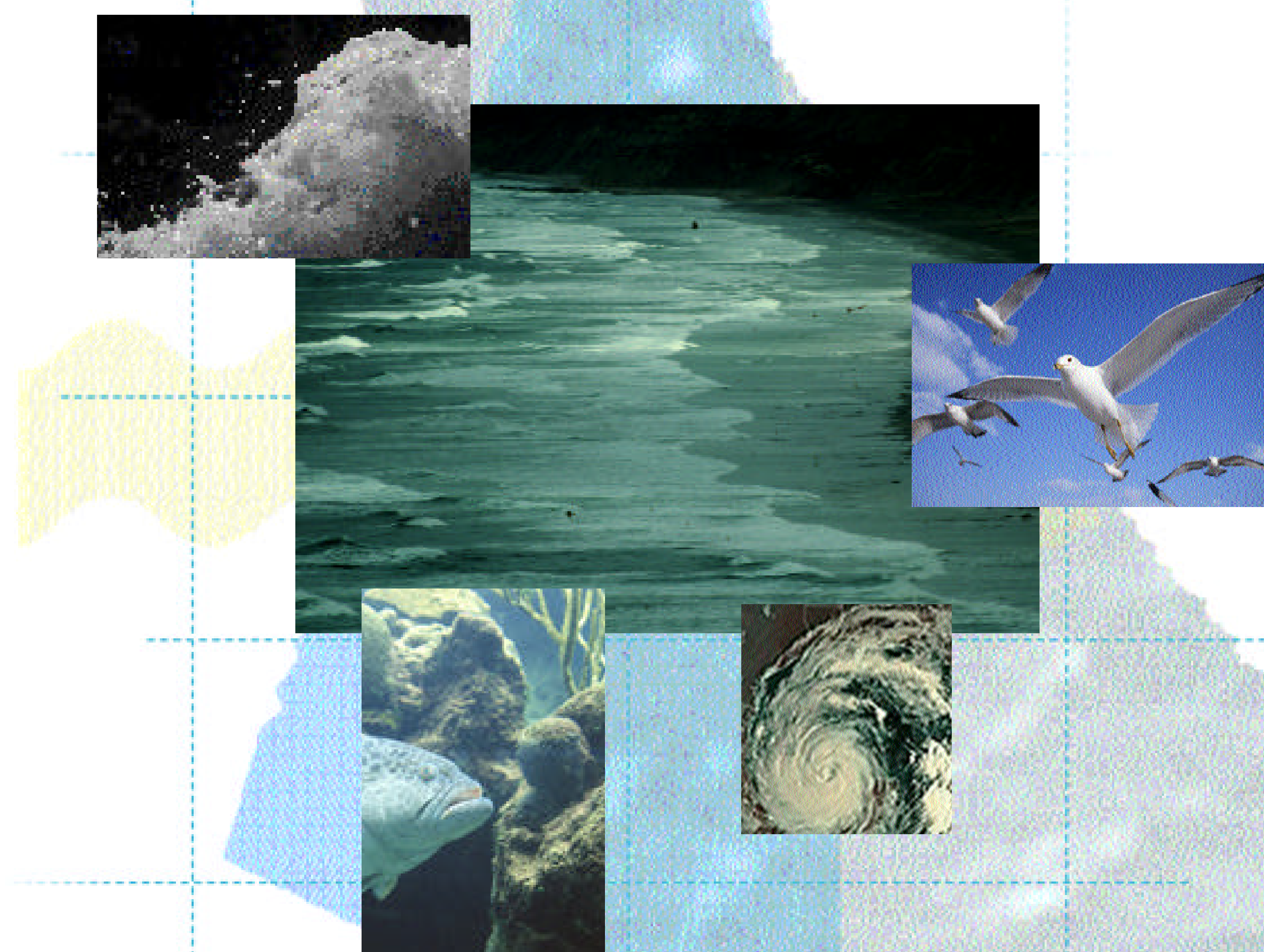
OCEANS



Into the Next Millennium of Oceanographic Research

NOAA
Office of Oceanic and Atmospheric Research
1315 East-West Highway
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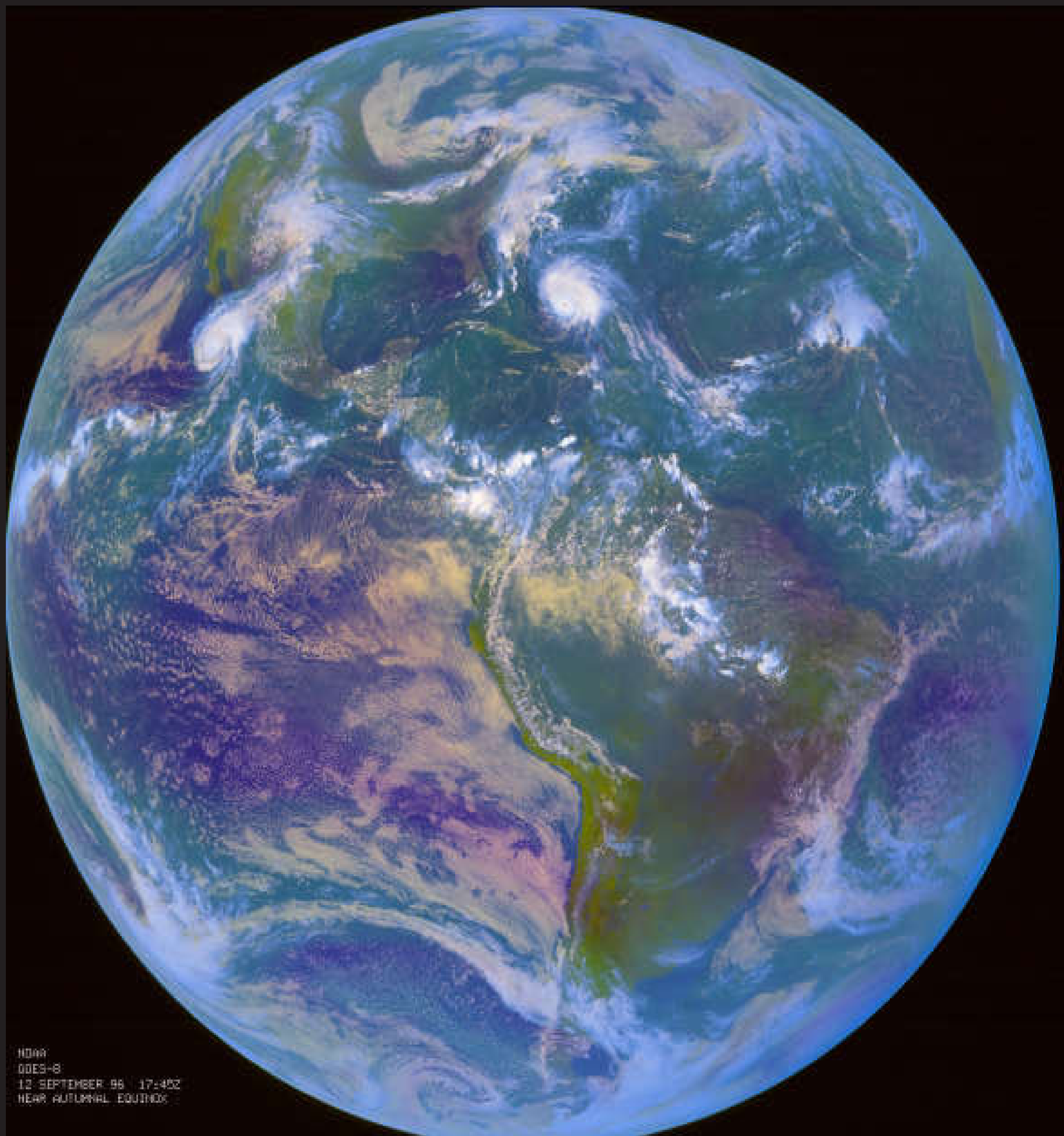
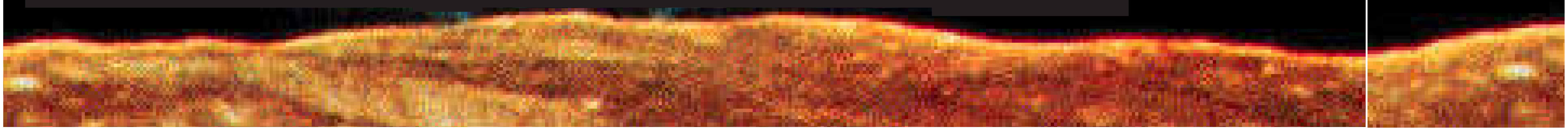
Oceans



Ours is the only known living planet, and its life is derived in large measure from its oceans—it is a water planet. When viewed from space, the oceans are a most distinctive feature; covering more than 70 percent of Earth's surface, they color the planet in rich blue-green hues.

We are only now beginning to understand how unique and different from each other the oceans are. From oceanographic research, we recognize that they play a critical role in regulating Earth's weather and climate, house extraordinarily diverse forms of life, and have a significant influence over the creation and ever-changing formation of the land. However, despite more than 100 years of oceanographic exploration, we are still only paddling at the surface of this immense resource. It is a powerful reality that knowledge of the oceans, their resources and their relationship to human activities is vital to our society's—and our world's—existence.

. . . An Overview



Why is Our Knowledge of the Oceans Essential to Humankind?

We are Frequently Unaware of How Significantly the Oceans Affect Us.

The oceans are vast—they constitute 70% of the earth's surface. Although we often think of the coasts as being "the ocean," in fact the average depth of the oceans is about 4,000 meters—roughly 2.5 miles. Only about 14% of the sea bottom is continental shelf (the continental edge, less than 130 meters deep).Besides regulating weather and climate, the oceans serve as a vital source of food, minerals, and pharmaceuticals; receive many waste products; offer means of transportation; and provide us with recreation and enjoyment.

As global population grows, it exerts more and more pressure on the oceans and their resources, significantly threatening the stability of marine ecosystems. In the United States alone, coastal populations have more than tripled since the 1940s, and it's estimated that 75% of our population will reside within ten miles of a coastline by the year 2010. That is why, in addition to improving our management and continued use of oceanic resources, it is critical that we improve our understanding of, and response to, potential dangers to the coasts. Coastal storm surges, dangerous flooding, significant erosion, and hazardous material spills have a tremendous impact on our lives and safety as well as the oceans' fragile ecosystems.

Oceanography: Our Eyes Under Water

Through the scientific discipline of oceanography we study and explore the oceans and their phenomena. The goal of oceanographic research is to provide a clear and systematic description of the oceans leading to accurate prediction of oceanic events and processes so that we will be able to predict oceanic behavior with increasing certainty.

As a science, oceanography is segmented into four major disciplines:

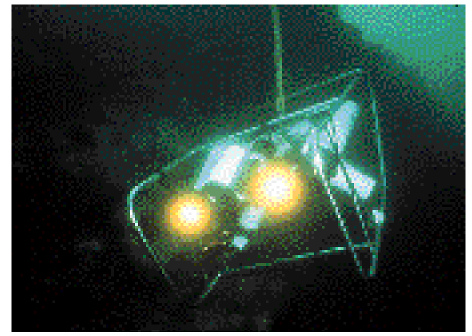
Physical Oceanography—the study of the properties and movements of sea water

Biological Oceanography—the study of marine plants, animals, and bacteria

Chemical Oceanography—how and why the chemical elements in the seas occur, their interactions with each other and with the atmosphere and land

Geological Oceanography—the study of the earth's crust beneath the sea and the coast, their development, and interpretation of earth and oceanic history from the rocks and sediments.

Although the major oceanographic disciplines can be defined and to some extent studied individually, oceanography is an integrated science in which all factors interact.We have come to realize that to understand and explain how marine resources and phenomen aoccur, we must take a broad, system-oriented approach. Nowhere is this more important than in studies of living resources, in which organisms must be viewed as part of a larger whole, the ecosystem, which is composed of all organisms within a physically defined region of the sea.



A small Remotely Operated Vehicle (ROV) being lowered to its operating location.

Long-term oceanographic observations are paramount to our ability to understand, describe, and predict climate variations and determine the potential impacts by humankind on climate.

Total insured losses produced by Hurricanes Andrew, Hugo, Iniki, and the winter storms of 1993 and 1994 were $24.7 billion.

How do the Oceans Influence Our Weather and Climate?

First, two quick definitions:

Weather—the state of our atmosphere at a given time and place occurring over periods of minutes to weeks (e.g., temperature, pressure, moisture, wind velocity, etc.).

Climate—the weather or atmospheric conditions that prevail in a particular region as measured over seasonal to centennial and longer time periods (e.g.,averages of temperature, precipitation, wind velocity, etc.).

To understand how weather and climate are influenced by the ocean requires an understanding of the Earth's heat budget: The primary source of heat to the Earth's surface is visible radiation from the Sun. Most of this heat is absorbed at the surface (principally in tropical regions) and is then redistributed by oceanic currents and atmospheric winds. The remainder is radiated back into space in the form of infrared radiation. This redistribution of heat over the Earth's surface is the driving force of weather and climate. Compared to the atmosphere, the denser and slower moving ocean waters have a much greater capacity to store heat energy. The longer the time period, the greater the effect of the ocean on weather and climate. Generally, over short periods of time only sea surface temperatures are involved. But over seasons and years, the upper layers of the ocean (as much as several hundred meters), begin to exert a stronger influence. On time scales of decades and longer, the entire ocean is involved, creating a major impact on our planet's weather and climate system.

As the Sun heats the ocean's surface, evaporation releases water vapor into the atmosphere. More than half of the total water vapor content in the lower atmosphere is supplied by the tropical oceans between 30˚N and 30˚S latitudes. During evaporation, the ocean loses energy stored in the water vapor which serves to fuel atmospheric motions. (As water vapor condenses into liquid droplets, stored energy is released in the form of heat.) Over thousands of miles of ocean surface, a tremendous amount of heat is released to the atmosphere. This heat supplies the energy for hurricanes, middle-latitude cyclones and thunderstorms; illustrating the importance of the oceans in understanding weather.

Over the past decade, tropical cyclones and other coastal storms (such as Nor'easters off the east coast of the United States) have been responsible for billions of dollars of damage around the globe. Recently, hurricanes Hugo, Andrew, Opal and Fran together produced almost $28 billion in damage. As coastal development and population continue to increase, so will storm damages. To reduce risks to life and property, we need to better understand the formation and intensification of tropical cyclones and other coastal storms. In part, this depends on our knowledge of sea surface temperatures.

Tropical cyclones only form over the ocean where sea surface temperature exceeds approximately 27˚C (80˚F). Here, the warm, moist air provides the necessary fuel which—when combined with the right atmospheric conditions—forms massive storms. Warm, moist air fuels middle latitude storms as well. A storm traveling across the ocean, or along the coast, is greatly influenced by local sea surface temperatures. While it remains over warm water, a storm continues to have a ready energy source and will either maintain its strength or intensify. However, if it moves over cooler water (or land) the storm will become energy-starved and weaken.

Dramatic Climate Fluctuations: The El Niño-Southern Oscillation Phenomenon

The effects of an El Niño—Southern Oscillation (ENSO) event on our world society can be dramatic. Commerce, agriculture and industry all depend on normal seasonal changes. When these are altered by an ENSO phenomena, the increased rainfall, flooding and droughts lead to human suffering and economic disruptions with damages running into the billions of dollars. But what is an El Niño event?

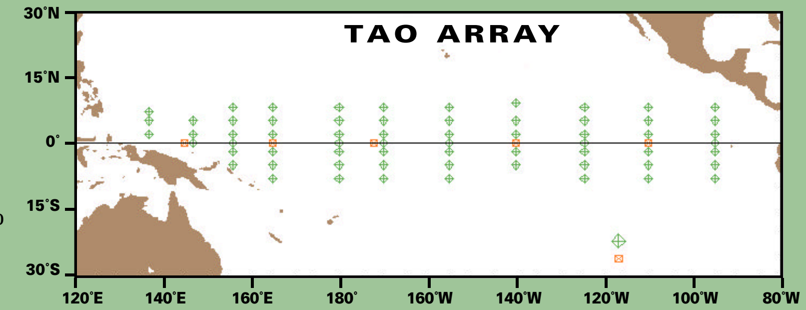
Severe erosion from El Niño storms endangers people and damages property.

El Niño is an unusual warming of the upper acean in the tropical Pacific. With the Southern Oscillation (a see-saw-like fluctuation in sea-level atmospheric pressure between regions near northern Australia and the central Pacific) The surface currents associated with the trade winds are deflected away from the equator by the earth's rotation. As this surface water moves away, it is replaced by colder, nutrient rich water that "upswells" from below, providing nourishment to support high production of marine organisms. Upswelling also occurs along the west coast of the United States and the coasts of Peru and Ecuador, and is responsible for the existence of numerous fisheries.

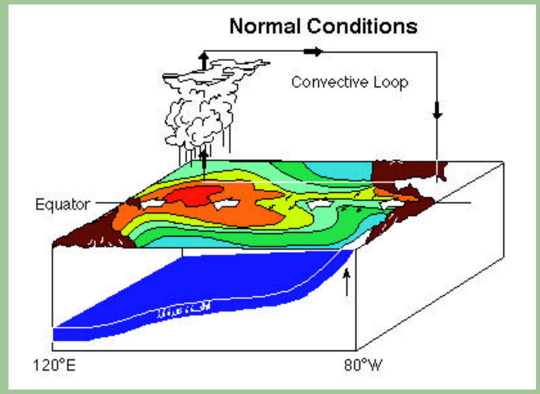
Prior to 1985, our understanding of the El Niño—Southern Oscillation was very limited. Oceanic observations were scarce and we were only beginning to understand the coupled ocean-atmosphere system. One of the largest ENSO events of the century occurred in 1982, yet we did not recognize it until it was already well underway. Since then, we have improved our ability to observe and predict the ENSO by collecting data (using buoys, ships, and other means) on oceanic and atmospheric phenomena such as surface winds and the thermal and velocity structure of the upper ocean.

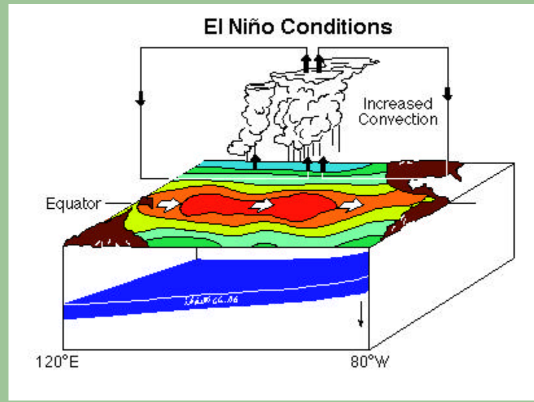
By incorporating these data into numerical climate models, we greatly improved our predictive capabilities. For example, we were able to forecast the warming events that occurred in 1986, 1991, and more recently 1997, and have demonstrated the ability to predict sea surface temperatures in the eastern Pacific up to a year in advance. We now know that the ENSO occurs periodically, but do not know if there is a recurring pattern. Predicting an El Niño at least six months in advance, with 60% probability could save billions of dollars for our global economy. The United States, Peru, brazil and Australia have already used these predictions for agricultural and water resource planning.

Although we have accomplished a great deal over the last decade, numerous questions about the ocean's role in global interannual variability remain unanswered. Unlike sea surface temperature, the long-term variability of other basic quantities such as surface and subsurface currents, and subsurface temperatures, remain largely unknown and will require many more years of observations before thay can be characterized. The nature of interannual variability in the Atlantic and Indian Oceans has yet to be fully investigated. As weather forecasting models become more sophisticated, the observing systems that provide the initial data will need to be re-evaluated and refined in the future. We still need to determine which of the upper ocean variables are most important for improving forecast, and insure that routine observations are made.

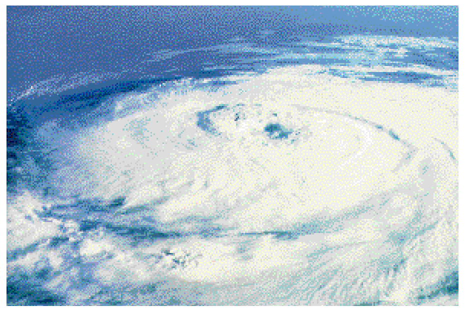


Map of buoys forming the Tropical Atmosphere Ocean (TAO) observing system that provides on-line data about weather and ocean conditions across the equatorial Pacific.

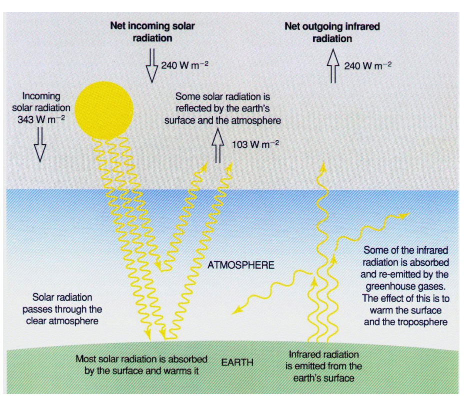




Normal (top) and El Niño condition. El Niño conditions include a reduction in the trade winds, an increase in sea surface temperatures, a reversal of surface water currents (white arrows), and a shift towards the east of rainfall.



The cyclonic nature of a tropical hurricane is clearly visible in this photograph.



The "Greenhouse Effect": incoming energy from the sun penetrates the atmosphere and heats the surface of the Earth. The warmed surface releases heat in wavelengths that are absorbed by CO_2 and other gases in the air. Only a small amount escapes back into space when large amounts of these contaminants are present: the rest is trapped, leading to a warmer Earth.

Beyond Our Knowledge of the Spatial Distribution of Sea Surface Temperatures.

Currently, we rely on very sophisticated numerical models to predict the formation, path,and intensity of tropical and middle-latitude coastal storms. These models require timely and accurate observations of specific atmospheric and oceanic variables, including sea surface temperature. In the past, observations of sea surface temperatures were made by ships at sea. While adequate for some purposes, for weather forecasts these observations were too scarce in both time and space to provide much useful information. Today, however—through the use of satellite sensors—we measure sea surface temperature on a global scale at a resolution of just a few kilometers; providing essential data for use in weather prediction.

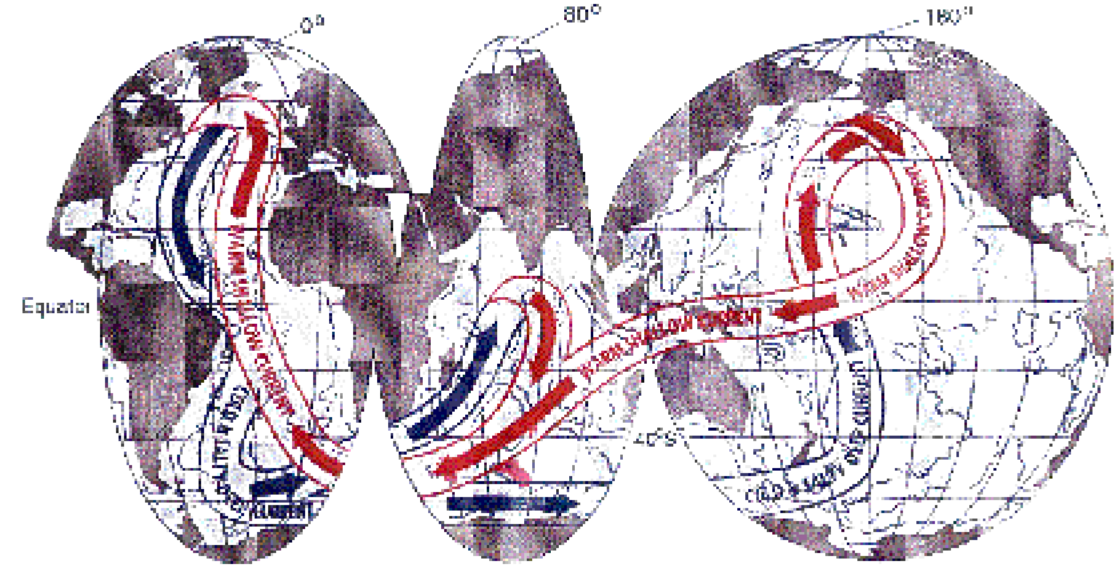
While this new high resolution data fills an important observational gap and contributes significantly to the improved predictive ability of today's forecasting models, many questions remain. For instance, what role do nearshore sea surface temperature variations play in the path and intensity of tropical cyclones? Why is the critical temperature for cyclone development between 27˚and 29˚C (roughly 80–85˚F)?

Changes in the composition of the atmosphere from human activities can affect climate.

Since the dawn of the industrial revolution in the late 18th century, the amount of carbon dioxide (CO2) in the atmosphere has increased by about 1/3; this increase is affecting our climate. Carbon dioxide and some other gases absorb infrared radiation from the Earth's surface and trap heat within the atmosphere. They are commonly called "greenhouse gases" because the heat is trapped within a relatively closed system, much like a greenhouse. Over the past few decades this trend has accelerated, owing to growth in both global population and energy consumption, and it is predicted to continue. Because atmospheric CO2 tends to warm climate, rapid increases in CO2 could mean increased temperatures on a time scale of centuries. Fortunately, the oceans—in addition to storing tremendous amounts of heat—are also the primary storage for dissolved carbon dioxide from the air. By absorbing heat and atmospheric CO2, the oceans tend to buffer the atmospheric temperature increase.

What is the Role of Oceanic Circulation?

In tropical regions, increased solar heating and evaporation produce surface waters that are both warm and salty. As these waters are carried towards the poles by surface currents, they lose heat to their surroundings and begin to cool. In higher latitudes, precipitation and river run-off have diluted local surface waters. As these saltier waters from the south cool, they become denser than their surrounding waters and begin to sink. This process is more pronounced in polar regions where very cold air temperatures and the formation of ice can significantly lower surface temperatures and increase salt content, resulting in extremely dense water. This cold, dense water sinks and enters into the



Through the oceans, water circulates globally. In the North Atlantic, colder water sinks to the deeps to resurface and be rewarmed in the Indian and Pacific Oceans; surface currents then carry the warmer water back to the North Atlantic, where the cycle is repeated. The circuit takes almost 1000 years to complete.

circulation of the deep ocean, taking heat and greenhouse gases away from the surface and out of contact with the atmosphere for hundreds to thousands of years. Eventually, these deep, slow moving currents re-enter surface circulation (primarily in the North Pacific) where they are again exposed to the atmosphere and begin the process again.

Despite years of research and refinement, representation of ocean climate processes on a global scale by today's models is still crude. Long term oceanographic observations are needed for us to understand, describe, and predict climate variations and determine the potential impact by humankind on climate. Over the past decade, we have collected information from all over the earth and established observing stations throughout the ocean. Data from these will provide us with more accurate estimates of CO2 absorbed and stored in the seas, as well as improve our understanding of variability deep in the oceans.To extend the observational record over much longer periods, we use oceanographic data from chemical analyses of deep-sea sediments, ice, and corals; allowing reconstruction of the global history of climatic and environmental change. Accurate recreation of past events improves our ability to predict future oceanographic and climatic conditions. For example, coral structure contains information on the seasonal variability of sea surface temperature, salinity, nutrient content and other trace elements; air trapped within Greenland and Antarctic ice provides insight into past CO2 levels. These and other sources yield information concerning past changes in sea level, evaporation, precipitation, and biological productivity.

Until We Understand How Natural and Human-caused Changes Affect Reef Growth and Survival, We Can Hardly Change Our Behavior To Minimize Its Harmful Effects.

What Can Be Gained From Knowledge of Our Past?

Comparison of recent observational data with historical records shows large-scale variability in ocean properties over decades; we are just beginning to understand the role of the ocean in global climate change. A few of the many questions that must be addressed in the coming decade are: What is the extent and structure of global interannual, decadal, and centennial climate variability? How has this variability changed over time? What is the response of the ocean to atmospheric forces and how is it reflected in sea surface temperatures and salinities? What is the nature of tropical-extratropical interactions? The answers will depend upon continued observations and careful modeling, and will determine how we manage fossil fuels, pollution, and other human activities that affect climate.

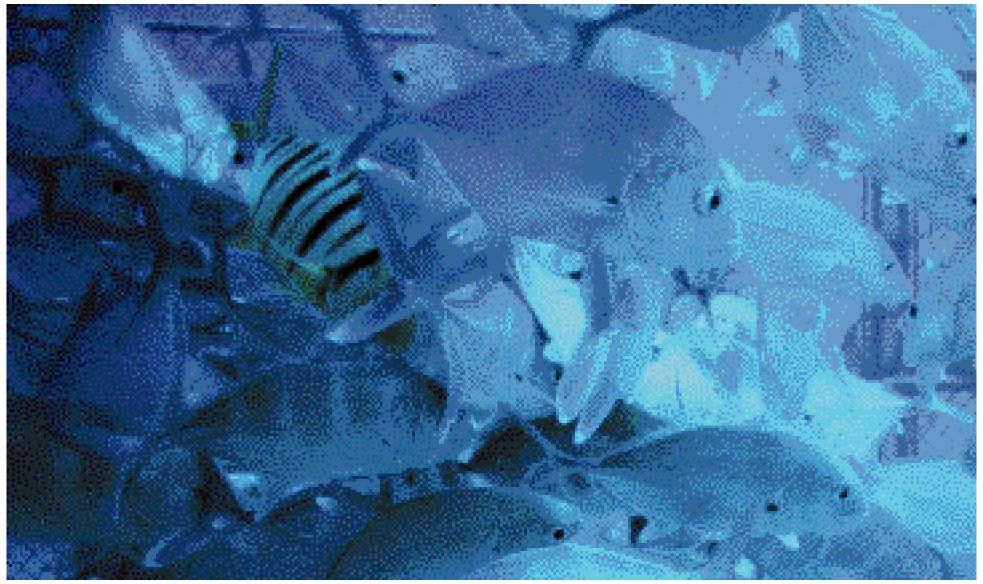
Preserving Biodiversity is Essential to the Future

How Do Oceans Contribute to Earth's Biodiversity and Natural Resources?

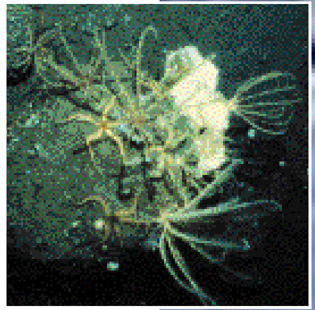
Biodiversity is the collection of gene pools, species, and ecosystems occurring in a geographically defined region. Oceanic life is much more diverse than life on land: oceans provide living space for more species and for more different groups of animals and plants than Earth's terrestrial environment, which lacks the many exclusively marine groups. Life on land lives in an essentially two-dimensional environment (no organisms live their lives entirely in the air), but the sea has a full three dimensions. Marine organisms are also more different from one another than are land organisms. Although the land has more known species—it is difficult to collect oceanic organisms and the land is much more completely explored.

Because of the difficulties sampling the oceans, vast areas of the seas have never been explored. Despite more than 100 years of oceanographic exploration, previously unknown species are routinely being discovered. In the deep sea alone, there may be as many as ten million unknown species. It's very clear that our oceans, which cover two-thirds of the Earth's surface, contribute at least half of our planet's biodiversity.

The natural resources of the sea were (like those of the land) long considered to be inexhaustible. While the limits of terrestrial resources have been recognized for some time, those of marine resources, until recently, have not. Through both the increasing size of our population and our actions, we are making a destructive—and potentially permanent—impact on life in the seas. Today, the great majority of commercially valuable fishes and invertebrates are either overfished or at their maximum yield capacity. Human activities such as pollution and the introduction of non-native species are causing often permanent disruption or destruction of native animal and plant communities.



The ocean is an important food source; for some people it is their only source of protein. However, it is not inexhaustible.



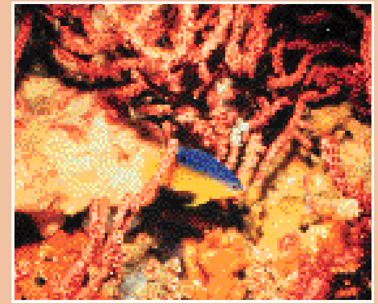
Why is preservation of biodiversity important?

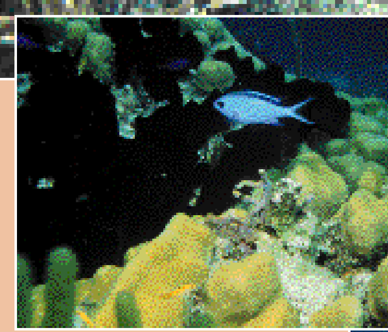
Biodiversity is important, and the loss of any species is significant, although we may not know how or why at the time. Every species is the survivor of hundreds of thousands (or millions) of years of evolutionary adaptation. When one species becomes extinct, the qualities that allowed it to survive and flourish are lost with it, and survival of species that depend upon it are also put at risk. There are two kinds of biodiversity: variability within species and between species. The first is important because it provides the best chance for adaptation by a single species to environmental change; similarly, the second provides the best chance for an ecosystem to adapt to environmental change. We depend upon other living things to provide the conditions under which we flourish, including clean air and water, food, medicines, and raw materials, and we depend upon living organisms to provide beauty in our lives. Every loss affects us: by causing reduction in the capacity of other species and ecosystems to adapt to change, we increase the risk of significant change to our quality of life.

We are causing potentially irreversible changes in the biological diversity of marine organisms.

Activities contributing the most to these changes are: commercial fishing, chemical pollution, physical alterations to the coasts, invasions of non-native species, and global climate change. The result is a serious decline in the abundance of most species of preferred edible fish and shellfish, reductions (or the

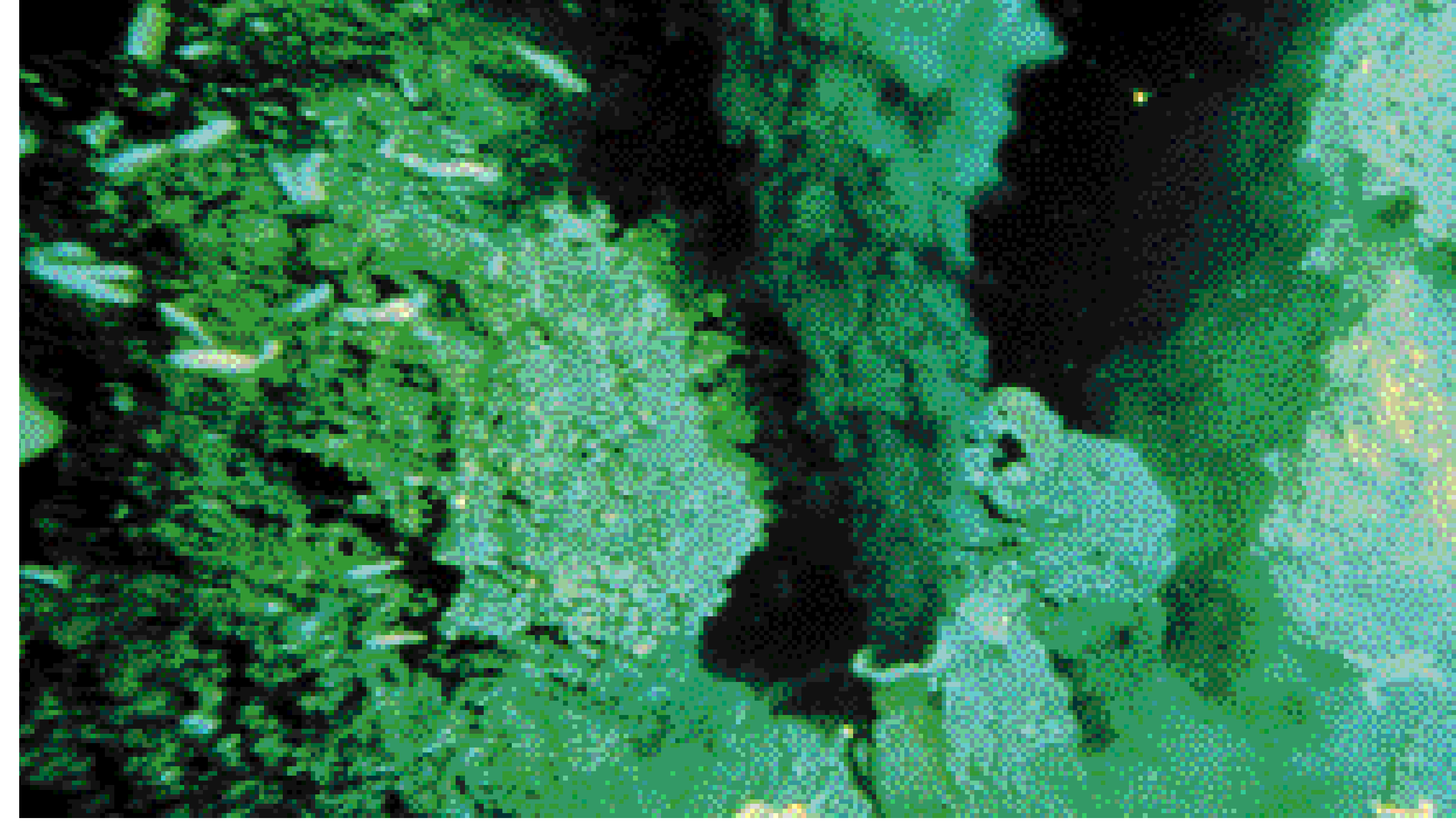
The Precipitous Decline of Our Coral Reefs





Coral reefs evolved over millions of years and are an extraordinary reservoir of marine biodiversity. Reefs include coral communities, sea grass beds, and mangrove forests in over 100 countries worldwide. They support almost a million species (including 25% of all fish species), protect coasts from erosion and storm surges, provide sources of food and medicines, act as recreation areas, and provide nursery areas for the young of many species. Today coral reefs are declining at a precipitous rate.

More than two-thirds of the world's reefs are dying. The decline is being caused by such things as: dynamite and cyanide fishing, chemical pollution, siltation from sediments carried by freshwater runoff from nearby land, and climate change. Pollution is a major threat: sewage, fertilizers, and sediment from coastal development, deforestation, and agriculture kill reef organisms. Estimates suggest that 10% of coral reefs may be beyond recovery and 30% are in critical condition and may die within 30 years or less. There are abundant examples demonstrating the damage to reefs from human activities. Until we understand how natural and human-caused changes affect reef growth and survival, we can hardly change our behavior to minimize its harmful effects. Unfortunately, we have little time remaining before irreversible changes occur.



A "black smoker" hydrothermal vent and some of the animals (white objects on left) living near it.

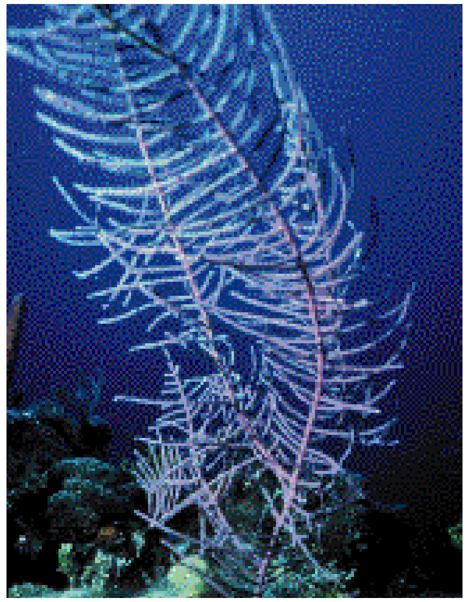
total loss) of species with biotechnological potential, reduced esthetic and recreational value of coastal habitats, unpredictable and serious changes to the structures and functions of ecosystems, and potentially harmful affects on human health and well-being.

It will not be easy to reduce and correct the changes we have caused. Before we can accomplish those objectives, we must improve our ability to predict the effects of our activities on the environment. Although we are making progress (such as our improved understanding of El Niño and fisheries), much more research is required: to understand the contribution and role of each species in its ecosystem and the effects of its reduction (or removal); to understand the linkages between physical oceanographic phenomena and biodiversity; to improve our ability to identify the millions of presently unknown species and their roles in ecosystems; and to develop new technologies, research and analytical methods, and predictive models.

Life Without The Sun

In 1977, scientists on a deep-dive expedition to study mid-ocean ridge processes near the Galapagos Islands discovered hydrothermal vents surrounded by large communities of completely unknown and unsuspected animals, living without benefit of energy derived from sunlight. Rather, they survive on a food chain based on bacteria that use sulfur and other elements included in the outflow from the vents. They also live in an environment of very high pressure (over 4,000 pounds per square inch) and high temperature (more than 300˚F). The vents may be widely separated and some are known to last only a few years. These organisms have developed unique metabolic and physiological capabilities that not only ensure survival in a great variety of extreme habitats, but also offer the potential for the production of metabolites which would not be observed from terrestrial microorganisms. It's possible that they are a major biomedical and

We Frequently Don't Understand and Are Usually Unable To Predict What Determines Recovery and Whether It Will Occur.



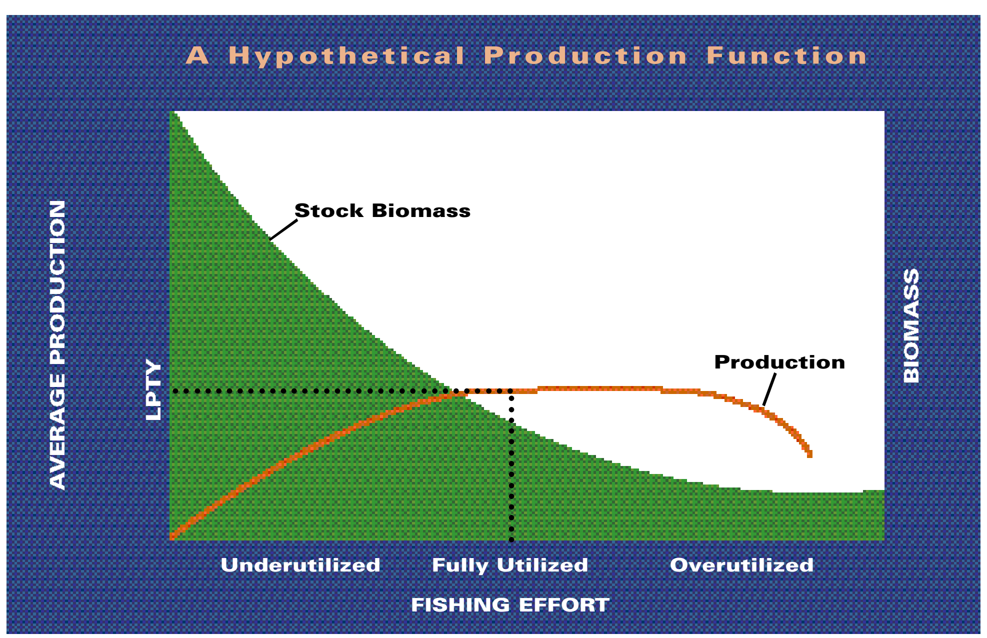
The Caribbean Sea Whip, the source of a new anti-inflammatory medicine for treatment of arthritis.

industrial resource. Of the thousands of miles of ocean ridge systems, very few have been studied, suggesting an extremely high potential for discovery of others. Future uses of these discoveries may be as varied as the species themselves.

Benefitting from Oceanic Biotechnology

Biotechnology is the use of living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop microorganisms for beneficial uses, including the development of materials that act like molecules or functions of living organisms. Humans have used biotechnology since prehistory: the selective breeding of grains from grasses, royal purple dye from Mediterranean snails, and the use of yeasts to produce bread and beer are all biotechnological developments. Today we have far greater capabilities for developing useful products from other organisms.

There is great potential for using marine organisms to produce medicines, plastics, enzymes, other chemical products, and to be used for industrial processes, as well as vaccines and genetically altered organisms for aquaculture and the seafood industry. We can use biotechnological methods to help understand the ecological and evolutionary relationships among organisms and for defining fisheries' stocks. All of these benefits are just beginning to be available; without continuing marine exploration, the potential for future products will be lost.



Above right: A net load of fish being brought aboard a trawler.
Right: The relationship between catch (production) and fishing effort for any species. Long Term Potential Yield (LTPY) is the maximum long-term sustainable catch. As production increases, stock biomass (population size) falls, and LPTY is obtained at the point where the maximum yield is first reached; after that point, stock continues to fall even though for some period the catch remains constant as effort increases.

Understanding Fisheries and Mariculture

For many years, visionaries promoted the idea that food from the sea would provide a large and sustainable part of the world's protein.Unfortunately, over the last several decades it has become clear that although the seas can provide a lot of food, they are exhaustible. Today, most of the world's major commercially valuable fish populations are overfished, and the remainder are exploited at their maximum possible level.

In fisheries, the concept of "sustainable yield" is based on the theory that any population can provide growth (production) above what is needed to maintain a certain population size. Theoretically, this production is available as a source of food through fishing. However, it is becoming abundantly clear that our ability to manage fish stocks is simply not good enough. In spite of our best efforts to avoid it, some of our most important and oldest fisheries have collapsed. The reasons for our inability to manage this process adequately include: lack of understanding of the relationships among physical and biological processes and ecosystem function, natural and human-influenced environmental changes, failures of fisheries management, inability to adequately limit our own fishing, natural variability in life history patterns of important species or their foods, and finally—but not least importantly—the effects of catching species that are ecologically, but not economically, important.

For future success in managing populations of wild fishes, we need to not only develop better models, we need to develop different models. These models will be aimed at managing "multi-species fisheries," which not only include many species (as at present) but also accommodate the requirements of all the captured species while maintaining their natural ecosystem.

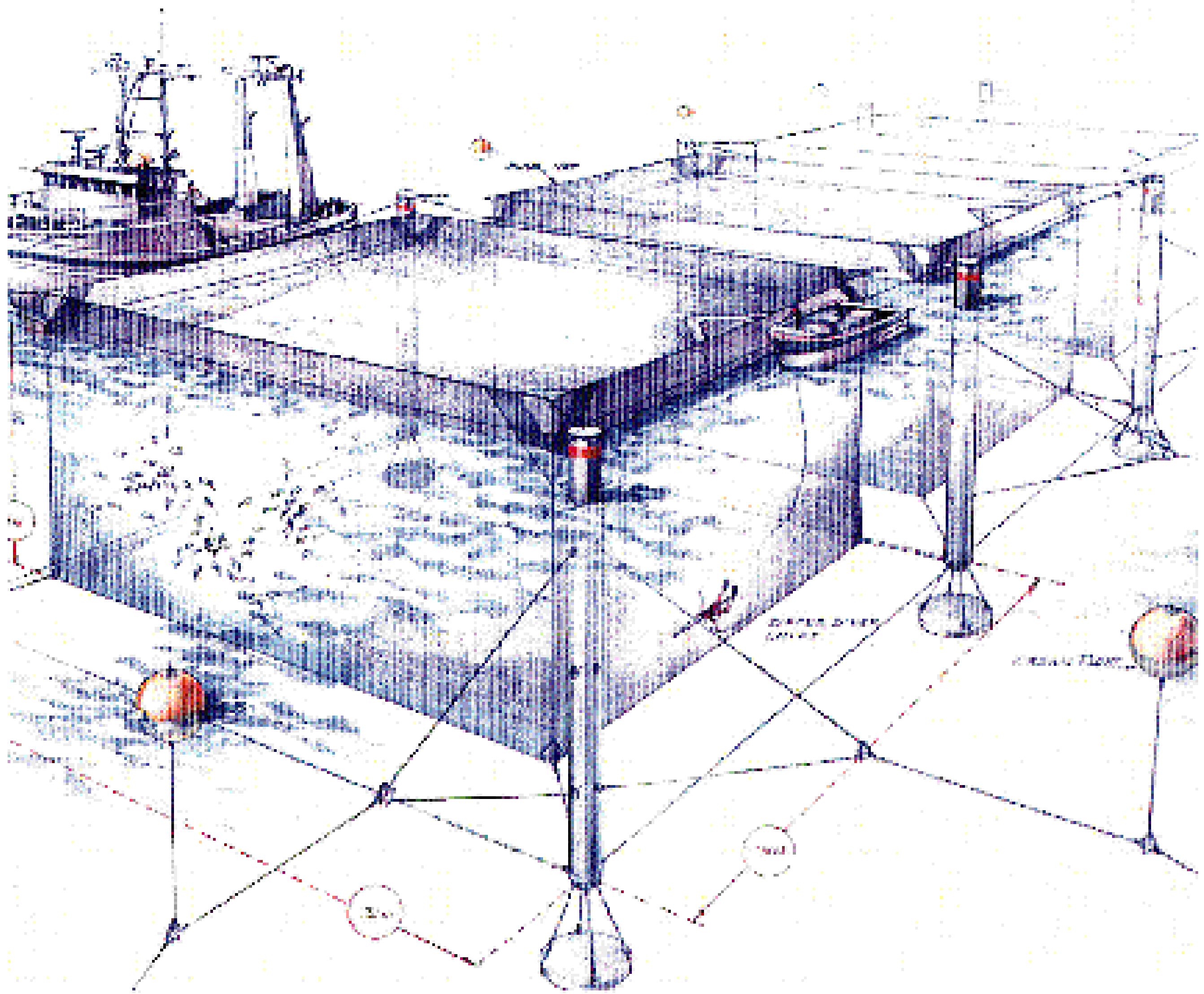
Overfishing Georges Bank

New Bedford Fleet.

Until today, fisheries have been managed to maximize the health of only a single target species; the remainder have been ignored. Aside from the waste of the unwanted catch (bycatch), such management results in other undesirable effects including major changes in ecosystem structure and function that affect production of the most economically valuable species. Georges Bank (off the coast of New England) provides a clear illustration of this problem. As the stock of cod and haddock were over fished, they were replaced over time by dogfish and skates. In turn, the dogfish and skates became endangered by being overfished themselves. To correct these problems allowable fishing has been reduced drastically; areas totaling about 6,600 square miles have been completely closed to bottom fishing. These reductions and closures are designed to allow recovery of the original cod and haddock stocks, but whether that will occur is unknown. Sometimes depleted populations never recover or recover only after decades. It's a measure of our ignorance that we frequently don't understand—and are usually unable to predict—what determines recovery and whether it will occur.

What Is Fisheries Oceanography?

The occurrence and abundance of marine organisms is determined by the characteristics of the waters in which they live. Factors such as food, temperature, water clarity, salinity, light, current speed, and bottom composition all affect population abundances and determine the occurrence of species. "Fisheries Oceanography" links physical and biological oceanography: it is the study of how oceanographic condi-



Large, moored pens for raising fish such as salmon and yellowtail in the open sea.

tions determine populations and capture availability of commercially valuable species.

Our ability to accurately predict future abundances and distributions of these species is crucial because if we cannot do so, we will not know how many adult fish can be caught without damaging future populations. For instance, the size of a future population is determined initially by reproductive success and survival of larvae and juveniles. Successful future adult population prediction depends on determining the number of surviving larvae and understanding how that relates to the future adult population. In turn, larval survival depends upon oceanographic conditions. In theory, if we knew what determined larval survival, we could measure those conditions and make accurate predictions. Such predictions allow setting catch limits that protect populations and allow maintenance of good catches indefinitely. Understanding the relationship between oceanographic conditions and behavior and occurrence ofvaluable fishes allows more efficient capture, reducing costs and lessening environmental damage.

Options For Fishing Wild Stocks

Throughout much of the world, marine animals, fishes, shrimps, oysters, abalone, and others are raised through fish farming or mariculture (marine aquaculture).This is a particularly important source for salmon (Scandinavia, Chile, Australia) and prawns (southeast Asia). In the United States, oyster culture is our most important form of mariculture. The potential for food from this source is huge, although there are problems including: the disposal of wastes produced by the animals, introduction of diseases from wild stocks to farmed animals (and vice-versa), the introduction of non-native species, and the necessary securing and maintaining of a clean environment in which to raise the stocks. Many of these problems can be overcome through research and careful planning.

The Impact of Non-indigenous Species

Humans and their activities disrupt natural systems. One of the most important but often least visible disruptions occurs through the introduction of non-native or “exotic” species to environments where they don’t naturally occur. These introductions are usually inadvertent, but in the past they were often quite purposeful. The effects range from beneficial (rarely) to extremely destructive. Ecosystems under stress are more susceptible to these invasions because they are already “out of balance.” Such non-indigenous species are almost constantly being introduced to our marine estuarine and coastal waters through the discharge of ship ballast water (taken on in other parts of the world) at an ever-increasing rate.

Since 1970, significant populations and effects of “exotic” species have been discovered in the Great Lakes (zebra mussels, ruffe), San Francisco Bay (Black Sea jellyfish, the Asian clam) and many other places. Diseases of cultured animals have also been introduced: MSX, a protozoan that attacks oysters in the Chesapeake Bay, and a number of viral shrimp diseases. These exotic species have the potential to threaten commercial and recreational fisheries and the native species they depend on.

We must develop methods for eliminating—or at least minimizing—the effects of such introductions. By supporting research on techniques for sterilization or safe disposal of ballast water, and by attaining better control of the transport of living marine animals, we will be much more able to control the introduction of the diseases that come with exotic organisms.

Green crab.

Another Threat to North American Fisheries

One of the “exotic” organisms introduced by ship ballast discharge to both the U.S. East and West Coasts is the European green crab. In the East, it eats steamer clams and is causing severe damage to their populations.In the West, it eats valuable Dungeness crab and oysters. Having no apparent North American predators, rapidly growing populations of non-indigenous green crab have now spread hundreds of miles on both coasts, threatening a primary East coast fishery and two major Pacific Northwest fisheries.

The Coastal Environment

What Effect Do the Oceans and Coastal Populations Have on Each Other?

Although they represent less than 5% of the ocean's total volume, the coastal oceans are extremely important to society in terms of pollution, fisheries, transportation, recreation, and mineral exploration. It's not surprising, that most of the world's population centers are located near the ocean. However, as coastal populations continue to grow, so does the conflict between the needs of these populations and those of natural ecosystems.

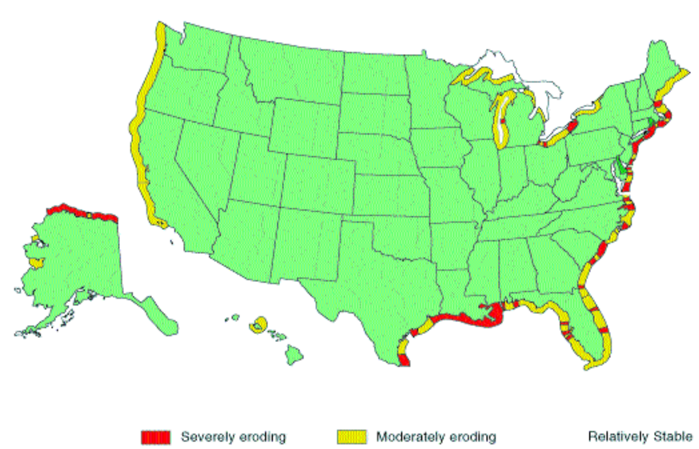
Human activities exert tremendous pressure on the coastal zone on both a global scale—sea level rise and climate change—and on a local scale—land use practices, pollution and overfishing. Coastal ecosystems are stressed by many factors including habitat loss and modification, loss of biodiversity, nutrient and toxic inputs, and diversion of fresh water. Fortunately, conflicting uses within this region have raised public awareness about the importance of the coastal ocean environment and the need to study it further.

Each year, natural and human-induced shoreline erosion causes the loss of tens of thousands of acres of land.

Storm surge flooding beach and low-lying coastal areas in North Carolina.

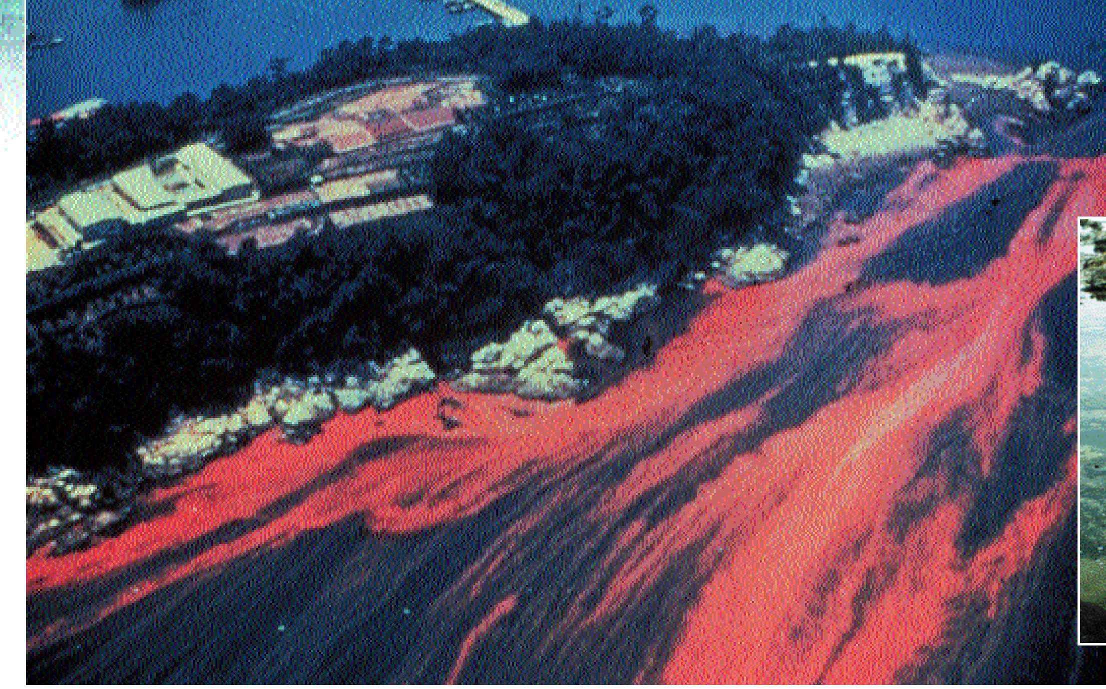
Erosion as well as sedimentation also severely affects the navigability of our waterways, affecting our continued use of those waterways for commercial and recreational purposes. Likewise, open water sedimentation and shoreline build-up affects many coastal areas and causes lower water quality in estuaries by restricting circulation. A better understanding of land runoff and estuarine sedimentation interactions, as well as the ability to predict future changes, are critical to reducing these losses and managing future development.

Waves and coastal currents sculpture shorelines through erosion and have serious effects on coastal ecosystems. Surface waves carry tremendous amounts of energy and are responsible for rapidly eroding shorelines, flooding low lying areas, destroying coastal structures and endangering mariners. Waves are produced on a variety of scales, and their periods (distance between crests) range from inches to miles, depending upon their source. Wind-produced waves (wind waves and swells) are shortest; the gravitational effects of the sun, moon, and planets produce tides, and earthquakes produce tsunamis. Size of wind generated waves depends not only upon wind speed, but the length of time the wind has been blowing (duration) and the distance over which it blows (fetch).The longer the fetch and duration, the larger the waves will be (up to certain limits).When these waves approach the shoreline at an angle, a longshore current is established which moves parallel to the shore. Such currents are best developed along straight coastlines and are the primary mechanism for moving sediments along the shoreline. Driven by wind, or by density differences—as is the case near large estuaries such as the Chesapeake and Delaware bays—currents transport sediments, pollutants, nutrients and organisms.When the winds blow away from shore, pushing surface waters out to sea, it may lead to the upwelling of the deeper, cold, nutrient rich water, resulting in areas of high biological productivity and exceptionally rich fisheries.



Estimated risks of coastal erosion for the United States

Excessive nutrient runoff into coastal waters has significantly affected ecosystem productivity, causing loss of dissolved oxygen—or eutrophication—in waters as diverse as the Chesapeake Bay and the Gulf of Mexico along the Louisiana coast, and may accelerate the frequency of noxious and harmful algae blooms. While the relationship between nutrient inputs and eutrophication is well understood for lakes, the same is not true for coastal waters. Managers cannot, at present, predict with confidence the effects on water quality of potentially very costly programs of nutrient reduction.



Concentration of algae in the surface waters of a Japanese bay, resulting in a remarkable "red tide" bloom.

Biotoxins produced by marine algae cause severe illness and death in many people annually. Biotoxins and large-scale blooms of single algae species can also affect fishery health. For example, in the late 1980s and early '90s the scallop fishery in New York state's Peconic Bay was devastated by a brown tide bloom. Currently, public health officials lack rapid, sensitive, and cost-effective methods to detect many of these substances, and blooms cannot be predicted. Any improvements in public protection will require the development of new methods for detecting these toxic compounds, as well as ecological research to support the development of a predictive capability.

Toxic substances are a critical problem in the coastal environment. In certain regions, many chemicals have been identified as "critical pollutants" based on their use, the amount of which is introduced, toxicity, and/or bioaccumulation in aquatic food webs. Impacts on aquatic organisms have been identified, especially on early development of sensitive species, and the accumulation of organic chemicals in fish poses a threat to both humans and wildlife. The resulting economic impact on commercial and sport fishing and the associated regional recreational industry has been immense. Pollution cleanup, particularly of contaminated sediments, represents a potentially enormous economicliability for the nation. Unfortunately, many major management decisions will be driven by the need to manage pollution, underscoring the urgent need for quantitative informationon contaminant sources, trends, transport fate and effects.

Protection of Life and Property, Efficient and Productive Use of Coastal Resources, and Maintenance of Economic Activities Such as Transportation, Will Require Major Advances in Our Understanding and Ability to Predict Changes in the Coastal Environment.

Protection of life and property, efficient and productive use of our coastal resources, and the maintenance of economic activities such as transportation, will require major advances in our understanding and ability to predict changes in the coastal environment. Although we are continually improving our ability to monitor the coastal environment, much more research is required to understand the coupled physical and biological processes that exist there, and to develop the tools and models necessary for their study.