U.S. Army Corps
of Engineers

Explore 4

The California Coastline
Arena Cove to the Golden Gate

The Year of the Coast

The beauty and physical diversity represented by California's coast, bays, harbors and estuaries are exceptional. Uniquely spectacular scenery features mountains dropping steeply to rocky shores, rolling headlands and bluffs, fertile marshes, wide sandy beaches and dramatic vistas extending some 1,100 miles from Oregon to the Mexican border.

The sea acts as the coast's chief architect, and continual changes take place as waves, rains and winds reshape shoreline contours. Currents and tides continually refresh and nourish coastal lands and waters, where life forms are as diverse as their habitats. Here the mighty whale and the tiniest of organisms, salt marsh plants and towering redwoods, live together with man in an intricately balanced state of interdependence.

The coast means something different to each individual. Some cherish the fresh salt air, the sea breezes and the opportunities for contemplative solitude. Others enjoy the coast as a place to picnic and swim, to fish, sun or sail, while many choose to search for driftwood or study the mysteries of rocky tide pools. Many choose birdwatching in coastal bays, marshes and lagoons, while others value the potential for commercial and recreational development.

To the U.S. Army Corps of Engineers, California's bay and coastal areas mean a continuing dedication to management and preservation through effective coastal engineering, interdisciplinary investigations, exercise of regulatory authority, flood prevention and water quality control, harbor development and protection, and conservation of fish and wildlife.

To assist you in developing a greater knowledge and appreciation for California's coastline and its valuable resources, the Corps of Engineers has prepared a series of brochures which highlight both natural and man-made features. The sites included in each brochure were selected for their unique scenic significance, recreational opportunities and accessibility. Related information on various natural phenomena such as tidal action, beach formation and movement of currents has also been included, along with reference to numerous indigenous plants and animals. Such detail provides the visitor with an opportunity to gain an increased understanding of the many fascinating aspects of coastal areas.

Bring your camera and binoculars, your curiosity and sense of adventure and join us in exploring nature's wonderful gifts.

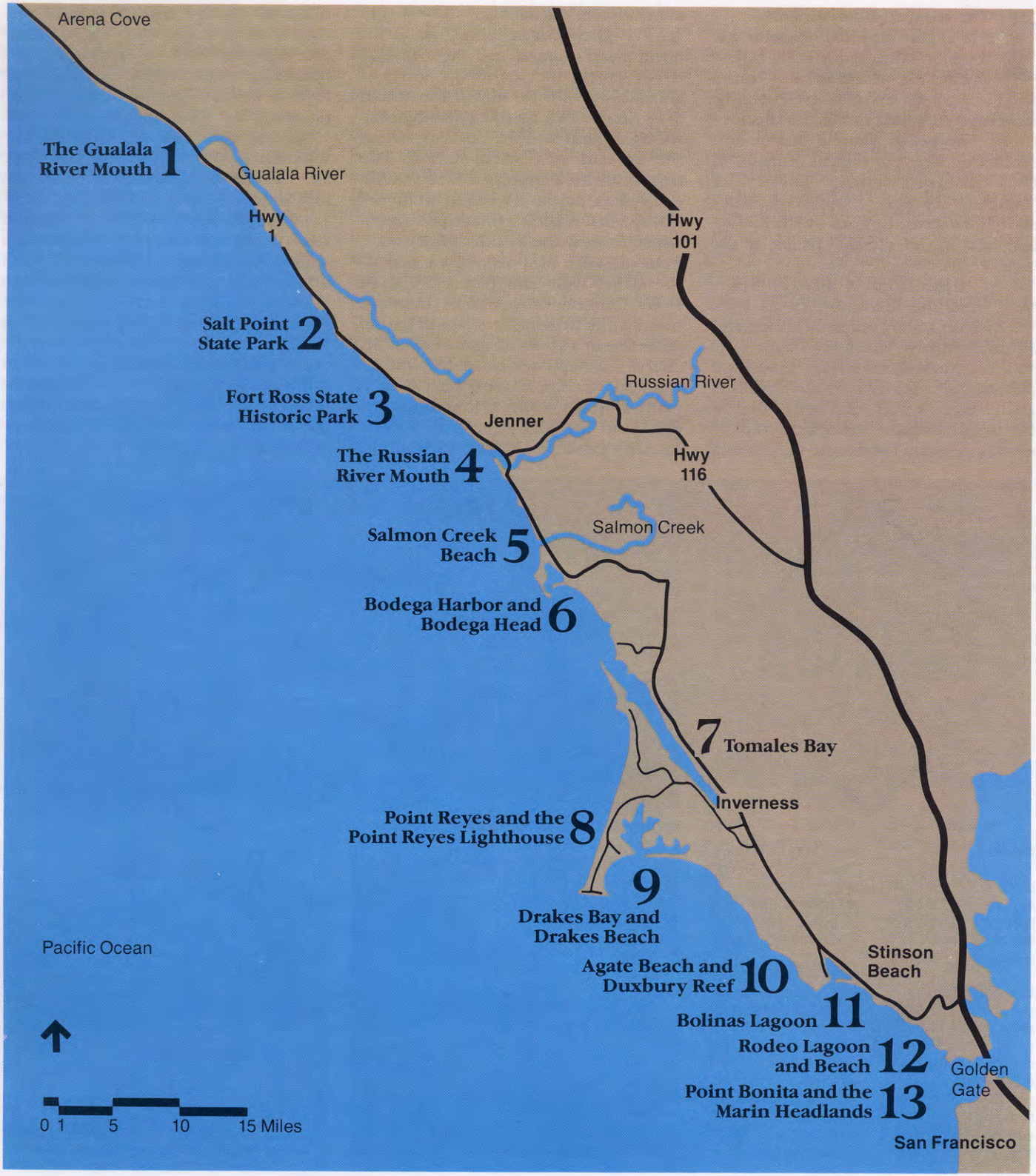
Arena Cove to the Golden Gate

The dramatic configuration of the California coastline between Arena Cove and the Golden Gate creates a landscape of unsurpassed beauty and scenic diversity. An extraordinary tapestry of line and form is created by its broad range of contrasts. Wide sandy beaches and sweeping sand dunes are interspersed with narrow, rocky inlets and steep cliffs splashed with waves. Broad lagoons, verdant wetlands and classic tombolos alternate with jutting promontories and sloping marine terraces. Several features—including Duxbury Reef, the Point Reyes Peninsula and Fort Ross—are recognized as being unique to the California Coast for their size, geologic composition and historic qualities. Because this 150-mile stretch of coastline is remarkably unspoiled and predominantly in its natural state, plant and animal life flourishes in rare abundance.

The coastal configuration has been largely shaped by nature's inalterable forces. Earthquakes and tectonic activity have brought cataclysmic changes, and the periodic rise and fall in sea level produced by glacial melt and freeze have significantly altered both shoreline form and location. To these changes have been added the perpetual action of wind and wave that continues, over the centuries, to create an ever-changing profile.

The history of the area has a particularly fascinating character as a result of the many races and creeds that have taken part in its development. Record of man's habitation begins with the coastal Indian tribes—the Coast Miwok and the Pomo. In time, European explorers, Spanish padres and Russian fur traders came, then moved on, each leaving behind a distinctive cultural contribution. A lively era of lumbering and ranching began during the days of the California Gold Rush, as hardy entrepreneurs reaped the bounties of the land to support a rapidly growing San Francisco population. Today, ranching continues to be a major force in the economy. Commercial fishing and tourism also have a significant impact.

Opportunities for enjoying the magnificence of this coastline are numerous and varied. Because the highway runs near the shoreline in most areas, access is easy and direct. The Corps of Engineers hopes that this guide will aid in your enjoyment of the area's many natural wonders and will enhance the richness of your explorations.


Arena Cove
The Gualala River Mouth 1
Gualala River
Hwy 1
Hwy 101
Salt Point State Park 2
Russian River
Fort Ross State Historic Park 3
Jenner
The Russian River Mouth 4
Hwy 116
Salmon Creek
Salmon Creek Beach 5
Bodega Harbor and Bodega Head 6
7 Tomales Bay
Inverness
Point Reyes and the Point Reyes Lighthouse 8
9 Drakes Bay and Drakes Beach
Pacific Ocean
Stinson Beach
Agate Beach and Duxbury Reef 10
Bolinas Lagoon 11
Rodeo Lagoon and Beach 12
Golden Gate
Point Bonita and the Marin Headlands 13
San Francisco
0 1 5 10 15 Miles

1 The Gualala River Mouth

The highly sculpted coastline extending south from Point Arena toward the mouth of the Gualala River is marked by sheer wave-cut cliffs, extensive reefs and numerous offshore rocks. The gently sloping marine terraces seen here are typical of much of the California coast. These flat "benches" mark the location of earlier shorelines thrust upward by the folding and bending of massive plates of the earth's crust.

Upwelling is also common here, resulting in heavy coastal fogs. Because prevailing winds of spring and summer blow parallel with the shoreline, nearshore surface waters are pushed out to sea by Coriollis forces. As colder waters from the ocean depths rise to take its place, the temperature of nearshore water lowers and the cooling effect creates coastal fog.

The Gualala River, one of the north coast's largest and most unique rivers, enters the sea at the town of Gualala—about 13 miles downcoast from Arena Cove. En route, the highway winds around hairpin curves skirting the mouths of coastal streams and through thick stands of redwood, eucalyptus, pine and a variety of broadleaf species. A good vantage point from which to view the mouth of the river is from the edge of a parking lot accross the street from the historic Gualala Hotel. Unlike most west coast rivers and streams, the Gualala flows parallel to the shoreline in a south-north direction. Its course has been determined by the location of the San Andreas fault zone. A pathway leads down a low sandstone cliff from the parking area to a short sand spit that typically extends from the shoreline on the upcoast side of the river mouth. At the water's edge, note the large flat slabs of sandstone that have dropped from the bluffs. The slabs form a natural revetment armor that protects the shoreline from current scour and wave erosion. Offshore, toward the mouth, are beds of bull kelp, a form of brown algae buoyed to the water's surface by large gas-filled bladders.

The town of Gualala was the site of one of Northern California's largest lumber mills. During more than 40 years of operation the mill processed redwood cut from over 14,000 acres of Sonoma County land. The mill closed in 1920, a victim of the same circumstances that ended lumbering activity in numerous coastal towns—depleted lumber supplies, overgrazed lands and the introduction of land-based transportation.

Caution

To fully enjoy your explorations of the California coast, it is important to be aware of its innate, and often unexpected, hazards.

In some areas, the possibility of landslides makes hiking on the cliffs particularly dangerous. Because loose materials can suddenly cascade to the water below, walking should be restricted to areas well away from cliff edges. Those walking along beaches beneath shoreline cliffs should be aware of the possibility of falling rocks.

Wear non-slip, protective footgear at all times while exploring tide pools or climbing rocks near the water's edge. Always be watchful of incoming tides, and beware of the dangers of rip currents, backwash and occasional large waves.

Heavy coastal fog common during the summer months

Abandoned farms dot the coastal bluffs

The Gualala River runs parallel to the shoreline

Pine and fir trees protecting Gualala Point Regional Park from blustery ocean breezes

Leaving the Gualala viewing area, continue downcoast and cross the river. The delta areas of the Gualala serve as nursery grounds for a variety of anadromous fish, including king and silver salmon, two of the north coast's most important commercial catches. From the fresh water, the young fish migrate to the ocean where they mature before returning to the river of origin to begin the spawning cycle once again.

About a quarter of a mile downcoast from the river mouth is the entrance to Gualala Point Regional Park. Located on a flat, grassy marine terrace dotted with pine and fir trees, this scenic reserve offers a visitor center with various interpretive exhibits, a campground largely protected from ocean breezes by a windbreak of trees and a paved pathway leading to the shoreline. Rock fishing for kelp greenling, cabezon and surf perch is popular, as are beachcombing and collecting driftwood.

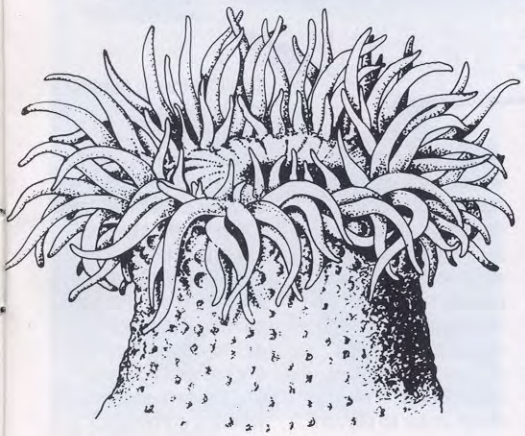
A double sand spit typically forms at the mouth of the Gualala River. This phenomenon is similar to that created at the mouth of the Klamath River south of Crescent City. The mile-long south spit here is made up of sediments carried toward the north by littoral drift, a current that moves parallel to the shore. This northern movement is common from fall to early spring due to offshore storm activity. Following stormy periods, the winds and waves change direction to the southeast to create the north spit. The north spit usually develops slightly seaward of the south spit because of the influence of river flow. Sediments carried seaward by the river feed the sand spits as well as other coastal beaches.

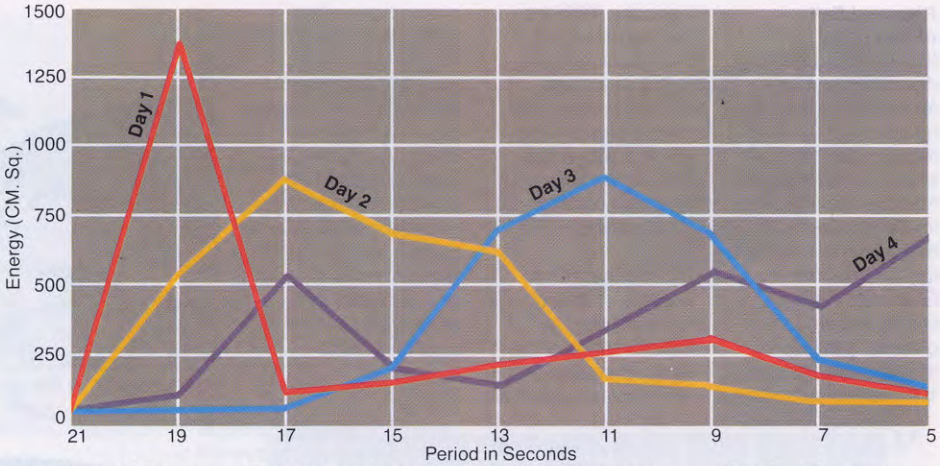
After enjoying the park's natural beauty and interesting features, continue downcoast on Highway 1 through Sea Ranch, a private housing development offering several points of coastal access. The highway runs nearly parallel with the shore for about 50 miles downcoast to Bodega Bay. Between Arena Cove and Bodega, the coastal area has been identified by geologists as part of the Salinian block, which lies west of the San Andreas fault. Geologic studies indicate that this land mass is made up of sediments originally deposited between 300 and 350 miles to the south. It is theorized that to create such dramatic displacement, some 100,000 repetitions of movement typical of the 1906 earthquake must have occurred. Many believe that the movement of the Salinian block began more than 20 million years ago.

Giant Green Anemone

The giant green anemone is a form of tide pool life familiar even to the most casual observer. The anemone is a solitary animal that thrives on rocks and ledges in the lowest intertidal zones, where it is continually washed by the ebb and flow of the tide. The bright green color often displayed by this anemone is created by a symbiotic green algae that lives in the animal's tissues.

The giant green anemone attempts to eat almost anything that comes within reach. Its waving tentacles are armed with *nematocysts,* or stingers, that quickly paralyze any small creature that makes contact. Although the poison is barely felt by the human hand, accumulations are deadly to small prey and highly effective in discouraging predators.





The Effect of Storms on Waves

Winds over the ocean are ultimately responsible for the types and sizes of waves approaching the shoreline. The approach and departure of storm fronts affect both the energy and the period of coastal waves. The period of a wave is the time it takes for the wave to travel a distance of one "wave length," or the horizontal distance between adjacent crests.

The accompanying diagram illustrates the energy and periods of waves approaching a particular California coastal location during a four-day storm. It should be noted that, off the Pacific coast, local seas are commonly defined as waves with periods from two to 12 seconds, and swells are defined as waves with periods of more than 12 seconds. Interpretation follows:

Day 1 — The storm front is far offshore. Long-period swells from the storm break on the shoreline every 19 seconds. Prevailing light winds produce small local seas of from 7 to 13 seconds.

Day 2 — The storm front has moved closer to land. Heavy swells of from 13 to 19 seconds approach the shore. Light local winds result in minor local seas.

Day 3 — The storm front strikes the shoreline. High south-to-southeast winds produce high-energy waves with periods of from 9 to 13 seconds.

Day 4 — The storm has passed. A shift occurs and north-to-northwest winds bring short-period seas of from 5 to 9 seconds. Longer period swells of 17 seconds begin to appear as another storm approaches from far offshore.

A few miles south of the Stewarts Point Store, watch for a sign marking the entrance to Kruse Rhododendron Reserve State Park. During April and May, when the rhododendrons are in full bloom, the four-mile drive is well worthwhile. A short distance beyond the reserve is the entrance to Salt Point State Park, one of the north coast's most scenic areas.

Divers returning from abalone hunt

2 Salt Point State Park

North of Salt Point State Park is Stump Beach, a good area for observing several coastal phenomena. From the parking lot and picnic area, a path leads down steep bluffs to the beach and mouth of Miller Creek. The creek provides a major source of sediment for a small pocket beach. Numerous small cobbles, carried seaward from the steep ridges of coastal hills during the rainy season, line the lower reaches of the creek bed. A result of high-energy wave action is evident in the assortment of driftwood scattered inland from the mouth of the creek. The location of the drift indicates the highest point of wave uprush during severe storms.

The entrance to Salt Point State Park is about a mile south of Stump Beach. Miles of riding and hiking trails, picnic areas and camping facilities complement the dramatic shoreline of this 4,300-acre park. Exposed to the full force of prevailing westerly winds, this desolate, but ruggedly beautiful area has not returned to a predominately natural state, following a time in the late 1800's when more than 1,000 people lived here. No evidence remains of this era, nor of the earlier Pomo Indian villages once scattered along the shoreline.

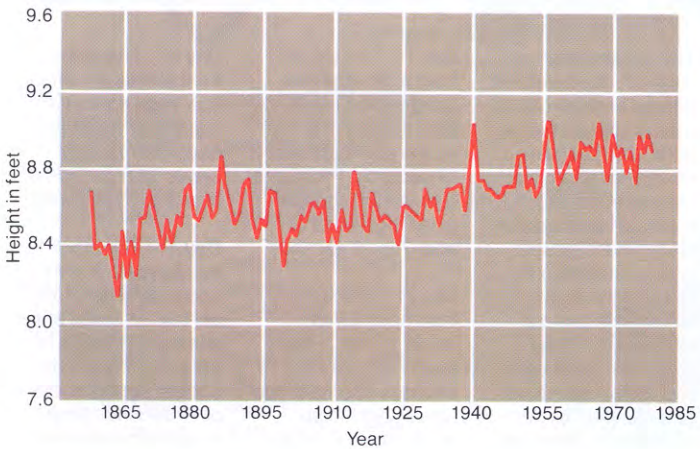
Gerstle Cove, a deep inlet that serves as the site for many scuba diving classes, is one of the park's many scenic features. The calmness of the water results from the protective influence of Salt Point, a rocky promontory on the upcoast side of the cove. To reach a lookout area above Gerstle Cove, turn left near the end of the main road to a parking area in front of the park headquarters. The lookout is behind the

Rise and Fall of Sea Level

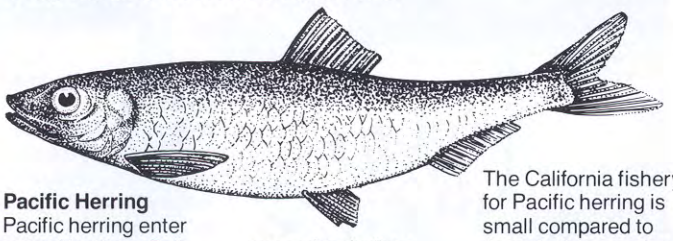
It is theorized that the rise in sea level responsible for the configuration of the California coastline as we know it today resulted from the melting of the immense sheets of ice that accumulated during the Wisconsin Glaciation Period. During the time of greatest glaciation, sea level was about 100 meters lower than it is today. With the melting of the last sheets of ice, some 11,000 years ago, earlier exposed continental plates were covered with water, forming the bays and estuaries common to our coastline.

The rise and fall of sea level is also directly affected by the movement of the earth's massive continental plates. It is this phenomenon that accounts for varying degrees of coastal emergence and submergence within particular geographic areas. Along the California coast, an emerged shoreline is evidenced by the presence of wave-cut marine terraces and ancient rocks that were once part of the coastal strand.

Stump Beach at the mouth of Miller Creek



Yearly Mean Sea Level — Golden Gate Station No. 94142290, San Francisco, CA



Pacific Herring

Pacific herring enter many Northern California lagoons, bays and estuaries to spawn during winter and spring months. Although the two major spawning areas are Tomales and San Francisco Bays, numerous minor sites line the coast. When spawning, the herring seem to show a preference for shallow waters influenced by river runoff. Most often, eggs attach to rocks, seaweed and eelgrass. Although usually no more than two layers deep, egg clusters up to two inches thick have been found. The eggs hatch in six to eleven days.

The California fishery for Pacific herring is small compared to that of other species, with annual harvests usually under two million pounds. Herring roe attached to edible seaweed is considered a great delicacy by many. It is often gathered, packed in dry ice and flown to Far Eastern markets where it commands a high price.

building, atop the steep cliffs that line the inlet. Because of its ecological value and fragile nature, Gerstle Cove has been designated as an Area of Special Biological Significance by the State Water Resources Control Board. Because the area has been set aside as an underwater reserve, abalone cannot be removed.

From Gerstle Cove, return to the main road and turn left into a large parking area. A short walk upcoast along the windswept, rugged bluffs leads to an area of unusual beauty. Here, wide reefs, exposed during periods of low tide, provide an opportunity for studying the fragile beauty of tide pools. Nearby, honeycombed sandstone rocks, created by the perpetual eroding action of waves, offer one of the most fascinating examples of differential erosion found along the entire coast.

After exploring Salt Point State Park, return to Highway 1 and continue downcoast through coastal hills lushly vegetated with redwood, madrone, deerfern and other species nourished by heavy annual rainfall and persistent coastal fog.

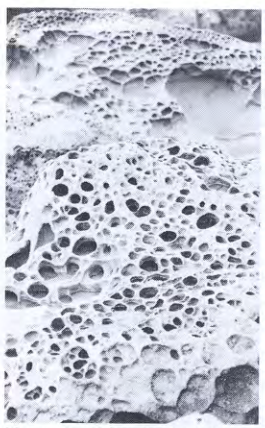
Stillwater Cove, a scenic inlet known for its tide pools, scuba diving and rock fishing, is located near the southern edge of Salt Point State Park. Here, thick stands of pine and redwood extend to the edge of steep, rocky cliffs and extensive kelp beds float offshore. Although such broad expanses of kelp significantly reduce the energy of shorter period, low-energy waves, they have little effect on longer period, high-energy waves. Between Stillwater Cove and Fort Ross, the route runs along the top of a flat marine terrace backed by coastal hills rising to 1,000 feet.

3 Fort Ross State Historic Park

Fort Ross State Historical Park is unique to the California coast as the site of the "southernmost permanent Russian settlement on the North American Continent." To visit this interesting landmark, turn right from Highway 1 about a mile downcoast from Timber Cove. Drive to a large parking lot and walk a short distance along the road leading to the stockade entrance. Several buildings, including a museum with fascinating historical displays and an excellent collection of artifacts, have been authentically reproduced to represent buildings of an earlier era. Self-guided tours are available.

The heritage of Fort Ross combines a wide array of nationalities. Its history begins with the Pomo Indians who selected the area for its proximity to fresh stream water, a sheltered harbor

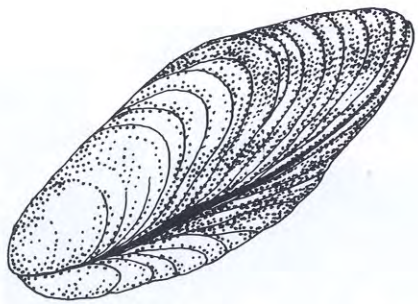
Gerstle Cove



Honeycombed sandstone

Flat coastal plains

Stillwater Cove



Mussels as Pollution Indicators

The blue-black California sea mussel, found in great quantities on rocks and pilings along the California coast, is the key element in what has become a dependable and inexpensive approach to monitoring water quality. An official Mussel Watch program was launched in California in 1977. Since then, the concept has been adapted by several other states and countries.

Mussels filter up to two quarts of water an hour and have an ability to bioaccumulate pollutants. Because they are sessile, they must adapt to changing water conditions. Twice a year, mussels of a certain size are collected from predetermined sites along the shoreline. The body tissue is dissolved and chemically analyzed under carefully controlled laboratory conditions. Specific toxic substances and trace materials are pinpointed, providing an indication of the water quality of the area. Through such monitoring, long-term trends in water quality can be determined.

and the abundant resources of the sea. In 1812, the Russian American Fur Company bought land here and named it Ross, disregarding all Spanish claims. In 1821, when Mexico took control of California, the land came under the control of General Vallejo's administration. The Russians remained, having by this time established a flourishing fur trade supported primarily by sea otter pelts. Some 20 years later, the sea otter population was decimated and fur trading operations ceased. The fort was soon sold to John Sutter and its contents moved to the Sacramento Valley. After the sale the land came under the control of Ernst Rufus, a German citizen who received it as part of one of the last Mexican land grants to be awarded. A prosperous era of ranching and lumbering followed, as hardy entrepreneurs sought to feed and house a San Francisco population that had increased dramatically since the discovery of gold in 1849.

About five miles south of the Fort, Russian Gulch enters the sea between high, nearly vertical cliffs. Approaching the beach, the road winds steeply downward, affording breathtaking views of the coast to the south. The dark sands of the pocket beach remain in a state of dynamic equilibrium throughout the year, due primarily to the protective influence of the rocky headlands both up and downcoast. High wave energy is typical here because the waves break directly on the shore, unaffected by offshore reefs and sand bars.

About 13 miles south of Russian Gulch, the Russian River, one of Northern California's most important waterways, flows into the Pacific.

4 The Russian River Mouth

Near the mouth of the Russian River, the coast highway carves its way along the sides of steep, virtually treeless hills. The sinuous route offers spectacular views of the rugged and beautiful shoreline. An overlook just upcoast from the Russian River mouth offers a particularly good vantage point from which to observe the river's entrance to the sea.

The 110-mile-long Russian River, the predominant river between Point Arena and the Golden Gate, drains over 1,400 square miles and is bordered by some of Northern California's richest agricultural lands. The river's high sediment content can be seen on satellite photographs in the form of a brownish plume extending up to 100 miles offshore. The sand delivered to the coast by the river is the primary builder

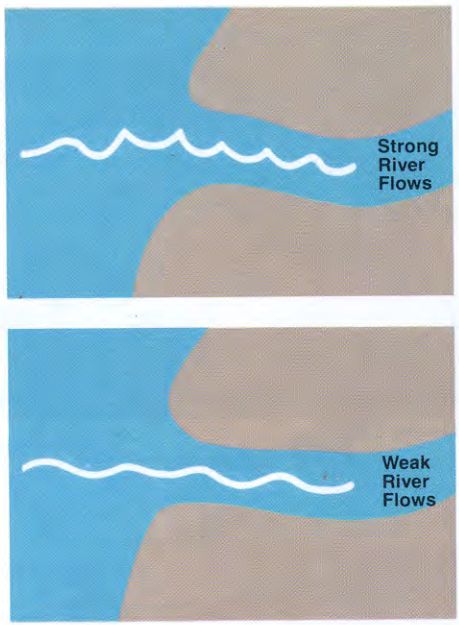
Rock Fishing
Fishing from shoreline rocks is a popular pastime along much of the Northern California coast. According to those who most enjoy the sport, skill more than patience brings the greatest rewards.

The most fundamental rule of this rugged sport is to cast into the hole or crevice that produced the prior bite, because once a fish has been removed from its preferred resting or feeding site, another quickly takes its place. In order to become familiar with the most likely fishing sites, the experienced rock fisherman studies the shoreline at low tide, searching for the best holes.

Rockfishing can be dangerous, primarily because of unexpected high waves and the slippery patches of algae common to intertidal rocks.

Fort Ross

Sheep grazing on shoreline pastures



Ocean Waves and River Currents
When fresh and salt waters meet at the mouths of major rivers, the resulting interaction of waves and currents can be intense. During ebb tides, when river flow is high, the greatest amount of interaction occurs. At such times, strong river currents move virtually uninterrupted into the open sea. As a result, approaching ocean waves tend to pile up and create dangerous navigation conditions in the area of the river mouth.

of the numerous sandy beaches that line this portion of the Sonoma Coast.

At the river mouth, a wide barrier sand spit separates the sea and a wide, shallow estuary that extends for several miles inland. Turbulent seas are common here; the result of interaction between river currents and ocean waves. This is especially evident during rainy winter months when the volume of river flow is high and vigorous.

Note that the location of the river mouth has been stabilized by a jetty built along the shoreward side of the barrier beach south of the mouth. This short concrete and rubblemound structure, built in the late 1920s and improved between 1938 and 1941, prevents the river mouth from the seasonal migration common to most coastal rivers and streams. A rubblemound revetment lines the downcoast bank of the river to the rear of the wall. The structures were built to maintain a navigable opening that would accommodate both fisheries and the commercial development of gravel deposits once excavated in the lower reaches of the river.

The short sandy beach to the north has a significantly larger amount of driftwood than the long south spit. This is because nearshore currents move northward during winter periods when most of the driftwood washes downstream from coastal hills. The north beach is, in fact, recognized as one of the area's best sites for collecting driftwood.

In the middle of the adjacent estuary is Penny Island. When the river mouth is open to the sea, harbor seals and California sea lions often come here to rest, feed and sun. The river serves as a primary migration route for spawning steelhead and salmon.

From the lookout area north of the river mouth, drive through Jenner-By-The-Sea and continue across the Russian River bridge. A short distance beyond the bridge, the entrance to Goat Rock State Park provides access to the river's south spit. The sand dunes here were planted with European beach grass by the California Conservation Corps in the 1930s. Similar in appearance to American dune grass, the European variety can be distinguished by its shorter blades and a tendency to grow in small clumps.

Along the beach, a pattern of distinctly formed beach cusps can often be seen. These evenly spaced crescent-shaped depressions are formed when water rushes up the beach, then loses its energy as it is deflected by the points, or horns, of the cusps. With the loss of

Jetty and barrier sand spit from the mouth of the Russian River

Blow out in the sand dunes at Russian River

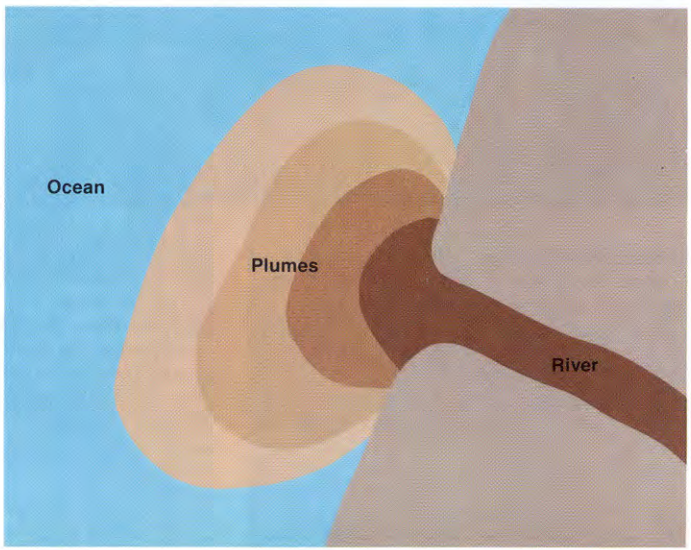
Waves erode natural bridges in coastal rock

Freshwater Plumes

The freshwater plumes often seen extending seaward from the mouth of the Russian River are common to many rivers and streams along the Northern California coast. The plumes are particularly visible during periods of heavy rain when rivers carry large amounts of suspended sediment. As the water flows over steep terrain its velocity increases, loosening great quantities of sediment that are carried seaward with the rushing water.

Because fresh water is lighter than salt water, river waters override those of the ocean to form a freshwater lense or freshet. This freshet, or plume, usually extends south from the river mouth because of predominant offshore current direction and prevailing northwest winds. Plumes sometimes extend in the reverse direction due to the effects of various oceanographic seasons and shifts in wind patterns.

If a river mouth is wide, flood tides substantially decrease the amount of water entering the sea. Groups of higher waves can also produce a temporarily higher water level that further retards the river currents. As a result of the varying flow of the river, a "pulsing" effect is created that can create a series of plume rings extending offshore. The plumes' striation remains visible until the mixing of fresh and salt water causes the sediments to settle through the water column.



energy, the water drops suspended sands on the beach and rushes back to the sea along the channels in the center of the cusp. Wading in the surf here can be dangerous since the steepness of the beach face can create a particularly strong backwash.

Goat Rock, the massive formation just offshore, is connected to the mainland by a man-made causeway. The causeway formed the foundation for a 36-inch gauge industrial railroad used in transporting quarried rock for the construction of the Russian River jetty. Once part of the mainland, the rock remained behind as softer materials eroded away.

From the State Park, continue about ten miles toward Bodega Head, the long point of land extending seaward in the distance.

5 Salmon Creek Beach

Wide, sandy Salmon Creek Beach is the most southern of the Sonoma Coast State Beaches. Extending downcoast from the mouth of Salmon Creek, the beach stretches a length of about two miles and ends at Mussel Point, a rocky protrusion on the ocean side of the Bodega Peninsula. To reach the beach parking lot, turn right just beyond Salmon Creek Bridge. Both surfing and surf fishing are popular in the ocean waters near the creek mouth. The surfing waves are created by the interaction of river flow and ocean waves. Fishermen come here primarily to catch surf and night smelt.

The sands for Salmon Creek Beach and those immediately upcoast come primarily from sediments carried to the sea by the Russian River. During summer, when moderate wave energy creates a barrier beach that completely closes the stream mouth, waters accumulate and increase the size of the small lagoon behind the barrier. Typically, winter rains bring increased flows that break open the barrier and allow the tidal interchange that flushes the waters of the lagoon and adjacent marshy areas.

The most interesting feature of Salmon Creek Beach is its long stretch of sand dunes. The dunes were planted with European beach grass in the 1930s to reduce the amount of sand blowing into Bodega Harbor. Over the years, as sand has been trapped by the grasses, the Bodega dunes have become recognized as some of the highest in the state. Although approximately 11,000 cubic yards of beach sand are blown inland annually, an equal amount of sand is deposited on the shoreline by littoral

European Beach Grass

Planted Dunes

Although the California coast is predominantly characterized by rocky cliffs and offshore rocks, nearly 25 percent consists of sandy beaches and extensive sand dunes. Some of the state's major dune fields are located in Northern California—along the Bodega peninsula, at Dillon Beach and along the western shore of Point Reyes.

The natural sand dune environment is extremely harsh, with high exposure to salt spray, wind and blasting sands. The dune's moving soil base has little moisture and low nutritional value. As a result, a limited number of plants can grow there. The species that has met with the greatest success along the Pacific Coast is European beach grass, or marram grass. Many credit the grass as being responsible for present dune topography in Central and Northern California. Its planting has resulted in series of dunes running roughly parallel to the shoreline. Valleys between individual dunes are aligned with the direction of prevailing onshore winds.

drift. Because of this, Salmon Creek Beach is in a state of dynamic equilibrium, with sand gain about equal to sand loss.

From Salmon Creek, the coast highway runs inland for about a mile. Nearing the town of Bodega Bay, watch for signs leading to the Bodega Dunes Campground. A drive through this large camping area offers a good perspective of the dune fields that back Salmon Creek Beach. Here, outstanding vistas can be enjoyed of the harbor and the dune-covered peninsula that connects Bodega Head to the mainland. In this vicinity, the San Andreas fault returns to the coast, then continues downcoast through Bodega Harbor, Bodega Bay and Tomales Bay.

From the campground, return briefly to the coast highway, then turn right on East Shore Drive in the town of Bodega Bay.

6 Bodega Harbor and Bodega Head

In the town of Bodega Bay, follow East Shore Drive to Bay Flat Road and turn right to drive along the winding western shoreline of Bodega Harbor, one of Northern California's important fishing ports. Catches including bottom fish, albacore and salmon are shipped to markets in San Francisco and Los Angeles. The harbor also serves as an important sport fishing center and as a harbor of refuge during northwesterly weather. Mooring problems can arise, however, when weather is from the south and east, particularly when tides are high.

Bodega Harbor consists of approximately 840 acres and is about 8,000 feet wide and 9,000 long, with more than 500 acres of mudflats and about 70 acres of salt marsh. The harbor floor is considered to be in a "depositing" state since a large quantity of sediments accumulate here after being blown inland from the sand dunes, carried in by tidal currents and brought down from neighboring hills by rain runoff.

The natural habitats of Bodega Harbor, also referred to as the "inner bay," are rich and varied. In addition to mudflats and salt marshes, the harbor area has open water, sub-tidal channels, freshwater streams and freshwater marshes. Marine and bird life populations are extensive. More than 200 species of invertebrates have been identified, including more than 30 species of clams and over 20 types of crab. An equally abundant and diverse fish population exists, nourished by a rich food supply of invertebrates, marine vegetation and detritus. The harbor's large

Grass tufts on sand dunes at Salmon Creek

Jetties protect Bodega Harbor

Rugged cliffs on the ocean side of Bodega Head

Blocks of ice being loaded into commercial fishing boats

Commercial fishing boats in Bodega Harbor

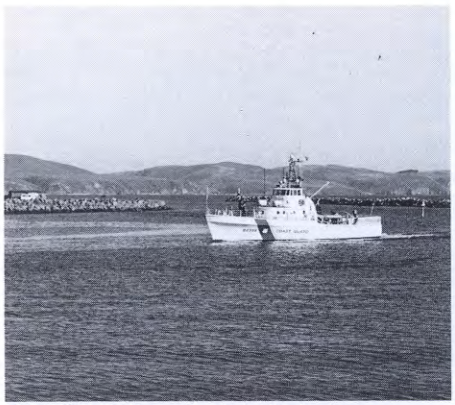
population of water-associated birds is likewise attracted by bountiful food resources, as well as by quiet waters and a mild climate.

Near the south end of the harbor, the road winds up Bodega Head, the large granitic formation at the southern end of the Bodega peninsula. The drive provides a fine opportunity to enjoy views of the harbor and the rolling, vegetated sand dunes that dominate much of the area. Continue to an overlook area on the ocean side of Bodega Head by making a right turn at a "Y" intersection near the end of the peninsula. From here, the rugged coast to the north and the rocky profile of the immediate shoreline can be seen.

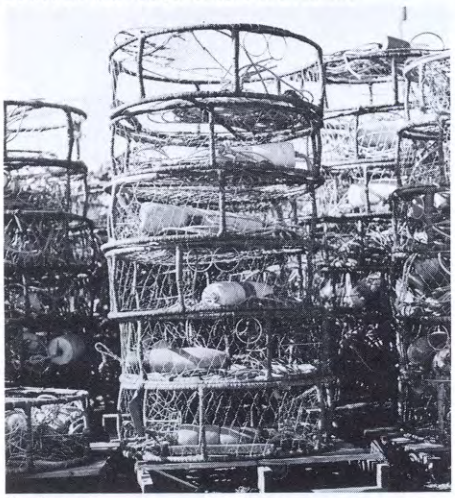
Bodega Head is the northernmost portion of the Point Reyes granitic block, which is believed by geologists to have originated far south. The rounded formation rises to about 250 feet and is faced on the west and south sides by steep cliffs and small pocket beaches. The promontory marks the upcoast end of Bodega Bay, a hook-shaped indentation extending in an unbroken spiral curve, or crenulate-shape, downcoast to Tomales Point and the entrance to Tomales Bay. The Head is connected to the mainland by a sand-covered isthmus with dunes ranging up to 100 feet in height.

Returning from the oceanside lookout, follow the road past the "Y" intersection to a large parking area above the Bodega Harbor entrance. The 100-foot-wide channel is protected by two jetties built by the Corps of Engineers in 1943. The south jetty is 1,650 feet long and the north jetty 1,130 feet long. The channel is defined by square green markers along the left and triangular red markers along the right. The 16,000-foot long channel runs to the north end of the harbor and down the northeast side. A bulkhead protects the tip of the long sand spit which extends along the ocean side of the harbor. The channel, bulkhead and harbor turning basins were also constructed by the Corps, which has continuing responsibility for their maintenance.

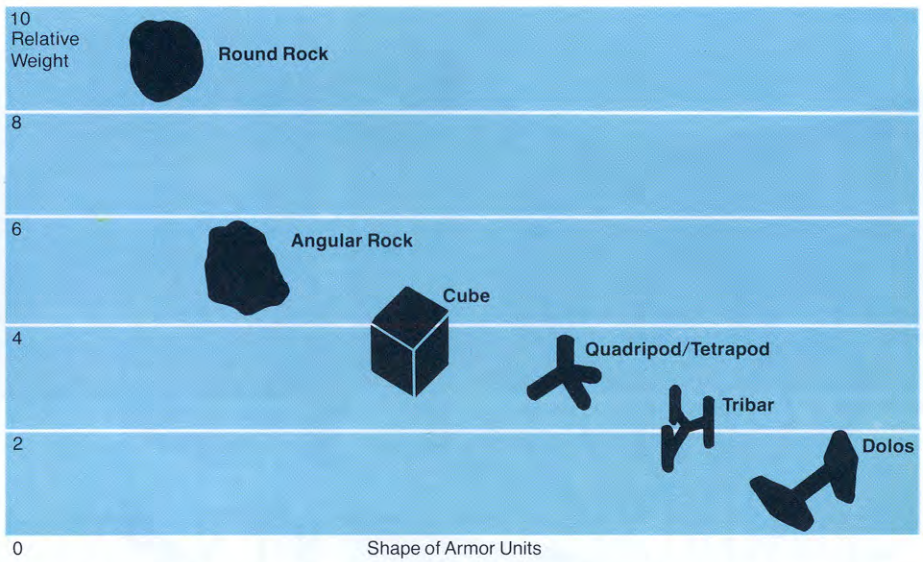
A long, dune-covered sand spit known as Doran Beach separates Bodega Harbor and Bodega Bay. The beach is made up of fine-grained sands, a typical beach composition at the upcoast ends of crenulate-shaped bays. Located behind its sandy expanse are a U.S. Coast Guard facility and a large salt marsh. From Bodega Head, return through the town of Bodega Bay and continue along the coast highway toward Tomales Bay.



Coast Guard vessel enters the harbor



Crab pots



Shape of Armor Units

Design of Shoreline Structures

The jetties delineating the entrance to Bodega Harbor were designed by experienced coastal engineers who used sophisticated mathematical formulas to arrive at an optimum design. The challenge was to create structures that would remain stable and effectively dissipate the energy of ocean waves.

The size, shape and slope of natural rock or man-made concrete armor units used in building shoreline structures such as these are the factors most critical to their success. Regardless of the type of unit used, an interlocking pattern is developed to prevent the units from being dislodged and to allow for settling. Openings or voids are incorporated to ensure that wave energy is absorbed, rather than being reflected back to sea.

Large, angular quarry rock is most often used in building protective structures. In the absence of natural rock, precast concrete units such as cubes, quadripods, tetrapods, tribars and dolosse are used. The accompanying graph shows the weight of various rocks and concrete units, relative to their ability to withstand equivalent amounts of wave energy.

7 Tomales Bay

From Bodega Bay, Highway 1 runs directly east, continuing its inland route for several miles before returning through the town of Tomales to the eastern shoreline of Tomales Bay. The entrance to this narrow estuary is flanked on the west by narrow, rocky Tomales Point and on the east by the small coastal town of Dillon Beach. From town, Tomales Point, the Tomales Bay entrance and the extensive grass-covered dunes of Sand Point can be seen. To reach Dillon Beach follow Tomales-Dillon Beach Road, a four-mile route running west from Tomales.

The best area for viewing the main points of interest is at Lawson's Landing, a private pier and boat-launching facility located on Sand Point. The dunes in this area vary from round, actively migrating hillocks to ancient formations. Vernal pools, natural depressions lined with a hardpan surface that prevents rainwater from draining downward, are occasionally found on deflated surfaces beyond the foredunes.

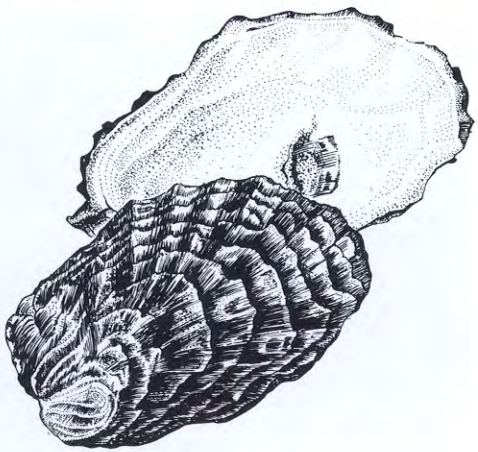
The entrance to Tomales Bay is located directly offshore. Extensive shoals in the entrance area create significant problems for navigators unfamiliar with the terrain. "Sneaker waves," the combined result of tides and wave groups, occur here. The combination of tides and winds can produce dangerous, quickly moving currents. Across the channel from Sand Point is Tomales Point, a mass of granite hills ranging up to nearly 550 feet. Its configuration and composition contrast sharply with the gentle slopes and low, sandy profile of the Dillon Beach area.

From Dillon Beach, return along Tomales-Dillon Beach Road to Highway 1. Turn right and drive through a narrow coastal valley along Walker Creek, the primary freshwater source for Tomales Bay. Near the mouth of the creek are some of the bay's most important marshes. Note the rows of sticks that protrude from the water here. These "fences" prevent sting rays from entering the commercial oyster beds located nearby.

The narrow inlet known as Tomales Bay is about 15 miles long and averages a half mile in width. Along its 33-mile shoreline are narrow, graveled beaches, mudflats and marshes, as well as bulkheads and revetments designed to prevent erosion. The bay's extensive mudflats provide prime habitats for a variety of mollusks, invertebrates and worms, and also serve as important feeding grounds for numerous shorebirds. The quiet estuarine envi-

Tomales Point from Dillon Beach

Tomales Bay marshlands, a prime habitat for mollusks, invertebrates, and shore birds



Many piers reach into Tomales Bay

Oysters are a major resource in Tomales Bay

Pacific Oyster

The Pacific, or Japanese, oyster is the species most commonly grown in area tidelands. Young seedlings, or *spat,* are imported from laboratories in Japan and attached to strings suspended from a platform. This raft culture method has numerous advantages. The suspended oyster grows more quickly, has a better flavor and has a higher survival rate than the bottom-bedded oyster. Survival rates are substantially increased because the suspended oyster is out of reach of snails, oyster drills, sting rays and other natural predators.

Growing oysters under controlled conditions has ancient origins. Historical records show that the Japanese have cultured oysters since the Third Century B.C. and the Romans since 100 A.D.

ronment, with its continual exchange of fresh and salt water, has long been recognized as ideal for the oyster growing industry that began here in 1875. The rich, biologically diverse bay also provides a habitat for surf perch, jacksmelt, silver salmon, steelhead, sharks, bottom fish and clams.

Driving south near the lower end of Tomales Bay, note the disparity between lands east and west of the bay. Here, craggy, tree-covered Inverness Ridge runs along the bay's western shore. In contrast, the eastern shore is backed by rounded, nearly treeless hills. Activity along the San Andreas Fault, which runs down the center of Tomales Bay, is responsible for the differing land masses. The entire Point Reyes peninsula exists in its present location because of the tectonic fault activity that has occurred over the millenia. Measurements have shown that the eastern edge of the massive Pacific Plate grinds against the North American Plate, continuing to move northwest at an estimated average of 1.5 inches a year.

Near the lower end of Tomales Bay, the Shoreline Highway runs slightly inland to Point Reyes Station and continues to Olema. In Olema, turn right on Bear Valley Road to the headquarters of the Point Reyes National Seashore. Nearby is Jule Loklo, a replica of a Coast Miwok Indian village. These early Marin county inhabitants once lived in several villages on the Point Reyes peninsula. From the park headquarters, return to Bear Valley Road, turn left and follow Sir Francis Drake Highway along the western shoreline of the bay. Along Pierce Point Road, just north of Inverness is the 1,018-acre Tomales Bay State Park. Continue along Sir Francis Drake, across the wide, rolling expanse of the Point Reyes National Seashore. Administered by the National Park Service, this spectacular, virtually undisturbed 165,300-acre land mass offers endless opportunities to enjoy the open coastline, study a variety of natural habitats and admire the area's wild, isolated beauty.

Wind swept cypress atop Point Reyes

San Andreas Fault

The San Andreas, classified by geologists as a strike fault, is a northwest-southeast trending fault that extends from the Imperial Valley in Southern California to Point Arena in the north. Its effects extend both east and west of this clearly defined line, in the form of groups of parallel faults running south into the Gulf of Mexico and north to Punta Gorda. Much of the primary fault zone closely parallels the California coastline, varying in width from several feet to several miles.

The movement along the fault is caused by the grinding together of two huge plates of the earth's crust. One, named the American Plate, is made up of the North and South American continents as well as part of the sea bottom of the Atlantic. The other, the Pacific Plate, consists of the sea bottom of the Pacific. The slow, but continual northwesterly progression of the Pacific plate causes a stress accumulation that is relieved by periodic earthquake activity.

8 Point Reyes and the Point Reyes Lighthouse

The historic Point Reyes Lighthouse sits high above the Pacific at the westernmost tip of Point Reyes. Its location has been identified as one of the foggiest and windiest along the entire California coast. En route, across the pastoral lands of the Point Reyes National Seashore, note Drakes Estero branching inland to the east, and the high, mounded sand dunes that form the land base for much of the area. Nearing the south end of the peninsula, Sir Francis Drake Highway branches both right and left, to run along the southern end of Point Reyes. The ridge of granite rock comprising the Point rises to more than 550 feet above sea level. Along its irregular shoreline are steep, wave-cut cliffs, rocky inlets, small sandy pocket beaches and offshore sea stacks.

Follow the road to the right to the parking lot for the Point Reyes Lighthouse. The short walk to the information center at the lighthouse offers outstanding views of the long, wave-fronting expanse of the west shore of Point Reyes Peninsula through cypress trees bent and sculpted by the winds. On clear days, Tomales Point, Bodega Bay, Bodega Head and, sometimes, Point Arena can be seen in the distance.

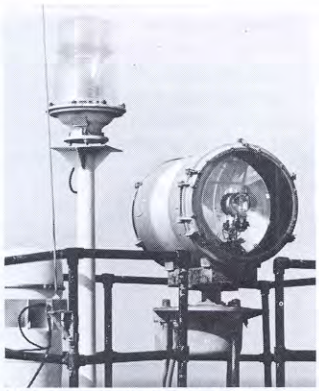
The Point Reyes Lighthouse is located near the base of high, rocky cliffs; sited on a massive chunk of rock about 300 feet above the ocean. Its light flashes underneath the heavy fog banks that characterize the area. Construction of the lighthouse, which became operational in 1870, was difficult and challenging because materials were moved by ox-drawn wagons from Drakes Beach, then lowered by cable to the construction site. Its forged iron tower was built with 16 sides to better withstand continual blasts of wind, which have been clocked up to 133 miles an hour. The tower houses an imported lens designed by Frenchman Augustin Fresnel. The lens weighs 6,000 pounds and measures eight feet, six inches in height. Its 24 focal lenses and 1,032 sections of handcut crystal are capable of transmitting light up to 24 nautical miles offshore. This precision machinery represents the finest in 19th-century lighthouse technology. To see the less picturesque but more functional light used since 1975, walk around the base of the old lighthouse to the coast side. Here, in addition to an automated light, are an electronic diaphone fog horn and a radio beacon.

Returning up the steep steps

The Point Reyes Lighthouse, one of the windiest

point on the California coast

The old lens representing the finest 19th Century technology



New automated light and foghorn

Changing Technology and the U.S. Coast Guard

The remnants of man-made structures found along the California coast often represent the effects of changing technology. The old railroad trestles extending into the surf near Drakes Beach and Point Bonita exemplify this phenomenon. These former Coast Guard rescue facilities were abandoned as safer, more efficient alternatives were developed. Prior to the development of the motor launch, large wooden boats manned with oars were used for Coast Guard rescues. The boats were manually dragged in and out of the water, even during the most dangerous wave conditions. A rail system, represented by the old surfside trestles, was later introduced. With this system, boats were placed on platforms attached to the rails and safely launched and recovered. With the introduction of improved engines and larger boats, these trestles soon became archaic and were abandoned. Today, large, powerful vessels, helicopters and aircraft make it possible for the Coast Guard to respond more quickly and efficiently than in the early days. As a result, search and rescue facilities can cover greater distances.

from the lighthouse, note the composition of the massive promontory on which it was built. The conglomerate of granite and sandstone visible along the walkway is believed to be more than 50 million years old. A variety of algae and lichen cover the rocks, offering a fascinating and colorful display of the only growth capable of flourishing in this harsh, windy environment.

From the lighthouse parking lot, return to the Sir Francis Drake Highway intersection and drive west on Chimney Rock Road to a parking lot at the top of the bluffs. From here, one can enjoy fine views of Drakes Estero, the gently curving sweep of Drakes Beach and the sandy white cliffs lining Drakes Bay. Many believe the area was that described by Sir Francis Drake when in 1579 he wrote of the "white bancks and cliffes, which lie toward the sea."

9 Drakes Bay and Drakes Beach

From the parking lot at the end of Chimney Rock Road a hiking trail leads to Chimney Rock, a large sea stack at the eastern tip of Point Reyes. The rock marks the upper end of Drakes Bay. Here, an overlook provides opportunities to admire the long, sweeping expanse of the bay. The smooth contour is broken only by the entrance to Drakes Estero, a large, many-fingered estuary. The entrance to the estuary is marked by the tip of a sand spit. Covered with low, active dunes and partially vegetated intermediate dunes, the spit extends for about three miles downcoast from the mouth of the estuary—along the edge of Estero de Limantour, a large lagoon to the east. Both the estuary and the lagoon are believed to be the drowned valleys of streams that eroded their way to the sea during a time of lower sea level. With glacial melting, sea level rose and filled the stream valleys.

Near the upcoast end of Drakes Bay, in the lee of Chimney Rock and the southeast tip of Point Reyes, is a semi-protected anchorage area. At the dock that extends into these seasonally sheltered waters, fish are unloaded and shipped by truck to San Francisco markets. An abandoned Coast Guard facility is located near the dock. From here, return to Sir Francis Drake Highway and turn right at a sign indicating Drakes Beach. A wide, sandy shoreline and moderate wave climate make this one of the most popular beaches along the Point Reyes shoreline.

Drakes Beach differs markedly from the exposed beaches along the west side of the Point Reyes peninsula because it is protected from high-

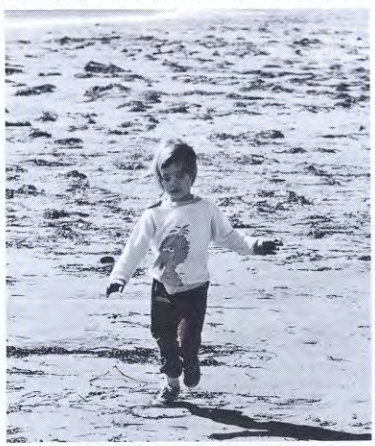
Coastal Indians

The Pomo and Coastal Miwok Indian tribes once populated the coastline between Arena Cove and the Golden Gate. The Pomo lived primarily along what is now the Sonoma coast; the Miwok were predominant in Marin County. Both were peaceful hunting and gathering tribes who depended on the bountiful resources of the land. Salmon, trout, elk, berries and nuts were mainstays of their diets. Furs, rushes and bark provided clothing and shelter.

The Pomo are believed to have come to the California coast some 2,000 years ago. The most treasured reminders of this lost culture are beautiful, intricately woven baskets. Much of what we know about the Coast Miwok comes from written accounts of early explorers. Other clues are found by studying kitchen middens, heaps of shells and bone fragments, and the associated scooped-out depressions that identify former home sites.

Sarah Smith, born in about 1881, was a Coast Miwok; the California Indian group that has lived in the Bodega Bay region for at least 2,000 years. The necklaces, made mainly from clamshells, are used as a form of wealth and status. The basket, made by nearby Pomo Indians, is of a type used as gifts.

Dramatic white cliffs at Drakes Beach



Clean white sand makes Drakes Beach a favorite

Johnson's Oyster Farm

energy waves by Point Reyes itself. The nearly vertical cliffs of weakly consolidated sediments that line its backshore have long been admired for their scenic qualities. Toward the east, a distinct pattern of breaking waves indicates the point of outflow from Drakes Estero. Along the cliffs just downcoast from the visitors center, large quantities of beach sand have migrated up the cliff face. The formation continues to develop as winds blown from the cliff curve down, around and upward to create an eddying effect.

Near the Drakes Beach visitors center, which is open only during summer months, a granite cross has been erected by the Sir Francis Drake Association to commemorate the popular theory that Drake came ashore at Drakes Estero in 1579 to repair his ship, the *Golden Hinde*.

From the beach, return to the main road and turn right; then make a left turn toward Point Reyes Beach North. This beach and others lining the western shoreline of the Point Reyes Peninsula are fully exposed, wave-fronting beaches characterized by misty sprays and the thundering sounds of breaking waves.

The development of the shoreline here began during a time of higher sea level, when cliffs were cut into the hills backing the beach. As the sea retreated during the glaciation period, longshore currents carried sands downcoast from the Russian River. Deposited along the beach face, the sands were blown inland over former sea cliffs to form new dunes. With the melting of the glaciers, sea level rose and a new beach area developed. The earlier dunes were buried by new sand. Another sea cliff was soon cut into the older dune deposits and the shoreline continued to develop.

From Point Reyes Beach North, follow Sir Francis Drake Highway eastward past the inland reaches of Drakes Estero. A short distance past the tip of Schooner Bay, the longest of the four fingers of the estuary, a road leads to a 3.5-mile hiking trail that runs along the edge of the water. Here, one of Northern California's most scenic estuarine environments can be enjoyed. Return to Highway 1 and continue southeast through the rift valley of the San Andreas fault toward Agate Beach, Duxbury Reef and the Bolinas Lagoon.

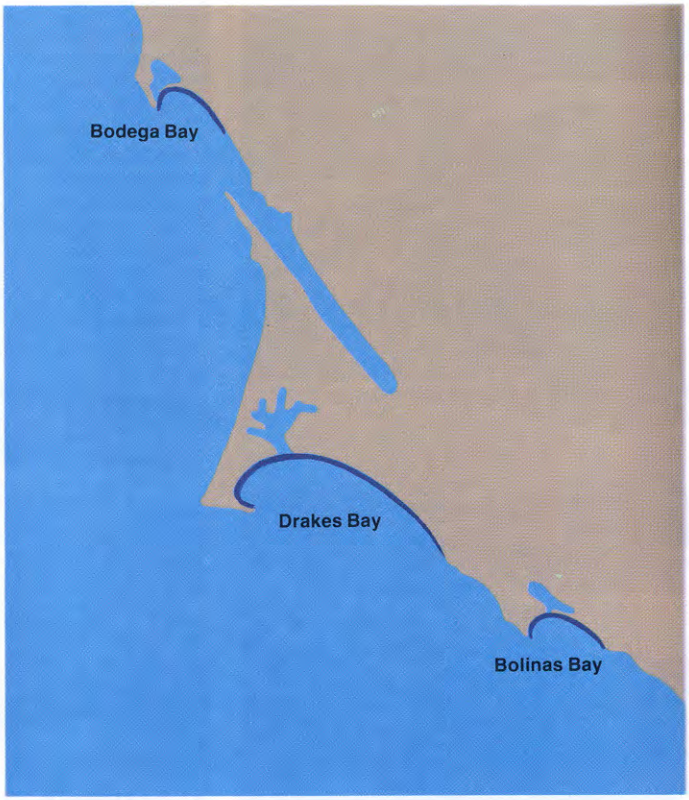
Dairy cows above Drakes Bay

Strong ocean winds blow sand drifts against the cliffs

Crenulate-Shaped Bays

Drakes Bay, Bolinas Bay and Bodega Bay are crenulate-shaped bays nearly identical in features and orientation. Each is associated with a resistant headland. Their well-defined, curved shapes result from the diffraction, or fanning out, of waves passing the headlands and the subsequent refraction, or bending, of the waves as they approach a less-resistant downcoast shoreline.

Crenulate-shaped or hooked bays are characterized by a coastline eroded sharply inland in the "shadow zone" immediately downcoast of the headland, where a distinct arc formation is created. The arc becomes less pronounced and gradually straightens as the influence of the diffracted waves lessens. This shape, in fact, mirrors the diffraction-refraction pattern of the waves. Beaches lining crenulate-shaped configurations are usually in a state of dynamic equilibrium relative to sand loss and gain. As a result, the beaches experience only minor seasonal variations in shape.



10 Agate Beach and Duxbury Reef

To reach Agate Beach and Duxbury Reef, exit from Shoreline Highway on Olema-Bolinas Road near the upcoast end of Bolinas Lagoon, about nine miles southeast of Olema. Drive along the lagoon's western shoreline, then turn right on Mesa Road at a sign for the Point Reyes Bird Observatory. Turn left on Overlook Drive and then make a right turn on Elm Avenue to the Agate Beach parking lot.

A path leads from the parking lot to the top of a high, wind-blown bluff faced by steeply eroded cliffs. From the edge of the cliffs a good perspective can be gained of the size and configuration of Duxbury Reef. Caution is advised because the cliffs are made of loosely consolidated materials that can quickly slide to the rocks below.

Duxbury Reef, named for a steamer that ran aground here in 1849, has been identified as the largest intertidal shale reef in North America. It extends from Agate Beach for about 2,000 feet along the edge of the mesa into Bolinas Bay. Much of the long, narrow formation is exposed at low tide. Believed to have been uplifted by the movement of the San Andreas fault, Duxbury Reef's rocks are estimated to be about 28 million years old. Sculpted crevices and tide pools line the surface of the reef. A variety of intertidal creatures lives in these natural oceanic aquariums.

At several points along the reef, waves diffract, or fan out, through openings in the rock and move into shallower areas along the shore. Wave reflection also takes place here, as approaching waves strike the reef and are hurled back to sea. A third wave phenomenon, refraction, also occurs. The waves bend, or refract, as they approach the shore and are slowed by friction against the shallow bottom.

From Agate Beach, return to Overlook Drive. Continue seaward to a lookout area offering excellent views of the Stinson Beach sand spit and the smooth, crenulate shape of Bolinas Bay, running downcoast about 3.5 miles to Rocky Point.

From the overlook, turn right on Terrace Avenue and drive down the bluffs through a lushly vegetated area toward downtown Bolinas. A right turn on Brighton Avenue and another right on Wharf Road leads to a point from which to study Bolinas Lagoon and its entrance to the sea.

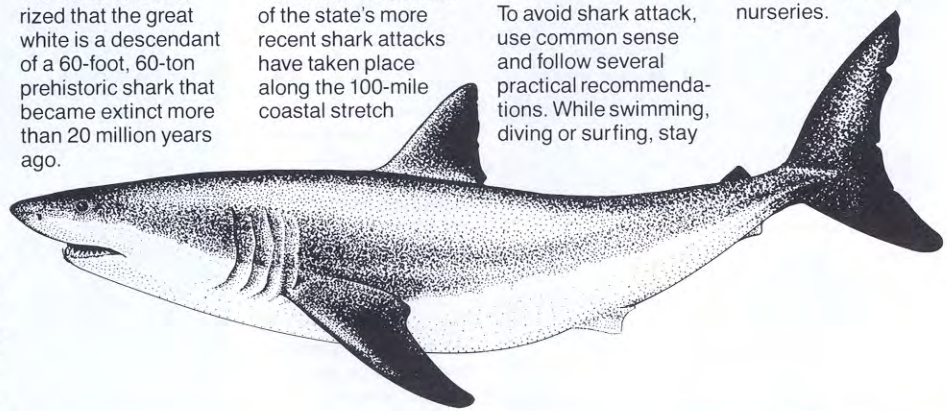
Waves defracting after passing through Duxbury Reef

Great White Shark

The great white shark, the largest and most feared of all flesh-eating animals, is found along the California coast, as well as in waters around the world. It is theorized that the great white is a descendant of a 60-foot, 60-ton prehistoric shark that became extinct more than 20 million years ago.

Attacks by the great white shark have sharply increased along the California coast during the past 20 years, largely due to increases in the population of marine mammals. About half of the state's more recent shark attacks have taken place along the 100-mile coastal stretch between Año Nuevo and Bodega Bay. Ten times as many attacks have occurred here per linear mile than along any other 100-mile coastal area north of Mexico.

To avoid shark attack, use common sense and follow several practical recommendations. While swimming, diving or surfing, stay out of areas of highest incidence, stay in or near kelp beds as much as possible and keep any speared fish afloat. Water sports are particularly hazardous in areas close to marine mammal nurseries.



Abundant sealife populates Duxbury tide pools

Eroding cliffs and protective sandstone reef

Agate Beach marks the northern end of Duxbury reef

11 Bolinas Lagoon

Along the shoreline, at the end of Wharf Road in Bolinas, a small, sandy beach forms the upcoast perimeter of the entrance to Bolinas Lagoon. This 1,035-acre wetland lies in a rift valley along the San Andreas fault. The valley was filled with water following the rise in sea level that succeeded the Age of the Glaciers.

The triangular, mile-wide lagoon is fronted on the ocean side by Stinson spit, a formation created as a result of the influence of Duxbury Point, just upcoast. The wave diffraction-refraction pattern created by the Point has caused the littoral currents to flow northward, building up the spit across the face of the lagoon. Records indicate that the shape and position of the Stinson spit have not changed substantially since the area was first surveyed in 1854. The majority of sediments making up the spit appear to be derived both from granitic materials transported downcoast from the Point Reyes headlands and carried seaward through the Golden Gate from the Sierra Nevada Mountains. Other sediments are likely derived from the Franciscan rocks in the immediate vicinity of Bolinas Bay.

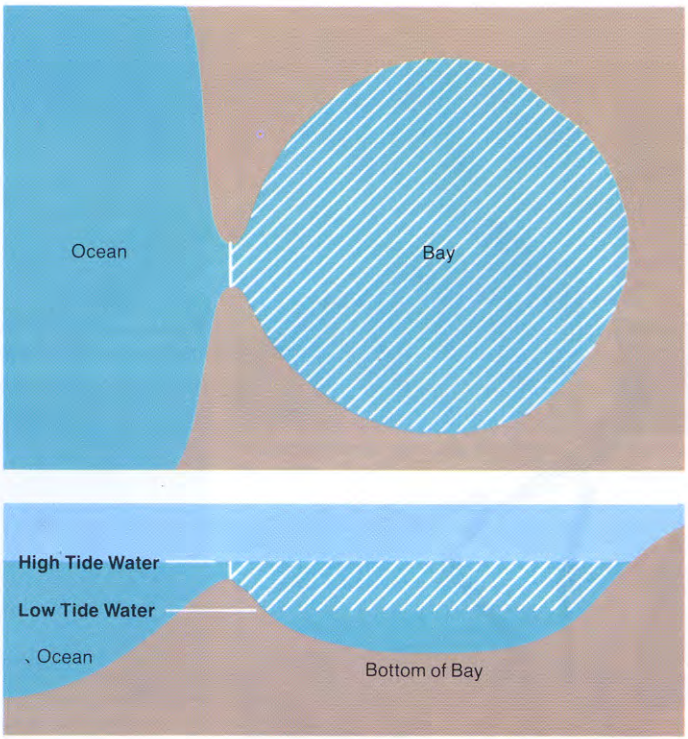
During low tide, about 70 percent of Bolinas Lagoon consists of tidal flats. The lagoon appears to be about midway in the transformation process that changes a coastal embayment to a meadowland. The lagoon's transition began when sand transported by longshore currents first developed a spit. As the spit began to restrict the amount of tidal interchange, sediments were deposited within the lagoon, raising the floor to the lagoon. As marsh vegetation developed, the filling process was accelerated. Normally, a developing barrier beach eventually closes off the lagoon, causing its waters to stagnate and its ecosystem to change. In time, dry land forms and the transformation process is complete. Current estimates indicate that unless man interferes Bolinas Lagoon may be transformed into meadowland sometime during the next 500 to 2,000 years.

The lagoon is considered one of California's most important coastal habitats. Because its tidelands are largely undisturbed, it provides important feeding grounds for great blue herons, egrets, ducks and numerous other types of waterfowl. Kent and Pickleweed islands, located a short distance inland from the entrance, have been set aside as wildlife sanctuaries.

From the end of Wharf Road,

Tidal Prism

A tidal prism is the volume of water contained in a harbor, lagoon or bay between low and high tides. It is the amount of water that typically passes in and out of the area during a 12.4-hour tidal cycle. Studies have revealed a definable relationship between the tidal prism and the cross-sectional area of the opening or entrance through which tides ebb and flow.



The size of natural openings to coastal lagoons and estuaries varies substantially. Some river estuaries stay open yearround; some nearly always close during summer months. Others open and close to varying degrees depending on the size of the body of water, coastline configuration, and local wave and current patterns. The degree of closure depends on the ability of incoming tides to bring sand in, and the ability of outgoing tides and river flows to flush sand away and keep the inlet open. The tidal prism and the dimensions of the inlet determine whether the channel is accreting, eroding or in equilibrium. It is interesting to note that at Bolinas Lagoon, which has a tidal prism of about 910 million gallons of water, the channel maintains a state of nearly perfect equilibrium.

Shorebirds in the Bolinas Lagoon

Stinson Beach is a favorite recreation spot

Muir Beach overlook

return through downtown Bolinas and follow Olema-Bolinas Road along the west shore of the lagoon to reconnect with Highway 1. Audubon Canyon Ranch, about three miles north of Stinson Beach, is a 1,000-acre private reserve, with one of California's most important rookeries for the great blue heron and the great egret. From a quiet lookout area, visitors can watch the courtship and nesting process, the feeding of the hatchlings and the first awkward flights of the young birds.

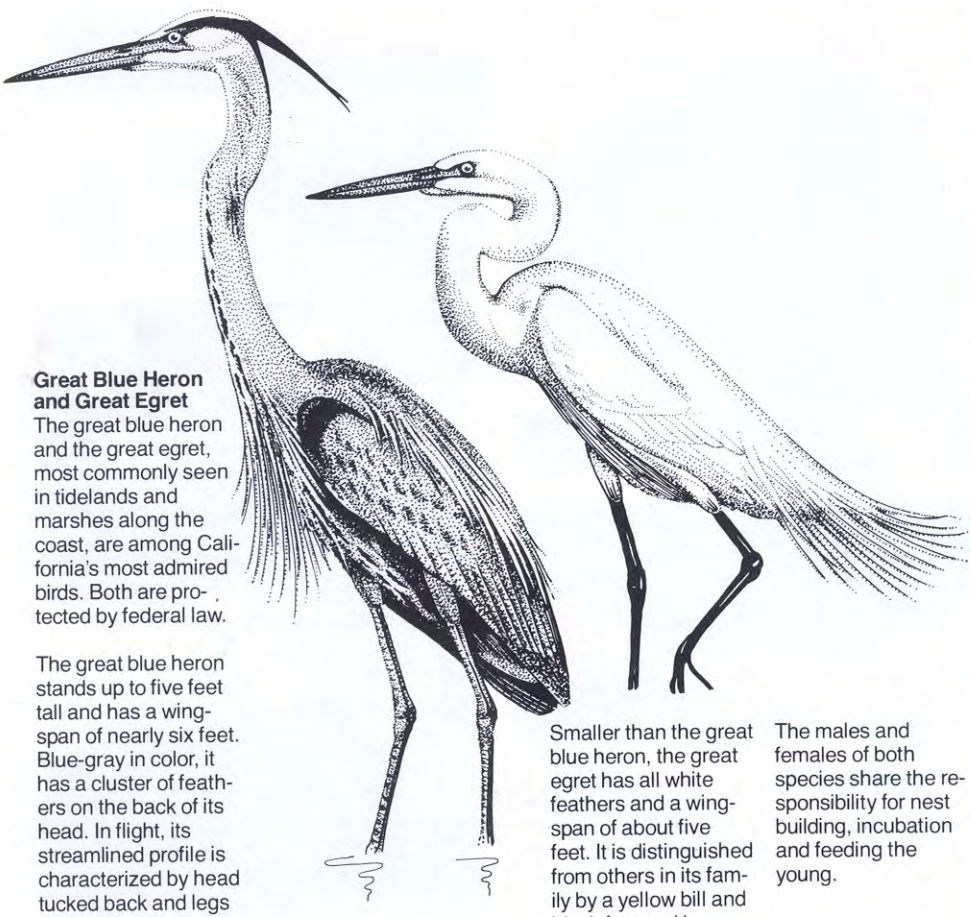
Stinson Beach State Park, a popular recreational area, undergoes seasonal change, with the summer profile being about 140 feet wider than the winter profile. From Stinson Beach, the Shoreline Highway winds along the rock-studded lower reaches of Mount Tamalpais, Marin County's predominant geographic landmark. Beyond the white line of foam breaking on the shoreline and the breathtaking views of the steep, rocky coastline, the City of San Francisco can be seen in the distance.

About four miles beyond Stinson Beach, turn right on Muir Beach Overlook to a small grassy park high above the Pacific. Here, a fence-lined walkway leads to the tip of a rocky promontory that offers inspiring views of the rock-strewn shoreline. Muir Beach, a small pocket beach recessed between two rocky headlands, can be seen a short distance downcoast. The beach is accessible from Pacific Drive. In area backing the beach, the final stage in the transition from lagoon to meadowland can be observed. Records indicate that a lagoon was located here during the mid-1800s. Today only small clumps of marsh vegetation offer evidence of the lagoon's existence.

12 Rodeo Lagoon and Beach

Nearing the north end of the Golden Gate Bridge, take the Sausalito exit and continue to the right, through a short tunnel under the freeway. A short distance beyond an intersection stop sign, turn left at a sign indicating the Golden Gate National Recreation Area. The drive leads through a one-way tunnel into beautiful Rodeo Valley, Rodeo Lagoon and Beach, and Forts Baker and Cronkhite. These forts and several other military installations in the vicinity of San Francisco Bay once formed the backbone of a coastal defense system established during the Civil War.

Rodeo Lagoon extends behind Rodeo Beach for several hundred yards inland from the Pacific. The beach extends completely across the lagoon en-



Great Blue Heron and Great Egret
The great blue heron and the great egret, most commonly seen in tidelands and marshes along the coast, are among California's most admired birds. Both are protected by federal law.

The great blue heron stands up to five feet tall and has a wingspan of nearly six feet. Blue-gray in color, it has a cluster of feathers on the back of its head. In flight, its streamlined profile is characterized by head tucked back and legs trailing behind.

Smaller than the great blue heron, the great egret has all white feathers and a wingspan of about five feet. It is distinguished from others in its family by a yellow bill and black feet and legs.

The males and females of both species share the responsibility for nest building, incubation and feeding the young.

The Lagoon is also the home of numerous marine species and aquatic birds

A nice place to talk about nature

trance during summer months when freshwater input into the lagoon is minimal and wave energy is more moderate. During rainy winter months, the lagoon waters breach the barrier and create an opening to the sea. As a result, changing water salinity levels can significantly affect shoreline vegetation. During summer months, for example, when the lagoon entrance is closed and the sun evaporates much of the fresh water, salt grass flourishes. As fresh water flow increases, freshwater plants often replace those that thrive in a more saline environment.

Rodeo Lagoon serves as a valued habitat for numerous marine species and a variety of bird life. The tidewater gobi, a tiny fish now on the endangered species list, thrives here, along with a variety of invertebrates and other organisms. Local birds include gulls, the California brown pelican, and common and snowy egrets.

The adjacent beach is perhaps most unique for the colorful minerals scattered in its coarse dark sands. Because the beach is set in a deep cove protected by rocky headlands, there is little deposition of the light-colored sediments carried northward from the San Francisco Bay outflow. Thus, beach sand consists primarily of graywacke sandstone, chert, greenstone, and carnelians eroded from the adjacent Franciscan formation cliffs.

Swimming and wading are inadvisable at Rodeo Beach because of dangerous rip currents and the strong return flows that characterize the steep beach face. A visitor center near the parking lot offers a variety of information and programs on the area's environment and history.

13 Point Bonita and the Marin Headlands

Returning from Rodeo Beach, turn right on Field Road, just beyond a small bridge that spans the upper reaches of Rodeo Lagoon. Drive up into the Marin Headlands toward Point Bonita. This narrow, rocky promontory is about 300 feet high and extends for hundreds of yards toward the southwest on the upcoast side of the Golden Gate.

Near the tip of Point Bonita is the Point Bonita Lighthouse. Built in 1865 to warn mariners of the hazards of the San Francisco Bay entrance, the lighthouse was one of the first 16 built along the West Coast of the United States and was the first to incorporate a fog signal. Originally located farther up the ridge above much of the coastal fog, the light was moved to its present

The Sand Dollar

The sand dollar is a form of urchin common to coastal lagoons and sandy underwater stretches. It is a prehistoric creature whose fossil remains date back to the Pleistocene Age, one to two million years ago. Its nearly circular, flat *test*, or shell, is thickly covered with minute spines that give it an almost velvety appearance.

In its natural habitat, the sand dollar is deep purple in color. It moves by means of spines and tube feet. The feet, which extend beyond the spines, also serve as respirators and assist in the feeding process by moving food toward the mouth. The creature lives either on top of or partially buried in sand. It sometimes can be seen at low tide, half-buried in a nearly vertical position with its upper half leaning away from the direction of the moving current. In this position, the creature's feet can more easily select the diatom-covered sand particles on which it feeds.

The ocean on a calm day soothes the spirit

The Headlands offer a spectacular view of the Golden Gate

Point Bonita marks the entrance to the Golden Gate

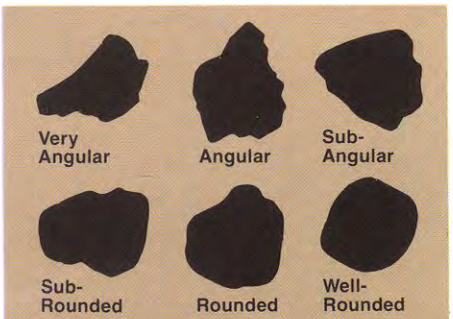
The Point Bonita Lighthouse was built in 1865

location in 1877. The Point Bonita Lighthouse is in the process of being transferred from the U.S. Coast Guard, which maintains administrative control over active coastal lighthouses, to the National Park Service. When the transfer is complete, the facility will be opened to the public. In the lee of Point Bonita, extending into the sheltered waters of Bonita Cove, is a marine railway trestle that was once used to launch Coast Guard rescue vessels.

Offshore from the western flank of the Marin Headlands are two northbound traffic lanes, one for vessels approaching the Golden Gate and one for those departing. The lanes vary in width from a mile to about 1.7 miles and are nearly 15 miles long. A separation zone nearly two miles in width runs between the two lanes. A similar combination of traffic lanes approaches the Golden Gate from the south, and a "main traffic area" approaches from the west. The main passage, which is about nine miles long, is approximately two miles wide at the west end and narrows to less than a mile between the Golden Gate Bridge pilings. A precautionary area at the confluence of the three approaches to San Francisco Bay is defined by a circle with a radius of six miles. The area is marked by a lighted horn buoy often visible about 11 miles offshore. The one-way inbound and outbound lanes, separation zones and precautionary area are part of what is known as a "traffic separation scheme."

In order to increase navigational safety in the vicinity of the Golden Gate, the Vessel Traffic Service maintains continuous communication with vessels operating within the traffic scheme. Precautionary measures such as these are particularly important in the vicinity of the Golden Gate because of extremely dangerous currents, prevalent fogs, pinnacle outcroppings and the narrow entrance to San Francisco Bay.

From Point Bonita, return to Rodeo Valley and continue east to McCullough Road, where a right turn leads once again to the top of the headlands. Turn left near the edge of the coastal bluffs toward Highway 101 and the Golden Gate Bridge. Numerous lookout areas along the way provide vantage points for enjoying the span of the world-renowned Golden Gate Bridge, the expanse of San Francisco Bay and the beauty of the San Francisco skyline.



Size and Shape of Beach Sand

The size and shape of beach sediments are determined primarily by local wave and current conditions and the composition of the rock from which the sand originated. Generally, beaches exposed to the full impact of waves have coarse sand grains, while those that are more protected have finer sands. Because sands are naturally sorted, based upon their ability to remain suspended in the water, high-energy waves deposit only the heavier, coarser sands on shore. When wave energy is more moderate, finer-grained sands are deposited.

The period of time involved in transport and the steepness of the terrain over which sand is carried also affect its ultimate size. Factors such as these also influence the shape of sand particles, although their shape is primarily determined by mineral content. Sand grain shapes are generally categorized as spherical or angular, with specific classifications ranging from "very angular" to "well rounded."

Coastal Fortifications

The Marin Headlands, the bluffs south of the Golden Gate and several sites along the edges of San Francisco Bay served as sites for an artillery defense system designed to protect the Bay from naval attack. The era represented by the area's now-abandoned fortifications began in 1794, with the building of *El Castillo de San Joaquin* high on a bluff near the southern end of the Golden Gate Bridge. The era ended in 1949, shortly after World War II, when more sophisticated military weaponry made former defense systems obsolete.

A major effort to update defense technology occurred during the later 1800s, when American industry developed the capability for forging and tooling large steel components, building more sophisticated mechanical parts and creating new explosives. Because the resulting generation of concrete battery emplacements was built before the airplane was invented, designs were strictly oriented to naval defense. Camouflage and concrete protection were added in the mid-1930s, when vulnerability to air attack became apparent.

Within a few short years following World War II, jet aircraft, guided missiles and nuclear weapons made artillery defense obsolete. For a time, Nike anti-aircraft missiles provided protection, but new intercontinental ballistic missiles soon ended the value of even this seemingly sophisticated alternative.

The Year of the Coast

In keeping with President Carter's declaration of 1980 as "The Year of the Coast," the U.S. Army Corps of Engineers has joined other public agencies and private organizations in focusing attention on the need to manage, preserve and protect our nation's coastal areas. To assist in this worthwhile objective, the U.S. Army Corps of Engineers will, throughout 1980 and 1981, publish a series of brochures highlighting key natural and man-made features of the California Coast. It is hoped that this series will both inform the public of coastal features and processes and assist in the development of a greater appreciation of the critical need to insure the protection and management of coastal resources.

For additional details on these brochures and other public information and education programs available from the Corps of Engineers, please contact the following Public Affairs Offices:

South Pacific Division
630 Sansome Street
San Francisco, CA 94111
(415) 556-5630

San Francisco District
211 Main Street
San Francisco, CA 94105
(415) 974-0356

Los Angeles District
300 N. Los Angeles Street
Los Angeles, CA 90012
(213) 688-5320

Sacramento District
650 Capitol Mall
Sacramento, CA 95814
(916) 440-2183

California Coastline
Explore Series

Explore 1
Oregon Border to
Klamath River

Explore 2
Klamath River to
Punta Gorda

Explore 3
Punta Gorda to
Arena Cove

Explore 4
Arena Cove to
Golden Gate

Explore 5
San Francisco Bay

Explore 6
Sacramento —
San Joaquin Delta

Explore 7
Golden Gate to
Davenport

Explore 8
Davenport to
Cape San Martin

Explore 9
Cape San Martin to
Point Conception

Explore 10
Point Conception to
Point Mugu

Explore 11
Point Mugu to
Point Fermin

Explore 12
Point Fermin to
Newport Beach

Explore 13
Newport Beach to
The Mexican Border

Prepared by U.S. Army Corps of Engineers