ENVIRONMENT SOUTHWEST
SAN DIEGO NATURAL HISTORY MUSEUM

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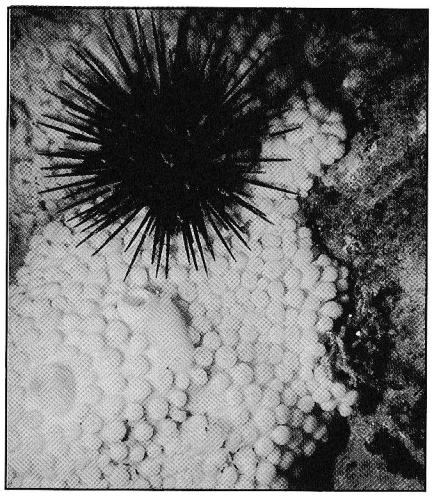
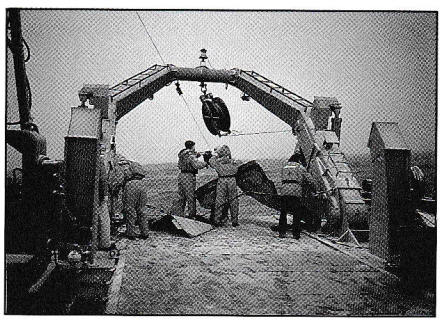


Our cover . . .
Predator and prey: both the black sea urchin and the camouflaged yellow nudibranch eat these pink and yellow sponges within the Gulf of California. See article on page 18. Photo by Hans Bertsch.

. . . and on the back
On a relatively calm day, the Bongo Net team, in red flotation suits, rigs the net for launch off research vessel Melville's *stern, just north of Elephant Island (Antarctic Peninsula). Nets are blue to reduce their visibility to plankton. The yellow object on deck is a depressor vane, an upside-down wing, which uses the ship's speed to pull the net deep into the water (much safer than the traditional 1,000-lb. weight). The white material on deck is, indeed, snow. For "science is fun" exercise, do this in a driving blizzard, at night, with the ship rolling 25 degrees. See article on page 3. Photo by Eric Shulenberger.*



An International Reconnaissance Expedition: Marine Zoogeography of Baja California Sur

Text and photos by Hans Bertsch

Part of the road 30 miles south of Los Cerritos, crossing a deep arroyo in which some water still remains.

Baja California is an alluring peninsula. The very existence of this elongate stretch of volcanoes, lava flows, sand dunes and deserts has served as a constant scientific gauntlet thrown against our ideas of what the world is all about. Even its basic geography defied correct description for nearly 200 years.

AN ISLAND FOR TWO CENTURIES

The first recorded landing of Europeans on the peninsula was in 1532. Hernán Cortés sent an exploring mission out from New Spain, but at sea the crew mutinied, and Ordoño Jiménez took command. Sailing into the Bay of La Paz, he was apparently the first "white man" to set foot on the Baja peninsula. The friendly native welcome turned to bloodshed when the explorers tried collecting Indian women as well as pearls. Swift justice meted out capital punishment to Jiménez and 20 of his crew.

California was its mythical name, and sporadic expeditions continued to be sent out to explore what was thought to be an island. In 1542-1543 Juan Rodríguez Cabrillo sailed past Cabo San Lucas far northward to the 44th parallel. He considered it to be a very long island.

Fifty years later Sebastián Vizcaíno was commanded to secure lower California, so that the riches-laden galleons returning from Manila could be protected from the depredations of British marauders. Vizcaíno's two journeys resulted in further explorations of the west coast of California, renaming sites previously named by Cabrillo (e.g., San Miguel became San Diego), and the discovery of Monterey Bay. Despite these lengthy voyages, the legend persisted and the first printed map of California (1625) shows it to be an extensive island.

In 1697 the Jesuit priests Juan de Salvatierra and Eusebio Kino sailed across the Mar de Cortez to establish the first ultimately successful mission at Loreto. Father Kino then recrossed the Gulf to Sonora. From there he travelled north, crossing New Mexico and Arizona and the Colorado River. He thus established that Baja California was an elongate peninsula attached to the mainland and not an island, nearly 200 years after the first European landing.

THE SCHOLARLY CHALLENGE

The challenge of its identity was solved but new challenges continually arose. The first book about Baja California was by Miguel Venegas: 1739, *Empresas apostólicas de los Padres Misioneros de la Compañía de Jesus, de la Provincia de la Nueva España, obradas en la Conquista de California*, a title nearly as long as the peninsula. But Vene-

gas was merely a compiler of missionaries' letters who had himself never visited the peninsula. Although myths and absentee speculation continued, the first scientific expedition to Baja California—led by Abbot Chappe d'Auteroche in 1769 to observe the transit of Venus across the sun— began scholarly investigations into the natural history, anthropology and geology of the Baja California peninsula. The observations of the Jesuit priests Baegert and Barco were soon published (in 1772 and 1790, respectively). The Englishman, Richard Brinsley Hinds, travelling on the exploring vessel *H.M.S. Sulphur*, made a botanical collection along the Pacific Coast of the peninsula during 1839 that resulted in the description of 78 new plant species by fellow countryman George Bentham.

John Xantus lived at the United States Tidal Observation Station at Cabo San Lucas from 1859 to 1861. He is not remembered for careful oceanographic measurements, but for his collecting of mammals, birds, lizards, insects, crabs, sea stars, molluscs, fish and land plants, that resulted in the descriptions of over 200 new species.

During 1887-1888, 4400 birds were collected from the Cabo San Lucas region by M. Abbot Frazor for Harvard ornithologist William Brewster. Probably the California Academy of Sciences expeditions from 1888 to 1894 (under Walter Bryant, A. W. Anthony and Gustav Eisen) and their resultant publications were the major stimuli to early twentieth century work in Baja California.

Since then, expeditions from institutions around the world have trekked the length of the peninsula by foot, muleback or four-wheel-drive vehicles. Others have explored its seas with well-equipped research vessels or in small two-diver zodiacs or leaky *pangas*.

The foci of their studies have been as diverse as the peninsula and its inhabitants: forests of gangling cirios; basalt rocks wrested from mainland Mexico by the spreading of the east Pacific rise; lifesize aboriginal cave paintings of red and black shamans and deer; fish-catching bats; lizard zoogeography; pesticide damage to brown pelican populations; or cascading underwater sandfalls.

This jagged land between two seas continues to amaze, captivate and challenge. For over 15 years I have been returning to Baja California, with varying frequency, to study the marine fauna of this unique region. Hence I was especially pleased when I was invited to participate in an international reconnaissance expedition along the Pacific coastline of Baja California Sur.

1984 CAS EXPEDITIONS

Under the auspices of the California Academy of Sciences in San Francisco, our team was supported by a grant from the George Lindsay Field Research Fund and consisted of CAS staff members and faculty and students of the Universidad Autónoma de Baja California and the Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE).

The purpose of these trips was to select sites for more intense study and to obtain preliminary data as a basis for a major grant proposal. We were interested in an ecological community (opisthobranch molluscs and their prey) in an area of great zoogeographic significance—the region of faunal overlap between the warm temperate Californian province and the eastern Pacific tropical province. During the course of two expeditions in January and June-July 1984, we surveyed the intertidal and subtidal fauna between Punta Eugenia and Cabo San Lucas (on the outer coast of Baja California Sur), and on up inside the Gulf of California to Las Cruces. (Politically, the peninsula consists of two states: the northern Baja California and the southern Baja California Sur. The dividing line is the 28th parallel.)

Participating in both expeditions were: Dr. Michael T. Ghiselin, CAS Research Associate and evolutionary biologist; Dr. Terrence M. Gosliner, Curator, Department of Invertebrate Zoology, CAS, opisthobranch taxonomist and phylogenist; myself, CAS Associate and opisthobranch taxonomist, scuba safety "officer" and Baja aficionado; Dr. Welton Lee, CAS Curator and sponge systematist; Robert Van Syoc and David Catania, curatorial assistants; and Oceanólogo Luis Aguilar Rosas, staff researcher at the Instituto de Investigaciones Oceanológicas of the UABC in Ensenada. As other personnel accompanied us on either of the expeditions, our team varied from eight to 11 people with three to four vehicles respectively.

The roads of Baja California are often flagrant in their disregard for repair. We knew that we would travel extensively over unpaved or non-existent roads, so all our vehicles were four-wheel drive. They were heavily laden with food, clothing, a compressor to fill our eight scuba tanks, diving gear, collecting equipment, jars and bags for preserved specimens, camera equipment, camping gear, and emergency repair tools.

Dive site south of Loreto. We crossed the mudflat which is exposed at low tide and dove outside the rocky point in the center of the picture.

BAHIA MAGDALENA TO LAS CRUCES JANUARY 1984

To achieve our reconnaissance objectives, we divided the pertinent coast of Baja California into two sections. In the January expedition we traversed the extreme southern portion of the peninsula. Since the winter rains had drenched nearly the entire peninsula, we drove through miles of verdant desert. Cacti and bushes were in bloom—at times carpeting the hillsides with swathes of yellow or pink. Even the cardones were blooming. Rest stops were often spent scurrying from bush to bush photographing the flowers.

We camped at Loreto to do a check-out dive in the shallow, clear, calm waters of the Gulf. I wanted to determine skills of some of the participants under a controlled situation, and test our equipment prior to the heavy use to which we would be putting it. As it turned out, the dive was more research than check-out. Most of the team had had lots of prior scuba experience.

We found 12 species of opisthobranchs, among which were some significant records. There were, of course, the expected tropical *Berthellina engeli* (the orange blob) and the green *Tridachiella diomedea* (it also has black and orange dots along a frilled margin and blue streaks in the green). We saw a few Southern California familiars including the bubble shell *Bulla gouldiana* and the predatory slug *Navanax inermis* (one of the few consistent eaters of opisthobranchs).

Erythea armata *(blue fan palm tree) in full bloom, late June 1984 in the Arroyo Cataviña.*

Of special interest was *Spurilla neapolitana.* This eolid nudibranch has been reported numerous times throughout the tropical Atlantic, including the Mediterranean and Caribbean Seas. Moreover, this species has been reported from the central Pacific (Oahu, Hawaiian Islands) and the eastern Pacific (I reported it from the Gulf of California in 1979). This distribution is not characteristic of Gulf of California opisthobranch species.

Prior to one to two million years ago, the land mass of Central America was underwater, and there was a single trans-isthmian faunal province: the tropical American region. One effect of plate tectonics was the slow formation of Central America. This rising land mass split the formerly single American tropical marine faunal province into two provinces: the Caribbean and the eastern Pacific. Because of the isolation—which separated the marine species into two separate populations—speciation occurred differently on the two coasts of Central America. Today numerous invertebrate species exist as pairs—a different species has evolved on each coast from an original common ancestor.

Apparently *Spurilla neapolitana* represents a species that was present before the isolation of the populations. This particular species did not evolve into separate species (evolutionary rates vary), and hence occurs on both sides. Distribution across the Atlantic or from the eastern Pacific to Hawaii took place by larval transport of the juvenile planktonic stage in water currents.

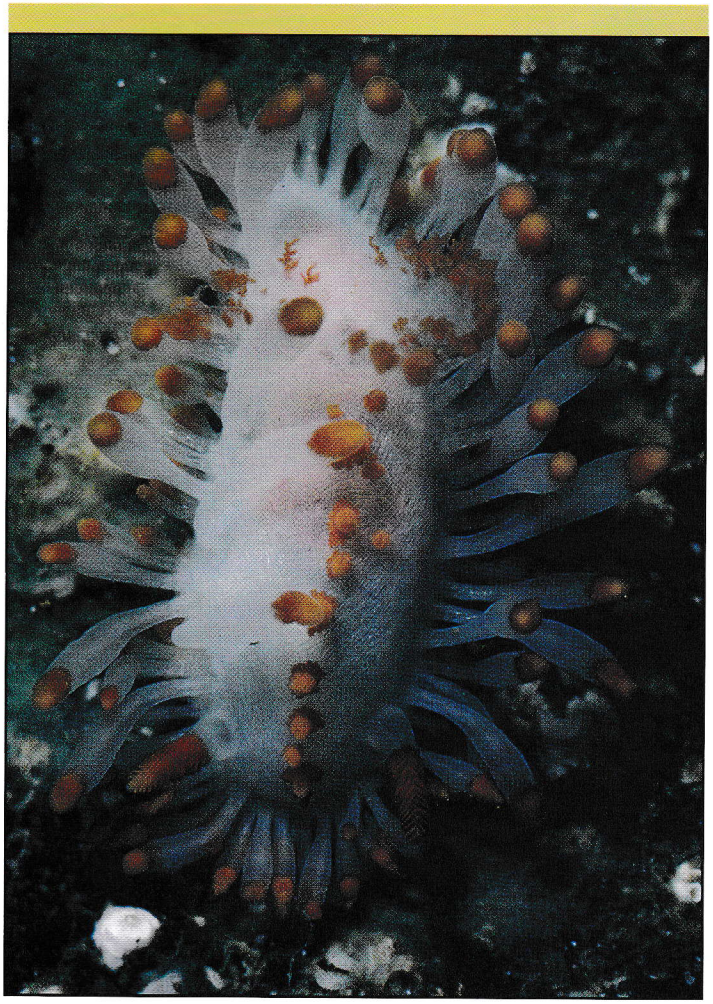
We found another Caribbean nudibranch species for the first time in the Gulf of California. In fact, the genus to which this species belongs has never before been reported from the entire Pacific Ocean. We have an article in press describing the anatomy of this intriguing species.

Leaving Loreto, the road traces a narrow path between sheer volcanic cliffs and the pristine blue waters of the Gulf. It crosses the Sierra de la Giganta, and then knifes straight across the flat plains to Villa Insurgentes and Ciudad Constitución. At this latter city we detoured from the main transpeninsular highway over to Bahía Magdalena. The low mountains on the far western horizon were the tops of the narrow islands that form this large protected bay. It was also the first area we wanted to examine zoogeographically.

Along the Pacific Coast of North America, there are a number of different faunal provinces (regions where the same plants and animals occur). These are mainly delimited by temperature. Since ocean currents flow along the coast, one would expect that some more widely temperature-tolerant species might occur over large areas, but that most species would have more restricted distributions. The Southern California and Northern Baja California coastline represents one such region: the California faunal province, a cool temperate water regime. The Gulf of California, Pacific Coast of Mainland Mexico and Central America—to the Galápagos—is the Panamic province (tropical eastern Pacific). The northern limit of the Panamic province is Bahía Magdalena. The entire outer lower half of the Baja California peninsula—from Punta Eugenia southward—is one of the lesser known regions of the peninsula. We wanted to get an idea of the fauna in this boundary region.

Intertidally, we worked in the mud of Bahía Magdalena across the vast flats exposed at low tide. Subtidally, we dove at Punta Entrada, where we swam among tropical angelfish and damselfish and Southern California's orange garibaldi (*Hypsypops rubicunda*); it was just the kind of tropical-temperate species mix we

Hypselodoris californiensis *is a Californian temperate faunal province nudibranch. This pair was collected subtidally at Campitos just northeast of Punta Eugenia. The larger animal is about 30 mm long.*

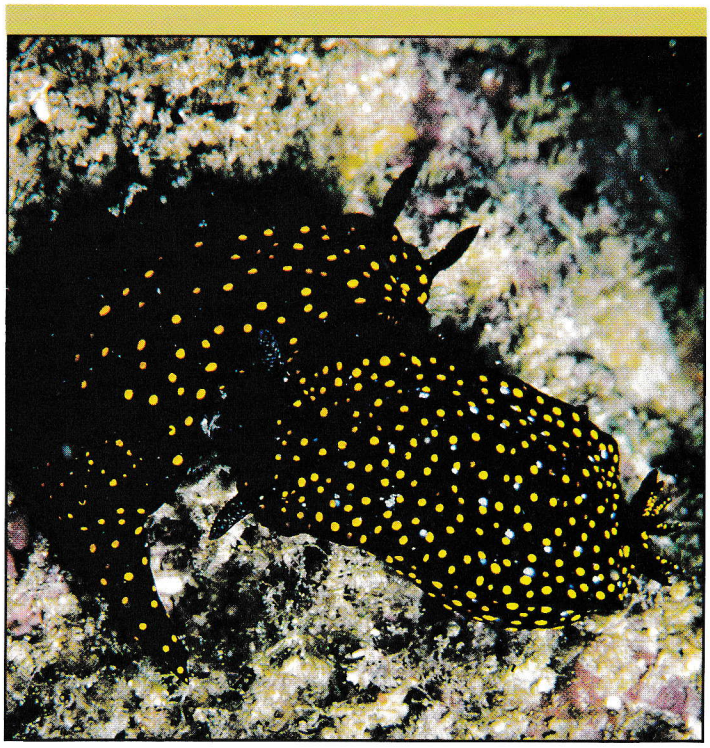


The nudibranch Laila cockerelli, *collected from the southeast entrance to Bahía Tortugas. This white and orange-red mollusc is about 20 mm long.*

expected.

Continuing our trek south, we bypassed the sandy beaches of the Magdalena Plain, returning to the coast near Todos Santos. We crossed the Tropic of Cancer at this small, verdant agricultural village. Along most of the southwestern coast of the peninsula below Bahía Magdalena, access to beach areas was restricted by surf on the rocky headlands. Isolated rocky points were separated by long sandy embayments. These were not the best habitats for sessile (attached) marine invertebrates and their predators.

Rounding the bottom of the peninsula, collecting sites became more numerous: Cabo San Lucas, Puerto Chileno, Bahía Los Frailes, Cabo Pulmo and Las Cruces. At Cabo San Lucas we



This copulating pair of Hypselodoris ghiselini *was photographed underwater by the author at Puerto Chileno. This species (similar in markings to* H. californiensis*) occurs in the tropical eastern Pacific faunal region, sometimes quite commonly within the Gulf of California. These animals were about 40 and 50 mm in total length.*

donned our wet suits and camera equipment and hiked along the cliffs to a slightly wider beach. Dave loaded the zodiac with our tanks and met us at our entry site. Less than 20 feet from shore the canyon walls drop straight down—very deeply. We had decided to limit our maximum depth to 60 feet. Working a sheer vertical cliff face is one of the more exhilarating experiences of diving. Within the safety-determined limits, one is free to roam up and down, sampling a variety of animals and plants at the different levels. It is a truly three-dimensional experience. An added treat at Cabo San Lucas was being able to see the sand-falls. The mountains of the Cape region are slowly eroding into the sea. The underwater sand cascades are flowing evidence of the geological cycles shaping and carving the born-of-fire volcanic peninsular rocks.

Each site was special: the twilight quiet of our dive at Puerto Chileno; the coral reefs at Cabo Pulmo (Baja California's only "true" coral reef); and the long shallow dive at Las Cruces after the torture of the dirt road that had torn my jeep's clutch apart. Las Cruces holds special memories for me, since some of my earliest research in the Gulf of California was done there. Dr. Rita Schafer of Immaculate Heart College used Bing Crosby's resort home as a summer marine station for her students in marine biology. I named several new species of opisthobranchs that I collected while a visiting investigator at the station. Two of these species, *Aglaja regiscorona* and *Phidiana lascrucensis*, have their type locality at Las Cruces.

At these more abundant collecting sites, denizens of the deep were more frequently encountered. Many of the invertebrates were variegated: Purple, yellow, orange, black, brown sponges underneath rocks. The red-wine colored network of sea fans outlined with translucent white polyps. Gaudy flatworms. Sea stars spiney and spikey, colored red-orange and gray, chocolate brown on tan, or with bright red-brown splotches on a red-pink background. Four to six-inch-long needled urchins. Toxic *Toxopneustes*, a globoid, short-spined tropical sea urchin with petaloid pink pedicellariae. Small gray and white striped commensal shrimps, living a camouflaged existence among the bumps and protrusions of the eastern Pacific crown-of-thorns sea star. Ectoparasitic *Thyca callista*, blond-shelled gastropods feeding on sea stars.

We documented over 30 species of opisthobranchs: nearly 60% are endemic to the tropical eastern Pacific; a few occur in the tropical Atlantic or east-central Pacific; several are shared with the temperate Californian province; and about 20% are unnamed or were not immediately referable to a known species.

Because of the success we had on our January expedition, as the June departure date approached, we became even more anxious to return to this peninsula and continue our research.

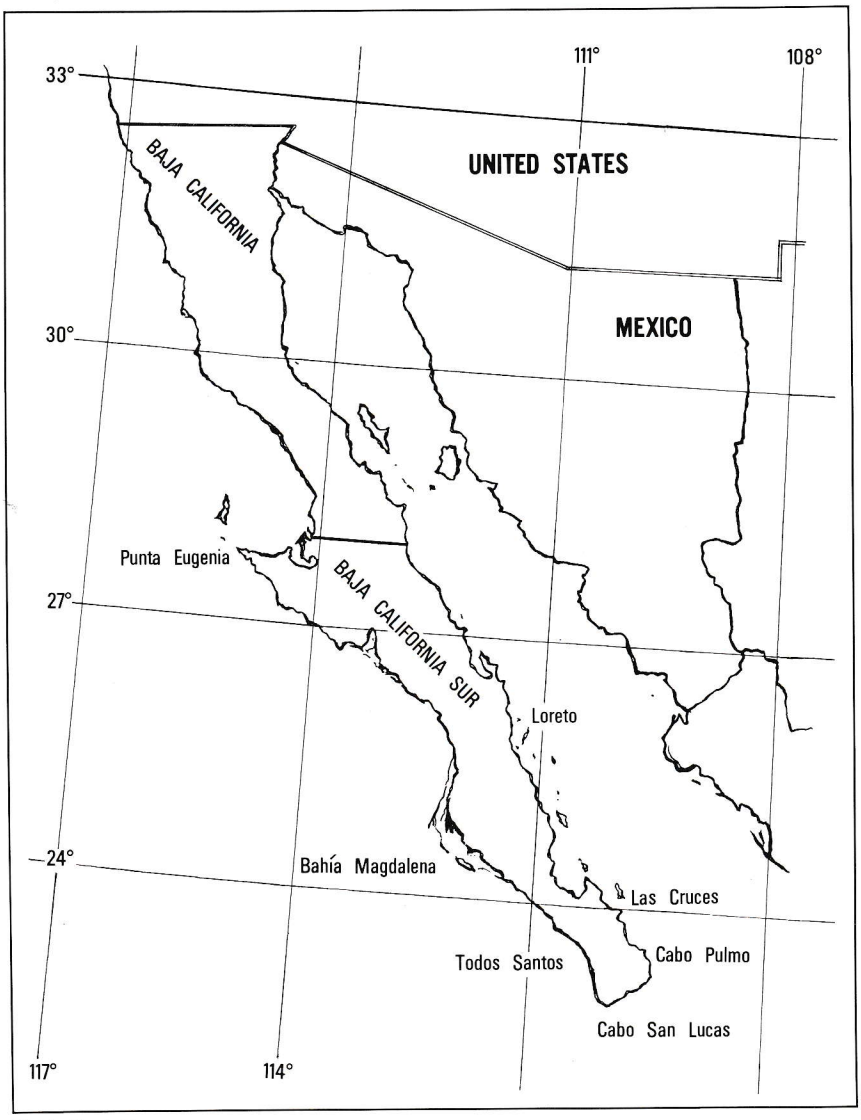
PUNTA EUGENIA JUNE—JULY 1984

We spent the June-July expedition in one of the more isolated regions of Baja California—the western-protruding Punta Eugenia peninsula. Between paved roads (which we left at Crucero del Pacífico, about 10 miles north of San Ignacio), we drove nearly 500 miles over unpaved washboard scrapings: across dry, desolate fossil-laden terraces; through narrow canyons gouged out by flash floods; past hillsides covered with pink-blooming elephant trees; and into small fishing villages where the only potable water is either hauled into the area in rusty 55-gallon drums or in exhaust-spewing water trucks, or is made from ocean water at a desalination plant. There are no telephone wires nor electric lines between towns. Communication is by radio or microwave; electricity is made at local diesel-powered generating stations.

One of the most bizarre driving experiences I have ever had was on the broad salt marsh flats northwest of Punta Abreojos. The road lifts over a small sand hillock leaving town, then crosses a hardpan paralleling a mangrove-lined *estero* (estuary). The road is just a harder-packed scar across the salt marsh, dividing and rejoining itself. One must choose carefully because some detours are dry, while the "main road" is covered with hypersaline water. Surrealistic mirages completely surrounded us. We drove straight across a constantly changing island of sand, keeping our eyes focused close in front of us. The dry road was only immediately around us; everywhere else we looked, we saw water. One could understand the source of those ancient cosmologies that said the Earth was an island surrounded by a flat sea. To our vision, we were driving right into the sea, and straight out of it! It would have inspired even Salvador Dali.

The roads were hard on the vehicles. We had five flat tires, two broken body frames (on the same vehicle—rewelding was done at Bahía Tortugas and Guerrero Negro), and a broken radiator that quickly fumed out all its water (removed, repaired and re-placed in my jeep at San Ignacio). Ah, the rigors of Baja California.

We did get into the water, sampling intertidal and subtidal locations in the Punta Eugenia area. The biological data we gathered gave us a much better perspective on the zoogeographic relationships of opisthobranchs along the outer coast of Baja California. The two expeditions yielded very different species, confirming faunal differences.



Map by Connie Cox

ZOOGEOGRAPHIC CONTRASTS OF BAJA CALIFORNIA SUR

During January's expedition, between Cabo San Lucas and Las Cruces, the animals we found were nearly all Panamic species; we found very few Californian species. Looking at our collecting records of chromodorid nudibranchs highlights the faunal contrast. The six species of

chromodorids collected around the southeast corner of Baja California Sur were all tropical Panamic species. The southern Gulf of California coast of the peninsula is distinctly tropical Panamic in its faunal composition. The zone of overlap between the temperate and tropical waters is pretty well restricted to the outer coast of the Baja California peninsula.

By contrast, the chromodorids collected during our study at the Punta Eugenia region included four Californian temperate water species and two tropical species.

Our total species count from Punta Eugenia consists of 51 species, four to seven of which are probably unnamed species. The named species were either Panamic tropical, Californian warm temperate, or shared Californian-Panamic species. For instance, *Chromodoris norrisi, Polycera alabe* and *Tambja eliora* are distinctly tropical species, at the northern periphery of their normal distribution. *Chromodoris macfarlandi* and *Polycera atra* are Californian species near their known southern distributional limits. *Spurilla chromosoma* and *Sclerodoris tanya* are species that are fairly well known from both Southern California and the Gulf of California. This region is definitely a zone of overlap between two faunal provinces.

The history of our knowledge of *Sclerodoris tanya* is most revealing. It emphasizes the importance of research along the outer Baja California coastline. The species was originally named from one specimen collected at Newport Bay, California. During the next ten years, it was found frequently in the San Diego area, and collected at various times throughout the Gulf of California. Since then I have collected it in the Ensenada area (northwestern Baja California). We found *S. tanya* at Bahía Tortugas, a significant midpoint between its previously disjunct known collecting sites from northwestern Baja California and Isla San Jose in the southern Gulf of California.

There are many gaps in our knowledge of species distributions. Numerous species are known only from either the adjacent northern or southern faunal regions. Probably many more of them will be found to occur along the central Baja California coastline. Northern species are consistently being found south of San Diego. Panamic species are regularly being reported from the outer coast of Baja California Sur. The southern Pacific coastline of the Baja California peninsula appears—based on our collections of opisthobranchs—to be a major zone of provincial overlap.

Having two different bodies of water so close together gives Baja its own unique zoogeography. I am struck by contrasts with Panama and Hawaii. Panama is bounded by two tropical seas: the Caribbean and the eastern Pacific. Although the shores are a scant 90-minute train ride apart, the animals have been separated for a million or more years and have speciated into two different major faunal assemblages. There is very little faunal interchange between these two regions today. On the Hawaiian Island of Oahu, different species of chromodorids occur in different leeward and windward habitats. But all the animals are basically tropical central Pacific or Indo-Pacific species. By contrast, animals from the eastern coast of Baja California are Panamic in nature, whereas animals from the western outer coast are a mixture of Californian temperate water and Panamic tropical water species, and a large percentage of shared species. There are very different isolating barriers (with varying efficiencies) operating in these areas. The excitement of zoogeographic studies is discovering the different ways different animals have evolved and adapted in different geographic regions.

The scientific challenges of Baja California continue.

Pulling the empty trailer up the steep, deeply-rutted road exiting a sand-filled arroyo, on the way to Las Cruces. This extremely rough road is maintained to discourage visitors to the coastal resort village of Las Cruces.

ADDITIONAL READING

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