

OREGON'S COASTAL OCEAN:

A GUIDED TOUR

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OUR DESIRE TO PROTECT WILD PLACES often emerges from our experiences with them. The places we love are the places we later fight to protect. On the other hand, some places ignite a desire to protect them because they are remote. For example, most of us are unlikely to visit some of Oregon's most inaccessible treasures—the summit of Mt. Hood, far-off wilderness in the high desert, or deep caves—yet we value them because they represent something beyond our ordinary lives.

Oregon's ocean, one of our special natural treasures, epitomizes the concept of protecting remote and wild places. We humans are creatures of the land with no adaptations for life in the ocean. Special equipment is required to view its underwater forests, canyons, and mountains. For the most part the affective bond we feel with our fellow creatures of the land does not come easily when we gaze at the surface of the sea. It requires concentration, knowledge, and a studied leap of imagination.

One of the reasons salmon are so beloved is because they bridge the known and unknown. They are born in our world--in streams we can wade in or in hatcheries that we engineer. Then they willingly leave all this behind and venture into a mysterious life in the sea. They make that world their home in a way we can never hope to. Yet to our human sensibilities they are not fundamentally of that ocean world after all, for they return to fresh water streams to lay their eggs and die.

Ironically, Oregon's ocean, one of its most special natural treasures remains almost completely unprotected and open to exploitation and destruction. Our aim here is to make Oregon's ocean a bit more familiar in the hope that we will learn to better conserve and protect it. We will take a brief guided tour of the waters that stretch three hundred and sixty three miles along Oregon's coastline, having a look at the physical forces that shape them and the array of plants and animals which make them their home.

Most of us know the sea from the intertidal zone. We walk its shores. We delight in dodging its spray. We are familiar with many of its creatures and have some awareness of its habitats of sand, mud, or rocks. Here are sea creatures we can see and touch. It is the transition zone where earth and air mix freely, sometimes violently, with the sea. The experience is exhilarating partly because we remain grounded in the familiar while edging into the unfamiliar. With deeper waters, we have little to go on except for the few who dive and view its wonders first hand.

Until very recently what we knew of sea life was based on what we hauled up on the end of a line or raised flapping in a net. What is missing in that experience is the context of the critter's life. That context is what biologists call an ecosystem. Our brains are built for connections. Things matter to us when we can understand them in relation to other things we already know. So when we yank something out of the sea leaving behind its biological context, we intuitively provide a different one. The creature then is seen as a meal, a delicacy, or a part of someone's livelihood. There is nothing wrong with viewing marine life this way; it's part of the picture. The problem is that it leaves out the rest of the picture that remains below the surface.

Ironically, as we haul more and more out of the sea worldwide, continue to use the oceans as our dumping ground, and unknowingly rearrange what's down there, we're being warned through collapsing fisheries, dying coral, disappearing populations of birds, and toxic algal blooms that what we can't see really does matter. It's becoming obvious that we're connected to all those creatures below in ways we never suspected and haven't imagined.

As we take this brief guided tour of "what's down there" off the coast of Oregon, we will also examine some warning signs of serious trouble and consider options for restoring health to our coastal waters. In that way, we will have a better opportunity to judge for ourselves what needs to be done to protect, preserve, and restore our ocean heritage.

Geological Forces

Several unique topographic features can be witnessed during a day's drive across Oregon: the high desert and mountain ranges of Eastern Oregon, the snowy peaks of the Cascades, the fertile Willamette Valley, the forested coastal mountains, and, finally, the headlands and bays of the coastline. The landscape changes dramatically within relatively short distances. The topographic variations that exist on land do not end where the ocean begins. Just like the land we see, the ocean floor is made up of high mountains, steep banks, flat plains, and deep gorges. This section will discuss the geologic forces that have shaped Oregon's offshore environment for millions of years and some of its most unique features. This underwater topography makes up the habitats for the rich biodiversity of the coastal sea. (Fig. 1).

Oregon's undersea margin consists of a comparatively flat, gently sloping continental shelf. It reaches a maximum depth of 100-200 meters before dropping off rather precipitously to a depth of up to 3000 meters further out where it meets the deep sea. This steep transition zone is called the continental slope. By worldwide standards the continental shelf off Oregon is relatively narrow, ranging from 10 miles in the south near Cape Blanco to about 46 miles in several regions of the central coast. (Fig. 2).

The topography of Oregon's coastline, like the margins of all the continents and oceans, has been shaped by the slow and inexorable movement of great crustal plates on the Earth's surface. The movement of these plates is powered by heat from radioactive decay that drives currents of molten rock deep in the earth's interior. This rock reaches the surface in long chains of undersea volcanoes that spill out their lava on the sea floor. As this newly solidified rock accumulates in great ridges, the weight of it

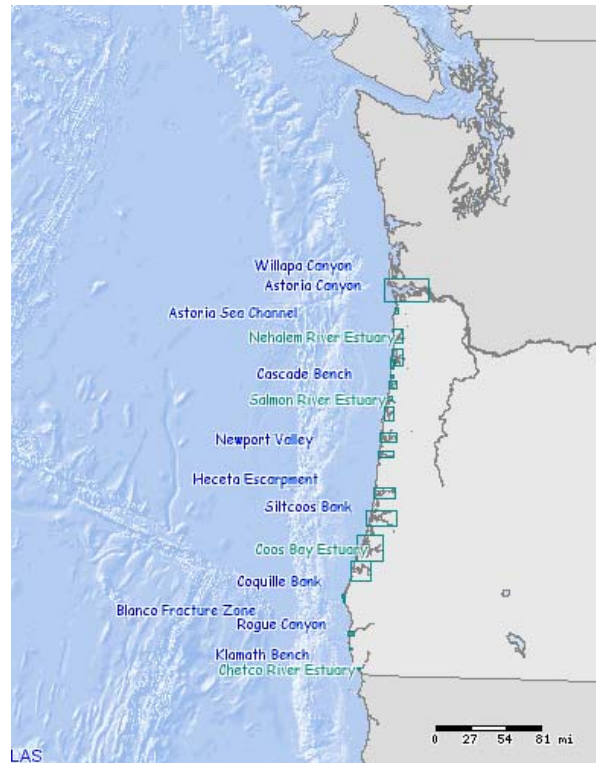


Fig. 1 This map illustrates the rugged underwater topography of the coastal ocean that provides varied habitats for Oregon's marine life.

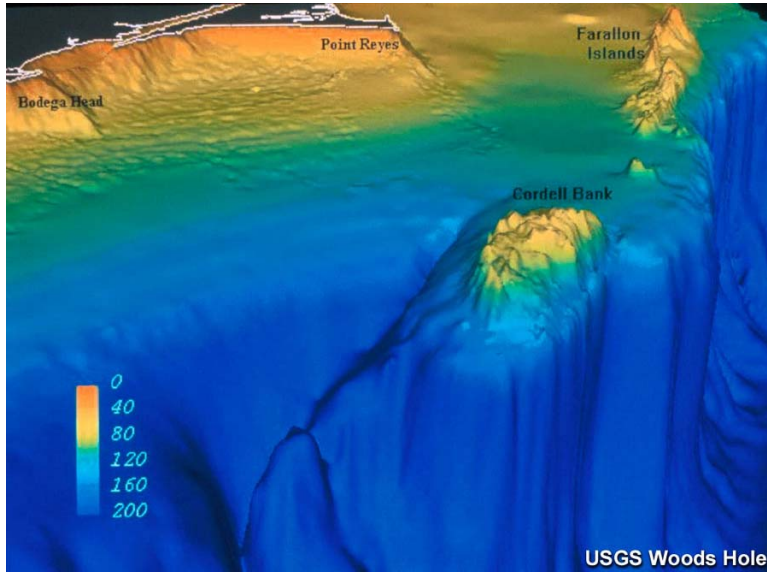


Fig. 2 In this view of the northern California coast, the relatively shallow continental shelf slopes gradually before plunging over steep cliffs to the bottom of the sea.

causes the plates to spread gradually away from each other along these volcanic ridges.

Because the earth has a finite surface area, the spreading of the crust along the ridges has to be balanced by a process whereby a corresponding volume of crust is returned to the earth's interior. This occurs in a process called subduction, a process in which one plate plunges underneath another, periodically releasing an enormous amount of energy in the form of major earthquakes.

Typically, volcanic ridges are found in midocean, but off the coast of Oregon and indeed all of western North America, the ridges lie quite close to shore. The Juan de Fuca ridge is only a few hundred miles off the coast of Oregon and the Juan de Fuca plate which it creates is moving towards us at a rate of between 4 and 10 cm. a year. It collides with the North American plate at the base of the continental slope, uplifting it to create submerged banks and escarpments, such as Heceta Bank off the coast of Newport. (Fig. 3). Surface debris scraped off by the subduction creates raised rocky ledges along the escarpment that are transitional between the shallow waters overlying the continental shelf and the much deeper waters of the oceanic abyss. One such area off Heceta Bank, for example, provides rich and varied habitats for rockfish and numerous invertebrate species. (Fig. 4). As the Juan de Fuca plate is thrust down under the North American plate, its crust melts, creating lava that later erupts to form the volcanos of the Cascades. In a very real sense, Mt. Hood, Mt. Saint Helens, and Oregon's other volcanos are conceived under the ocean.

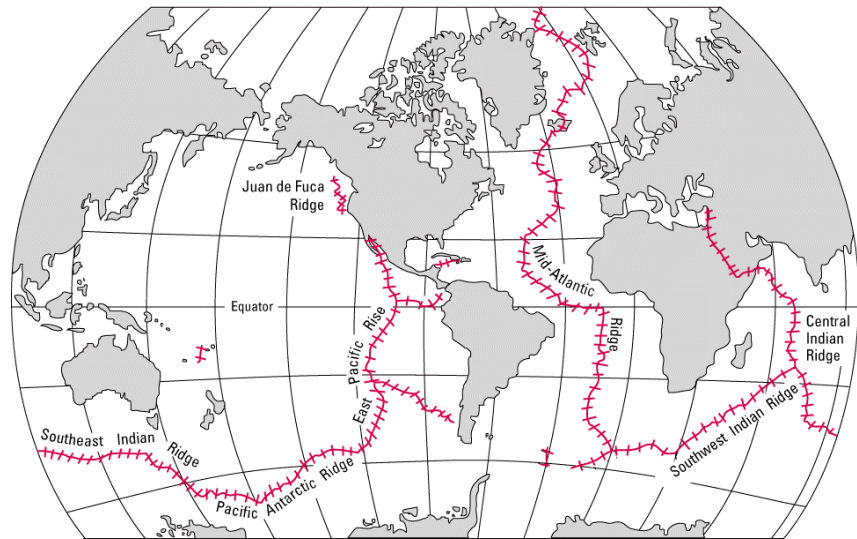


Fig. 3 The position of the midocean ridges, shown here, is rather like the seams on a baseball. Notice that the Juan de Fuca Ridge is uncharacteristically close to the Pacific Northwest shoreline compared with other oceanic ridges.



Fig. 4 A diver in the Cordell Marine Sanctuary off the coast of California explores a rocky ledge similar to those found on Oregon's Heceta Bank.

The Continental Shelf

The coastal ocean extends from the shoreline to the outer edge of the continental shelf, which in Oregon varies from ten to forty miles offshore. Although worldwide, coastal oceans contain only about ten percent of the area of the open ocean, they are the most productive part of the sea.¹ This is primarily because of an oceanographic process called upwelling. On the western margins of continents such as the Pacific coast of North America, seasonal prevailing winds drive the surface waters away from shore. This water is replaced by nutrient-rich water that wells up from deep, offshore locations. Upwelling provides the relatively shallow waters over the continental shelf with a rich source of nutrients that sustains abundant life. Waters over the continental shelf in Oregon are an extremely productive area of the Pacific Ocean, supporting a wide variety of invertebrates, fish, and marine mammals and birds.

Approximately 15,000-20,000 years ago, a mere instant in geologic time, the climate of North America was quite different than it is now. Great ice sheets extended south as far as Puget Sound. Because so much water was locked up in ice, the sea level was considerably lower than it is now, and the ocean lapped at a shoreline along the outer edge of what is now the continental shelf. Indeed, recent oceanographic exploration of the continental shelf has brought up shells which are very similar to present day intertidal organisms. The Columbia River flowed across this exposed plain, cutting a massive seaward gorge which is now submerged. We know it as the Astoria Canyon which empties across the continental slope into the Cascadian Basin of the deep ocean. Other smaller rivers also cut shallower canyons across the exposed continental shelf. Today they provide channels where fauna from the depths meet those of the shallower waters near the shore.²

At about this same time, the first humans are thought to have entered North America from Asia, crossing a land bridge exposed by the low sea level in the region of the Bering Sea. They probably migrated southward and may well have walked along what is now Oregon's submerged continental shelf. It is fascinating to imagine these first North Americans resting atop a rocky headland on what is now Heceta Bank as they gazed out to sea. (*Fig. 5*). If this indeed happened, archaeological treasures as well as rich marine life may well lie submerged off our coast.³

¹ Thorne-Miller, B. The Living Ocean, 2nd ed., p. 59 (1999). Island Press.

² National Ocean and Atmospheric Administration Ocean Explorer: Continuing The Legacy of Lewis and Clark. <http://oceanexplorer.noaa.gov/projects/02lewis/midcruise>.

³ *ibid*

We have only a vague idea of the plant and animal life of that ancient coastal Oregon because its remains are now largely submerged, but its place has been taken today by an equally fascinating array of creatures who make the shallow sea of the continental shelf their home. In the next sections we shall have a look at this rich biological community and the dynamics which shape it.



Fig. 5 Fifteen thousand years ago, the sea level was much lower than it is now. The first Americans looking out from this Heceta headland might have seen a flat coastal plain instead of the open ocean.

The Productivity of the Sea

The ocean covers seventy-one percent of the Earth's surface and was the original source of life on Earth.

There is no place in the ocean where life is absent—from the rocky shorelands to the deepest underwater canyons, the ocean supports a wide diversity of plants and animals. Although more individual species exist on land, the oceans contain a much greater array of overall genetic diversity as represented by families, orders, and phyla. In fact, several phyla, groups of animals which differ in fundamental body plan, are found only in the ocean and have no counterparts on land. The deep sea, which was once thought to be a watery desert, is now believed to harbor a diversity that rivals tropical rainforests. In recent decades, new technologies have enabled scientists to explore areas of the deep ocean never before accessed, and they have found hundreds of new species and even new ecosystems. Yet many of the mysteries within the deep ocean remain unsolved.⁴

Our understanding of the productivity of the ocean is made easier because basic principles apply equally on the land and in the sea. The specifics, naturally, differ. In both environments, photosynthetic green plants are the primary producers. They are called primary because they use the sun's energy for growth and reproduction rather than relying on consuming other living things. In the process they fix carbon in carbon dioxide into organic compounds, thereby completing the process of photosynthesis. All energy for life on earth comes originally from the sun and is captured by the primary producers.

On land most plants are multicellular and have an internal cellulose skeleton that holds them upright, displaying their leaves to the sun and allowing them to resist being blown over by the wind. By contrast, the ocean's primary producers are overwhelmingly microscopic planktonic algae, and though individually tiny, the aggregate mass is enormous. Just two species of blue-green algae alone have a global biomass of roughly 1 billion metric tons and they account for only a fraction of the planktonic algae.⁵ Photosynthetic plankton have no need of a multicellular skeleton because planktonic algae simply drift in the prevailing currents where they are buoyed up by the water and can absorb the ambient light.

⁴ National Oceanic and Atmospheric Association. www.noaa.gov.

⁵ Sogin, M. and D. E. Jennings. *Biological Bulletin* 204:159 (2003).

In addition to sunlight and carbon dioxide, primary productivity depends on water and mineral nutrients. In the ocean, water is obviously not a problem, but light and nutrients can become limiting. Although it varies seasonally, light penetrates to depths of approximately 30 meters over the Oregon continental shelf. All life below this upper lighted region, called the photic zone, either depends on a gentle “rain” of dead plants and animals from above or requires capturing drifters or swimmers who venture into these lower depths.

There is a marked seasonal cycling of nutrients in Oregon's waters. As dead organisms fall downward from the productive surface waters during the spring and summer, they carry along essential nutrients, especially nitrogen and phosphorus, that are locked up in their bodies. This process gradually depletes the surface waters. Beginning in the spring, a shift in the prevailing winds drives these warmer, nutrient-poor waters offshore and their place is taken by colder water that wells up from below. This upwelling water is rich in nutrients and returns to the surface the very elements such as nitrogen and phosphorus which are in short supply. Upwelling feeds the phytoplankton blooms that commonly occur along Oregon's coast after sunlight increases in the early spring. These upwellings continue episodically throughout the spring and summer and along with nutrient-rich runoff from the land they account for the very high productivity of Oregon's coastal waters.

Ocean currents are controlled by a complex interaction of prevailing winds, warming from the sun, and the rotation of the earth.⁶ In El Niño years, the usual springtime offshore movement of warmer surface waters decreases along the west coasts of North and South America. As a result seasonal upwellings are less intense and nutrient-poor warmer water remains at the surface throughout the summer season. This change diminishes the productivity of the sea in these years and has a marked effect on some fish populations and more broadly on ecosystem dynamics. For example, in Oregon during the El Niño summers of 1982 and 1983, pelagic cormorant colonies successfully fledged only about half as many chicks as usual and dead seabirds washed up on the beaches in unusual numbers. These events most likely reflected the scarcity of fish on which the cormorants usually prey and illustrate the interconnectedness of species through the food web.⁷

Ecosystems and Habitats

Oregon's ocean environment supports many different ecosystems and habitats. Near shore areas over the continental shelf contain rocky intertidal zones, kelp forests, sea grass beds, submerged rocky reefs, and estuaries. Marine life such as fish, shellfish and other invertebrates, marine mammals, and sea birds are commonly found in these habitats. Further offshore, features such as banks, canyons, rocky ledges and other submerged irregularities in the sea floor and on the continental slope create local current patterns

⁶ A detailed discussion of Oregon's ocean current system and its effect on biodiversity is available at the website of the Pacific Northwest Coastal Ecosystems Regional Study: <www.pncers.org/changeinecosystems.htm>

⁷ Schultz, S. T. *The Northwest Coast. A Natural History*, p. 93 (1990). Timber Press.

that support diverse communities of organisms from microscopic plankton and small fish to top predators such as large fish, sharks, and marine mammals.

Ecosystem is a term which describes the exchange of nutrients and energy among the members of a community of organisms and between them and their environment. Within an ecosystem nutrients and energy flow through a succession of steps which can often be reduced to a question of “who-eats-whom?” Habitats are geographic localities that contain an array of species adapted to that environment.

Ecosystems encompass organisms with many different life styles. Plants and animals that live in the water column are collectively referred to as pelagic, regardless of whether they swim or drift. Tiny animals or the unicellular algae that are the ocean's primary producers are planktonic because they rely on wind or currents to move them about. (Fig. 6). Many fish, some jellyfish, squid, whales, and porpoises who swim actively in the water column are said to be neritic.(Fig. 7). Different species tend to be distributed into zones stacked one atop the other due to environmental factors such as currents, temperature, and light intensity. Benthic species live on or near the bottom and include commercially important ground fish such as various types of rockfish, lingcod, whiting, and flatfish, as well as crabs, encrusting organisms, and sea anemones. As adults, these organisms are associated with or attached to the bottom substrate, venturing only a short distance into the water column, if at all. Many clams and worms burrow into the sand or mud. (Fig. 8).

Even though the organisms bound up in a single ecosystem can have as radically different life styles as a sea lion and a bacterium, the connections among them can be traced through the path of nutrients. Scientists refer to this as a set of trophic relationships or, more simply, the food web. It is a web rather than a chain because the connections are complex and nonlinear. For example, the juveniles of a large predator may be eaten by adults of the very food fish that the adult predator targets. Despite many nonlinear detours through the web, the overall direction that energy and nutrients move is downward from the phytoplankton who are primary producers on the surface to the bottom dwelling creatures who depend on the rain of nutrients from above. These complex trophic interactions, which are not always understood, are one reason why it is difficult to predict the effect that human interventions will have on ecosystems.



Fig. 6: This euphausiid shrimp is only about ¼ inch long. Although it is capable of swimming on its own, its small size limits its mobility and it is usually considered planktonic. Huge numbers of tiny organisms like these in the water column provide abundant food for larger predators such as fish and whales.

Fig. 7: This large neretic jellyfish is itself a predator of smaller organisms unwary enough to come in contact with its stinging tentacles.

Fig. 8: A particularly choice area of rocky bottom which is crammed with anemones, starfish, several kinds of seaweed, and other encrusting organisms.



Fig. 9 A large anemone in Washington's Olympic Marine Sanctuary shares the space on a large boulder with many small organisms which have encrusted every available square inch.

Fig 10 Nudibranches, shellless marine snails, are among the most beautiful creatures in the sea. This one, off the coast of Washington, is making its way across a rocky bottom.

Fig 11 A China rockfish. It is no doubt hoping that a meal will emerge from the hiding place between the two boulders it is facing.

Some of the most important members of an ecosystem are invisible to the naked eye—billions of microscopic animals and bacteria that live among the particles of the bottom sediment. It is their job to finish off what their larger partners in the water column above have left unfinished, namely to complete degrading the remaining particles of uneaten food, dead bodies, and fecal matter. In the process, they break down the last complex organic molecules, harvesting the energy for their own use and liberating the inorganic constituents, ready to be returned to the surface at the next upwelling to begin the cycle all over again.

Many diverse habitats exist in Oregon's ocean, either as specialized regions of the water column or the bottom substrate. Neritic and planktonic inhabitants of the water column may be found in habitats that are loosely defined by depth, temperature, ocean currents, and wave action. To take one example, the Columbia River discharges vast quantities of fresh water into the ocean near Astoria. As the river water mixes with the ocean, it makes a plume of less dense sea water that floats outward from the mouth of the Columbia. Certain plankton, fish, and invertebrates are adapted to waters of lower salinities found near estuaries such as the mouth of the Columbia, whereas others occupy deeper, more saline waters farther out on the continental shelf. Predators such as marine mammals, birds, and large fish congregate where their preferred prey are located, and so their distribution too may reflect differences in salinity.

Bottom dwellers are adapted to particular types of substrates. Worms found on hard bottoms build calcareous tubes atop rocks which offer protection from predators and keep them from being swept away by currents. For similar reasons, worms living in muddy bottoms burrow into the soft substrate. Mussels attach to rocks but most clams burrow. Likewise different species of bottom-dwelling fish favor either soft or rocky bottoms. There are preferences of scale also. Some tiny creatures are sensitive to the size of bottom particles that a larger creature would ignore.

Oregon's bottom habitats include deep canyons, mud flats, rocky banks and ledges. Taken together they provide a variety of depths and substrates which are home to a rich array of benthic species, each adapted to its particular habitat. For example, Astoria Canyon and several smaller canyons are clefts in the floor of the continental shelf cut by ancient rivers. Today their channels provide pathways where species from the ocean depths can come into contact with those from shallower waters. Rocky reefs and ledges such as Heceta Bank near Newport and Nehalem Bank off Tillamook Head provide substrates for populations of rockfish and invertebrates adapted to their rocky bottoms. (Fig. 9, 10, 11).

Forests of bull kelp can be found on submerged rocky reefs along Oregon's central and southern coasts. They provide a complex habitat for a rich three dimensional community of plants and animals. Epiphytes and sessile invertebrates attach to its fronds whose undulating movement assures a steady supply of nutrients. The canopy also provides a nursery refuge for feeding larvae and juveniles of many fish and invertebrates species. It is home to adult fish who find food among the smaller animals of the forest and is visited by sea birds and marine mammals that come to feed on the fish. (Fig. 12).



Fig. 12 Bull kelp forests provide nursery habitats for juvenile fish.

Although the array of species in a habitat and an ecosystem generally coincide, there are exceptions. For example, a migratory predator may only be transient in a particular habitat, feeding there and then moving on. Nevertheless, it can have an important effect on the community of organisms and thus belong to that ecosystem even if temporarily. Equally important, organisms sometimes dwell in different habitats at different stages of their life cycle. Many juvenile fish frequent nurseries in shallow waters and then move offshore to feed as adults. Fishes and bottom dwelling invertebrate species like crabs, scallops, and sea urchins release huge numbers of planktonic larvae into the water column where they drift for periods that vary from hours to months. Larval dispersal permits species to colonize new habitats and may mediate genetic exchanges between populations that are necessary for the long term health of species. Because organisms may make use of diverse habitats at different stages of their life history, it may be necessary to protect networks of habitats in order to adequately protect a given ecosystem.

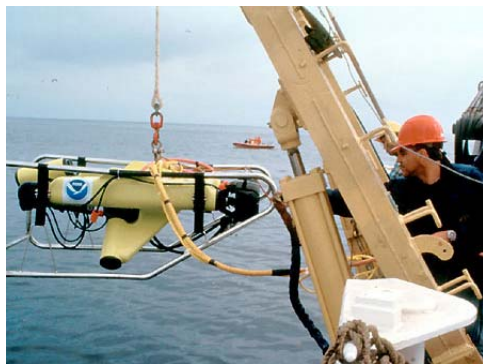


Fig. 13 Launching of an unmanned submersible instrument from an oceanographic vessel.

Recent advances have allowed marine scientists to gauge the association between species and habitats using instruments located in ships on the surface in tandem with submersibles and remotely operated vehicles. In these experiments in Oregon waters, videotapes were made from a manned submersible passing over transects that included different types of bottom habitat on Heceta Bank. The abundance of several species of ground fish and the type of habitat with which they were associated was assessed by direct visual inspection of the tapes. The location of these habitat types filmed from submersibles was shown to correlate positively with sea floor topography mapped with state-of-the-art multibeam sonar located on surface vessels. These data confirm that habitat type assessed by sonar can be used as an indicator of the species array below.⁸ The use of multibeam sonar to indirectly assess sea floor habitat potentially provides an important tool for conservation because surface-based methods are far less expensive in time and money than deploying submersibles. (Fig. 13).

⁸ Nasby-Lucas, N. M. et al. Fish Bulletin 100:739-751 (2002).

Oregon's Coastal Ocean: A Vulnerable Ecosystem

In 1999 the oil tanker *New Carissa* ran aground off Coos Bay, spilling nearly 40,000 gallons of oil on the southern Oregon coast. The response of ordinary citizens was heartening. People flocked to the coast to help organize beach cleanups, nurse oiled sea birds, and monitor miles of shore line. A pollution crisis like the *New Carissa* spill is dramatic, but in more pervasive ways Oregon's coastal waters are in daily jeopardy from chronic pollution such as industrial discharges, runoff from agriculture, leakage from failing septic tanks, overflow from aging sewage treatment plants, silting from forest clear-cutting, and dumping of sediments from dredging. These harmful human activities threaten the rich biodiversity of offshore marine life, and the stresses they create reduce the resilience of ecosystems to inevitable natural perturbations such as ocean storms and El Niño events.



Fig. 14 Fishing is presently allowed in Marine Sanctuaries, shown here off the Olympic Coast of Washington.

In the next section, marine reserves or ocean no-take zones will be discussed as an important tool for marine conservation. We will focus in detail on three off shore practices for which marine reserves provide a partial antidote, namely, overfishing, mortality due to unintended bycatch, and habitat destruction.

In recent decades the demand for seafood has risen dramatically. Fishermen responded by targeting fish species that were most abundant and easiest to catch. (Fig. 14).

Traditionally the resources of the sea have been thought to be inexhaustible. Despite heavy exploitation, for many years catches held steady and the toll on fish populations was hidden because increases in fishing efficiency and technological advances captured fish in previously inaccessible regions of the ocean. However, contrary to expectations of unlimited bounty, in recent decades populations have plummeted. Alarmed, governmental regulatory bodies charged with promoting sustainable fishing practices introduced a number of restrictions including reducing the number of fishing vessels and the length of the fishing season, or limiting the types of gear permitted. In the face of increased restrictions and falling income, fishermen reacted by employing even more technically sophisticated gear or increasing their effort. Regulators then responded by limiting the total allowable catch. The result has been a sort of escalating tug of war in which both fish and fishermen are the losers.



Fig. 15 Mature rosy rockfish in the Cordell Marine Sanctuary, northern California.

In Oregon, populations of groundfish have been particularly hard hit. (Fig. 15). Catches of groundfish such as bocaccio and yelloweye rockfish have declined substantially. Part of the problem is that the data

government regulators need to determine the size of sustainable catch are often inadequate. Censusing populations in waters more than 100 meters deep is difficult and expensive and so catch limits are determined by educated guesswork. Despite increasingly stringent regulations, fish stocks have continued to decline. The allowable catch has had to be drastically reduced, and this has resulted in the virtual closing of some fisheries causing much hardship to coastal communities. Recently, the Pacific Fisheries Management Council, the body charged with regulating fisheries on behalf of sustainable yields, has estimated that the existing biomass of several species of rockfish have plummeted to less than one tenth of their unfished value. Recovery of bocaccio and yelloweye rockfish populations could take as long as 100 years in Washington and Oregon waters.⁹

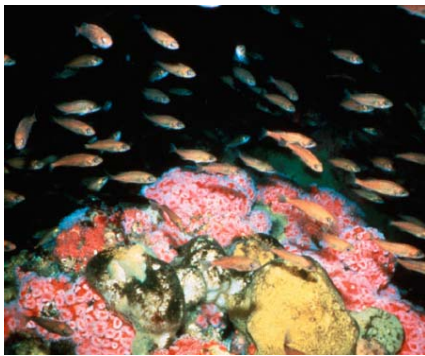


Fig. 16: A school of juvenile rockfish. There is safety in numbers.

Rockfish populations are especially sensitive to overfishing for a number of reasons. Studies have shown that some species are exceedingly long-lived, typically 25-40 years and in some cases even 100 years. These same fish also have delayed sexual maturity, young adults often not reaching egg-bearing age until the end of their first decade or more. Therefore, even if a fishery is completely closed, recovery cannot occur until the youngest fish reach full sexual maturity which in the case of rockfish can be many years. (Fig. 16). The situation is analogous to harvesting old growth forest. The yield is initially very high, but replacement cannot possibly keep up with harvesting.¹⁰

The problem is rooted in the life history of most species of fish. Large, older fish produce many more eggs in proportion to their size than young adults or juveniles. A fish twice the size of a young adult may well produce four or more times the number of eggs. When a stock is first exploited, the largest, most mature fish are typically fished out first because they are commercially the most valuable. This results in a disproportionate reduction in the ability of the population to reproduce itself. Later, smaller adults and juveniles are targeted, resulting in fishing down the age structure and even further decreasing the population's ability to reproduce.

Overfishing seriously endangers not only the target species but entire ocean ecosystems. Dr. Boris Worm, coauthor of a comprehensive study¹¹ of the worldwide depletion of large predator fish, has said, "You can't cut off the head of an ecosystem and expect it to behave the same way....you can end up with things being less stable, less predictable, and maybe less hospitable."¹²

⁹ <http://www.pcouncil.org/groundfish>

¹⁰ Munk, K. M. Alaska Fishery Research Bulletin 8:12-21 (2001). Pew Oceans Commission. Ecological Effects of Fishing, p. 12. Easthouse, K. North Coast Journal (California). July 18, 2002 cover story.

¹¹ Myers, R. A. and Worm, B. Nature 423: 280 - 283 (2003).

¹² New York Times, May 15, 2003.



Fig. 17: A California sea lion diving in search of rockfish.

The consequences of overfishing are sometimes mediated through dietary changes caused by shifting the delicate balance of the ecosystem. One example concerns a recently noticed dietary shift in orcas. Normally orcas feed on Steller's sea lions and harbor seals, but in the north Pacific these marine mammals are less abundant than they used to be. The declines in sea lion and seal populations are most likely associated with changes in ocean conditions and overharvesting of certain fish that these marine mammals prefer to eat. (Fig. 17). This shift has forced the orcas to target sea otters instead. In California a similar ecosystem shift has occurred. There, sea otters, apart from being cute and cuddly, play an important role in the ecology of kelp beds which provide nurseries rich in biodiversity. Otters feed on sea urchins, which in the absence of predation, reproduce unchecked and overgraze the kelp destroying hiding places for the young of many species of fish and invertebrates. Many other examples like this no doubt escape our notice because they involve small or uncharismatic creatures which nevertheless play an important role in maintaining the health of ecosystems.

In another example of behavioral effects, large predators such as tuna induce schooling in potential prey. Some sea birds are opportunistic feeders and follow tuna to take advantage of the concentrations of small fish in these schools. Reduction in the number of top predators thus unexpectedly reduces the feeding efficiency of these birds. (Fig. 18).



Fig. 18: A dense school of jack mackerel which draws sea birds and marine mammals to feed on them.

Environmental assaults do not exist in isolation and they sometimes interact. Overfishing, for example, increases vulnerability of populations to other perturbations for several reasons. Natural stresses, such as severe storms or El Niños or man made ones such as pollution or the introduction of foreign species, usually means that affected populations produce fewer viable offspring until recovery occurs. If the reproductive potential of a population has already been depleted by overfishing, it remains more vulnerable to occasional catastrophes whether natural or man made.

In addition to overfishing, bycatch, the inadvertent capture of other nontargeted species, is a serious problem. One example known to many people is the drowning of dolphins which become entangled in nets set out to entrap tuna. The extent of bycatch is not trivial. In some cases it exceeds the target species in biomass. Because fishing quotas are set for target species, fishermen are not permitted to retain other catch even if they are commercially valuable. In this case the bycatch is usually thrown back but the number of survivors can be very low and leads to enormous waste.

Most groundfish are caught by bottom trawling which produces significant bycatch of juveniles and other commercially important species, further reducing endangered stocks. Many fishermen, scientists, and conservationists are calling for more stringent regulations on the types of fishing gear that produce large amounts of bycatch. One partial solution to the bycatch problem is setting individual quotas for valuable fish species, which would allow fishermen to keep both the intended and unintended catch within their quotas. Another solution is to develop improvements in fishing gear that improve accuracy for catching target species and excluding non-target species. Although not used in Oregon waters because sea turtles are not found here, Turtle Excluder Devices are a well-known example of an apparatus used to reduce bycatch.



Fig. 19: Dragging huge trawling gear, like this one, across the sea floor, tears up the bottom substrate and seriously damages the ecosystem which depends upon it.

Almost never mentioned because they have no direct commercial value is the bycatch of nonfood species. Billions of invertebrates such as sponges, anemones, crabs, shrimp and other creatures are damaged, uprooted, or killed every year by bottom trawling. Their mortality may have very serious unintended consequences in disturbing marine ecosystems. Effects such as these remain almost entirely undocumented.

The dumping of dead and dying bycatch as well as offal from processing commercial fisheries at sea can result in vast quantities of decomposing organic refuse accumulating on the bottom. This encourages the unrestricted growth of scavenger populations and may well have toxic effects on the bottom community. It also lures seabirds to the vicinity of fishing vessels where they can become entangled in fishing gear. Even

dumping live bycatch causes the translocation of organisms from one environment to another with unpredictable effects.

In yet another result of trawling, gear sometimes becomes detached from the mother ship. The abandoned nets smother the habitat underneath them and continue to entangle fish, crabs, and other invertebrates. In some places this has become such an important problem that the term “ghost fishing” has been coined to describe it.

Rigid structures are used to hold the mouth of the nets open as they are dragged. (Fig. 19). Scraping heavy gear across the bottom effectively grades the substrate to a relatively flat plain and in the process uproots rock formations which provide habitats for many sessile organisms and hiding places for fish. Many benthic creatures are sensitive to small variations in the texture of the substrate particles. The disturbance may even shift the balance of bacterial communities that live in the substrate and carry out some of the most important chemical work of the entire ecosystem. Because the disruption is physical, it is effectively permanent. In some well-documented instances habitat destruction has been so severe that it is questionable whether the original ecosystem could ever recover.

Despite the numerous threats to the health of marine ecosystems, solutions are available. What is lacking in most cases is the political will to implement them. In the next section, we will discuss one particularly promising tool—marine reserves.

Marine Reserves: A Tool for Conservation and Restoration

Despite the growing threats to marine environments along Oregon's coast and worldwide, it is not too late to restore our coastal seas to health. We now have the opportunity to establish management systems that achieve a sustainable equilibrium between human use and adequate protection. The establishment of marine protected areas (MPAs), ocean areas that receive some degree of protection from extractive activities, is becoming increasingly recognized as an effective tool for achieving this equilibrium. MPAs, as they currently exist, however, rarely prohibit all fishing and thus provide only a partial solution. By contrast, marine reserves, a special kind of MPA in which all extractive activities including fishing are prohibited, hold great promise in helping to restore our oceans to their former vitality.

Worldwide, marine reserves that offer full legal protection from fishing probably comprise only about one ten thousandth of the ocean, yet they provide marine scientists with invaluable laboratories. Currently, no fully protected marine reserves exist off the coast of Oregon. After reviewing the scientific literature, the National Academy of Sciences¹³ and the Pew Oceans Commission¹⁴ independently have recommended that marine reserves be included as an important part of any comprehensive ocean management strategy. They are a conservation tool whose time has come.

What then are the advantages of marine reserves? They offer refuge to species that are victims of overfishing or bycatch and they prevent habitat destruction caused by invasive bottom trawling or mineral extraction. They also provide scientists with an invaluable point of comparison for assessing the effect of exploitation in similar unprotected areas. Most important, unlike fisheries management that focuses on single species and ignores damage to other organisms, reserves protect whole ecosystems. Marine reserves are an essentially conservative or precautionary management tool. Their approach is, "when in doubt, leave it alone," in contrast to other strategies which aim to moderate harmful effects through interventions often based on educated guesses that all too often prove incorrect.

Precautionary though they may be, scientific studies worldwide have shown that the benefits of marine reserves are decidedly proactive. Since adults are not removed, animals in reserves grow substantially larger. Larger animals lay many more eggs in proportion to their size and this results in more offspring and increased population densities. Sessile animals that cannot move to seek out mates have even more progeny because eggs and sperm are released in close proximity to one another. As the population density grows, mobile adults are likely to spill over into adjacent waters where they are accessible to fisheries or increase populations outside the reserve. Species with sessile adults usually

¹³ Marine Protected Areas. Tools for Sustaining Ocean Ecosystems. National Research Council. National Academy Press. 2001.

¹⁴ Palumbi, S. R. Marine Reserves. A Tool for Ecosystem Management and Conservation. Pew Oceans Commission. 2003.

compensate by producing huge numbers of larvae that disperse in the water column. These larvae can seed suitable habitats outside the reserves.

Two examples are illustrative. In 1962 for security reasons the federal government banned all access to waters adjacent to Cape Canaveral, creating the Merritt Island Marine Reserve. Compared to nearby waters, fish in the reserve are much larger and between 2 and 13 times as abundant. Fish tagged there have been recovered at substantial distances demonstrating the spillover effect. Game fishermen now crowd the borders of the reserve because record-breaking catches occur there far more frequently than in other parts of Florida.¹⁵

In another instance, in 1994 the federal government closed 6500 square miles of the Georges Bank to all fishing gear except lobster traps in an effort to deal with severe declines in groundfish caused by bottom trawling. Within four years bottom-dwelling scallops increased fourteen fold and the size of individuals was larger than anyone thought possible. Even more impressive, the scallops seeded populations outside the closed areas and populations there increased five fold.¹⁶

Recent modeling studies suggest that a network of closely spaced smaller reserves may be more effective than one large uninterrupted region. Smaller reserves have more perimeter relative to their area than large ones and this enhances spillover. A network can potentially protect more varied habitats, especially spawning sites or locales where juveniles congregate in nurseries that are not contiguous with the adult habitat. The redundancy of the network also provide better insurance against the effects of localized catastrophes. In order to be maximally productive, the components of a network must be located in such a way that animals can move among them, in some cases taking advantage of prevailing currents.¹⁷

It is worth noting that, effective as they are, marine reserves cannot cure all ills. Specifically, they cannot undo the effects of pollution, although if they are carefully situated they may be able to avoid it. Like the rest of the ecosystem, they also are vulnerable to invasion by foreign species. Also migratory species may not remain long enough in reserves to benefit from their protection. Because of these limitations, it is essential that marine reserves be part of an effective management plan which controls these other threats.

On the West Coast a number of promising marine conservation initiatives are underway. In Southern California, the existing network of marine reserves around the Channel Islands has just been enlarged. In

¹⁵ Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). The Science of Marine Reserves, p.10. 2002.
Roberts, C. M. and J. P. Hawkins. Fully Protected Marine Reserves: A Guide. World Wildlife Fund, p. 18. 2000.
Palumbi, S. R. Marine Reserves. A Tool for Ecosystem Management and Conservation. Pew Oceans Commission, p. 26. 2003.

¹⁶ Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). The Science of Marine Reserves, p.11. 2002.

¹⁷ Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). The Science of Marine Reserves, pp.16-17. 2002.
Palumbi, S. R. Marine Reserves. A Tool for Ecosystem Management and Conservation. Pew Oceans Commission, p. 29. 2003.
Roberts, C. M. and J. P. Hawkins. Fully Protected Marine Reserves: A Guide. World Wildlife Fund, pp. 57-58. 2000.

Alaska, a team of marine scientists recently prepared recommendations for the protection of a series of conservation “hot spots” in Prince William Sound, the site of the 1989 Exxon Valdez spill. In British Columbia, the Living Oceans Society is using computerized modeling based on biological and oceanographic data to generate a series of possible marine reserve networks for the entire coast of the province.¹⁸ And to our immediate north, the Georgia Strait Alliance (Canada) and People for Puget Sound (US), are working on an international conservation plan, including marine reserves, for the Orca Pass region made up of the Canadian Gulf Islands and the American San Juans.¹⁹

Oregon has some of the most beautiful coastline and productive waters on the west coast of North America. It also has a tradition of wise stewardship of its natural resources. Statewide Planning Goal 19, Ocean Resources, was adopted in its present form in 2000 and sets forth an extraordinarily enlightened vision of ocean conservation. It states in part,

[Our goal is] to conserve marine resources and ecological functions for the purpose of providing long-term ecological, economic, and social value and benefits to future generations.

It continues,

[Ocean policy is to] give higher priority to the protection of renewable marine resources--i.e., living marine organisms--than to the development of nonrenewable ocean resources.

Ocean management strategies of the past are no longer adequate in the face of increased exploitation. We need new tools in order to live up to the vision articulated in Goal 19. Marine reserves are one of the most promising of such tools. The time is now.

Conclusions

This concludes our brief nature tour of Oregon's coastal ocean. Hopefully your curiosity and appreciation have been aroused by what you've read and you will want to continue learning more and act to conserve our marine heritage.

The coastal ocean is a field where an astonishing array of creative forces are at play. Vast eddies of molten rock erupt under the sea and shape the topography of the bottom over geologic time. Powerful global cycles bring about dramatic seasonal changes in winds, currents, and nutrients. Ecosystems adapted to this watery world flourish here. Primary producers capture the sun's energy through photosynthesis and the resulting nutrients pass through an interconnected web of life, beautiful in its complexity. It is a spectacular example of nature at work.

¹⁸ Ardron, J. A. et al. 2002. Modelling a Network of Marine Protected Areas for the Central Coast of British Columbia. Version 3.1. Living Ocean Society. Available at: <http://www.livingoceans.org>.

¹⁹ Nichols, B. 2002. Wave of the Future: Orca Pass International Stewardship Area. Georgia Strait Alliance. Available at: <http://www.pugetsound.org>.

For millennia humans have fished and played a part in coastal ecosystems. As extractive technologies have become more sophisticated, however, we are now in danger of destroying the very ecosystems that we value and on which we depend. Tools to restore them to health are not lacking. These include rules that promote sustainable use and networks of fully protected marine reserves. As conservation-minded citizens our role must be to provide the political will to implement these policies while there is still time.

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Credits

Figure 1: Oregon Coastal Atlas, www.coastalatlus.net

Figure 2: United States Geological Survey, Woods Hole

Figure 3: United States Geological Survey

Figure 4: Cordell Expeditions

Figure 5: Dave Ragsdale, Draco Designs

Figure 6: National Marine Fisheries Service, La Jolla

Figure 7: Gulf of the Farallones National Marine Sanctuary

Figure 8: Nancy Sefton

Figure 9 - 12: Steven R. Fisher

Figure 13: Jamie Hall

Figure 14: Olympic Coast national Marine Sanctuary

Figure 15 - 16: Cordell Expeditions

Figure 17 - 18: Gulf of the Farallones National Marine Sanctuary

Figure 19: National Oceanic & Atmospheric Administration Photo Library