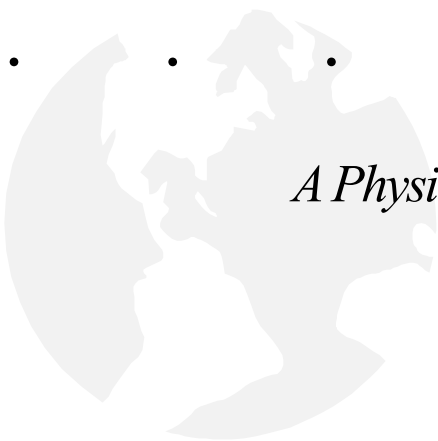


The Gulf of California



A Physical, Geological & Biological Study

•
•
•
•
•
•
•

The Gulf of California

Located between the lower California Peninsula (Baja California) and the state of Sonora on the mainland of Mexico, the Gulf of California (“the gulf”) is also known as the Sea of Cortes and the Vermilion Sea. It has an interesting and long history. This report presents an overview of the physical, geological and biological highlights of the Gulf of California.



Gulf of California as seen from the Gemini 12 spacecraft during its 30th revolution of the earth. Baja California Sur is the peninsula on the left. At lower left is the mainland of Mexico. A 100 ft. tether line connects the Agena Target Docking Vehicle with the Gemini 12 spacecraft. View is looking south.

Image Credits

Gulf of California as seen from the Gemini 12 spacecraft; Nasa Photo ID S66-63517 downloaded from <http://images.jsc.nasa.gov>

A Physical Study

Map of Baja California and Surrounding Areas; captured from <http://www.trybaja.com>

Basins and shelves in the Gulf of California; scanned from *Ocean World Encyclopedia*

Spiral Eddies near Santa Catalina Island, Gulf of California; Oceanography from the Space Shuttle 51J-47-019 downloaded from <http://daac.gsfc.nasa.gov>

A Geological Study

Looking toward southwest at Bahia de los Muertos on the East Cape of Baja; captured from <http://www.geocities.com/CapeCanaveral/Lab/6488>

Map of Tectonic Plates surrounding the Gulf of California; scanned from *Plate Tectonics & Crustal Evolution*

Geologic cross-section across peninsular California showing hypothetical relation between the western edge of Precambrian crust and a structural and geochemical suture; captured from <http://www.geocities.com/CapeCanaveral/Lab/6488>

A Biological Study

Desert beach on Isla Espiritu Santo; captured from <http://bajawhale.com/searcher/journal.html>

Pinnipeds of the Southern California Planning Area; captured from <http://www.mms.gov>

Whale watching group; captured from <http://www.bajawhale.com/searcher>

Sport fishing catch; captured from <http://www.geocities.com/CapeCanaveral/Lab/6488>

.....

The Gulf of California

A Physical Study

The Gulf of California is a narrow, marginal sea with deep, cold waters that provide abundant nutrients transported toward the surface by upwelling.

Location



The Gulf of California is located in the Pacific Ocean, between the lower California Peninsula (Baja California) and the state of Sonora on the mainland of Mexico.

Situated between 24°N and 32°N latitude, the gulf offers a pleasant subtropical marine environment. Because the peninsula is formed by an almost uninterrupted chain of mountains, the climate of the gulf is more continental than oceanic.

The region is accessible by air, land and sea. There are daily flights to Tijuana, Loreto, La Paz and Los Cabos. Greyhound busses run from the United States and three major bus companies provide regular service within the area. The transpeninsular highway is open and maintained on a year-round basis. The roads are narrow but safe to drive. There are also ferry services available.

US and Canadian citizens need a valid passport and a tourist card available at the border.

Basin Characteristics



The Gulf of California is a long and narrow extension of the Pacific Ocean separating the peninsula of Baja California from the mainland of Mexico. Its physical dimensions are summarized below:

Length	700 mi (1126 km)
Width	30 to 50 mi (48 to 241 km)
Area	68,322 mi ² (177,000 km ²)
Mean Depth	2684 ft (9818 m)
Volume	34,985 mi ³ (145,000 km ³)

The gulf was formed as a result continental drift, specifically the interaction between the floor of the Pacific Ocean and the North American continent. The East Pacific Rise extends north to the Gulf of California. It is a marginal sea that is in the earliest stages of a spreading center (see next section). Related to the complex faults and fractures along the western coast of North America, the axis of the basin trends northeast-southwest. The present configuration of the gulf has a modest continental shelf along the east side and precipitous slopes along the western edge. The eastern continental shelf ranges up to 31 mi (50 km) in width and breaks at a depth of about 361 ft (110 m).

The gulf coastline is irregular and forms numerous small bays. The head of the gulf is dominated by the Colorado River delta, which extends offshore for as much as 20 mi (32 km) with depths as shallow as 60 ft (18 m). Its eastern shores are bordered by highlands, broken by a number of rivers, including the Sonora, Yaqui, and Fuente, that contribute considerable amounts of terrigenous sediments to both the shelf and the deeper basins through numerous submarine canyons. No rivers feed the gulf from the arid Baja California peninsula on the western edge which is an almost unbroken mountain wall. Many islands are also contained within the gulf.

The deeper floor of the gulf consists of a series of basins which become progressively deeper to the south. Deep basin sediments consist of alternating plankton and clay layers.

Water Characteristics

One of the richest and youngest bodies of water on the planet, the combination of temperature and nutrient-laden water in the Gulf of California results in an abundance of sea life.

Temperature

The temperature of the Pacific coast of Baja averages 60-75°F (16-24°C). Summer temperatures can reach 85°F (30°C), winter nights can drop to 48°F (9°C). Inland summer temperatures can reach 110°F (43°C). The Baja Cape from La Paz to Cabo is warm year round with summers as hot as inland and winters a moderate 70-80°F (21-27°C). The temperature of the surface water ranges from 86°F (30°C) in summer to 60.8°F (16°C) in winter.

The approximate median air and water temperatures (°F) in Baja and the Gulf of California are summarized below:

<i>Month</i>	<i>Air</i>	<i>Water</i>
January-April	60-75	60-65
May	72-85	65-70
June	79-90	68-75
July	85-100	75-80
August-October	85-100	80-85
November	78-85	78-80
December	68-80	68-75

In the Ballenas Channel, completely isolated from the rest of the gulf below 250 m, the bottom (1500 m) temperature is about 11°C, about 8°C higher than at comparable depths outside the channel. This condition is not encountered anywhere else in the eastern Pacific.

Salinity

The surface salinity varies between 35‰ and 35.8‰ with little seasonal change. The subsurface salinity distribution (50-100 m deep) indicates that there is an inflow of low-salinity water along the east coast and an outflow of high-salinity water along the west coast. Below the thermocline, the gulf water is basically the same as that off the coast of southern Mexico, with a salinity minimum of less than 34.6‰ between 400-800 m, and an oxygen minimum of less than 0.2 ml/L between 200-800 m.

Circulation

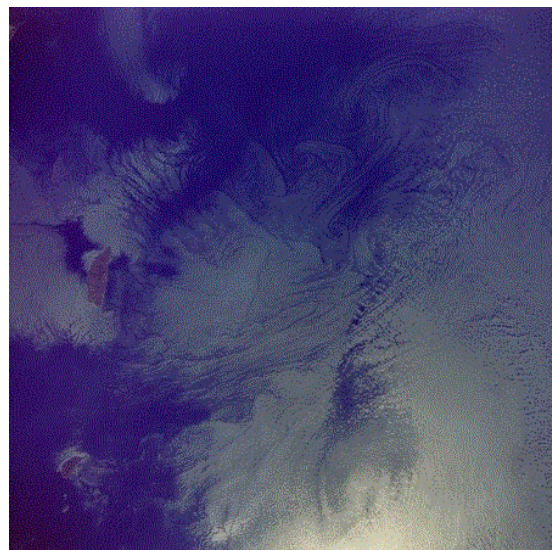
Water circulation in the Gulf of California is primarily controlled by the prevailing wind pattern. In the winter, winds blow from the northwest, moving the surface water out to be replaced by deep, nutrient-rich Pacific water. In the northern part of the gulf, winter cooling can cause convective overturn that extends 100 m downward. In the summer, winds shift to the south and move surface water from the Pacific into the gulf, forcing the deeper water to flow out.

Coromuel Wind

The *Coromuel Wind* is a term that refers to the cooling westerly breeze that blows over La Paz, Baja California almost every afternoon. Because of the temperature difference between the cooler Pacific Ocean and the warmer Gulf of California waters, a mid-thermal low pressure area develops regularly in the gulf area. Because frontal passage and tropical cyclones are infrequent and no mountainous features are located on the peninsula in the area west and southwest of La Paz, the air flow is not disrupted.

Spiral Eddies

As part of the oceanographic observations from the space shuttle, on October 6, 1985, the crew of the Atlantis confirmed a theory about spiral eddies in the open ocean. It had been postulated that when eddies are forced by currents moving past an island, a series of counter-rotating eddies will appear downstream, behind the island, as do atmospheric vortices.



This image shows a counter-clockwise rotating eddy forming on the eastern end of Santa Catalina Island in the southern Gulf of California as the incoming tidal current flowed past the island. Initially, the “downwind” eddy stream seemed to be composed of sets of counter-rotating eddies; however, on closer observation, each eddy stream has eddies that are rotating counter-clockwise, conforming with other spiral eddies in the Northern Hemisphere.

Tides

The Gulf of California experiences a mixed tide with an unusually large tidal range. As a result of the basin shape, at the northern apex of the gulf, the tidal range is extreme, reaching 30 ft (9 m). Typically, the mean tidal range increases from 1 m at the gulf entrance to 7 m near the mouth of the Colorado River. As in other Pacific ports, the tidal curve is mixed, with two high and two low tides per day.

History

Archaeologically, little is known of the pre-history of the arid peninsula of Baja California. Near the middle and southern sections of the peninsula, hundreds of rock canyons serve as the canvas for traditional wall murals painted by early hunter-gatherer groups. These images depict human and animal figures in red, black, white and yellow. In December 1993, the Sierra de San Francisco, one of the world’s largest prehistoric painted rock art, was named to the UNESCO World Heritage List. Obsidian artifacts (Clovis-type points) are also common in the area.

Three native Indian tribes inhabited the Baja area at the time of the Spanish expeditions. One group migrated from the northern mainland and the other two supposedly came from nearby Pacific islands. There were many legends about gold and pearls and Amazon women in the Baja peninsula, which was originally thought to be an island.

In 1533, the Spanish conqueror Hernan Cortes accidentally discovered the Baja peninsula while exploring the Pacific coast of Mexico. (In his honor, the Gulf of California is often referred to as the Sea of Cortes.) They returned to Spain with stories of handfuls of pearls gathered in the gulf. In 1539, the Spanish explorer Francisco Vasquez de Coronado came to the area seeking the Seven Cities of Cibola. Many similar expeditions followed. In 1565, Spain initiated the Manila galleon route which was sailed by thousands of ships for over 250 years. Baja became a hide-out for Dutch, English and French pirates.

Baja remained unconquerable until 1697 when Jesuit priests established a colony at Loreto. They built churches and communities throughout the region until they were expelled by Spain in 1768. Franciscan priests and later Dominicans dominated the peninsula until Mexico obtained its freedom from Spain in 1821.

The US tried to purchase the territory north of the 38th parallel for \$3.5 million, then \$40 million – both offers were rejected by Mexico. After assuming control of the Californias during the war with Mexico, the US ceded the Baja peninsula and a thin strip connecting it to the mainland to Mexico in the Treaty of Guadalupe.

Between 1936 and 1940, an unknown disease attacked the mother-of-pearl shell, destroying the pearling industry. Agriculture was implemented on a large scale with irrigation from deep wells.

Today, the Gulf of California is a popular tourist area with local architecture and small-town charm, shopping and a booming recreational industry including bicycling, scuba diving, snorkeling, fishing, hiking, horseback riding, mountain biking, archaeological tours, sea kayaking, windsurfing, whale watching and much more.

•
•
•
•
•
•
•

The Gulf of California

A Geological Study

The Gulf of California is an integral part of the North American Cordilleran segment located between latitude 18°N and 35°N, the trans-Mexico volcanic belt of central Mexico and the Transverse Ranges of southern California.



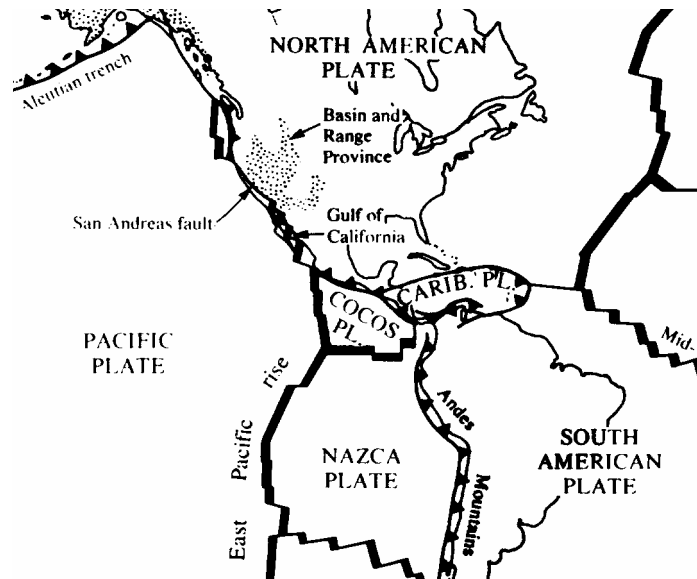
Formation

The Gulf of California is a Tertiary continental rift system, similar to the Gulf of Aden, produced by combined extension and shear. The detailed history of its formation is the topic of debate among geologists and paleomagnetic researchers.

Plate Tectonics

The Gulf of California is located along a divergent plate boundary, where heated subsurface material wells up, cools, and is added to the edges of the plates which move away from each other on opposite sides of a spreading center. As part of the Pacific plate, Baja California will eventually be pulled away from the mainland as the Gulf of California extends northward.

The East Pacific Rise lies near the eastern portion of the Pacific Ocean and separates the Pacific Plate from the Nazca and Cocos Plates. It extends into the gulf and is evidenced on land as a series of transform faults of which the San Andreas fault is a major component. The Rise reappears in the Pacific Ocean just north of Cape Mendocino in northern California.



The San Andreas fault system is an enormous shear zone, generally referred to as a right lateral strike-slip fault. Earth movement along the fault is caused by spreading beneath the East Pacific Rise. The southern point of the fault, is marked by a triple junction that migrates south as subduction of the Rise system continues. The great California and recent Mexican earthquakes and Mexican volcanoes are a result of this tectonic activity.

About 3-4 million years ago, the Baja peninsula was created by northward movement along the fault that detached Baja California from the mainland of Mexico. The Gulf of California began to open as a series of offsets along transform faults. Activity along the faults continues as the plates spread apart and the gulf between the peninsula and mainland Mexico grows.

Paleomagnetism

There is some question as to the tectonic history of the Baja California region. The paleomagnetism versus geology controversy remains unresolved due to political issues and the desolate climate and terrain of the area.

The Earth's magnetic field reverses over time. Certain iron-bearing minerals that naturally occur in sedimentary and igneous rocks act like magnets and record the direction of the magnetic field at the time of lithification. Magnetic striping, preserved in the oceanic crust, occurs as new rock is added at spreading centers is one of the key supports for continental drift. This paleomagnetic signature can be correlated to the geomagnetic reversal time scale and the relative orientation of the rocks determined for a particular age.

The Peninsula Range Batholith runs from southern California to nearly the 28th parallel in Baja California. It was formed between 90-130 million years ago, during the Cretaceous period, as the Farallon Plate was subducted along the western margin of North America. The paleomagnetism recorded in the resulting granitic rocks suggests that Baja peninsula was located 900 km south of its current geographic position. Some suggest that the peninsula may have been an island arc near the Mexican coast during the Cretaceous.

However, geologic observations of 900-254 million year old Proterozoic and Paleozoic facies suggest that the simple closing of the Gulf of California would place the Baja peninsula in its original geographic position. During the Eocene epoch, 58-37 million years ago, volcanic sediments were deposited in an extensive fluvial system. These rocks match outcrops in northwestern Sonora, Mexico, requiring that the gulf be closed about 300 km southeast of its present location.

These relationships imply that the Baja peninsula rifted from the Sonora region after the end of the Paleozoic, and then traveled 900 km south to obtain the paleomagnetic signature. After 90 million years, the peninsula traveled 900 km north to its original position. This scenario is highly unlikely and may be explained by tectonic tilting of the batholith. The paleomagnetic data also suggests that the batholith was south of Sonora during the Eocene, which would not support deposition of the volcanics across the peninsula into San Diego.

One theory, based on studies of Deep Sea Drilling Project cores from the Gulf of California, suggests that a supernova caused a geomagnetic excursion which resulted in a shift in the Earth's magnetic field, explaining the paleomagnetic anomalies.

Geology

The geology of the Gulf of California is amazingly varied for such a small area. It is situated in a region of structural instability which influences most of its geologic features.

History

Two igneous rock types dominate the Pacific margin of North America: granites and andesites. They generally occur as linear bodies paralleling each other and major tectonic elements including metamorphic foliation, fold axes, volcanic flows and major fault strikes.

The geologic history of the area is greatly simplified in the summary below:

Mesozoic/Cenozoic	Granitic rocks form basement
Cretaceous	Plutonic intrusions; marine sediments deposited in Sonora and western Baja
Mid-upper Cretaceous	Erosion, extensive sheet volcanics, and tilting Erosional unconformity
Late Cretaceous	Marine transgressive deposits form on Baja plutonics
Paleocene/Eocene	Subsidence allows sea to cover western flank of peninsula; volcanism and red-bed formation in Sonora; local folding and erosion; sandstone deposition; continued volcanism
Mid-Tertiary	First sea invasion of gulf coasts; thick accumulations of coarse breccias, marine conglomerates; deposition of marine shales; uplift and erosion
Late Miocene	Extensive volcanism (Comondu Formation) - centers coincide with western margin of present gulf; deformation along eastern border of lower California resulted in tilting, followed by sea invasion to the east, isolating the Baja peninsula; faulting and folding along east side with displacement along main axis; islands break off as gulf opened
Pliocene	Narrow gulf formed, with shallow-water marine deposits
Pleistocene	Uplift continues, especially on east side of peninsula

Basin

Unique among marginal seas of the Pacific Ocean, the Gulf of California comprises a large evaporation basin. Geophysical surveys indicate that the crustal structure in the central and southern Gulf of California is more oceanic than continental in character. The crust is abnormally thin in the northern section of the gulf.

A series of deeply incised submarine canyons extend down the slopes near the lower part of Baja California that contain crystalline rocks, along with Miocene and Pliocene sedimentary rocks. Sand flows and other gravity-induced movements currently scour the heads of these canyons which are the result of submerging stream valleys, tectonism, and slumping.

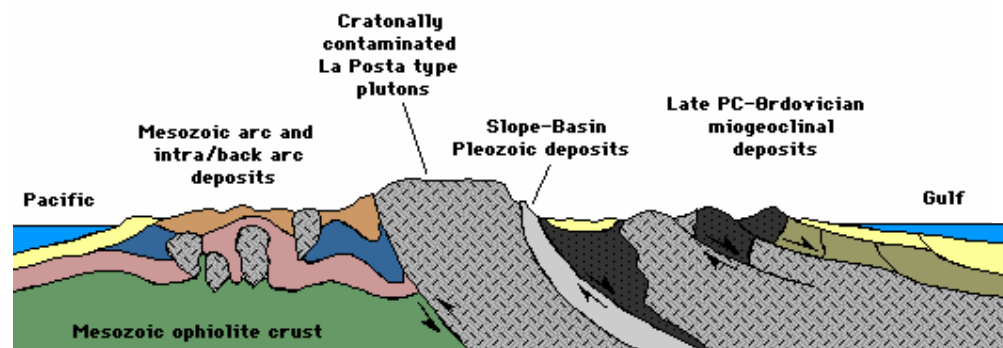
In the northern gulf, modern deposition is limited to the Colorado River delta, areas of sandy littoral sediments fringing the margins and to diatomaceous clays in the deepest basin. Glauconitic sands occur at the surface over most of the area. In the central and southern gulf, deposition is mainly erosional from the east side. In the deeper sections, fans occur within thin sand layers (turbidites). Deposits in the central basins are primarily diatomites as a result of the high organic productivity at the surface. The southern basin sediments are predominantly terrigenous and very fine-grained.

The average sediment accumulation rate in the Gulf of California is 100 cm/thousand years.

Islands

The islands within the Gulf of California present a variety of geological formations and structural relationships. Most of the islands are barren, without water, and uninhabited. Rainfall is sparse and sporadic so there is little plant life, except for low desert shrubs or cactus. Wave action has eroded great sea cliffs with few good harbors.

Islands near the east shore of the southern peninsula are geologically similar to the adjacent sections of Baja California. The water between the islands and the peninsula is generally shallow. The islands were probably a part of the peninsula at one time. *Isla Cerralbo* is composed mainly of coarsely crystalline, greenish-white granitic rocks with many large vertical fractures and small intrusive dikes. *Isla Espiritu Santo* is composed of lavas, mud flows, tuffs and other eruptive rocks resting on a granitic base. *Isla San Diego* is actually a group of small granitic islands that emerge from a submerged ridge. Several other islands exhibit similar features. *Isla Coronado* includes a volcanic cone and Pliocene sediments.



Other islands in the gulf are not closely structurally related to the peninsula or to each other. *Isla Tortuga* is made up of dark, recent lava with a crater in its center. *Isla San Pedro Martir* is composed of crystalline rocks with a smooth, dome-like profile. *Isla Tiburón* is composed of lavas, tuffs and other eruptive rocks overlying granitic and metamorphic rocks. Numerous other islands dot the gulf.

Hydrothermal Activity

The Gulf of California is characterized by a zone of unusually high heat flow. This suggests that convection currents in the mantle are rising beneath this region, maintaining the East Pacific Rise.

Vents

In March 1993, an educational JASON expedition along the Baja peninsula explored five active hydrothermal vents in the Southern Trough of the Guyamas Basin, Gulf of California. The mounds of mineral deposits stand 4-15 m above the soft sediment-covered valley floor.

Clear and grey hydrothermal fluids emitted by the white smokers and flanges reach temperatures of 300°C. Tubeworms and other organisms were observed living off the vents.

Thermal Alteration

In the Guyamas Basin, a sediment-covered section of the East Pacific Rise, hydrothermal fluids escape to the sea floor directly from spires and chimneys and by diffuse circulation through hemipelagic, diatomaceous, organic carbon-rich material of low density and high permeability. Thermal alteration of the organic matter generates hydrothermal gas and petroleum with a wide range of composition and maturity. Significant amounts of hydrothermally-generated oil have been transported laterally at 140-250 cm depth. Below 782 cm, sandy layers have experienced substantial hydrothermal alteration evidenced by the presence of gypsum and dolomite.

•
•
•
•
•
•
•

The Gulf of California

A Biological Study

The Gulf of California is often referred to as “the world’s largest fish trap”. Its fertile waters are home to over 800 species of fish and 2,000 species of invertebrates. The area has been influenced by culture and commerce for over four centuries. The islands and waters of the gulf are a haven to many species of plants and animals found nowhere else on Earth.

Coastal Environment

Located near the Tropic of Cancer, the southern gulf is renown for its combination of desert and tropical landscapes. Huge cacti forests, mangrove channels and a great diversity of birdlife complement the sandy white beaches and clear azure water.



Several unique sea formations have been sculpted in the rugged coast by the gulf waves. The Cabo San Lucas Arch is the only finisterra (latin for “land’s end”) in the world. It is a fantastic rock arch of impressive beauty and international fame, becoming a regional symbol. Beneath the arch, at ebb tide, the “Playa de Amor” (Love Beach) becomes larger. At 100 m down, sand cascades from the tributaries of an enormous underwater canyon is a sight observed only by expert divers. Colonies of corals, a diversity of fish, and sea lions frequent this favorite landmark. The Bay of La Paz is the largest bay in the gulf. It has many calm beaches with gentle slopes and white sands. The famous “mushroom rock” is in La Paz, patiently carved by wave action. Isla Espiritu Santo is one of the most spectacular islands in the gulf with a beautiful landscape and various rock formations. The escarpments reveal multi-colored volcanic strata of red, rose, yellow, white, and black.

Numerous small bays, coves and white beaches are accessible by car from the main peninsula, local ferries, and a multitude of tour services that explore the gulf area.

Many coastal wetland systems function as ‘ecological oases’ with high productivity contrasted to the surrounding desert ecosystems. The Colorado River delta is historically the most important in the area. It is often assumed to be a “dead” ecosystem as a result of upstream water diversion for agriculture and city use. On the western side, the Rio Hardy wetland (formerly 18,000 ha) is the main wetland; on the eastern side, the Cienega de Santa Clara (4,200 ha of vegetation) is the main wetland and has been incorporated into the core area of the Biosphere Reserve of the Northern Gulf of California and Colorado River delta.

These delta wetlands are still the largest in the Sonoran desert and provide important resting and feeding grounds for a variety of shore birds, including Peeps, Black-bellied Plovers, Dowitchers, Marbled Godwit, Willet and American Avocet. A 1992 survey counted more than 160,000 shorebirds of 10 different species. The Colorado River delta is on the fall migration corridor in western North America, supporting the white-fronted goose, lesser snow goose, brant, northern pintail, blue-winged teal and canvasback. Non-migratory waterfowl and shorebirds also inhabit the area, including least bittern, white-faced ibis, snowy plover, long-billed curlew and numerous other species. The brackish waters provide a nursery habitat for the fish and crustaceans that support the commercial fishing industry in the northern gulf.

Marine Life

Plankton, the basic link in the food chain, are prolific in the gulf and support an extraordinary fish population, oyster beds and sponge fisheries along the east coast. Pearl fisheries are on the western coast. The gulf is also referred to as the Vermilion Sea because of the red color of plankton blooms, similar to the Red Sea.

Fish

Ocean currents and geologic structure allow for world-class fishing off the Baja peninsula. The variety and abundance of sea species in the gulf has attracted fishermen throughout its history from pearl oyster and commercial to the more recent, sport fishing. International fishing tournaments take place year-round. The main sport fishing species and seasons are summarized below:

Medregal	April – October
Bonito	Year-round
Dorado	June – October
Garropa	April – November
Blue Marlin	August – October
Black Marlin	August – November
Striped Marlin	April – November
Roosterfish	Year-round
Flying Fish	July – September
Swordfish	Year-round
Wahoo	Year-round
Jurel	January - April

The Black Sea Bass, or Giant Sea Bass, ranges from the Gulf of California to Humboldt Bay, California, and may live to be over 100 years old. They were rapidly disappearing in the 1950s, but are making a slow recovery with strong protection by State of California. They are more plentiful and may be fished in Mexico. The Shovelnose Guitarfish ranges from the gulf to San Francisco. It inhabits sandy areas and stays in shallow waters. Very dangerous to humans, sea snakes also inhabit the gulf.

Pinnipeds

Pinnipeds – seals and sea lions – are an important part of the marine life in southern California. Four species are non-endangered: the California sea lion, northern fur seal, northern elephant seal and harbor seal. Two species are listed as threatened under the Endangered Species Act: the Guadalupe fur seal and the Stellar sea lion. Many species breed on the gulf islands during the summer months. The pinnipeds are playful and a favorite tourist attraction throughout the year.



Sea Turtles

Five species of sea turtles, all considered threatened or endangered, frequent the Gulf of California. The leatherback, ridley, loggerhead, black and hawksbill turtles make long migrations from their nesting beaches in southern Mexico to use the gulf as feeding, over-wintering and nursery areas. Sea turtle behavior in the gulf is poorly understood.

Whales

Each winter, thousands of gray whales migrate to the lagoons and bays of Baja California to breed, calve and nurture their young. Numerous other species of whales – finbacks, blues and humpbacks – are also found in the gulf. Commercial whale watching dates from 1955 and is a main attraction of the gulf region. The season for gray whale watching varies along the California coast during the winter and spring as the grays migrate south to the mating and calving lagoons of Mexico, then return north to feed mainly off Alaska. Many commercial whale-watching companies operate in the gulf. Groups can often spend several hours observing the whales as they blow and re-surface to show their heads, blowhole, entire back and dorsal fin, and flukes.



Found only in the north Gulf of California, the vaquita is the smallest of all whales, dolphins and porpoises - and the most endangered of all marine species. Only a few hundred animals remain. The vaquita was not recognized as a species until 1958 and very little is known still. Unfortunately, most of the information about them comes from stranded or drowned vaquita.

Phocoena sinus is also referred to as the gulf porpoise or the Cochito. The average adult length is 1.3 meters. Calves are about 60 cm at birth. The vaquita is similar to the Harbor porpoise in body shape; however, the flippers are proportionately larger and the dorsal fin slightly higher. Its overall color is a medium to dark gray with a white belly, throat and chin. It feeds on bottom fish and is rarely seen in daily encounters.

Impact of Man (“A Dying Sea”)

Sheltered by the long, narrow Baja peninsula and nourished by great masses of plankton, the Gulf of California is one of the most productive and diverse marine nurseries on Earth. Recognized and enjoyed by a growing number, its unique attraction is ironically being destroyed in biological respects.

Development

The completion of the Transpeninsular Highway (Mexico 1) in 1973 marked the beginning of a new era for the Baja California region. It extends the entire length of the 800 mile long peninsula and has literally paved the way to fast-growing cities and resort areas.

Ensenada is Baja's leading seaport, handling agricultural products from the Mexicali valley. *San Felipe* is a major shrimping center and winter resort. *San Quintin* is the market center for this fast-growing agricultural region. It also offers excellent fishing, clam digging and safe harbor for small boats. *Bahia de Los Angeles* is a beautiful bay with excellent fishing. *Guerrero Negro*, located in the Vizcaino Desert, is one of the world's leading salt producers with acres of evaporating ponds. In the nearby lagoons, gray whales give birth between January and March. *San Ignacio* is an oasis community with forests of lush date palms. *Santa Rosalia* was a mining town, established in the 1880s by the French El Bolco Copper Company. In *Mulege*, dates, figs, oranges, bananas and olives are cultivated. Sport-fishing and diving is excellent. *Bahia de la Concepcion* provides great camping beaches. *Loreto* is being developed into a major resort destination by the Mexican government. *Ciudad Constitucion* is a major agricultural center, producing cotton which is ginned locally. *La Paz*, the capital, has good sport-fishing and abundant tourist facilities. *San Jose del Cabo* is the commercial center for the southern Baja peninsula. Surrounding ranches raise cattle; mangos, avocados and oranges are also grown nearby. *Cabo San Lucas* is the primary tourist destination renowned for sport-fishing.



Over-Fishing

For every pound of shrimp caught in the Sea of Cortes (the southern part of the gulf), nearly 10 pounds of other marine life dies. According to a 1994 UN scientific report, this is one of the highest ratios in the world. A fishing armada of shrimp, sardine, squid, tuna, Mexican “panga”, and small open vessel boats and nets of nearly every size and shape, not to mention the sport-fishing industry, has caused most of the damage to the gulf waters over the past 20 years. Although overfishing is acknowledged as a serious problem by fishermen, scientists and others, political officials put the blame on changes in the weather, ocean currents and natural cycles. Most fishing is driven by the simple, single force of money. Asia and the US, especially California, are the largest buyers of Mexican seafood.

Many gulf species - including tuna, sea bass, grouper, yellowtail, shark, marlin, scallops, lobster, snapper, shrimp, halibut and sardines – have suffered sharp declines. Two species – the totoaba and vaquita – are considered endangered. The single biggest threat to the rare Vaquita is entanglement in gillnets, which causes death by drowning. At least 35 vaquitas are killed each year by entanglement – a statistic that is clearly not sustainable for a population that numbers in the low hundreds. The sea birds are also suffering because of drastically reduced food supplies.

Habitat Destruction

Upsets in the ecological balance of the environment also contribute to changes in the gulf.

The freshwater flow from the Colorado River into the delta area has been substantially diminished with the creation of the Hoover Dam (for hydroelectric power) and other installations. In its natural state, the Colorado River annually delivered about 18 billion m³ of water into the Gulf of California, along with 160 billion kg of sediment. Since construction of the dam, freshwater flow is estimated at less than 8 billion m³ of water, with only 12 billion kg of sediment per year. This drastic change has certainly had an impact on the ecosystem.

Exportadora de Sal (ESSA), a salt export company owned by Mitsubishi Corporation and the Mexican government, plan to construct an industrial complex, sacrificing 21,000 acres of protected land in the Vizcaino Desert Reserve. Temporarily halted by the National Ecology Institute of Mexico (the Mexican equivalent of the US Environmental Protection Agency), this expanded salt mining will most likely devastate the lagoon, estuaries and flats of the Laguna San Ignacio area. This is the only unspoiled lagoon of three remaining bays where migrating gray whales spend the winter months. The fragile breeding and calving environment is also home to sea turtles, dolphins, the endangered pronghorn antelope, mountain lions, coyotes, peregrine falcons, golden eagles, black brant geese, osprey, and blue-wing teals. Scallop, clam, lobster and abalone fisheries sustain a small resident community.

Pollution and ship traffic already affects the delicate ecological balance of the entire gulf.

Several solutions have been proposed to rejuvenate the gulf area and increased awareness is helping motivate critical action, including: simply enforcing the protective laws, declaring the area a marine preserve, giving control of select areas to local fishermen, banning gill nets and shrimp trawlers, developing domestic “fish farms”, and encouraging “eco-tourism” and “catch-and-release” sport fishing.

⋮

The Gulf of California

References

Internet Sites

<http://images.jsc.nasa.gov>

<http://www.trybaja.com>

<http://www.bajatravel.com>

<http://www.navtec.com/nav-baja.htm>

<http://www.deltanet.com>

<http://southwest-mall.com/cortez/>

<http://www.bajaex.com>

<http://gds.esrin.esa.it>

<http://www.math.ucr.edu/~ftm/bajaPages/Stories/Coromuel.html>

<http://daac.gsfc.nasa.gov>

<http://www.virtualmex.com/bajahist.htm>

http://www.qal.berkeley.edu/arf/newsletter/2.1/rock_art.html

<http://www.geocities.com/CapeCanaveral/Lab/6488>

<http://www.dla.utexas.edu/depts/anthro/kappelman/paleomag.html>

<http://www.amsci.org/amsci/issues/Sciobs95/Sciobs95-07.html>

<http://citt.marin.cc.ca.us/ring/rplates.html>

<http://www.ldeo.columbia.edu/~polsen/nbcp/withjack.html>

<http://www.geosociety.org/pubs/9509bul.htm>

<http://vishnu.glg.nau.edu/wsspc/usdot.html>

<http://www.detnews.com/menu/stories/16503/htm>

http://www.nando.net/newsroom/ntn/world/100995/world857_7.html

http://www.agu.org/sci_soc/demets.html

<http://www.cicese.mx>
<http://www.earthwatch.org/g/Gerlich.html>
<http://www.bajaquest.com>
<http://www.mexico-travel.com/states/s03/80zz1.htm>
http://www.jason.org/JASON/HTML/EXPEDITIONS_past.html
<http://uib.gym.itesm.mx/hardy>
<http://www.csn.net/cruises/coastal/mexico1.htm>
<http://www.bajawhale.com/searcher>
<http://www.adventurequest.com/adven/htm/51rt.htm>
<http://www.physics.helsinki.fi/whale/usa/californ/californ.html>
<http://www.netaxs.com/~chaz4/spexbaj2.html>
<http://www.users.interport.net/~giraffe/vaquita/>
<http://www.eathisland.org/ei/immmp/graysbaja.html>
<http://www.ppss.arizona.edu/htmls/tide.htm>
<http://www.mms.gov/omm/pacific/scpinapd.html>
<http://www.cris.com/~cserret/nonfish.html>
<http://gurukul.ucc.american.edu/TED/COLORADO.HTM>
<http://www.quiknet.com/~flodin/seaofcortez.html>
<http://www.scabee.com/news/projects/dyingsea>

Bibliography

Conde, Kent C., New Mexico Institute of Mining and Technology, *Plate Tectonics & Crustal Evolution*, Pergamon Press, NY, 1982.

Sturz, A.A., Sturdivant, A.E., Lief, R.N., Simonet, B.R.T., Gieskes, J.M., "Evidence for Retrograde Hydrothermal Reactions in Near Surface Sediments of Guaymas Basin, Gulf of California", *Applied Geochemistry*, Volume 11, Number 5, Pergamon Press, NY, 1996.

Robigou, V., Stewart, K., Ballard, R., "Hydrothermal Vent Sites in the Guaymas Basin Revisited by ROV; High Precision Bathymetric, Geological and Biological Mapping", *Eos, Transactions, American Geophysical Union*, Volume 74, Number 43, Supplement, American Geophysical Union, Washington, D.C., 1993.

Robigou, V., "JASON Project IV, Combined Operations of JASON ROV, TURTLE Submersible and Satellite Link to Land", *Eos, Transactions, American Geophysical Union*, Volume 74, Number 43, Supplement, American Geophysical Union, Washington, D.C., 1993.

- King, Philip B., *The Evolution of North America*, Princeton University Press, NJ, 1977.
- Beal, Carl H., *Reconnaissance of the Geology & Oil Possibilities of Baja California, Mexico*, GSA Memoir 31, Waverly Press, MD, 1948.
- 1940 *E.W. Scripps Cruise to the Gulf of California*, GSA Memoir 43, Waverly Press, MD, 1950.
- Andel, Tjeerd van, and George G. Shore, Jr., Scripps Institute of Oceanography, University of California, *A Symposium: Marine Geology of the Gulf of California*, AAPG, Tulsa, 1964.
- Groves, Donald G. and Lee M. Hunt, Professional Staff, National Academy of Sciences, *Ocean World Encyclopedia*, McGraw-Hill, NY, 1980.
- Microsoft Encarta 96 Encyclopedia, "Gulf of California", Funk & Wagnalls Corporation, 1995.
- Garrison, Tom, Orange Coast College, *Oceanography, An Invitation to Marine Science*, Wadsworth Publishing Company, CA, 1996.
- Gross, M. Grant, *Oceanography, A View of the Earth*, Prentice-Hall, Incorporated, NJ, 1972.
- Microsoft Encarta 96 Encyclopedia, "Corets, Hernan", Funk & Wagnalls Corporation, 1995.

Additional Information

- Argote, M.L., Amador, A., Lavin, M.F. and Hunter, J.R., "Tidal dissipation and stratification in the Gulf of California", *Oceanographic Literature Review*, Volume 43, 3, March 1996.
- Aurioles-Gamboa, D. and Zavala-Gonzalez, A., "Ecological factors that determine distribution and abundance of the California sea lion *Zalophus californianus* in the Gulf of California", *Oceanographic Literature Review*, Volume 42, 9, September 1995.
- Axen, G., "Extensional segmentation of the Main Gulf Escarpment, Mexico and United States", *Oceanographic Literature Review*, Volume 42, 11, November 1995.
- Bohannon, R.G. and Parsons, T., "Tectonic implications of post-30 Ma Pacific and North American relative plate motions", *Oceanographic Literature Review*, Volume 43, 2, February 1996.
- Brogan, M.W., "Distribution and retention of larval fishes near reefs in the Gulf of California", *Oceanographic Literature Review*, Volume 42, 6, June 1995.
- Bustos-Serrano, H., Millan-Nunez, R. and Cajal-Medrano, R., "Tidal effect on organic primary productivity in a coastal lagoon of Ballenas Channel, Gulf of California", *Oceanographic Literature Review*, Volume 43, 12, December 1996.
- Calambokidis, J., "Interchange and isolation of humpback whales off California and other North Pacific feeding grounds", *Oceanographic Literature Review*, Volume 43, 12, December 1996.
- Cutler, A.H., "Taphonomic implications of shell surface textures in Bahia la Choya, northern Gulf of California", *Oceanographic Literature Review*, Volume 42, 10, October 1995.

D'Agrosa, C., Vidal, O. and Graham, W.C., "Mortality of the vaquita (*Phocoena sinus*) in gillnet fisheries during 1993-94", *Oceanographic Literature Review*, Volume 43, 10, October 1996.

Del Socorro Muneton-Gomez, M., Soledad Cotameza, M. and Vera A, G.R., "First record of the presence of eggs and larvae of *Sardinops caeruleus*. (Girard, 1856) in Bahia Concepcion, Baja California Sur, Mexico", *Oceanographic Literature Review*, Volume 43, 5, May 1996.

Delgado-Gonzalez, O.E., Ocampo-Torres, F.J. and Larios-Castillo, S., "Breezes during some months of spring and summer in the northwest of the Gulf of California", *Oceanographic Literature Review*, Volume 42, 7, July 1995.

DeMets, C., "A reappraisal of seafloor spreading lineations in the Gulf of California: implications for the transfer of Baja California to the Pacific plate and estimates of Pacific-North America motion", *Oceanographic Literature Review*, Volume 43, 8, August 1996.

Dunn, P.J., Robbins, J.W., Bosworth, J.M. and Kolenkiewicz, R., "Crustal deformation around the Gulf of California", *Oceanographic Literature Review*, Volume 43, 8, August 1996.

Estrella, A.D., Ortiz, J.G.O. and Rios, A.S., "Marine mammal stranding during the spring and autumn, and its relationship with human activity in the northern Gulf of California", *Oceanographic Literature Review*, Volume 42, 12, December 1995.

Galvan-Magana, F., Abitia-Cardenas, L.A. and Rodriguez-Romero, J., "Systematic list of the fishes from Cerralvo Island, Baja California Sur, Mexico", *Oceanographic Literature Review*, Volume 44, 1, January 1997.

Gaxiola-Castro, G., Garcia-Cordova, J., Valdez-Holguin, J.E. and Botello-Ruvalcaba, M., "Spatial distribution of chlorophyll a and primary productivity in relation to winter physical structure in the Gulf of California", *Oceanographic Literature Review*, Volume 42, 9, September 1995.

Gendrop-Funes, V. and Valenzuela-Espinoza, E., "Unilateral ablation of *Penaeus stylirostris* (Stimpson)", *Oceanographic Literature Review*, Volume 43, 7, July 1996.

Gerrodette, T., Fleischer, L.A., Perez-Cortes, H. and Ramirez, B.V., "Distribution of the vaquita, *Phocoena sinus*, based on sightings from systematic survey", *Oceanographic Literature Review*, Volume 43, 10, October 1996.

Gluyas-Millan, M.G. and Quinonez-Velazquez, C., "Evidence of different stocks of mackerel *Scomber japonicus*", *Oceanographic Literature Review*, Volume 44, 1, January 1997.

Gomez-Gutierrez, J., Palomares-Garcia, R. and Gendron, D., "Community structure of the euphausiid population along the west coast of Baja California, Mexico, during the weak ENSO 1986-1987", *Oceanographic Literature Review*, Volume 42, 10, October 1995.

Goodfriend, G.A., Flessa, K.W. and Hare, P.E., "Variation in amino acid epimerization rates and amino acid composition among shell layers in the bivalve *Chione* from the Gulf of California", *Geochimica et Cosmochimica Acta*, Volume 61, 7, April 1997.

Guezennec, J.G., Dussauze, J. and Bian, M., "Bacterial community structure in sediments from Guaymas Basin, Gulf of California, as determined by analysis of phospholipid ester-linked fatty acids", *Oceanographic Literature Review*, Volume 44, 4, April 1997.

Hendrickx, M.E., Salgado-Barragan, J. and Meda-Martinez, M.A., "Abundance and diversity of macrofauna (fish and decapod crustaceans) in *Penaeus vannamei* culture ponds in western Mexico", *Oceanographic Literature Review*, Volume 44, 2, February 1997.

Hsieh, W.W., Ware, D.M. and Thomson, R.E., "Wind-induced upwelling along the west coast of North America, 1899-1988", *Oceanographic Literature Review*, Volume 43, 2, February 1996.

Kawka, O.E. and Simoneit, B.R.T., "Hydrothermal pyrolysis of organic matter in Guaymas Basin: I. Comparison of hydrocarbon distributions in subsurface sediments and seabed petroleum", *Organic Geochemistry*, Volume 22, 6, December 1994.

Kawka, O.E. and Simoneit, B.R.T., "Hydrothermal pyrolysis of organic matter in Guaymas Basin: I. Comparison of hydrocarbon distributions in subsurface sediments and seabed petroleum", *Oceanographic Literature Review*, Volume 42, 6, June 1995.

Lavaniegos, B.E., "Vertical distribution of euphausiid life stages in waters adjacent to Baja California", *Oceanographic Literature Review*, Volume 43, 11, November 1996.

Laxin, M.F., Gaxiola-Castro, G., Robles, J.M. and Richter, K., "Winter water masses and nutrients in the northern Gulf of California", *Oceanographic Literature Review*, Volume 42, 11, November 1995.

Leif, R.N. and Simoneit, B.R.T., "Ketones in hydrothermal petroleum and sediment extracts from Guaymas Basin, Gulf of California", *Organic Geochemistry*, Volume 23, 10, October 1995.

Leif, R.N. and Simoneit, B.R.T., "Ketones in hydrothermal petroleum and sediment extracts from Guaymas Basin, Gulf of California", *Oceanographic Literature Review*, Volume 43, 10, October 1996.

Lonsdale, P., "Segmentation and disruption of the East Pacific Rise in the mouth of the Gulf of California", *Oceanographic Literature Review*, Volume 43, 2, February 1996.

Lui-Heung, C., Gieskes, J.M., Chen-Feng, Y. and Edmond, J.M., "Lithium isotope geochemistry of sediments and hydrothermal fluids of the Guaymas Basin, Gulf of California", *Oceanographic Literature Review*, Volume 42, 5, May 1995.

Maldonado, J.E., Davila, F.O., Stewart, B.S., Geffen, E. and Wayne, R.K., "Intraspecific genetic differentiation in California sea lions (*Zalophus californianus*) from southern California and the Gulf of California", *Oceanographic Literature Review*, Volume 42, 9, September 1995.

Marteinsson, V.T., Birrien, J., Kristjansson, J.K. and Prieur, D., "First isolation of thermophilic aerobic non-sporulating heterotrophic bacteria from deep-sea hydrothermal vents", *FEMS Microbiology Ecology*, Volume 18, 3, November 1995.

Marteinsson, V.T., Birrien, J.-L., Kristjansson, J.K. and Prieur, D., "First isolation of thermophilic aerobic non-sporulating heterotrophic bacteria from deep-sea hydrothermal vents", *Oceanographic Literature Review*, Volume 43, 6, June 1996.

Martin, R.E., Harris, M.S. and Liddell, W.D., "Taphonomy and time-averaging of foraminiferal assemblages in Holocene tidal flat sediments, Bahia la Choya, Sonora, Mexico (northern Gulf of California)", *Oceanographic Literature Review*, Volume 43, 8, August 1996.

Meldahl, K.H., "Biofacies and taphofacies of a Holocene macrotidal environment: Bahia La Cholla, northern Gulf of California", *Oceanographic Literature Review*, Volume 42, 9, September 1995.

Meldahl, K.H., "Pleistocene shoreline ridges from tide-dominated and wave-dominated coasts: northern Gulf of California and western Baja California, Mexico", *Oceanographic Literature Review*, Volume 42, 9, September 1995.

Michaud, F. and Bourgois, J., "Is the Rivera fracture zone a transform fault as currently accepted?", *Oceanographic Literature Review*, Volume 43, 5, May 1996.

Molina-Cruz, A., "Biostratigraphy and paleoceanographic significance of the radiolarians from the protomouth of the Gulf of California", *Oceanographic Literature Review*, Volume 42, 9, September 1995.

Monteforte, M., Kappelman-Pina, E. and Lopez-Espinosa, B., "Spatfall of pearl oyster, *Pteria sterna* (Gould), on experimental collectors at Bahia de La Paz, south Baja California, Mexico", *Oceanographic Literature Review*, Volume 43, 1, January 1996.

Morgan, M.B. and Cowles, D.L., "The effects of temperature on the behaviour and physiology of *Phataria unifascialis* (Gray) (Echinodermata, Asteroidea) Implications for the species' distribution in the Gulf of California, Mexico", *Journal of Experimental Marine Biology and Ecology*, Volume 208, 1-2, 3 January 1997.

Pacheco-Ruiz, I. and Zertuche-Gonzalez, J.A., "Brown algae (Phaeophyta) from Bahia de los Angeles, Gulf of California, Mexico", *Oceanographic Literature Review*, Volume 44, 3, March 1997.

Perez-Espana, H., Galvan-Magana, F. and Abitia-Cardenas, L.A., "Temporal and spatial variations in the structure of the rocky reef fish community of the southwest Gulf of California, Mexico", *Oceanographic Literature Review*, Volume 44, 3, March 1997.

Pierce, Graham J. and Guerra, Angel, "Stock assessment methods used for cephalopod fisheries", *Fisheries Research*, Volume 21, 1-2, December 1994.

Polis, G.A. and Hurd, S.D., "Linking marine and terrestrial food webs: allochthonous input from the ocean supports high secondary productivity on small islands and coastal land communities", *Oceanographic Literature Review*, Volume 43, 10, October 1996.

Quintanilla-Montoya, A.L. and Suarez-Vidal, F., "Cerro Prieto and its relation to the Gulf of California spreading centers", *Oceanographic Literature Review*, Volume 43, 10, October 1996.

Ramirez-Garcia, P. and Lot, A., "The distribution of mangrove and sea grasses in the Gulf of California, Mexico", *Oceanographic Literature Review*, Volume 42, 9, September 1995.

Righter, K., Carmichael, I.S.E., Becker, T.A. and Renne, P.R., "Pliocene-Quaternary volcanism and faulting at the intersection of the Gulf of California and the Mexican Volcanic Belt", *Oceanographic Literature Review*, Volume 42, 10, October 1995.

Rios-Jara, E., Perez-Pena, M., Lizarraga-Chavez, L. and Michel-Morfin, J.E., "Additional gastropod records from the continental shelf off Jalisco and Colima, Mexico", *Oceanographic Literature Review*, Volume 44, 3, March 1997.

Riosmena-Rodriguez, R. and Siqueiros-Beltrones, D.A., "Morphology and distribution of *Corallina vancouverensis* (Corallinales, Rhodophyta) in northwest Mexico", *Oceanographic Literature Review*, Volume 43, 1, January 1996.

Roberts, C.M., "Ecological advice for the global fisheries crisis", *Trends in Ecology & Evolution*, Volume 12, 1, January 1997.

Sancetta, C., "Diatoms in the Gulf of California: seasonal flux patterns and the sediment record for the last 15,000 years", *Oceanographic Literature Review*, Volume 42, 9, September 1995.

Simoneit, B.R.T. and Fetzer, J.C., "High molecular weight polycyclic aromatic hydrocarbons in hydrothermal petroleum from the Gulf of California and Northeast Pacific Ocean", *Organic Geochemistry*, Volume 24, 10-11, October/November 1996.

Simoneit, B.R.T. and Schoell, M., "Carbon isotope systematics of individual hydrocarbons in hydrothermal petroleum from the Guaymas Basin, Gulf of California", *Organic Geochemistry*, Volume 23, 9, September 1995.

Simoneit, B.R.T. and Schoell, M., "Carbon isotope systematics of individual hydrocarbons in hydrothermal petroleum from the Guaymas Basin, Gulf of California", *Oceanographic Literature Review*, Volume 43, 6, June 1996.

Simoneit, B.R.T., Leif, R.N. and Ishiwatari, R., "Phenols in hydrothermal petroleum and sediment bitumen from Guaymas Basin, Gulf of California", *Organic Geochemistry*, Volume 24, 3, March 1996.

Simoneit, B.R.T., Leif, R.N. and Ishiwatari, R., "Phenols in hydrothermal petroleum and sediment bitumen from Guaymas Basin, Gulf of California", *Oceanographic Literature Review*, Volume 44, 4, April 1997.

Sturz, A.A., Sturdivant, A.E., Leif, R.N., Simoneit, B.R.T. and Gieskes, J.M., "Evidence for retrograde hydrothermal reactions in near surface sediments of Guaymas Basin, Gulf of California", *Applied Geochemistry*, Volume 11, 5, September 1996.

Thunell, R., Pride, C. and Ziveri, P., "Plankton response to physical forcing in the Gulf of California", *Oceanographic Literature Review*, Volume 44, 5, May 1997.

Umhoefer, P.J. and Stone, K.A., "Description and kinematics of the SE Loreto Basin fault array, Baja California Sur, Mexico: a positive field test of oblique-rift models", *Oceanographic Literature Review*, Volume 43, 10, October 1996.

Valdez-Holguin, J.E., Gaxiola-Castro, G and Cervantes-Duarte, R., "Primary productivity in the Gulf of California, calculated from the relationship between superficial irradiance and chlorophyll in the euphotic zone", *Oceanographic Literature Review*, Volume 43, 5, May 1996.

Van Geen, A., Fairbanks, R.G. and Dartnell, P., "Ventilation changes in the northeast Pacific during the Last Deglaciation", *Oceanographic Literature Review*, Volume 44, 4, April 1997.
Vidal, O., "Population biology and incidental mortality of the vaquita, *Phocoena sinus*", *Oceanographic Literature Review*, Volume 43, 10, October 1996.