Richness and productivity

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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.

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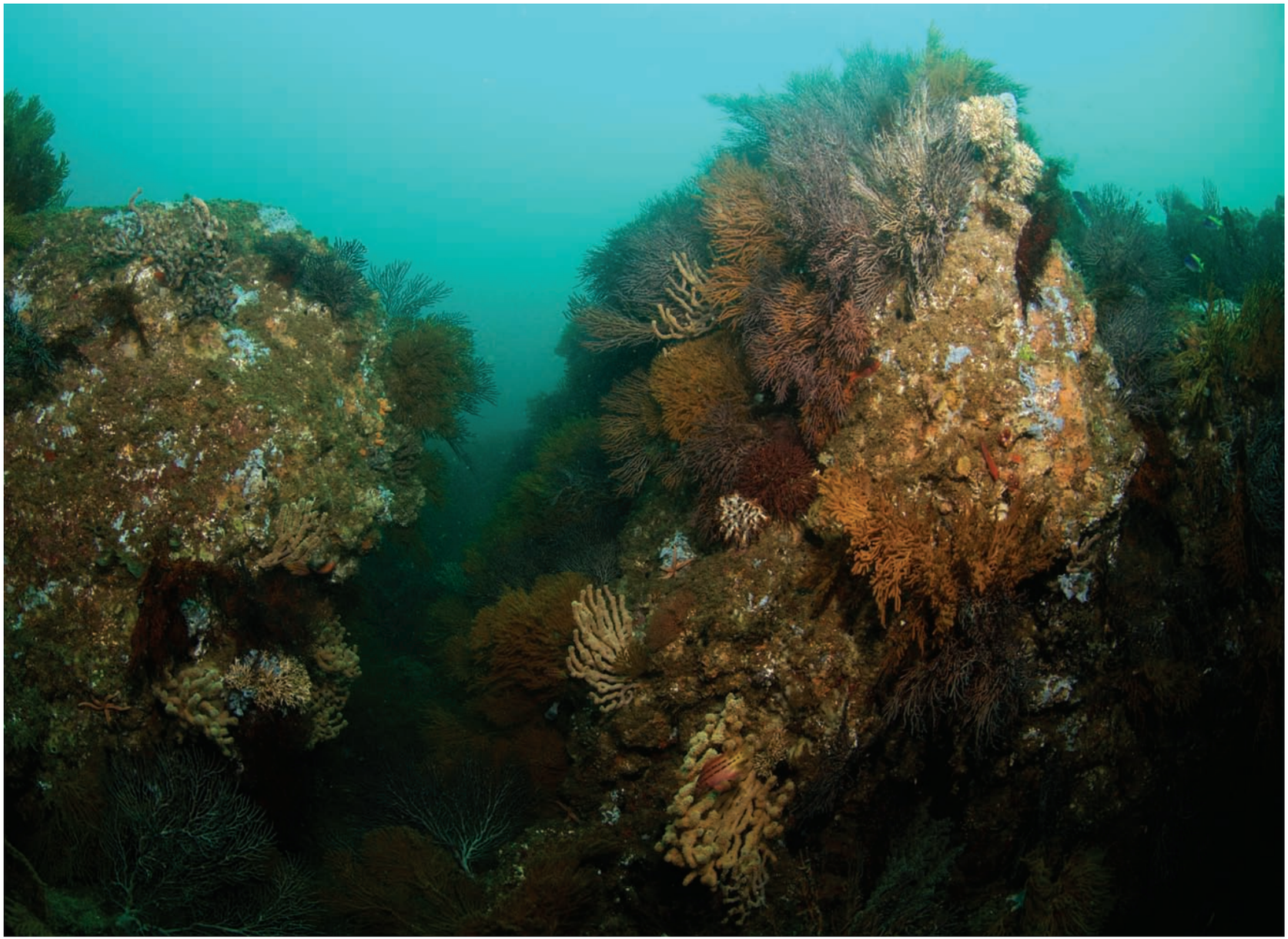
Voracious and agile predators, a group of green jacks *Caranx caballus* attacks a school of sardines.
Photo © Octavio Aburto-Oropeza.



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.