OCEAN SCIENCE SERIES

MARINE ECOSYSTEMS AND FISHERIES

Highlights of National Academies Reports

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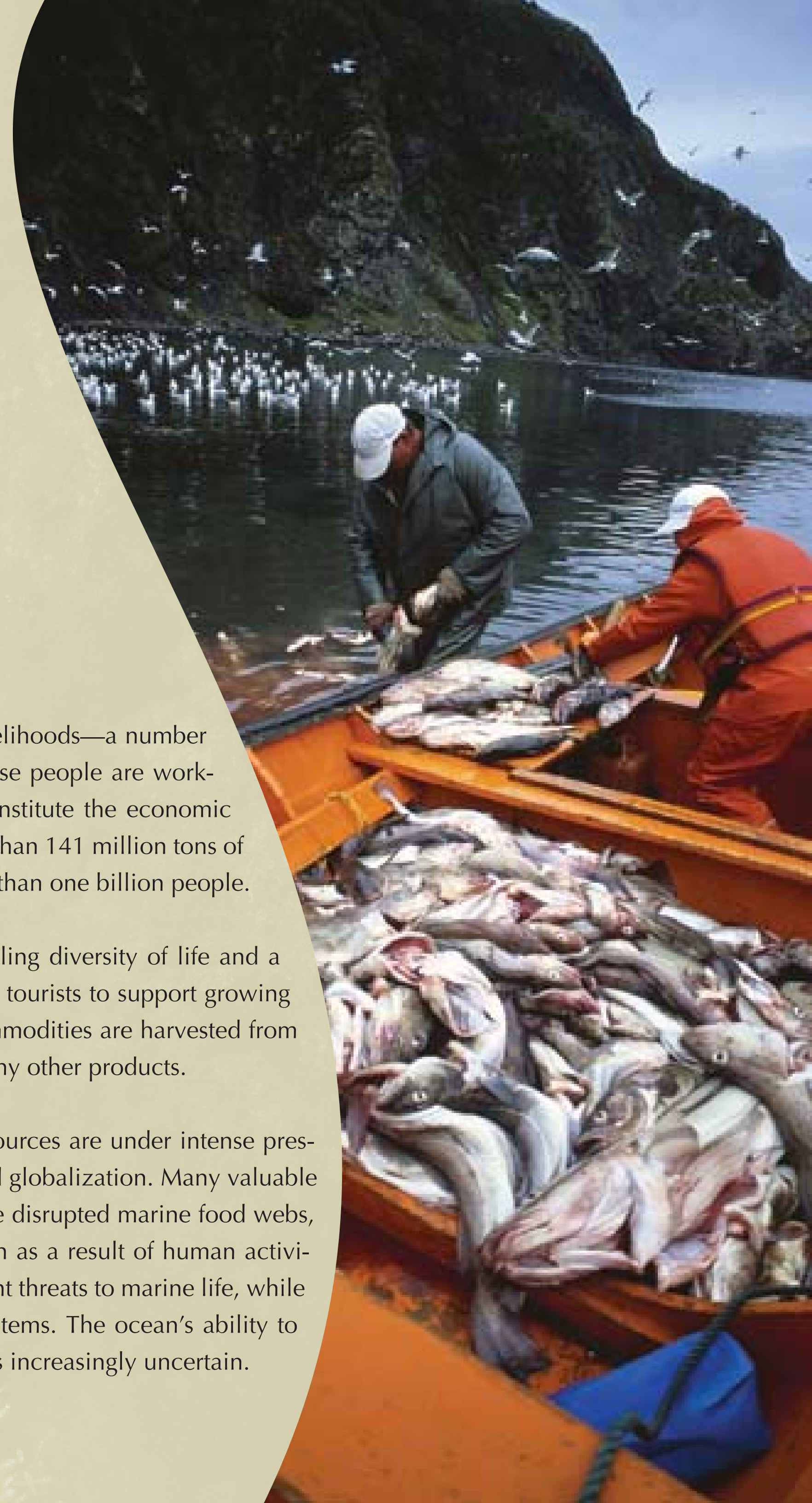
MORE THAN 40 MILLION PEOPLE

around the world depend on fishing or fish farming for their livelihoods—a number that has more than tripled since 1970. The vast majority of these people are working in developing countries, where fishing and aquaculture constitute the economic backbone of most coastal areas. Their efforts now bring in more than 141 million tons of seafood per year, supplying a primary source of protein to more than one billion people.

But the ocean provides more than just fish—it contains a dazzling diversity of life and a seemingly endless bounty of marine resources. Coral reefs draw tourists to support growing ecotourism industries. Medicines and other highly valuable commodities are harvested from the sea. Fish and mollusks are caught for food, fertilizer, and many other products.

Despite the vastness of the ocean, it is not limitless. Ocean resources are under intense pressure to satisfy expanding demands due to population growth and globalization. Many valuable fisheries around the world have collapsed, invasive species have disrupted marine food webs, and an increasing number of species are in danger of extinction as a result of human activities. Changes such as habitat loss and degradation pose significant threats to marine life, while global change has the potential to modify entire marine ecosystems. The ocean's ability to continue to sustain the multibillion dollar industries it supports is increasingly uncertain.



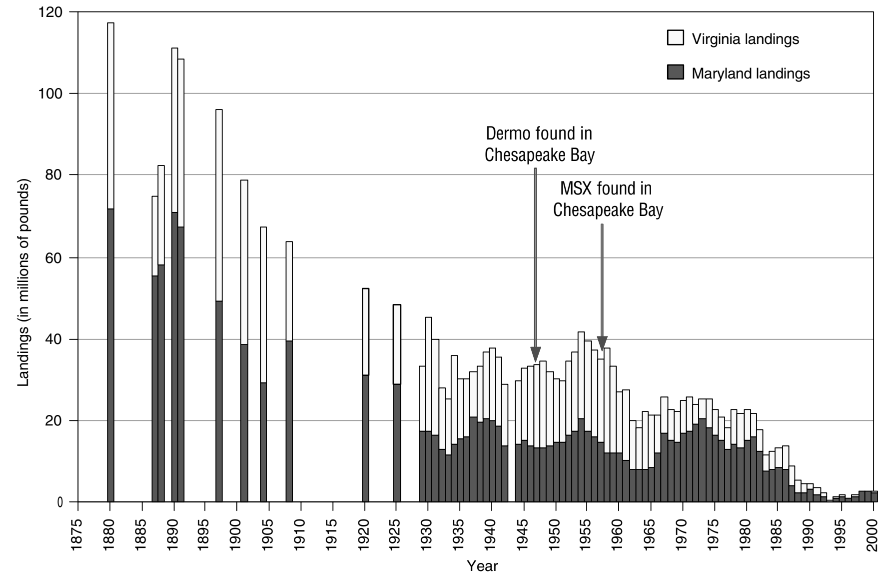
NO EASY ANSWERS: THE STORY OF THE CHESAPEAKE BAY OYSTER

Something's missing from the Chesapeake Bay: oysters. Decimated by decades of heavy fishing, deadly diseases, and environmental pressures, native oysters in the Bay, *Crassostrea virginica*, today number less than 1% of levels a century ago. As recently as 1980, the Chesapeake Bay accounted for roughly 50% of the U.S. oyster harvest, but over the past decade this number declined to just 1-5%.

C. virginica once yielded harvests estimated at millions of bushels a year, earning the Bay's reputation as an "immense protein factory." But when its populations were large, this oyster did far more than feed people. The oysters also kept the water clear—by filtering the water of algae and other suspended materials at an estimated rate of five liters of water an hour. In addition, oysters grow in clusters that form reefs, providing a place for countless crabs, snails, sponges and juvenile fish to live: all of the nooks and crannies created by oyster reefs encompass some 50 times the surface area of a comparable-sized area with a flat bottom.

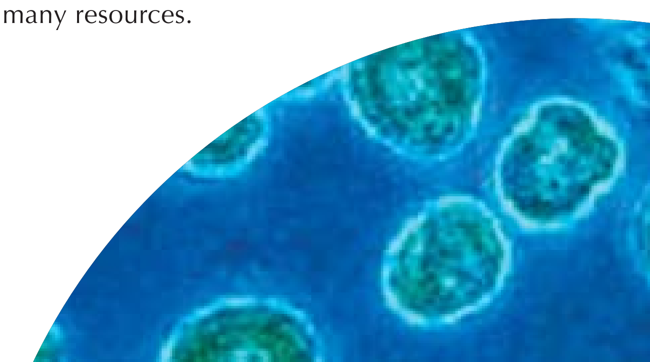
The decline in *C. virginica* over the past 150 years is a consequence of many factors in combination, including increased sedimentation and pollution, overfishing, and two diseases—MSX (caused by *Haplosporidium nelsoni*) and Dermo (caused by *Perkinsus marinus*). To restore the populations of oysters in the bay, some have suggested introducing a non-native oyster from Asia to save the Bay's dying oyster industry. Proponents of this approach also suggest that the introduced oysters would help improve the Bay's water quality. Opponents, however, are concerned that the introduced oyster could cause irreversible ecological and economic damage in the Bay if it fails to fill the niche left by the native oyster.

There are no easy answers to solving the decline of oysters in the Chesapeake, nor in managing the ocean's other living resources. Marine ecosystems are sensitive to environmental changes, fluctuating dramatically with shifts in climate or due to human impacts such as overfishing, introduction of invasive species, habitat loss or modification, or pollution.



History of commercial oyster landings in the Chesapeake Bay. (Data from the Chesapeake Bay Program and the National Marine Fisheries Service)

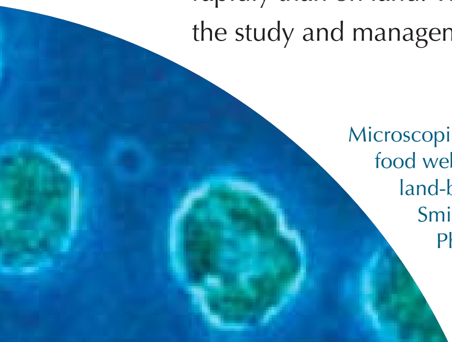
As scientists have come to better understand marine ecosystems, they have developed new approaches to ocean management that seek to balance the human uses of coastal and ocean environments while maintaining the integrity of the marine ecosystem. Scientific research on how marine ecosystems function and react to change has helped inform policy decisions that promote the sustainable use of marine resources. Continued investments in research and strategic, long-term planning can help to ensure that future generations will have an opportunity to experience and enjoy the ocean and its many resources.



MARINE FOOD WEBS ARE MORE DYNAMIC AND VARIABLE THAN THOSE ON LAND

Terrestrial food webs often are based on grasses and an abundance of large, long-lived plants, such as trees. On land, food webs can be described as pyramids: they start at the bottom with spectacular stands of plants that support smaller quantities of plant-eating animals, which support an even smaller number of meat-eating animals. This system of trophic—or feeding—levels forms the basis of our understanding of natural food webs.

Traditional land-based trophic models are not directly applicable to marine ecosystems, however. One reason is that ocean food webs are based predominantly on short-lived, microscopic plants called phytoplankton, or algae. These tiny photosynthetic organisms use the radiant energy of the sun to capture carbon dioxide and turn it into sugar, filling the same role in the marine food web as land plants. Because phytoplankton have short lifespans (measured in days) compared to land plants (measured in years), the standing stock of plant biomass in the ocean is a thousand times less than that on land, even though the global productivity of the ocean is comparable to land. The small size and rapid turnover of the base of the ocean's food chain make marine ecosystems particularly dynamic and variable; disturbances to the food web propagate through marine ecosystems much more rapidly than on land. This has significant implications for the study and management of ocean ecosystems.



Microscopic marine algae are the basis of the marine food web, a role equivalent to that of plants in land-based ecosystems. (Images courtesy of the Smithsonian Environmental Research Center. Photo by Sharyn Hedrick)

CHANGES IN CLIMATE AFFECT MARINE ECOSYSTEMS

El Niño, a seasonal weather pattern that takes place every three to seven years, is one of many examples of how climate influences ocean productivity and causes dramatic changes in marine ecosystems.

Normally, prevailing equatorial winds off the coast of South America push surface water offshore, upwelling colder, nutrient-rich deep water to the surface. The nutrient-rich water stimulates the growth of algae that support large populations of fish, birds, and other marine species. During an El Niño event, the offshore winds die down or even shift direction, suppressing upwelling and leading to the build-up of a lens of warm, nutrient-depleted surface waters off the coasts of Ecuador and Peru. As a result, productivity is dramatically reduced, leading to rapid declines in the abundance of sardines, pilchards, and anchovies, affecting predatory fish, sea birds, marine mammals, and the fisheries that depend upon them. During particularly strong events, the effects can be felt even in the U.S., with more warm water species washing ashore on California beaches.

The major declines in commercially important fish stocks associated with climatic shifts like El Niño illustrate the importance of considering climate in the development of fishery management programs, as recommended in the National Research Council report *Sustaining Marine Fisheries* (1999).

SURVIVAL OF THE STELLER SEA LION

In the Gulf of Alaska, the Aleutian Islands, and the eastern Bering Sea, the Steller sea lion (*Eumetopias jubatus*) is listed as an endangered species. The population dropped precipitously during the 1980s and continued to decline, albeit less sharply, through the turn of the millennium to less than 20% of its former abundance. Scientists have investigated whether the sea lion populations are affected by a "bottom-up" change—such as a decreased food supply—or a "top-down" change—such as a predator that directly kills the juvenile or adult animals.

Bottom-up hypotheses include both a decrease in available prey and a shift to less-nutritious prey due to fishing or a climate driven shift in the ecosystem. Top-down causes may include fisheries if sea lions get tangled in fishing gear or become more vulnerable to predators when they follow fishing boats. Increased mortality could also be a result of natural fluctuations in infectious diseases or toxic algal blooms. Based on the available evidence, it is likely that a combinaton of factors, including a change in the sea lions' food supply and deaths from interactions with fishing operations, drove the steep decline.

In *The Decline of the Steller Sea Lion in Alaskan Waters* (2003), the National Research Council makes several major recommendations. Populations of sea lions and fisheries in sea lion habitat should be monitored to distinguish the impacts of fisheries from other factors; Steller sea lion vital rates (such as age distribution and adult and juvenile survival) should be measured, and the potential impact of predators, such as killer whales, should be further investigated.

Image from NOAA; photo by Bob Wilson.

Another distinction of marine ecosystems is the complexity of their food webs. Many marine animals consume food at different trophic levels at different stages of life. Also, many marine animals are *generalists*—eating a broad range of foods depending on what is available. On land, herbivores, such as deer, consume foliage throughout their entire life and carnivores feed on other animals from the start. In the ocean, an animal may start life as an herbivore but become a planktivore or carnivore as it matures. Other marine animals eat plankton for their entire lives.

Sometimes, one species is both predator and prey of another species. For example, while adult squid are predators of larval bluefish, they are also prey for adult bluefish. Such feedbacks in the marine food web dynamically determine the distribution and abundance of marine populations.

MARINE ECOSYSTEMS HAVE FLUID BOUNDARIES

There are few true boundaries in the marine ecosystems of the global ocean. The hunters and grazers of the ocean often swim great distances in pursuit of food and sheltering habitats. Many marine species move to new locations with each new stage of life, reproductive cycle, season, or change in food supply. Night-feeding dwellers of the deep swim toward the surface to feed,

Many marine organisms, like this sea turtle, travel enormous distances to feed or spawn.

then return to the darkness below at dawn. Some marine creatures travel great lengths to return to a favorite feeding ground or place to spawn. For example, female sea turtles have been known to paddle a thousand miles to return to the beach of their birth to lay their eggs. Such long-range mobility of marine animals creates challenges for scientists determined to observe and monitor these populations.

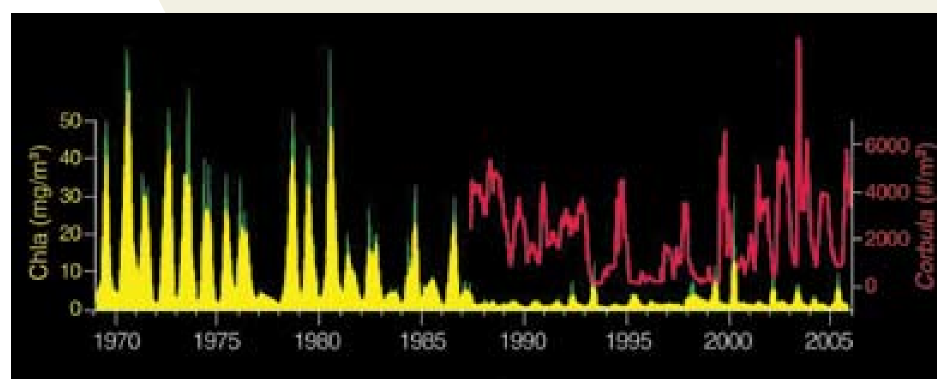
INVASIVE SPECIES DISRUPT ECOSYSTEM BALANCES

When people move animals, plants, and other organisms beyond their natural geographic range, those organisms may spread rapidly in the absence of natural enemies to keep them in check. In such cases, these introduced species become invasive, affecting ecological processes and often undermining the value of the ecosystem for such human activities as fishing and recreation.

One ecosystem in which invasive species have had a dramatic effect is the San Francisco Bay. The bay naturally experiences annual algal blooms as a result of seasonal fluctuations in water inflow from rivers. These blooms are not harmful; on the contrary, they are an important and integral feature of the bay's food web, because they support the early stages of many organisms, including commercially valuable fish species like striped bass.

For several years over the past few decades, these algal blooms stopped occurring. Scientists point to the invasion of the bay by the Asian clam *Corbula amurensis* to explain this sudden change. Relative to the resident clams that the Asian clam replaced, the Asian clam is a voracious filter feeder that can consume huge quantities of phytoplankton. The invasive clams are also capable of living in more extreme conditions than the resident clams. According to the National Introduced Marine Pest Information System, this invasion "is thought to be responsible for the collapse of some commercial fisheries in addition to the decline in the diversity and abundance of many [other] species in the area. The clam is also a dominant species in the bay, accounting for 95% of the biomass in some areas. This reduces the amount of available space for other species to grow and reproduce." *Corbula amurensis* has been nominated for the list of the 100 "World's Worst" invaders.

Time series of chlorophyll a concentration (yellow line), which indicates phytoplankton biomass, and abundance of the clam *Corbula amurensis* (red line) in Suisun Bay, a part of San Francisco Bay. Figure provided by James Cloern (USGS), a compilation of measurements by the US Geological Survey (data available at http://sfbay.wr.usgs.gov/access/wqdata) and the Interagency Ecological Program (data available at http://www.iep.ca.gov/).



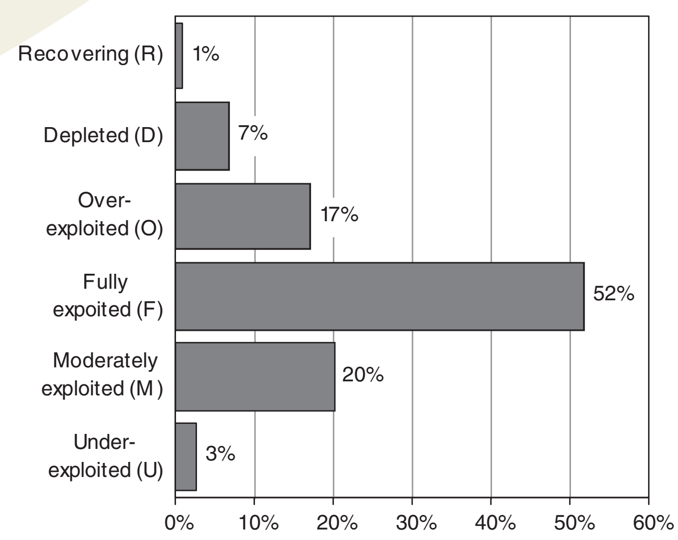
HUMANS ARE CHANGING THE OCEAN'S FOOD WEB

When we try to pick out anything by itself, we find it hitched to everything else in the universe.

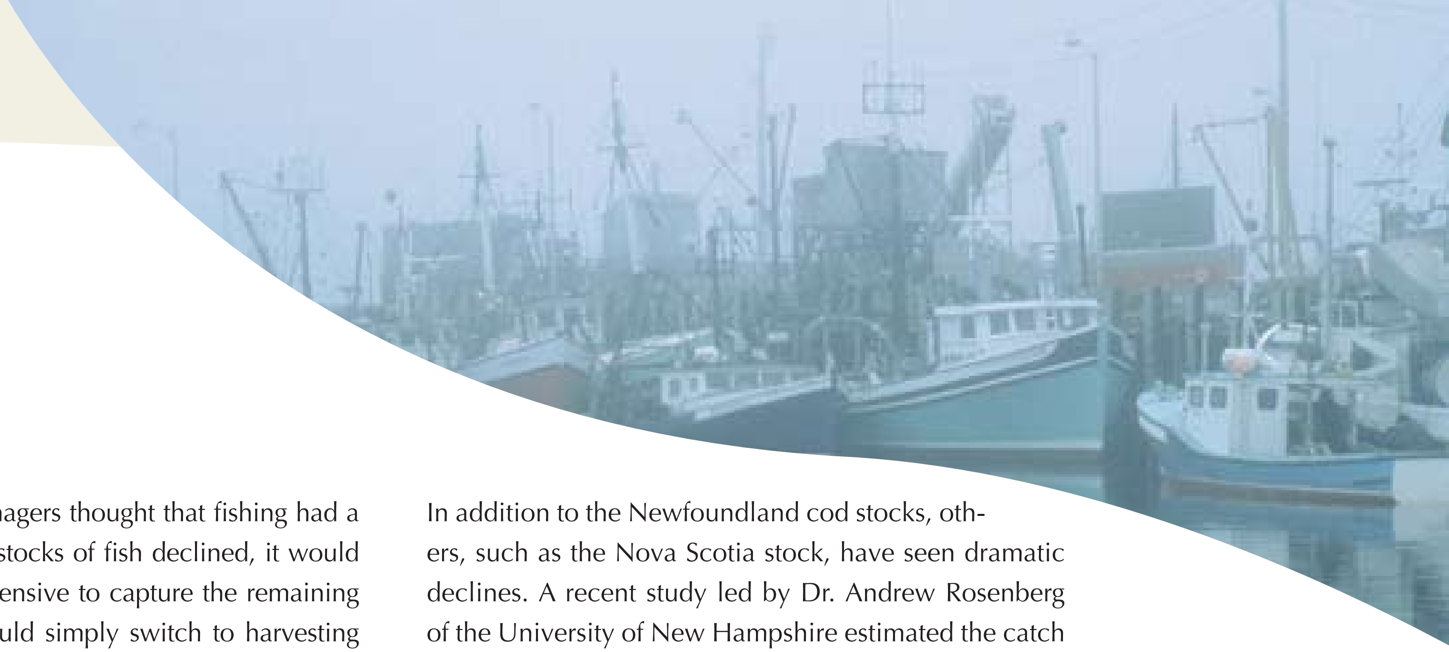
—**John Muir**, American naturalist

Seafood is an important source of protein globally. More than 3.5 million vessels currently fish the ocean waters worldwide, and NOAA projects that the global seafood demand will more than triple by 2025.

Agriculture is our main source of food from the land. More than 10,000 years ago, humankind learned how to cultivate crops and domesticate animals for food. On the other hand, until recently almost all of our seafood has been obtained by fishing—essentially hunting at sea. However, as demand has increased and the availability of wild fish has declined, interest in aquaculture has increased, with new technologies being developed to raise a greater variety of fish and shellfish for the seafood trade. (For more details about this new industry, see the box titled "Weighing the Pros and Cons of Farming Fish" on page 16.) In 2005, aquaculture accounted for about 20 percent of the total harvest of marine fishes, up from less than 12 percent in 1996. This upward trend is expected to continue as the demand for fish exceeds the ocean's capacity.



A 2004 global assessment of 441 different stocks of fish showed that 75 percent are fully exploited, overexploited, or depleted. (Image from the Food and Agriculture Organization of the United Nations)



In the past, fisheries managers thought that fishing had a built-in safety catch. As stocks of fish declined, it would be harder and more expensive to capture the remaining fish; thus, fishermen would simply switch to harvesting more abundant species. But seafood demand, new technologies, and expansion of fishing fleets have made it economical to fish even depleted stocks, leading to the decline of such major commercial populations as cod and bluefin tuna. In 2006, the Food and Agriculture Organization of the United Nations reported that 20–30 percent of the world's fish species are overexploited or depleted.

A well-known example of the effects of overfishing is the collapse of the northern cod fishery in the North Atlantic. Cod catches expanded from about 240,000 tons annually in the mid-1950s to a peak of 700,000 tons annually in 1968. The catch declined thereafter, however, and eventually collapsed in the late 1980s, which led Canada to place a moratorium on the Newfoundland cod fishery in 1992, resulting in the loss of 40,000 jobs. The cod have yet to recover, and the Newfoundland fishery is still closed.

In addition to the Newfoundland cod stocks, others, such as the Nova Scotia stock, have seen dramatic declines. A recent study led by Dr. Andrew Rosenberg of the University of New Hampshire estimated the catch and abundance of cod off the coast of Nova Scotia in 1852. Amazingly, the study found that even with limited technology, the schooners fishing in 1852 caught far more fish than the mechanized fleet does now in the Nova Scotian fishery (which remains open). At that time, the total cod biomass was 1.2 million metric tons, compared to less than 50,000 metric tons today.

Even low-tech schooners like this one caught far more cod in Nova Scotia than the mechanized fleet does now, due to the dramatic decline in cod populations. (Image from NOAA)

As these statistics and examples demonstrate, meeting the world's demand for seafood and other marine products could have serious implications for the health of marine fisheries and ecosystems. Improved fisheries management around the globe, which involves a variety of stakeholders and many governments, will be essential to ensuring that these resources will be available to future generations.

FISHERIES MANAGEMENT IS A COMPLEX PROCESS

Scientists collect data on the abundance of fish from field surveys and from the catch statistics of the fishing industry. Using sophisticated statistical techniques and modeling methods, scientists assess the data to determine the health of the stocks and to estimate the number of fish that can be caught each year without reducing the capacity of the population to replenish. The term *maximum sustainable yield* describes the theoretical limit for harvesting a given fish population sustainably. Fisheries managers can use maximum sustainable yield estimates and other types of scientific data to guide their decisions. Ideally, target harvest limits are set below the estimated maximum sustainable yield to prevent accidentally harvesting too many fish and to account for the level of uncertainty in the data and models.

In the real world, many variables affect the *actual* sustainable yield from fisheries. For instance, spawning success and survival of juvenile fish vary from year to

DID YOU KNOW . . .

- The United States is the third largest global consumer of seafood in the world.
- Americans ate an average of 16.5 pounds of fish and shellfish per person in 2006.
- Our commercial marine fishing industry contributed $35.1 billion to the 2006 U.S. Gross National Product.
- Americans spent $46.6 billion in seafood restaurants in 2006, a $2.1 billion increase over 2005. They also purchased $22.7 billion worth of seafood for home consumption.
- The United States imports more than 75 percent of the seafood Americans eat, at least 40 percent of which is farmed overseas.

SOURCE: Fisheries of the United States, National Oceanic and Atmospheric Administration, 2006.

year, and fish populations frequently show fluctuations in abundance as a result of ecosystem interactions or other environmental factors. Sometimes, information about a particular species is limited, and the resultant model estimates for maximum sustainable yield will contain a high degree of uncertainty. If a management plan does not account for that uncertainty, harvesting at the estimated maximum sustainable yield could result in overfishing the stock.

In its report titled *Improving the Use of the "Best Scientific Information Available" Standard in Fisheries Management* (2004), the National Research Council recommends that scientific reports explicitly identify the level of uncertainty in results, explain the sources of uncertainty, and assess the relative risks of a range of management options. That way, fisheries managers will be better equipped to take into account both short- and long-term effects of management actions with a clearer understanding of the level of uncertainty involved.

Despite the dramatic declines in the yields of some fisheries, there is reason for optimism. Management measures that more fully account for uncertainty in determining the acceptable level of exploitation to ensure that the catch is at a sustainable level have been demonstrated to effectively boost even depleted stocks. Today, fisheries managers in the United States and around the world acknowledge the value of the "precautionary approach," in which uncertainty is handled by setting conservative target catch levels. Although managers

IF YOU FISH LESS, YOU CATCH MORE: THE STRIPED BASS STORY

Striped bass has been one of the most popular fish caught along the U.S. Atlantic coast since colonial days. Recreational and commercial fishers alike enjoyed a plentiful catch for decades until the stock became so severely depleted that Congress passed the Striped Bass Conservation Act in 1984, spurring strict regulations to resurrect decimated populations along the entire East Coast.

Several factors—overfishing, poor water quality in spawning and nursery areas, contaminants, natural stresses, and pollution, among others—contributed to the sharp decline in striped bass stocks, and a suite of regulations and management measures was enacted in the 1980s to address these factors. The federal government closed waters beyond state jurisdictions, and the states enforced fishing restrictions including size limits, seasonal closures, recreational daily catch limits, and annual commercial catch quotas. Other measures included reducing water pollution and stocking the waters with hatchery-produced striped bass to supplement the population.

Although the striped bass fishery seemed doomed after the severe stock depletion in the 1970s, these management efforts were a resounding success. Just over a decade after the conservation effort began in earnest, Atlantic striped bass was officially declared a restored stock in 1995. Having now relaxed the strictest regulatory measures, the striped bass fishery still operates with an eye toward conserving the stocks so that they will be available for harvest in the years to come.

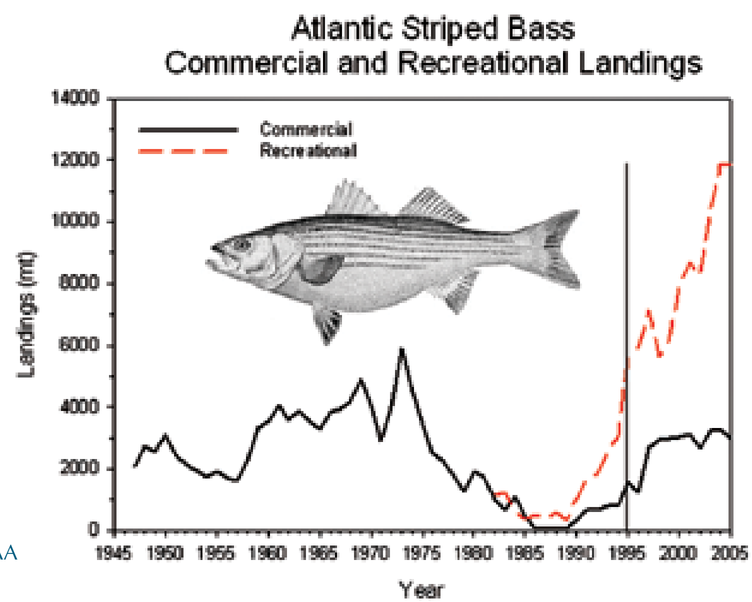


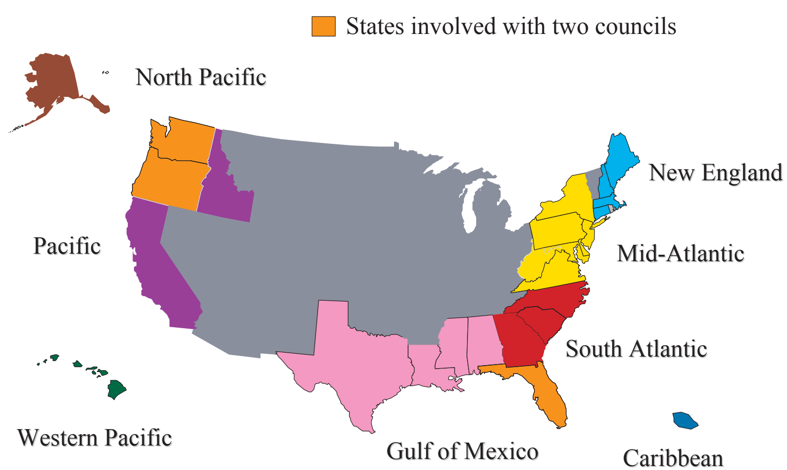
Image and graph from NOAA

WHO'S IN CHARGE OF MANAGING AMERICA'S FISHERIES?

Fisheries in the United States are managed by state and federal bodies that work together to develop and enforce fishing regulations. In some cases, this multitiered approach works well to address the concerns of these various jurisdictions; in other cases, however, conflicting interests, combined with pressure from fishing communities and environmental interest groups, can create challenges for developing a coordinated, balanced approach to fisheries management.

Regarding federal waters (3 to 200 miles offshore), regional fishery management councils are responsible for developing management plans for the major targeted fish populations in their region. There are eight regional councils: New England, Mid-Atlantic, South Atlantic, Caribbean, Gulf of Mexico, Pacific, North Pacific, and Western Pacific. These councils were established in the federal Magnuson-Stevens Fishery Conservation and Management Act of 1976. Their membership includes, in addition to state and federal fisheries managers, representatives of the commercial and recreational fishing industries, as well as other stakeholders.

Each coastal state is responsible for managing the fisheries in state waters (typically, from the coastline to 3 miles offshore). In addition, three marine fisheries commissions—Pacific, Atlantic, and Gulf—manage stocks of fish that cross boundaries between states and between state and federal waters.



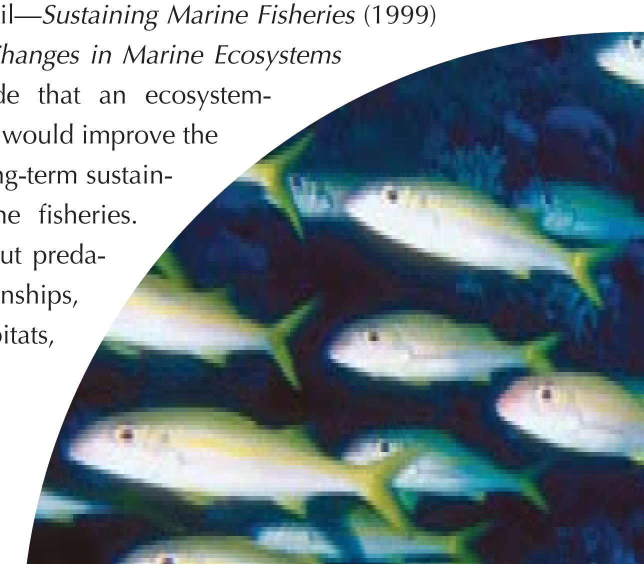
The eight regional fishery management councils (Image from NOAA).

are not always successful in implementing precautionary management—often because of concerns about the economic and societal impacts of the regulations—risk-averse management is now generally accepted as the goal for fisheries.

ECOSYSTEM-BASED MANAGEMENT TAKES A BIG-PICTURE APPROACH

An approach that has gained increasing traction is the idea of ecosystem-based management. In this approach, the many aspects of human interactions with the oceans—fishing, shipping, water quality, extraction and transport of oil and gas, and invasive species, among others—are taken into consideration as a whole in fishery management decisions.

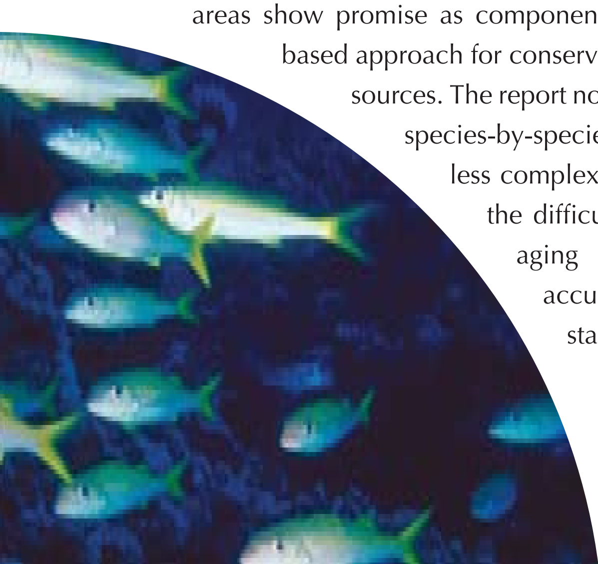
Although fisheries management is not its only application, ecosystem-based management represents a new approach to harvesting marine resources. Ecosystem-based management recognizes the complex interactions among fished species, their predators and prey, and other aspects of the marine environment. Two reports of the National Research Council—*Sustaining Marine Fisheries* (1999) and *Dynamic Changes in Marine Ecosystems* (2006)—conclude that an ecosystem-based approach would improve the prospects for long-term sustainability of marine fisheries. Information about predator-prey relationships, food webs, habitats,



and the effects of climate variation, ocean circulation patterns, chemistry, seafloor terrain and fish distributions, for instance, should assist attempts to improve fisheries management.

While the approach is promising, more data and new methods are needed to support ecosystem-based strategies. *Dynamic Changes in Marine Ecosystems* recommends that food-web, species interaction, and ecosystem models be used to evaluate alternative policy and management scenarios. However, many believe that stepwise, incremental implementation of appropriate ecosystem-based management measures, such as considering the needs of other species when allocating harvest levels, can be undertaken now. For example, fisheries managers can help boost populations of predatory fish by limiting harvests of their prey species, even with relatively little data on the needs of the predatory fish populations.

Another National Research Council report, *Marine Protected Areas* (2001), concludes that marine protected areas show promise as components of an ecosystem-based approach for conserving living marine resources. The report notes that although the species-by-species approach seems less complex, it does not resolve the difficulties of either managing multiple stocks or accurately assessing the status of fish populations. Marine protected areas could provide some insurance against accidental overharvesting and also provide an effective way to protect vulnerable habitats, such as coral reefs, from the effects of fishing and other human activities (see box on page 12).



BYCATCH INCREASES THE IMPACT OF FISHERIES ON ECOSYSTEMS

Fishing not only takes the desired species but also unintentionally captures fish and other marine animals that may be killed or severely injured as a result. Such unwanted species are referred to as “bycatch.” Although in most fisheries at least some bycatch is kept or recorded in official landing statistics, most bycatch is discarded before it can be recorded. In some fisheries, much of the bycatch includes commercial fish that are below market size. In such cases, the bycatch is not only wasteful—it

Crabs and fish continued to be caught in this crab trap long after its owner lost the trap. Continued ensnarement by derelict fishing gear may cause a significant amount of fish mortality. (Image from the Virgnia Institute of Marine Sciences)

MARINE PROTECTED AREAS

Marine protected areas are parts of the ocean that are designated for special protection, and they represent one management method to assist in restoring depleted fish populations in concert with habitats and the other components of the ecosystem. Marine reserves—one type of marine protected area sometimes called “no-take” zones—impose limits or bans on removing or disturbing marine resources. Although marine protected areas, combined with other fishery regulations and management tools, can help restore and maintain some living marine resources, they are unlikely to be sufficient for managing most commercial species.

Marine reserves and marine protected areas can help replenish depleted, threatened, rare, or endangered species and restore the viability of key habitats. These areas also provide critical scientific data that can be used to study fishing impacts under different management regimes. Additionally, they often enhance recreational activities, benefit tourism, and provide an opportunity for the public to learn about how human activities can influence the health of the marine environment.

Because marine protected areas restrict fishing and other activities, this approach is often controversial. In *Marine Protected Areas*, the National Research Council concludes that effective implementation of marine protected areas depends on participation by the community of stakeholders in the development of the management plan. Careful consideration should be given to setting objectives, determining an area’s conservation needs, and identifying the appropriate location, size, and restrictions that best achieve conservation goals.

can deplete the fishery of larger, older fish. For example, in the Gulf of Mexico, the shrimp trawl fishery presents the largest human threat to survival of juvenile red snapper. In this case, management of the red snapper fishery must include implementing solutions to reduce snapper bycatch from shrimp trawls.

Other sources of fishing mortality that are not counted in landing statistics include illegal fishing, underreporting, deaths of fish that escape from fishing gear, and ghost fishing (when fishing gear such as nets or traps are lost in the sea and continue to ensnare fish).

Sustaining Marine Fisheries (1999) concludes that because bycatch adds to fishing mortality, estimates of bycatch should be incorporated into stock assessments and fishery-management plans. More information is needed on the fate of bycatch and discards: for example, do discards survive or die, and is bycatch retained or discarded? The report recommends that technological developments, such as bycatch-reduction devices, be encouraged, developed, and required where appropriate. Recognizing the removal of bycatch as part of fishing activities would help support ecosystem-based management approaches.

FISHING ACTIVITIES PHYSICALLY DAMAGE HABITATS

Many marine organisms, including commercially valuable species, depend on seabed habitats at some point

Image from NOAA

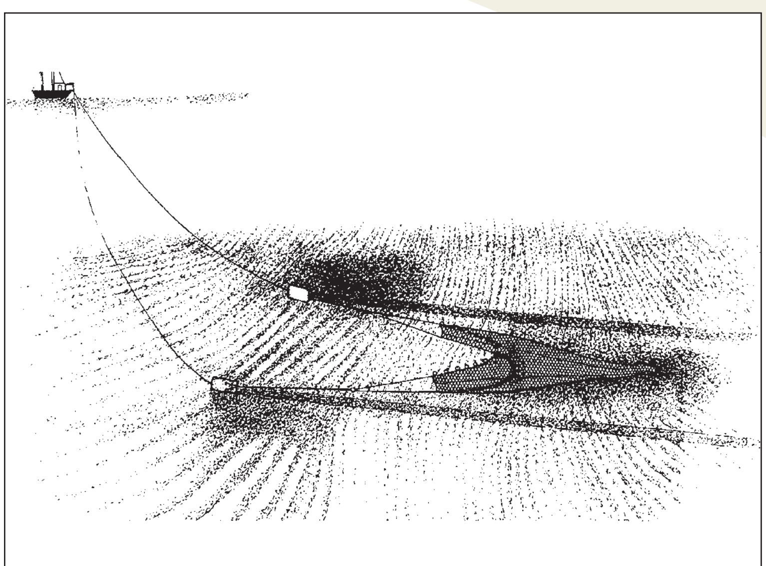
Intact seafloor habitat (left) and seafloor that has been trawled (right). Images courtesy of Fisheries and Oceans Canada.

in their life cycle, especially for spawning and early development. Many fishing practices—particularly trawling and dredging—can disturb these important seafloor habitats. The Gulf of Mexico, for example, is one of the most intensely bottom trawled areas off the coast of the United States, with some areas being swept 37 to 75 times per year.

As newer, faster, and larger fishing gear is used in modern fisheries, increasingly bigger swaths of seabed habitats are being affected. Changes to the physical structure of biological communities on seafloor habitats can have potentially wide-ranging consequences and can indirectly affect food webs.

The National Research Council report *Effects of Trawling and Dredging on Seafloor Habitat* (2002) concludes that although seabed habitats and gear impacts have not been thoroughly characterized in every geographic region, enough information is available to support more effective management of trawling and dredging to maintain marine habitats on the ocean floor. Management efforts should be tailored to specific habitats and fisheries using a variety of management tools.

Some of the management tools described in the report include: reducing fishing effort, modifying gear design or type, and establishing protected areas that are closed to bottom trawls and dredges. In the Browns Bank scallop fishery of the Gulf of Maine in the late 1990s, for example, better seafloor mapping made it possible to direct the fishing effort to the highest density scallop beds. This made it possible to maintain scallop harvest levels while



A bottom trawl as it is dragged over a soft-bottom seabed. (Image from DeAlteris et al., 1999; used with permission from American Fisheries Society) reducing the effort involved. Because the dredging gear spent less time on the bottom to obtain the same number of scallops, less seabed habitat was disturbed.

The report also recommends studying the effects of other types of fishing gear, such as traps, pots, and longlines, on seafloor habitat.

MONITORING THE RECREATIONAL CATCH IS CHALLENGING

In 2006, marine recreational fishers, or anglers, made almost 90 million fishing trips along the coastlines of the United States. Recreational fishing is a vital social and economic component of many coastal communities, but in some cases, marine anglers catch as many or even more fish than commercial fishermen do. While commercial fisheries are readily monitored, it is much more difficult to esti-

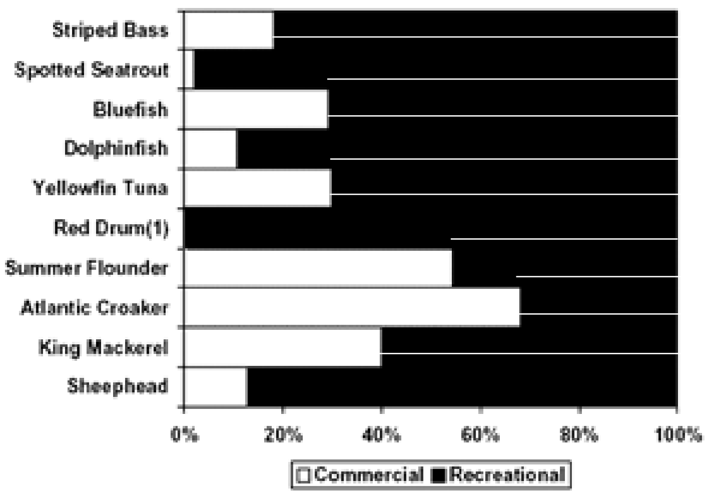
PRESERVING UNIQUE MARINE ECOSYSTEMS FOR EXPLORATION

Seamounts are undersea mountains that rise at least 1,000 m above the surrounding seafloor but don't reach the surface. They are remarkable for their biodiversity, often harboring many unique species. Thousands of new species have been discovered on seamounts in recent years, yet only a small percentage of seamounts have been studied in detail.

These productive, relatively pristine habitats have also attracted commercial fisheries that are searching for new stocks of high-value fish species such as orange roughy. Using sophisticated sonar equipment to locate seamounts, fishermen catch the fish by dragging the bottom with trawl nets. Unfortunately, trawling can crush, bury, or expose marine flora and fauna, reducing the structural complexity of these novel fish habitats; recovery, if it occurs, can take on the order of decades.

When habitats such as seamounts are damaged by trawling, we may never know what unique species have been lost. *Effects of Trawling and Dredging on Seafloor Habitats* concludes that prohibiting trawling in some habitats, especially those with corals and other long-lived species, is an effective approach to preserve biological diversity and fish habitat. For example, trawling (and other methods used to catch groundfish) is prohibited in the Sitka Pinnacles Marine Reserve in the Gulf of Alaska, thereby protecting the red tree corals and associated long-lived fishes on those seamounts.

Coral and brittlestars from a seamount. Image from NOAA Office of Ocean Exploration



These are the top ten recreational fished species, in order of decreasing abundance by weight, showing comparisons between recreational fishing and commercial harvests (2006). (Note: This figure does not include data for Alaska.) (Graph from NOAA)

mate how many fish are caught during recreational fishing because there are so many anglers and they fish from so many different locations.

Currently, fisheries managers monitor recreational fishing through phone surveys and interviews at common fishing spots. Because saltwater anglers were not required to register to fish in federal waters, these surveys have been based on calls to coastal county households chosen at random. The National Research Council report *Review of Recreational Fisheries Survey Methods* (2006) concludes that the most effective way to improve these surveys is to establish a national registry of all saltwater anglers to enable targeted sampling rather than random surveys of the population at large. This recommendation was adopted in the December 2006 reauthorization of the Magnuson-Stevens Act: "The Secretary (of Commerce) shall establish and implement a regionally based registry program for recreational fishermen in each of the [eight] fishery management regions."

Image from NOAA

WEIGHING THE PROS AND CONS OF FARMING FISH

The farming of fish, mollusks (such as clams or oysters), crustaceans (such as shrimp), and marine algae—also known as aquaculture or mariculture—has a long and, at times, controversial history. Aquaculture currently accounts for about one-third of the world's seafood supply and will likely increase in importance as the demand for seafood grows and wild stocks shrink. It is also used to rear organisms for the aquarium industry, to grow cultured pearls, and to produce other marine resources such as carageenan, an ingredient in ice cream and some cosmetics that is derived from marine algae.

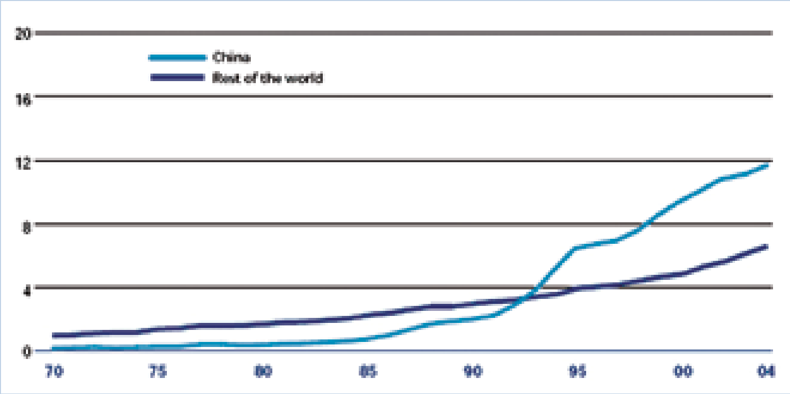
Fish farming is a promising way to feed our demand for marine products. However, without proper protections there could be some serious downsides to this industry. One is the potential for farmed fish to escape and endanger wild populations. Escaped farm fish could transmit diseases or parasites to wild populations and compete with the native species for feeding and spawning grounds.

Because farmed species are genetically distinct from wild populations, escaped farm fish can change the genetic makeup of wild populations. In Maine, for example, farmed salmon are a mix of European, Canadian, and Maine strains, and there is evidence that many have escaped from the aquaculture facilities where they were being raised. The National Research Council report *Atlantic Salmon in Maine* (2004) concludes that more research is needed to determine the impacts of salmon farming on wild stocks.

Aquaculture facilities can also threaten natural habitats. In some Asian countries, for example, the destruction of mangrove forests to create shrimp farms has resulted in the loss of important nursery areas for the native species. Fish farmers sometimes treat the water with pesticides and antibiotics to protect their cultured stocks, but these treatments can have adverse effects on surrounding ecosystems. Another problem is controlling the production and disposal of waste products from aquaculture facilities.

Sustaining Marine Fisheries concludes that the potential for aquaculture to supplement marine capture fisheries should be carefully evaluated wherever aquaculture is being used or proposed. The report also identifies the need to consider the amount of wild fish that are caught and used for breeding purposes or food in these facilities. Generally, farming mollusks that are filter feeders and require no supplemental feeding is considered to have fewer environmental risks than farming organisms higher on the food chain, such as salmon.

An aquaculture facility. Image from USDA



Marine aquaculture production 1970-2004 (in millions of tons). Aquaculture is an increasingly important source of seafood. (From The State of World Fisheries and Aquaculture, the Food and Agriculture Organization of the United Nations, 2006)

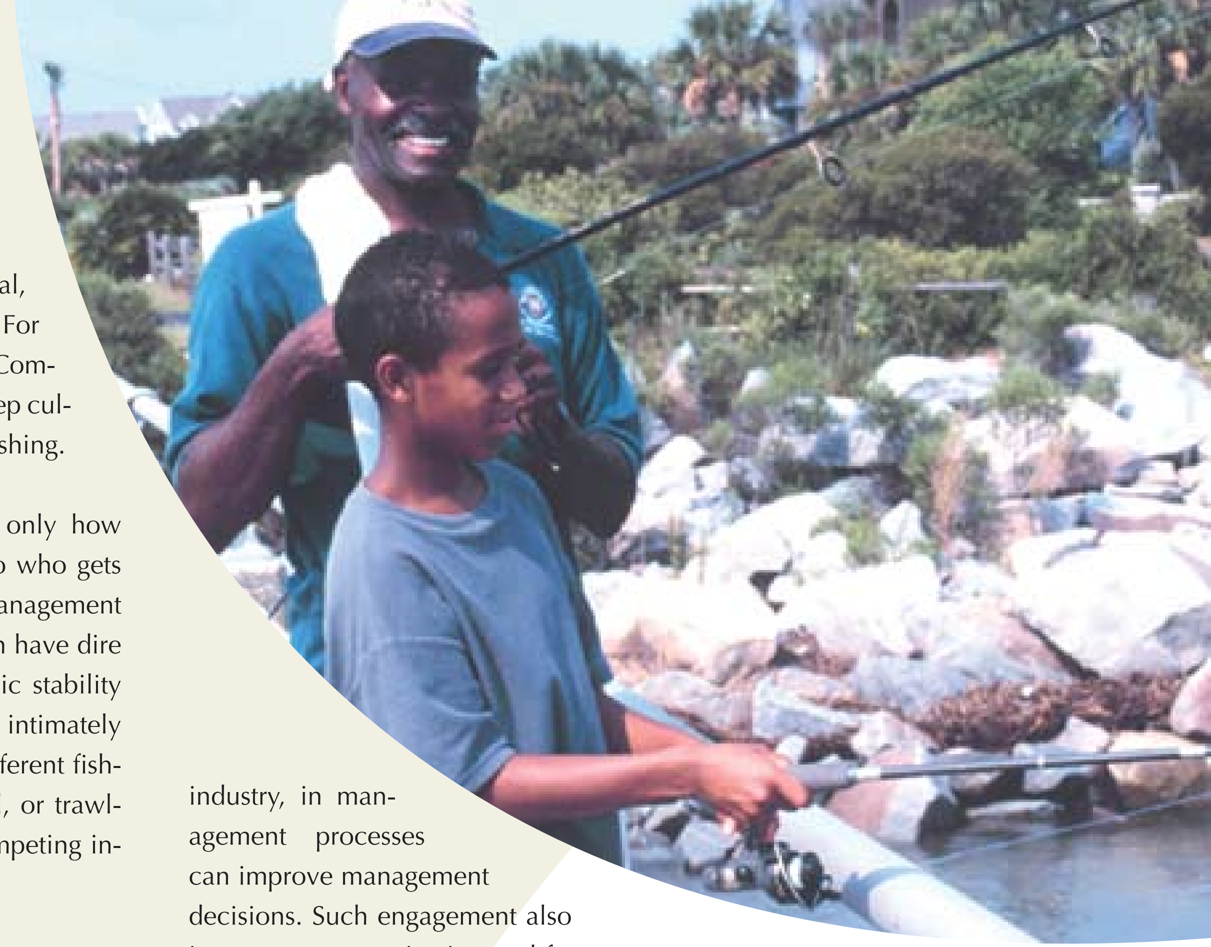
FISHERIES HAVE CRITICAL SOCIAL AND ECONOMIC IMPACTS

Fisheries have played a long historical, cultural, and economic role in coastal communities. For many, fishing isn't just a job—it's a lifestyle. Commercial and recreational fishers alike have deep cultural and social, as well as financial, ties to fishing.

Fisheries management strategies affect not only how many fish are allowed to be caught but also who gets what share of the total catch. Changes in management practices or decreases in fish populations can have dire consequences for employment and economic stability in coastal areas. Just as marine species are intimately interconnected in marine ecosystems, the different fishing sectors (such as commercial/recreational, or trawlers/hook and line) have overlapping and competing interests in regulatory decisions.

Various fishing sectors compete for fish—and they compete for the right to harvest them. Management decisions, therefore, can have uneven impacts on different fishing sectors. For example, restrictions on commercial fishing activities may boost the revenues of recreational fishing charters. Management schemes that attempt to address the interests of each of the various fishing sectors can sometimes result in catches that exceed the target levels and lead to depletion of the stocks.

Actively engaging recreational and commercial fishers, with their firsthand experiential knowledge of the industry, in management processes can improve management decisions. Such engagement also improves communication and fosters constructive working relationships among fishermen, fisheries managers, and scientists, thus creating an environment that should promote greater acceptance of fishing regulations.



Dynamic Changes in Marine Ecosystems describes a new experimental approach taken by the National Marine Fisheries Service that increases the access and involvement of a wider group of stakeholders in fisheries management decisions. For example, in the South Atlantic region, a series of workshops has been held that

SHARING THE FISH

Some fisheries are managed by setting annual total harvest levels at the beginning of each season; the fishery is closed once the set amounts have been caught. The rush to compete for the season's limited harvest has prompted the industry to increase the number of vessels used, to use larger vessels and more gear, and even to operate in dangerous weather during their race to catch the most fish as quickly as possible. The cyclical nature of these fisheries provides consumers with gluts of fresh fish for a few weeks each year and with tons of frozen fish for the remainder of the year. This race for fish also exacerbates the problems of lost gear and wasted bycatch.

To address these problems, some fisheries have adopted systems in which the predetermined annual harvests are allocated to individuals or communities. These systems include the Individual Fishing Quota (IFQ), the Individual Transferable Quota (ITQ), and the Community Development Quota (CDQ) systems, as well as others. The National Research Council report *Sharing the Fish* (1999) describes how IFQs can be used to address social, economic, and biological issues in fisheries management. The report concludes that this management approach can help industry better align harvesting and processing capabilities to the resource available, slow the "race for fish," provide consumers with a better product, and reduce wasteful and dangerous fishing practices.

The 1996 reauthorization of the Magnuson-Stevens Act prohibited the implementation of new individual allocation plans. The tide has literally turned, however, and the most recent reauthorization (December 2006) allows these types of dedicated-access privileges. Several regional councils are now instituting this approach to resource allocation—an approach many economists and fisheries scientists believe is beneficial in managing stocks sustainably.

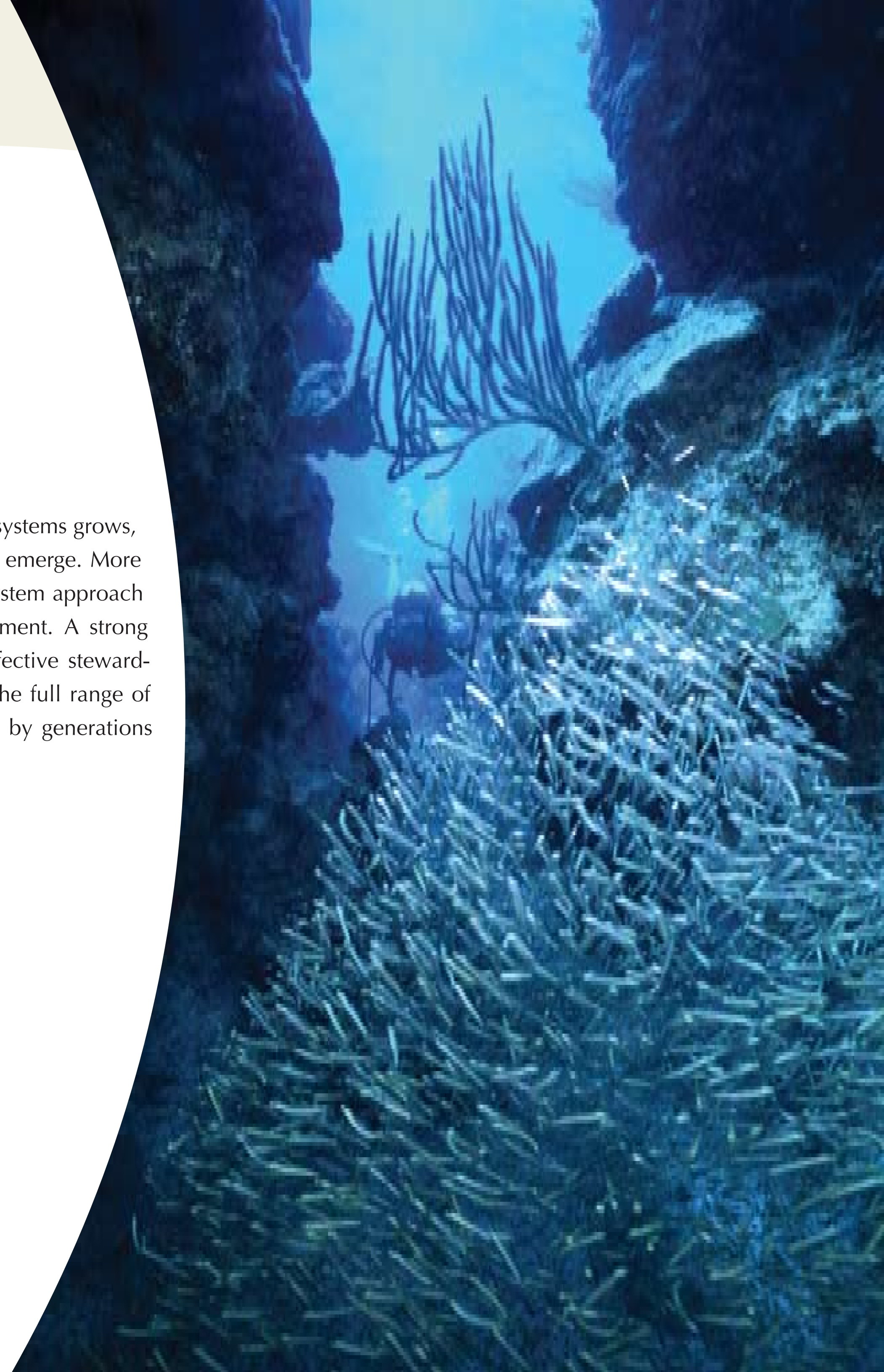
brings together fishermen, NOAA scientists, nongovernmental organizations, industry consultants, academics, state biologists, economists, and others to assess different management scenarios.

Fishing isn't the only way humans benefit from marine ecosystems, and the values of the ocean for activities such as research, drug discovery, education, tourism, recreation, and transportation, to name a few, should also be considered in making management decisions. *Dynamic Changes in Marine Ecosystems* recommends that when groups are evaluating various management scenarios, they include people who have a non-fishery-focused stake in the management decisions.

Effective fisheries management involves a variety of stakeholders, including fishers, scientists, and policy makers. (Image from the Virginia Institute of Marine Sciences)

CONCLUSION

As our understanding of threatened marine ecosystems grows, a new ocean stewardship ethic is beginning to emerge. More and more stakeholders are embracing an ecosystem approach to fisheries management and coastal development. A strong commitment to answering the challenge of effective stewardship of our marine resources will ensure that the full range of benefits of marine ecosystems will be enjoyed by generations to come.



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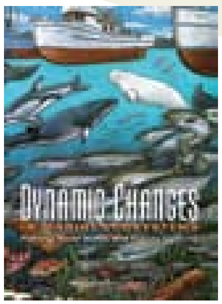
This booklet was prepared by the National Research Council based on the following reports:

Dynamic Changes in Marine Ecosystems: Fishing, Food Webs, and Future Options (2006)
Sponsored by: National Oceanic and Atmospheric Administration.



Review of Recreational Fisheries Survey Methods (2006)
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Atlantic Salmon in Maine (2004)
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Improving the Use of the "Best Scientific Information Available" Standard in Fisheries Management (2004)
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The Decline of the Steller Sea Lion in Alaskan Waters: Untangling Food Webs and Fishing Nets (2003)
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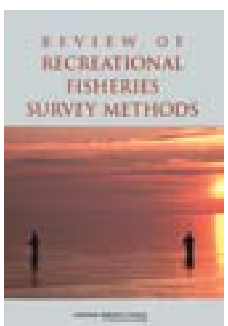

Effects of Trawling and Dredging on Seafloor Habitat (2002)
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Marine Protected Areas: Tools for Sustaining Ocean Ecosystems (2001)
Sponsored by: National Oceanic and Atmospheric Administration, National Park Service, U.S. Fish and Wildlife Service.

Sustaining Marine Fisheries (1999)
Sponsored by: the Academy Industry Program Fund, the Mellon Fund, the Casey Fund of the National Research Council, and the Kellogg Endowment Fund of the National Academy of Sciences and Institute of Medicine.

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