corals in the region is high, but information on regional distributions as well as basic information on the biology and ecology of these habitats is lacking. Since the time of that review, little research on deep-sea corals has been conducted in this region. Recent investigations and observations in the Caribbean include an OAR-funded expedition to the Bahamas where investigators explored deep coral habitats on the deep slopes of the northern Bahamas, two Southeast Region deep-sea coral cruises funded by the Deep-Sea Coral Research and Technology Program, where investigators re-visited known deep-sea coral locations in the Straits of Florida, exploration of the Mesoamerican Reef off Honduras, and the report of the occurrence of deep-sea corals in the Mona Passage (Garcia-Moliner, Caribbean Fishery Management Council). Thus, there is still much to learn about the majority of known deep-sea communities in the region. Although some mapping has occurred around Grappler Seamount, other distributional, habitat, and ecological data are lacking. In fact, even the presence of deep-sea corals at these Caribbean seamounts has not been documented.

6.4 Naval Craft in the Caribbean

Author and collaborators

Robert Neyland robert.neyland@navy.mil
Underwater Archaeology Branch, Naval History & Heritage Command

Dr. Alexis Catsambis alexis.catsambis@navy.mil
Underwater Archaeology Branch, Naval History & Heritage Command

Why this area may be of interest

Biology

Geology

Chemistry Corrosion Studies

Physical oceanography

Archaeology/history Sunken Naval Craft

Other

Rationale for exploration in the target area I. Greater Antilles (Puerto Rico) A survey to locate the lost naval graveyard would have a vast potential for archeological information in terms of future study of metal degradation in shipwrecks. The great number of sunken Navy vessels will naturally have an effect on the surrounding areas, although whether this effect is constructive in nature, such as reef building, or destructive, is currently unknown. The submerged vessels offer study potential in terms of corrosion and the associated chemical climate, any effects of human interaction, and formulating a timeline of deterioration.

II. Western Caribbean (Panama) The USS Dorado is rumored to have been downed by friendly fire from a PBM Mariner although the U.S. Navy strongly suspects either technical failure or mine hit. Searching the former mine field laid by U-214 will potentially prove or disprove the validity of rumors about Dorado's fate, and potentially solve a near 70-year old Naval mystery.

III. Western Caribbean Sea (Columbia) The USS Kearsarge has been subject to some limited salvage activity but should remain relatively undisturbed and thus present a valuable opportunity for site study. An ROV survey of the wreck site would provide baseline data for the shipwreck, help determine the necessity or feasibility of future excavation planning, and give preliminary information to those who wish to study wood and metal deterioration in higher energy environments.

Overview of target area I. Greater Antilles (Puerto Rico) The U.S. Navy practiced the sinking of decommissioned ships during the 1960's through the 1990's in the area around Vieques Island and off Puerto Rico at a range of at least 50 NM offshore. Several ships were sunk off the north coast of Puerto Rico, north of the Puerto Rico Trench in depths of 1500-5000m. These vessels are expected to remain largely intact or in large pieces on a generally smooth sea floor.

II. Western Caribbean Sea (Panama) This target area is a former minefield located outside of the mouth of the Panama Canal, between 50-500m depth, where the USS Dorado was presumably lost in 1943. The area is primarily sandy silt and has a gentle slope into the Caribbean Sea.

III. Western Caribbean Sea (Columbia) The USS Kearsarge (1861) is known to have sunk near Rancador Bank, which is a small atoll that comprises Rancador Cay and several other sandy cays. The Cay lies mostly-submerged at 13N34 80W04 is about 15 by 6 kilometers in size, with an area of 65 km? composed mostly of lagoon. In the submerged areas the depth ranges from sea level to around 1000m.

Summary of what is known about the target area I. Greater Antilles (Puerto Rico) Over twenty U.S. Navy vessels built during WWII were deliberately sunk for target practice in the proposed survey areas surrounding Puerto Rico between 1963-1983. The resting places for U.S. Navy destroyers, escort ships, and a submarine make up what would be a thirty to forty year old Navy graveyard. The area in which the vessels lie has not been the subject of detailed research; consequently little is presumed about their effect in the surrounding ecosystem.

II. Western Caribbean (Panama) The USS Dorado has been missing since 1943 and is the subject of rumors of both friendly-fire attack and U-boat mine victim. The German submarine U-214 laid a 15-mine field off the coast of Colon on the 8th of October 1943. The field was swept in 1943 and 10 mines recovered, suggesting the detonation or loss of 5 mines.

III. Western Caribbean Sea (Columbia) The USS Kearsarge is a screw sloop built in 1861 to hunt for confederate raiders during the Civil War. She was famously involved in a battle with CSS Alabama and then spent her remaining years of service protecting American interests in the West Indies, off Venezuela, and along the Central Americas. The USS Kearsarge was bound for Bluefields, Nicaragua, when she foundered off of Roncador Cay in 1894. There are no deaths associated with the sink event but the ship burned and was dispersed over the area.

6.5 Deep sea corals

Author and collaborators

Nancy Prouty nprouty@usgs.gov
US Geological Survey

Amanda Demopoulos ademopoulos@usgs.gov
USGS

Cheryl Morrison cmorrison@usgs.gov
USGS

Christina Kellogg ckellogg@usgs.gov
USGS

Why this area may be of interest

Biology 1. Biodiversity and trophic dynamics: Deep-sea corals are complex ecosystems, representing essential habitat for a variety of invertebrates and fishes. While these

systems may harbor substantial levels of biodiversity, they remain inadequately investigated. Examining organisms associated with deep-sea coral ecosystems in the Caribbean region will enhance our understanding of the biodiversity associated with these environments. Through quantitative collections within corals and adjacent sediments, our preliminary research indicates discrete communities living within the corals relative to adjacent sediments. Increasing the regional perspective through sampling in the Caribbean will address whether these community patterns apply to the broader region. Understanding food webs of deep-sea corals and trophic linkages among adjacent deep-sea ecosystems is in its infancy. However, we do know that the primary source of food for the deep sea corals appears to be composed of zooplankton and/or sinking particular organic matter that has been microbially degraded. Therefore, it is critical to understand the nature and periodicity of particle flux and the degree of trophic interactions of deep-sea coral communities in order to evaluate ecosystem controls on abundance, biodiversity, and community function. Continued exploration and sampling would facilitate broader understanding of the biodiversity of coral ecosystems, energy transfer among coral associates, and trophic connectivity among corals and adjacent environments, including the upper water column and chemosynthetic ecosystems.

2. Genetic connectivity: Sampling of deep sea corals from the Caribbean region will contribute to our knowledge of how coral biodiversity is distributed in hard bottom habitats in the region, expanding our assessment of coral diversity (phylogeny) and connectivity (population genetics) between deep coral reefs throughout the Atlantic Ocean. Utilizing genetic techniques to characterize biodiversity and genetic connectivity among corals and associated fauna inhabiting hard grounds in the Caribbean will increase our knowledge of the spatial scale and structuring of corals and the biodiversity they support. Population connectivity includes the dispersal, survival, and reproduction of migrants, thereby creating linkages between populations that contribute to population structuring, genetic diversity, and ultimately, resilience to disturbance. Therefore, identifying patterns of connectivity among deep-sea coral populations is crucial for developing sound conservation and management strategies. Through population genetic analyses, our team has identified four regionally distinctive groupings of Lophelia pertusa in the northern Atlantic Ocean: the Gulf of Mexico, SEUS, New England Seamounts, and eastern North Atlantic (Morrison et al., 2011). Increasing the geographic scope of L. pertusa sampling, including the Caribbean and Bahamas, would contribute greatly towards our understanding of basin-wide connectivity patterns. Similar connectivity studies are underway for the L. pertusa reef associate squat lobster, Eumunida picta and the structure-forming coral Madrepora oculata. Taken together, these studies will form a more complete picture of connectivity patterns in deep reefs in the North Atlantic Ocean, which may inform ecosystem-based management of these vulnerable habitats.

3. Microbial Ecology: Microbial associates have been shown to be key players in coral biology, serving functions such as fixing nitrogen, chelating iron, cycling waste products, and producing antibiotics to keep unwanted microbes from infecting the coral. Most known coral diseases are linked to microbial pathogens. There has been very little research on the microbial associates of mesophotic and deep-sea corals and the Caribbean is a particularly understudied area. This type of research will increase our knowledge of the biodiversity in these ecosystems and provide insight into the variability or uniqueness of the corals in the Caribbean Sea.

Geology

Chemistry 1. Growth rates and age distribution of deep sea corals: Information on growth rates and life spans of deep-sea corals is essential for conservation and management and for assessing the vulnerability of these organisms to both natural and anthropogenic perturbations. Accurate determination of the age, longevity and growth rates of deep-sea corals is required for, biological and ecological assessments as well as to develop highly resolved age models for paleoceanographic studies. A combination of factors such as low frequency of recruitment events, delayed first reproduction, limited larval dispersal, and the demonstrated longevity and slow growth rates suggest that it may take centuries for deep sea corals to recover from negative impacts. Longevity seems to be the key factor for population maintenance given the limited and complex genetic flow among black coral populations for example over long distances. Consequently, overexploitation of deep sea corals without proper management could easily lead to local population extinction.

2. Paleoceanographic studies: As the "bristlecone pine" of the oceans, skeletons of deep sea corals are excellent archives of past climatic conditions. The skeletons of DSC are new and unique paleoceanographic and paleoclimate archives. Geochemical records derived from the skeletons of DSC offer continuous, high-resolution archives that are vital for assessing the vulnerability of these organisms to natural and anthropogenic disturbances and the time scales of their recovery. These records can also extend our observations of ocean dynamics and climate to periods well before the onset of instrumental records. Given that some species of DSC grow in tree like fashion depositing growth rings, decadally resolved and perhaps even sub-decadally resolved records are possible with high resolution sampling techniques such as laser ablation.

3. Baseline measurements of temperature, oxygen, and turbidity will inform us as to current conditions and range of environmental conditions tolerated by DSC, and provide us perspective on their tolerance and environmental thresholds. In addition, data for particulate organic carbon flux, the fuel the feeds these ecosystems, to the deep Caribbean are scant.

Physical oceanography The Caribbean Region is topographically complex, potential resulting in substantial habitat heterogeneity which can influence deep-sea coral community diversity, connectivity, and food webs. Gradients in depth, water mass characteristics, currents, topography, oxygenation, temperature, nutrients, and productivity influence the biodiversity, structure, and growth of deep-sea corals, but these parameters are not well characterized in the deep Caribbean region. Deep-sea corals are typically associated with oceanic boundary conditions or with sea-floor topographic features that possibly modify the hydrodynamic environment. Repeated CTD casts, in conjunction with high resolution mapping activities, will help characterize the oceanographic environment of the deep-sea corals, by providing information on the topography, currents, water mass exchange, and local hydrodynamic regime in and around the habitats. This information is important for predicting and understanding where corals thrive and related food supply dynamics.

Archaeology/history

Other

Rationale for exploration in the target area The Caribbean region represents an important transition zone, physically connecting the Gulf of Mexico and the Atlantic Ocean. Information on deep-sea corals in the Caribbean is limited, and while a wide variety of deep-sea corals occur within the wider Caribbean region, distribution of these corals is generally considered poor. To date, no research efforts in the Caribbean are focusing on the biology and ecology of deep-sea coral communities. Information on bathymetric and hydrographic conditions is crucial to understanding the conditions favorable for deep-sea coral communities. However, ecosystem based management of these important and sensitive communities require a multidisciplinary effort that integrates geologic, biologic and oceanographic data. For example, in the Caribbean, there is still debate on the minimal size of hard substrate required to promote settlement, and little if any information exists on regional transport of deep coral larvae in the region. Therefore, to quantify anecdotal evidence suggesting long term connectivity through the basin and open exchange between the Atlantic and Gulf of Mexico, critical scientific data needs to be systematically collected in the Caribbean. Previous research in the Gulf of Mexico and SEUS by the USGS and its partners demonstrate how hydrodynamics influence connectivity, and flux rates and water-column properties past the corals, setting food, nutrient, and contaminant uptake rates. Therefore, coupling geologic and oceanographic studies to the biological studies greatly enhances our understanding of deep-sea coral ecosystems.

Overview of target area Deep-sea coral (DSC) ecosystems are now widely recognized as biodiversity hotspots consisting of a large number of different mega- and macrofauna

species (Roberts et al. 2009). These ecosystems provide habitat and reproductive grounds for certain commercially important fish species. Recent research expeditions conducted over the last decade have provided considerable new information on the distribution, habitat, and biodiversity of the DSC communities in ocean regions neighboring the Caribbean, such as the Gulf of Mexico, and off the southeastern coast of the United States (SEUS). The Caribbean generally has higher diversity of deep-sea corals, and previously sampled regions are hypothesized to be depauperate extensions of Caribbean fauna (Cairns 1979), suggesting a degree of connectivity among regions.

Summary of what is known about the target area The spatial distribution of deep sea coral habitats in the Caribbean is based primarily on sporadic submersible and ROV research. Seventy six species of azooxanthellate hard corals occur in the Caribbean region (Cairns 1979), including six species regarded as the major structure-forming species in the Caribbean: Enallopsammia profunda, Enallopsammia rostrata, Lophelia pertusa, Madrepora carolina, Madrepora oculata and Solenosmilia variabilis. In addition to these stony corals, gorgonians, soft corals, stylasterids, black corals, lithotelestid coral and sea pens are also occur within the wider Caribbean region. Early research suggests that the distribution of deep sea coral habitats follows the Antilles and continental shelves of Central, South and North America. The greatest distribution and diversity is believed to be at the northern islands of the Lesser Antilles at approximately 200-350 m. In contrast to the Straits of Florida and the Lesser Antilles, the southern coasts of the Greater Antilles and Costa Rica are not well sampled and information on regional distribution of deep corals is limited and needs great expansion.

6.6 Deep water sponges and gorgonians

Author and collaborators

Shirley Pomponi spomponi@hboi.fau.edu
Harbor Branch Oceanographic Institute - Florida Atlantic University

Dr. Amy Wright awrigh33@hboi.fau.edu
HBOI-FAU

John Reed jreed12@hboi.fau.edu
HBOI-FAU

Dr. Rene Wijffels rene.wijffels@wur.nl
Wageningen University

Dr. Robert Thacker thacker@uab.edu
University of Alabama

Dr. Joana Xavier jxavier@uac.pt
University of the Azores

Why this area may be of interest

Biology Biodiversity, taxonomy, habitat characterization

Geology

Chemistry Discovery of novel marine-derived compounds with pharmaceutical relevance

Physical oceanography

Archaeology/history

Other Testing new tools and platforms for non-destructive sampling

Rationale for exploration in the target area We have done no exploration at sites deeper than 3000 ft. A focus on deepwater sponges and gorgonians–dominant components of hard-bottom communities–would fill a gap in our understanding of the biodiversity and biogeography of these important taxa. There is a very high probability for discovery of new species and habitats at greater depths, including carnivorous sponges and deep coral communities.

This would be a good opportunity to partner with colleagues from the Netherlands who are beginning exploration, research, and assessment of marine resources in the Dutch Caribbean.

Comparison of deepwater sponges throughout the Atlantic is in progress, with collaborators from the US, Canada, Spain, Portugal, Italy, France, and Poland.

Data obtained from collected material could also enhance development of the NSF-funded Porifera Tree of Life project (of which Dr. Pomponi is a collaborator).

Overview of target area We have done extensive exploration and undersea research throughout all of the Bahamas and most of the Caribbean since 1984, using the Johnson-Sea-Link I and II submersibles. Sponges and gorgonians are dominant components of benthic habitats throughout the Caribbean, and we propose to focus on documentation of their biodiversity and changes in community structure over time. If samples can be collected, we propose to discover and publish new species descriptions, perform bioactivity analyses, and conduct population genetics studies of key species.

Summary of what is known about the target area Based on what we have already studied, we know that there are dozens of new species of deep water sponges and gorgonians from the Bahamas and Caribbean, and we have discovered significant biological activity (with pharmaceutical relevance) in many of these sponges and gorgonians.

We have an extensive database and photo repository that document the occurrence of sponges and gorgonians (as well as other invertebrates) at studied sites in mesophotic and deep-reef environments.

6.7 Biofluorescence/Bioluminescence

Author and collaborators

David Gruber David.Gruber@baruch.cuny.edu
Baruch College, City University of New York

Vincent Pieribone vap5@email.med.yale.edu
Yale University/Pierce Laboratory

Dan Tchernov dtchernov@univ.haifa.ac.il
University of Haifa

Chris Roman cnr@gso.uri.edu
University of Rhode Island

John Sparks jsparks@amnh.org
American Museum of Natural History

Why this area may be of interest

Biology Yes

Geology No

Chemistry No

Physical oceanography Yes

Archaeology/history No

Other Biomedical Research

Rationale for exploration in the target area Over the past few years, the collaborators of this project have been designing underwater camera equipment to study and record both biofluorescence and bioluminescence. With the assistance of Chris Roman, we have specifically designed this equipment so it could be compatible with ROVs deployed from exploration vessels Nautilus and Okeanos Explorer.

Our objectives are to conduct a comprehensive field survey of biofluorescence in corals, marine fishes and other not-yet-discovered fluorescent organisms in the Caribbean. This would be one of the first studies to broadly investigate biofluorescence in fishes and the project would provide valuable insight into the distribution and potential function of fluorescence in both shallow and deepwater species, where biofluorescence is known to occur, but is unexpected due to low ambient light levels. Collaborators of this application are credited with the discovery of over 30 of the 120 published fluorescent proteins and are well prepared with cloning novel biofluorescent genes.

Exploration in this target area would also provide the highest resolution bioluminescent and biofluorescent imagery ever obtained –that can be shared with the general public. Collaborators of this application recently curated "Creatures of Light: Nature's Bioluminescence" an exhibit at the American Museum of Natural History which has been extremely well received since its opening on March 31, 2012. Yet, we discovered that while there is a very strong public interest in this area, sparse imagery of these creatures exists. Exploration in this target area would address this gap.

Overview of target area Fluorescent proteins are a family of spontaneously fluorescent proteins, found primarily in coral, which are highly prized biotechnology tools. The pioneers of fluorescent proteins research were recently awarded the 2008 Nobel Prize in Chemistry for their discovery and development. The ecological/biological function that fluorescent proteins play in coral reef organisms remains a mystery.

Summary of what is known about the target area Biofluorescence exists only in a few classes of animals (mainly Anthozoa). The majority of species within the Anthozoa subgroup Scleractinia (reef-building corals) not only express green fluorescent-like proteins, but localize the proteins in distinct visual patterns along the colony. Just as the functions of these proteins remain unknown, their coloration and patterns of expression within reef organisms have been debated for many years (Longley, 1917; Kawaguti, 1944, Marshall, 2000). The first fluorescent protein discovered, green fluorescent protein (GFP), was found in the bioluminescent marine hydroid, Aequorea victoria (Shimomura et al., 1962). GFP-like fluorescent proteins have since been identified in a number of different members of the Cnidarian phylum including corals, anemones, hydroids, penntalunia, and coralmorphorallian (Shagin et al., 2004). In some cases, multiple different fluorescent proteins have been

isolated from a single Anthozoa species, and proteins with different spectral properties were found in the same animal (Kelmanson and Matz, 2003; Sun et al., 2004). However, outside of Cnidaria, fluorescent proteins have only been isolated from the copepods (Phylum Crustacea), Pontellina plumata and Labidocera aestiva (Shagin et al., 2004). Fluorescent proteins have not been found in the terrestrial environment, although non-fluorescent structural homologues exist (Hopf et al., 2001). In bioluminescent Aequorea, GFP acts to convert blue light to green (Morin and Hasting, 1971), but it remains unclear how fluorescent proteins function in non-bioluminescent organisms.

Recently we have discovered evidence that biofluorescence is widespread among marine cartilaginous and bony fishes. We have new data showing that biofluorescence is a common feature of cryptically colored reef fishes (e.g., blennies, eels, scorpionfishes, and lizardfishes), occurring throughout these disparate groups, and is also present in sharks and rays, anglerfishes, groupers, clingfishes, pipefishes, gobies, and several other groups. We found that, in addition to red fluorescence, marine fishes commonly exhibit green fluorescence, or a combination of both, in unique, species-specific patterns ranging from simple eye rings, to unique and complex patterns on the head, jaws, fins, flank, and belly; even bright fluorescence of the entire fish.

6.8 Former CARICOMP marine laboratory network sites spanning the Wider Caribbean

Author and collaborators

John Ogden jogden@usf.edu
University of South Florida

Dr. Jorge Cortés Núñez JORGE.CORTES@ucr.ac.cr
Universidad de Costa Rica

Dr. Eric Jordan Dahlgren ejdahljor@gmail.com
Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autonoma de Mexico (UNAM)

Why this area may be of interest

Biology Intensive monitoring of ecosystem structure and functioning over 20 years, 1986-2007; biological linkages between shallow and deep

Geology Coral reefs, seagrasses and mangroves buffer the contact between land and sea

Chemistry Potential chemical linkages between shallow and deep water ecosystems

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area There is abundant scientific evidence that the wider Caribbean functions as a large marine ecosystem with physical, biological and chemical inter-connections. This is a compelling rationale for the CLME approach to regional governance that encompasses the geographic scales of marine biodiversity, human uses and the ecological processes that sustain both. A large missing piece of our understanding is the deeper coastal shelf. By selecting a series of three or more target sites–mainland, large island, and small island–connections between shallow and deep ecosystems may be hypothesized and provide a background for future work. The results will help the design of future long term monitoring and comparative ecological research within a new marine laboratory network and ultimately help to advance the CLME.

Overview of target area Beginning in 1986 and continuing for over 20 years, the Caribbean Coastal Marine Productivity (CARICOMP) network of 15 cooperating marine laboratories synoptically monitored, with standardized methods and equipment, the structure and functioning of shallow coastal ecosystems– coral reefs, seagrasses and mangroves– of the Wider Caribbean. These data provide dramatic documentation of the status and trends of coastal ecosystems in an era of global change. The program ended in 2007 and the results are being written up. A group of former CARICOMP laboratories (lead by the two colleagues below and myself) are planning to continue their region-wide research association in a new laboratory network which will provide scientific input to the Caribbean Large Marine Ecosystem (CLME) project of IOCARIBE. While the target areas would be determined later, depending upon the ship's itinerary and with input from the new laboratory network, we propose that at least three former CARICOMP sites spanning the mainland and islands arcs of the Caribbean Sea be selected for exploration of the offshore, meso-photic and deep environments which are linked to the intensively monitored shallow sites.

Summary of what is known about the target area The shallow marine ecosystems at each of the target sites eventually selected for offshore exploration have been intensively monitored in shallow water over approximately 15-20 years in coordination with each other. As marine laboratories are established in relatively unspoiled areas and are the repositories of local knowledge and data, the exploration of deeper areas will benefit from local input and data from intensive prior monitoring. The NOAA OET surveys will expand the

understanding of the linkages between shallow and deep waters and thus achieve a greater bang for the exploration buck.

6.9 Ciguatera Fish Poisoning in the Caribbean

Author and collaborators

Patricia Tester pat.tester@noaa.gov
Center for Coastal Fisheries and Habitat Research, National Centers for Coastal Ocean Science, National Ocean Service, NOAA

Why this area may be of interest

Biology Depth distribution of organisms causing ciguatera fish poisoning in the Caribbean

Geology

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area The rationale for exploration of Gambierdiscus abundance at depth is to assess the reservoir of toxic cells. Recent breakthroughs in qPCR methods and sampling techniques will facilitate the first cell-based monitoring program for ciguatera fish poisoning. Prior to implementing monitoring, it is important to know the potential risk that may lie at depth before assuming that shallow habitat based monitoring will provide the predictive capabilities needed to manage resources and protect public health.

Overview of target area Ciguatera fish poisoning (CFP) is the most commonly reported nonbacterial illness associated with seafood consumption in the tropics. The organisms that cause CFP are toxic, benthic dinoflagellates of the genus Gambierdiscus. Their toxins are bioconcentrated in marine food webs making the top predators in reef ecosystems the highest rick factors for human consumption. Recent work indicates that positive Gambierdiscus growth can be maintained at light levels found between 100-150 meters in tropical waters. However only rarely have samples been taken below 20 meters. There is concern that large reservoirs of toxic cells exist throughout the Caribbean at depths never

sampled. A survey of Gambierdiscus abundance at depth will will provide an assessment of the risk of CFP in endemic regions of the Caribbean.

Summary of what is known about the target area We have recently published quantitative polymerase chain reaction assays for all the Caribbean Gambierdiscus species. This will allow rapid detection and quantification of field samples collected at depth. In addition we have comparative Gambierdiscus abundance data in numerous shallow water habitats in the Caribbean. This would allow us to take advantage of a joint effort in any location, except the central basin of the Caribbean, to obtain samples at depths to 150 meters.

6.10 Ciguatera Fish Poisoning

Author and collaborators

Errol Dakin ecdakin@yahoo.com
University of the West Indies, Ministry of Agriculture and Fisheries

Dr. Patricia Tester pat.tester@noaa.gov
NOAA

Dr.Winklet Gallimore winklet.gallimore@uwimona.edu.jm
University of the West Indies

Why this area may be of interest

Biology Ciguatera associated dinoflagellates

Geology

Chemistry Toxicity profiles of these dinoflagellates

Physical oceanography Environmental factors contributing to growth

Archaeology/history

Other

Rationale for exploration in the target area The fishery sector plays a significant role in Jamaica's economy. It is a major source of income and food for fishermen and their families who are dependent on this industry for their livelihood and source of protein. There are also several fishery products that are harvested and exported to other countries mainly

U.S.A and Europe. These products include Conch, lobster and Tilapia. Ciguatera Fish Poisoning (CFP) is a major Public Health concern in Jamaica and the wider Caribbean with sporadic and unpredictable outbreaks from time to time. Species from the Gambierdiscus genus namely G. toxicus has been implicated in the production of Ciguatoxins which is the major toxin responsible for CFP. Previous studies in Jamaican coastal waters have identified several species of Gambierdiscus. Due to the similarities in morphology of these species, determination of their identities has been difficult. It is therefore proposed that a study be done in this area to determine the number of different species of Gambierdiscus in this area and also to confirm their identity using PCR technique, in addition to light and electron microscopy which are normally used to identify these species. Study also needs to be carried out to determine the toxicity of the species identified.

Overview of target area Jamaica is a Caribbean island located in the Greater Antilles. Its' coastline is approximately 1,022km in length. The coastline has several white sand beaches which are a major tourist attraction. A lot of fishing activities takes place around the coastline including harvesting of marine fishes and oysters. It is also the source of a great biodiversity of other marine organisms which are is research and commercial interest. These include sponges, dinoflagellates and diatoms.

Summary of what is known about the target area Ciguatera Fish poisoning (CFP) is a major marine food borne illness that is a result of the consumption of reef fishes that have accumulated Ciguatoxin, through the food chain. The source of this toxin is reported to be dinoflagellates belonging to the genus Gambierdiscus, which has two species G.toxicus and G polynesiensis that are confirmed producers of these toxins. There are now eleven known species of this genus five of which have only recently being discovered, Four by Litaker et in 2009 and one discovered by Fraga 2011. The role that each of these species play in causing CFP and their toxicity is unknown in some of these species and therefore there is need of further research in this area.

6.11 Deep reefs

Author and collaborators

Carole Baldwin baldwinc@si.du
Smithsonian Institution

D. Ross Robertson drr@stri.org
Smithsonian Tropical Research Institute

Lee A. Weigt weigta@si.edu
Smithsonian Institution

Jerry Harasewych harasewych@si.edu
Smithsonian Institution

David Pawson pawsond@si.edu
Smithsonian Institution

Haris Lessios lessiosh@si.edu
Smithsonian Institution

Why this area may be of interest

Biology Systematics and Evolution of Fishes/Conservation

Geology

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area Deep reefs harbor diversity that is not accessible by SCUBA. Little is known about the diversity of life on deep reefs, how it changes over space and time, and how it compares with – and what role it may play in the survival of – shallow reefs above. DROP aims to fill these gaps in our knowledge.

Overview of target area Deep reefs are natural extensions of shallow reefs, yet they are underexplored and poorly monitored marine ecosystems worldwide. Little is known about diversity of life on deep reefs, how it compares with shallow reefs above, and how it changes over space and time. Are water temperatures on deep reefs rising and are these ecosystems exhibiting degradation and loss from major agents of environmental impact?

Summary of what is known about the target area In 2011, we initiated DROP (Deep Reef Observation Project), a collaborative effort between Smithsonian scientists and Substation Curaçao to investigate deep-reef fishes, invertebrates, and algae to address questions related to biodiversity, biogeography, and conservation. More than a dozen Smithsonian researchers from NHB, STRI, LAB, NOAA, and SMSFP participated in Phase I field work. From 21 submersible dives nearly 200 deep-reef specimens were collected, processed

for genetic analysis, and exported to the U.S. for archival into NMNH collections. Initial discoveries include new species and new depth and range records. Over 1,000 shallow-water specimens were similarly sampled for investigations of biodiversity and genetic connectivity among shallow and deep reefs. Some methods of standardized sampling (e.g., submersible video transects, traps, temperature/depth profiles) that can be repeated over time and geographical area were implemented and produced preliminary baseline data for long-term monitoring of Curaçao deep reefs. Smithsonian research in Curaçao was publicized in both scientific and public forums, and site visits to Substation Curaçao by Smithsonian and affiliate marine educators provided a foundation for international educational initiatives.

Renovations are nearly completed of a former NOAA ship now owned by Substation Curaçao (R/V Chapman), which will enable it to transport the sub to other sites throughout the Caribbean. In addition to exploratory sampling and monitoring on deep reefs adjacent to the Curaçao Sea Aquarium, a major focus of the proposed work in 2012 is transporting the submersible to nearby Caribbean sites for comparative purposes. Data collected as part of DROP also will be compared with historical and more recently collected data from NOAA and JSL investigations of deep reefs off Florida, the Bahamas, and the Caribbean.

6.12 Marine Mammals

Author and collaborators

Grisel Rodriguez grisel15@gmail.com
UPRM

Why this area may be of interest

Biology Population genetic structure

Geology

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area As part of the research effort a visual survey and biopsy sampling (if possible) is proposed for the Caribbean portion of the study.

My research area is Puerto Rico, but this type of research could also impact the Caribbean population .

I am a PhD student at the University of Puerto Rico, Mayaguez. Thesis Population Structure of the Bottlenose Dolphin (Tursiops truncatus). I am also a Puerto Rico's Government employee for the Puerto Rico Department of Natural and Environmental Resources where I work as the Marine Mammal Stranding Coordinator and project leader to the Puerto Rico Marine Recreational Statistics Program. As part of the United Nations SPAW Protocol I have worked with the Spanish speaking Caribbean countries marine mammal experts and I can contact them to include then on this research effort.

Overview of target area Caribbean marine mammals are poorly known. The United Nations Marine Mammal Action Plan calls for stock assessment, populations descriptions (distribution, genetics, behavior etc). Three surveys have been done in the last 30 years. To maximize this research effort I propose to include a Marine Mammal survey, this will not interfere with underwater work and will help to understand the Caribbean stock.

Summary of what is known about the target area At least 32 marine mammal species have been recorded for the Wider Caribbean Region. Due to the complexity of the area, lack of funding and research opportunities this stock is poorly known.

6.13 Fish Kills and Coral Bleaching

Author and collaborators

Lyndon Forbes Robertson lrobertson@oecs.org
Organisation of Eastern Caribbean States (OECS)

Why this area may be of interest

Biology Trigger of susceptibility to Strep. inaei causing mass mortality in reef fish Sea water temperature affecting zooxanthellae

Geology Caribbean Sea, CARICOM region and OECS Sub-region

Chemistry Pollution loading into the Caribbean Sea from landbased sources inducing susceptibility in reef fish and corals

Physical oceanography Role of climate change and impacts on coastal and marine resources

Archaeology/history Fish kills and coral bleaching episodes have been affecting the Caribbean region

Other Evaluating the impacts of freshwater lenses from south America traversing the Caribbean region and contribution of fish kill episodes and coral beaching due to alteration of sea water chenistry

Rationale for exploration in the target area Determination of the causes of fish kills and coral bleaching and importantly finding scientific approaches to reduce the impact these episodes are having on the marine and coastal resources. This will assist in the protection of of this resource which is vital to the economic survival of the Caribbean.

Overview of target area The OECS sub-region covers the Eastern Caribbean consisting of 9 Member States while the CARICOM Caribbean consist of 16 Member States including the 9 OECS territories Belize, Guyana, Suriname, Bahamas, Barbados and Haiti.

Summary of what is known about the target area The coastal and Marine resources of the Caribbean region are important to the sustainable development providing food and driving the tourist industry. Fish Kills have been occurring throughout the region since the 1990s and in recent times have been more localised (Bahamas 2011). Coral bleaching has been a recurring episode during the summer months affecting the coral health and impacting on the dive tourism and long term sustainability of the reefs.

There are many suggestions with regards to the cause of the Fish Kills including: freshwater influx from South America, algal blooms, Sterp. ineai, low Dissolved oxygen in the nearshore etc. The coral bleaching has been linked to increase sea temperature from climate change.

6.14 Burrow morphology and ichnofacies

Author and collaborators

Marti Lopez Gonzalez odysseypr@gmail.com
University of Puerto Rico, Mayaguez

Why this area may be of interest

Biology

Geology

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area Contributions of ichnology to sediments geology are considerable: the production of sediments by boring organisms; the construction of new fabrics and sediments structures; the initial history of lithification; the interpretation of deposition environments; and, the delineation of facies and facies succession.

Overview of target area Burrow fossils have a unique morphology that provides a great beach fancies indicator. In situ burrow casting will bring a greater understanding in both facies interpretation and stratigraphic correlation. In situ investigations of the burrows morphology will be carried out on the following environments: backshore, swash zone, surf zone and break zone.

Summary of what is known about the target area Sedimentary structures formed by the burrowing, boring, feeding, movement and resting that have a direct relation with the behavior of the organisms are known as inchofossils. In addition, their importance as indicators of stratigraphic age, trace fossils are valuable clues for depositing environments.

Chapter 7

Technology

7.1 Caribbean Sea

Author and collaborators

Shahriar Negahdaripour shahriar@miami.edu
University of Miami

Why this area may be of interest

Biology

Geology

Chemistry

Physical oceanography

Archaeology/history

Other Needed imaging and mapping technological developments

Rationale for exploration in the target area N/A

Overview of target area I am not a marine scientist, but engineer. I have devoted over 2 decades of research on the development of novel technologies and capabilities for automated deployment of remotely operated platforms for the imaging and mapping of subsea world, both manmade targets (ship hulls, bridge pilings, shipwrecks, etc.) and

natural objects (reefs and various benthic habitats). The expertise involves the use of both optical sensors (cameras) and new generation of high-resolution foward-scan short-range sonar video systems as the 2-D imaging devices. The 2-D forward-scan sonar systems have not been commonly adopted for many marine science applications, despite tremendous potential in turbid environments.

Another rather interesting untapped application of my recent work for marine sciences is the integration of optical and sonar imaging, which can provide valuable information for object identification and classification (in addition to mapping), based on both visual and acoustical properties.

My interest for attending is to learn more about the immediate application areas where these novel technologies may be deployed in the Caribbean Sea, identify stakeholders and establish contacts, as well as to inform the marine science community of these upcoming technologies and their potential impact on new scientific studies and discoveries.

Summary of what is known about the target area N/A

7.2 Technology development

Author and collaborators

Douglas Kesling Dkesdiver@aol.com
Aquatic Training Systems, LLC

Why this area may be of interest

Biology Corals, plants, invertebrates, and fishes

Geology Hard bottom and corals

Chemistry Ocean Acidification

Physical oceanography Storm events - Hurricanes

Archaeology/history Unmapped shipwrecks

Other Apply EXOSUIT (ADS) Technology to research vessel platform

Rationale for exploration in the target area See above

Overview of target area Apply Atmospheric Diving System (ADS) to "Exosuit" to research vessel survey/exploration platform. 1000 fsw tethered system, neutrally buoyant with fiber optic, 3D video technology. Manned pilot/operator inside suit. Supported by vessel of opportunity. Marine science and exploration tool.

Summary of what is known about the target area See above

Chapter 8

Terrestrial/Shallow

8.1 Novel Antibiotics and Anticancer Drugs from Marine Communities

Author and collaborators

Alan Decho awdecho@mailbox.sc.edu
University of South Carolina

Why this area may be of interest

Biology Microbiology of microbial mats and other shallow water systems

Geology

Chemistry

Physical oceanography

Archaeology/history

Other

Rationale for exploration in the target area Most currently-used antibiotics are derived from a relatively small group of soil bacteria. Antibiotics are naturally produced by bacteria to inhibit other bacteria, especially when they live in dense communities. Hypersaline bacterial communities are easily accessible and contain tens of thousands of bacterial species living in close proximity. Therefore, an entire store house of novel antibiotics (and

compounds having anti-cancer activities) can be found there. Bacteria living commensally or symbiotically within animals in the shallow ocean also produce many such compounds. We have explored next to nothing about these naturally-produced antimicrobials. Entirely new antibiotics, having novel mechanisms of action are needed to off set and manage antibiotic resistance – an emerging health crisis in the 21^{st} Century.

Overview of target area Hypersaline ponds are abundant on islands of the Bahamas, and contain highly-diverse microbial communities which are a source of novel antibiotics.

Summary of what is known about the target area We have worked on bacterial communities and other processes in these communities for over ten years.

8.2 Lost pre-Columbian landscapes of the Caribbean

Author and collaborators

Corinne Hofman c.l.hofman@arch.leidenuniv.nl
Leiden University

Siegel Peter siegelp@mail.montclair.edu
Montclair State University

Hoogland Menno m.l.p. Hoogland@arch.leidenuniv.nl
Leiden University

Why this area may be of interest

Biology

Geology

Chemistry

Physical oceanography

Archaeology/history Current landscape modifications due to human and natural factors

Other Heritage

Rationale for exploration in the target area The pre-Columbian archaeological record of the Caribbean is under threat from endogenous and exogenous factors (e.g., climate change, coastal erosion due to rising sea levels, earthquakes, volcanic eruptions, marketing of antiquities, infrastructural development). We propose to investigate the loss of Caribbean coastal landscapes and the remnants of heritage that they contain through a combined approach of oceanic and near-shore exploration of submerged archaeological sites and to assess impacts of cultural resources in the target area. The pre-Columbian archaeological record of the Caribbean is under threat from endogenous and exogenous factors (e.g., climate change, coastal erosion due to rising sea levels, earthquakes, volcanic eruptions, marketing of antiquities, infrastructural development). We propose to address the loss of Caribbean landscapes and the remnants of heritage that they contain through a combined approach of oceanic and near-shore exploration of submerged archaeological sites and to assess impacts of cultural resources in the target area. Heretofore, these landforms have never been systematically explored. By placing the Caribbean's pre-Columbian past within a contemporary heritage agenda, this research strives to increase the awareness and protection of heritage resources.

Overview of target area Our target area includes selected locations in the Greater Antilles, Bahamas/Turks and Caicos, Lesser Antilles and southern Caribbean islands (i.e., Aruba, Curacao and Bonaire, Los Roques and Los Aves, Trinidad and Tobago). Within this broad geographic frame our research will address coastal locations with archaeological sites dating from the mid-Holocene to the early colonial period (early 17th century) and which are increasingly under threat from endogenous and exogenous factors. Kinds of sites range from small camps, workshops, small ritual sites, and hamlets to large intensively occupied villages and ceremonial centers. In the chronology of the Caribbean this time span includes the Archaic, Early and Late Ceramic Age and the early colonial period. The early colonial period of the 16th and 17th centuries is defined as a time of indigenous resistance to European encounters.

Summary of what is known about the target area Evidence indicates earliest human occupations in the Caribbean dating to approx. 6000 BC with points of entry located in different parts of the American continent. People settled into diverse ecological islandscapes and built on and modified webs of social, political and economic relations within and across islands. To the early occupants of the Caribbean the ocean was viewed as a highway or a passage rather than as a barrier to expanding communication between communities. Archaeological research in the Caribbean has been active for much of the past century, producing a rich body of data relating to early human migration(s) into the islands, changes in subsistence and settlement strategies over time, mobility and exchange, and the evolution of sociopolitical organization. Studies have addressed biogeography, environmental change,

and oceanographic issues as they relate to changes in human adaptations to island settings over the millennia.

8.3 Historical Ecology

Author and collaborators

Scott Fitzpatrick scott_fitzpatrick@ncsu.edu
North Carolina State University

William F. Keegan keegan@flmnh.ufl.edu
Florida Museum of Natural History

Why this area may be of interest

Biology

Geology

Chemistry

Physical oceanography

Archaeology/history Pre-Columbian human impacts on island environments

Other Biological invasions, diachronic perspectives on human settlement from prehistory to modern times

Rationale for exploration in the target area Despite a paucity of archaeological research into questions related to human impacts in the Caribbean prehistorically, scholars are now moving toward identifying questions within the historical ecology framework to better understand how humans may have affected their island environments after colonization. This becomes an even more pressing issue given that the Caribbean islands are comprised of and surrounded by dozens of independent nations, all of whom bear responsibility for managing their resources. To effectively do this, it is imperative that there is a level of regional cooperation that utilizes an historical point of view so that the availability and changes to both marine and terrestrial ecosystems across time and space can be ascertained and used to help develop conservation measures in the future. Humans are the primary cause behind changes to Caribbean island biodiversity which have been traced archaeologically, historically, and ecologically. Historical ecology is able to effectively examine human modification on island landscapes in the Caribbean by working closely with scientists from various disciplines. And by doing so, we can provide more

complete explanations of what human-environmental interactions were like and use these to develop strategies for ecological conservation that would not have been possible without these integrative efforts.

Overview of target area Historical ecology can be defined as the complex, historical interactions between human populations and the ecosystems they have inhabited. This field of study, also referred to as "human ecodynamics" combines palaeoecology, archaeological investigation, land use history, and more recent long-term (decadal) ecological research, to help examine the 'life history' of a region. Given the broad multi- and inter-disciplinary focus of archaeology, many researchers have been attracted to this field of study because it provides a foundation for observing anthropogenic changes through time and how they relate to the environment. This perspective is not without its difficulties, however, because it is often challenging to document how and when environments change–they are rarely constant and humans can adapt to these fluctuations in so many different ways.

Despite these challenges, the interdisciplinary approach that historical ecology has to offers is particularly useful for examining island and coastal ecosystems. As research has shown for the Caribbean, Pacific, and other island regions, these landforms were relatively stable prior to human arrival and because the flora and fauna on islands reflect biogeographic distributions that typically limit the kinds of biota that cannot disperse easily by air or water, they have high rates of endemism (biological characteristics found exclusively in a given area). As a result, islands are particularly fragile ecologically and the presence of omnivorous humans and the things they brought with them can dramatically disrupt these environments. As such, we should expect to see a number of changes to islands after humans arrive, though this is dependent on a number of factors, including population size, distance from islands to other land masses, and many others.

One of the primary reasons why many scholars have moved toward a temporally broader perspective on human-environmental interaction on islands and elsewhere is the recognition that global climatic problems and human interference on land and sea is not a recent phenomenon, but something rooted in the ancient past. Historical ecology as a multidisciplinary approach that branches across various scientific disciplines is needed to answer questions about how the environment changed or was impacted before and after human arrival. In part, this approach is a result of scholars having recognized that peoples in the past did not necessarily live in harmony with their environment but were active participants in exploiting resources, sometimes to the point of extinction. Even relatively small groups of hunter-gatherers can have dramatic impacts depending on the kinds of activities in which they are engaged. In general, it is becoming clear through archaeological and other lines of evidence that all humans can affect their environment in some fashion, though the levels of impact often tend to intensify as populations grow.

Summary of what is known about the target area Archaeological research demonstrates that the Antilles were settled by at least four different major migratory groups with different levels of technology and economies. Foraging "Lithic" groups settled Cuba and Hispaniola around 6000-3000 BP. Archaic (or "Preceramic") peoples, who appear to have been mostly seasonal hunters and gatherers, then began to occupy numerous islands in the Antilles as well as those islands adjacent to the South American mainland by ca. 4000 BP. Later, Saladoid horticulturalists settled the Virgin Islands, Lesser Antilles, and Puerto Rico by as early as ca. 2500 BP. Over two millennia later, Europeans arrived to the New World. In essence, these multiple migrations of people, who originated from different parts of the world, brought with them a host of different plants, animals, parasites, diseases, and cultural behaviors that had profound effects on Caribbean island landscapes, vegetation, and faunal composition.

While it is more difficult to discern what impacts early hunting and gathering groups had on the islands during the Lithic and Archaic periods given that there are fewer sites dating to these periods available for study, research does show that Archaic groups had probably brought in plants from South America and may have even participated in small scale gardening. There is also evidence that sloths in the Greater Antilles became extinct after humans arrived and which was independent of any major climatic fluctuation, suggesting that people were the cause. During the Ceramic Age ca. 2500 BP, however, we see populations expanding as Saladoid groups quickly spread throughout the Lesser Antilles and Puerto Rico and bring with them a horticultural lifestyle that included the cultivation of manioc, one of the their major food staples. Even on a small scale, this would have necessitated the clearing of land and an increase in erosion and sedimentation.

There is evidence that terrestrial resources like land crabs as well as marine foods such as fish and shellfish were being overexploited on numerous islands including Puerto Rico, Jamaica, and Grand Turk. These kinds of impacts can be assessed a number of different ways. For example, archaeologists can: 1) quantify the change in size of a particular taxon over time (a species of mollusk would get smaller over time if it was being continually over-harvested since the juveniles could not grow to full maturity); 2) look for observable trends in the archaeological record of people switching resources from one that becomes less frequent over time to another that is more plentiful; 3) document a group's effort to exploit a particular environment like a lagoon to one with deeper waters if fish have been exhausted; or 4) see an increase in charcoal particles in the soil indicative of fire used to clear land.