DIMENSIONS OF THE SEA

A MARINE EDUCATION SLIDE AND NARRATIVE SET

SEA GRANT PROGRAM
UNIVERSITY OF SOUTHERN CALIFORNIA
HANCOCK INSTITUTE FOR MARINE STUDIES
UNIVERSITY PARK, LOS ANGELES, CA 90089-0373

USC Sea Grant

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The Physical Ocean

PO-1. Wind waves on the sea surface (North Pacific).

Water is the most important substance on earth. It makes our planet habitable and is the very essence of life. At the sea surface where air, sun and water interface, we find important physical processes taking place which define the climate of adjacent land masses.

PO-2. Sun on sea surface (Long Island, New York).

As the sun shines on the sea, water evaporates to form clouds which move over the land and irrigate it. The sun and sea are prominent figures in the water cycle. Unequal heating of the sea from north to south creates the great circulating ocean currents which redistribute heat over the surface of the earth, warming polar regions and cooling the tropics. Thus the oceans are our global thermostat.

PO-3. Thunderhead over a tropical island (Wuvulu Island, Papua New Guinea).

Heat from the sea is transmitted to the atmosphere through water vapor. As the water vapor rises, it condenses, forming rain which releases heat. This heat fuels the rising columns of humid air and forms a thunderhead. An average thunder storm of this type may release as much energy as an atomic bomb.

PO-4. Storm runoff entering the sea (Santa Ana river, CA).

As rainwater runs back to the sea, it brings important nutrients for phytoplankton, sediments to replenish beaches, and all too often, pollutants.

PO-5. Storm runoff being carried by currents (Newport Bay, CA).

As material is washed from land and enters the sea, currents carry it and disperse it along the continental borderland. Often currents run parallel along the shoreline, creating a lateral movement of sediments.

PO-6. Waves breaking on sand beach (Surfside, CA).

Waves create these longshore currents, eroding beaches in some places and depositing sand in others. As a result, beaches are rivers of sand. Waves are important forces which shape the face of the continents.

PO-7. Breakwater at Santa Monica Pier (Santa Monica, CA).

When man prevents the waves from reaching the beach, he interrupts the longshore current, and without the current, sand becomes deposited. Notice how the beach is built out opposite the breakwater. Without the force of the waves, the river of sand stops and a beach is built. This often creates problems further along the beach since areas down current are deprived of their supply of sand. These areas are subject to erosion. As a result, human-made structures are often threatened by the loss of beach sand and the encroachment of the sea. Anyone developing a coastline should be aware of the dynamic processes of beaches.

PO-8. Tidepool with anenomes, surrounded by mussels and starfish (Catalina, CA)

Another important dynamic process seen along coastlines is the tide. The degree of exposure to air and direct sunlight, as a result of tides, determines what type of community will thrive at each zone on the rocks. Notice the difference in life inside the tidepool to that on the exposed rocks surrounding the pool.

PO-9. Schooner underway (Antigua, British West Indies).

The winds, tides and currents had a profound effect on early explorers and traders. It was with early sea captains that the science of oceanography had its beginnings. This was to be expected, since they were totally dependent on the winds and currents as a means of travel.

PO-10. Schooner under full sail (Antigua, British West Indies).

Eventually captains' logs were compiled into a book giving sailors knowledge of currents and winds to be anticipated in various parts of the world. Making use of favorable conditions, and avoiding unfavorable currents and winds, cut considerable time off the many voyages.

PO-11. Bottom profile showing schools of fish (North Pacific).

Sound has become an important tool of oceanographers, providing information about the bottom of the sea and concentrations of marine life in the waters below a ship.

PO-12. Thunderhead over the sea (South Pacific).

The most important concept of this unit is the fact that water is a unique substance and through its ability to store heat both as a liquid and as a gas, it regulates the climate of the earth.

PO-13. Sunset behind sailing ship (South Carolina).

The sea is a source of intellectual inspiration to everyone who is associated with it. We have a rich heritage of sea literature, music and art.

Ocean Management

OM-1. View of the ocean from within a cave (Laguna Beach, CA).

This view, hopefully, symbolizes our present situation regarding ocean management. We are leaving the dark ages and are approaching an enlightened perspective of how to use the sea and cooperate in ocean activities.

OM-2. View of undeveloped Oregon coastline (Oregon).

This view of a relatively undeveloped stretch of Oregon coastline can be contrasted with a similar stretch which is heavily used by humans. It is obvious which one is more beautiful, but which is better is a difficult question.

OM-3. View of lumber stacked on Oregon coastline (Oregon).

This lumber yard is a very important economic part of the local economy, providing jobs, income, and useful materials. Decisions of good and bad must be carefully evaluated, according to how much of the total coastline is developed, impact on other marine resources such as fishing or recreation, economic benefit, importance to the natural system, etc.

OM-4. View of private beach in Southern California (Laguna Beach, CA).

Ownership is an important aspect of management. Can owners deny the public access to public beaches, and can owners of coastal land develop it in ways which harm coastal and marine resources in other areas? Many private beaches which have become public are now littered and face environmental problems due to overuse and misuse. Resolving these problems hits the very core of the American way--right to own land and do with it as one chooses.

OM-5. Upper Newport Bay and residences on cliff above (Newport, CA).

Our nation's wetlands are a particularly difficult problem. How many owners of marshes and estuaries continue to pay taxes on land which brings no revenue, particularly as the value of the land and thus taxes increases? Owners of natural open spaces are forced by the taxation structure to develop it and get the maximum economic benefit from the land. We cannot blame owners who dredge and fill estuaries; instead, we must change our view of the value of undeveloped lands.

OM-6. Lower Newport Bay (Newport, CA).

Marsh grass, tidal inlets, and birds feeding on mud flats have given way to yachts and homes, each valued in the thousands to millions of dollars. The tax benefit to the local community from this type of development is substantial. There are certainly more people who will come here for recreation than to the undeveloped estuary.

OM-7. Aerial view of the Isthmus at Catalina Island on a holiday (Catalina, CA).

Recreation would seem to be a relatively harmless use of marine resources, but even people having fun can do damage. The impact of pleasure boat sewage can contaminate the water; people walking along the rocky shores kill many organisms; and if those people turn over rocks, they are harming countless more by exposing them to light and air; shell and fish collectors are having a significant impact on tropical reef fauna; and the grasses which stabilize dunes are vulnerable to foot and vehicle traffic. Consequently it is very important to control the use of our marine resources and develop management plans to balance use with impact.

OM-8. Salt marsh (South Carolina).

In order to properly evaluate the value of the salt marsh, we must consider the services it renders as it exists in its pristine state. Most of the fish and shellfish caught on our east coast depend on the salt marsh during some period of their lives because the marsh acts as a buffer, protecting inland areas from the effects of hurricanes. Because of the high organic content in the waters, marshes can act as limited sewage treatment facilities, and these areas are the perfect sites for oyster and other shellfish farms. These are values which must be compared to those of a "developed" salt marsh. Studies done in Georgia have concluded that their marshes are more valuable left undeveloped.

OM-9. Salmon spawning facility (University of Washington, Washington).

Management of our fisheries is very important to a continued harvest of seafood. Most exploited stocks are already being over-fished and are in danger of collapsing. Research is very important as are conservative regulations, which limit fishing enough to consider natural variations in the populations of fish. The concept of maximum sustainable yield has not proven to be an acceptable approach to management. Due to environmental variations and other factors, populations of fish fluctuate, making it almost impossible to predict the maximum number of fish one can take without jeopardizing the breeding stock.

OM-10. Tagged salmon in a pen (University of Washington, Washington).

These salmon are tagged and will be released to the open sea. When the salmon return to the pens where they were hatched, the scientists will be able to study them and compare them to what they were when they left. International agreement is particularly important in relation to salmon. We rear these fish in streams, then let them go out into the North Pacific to grow. The fish are in international waters and are heavily fished by foreign fishermen. The fish which we are ranching are being rustled, out there on the range, and as a result we are obtaining a reduced harvest of our fish.

OM-11. Aerial view of oil tanker (Los Angeles Harbor, CA).

The subject of pollution has become an international problem. Although oil is receiving the most publicity, by no means is it the only pollution problem affecting the seas. Bigger ships are more vulnerable to breaking up in heavy seas and more vulnerable to collision; some require more than a mile in which to stop. Bigger ships mean bigger oil spills. But it is also important to remember that bigger ships mean cheaper shipping fees.

OM-12. Oil on rock (Santa Barbara, CA).

We have the technology to prevent almost any oil being spilled on the sea. The problem is human error, negligence, and lack of proper enforcement. Almost every tanker collision or well blowout could have been prevented.

It is not necessary to flush oil-coated ballast tanks at sea, it is only cheaper. We need strong enforcement policies which make sure the management decisions already in existence are carried out.

OM-13. Oil spots on beach (Los Angeles Harbor, CA).

Oil is dramatic. It smells, it is gooey, and it is easy to see. Other pollutants are more subtle, unfortunately, and do not cause such a public uproar. Exotic organic chemicals, pesticides, and heavy metals are much more dangerous to health. We presently have laws to prevent dumping them into the sea but the laws are not being enforced.

OM-14. Dead fish floating on water (Los Angeles Harbor, CA).

In the U.S. there are laws, at least, preventing ocean release of toxic pollutants into the sea; in many countries there are no laws at all regarding pollutants. Since the sea knows no boundaries, international agreements regarding pollutants are vital to protect the health and perpetuation of marine fisheries. It is an increasing problem around the world to have fish or shellfish from an area determined unfit for consumption because of contamination.

OM-15. Rocky shore with wave behind (Laguna Beach, CA).

The seas belong to all of us, they are the common heritage of mankind. Let's make sure that neglect and poor management do not render the sea useless to humanity and uninhabitable to its natural residents.

Ocean Research

OR-1. Sailing vessel (Antigua, British West Indies).

Humans have always been fascinated with the sea, but it was not until the mid-1880s that extensive research was conducted on a broad scientific basis. Sea captains involved in trade and exploration were the first oceanographers, as they recorded their observations and conducted a few simple experiments. Magellan attempted to record the depth of the ocean but did not have a line long enough to reach bottom. Captain Cook accurately measured longitude and latitude during his geographic exploration of the seas.

OR-2. Sails of a schooner (Antigua, British West Indies).

The practical aspects of oceanography were advanced by Matthew Fontaine Maury when he reviewed hundreds of ships' logs and compiled the information of wind, current direction and speed in his "Physical Geography of the Sea." His charts enabled captains to avoid opposing winds and currents and use favorable ones, thus reducing the sailing times from New York to Rio de Janeiro from 55 to 35 days, and from New York to San Francisco from 183 to 135 days.

OR-3. Drawing of the H.M.S. Challenger.

The first great oceanographic expedition was a British effort conducted by the Royal Society, the Challenger Expedition. Scientists studies plants and animals from the surface to the bottom, collected sediment samples, measured temperature and salinity, and analyzed a number of chemicals in sea water. It is amazing that some of the chemical analyses conducted on the cruise, from 1872 to 1876, had an accuracy comparable to those we do today. The final report of the cruise filled 50 volumes, containing over 29,000 pages.

OR-4. Dredge from the Challenger Expedition.

Although much of the equipment from the Challenger Expedition was not sophisticated, it proved effective and durable. Compare this dredge to the one in the next photo; they are basically the same.

OR-5. Bottom dredge (Vantuna, Los Angeles Harbor, CA).

This dredge is dragged across the bottom and picks up anything larger than the mesh size of the net. It has to be very strong to withstand hitting and bouncing over rocks and other obstacles.

OR-6. Nansen bottle (Vantuna, Los Angeles Harbor, CA).

The Nansen bottle is a water sampling device. After is is lowered to the desired depth, a metal weight is dropped down the cable, which causes the bottle to flip over and close off both ends with the water sample inside. At the same time, a thermometer records the temperature.

OR-7. Bottom grab (Vantuna, Los Angeles Harbor, CA).

When this bottom grab hits the bottom it snaps shut, enclosing a segment of the sediment, as well as the animals on the sediment surface.

OR-8. Submersible (U.S. Navy Photo).

Submersibles have become important research tools. Studying the bottom and its life from the surface using grabs and dredges would be like trying to understand what life was like on the surface of the earth by scraping and grabbing segments of the land from the height of the clouds while being blindfolded. Submersibles allow scientists to explore the deep sea first-hand. The disadvantage of this research tool is the extreme expense and need for a mother ship standing by.

OR-9. Echogram of Deep Scattering Layer (Mediterranean).

Although there were a few notable oceanographic expeditions conducted by the United States, ocean research was not thriving until the Second World War. As submarine warfare became important, the military realized it must know more about the ocean: the properties of sound in water, biological sources of underwater sound, and a special phenomenon called the Deep Scattering Layer (DSL). Scientists eventually learned that the DSL was populations of animals which remained in the deep sea during the day, then rose to the surface at night. Notice the fuzzy line at the top of the slide which descends toward the left. This is a recording of the sound reflected from these DSL animals, as the rising sun caused them to swim back down to the deep. Understanding this DSL was important because it might be possible for a submarine to hide below this false bottom layer.

OR-10. Work boat for oil exploration (Los Angeles Harbor, CA).

This work boat is designed to get as much equipment as possible on it at once to study the land below the sea. It can drop explosives which provide sound waves that reflect off subbottom layers of rocks, possibly containing oil, or it can drill into the bottom to study the submarine geology.

OR-11. Chambers to study benthic metabolism (Laguna Beach, CA).

Much ocean research takes place on a smaller scale than what we have discussed so far. Here, chambers isolate part of the bottom, allowing scientists to determine the biological activity of the plants and animals living on and in the sediments. It is here where much of the waste material falls and is converted by bacteria into nutrients.

OR-12. Scientist doing analyses in the laboratory (USC Lab, Catalina, CA).

Many marine organisms contain potentially useful chemicals. Here a scientist is isolating chemicals from a marine algae. Laboratory studies are an essential part of marine research.

OR-13. Diver with respiration gas analysis unit (USC Lab, Catalina, CA).

Another important aspect of marine research is how the human body functions with respect to the marine environment. This diver is exercising hard and recovering his expired breath. These samples can then be analyzed in the laboratory to determine the effects of work, pressure, and cold on metabolism.

OR-14. Diver and garibaldi (Catalina, CA).

Thanks to the aqualung and adventuresome diving scientists, we are now beginning to understand the ethology of many marine animals. The more we learn about marine life, the more we realize the importance of interactions between organisms. This garibaldi is protecting its nest, yellow above, from all who venture too near. Such territoriality has an important effect on the distribution of both plants and animals which live within that territory.

OR-15. Diver on the edge of a tropical reef (Wuvulu, Papua New Guinea).

Often throughout the course of human history, we have thought we knew as much about the world as there was to know. And even more often, we have scoffed at new and innovative theories because they seemed contrary to the accepted wisdom of the day. But even today, we are constantly changing our concepts of how the natural world functions. A good example of this is the theory of continental drift. Alfred Wegner proposed the theory that continents have moved over the face of the earth, and he was ridiculed for his theory. In the early sixties his theory was confirmed, almost 50 years after he proposed it. Our quest for the Loch Ness Monster is a good reminder that the sea is still largely unexplored and surely holds many exciting discoveries for the future.

The Biological Ocean

BO-1. Brown algae, Egregia, on sandy bottom (Laguna Beach, CA).

This unit is the story of the biology of the ocean, from intertidal life out to the open sea, beginning with plants, and moving on to the largest creatures of the ocean. Algae are simple plants. There are three main types of large algae, brown, green and red. This plant is a close relative of kelp and it is a brown alga (the singular of algae is alga).

BO-2. Red alga, Calliarthron (Palos Verdes, CA).

Red algae are another type of marine plant. They may be delicate and fleshy, jointed and hard as is this one, or cement-like encrusting the bottom.

BO-3. Green alga, Codium (Laguna Beach, CA).

There are fewer types of green algae than reds or browns. They are also considered to be more primitive.

BO-4. Dinoflagellates, Ceratium (Southern California).

A very important group of plants is phytoplankton, one-celled plants which drift about in open water above the bottom. This organism is a dinoflagellate and is related to species which cause red tides. The other important subdivision of this group are diatoms which have shells of silicate, and comprise the substance of diatomaceous earth.

BO-5. Sponges (Roatan, Caribbean).

Sponges are the most primitive multicellular animal. They may be considered as an aggregation of cells. They have no digestive system, ability to move, or specialized nervous system.

BO-6. Acropora coral (Wuvulu Island, Papua New Guinea).

Corals, anemones, and jellyfish constitute the next group on the continuum toward greater specialization of body parts. This group has well developed muscles, nerves and a digestive system. Corals are important in the tropics where they create the structure of the coral reef community.

BO-7. Soft Coral (Wuvulu Island, Papua New Guinea).

Within the coral and anemone group called coelenterates, we find incredible diversity. These soft corals are colonies of individuals, just as are the corals, except that they do not secrete a hard skeleton around themselves.

BO-8. Hermit crab in a conch shell (Belize, Caribbean).

This shell is that of a queen conch. It is a snail and a representative of the mollusk group. Mollusks include octopi and squids, clams, tusk shells and chitons. Within the conch shell is a hermit crab. Crabs are arthropods, the joint-footed animals. Crabs, lobsters and a variety of planktonic forms are included in this group.

BO-9. Urchins eating kelp (Laguna Beach, CA).

Sea urchins are echinoderms, the spiny skinned group. Although they are more closely related to us than are the previous groups, they are relatively simple. These urchins are grazing on kelp. In some areas urchins can denude the bottom by overgrazing.

BO-10. Starfish in sand dollar bed (Laguna Beach, CA).

Starfish are also echinoderms, as are these sand dollars. Notice that the sand dollars are not white; they are pigmented and have tiny spines. Sand dollars along the coast of California stand on edge, unlike most other species.

BO-11. Goatfish (San Salvador, Caribbean).

Fish are vertebrates like ourselves. All the previously discussed animals were invertebrates; they lacked a vertebral column. These goatfish live in schools and forage over gravel and sand bottoms, tasting the substrate with their chin whiskers before eating.

BO-12. Squirrelfish (Antigua, British West Indies).

These squirrelfish are typical fish in that they have dorsal and ventral fins (unpaired), pectoral and pelvic fins (paired) and a single tail fin. Their bodies are covered with protective scales.

BO-13. Unicornfish (South Pacific).

There is much yet to learn about fish. For example, the function of the projection from the head of these unicorn fish is unknown. We know almost nothing about the life history of most fish, why they are colored as they are or their role in the ecosystem.

BO-14. Flatfish (Catalina Island, CA).

Although a flatfish begins life as a normal fish with eyes on either side of its head, at metamorphosis one eye begins to migrate to the other side of the head. Eventually the flatfish takes up life swimming and resting on its side and both eyes lie on one side of the head.

BO-15. Pufferfish (Antigua, British West Indies).

The pufferfish has scales modified into spines which are hinged such that they are erected when the pufferfish gulps water and inflates its body.

BO-16. Butterfly fish(Wuvulu, Papua New Guinea).

Many fish have false eyespots near the posterior of the body or a black bar through the eye, presumably to deceive the predator. But these butterfly fish appear to have camouflaged their faces completely.

BO-17. Toadfish (South Carolina).

The toadfish is well camouflaged. It lives in crevices and is very vocal. During the mating season the males make sounds not unlike a foghorn.

BO-18. Goby and shrimps (Wuvulu, Papua New Guinea).

No animal exists alone. All of those we have seen so far depend on others in one way or another for survival. In the case of this goby, it is the sentinel in its relationship with the shrimp. The goby does no work, it merely watches while the shrimp industriously digs. The shrimp constantly contacts the goby with its antennae, and if the goby is removed, the shrimp is reluctant to venture out.

BO-19. Diver with turtle (Wuvulu, Papua New Guinea).

Reptiles are the next advancement on the evolutionary tree of vertebrates. Marine reptiles include sea turtles, sea snakes and marine iguanas. They are all cold-blooded and air breathers.

BO-20. Sea gull (California).

Many birds can be considered truly marine animals. Gulls, pelicans, cormorants, and penguins are good examples of these warm blooded vertebrates.

BO-21. Walrus (Sea World, CA).

There are many kinds of mammals of the sea. Let's consider a few in increasing degrees of commitment to an aquatic existence. Polar bears have webbed toes and can swim for many miles in the open Arctic seas. Sea otters are more adapted to the sea while seals and sea lions are hardly functional on land; but they are still linked to land through the requirement to give birth on land. This walrus is in the sea lion family and uses its sensitive whiskers to help it feed on bottom dwellers.

BO-22. Dolphin (Sea World, CA).

The dolphin is the master of its medium; its body is streamlined, the nostrils have moved to the top of the head, it can communicate and maneuver by using sonar, and it can give birth at sea. It is considered a toothed whale andis placed in the same group as killer whales and sperm whales. The other group of whales is baleen whales, which use baleen to strain their food from the water, which is taken in the mouth in large gulps and then ejected through the baleen.

The Economic Sea

ES-1. Oil Island (Thums, Long Beach, CA).

Economics is one of the most important dimensions of the sea, and one that is often the least understood. There is no doubt that the sea is full of riches, but most of these resources are expensive to exploit and are vulnerable to over-harvesting. On a dollar basis the three most important ocean enterprises are military activities, oil exploration and recovery, and recreation.

ES-2. Kelp bed with schools of fish (Catalina, CA).

We can divide ocean resources into a number of categories: living and non-living, and renewable and non-renewable. Let's first consider the living or renewable resources. It is important to mention that renewable means that we must exercise careful management to insure that populations of plants and animals are maintained in sufficient numbers and state of health to provide food and products on a continuing basis.

ES-3. Kelp fronds with sun rays filtering through (Catalina, CA).

In the coastal ecosystem, kelp beds provide structure and habitat not unlike that of trees in a forest. They are home to lobster, abalone, and many species of fish. They are the fastest growing plant in the sea. These plants are regularly harvested along coastlines and provide an important chemical called algin, which facilitates the mixing of water and oil. This chemical is used in over three hundred commonly used products including salad dressing, medicines and paints.

ES-4. Kelp stipe with growing bladders and fronds (Catalina, CA).

Scientists are exploring the use of kelp, grown on massive ocean farms, as a source of both food and energy. To provide energy, the plants would be "digested" by bacteria, which convert the plant material into methane gas. We could then use the gas to generate electricity, or we could use it directly, as we do now, in gas stoves or ovens.

ES-5. Iridescent algae (Catalina, CA).

Marine algae may be useful in other ways. Many species contain chemicals which protect them from bacterial invasion and from various herbivores. These biologically active chemicals are potential sources of pharmaceuticals and a number of laboratories are experimenting with them.

ES-6. Jack mackerel (Anacapa, CA).

Fish are the most important marine food resource of the sea. These fish are swimming in a school which makes them easier for fishermen to catch.

ES-7. Commercial tuna boat (Los Angeles Harbor, CA).

The migrating schools of fish, like tuna, which live in the open sea, know no international boundaries. To catch tuna, U.S. fishermen often travel thousands of miles to waters off Central and South America. Thus international law and regulations are involved in commercial fishing. An international tuna commission regulates how many fish can be taken from these waters every year; in addition, much of the fishing grounds are in territorial waters and thus fishermen are subject to national restrictions and tariffs.

ES-8. Tuna on conveyor to cannery (Los Angeles Harbor, CA).

Many weeks after the tuna are caught, and thousands of miles away, the frozen tuna are processed in canneries. White meat is packed into cans while the bones, viscera, and dark meat are ground up for cat food or fertilizer. Waste from the cannery is being studied as a source of nutrition for farming fish and shellfish.

ES-9. Trawl catch being unloaded on a commercial shrimp boat (Hilton Head Island, South Carolina).

Shellfish is another important group of living marine resources. Here a trawl net is dragged along the bottom of shallow bays to catch shrimp, which are dumped aboard ship, and then separated from other species.

ES-10. Contents of net in previous slide, horseshoe crabs, small fish and assorted invertebrates (Hilton Head Island, South Carolina).

From this netload, only ten shrimp were found, and all the rest of the marine life was "trash." These fish and shellfish were thrown back--almost all of them will die. A better utilization of our living marine resources would be to avoid such waste, and instead to use this protein in marine protein concentrate. The animals could be ground up, fishy tasting oil could be removed, and the material could be dried into a powder. This protein concentrate would then be available to use as a supplement in many foods, including bread.

ES-11. Abalone farm (Cayucas, CA).

As demand increases for seafood and as natural stocks dwindle, we will be forced to farm the sea. This is a difficult and expensive enterprise and many attempts have failed in bankruptcy. In spite of this, success is becoming more frequent, particularly with shellfish such as oysters, clams and shrimp. This farm is providing young abalone to Japanese markets for consumption and for repopulating natural stocks along our coast.

ES-12. Abalone farm (Cayucas, CA).

Here baby abalone graze on algae which grow on the vertical plates hanging into the water. A six-inch abalone may require ten years to attain that size, which means that farming such species will be a slow and expensive operation. Such luxury food items will not help feed the hungry mouths of the world, but these luxury species are the only ones which can bring high enough prices to make it profitable. Such are the economic realities of mariculture.

ES-13. Oil well (Long Beach, CA).

Although oil is not specifically a marine resource, much of the world's oil comes from wells on the sea or its shorelines. Its exploitation is very much an ocean activity. Oil is a non-living, non-renewable resource.

ES-14. Oil drilling platform (Los Angeles Harbor, CA).

Drilling for oil at sea is an extremely expensive operation. Here a jack-up oil drilling platform is being readied to be towed off-shore. Once on site, the legs will be lowered to the bottom, and the platform will be jacked-up on the legs until it is above the water. After the structure is stable, drilling will proceed.

ES-15. Coastline oil wells (Soliman, CA).

Controversy surrounds the development of oil reserves as oil leaks, blowouts and spills affect the environment. The exploration of one resource, oil, negatively affects others, such as fish and shellfish populations, and recreational activities.

ES-16. Wave on a beach (Huntington Beach, CA).

Harnessing the power of waves is much less harmful to the environment than oil development, but much more difficult. Waves are a non-living, renewable source of energy. A number of different systems have been devised to capture wave energy, but none have proven successful. A major problem is the variability of waves, which requires that a system be able to withstand the extreme force of storm waves, yet retain the capability of functioning in small and medium surf.

ES-17. Manganese nodule (from North Pacific).

On the ocean floor, there is a vast mineral resource of manganese nodules. These baseball-sized rocks are rich in cobalt, nickel, iron and manganese. Manganese nodules carpet the deep sea bottom in some areas and are found only below about 10,000 feet; they form expansive beds.

ES-18. Glomar Explorer designed (partially) to dredge up manganese nodules (Los Angeles Harbor, CA).

Although the nodules are sitting on the bottom just waiting to be taken, exploitation has not yet begun on a commercial basis. It has taken a number of years and many millions of dollars to develop the technology to harvest the nodules from such depths. But, just as the equipment has become available, international problems associated with Law of the Sea have hindered progress. The essence of the problem is economics. Are those who have invested great sums of money in developing mining systems going to share the profits with all the countries of the world? On one hand, the nodules of the open sea beyond territorial boundaries are the common heritage of mankind, and thus all should benefit from their exploitation. On the other hand, all the countries of the world have not made the economic investment, nor shared the economic risk, of research and development. This very question is a major obstacle to progress in the Law of the Sea conferences.

ES-19. Container ship in harbor (Los Angeles Harbor, CA).

One of the oldest ocean enterprises is shipping. This is still a very important economic dimension of the sea, and the only means of transport for most international trade. Mechanized cargo systems and computer driven ships continue to facilitate trade.

ES-20. Tug boats (Los Angeles Harbor, CA).

Commerce requires many different types of craft. As ship traffic increases and the size of ships become greater, so does the risk of collision. The management of ports is an important aspect of ocean trade, and job opportunities in this field are expanding.

ES-21. Pirate ship (South Carolina).

Treasure in the sea has always been an alluring, but hardly realistic, thought as an occupation today. The loot which went down with the Spanish galleons and pirate ships is difficult to find, difficult to retrieve, and even more difficult to keep after one finds it, as a result of complex legal ownership problems.

ES-22. Scrimshaw on sperm whale tooth (personal collection).

Whaling is a thing of the past. As the number of ships increased and the sophistication of equipment increased, the populations of whales decreased. Nowhere else can the myth of the bountiful sea be shown so dramatically as in the history of whaling. A once thriving industry is now remembered only by the etchings on the teeth of its prey, an unfortunate testimonial to inadequate management.

ES-23. Sailboats in marina (Long Beach, CA).

Recreation is an important ocean industry; it is growing and for the most part does not deplete the resources on which it depends. There are conflicts, though, as we strive to maintain a balance between pristine wetlands needed by many species as a habitat and breeding ground, and the dredging and filling of estuaries for boat harbors.

ES-24. Sailboat (coast of southern California).

Sailing is an important form of ocean recreation.

ES-25. Marineland of the Pacific (Palos Verdes, CA).

Marine attractions provide a glimpse of ocean life, unavailable to all but the hardy.

ES-26. Diver with sea urchin (Antigua, British West Indies).

The only thing better than visiting an oceanarium is actually diving in the sea. Sport diving and dive expeditions are becoming important economic aspects of ocean recreation.

ES-27. Diver with banded coral shrimp (Roatan Island, Caribbean).

We must not forget that the ocean is more to us than a source of revenue. The intangible aesthetic benefits from a healthy marine environment are beyond the constraints of present economics; it is a source of inspiration of immeasurable value.

Marine Ecology

ME-1. Gorgonians - relatives of sea fans (Catalina, CA).

Ecology is the study of the relationships between different organisms and between those organisms and their environment. As we have mentioned, no organism exists alone, all living things are dependent on the cycles of matter and nutrients and the flow of energy through ecosystems, in which plants, animals, and bacteria are important parts.

ME-2. Intertidal zonation (Laguna Beach, CA).

Along rocky coastlines in temperate regions we find animals and plants living in distinct zones. This is called intertidal zonation and it serves as a graphic example of the influence of both biological and physical factors on the distribution of life. The whitish texture at the top of the slide is barnacles. They cannot live higher because they do not get enough exposure to sea water and they do not live lower because other animals out-compete them for space. Below the barnacles are the mussels; they are limited above because only the highest tides cover them, and below because they are preyed upon by starfish. Below the mussel zone is a dense bed of algae. The algae do not live higher because of the heat and drying effect of the sun and air. They do not live deeper because below the tide is the upper limit of sea urchins, which can graze on the algae in some areas. At each zone the dominant organism is limited by physical factors which result from the tidal cycle and resultant exposure to air. At the lower limit of each zone, biological factors limit the organisms. These types of interactions exist all over the face of the earth, up mountains, toward deserts, or deeper in the sea, but they are not as dramatic because the gradation occurs over a much greater space.

ME-3. Garibaldi with starfish (Catalina, CA).

This garibaldi male is protecting its nest from a starfish which could eat its eggs. The more we study the sea the more we find that involved relationships exist between organisms. In many cases the distribution of one organism is enhanced or limited by the distribution of another.

ME-4. Garibaldi attacking reflection in mirror (Catalina, CA).

Many fish are territorial and will attack their reflection in a mirror, presumably thinking it is another fish. Some fish have a number of territories: a large territory for species which may eat the eggs or compete for space, and smaller for other species which are less a threat, and very small for species which neither want food in the area nor want the space.

ME-5. Hermit crab "love-in" on the sandy bottom (Laguna Beach, CA).

To most people the sandy bottom is a biological desert, but a closer look shows a surprisingly diverse community. Here hermit crabs assemble periodically to swap shells. Since they grow, and since they use snail shells, they must find a new shell to accommodate growth. Getting together en masse has advantages for shell swapping as well as for reproduction. In the background is a bed of eel grass which serves as an oasis. The blades of this sea grass slow the currents and enable organic material to settle out and enrich the sea. The bed provides a habitat and source of food for residents.

ME-6. Gelatinous zooplankton, siphonophore (Wuvulu, Papua New Guinea).

The open sea is also considered by many to be a biological desert. Measures of productivity (photosynthesis) indicate it is comparable to many deserts. But here again, there are some fascinating organisms and some that are completely different from animals in all other ecosystems. This animal is a relative of the Portuguese man-of-war; it is a colony of individuals, and it stings like a jelly fish. It is transparent and extends a web of tentacles to ensnare other smaller planktonic animals. This siphonophore is about two inches long and is a part of an important group recently discovered called gelatinous zooplankton. These animals had not been appreciated before because they could not be captured intact in nets; diving scientists have brought them to our attention during the last ten years.

ME-7. Schools of goatfish and jacks (Cabo San Lucas, Baja California, Mexico).

Schooling is an important way of life for many fish and even invertebrates. Most fish of the open sea are schoolers, and many like these goatfish (pink) and jacks (silver) which live along coastlines also school. Among the advantages to this relationship are protection from predators by such a great mass of fish, proximity for reproduction, communication in feeding (when one begins to feed the others also begin), and more eyes to see food or predators.

ME-8. Mangroves (Hermit Islands, Papua New Guinea).

Mangroves are the woodlands which have adapted to the sea. These trees actually create land; as their prop-roots grow out into the water and extend the tree, water movement is slowed, and sediment accumulates, building up the land. The leaves which fall provide organic matter to enrich the waters and create a more productive environment. Mangroves are primarily a tropical ecosystem; their temperate counterpart is the Spartina marsh.

ME-9. Mangrove prop-roots (South Pacific).

In addition to the nourishment mangroves provide to the waters, they are important as a nursery ground and habitat for the juveniles of many species of fish. The things hanging down are prop-roots from the mangrove branches above the water. These are the roots which grow out and extend the tree.

ME-10. Coral reef (Belize, Caribbean).

Let's take a closer look at the coral reef and examine its functional parts, paying particular attention to the components of the system which are analogous to our human system. By studying how the reef ecosystem solves its problems, we may find insights to solving our problems. This may be possible because all communities face the same problems, whether human or natural; they must obtain energy, deal with waste, allocate space which is usually limited, and house a variety of inhabitants, all of slightly different occupations and life styles.

-- The following slides will compare a coral reef to a human community.

ME-11. Close-up of a coral with green zooxanthellae (Caribbean).

An essential part of the reef ecosystem are the tiny one-celled plants which live within the corals. These plants allow the coral to make food and be a closed system where the waste from the animal is a resource for the plant and the food of the plant can be used by the coral in an endless cycle. This is very efficient and allows the coral to grow rapidly and create the massive reef structure we see today. The green color in the photo is due to the green plant cells in the coral, the small white dots are the mouths of each individual of the colony.

ME-12, ME-13. Farmland (California).

In our communities we produce food at some distance from the city. In the reef system the corals, with their plant symbionts, produce food right in the center of the city.

ME-14. Corals carpeting the bottom (Wuvulu, Papua New Guinea).

These coral colonies are creating the structure of the reef. They take calcium out of the water and make calcium carbonate skeletons around themselves. It has taken billions of coral polyps millions of years to create the reefs we see today in the South Pacific. Some of these reefs rise up thousands of feet from the deep sea -- they are the greatest structures on earth created by living organisms.

ME-15, ME-16. Pillar Coral (Antigua, British West Indies).

These coral colonies grow upward, increasing their surface for catching food and receiving sunlight. They almost look like tall buildings in a city. In both communities space is limited and growth is only possible upward.

ME-17, ME-18. Tall buildings in cities (New York, Los Angeles).

Like the structures in the reef community, upward growth provides a greater space for residents. Notice the similarity in appearance between the coral colonies and the buildings.

ME-19 ME-20. Trash (California).

We are not effective at recycling materials within our system. We only partially use things and what is left over accumulates unused and unusable, for the most part. We call this waste.

ME-21. Sewage treatment facility (Los Angeles, CA).

At this sewage treatment facility we collect the waste from the City of Los Angeles and concentrate it. We reduce some of the organic material to nutrients and some of it settles out as a very highly concentrated organic semifluid. This treated sewage is pumped out to sea.

ME- 22, ME-23. Dead mussel and dead fish (Los Angeles Harbor, CA).

When we release high concentrations of nutrients and organic material into the sea, we stimulate plankton and bacterial growth. If growth is excessive, the organisms may consume all the oxygen, and as a result marine life suffocates. Organic material and nutrients are not necessarily bad: good or bad depends on the concentration.

ME- 24, ME-25, ME-26. Fecal pellets on a sandy bottom (California, South Pacific).

In the sea, waste is not concentrated and then dumped. In fact, the word waste is not really appropriate. Here, waste and resources are really synonomous. As fecal material and dead organisms fall to this sandy bottom, they are consumed by bacteria and small organisms, which are then strained from the sand by worms and sea cucumbers. The waste is so dilute that it does not overtax the system and sufficient oxygen remains to keep the system healthy. These fecal pellets from worms and sea cucumbers are mostly sand. They will soon disperse as part of the recycling process in the sea.

ME-27, ME-28. Sponges (South Pacific).

Much of the waste in the reef is small particles of organic matter. This is a source of nutrients and energy which should not be lost from the reef. As this organic material falls into the small cracks and crevices of the reef, sponges filter the water and extract this resource.

ME-29, ME-30. Colonial and solitary sea squirts (South Pacific).

These sea squirts provide a service to the reef community not unlike the sponges. They are the water conditioners and purifiers. They remove organics from the water and at the same time draw water into the interior of the reef, providing oxygen to help bacteria and other organisms convert organics into nutrients, which can then be used by plants. Water is pumped inside the bodies of these tunicates (sea squirts), then passed across the gills, where oxygen and food is retained and then pumped back out.

ME-31. Feather duster worm (Caribbean).

This feather duster worm is like the sponges and tunicates in that it captures small organic particles. To it, one organism's waste is a resource, and its waste in turn becomes a resource to others in the reef system.

ME-32. Queen trigger and jack (Caribbean).

As in a city, reef inhabitants interact on many different levels. Here a jack is using the queen triggerfish as a shield, so small reef fish will not suspect a predator is approaching. The queen triggerfish does not feed on fish so when the fish see the triggerfish they do not flee. By hiding behind the triggerfish, the jack can get closer, then dart out from behind its decoy to catch a meal. This is a commensal relationship -- one benefits while the other is neither helped nor harmed.

ME-33. Creole wrasses being cleaned (Caribbean).

Another important type of relationship is called mutualism. These creole wrasses are hovering, head down, soliciting the services of small yellow cleaner fish. This head down posture signals the cleaners that they can come up to pick off parasites and diseased tissue from the host. These fish are the doctors of the reef, an important difference from our doctors is that they work for free. In mutualism, both partners benefit.

ME-34. Grouper with isopod parasites (Caribbean).

This grouper is host to two isopod parasites. Parasitism is the third type of symbiotic relationship, where one member benefits and the other is harmed.

ME-35. Two fish in a worm tube (Caribbean).

On reefs there is a housing shortage. In some spaces in a reef, one fish may occupy a space during the day and a different fish may rest there at night. The space shortage results in vigorous competition with many species being territorial.

ME-36. School of goatfish (Caribbean).

Many fish of the reef school often rest as a group during the day, then forage over the reef for food at dawn and dusk. These goatfish use chin whiskers to taste the bottom and explore the sand in search for food.

ME-37. Goatfish with night coloration (Caribbean).

At night some goatfish separate from the school and rest singly. They also put on their pajamas, or change to this red phase. The function of this color change is not known.

ME-38. Butterfly fish (South Pacific).

As we mentioned above, there is a shortage of space on the reef just as space is limited in a city. This results in vigorous competition with many species being territorial. This butterfly fish will attack its reflection not with its mouth but by thrusting its dorsal spines at the presumed intruder. Some fish like the surgeon fish attack their reflection with a sharp spine at the base of the tail.

ME-39. Sheet of coral growing over other corals (South Pacific).

Fish are not the only reef inhabitants competing for space. Scientists have recently discovered that corals compete. Some of the slower growing corals can extend digestive filaments out to an adjacent coral and digest it, preventing the other coral from overgrowing it. Fast growing corals avoid the problem by growing up and over those species with the digestive filaments. Each strategy is partially effective, because these corals can coexist.

ME-40. Elkhorn corals growing upward (Caribbean).

The reason corals compete for space is primarily to increase the amount of sunlight they receive. The sunlight is necessary for the survival of the plant cells living within the coral, and without the plant symbionts, the coral will die. Thus an animal, the coral, behaves and must face some of the same problems as a plant. Notice how these elkhorn branches appear to be reaching up for more sunlight.

ME-41. Coral flattened on top (South Pacific).

This coral is another graphic example of how the morphology of the colony is adapted to maximize its surface for the capture of sunlight. In a sense the coral animals are farmers, cultivating their crop on the roof tops. They recycle nutrients within the same structure and need not face the problem of waste, since the byproduct of one process is needed as a resource for the other process and so on.

ME-42, ME-43. Garden on a roof top (Southern California).

Possibly we should take notice of the coral reef and also farm on our roof tops. Possibly we should emphasize a form and function relationship as we design human communities. Possibly we should treat what we now call waste as a resource, taking for example the organic component of sewage, drying it, and using it for burning as a source of energy; taking the nutrients and using them for fertilizer; and taking the water out of the sewage and using it for irrigation. There are many options, but it is obvious that our system does not function as effectively as the natural system and that we could use innovative designs to make the best use of space and material resources.

ME-44. Wave on a beach (California).

This slide series is designed to inspire the educator to use our curriculum material, add to it, and to share ideas with other educators. The sea is not the exclusive domain of science: We have a rich ocean tradition and heritage, the subjects of economics and management are where the action is today, and in one way or another we are affected daily by the sea, whether through our weather or the products we use. The ocean is fun, it is exciting, and it can be used to teach almost any subject in the curriculum.