LOG OF THE DEEP SEA

AN EXPEDITION TO THE GULF OF CALIFORNIA

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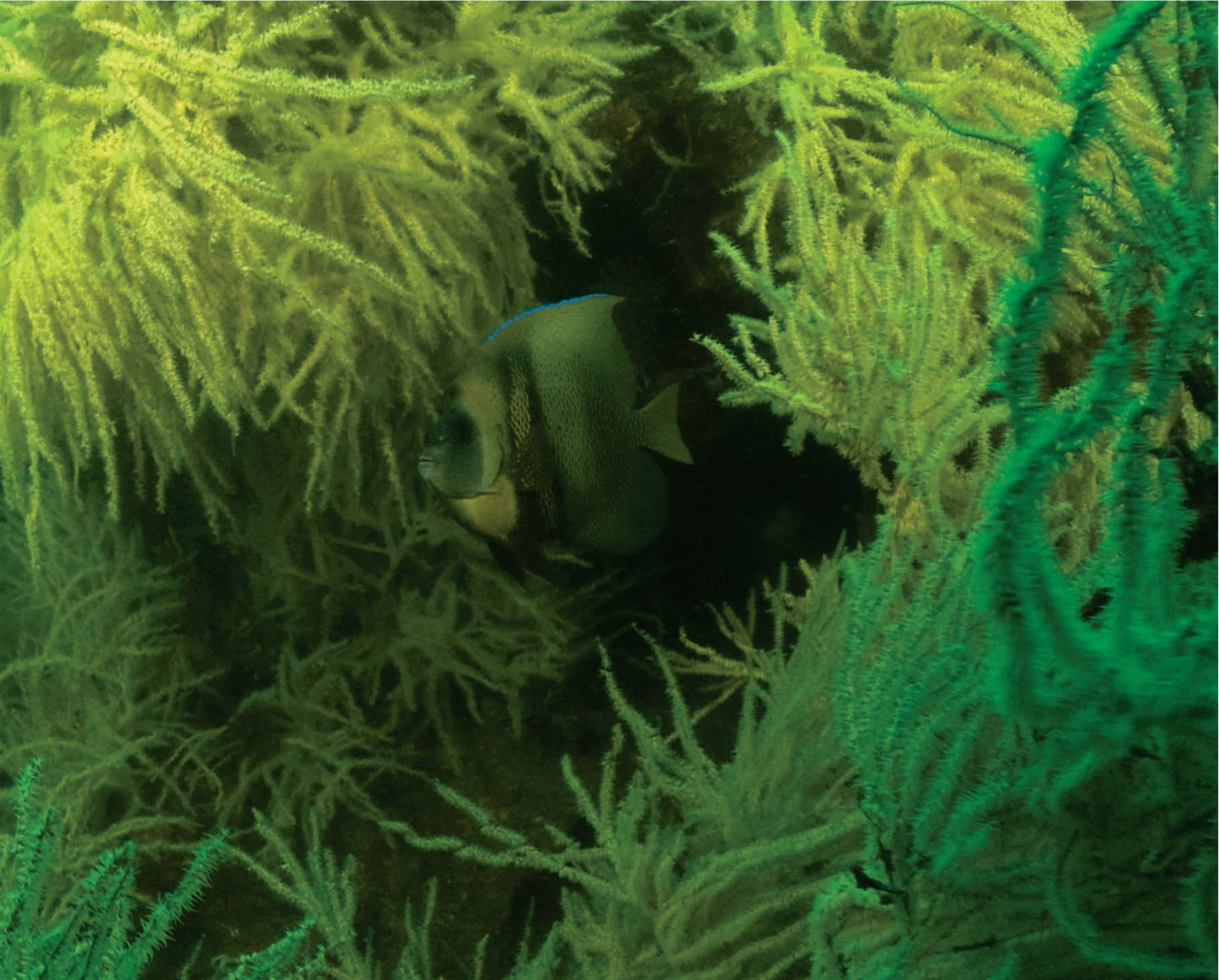
This book is dedicated to
Steve Drogin, *in memoriam*,
and Christy Walton,
who believed in this project
from the very first day.



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Marisla
Cerralvo
La Reina


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ARGO

Prologue

Steve Drogin

During the months of August, September, and October of 2008 we brought our newly remodeled 132-feet vessel ARGO from Costa Rica to Mexico. At first, she was deployed in the Gulf of California, where we conducted several charters for tourism, science, filming, and discovery. My personal objective was to film the giant Humboldt squid, which has spread all over the Gulf during the past 5–10 years. I thought that by using my DeepSee submersible, we could get down amongst them. We spent a total of 84 days in Mexico, which also included time at Guadalupe Island. We had 63 days of submarine diving, during which we made 118 dives.

We supported a group of scientists from several Mexican universities and research centers, Scripps Institution of Oceanography, and the San Diego Natural History Museum. This great team of scientists came onboard and was able to SCUBA and submarine dive for their research. During their expedition, the scientists gathered lots of samples, took thousands of photos, shot hours of video, and made a large number of observations. Scientists and divers from Mexico and California joined together to accomplish many tasks and conduct exciting new research. With the DeepSee submarine, many scientific dives were made and hundreds of samples were picked with our new remote manipulator system and robotic arm and brought to the surface to deposit into museum and research collections in Mexico.

It was a pleasure to be able to collaborate with my friends Brad Erisman, Octavio Aburto, and Exequiel Ezcurra, and with the great team of Mexican scholars assembled to study the seamounts between La Paz and Loreto.

Oceanographic vessel "Argo",
mother ship of the DeepSee submersible.
Photo © Undersea Hunter Group.

And then, so many exciting events, so many stories to remember, and so many adventures!

One day I was making a dive on the sub searching some new geological features. At a depth of 136 meters off the north end of Danzante Island, we came upon a huge pile of rocks. Looking more closely, we saw what appeared to be a scene like you experience in the desert in the summer—a mirage that made the water shimmer in the eddies of a vertical turbulent flow. We positioned the sub very close to the rocks, and to our amazement, it turned out to be a hot water vent with water coming out of the rocks at a temperature which has now been estimated by Scripps scientists at 135°C.

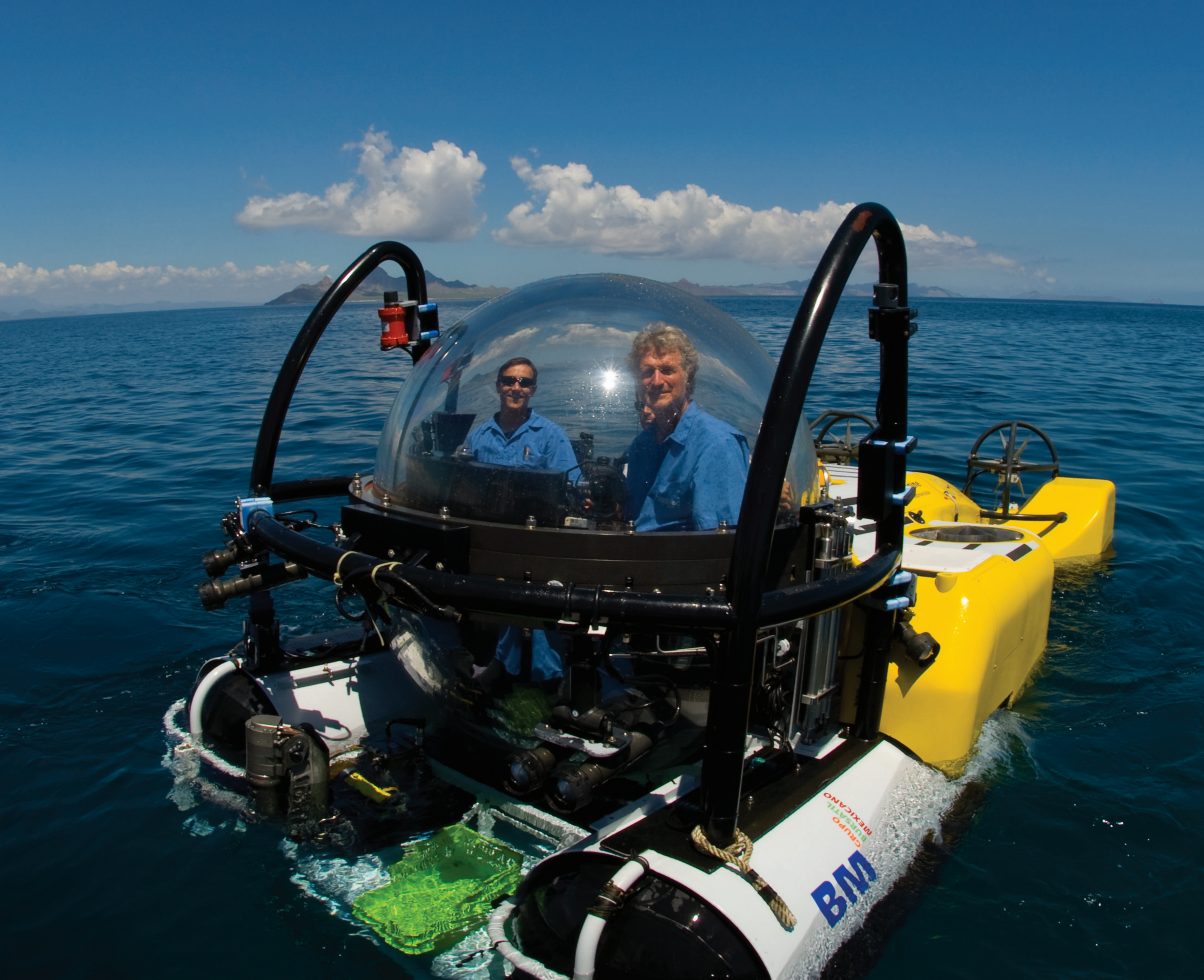
In my 50 years of SCUBA diving, I had never seen anything like this. The area around the rocks was covered with multi-colored bacteria. It was stunningly beautiful.

Then, we saw a school of baitfish, and soon, from out of nowhere, the sub got attacked by a huge school of the Giant Humboldt Squid. They went crazy. They banged into the sub, ate baitfish, ate each other, and flashed like crazy, surrounding the sub completely like a swarm of bees. The squids shot in and out of our view, and when all the baitfish were eaten, they disappeared. This deep water vent has never been seen by anyone else. It was a huge thrill for us to discover something new; especially in the Sea of Cortez, one of the most beautiful seas in the world.

It is a cause of deep emotion for me to prologue the work of the expedition's research team. I hope this report signs the beginning of many future discoveries in this marvelous and unique ecosystem.

Brad Erisman and Ralph Chaney starting a dive in the DeepSee. Photo © Octavio Aburto-Oropeza.

Pages 18–19: At sunset, the DeepSee submersible is towed back to the Argo by the support boat TopSee. Photo © Margarita Caso.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Las Animas
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Rio Acaponeta
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Rio Culiacan
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Rio Piastla
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Introduction

Exequiel Ezcurra

Coasts are fine lines that separate the sea from land and define two totally segregated worlds. From the very moment we dive underwater we feel surrounded by a completely different universe; a silent world, with dim and oddly bluish lights and life forms incredibly different from the ones we are familiar with on land.

In the 3.7 billion years of the existence of life in this planet, the first multi-cellular life forms appeared just 700 million years ago beneath the shallow waters of the Precambrian oceans. About 300 million years later, during the Silurian, macroscopic life started to appear outside the oceans' water. If, in order to understand the concept of deep time, we imagine the time that has passed from the appearance of the first complex multi-cellular organisms in a scale of one year, then during the first four months of this "evolutionary year" life was present exclusively in the oceans. The first forms of emerged life capable of inhabiting land became visible in June, when living species had been teeming in the ocean's waters for hundreds of millions of years. Only a few biological groups were capable of adapting to survival on earth, and once they emerged they evolved and radiated into countless species, almost all of them developing from a few basic morphologic designs: arthropods with a chitinous exoskeleton; vertebrates with a central nervous system and a spinal cord; vascular plants with green leaves distributed around a stem; and fungi with white, cotton-like tissue capable of growing over decomposing organic material.

The memory of past evolution survives in present life, and for this reason the diversity of evolutionary groups is overwhelmingly greater below the sea than it is on land. While the land-dwelling invertebrates are reduced to mainly insects and other groups, great quantities of

The islands of Baja California Sur as depicted in an official chart from 1823 (fragment of the *Carta Esférica de los Territorios de la Alta y Baja Californias y Estado de Sonora*; by José M. Narváez, México, 1823).

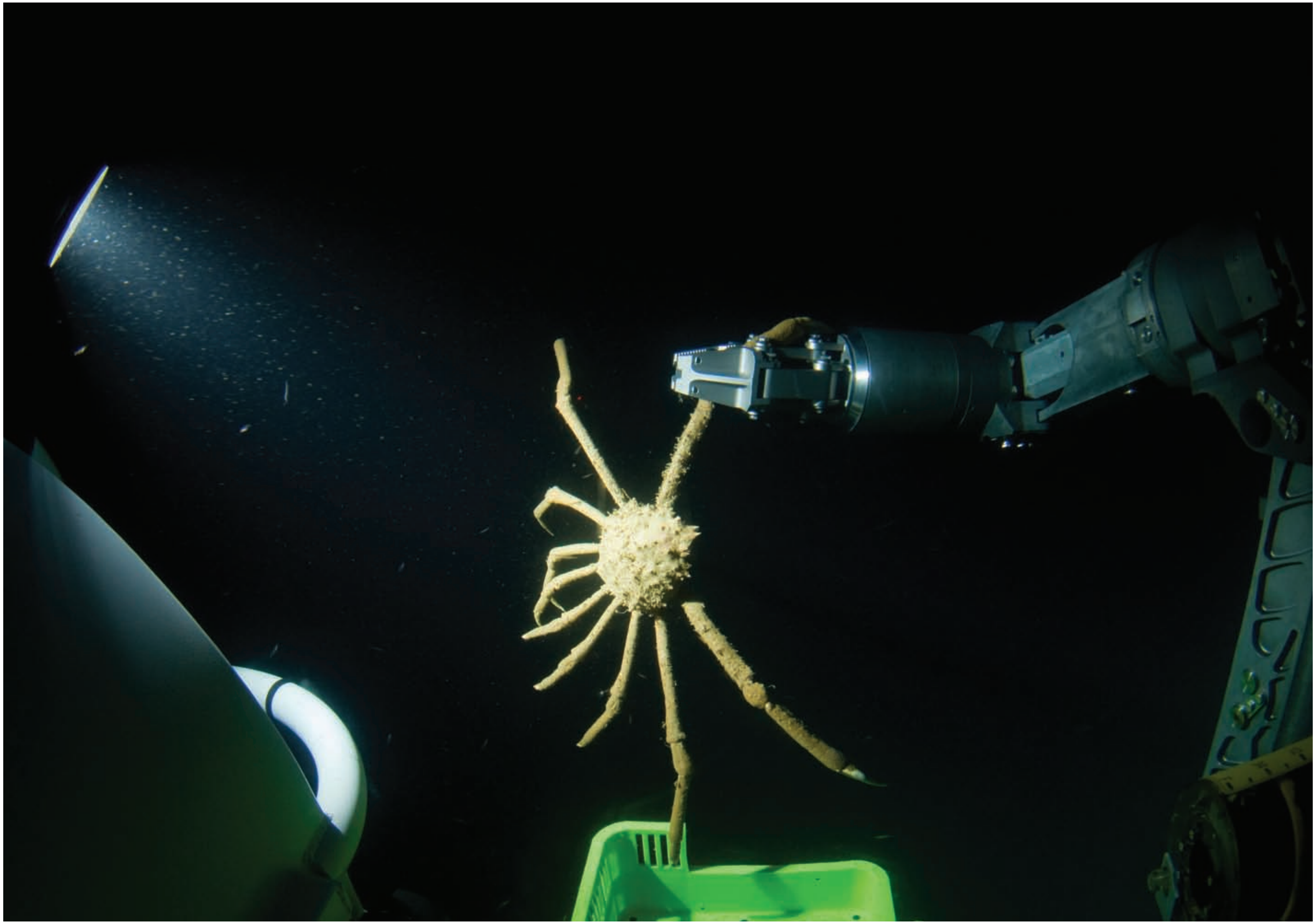
sponges, anemones, corals, jellyfish, sea urchins, polychaetes, echinoderms, crustaceans, and mollusks survive underwater, to mention only a few groups within a truly prodigious biological mixture. The same occurs with photosynthetic plants, which showcase an incredible collection of ancient organisms whose evolutionary age amounts to thousands of millions of years, with strange and variable forms that go from microscopic diatoms, red algae and dinoflagellates, to coralline algae and giant kelp.

The land and the sea are, in effect, two worlds dramatically divided by the thin line of coasts and sandy beaches. Through surf and tides they meet and watch each other from afar, as if wanting to keep a respectful distance.

With the hopes of breaking that evolutionary gap and to better understand the dynamics of life in the depths of the ocean, we organized an expedition to the deep waters of the Sea of Cortés. We wanted to dive into that unknown microcosm untouched by light, witness the diversity of life forms, the richness of species and the abundance of life below water, and wonder at this world that has been evolving for thousands of millions of years before ours, and which we often destroy without even being aware of what we are losing. We wanted to see evolutionary time reflected in the splendor of the algae, sponges, corals, anemones, polychaetes, crustaceans, seashells and clams, cephalopods, echinoderms, tunicates, and fishes of all kinds.

We wanted to witness the deep treasures of the Gulf of California; to discover an unknown environment to satisfy a personal urge of exploration, but also to reflect on ourselves, our relationship with the rest of the biological world, and on the mysterious sense of our perception of nature.

Collecting of the deep water crab *Maiopsis panamensis* with the robotic arm of the DeepSee at more than 300 meters deep. Photo © Octavio Aburto-Oropeza.



The expedition team

Exequiel Ezcurra

Like many other improvised and somewhat frantic ventures, we organized the expedition in less than two months, calling upon the best specialists and support personnel within the small timeframe that we had. The original idea was incubated jointly by Octavio Aburto-Oropeza, research scientist from the Universidad Autónoma de Baja California Sur and doctoral candidate at Scripps Institution of Oceanography, Brad Erisman, a young post-doctoral investigator at Scripps, and myself, Exequiel Ezcurra, at that time Provost of the San Diego Natural History Museum, under the inspiration of Steve Drogin, a renowned explorer and submarine photographer, owner of the DeepSee submersible and personal friend of all three of us. The proposal was simple, but at the same time very difficult and daring. Steve was willing to generously donate the use of his submersible for ten days to explore the Gulf of California on the condition that we could obtain the resources needed to pay for the mother ship that transports and supplies the submersible, and that we develop a research project interesting enough to make the whole venture worthwhile.

The endeavor was truly exciting. The submersible we were being offered—the "DeepSee"—was a three-person Triumph model, built by SEAmagine Hydrospace Corporation in Claremont, California. It is a self-propelled electric vessel that can carry three occupants (the pilot and two passengers) sealed inside a one-atmosphere acrylic

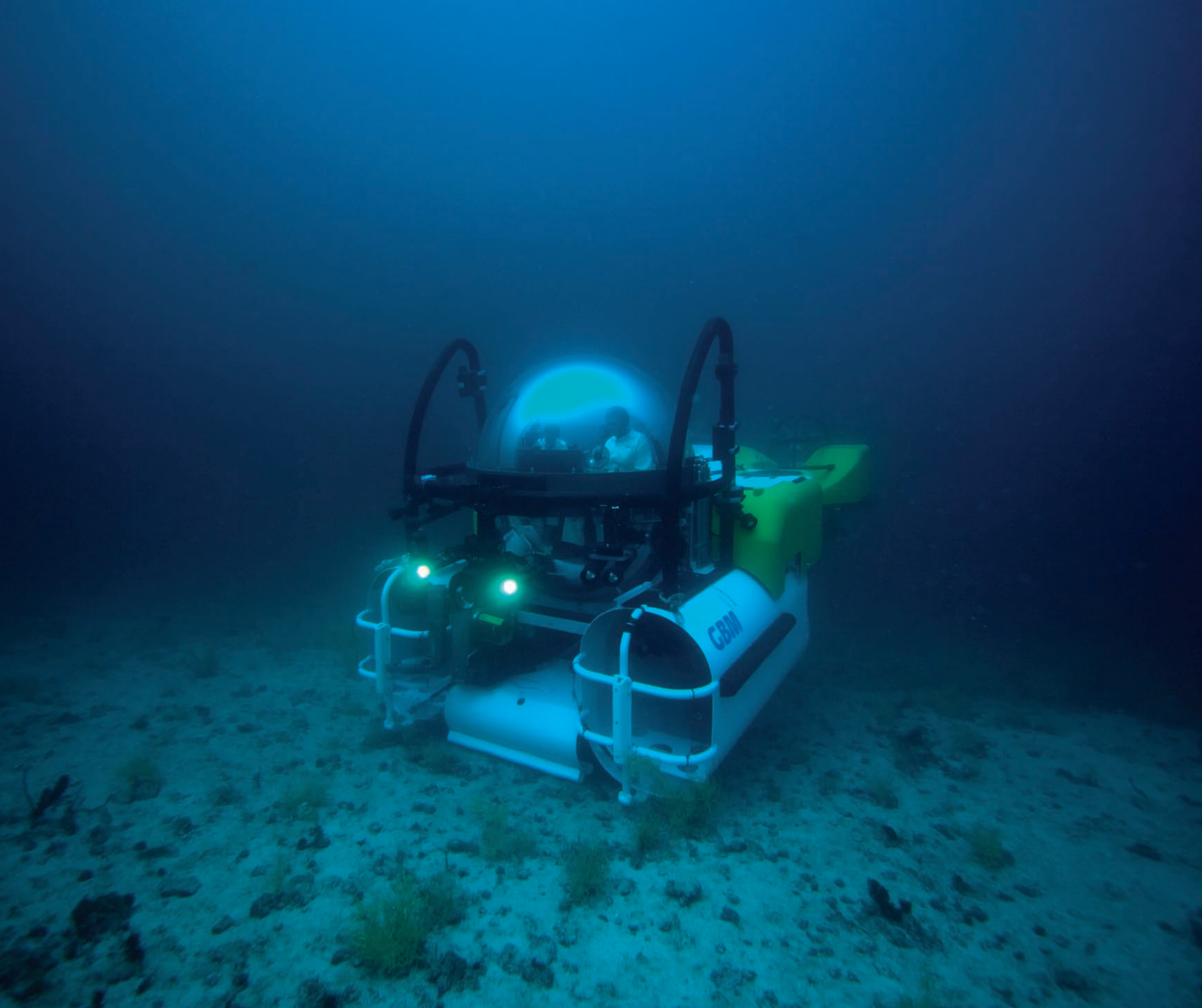
Expedition team:
Front row, left to right, Octavio Aburto-Oropeza, Lorenzo Rosenzweig, and Francisco A. Solís-Marín; second row, Carlos Sánchez-Ortiz, Vivianne Solís-Weiss, Paula Ezcurra, Ana Ezcurra, Richard Cudney-Bueno, and Exequiel Ezcurra; background, in the DeepSee cabin, Brad Erisman and Ralph Chaney; out of the picture, Margarita Caso. Photo © Octavio Aburto-Oropeza.

cabin to depths of 450 m of sea water. It is 5.3 m long, 3.1 m wide, and 3 m high, and runs on electric batteries that allow up to six hours of immersion time (normally, two dives) and take six hours to recharge. The reinforced spherical acrylic cabin opens as a clam shell along its equator to allow the entry and exit of the occupants. The sealed cabin is equipped with an air regulation system, where scrubbers constantly remove the carbon dioxide emitted by the occupants, oxygen is replenished at a controlled flow, and the environment is constantly monitored by electronic air analyzers. The cabin is pressurized to one atmosphere and regulated constantly to maintain good breathing conditions.

Two large inflatable bladders allow the submersible to float on the surface of the ocean and navigate autonomously. When the surface flotation devices are fully deflated the craft remains slightly positively buoyant and will only submerge when driven downwards by its vertical thrusters. Both depth control and horizontal movements are controlled by fixed electric propulsion thrusters that can either push or pull depending on the direction of rotation of the propellers. The pilot operates the craft using a joystick in the cabin. At the end of a dive the flotation bladders are re-inflated such that the craft floats back on the surface and, once docked by the mother ship, the cabin can be opened. The submersible's 1.5 m acrylic cabin offers a wide and open field of view in all directions including directly below the occupants. The craft is equipped with a robotic hydraulic arm to collect underwater samples, a system of underwater lighting illuminating the front of the vessel, and a hydraulically controlled high-definition video camera that allowed the occupants to film marine life. For a submarine explorer, the opportunity seemed truly a dream, a fantasy come true.

We began working frantically to raise the resources that would make this fantasy a reality. To our amazement, in a few weeks we had secured the generous donations that

Forty meters below the surface, the DeepSee descends into the deep Gulf gliding over a sandy slope rich in black corals *Antipathes galapagensis*. Photo © Ofer Ketter.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made this project possible. We received support from two Mexican Federal Government institutions that immediately understood the value of the project and gave their support from the start: the National Institute of Ecology (INE), and the National Commission for the Knowledge and Use of Biodiversity (CONABIO). The Mexican Fund for the Conservation of Nature (FMCN) also endorsed our endeavor from the beginning. Christy Walton, a personal friend and an ardent Gulf of California enthusiast, sent us a personal donation as soon as she learned of our dream. Almost at the same time we received news from Susan Anderson and Anne Gondor, two dear friends at The Nature Conservancy's offices in Tucson, Arizona, that their organization would also be supporting the project financially. The rest of the funds arrived shortly thereafter from other philanthropic institutions interested in conservation: the Sandler Foundation, the Marisla Foundation, the Walton Family Foundation, the David and Lucile Packard Foundation, the International Community Foundation, and the National Geographic Society, to all of which we are deeply grateful for making this project possible.

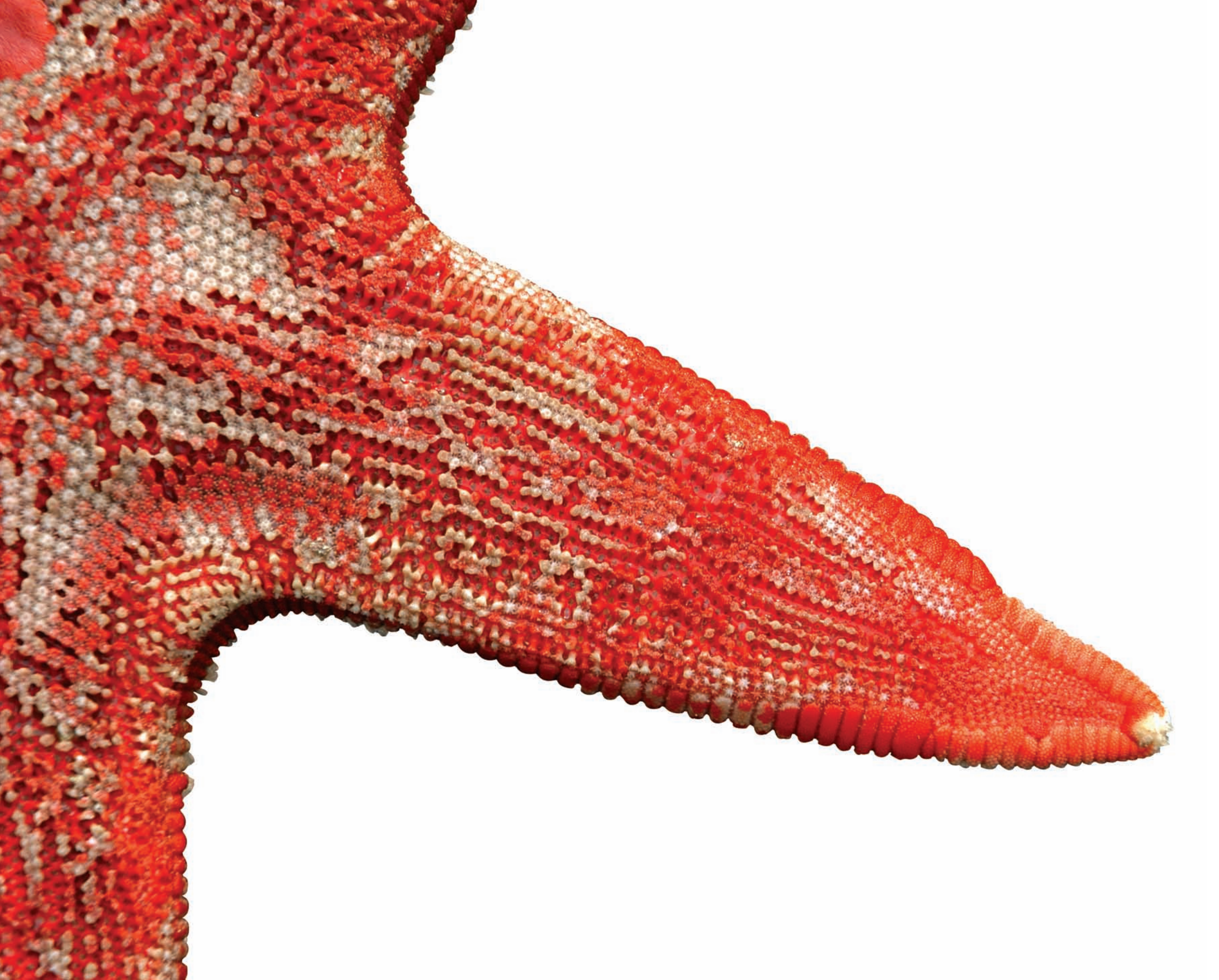
With little less than two months to go we organized the expedition team. Honoring the excellent natural scientists of Mexico, we decided that the expedition team should consist mostly of Mexicans. The scientific core would be integrated by five specialists from different marine groups and two ecologists, who would be in charge of putting the taxonomic specialists' information in the context of the general ecosystem. In a few days, the researchers invited had agreed and the group was complete: Carlos Sánchez-Ortiz, a research scientist at the Universidad Autónoma de Baja California Sur, would study cnidarians and other reef species; Francisco A. Solís-Marín, from the Instituto de Ciencias del Mar y Limnología at the Universidad Nacional Autónoma de México, would concentrate his efforts on the echinoderms, his specialty group; and Vivianne Solís-Weiss, also from the Instituto de Ciencias del Mar, would focus on the polychaetes. Octavio Aburto-Oropeza, Brad Erisman and Richard Cudney-Bueno would concentrate on the study of fishes and fisheries, and Margarita Caso, a researcher at the National Ecology Institute (INE), together with me, would devote our efforts to integrate the information and interpret it in the context of ecosystem processes.

The rest of the group was completed by Lorenzo Rosenzweig, from the Mexican Fund for the Conservation of Nature (FMCN), who would photographically document the group's work; Ana Ezcurra, a book editor, who would be in charge of editorially formatting the material gathered during the expedition; Ralph Chaney, a San Diego videographer in charge of documenting the entire project in digital video images; Paula Ezcurra, a student of environmental sciences, responsible for supporting the general processing of samples and images; and, finally, Christian McDonald, SCUBA diving safety officer at Scripps, in charge of security during tank dives and of the expedition in general.

Most of the team members did not know each other until the expedition launch date, and the question of how this sudden and spontaneous expedition would work was floating in the air. Could we live together for ten days in harmony amidst the tension and stress of the expedition? Could we each make our visions and research focus compatible with those of the rest of the team, work in harmony, and deliver a quality product at the end of the expedition? Would we be able, as a group, to work together creatively?

This narrative is, in a way, the answer to those questions. An answer we did not have at the beginning, but that we found along the long journey.

Pages 30–31:
In Las Ánimas, some 120 meters deep, the lights of the submersible shine on a rocky mound with colonies of orange sea-fans *Ellisella limbaughi*, and a new species, still to be described, of a white sea-fan *Eugorgia* sp. Photo © Carlos Sánchez-Ortiz.



San Marcial

Octavio Aburto-Oropeza, Margarita Caso, Richard Cudney-Bueno, Brad Erisman, Exequiel Ezcurra, Lorenzo Rosenzweig, Carlos Sánchez-Ortiz, Francisco A. Solís-Marín, and Vivianne Solís-Weiss

Close-up view of an arm of the deep water sea star *Tethyaster canaliculatus*. Photo © Lorenzo Rosenzweig.

Seamounts cannot be seen with the naked eye. They lie below the surface and are only detectable through a depth sounder. The San Marcial seamount, or Bajo Sur de Catalana, the first seamount of our expedition, is found some eight nautical miles south of Isla Santa Catalina, the name given to this island by the Jesuits in the 18th century, or Isla Catalana, as the fishermen know it today.

Like all the other seamounts we explored in the Sea of Cortés, the San Marcial seamount is formed by the remains of an underwater volcano whose basalt column stretches upwards, short of a few meters of the surface. The mount has a rocky center that reaches in its shallowest part around ten meters below water, and is surrounded by a sandy platform that descends gradually towards the Gulf's depths. Because of the gradual slope of this seamount, outside the rocky center the seafloor is sandy, populated by a benthic fauna typical of sedimentary floors.

The shallow, rocky reef harbors many of the typical elements of shallow coastal communities of Baja California, like starfish and sea cucumbers, and a diverse array of reef fish. Unlike coastal reefs, however, it has an abundance and rich assemblage of soft corals, such as sea fans and black corals. They all feed on organic particles suspended in the water, and rely on intense currents and high productivity in the water column for their development. For example, the sun coral (*Tubastrea*) is seen here in great abundance, while it can only be observed in the coast in rocks protected within holes or crevices.

The typical rock corals of warm, shallow waters are not found here although they are common, for example, less than 150 miles south in Cabo Pulmo. These hard corals are internally colonized by dinoflagellates, symbiotic algae inside the polyp that form photosynthetic structures called "zooxanthellae" that contribute organic material to the coral colony's metabolism. All the corals observed at San Marcial, both in shallow and deep waters, lack zooxanthellae and thus their survival is completely dependent on the organic particles suspended in the water. This suggests that the water around this seamount is rich in nutrients.

Shallow zone

The rocky, shallow zones (less than 30 m deep) bordering the San Marcial seamount are inhabited by colorful species of echinoderms like the purple starfish (*Tamaria* sp.), the blue starfish (*Phataria unifascialis*), red starfish (*Pentaceraster cumingi*), chocolate starfish (*Nidorellia armata*), and yellow starfish *Pharia pyramidatus*. All these species are adapted to living on shallow reefs and feeding in a variety of ways. The flower urchin (*Toxopneustes roseus*), a common species found in the Gulf, together with the brown sea cucumber (*Isostichopus fuscus*), can be seen between the rocks, protected from the light that filters in at those depths. The latter, a delicacy in oriental cuisine and some countries in Europe, has been aggressively harvested since the 1980s. The federal government has now protected this species, and it is now the only echinoderm in Mexican waters protected by the International Convention on the Trade of Endangered Species (CITES).

Deep zone

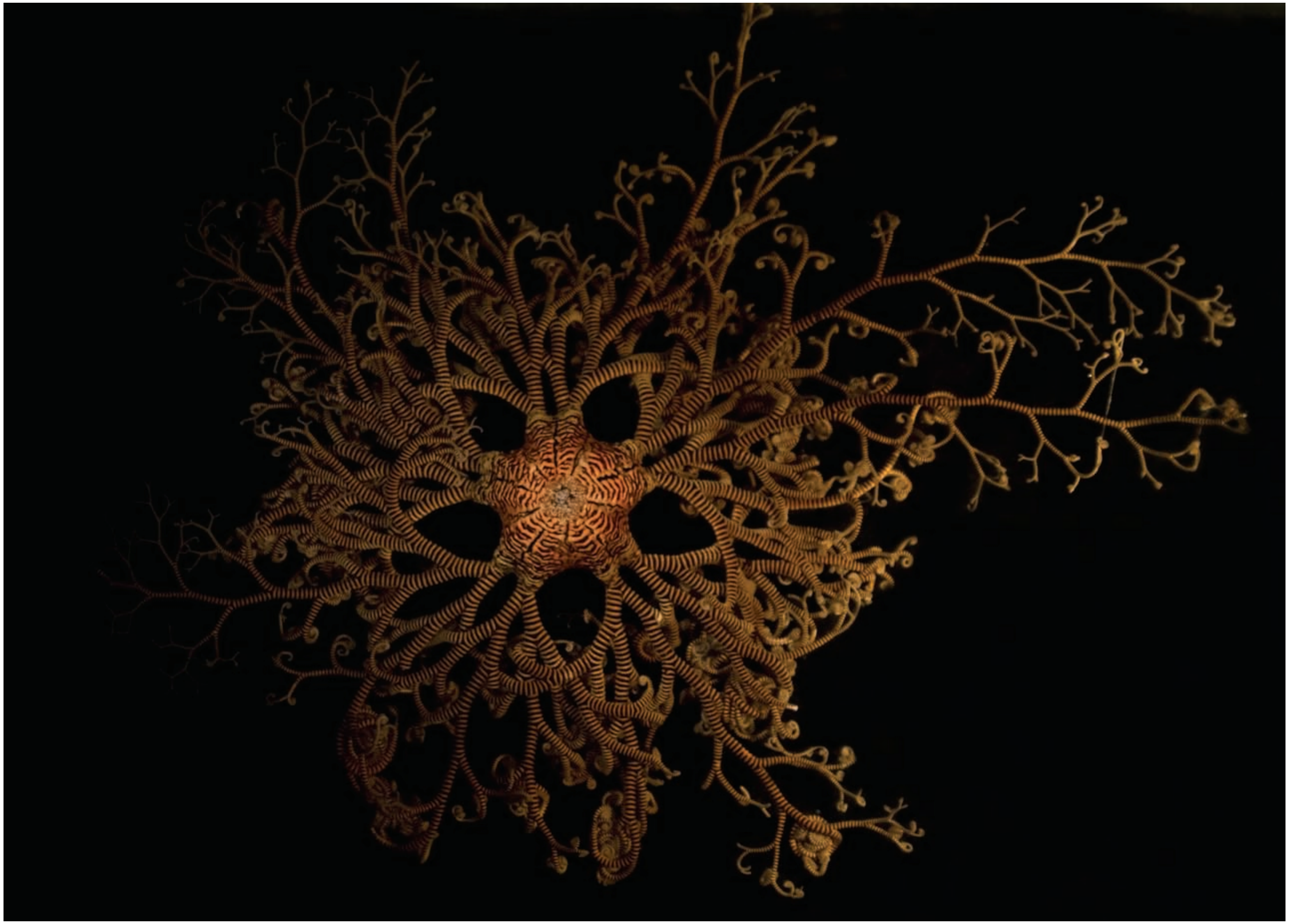
The sandy seafloor surrounding the large stone boulders show a typical sandy bottom assemblage of echinoderms: carnivore starfish like *Tethyaster canaliculatus*, *Luidia phragma*, *Luidia ludwigi ludwigi,* and *Narcissia gracilis,* crawl along the bottom looking for smaller prey such as mollusks and crustaceans. Because of their abundance, large populations of the ophiuran (brittle star) *Ophiolepis crassa* form extensive groups along the seafloor and feed on the detritus that falls down the water column. Close to the boulders, on the transitions from sand to rock, we found species of echinoderms adapted to these habitats: the starfish *Amphiaster insignis* and the basket

Top row,
left, *Tethyaster canaliculatus.* Photo © Paula Ezcurra;
center, *Pentaceraster cumingi.* Photo © Margarita Caso;
right, lower part or actinal zone of *Narcissia gracilis*. Photo © Margarita Caso.

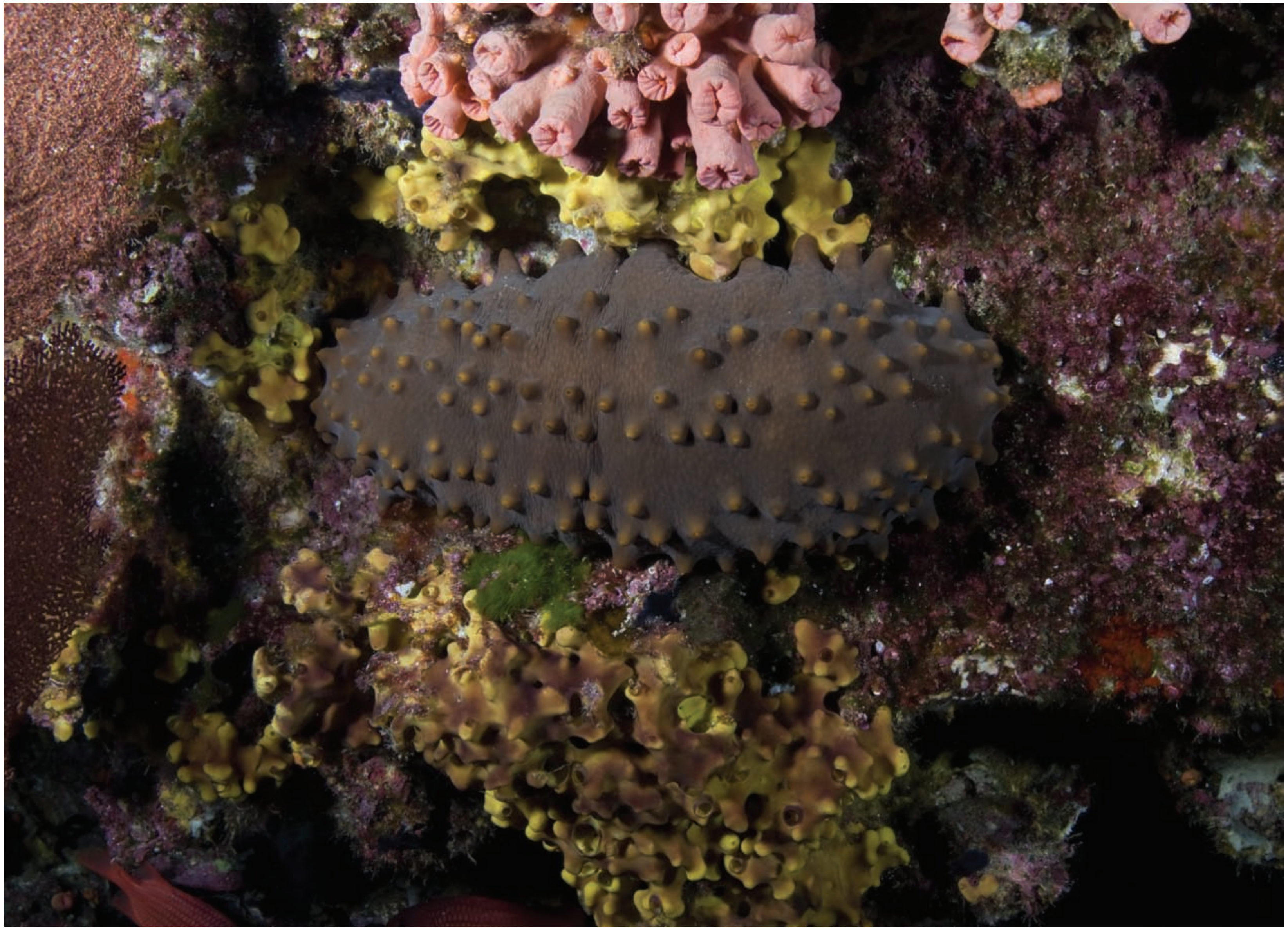
Lower row,
left, *Astereopsis espinosus.* Photo © Carlos Sánchez-Ortiz;
center, *Nidorellia armata*. Photo © Paula Ezcurra;
right lower part or actinal zone of *Pentaceraster cumingi*. Photo © Margarita Caso.





Basket star *Astrocaneum spinosum*
Photo © Carlos Sánchez-Ortiz.



Sea cucumber *Isostichopus fuscus* in its native rocky habitat.
Photo © Carlos Sánchez-Ortiz.

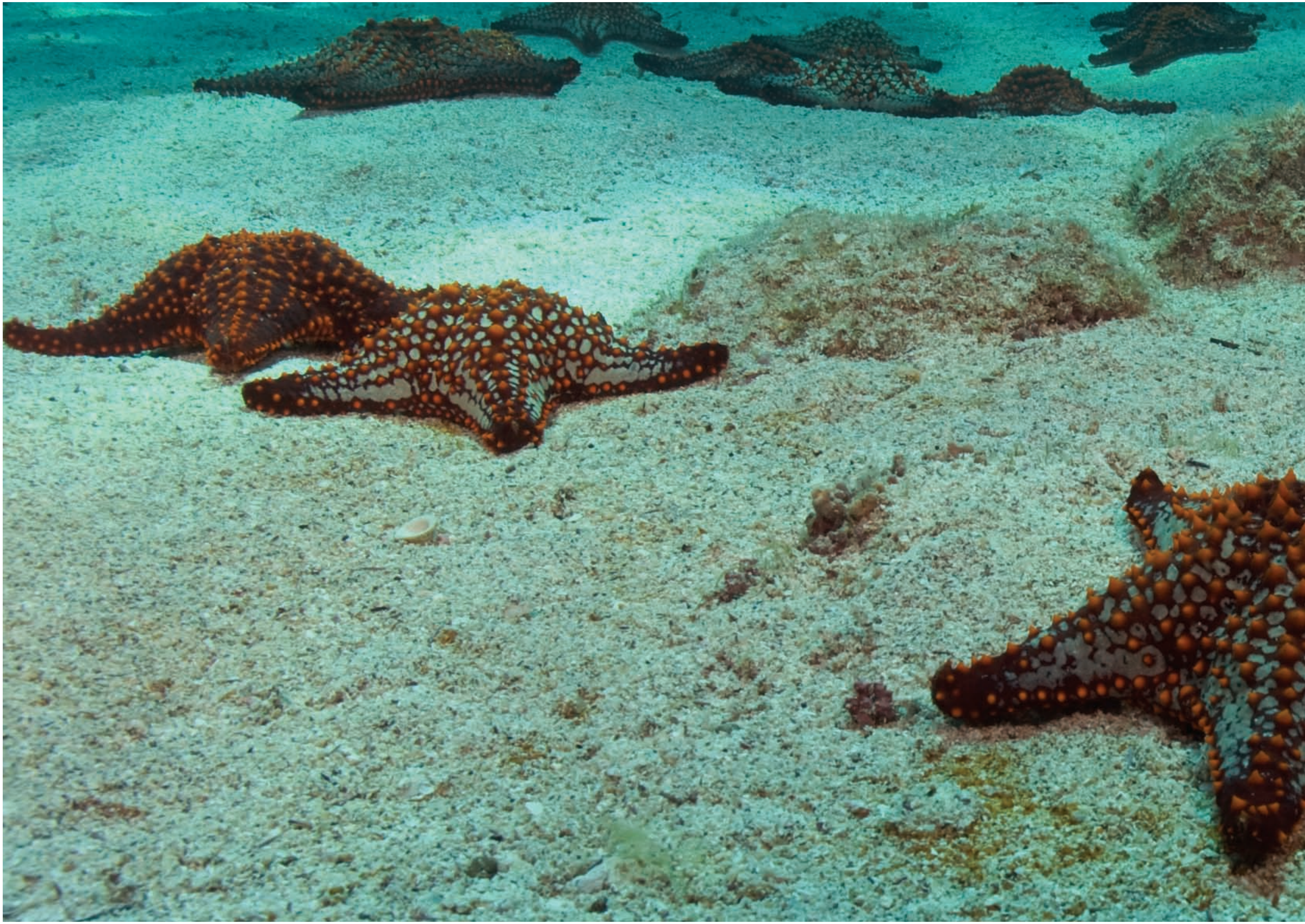
star *Astrocaneum spinosum*. The latter is amply distributed from shallow zones (12 m deep) in the Gulf of California to areas under 300 m; it is a carnivorous species that feeds at night on small fish and microcrustaceans, extending its long arms like a large, living cobweb to capture its prey. In the sandy seafloor at the San Marcial seamount, we observed a species of excavating sea urchin *Metalia espatagus*; a rare species, usually very difficult to observe in other parts of the Gulf. Here we saw dozens of its skeletons scattered throughout the seafloor, very possibly victims of the voracious *Cassis* mollusk.

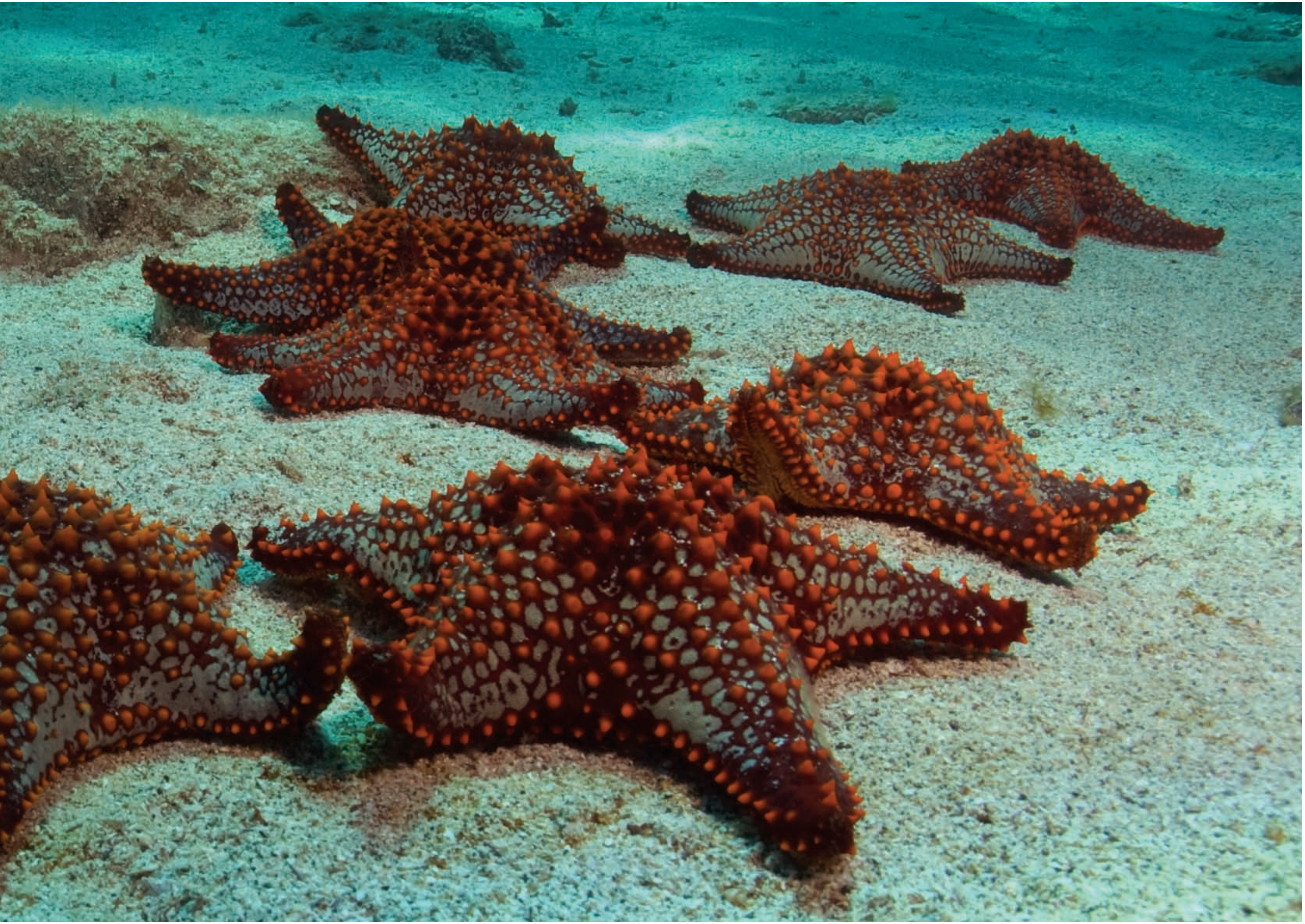
Despite the gradual slope and the predominant presence of sandy seafloors, several fish species were observed. At a depth of 100–120 m we observed various schools of small wrasses (Family Labridae) that experts could not identify. However, several months later ichthyologist and fish taxonomist Benjamin Victor from the Ocean Science Foundation recognized them from our photographs and video. The species was identified as *Halichoeres raesnori*, a rare wrasse that was only recently described from observations and collections at the Galapagos Islands. This finding is of the highest importance since this simple observation extends the distribution range of this species for several thousands of kilometers, and points towards the existence of an important biogeographical connection between the seamounts of the Gulf of California and the Galapagos reefs.

Two subsequent immersions confirmed the sandy-sedimentary nature of this seamount with the identification of several fish species typical of such environments, including several species of snake eels buried in the ocean floor sand with only their heads emerging. We also found tilefishes (*Caulolatilus affinis*) and catalufas (*Pristigenys serrula*) that had dwellings in small burrows and sand pits at the bottom. We saw a few swell sharks (*Cephaloscyllium ventriosum)* and banded guitarfish (*Zapteryx exasperata)*, two species typically associated with shallow waters in the Pacific near California. In the Gulf they search for dwellings in deeper waters to find similar temperatures. Lastly, we also observed a number of species belonging to the families Triglidae, Synodontidae, Paralichthyidae and Lophiidae.

At a depth of 25 meters in Bajo San Marcial a new species of fan coral in the genus *Muricea* is seen surrounded by rainbow and señorita wrasses — *Thalassoma lucasanum* and *Halichoeres dispilus*. Photo © Carlos Sánchez-Ortiz.

Pages 40–41:
Aggregation of sea stars *Pentaceraster cumingi* on a sandy bottom in San Dieguito. Photo © Octavio Aburto-Oropeza.





Chubasco

Exequiel Ezcurra

The great coastal deserts of the world—the Namib in southern Africa, Atacama in Chile, the coastal desert of Morocco in the African Sahara, and Baja California in Mexico—lie on the western margin of the American and African continents. They are associated with the cold currents that flow towards the equator on the eastern side of the Atlantic and the Pacific: the Benguela and the Humboldt currents in the southern hemisphere, and the Canaries and California currents in the northern one. Baja California is arid because the cold California Current runs along its Pacific coast, and the cold waters bring stability to the atmosphere, preventing the formation of large low-pressure centers, which bring rain.

But the peninsula is so long that the seasonality of rains changes dramatically from north to south. The north Pacific coast receives storms from December to March, when the prevailing northwesterly winds enter the winter-cooled coast condensing their moisture and discharging it over the land in seemingly endless days of gray skies and incessant showers. In the south, on the other hand, storms are brought by the late summer *chubascos*, when the tropical Pacific, heated up by the intense summer temperatures, starts to evaporate water into the atmosphere forming immense centers of low pressure over the ocean—the dreaded tropical cyclones. Most cyclones travel westward, away from Mexican coasts, fueled by the warm waters of the equatorial currents, but some head for the continent where they hit the coastal communities like a true wrath of nature. In southern Baja California's arid deserts, these late

Tropical storm Julio unleashes its full force on Baja California Sur on August 25, 2008 (MODIS satellite image, Goddard Space Flight Center, NASA).

summer downpours are the only significant source of water. Like a blessing in disguise, they unleash their fury of winds and rains only to disappear shortly after, leaving behind a trail of destruction in the form of floods, eroded fields, flooded cities, and mudslides; but also leaving oases filled with life, refilled springs, water-saturated soils, and a flowering desert whose greenness will last three or four months until once again everything dries up and life resumes its daily arid routine.

The sea whose cold currents bring aridity to the earth is the same one that brings the late summer chubascos. In Baja California, the desert and the sea depend on one another; without oceanic variations there would be no humidity on land, and without the occasional water pulses that drench the desert, the rivers and lagoons would run dry, mangroves would decline, and the life cycles of the coast would lose the vital inflow of nutrients that arrive to the sea with each storm.

On the morning of August 24 black clouds began to gather on the horizon just at the time when one of our groups was starting a SCUBA dive in the San Marcial reef and another was beginning an immersion in the submersible to explore the deepest part of the seamount. Two hours later the forecast was clear: A tropical storm was approaching Los Cabos and would travel north afterwards. The 2008 downpours were starting early, before the end of August. Prudently, Captain Mora decided to cancel the rest of the day's activities and seek refuge in Puerto Escondido, where we arrived around five o'clock in the middle of heavy rainfall.

At dawn the next day the wind gradually picked up, and by ten in the morning the tropical storm Julio had unleashed its full force upon the coast. Water cascaded impressively down from the high cliffs of the Sierra de la Giganta, and ran in torrents and floods towards the coastal plains in a ritual that nature repeats year after year. Chubascos and hurricanes, source of destruction and ravages, are also part of the life cycle of this incredible ecosystem.

As tropical storm Julio approaches the Gulf of California, the DeepSee submersible seeks refuge in its landing dock on the mother boat. Photo © Lorenzo Rosenzweig.

After the fury of tropical storm Julio had passed, giant waterfalls kept descending from the cliffs of Sierra del Tabor replenishing aquifers and feeding the coastal wetlands and mangrove lagoons of the Gulf of California. Photo © Paula Ezcurra.

Las Ánimas

Octavio Aburto-Oropeza, Margarita Caso, Richard Cudney-Bueno, Brad Erisman, Exequiel Ezcurra, Lorenzo Rosenzweig, Carlos Sánchez-Ortiz, Francisco A. Solís-Marín, and Vivianne Solís-Weiss

Amabulacral tube-feet in the actinal part of the sea star *Tethyaster canaliculatus*, used for locomotion on the sea floor. In the arm at the center of the image a small polychaete, which defends itself from predators by taking the color of its host, can be seen. Photo © Vivianne Solís-Weiss.

The Las Ánimas seamount breaks the water surface as a small rocky islet crowded by seabirds. The effect of the Las Ánimas seamount on the local fertility of the sea is evident in the concentration of cormorants, pelicans, frigate birds, and petrels, and in the intense white color of the guano that covers the emerging rocks. Las Ánimas, the second seamount in our expedition, is about 10 nautical miles east of Punta Calabozo, the northernmost point of San José Island.

Geologically, Las Ánimas is very similar to San Marcial: the islet is formed by the remains of a submarine volcano, whose basalt column rises 20 m above the water's surface, and slopes underwater along a pronounced incline down to a depth of 100 m. At that point, the slope changes to start descending gradually along an extensive sandy platform, approximately 7 kilometers (4 nautical miles) in diameter. At the margin, approximately 300 m deep, the eastern slope becomes pronounced once more and falls abruptly to the depths of Gulf of California.

We observed a great gathering of more than a thousand Pacific red snappers (*Lutjanus peru*), roaming around 40–80 m deep along the north side of the islet. A few small boats were fishing there, quickly filling their iceboxes with the fish that they captured every time they cast their lines. Among the Gulf's reef fishes, the red snapper has the highest commercial value and is highly demanded in fresh fish markets because of the excellent quality of its meat. We purchased a few samples from fishermen and performed dissections to confirm that the fish were spawning.

Octavio and Brad went on another immersion at dawn and could observe and film many species spawning, including yellow snapper (*Lutjanus argentiventris*), giant hawkfish (*Cirrhitus rivulatus*), pacific creolefish (*Paranthias colonus*), king angelfish (*Holacanthus passer*), and big-eye jacks (*Caranx sexfasciatum*).

Reviewing the video footage obtained here and the list of fish documented in this seamount, Las Ánimas seems to be very similar to the San Marcial seamount. A large part of the habitat was formed by rock debris and sandy slopes, inhabited by small garden eels and snake eels; as well as benthic fish like searobins, goosefishes, scorpionfishes, sand perch (*Diplectrum* spp.), blackspot wrasse (*Decadon melasma*), and seabases (*Pronotogrammus multifasciatus*). In the rocky patches we observed California sheephead (*Semicossyphus pulcher*), sawtail groupers (*Mycteroperca prionura*), Mexican goatfish (*Mulloidichthys dentatus*), yellow snappers (*Lutjanus argentiventris*), rainbow basslets (*Liopropoma fasciatum*), and scythe-marked butterfly fish (*Prognathodes falcifer*).

Shallow zone

At this seamount we found a considerable cover of green algae, common in coralline environments, as well crustose red algae. The cup coral *Tubastrea coccinea* dominates the sessile fauna and is ubiquitous throughout the seamount. There was also a large amount of sea fans (gorgonians of the genus *Muricea*). A particular and unique trait of this seamount was the presence of very large specimens of the bivalve mollusk *Pinctada mazatlanica*. The

A Pacific mutton hamlet, or "guaseta", *Alphestes immaculatus* finds refuge and camouflage in the colonies of the sea-fan *Muricea appressa*.
Photo © Octavio Aburto-Oropeza.

Above: Zebra moray *Gymnomuraena zebra* and orange cup-coral *Tubastraea coccinea* at Bajo Las Ánimas. Photo © Carlos Sánchez-Ortiz.
Left: A group of green morays *Gymnothorax castaneus* surrounded by soldier-fish *Myripristis leiognathus*. Photo © Octavio Aburto-Oropeza.

same crustose algal growth that covers the neighboring rocks is also found covering the shells of this mollusk, forming a hard substrate that shelters a great variety of small crustaceans and polychaetes. This helps the mollusk blend in with the surrounding landscape, with its covering substrate as a cryptic camouflage that possibly protects individuals from predators.

The shallow zones in Las Ánimas contain a rich and varied array of echinoderm species that prosper in the different microhabitats of the reef. Numerous species of starfish live on the rocks, predominantly *Nidorellia armata*, *Narcissia gracilis* and *Phataria unifascialis*. The small purple urchin (*Arbacia incisa*) is most abundant among the sea urchins. Several species of micro-ophiurans inhabit the soft coral branches, gripping them with their six arms. The rocky areas hide a small oasis of sand that houses species like the burrowing sea urchin (*Brissus obesus*) and the sand-bottom sea cucumber (*Holothuria impatiens*).

Between the cracks in the rocks of Las Ánimas we also found numerous, large green moray eels (*Gymnothorax castaneus*); on one occasion there were seven of them in a single crevice. There were also zebra morays (*Gymnomuraena zebra*), although these were more rare. The density of reef fish species in this seamount was impressive, bearing witness to the high productivity of this site possibly aided in part by the nutrients derived from bird guano that runs-off from the emerged rocks into the surrounding waters. There was also a great diversity of small polychaetes and crustaceans in general, with dominance of species from the families Syllidae and Eunicidae.

During the first SCUBA dive we visited a cave where the walls were densely populated with the same encrusted life forms as in the exterior rocks, at least for the first few meters. Hidden deep in the bottom we found several large lobsters (*Panulirus inflatus*)and an enormous and

Aniculus elegans, the giant Gulf of California hermit crab. Photo © Octavio Aburto-Oropeza.

spectacularly beautiful hermit crab belonging to the species *Aniculus elegans*.

The large gorgonians often show basket starfish wrapped around them, differently colored and mimicking the coral branches. There were large tubular, yellow sponges, and others that form yellow carpets (*Aplysinia fistularis*), irregularly shaped and about a meter to 80 cm in diameter.

During the dive we observed that the bottom between 15 and 40 m deep was covered almost entirely with live coral (*Tubsatrea coccinea*), which was very hard to pull off. Dead coral was below the permissible depth with Nitrox, so we collected sandy substrate and large seashells, mainly mother-of-pearl (*Pinctada mazatlanica*). These substrates shelter cirratulid polychaetes of the family Phyllodocidae, easily distinguishable by their green color; and serpullidae polychaetes that stand out for their red color and their sensitive crests that retract when they feel any disturbance. We also collected specimens from the families Polynoidae, Eunicidae, Terebellidae, Sabellidae (a *Megalomma* crown), and Amphinomidae (*Eurythoe complanata* and *Chloeia* sp.).

Deep zone

While exploring the seamount at 190 m, we stumbled upon an area with small, loose rocks. Among them, hiding from the submersible's light we found a small starfish (*Rathbunaster californicus*) with multiple arms. This fragile and seemingly harmless starfish is a terrible predator of other invertebrates. Its body is covered with thousands of pedicellariae or "tube-feet", small structures that act like tiny claws, biting everything in the sea star's path.

In a steep, sandy slope, we observed an echinoderm fauna associated to these types of seafloors, including a purple sea cucumber, *Holothuria* (*Vaneyothuria*) *zacae*, which is very common here but previously poorly documented; the starfish

Testa (skeleton) of the heart urchin *Brissus obessus*. Photo © Lorenzo Rosenzweig.

Pages 58–59:
Ambulacral tube-feet, or podia, in the ray arms and feeding orifice area of the carnivorous sea star *Heliaster kubinijii*. Photo © Lorenzo Rosenzweig.

Astropecten ornatissimus and *Narcissia gracilis*, that singly patrol the seafloors in search for food; the armored urchin *Hesperocidaris asteriscos,* which we found in small populations, sparsely scattered in the sandy areas, an unexpected encounter being that they usually prefer rocky areas. We also found scattered at the bottom some skeletons of *Metalia espatagus* and in some cases we could observe spiny starfish, *Amphiaster insignis,* feeding on the remains of these sea urchins, a behavior never before seen.

On a rocky slope located on the seamount wall at 200 m deep, we found an extensive population of *Ophiothrix galapagensis*, an ophiuran with lively orange and red colors that cropped-up right before our eyes as the submersible's light shined upon the specimens. They live under the rocks, only showing their arms capturing fine particles of food falling from the distant surface in the form of organic detritus.

The crustose red algae were always present, even in small rocks. Several stingrays and a couple of guitarfish swam close to the seafloor, and in the sandy parts we saw black-spotted brown sea cucumbers (*Brandthoturia impatiens*) scattered on the seafloor. Finally, we were able to collect a sample of *Conus*, a gastropod whose shell can reach a high commercial value.

In our second immersion at this seamount, at a depth of 180 m, we found a dense community of bottom-dwelling invertebrates, mainly hermit crabs that congregate densely in some patches of sand (20 individuals or more per m^2). As we travelled deeper the abundance of urchins and sea pens increased. A few oval flounders (*Syacium ovale*) swam among these invertebrates, as well as scorpion fish (*Pontinus clemensi* and *P. furcirhinus).* Octopuses, the most active species, dragged themselves over the seafloor and abruptly changed color when the

Colony of orange cup-corals
Tubastraea coccinea.
Photo © Lorenzo Beltrán.

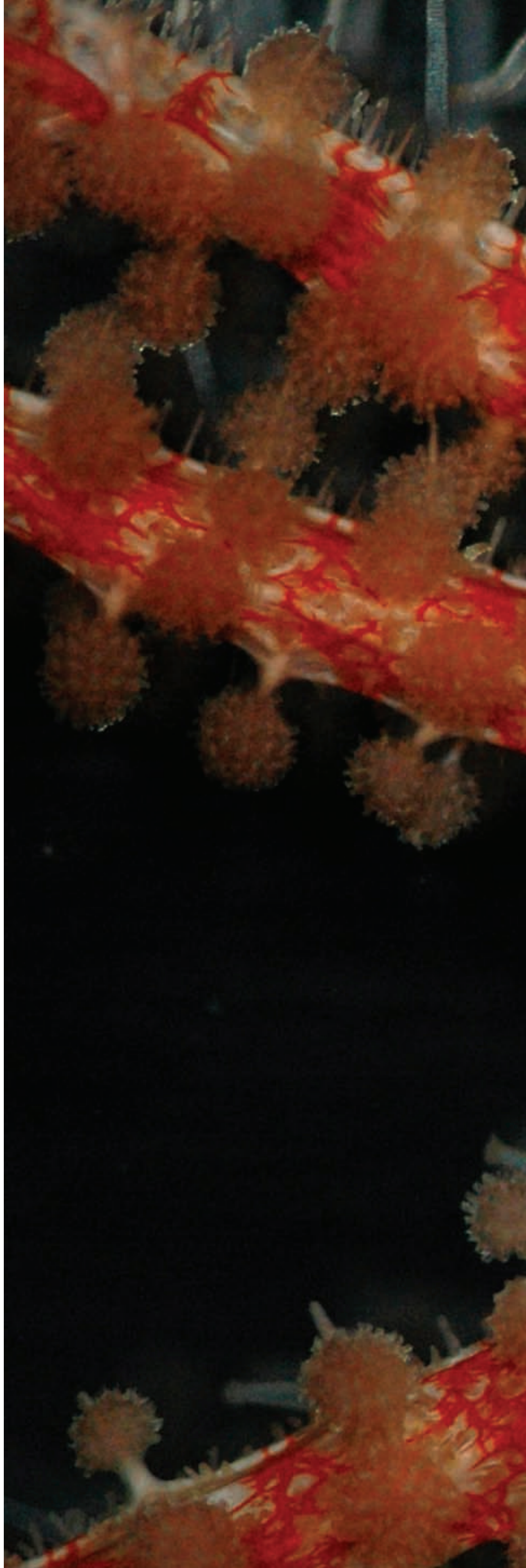
submersible illuminated the seascape. On two occasions we were able to observe the octopuses feed, using their tentacles to dig in the sand and bring the food to their mouths.

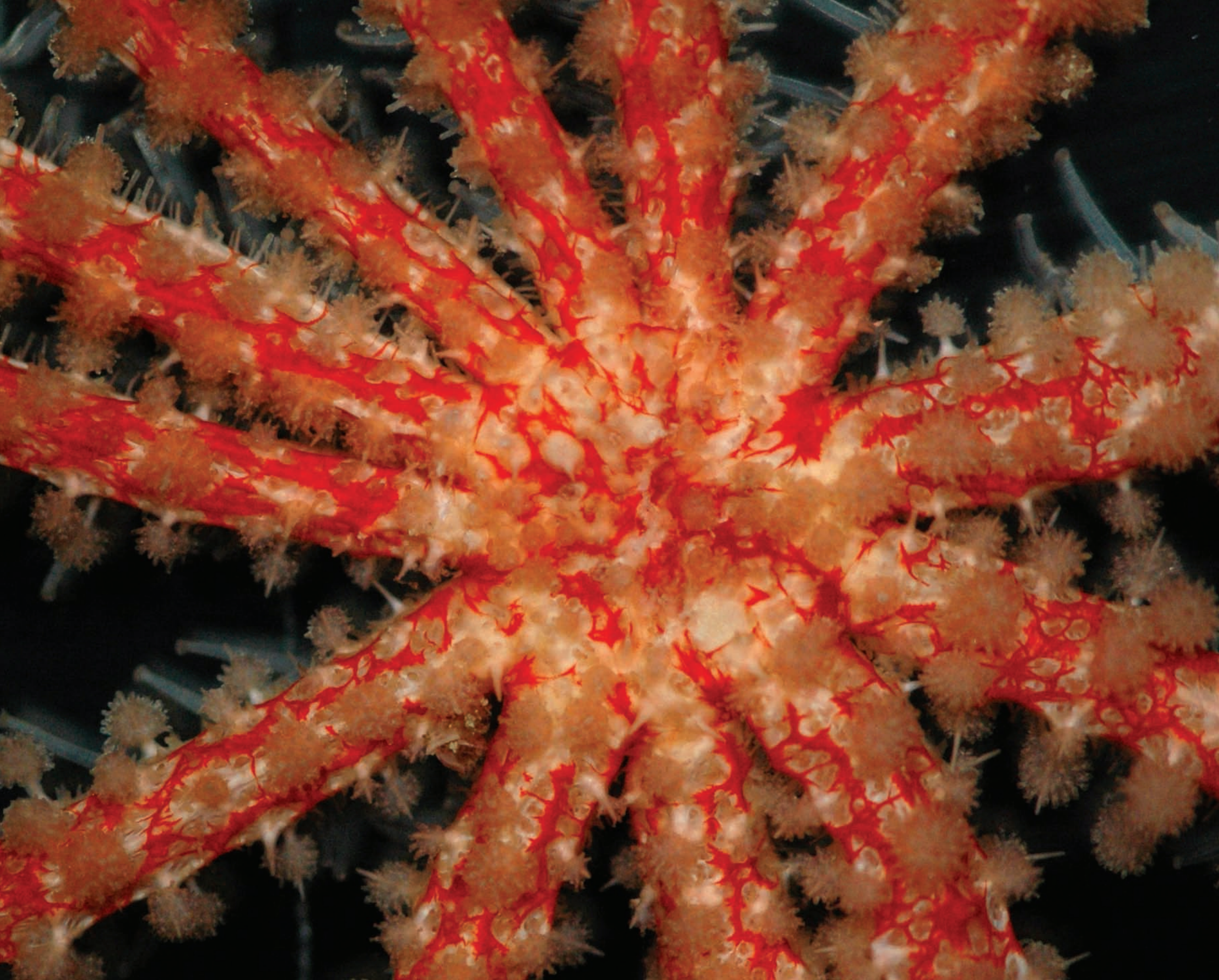
The marine community here is typical of subtidal communities with soft bottoms and no vegetation. The patchy distribution is an important aspect, driven by predation and natural disturbances that are provoked by excavating species (possibly sea cucumbers and oysters). Although we did not observe a high density of sea pens (pennatulaceans), they are the principal structural components of the habitat, acting as fixers of the bottom substrate. In other latitudes, these beds of sea pens are the habitat of specific marine communities, where nudibranchs and starfish are the main predators. In the sandy bottom, two small rocks (1 m^2) formed an oasis in the monotonous sand plane, sheltering a large amount of brittle stars, hermit crabs, and sand crabs.

We were able to observe an extremely interesting species of jawfish (Opistognathidae) in the sandy seafloor, about 100 m below the surface. It was a little less than half a meter long and had streaks of vibrant green color through the length of its body. We managed to film it and turn the images over to Richard Rosenblatt, a Scripps expert in jawfishes (Opistognathidae) from the eastern Pacific. He informed us that surely this was a new species, and that he had never seen a specimen like it before.

Ambulacral tube-feet and feeding orifice of the sea star *Coronaster marchenus*. Photo © Lorenzo Rosenzweig.

Pages 64–65:
Barber-fish *Johnrandallia nigrirostris* and hogfish *Bodianus diplotaenia* swimming in Bajo Las Ánimas among seafan colonies of ochre-colored *Muricea appressa* and white *Muricea austera*. Photo © Octavio Aburto-Oropeza.





Spawning aggregations

Octavio Aburto-Oropeza, Richard Cudney-Bueno, and Brad Erisman

Spawning aggregations —hundreds of thousands of fish coming together simultaneously to reproduce— are one of the most impressive biological events in the marine environment. These congregations are carried out by many different species at given times of the year, during a specific lunar phase (mostly full moon or new moon), and in locations with very specific characteristics. Seamounts, in particular, are typical habitats where spawning groups are frequently observed, mainly because of the presence of strong currents and upwelling, pronounced slopes, and a great variety of benthic species like black corals and sea fans that cover the seafloor and provide shelter for many fish species.

Spawning aggregations are, indeed, impressive events to watch. The sheer number of fish that cover the seascape is in itself imposing, but the behavior and color display of each individual makes the spectacle truly amazing. In most species, males become floating rainbows, trying to impress the females with the metallic blue and green colors in their heads, fins, and tails. Meanwhile, the females display their bulging bellies where they keep thousands of eggs that will be released for fertilization by the gametes of more than a dozen males. Courtship usually begins in the early hours of the afternoon when the schools begin to condense and each male tries to remain close to a selected female until spawning time. At dusk, females begin to repeatedly rise to the surface to immediately

An aggregation of yellow snappers *Lutjanus argentiventris* showing the swollen abdomens of the females before spawning. Photo © Octavio Aburto-Oropeza.

descend towards the rocky bottoms. Dozens of males surround them, but only the fastest and most vigorous manage to keep up with their ups and downs. Finally, the time comes. The sun has disappeared below the horizon and the twilight barely allows one to see the immense fish clusters, formed now by each individual female and her many suitors, ascending towards the surface like fireworks whose flares are actually bursts of milt and eggs released close to the surface. Finally, the frenzy stops and, in total darkness, the reef becomes quiet and calm until the next reproductive event of the following day.

Group spawning usually continues for several days or even weeks, often associated with the moon-driven tidal currents that disperse the eggs and larvae away from the spawning site. Seamounts and rocky reefs are extremely important places for the procreation of marine life, functioning as life-generating sources from where larvae are dispersed into the wider sea. There are two important elements that allow the identification of a spawning aggregation event. First, the density of individuals increases at least one order of magnitude above the normal density of the species. Secondly, the individuals migrate to specific locations that may be at considerable distances from their usual home ranges. These two characteristics, together with the fact that spawning locations are predictable because of their association with seamounts and reefs, make reproductive aggregations inherently vulnerable to fishing activities. In a few hours, with a small boat and using a gill net (*chinchorro*), a single fisherman can remove several tons of actively spawning fish, preventing them from completing their life cycle and from producing millions of fertilized eggs needed to renew the populations in the future. In fact, the staggering increase of fishing pressure over spawning aggregation sites has caused an alarming decrease in species with gregarious reproduction, a fact that threatens to drive these species towards extinction in many parts of the world.

Spawning run of the Gulf grunion *Leuresthes sardina* endemic to the Gulf of California. Photo © Octavio Aburto-Oropeza.

Pages 70–71: Aggregation of leopard groupers *Mycteroperca rosacea*, a species of high commercial value. Photo © Octavio Aburto-Oropeza.

Several species of sharks, stingrays, groupers, snappers, jacks, and parrotfish form spawning groups in the Gulf of California, and all of them are targets for commercial fishing, sportfishing, and traditional fishing. Despite the attention this region has drawn as one of the most biologically diverse seas of the world, few efforts have been made to study, manage and conserve these reproductive phenomena. Examples of the most impressive spawning aggregations are the corvinas, including the totoaba, which form massive aggregations in spring to reproduce at the Colorado River delta. With its steel blue color, two meters in length, and weighing over 100 kilograms, the totoaba once crowded the delta waters during their reproductive migration time at the end of spring. At the beginning of the 20th century, the species was so abundant that the great fish could be caught from boats or even from the shore with merely a hand-held harpoon. In 1943, 2,000 tons were landed, the maximum capture ever recorded. In 1975, the year in which totoaba fishing was finally prohibited, a decrease in fresh water in the delta and the uncontrolled fishing of the species had reduced the populations and collapsed the fishery to less than 20 tons a year. The totoaba is one of the few commercial fish species included in the list of protected species in Mexico. The Gulf corvina, a species taxonomically close to the totoaba and also a beneficiary of the rich ecosystem of the Colorado River delta, faces now in the 21st Century a similar history of exploitation — a product of unregulated and excessive catches during their reproductive activities. If this scenario continues, it is possible that the Gulf corvina will face the same destiny as all species that form aggregations to reproduce in the spring (a period of high demand for fishing products as it coincides with the Catholic time of Lent).

During our stay at Las Animas we had the opportunity to observe one of the most spectacular reproductive events we have ever observed at a seamount. Temperature was

Fishery of the Gulf corvina (a croaker) at Golfo de Santa Clara in the Colorado River Delta. Photo © Octavio Aburto-Oropeza.

ideal (>28°C), it was only half an hour before sunset, and the currents were strong. We jumped into the water and swam until we found a place protected from the currents where we could get a better view of the spectacle that was developing. The yellow snappers (*Lutjanus argentriventris*) started first, forming compact groups of 30 to 50 individuals that came in and out between the crevices and cavities of the rocks. The red heads, which show up from the yellow bodies during reproductive season, stood out against the turquoise water and the shadows of the nooks and cracks where the courtship took place. Soon, three other species of snappers appeared—Pacific dog snapper (*Lutjanus novemfasciatus*), mullet snapper (*L. aratus*), and Mexican barred snapper (*Hoplopagrus guentherii*)—whose abundance and bright colors left no doubt about their reproductive condition. These species normally display their courtship between the rocks and near the surface, approaching and then retreating away from the reef, so it is very difficult to observe and document their reproductive behavior. In contrast, benthic species use the reef to dance and flirt before spawning. Males generally compete for the best territory to captivate more than one female. In fact, we were surrounded by male giant hawkfish (*Cirrithus rivulatus*). The males with territories, known in behavioral ecology as "alpha males", fought against males that were not able to secure a territory of their own, known as "satellite males" because they constantly swim around occupied territories trying to reproduce with one of the three to five females that have been secured by the alpha males. When the time comes, alpha males start to swim frantically with the females, one at a time, distancing themselves from the rock to the surface, where they release a small cloud of gametes. The satellite males take advantage of the opportunity to seduce one of the females that remain in the territory, so they too can swim to the surface and release their sperm in the cloud of eggs that the female spawns. The dominant male usually notices this and chases away the opportunist, then comes back quickly to reproduce as soon as possible with the female seduced by the impostor. This is repeated countless times during the 20 minutes that the reproductive activity lasts, requiring an impressive amount of energy from the alpha males, the strongest and biggest males of the reef.

That day at Las Animas, we were lucky enough to observe at least 14 species of fish and two species of mollusks (red clam and black mussel snail) in a reproductive frenzy that we had never witnessed before. The climax of the event happened towards the end when dozens of Pacific creolefish (*Paranthias colonus*) covered the landscape and began to spawn in clusters of fish balls near the surface. This species is currently one of the main coastal fisheries in the region and is known by the fishers as "sandía" ("watermelon" in Spanish). The name refers to the red coloration that the individuals acquire during the reproductive season, which becomes apparent mainly in the caudal fin that has a crescent shape like a red watermelon slice. If this name, on the one hand, demonstrates the close relationship fishers have with the resources they catch, it also highlights one of our greatest weaknesses in the sustainable use of fisheries: the high correlation between the reproductive seasons and the main fishing seasons.

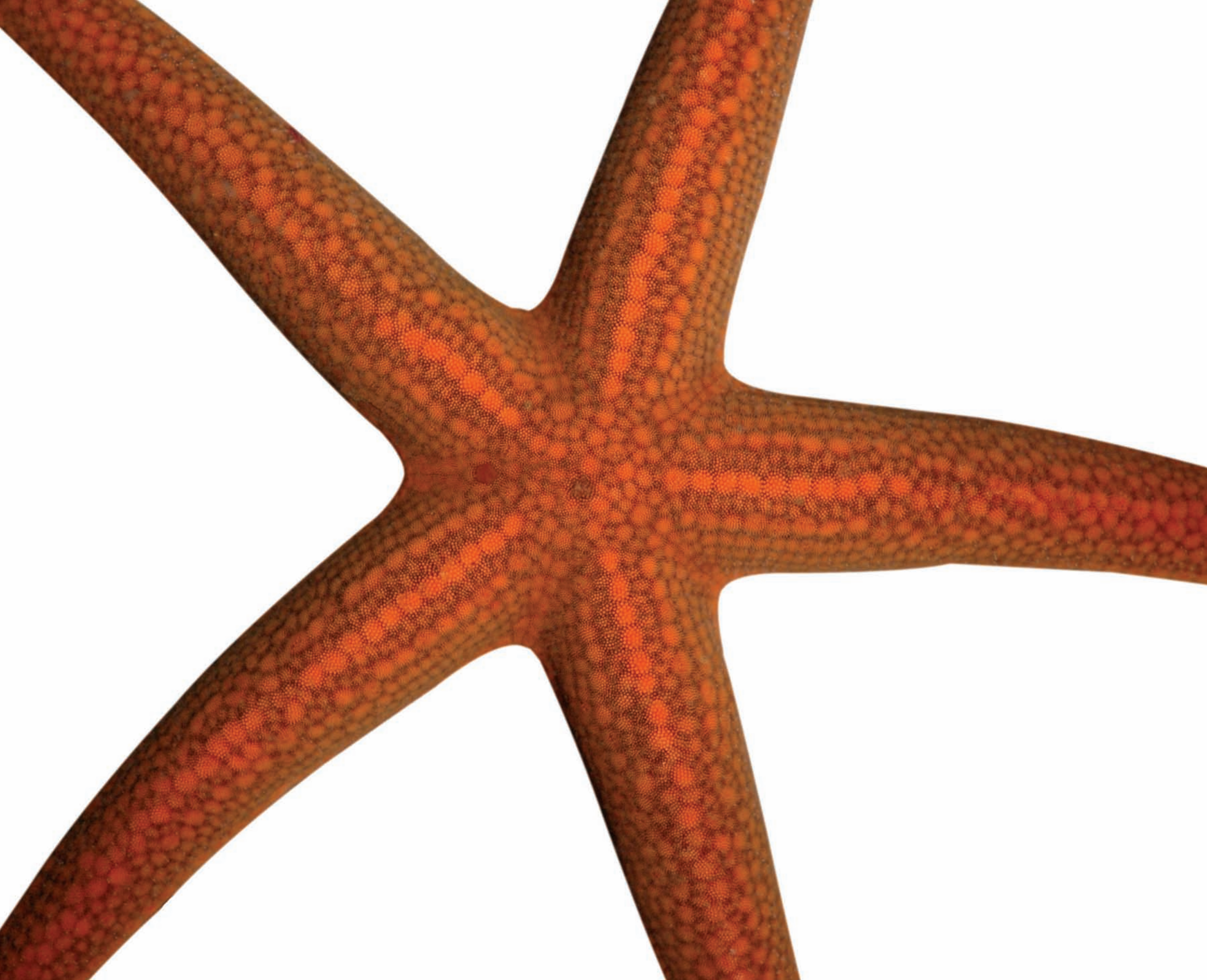
Over the last three decades there has been an enormous increase in fishing pressure in many areas of the Gulf of California, which has resulted in substantial decreases in the landings of many gregarious species. For example, fish like the Gulf Grouper (*Mycteroperca jordani*), Goliath Grouper (*Epinephelus itajara*), and Broomtail Grouper (*Mycteroperca xenarcha*) represented important fisheries in the 1970s, but today have collapsed. Fisheries are now concentrating in congregations of smaller fish, like seabasses, snappers, and parrot fish, many of which are also decreasing.

The crisis facing the conservation of spawning aggregations has been globally recognized. As a result of this growing concern, a "Call for Action" was subscribed in the second International Tropical Marine Ecosystems Management Symposium (ITMESM) in March of 2003. The key recommendation was:

Fish spawning aggregations must be conserved through sturdy management strategies. This should include, to the extent possible, complete protection to ensure the permanence of the populations that make up these aggregations, the integrity of the reef ecosystem, and the sustainability and food supply for the communities that depend on these gregarious species.

It is obvious that these reproductive aggregations need to receive more attention from fishing administrators and the general public, and at the same time, that the vulnerability of this ecological process needs to be placed as a top priority in conservation, research and management agendas. The time has come for large-scale collaboration between the interested parties to protect and conserve spawning aggregations in all marine ecosystems.

Advertising reproductive maturity with red coloration, a school of creolefish *Paranthias colonus* aggregates to spawn.
Photo © Octavio Aburto-Oropeza.



Marisla

Octavio Aburto-Oropeza, Margarita Caso, Richard Cudney-Bueno, Brad Erisman, Exequiel Ezcurra, Lorenzo Rosenzweig, Carlos Sánchez-Ortiz, Francisco A. Solís-Marín, and Vivianne Solís-Weiss

Sea star *Narcissia gracilis.*
Photo © Lorenzo Rosenzweig.

The Marisla seamount—known also in oceanography literature by its acronym in Spanish, "EBES" (meaning "El Bajo de Espiritu Santo"), and known by fishermen simply as "El Bajo"—is located some ten nautical miles northeast of Los Islotes, the northern tip of Espiritu Santo island. The shallowest part is 15 m deep. This seamount is part of a bathymetrically complex region and a pronounced submarine relief west of the Farallón deep basin, where depth surpasses one thousand meters. Two submarine seamounts rise to near the surface around 150 km north of the mouth of the Gulf: the Marisla seamount, subject of our submarine exploration, and the El Charro seamount, 12 kilometers east, which does not appear in navigation charts but is well known among local fishermen because of its richness of fish.

The upper part of the seamount ends in two peaks that reach very near the surface, both less than 20 m deep and at a distance of ca. 100 m from each other and linked by a submarine valley some 100 m deep. With steep slopes, the Marisla seamount descends abruptly in its northern side over 400 m deep along a sheer wall of basalt rock.

The Marisla seamount is recognized by both fishermen and scientists alike as a place where different pelagic fish species congregate in large densities, including tuna, marlin, giant mantas, whale shark, and large aggregations of hammerhead sharks. During summer and fall, thermal conditions prevail that are typical of tropical seas, with surface temperatures between 25° and 29°C. During the rest of the year oceanographic conditions are subtropical, with water temperatures between 19° and 24°C.

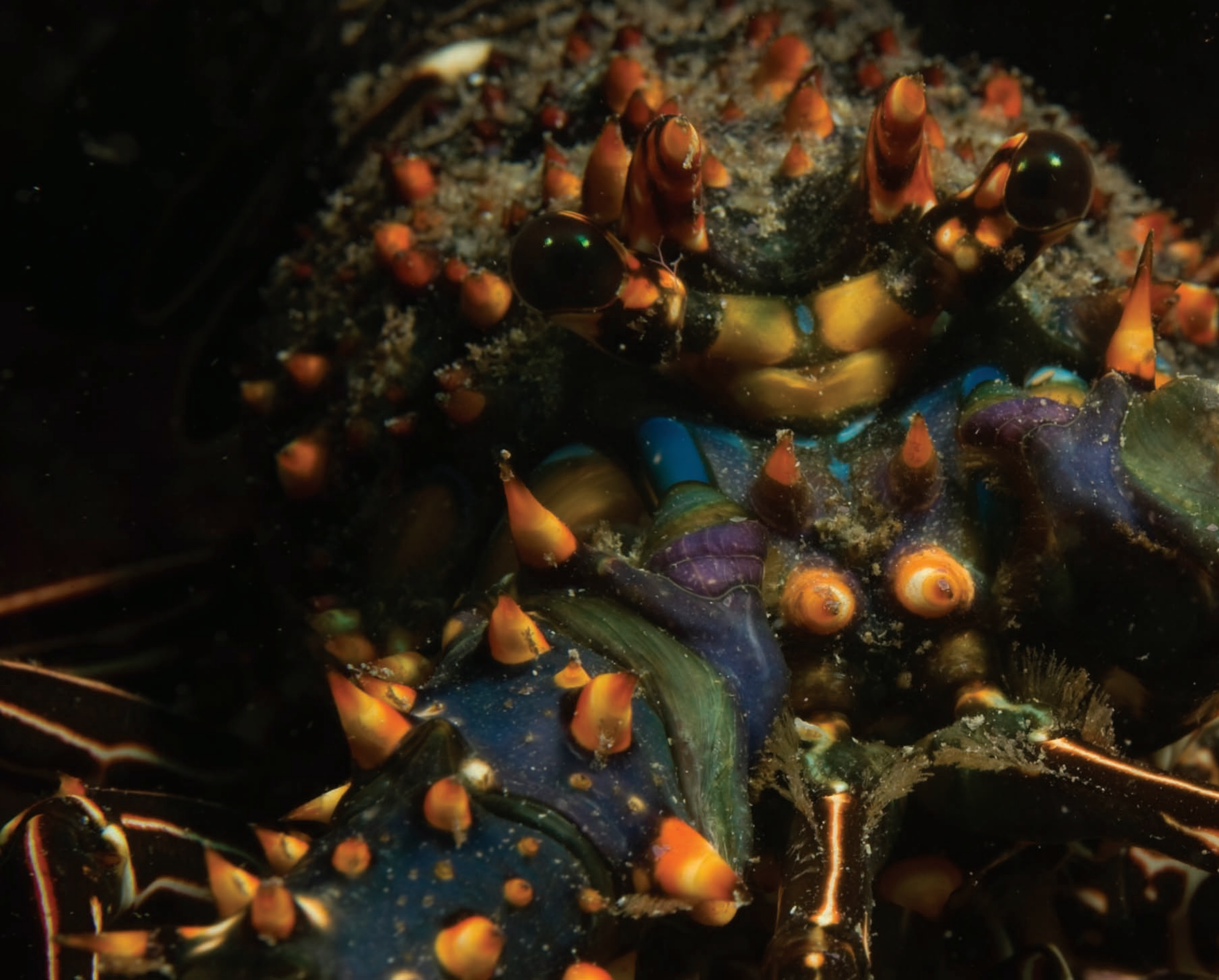
Of all the seamounts we visited, Marisla offered by far the greatest diversity in types of habitats and fish species of the entire expedition. The upper part of the seamount consists of rocky reefs whose volcanic rock walls dive abruptly to depths of 300 m or more. The larger near-surface reefs are formed by immense basalt boulders with extremely steep lateral slopes. These large reef rocks are separated by deep underwater canyons with bottoms of accumulated sand and rubble.

Shallow zone

In the different SCUBA diving explorations that we did over this seamount we observed dense gardens of corals, crustose red algae, and foliose green and brown algae, growing in association with a large number of anemones. Two species of moray eels were seen frequently, clustered in cavities and crannies, and many different species of fish were seen swimming around the reef in great numbers. On the 29th a whale shark joined us and playfully swam around the boat for almost the entire day, and on the 30th a very large and rather sociable sea lion approached us while we were diving.

At this seamount we saw an *Acanthaster* starfish and we could observe in detail a very interesting form of commensalism between a polychaete and an echinoderm. The guest, a polynoid probably belonging to the genus *Malmgreniella*, was a much smaller than its host, an ophiuran (*Ophionereis perplexa*). The polychaete's dorsal colors and texture were strikingly similar to the ophiuran's arm, around

Imitating the colors of its host, the ophiuran *Ophionereis annulata*, a polinoid polychaete funds refuge and food in the arms of this delicate brittle-star. Photo © Octavio Aburto-Oropeza.



Blue lobster *Panulirus inflatus*,
a species of great commercial value.
Photo © Octavio Aburto-Oropeza.

which the small worm wraps itself apparently finding refuge against possible predators.

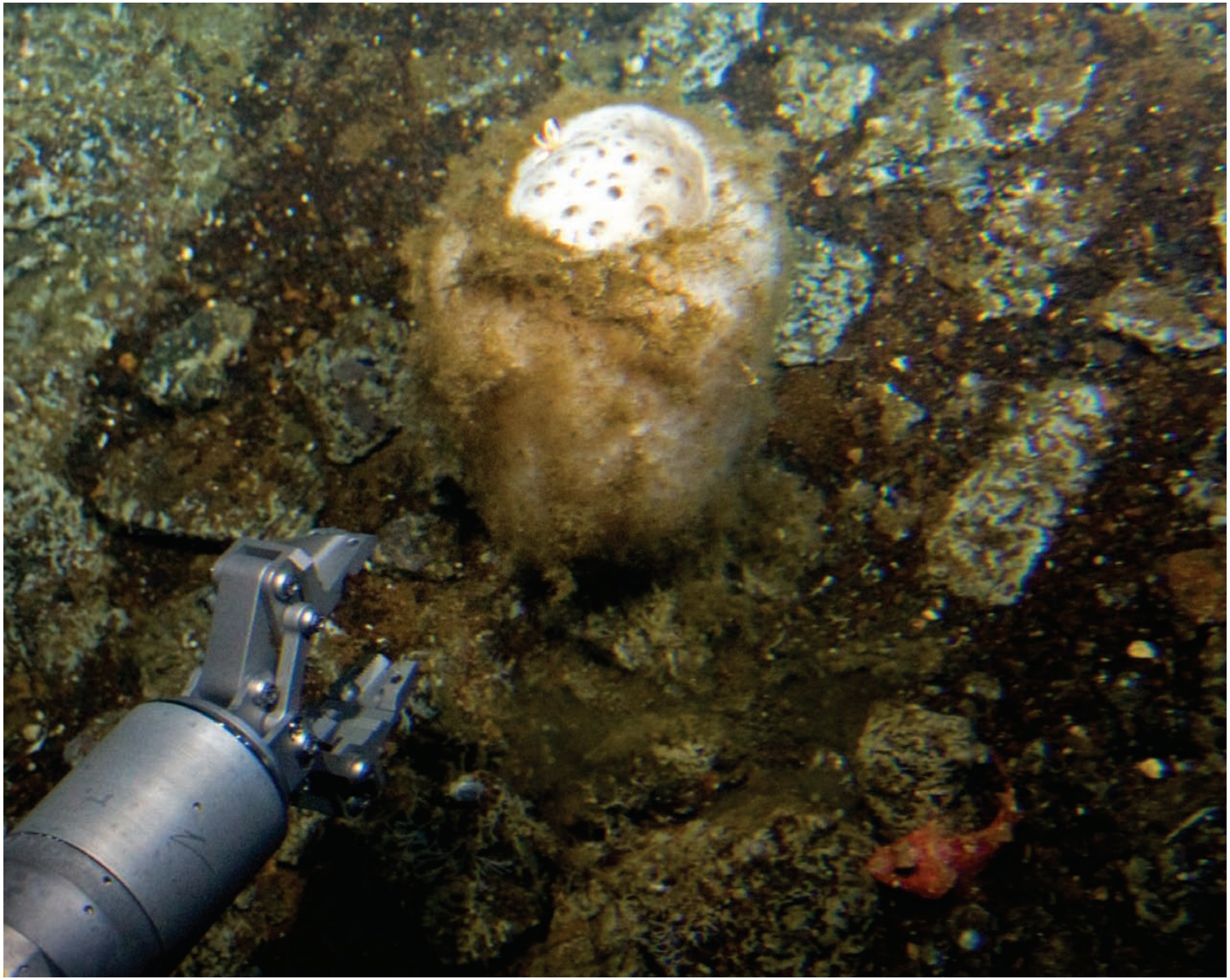
We also observed a polychaete attached to the inferior part of the arm of a large red-and-white starfish (*Tethyaster canalicalatus*). Although we could not confirm the exact nature of this novel interaction, it could have been a form of external parasitism, commensalism, or even mutualism. Research on this interesting interaction process is still under way through the specimens collected.

Deep zone

We explored the rocky zone along a steep slope at a depth of 190 m where, in an area dominated by sessile fauna like glass sponges and soft corals, we found some scattered specimens of two species of white starfish *Henricia clarkii* and *Henricia nana*. The most common echinoderms in this area were two species of ophiurans, *Ophiothrix galapagensis* and *Ophiacantha* cf. *diplasia*, which almost completely cover some deep areas of the Marisla seamount with dense populations of hundreds of individuals. In this deep rocky zone where we also found a new species of echinoderm: a small pale yellow starfish belonging to the family Echinasteridae that is being currently studied by specialists.

We collected black coral with associated polychaetes living in the branches. Among them we found a nereidid living in a transparent chitinous tube attached along one of the coral's branches, a very unusual trait in these polychaetes that usually wander and are active hunters. Other polychaete species included a polinoid worm, a few terebellids, and a second species of the family Nereididae, in this case without a chitin tube, as is the norm for the group. There was also a very small crystal-like ophiuran —possibly belonging to a new and yet undescribed species currently under study for its taxonomic description— and two very small red planarians.

A deepwater ofiuran, or brittle-star, *Ophiothrix galapagensis*. Photo © Carlos Sánchez-Ortiz.



A glass-sponge in the class Hexactinellida, collected at a depth of 320 meters in Bajo Marisla. Photo © Carlos Sánchez-Ortiz.

The next day (August 29th) we collected a very large glass sponge, a smaller sponge, a dead coral that harbored a myriad of minute ophiurans, so small that you could hardly see them, as well as a live black coral with polychaetes attached to its branches. Among them there was a phyllodocid inside a tube made of grains of sand, which is very unusual in this family, and a spawning terebellid female, as well as a polinoid. On August 30th we ran into another very large glass sponge, around 70 cm tall. It grew surrounded by a horizontal accumulation of volcanic rock, and in its interior we could see (although we were not able to collect) a large starfish and a crab, as well as a small black urchin, possibly of the genus *Diadema*. Its exterior was covered by dark green hydroids that had nematocysts with powerful stinging capabilities, which we witnessed back in the boat when we dipped our hands into the container that held the sponge.

We also found a high diversity of fish taking shelter between the cracks and crevices of the rocks, including species from the families Antennariidae, Lophiidae, Labridae, Muraenidae, Ophichthidae, and Scorpaenidae. The catalufas (*Pristigenys serrula*) were dominant in this landscape. However, the most remarkable species of all was a black cusk eel (Ophidiidae) that we were able to capture on film. We have covered all the field guides available and talked to the best specialists in the Marine Vertebrate Collection at Scripps, but so far no one has been able to identify this species beyond the family level.

In the sand and ruble slopes we observed fish communities similar to the ones we saw in San Marcial, with searobins, scorpionfish, and lizardfish, and particular species like the swell sharks (*Cephaloscyllium ventriosum*). Other species in the families the Moridae, Callionymidae, Rajidae, and Dasyatidae were also observed.

At a depth of 200 m we were able to spot a mobula ray (*Mobula thurstoni*) swimming around the reef. This deep swimming behavior in a planktivorous, shallow-water species has also been observed in Cocos Island, in the Pacific coast of Costa Rica, but the reasons for this conduct are not known. It is possible that the amount of suspended nutrients in the water surrounding the seamount are high even at those depths, and that the deep immersion of these rays is the result of a search for food.

Another important event was our encounter with a star-studded grouper (*Epinephelus niphobles*) in the Marisla seamount. During our ten day expedition, we failed to observe it anywhere else but here. This species is incredibly important for the commercial fisheries in the Gulf of California, and its low density, as well as its decrease in capture volumes, suggests that it is being devastated by overfishing. This is the first documentation of this species in the Gulf of California, observed alive in its natural habitat.

Finally, as we descended towards the reef in the evening, we saw an immense reproductive aggregation of pacific dog snapper, *Lutjanus novemfasciatus* (some 300 fish, 30–50 m deep), together with another group of yellow snapper (*L. argentiventris*) roaming the nearby rocks. Despite being affected by overfishing, the richness and diversity of Marisla is still exceptional in this region.

Deepwater sea-anemone (possibly belonging in the genus *Antiparactis*), found living in association with the sea-fan Leptogorgia chilensis at Bajo Las Ánimas. Photo © Carlos Sánchez-Ortiz.

Richness and productivity

Exequiel Ezcurra

One of the most remarkable observations made during our immersions into the deep waters was the presence of an intense green layer of water that gradually appeared between 40 and 80 m below the surface. The color inside the submersible's cabin changed from dark blue to intensely green tones, and the blurry texture of the water was a clear signal that we were crossing through a layer where waters of different temperatures and salinities mixed. The intense green coloring betrayed the abundance of chlorophyll-a suspended in the water column; that is, a high density of microscopic phytoplankton algae. This phenomenon has been studied in the Gulf of California and described in detail by a group of prominent Mexican scientists from several regional research centers, who have demonstrated that around these seamounts there is a layer of water with rapidly changing density called the pycnocline, where the colder water from the deep meets the warmer surface layer, and where the majority of biological productivity concentrates. In the green color of this marine stratum was in large part the key to the richness in the seamounts we visited during our expedition.

Paradoxically, in order to understand the ecology of the underwater seamounts it is helpful to think about the ecology of mountains on land. Scientists on land, especially those who work with desert ecosystems, know that the mountains generate their own climate. The winds that ascend through the hillsides decompress and cool down as they

Thousands of tons of sardines concentrate in large schools in the Gulf of California. Photo © Octavio Aburto-Oropeza.

move upwards, condensing moisture that falls in the form of rain or fog over the highest slopes, feeding the springs that descend in torrents through canyons and streams. The desert explorers know that, when a mountain emerges from the arid plains, they will find with certainty abundant life and an immense biological diversity accumulated in montane scrubs and forests and in moisture-laden oases in the foothills. It is a rule of thumb of biological geography: relief generates richness, abundance, and diversity.

Although from the surface, all water bodies seem uniform, something similar occurs under the sea. Marine life is not distributed homogenously throughout the ocean; rather it accumulates near the coasts and the shallow seafloor. Marine biomass and diversity decrease as we move away from the coast to the open sea, and the general explanation for this is very much like that of the mountains on land: through upwellings, turbulent currents, and hard substrate for sessile life, the coastal relief maintains the water's productivity and nourishes an abundance of marine life.

The upwelling and high concentration of nutrients that occur near the coasts, together with the abundant light of shallow waters, allow phytoplankton —microscopic algae— to grow abundantly in these coastal environments, nurturing at the same time the food chain of the sea. These highly productive shallow areas include, among other regions, seamounts and ocean islands. The biological richness and elevated productivity of seamounts is due to a complex series of factors. On the one hand, the substrate is in itself an important factor: the seamounts and islets of the Gulf of California are immense volcanic headlands that emerge from the bottom of the sea and offer a rocky substrate where sessile or reef life forms (corals, mollusks, echinoderms, and reef fish among many others) can establish and prosper, at the same time providing sustenance for other elements in the complex food chain of these ecosystems.

Sea-fan colonies with *Muricea appressa*, *Muricea austera*, and *Muricea fruticosa* in Bajo Marisla. Seamounts concentrate primary productivity, evidenced by the green water color and the high density of suspensivorous (particle-eating) species such as sea-fans. Photo © Octavio Aburto-Oropeza.

Pages 94–95:
Voracious and agile predators, a group of green jacks *Caranx caballus* attacks a school of sardines. Photo © Octavio Aburto-Oropeza.

On the other hand, the seamounts produce an irregularity in the movement of currents, with associated turbulence that leads to the mixing of surface water with deep water that ascends from the depths, colder and loaded with nutrients. Thus, the vertical disturbance that the slopes of the seamounts produce on the currents drives the dynamic instability of the water column, mixing the deep and the surface waters. The contribution of seamounts and islets to the production of eddies, with vertical disturbance of the water column, the upwelling of deep water, and the vertical mixing of water layers, together with the effects of adequate substrate, ecological shelter, and protected habitats, allow the proliferation of life in the seamounts. This life is often visible to the naked eye through the green coloring of the water that indicates a great concentration of phytoplankton and high marine productivity. Just like the ascending movement of the air maintains the climate in the mountains on land, the complex movements of the water and ocean currents around the seamounts maintain its richness and productivity. The phenomenon attracts individuals that travel long distances to participate in the feeding feast. In the Gulf of California, a great number of pelagic fish crown the top of the seamounts in immense feeding and reproductive aggregations.

Additionally, in the southern peninsular coast of the Gulf of California, between La Paz and Loreto, the great biogeographical connectivity is another element that bolsters the richness and biological diversity of the local seamounts. Geographically linked to the tropical seas of the south of Mexico, connected to the north with the cold waters of the gulf's Midriff region (Tiburón and Ángel de la Guarda islands), and influenced by the California Current that flows close nearby, to the other side of the Cape, the seamounts of the south of the peninsula are a real hotspot of geographic transition. Their waters, frequently stirred-up by hurricanes and local winds, such as the winter and spring "toritos", and the "coromuel" that blows from the Bay of La Paz in summer and fall, their waters are driven by strong flows that transport larvae and plankton organisms from other regions, maintaining a constant supply of new migrant species that settle in these seamounts and increase their richness.

In all our immersions, with small variation, the pattern was the same: we began the immersion over a dark blue layer of surface waters—the euphotic zone, where the sun's light penetrates with greater intensity. The color of the water changed gradually towards a green transitional stratum with a high concentration of phytoplankton, where marine productivity is at its maximum and below which light quickly disappears. It is from this stratum that the greater part of the biota from upper levels of water feeds and this appears to be the key to the biological richness in the seamounts and islets of the Gulf. Below 100 m, we entered a darker zone marked by a rain of organic detritus from higher water levels and with little life, possibly because of the lack of oxygen that this organic matter produces, similar to the conditions in "dead zones" that appear at river mouths and estuaries contaminated by an excess of organic material. At approximately 170 m deep we passed a new transitional layer; darkness was now complete —the disphotic zone—water became finally transparent, the detritus rain stopped, and biological abundance returned but with new, very different species, like the strange corals of the deep seafloor. We were finally in the deep waters of the seamounts, in the depths of the Gulf of California where everything seems to be unexplored and the amazing submarine landscape is filled with new and unexpected things.

Like the mountains on land, under the sea the relief of the seamounts is a vital source of productivity and biological diversity.

Yellow snappers
Lutjanus argentiventris display their courtship behavior: In a dense reproductive aggregation, the individuals move frantically around the crevices and cavities of the reefs, searching for a mate. Photo © Octavio Aburto-Oropeza.

San Dieguito

Octavio Aburto-Oropeza, Margarita Caso, Richard Cudney-Bueno, Brad Erisman,
Exequiel Ezcurra, Lorenzo Rosenzweig, Carlos Sánchez-Ortiz,
Francisco A. Solís-Marín, and Vivianne Solís-Weiss

Sea star *Pharia pyramidatus*.
Photo © Lorenzo Rosenzweig.

This group of shallow banks harbors several seamounts and reefs, product of the volcanic cone that formed San Diego Island, a small island between the larger San Jorge and Santa Cruz. In the shallowest part, the San Dieguito seamount (25°10'N, 110°44'W) lies 5 to 10 m below the surface of the water, two nautical miles southeast of the island of the same name. The El Rifle seamount runs along a line of shallow rocks, 1 to 2 m deep, in a southwest direction from the western tip of San Diego Island. It descends onto a sandy bottom towards the San José channel to the west and towards the deep gulf basin to the east.

The immersions in the submersible produced scanty information on deep water reefs. Below the shallow waters, at depths below 30–40 m, the rocky habitat disappears into gently-sloping sandy bottoms, where we could not locate steep slopes from where to dive deeper. In spite of this, we were able to observe dense groups of spotted rose snapper (*Lutjanus guttatus*), green jacks (*Caranx caballus*), conger eels, scorpionfishes, and several species of manta rays belonging to the families Dasyatidae and Rajidae.

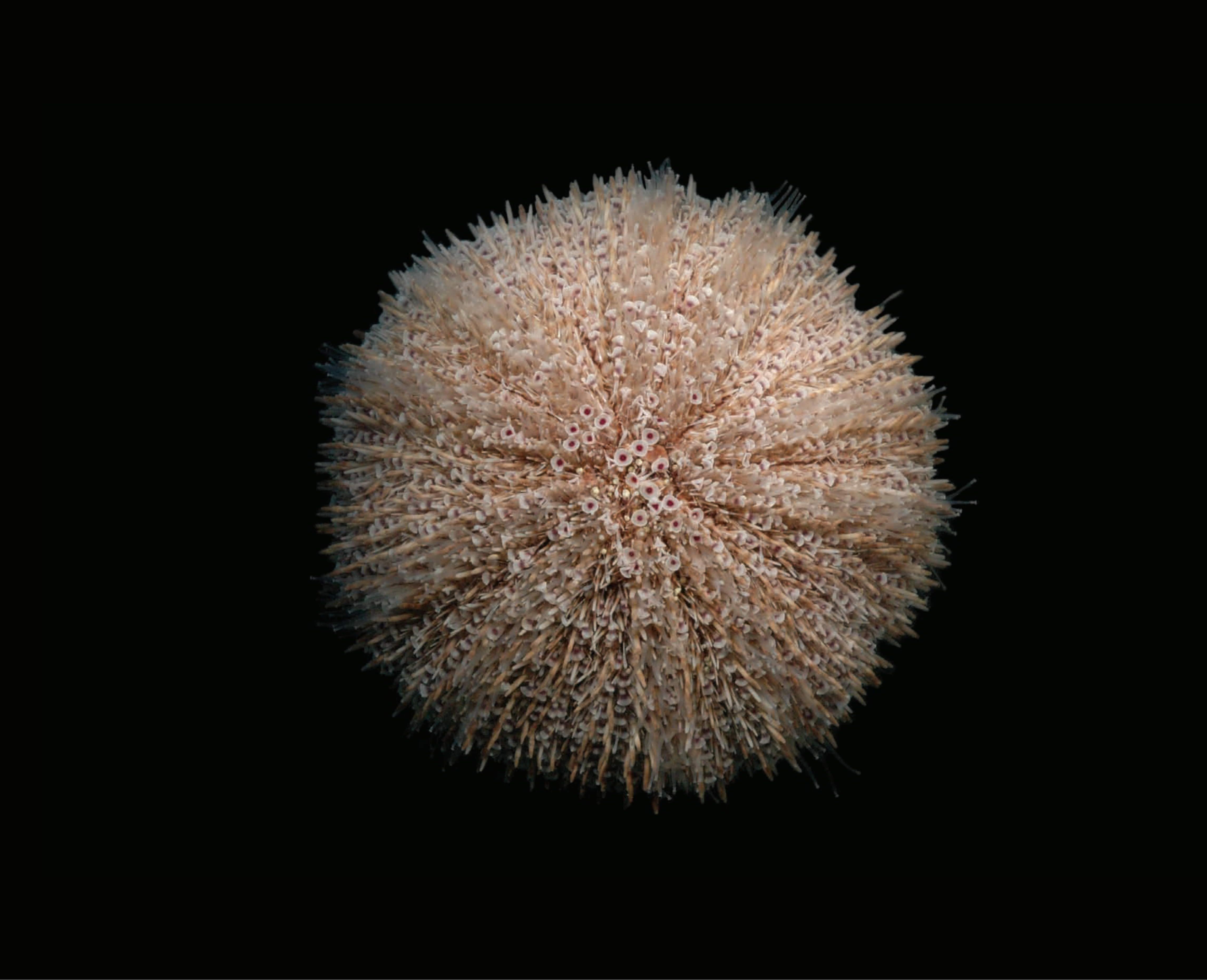
Shallow zone

In the surface water, the shallow platform of the San Dieguito reefs (10–11 m deep) revealed a rich and diverse community of echinoderms, typical of coral reefs. In this habitat more than 15 species of starfish, ophiurans, sea urchins, and sea cucumbers cluster in complex micro-habitats. The most typical species of the reef zone are the sea urchins *Toxopneustes roseus* and *Arbacia incisa*, the red starfish *Mithrodia bradleyi*, the starfish *Eucidaris thouarsii*, and the ophiurans *Ophioderma variegatum* and *Ophionereis perplexa*. The sandy areas that surround the reef zone shelter a cryptic fauna like the fragile sea urchin *Lovenia cordiformis*, also called sea mouse because of its appearance, and the sand dollar/heart urchin *Brissus obesus*.

We also observed some sabelid tubes in the sand, as well as a specimen of *Bispira* (a filtrating sessile polychaete, quite similar to the sabelids). There were many sea urchins of the genus *Diadema*, all of them very small, and we saw a large, black nudibranch, and two polynoids. We also collected a blue, relatively small medusa (4 to 5 cm long), commonly known as "Portuguese man-o-war" (probably *Physalia utrilculus).*

Flower sea-urchin *Toxopneustes roseus*.
Photo © Lorenzo Rosenzweig.

Pages 104–105:
Surgeon-fish *Prionurus punctatus*, a colorful species of herbivorous fish, congregate in schools to feed on the filamentous algae that cover the rocks of the reef. Photo © Octavio Aburto-Oropeza.



Life zones

Carlos Sánchez-Ortiz

Between the surface euphotic zone (above the picnocline, 0 to 150–200 m deep), and the deep disphotic zone (below the picnocline, over 150 m deep) a marked contrast exists in taxonomic families, genera, and species composition. While in the surface zone we found families of sponges, corals, crustaceans and mollusks of tropical-subtropical origin, both from Indo-Pacific and Eastern Tropical Pacific origin, the families and species in the deep zone were mostly of temperate and cold-temperate origin, reported in the deep cold water zones of Canada, Alaska, and the North Sea.

Shallow zone

Seamount communities near the surface zone do not form a gradual continuum from the surface to the 150–200 m, but rather the majority of species show a discontinuous distribution, grouping into two sub-zones: (a) a shallow surface subzone above 50 m deep, and (b) an intermediate surface subzone (or sub-euphotic subzone) between 50 and 150–200 m. Both of these habitats are biologically connected by the presence of evolutionarily related families and genera (unlike the deep zone where many groups have different evolutionary origins), but at the species level the layers are different.

Shallow surface subzone. This shallow and warmer layer is dominated by the presence of species of tropical and subtropical origins, like sponges (*Aplysina* cf. *fistularis* and

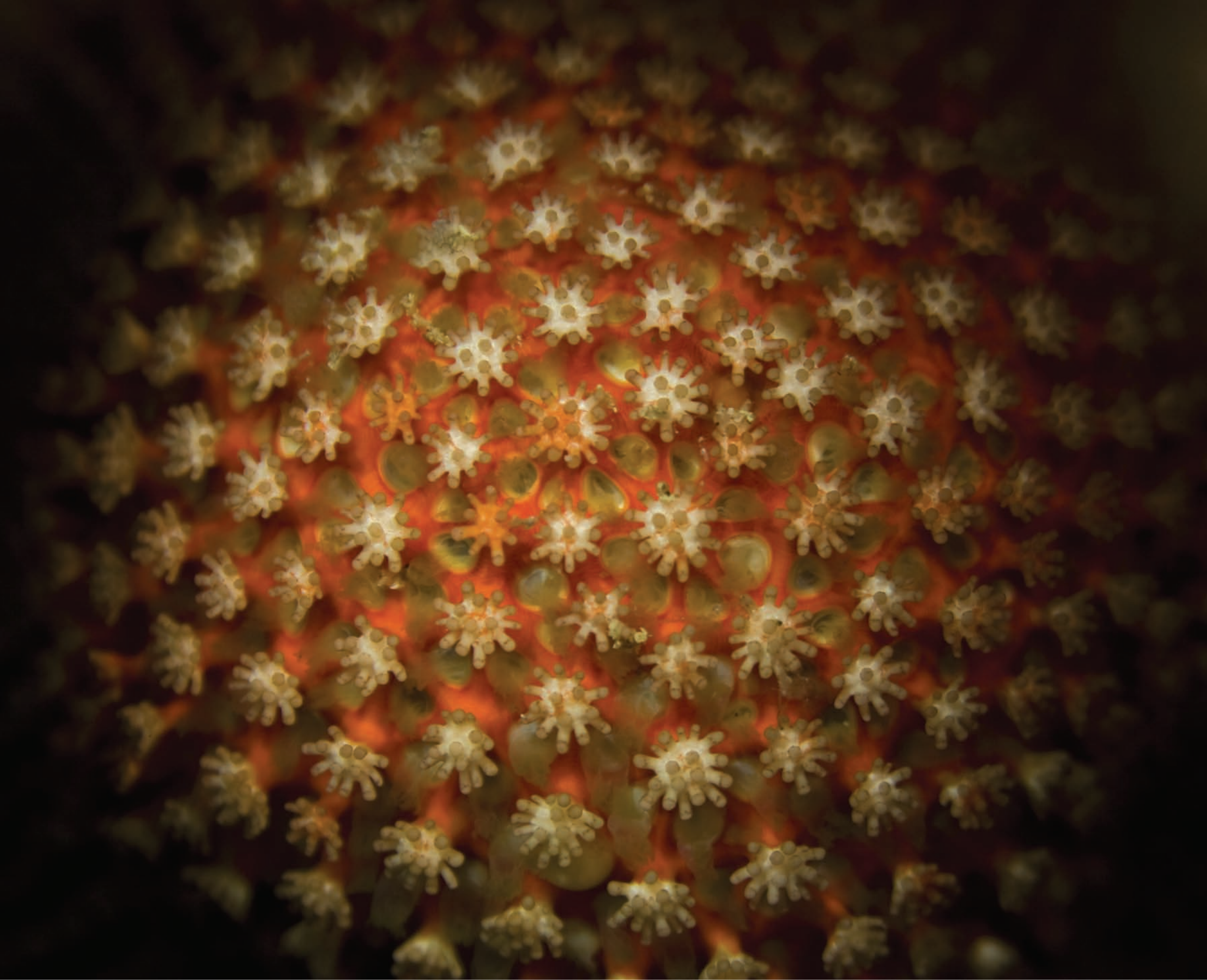
Soldier-fish *Myripristis leiognathus*, of nocturnal habits, find refuge during the day in the crevices of rocky reefs. Photo © Octavio Aburto-Oropeza.

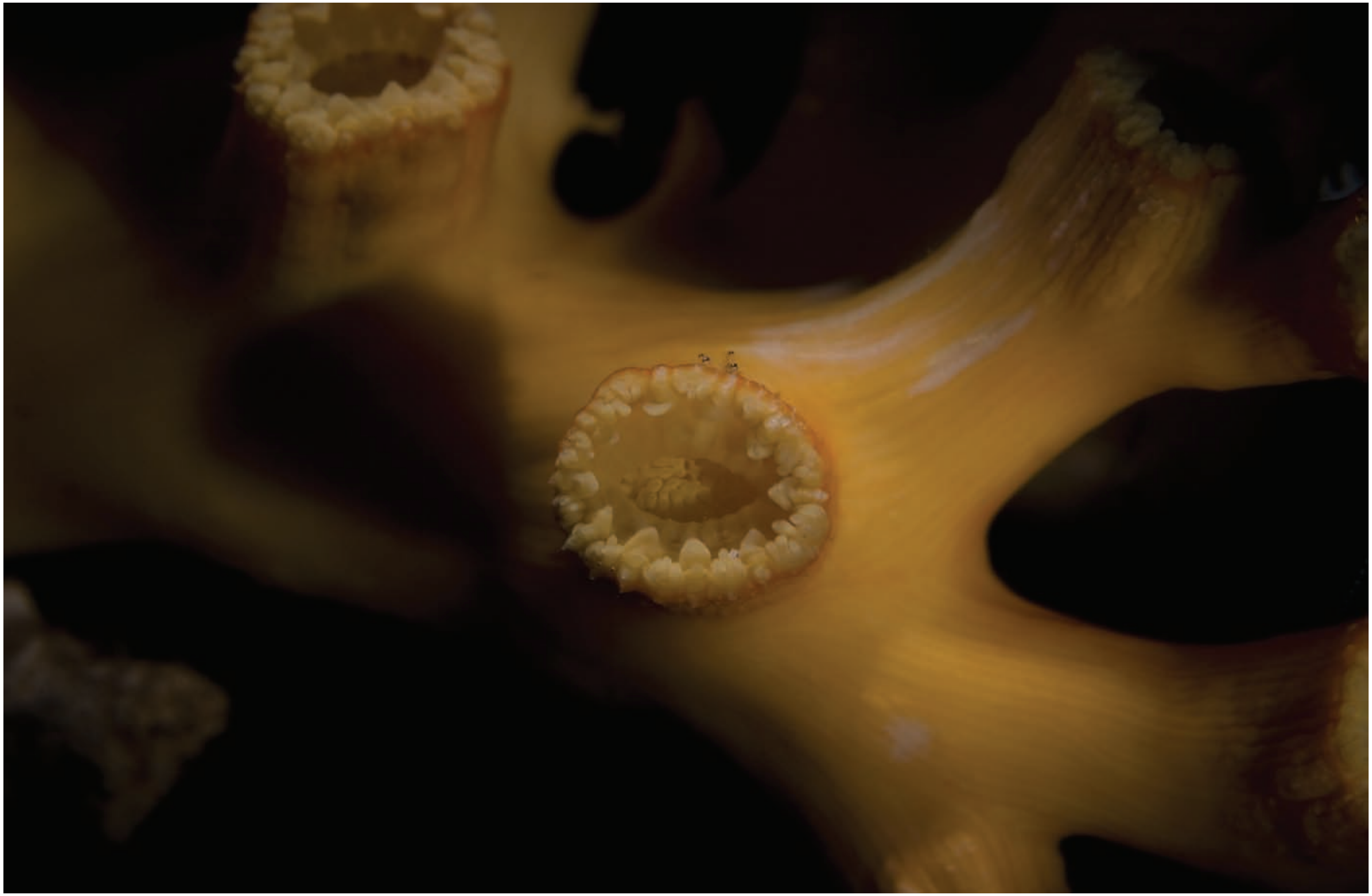
A. gerardogreeni), hydrozoans (*Lytocarpus nuttingi* and *Plumularia* sp.), seafans (*Leptogorgia rigida, Eugorgia multifida* and *Pacifigorgia agassizii*) and hard (hermatypic) corals (*Porites panamensis, Pocillopora elegans* and *Pavona gigantea*).

Intermediate surface subzone. Between the upper boundary at 40–50 and the lower one at 150–200 m, it is possible to observe some species from the shallow zone, together with (a) some species previously reported as frequent at these depths (black coral *Antipathes galapagensis*, the octopus *Octopus rubescens*, crabs *Maiopsis pamamensis* and *Stenorhincus* sp., and some species of squat lobsters), (b) species not previously reported at these depths (seafans *Leptogorgia* sp., *Eugorgia* sp., *Pacifigorgia* sp. and *Muricea* sp., sea pen *Cavernulina* sp. and several small species of crustaceans living in symbiosis between the branches of soft corals), and (c) species previously observed in the Pacific side of Baja California (giant keyhole limpet *Megathura crenulata*) and of California (*Leptogorgia chilensis*, a sea fan), but not previously recorded in the Gulf. The intermediate sub-zone proved to be an ecosystem rich in novelties, still partially illuminated by sunlight but is in the shadows most of the time, sheltering various species that belong to families or genera closely related to shallow water species, and to a lesser extent, to deep water species from the disphotic level, over 200 m deep.

Finally, approaching the 200 m lower boundary, after crossing the thermocline some 40–100 m deep, the greatest densities and cover of rocky-bottom macro-invertebrates are seen, associated with the green layer of high phytoplankton density. This group is mostly made up of suspension feeders (which obtain nourishment on the abundant plankton and organic matter suspended in the water) forming extensive “forests” of black coral and sea fan reefs, and sheltering crabs, squat lobsters, basket starfish, and fish. Undoubtedly, this layer is an important source of larval settlement and refuge for species of other water layers.

Close-up view of the epidermis (covered by paxillae) of the dorsal surface of the disk of the sea star *Tethyaster canaliculatus*. Photo © Carlos Sánchez-Ortiz.





Deep-water (200–400 m) azooxanthelate stony coral, of the family Dendrophylliidae, at Bajo Marisla. Photo © Carlos Sánchez-Ortiz.

Pages 112–113:
At Bajo Candeleros, a sea-cucumber *Holothuria fuscocinerea* expels a toxic, filamentose, and sticky compound as a defense against predators. Photo © Carlos Sánchez-Ortiz.

Deep zone

The sponges in this zone belong to the class Hexactinellida, commonly known as "glass sponges" because of the siliceous spicules that make up their skeletons. The extraordinary specimens collected (*Acanthascus* sp. and *Farrea* sp.) belong to genera commonly found in deep waters in California, Canada, and Alaska. These sponges, together with the octocorals *Anthomastus* sp. and *Paragorgia* sp., had not been seen before in Mexico; they all are part of taxa typically found in deep waters of up to 2,500 m deep. In fact, there is a close phylogenetic relationship between *Paragorgia* spp. and the species of red or pink coral *Corallium rubrum*, typically found in deep zones and widely used for fine jewelry.

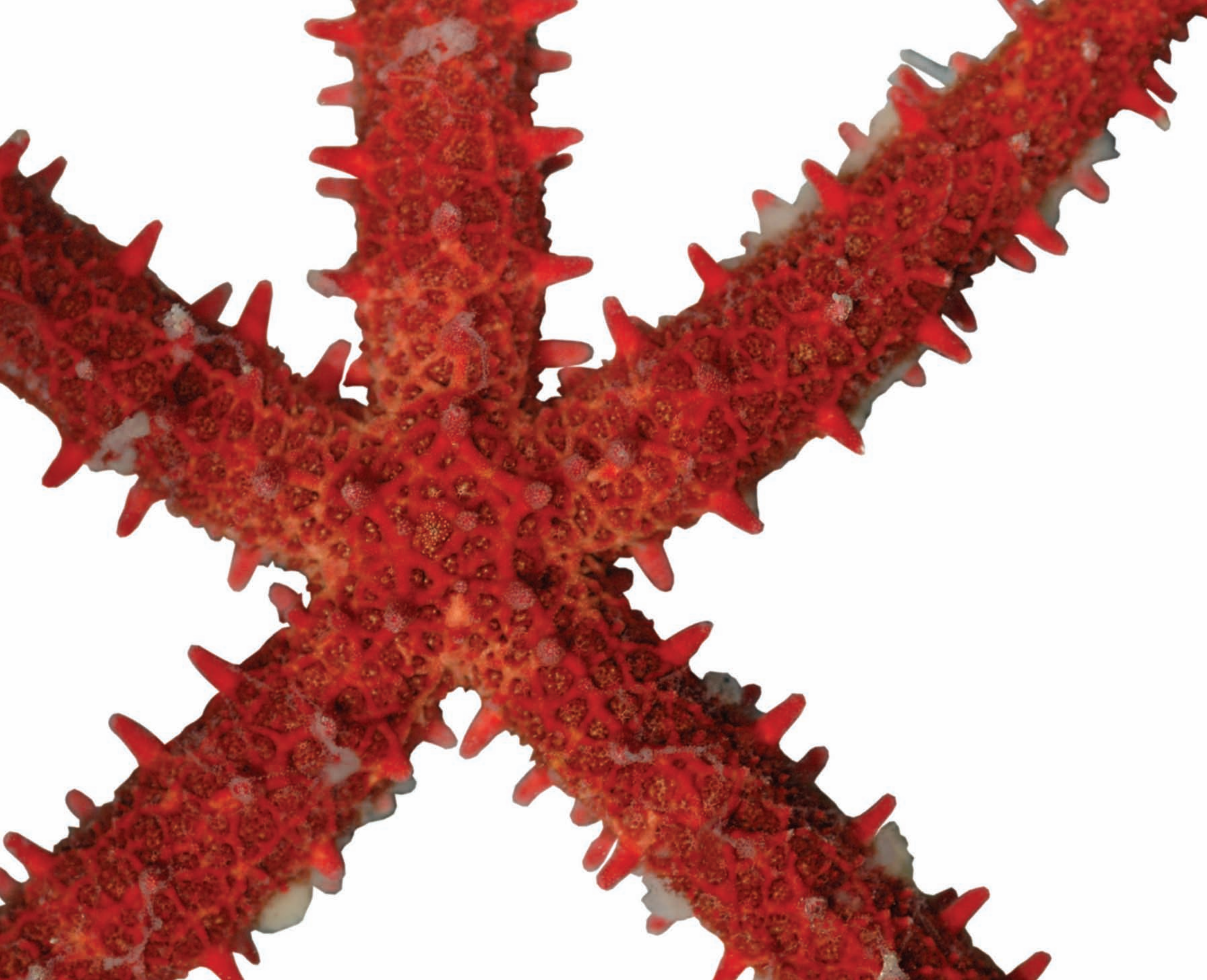
We also registered another group characteristic of deep zones: the Scleractinia or stony corals, which belong to a diverse group (1,300 species) that divides into two ecological groups. The first includes the corals that form reefs in surface and tropical waters (656 species), generally associated in symbiosis with microalgae (the zooxanthellae that live together with the coral polyp and give the colony a greenish hue). The second group, to which our findings belong (formed by three species of the family Dendrophylliidae whose precise identification is in process), is composed by 669 species that do not construct extensive reefs and widely distributed all over the world's oceans, including both temperate and polar regions, from near the sea surface to depths of up to 6,000 m. These corals are not associated with microalgae, because they do not depend on sunlight and can hence reach great depths. Their color is often transparent or white, but in some species it is can be bright yellow, red or pink.

Productivity in deep water systems

The seamount region that stretches between Bahia de La Paz and Loreto maintains geooceanographic processes that contribute to maintain an elevated primary and secondary production. Three species of krill (small euphausid shrimps: *Nyctiphanes simplex, N. difficilis* and *Euphausia distinguenda*) are a major component of secondary productivity. In particular, in the dominant species *N. simplex* elevated levels of larval productivity have been registered, much higher than those registered in the Pacific coast west of Baja California or the rest of the Gulf. This high productivity points to this euphausid as a cornerstone species in the trophic dynamics of the region that attracts the annual presence of blue whales (*Balaenoptera musculus*), fin whales (*Balaenoptera physalus*), humpbacks (*Megaptera novaeangliae*), whale sharks (*Rhincodon typus*), and smooth tail mobulas (*Mobula thurstoni*). Euphausids are also the principal source of food for the ocean whitefish (*Caulolatilus princeps*), the species with the highest importance for traditional artisanal fishing in the region.

During the expedition, especially during the immersions in the DeepSee at dusk, we confirmed the presence of euphausids and other groups in suspension (annelids and polychaetes, among others) over the reefs near the surface. We believe that the great density of suspension feeders like the black coral, sea fans, and basket starfish between 30 and 100 m deep is probably due to the high densities of euphausids and other small invertebrates suspended during their day-to-night vertical migration in the water column. It is also possible that the benthic organisms in the deep zone (the majority of which are suspension and detritus feeders) take advantage, in some degree, of the great production in the surface that reaches the sea bottom in the form of detritus.

Understanding these complex flows of energy between the different communities (benthonic-pelagic) will provide a complete vision of the production dynamics in the Gulf of California. Future investigations directed in this sense will support management and use strategies for these ecosystems.



El Cochi

Octavio Aburto-Oropeza, Margarita Caso, Richard Cudney-Bueno, Brad Erisman,
Exequiel Ezcurra, Lorenzo Rosenzweig, Carlos Sánchez-Ortiz,
Francisco A. Solís-Marín, and Vivianne Solís-Weiss

Sea star *Mithrodia bradleyi*.
Photo © Carlos Sánchez-Ortiz.

Located some four nautical miles south of Punta Baja, the extreme southern tip of Isla del Carmen, and some four miles east of Danzante Island (25°46′N, 111°11′W), these seamounts lie about 10 m below the surface in the shallowest part, and descend rapidly towards the Danzante Channel and the deep Gulf basin east of Isla del Carmen.

Shallow zone

The upper part of the seamount, at depths reachable by SCUBA diving, looked as if it had been ravaged by trawling nets. Despite being a rocky environment, the top part of the reef looks flat and devastated, suggesting the frequent razing of the substrate by trawling nets. We were able to observe more evidence of the impact of these nets in this seamount as we made deeper immersions in the submersible.

The rocky zone (22 m deep) of the Cochi seamount is inhabited by species typically found in shallow zones. The purple sea stars (*Tamaria* sp.) are the dominant echinoderms in this landscape. Disturbing the rocks, it was possible to observe the small, irregular starfish (*Astrometis sertulifera)*, which despite the difficulty in seeing it are quite abundant in this seamount, almost as much as *Tamaria*. *Astrometis sertulifera* reproduces asexually, dividing its body in two separate segments, a phenomenon called "fisiparity," and, for this reason, it is common to find individuals with arms of different lengths. The sea cucumber fauna is scarce and the most common species is *Holothuria impatiens* a common sea cucumber in the Gulf of California.

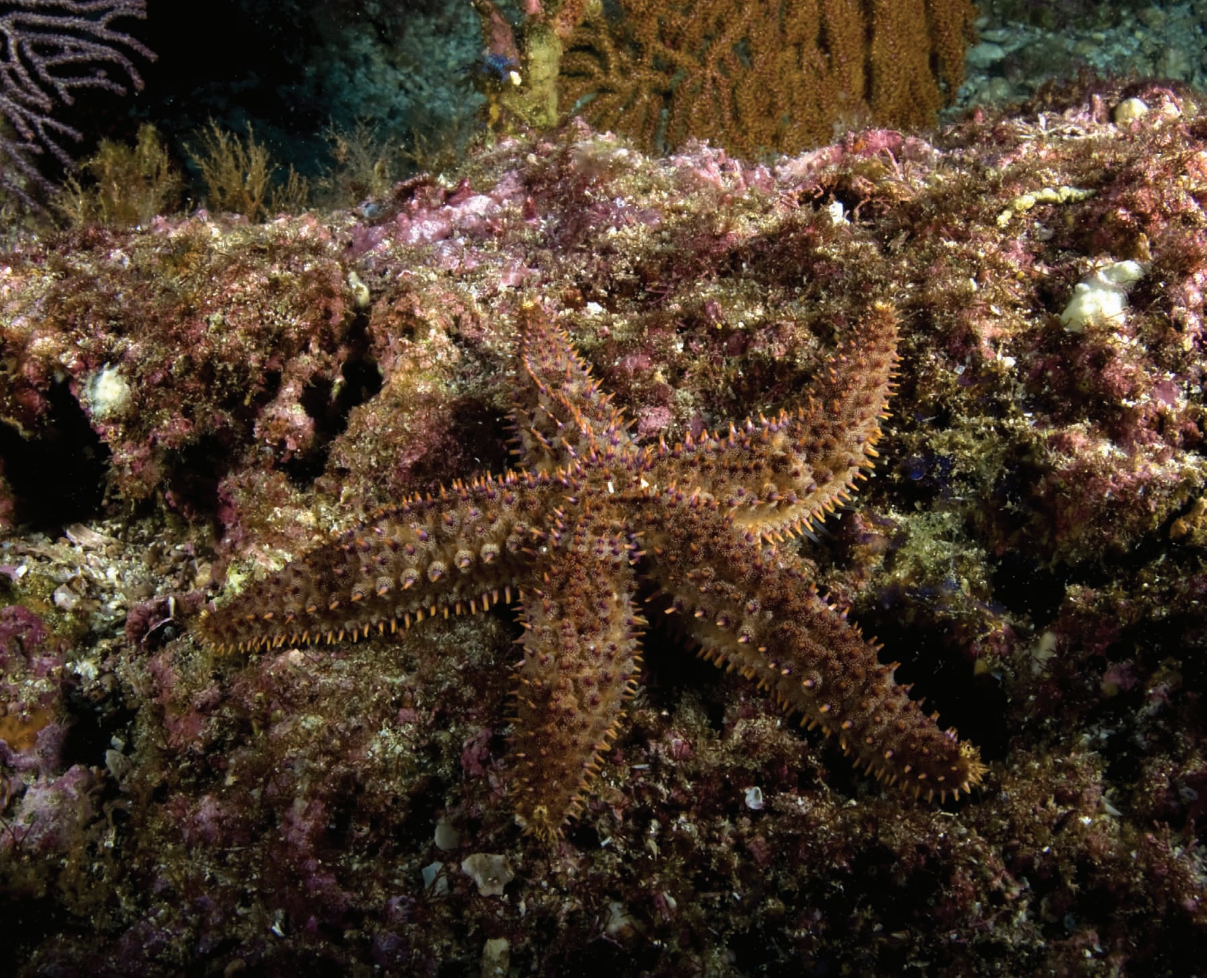
Deep zone

Most of the slopes of this seamount are formed by sandy inclines with some patches of rock and rubble. Large grooves, apparently created by the trawling nets for shrimp or other species, could be seen in the sand. It looked as if the bottom had been devastated by explosives or plowed like that of a farm. Fragments of dead gorgonians were found scattered on the bottom, around the grooves. In this sandy zone, we frequently observed the sea cucumber *Holothuria* (*Vaneyothuria*) *zacae*, a solitary species that lives in sandy seafloors.

Despite the apparent devastation, the sandy slopes harbored a series of elasmobranchs like swell sharks (*Cephaloscyllium ventriosum*), stingrays (Dasyatidae), skates (Rajidae), and electric eels (Narcinidae), together with the whitefishes (*Caulolatiulus affinis)* and other fish species belonging to the families Triglidae, Scorpaenidae, Congridae, Paralichthyidae, and Callionymidae.

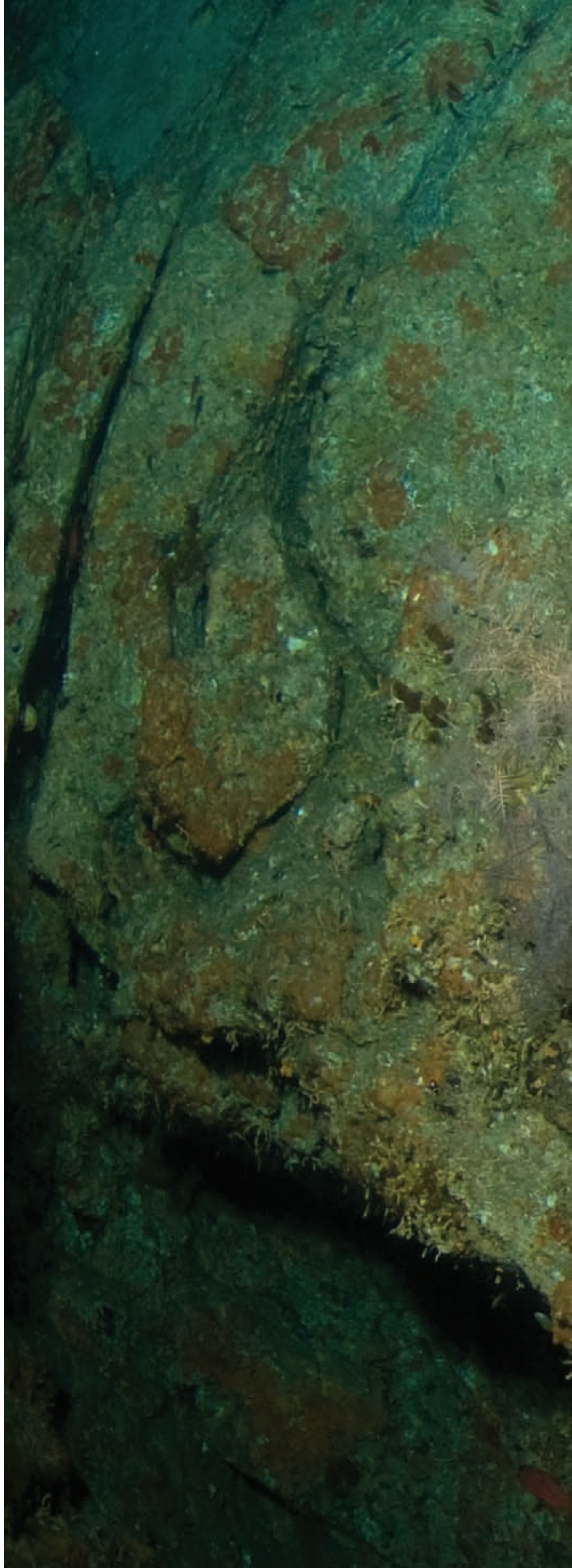
At around 100 m deep, we came across a large patch of reef made up of several large rocks covered with gorgonians and perforated with small cavities and crevices. Protected from the disturbances that impact the shallow waters, this deeper part of the seamount housed many different species of reef fish. We observed popeye catalufas (*Pristigenys serrula*), pink surfperches (*Zalembius rosaceus;* a species predominantly from the cold waters of the California Current and rarely seen in the Gulf of California*),* scythe-marked butterflyfish (*Prognathodes falcifer*), and dense groups of Limbaugh's

Sea star *Asteropsis spinosa* in its typical rocky habitat. Photo © Carlos Sánchez-Ortiz.

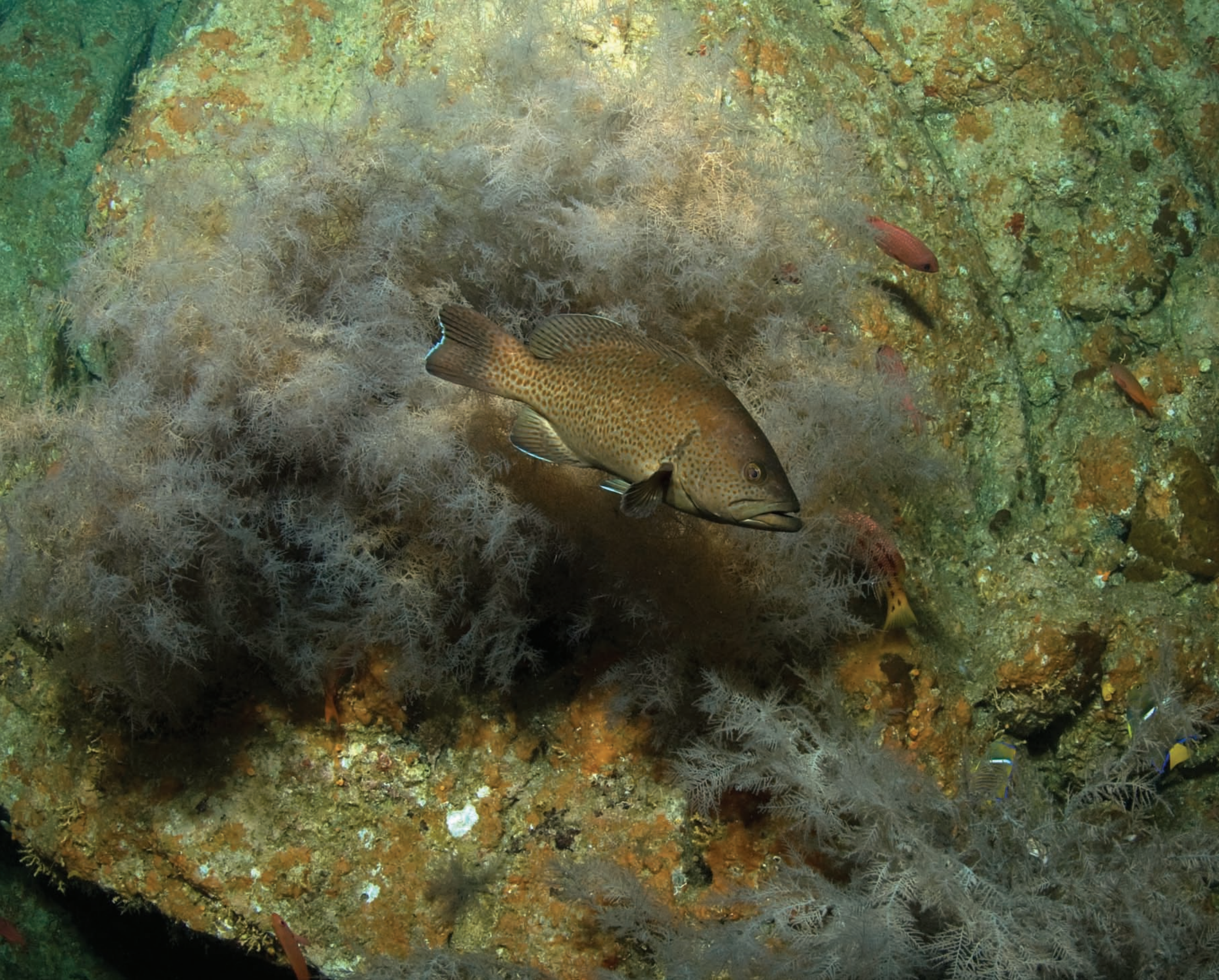


damselfish (*Chromis limbaughi*). As we diverted the submersible's lights away from the catalufas, we could see them in the dim-lit penumbra as that they started their courtship ritual. We could observe several couples spiraling around one another. We tried to capture the scene on video, but unfortunately, they dispersed as soon as the light shone on them.

Surprisingly, though, we also saw gatherings of Gulf groupers (*Mycteroperca jordani*) and leopard groupers (*Mycteroperca rosacea*), living in the large cracks in the rocks. It was an unexpected discovery because both species are usually associated with shallow waters and are believed to be rare below 30 m. We also saw in the deep waters of this reef gold-spotted sand bass (*Paralabrax auroguttatus*; important for their commercial value), barred snappers (*Hoplopagrus guentherii*), and even a few California sheephead (*Semicossyphus pulcher;* a shallow water species from the California coasts that follows the cold temperatures of deep waters into the Gulf). We also frequently saw rainbow basslets and other smaller sea basses (Serranidae).



Leopard grouper *Mycteroperca rosacea* surrounded by the branches of a black coral. Photo © Octavio Aburto-Oropeza.



The impact of fisheries

Brad Erisman, Octavio Aburto-Oropeza, and Richard Cudney-Bueno

The deep sea is out of sight and out of mind to most people and even most scientists, because it is truly a distant world that cannot be visited without the most technologically-advanced vehicles. For this reason, we know very little about the organisms and ecosystems of the deep oceans compared to areas accessible through conventional SCUBA gear and even less about our impacts on them.

Despite our limited information on these deep water ecosystems, seamounts and deep reefs have been exposed to the impacts of commercial and sport fishing activities for over half a century, but only recently has the widespread damage inflicted by such practices gained our attention. It is widely known that fisheries of shallow seas and coastlines have declined and even collapsed in many areas of the world, but few people realize that the same trend has occurred in the deeper, offshore waters.

Commercial fisheries of deep-water reefs and seamounts have been increasing with the demand for seafood, with the crash of shallow water stocks, and with the advances in fishing technology that have allowed large vessels to fish deeper and further offshore. In the Gulf of California, commercial fishing on seamounts and deep reefs coincided with the growth of the commercial shrimp and reef-fish fisheries in the region. For decades, these industries focused their efforts on coastal lagoons and near shore waters, where

The star-studded grouper *Epinephelus niphobles*, also called "estacuda" or "baqueta ploma", constitutes one of the main fisheries in Bajo de El Charro.
Photo © Octavio Aburto-Oropeza.

they could harvest vast amounts of shrimp, sharks, groupers, and other valuable species with little effort. This all changed by the late 1970s, when the region experienced a tremendous growth in the number of fishing vessels and the amount of fishing effort. When this occurred, nearshore fisheries declined rapidly and fishers began to move to deeper waters in order to maintain their profits and fulfill the growing demand for seafood.

Today, commercial fisheries in the Gulf of California target at least 30 species of fish from deep-water reefs and seamounts. These include sharks that make use of seamounts as feeding and cleaning stations, particularly hammerheads; groupers such as the Gulf coney (*Epinehelus acanthistius*), star-studded grouper (*E. niphobles*), and Gulf grouper (*Mycteroperca jordani*); snappers (*Lutjanus* spp.), and tilefish (blanquillos, *Caulolatilus* spp.), among others. Like all deep sea and seamount fisheries of the world, those in the Gulf of California have shown a boom and bust pattern, in which short- term high landings and profits are followed by collapses within 5 to 10 years of their initial development. For instance, the Gulf coney was heavily fished throughout the 1970's and during that period it was common for a vessel to carry up to a ton after a single day's work. Today the fishery has collapsed in most areas, and a landing of 100 kg is considered a good day's catch. As large groupers and sharks have all but disappeared from both the shallow and deep reefs, fishers have resorted to fish their way down the food web, harvesting smaller fishes and less valuable invertebrates from these areas until little remains but mud and slime.

The impact of fishing activities on these deep water ecosystems is certainly not limited to commercial activities. Barely regulated sport fisheries have also taken a toll on fish populations of these reefs. For instance, in some places of the Gulf of California, such as

The juvenile individuals of the gold-spotted sand bass *Paralabrax auroguttatus* develop in the sea-grass beds of shallow Gulf waters, and after reaching sexual maturity migrate to the seamounts as new recruits in adult populations. Photo © Octavio Aburto-Oropeza.

Pages 124–125:
The Gulf of California has a large fleet of shrimp boats whose dragnets scour and damage the ocean floor in many parts of the region. Photo © Octavio Aburto-Oropeza.


CARRANZA IV
BAHIA ADAIR IX
NAUTICO


COZAR I
ALEX-E

the deep water reefs of the Northern Gulf, sport fishers have the highest impact on populations of the giant sea bass, *Stereolepis gigas*, a species protected in California waters and listed as "Critically Endangered" in IUCN's *Red List of Threatened Species*. Sport fisheries will also often target breeding aggregations of deep groupers such as pinto and Gulf grouper, with no enforced limits on catches or season restrictions.

Clearly, the rapid rise and fall of deep sea fisheries in the Gulf resulted from an absence of management or regulations; however, the lifestyles of organisms that inhabit these ecosystems have also played a key role in their own demise. Most fishes living on deep reefs and seamounts grow very slowly, take many years to mature, reproduce sporadically, are long lived, and have few natural predators. For example, fishes like Gulf coney or the star-studded grouper do not reproduce before they are seven or eight year of age, and they can live for more than 30 years. This means that when populations are heavily fished, it could take them many years or even several decades to recover.

Seamounts and deep reefs are often referred to as ocean oases: small patches of lush reefs surrounded by miles of sand or mud. Thus these areas often concentrate dense aggregations of fishes and other marine life that are concentrated over small, finite areas to reproduce and or feed. When fishers locate these areas, entire aggregations of these animals can be removed in a period of just a few weeks or, in some cases, a few days. During our expedition, we observed fishers in most of the seamounts visited. The main target was the pacific red snapper (*Lutjanus peru*), an important commercial species in the region with high prices in the market, which reproduces in the transition season between summer and autumn. We bought three individuals larger than 60 cm in length from one of the small boats fishing around Las Ánimas seamount. These animals were two females

Some species of groupers, or "cabrillas", may reach sizes over 1.5 meters and include the main commercial species that are harvested in the Gulf's seamounts. Photo © Octavio Aburto-Oropeza.

and one male ready to reproduce. Even though much of this fishery is carried out using only hook and line, if the majority or all of the breeding adults are harvested from a spawning aggregation, the population may disappear from the reef completely.

In addition to commercial and sport fisheries that target deep water reef species, deep reefs in the Gulf of California have not been immune to the effects of bottom trawling, where boats essentially drag a net in search of shrimp and fish. Most bottom trawling boats in the Gulf of California target shrimp in sandy areas and avoid rocky outcrops as these can destroy their fishing gear. However, these nets often accidentally end up passing through deep water reefs, indiscriminately collecting everything on their pathway. Unfortunately, in the last decade a number of bottom trawling boats called *escameros*, which do target fish, have also been equipped with a special net with rollers capable of passing through some reefs, especially flat patchy reefs known locally as *tepetates*.

Trawling activities on rocky reefs can not only harvest large amounts of unwanted bycatch. They can destroy entire benthic (bottom-living) communities, particularly those dominated by corals, sponges, sea fans and other suspension feeders. Bottom-trawling is known to strip up to 95% of these fauna, pulverizing two hundred year old corals and groves of invertebrates and transforming them into scraped, barren habitats. These benthic organisms constitute the foundation of their respective communities where they serve as essential habitat for fishes and invertebrates, recycle vital nutrients, and improve water quality by filtering out viruses and bacteria. These rich bottom communities provide food and shelter for immense schools of small fishes and predators that feed on them. Marine mammals, sharks, tuna, and octopuses all congregate over seamounts to feed on the rich booty. Even seabirds have been shown to be more abundant in the vicinity of shallow seamounts. The massive removal of these natural and structural components of the ecosystem has a dramatic cascading effect on the entire ecosystem, causing the breakdown of entire food webs and a decline in local biodiversity and productivity.

Although our expedition reminded us of how unique and diverse these deep reefs can be, it also gave us an unfortunate picture of the impacts of fishing activities. These extended well beyond our expectations and were visible from the shallow surface waters down to 350 m. In El Bajo (Marisla) seamount, the large schools of sharks and jacks that once roamed the top of the seamount in the past were not present. Ghost nets, rusted traps, and old fishing line draped over large stretches of reef down to 300 m, some still containing carcasses of fish and crabs. Many of the reefs were also devoid of the large deepwater groupers that used to dominate the fisheries of these areas in decades past. To our surprise, we also found evidence of the effects of trawling in most of the reefs visited in the Bahía de Loreto area. Reefs and sandy slopes were covered by large trenches and scraped clean by trawling nets. There were broken corals, drag marks, and small patches of reef that were devoid of fishes, invertebrates, or much life at all.

The destructive effects of fishing on deep reefs and seamounts are particularly disturbing considering that entire suites of species are often found at a single location so their removal can result in immediate local extinction. Throughout the world, the unique fauna of these ecosystems are being trawled and dredged away at rates faster than the clear-cutting of the Amazonian rainforests, resulting in the permanent loss of species, some of them before they are ever even described.

Deep-sea fisheries all over the world have proven to be economically unsustainable and have resulted in the rapid depletion of biota, biological extinction, and irreparable damage to old-growth habitats. A few countries such as Australia, New Zealand, and Canada have recognized this problem and have taken the first steps towards protecting seamounts through inclusion of certain seamount and deep reefs within marine reserves.

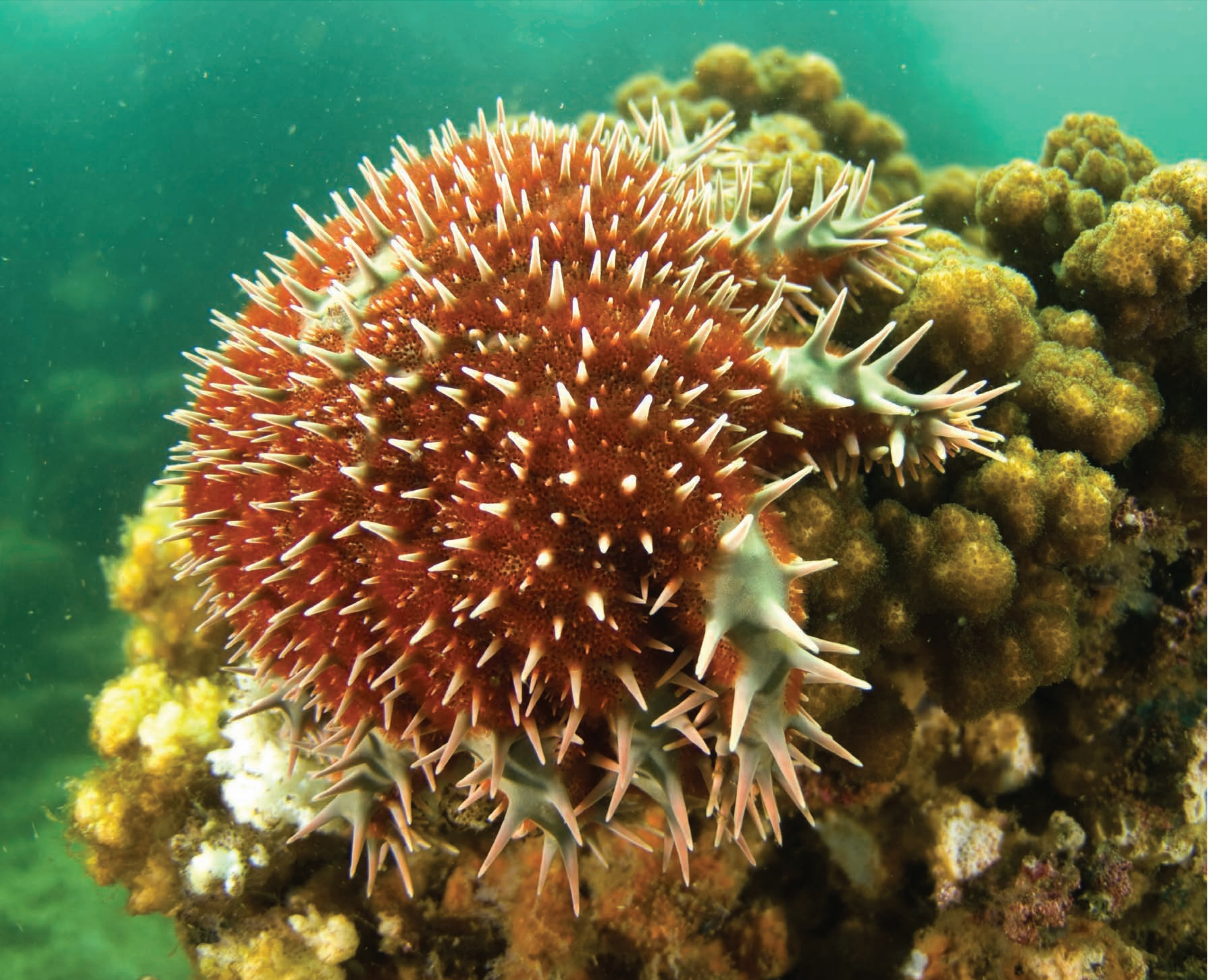
Similar actions are desperately needed to conserve these fragile marine ecosystems in the Gulf of California. If drastic changes to the deep sea fisheries in the Gulf are not made in the near future, the marine biodiversity and productivity of this unique region will continue to deteriorate and so will the communities that depend on the Gulf's resources for their livelihoods and survival.

Schools of large predators like the bigeye jack *Caranx sexfasciatus* congregate around the seamounts searching for preys. Photo © Octavio Aburto-Oropeza.

Pages 132–133:
Artisanal fishers in Bajo Marisla harvesting triggerfish *Balistes polylepis* and red snappers *Lutjanus peru*. Photo © Lorenzo Rosenzweig.


CAMINANTE


LA PAZ B.C.S.



The web of life on the reef

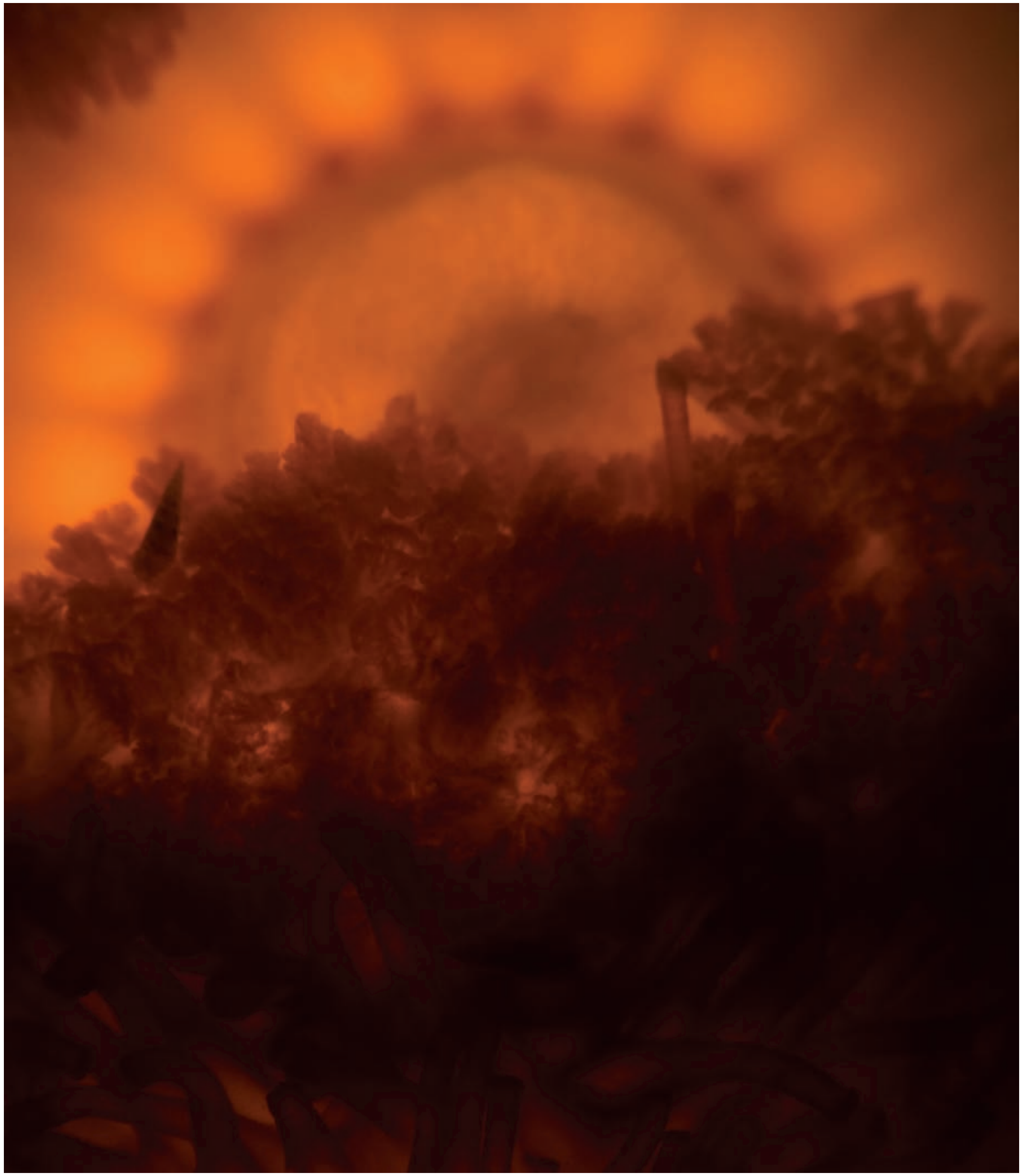
Carlos Sánchez-Ortiz

Crown-of-thorns sea star *Acanthaster planci*, preying on the polyps of a stony coral. Photo © Octavio Aburto-Oropeza.

Seamounts form a cluster of living organisms interacting with one another in an extremely complex network. In the ocean, predation relationships are common and survival is often a matter of competition and supremacy: of killing or being killed, of eating or being eaten. But on the seamounts and reefs positive interactions—those in which two species help each other to in order to survive—are very frequent and can be quite extraordinary. In the reef, life is not only driven by competition and predation but also by symbiosis and joint survival. It is not so much a matter of supremacy as it is one of cooperation.

Positive interactions between species can occur in several ways; the most common ones are: 1. mutualism, where the relationship is obligate and beneficial for both species, as in the anemone and the clownfish, or the microalgae (zooxanthellae) and the polyps of stony corals; 2. commensalism, where one species benefits from its interaction with the host, while the host is largely unaffected, as in manta rays and the suckerfish, or whales and the barnacles attached to their skin; and 3. parasitism, where the guest species survives at the expense of the host, and by doing so affects the host's development, as in the copepod crustaceans that parasitize the swordfish skin, or nematodes that thrive on the skin of many fish.

Several of these relationships were observed in macroinvertebrates during our expedition. The epibionts, or guest species, we found belonged mostly in the cnidaria (anemones), crustaceans (shrimp, crabs, hermit crabs, and goose barnacle), mollusks (snails) and polychaetes (sea worms); while the most common hosts were sponges, cnidaria (sea fans, sea pens, stony corals, black corals and hydrocorals), echinoderms (starfish, sea urchins, sea cucumbers



and sea spiders), and mollusks (clams and oysters). We were able to witness the remarkable parasitic relationship of minutely small snails that feed on the mouth tentacles of the sea cucumber (*Isostichopus fuscus*), and photographed the phenomenon for the first time.

Corals and their symbionts

Because they are easily accessible to divers, corals (stony corals, black corals, sea fans) from tropical seas are well known for their rich diversity and beauty. It is a lesser-known fact, however, that corals are also widely distributed in cold or deep ocean waters. These cold water corals offer a rich array of microhabitats and substrate for other species that become intimately associated with them for most or part of their life. The key is the arborescent, or tree-like, morphology of the corals, which allows the colonies of polyps to rise above the substrate's boundary layer, where water flow is higher. It follows then, that any epibiont, or guest species living within the coral branches can maximize the volume of water where they can search for the suspended food that drifts through the coral branches.

Crustaceans as coral epibionts

Many animals like sponges, flat worms, polychaetes, shrimps, crabs, sea spiders, mollusks, and fish live in the corals without causing their hosts any apparent harm under normal circumstances. In most cases the relationship between corals and their associated guest species is casual and non-specific, as the visitor is capable of living independently or associated with different species of corals. The most extraordinary association occurs when the guest species has an obligate association to a particular species of coral and the epibiont, through the processes of evolution and natural selection, has modified its color, morphology, conduct and reproductive cycle to adapt to the host.

At least 120 species of shrimp and crabs have been reported in the Indo-Pacific as obligate epibionts that frequently live between branches or tentacles of larger host organisms. Others, like the coral-gall crab *Hapalocarcinus marsupials*, live in the tips of the corals where

Feeding tentacles and calcareous ring of a sea cucumber *Isostichopus fuscus*. Diminutive parasitic snails *Melanella townsendi* can also be seen feeding around the tentacles. Photo © Carlos Sánchez-Ortiz.

they build a permanent home made up of galleries that cause the coral to grow abnormally. There are also species that can penetrate even further and live in the coral's cavities, like small oysters (*Fungiacava*) or polychaete worms (*Toposyllis*). In the American Pacific region, there have been close to 30 reported species of shrimp and crabs in obligate symbioses with corals, urchins and starfish. These symbionts can feed off the host's mucus, as well as eat small invertebrates, algae, or organic sediment.

The shallow rocky reefs (up to 20 m deep) of the southern Gulf of California harbor 16 species of stony coral of the genera *Pocillopora, Porites, Pavona* and *Psammocora*. Nine species of obligate symbiotic shrimp and crabs have been reported for the species of *Pocillopora* (seven were seen in our expedition), and the majority of these species (both host and symbionts) are widely distributed, having been recorded as far as in the Indo-Pacific and Red Seas. The crabs from the genus *Trapezia* and the snapping shrimp *Alpheus lottini,* are dominant symbionts that hide in the coral branches and feed on the coral's mucus, which is rich in lipids. Both crabs and shrimp actively defend the coral from intruders, even during attacks from their worst predators like the crown of thorns (*Acanthasther ellisii),* snapping them with their claws. This symbiosis increases the vitality of the coral colony, promoting the cleansing of its fragile surface and the safe elongation of its branches.

Crypsis, mimicry, camouflage

In several of the symbiotic crab and shrimp species we observed a striking morphologic similarity of the symbiont with the anatomical parts of its host (morphological mimicry), or a marked convergence in coloring that allows the symbiont to hide from potential predators (camouflage or visual mimicry). Crypsis is an even wider phenomenon than strict mimicry or camouflage, involving the evolution of a set of traits that allow the organism to hide in the surrounding environment. This evolutionary adaptation can produce extraordinary and unique symbiotic forms as a result of the reciprocal influence between host and symbiont.

In our submarine expedition we could observe that seamount environments 20 to 150 m

Porcelain crab *Quadrella nitida* (female with eggs), a symbiont of the sea fan *Muricea fruticosa*. Photo © Lorenzo Rosenzweig.

Male individual of a new species of caridean shrimps, in the subfamily Pontoniinae, that lives in symbiotic association with the sea fan *Ellisella limbaughi*, protecting itself from predators by copying the host's color. Photo © Lorenzo Rosenzweig.

The caridean shrimps *Sandyella tricornuta*, symbionts of the black coral *Antipathes galapagensis*, mimic their host not only by copying its color but also by imitating the form of its polyps. Photo © Carlos Sánchez-Ortiz.

deep are dominated by high densities of sea fans (*Muricea, Leptogorgia, Eugorgia, Pacifigorgia* and *Ellisella*), and black corals (*Antipathes*), forming true "forests" of high biological diversity. Knowledge on the fauna associated with these corals, especially those from deep waters, is mainly anecdotal. In particular, we witnessed a remarkable association between a sea fan *Muricea fruticosa* and its symbiotic crab *Quadrella nitida*. This crab, which lives among the branches of the sea fan, is successfully camouflaged by mimicking with its porcelain-white body the white bases of the coral branches, while its red claws mimic the fiery red the tips of the branches.

Other extraordinary cases were found: Numerous species of small shrimps live in association with sea fans and black corals, showing a high specificity in their host-guest relationship. Little is known on the species that conform these biotic interactions in the Gulf of California, but endemic genera of symbiotic shrimp (i.e., *Chacella, Veleronia* and *Pseudoveleronia*) have been reported in the colder waters of the American Pacific coast. In our expedition we found at least two new species of small symbiotic shrimps from the subfamily Pontoniinae associated with sea fans. One of them (Pontoniinae sp. 1) lives in association with the sea fan *Leptogorgia* sp. (also a new species), and has a transparent body with several white blotches that imitate the color and form of the fan's white polyps. The other one (Pontoniinae sp. 2) was found living with the sea fan *Ellisella limbaughi*. The bright orange color of the shrimp helps them to blend perfectly with the sea fan, which has the exact same color in its polyps. The four species were photographed for the first time during our expedition.

The shrimp *Chacella tricornuta*, a symbiont of the black coral *Antipathes galapagensis*, mimics the fluorescent greenish yellow color of the coral's polyps. The most extraordinary thing is that only the females (which are twice as large as the males with maximum size 1cm) possess noticeable dorsal spines that mimic the coral's polyps.

In another species of black coral (*Miyriopathes* cf. *ulex*) we were able to see another striking case of convergent morphologies: its symbiont, the stalked barnacle (*Oxynaspis* cf. *rossi*) has developed small spines in its body that look like the spines in the coral's skeleton (these two last cases were also photographed for the first time during our expedition).

Another extraordinary association observed is that of the hermit crab *Manucomplanus varians* with its epibiont, the hydrocoral *Janaria mirabilis*. This seems to be a mutualistic relationship as the hydrocoral grows over the shell where the hermit crab lives and acts as a camouflage for the crab's "house"; on the other hand, the hermit crab has developed a flat claw (hence the scientific name) that acts as a cover that prevents the incursion of or predators into its dwelling.

Coloration

The evolution of mimicry in epibiotic species is driven by the differential survival from predators of the mimetic symbionts, a trait that depends critically on an almost perfect similarity with the colors of their host. Thus, the evolution of color is of great ecological importance. Color, and especially pattern, are important diagnostic characteristics in the classification of symbiotic shrimp and crab. The extraordinary mimicry observed in several species of crustaceans, mollusks and annelids makes it difficult to detect the epibiont from the host. The perfect imitation of the host's color is achieved through different ways or through a combination of them. One of them is homochromic coloration driven by the food source, as in the case of the snail *Epidendrium billeeanum* that forages on the cup coral *Tubastrea coccinea* and acquires the orange color of its prey. In these cases the color of the body is a direct consequence of the intensity of pigmentation of the food source. Another evolutionary pathway is through hormonal control in the epibiont, which determines the pattern, and pigment density in the chromatophores, a specialized type of cells that can produce specific hues and tonalities, through the metabolic synthesis of different classes of pigments (xanthophylls) and their combination.

Many of these organisms frequently show, besides color, another form of mimicry through the imitation of the host's external structure. This is the case of the sea spider *Ophionereis annulata* and its associated polychaete epibionts, where camouflage is so remarkable that it makes it difficult to see the polychaete with the naked eye, or the crabs associated with sea fans and imitate the color and structure of the host's polyp.

Pages 144–145:
Mutualistic association between the hermit crab *Manucomplanus varians* and the staghorn hydrocoral *Janaria mirabilis*. The colonial hydrocoral encrusts the gastropod shell that houses the hermit crab, and starts to grow over it. The hermit crab trims the opening as the hydrocoral grows over the entrance, eventually replacing the shell completely in an amazing association between two species. Photo © Octavio Aburto-Oropeza.

Epilogue

Exequiel Ezcurra and Lorenzo Rosenzweig

In theory, scientific work should be detached from emotions. Science belongs in the realm of objective knowledge, the field of irrefutable truths, the space of testable hypotheses, the universe of demonstrations and theorems. Emotions, in contrast, reside in the impetuous terrain of passions and subjective feelings. But what is reality if not the result of perceptions? What meaning does the natural world have if it is not seen through the eyes of commitment, if it is not sensed with eagerness, if it is not lived with emotion?

Perhaps because of this apparent contradiction between scientific objectivity and the passionate commitment for nature conservation, the day we finished our expedition we were all feeling a lump in our throats, and some had their eyes most with emotion. We had lived some of the most intense weeks of our lives, surrounded by strange and wonderful life forms that perhaps we were not going to see ever again, and the group had worked with a commitment and a dedication that we had rarely seen before. The richness of the creative interaction between the group and the submarine world we had entered took over our feelings.

Biology often teaches us that evolution is a matter of supremacy between organisms, of competition between species, of killing or being killed. We often see evolutionary change chiefly as the result of nature red in tooth and claws. But in the sea mounts, however, life seems to be rather a feast of cooperation and symbiosis. During our expedition we could see the dance of fishes in large reproductive aggregations, we dived among them and could observe closely their living frenzy. A whale shark followed us for two days, coming to our encounter each time we dived; two species in direct contact in a biological interaction that seemed more about rejoicing than it was about aggression.

And we saw the waterfalls descending from the high peaks of the Sierra de la Giganta, sparkling and glittering under the sunset light after Tropical Storm Julio brought its pulse of life and nutrients down into oases and estuaries and coasts and mangroves. The desert and the coast changed in just a few hours to cover themselves in green.

We saw crabs that looked as if made out of porcelain, sheltered within the branches of corals and protecting the health of their hosts by driving away any predator that dares to approach. And small shrimps that mimic exactly the color of the coral that gives them refuge, feeding on the mucus that is secreted by the polyps while cleansing the surface of the colony from potential infections from microbial diseases.

And we dived among multitudes of reef fishes, with the most extraordinary colors one may imagine; cryptic colorations with which they hide from predators, dazzling hues that signal reproductive preparedness and attract the best mates, thousands of designs and patterns and forms used to seduce sexual partners, to hide from possible assailants, to attract beneficial species. Forms, colors, chemical messages, and ritual choreographies that send other individuals unmistakable signals, attract reproductive individuals to the aggregation, motivate a couple to spawn together, or disguise organisms in a camouflage so perfect as to become undistinguishable from their surroundings. Subtle signals that guide the swimming of fish or direct the vertical movement of small crustaceans floating in the water column.

The seamounts vibrate in a communication web of their own.

We often see nature as a universe of death and conquest, but visiting the seamounts of the Gulf of California it became apparent to us that the survival of life on earth is based on cooperation as much as it is in struggle and contest. In the seamounts, the flow of life is fundamentally the result of interactions for survival and reproduction.

Or, putting it in direct terms; of symbiosis and sex.

Pages 146–147:
Whale shark *Rhincodon typus.*
Photo © Octavio Aburto-Oropeza.

We collected new species that will keep expert taxonomists busy for years. We measured densities, we counted species, we estimated the biodiversity, and we organized archives of images and video as a baseline to monitor environmental changes in the future. But in only ten days, we could only but glance into a fraction of this wonderful, unknown universe. So many species remained to study in more detail, so many environments to explore deeper, so many things to learn, so many questions to answer.

But we were able to understand that these seamounts are sites of immense biological richness, degraded by depredatory overfishing but with the potential of recovering, and still treasuring this unique fraction of our planet's evolutionary richness.

In extension, the seamounts and coastal rocky reefs of the Gulf of California occupy only a hundred square kilometers, less than a thousandth of the entire Gulf's area, but provide reproduction havens for a disproportionate amount of fish species of great commercial value. Together with mangroves, where myriad open-sea fishes spend their juvenile stages; the upwelling areas of the Midriff Islands, which support the large Gulf fisheries of sardines and anchovies, and the rich tidal flats of the Upper Gulf, which maintain the fisheries of shrimp and corvina, the seamounts are a keystone habitat of the Gulf's large marine ecosystem. Here is where open sea species find food, here is where they find habitat for reproduction, here is where a large fraction of the Gulf's reef life finds refuge,

There was a time in which humans were also a functional part of nature, of this chain of symbiosis and passion of the senses. A time in which we made our houses with mud and stone and plant remains, in which we dyed our fabrics with the purple secretions of the murex snails, in which we painted our houses with the spotless white of kilned limestone, formed by millions of years of accumulated marine sediments. A time in which we were able to obtain our food from the sea without devastating and razing the sea bottom into an underwater desert. A time in which we protected the desert oases to water our crops with green vegetated ditches, in which we shared water with the rest of live species instead of ransacking it from the entrails of the earth. A time in which mangroves lived with lived with the freshwater that flowed down the rivers and delivered their richness of fish and larvae and nutrients into the open sea. Until only a few centuries ago humans were unquestionable part of the immense living network of the natural world, indivisible part of the complex web of life. There was a time, to conclude, in which we understood the signs and messages of the rest of nature and we spoke the language of the earth. Then came the indiscriminate looting of the seas and, with it, the collapse of global fisheries: cod in the North Atlantic, sardines in California, anchovies in Peru, blue fin tuna in the Mediterranean, sharks in all seas, and the decline of the big fishes.

The expedition to the seamounts led us to try to articulate again that ancestral language of life, to vibrate in synchrony with the immense network of living signals of the reef.

We could appreciate firsthand that our seas and our coasts, so highly productive and so rich in resources, are also immensely fragile. Like submerged islands, like underwater oases, the life spawned by these ecosystems disperses throughout the Gulf of California and perpetuates the entire marine ecosystem.

The conservation of the seamounts is vital. As sites of reproduction and spawning they ensure the health of the whole marine ecosystem, and indispensable step in ensuring the viability of the whole region. But the conservation of the seamounts is also a moral obligation, an issue of pride and belonging, a responsibility of Mexico with its natural legacy.

The submarine richness of the Gulf of California opened its doors to our visit, but upon seeing the beauty of deep life we could also see, with some fear, our own selves and our destructive capacity. And we could understand the immense responsibility that rests upon our shoulders.

Over the breathtaking background of a sunset over the Sierra de la Giganta, the DeepSee submersible returns to its nurse boat Argo after the last dive of the day on Bajo San Marcial. Photo © Lorenzo Rosenzweig.

Pages 152–153:
Evening twilight in Bajo Las Ánimas: yellow groupers *Lutjanus argentiventris* and a blue-chin parrotfish *Scarus ghobban* search for a safe place to spend the night, while the orange cup-corals start to open their polyps to feed from the rich nutrients suspended in the water column. Photo © Octavio Aburto-Oropeza.


Nikon

About Steve Drogin

Exequiel Ezcurra

On April 15, 2009, some seven months after our submarine expedition to the Sea of Cortés ended, Steve Drogin passed away while at a retreat in a remote part of India. He died peacefully from a heart attack, with his wife Hiro Drogin at his side. He was 69 and, up to that sad day, had always been extremely fit and in excellent health.

Steve prospered in San Diego as a real estate developer, but ever since he got his SCUBA certification in 1958, his real passion became diving, SCUBA photography, and traveling to remote destinations looking for adventure. In 1998 he retired to devote his life to his true love—the exploration of the sea. That is when I first met him.

We met at the Natural History Museum thanks to our mutual friend, the great naturalist Norman Roberts, who introduced us. Soon after, Steve invited me to his home for dinner with Barbara, my wife, and our two children. He had a gift to make friends with people of any age, and very soon he realized that my son Pedro, around nine years at that time, was studying at Lemon Avenue Elementary, exactly the same school where he had completed his elementary education half a century before. From that point onwards the two of them became like old buddies, talking about their school experiences as true classmates. Pedro was quite awestruck by this fascinating adventurer paying so much attention to him. I later learnt that Steve had always had a deep commitment towards education. He had prepared a slide show with his underwater photographs that he often presented in inner-city schools to attract children to research and to the marine environment.

Steve Drogin shooting a photo
during a diving expedition to the Philippines.
Photo © Hiro Drogin.

After that first dinner, we continued bumping into each other on myriad occasions: the annual meeting of the North American Nature Photography Association, lectures at Scripps Institution of Oceanography, exhibit openings at the Museum, and many other similar events. As a ritual of friendship and appreciation, I started to send him copies of books I had edited, or reprints of research papers I had published, and he would send me copies of his wonderful photographs. It was a joyous exchange on which I was always the winning part.

And then, the e-mails started. As computer communications developed, Steve rapidly became expert in e-mailing from all over the world, letting you know what he was doing, where he was, what his latest adventure was all about, what amazing sight was driving his exploits. And he would attach wonderful digital photographs to his messages, sharing his discoveries with all his friends around the globe.

He would write his messages using a massive and somewhat uncanny 24-point blue Arial font that was impossible to miss. His texts jumped at you from the computer screen, screaming Steve Drogin all over. The messages were newsy, humorous, informative, and funny. He had the rare gift of writing exactly like he spoke. It was like having him talking next to you.

Enthused with our book project, on January 31 he sent us the draft for the prologue. A month and half later I got his last e-mail. In the customary colossal blue print, it read:

> This morning I presented my new HiDef sub film to school kids in Chicago.
> A 4th grader asked me... "Why doesn't the US put more money into exploring the ocean similar to what they spend on exploring outer space?"
> I gave the best answer I could at the moment.
> But, it made me think.
> What kind of answer would you guys give to this very informed question?
> Many thanks for your help.
> Steve

Almost exactly a month later, he had passed away. I do not know if he found a satisfactory answer to his question—I know for certain that I have not. But in many ways he died while searching for these answers, and that is what he wanted to do to the last day of his life. He lived according to his principles, and followed with passion his quest for new horizons and new endeavors, always searching for ways to protect his beloved seas.

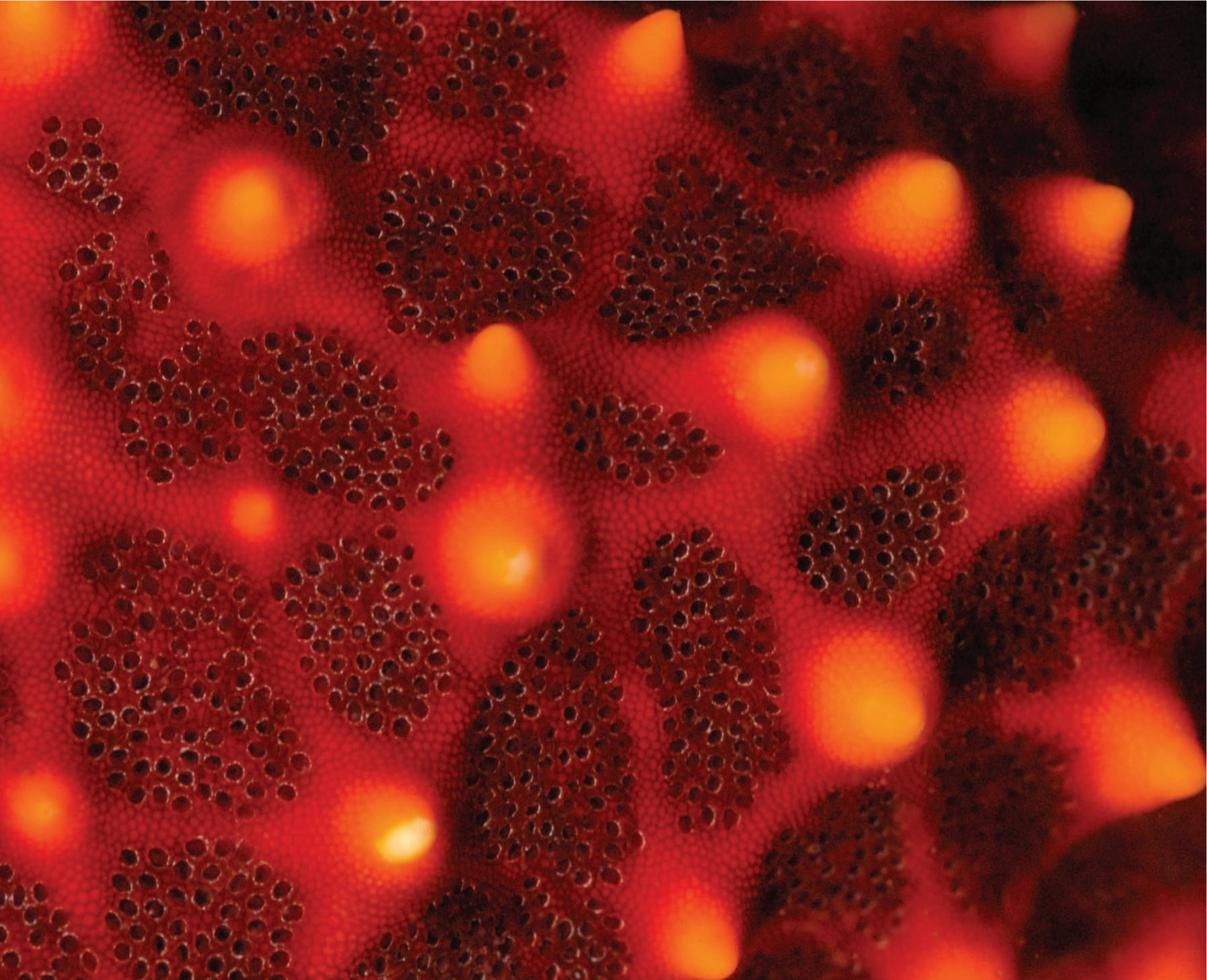
Steve was also one of the most generous souls I have ever met. He supported the work of young students at Scripps, in the same spontaneous and bighearted manner he also supported the work of young Mexican nature photographers. His kindness knew no bounds.

His thirst for adventure was unquenchable, always looking for new destinations, for new cultures, new voices, new environments. In one of those wonderful dinners at his house in Pacifica Drive, he told me about his plans to have a deep-water submersible built for his explorations. I could not believe what I was hearing; I did not even know at that time a thing about deep-water submersibles, and could not imagine that a person could individually own one. But with Steve, everything seemed to be that way. He would make bold decisions and follow them to their ultimate consequences. Discovery and awe — that is what his life was all about.

And so, he got the sub.

Last year, Steve gave me a call, telling me that the sub would be coming to the Sea of Cortés and generously offering some of the sub's time for research. The rest is history; a piece of history we owe to Steve Drogin and his immense generosity.

A basket star *Astrocaneum spinosum* extends its branched arms over a sea fan *Muricea* sp. Photo © Lorenzo Rosenzweig.



Macro-invertebrates of shallow waters

Order	Family	Species	Depth (meters)	San Marcial	Candeleros	Las Ánimas	Marisla	San Dieguito	El Cochi	Observations
Porifera		*Aplysina cf. fistularis*	5 - 20	•	•			•		H
		Aplysina gerardogreeni	20 - 40	•		•	•	•	•	H
Cnidaria	Hydrozoa	*Aglaophenia sp.*	5 - 20	•	•	•	•	•	•	
		Lytocarpus nuttingi	5 - 30	•	•	•	•	•		
		Obelia sp.	10 - 20	•		•			•	
		Plumularia sp.	5 - 30					•		
		Janaria mirabilis	20 - 50	•	•	•	•		•	H
	Octocorallia	*Eugorgia auriantiaca*	20 - 30			•	•		•	H
		Eugorgia multifida	10 - 30	•		•	•			
		Eugorgia rubens	5 - 10		•			•		
		Leptogorgia rigida	0 - 10			•		•		H
		Pacifigorgia agassizii	10 - 30	•		•	•	•	•	
		Pacifigorgia media	15 - 50	•		•		•		
		Pacifigorgia gracilis	20 - 50	•		•				
		Pacifigorgia n. sp.1	10 - 30	•		•	•			*
		Muricea appressa	15 - 50	•		•	•		•	
		Muricea austera	10 - 40	•	•	•	•		•	
		Muricea fruticosa	20 - 50	•		•	•			H
		Muricea n. sp.1	20 - 50	•		•	•			*
		Muricea n. sp.2	30 - 40	•						*
		Heterogorgia verrucosa	20 - 50	•		•	•			H
		Psammogorgia teres	20 - 50	•		•				
	Hexacorallia	*Epizoanthus* sp.	20 - 50			•	•		•	
		Pavona gigantea	5 - 20	•	•	•				
		Pocillopora elegans	5 - 20	•	•	•	•	•		
		Porites panamensis	5 - 20		•	•	•	•	•	
		Tubastrea coccinea	10 - 40	•		•	•	•		
		Antipathes galapagensis	20 - 50	•		•	•		•	H
Annelida	Polychaeta	Familia Amphinomidae sp.	5 - 40		•	•	•	•		

Order	Family	Species	Depth (meters)	San Marcial	Candeleros	Las Ánimas	Marisla	San Dieguito	El Cochi	Observations
		Eurythoe complanata	5 - 40		•	•				
		Chloeia viridis	15 - 40			•				
		Familia Cirratulidae sp.	5 - 40		•	•		•		
		Familia Dorvilleidae sp.	15 - 40			•		•		
		Familia Eunicidae sp.1	5 - 40	•	•	•	•	•	•	
		Familia Eunicidae sp.2	5 - 40	•	•	•	•	•	•	
		Familia Flabelligeridae sp.	20 - 40			•				
		Familia Glyceridae sp.	20 - 40			•		•		
		Familia Hesionidae sp.	20 - 40	•		•		•		
		Familia Maldanidae sp.	10 - 20						•	
		Nicon moniloceras	superficie		•					E
		Familia Nereididae sp.1	superficie		•					E
		Familia Nereididae sp.2	10 - 40			•		•	•	
		Familia Oenonidae sp.	20 - 40			•		•		
		Familia Onuphidae sp.	5 - 40	•	•	•	•	•	•	
		Familia Phyllodocidae sp.	15 - 40	•		•	•	•	•	
		Familia Pilargidae sp.	15 - 40	•		•				
		Familia Polynoidae sp.1	5 - 40	•	•	•	•	•	•	
		Familia Polynoidae sp. 2	10		•					S
		Bispira monroi	5 - 30		•	•		•	•	
		Familia Sabellidae sp.1	5 - 40	•	•	•	•	•	•	
		Familia Sabellidae sp.2	5 - 40	•	•	•	•	•	•	
		Salmacina sp.	5 - 15		•			•		
		Familia Serpulidae sp.1	5 - 30		•	•	•			
		Familia Sigalionidae sp.	5 - 40		•	•				
		Familia Spionidae sp.	5 - 40		•	•				
		Familia Syllidae sp.	5 - 40	•	•	•	•	•	•	
		Familia Terebellidae sp.	5 - 40		•	•	•	•		
Mollusca	Bivalvia	*Hyotissa hyotis*	20 - 50	•		•	•			
		Ostrea sp.	10 - 20	•	•	•	•			
		Pinctada mazatlanica	0 - 15		•			•	•	H
		Pinna rugosa	10 - 20		•			•	•	
		Pteria sterna	20 - 50	•		•	•			
		Spondylus calcifer	0 - 15		•	•		•		

Order	Family	Species	Depth (meters)	San Marcial	Candeleros	Las Ánimas	Marisla	San Dieguito	El Cochi	Observations
	Gastropoda	*Conus* sp.	10		•	•		•		
		Epidendrium billeeanum	10 - 30	•		•	•	•		S
		Hexaplex princeps	20 - 40	•		•	•	•	•	
		Melanella townsendi	10 - 30	•	•	•	•			S
		Neosimnia aequalis	0 - 10			•		•		S
		Phestilla melanobrachia	10 - 30			•	•			S
		Thais sp.	20	•		•		•	•	
		Thyca callista	0 - 20	•	•	•		•		S
		Tylodina fungina	0 - 10		•	•				S
Crustacea	Stomatopoda	*Neogonadactylus zacae*	10					•		
	Caridea	*Allopontonia iaini*	15 - 20			•				S
		Alpheus lottini	5 - 20	•	•	•	•	•		S
		Sandyella tricornuta	20 - 50	•	•	•	•			S
		Fennera chacei	5 - 20	•	•	•	•			S
		Harpiliopsis depressa	5 - 20	•	•	•	•	•		S
		Harpiliopsis spinigera	5 - 20	•	•	•	•	•		S
		Palaemonella cf. *asymmetrica*	20						•	
		Periclimenes soror	5 - 20			•	•			S
		Pomagnathus corallinus	5 - 20	•	•	•	•			S
		Pontonia margarita	5 - 10		•	•	•			S
		Pseudoveleronia laevifrons	10 - 40	•		•	•			S
		Synalpheus sp.	10					•		
		Synalpheus charon	5 - 20	•	•	•	•			S
		Tuleariocaris holthuisi	10 - 30			•	•			S
	Anomura	*Aniculus elegans*	20 - 40		•	•				
		Manucomplanus varians	20 - 50	•	•	•	•		•	S
		Panulirus inflatus	10 - 40		•	•				
	Brachyura	*Hapalocarcinus marsupialis*	5 - 20	•	•	•	•			S
		Microphrys branchialis	5		•					
		Paractea sulcata	10					•		
		Percnon gibbesi	20 - 40			•		•		

Order	Family	Species	Depth (meters)	San Marcial	Candeleros	Las Ánimas	Marisla	San Dieguito	El Cochi	Observations
		Pilumnus sp.	30	•						
		Podochela veleronis	10					•		
		Quadrella nitida	20 - 50	•	•	•	•			S
		Trapezia corallina	5 - 20	•	•	•	•	•		S
		Trapezia bidentata	5 - 20	•	•	•	•	•		S
Echinodermata	Asteroidea	*Acanthaster planci*	5 - 10		•					
		Amphiaster insignis	30			•				
		Asteropsis spinosa	5 - 10		•					
		Astrometis sertulifera	10 - 30			•			•	
		Heliaster kubinijii	5 - 10		•					
		Mithrodia bradleyi	5 - 10		•			•		
		Narcissia gracilis	5 - 30		•	•				
		Nidorellia armata	10 - 30	•		•		•	•	
		Pentaceraster cumingi	30	•						
		Pharia pyramidatus	5 - 30	•	•			•	•	
		Phataria unifascialis	20 - 30	•		•				
		Leiaster teres	10 - 30	•				•	•	
	Ophiuroidea	*Astrocaneum spinosum*	30			•				
		Ophiacantha n. sp.	30				•			*
		Ophiactis sp.	5 - 10		•					
		Ophiactis simplex	20 - 30	•		•	•			
		Ophiactis savignyi	5 - 30	•	•	•	•	•		
		Ophiocoma alexandri	5 - 10		•					
		Ophioderma vansyoci	10 - 30			•		•		
		Ophioderma variegatum	10 - 30			•		•		
		Ophionereis perplexa	5 - 10		•			•		
		Ophionereis annulata	5 - 10		•			•		
		Ophiothela mirabilis	30			•				
		Ophiothrix spiculata	30				•			
	Echinoidea	*Arbacia incisa*	5 - 30		•		•			
		Eucidaris thouarsii	5 - 30		•		•	•		
		Diadema mexicana	5 - 30		•		•			
		Hesperocidaris perplexa	30				•			
		Toxopneustes roseus	10 - 30	•				•		

Order	Family	Species	Depth (meters)	San Marcial	Candeleros	Las Ánimas	Marisla	San Dieguito	El Cochi	Observations
		Tripneustes ventricosus	5 - 10		•					
		Brissus obesus	10 - 20			•		•		
		Lovenia cordiformis	0 - 10					•		
	Holothuroidea	*Euapta godeffroyi*	5 - 10		•					
		Holothuria arenicola	5 - 10		•					
		Holothuria fuscocinerea	5 - 10		•					
		Holothuria imitans	10					•		
		Holothuria impatiens	10 - 20			•		•	•	
		Holothuria inhabilis	5 - 10		•		•			
		Isostichopus fuscus	5 - 40	•	•	•	•			
Urochordata	Ascidacea	*Ascidacea sp. 1*	10 - 50	•		•	•			

* New species

E Epitoci (free-swimming reproductive phase)

H Symbiont host

S Symbiotic guest

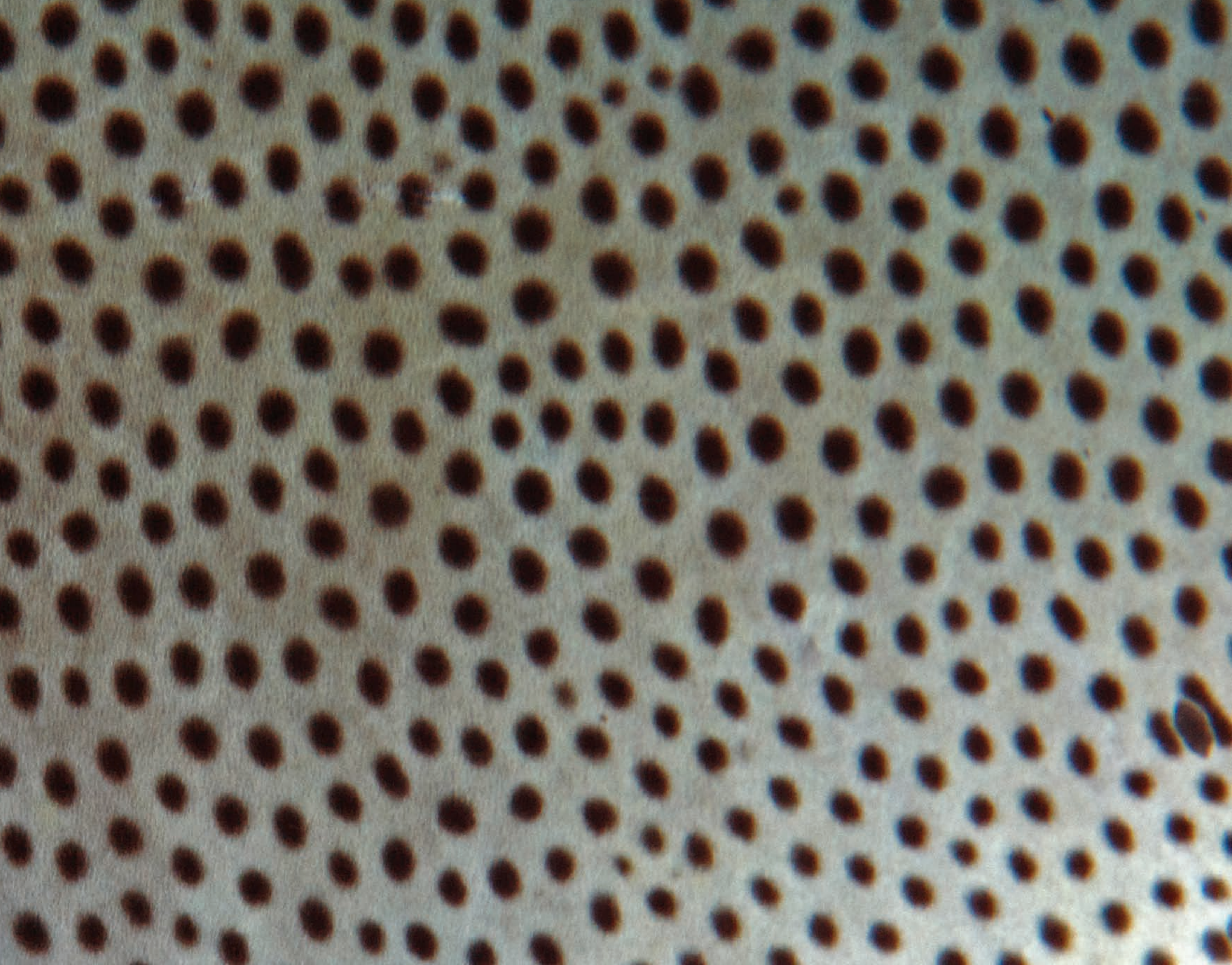
Macro-invertebrates of deep waters

Order	Family	Species	Depth (meters)	San Marcial	Las Ánimas	Marisla	San Dieguito	El Cochi	Observations
Porifera		*Acanthascus* sp.	180 - 400			•			■ ∆
		Farrea sp.	180 - 400			•			■ ◊
		Clase Hexactinellida sp.	200 - 400			•			■
Cnidaria	Hidrozoa	Suborden Conica sp.1	200 - 300			•			
		Suborden Conica sp.2	200 - 300			•			
		Tubularia sp.	80 - 160			•			
	Octocorallia	*Anthomastus* sp.	200 - 400			•			■
		Paragorgia sp.	170 - 400			•			■
		Eugorgia n. sp.	60 - 120		•	•			*
		Leptogorgia n. sp.	60 - 140		•	•			* H
		Leptogorgia chilensis	60 - 120		•	•			■ H
		Pacifigorgia gracilis	20 - 60	•		•			o
		Pacifigorgia n. sp.2	50 - 70		•	•			*
		Muricea fruticosa	20 - 100	•	•	•			oH
		Muricea n. sp.3	60 - 150		•	•			*
		Heterogorgia verrucosa	50 - 80	•	•	•			oH
		Psammogorgia teres	50 - 100		•	•			o
		Ellisella limbaughi	60 - 150		•	•			H
		Cavernulina sp.	60				•		■
		Ptilosarcus sp.	100		•	•			H
		Virgularia sp.	60 - 100	•	•				
		Orden Pennatulacea sp.	100	•		•			■
	Hexacorallia	cf. *Antiparactis* sp.	60 - 120		•	•			S
		Epizoanthus sp.	50 - 100	•	•	•			o
		Familia Dendrophylliidae sp.1	150 - 300			•			
		Familia Dendrophylliidae sp.2	150 - 300			•			
		Familia Dendrophylliidae sp.3	150 - 300			•			
		Antipathes galapagensis	50 - 120	•	•	•			oH
		Miyriopathes cf. *ulex*	50 - 150		•	•			*

Order	Family	Species	Depth (meters)	San Marcial	Las Ánimas	Marisla	San Dieguito	El Cochi	Observations
Annelida	Polychaeta	*Chloeia* sp.	200			•			C
		Paleonotus sp.	200			•			C
		Eunice vittata	200			•			C
		Familia Nereididae *sp.*	200		•	•			C
		Aricia pacifica	200			•			C
		Eulalia bilineata	200			•			C
		Subfamilia Harmothoinae sp.	200		•	•			C
		Syllis armillaris	200			•			C
		Loimia medusa	200			•			C
		Eupolymnia sp.	200			•			C
		Thelepus sp.	200			•			C
		Pista sp.	200			•			C
		Thelepodinae sp.	200			•			C
Mollusca	Gastropoda	*Hexaplex* sp.	60			•			
		Hyotissa hyotis	50 - 100		•	•			o
		Megathura crenulata	150 - 200			•			■
		Neosimnia cf. *barbarensis*	100			•			S
		Orden Opisthobranchia sp.1	100			•			*
	Cephalopoda	*Octopus rubescens*	50 - 150	•	•	•			
Crustacea	Caridea	*Sandyella tricornuta*	50 - 100	•	•	•			oS
		Subfamilia Pontoniinae n. sp.1	60 - 140		•	•			*S
		Subfamilia Pontoniinae n. sp.2	60 - 140		•	•			*S
		Alpheus bellimanus	100		•				
	Anomura	*Munida mexicana*	100 - 200		•	•			
		Familia Galatheidae sp.	50 - 200	•	•	•			
	Brachyura	*Maiopsis panamensis*	60 - 300			•			
		Stenorhynchus sp.	50 - 200		•	•			
		Stenorhynchus debilis	100		•				
		Quadrella nitida	50 - 100		•	•			S
	Cirripedia	*Oxynaspis* cf. *rossi*	50 - 150		•	•			
Echinodermata	Asteroidea	*Amphiaster insignis*	20 - 190	•	•				
		Astropecten ornatissimus	190 - 295		•	•			
		Henricia sp.	190			•			
		Henricia clarkii	190 - 200			•			

Order	Family	Species	Depth (meters)	San Marcial	Las Ánimas	Marisla	San Dieguito	El Cochi	Observations
		Henricia nana	170 - 200			•			
		Luidia ludwigi	190	•					
		Luidia phragma	190	•					
		Narcissia gracilis	75 - 190	•	•				
		Coronaster marchenus	75 - 190		•	•			
		Tethyaster canaliculatus	295			•			
	Ophiuroidea	*Astrodictyum panamense*	60		•				
		Astrocaneum spinosum	190	•					
		Ophiacantha sp.	170 - 180			•			
		Ophiacantha sp.1	170			•			
		Ophiacantha sp.2	170			•			
		Ophiacantha n. sp.	190			•			*
		Ophiactis sp.	200			•			
		Ophiolephis crassa	190	•					
		Ophiostigma sp.1	200			•			
		Ophiostigma sp.2	170			•			
		Ophiothela mirabilis	75 - 170				•	•	
		Ophiothrix galapagensis	100 - 170		•	•			
		Orden Ophiurida n. sp.	170 - 200			•			*
	Echinoidea	*Hesperocidaris perplexa*	190 - 295		•	•			
		Metalia espatangus	190		•	•			
	Holothuroidea	Orden Aspidochirotida	190			•			
		Holothuria zacae	100 - 190	•		•		•	

* New species
o New depth record
■ New record for the Gulf of California
H Symbiont host
S Symbiotic guest
C Associated to the skeleton of black corals

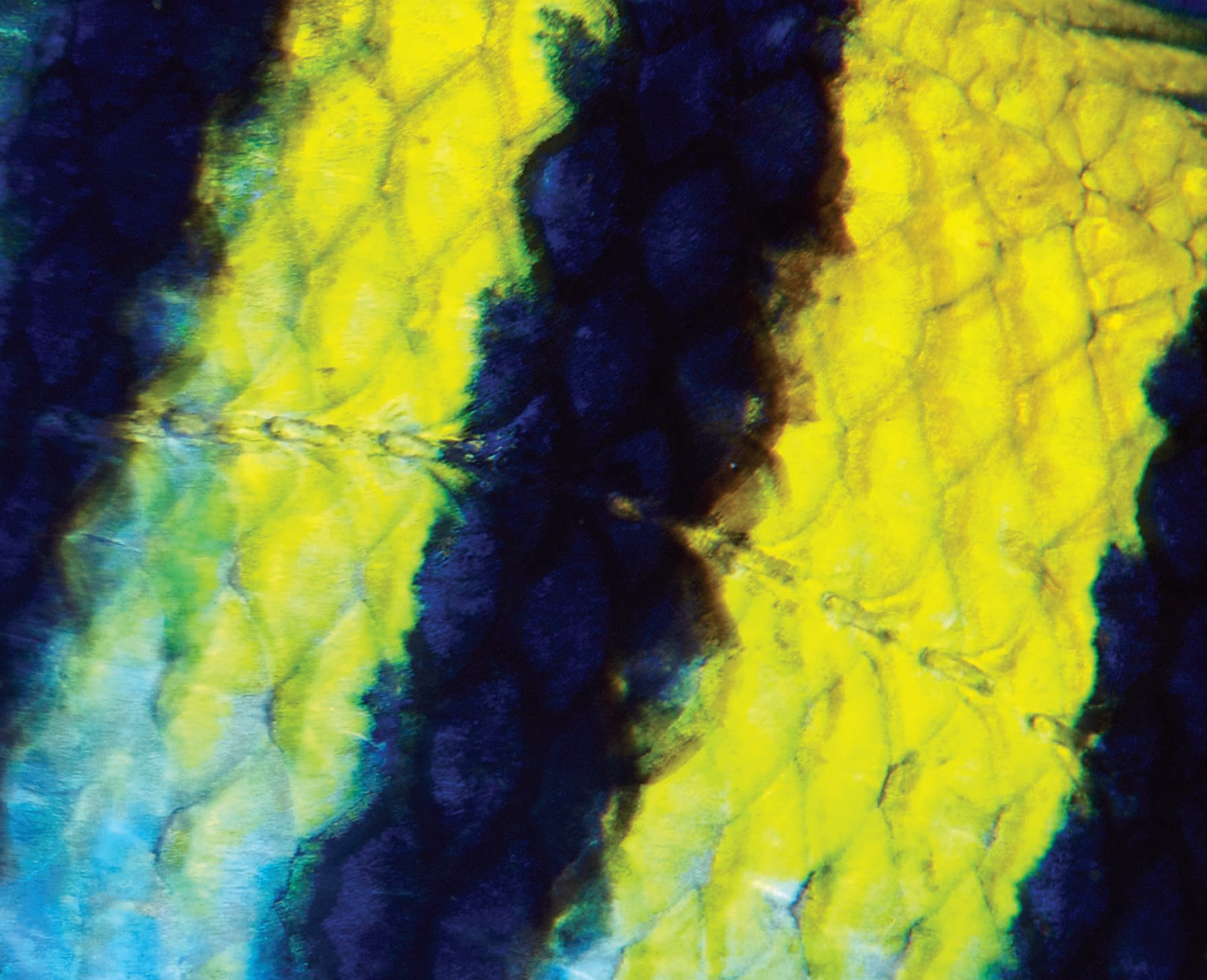


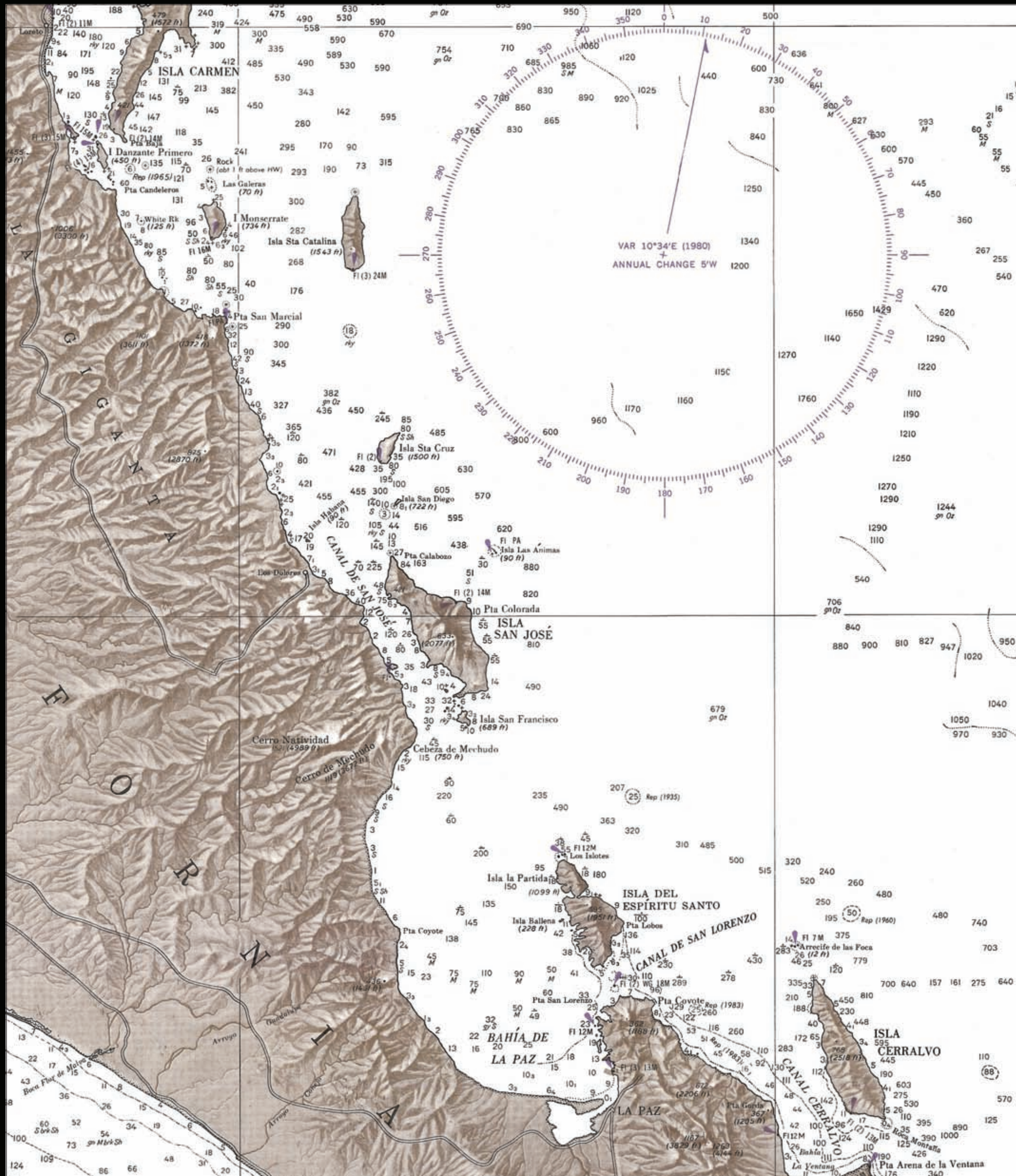
Fishes

Order	Family	Species	Depth (meters)	San Marcial	Las Ánimas	Marisla	San Dieguito	El Cochi
Anguilliformes	Congridae	*Ariosoma gilberti*	100	•				•
		Paraconger californiensis	70				•	
	Ophichthidae	*Bascanichthys cylindricus*	120		•			
		Pisodonophis daspilotus	150	•				
		Quassiremus notochir	50 - 80	•	•			
Aulopiformes	Synodontidae	*Synodus evermanni*	90 - 180	•	•	•		
Carcharhiniformes	Carcharhinidae	*Carcharinus limbatus*	10 - 15		•			
	Scylirhinidae	*Cephaloscyllium ventriosum*	100 - 200		•	•		
Gadiformes	Moridae	*Physiculus rastrelliger*	100 - 200	•		•		
Lamniformes	Alopiidae	*Alopias* sp.	10 - 15				•	
Lophiiformes	Antennariidae	*Antennarus avalonis*	100 - 200			•		
	Lophiidae	*Lophiodes caulinaris*	100 - 200	•		•		
		Lophiodes spilurus	100 - 200	•	•	•		
Ophidiiformes	Ophidiidae	Ophidiidae n. sp.	120 - 200			•		
Perciformes	Apogonidae	*Apogon pacificus*	50 - 90	•	•	•		
	Callinimydae	*Synchiropus atrilabiatus*	100 - 150		•	•		•
	Carangidae	*Caranx caballus*	100				•	
		Seriola rivoliana	30 - 200		•	•		
	Chaetodontidae	*Prognathodes falcifer*	50 - 200		•	•		•
	Embiotocidae	*Zalembius rosaceus*	90 - 150					•
	Labridae	*Decodon melasma*	80 - 220	•	•	•		•
		Halichoeres raisneri	80 - 120	•				
		Semicossyphus pulcher	50 - 150		•	•		•
	Lutjanidae	*Hoplopagrus guentheri*	100					•
		Lutjanus argentiventris	10 - 90		•	•		•
		Lutjanus guttatus	100 - 120				•	
		Lutjanus peru	40 - 80		•			
	Malacanthidae	*Caulolatilus affinis*	80 - 150	•	•			•
	Mullidae	*Mulloidichthys dentatus*	5 - 110	•	•	•		

Order	Family	Species	Depth (meters)	San Marcial	Las Ánimas	Marisla	San Dieguito	El Cochi
	Muraenidae	*Muraena argus*	80 - 120	•		•		
	Ophistognathidae	Ophistognathidae n. sp.	100		•			
	Pomacentridae	*Chromis limbaughi*	120					•
	Priacanthidae	*Pristigenys serrula*	120 - 250	•	•	•		•
	Serranidae	*Diplectrum* sp.	50 - 120		•	•		
		Epinephelus niphobles	100 - 250			•		
		Hemanthias signifer	150 - 210	•	•	•		•
		Liopropoma multifasciatum	20 - 100		•	•		•
		Mycteroperca jordani	100					•
		Mycteroperca prionura	20 - 90		•	•		
		Mycteroperca rosacea	5 - 100					•
		Paralabrax auroguttatus	30 - 120					•
		Paranthias colonus	5 - 120	•	•	•		•
		Pronotogrammus multifasciatus	100 - 250	•	•	•		•
Pleuronectiformes	Paralichthyidae	*Cyclopsetta panamensis*	120			•		
		Syacium ovale	90	•				•
Rajiformes	Myliobathidae	*Mobula* sp.	220			•		
	Narcinae	*Diplobatis ommata*	100 - 150					•
	Rajidae	*Raja inornata*	180			•		
	Rhinobatidae	*Zapteryx exasperata*	30 - 200	•	•	•	•	•
	Urobatidae	*Urobatis concentricus*	5 - 120	•	•	•	•	•
		Urobatis maculatus	90					•
Scorpaeniformes	Scorpaenidae	*Pontinus clemensi*	250			•		
		Pontinus furcirhinus	80 - 250	•	•	•		•
		Scorpaena histrio	80 - 200	•	•	•		
		Scorpaena mystes	5 - 100	•	•	•	•	•
	Triglidae	*Bellator xenisma*	100 - 150	•	•	•		

The taxonomic list of all the species collected or registered, with complete scientific names and authors, can be requested from Dr. Margarita Caso at the Instituto Nacional de Ecología (casom@ine.gob.mx), and will also be available at the internet webpage of the institute (www.ine.gob.mx).




ISLA CARMEN
Loreto
I Danzante Primero
Pta Candeleros
Las Galeras
I Monserrate
Isla Sta Catalina
White Rk
Pta San Marcial
VAR 10°34'E (1980)
ANNUAL CHANGE 5'W
Isla Sta Cruz
Isla San Diego
Isla Habana
Pta Calabozo
Isla Las Animas
CANAL DE SAN JOSÉ
Los Dolores
Pta Colorada
ISLA
SAN JOSÉ
Isla San Francisco
Cerro Natividad
Cerro de Mechudo
Cabeza de Mechudo
LA GIGANTA
CALIFORNIA
Los Islotes
Isla la Partida
ISLA DEL
ESPÍRITU SANTO
Isla Ballena
Pta Lobos
CANAL DE SAN LORENZO
Pta Coyote
Pta San Lorenzo
BAHÍA DE
LA PAZ
LA PAZ
Arrecife de la Foca
ISLA
CERRALVO
CANAL CERRALVO
Pta Arena de la Ventana

Appendix 1.

Geographic description of the Gulf of California seamounts

From Loreto Bay southwards to the Bay of La Paz there are at least 11 underwater peaks and promontories sufficiently removed from the coastline as to be considered true seamounts. Most of them are entirely submerged and are not visible from the surface; a few emerge forming islets and rocky outcrops. Geologically, the latter are practically identical to the submerged seamounts, only differing in the presence of a small rocky tip. It is likely that as sea levels descended during Pleistocene glaciations many of the seamounts that are currently submerged were also partially emerged forming similar rocky islets. Following the line of the coast from Carmen Island in Loreto Bay to Cerralvo Island south of the Bay of La Paz, the seamounts form the following list:

1. Bajo El Cochi (or *Bajo de Punta Baja*; 25°45'N, 111°11'W). Located some 4 nautical miles south Punta Baja, the southernmost tip of Carmen Island, and some 4 miles east of Isla Danzante; these banks lie, in their shallowest part, some 10 meters below the surface and descend rapidly towards Danzante Channel and towards the Gulf's deep basin east of Carmen Island.

2. Bajo La Reinita (or *Islotes Las Galeras*; 25°45'N, 111°03'W). The Las Galeras islets emerge from the deep seabottom and break the Gulf's surface some three nautical miles north of Isla Montserrate; and some three miles farther north the La Reinita banks are found. Separated from the Baja mainland by a channel more than 250

The coastal corridor of Baja California Sur (Nautical Chart 21014 "Cabo San Lazaro to Cabo San Lucas and Southern Part of Golfo de California", Defense Mapping Agency, Bethesda, Maryland, USA, 1984).

meters deep, the bottom relief of La Reinita descends abruptly eastwards into the depths of the El Carmen basin.

3. Bajo norte de Catalana (25°46′N, 110°47′W). In a manner similar to La Reinita banks, the northern tip of Isla Catalana shows a series of islets and rocky reefs that rise from the sea bottom north of the island, continuing underwater the geologic promontory of the island itself. A mile north this chain ends in a seamount that descends westwards towards the Montserrate Channel, and eastwards into the depths of the Carmen Basin.

4. Bajo San Marcial or *Bajo sur de Catalana* (25°31′N, 110°46′W). Located ca. eight nautical south of Isla Catalana, this rocky bank reaches 20 meters below the Gulf surface. At a depth of 80 meters the slope of its steep rocky basaltic crest becomes less inclined and changes gradually into a sedimentary slope that descends gradually eastwards towards the deeps of the Gulf of California or westwards towards the San Marcial Channel that separates the seamount from the peninsular mainland.

5. Bajo Las Ánimas (25°07′N, 110°31′W). The Las Ánimas islet emerges as a large basalt promontory some six nautical miles northeast of Punta Colorada, in San José Island. The steep basaltic rock formation plunges around 100 meters deep, where it expands into a sandy incline that descends gradually to 300 meters, from where it descends steeply again towards the deep of the Gulf.

6. Bajo San Dieguito and *El Rifle* (25°12′N, 110°42′W). The San Dieguito banks lie, in their shallowest part, 5–10 meters under the water surface some two nautical miles southeast of San Dieguito Island. El Rifle is a rocky projection of San Diego Island that runs in a southwest direction forming a long line of shallow rocks, 1–2 meters deep. Both banks rapidly lose steepness in their slopes, transforming the rocky banks into a sandy bottom that descends westwards towards the San José channel, and eastwards towards the deep Gulf basin.

7. Bajos de Punta Calabozo (25°06′N, 110°42′W). Some three nautical miles southwest of the San Diego banks, the shallows of Punta Calabozo are, more than a true seamount, a northwards submarine extension of the large formation of Isla San José. The ridge of rocks reaches 20 meters below the surface and extends two miles north, gradually sloping westwards towards the San José channel and the peninsula, and eastwards towards the Gulf.

8. Bajo Marisla (24°42′N, 110°18′W). Marisla lies some 10 miles northeast of Los Islotes, the northernmost point of Isla Espíritu Santo. With a pronounced relief, the shallowest part of this seamount reaches 15 meters, and descends abruptly to over 400 meters deep along a sheer escarpment of basaltic rock.

9. Bajo El Charro (24°42′N, 110°10′W). Around eight nautical miles northeast of Marisla, the El Charro seamount lies 60–80 meters deep, away from the reach of SCUBA diving. For this reason, it is one of the least explored and more poorly known seamounts of the region.

10. Arrecife Las Focas and *Bajo La Reina* (24°26′N, 109°58′W). Formed in a manner very similar to the Bajos de Calabozo, Las Focas is an extension of Isla Cerralvo. Continuing the longitudinal southeast–northwest axis of the island, the Las Focas reef reaches the surface some four miles northwest of the island's northern tip. La Reina, a fully submerged seamount some 20 meters deep follows along the geologic chain a few miles northwest.

11. Bajo Cerralvo (24°29′N, 109°51′W). Situated some six nautical miles northeast of La Reina, and separated from Cerralvo Island by a deep ocean basin, Bajo Cerralvo is the last seamount of this corridor. Of considerable extent, some two to three miles in diameter, the relief of this underwater plateau —essentially unexplored— seems to be one of rounded contours without steep slopes or pronounced escarpments.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Appendix 2.

Expedition participants

Research team and support staff

Organizers

- Octavio Aburto-Oropeza, Scripps Institution of Oceanography, leader and organizer of the expedition
- Brad Erisman, Scripps Institution of Oceanography, leader and organizer of the expedition
- Exequiel Ezcurra, San Diego Natural History Museum, leader and organizer of the expedition

Researchers

- Margarita Caso, Instituto Nacional de Ecología, oceanographer and marine ecologist
- Richard Cudney-Bueno, The David and Lucile Packard Foundation and University of California Santa Cruz, specialist in fisheries and marine conservation
- Carlos Sánchez-Ortiz, Universidad Autónoma de Baja California Sur, reef ecologist, specialist in cnidarians
- Francisco A. Solís-Marín, Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México, specialist in echinoderms
- Vivianne Solís-Weiss, Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México, specialist in polychaetes

Support team

- Ralph Chaney, videographer

Exequiel Ezcurra during one of the DeepSee diving trips. Foto © Octavio Aburto-Oropeza.

- Ana Ezcurra, editorial support
- Paula Ezcurra, field assistant
- Christian McDonald, Scripps Institution of Oceanography, diving safety
- Lorenzo Rosenzweig, Fondo Mexicano para la Conservación de la Naturaleza, photography lab manager and financial adviser

Argo crew

- Yosy Naaman, director general and boat owner
- Rodrigo Roesch de Bedout, cruise director
- Shmulik Blum, DeepSee submersible pilot
- Ofer Ketter, DeepSee submersible pilot
- Lorenzo Beltrán, dive master
- José Mora, captain
- Warren Fernández, TopSee boat operator (DeepSee support)
- José Antonio Castro, diving boat operator
- Rafael Solano, engineer
- Roger Quesada, waiter and bartender
- Raúl Jaén, chef
- Roberto Ramírez, kitchen assistant

Visitors on board the Santísima

- Rubén Coppel, businessman
- Martín Goebel, Sustainable Northwest, Oregon, and Walton Family Foundation
- Mick Hager, President, San Diego Natural History Museum
- Humberto Iriarte Salazar, Director, Zoológico de Culiacán
- Gastón Luken, businessman and conservationist
- Mónica Robinson, environmental educator
- Alejandro Robles, Noroeste Sustentable, México
- Christy Walton, philanthropist, naturalist, and supporter of the expedition


Carlos Sánchez-Ortiz


Richard Cudney-Bueno


Vivianne Solís-Weiss


Paula Ezcurra


Ana Ezcurra


Margarita Caso


Francisco A. Solís-Marín


Octavio Aburto-Oropeza
and Brad Erisman


Lorenzo Rosenzweig


Ralph Chaney


ARGO

Appendix 3.

Travel log

Friday, August 22

The different research groups arrive to Loreto from Mexico and the U.S. At 17.00 we loaded our gear onto Argo at the public pier of Puerto Escondido and returned to sleep in the La Pinta Hotel in Loreto where the whole team had its first meeting, with the absence of Octavio who had to stay in San Diego with a bad cold and high fever.

Saturday, August 23

Day 1. Bajo San Marcial. We departed at 9.00 to Bajo San Marcial (25°31'N, 110°47'W), where Brad led our first immersion in the DeepSee (w/Shmulik and Yosi as crew). A second dive was done in the afternoon with Vivianne and Francisco (Ofer as pilot). The rest of the team dived with tanks in the afternoon, under strong currents. We spent the night anchored south of Isla Catalana.

Sunday, August 24

Day 2. Bajo San Marcial. Third dive in the DeepSee with Ana and Exequiel (Shmulik piloting). Scuba diving in group with calmer currents and very good collecting. The day becomes cloudy and a warning is received of a tropical storm reaching Los Cabos. The weather conditions force the boat to return to Puerto Escondido around midday as tropical storm Julio approaches. We anchor at Puerto Escondido and, taking advantage of the forced break, Brad and Exequiel travel to Loreto in search of information and charts. They interview Rafael, the owner of the local dive shop, and Fernando Arcas, founder of Grupo Ecologista Antares. Fernando loans the expedi-

Argo (watercolor by Lorenzo Rosenzweig).

tion a sport fishing map that proved to be really helpful along the trip. Meanwhile, the taxonomists (Vivianne and Francisco) organized a photography lab in the boat where the collected specimens are deposited in special glass tanks for photo registration. Lorenzo, Margarita, and Ana assist in the establishment of the lab and take over the responsibility of documenting and photographing all the collected specimens.

Monday, August 25

Day 3. Puerto Escondido. We stay anchored in the shelter of Puerto Escondido. At 10.00 hours tropical storm Julio reaches its maximum intensity. It rains heavily, and gigantic waterfalls descend in torrents from the sheer cliffs of the Sierra de la Giganta. Around 13.00 the storm calms down, and we prepare for departure. In the afternoon we Scuba-dived down into Bajo Candeleros (25°45′N, 111°11′W), adjacent to Isla Danzante. In the evening Octavio rejoins the group with three hours of delay, after an erratic trip Tijuana–Hermosillo–Loreto, delayed and threatened by the bad weather. The photographic work continues on board.

Tuesday, August 26

Day 4. Las Ánimas. With Octavio on board, the team is complete! We depart at 7.00 towards Las Ánimas, where the fourth immersion of the DeepSee is done with Octavio and Christian (Ofer as pilot). A fifth DeepSee immersion for specimen collecting is led by Carlos (w/Shmulik and Yosi). We all approved our Nitrox certification! To celebrate we do two Scuba-dives with Nitrox around the Las Ánimas rock, one in the morning and one in the afternoon. In the evening we sail to San José and anchor in a cove north of the island, facing the peninsula on the western side of the island. From this day onwards all our dives were done with Nitrox.

Wednesday, August 27

Day 5. Las Ánimas (25°07′N, 110°31′W). We hoist anchor at 7.00 and depart towards Las Ánimas. Sixth DeepSee dive in the morning with Lorenzo and Margarita (w/Ofer as pilot). Seventh dive at 15.00 h for specimen collecting, led by Francisco

Crab I (watercolor by Lorenzo Rosenzweig).

(w/Shmulik and Yosy as crew), and eighth dive at 18.00 h with Vivianne and Carlos (Shmulik as pilot). We did three Nitrox dives around the Las Ánimas rock, one in the morning, one on the afternoon, and a late dive at 18.00 h. The team work photographing and documenting collected specimens continues.

Thursday, August 28

Day 6. Bajo Marisla (24°42'N, 110°18'W). In the morning, ninth DeepSee dive with Exequiel and Paula (Ofer as pilot); tenth dive in the afternoon for specimen collecting led by Vivianne and Francisco (w/Shmulik). Three tank dives, one in the morning (whole group), one at 15.00 h, and a last one at dusk with Octavio and Carlos, to photograph.

Friday, August 29

Day 7. Bajo Marisla (24°42'N, 110°18'W). Eleventh DeepSee dive with Brad and Richard (Ofer piloting) in the morning, followed by the twelfth dive in the afternoon, a collecting dive led by Carlos with Shmulik and Yosy as crew. In the morning, one group SCUBA-dived in the pelagic environment while other explored the seamount reefs counting sea cucumbers (*Isostichopus fuscus*) to compare with their abundance in the coastal reefs. This second group encountered a whale shark which an hour later approached the boat and everybody jumped into the water with their snorkels to see it. During our second tank dive in the afternoon the whale shark swam among the divers while feeding in the plankton soup that wells-up around the seamount, offering an opportunity for excellent photos. Lorenzo and Octavio devoted this second dive to photographing and documenting in detail the life in the reef.

Saturday, August 30

Day 8. Bajo Marisla. Thirteenth DeepSee dive, in the morning, collecting under the lead of Vivianne and Francisco (Shmulik as pilot); fourteenth dive at 15.00 h with Octavio and Exequiel (Ofer piloting). Last dive of the day (fifteenth of the cruise) in the afternoon, at 17.30, with Carlos and Richard for collecting purposes (Shmulik at the controls). The day has provided good collections of corals, echinoderms, mollusks, and a gigantic sponge from the deep, ca 300 m. Two SCUBA-dives, one in the morning and one in the afternoon, basically to photograph the shallow top of the seamount.

Sunday, August 31

Day 9. Bajos de San Dieguito (25°12’N, 110°42’W). At 9.00 h, sixteenth DeepSee dive with Margarita and Vivianne (Shmulik piloting), and at 15.00 dive number 17 was done with two of our visitors and expedition supporters from the “Santísima”: the DeepSee descended with Christy Walton and Martin Goebel (Ofer in the controls). The SCUBA group dived in the morning in the central reef of San Dieguito, and in the afternoon we did a second dive drifting in a strong warm current counterclockwise around Isla San Diego until a point north of the island where we hit a cold west-east countercurrent flowing from the San José channel.

Monday, September 1

Day 10. Bajo El Cochi (Punta Baja; 25°45’N, 111°11’W) and return to Puerto Escondido. In the morning, eighteenth DeepSee dive for specimen collecting led by Richard and Octavio (Ofer at the helm); nineteenth and last dive at 13.00 h with Brad and Ralph (Shmulik as pilot). The SCUBA team dived first at 10.00 and then in the afternoon at 15.00, both times to document and photograph the shallow part of the seamount. Evening in Puerto Escondido where we had a farewell dinner with Steve and Hiro Drogin, and the crew of the “Discovery”.

Tuesday, September 2

Puerto Escondido. With the sadness of separating and parting after one of the most marvelous and intense weeks of our lives we disembark, load our vans, and take our different ways back home.

Whale shark
(watercolor by Lorenzo Rosenzweig).

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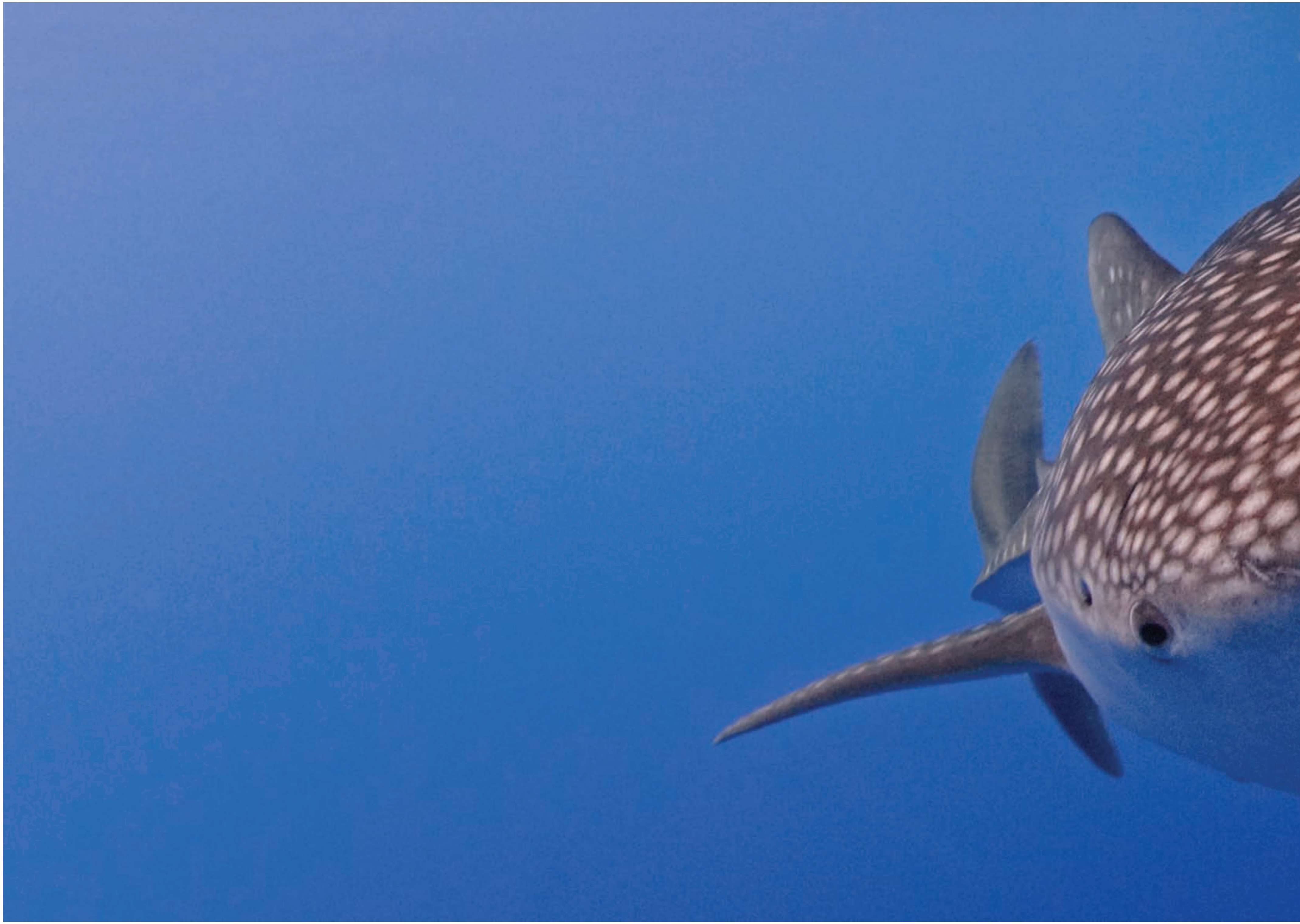
Page 5: Lower (actinal) surface of the cushion star *Pentaceraster cumingi*. Photo © Lorenzo Rosenzweig.
Pages 6–7: At Bajo Marisla, a juvenile creolefish *Paranthias colonus* swims among colonies of sea fans *Muricea fruticosa*. Photo © Octavio Aburto-Oropeza.
Pages 8–9: At Las Ánimas, a male Cortez angelfish *Pomacanthus zonipectus* searches for refuge among the colonies of black coral *Antipathes galapagensis*. Photo © Octavio Aburto-Oropeza.
Page 160: Close-up view of the cushion star *Pentaceraster cumingi* showing the pores used for respiration. Photo © Lorenzo Rosenzweig.
Page 166: Close-up view of the interlocked arms of the basket star *Astrodictyum panamense*. Photo © Lorenzo Rosenzweig.
Page 170: Zoomed shot of the epidermis of the yellowtail surgeonfish *Prionorus punctatus*. Photo © Octavio Aburto-Oropeza.
Page 173: Zoomed shot of the epidermis of the sergeant major *Abudefduf troschelii*.
Photo © Octavio Aburto-Oropeza.
Pages 174–175: Standing on a mooring bollard of the dock at Puerto Escondido,
a seagull *Larus livens* shows its profile against the cliffs of the Sierra de la Giganta.
Photo © Lorenzo Rosenzweig.
Pages 190–191: A polychaete worm of the family Nereididae in its sexual reproduction phase displays the typical body segmentation of reproductive adults. Photo © Carlos Sánchez-Ortiz.
Page 192: A school of Gulf groupers *Mycteroperca jordani*, a species related to sea basses and cabrillas, explores a sandy bottom. Photo © Octavio Aburto-Oropeza.
Pages 198–199: A whale shark *Rhincodon typus* searched shelter and food under the shade of our boat, Argo, and followed the expedition for two days. Photo © Octavio Aburto-Oropeza.
Page 200: Crab II (watercolor by Lorenzo Rosenzweig).

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