

# Conserving California's Vibrant Deep-Sea Ecosystems

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## Relevant Acronyms:

CenSeam	Census of Seamounts
EFH	Essential Fish Habitat
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
EIS	Environmental Impact Statements
MPA	Marine Protected Area
MBARI	Monterey Bay Aquarium Research Institute
NOAA	National Oceanic and Atmospheric Administration
NWTT	Northwest Training and Testing Study Area
ROV	Remotely Operated Vehicles
SCRC	Southern California Range Complex
SMS	Seafloor Massive Sulfides
USGS	United States Geological Survey

## Executive Summary

Protection for the diverse offshore and deep-water environment of California will provide a lasting benefit to the people of the United States. The ocean off California's coastline is home to an exceptional array of seamounts, ridges and banks that host spectacularly diverse marine wildlife and habitats, as well as extraordinary geological features. These areas serve as oceanic oases, providing nutrient-rich waters, unusually high productivity and relatively large concentrations of sea life. Endangered sperm, fin and blue whales; unique angler fish; octopuses and sea jellies; and extremely long-lived deep-sea corals and sponges are just some of the species that rely upon these valuable habitats.

The following report describes several deep-sea sites that include a diversity of geologic features within the federal marine waters off California that are noteworthy areas for protection. A deep-sea network of areas will complement the marine protection efforts in state waters, provide enhanced protection for the marine environment that Californians depend on, and will result in the most comprehensive system of marine protected areas yet developed for any region of the United States, and perhaps the world.

The biological and geological hotspots under consideration include: **Gorda Ridges** (the portion off California) and **Mendocino Ridge** in the north; **Gumdrop, Pioneer, Guide, and Taney Seamounts** off Central California; and **Rodriguez and San Juan Seamounts, and Northeast, Cortes and Tanner Banks** in the south. All nine sites are in federal waters.

From the world's largest whale-- the blue whale-- to currently undiscovered marine species, California's deep-sea marine life are in dire need of protection from imminent and numerous threats: commercial fishing, oil and gas exploration and drilling, deep-sea mining, telecommunications cables and deep-sea arrays, shipping and vessel strikes, invasive species, kelp harvest, bioprospecting, naval training and testing, climate change as well as future activities such as submarine tourism to name a few. Taken together, the biological and geological treasures found within California's seamounts, ridges and banks exhibit significant importance and warrant strong protection for us, and future generations.

## Introduction - Conservation Opportunity for California's Offshore Waters

The deep sea off California is home to a number of seamounts, banks, ridges and other large undersea features as well as hydrothermal vents, all of which are important ecosystems harboring marine biodiversity. The incredible seafloor complexity promotes unique ecosystems and endemic species (species that are not found in other locations) (1). The patterns of species diversity and endemism vary greatly across the offshore waters of California, with the remoteness of these features to other communities playing a key role (2). Recent exploration of hydrothermal vent communities off northern California also points to unique and sensitive chemosynthetic communities (where energy is provided by chemical reactions) that form around the sulphur-rich, heated waters that escape the Earth's crust at these places, and contain large percentages of endemic species.

With the 2005 expansion of Monterey Bay National Marine Sanctuary to encompass Davidson Seamount, a notable first step was taken in acknowledging the significance of deep-sea ecosystems and the necessity for conservation. This current proposal includes nine additional deep-sea seamounts, ridges and hydrothermal vents of ecological significance and conservation importance. Based on what is now known about the dispersal of marine animals and connectivity among populations, this proposal provides a first step towards an ecological network of deep-sea sites off California. This action would be a globally noteworthy advancement of marine conservation, and is on par with America's first declaration of a national park in 1873. Looking forward to this notable achievement once again demonstrates the strong leadership of the United States in protecting our planet, recognizing and promoting the tremendous value of a healthy environment to future generations around the world.

By virtue of our terrestrial nature, people are unfamiliar with the deep sea, and to many it is a terrifying thought to be in water where one can no longer touch the bottom. Thus it is no surprise that perhaps one of the most significant and underappreciated aspects of our oceans is that it is a spectacularly diverse three-dimensional world. The average depth of the oceans is over 12,000 ft, and 99% of the habitable space on Earth is in the sea. The offshore waters of California reach depths of over 15,000 ft. Two-dimensional maps of the planet's surface describe the terrestrial experience relatively well, but fail to provide us key insights into our oceanic realm. The seamounts, ridges and vents that are part of this proposal represent a vast diversity of latitude, longitude and depth. They reach from the deepest depths to the surface of the ocean, and the shallowest bank breaks the surface when large waves pass through. The water column itself contains sunlit waters that are highly productive as well as dark depths that are fueled by chemicals from the Earth's core. The chemosynthetic communities along Gorda Ridges are unlike anything else found in the region. Some of the seamounts stretch from the abyss thousands of feet upward and the assemblages of species found across these depths vary tremendously. California's undersea realm descends nearly 15,000 feet from the sea surface, rivaling Mt. Whitney and Shasta in sheer vertical magnitude.

Along these depth gradients, temperature, oxygen and other physical parameters lead to unique communities within the water column that scientists are just starting to appreciate. Globally these prominent features are drawing increasing attention because of threats from human impacts, especially deep-sea fishing and the prospect of future seabed mining (2). Seamounts provide homes for deep-sea coral, sponges and a wide variety of other invertebrates that are long-lived, extremely fragile and vulnerable to human activities. Longevity for some individual deep-sea corals is several thousand years (3). Recovery times for corals damaged by mining or fishing are likely to be multiple generations (decades to centuries) at best. Recent research showed little recovery of deep-sea corals after 8 years, supporting precautionary management and protections that prohibit any damaging activities in these ecosystems (4). Increasingly the threats from rising atmospheric carbon dioxide and climate change are being observed to impact the deep sea as well (5).

Marine scientists have greatly advanced our knowledge of these ecosystems in recent years as tools such as remotely operated vehicles (ROVs) and underwater cameras have become more widely used. Their findings document incredibly diverse communities in the offshore and deep waters off California (6) (7). Large, international research programs such as the Census of Seamounts (CenSeam) have greatly expanded our knowledge of such ecosystems (8) (2), at the same time recognizing the greater need for conserving these highly productive and unique ecosystems (9) (10).

Marine protected areas (MPAs) are increasingly documented as an effective strategy for conserving marine life (11) (12) (13). The benefits include safeguarding populations from direct exploitation such as fishing, allowing populations to recover and as a tool to increase resilience (14). The state of California established a network of marine protected areas in its coastal waters (0-3 miles from shore) (15), but existing protection for deep-water habitats is very limited in the adjacent federal waters (3-200 nm from shore). The significant exception to this is protection of Davidson Seamount off the central California coast as part of Monterey Bay National Marine Sanctuary. One of the most comprehensive seamount assessments of species diversity is from Davidson



Figure 1. Newly discovered species of soft coral (*Gerssemia juliepackardae*) discovered on Taney Seamounts. Photo: MBARI.

Seamount (16), and this was one of the first such areas formally protected in recognition of its ecological significance (9).

Here we describe several deep-sea features within the federal marine waters off California that are noteworthy areas for protection. A deep-sea network of areas will complement the state's efforts, provide enhanced protection for the unique marine environment that Californians depend on and will result in the most comprehensive marine protected area strategy yet developed for any region of the United States, and perhaps the world.

### Seamounts, Banks and Ridges

Seamounts are underwater mountains rising 1,000 meters (3,300 ft) or more from the seabed, but which do not reach the surface of the ocean. Most of the world's ocean basins are flat, muddy abyssal plains, but seamounts are mountains that tower above the plains (2). Seamounts are widespread throughout the world's oceans, and can arise along mid-ocean ridges or as isolated features on the seafloor. Nearly all seamounts are volcanoes and most often occur in chains or clusters. Offshore the California coast a number of seamounts (Pioneer, Davidson, Rodriguez, among others) share an ancient origin along a spreading center tens of miles from today's shoreline. Several of these locations are ancient islands that were once hundreds of feet above sea level, but over the last several millions of years they have subsided into the depths (17). Seamounts with flattened tops that typically arise from wave erosion at sea level are referred to as *guyots*.

Seamounts are a relatively poorly understood by scientists but have been the focus of much research in the last decade. In 2001, only a very small number (~300) of the estimated 14,000- 100,000 seamounts worldwide had been visited and sampled by scientists (18). This number has been expanded by initiatives such as CenSeam, but

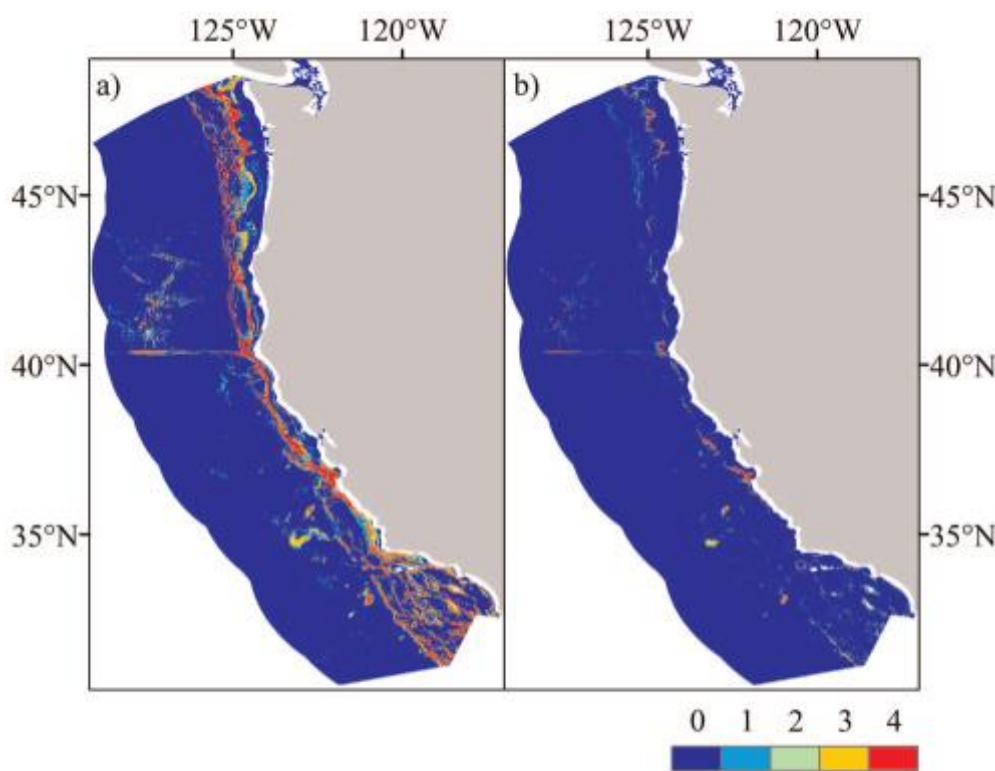


Figure 2. Likely habitats for deep-sea corals along the west coast (Guinotte and Davies, 2014). Red color indicates best habitat. A and B are different thresholds for habitat probability.

seamounts remain mostly unexplored and, consequently, many deep-sea species remain undiscovered. Fortunately, in the Pacific Ocean off California, scientists from Monterey Bay Aquarium Research Institute (MBARI), U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA) and others have visited many of these undersea features (19) (20) (6) (7).

Early research on seamounts suggested that they were incredibly biodiverse, and as many as a third of species found on seamounts in the

Tasman Sea and Coral Sea were either new to science or seamount endemics (1). As more research has

accumulated, the patterns of seamount biodiversity have been more extensively studied, and endemism rates seem to be typically lower, especially where seamounts are closer to the continental margins. In these cases patterns of species diversity appear to reflect the depth ranges occupied by seamounts and the local deep-sea diversity (2). In California, scientists have suggested that seamounts may be preferred habitats and act as sources of larva to coastal populations (7). Despite a much-improved understanding of seamounts, there are likely still enormous pools of undiscovered species in the deep sea, and therefore all estimates of biodiversity loss and extinction are conservative because scientific study is still meager.

Communities that live on the rocky crests and slopes of seamounts can also be very diverse. These include many suspension-feeding animals such as deep-sea corals and sponges. Deep-sea corals are commonly found on seamounts because the hard, rocky substrate provides sites for attachment and current acceleration, which delivers nutrients (21). Corals are especially important in seamount ecosystems because they can form extensive, complex-but-fragile three-dimensional structures that provide habitat for many other kinds of animals.

Unique and undiscovered seamount species hold tremendous potential as sources for new medicines and for biomedical research. Many deep-sea species contain compounds that are currently in clinical trials to treat diseases such as cancer and AIDS. There is strong scientific evidence that deep-sea biodiversity holds major promise for the treatment of illnesses that plague mankind. Deep-sea fish species are known to gather on seamounts to spawn. While a great deal of focus has been on the ancient, large and very long lived deep-sea corals, as well as sponges, seamounts are teeming with a wide variety of invertebrate and fish species. An analysis of the U.S. west coast found that deep-sea coral and sponge habitat is likely to occur across many of these seamounts and banks reviewed in this report (22). Significantly, as we consider options to mitigate climate change, deep-sea habitats contribute to ecosystem services such as carbon capture and storage; scientists recently estimated that the collective value of this benefit in the Eastern Tropical Pacific Ocean—which includes the California offshore sites discussed herein—is worth ~\$12.9 billion annually (23). Additional research shows that the loss of biodiversity results in exponential declines in such ecosystem services, strongly suggesting that maintaining biodiversity is key to the oceans' capacity to sustain the ecosystem benefits that humans rely upon (24).

### Hydrothermal Vents

Hydrothermal vent communities were only discovered relatively recently, in 1977, in the deep waters off the Galapagos Islands by scientists onboard the manned submersible *Alvin* (25) (26). Hydrothermal vent communities are now known to occur throughout the world's oceans along the global mid-ocean ridge system. Vents in the seafloor spew metal- and sulfide-rich brine into overlying seawater, forming chimneys and ore deposits called seafloor massive sulfides (SMS), both of which contain high-grade copper, gold and other metals. SMS deposits are often ten times richer in copper and gold than analogous deposits on land. Hydrothermal vent ecosystems are driven by chemosynthesis, a process by which microorganisms convert the sulfides in the vent fluid into organic compounds (26).

Hydrothermal vents are unique oases of highly dense and biologically diverse communities. They result from chemosynthetic energy-harboring animals quite different from those of most other deep-sea ecosystems. The composition of these communities varies among ocean basins and is dominated by specialized vent-dwelling organisms such as giant tube worms, shrimps, clams and mussels. They are potential hot spots for unique natural products that can be valuable medicinally relevant compounds (27).

The only hydrothermal vent systems that occur within the U.S. exclusive economic zone (EEZ) are off the north coast of California, at the plate boundaries along the triple junction at Gorda Ridges (28). The fractures in the seafloor allow ambient seawater to percolate down through the seabed and be warmed by the heat of the molten



rock (magma) below the oceanic crust. As the water seeps deeper into the seabed, temperatures increase to 350-400°C, and changes in seawater chemistry cause metals (including precious metals), silica and sulfide to leach from the surrounding rock. Although this downward seepage is a slow and diffuse process, as water is heated far above the ambient 2-4°C, it becomes buoyant and ascends rapidly through the permeable ocean crust to the seafloor. When these acidic, chemical-rich fluids mix with the ambient, cold, deep-ocean waters the metals and sulfides in the water precipitate to form a cloud of tiny black particles that are carried by the rising plumes of hot water, giving the impression of smoke. Many of the particles settle around the mouths of the vents where, over time, they build chimneys through which the 'smoke' escapes. This creates the familiar 'black smoker' chimneys that are 3-100 ft tall in areas where venting is strong.

The basis of energy production in terrestrial systems and shallow ocean waters is plant photosynthesis, but in the deep sea, plant life cannot exist and most deep-sea food web are supplied by organic material that rains down from the surface waters. Only a very small fraction (1% or less) of this surface productivity reaches the deep-ocean floor. As a result, animal life in the deep sea is usually dispersed and of relatively low abundance. The discovery of dense communities of giant worms, clams and mussels clustering around hydrothermal vents at depths of more than 6,600 ft came as a surprise to scientists, as the food source for these unusual ecosystems was not immediately apparent (25). Other unusual features exhibited by the vent organisms, most of which were previously unknown to science, were feeding physiology and tolerance to the extreme thermal environment and potentially toxic hydrothermal fluids with high levels of sulfides. High animal density and the presence of unusual species are now known to be common characteristics of deep-sea hydrothermal vents. Vent fauna are physiologically adapted to live in the extreme conditions of hydrothermal vents, and unlike shallow water and terrestrial ecosystems, the deep-sea hydrothermal food web is not driven by the availability of light for photosynthesis. Instead, it is based on microbial processes that use sulfur compounds (primarily hydrogen sulfide) to produce organic carbon (27).

### Open Ocean Surrounding Seamounts and Banks

While the open ocean is considered to be lower in productivity, waters overlying seamounts are often oases with higher than normal productivity, and concentrate a variety of species (29). Seamounts protrude into the water column and have dramatic effects on the water currents around them. Ocean currents bring seamounts an unending supply of nutrients, resulting in a remarkable diversity of fishes and other open ocean animals (30). This occurs because semi-stationary eddies, known as Taylor columns, sometimes form above seamounts and lift nutrients from the surface of the seamount up towards the surface of the ocean (31). Thus aggregations are likely in response to foraging opportunities, but seamounts can also serve as

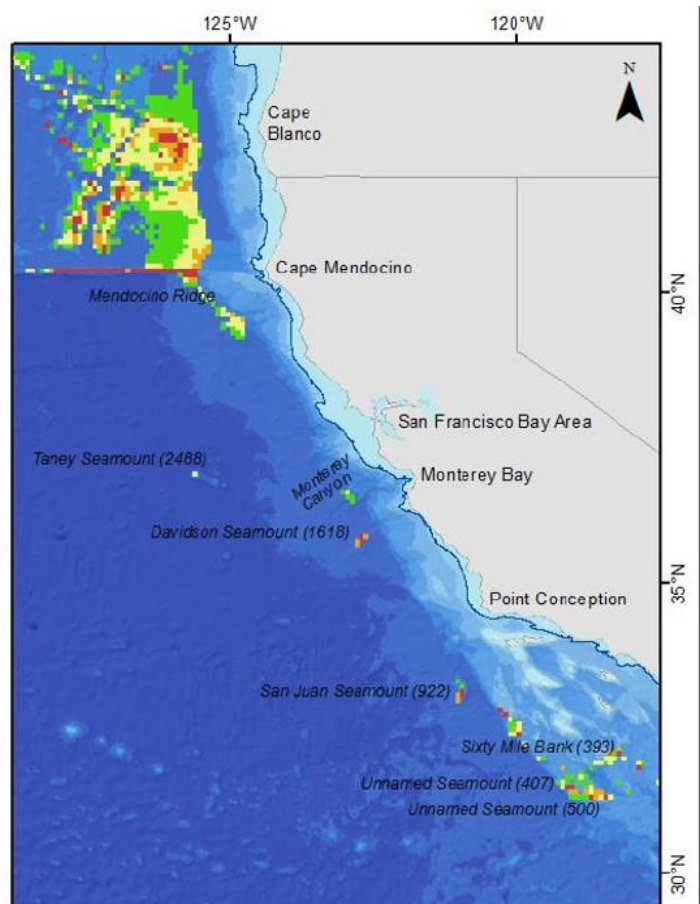


Figure 3. Map of offshore seabird distributions, note the strong coherence with deep-sea features. Red is highest abundance (top 1%), green is top 10%.

navigational landmarks for migratory species (32). This enhanced productivity concentrates predators such as sharks, tunas, billfishes, sea turtles, seabirds and marine mammals also makes them targets of fishermen. In recent decades, industrialized fishing has significantly impacted both target and non-target populations of marine wildlife and severely depleted fisheries in the open ocean (33) (34) (35) (36).

The enhanced productivity around seamounts also supports many smaller fishes. Scientists recently estimated that the biomass of lanternfish, small bioluminescent fishes that live in the twilight between the surface and the deep sea, is probably 10 times greater than previously thought, making them the most abundant fish in the sea (37). This layer between 600 and 3000 ft in depth is a key foraging area for surface dwelling marine mammals and seabirds that feed heavily on these fish in offshore California waters (38).

### Offshore Distribution of Seabirds in California

The physical structure of seamounts and the biological inhabitants of the seamounts provide an important ecological service for seabirds. Seabirds are drawn to places where their prey is concentrated. It may at first seem obvious why seabirds would aggregate adjacent to shallow seamounts where subterranean mountains bring prey closer to the surface. Seabirds are known to aggregate in waters above deep-sea seamounts. Scientific studies and anecdotal accounts indicate that seabirds at sea can be found gathering within the vicinity of the deep-sea seamounts off the coast of California (39) (40) (41) (42). The relatively nutrient-rich water attracts prey such as tiny fish, which are an important food source for seabirds that forage for food at sea. Seasonally, seabirds that nest on islands in the south Pacific, such as shearwaters and petrels, arrive in the California current to feed. These species hone in on productive regions such as frontal zones and eddies.

### Scientific Value of Protection

The deep sea is the most significantly under-explored region on Earth. Seamounts, ridges and vents are sources of numerous undescribed species and perhaps many new discoveries. The areas described herein provide scientific opportunities to study past shorelines from ancient, sunken islands (San Juan and Rodriguez Seamounts and Cortes, Tanner and Northeast Banks), climate archives stored in deep-sea corals, and new bio-active compounds in sponges, corals and other invertebrates (27). Cortes Bank is also of historical interest because of numerous past shipwrecks on its shallow summit. Hydrothermal vents on Gorda Ridges have not yet been extensively explored, and new vent locations may still be discovered. The role deep-sea corals can have in understanding past conditions is of special significance; the skeletons of deep-sea corals incorporate elements from seawater that scientists can use to reconstruct past conditions. Since these corals may live hundreds to thousands of years, they are enormously valuable to our understanding of climate change. Without protection for these seamounts and ridges these coral archives are susceptible to damage, and their valuable archives lost.

### Cultural Value of Protection

While most of these proposed conservation areas are beyond the depths that humans can regularly access, Cortes Bank, and specifically Bishop Rock, the tallest peak on Cortes Bank, rises to within six feet of the surface. This bank, nearly 100 miles offshore, was first sighted in modern times by Lt. James Alden from the deck of the U.S.S. Constitution. It battered several ships including the *Stillwell S. Bishop* in 1855, the *Santa Rosa* in 1717, the *El Capitan* in 1952, the *SS Jalisco* in 1966 (which was part of an incredible plan to create a new island nation atop the Bishop Rock), the *Sea Way* in 1971, and the *USS Enterprise* in 1985. The shipwrecks, coupled with unparalleled clarity and abundant life, make the Banks great SCUBA diving locations. In addition, this bank was above sea level in the recent past and, along with Tanner Bank and the surrounding islands, likely hosted the very first people to settle the California coast ten thousand years ago. The Kinkipar people inhabited San Clemente Island, leaving behind the greatest density of documented archeological sites per unit area in North America, and are believed to

have foraged at Tanner and Cortes Banks, then exposed islands (43). The underwater mountain at Cortes Bank creates the largest popular surfing wave on the planet; as a result, it has been the subject of movies, documentaries and books and draws the world's most accomplished surfers.

## Areas of Conservation Interest Offshore California



Figure 4 Areas proposed for enhanced protections in this report. Source: Marine Conservation Institute.

# Potential Threats to California's Offshore Waters

## 1. Commercial Fishing: California Drift, Set Gillnet and Abalone

Fisheries management in the waters off California is the responsibility of the federal government working in conjunction with the State of California, the Pacific Fisheries Management Council and California Department of Fish and Wildlife.

### *Drift and Set Gillnet Fisheries*

Throughout the world, fishery bycatch is an incessant problem, with bycatch estimates as high as 40% of global catch (44). In the U.S., estimates are that 17-22% of catch is discarded every year and thousands of whales, dolphins, seals, sea turtles and sharks are injured or killed as bycatch. In California, the set gillnet and drift gillnet fisheries are the second and the fourth worst bycatch fisheries in the nation, with staggering bycatch rates of 65% and 63%, respectively (45).

In federal waters off the coast of California, the drift gillnet fishery for swordfish and thresher sharks is a major conservation concern. The nets, extending a mile in length, are cast overnight to drift and catch large, pelagic fish. The expansive nets inevitably entangle a wide array of sea creatures. Marine animals that breathe air, like sea turtles and marine mammals, generally drown or are seriously injured from entanglement. In 2010 alone an estimated 49 dolphins and 16 endangered sperm whales were entangled and killed in this fishery. These numbers are likely to be underestimates as well, as observers cover less than 20% of the total fishing effort (46; 47). The drift gillnet fishery was responsible for the entanglement or death of almost 550 marine mammals over a five-year period. The estimated worth of this fishery is \$1.1 million (\$2011) (46).

Another fishery with bycatch concerns is the "set" gillnet industry that targets California halibut, angel shark and white seabass ("set" gillnets are those that are anchored to the seafloor). Because of the devastating ecological impacts gillnets were banned in nearshore waters off southern California in 1994, yet they are still permitted in federal waters (45). Today, the set gillnet fishery is the principal known threat to the precariously small population of great white sharks along the U.S. Pacific coast. From 2008-2013, fishers voluntarily reported accidental catch of 94 great white shark pups, nearly half of which were dead (48). In just a three-year period, more than 30,000 sharks and rays were discarded as waste by the set gillnet fishery (45). The estimated worth of this fishery is \$450 thousand (\$2011) (45) (49).

### *Abalone Fishery*

North American west coast abalones have been fished since before recorded history. The commercial fishery, however, which targeted red, pink, green, black and white abalone, was short lived. The decline, and, in many cases, closure of California's abalone fisheries at the end of the 20th century was due primarily to commercial and recreational overfishing, as well as disease and natural predation. The intense declines of the abalone fishery south of San Francisco, which landed more than 2,000 metric tons over the 1950s and 1960s, gave way to a moratorium on take for both the commercial and recreational fishery in 1997 (50). In 2001, the white abalone (*Haliotis sorenseni*) became the first marine invertebrate to be listed under the Endangered Species Act (ESA). Since the species' listing as federally endangered, ensuing population surveys of white abalone have found the highest densities of white abalone at Cortes and Tanner Banks (51).

## 2. Oil and Gas Exploration and Drilling

California, like other states, owns and controls the mineral resources within three nautical miles (nm) of the coast. There are four offshore oil platforms in state waters off the coast of California and 29 offshore oil and gas

agreements in California waters, which are controlled by the California State Lands Commissions (52). There are 43 active leases in the Pacific Outer Continental Shelf Region of Southern California granted by the Federal Government through the Bureau of Ocean Energy Management (53).

The California State Lands Commission halted further leasing of state offshore tracts after the Santa Barbara oil spill in 1969 that spewed an estimated 4.2 million gallons of crude oil into the ocean, creating an oil slick 35 miles long along California's coast and killing thousands of birds, fish and sea mammals (54). In 1994 the California legislature ordered a ban on new leases by passing the California Coastal Sanctuary Act, which prohibited new leasing of state offshore tracts.

Yet, just last year in 2015, 142,800 gallons of crude oil spewed into one of the most biologically diverse coastlines on the western seaboard after a corroded, 28-year old pipeline ruptured near Refugio State Beach in Santa Barbara County. The oil spread along seven miles of the coastline, reaching four MPAs that safeguard ecologically sensitive and cultural significant regions (55).

The thick crude oil damaged the coats, skin, beaks and appendages of hundreds of unique marine animals. State wildlife workers eventually collected 202 dead birds and 99 dead mammals, which included at least 46 sea lions and 12 dolphins. The full impact will never be known since many marine animals can travel an appreciable distance before yielding to their injuries. Sixty-five live birds and 63 live mammals were rescued (56).

### 3. Deep-Sea Mining

The deep sea is believed to hold large quantities of untouched energy resources, precious metals and minerals. The presence of high-grade SMS deposits makes hydrothermal vents a target for deep-sea mining interests. Increasing worldwide demand for copper and gold prompted two mining companies to explore the seafloor for high-grade sulfide deposits found at hydrothermal vents. Mining companies are targeting inactive sites where the hydrothermal fluids have stopped venting, and therefore are no longer home to the thriving chemosynthetic ecosystems characteristic of active hydrothermal vents. Instead, the hard substrate is colonized by non-vent, deep-sea fauna such as corals, anemones and sponges. Mining operations would destroy ecosystems at the mined inactive sites and also likely affect nearby active vent communities.

Technological advancements have enabled greater access to these resources, making deep-sea mining increasingly possible. No commercial deep-sea mining operation has taken place to date, but plans to begin deep-sea mining have recently been announced (57) (58). Early leases in the 1980s by the Minerals Management Service (now the Bureau of Ocean Energy Management, Regulation and Enforcement) of the U.S. for minerals on Gorda Ridges were precluded due to a lack of technology, low commodity prices, untapped ore bodies on land, prohibitive costs and unpredictable environmental impacts associated with an offshore mineral extraction industry (59).

*Degradation of surface water quality associated with increased turbidity and heavy metals would have some lethal and sublethal effects on phytoplankton. Reductions in primary productivity would be short-term and localized around and down current of the water discharge point... Uptake of heavy metals by primary producers poses potential long-term impacts from bioaccumulation of metals in primary, secondary, and top consumers... Marine mammals and endangered species would be affected by vessel traffic and possibly by the use of explosives... Vessel collisions could affect marine birds and onshore development could affect coastal birds... Estuaries around port areas that serve as bases of operations during mining could be affected by repeated, small spills of fuel and PMS ore materials. Heavy metal impacts on estuarine ecosystems include impacts on birds, anadromous fish, resident fish, and shellfish. (60).*

Another convincing reason to postpone plans to capitalize on hydrothermal vent mineral resources, such as Gorda Ridges, was the growing awareness that deep-sea hydrothermal vents sustain unique communities of animals and microorganisms remarkably adapted to these areas (59) (61). The discovery of novel ecosystems, microbe–invertebrate associations and biochemical and physiological adaptations altered the way scientists view life in extreme environments on Earth and in the universe (62).

Active hydrothermal vent sites, such as the Gorda Ridge, where particularly mineral-rich SMS deposits occur, support the chemosynthetic bacteria at the base of the vent food web (61) and host vent-endemic organisms such as barnacles, snails, mussels, tubeworms, crabs, shrimps and various fish (63). Beyond the vent sites there are other species that reside on the sea floor such as cold, deep-water corals and sponges that rely on a clean current to supply their nutrients. These unique benthic communities are vulnerable to disturbance and localized loss; mining SMS deposits would remove all benthic organisms inhabiting the substratum, with highly turbid and potentially toxic sediment plumes resulting from mining activities likely to affect benthic communities downstream (64).

The recovery of communities disturbed by mining at SMS deposits will be dependent on recolonization from nearby populations; however, little is known about the genetic and demographic connectivity of populations or the distribution of benthic communities at SMS deposits (65; 66).

#### 4. Telecommunications Cables and Acoustic Arrays

In 1995, a telecommunications cable was installed at Pioneer Seamount as part of an experiment to identify changes in ocean temperature by watching the speed of sound waves in the deep sea. In 2003, MBARI researchers used underwater surveys to study how the cable had affected marine life, and found that the cable had limited measurable effects on marine life. There were no significant differences in the numbers or types of animals in sediment samples collected adjacent to the cable relative to samples collected away from the cable. Anemones and flatfish were the only two animals significantly affected by the cable out of the 17 broad groups of animals observed in video footage; both were more abundant near the cable than in the untouched areas (67).

Waves that had moved the cable at the shallowest site created small trenches in the soft bedrock that displaced bottom-dwelling animals. However, where the cable spanned deeper rocky-bottom areas, like Pioneer Seamount, no differences were observed between the numbers of soft corals, sponges and other deep-sea animals near the cable and the numbers of these animals in undisturbed areas.

In 2001, a vertical array of four underwater hydrophones was installed on Pioneer Seamount to remotely monitor and record ocean sound to further understand the sources and effects of ocean noise. The hydrophones, connected to land via the telecommunication cable, stopped working in 2002 due to cable fault (68).

#### 5. Shipping, Invasive Species and Vessel Strikes

California hosts 11 major ports spanning the 1,000 miles of coast between the North Coast and San Diego County. Los Angeles and Long Beach Ports contain the largest port complex in the United States and are essential elements in global enterprise. Together, these ports facilitate one-fourth of all container cargo traffic in the United States (69).

Vessel traffic poses a number of threats to the marine environment, including oil or chemical spills, discharges, loss of cargo and other marine debris, ship-based pollution (i.e., residues from tank cleaning), exchange of ballast water and noise pollution (70).

International shipping represents a major means of introduction of invasive species to marine environments. The most damaging of these invaders displace native species, alter community structure and food web dynamics, and change fundamental processes like nutrient cycling and sedimentation (71). Northern California, including San Francisco Bay, has 85 known invasive species, 60 of which species used shipping as their invasion pathway. The Southern California Bight has 31 known invasive species, 25 of which used shipping as their invasion pathway (71).

California's high frequency of vessel traffic exposes marine mammals to elevated risk of vessel strike and to chronic underwater engine and propeller noise. Of the 11 species known to be hit by ships, fin whales are struck most frequently; right, humpback, sperm and gray whales are also commonly hit (72). From 1988 to 2007, 21 endangered blue whale vessel collision deaths were reported along the California coast. Blue whale strandings were associated with locations of shipping lanes, particularly those linked with the Ports of Los Angeles and Long Beach, and were most frequent in the fall months (73; 74).

## 6. Climate Change

Changes in temperature, acidification, circulation patterns and primary productivity of the world's oceans are occurring in response to climate change (75). These changes are altering the distribution and abundance of marine life and will continue to alter the ocean environment well into the future (76). A study in 1995 showed that we were already observing long-term changes in species ranges in California's intertidal communities (77). In the past decade seabird declines in the southern California current system have also been tied to lowered productivity resulting from climate change (78).

Survival for terrestrial species in a globally warming environment is believed to depend partially upon neighboring "cool refuges" (79). It has been contended that seamounts served as refugia during historic, intense environmental change (80; 81; 82), and therefore the deep, cool waters surrounding seamount slopes could potentially function as refugia for benthic marine life from the impacts of present-day ocean warming (18).

Ocean acidification, associated with increased atmospheric CO<sup>2</sup> levels, is likely to cause serious consequences for benthic, marine communities (83). It has been predicted that the majority of deep-sea stony corals could be in water too acidic to build their skeletons by the end of the 21st century (84). However, it has been found that the effects of ocean acidification on coral habitat, while intense, are likely to be less extreme for seamounts than for other deep-sea habitats in that they may act as 'shallow-water' refugia for stony corals from the detrimental effects of ocean acidification at greater depth (85). Another significant impact on marine life from climate change is lowered dissolved oxygen levels (86).

## 7. Kelp Harvest

The first commercial use of kelp in California was for producing potassium carbonate during World War I. The kelp was harvested by wrapping a strand with a cable and then pulling to rip out the entire kelp plant, including the holdfast. By comparison, today's harvest methods are limited to cutting the kelp canopy about four feet below the surface. Kelp that is harvested in California today is primarily used in industrial chemical applications, as well as food for cultured abalone and as a substrate for the herring-roe-on-kelp fishery (87). Kelp canopy harvesting affects the distribution of associated fishes, especially juvenile rockfishes, as they tend to move away from the impacted area. The removal of canopy cover may also contribute to greater predator success (88) (89).

Kelp forests are declining, particularly in southern California, where a variety of activities impact kelp growth and survival (90). Full removal of the kelp forest has been shown to create a lack of ecosystem structure between the substratum and the surface. This eliminates refugia, foraging substratum and physical orientation that the forest provides to fish assemblages. Following removal of the kelp forest, researchers observed a significant decline in

abundance of seven fish species within the clearing (91). Today, although the surface canopy can be harvested several times each year, regulations state that kelp may be cut no deeper than four feet beneath the surface (87).

*“There is one marine production, which from its importance is worthy of a particular history. It is the kelp, *Macrocystis pyrifera*. This plant grows on every rock, from low-water mark to a great depth, both on the outer coast and within the channels. ... The number of living creatures of all Orders, whose existence intimately depends on the kelp, is wonderful. A great volume might be written, describing the inhabitants of one of these beds of sea-weed. ... I can only compare these great aquatic forests of the southern hemisphere, with the terrestrial ones in the inter-tropical regions.” - Charles Darwin (1845)*

## 8. Bioprospecting

The world's oceans are home to 32 of the 34 discovered phyla<sup>1</sup> on our planet (92). Extraordinarily diverse, marine organisms are a key focus of bioprospecting: the search for, and commercial development of, valuable natural compounds. The ratio of possibly valuable natural compounds to compounds screened is greater in marine-sourced materials than for terrestrial materials, giving marine bioprospecting a higher probability of commercial success (93). Prospective commercial applications for marine organisms include: pharmaceuticals, enzymes, cryoprotectants, cosmeceuticals, agrichemicals, bioremediators, nutraceuticals and fine chemicals. Every major pharmaceutical firm (Merck, Lilly, Pfizer, Hoffman-Laroche, Bristol-Myers Squibb etc.) have marine research programs (93). Marine scientists and bioprospectors have shown special interest in species with unique traits that allow them to endure extreme environmental conditions. Many of these species, known as extremophiles, live on seamounts and other deep seabed ecosystems (27).

Scientific research in these extreme environments will likely increase, as technology advances and becomes more broadly available. Bioprospecting of marine resources presents challenges for sustainable use and conservation. The slow growth rate, delayed sexual maturity and restricted distribution of many species inhabiting seamounts and other deep seabed ecosystems make them vulnerable to changes in the immediate environment that can considerably impact key biological processes, such as reproduction (94).

## 9. Naval Presence

The U.S. Navy uses state and federal waters along the western seaboard for a wide variety of activities. Off the coast of southern California and in the Pacific Northwest, ocean area is used for training, testing and evaluation in the air, sea surface and underwater. The Southern California Range Complex (SCRC) is a very large area that extends more than 600 nm southwest into the Pacific Ocean, encompassing (a) 120,000 nm<sup>2</sup> of sea space, including Cortes and Tanner Banks and the Northeast Bank; (b) 113,000 nm<sup>2</sup> of special use airspace; and (c) over 56 mi<sup>2</sup> of land area spread across several islands (95). Likewise, the Northwest Training and Testing study area (NWTT) encompasses land, air, and sea areas that extend westward approximately 250 nm into the Pacific Ocean from the Strait of Juan de Fuca and southerly parallel to the coasts of Washington, Oregon and northern California, encompassing Gorda and Mendocino Ridges (96).

In recognition of the undeniable ecological significance of the SCRC and NWTT, the Navy prepared Environmental Impact Statements (EIS) for its activities in 2013 and 2014. Environmental impacts that result from the Naval activity on sediments and water quality, air quality, marine habitats, marine mammals, sea turtles, sea birds, marine vegetation, marine invertebrates, fish, cultural resources, socioeconomic resources and public health and

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<sup>1</sup> Phyla are the major variations of organisms at the root of the tree of life. They represent the fundamental body type differences between groups such as vertebrates, sponges, and sea stars among the various phyla of the animal kingdom.



safety were analyzed in the EIS'. From explosive byproducts, acoustic interference (sonar and underwater detonations), vessel strikes, entanglement, ingestion, etc., there are many threats to marine life associated with the U.S. Navy's activity in both the SCRC and NWTT (95).

The Point Mugu Sea Range is the Department of Defense's largest and most extensively instrumented over-water range. Located off the coast of Southern California between the SCRC and the NWTT, the Sea Range consists of 36,000 mi<sup>2</sup> of controlled sea/airspace, encompassing San Juan and Rodriguez Seamounts, and regularly requires access to over 220,000 mi<sup>2</sup> of ocean area and airspace (97). The Navy has prepared EIS' for the Point Mugu Sea Range to address effects that testing and evaluation of sea, land and air weapons systems, fleet training exercises, Theater Missile Defense testing, small-scale amphibious warfare training, special warfare training, etc. have on geology and soils, air quality, noise, water quality, fish and sea turtles, marine mammals, cultural resources, land use, socioeconomics, and public safety (98).

A comprehensive database on world-wide ship strikes to large whales reveals that 17.1% of reported/discovered world-wide incidents were wrought by the U.S. Navy and 14.9% by U.S. Coast Guard (99; 100). The distribution of vessel strikes to large whales in North America shows the U.S. West Coast has the greatest frequency of strikes only behind the U.S. East Coast.

Naval shipyards along the western seaboard also pose risk to marine life via water contamination. For example, Hunters Point Naval Shipyard, located on a peninsula that extends into the San Francisco Bay, was designated by the Environmental Protection Agency as a Superfund site in 1989 due to radioactive contamination and pollution from petroleum fuels, pesticides, heavy metals, polychlorinated biphenyls, organic chemicals and asbestos (101).

#### 10. Submarine tourism

Submarine dives, conducted by Russian scientists in 1999, brought tourists to the Rainbow hydrothermal vent fields on the Mid-Atlantic Ridge. Sponsored in part by a Seattle-based tour operator, these joint science-tourist dives using the Russian Mir submersibles point to the possibility of additional future endeavors. The dives were conducted on the high seas without need for clearance by any governing body concerned with the protection of vent habitat or biodiversity (102).

# California's Offshore Areas of Conservation Interest

## Cortes and Tanner Banks

### Geologic Setting

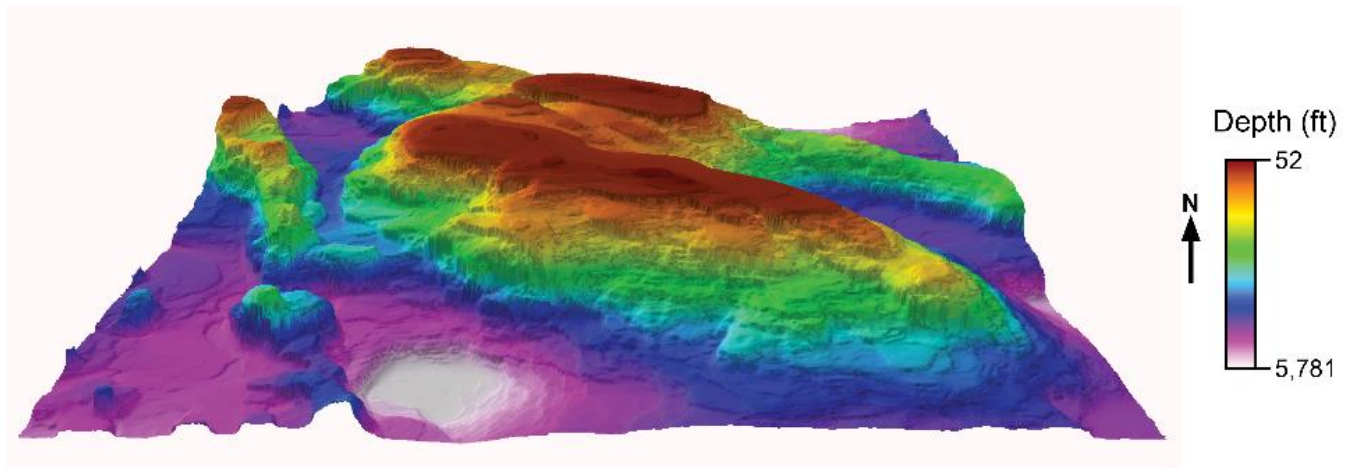


Figure 5. Seafloor image of Cortes (lower) and Tanner (upper right) Banks. Image: Marine Conservation Institute, Source: National Geophysical Data Center

Cortes and Tanner Banks are located among the narrow continental shelf and the continental slope of southern California. The basins have a maximum depth of 6000 ft and are present-day areas of sediment accumulation. The ridges, often expressed as islands or banks, rise from the basin areas with remarkably steep slopes and are areas of sediment bypassing. The banks are in a region of fluctuating and differing currents that cause appreciable turbulence. This turbulence may be significant in maintaining and suspending fine materials. Surface waters are saturated with oxygen, but below the region of photosynthetic activity, the oxygen content quickly decreases (103).

### Biological Setting

Cortes and Tanner Banks are neighboring seamounts about 110 miles west of San Diego. The banks rise about one mile from the deep sea that surrounds them, creating rich marine habitats as the cold, deep, nutrient-rich water is forced to the surface from turbulent upwelling. This supports high pelagic productivity as well as rich benthic communities dominated by slow-growing corals and sponges; these productive waters have been the discovery site of many new marine organisms (104) (105) (22).



Figure 6. Elephant seals. Photo: NOAA

Cortes and Tanner Banks host over 34 structure-forming species of algae that greatly contribute to the productivity of the community (106) (107). Additional structure-forming large invertebrates (sponges, deep-water corals, sea anemones, sea stars, etc.), provide substantial fish habitat on the deep rock of Cortes and Tanner Banks (108) (109) (110). Economically important crustaceans and molluscs, including the California spiny lobster and the endangered white abalone endemic to southern California, are also found on the banks (111) (51) (112) (113) (50).

Over 137 unique fish species have been observed at the outer-banks, at least 50 of which are rockfish species and at least 56 of which are economically important species, (i.e. those targeted or retained by recreational and commercial fishers) (114). Several highly-migratory predatory species that are important components of open-ocean (pelagic) ecosystems frequent the productive outer-banks habitat, including albacore, skipjack and northern bluefin tuna, bigeye thresher sharks, leopard sharks, swordfish and many others (108).

The outer-banks attract four of the world's seven species of sea turtles: loggerhead, olive ridley, green and leatherback. These species, all four of which are listed as *endangered* or *threatened* under ESA, migrate from tropical nesting beaches to forage in the highly productive waters around the outer-banks and coastal waters of the Southern California Bight (108) (115) (116).

The waters surrounding Cortes and Tanner Banks are essential feeding, reproduction and migration habitat for one of the largest populations of marine mammals in the world (over 35 species). Some species, such as bottlenose dolphins and California sea lions are year-round inhabitants. Others, like orca whales and sperm whales, are occasional visitors, while gray and humpback whales pass through the Bight during yearly migrations (117) (118) (108).

The waters surrounding Cortes and Tanner Banks seasonally host a globally important population of endangered blue whales and have the highest recorded densities of endangered fin whales in the world (119) (120). Pinnipeds, such as the northern elephant seal, have been observed foraging near the seafloor of Cortes and Tanner seamounts (see cover image), highlighting seamounts as important foraging areas for marine mammals (121).

The biodiversity of Cortes and Tanner Banks continues in the water-air interface as over 74 species of seabirds have been observed breeding, overwintering and migrating in the Southern California Bight. The southwestern stretch of the Bight surrounding the Banks contains large expanses of open-ocean that attract the greatest at-sea species diversity in the Bight (122) (123) (124).

#### Site users:

- **U.S. Navy:** The U.S. Navy historically uses the SCRC for training, testing and evaluation in the air, sea surface and underwater. Making conservative assumptions and taking usage data from the 2013 Environmental Impact Statement on SCRC, it is estimated that the Navy trains and tests at Cortes and Tanner Banks and the SWTR-OS, which includes the Banks, for an estimated 0.69-2.4% of the total time spent in SCRC<sup>2</sup> (95).
- **Commercial fisheries:** Since 1984, the commercial catch of all fish, shellfish and marine life taken from Cortes and Tanner Banks has decreased drastically. In the 1970s and early 1980s, catch from the two banks was valued at between \$2 and \$7.5 million. For the most recent years of commercial landing data available (2000-'09),

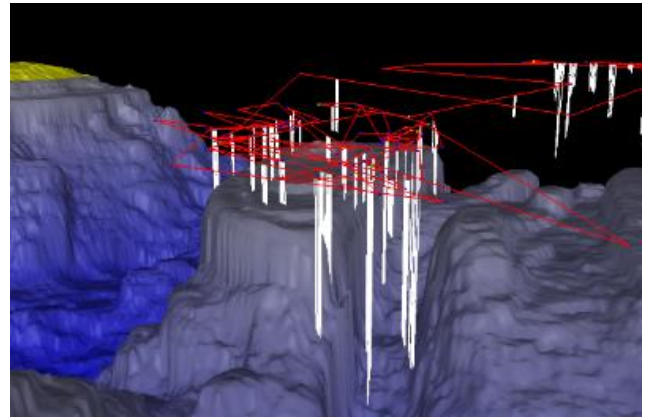


Figure 7. Image: Telemetry track (red) and dives (white) of a male elephant seal foraging on Cortes Bank. Image: Maxwell

<sup>2</sup> Percent time spent training and testing at Cortes and Tanner Banks relative to the SCRC was calculated by first identifying all activities that occur 1) at Tanner and Cortes Banks, as well as 2) in the SWTR-OS (as this area encompasses the Banks) reported in the EIS. The number of events per year of each identified activity was multiplied by the duration of each activity (acquired from Appendix A of the EIS). When the duration of an activity was reported as a range, total annual time was calculated as a range. Each activity's total annual time was divided evenly amongst all locations where the activity was reported to occur. This process resulted in a minimum and a maximum estimate for the total time spent training and testing specifically at Cortes and Tanner Banks and/or the SWTR-OS. Because the SWTR-OS was included in the analysis, the time estimates are likely to be highly conservative as Cortes and Tanner Banks are just part of the larger offshore SWTR.

landings from the two banks averaged about \$400,000 per year with a range of \$200,000 to \$900,000 (\$2015). For the last year geospatial catch data is available, seafood caught on the two banks was 0.5% of total California landings (125).

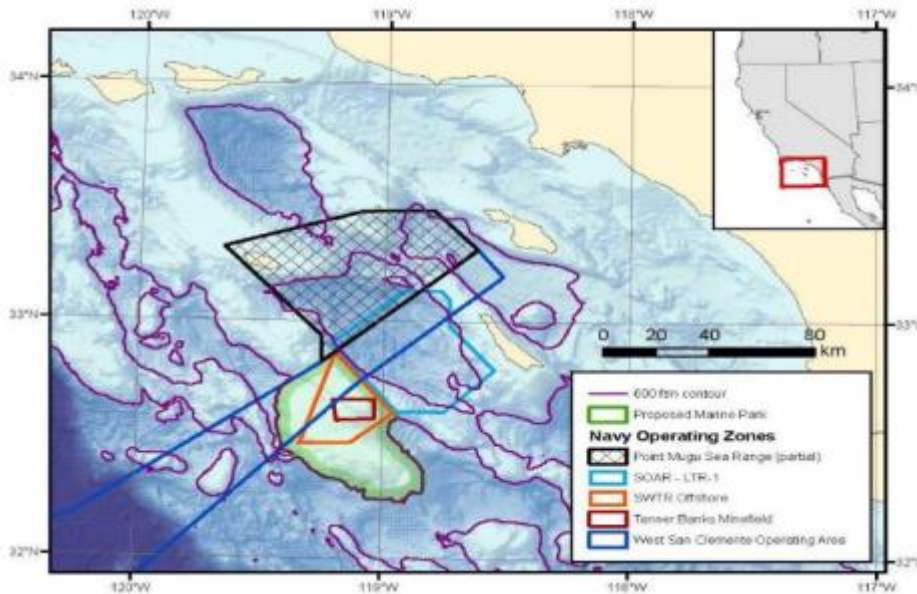


Figure 8. Proposed boundaries– Cortes and Tanner Banks. Map redrawn from NOAA nautical charts and U.S. Navy maps in the EIS for the Southern California and Hawaii Testing and Evaluation Ranges. (<http://hstteis.com>).

- Recreational fishers:** Recreational charter boat 1½-2 day fishing trips on Cortes and Tanner Banks is a small but valuable portion of charter boat fishing in the San Diego area. Today, catch from the Banks averages 5,000 – 10,000 fish per year. At a conservative estimate, the Banks recreational fishery is valued at around \$6.5 million, making the cost per fish as high as \$650 dollars to take home. Empirical evidence suggests that marine reserves with strong monitoring and enforcement benefit fisheries neighboring reserve boundaries (126).

- SCUBA Divers:** Both Cortes and Tanner Banks are infamous diving locations that provide unparalleled clarity, vast kelp forests, abundant life and diverse diving opportunities, including wreck diving the *Santa Rosa* in 1717, the *El Capitan* in 1952, the *SS Jalisco* (a WWII surplus ship a team of entrepreneurs hoped to sink in the Bank to form a tax-free island nation) in 1966, the *Sea Way* in 1971, and the *USS Enterprise* (the longest U.S. Navy ship ever put into the sea) in 1985 (127) (128).
- Surfers:** The underwater mountain range at Cortes Bank creates the world's largest surfing wave. The world record for surfing the largest wave ever (77 ft) was held by Mike Parsons at Cortes Bank until 2008. The epic swells of Cortes Bank continue to draw the world's most accomplished surfers and have been the subject of movies, documentaries and books (43).

## Northeast Bank

### Geologic Setting

Northeast Bank is located 146 miles west of San Diego. It is a volcanic seamount that formed approximately 7-11 million years ago. Features of Northeast Bank, along with Rodriguez and San Juan seamounts, differ from those at other seamounts off the continental margin of California. Most notably distinct are the features indicating that these three seamounts are ancient islands. These features include but are not limited to: rounded summits blanketed with sediment; bedded sandstone deposits; sculpted rocks that appear weathered; and lava flows typical of flows above water (129) (130). Both Northeast Bank and Rodriguez seamount have “smooth, gently domed” summits (129). Researchers suggest that the summits of these two seamounts were smoothed by

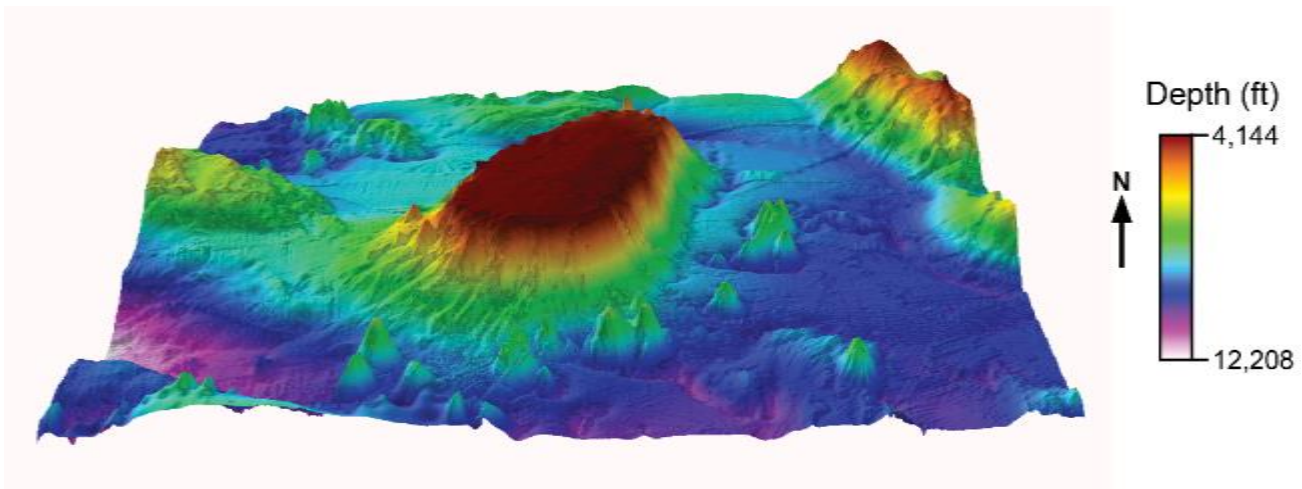


Figure 9. Seafloor image of Northeast Bank. Image: Marine Conservation Institute, Source: National Geophysical Data Center

erosional forces like wind and waves at the surface of the ocean before the volcanoes subsided to their current depths (the summit is 1,181 ft below sea-level). Geologic features including beach deposits and breaks in slope suggest that Northeast Bank was an island that stretched a minimum of 656 ft above sea level and was at least 35 mi<sup>2</sup> in area.

### Biology

In addition to geological evidence, scientists have used paleontological evidence to determine that Northeast Bank was once an island. In 1971 a researcher found fossils of a species of oyster and a species of barnacle on Northeast Bank that today only live in rocky habitat in warm Pacific areas at depths no greater than 164 ft. The fossils were found in layers of rock that are approximately 1.7 to 3.5 million years old (131).

There is a paucity of research published on the fauna of Northeast Bank. One exception to this is a 2011 study that investigated a species of deep-sea clam, *Acesta sponi*. Researchers sampled a total of seven seamounts off the California coast and found that the deep-sea clam only occurred on Northeast Bank and San Juan Seamount. These two seamounts provide the optimal habitat for this species of clam, which require warmer water, minimal dissolved oxygen and low salinity (132). The clam was found to occur on the steep canyon walls of Monterey Canyon and Pioneer Canyon as well.

A number of deep-sea corals have been recorded from Northeast Bank (133), and the area has been predicted as a high coral abundance zone in an analysis of the west coast (134). The area has been explored by MBARI, but because the site is far from shore it is not as well sampled as areas closer to shore.

### Site Users

- **Recreation:** Northeast Bank is used by recreational fishers, whale watching tours and pelagic bird watching tours (135) (136). Pelagic bird watching tours often use chum in order to bring birds in closer for viewing.

## San Juan Seamount

### Geologic Setting

San Juan Seamount, like Rodriguez Seamount and Northeast Bank, is a feature that was once an ancient island. San Juan Seamount is unique because its summit is not smooth like Rodriguez Seamount and Northeast Bank; rather, it is rough and has pronounced ridges. During its time above sea level it would have appeared as eight separate smaller islands, with the highest peak standing approximately 460 ft above sea level (129). Eventually the volcano sank to its current depth with its base at ~6,850 ft (~1.3 miles) below sea level, and its summit at ~1,837 ft below sea level (137).

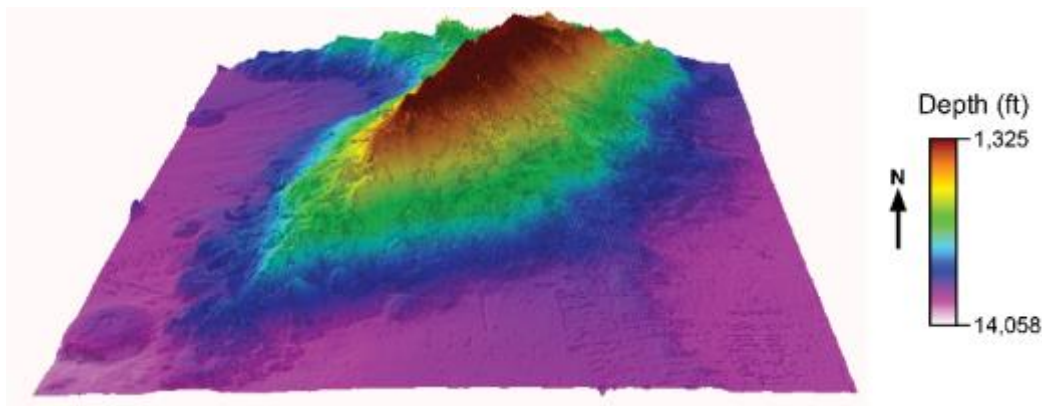


Figure 10 Seafloor image of San Juan Seamount. Image: Marine Conservation Institute, Source: National Geophysical Data Center

### Biology

In addition to being a site of great biodiversity, San Juan Seamount is home to some rarer deep-sea species. One is the deep-sea file clam, *Acesta sphoni*, which has specific and unique physiological and habitat requirements. It occurs on rocky features in seawater that is relatively warm, has minimal dissolved oxygen and low salinity (132). In 2011, researchers sampled a total of seven seamounts off the California coast and found that this deep-sea clam occurred only on Northeast Bank and San Juan Seamount. The clam was also observed on the steep canyon walls of Monterey Canyon and Pioneer Canyon.

San Juan Seamount also provides habitat for a long-lived, relatively rare bamboo coral that is important in past climate reconstructions. This type of coral tends to occur in the deep sea on features such as seamounts and canyon walls. Chemical analysis of bamboo corals can provide decadal to centennial scale records of oceanic and atmospheric climate changes over time (138).

Whenever scientists have the opportunity to make observations and sample these deep-sea locations they always seem to discover new species, or find them in new places where they were previously unknown. As recently as 2009, observations at San Juan and Rodriguez seamounts resulted in a range extension for a hard coral, *Caryophyllia quadragenaria*. These observations extend the bathymetric range of the species by ~3,280 ft, and the latitudinal range by 65 degrees (roughly 3,900 nm) (139).

There is evidence that the area around San Juan Seamount is important to pelagic animals such as large predatory fish, seabirds and marine mammals (140). In particular, the area between Cortes and Tanner Banks and San Juan Seamount is an important feeding location for seabirds, especially during the summer when flying fish are

abundant (123). In addition, the area between San Juan Seamount and Rodriguez Seamount is also a place where seabirds feed. A NOAA marine mammal aerial survey (1993-1994) conducted within the U.S. Navy outer sea test range found the area just east of the San Juan Seamount to have “relatively high animal encounter rates” (141).

### Site Users

**Recreation:** San Juan Seamount is used by recreational fishers, whale watching tours and pelagic bird watching tours (136). Pelagic bird watching tours chum in order to bring birds in closer for viewing. Since their business depends on this practice it may be important to work with these groups to ensure that their activities can continue with any modifications necessary to limit their impact on wildlife. San Juan Seamount lies within the boundaries of the Point Mugu Sea Range (142).

## Rodriguez Seamount

### Geologic Setting

Rodriguez Seamount is located 93 miles west of the central California coast. It is a volcanic seamount that formed approximately 7-11 million years ago. Rodriguez Seamount, along with Northeast Bank and San Juan Seamount are different from other seamounts off the continental margin of California. Most notably are the features that indicate that these three seamounts are ancient islands (129) (143). Features such as rounded summits blanketed with

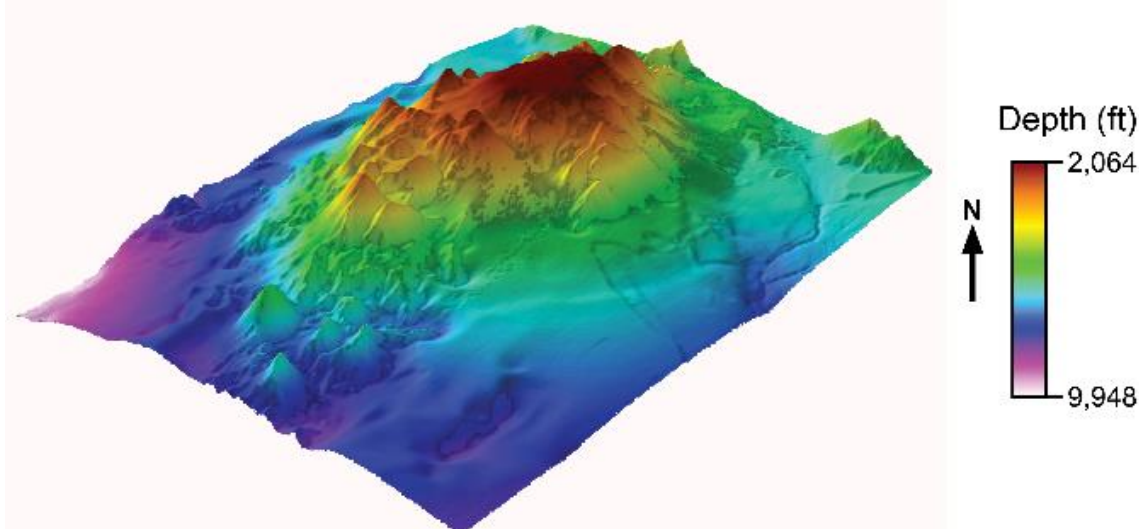


Figure 11. Seafloor image of Rodriguez seamount. Image: Marine Conservation Institute, Source: MBARI

sediment, bedded sandstone deposits, sculpted rocks that appear weathered and lava flows that are typical of flows above water have been observed on these three seamounts (129) (139). Both Rodriguez Seamount and Northeast Bank have “smooth, gently domed” summits (129). There is evidence that these seamounts first “grew to sea-level” and were then cut down by erosional forces like wind and waves at the surface of the ocean before the volcanoes subsided to their current depths (129) (144). At its tallest, Rodriguez stood at least 230 ft above sea level and formed an island 2.6 mi<sup>2</sup> in area prior to subsiding below the surface. Currently the base of Rodriguez Seamount is 1.4 miles below sea level, and its summit is 2,031 ft below sea level (137).

## Biology

Rodriguez Seamount is a site of great biodiversity (137) (145) (146). Using ROVs, researchers have observed assemblages of animals that include sponges, crinoids, anemones, deep-sea corals, sea cucumbers, sea urchins, brittle stars, asteroids and polychaete worms. Several tiny crabs were discovered living on a collected sponge, large *Paragorgia* sp (bubblegum coral) and bamboo corals (147). Unlike the summits of other seamounts that were sampled, the summit of Rodriguez Seamount is within the oxygen minimum zone. This means that the summit of this seamount, which might usually have “complex biologic communities” (148), has fewer species and fewer individual animals but still

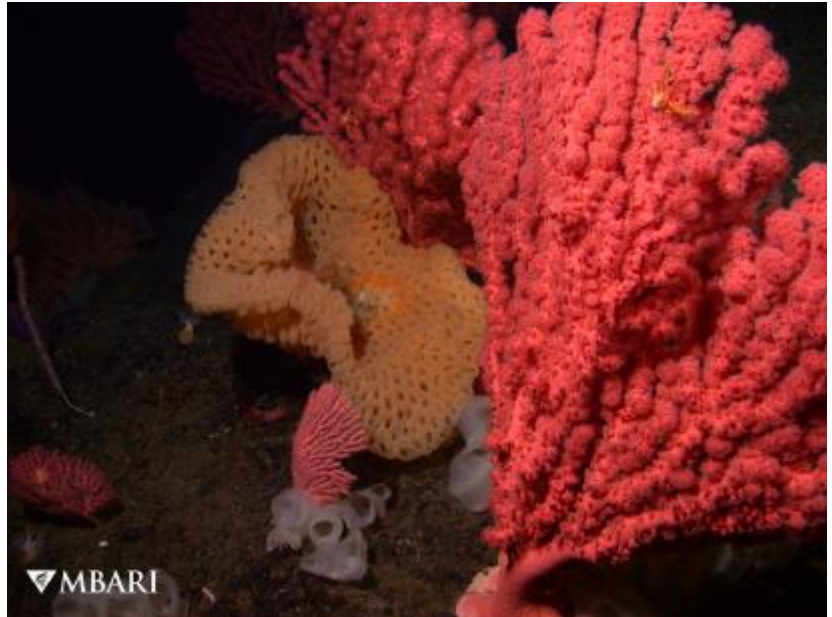


Figure 12 Deep-sea Coral and Sponge community on Rodriguez Seamount. Photo: MBARI.

provides a unique habitat for species that are well adapted for low oxygen conditions. Clague remarked during a 2003 research cruise state that “the assemblages of animals were distinct from any we have seen on other seamounts farther north along the margin” (148). Researchers have also noted that the distribution of animal assemblages on these seamounts, including Rodriguez, is patchy. This means that the integrity of the entire seamount must be maintained in order to maintain the biodiversity at each location.

During one expedition in 2003 the following log entry was made by Dr. Clague: “Today, we collected a predatory tunicate, another animal being studied by a colleague, only to find that it was partly filled with well-developed fish eggs. These eggs are being incubated in a cold seawater tank to see if they can be hatched” (149). It is clear that there is much to learn about life on these seamounts.

Whenever scientists have the opportunity to make observations and sample these deep-sea locations they frequently discover new species, or find species in a location where that species was previously unknown. As recently as 2009 observations made at Rodriguez and San Juan seamounts resulted in a range extension for a hard coral called *Caryophyllia quadragenaria*. These observations extend the bathymetric range of the species by about ~3,280 ft, and the latitudinal range 65 latitude degrees in this region (139). In 2008 a new species of bamboo coral, *Isidella tentaculum*, was described based on observations made from Rodriguez and Pioneer seamounts (150).

## Site Users

- **Recreational fishers** are known to use this site.
- **Military:** Additional users include the military as Rodriguez Seamount lies within the boundary of the Point Mugu Sea Range (95).
- **Commercial Fishing:** Damage due to bottom trawling was observed at Rodriguez Seamount during a MBARI ROV expedition (137). The scar is likely old as Rodriguez Seamount is within an Essential Fish Habitat (EFH) area and bottom trawling, other than demersal seine gear, is prohibited.





Figure 13 Ancient shoreline formed from wave erosion when Rodriguez Seamount was above sea level. Photo: MBARI.

## Taney Seamounts

### Geologic Setting

The Taney Seamounts are located on the Pacific plate 186 miles west of San Francisco, CA. The Taney Seamounts consist of a linear chain of five volcanoes oriented with the oldest volcano on the northern part of the chain, and the youngest volcano on the southern-most portion of the chain. The volcanoes have steep sides and nearly flat tops due to partially collapsed calderas. The depth of the summit of the tallest volcano is approximately 2,000 m (1.2 miles). The depth of the seafloor at the base of the seamounts is approximately 2.6 miles (151) (152).

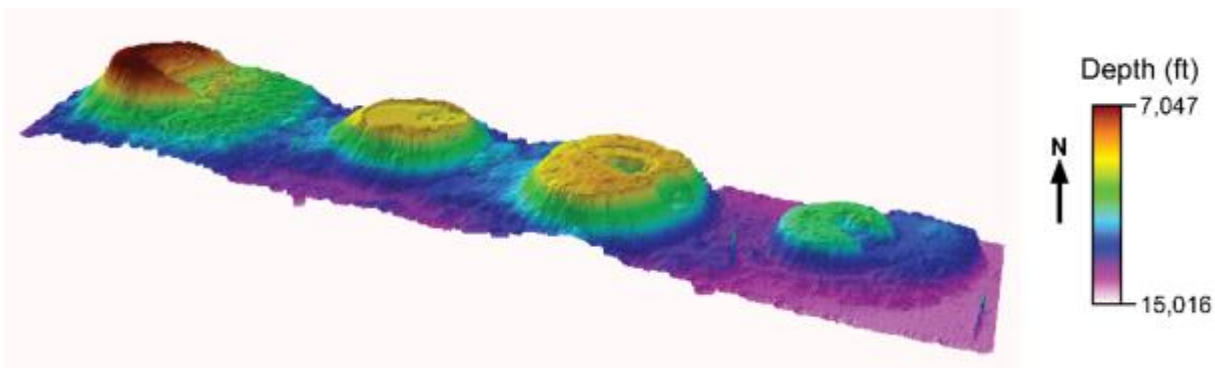


Figure 14. Seafloor image of Taney Seamounts, ancient volcanoes with collapsed calderas result in flat tops. Image: Marine Conservation Institute, Source: MBARI

## Biology

With the exception of Davidson Seamount, seamounts off the central coast of California have not been thoroughly surveyed for living creatures. As a result, when scientists get the opportunity to make observations at these deep depths, there is a possibility of discovering a new species. In 2012, a new species of acorn worm (*Saxipendium implicatum*) was described, and sampling suggests that this species only occurs within the vicinity of Guide, Davidson and Taney seamounts (153).

In addition to finding new species, scientists use ROVs to observe animals in their deep-sea habitats. At sites on Davidson and Taney Seamounts, scientists had the opportunity to observe a rare angler fish (*Chaunacops coloratus*) in its deep-sea habitat. Their observations revealed that this species occurs at depths approximately a mile deeper

than formerly known, and resulted in a northward range extension of 3,418 miles (154). As recently as 2010, MBARI researchers observed six more of these fish on a deep-sea dive on the Taney Seamount chain and had the opportunity to learn even more about the behavior and natural history of this species in its habitat (155).

In 2003 scientists used observations at Davidson, Pioneer, Gumdrop and Taney seamounts to define an entirely new species of sea jelly (*Tiburonia granrojo*) that is rare but has a wide range of occurrence within the northern Pacific Ocean. This sea jelly can grow up to approximately 10ft in diameter and is the only known member of its genus (156).

## Site Users

- **Commercial and Recreational fishing:** The Taney Seamounts are included within the 700 fathom EFH designation and as such bottom trawling is prohibited. No other types of commercial and recreational fishing are expressly prohibited, but owing to its great distance from shore little fishing is likely to occur at present.

## Pioneer Seamount

### Geologic Setting

Pioneer Seamount is located at the continental margin off the California coast at the base of the continental shelf. It is located approximately 47 miles offshore, just to the southwest of Gumdrop Seamount (157). It is located just beyond the boundary of the Monterey Bay National Marine Sanctuary. Pioneer Seamount is an example of a unique type of intraplate (hotspot) volcano—a volcano that has formed within the boundaries of a tectonic plate. Pioneer Seamount has a northeast-southwest alignment similar to many oceanic volcanoes (157). Just like Davidson, Gumdrop, Guide and Rodriguez Seamounts, Pioneer Seamount has some features that are quite unique



Figure 15 Deep-sea angler fish (*Chaunacops coloratus*) photographed at Taney Seamounts. Photo: MBARI.

when compared to other oceanic-island volcanoes or near-ridge seamounts (158). Instead of being made up of conical structures that are circular when viewed from above, Pioneer Seamount is a series of cones separated by sediment-filled troughs (157). The ridges and troughs on Pioneer Seamount are less obvious than they are on other seamounts of the type. This seamount has a width and length of nearly 8 miles. Also unique to these seamounts, but present on most oceanic volcanoes, is evidence of calderas at the summit. The summit of Pioneer Seamount is approximately 2,660 ft below sea level, and its base is approximately 9,022 ft below sea level (1.7 miles) (137).

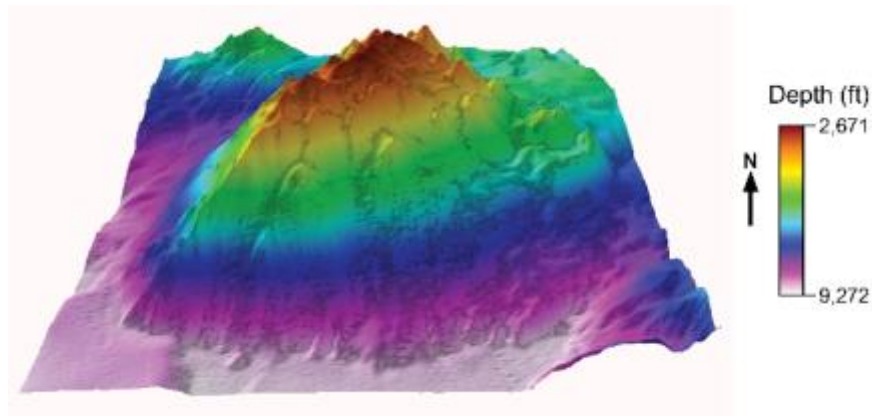


Figure 16. Seafloor image of Pioneer Seamount. Image: Marine Conservation Institute, Data: MBARI

## Biology

A number of deep-sea corals and sponges, including a newly described bamboo coral (*Isidella tentaculum*), a deep-sea gorgonian, occur on Pioneer Seamount (159). Gorgonians and other deep-sea corals are important habitat providers for many other deep-sea animals. Growth rings on this long-lived coral can indicate growth cycles and changes in certain oceanic conditions (159). In addition, chemical analysis of bamboo corals can provide decadal to centennial scale records of oceanic and atmospheric climate changes over time (138). Material taken from bamboo coral has shown to be potentially useful as a living bone implant (160).

In 2009, MBARI led a survey of Pioneer Seamount in which they were able to survey 66% of the depth range of the seamount. Researchers found a total of 110 different invertebrate species (137). Most of the species observed (87%) were sessile (stuck to the rocks).

Scientists acknowledge that more studies including documentation of important life cycle processes including reproduction, growth and survival are necessary to more completely understand these deep-sea seamount communities (137).



During the same survey, scientists observed that the fish assemblages at Pioneer Seamount are similar to the assemblages found at Davidson and Rodriguez seamounts. While fish communities on these three seamounts are similar, scientists found that seamount assemblages were different than those found on non-seamount sites. At present none of the fishes observed on Pioneer Seamount and nearby seamounts appear to form assemblages that can be commercially exploited (19).

Figure 17 Diverse invertebrate community on Pioneer Seamount.  
Photo: MBARI.

Foraging seabirds concentrate in the waters over Pioneer Seamount (40). Some of these species travel over very large regions of the world, including Cook's petrel (*Pterodroma cookii*), listed as vulnerable by the International Union for Conservation of Nature (161). This seabird nests on just a few small islands off the coast of New Zealand and depends on sites like Pioneer Guide and Gumdrop seamounts for food (40) (162). Great effort has been put into ensuring that their breeding and nesting grounds are free of predators, but their survival also depends on having plentiful foraging grounds. Many ocean dwelling seabirds find locations such as seamounts prime feeding locations.

## Site Users

- **Commercial and Recreational Fishing:** Pioneer Seamount is included within the 700 fathom EFH designation and as such bottom trawling is prohibited. No other types of commercial and recreational fishing are expressly prohibited. Since the summit of Pioneer Seamount is approximately 2,660 ft below sea level this effectively safeguards the summit for now, but not necessarily into the future should newer gear be developed that could exploit these deep areas.
- **Communications Cable:** The Pioneer Seamount cable was originally installed in 1995 as part of an experiment to detect changes in ocean temperature by monitoring the speed of sound waves in the deep sea. The cable runs about 60 miles offshore from Half Moon Bay to Pioneer Seamount. Eight years after the cable was installed, detailed surveys and data analysis led researchers to conclude that the cable had few detectable effects on marine life. This was especially true on the hard rock of Pioneer Seamount (163). In 2001, a vertical array of four hydrophones was installed on Pioneer Seamount to passively monitor the Pacific Ocean in the region south of San Francisco. The hydrophones allowed researchers to remotely monitor and record ocean sound to further their understanding of the sources and effects of ocean noise. In 2002 acoustic signals stopped. The 2003 cable surveys indicated that there was damage to the cable. The cable was not repaired due to cost and environmental impact (164).

## Guide Seamount

### Geologic Setting

Guide Seamount is a volcanic seamount that lies just to the west of the Monterey Bay National Marine Sanctuary, approximately 53 miles off the coast of central California, at the base of the continental slope. Like many other oceanic seamounts off the west coast, it has a northwest-southwest orientation (157). It has a unique shape and shares geological characteristics with four other oceanic-island volcanoes including Gumdrop, Pioneer, Davidson and Rodriguez seamounts off the central California coast (17). Guide Seamount is made up of four parallel volcanic ridges separated by sediment-filled troughs. Its summit is approximately one mile (~5,528 ft) below sea level (17).

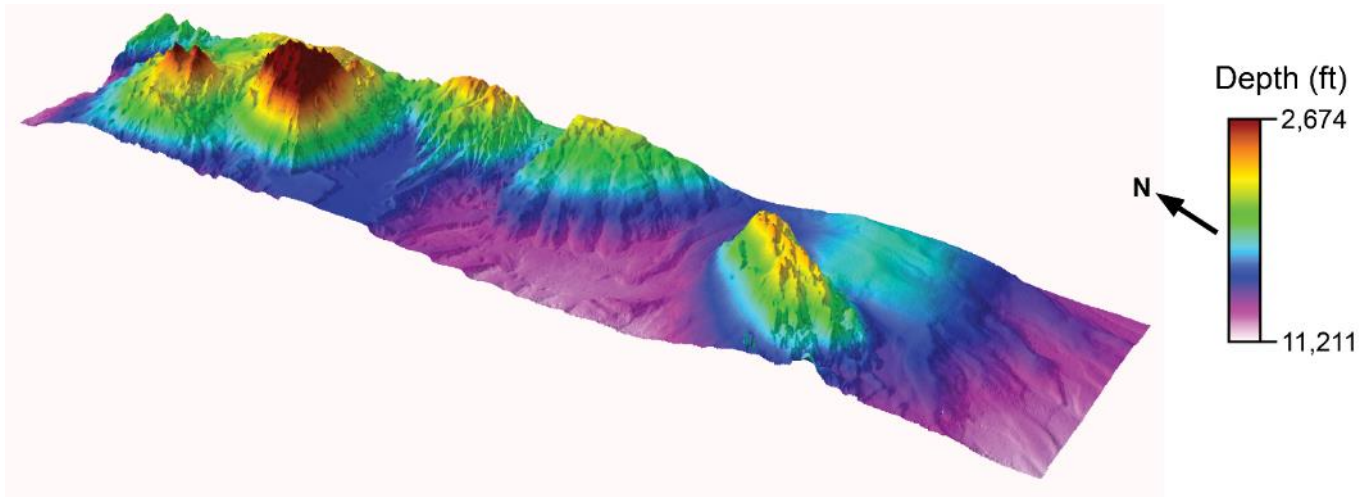


Figure 18 Seafloor image of Guide Seamount, far right feature. Image: Marine Conservation Institute, Data source: MBARI

## Biology

A new species of acorn worm (*Saxipendium implicatum*) was recently described, and sampling suggests that this species only occurs within the vicinity of Guide, Davidson and Taney Seamounts (153).

Seamounts are sites of upwelling that makes more nutrients available for fish, which in turn attracts seabirds. Seabirds, presumably from colonies on Farallon Islands, are known to occur within the vicinity of the Guide Seamount (123) (42). Some seabirds forage over very large regions of the world. Cook's petrel (*Pterodroma cookii*), which nests on just a few small islands off the coast of New Zealand, depend on sites like Guide, Gumdrop and Pioneer seamounts for food (40) (162).



Figure 19. Blue sharks are common residents off the open ocean off California. Photo: Southwest Fisheries Science Center/ NOAA.

## Site Users

- **Commercial and Recreational Fishing:** Guide Seamount is included within the 700 fathom EFH designation and as such bottom trawling is prohibited. No other types of commercial and recreational fishing are expressly prohibited. Recreational fishing does occur at Guide Seamount. In particular, there is a seasonally popular site with recreational tuna fishers (165) (40).
- **Recreation:** Pelagic bird watching tours occasionally venture out to Guide Seamount but it appears that these trips are infrequent (166). It is customary for pelagic bird watching tours to use chum in order to attract seabirds. This activity may introduce sources of nutrients to the waters that would normally not be present.

# Gumdrop Seamount

## Geologic Setting

Gumdrop Seamount is located at the continental margin off the California coast at the base of the continental shelf. It is located approximately 45 miles offshore, just to the northeast of Pioneer Seamount (157). It lies just beyond the boundary of the Monterey Bay National Marine Sanctuary. Gumdrop seamount is an example of a unique type of intraplate (hotspot) volcano—a volcano that has formed within the boundaries of a tectonic plate. Gumdrop Seamount has a northeast-southwest alignment similar to many oceanic volcanoes (132). Just like Davidson, Pioneer, Guide and Rodriguez seamounts, Gumdrop Seamount has some features that are quite unique when compared to other oceanic-island volcanoes or near-ridge seamounts. Instead of being made up of conical structures that are circular when viewed from above, Gumdrop Seamount is a series of cones separated by sediment-filled troughs (132). Also unique to these seamounts, but present on most oceanic volcanoes, is evidence of calderas at the summit. The tallest cone is at a depth of approximately 3,960 ft below sea level (132). An estimate of the depth of this seamount has been omitted because base of the seamount is poorly defined.

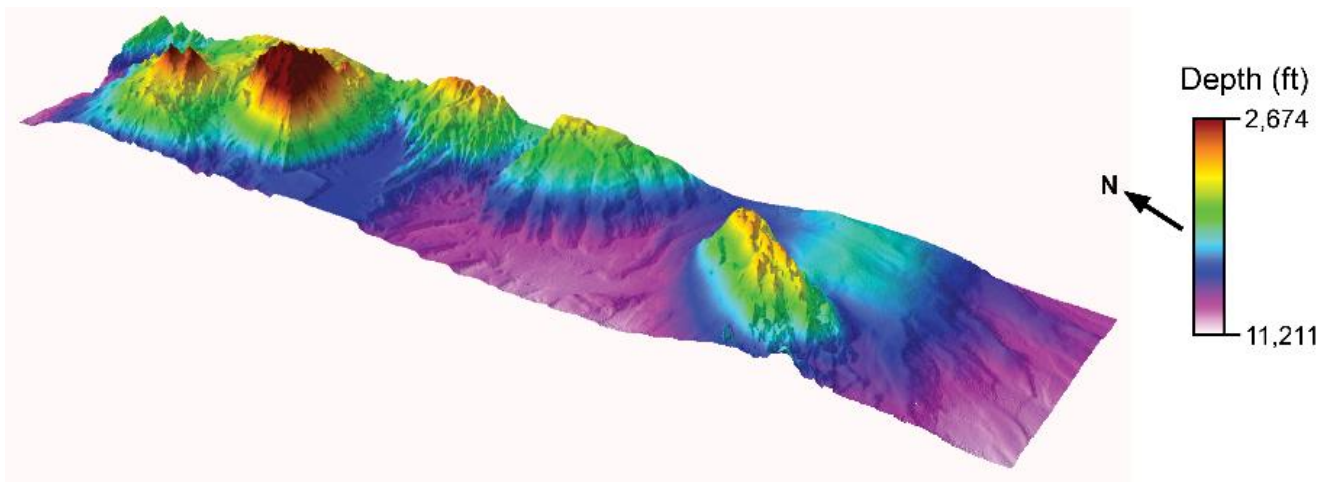


Figure 20. Seafloor image of Gumdrop Seamount, far left feature. Image: Marine Conservation Institute, Data: MBARI

## Biology

Researchers have discovered that species on seamounts have specific habitat and physiological requirements for survival. Contrary to early hypotheses, they have found that some populations of animals living on deep-sea seamounts are not experiencing genetic isolation. Even over large expanses of ocean, it is clear that these populations are not isolated. One example of this is the mulberry File clam (*Acesta mori*). It has specific requirements for survival, including rocky substrate and specific temperature, dissolved oxygen and salinity ranges. The population of mulberry File clams off the California coast has a high degree of genetic relatedness over the 1,370 miles of ocean sampled for this species. Scientists think that seamounts may provide important stepping stones for species like the mulberry File clam. Another species of File clam, called the siphon File clam (*Acesta sphonii*), is found on seamounts and deep-sea canyons, but it survives in a much narrower band of physical parameters. As a result, the stepping stones at the correct depth become even more important stepping stones for these deep-sea creatures as they provide these animals with rocky substrate at the appropriate low oxygen level that they require (132).

The Gumdrop sea jelly (*Tiburonia granrojo*) is species of sea jelly that was not scientifically described until 2003 (156). Observations of this animal have been recorded only 22 times between 1992 and 2002. It has been sighted at places throughout the North Pacific Ocean; more specifically, it has been sighted off the coast of Japan, Hawaii and California. During a 1996 dive by MBARI, the Gumdrop sea jelly was observed near the base of Gumdrop



Figure 21. Black-footed albatross, a frequent visitor to California's ocean waters. Photo: Sophie Webb, <http://www.sophiewebb.com>

Seamount. Although this sea jelly was observed in 1993, it was not until 2002 that a research team could collect it and properly examine it. This species' story demonstrates how continuing to investigate deep-sea habitats will further clarify our understanding of these ecosystems.

As previously noted, seabirds forage on the central coast seamounts such as Gumdrop (40), traveling tens of thousands of miles in a year. Shearwaters, albatrosses, petrels and terns are a few of the species that feed in the offshore waters of California (162).

## Site Users

- **Commercial Fisheries:** Gumdrop Seamount is located within an EFH 700 fathom area, which means it is protected from bottom trawling activities above this depth. Accidental discharge of by-catch is another possible impact commercial fisheries could have on the seamount's inhabitants.
- **Recreational Fisheries:** Gumdrop seamount is a known target location for recreational fishing (167) (168) (169).
- **Pelagic Bird Watching Tours**

## Mendocino Ridge

### Geologic Setting

Mendocino Ridge is the crest of the Mendocino Fracture Zone. This fracture zone is a 1,864 mile -long transform fault that extends from the San Andreas Fault at Cape Mendocino, California due west into the Pacific Ocean well beyond the westward extent of the U.S. EEZ. The shallowest portions of the Mendocino Ridge are approximately 3,600 ft below sea level (170).

The Gorda Escarpment is located on the Mendocino Fracture Zone at the Mendocino Triple Junction where the North American, Gorda and Pacific tectonic plates come together. The northward movement of the Pacific plate has caused the uplifting and faulting of oceanic crust along the Mendocino transform fault, thus creating the Gorda Escarpment. Researchers have found evidence of active venting of biogenic methane at this site that has resulted in unique biological communities adapted for this specific environment (171).

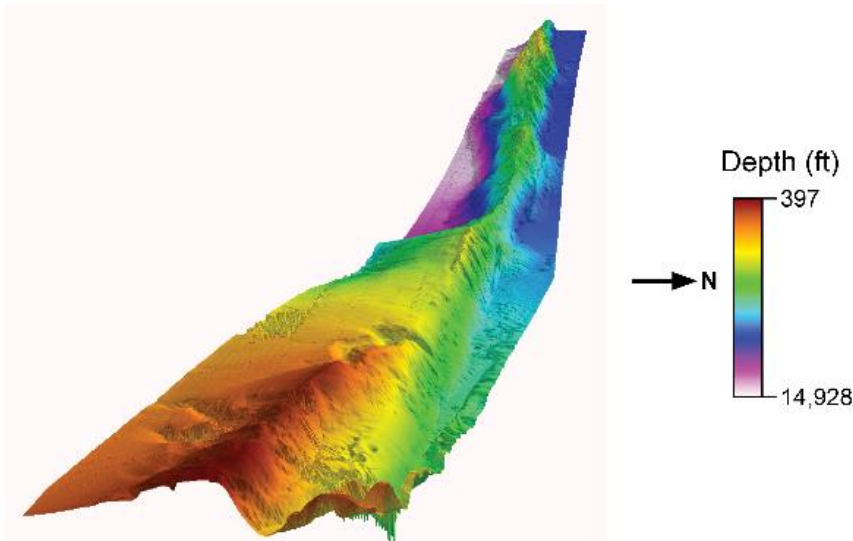


Figure 22. Seafloor image of Mendocino Ridge looking west from the shore. Image: Marine Conservation Institute, Data: Center for Coastal and Ocean Mapping Joint Hydrographic Center and the National Geophysical Data Center

## Biology

As recently as 2002, a methane-seep community was discovered on Gorda Escarpment (171). This community, which includes vestimentiferan tubeworms and vesicomyid clams, only occurs at seeps and vents because they are dependent upon chemoautotrophic bacterial symbionts for nutrients. These animals are long-lived, and as a result they influence the productivity of localized deep-sea environments (172). Very few deep-sea reproductive aggregations have ever been documented. Some of the highest fish biomass and octopus densities ever reported in the deep sea are at Mendocino Ridge and Gorda Escarpment (173). The high densities of brooding *Graneledone* sp. led scientists to describe this area as a reproductive “hot-spot”. This octopus is the longest recorded egg-brooding animal of any kind (53 months or roughly 4 and a half years) (174). Since individuals die after brooding, that these areas may be remarkably susceptible to disturbance. Scientists have suggested that these areas, and areas that have similar characteristics, should be considered for fishing restrictions because of their ecosystem value.

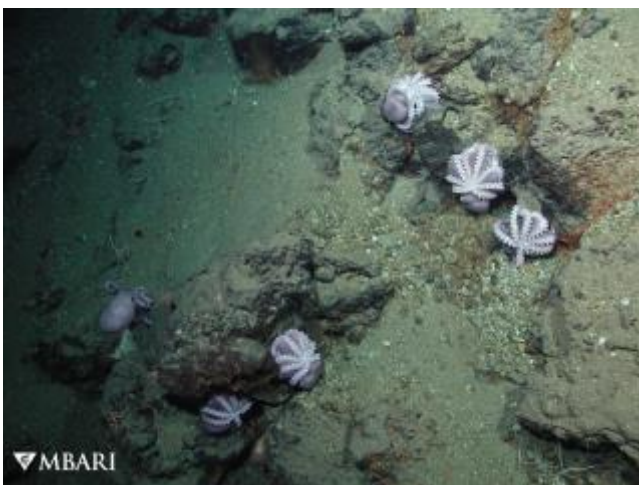


Figure 23. Brooding deep-sea octopi such as these from the nearby Gorda Ridges are found on Mendocino Ridge also. Mendocino Ridge has been described by scientists as a deep-sea reproductive hot-spot. Photo: MBARI.

## Site Users

- **Commercial and Recreational Fishing:** Mendocino Ridge is included within the 700 fathom EFH designation and as such bottom trawling is prohibited. No other types of commercial and recreational fishing are expressly prohibited.
- **Military Use:** Mendocino Ridge is within the North West Training and Testing Area (97).



## Gorda Ridges

### Geologic Setting

The Gorda Ridges is a mid-ocean ridge that has a geologically unique seafloor feature off northern California and southern Oregon. It forms the boundary between the Pacific and Juan de Fuca tectonic plates (175). The area is an active spreading center and the ridge-axis hydrothermal vent sites are the only vent sites within the U.S. exclusive economic zone (176). It is the site of up to six active hydrothermal vent fields including two in the Escanaba Trough (177) (178). At these active spreading centers water sinks through cracks and comes into contact with hot volcanic rocks. The heated water leaches minerals from the volcanic rocks and then rises and redeposits the minerals on the ocean floor when the heated water makes contact with the cold ocean water (175) (179) (180). Research indicates that this process may have deposited broad blankets of minerals within the thick sediments in a valley at the southern end of the Gorda Ridges, called the Escanaba Trough (181). Metals that have been identified at Escanaba Trough include, but are not limited to, copper, gold, silver, lead, cobalt and tin (182).

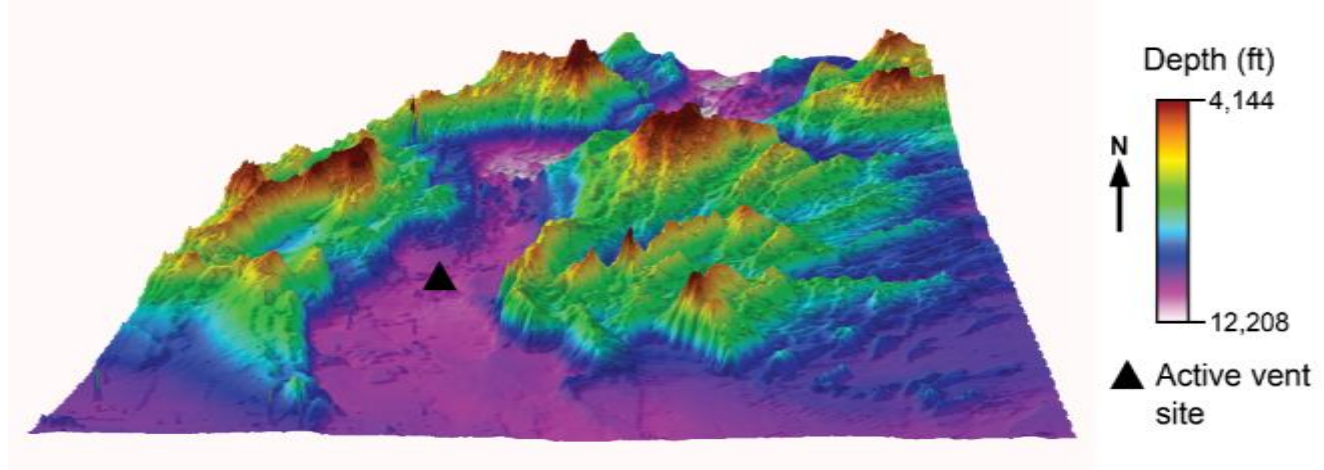
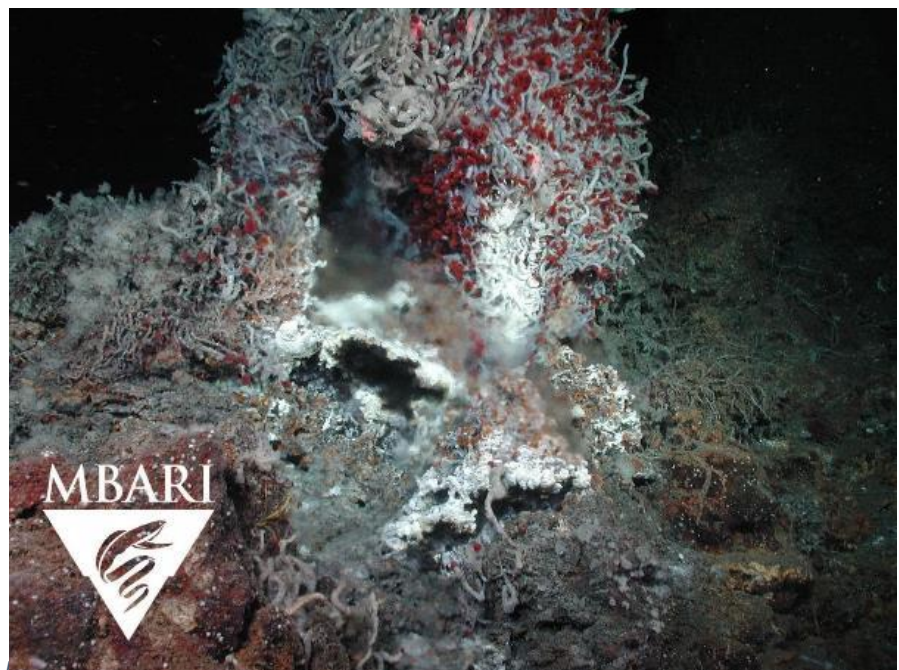


Figure 24 Seafloor image of Gorda Ridges. Image: Marine Conservation Institute, Data: National Geophysical Data Center

### Biology

The areas surrounding the active hydrothermal vents at Gorda Ridges are home to species well adapted to the harsh environment of a deep-sea hydrothermal vent. Researchers have observed diverse and complex biological communities living in water at low salinities, high temperatures, and high sulfide concentrations. A vestimentiferan tubeworm (*Ridgeia piscesae*) that occurs at hydrothermal vents throughout the northeast Pacific occurs on Gorda Ridge (183). The clumps of tubeworms, with tubes that can grow up to 4 ft tall, are a foundation species that provides



habitat for biological communities at the vents. These tubeworms depend upon bacteria to process the sulfide-rich water into nutrients that the worms use as their energy source. Other members of the biological vent communities include various types of limpets, clams, crabs, worms, and anemones.

Researchers have discovered that some animals are adept at dispersing throughout the Gorda Ridges and beyond to other hydrothermal vent fields throughout the northeast Pacific, while other animals are actually being split up into new species because of the challenges presented by dispersing past the faults subdividing this active spreading center (184). It is important to minimize anthropogenic effects on Gorda Ridges because there are biological communities and processes occurring there that we are just beginning to understand.

### Site Users

- **Commercial and Recreational Fishing:** Gorda Ridges are included within the 700 fathom EFH designation and as such bottom trawling is prohibited. No other types of commercial and recreational fishing are expressly prohibited. A small portion of the Gorda Ridges at its northwest flank is within an EFH Conservation Area. All bottom trawling is prohibited within this designated area.
- **Mining:** Escanaba Trough is known to be a site where metals are present. Due to the cost of extraction, no efforts have been made to move forward with extraction, but as metal sources are depleted globally, this site might once again become a site of great interest for metal and mineral extraction. Mineral Management Service ran a lease sale for mineral rights in Escanaba Trough in the 1980s, but no bids were made (176).
- **Military Use:** Gorda Ridges are within the North West Training and Testing Area (96).

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