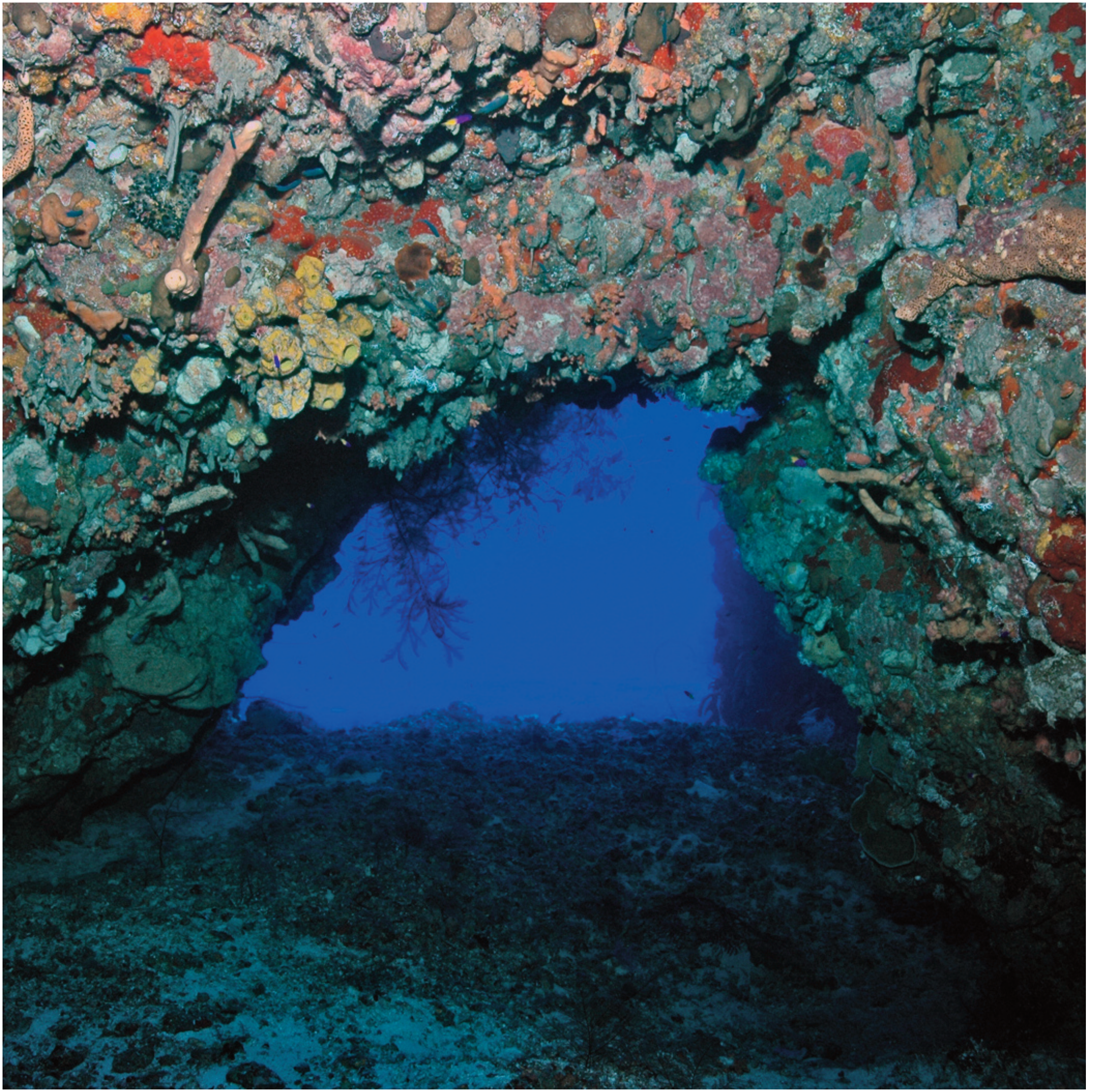
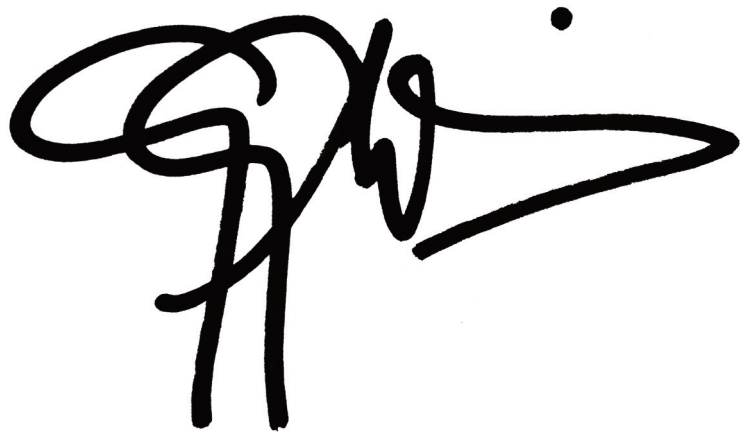


It is always something new… new because you have not seen it before…
most exciting because you have not seen it before in your own backyard!
Think about it, how cool would it be to see something before anyone else,
to explore and to see different life forms and their habitats.
Dreams and reality come together in this book,
for the three of us and for all of you, we hope!

It is a little contribution, thanks to many,
a piece of the puzzle of getting to know something about
the large percent of the Earth's ocean still unknown.
Contribution to record these previously unknown spaces
where these seldom seen species inhabit.
A window to see these fish alive and the colors they have in nature.
It is one thing to see the documentaries of other areas
but what an experience to document the marvels of our own!
Now, get ready to embark on an exciting journey of discovery
to the bottom of the sea around us, the Caribbean Sea!



Graciela García-Moliner

Fishes and their habitats

Fish are animals that live almost exclusively in the water, having gills as their breathing apparatus, contrary to humans that need an air tank (self-contained underwater breathing apparatus or SCUBA) or other technological gadgets to remain submerged for a prolonged time. Fish also have some type of fins to move by swimming (we use flippers to help us move better underwater) and eyes that remain open to see in their fluid environment. Humans need masks to be able to see clearly while immersed in the water. These are some evolutionary adaptations that allow fish their successful existence underwater.

The senior author SCUBA diving once upon a time photographed by Dr. Yvonne Sadovy at El Palo, La Parguera, Puerto Rico.

By Jadiel A. Sánchez Cruz

Cayetano Sánchez Public School,
5th grade
Arroyo, Puerto Rico

SCUBA diver drawing presented to Graciela García Moliner on behalf of his teacher Mrs. Yolanda Ocasio and his classmates.
11 October 2011.

Rebreather diver, Dr. Jorge García-Sais at the wall (>40 m) at Desecheo deep reef. Note the absence of bubbles.

The Essential Fish Habitat

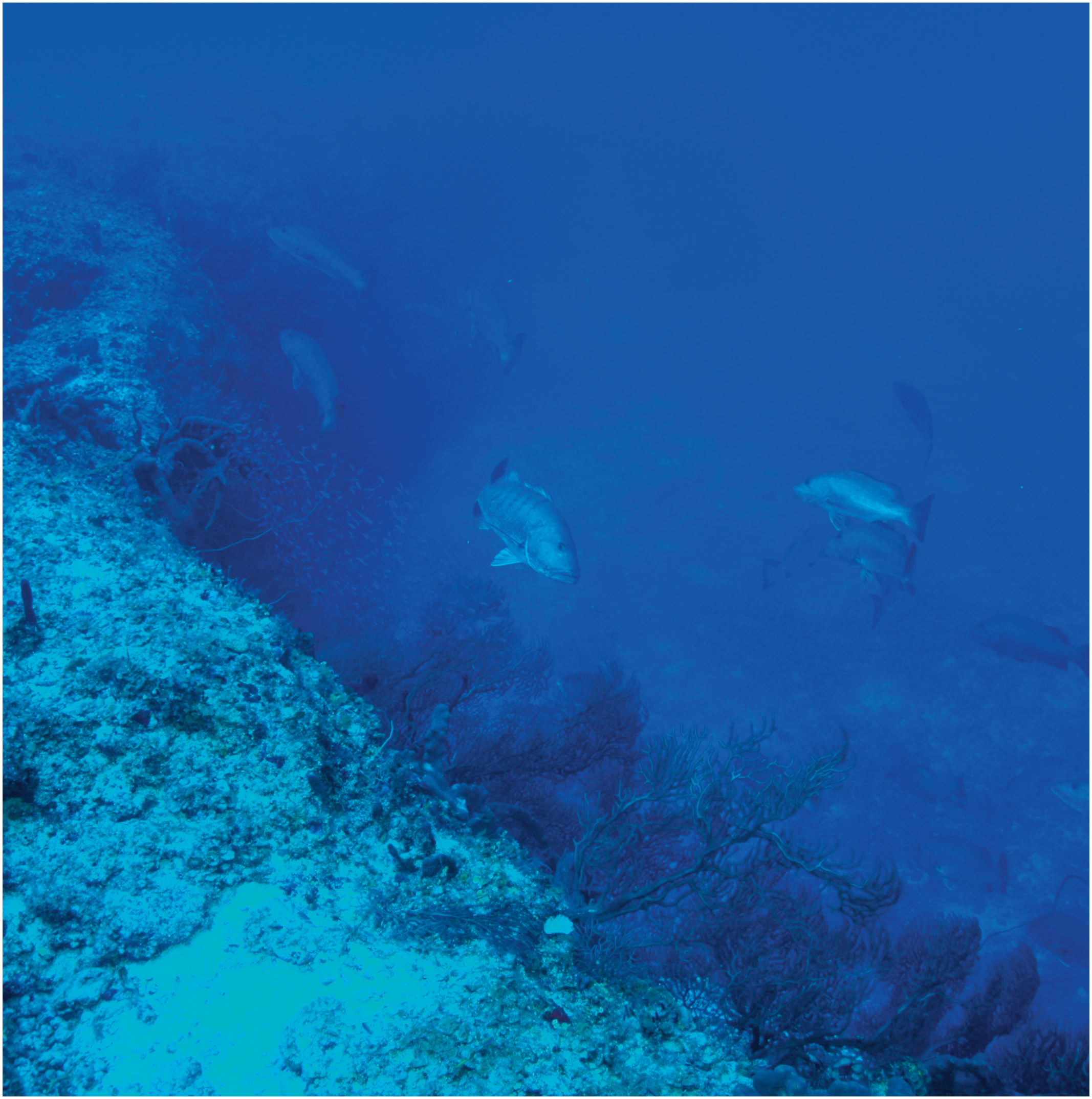
Seawater, from the surface to the bottom of the ocean, is considered the Essential Fish Habitat (EFH). Surface waters are continuously modified by winds, currents, tides, mixing, and rain among others factors. Annual modifications of these surface waters to depths of about 30 m occur with varying degrees of intensity every year. Waters from the Amazon and Orinoco Rivers of South America may reach the coastal areas of Puerto Rico and the Virgin Islands, as it happened in 2009. Fish have mechanisms to adapt to environmental changes, one of these changes being in salinity due to river discharges. One of the mechanisms is osmoregulation and another is to flee or escape. Most fish will not survive out of the water, with some exceptions. Their survival out of the water is limited.

The water column, as described in the Cocktail Section of Chapter 1, is influenced by water currents from other parts of the world, from the surface to the bottom of the ocean. We can feel the differences in temperature when we are swimming about even in shallow water. Therefore, fish habitats vary.

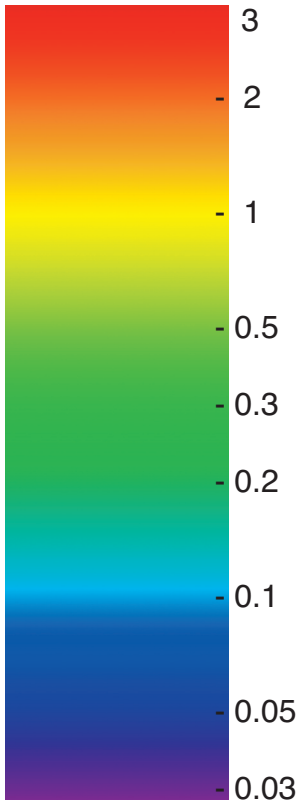
We are mostly familiar with the shallow water coral reefs, the sandy areas, the seagrass beds, and areas where we anchor boats and are able to see the bottom. White sand, green grasses, colorful corals – orange, green, yellow – and the colorful fish also associated with these habitats is what is most familiar. The crystal clear waters of the Tropics allow us to see the bottom from the surface, but only to a certain depth. Beyond that depth we need help to explore and describe what we cannot see from the surface. The interest in finding out what lies beneath gave birth to the development of gear that would allow us to breathe and remain underwater for longer periods of time to observe the fauna and its interactions with their environment.

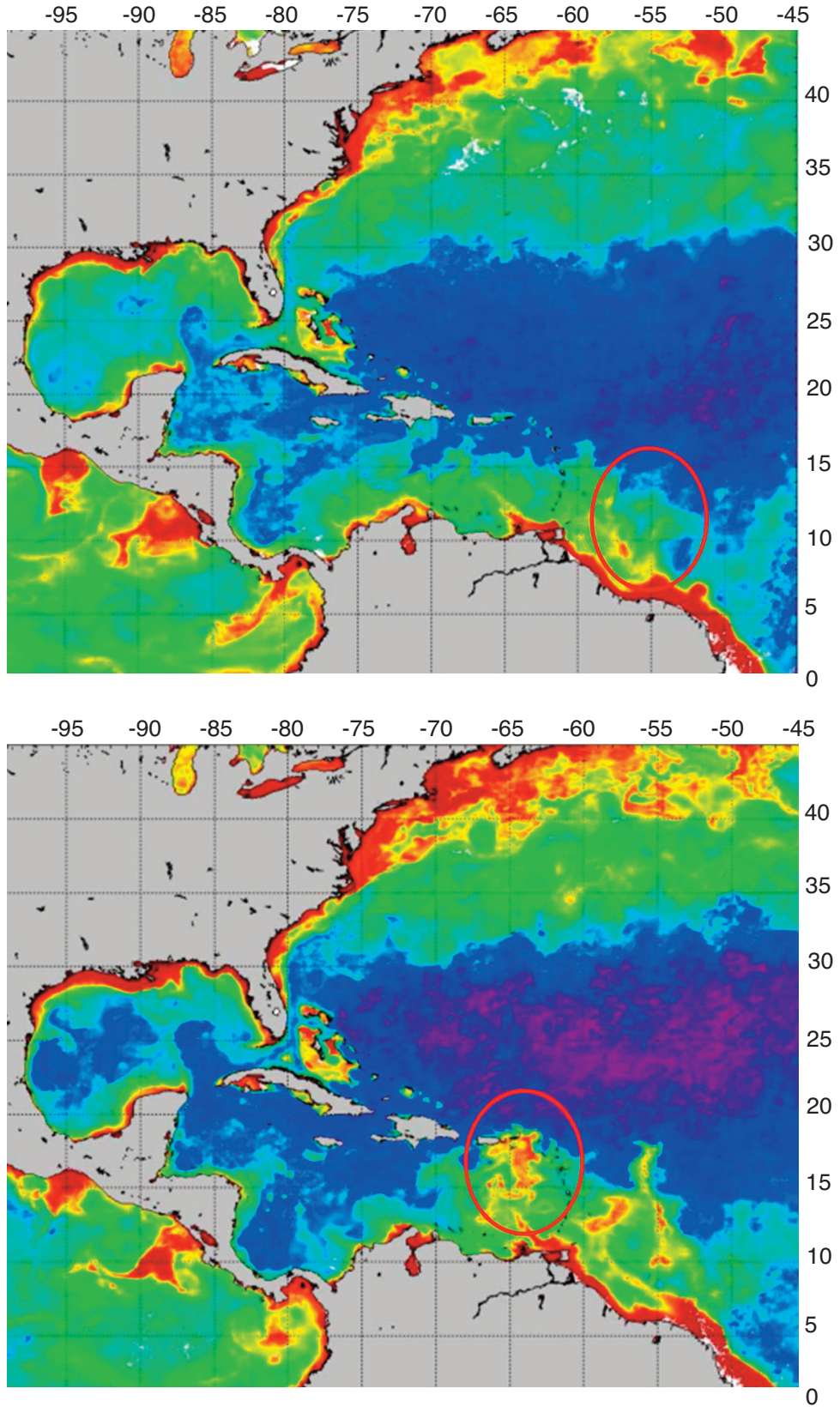
Indeed, we have known about fish and shellfish throughout history given that most civilizations included fish in their diets, both from fresh and salt water. Scientists, in organizing life, then began giving animals names in Greek or Latin to establish their genealogy and taxonomy, and to group fish into families of similar characteristics, such as groupers in one family and snappers in another.

How do we discover what lies under the sea surface depends upon the knowledge of fishers and the technology available. Fishers, especially those who live to fish, pay much attention to their surroundings and observe what fish are biting (for example what bait is best), and when and where fish are available (for example, more or less fish during the full moon). In fishing new areas and depths, they are bound to find fish they have not seen before. Their exploration gives us scientists the opportunity to describe and name new species, which is exciting and a great privilege.



GlobColour Products
Chlorophyll-a Concentration





March 6-13, 2009

Acknowledgement: ACRI & the GlobColour,
GlobColour is funded by ESA with data from NASA, ESA

April 15-22, 2009

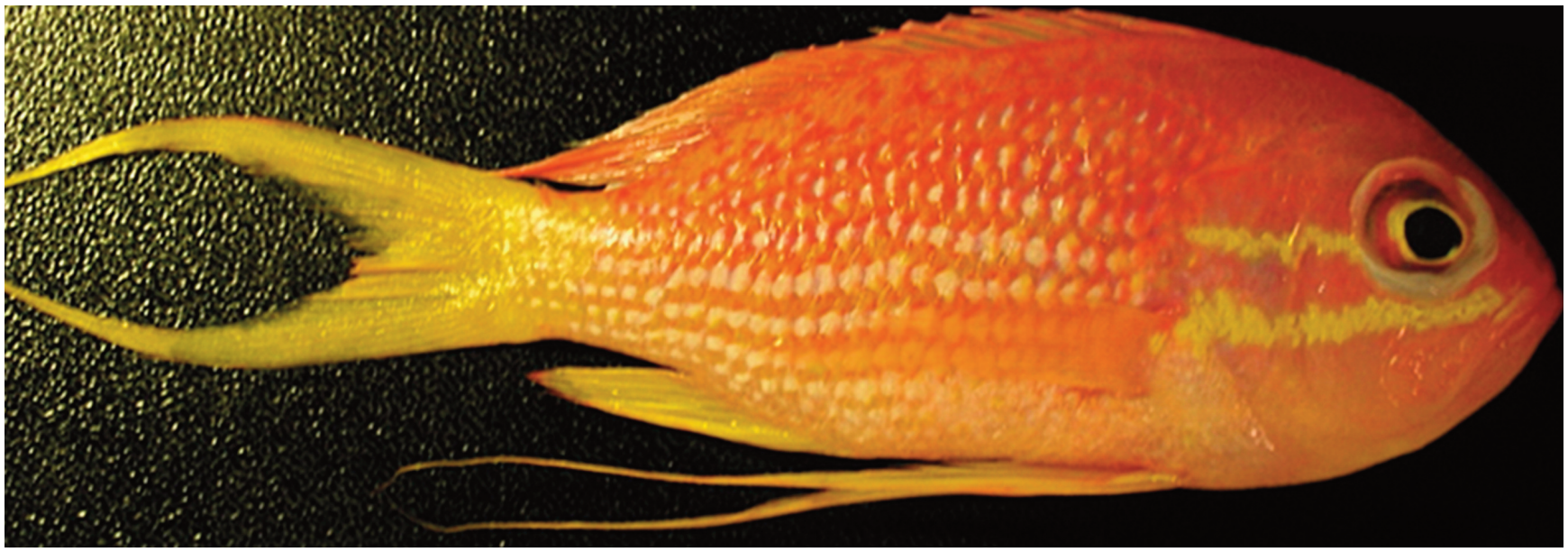
Commercial fisher Mr. Miguel “Guelo” Vargas with Dr. Graciela García-Moliner fishing in the Mona Passage.Mr. Eugenio “Geño” Piñeiro Soler in Dr. García-Moliner’s office with a cooler of fish species waiting to be identified.

Discovering New Species

The most important way of discovering fish under the sea is by fishing. Commercial fishers have been the discoverers of many species of fish and also of archeological finds. A very recent example comes from two fishers of western Puerto Rico who, while fishing for the deep water queen snapper, found a beautiful fish that they had never seen before. They were right as it turned out to be a new species. This new species is more closely related to the groupers than the snappers. They gave us scientists a great and unique opportunity to describe and name a species, Odontanthias hensleyi (Anderson and García-Moliner 2012), after one of my mentors, Dr. Dannie Hensley (deceased), who was the ichthyologist (fish specialist) at the Department of Marine Sciences of the University of Puerto Rico, Mayagüez. Dr. Hensley also named, among other fish, two new species of lamprey, Eptatretus mendozai (Hensley 1985), and Myxine mcmillanae (Hensley 1991), found during the first and only manned-submersible exploration of the depths around Puerto Rico and the deep water trap survey off the Southwest coast of Puerto Rico. Dr.

Hensley named the species E. mendozai after Captain 'Uchi' Mendoza (deceased) who was the Captain and fishing master at the Department of Marine Sciences and who also served under the auspices of the Caribbean Fishery Management Council as a teacher to other fishers in training. These named species come from very deep waters around Puerto Rico and the U.S. Virgin Islands, and we hope there are a few others waiting to be discovered.

Deep water snapper Etelis oculatus commercially caught from over 1,000 ft (330 m) by commercial fisherman Mr. L. Román. Catch of the day queen snappers on ice. Queen snapper seen alive in picture taken from the Okeanos Explorer 2015 Océano Profundo mission to Puerto Rico and the USVI.



Odontahthias hensleyi Discovered by Captain Eugenio "Geño" Piñeiro Soler and Miguel "Guelo" Vargas. Description by Anderson, W.D., Jr. and G. García-Moliner. 2012. A new species of Odontanthias Bleeker (Perciformes: Serranidae: Anthiinae) from Mona Passage off Puerto Rico, the first record of the genus from the Atlantic Ocean. Aqua, International Journal of Ichthyology 18 (1):25-30. Photograph by Dr. Denise De Vore Borrego

The characterization of shallow water coral-dominated reefs has been described by many and these are the coral reefs best known to divers, fishers, and the general public. These are within the depths of free and SCUBA diving and where most scientific work is done. Although SCUBA divers have explored depths to about 60 m, these deeper areas are where the mesophotic reefs are. Among a few good references to review are those of Dr. Jorge García-Sais, Dr. Richard Nemeth, and Dr. Roy Armstrong. Most of these reports and papers can be found at the Caribbean Fishery Management Council's web page, http://caribbeanfmc.com/technical_scientific_documents.html

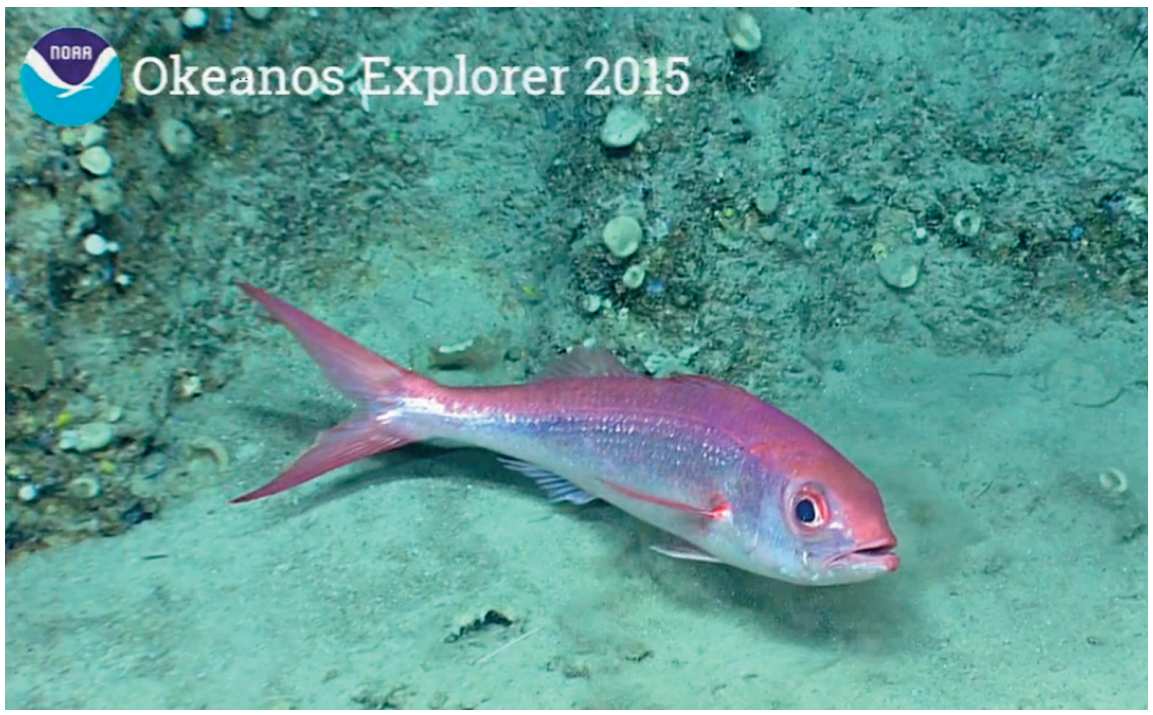
The mesophotic realm will be explored later in this chapter, under technical diving. A photograph of habitat at 50 m in Bajo de Sico by Jorge Sabater (for Coral Reef Conservation Grant NA04NMF4410345) gives a glimpse of the very little known mesophotic reefs around Puerto Rico and the U.S. Virgin Islands. Mesophotic areas are like the twilight zones, between the photic (light dominated) and the aphotic (no light) depths. These can be found at depths of minimal light penetration where coral can still grow or to about 150-200 meters. Beyond 200 meters there is little light from the sun until we finally reach the aphotic or no-light realm in the deepest parts of the ocean. One of the very deep parts of the ocean lies just to the north of the Antilles known as the Puerto Rico Trench.

The exploration of the E/V Nautilus gave us an opportunity to attempt to see this newly discovered fish alive. The original vessel Nautilus was a design by the American engineer Robert Fulton during the 1800s by request of Napoleon Bonaparte. Jules Verne (1871) used the name in the submarine in both 20,000 Leagues Under the Sea and Mysterious Island. The character in charge was Captain Nothing, known to us as NEMO. Fishers provided, and were discussed with the scientists and the E/V Nautilus staff, very specific locations of their fishing grounds where we could find high diversity of deep water corals and fish. These fishing grounds are protected very seriously by deep-water snapper commercial fishers who make a living fishing for queen snapper (Etelis oculatus). These queen snappers are fished at more than 1,200 feet (366 meters) and at a distance of more than 15

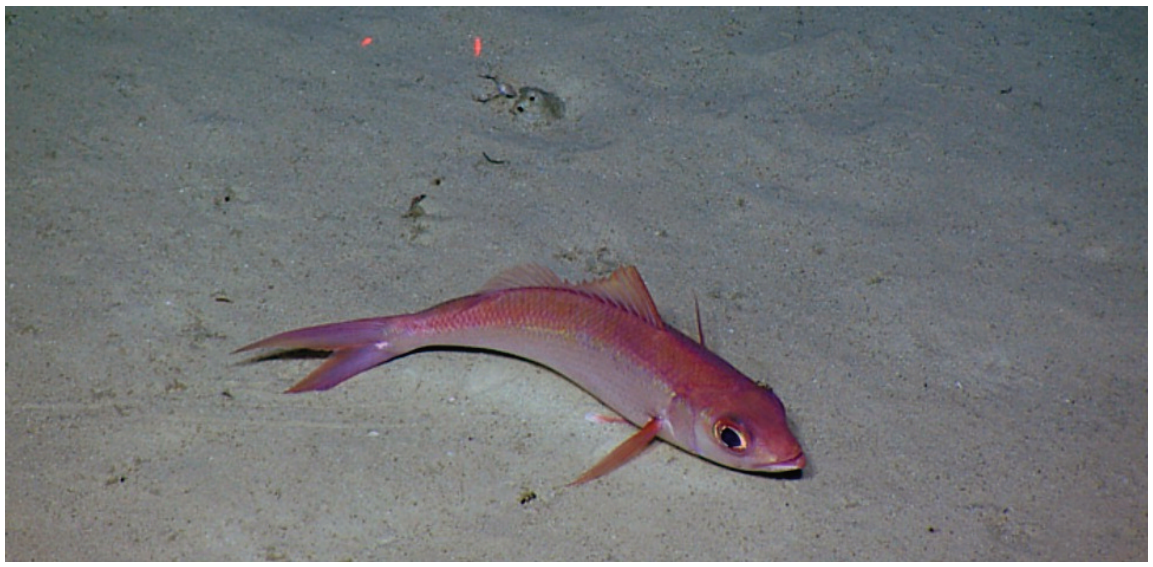
miles from shore. The vessel of operations is on average 22 feet in length (7 m) with 1 or 2 outboard engines, which they take all the way to the limit of the exclusive economic zone (EEZ) or to the international boundary with the Dominican Republic (about 80 miles or 129 km) offshore. The effort to fish using 'calas' or vertical longlines, and the cost of the gear, if lost, amount to a significant investment and thus they do not want to have their fishing grounds fished out by others who did not make the effort to study these areas. Studying the fishing grounds include knowing about the tides and the currents, both at the surface and at depth, the changes in the oceanography with the lunar cycles and season, the impact of the cold front from the north; in fact, it is keen observations and understanding of these changes that allow deep water fishers to be successful.

Mesophotic habitats of sponges and flat-surface corals at 50 m in Bajo de Sico by Jorge Sabater (for Coral Reef Conservation Grant NA04NMS4410345). Black coral and Nassau groupers are found at Bajo de Sico and are protected by law from being harvested.

One of our principal objectives of the 2013 E/V Nautilus expedition was to find the habitat of both the queen snapper and the Odontanthias and to try and see them alive, but unfortunately this was not possible during this exploration. Nevertheless, the CFMC and Dr. Roy Armstrong were awarded a grant through NOAA's Coral Reef Conservation Program to describe the habitats of the queen snapper, or "cartucho", (Etelis oculatus Valenciennes 1828) using the SeaBED Autonomous Underwater Vehicle (Chapter 2). The findings of this project will be available to the public in the future. More recently, the NOAA Research Vessel Okeanos Explorer visited Puerto Rico and the U.S. Virgin Islands in 2015, and obtained photographs and video of the queen snapper alive and well at depth. We all wish we had had more time to see more! [Photo: QueenSnapper_Okeanos_solitoBackground picture of the queen snapper at depth]



Por fin encontramos un cartucho de aproximadamente 50 cm (20 pulgadas). Image courtesy of NOAA Okeanos Explorer Program, Océano Profundo 2015: Exploring Puerto Rico's Seamounts, Trenches, and Troughs.



Okeanos Explorer recorded queen snapper http://oceanexplorer.noaa.gov/

Fish and the Law

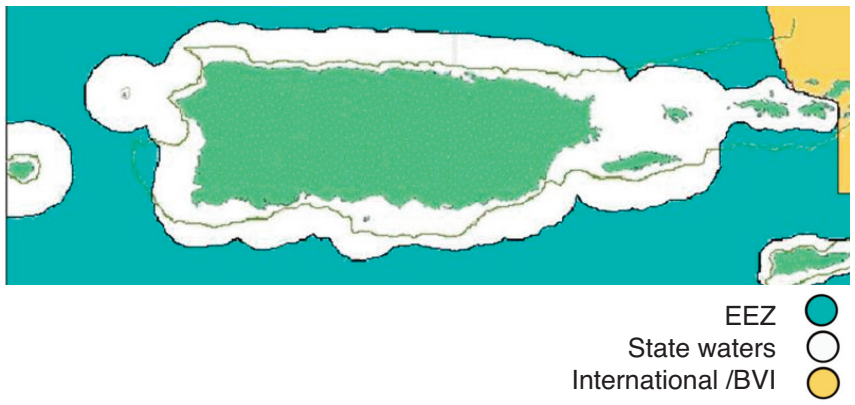
How many species of fish are there and how are these distributed? How many species are there in the Caribbean, in the U.S. Caribbean meaning Puerto Rico and the United States Virgin Islands and Navassa Island? How deep are they found? What is the habitat where they live? What is the ocean bottom like? Are there many corals? Or is it sand and mud? Do we find juveniles and adults together? Do the fish we eat live in a healthy environment?

The marine waters around Puerto Rico and the U. S. Virgin Islands are home to a very diverse community of fish. These fish inhabit waters from the shallow to the deep, and from nearshore to far away from land. These fish are food fish, non-edible fish, small and large, beautiful and ugly. The armored gurnard is also found where the queen snappers are. These are all fish brought to us by commercial fishers interested in knowing what these creatures are and these creatures are an integral part of the marine ecology of Puerto Rico and the Virgin Islands. As such, they are under government management, intending to maintain and preserve the marine ecological integrity while allowing for harvest – for food and fun – under sustainable conditions. These waters are under jurisdictional management of the Territory of the United States Virgin Islands, from the shoreline to 3 nautical miles (nm); of the Commonwealth of Puerto Rico, from the shoreline to 9 nm; and of the Federal Government, from the 3 nm or 9 nm boundary to 200 nm, for what is known as the exclusive economic zone (EEZ). The EEZ, or rather the fishable EEZ is depicted in blue. Depths beyond those shown here are too deep for fishing fish associated with the bottom. They are, however, fished for highly migratory species such as blue marlins. The EEZ was originally established as the Fishery Conservation Zone to protect the resources of the country from foreign fishing (The Fisheries Conservation and Management Act 1976).

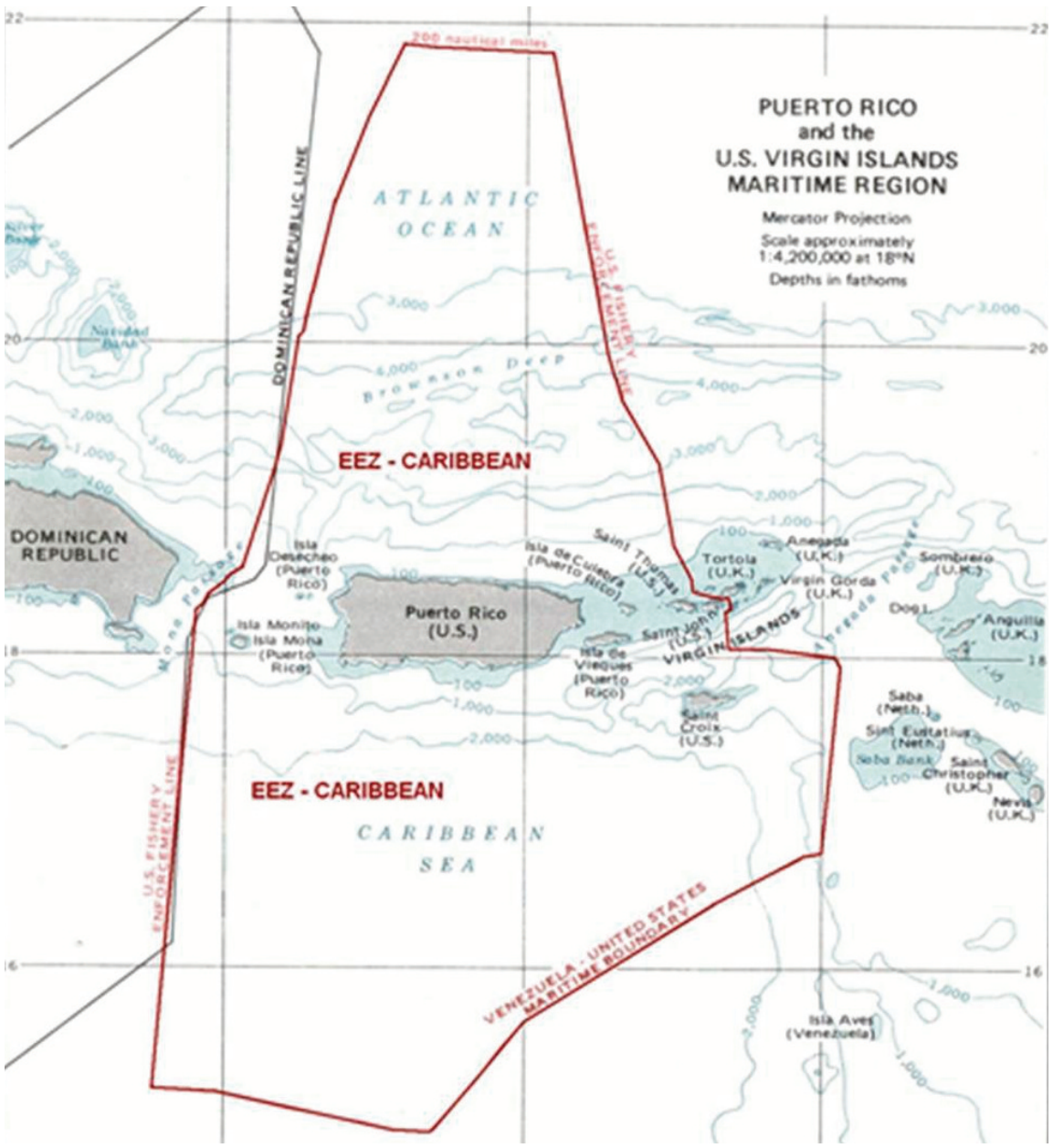
The Magnuson Stevens Fishery Management and Conservation Act (MSA), the order by U. S. Congress that created the Regional Fishery Management Councils (Section 3 of the MSA) of which the Caribbean Fishery Management Council (CFMC) is one, also defines fish as:

"The term fish means finfish, mollusks, crustacean and all other forms of marine animal and plant life other than marine mammals and birds."

Pretty queen snappers and ugly Centrolophidae fish from depths over 1,200 feet (366 m). Fish provided by commercial fishers of Rincón. The armored gurnard, photograph by Geraldo, commercial fisherman from Rincón, is also found with the queen snappers. A collage of these fish found in the same habitat as the queen snapper shows the diversity at depths of over 1,000 feet around Puerto Rico and the U.S. Virgin Islands. These are all fish brought to us by commercial fishers interested in knowing what these creatures are.

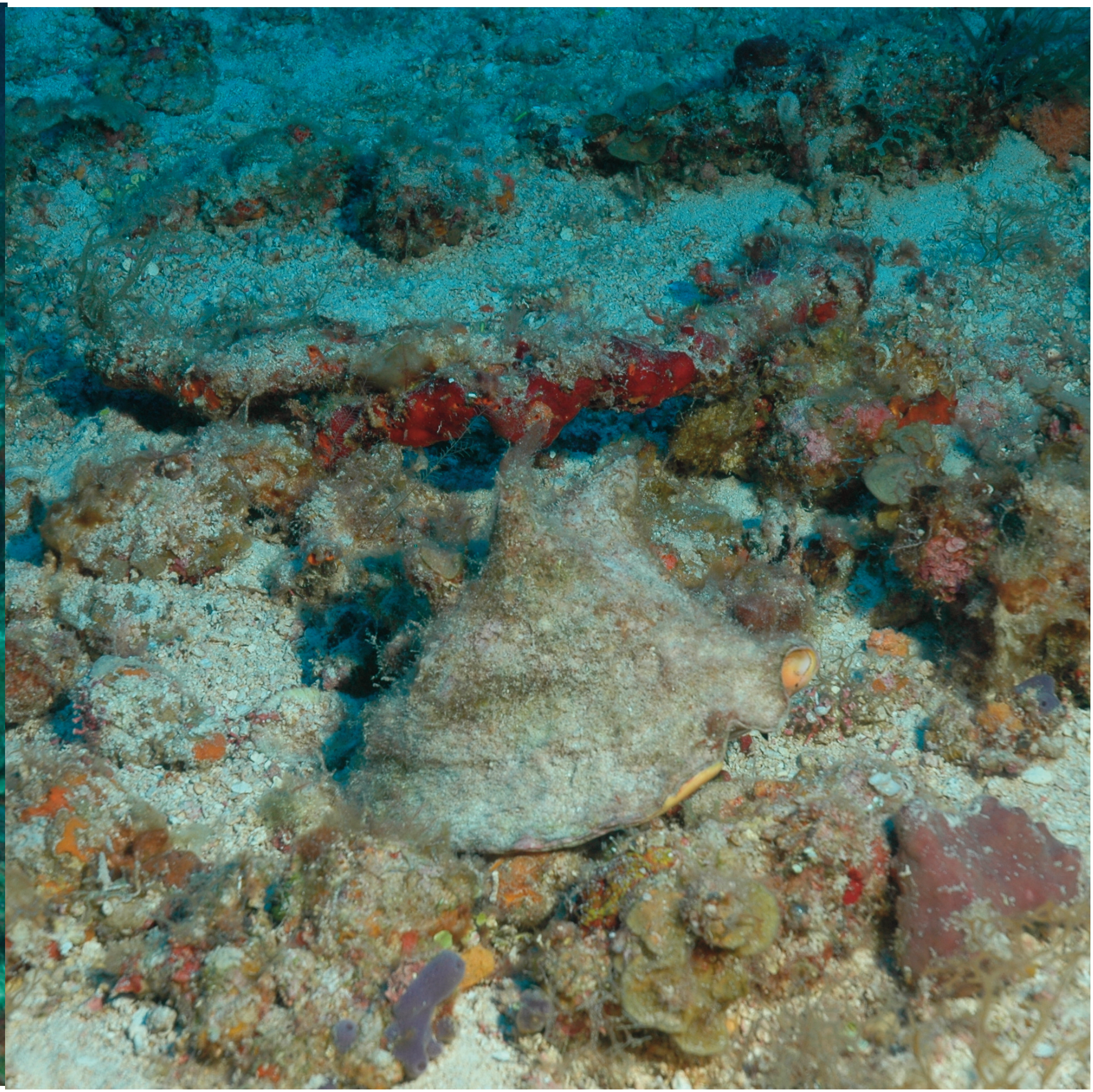


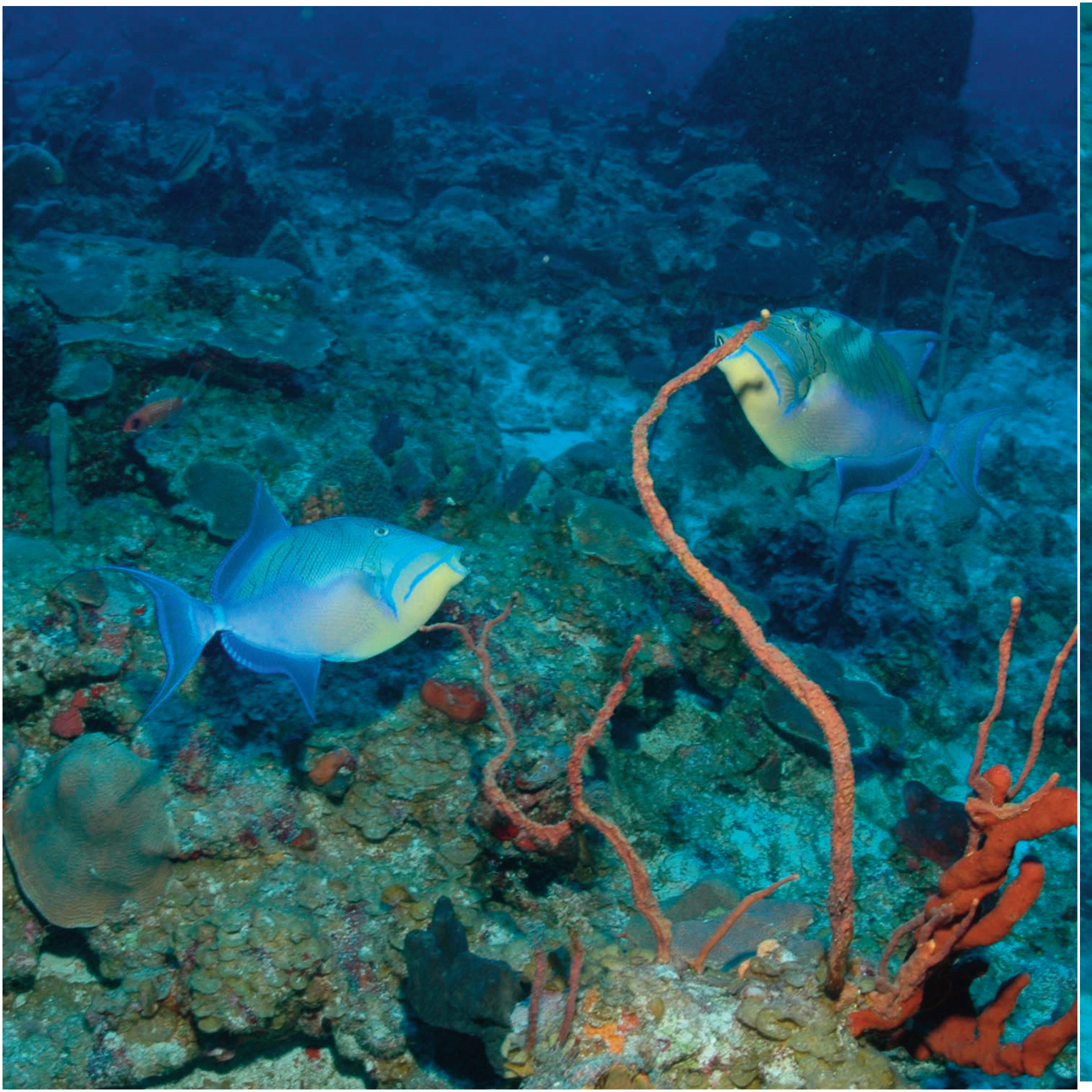
Federal and state waters around Puerto Rico and the US Virgin Islands.



The 3 nm and 9 nm state waters are depicted in white. The EEZ, or rather the fishable EEZ is depicted in blue. Depths beyond those shown here are too deep for fishing fish associated with the bottom; they are however fished for highly migratory species such as blue marlins.

Food fish in the U.S. Caribbean (a) red hind, a grouper from the shallower and mesophotic reef areas accompanied by the now ubiquitous invasive lionfish (Desecheo Ridge approximately 115 m, EV Nautilus October 2013). (b) snappers, (c) hogfish, or (d) other groupers- tiger grouper, (e) queen conch, (f) triggerfish or peje puerco.

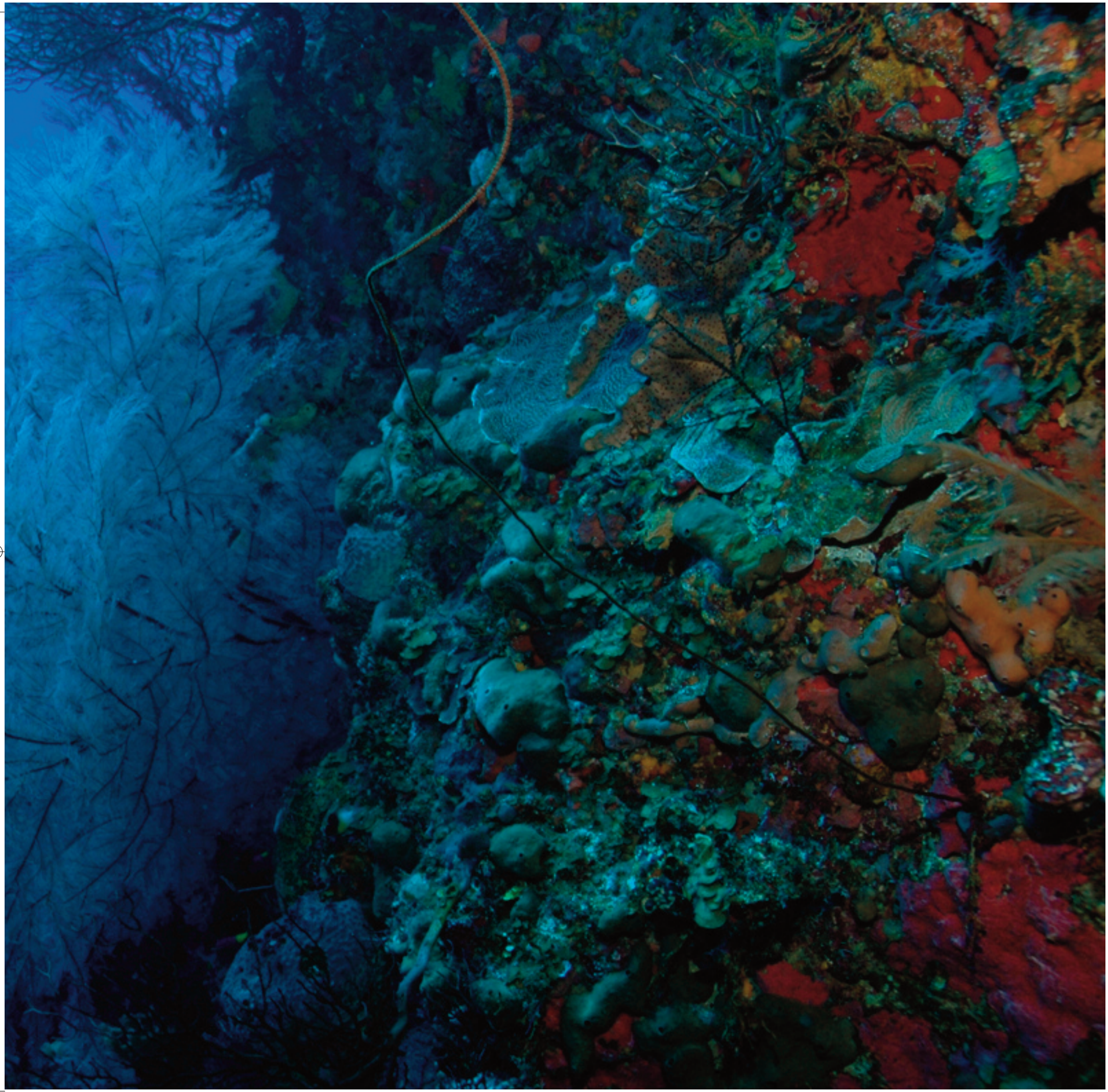




Various sources of information estimate the number of species worldwide within each of the groups fitting under this definition of fish as follows: approximately 31,300 fish species, 47,000 mollusk species, 45,000 crustaceans, about 1,000 coral species, 8,581 sponges, 72,500 algae. Within the U.S. Caribbean, these organisms contribute to the biodiversity of the area (based on Grana Raffucci (1993) and Weil et al. 2005) as follows: over 1,500 fin fish species, over 1,100 mollusks, 342 crustaceans, more than 40 corals, 61 sponges, and 492 algae. Locally there are over 200 fish and shellfish species that are used as food for humans. Food fish in the U.S. Caribbean include red hind, a grouper from the shallower and mesophotic reef areas accompanied by the now ubiquitous invasive lionfish (Desecheo Ridge approximately 115 m, E/V Nautilus October 2013), among many others. Coral and sponges, for example, are used as habitat for other species, as well as food since fish feed on corals, algae, sponges, and other fish and invertebrates. We cannot talk about isolated fish. We have to talk about fish in the marine environment as a whole. Therefore, in attempting to understand the importance of the environment where fish live, the law, as amended, further defined essential fish habitat (EFH) (Magnuson-Stevens Reauthorization Act 1996):

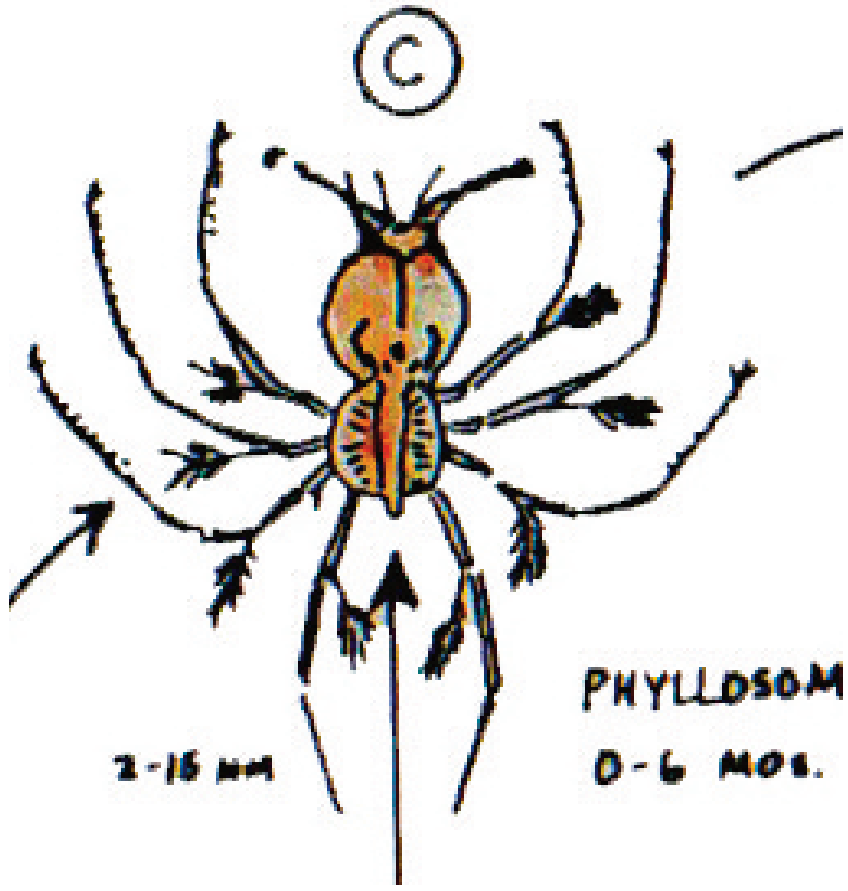
"The term "essential fish habitat" means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

Sponges serve as habitat (photograph from reef top at Bajo de Sico), these are the biotopes of mesophotic reefs since corals tend to be flat, forming plates differentiating them from the shallow water rugose coral reefs. Coral s and sponges serve as refuge for Nassau grouper, lobster and red hinds, and also lionfish, as well as for a cephalopod in much deeper waters.

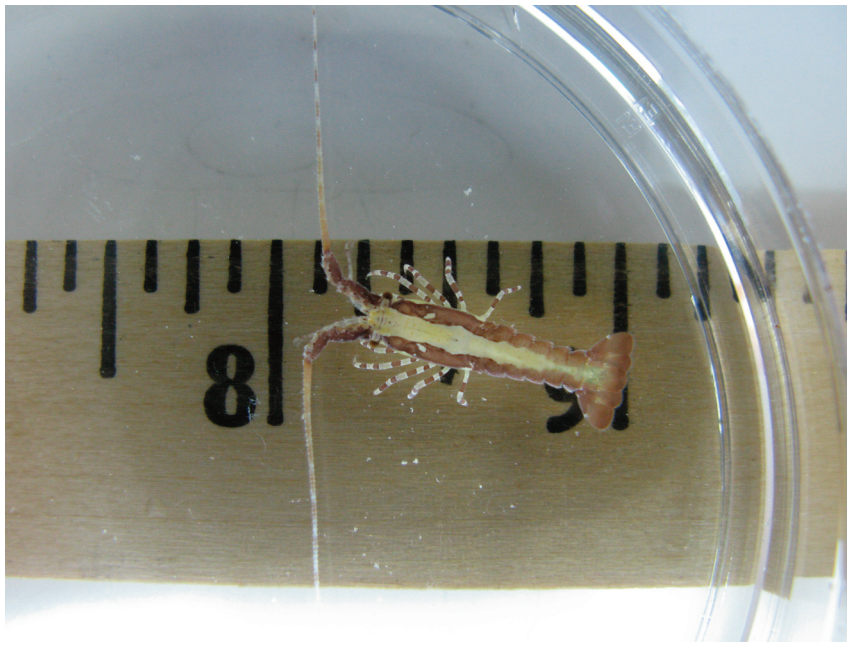


Although there are legal definitions and jurisdictional boundaries, fish at their various life stages do not understand these definitions and boundaries and move following winds, currents or temperature gradients.

Larvae of marine fish are of very diverse forms and are at some stages at the mercy of the currents and tides and winds, and can be "thrown" or transported from their normal tropical range to as far as the temperate waters of New England. An example of this is the larva of the spiny lobster that was first described from temperate waters. Another example is the appearance of juvenile tropical fish during the summer months in areas north of latitude 35. When the temperatures at temperate latitudes are within the range of temperatures of the colder months in the tropics, these juvenile fish can survive. These tropical fish will only survive until the temperature becomes too cold. Therefore, temperature is one of the limiting factors to the distribution of species. Other long-lasting larvae include the queen conch larvae that can also potentially survive a complete cycle through the North Atlantic gyre and recruit into the seagrass beds of the tropics. During the early life stages, these organisms are really at the mercy of the oceanographic phenomena and they would not wander that far on their own. Nevertheless, vertical movement can keep them in a more appropriate environment for developing and growing to the stage when they become ready to recruit. The spiny lobster and queen conch larvae, and perhaps other invertebrate larvae, can survive for longer periods of time and have been found many miles away from Puerto Rico and the U.S. Virgin Islands. However, only if they return to the tropics via currents such as the Gulf Current, the Canary Current, and the Equatorial Current will they survive to adulthood and be able to reproduce.



Larvae of the spiny lobster, Panulirus argus, the most coveted lobster in the Caribbean. The larval stage can last more than 6 months and be transported from the Caribbean through the Atlantic and back to the Caribbean. Art by Tundi Agardy for the CFMC 1980.



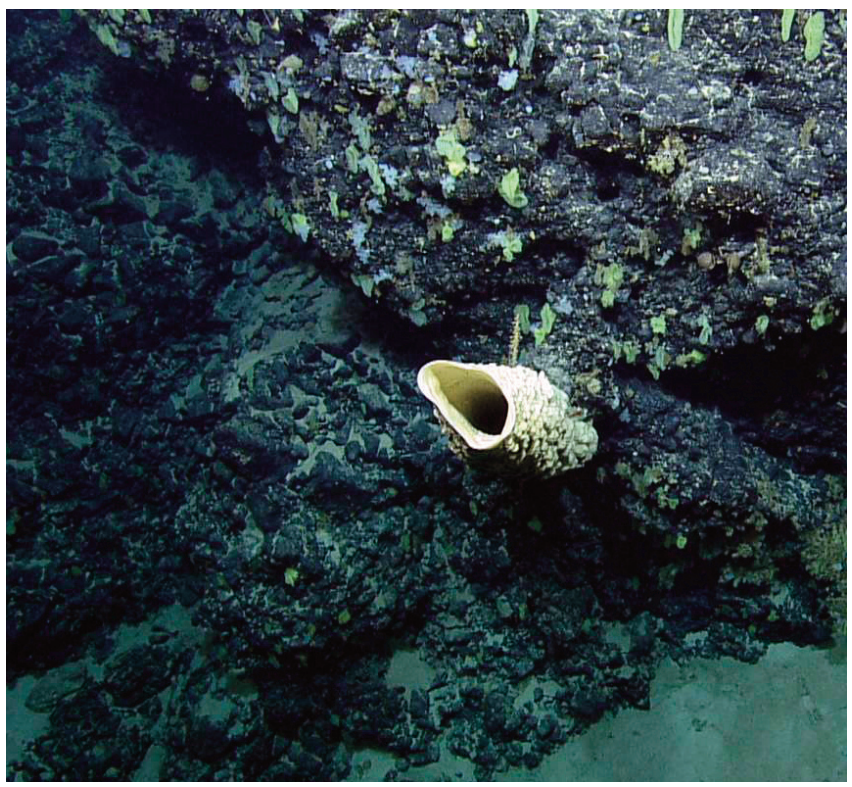
Spiny Lobster larvae. Photograph by V. Seda

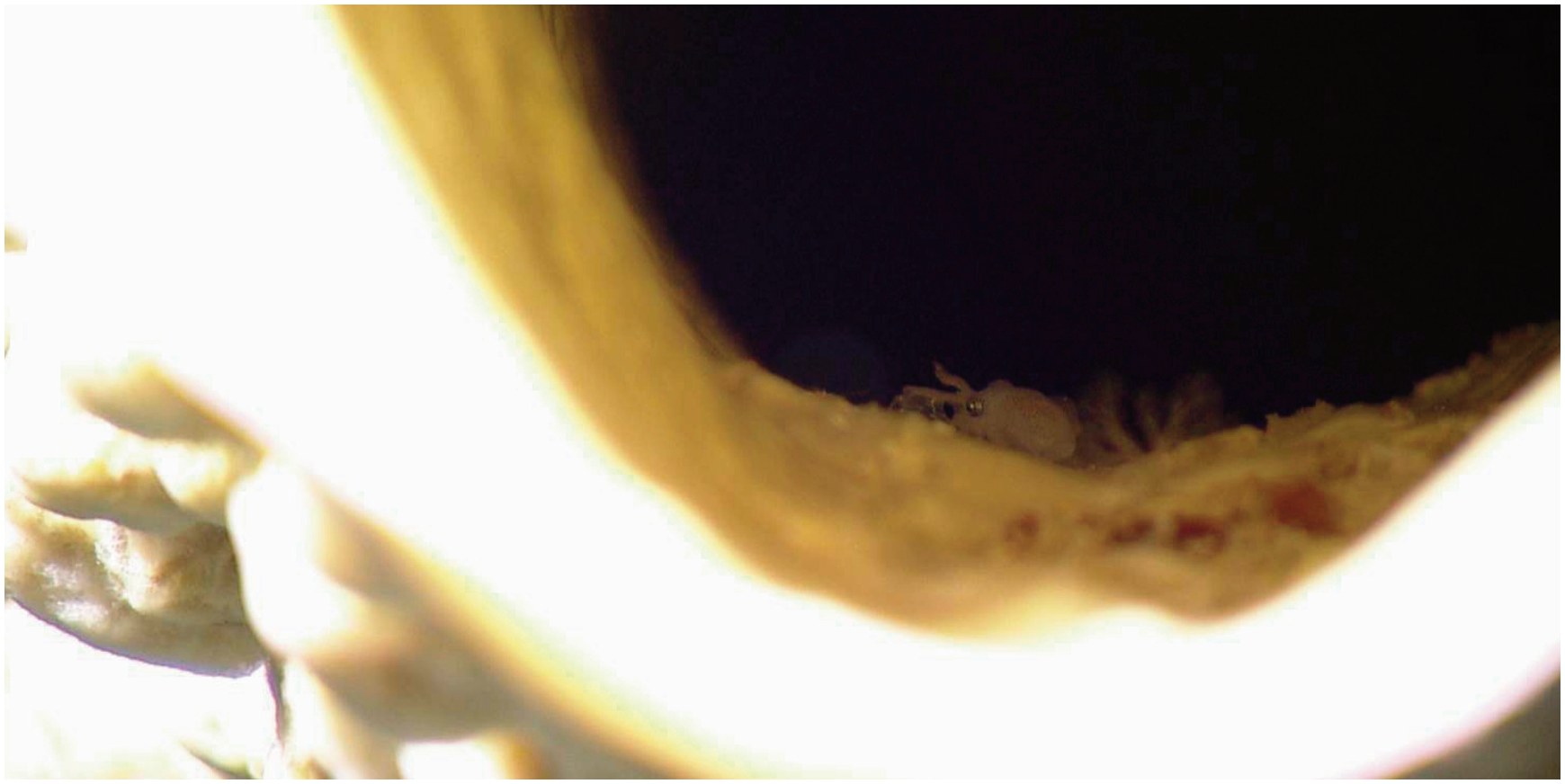
Larvae of the queen conch Lobatus (Strombus) gigas known as veliger. Photograph by D. Ballantine.

Essential fish habitat is as varied as are the shapes and forms, feeding habits, and behaviors of fishes. Sponges are the main habitats of mesophotic reefs. These offer relief over the bottom and cover for refuge. This also appears to be the case in much deeper waters, where a sponge serves as habitat for a cephalopod.

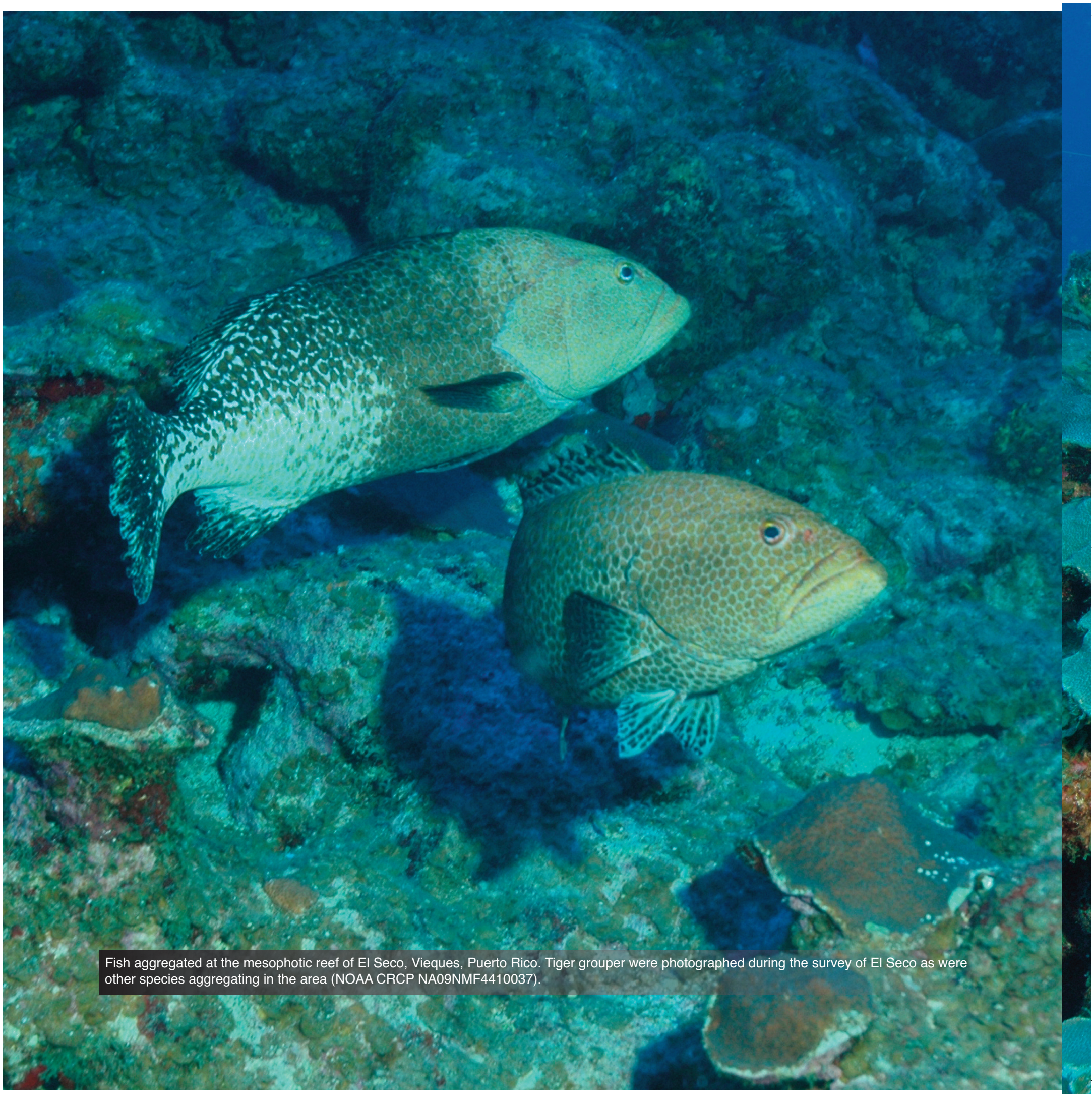
The areas where most of the larvae are produced are sites within the productive fishing grounds beyond the shelf edge, beyond 100 feet or so (about 30 m). These larvae are the product of the reproductive activity of fish. The biology of the numerous species in our waters offers a very varied mating menu, from species that are monogamous and pair-forming parental guarding fish to massive fish spawning aggregations that spawn all together at once and leave egg fertilization and larvae development to serendipity. It is generally hypothesized that fish aggregate to spawn in areas with the right environment for successful fertilization of the eggs and better dispersal for larvae survival. These fish aggregations are mostly known from fishers' knowledge, protected by managers and just recently began to be characterized by scientists. The characterization of the mesophotic reefs has just begun, and, because of the importance of these sites as spawning grounds, the protected areas were the first to be surveyed. These are: Bajo de Sico, Tourmaline, and Abrir la Sierra off the west coast of Puerto Rico; Hind Bank Marine Conservation District and Grammanik Bank off St. Thomas; and Lang Bank and the Mutton Snapper Spawning Area off St. Croix. The area known as El Seco, to the east of Vieques, an Island off the East Coast of Puerto Rico, is a well-known tiger grouper spawning aggregation site. This aggregation of tiger groupers, Mycteroperca tigris,

was first discovered by commercial fishers in the 1970's and, for all accounts, hand in hand with the introduction of SCUBA into commercial fisheries. In the 1980's, there was information already about the declining population of tiger groupers and the increase in the number of diving accidents. A commercial fisher from Vieques brought to the attention of the Caribbean Fishery Management Council his concern about the safety of divers and the decrease in the number of tiger groupers. In the 1990's, tag and release studies were conducted to monitor the numbers of fish at the aggregation. A number of socio-political issues distracted fishers from fishing for a significant number of years, probably contributing to the sustainability of the fish aggregating there. Other fish aggregating in the area include 'chapines' (trunk and boxfish), snappers, and other groupers.

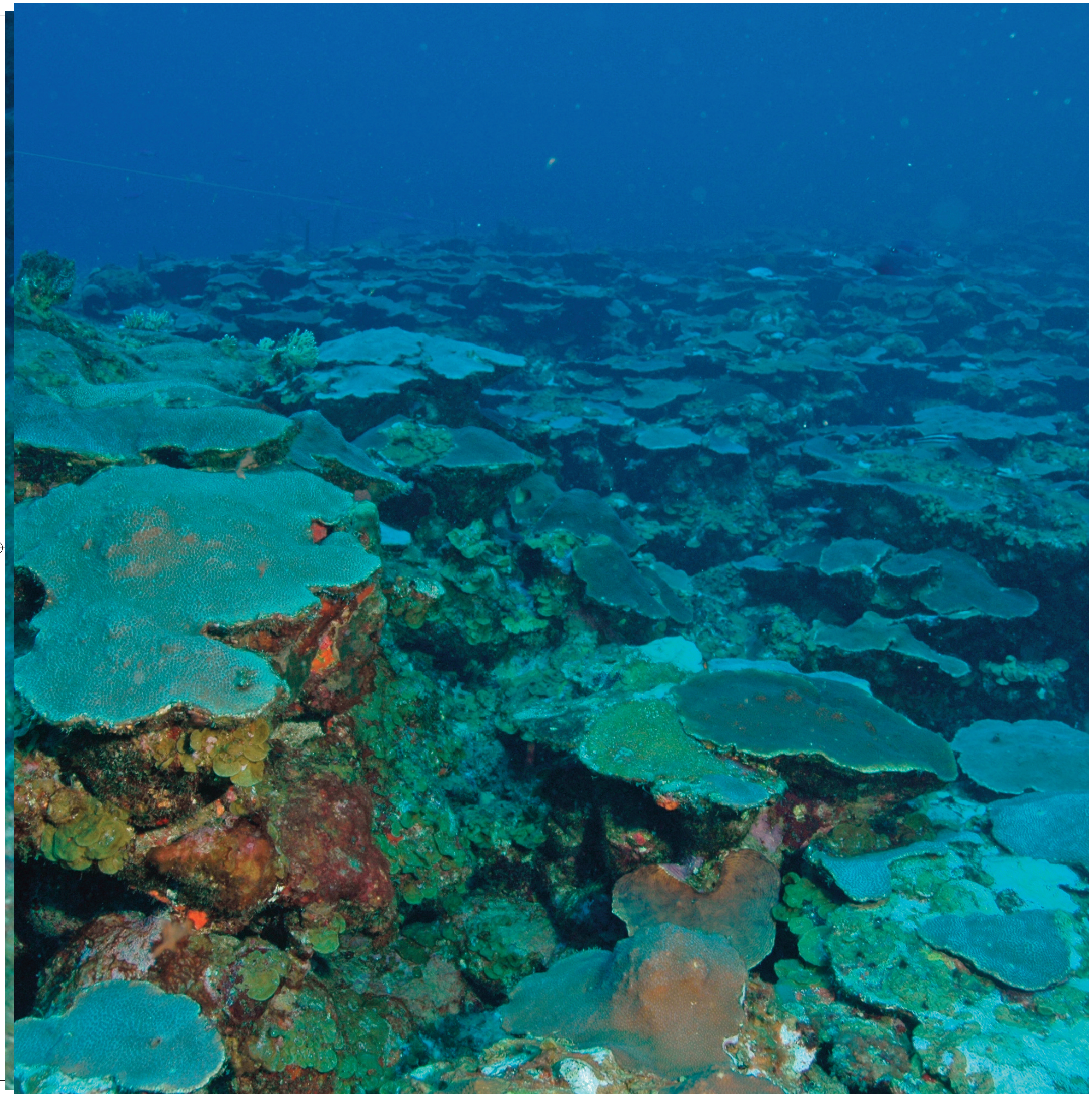




Essential fish habitat of a cephalopod from the deep waters of the U.S. Caribbean photographed from the EV Nautilus 2013.

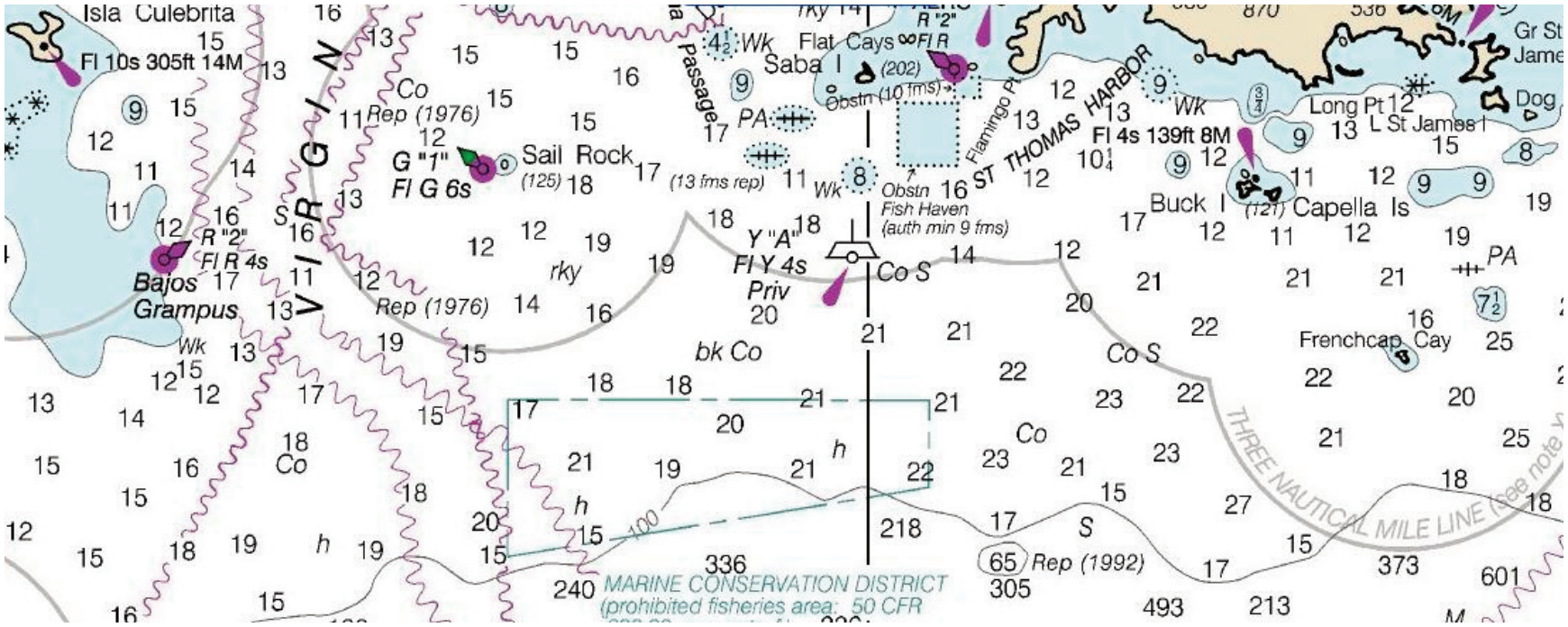


Fish aggregated at the mesophotic reef of El Seco, Vieques, Puerto Rico. Tiger grouper were photographed during the survey of El Seco as were other species aggregating in the area (NOAA CRCP NA09NMF4410037).

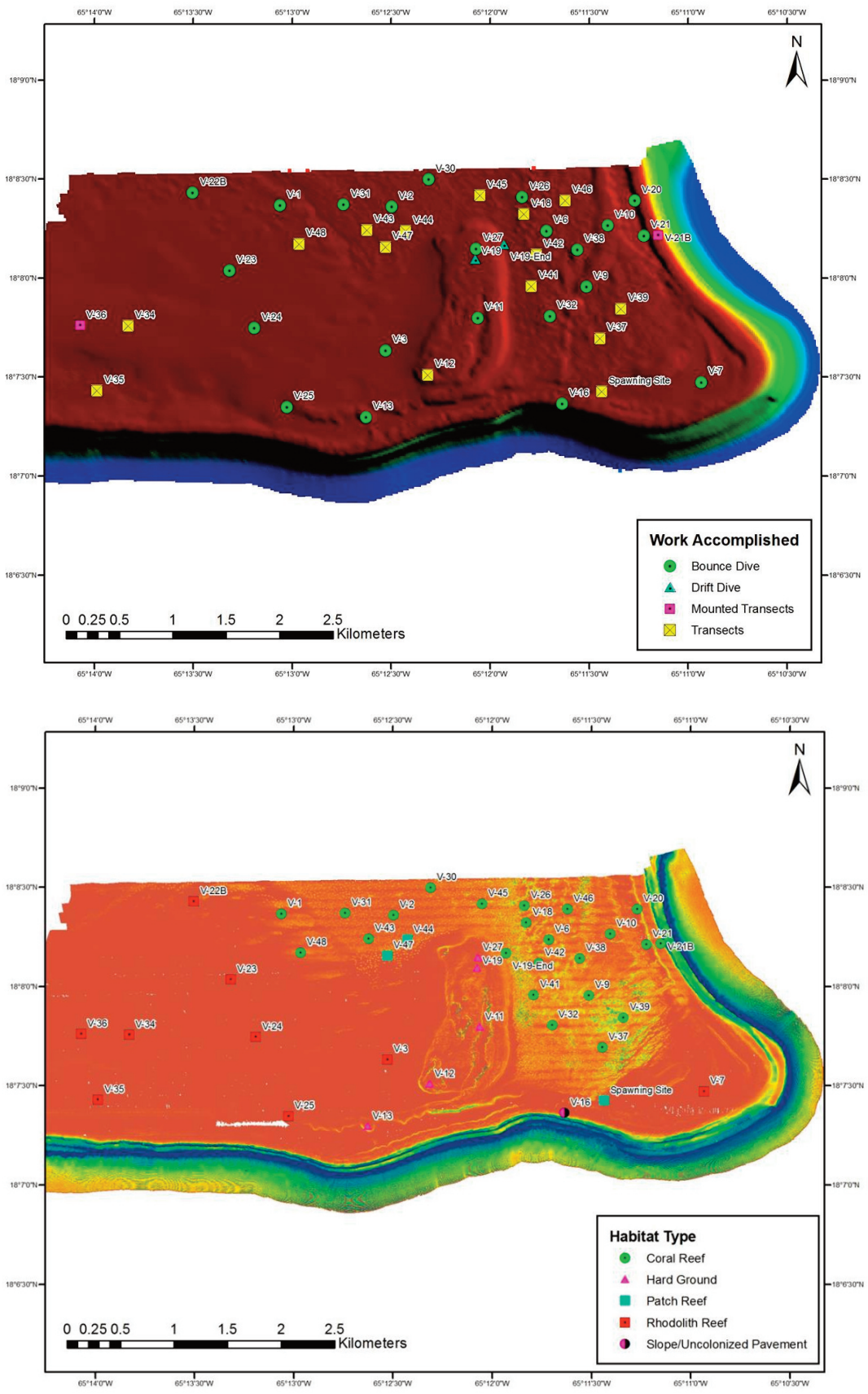


The basic tool for research and exploration is a map, on land as it is at sea. The nautical charts have been and are very helpful, but for divers to plan dives accurately, more detailed maps of the areas are needed. These have been provided over the years by the National Ocean Service (NOAA-NOS). Benthic habitat maps of Puerto Rico and the U.S. Virgin Islands were first comprehensively available in 2000. These maps had very low resolution (1 hectare) delineated from aerial photographs. However, the deepest areas for which these maps were available were for depths less than 30 m. The NOS, in collaboration with many partners including the local governments and universities has provided high resolution depth profiles for these protected spawning grounds to depths of 1000 m. An example of the high resolution bathymetry and benthic habitat maps recently produced and where divers have been able to work to provide the first ever characterizations of these mesophotic reefs. High resolution bathymetry maps of mesophotic reefs, areas where fish aggregate for spawning are critical for describing essential fish habitat and for good fisheries management.

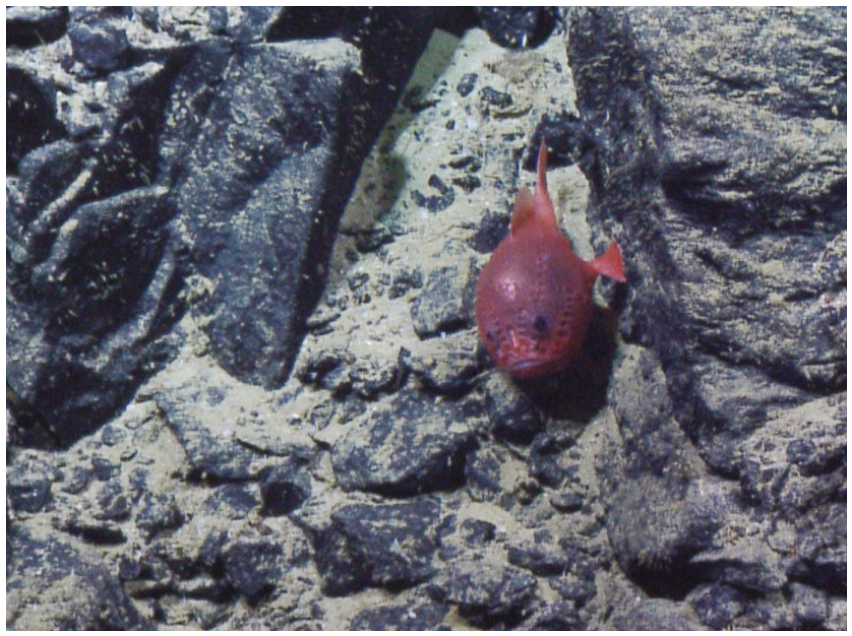
There are many studies that have described habitat for fish species in shallow water. What was always missing was the information for species that have EFH that extend to waters deeper than 30 m, beyond diving depths. Even more information is missing for species that occur in the greater depths. For example, fish such as the Chaunacidae (family of deep-sea anglerfishes that includes sea toads and coffinfishes) can be found beyond 200 m and in habitats as different as rock and sand-like bottoms. These fish look like small globes, a shape that would not seem fit for deep water living since strong currents could possibly move them around. However, the appendages look more like legs than fins and behave as such.



Nautical chart (http://www.charts.noaa.gov/OnLineViewer/25640.shtml) of the area around St. Thomas where there is a no-take zone – no fishing allowed—to protect the spawning aggregations of groupers. The area is known as the Hind Bank Marine Conservation District.



High resolution map of depths of the ocean floor, bathymetry maps [bathy = depth, metry=measure] and habitats within. The groundthrughing or the use of ROV or cameras provide confirmation of the type of habitat in the area. High resolution bathymetry maps of mesophotic reefs, areas where fish aggregate for spawning. Survey stations are over imposed on depth (a) and habitat type (b) at El Seco. A nautical chart of the area is included for comparisons of resolution.



Deep water fish are found at different habitats and different depths. The fish from the family Chaunacidae can be found form shallow to deep waters. Fish from the family Chaunacidae are photographed in two different habitats. These fish look like small globes, a shape that would not seem fit for deep water living since strong currents could possible move you around. However, the appendages more than fins look like legs and behave as such.

Technical Diving

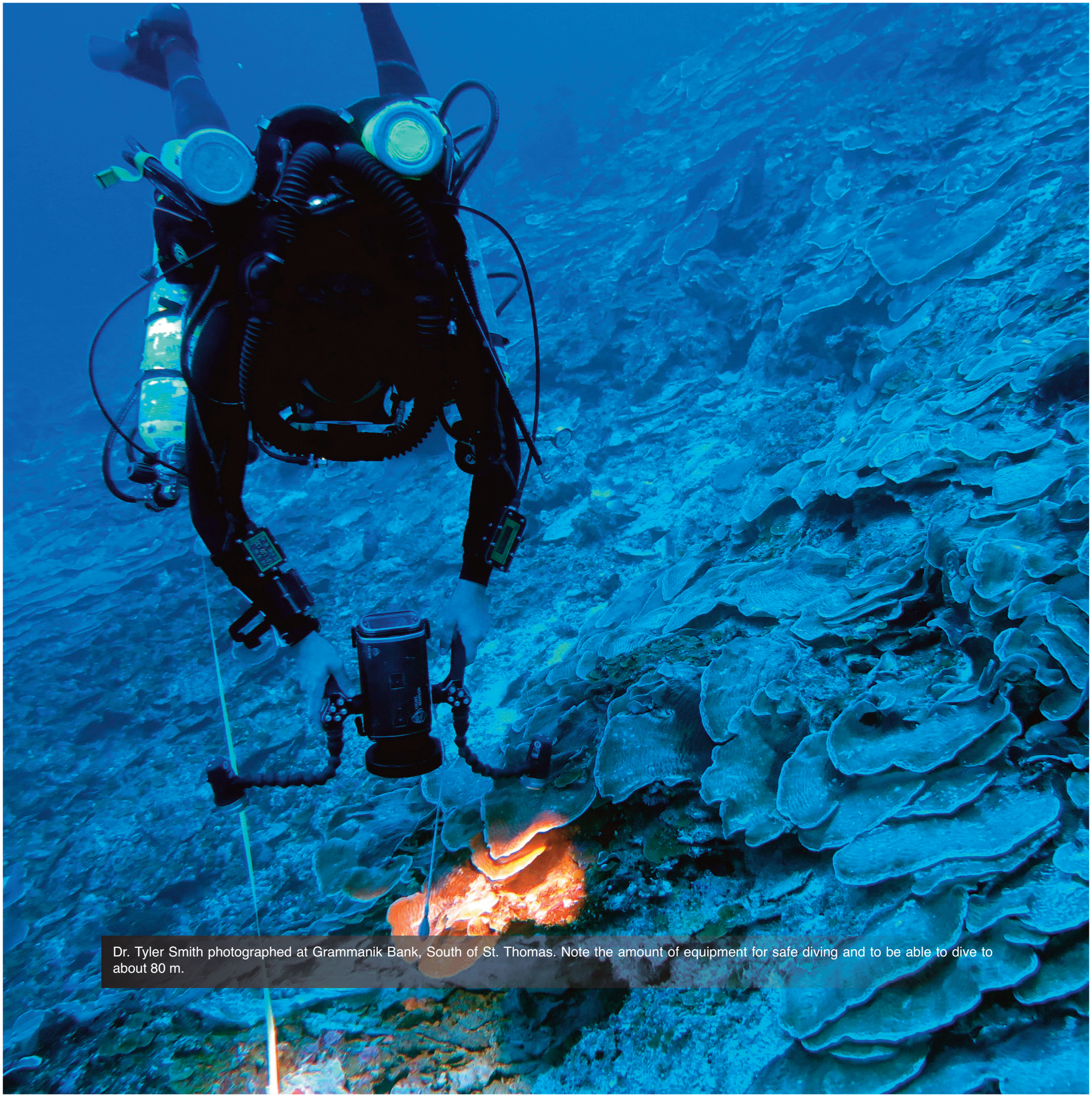
The exclusive economic zone (EEZ), the management area of interest to the Caribbean Fishery Management Council, includes waters that are deeper than those regularly visited by SCUBA (self-contained underwater breathing apparatus) divers. The most visited areas are those less than 100 feet (30 meters), with some advanced divers pushing these limits to 130 feet (about 40 m). SCUBA divers in these shallower depths use only compressed air in their tanks. Diving in deeper waters requires mixed gases and even more complex equipment. These are the best known areas and from where most of the fish and habitats have been described, and where most scientific work has been done. SCUBA diving became popular in Puerto Rico and the U.S. Virgin Islands in the 1970's. Sports divers became avid treasure hunters as Pili Pagán commented in a recent conversation. Scientists were able to document behaviors, new species, describe the fish and invertebrates in their natural habitats, and changes to these habitats and species distributions over time through direct observations underwater. Fish spawning aggregations were documented during this time. Further scientific observations were carried out from underwater laboratories at depths to over a hundred and thirty feet including one in U.S. Virgin Islands and one off the west coast of Puerto Rico. The TEKTITE and La Chalupa were among the underwater sites dedicated to the study of marine resources. Nevertheless, before SCUBA diving there were the free divers, those who were capable of visiting depths to 100 feet (30 m) with only the air in their lungs. Free divers targeted

reeffish such as Nassau grouper and hogfish captured by spearfishing, but mostly demersal fish were captured. Today, free divers call it apnea and have developed blue water hunting, spearfishing pelagics such as wahoo and tunas, as well as harvesting reef fish. In addition, there were the "escafandras", hard hats or diving helmets with the appropriate body suit and heavy weights to be able to walk on the bottom and with air being fed from the boat at the surface. Some of the first SCUBA divers or frogmen and women in Puerto Rico included Miguel 'Pili' Pagán Mir, Jaime Braulio (deceased), and Walt Hendrick (deceased); the first two, master divers for many of us, and Walt, the first dive master at the University of Puerto Rico, Department of Marine Sciences. The U.S. Virgin Islands saw its share of divers, including commercial fishers, who worked with scientists to document the fisheries, as for example, Joe LaPlace (deceased) and David Olsen's description of the 1,000's red hind and Nassau grouper spawning aggregations off the coast of St. Thomas in 1978.

Escafandras or diving helmets photographed by Mr. Carlos Jove.

Commercial and recreational fishers free dive or use SCUBA for harvesting fish and shellfish. These fishers are aided by spearguns and Hawaiian slings, hand nets, and snares (lazos) for harvesting lobster or use their hands to capture queen conch. SCUBA diving requires training and an understanding of the changes that take place when one is submerged at depth. The best example is shown in the picture of the regular size foam head and what happens to it at depth! This also happens to the bubbles of gases in the blood stream, becoming very small with depth. When the diver begins the ascent, these bubbles expand, increase in size and lodge in different places causing the bends or decompression sickness. Divers exhale all the way to the surface and follow the bubbles for a very controlled and slow ascent to avoid accidents.

Styrofoam head normal size and shrunken compacted head due to pressure at depth



Dr. Tyler Smith photographed at Grammanik Bank, South of St. Thomas. Note the amount of equipment for safe diving and to be able to dive to about 80 m.

Dr. Jorge García-Sais photographed by Jorge Sabater Clavell at Bajo de Sico seasonally closed area looking at a massive black coral. Identification of the species can only be done by collecting a piece of the coral.

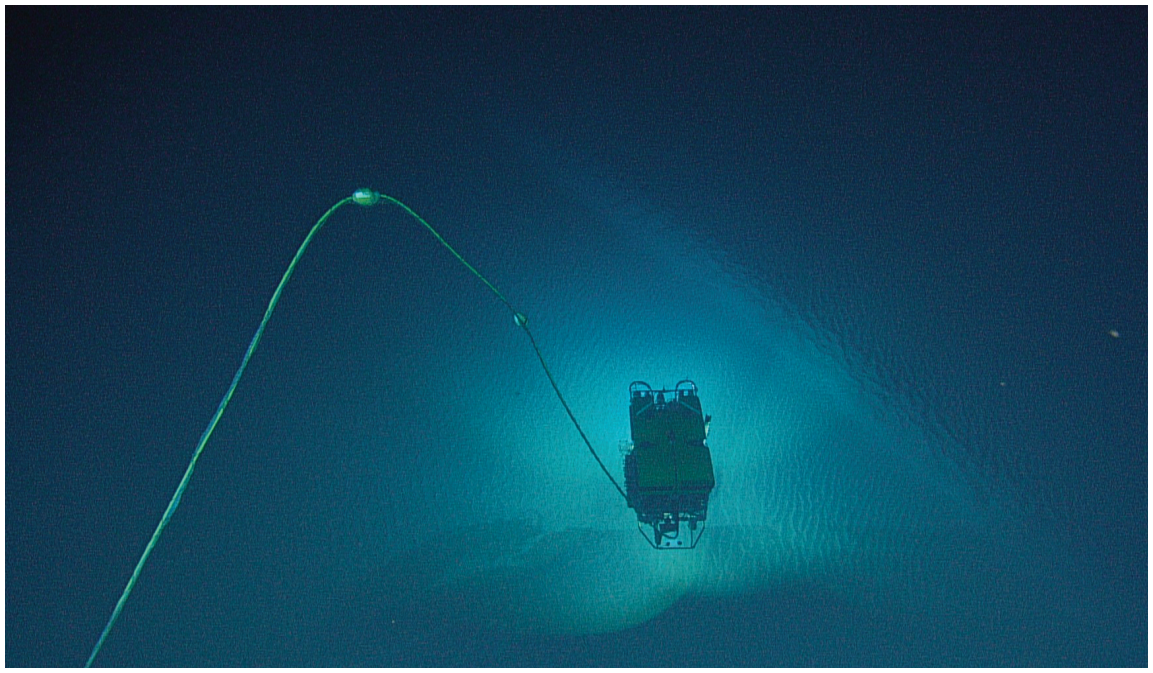
The development of re-breathers have advanced our scientific knowledge of the mesophotic communities from 50 m (164 ft), to almost 100 m, but to a very limited extent. We have only begun to explore those mesophotic reefs. Mesophotic communities are found where light is limited for photosynthesis, and corals tend to be flat and plate-like. Sponges and soft corals become dominant. Dr. Jorge García-Sais and his team of very advanced and well-trained divers have described and characterized a number of these mesophotic reefs including Desecheo, Bajo de Sico, Abrir La Sierra and Tourmaline off the West Coast of Puerto Rico; El Seco off the East Coast of Vieques; and Lang Bank, east of St. Croix U.S. Virgin Islands. Dr. García-Sais' team includes Jorge Sabater, Bob Castro, René Esteves, and Stacey Williams). Dr. Richard Nemeth at the University of the Virgin Islands (UVI), and his very experienced advanced divers, also using re-breather technology, have described and characterized the no-take (no fishing) Marine Conservation District Hind Bank and the area known as Grammanik Bank south of St. Thomas. The scientific team of divers at UVI includes Elizabeth Kaddison, and Dr. Tyler Smith). They have also contributed to the characterization of the mesophotic reefs between St. Thomas and El Seco in Vieques and the Lang Bank east of St. Croix. Highly-trained divers of the Department of Marine Sciences

from the University of Puerto Rico Mayagüez have pushed beyond 50 m to a maximum depth of 80 m. These divers under the guidance of Dr. Richard Appeldoorn [Milton Carlo, Dive Master; Dr. Ivonne Bejarano, NOAA Fellow; Dr. Héctor Ruíz, Photographer, both graduates of the Department of Marine Sciences UPR-M] and Dr. Sherman, professor at the DMS-UPR-M have dived off many sites in the U.S. Caribbean.

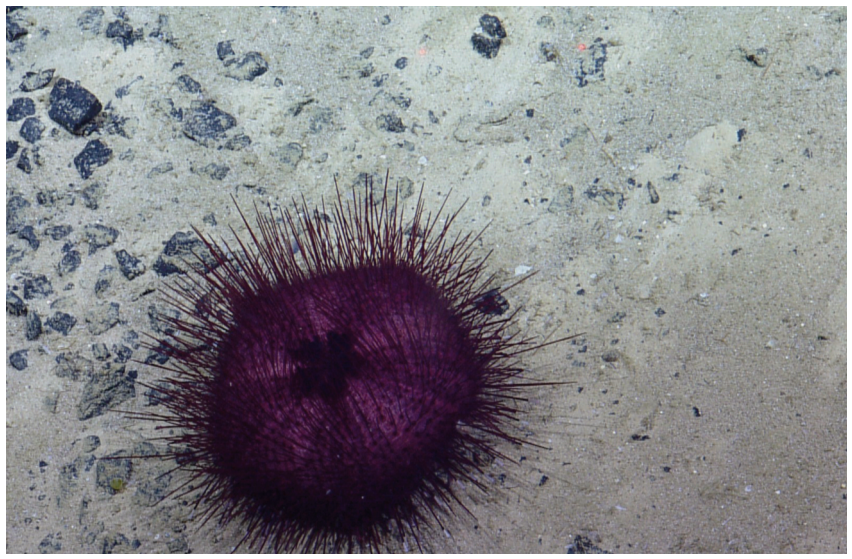
Re-breathers are a technology that allows the diver to re-circulate clean air and make no bubbles while exhaling. Normally, with SCUBA tanks filled with air, the diver inhales clean air – the same you breathe – and upon exhaling through the mouthpiece, air is expulsed in the form of bubbles. The dive is limited by the amount of air one has in the tank. The concentrations of other gases increase in your body while SCUBA diving and these are released as you slowly return to the surface. When diving, the water pressure exerted on your body increases by one atmosphere every 33 feet (10 meter) so that added pressure makes all the gas bubbles in your body small in size. When you begin your ascent, you have to allow for all the gas bubbles in your body to be released slowly. The release of gases from your blood stream has to be completed underwater and, with SCUBA, the decompression time as it is known can be long. Re-breathers reduce this decompression time because one is recirculating the air and extracting the carbon dioxide through filters, and the oxygen needed from an oxygen tank and/or a mixture of gases is increased. These make much less noise and fewer bubbles than SCUBA thus making the observation of marine life less intrusive. These are considered very advanced diving techniques and require very specialized training.

Milton Carlo, Ivonne Bejarano, and Michael Nemeth; Project CRES 2006 (Coral Reef Ecosystems Studies).

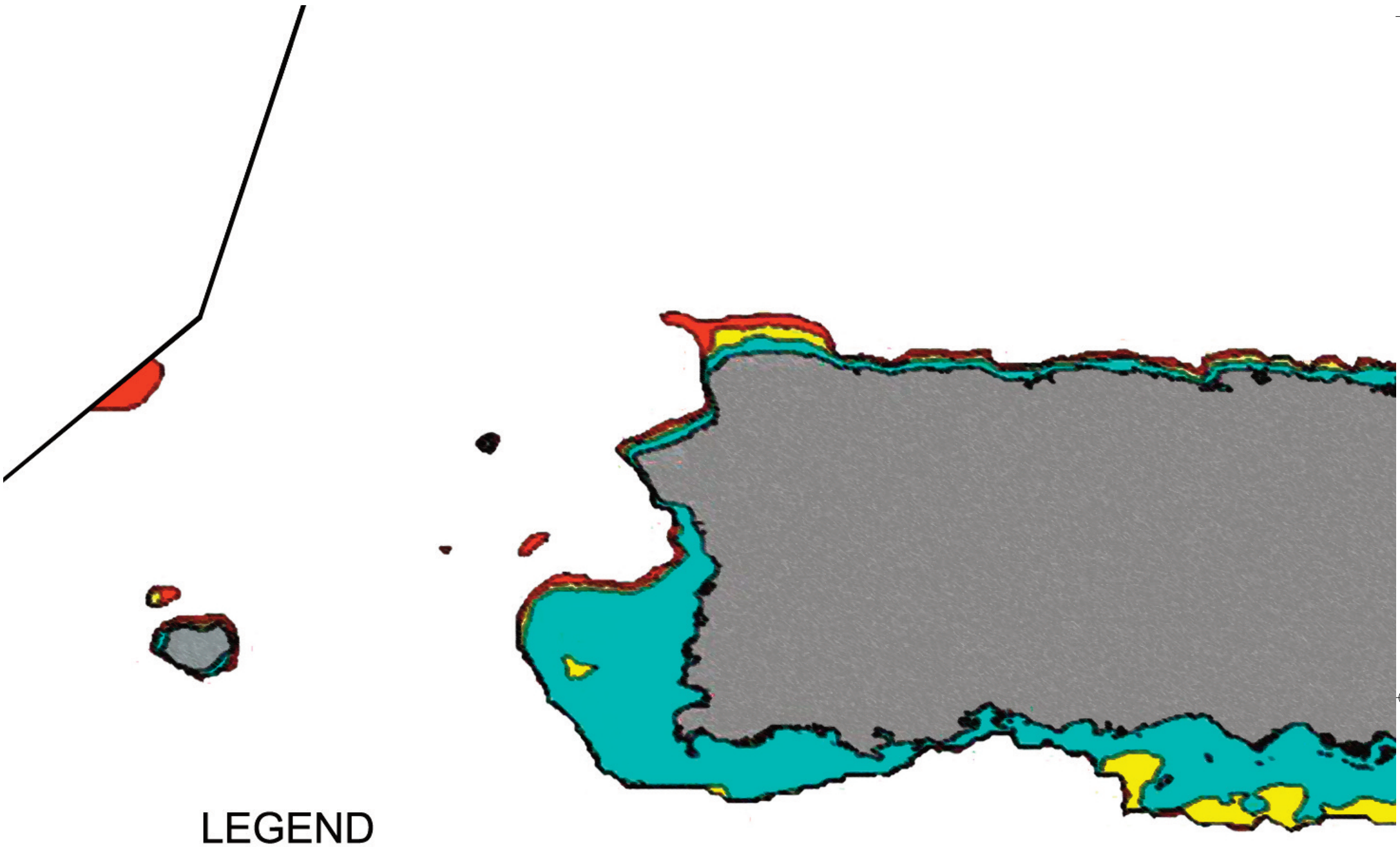
Beyond 80 m depths humans have to be enclosed in some kind of armor in order to survive both the extreme changes in temperature and the increasing pressure with depth, as well as to be able to work at these depths. There are hardsuits, diving suits capable of allowing divers to work to thousands of feet that are designed to maintain the inside pressurized. Other ways of exploring and characterizing the deep ocean ecosystems include the use of remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs) and manned submersibles. During the expedition of 1985, the submersible Johnson Sea Link on board the R/V Seaward Johnson surveyed 30 stations around Puerto Rico and the U.S. Virgin Islands. Technology on board at the time provided a glimpse of the bottom and the fish at these sites. The video and the temperature recorded by depth, along with the strength of the currents, are available and have served as the basis for the on-going and future research in the area. Photographs comparing the quality of the video grabs or snapshots from 1985, the still photograph from the AUV from 2008 and the video grabs from the 2013-2015 ROV missions show much improvement in the quality of the video; each snapshot taken with state-of-the-art technology available at the E/V Nautilus and the Okeanos Explorer.



Remotely operated vehicles (ROVs) are tethered, have cables attached to the vessel while autonomous underwater vehicles (AUVs) are self-propelled and independent of the vessel underwater.



State-of-the-art photographs 1985, 2013 and 2015.



LEGEND

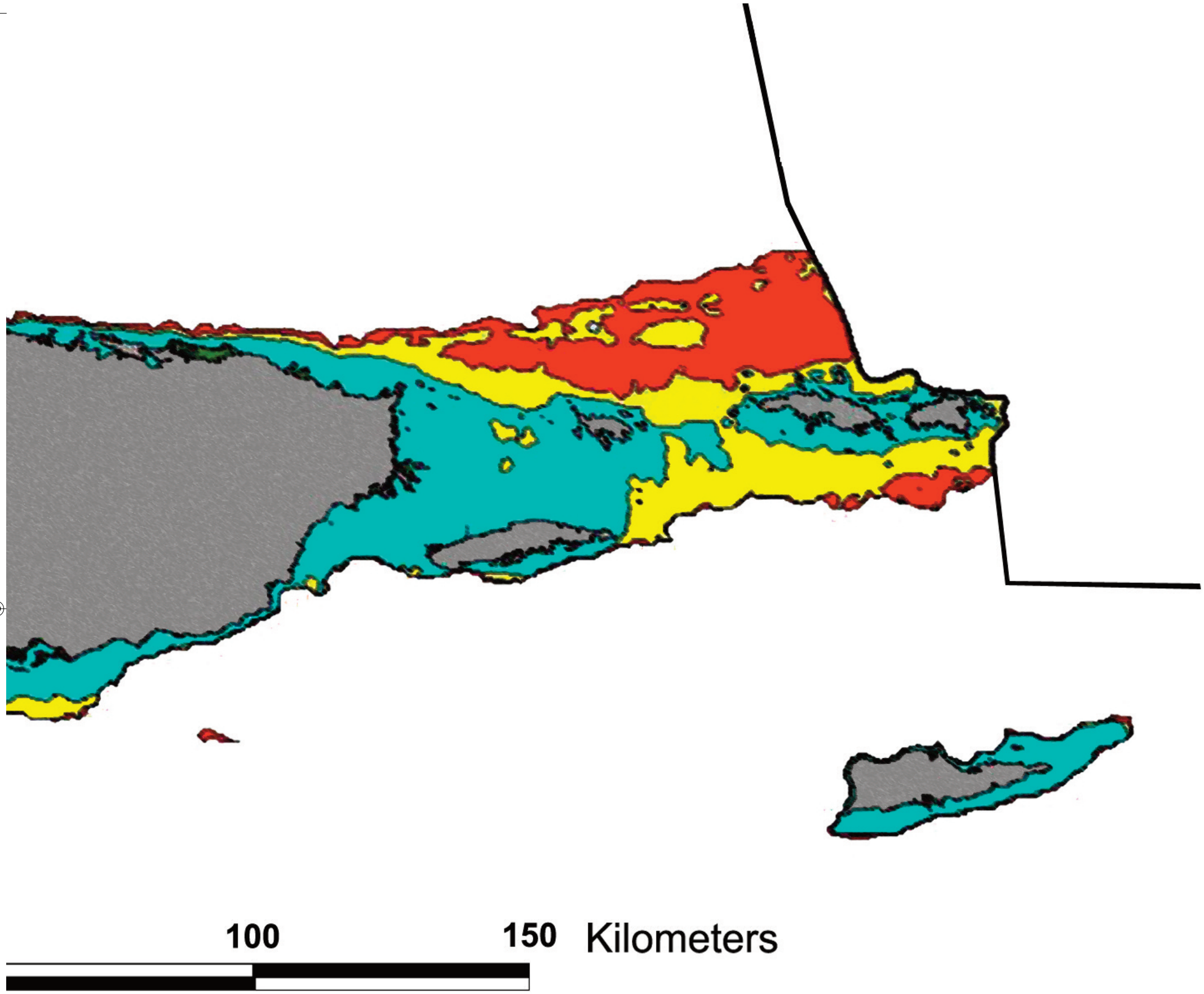
0 - 30 m

30 - 50 m

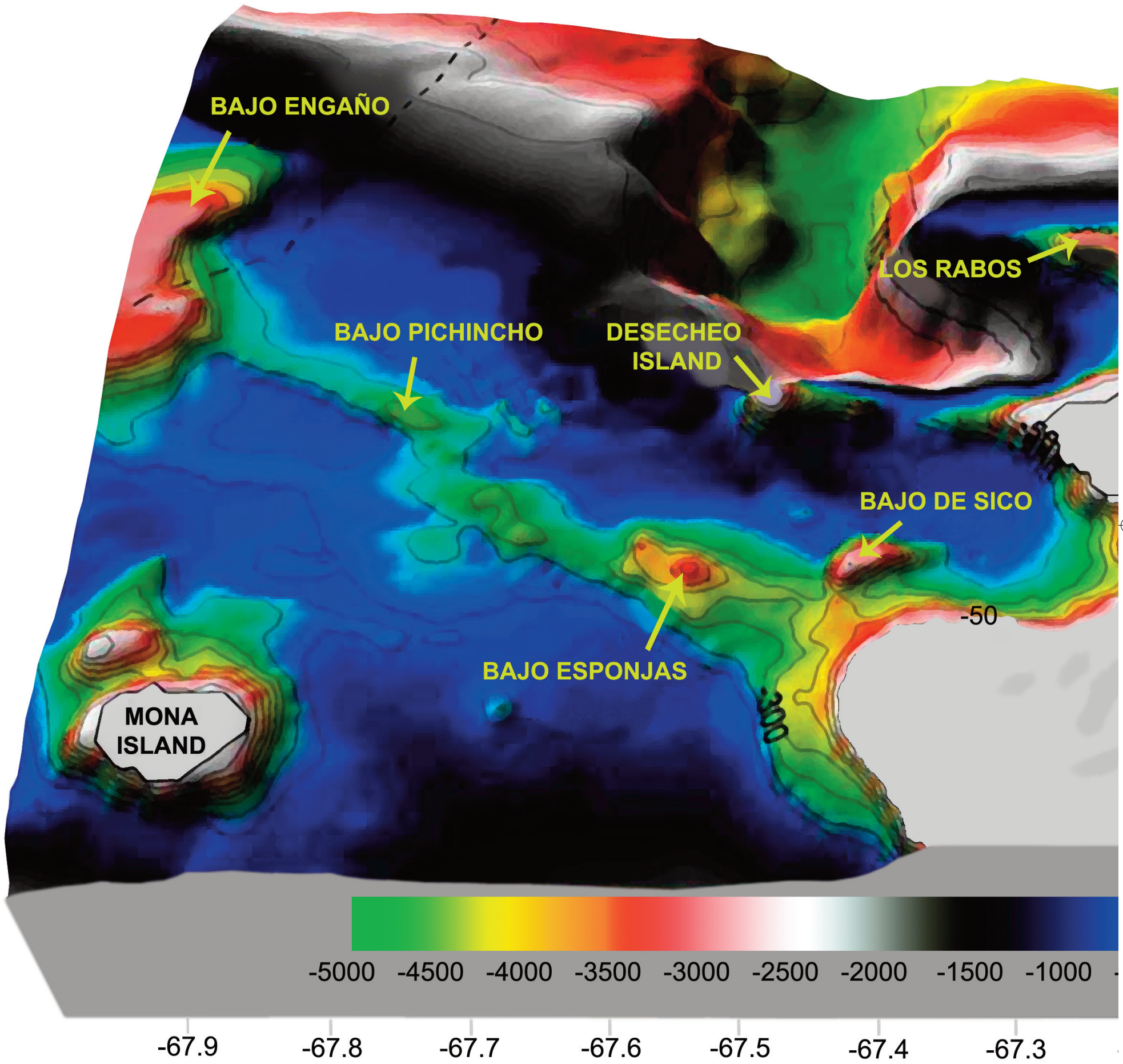
50 - 100 m

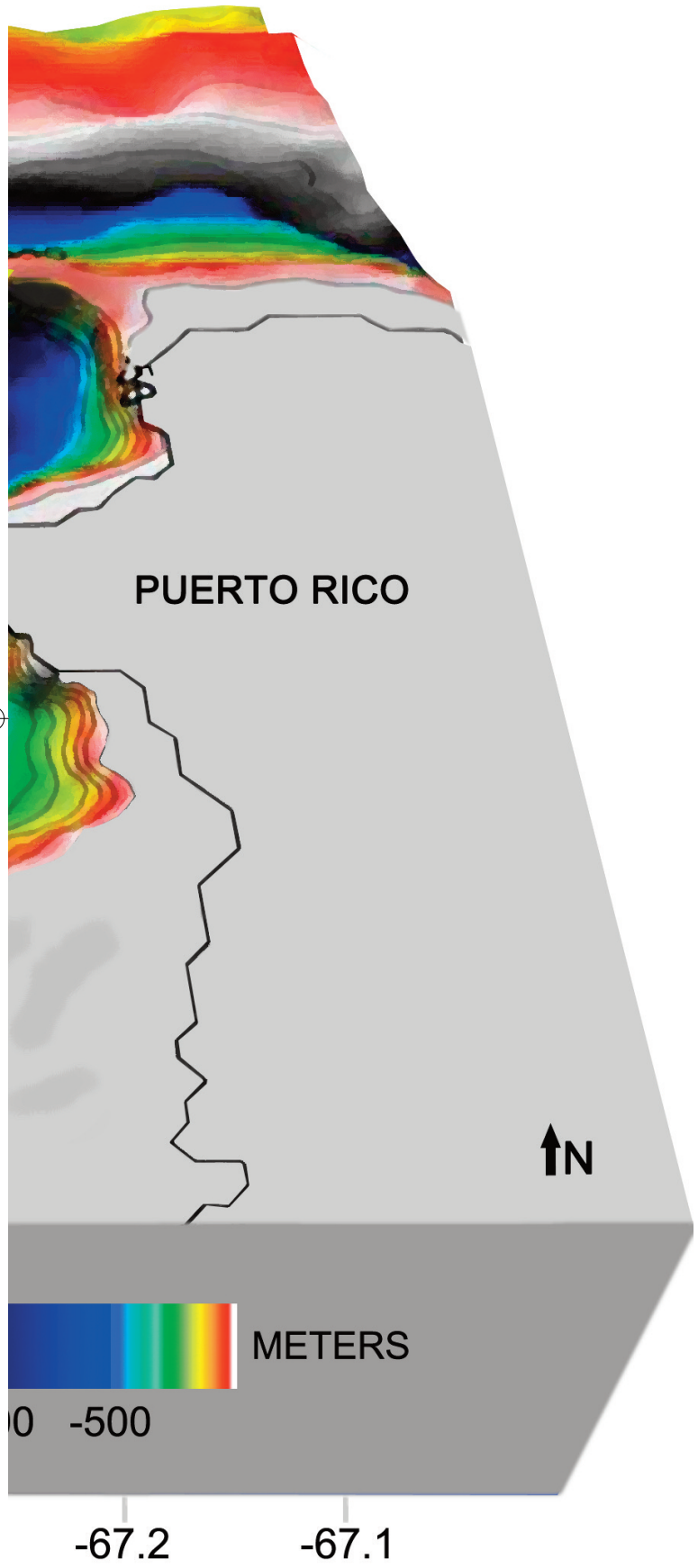
EEZ

50 0 50



Map showing the various depths of 0-30 m, where most activities take place including scientific research, recreational activities and fishing; 30-50 m and 50 – 100 m. The area between 0-30 m is about 56% of the total and it is where most reef forming corals are found. Twenty three percent of the total 0-100 m bottom is between 30-50 m, with the remainder 21% being between 50 and 100 m, still potential habitat for coral given the clarity of the waters.


BAJO ENGAÑO
LOS RABOS
BAJO PICHINCHO
DESECHEO ISLAND
BAJO DE SICO
-50
BAJO ESPONJAS
MONA ISLAND
-5000 -4500 -4000 -3500 -3000 -2500 -2000 -1500 -1000
-67.9 -67.8 -67.7 -67.6 -67.5 -67.4 -67.3



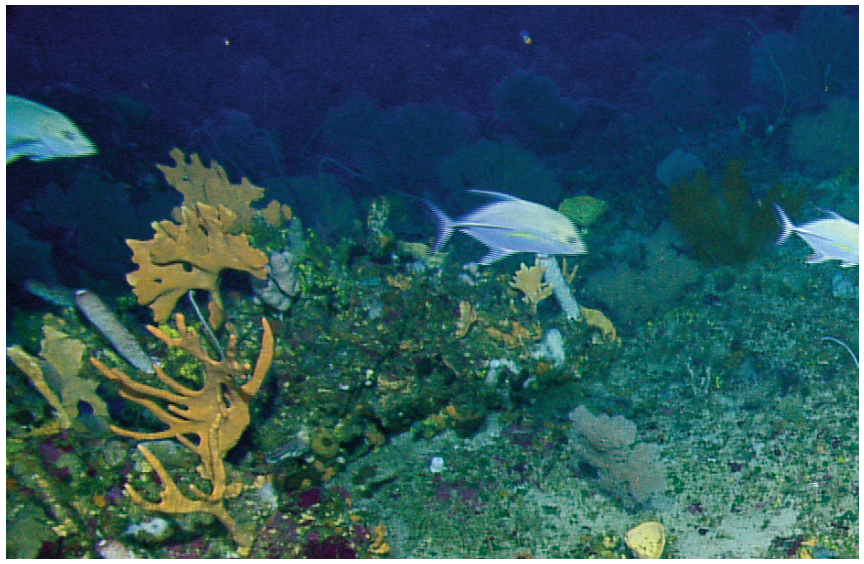
Monax shows the queen snapper habitat off the west coast of Puerto Rico indicating the depths along the Mona Passage where 22' open skiffs commercially fish for deep water snappers among these the queen and cardinal snappers.

Invertebrates

Invertebrates are animals without a vertebral column, a laywoman's definition in simple terms. Examples of invertebrates include corals, lobsters, sea cucumbers and sea urchins, starfish (soft or brittle stars as well as hard starfish), and many others. These occur in both shallow and deep waters. The numbers of these might vary with depth but since we only have mapped less than 5% of the total ocean bottom from Earth that is composed of 70% water. About 68% of the water in Planet Earth is sea water. Thus, we might still have many species to discover! However, physical factors such as light, temperature and pressure change with depth creating a very different environment from the one we know.

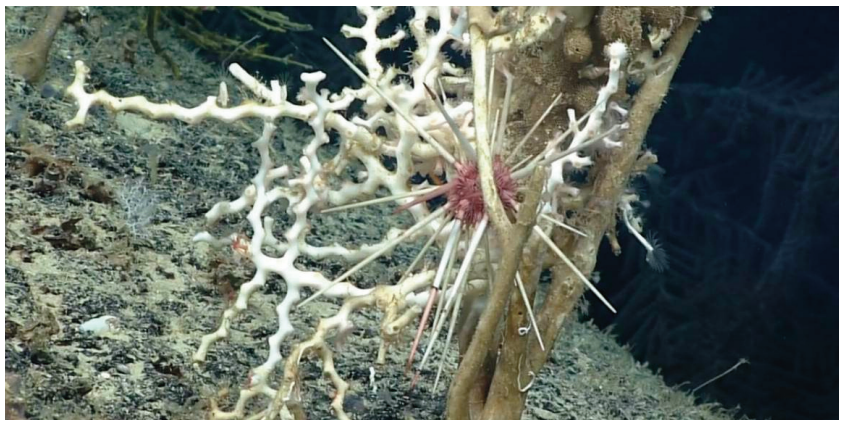
Some corals are both plant and animal; they have polyps and associated algae that contain chlorophyll. They grow from using solar energy and particulate organic matter; that is, photosynthesizing and ingesting food. The fact that they use sunlight influences the shape they take changing from having large rugose shapes to forming flat, plate-like colonies. Deep water corals don't have chlorophyll and do not form large skeletons, are more solitary corals and can be more similar to the soft corals of the shallow waters forming fans and tree-like structures.

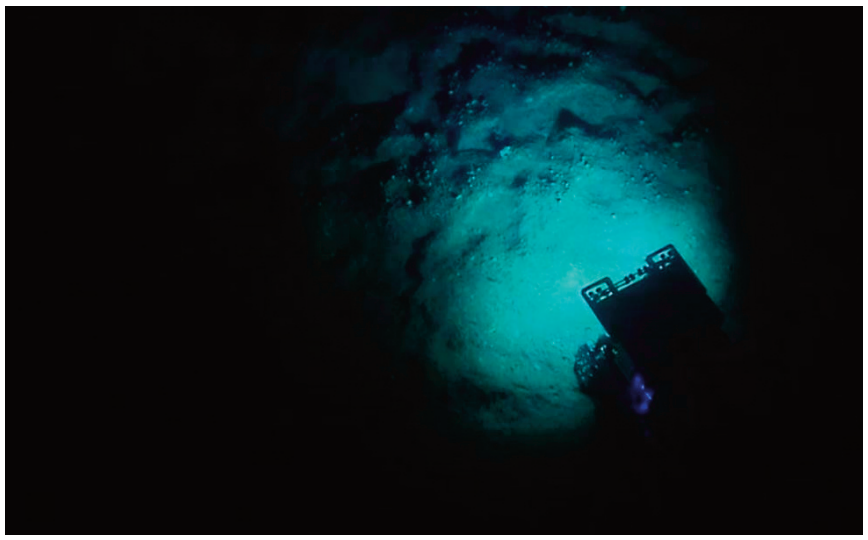
The plate like structure is to increase surface area to capture more sunlight. As depth increases, light penetration decreases. These figures show the real light (dark) at about 120 m and what it looks like with artificial light so that we can see the colors!

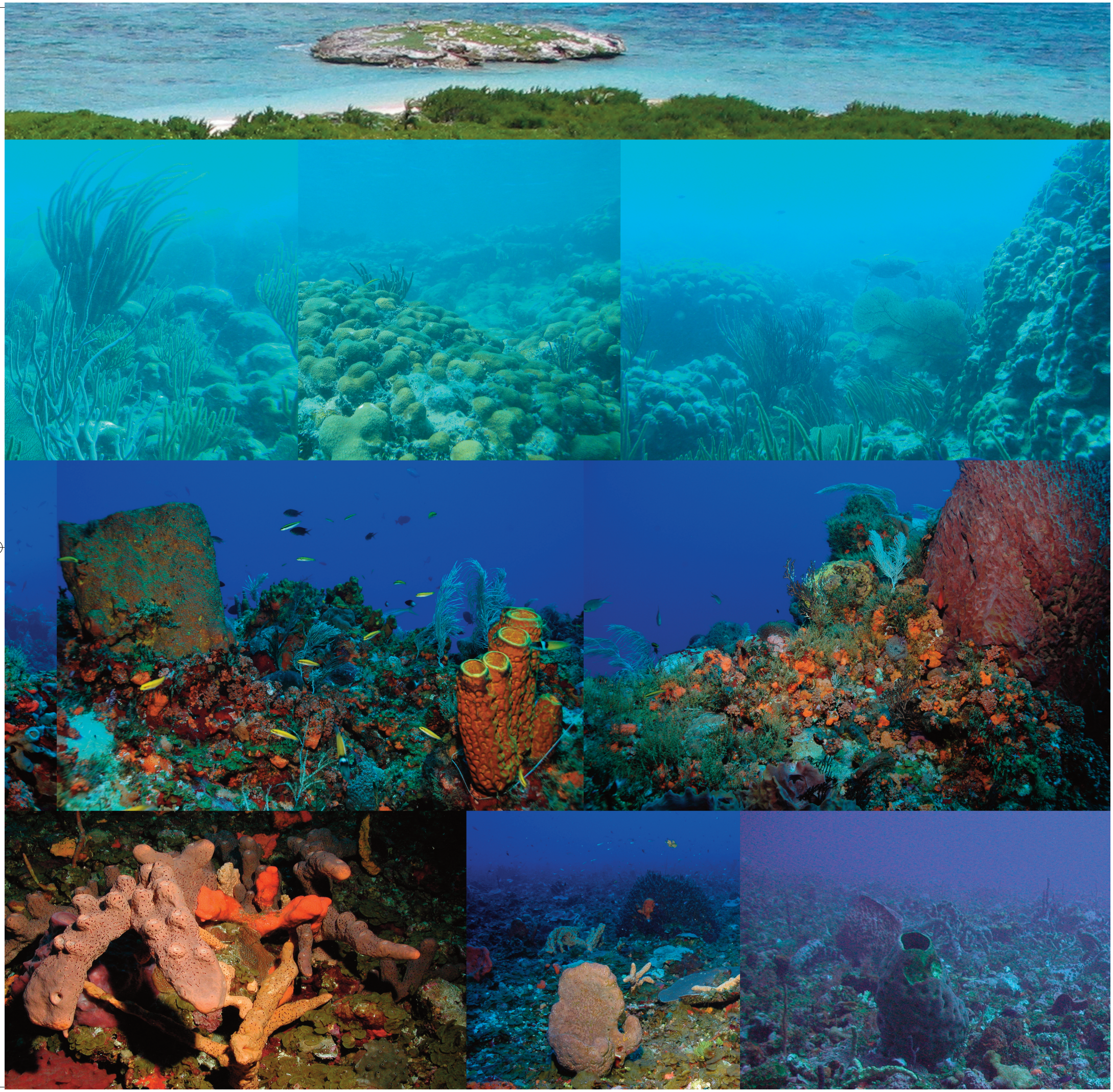


Photograph from the EV Nautilus (October 2003) at the Desecheo Ridge without lights and with artificial lights form the ROV. The fish are jacks of the family Carangidae (Caranx lugubris).

Adaptations to the deep ocean environments include tolerating low, cold temperatures, low or very low light levels, increased pressure, and flow of water that brings characteristics from other parts of the world.





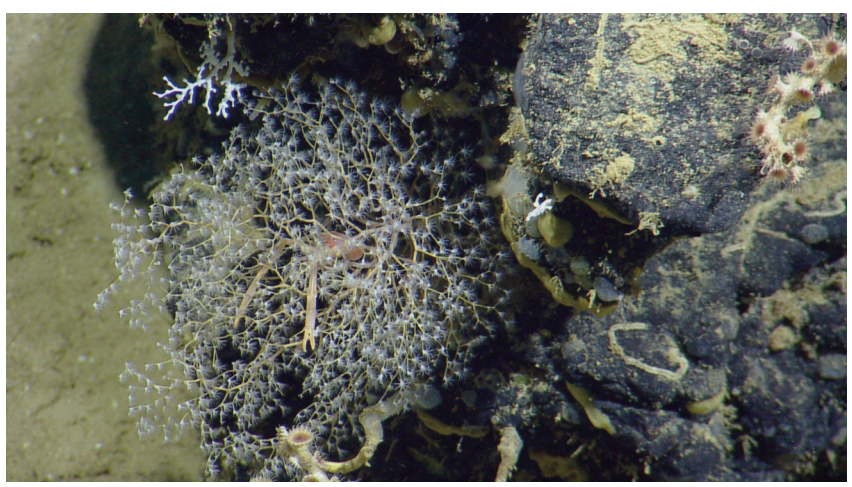


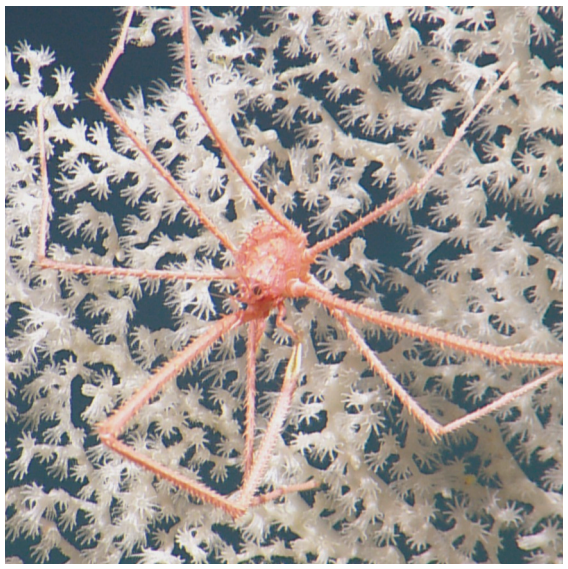
Nassau being cleaned.

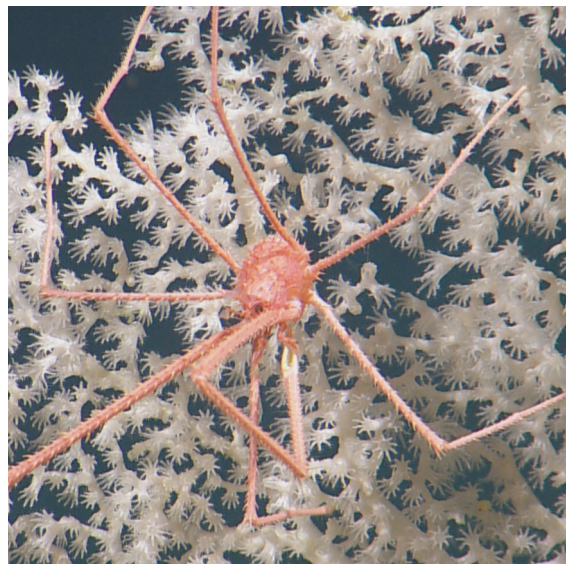
Corals are also habitat for many species providing shelter, food, structure that helps in creating a community of fish aggregated around this structure. A number of organisms that are known as cleaning gobies or shrimp are associated to these structures and provide their services for maintaining the health of other fish.

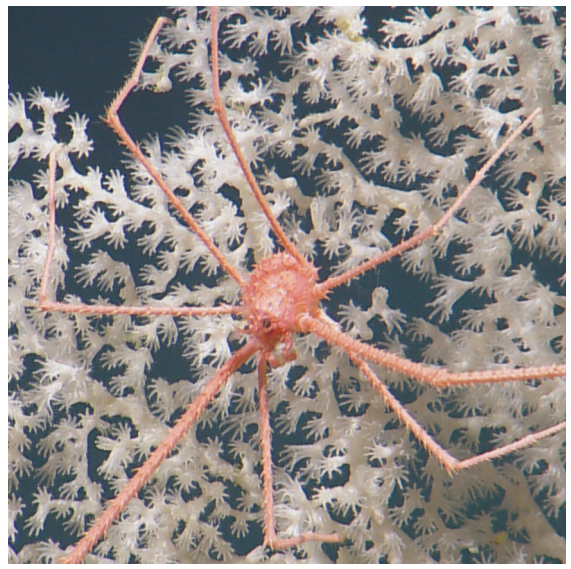
Most marine activities take place in shallow areas including commercial and recreational fishing. The number of coral species and coral reef associated organisms surpass 300 hundred. A very complete list of fish (cnidarians, ctenophores, decapods-crustaceans, mollusks, and finfish) reported from all depths around Puerto Rico and the Virgin Islands was compiled by Felix Grana-Raffiucci and are upwards of 2,000 as of 2007. These catalogues are very valuable because they are a basic tool to consult when you want to describe the biodiversity of an area.

Associations of organisms in deep waters are hard to study. Is the motile organism feeding on the sessile one? Using it as refuge?







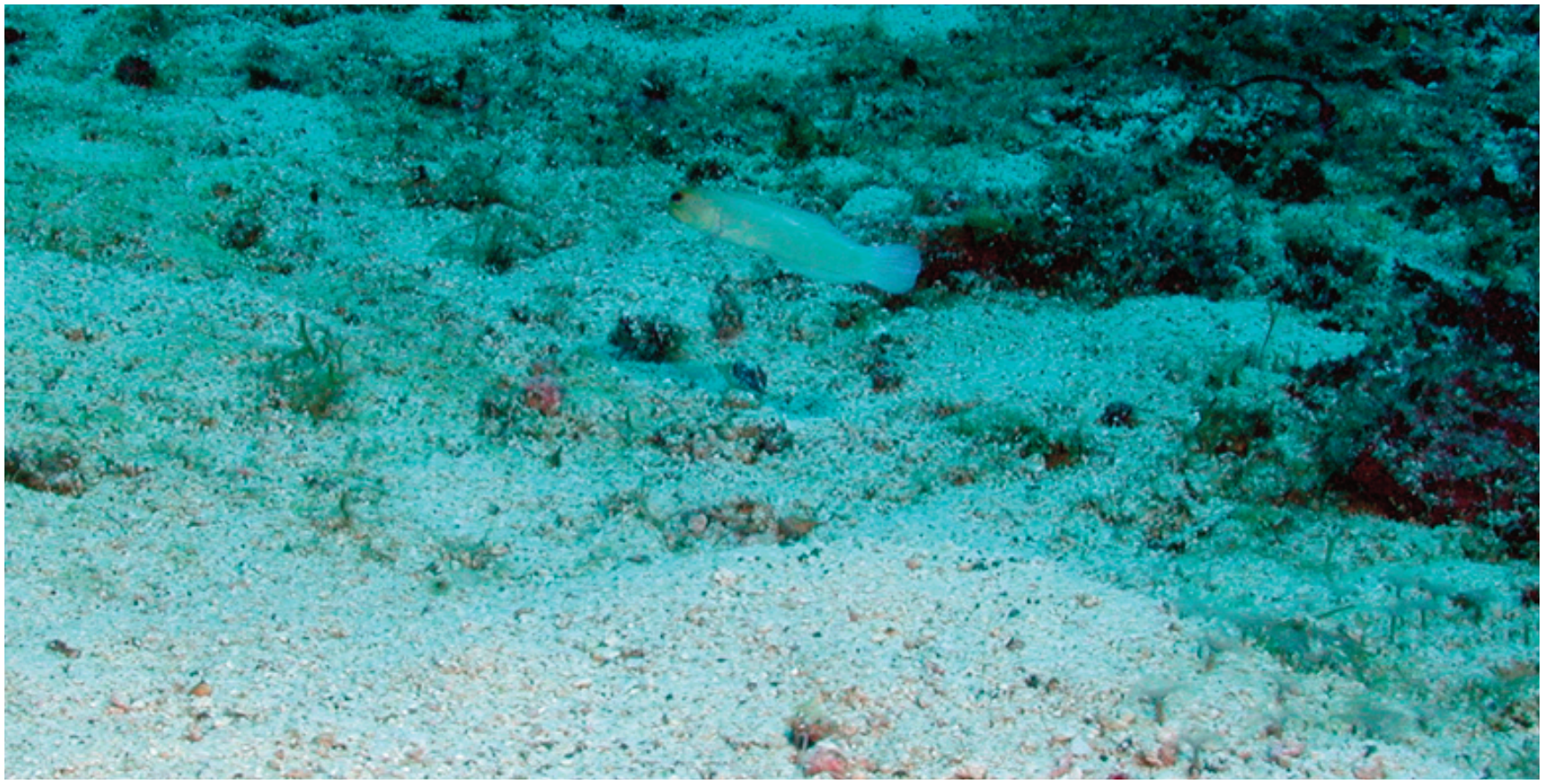


What do we fish for?

There are about 400 species, including lobsters and conchs, in the various lists of commercial and recreational fish landings data, where most are edible and others are just harvested incidentally and might be used for bait. These species range in depths between shallow, less saline waters to deep and darker waters at about 2,000 ft (610 m). The shallowest species-groups or families include, for example, grunts of the family Haemulidae of which 15 individual species are captured by fishers. Another example is the family of the parrotfishes one is not a parrotfish but a wrasse (cousin of the hogfish)! Parrotfish consist of more than the 11 species that are captured by fishers. These fish are identified by the modified teeth that look like beaks and because of their beaks and their carnival colors they are described as parrotfish. It is important to know the species because they can have different habitats, different life history (for example different size at maturity, or size at which they change sex), different feeding preferences, and might play different roles in the ecosystem. Parrotfish as many other fish species are hermaphrodites, changing from females to males and even to supermales. Parrotfish are a preferred food fish in St. Croix where their harvest is managed by minimum sizes and their occurrence appears to be greater than in the surrounding Islands.

One is not a parrotfish! They are called parrotfish because of their modified teeth or rather beak like the bird parrots.

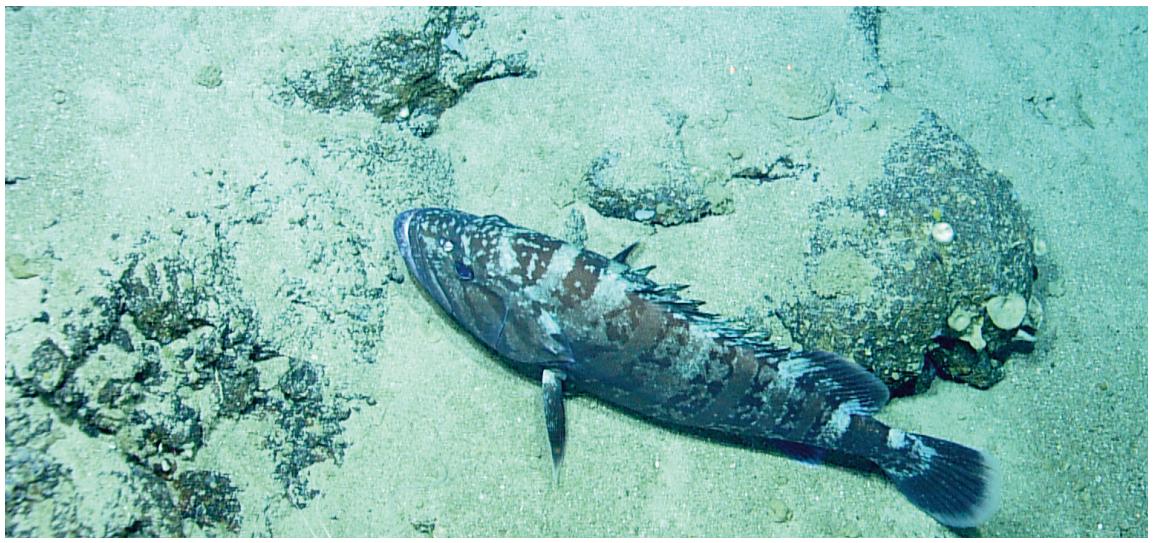
Another group of hermaphrodites are the groupers, many of the family Serranidae. Smaller groupers such as the red hind are found in shallow water but their range extends to deeper waters and the much larger-sized groupers like the tiger or the misty grouper occurring in the waters well beyond 50 m. Not all species are harvested for food but some are harvested for the aquarium trade. Most of the information on the depth distribution of the groupers is obtained from the commercial fishers. Recently more information on their distribution is being obtained from research that includes diving, acoustic signals, and the use of ROVs and AUVs.



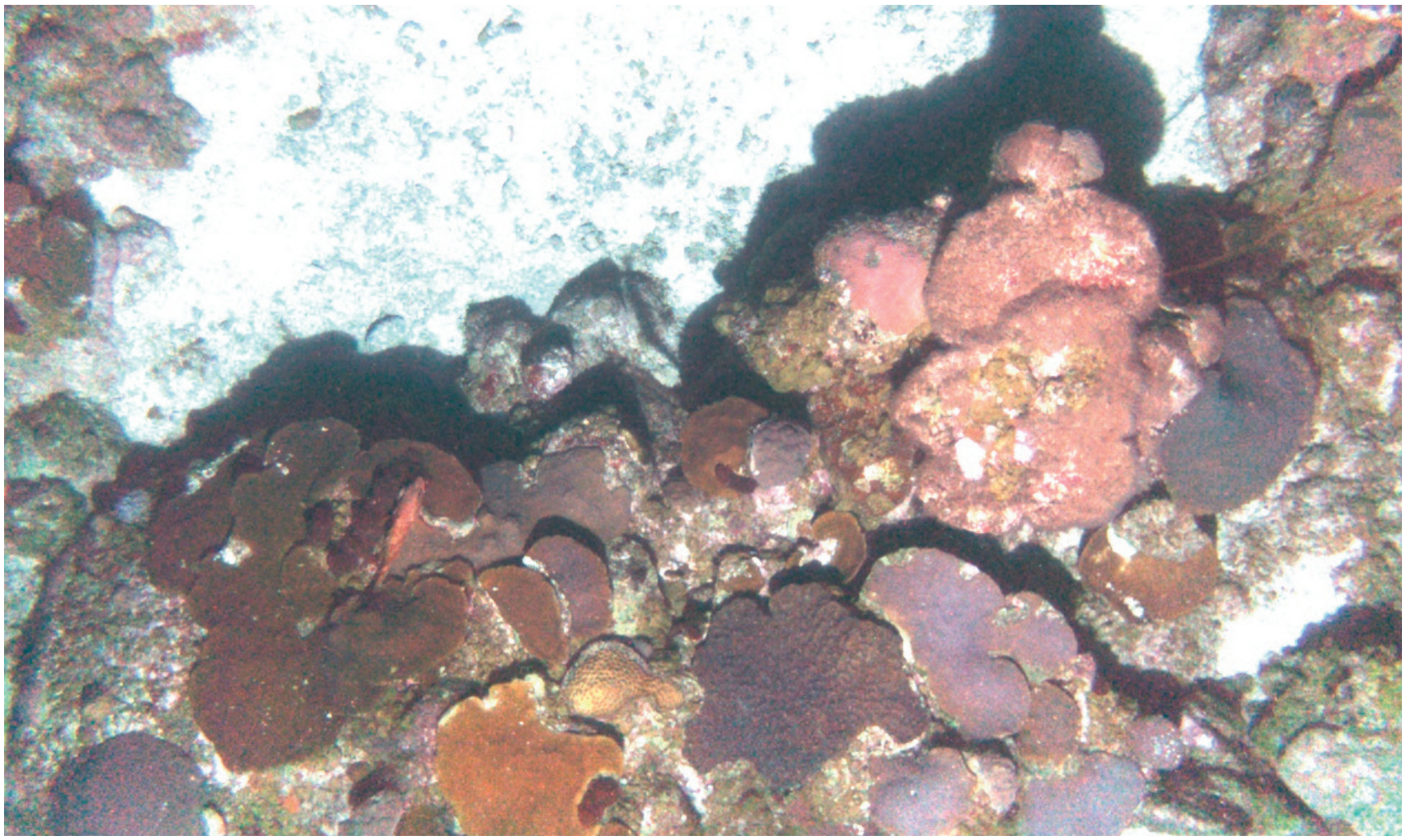
Serranus

The families with the largest number of species in deeper waters reported from Puerto Rico and the U.S. Virgin Islands include the Serranidae, the snappers such as the silk and the queen snappers but also shallower species such as the mutton and lane snappers. Along with the deep water snappers, commercial fishers sometimes collect Spanish flags. Other groups or fish families that have been reported to occur in numbers, but not part of the commercial or recreational catch, include the Stomiidae.

Coney and butterfly fish.



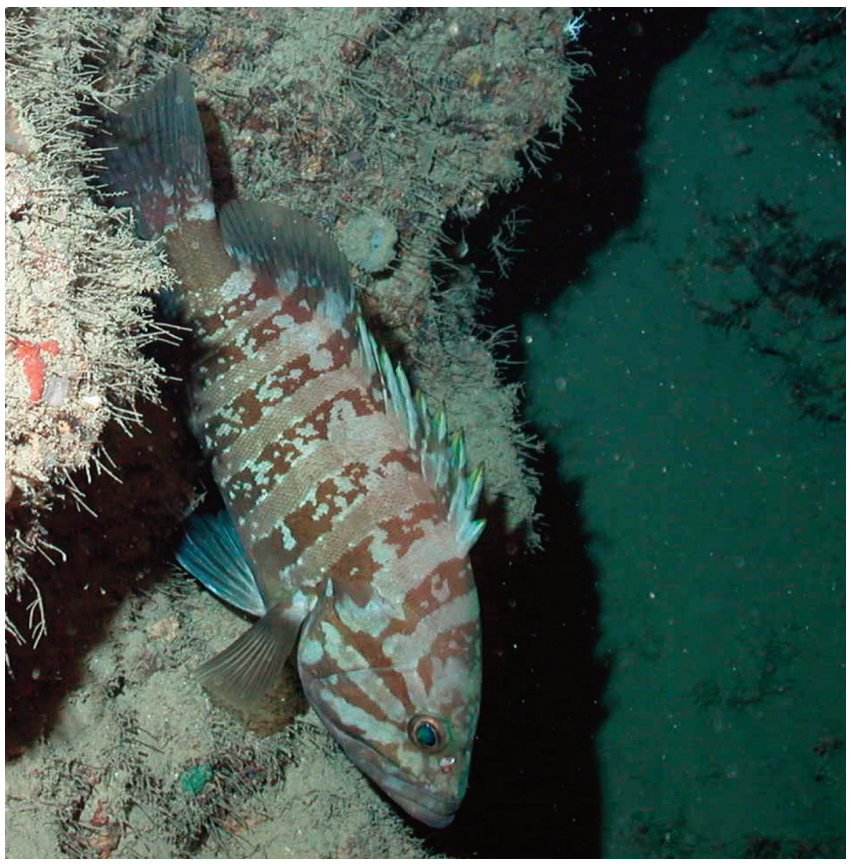
Red grouper.



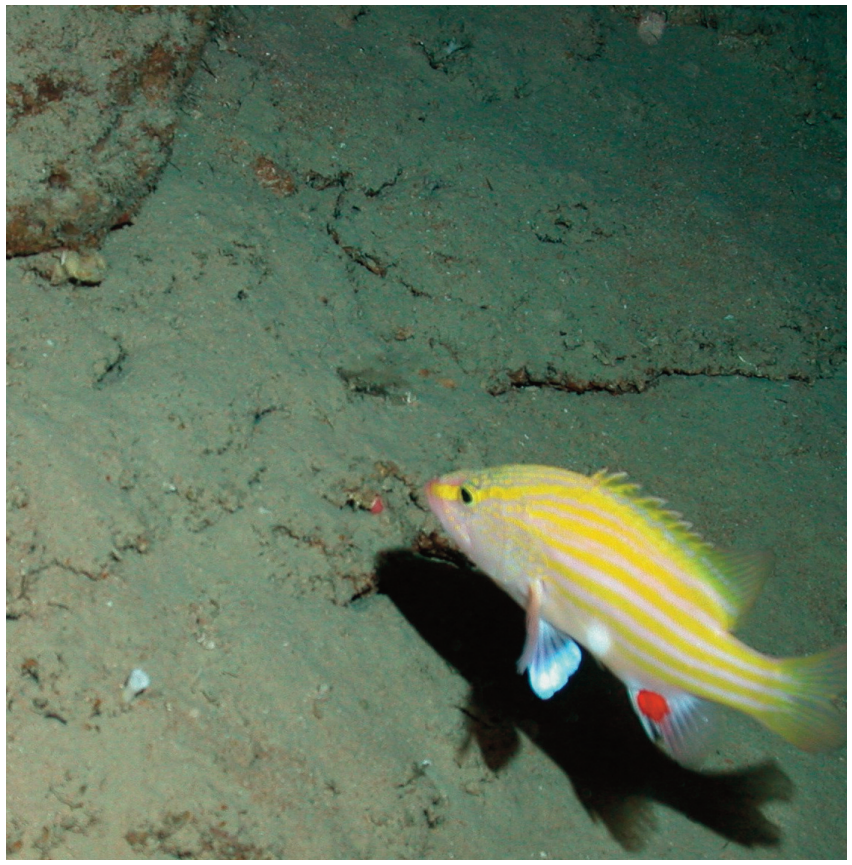
Red hind and eye parasite.

Red hind

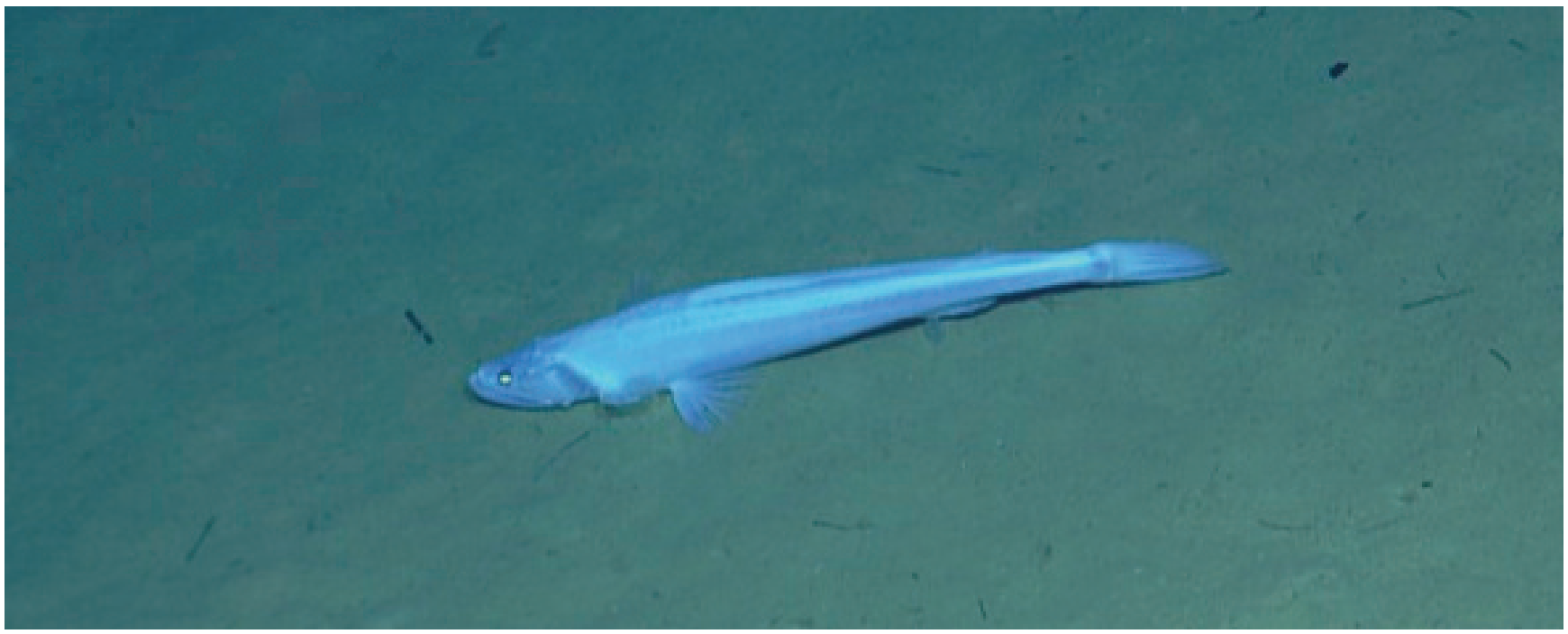
Nassau grouper



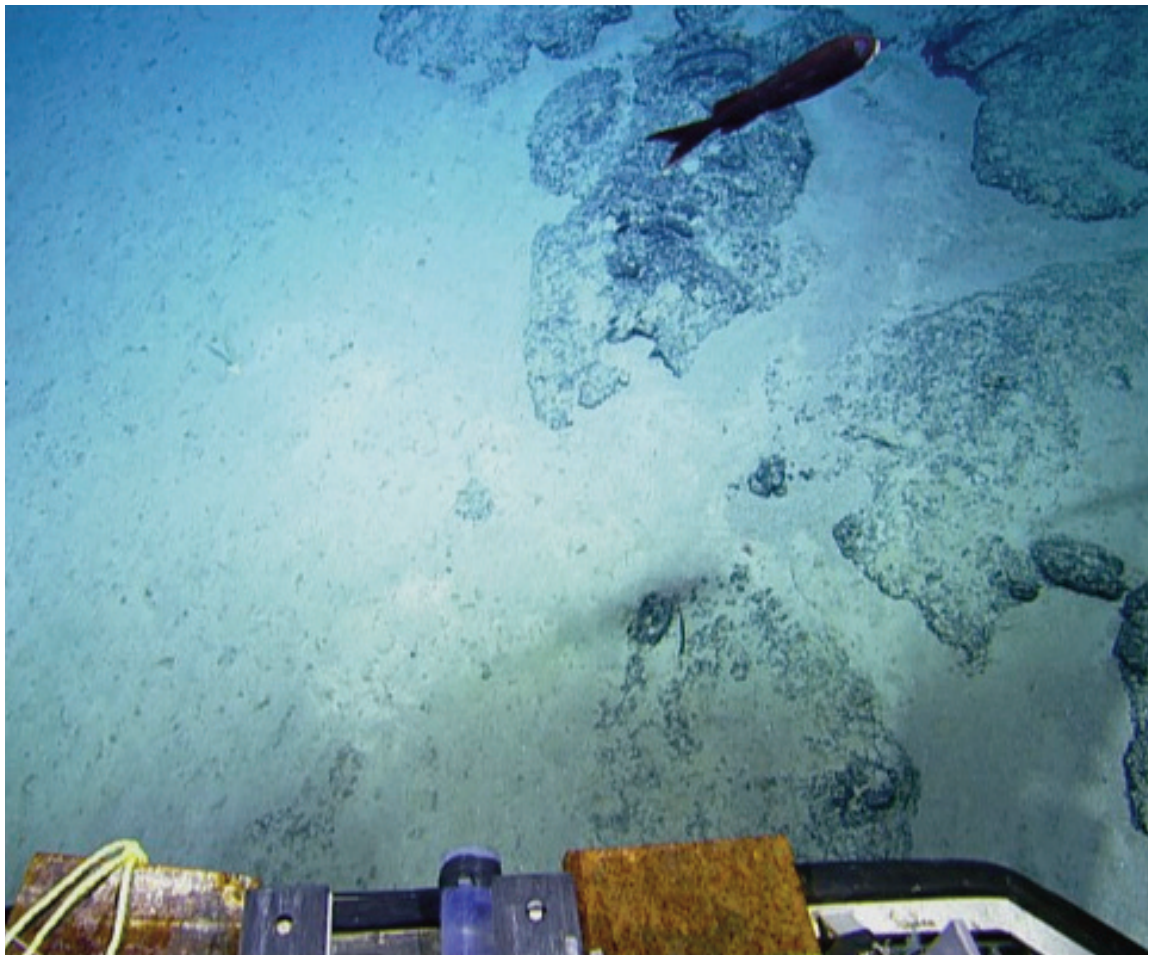
Red grouper at Grappler Bank.



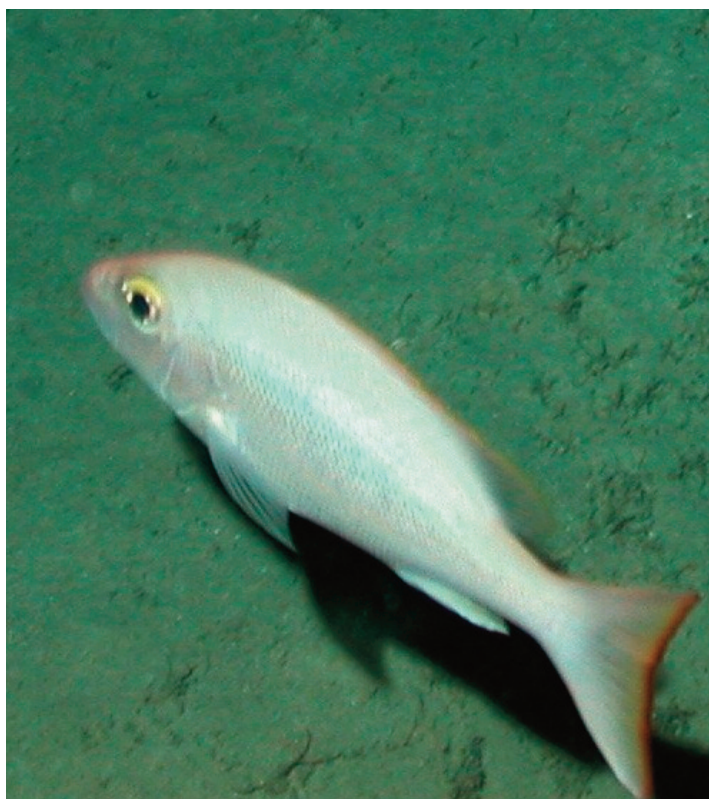
Spanish flag at Grappler Bank.



Stomiidae (barbel dragon fish).



Myctophiidae (lantern fish).



Silk snapper.

Of the species of deep water snappers, we only have local pictures of the silk snapper alive and in its habitat (Fig. 40 COVER picture of book and from Grappler Bank Dive 2167 silk). The collection of photographs taken by the Seabed AUV show the same silk snapper (Lutjanus vivanus) as it moves and turns to check out the photographic vehicle. The other photographs show a school (in Spanish cardumen) of silk snappers photographed by the autonomous underwater vehicle as the vehicle descends to the bottom. When it reaches the benthos, the bottom of the sea where the silk snappers are found, it starts a 500 m long transect before returning safely to the surface. Deeper water snappers like the queen snapper (Etelis oculatus) and the cardinal snapper (Pristipomoides macrophthalmus) were also recently photographed by the AUV SeaBed and the Okeanos Explorer.

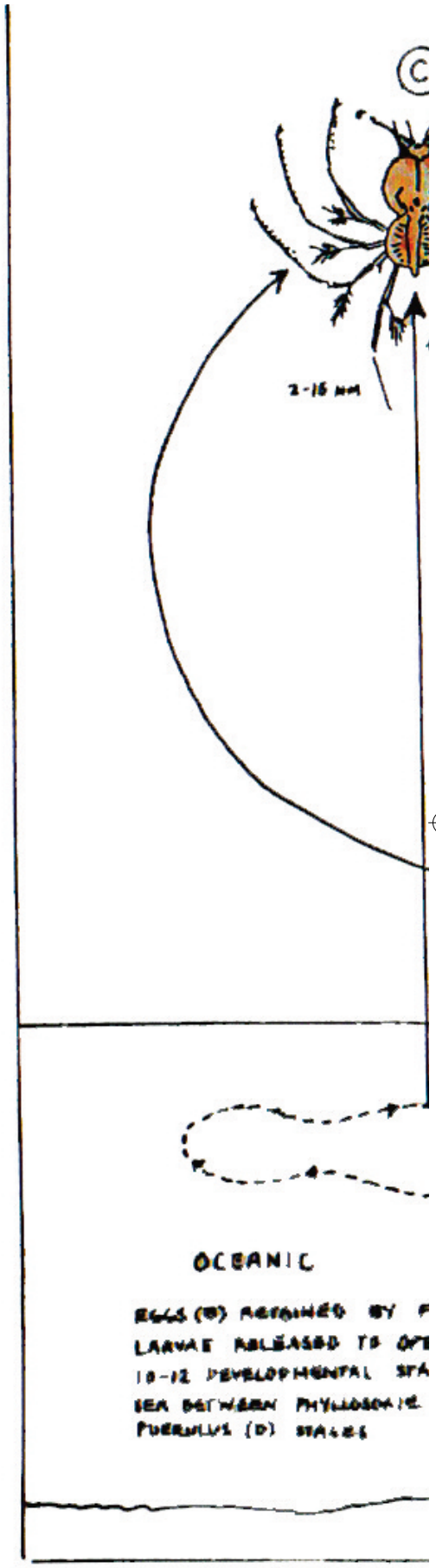
Queen snappers. Photo from AUV.

Queen snapper from Okeanos Explorer.

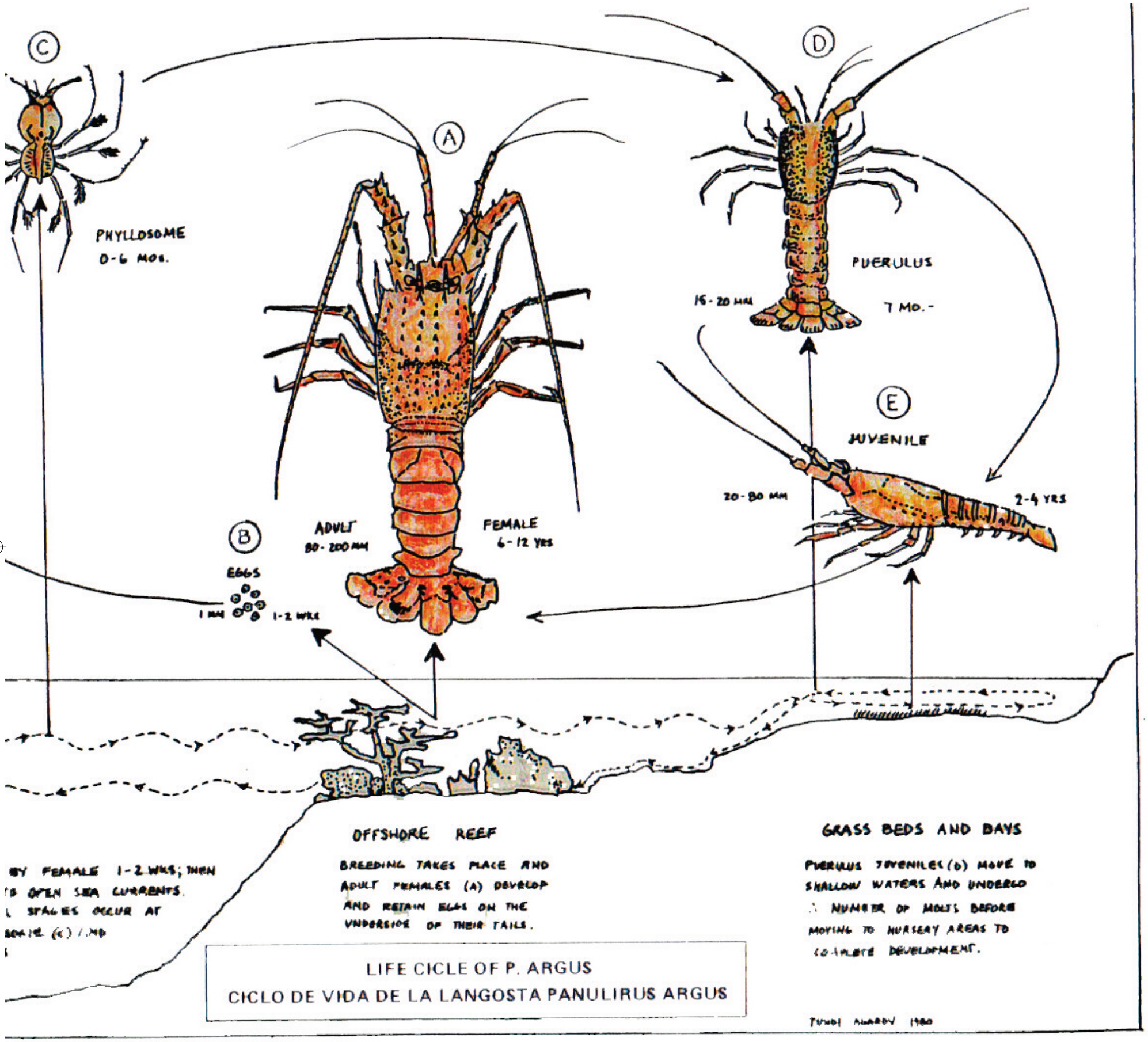
The first step in describing the EFH for these commercially important fish is to obtain photographic records of the fish in their habitat. Commercial fishers have demonstrated an interest in exploring the sites where they fish to prevent unwanted interactions of their fishing gear with the habitat. Their participation on the determination of diving sites for the AUV and ROVs contributed to the success achieved in videotaping and photographing the silk and queen snappers, as well as other associated species, 'vivito y coleando' (alive and well), in their natural habitat.

We are lacking information on the abundance and densities at which these fish are found that would allow us to be able to describe the essential fish habitats by life history stages. Larvae of marine fish are of very diverse forms and are at some stages at the mercy of the currents and tides and winds and can be "thrown" as far away from their normal tropical range (U.S. Caribbean) to as far as the temperate waters of New England as we described earlier for the larvae of the spiny lobster. There are also deep water organisms whose larvae are found in surface waters and its mechanisms to vertically travel 1,000s of meters are still unknown.

The life history cycle of the spiny lobster, Panulirus argus, can be long and can spread over a very wide geographical range. The larvae can last for months in open water but the larvae needs structures to grow to maturity. Spiny lobsters occur from North Carolina to Brazil, throughout the Gulf of Mexico and the Caribbean. It is a commercially important species throughout its range. It is mostly found associated to coral reefs but is also found in hard ground and seagrass and algal beds.



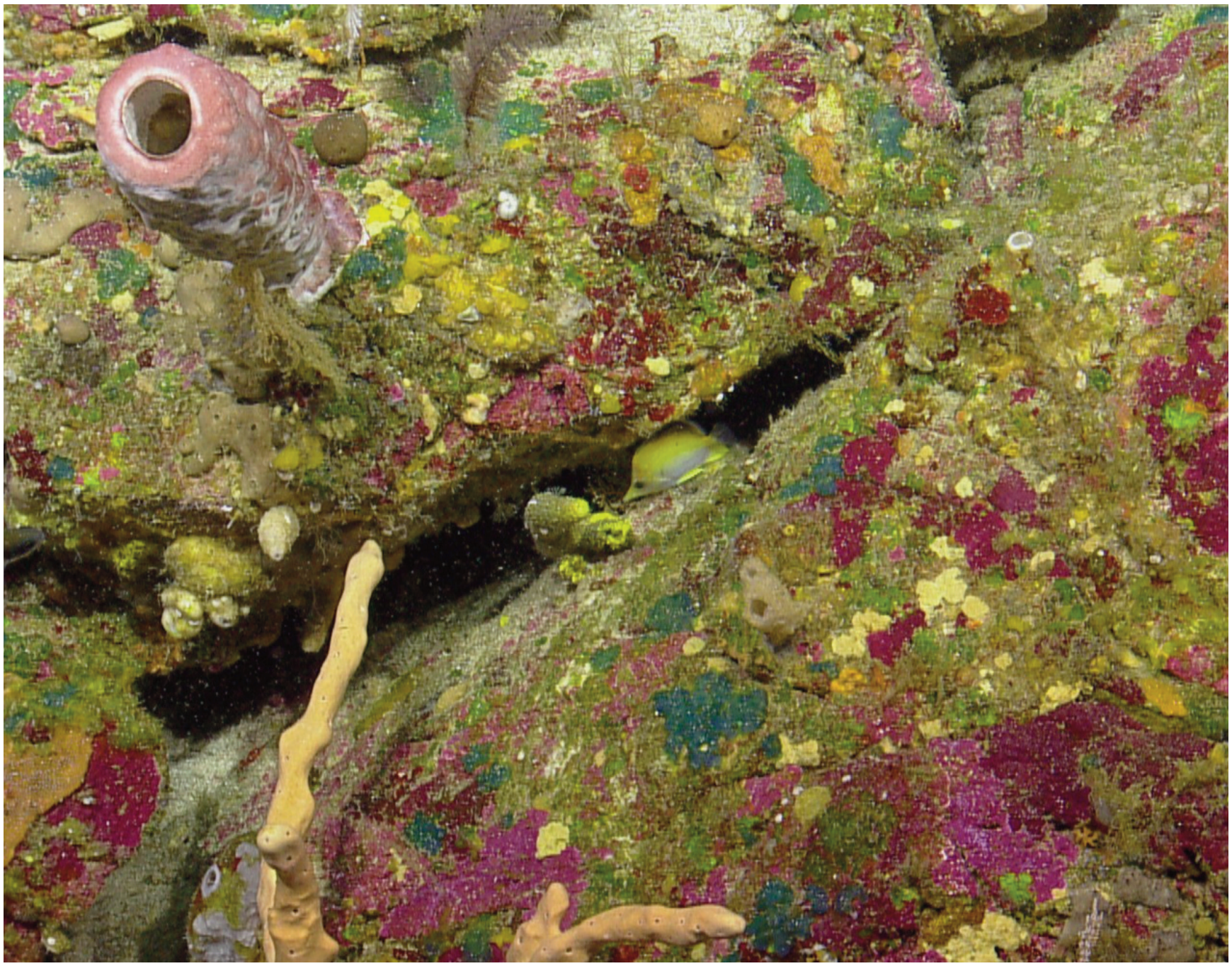
Lobsters life cycle shows a schematic of the three dimensional spaces that lobsters can occupy.



LIFE CICLE OF P. ARGUS

CICLO DE VIDA DE LA LANGOSTA PANULIRUS ARGUS

Spiny Lobster at Lang Bank.



Butterfly fish at mesophotic reef.

Most people are familiar with the very colorful fish of the shallow waters like the butterfly fish and the delicious crustacean ("having a crust or shell") one eats like the lobster. These two species, as do many others, overlap the shallow and mesophotic depths. Of all the fish that we eat, many are harvested from mesophotic reefs and deeper including the groupers and snappers. These species make up the bulk of the food-fish consumed in Puerto Rico and the U.S. Virgin Islands and yet we know very little of their life histories and associations to their essential habitat. The reason for this is because they are found beyond depths only accessible through the use of technologies other than diving.