MARINE ECOSYSTEMS AND FISHERIES

Balancing Ecosystem Sustainability and the Socio-Economics of Fisheries

This Report Is Part Of The Ocean On The Edge Series Produced By The Aquarium Of The Pacific As Products Of Its National Conference—**Ocean On The Edge: Top Ocean Issues, May 2009**

Aquarium of the Pacific

Ocean on the Edge: Top Ocean Issues

Making Ocean Issues Come Alive for the Public

The conference brought together leading marine scientists and engineers, policy-makers, film-makers, exhibit designers, informal science educators, journalists and communicators to develop a portfolio of models for communicating major ocean issues to the public. This report is one of a series of reports from that conference. The reports include: *Coastal Hazards*, *Marine Ecosystems and Fisheries*, *Pollution in the Ocean*, and *Critical Condition: Ocean Health and Human Health*. There is also a series of briefer reports on film-making, kiosk messaging design, and communicating science to the public. All reports are available at www.aquariumofpacific.org

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Introduction

The dependence on and use of fisheries and aquaculture continue to rapidly expand.

More than 47.5 million people around the world are directly, indirectly or occasionally involved in capture fisheries and aquaculture—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. Over half a billion people depend on the sector when factoring in employment in fish processing, marketing, and service industries, including the families of all people employed directly or indirectly from fisheries and aquaculture.

Fish provide more than 2.9 billion people with at least 15 percent of their average per capita animal protein intake. Fish contribute at least 50 percent of total animal protein intake in many small island developing states as well as in Bangladesh, Cambodia, Equatorial Guinea, French Guiana, the Gambia, Ghana, Indonesia and Sierra Leone.

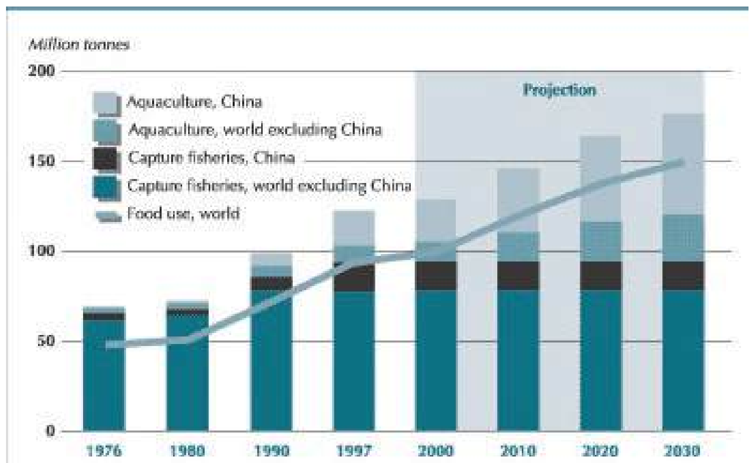


Fig 1A. World fish production and seafood consumption, 1976-2030 from the FAO's The State of World Fisheries and Aquaculture.

The ocean provides more than just food for human consumption.

The ocean provides more than just fish. It contains a dazzling diversity of life and a seemingly endless bounty of marine resources. Diving on coral reefs and swimming with sharks and rays (some of which are replacing artisanal fishing operations) draw tourists to support growing ecotourism industries. Medicines and other highly valuable commodities are harvested from the sea. Fish, crustaceans, 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 caused by 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 environmental degradation pose significant threats to marine life, while climate 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 threatened.

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 Ecosystems

Marine ecosystems are biologically diverse and more complicated than terrestrial ecosystems.

It has been said that something lives in almost every cubic inch of the ocean's 326 million cubic miles (1,358,827,275.1 cubic kilometers) of water with wildlife ranging in size from bacteria and viruses to microscopic diatoms to the blue whale and the whale shark. All are connected by feeding strategies. Everything feeds on something else with every ocean dweller, even the apex predators, vulnerable to predation by another animal at sometime in its life.

Biodiversity is composed of three main categories: (1) genetic diversity, (2) species diversity and (3) ecosystem diversity. These different components show how biodiversity encompasses a number of different scales ranging from the gene to the ecosystem.

Genetic diversity is the variation in the amount of genetic information within and among individuals of a population, a species, an assemblage, or a community. It is reflected by the level of similarity or differences in the genetic makeup of individuals, populations and species.

Species diversity is the variation in the number and frequency of species in a biological assemblage or community. Species diversity is the most commonly used synonym for biodiversity, where species richness (number of species in a given habitat) is the main index used for its measurement. The working estimate of the total number of species on earth is 12.5 million, exclusive of microbes. The discovery of enormous concentrations of microbial populations in the ocean sediments down to several hundred feet have led to the theory that as much as 50% of the biomass on earth resides in the deep sediments. There is a plethora of information on whales, dolphins, porpoises and fish, while only recently are scientists beginning to understand the extreme diversity present in microorganisms such as bacteria and phytoplankton (i.e. the plants of the sea).

Formal use of the word "biodiversity" started in 1986. Since that time it has become the most commonly used word of scientists, conservationists, educators, and policy makers to describe a scientific discipline and approach as well as a critical—indeed life-threatening—issue. We know that because we are losing biodiversity at an alarming rate. (Ellis, 2003)

Ecosystem/habitat diversity is the variation in the collection of assemblages, communities, and habitats within a region. Currently, there is no universal classification or unique definition of ecosystems at a global scale. However, this area of research is evolving rapidly. Inherent in ecosystem diversity are both biotic (living) and abiotic (non-living) components, which differs from both genetic and species diversity. Biotic structure describes the way organisms interact within an ecosystem. The opposite of biotic is abiotic, which includes the physical and chemical factors present in the environment. Every species has a limit of tolerance, zone of stress, and optimum range for the abiotic factors present in its environment.

Marine ecosystems include a unique combination of animals, plants, microorganisms and coastal and ocean habitats.

The definition of an ecosystem is a group of living organisms existing in a network of interactions with each other and their environment. Marine ecosystems are a part of the largest aquatic system on the planet, covering over 70 pervent of Earth's surface. The habitats that make up this vast system range from the productive nearshore regions to the ocean floor. Some examples of important coastal marine ecosystems are estuaries and salt marshes, coral reefs and other tropical communities (mangrove forests), coastal areas such as lagoons, kelp and sea grass beds, and intertidal systems (rocky, sandy, and muddy shores).

Feeding relationships in an ecosystem are the food chain of trophic levels and the food web.

Non-feeding relationships can be defined as symbiotic or competitive. A food chain is different from a food web. A chain illustrates only one energy and nutrient path in an ecosystem. Each platform is a trophic level with one organism that begins with one primary producer and ends with a secondary or tertiary consumer. Figure 1 is an example of a typical food chain. It illustrates the position of the northern sea otter in the food chain. Figure 2 shows relationships in an Arctic food web. Food webs are more intricate than food chains and illustrate the feeding relationships among a number of organisms at different trophic levels in an ecosystem. They also show the diversification of prey by predator.

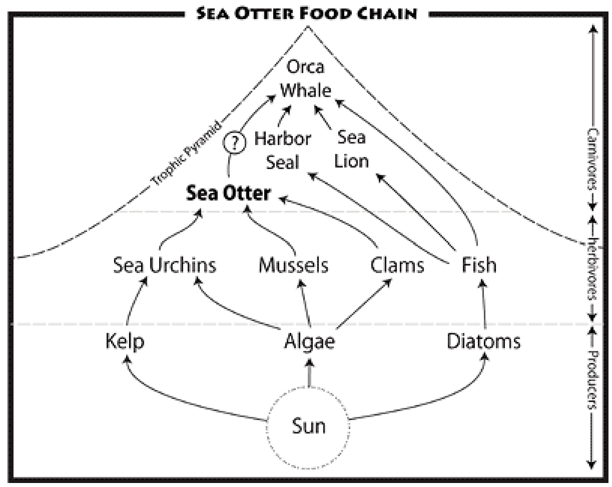


Fig. 1 An illustration of the position of a northern sea otter in an Arctic food chainA food chain illustrating the position of the northern sea otter, (Source Sea Grant Alaska: http://seagrant.uaf.edu/marine-ed/curriculum/grade-4/investigation-1/marine-mammals.html)

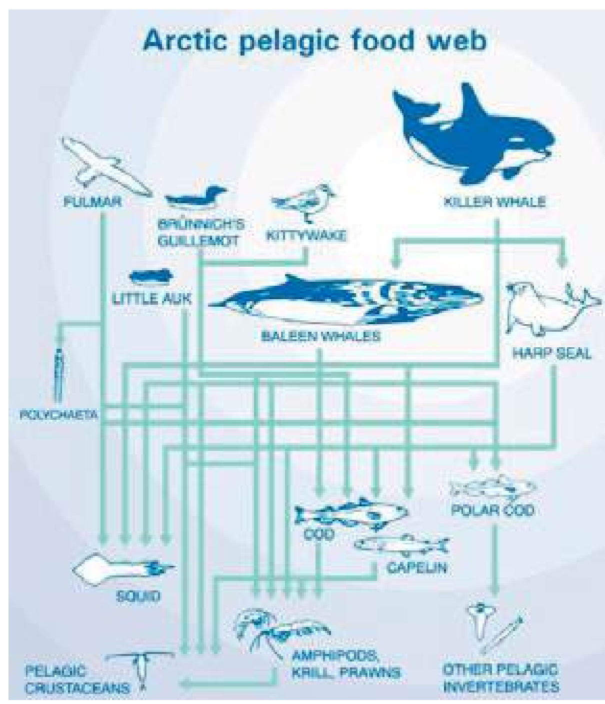
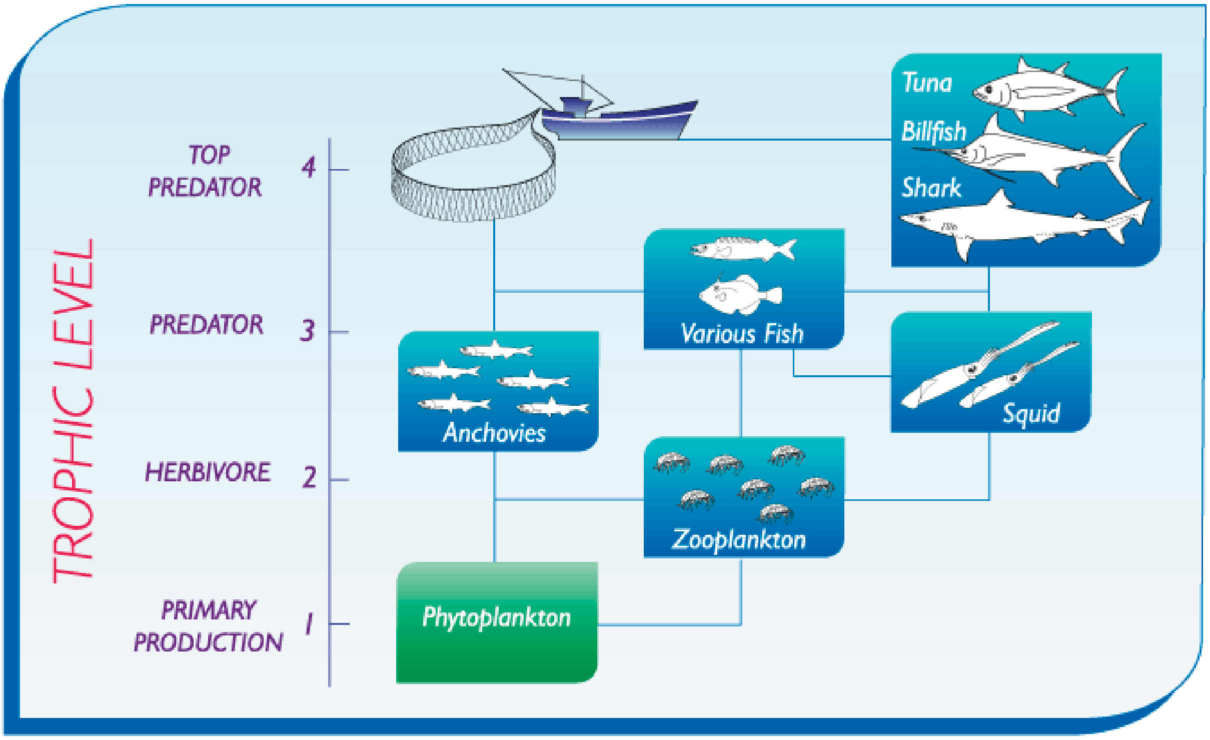


Fig. 2. Arctic pelagic food web. The marine animal food web is very complex and multilayered.. This is a quick reference to represent the complete food pelagic food web in Arctic waters.(Source: UNEP/GRID-Arendal): http://maps.grida.no/go/graphic/arctic-pelagic-food-web)



Fig, 3, This four level trophic pyramid illustrates humans as the top predators

The primary producers capture energy through photosynthesis. At each level of the energy pyramid there is a loss of biomass in the movement between the levels caused by the relatively inefficient transfer of only 10 percent of the energy produced. There is a loss of an average of 90 percent of the biomass, each level become smaller and smaller resulting from the reduction in food at each level, of the pyramid. The efficiency with which energy or biomass is transferred from one trophic level to the next is called the ecological efficiency.
(Source: OFCP: http://www.spc.int/oceanfish/html/teb/Env&Mod/OFCCP.htm)

A marine tropic pyramid is made up of a number of levels that refer to an organism's position in the food chain. The first level, the base, is occupied by the primary producers of energy, phytoplankton, (sea grasses and algae). The second level, the start of the predator-prey relationship, contains the primary consumers or herbivores that consume the producers. The third level consists of secondary consumers or carnivores that eat the herbivores with the next level occupied by tertiary consumers that feed on lower level carnivores. There are carnivores at these levels, the omnivores, that consume both herbivores and other carnivores. Carnivores at the top of the pyramid, usually the fifth level, are the apex predators—in some pyramids, a marine animal, in others, humans.

Traditional land-based trophic models are not directly applicable to marine ecosystems. One reason is that most 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 life spans (measured in days) compared to land plants (measured in years), the standing stock of plant biomass in the ocean is a thousandth that on land, even though the global productivity of the ocean is comparable to land. This assessment ignores, however, the contributions made by higher plants in the marine environment – sea grasses, salt marsh grasses, mangroves, etc. 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.

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 birth. In the ocean, a fish species may start life as an herbivore but become a planktivore or carnivore as it matures. Some species of marine animals eat plankton for their entire lives; in contrast, marine mammals gain their early energy from nursing.

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 predator-prey relationships in the food web dynamically determine the distribution and abundance of marine populations.

There are large ecosystems in the coastal and ocean environment referred to as LMEs, (Large Marine Ecosystems).

The concept of large marine ecosystems (LME) was pioneered in the mid-1980s when it was recognized that large areas of the oceans, regions around the margins of the global ocean, function as ecosystems, and that pollution from air, land, and water and overexploitation of living resources, along with natural factors, influence the productivity of these ecosystems. LMEs produce 95 percent of the world's fish catch, making them the focal point of global efforts for sustained and predictable productivity.

There are five characteristics applied to LME modeling—biological productivity, fish and fisheries, pollution and health, socioeconomics, and governance—accompany each of the world's 64 LME's. They help scientists and managers understand and integrate the elements of monitoring, assessing, and managing LMEs.

- **Productivity** indicators measure the carrying capacity of an ecosystem for supporting living marine resources. The productivity module describes the availability of nutrients and primary productivity.
- **Fish and Fisheries** module (commercial and sport) conducts assessments of dominant species within fish communities; and considers effects of naturally occurring environmental shifts in climate regime and excessive fishing effort causing shifts in species composition and abundance.
- **Pollution and Ecosystem Health** module help assess changes in coastal waters, estuaries and wetlands, and highlight eutrophic conditions. It defines the types and degree of pressure from pollutants such as sediments and excessive nutrients.

Fig 4. There are 64 LME worldwide. With 11 identified that are in or partially in US waters: East Bering Sea, Gulf of Alaska, California Current, Gulf of Mexico, Southeast U.S. Continental Shelf, Northeast U.S. Continental Shelf, Beaufort Sea, Chukchi Sea, West Bering Sea, and Insular Pacific Hawaiian. (Source: NOAA: http://www.lme.noaa.gov/LMEWeb/downloads/us_lme.pdf)

Fig. 5. The Gulf of Alaska LME is an example of the nature and complexity of interacting components in an LME. Ecologists and resource managers attempt to understand the various interactions and consider them in resource use and management decisions. (Source NOAA: http://celebrating200years.noaa.gov/breakthroughs/ecosystems/gulf_of_alaska_lme_650.html)

- **Socioeconomics** module examines how a sustainable marine resource base can meet the nutritional, social, economic and developmental needs of humans living in LME border countries. It specifies the size and scope of activities by surrounding human populations and the various ways that humans exploit or manage the resources

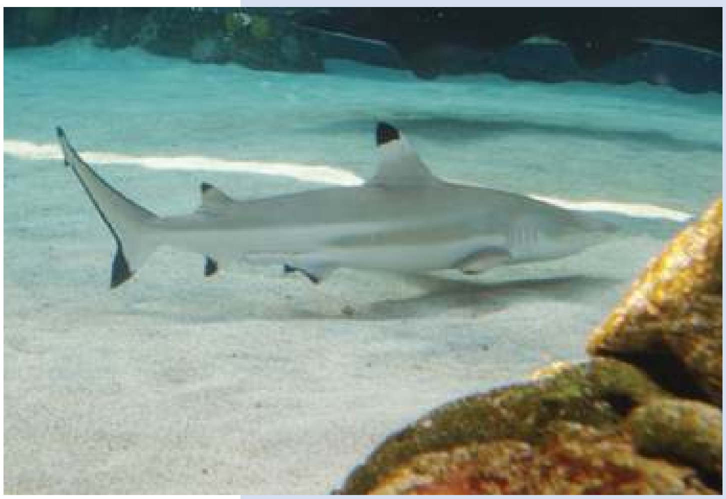
- **Governance** module engages multiple scales of national, regional and local jurisdictional frameworks needed to select and support ecosystem-based management practices leading to sustainable use of resources. It analyzes the laws and regulations, as well as the various entities responsible for managing the resources and enforcing laws. These modules offer a conceptual way to integrate science and management at the ecosystem scale.

The LME approach is a way forward for promoting ecosystem-based management of coastal and marine resources within a framework of sustainable development. While ecologists have long studied and taught the concept of ecosystems, the concept of LMEs is a breakthrough in understanding how best to manage large ocean areas for sustained biological productivity. Previous management approaches had failed to look beyond individual sectors (such as pollution discharge, mineral extraction, transportation, or fisheries harvest) and political boundaries. Those with regulatory authority over one sector made decisions on each of these uses in isolation from decisions on the others. Fish harvest decisions were made on a single-species basis, without recognizing interactions among species, such as predator-prey or competitive relationships. Another innovation in the LME concept is allowing resource managers to characterize and develop management approaches at an ecosystem scale, typically vast ocean areas crossing one or more national boundaries, providing a basis for cooperation among the countries that share them.

Coastal and Marine Spatial Planning (CMSP) is important in the management of LMEs. In addition to commercial and recreational fishing, the United States coasts and ocean support a growing number of often competing uses and activities, some of which are non-consumptive, recreational, cultural, energy, scientific, conservation, and homeland and national security activities. CMSP is an important approach to managing LMEs to meet the rapidly expanding demands on the coast and ocean while at the same time balancing the impacts on marine ecosystems.

Connectivity of marine ecosystems: Their 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, and 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, Pacific salmon are born and spend a few months to four years in freshwater and estuaries, then migrate to the open ocean where they live for two to six years, returning to the freshwater rivers and streams where they spawn and die. Such long-range mobility of marine animals, some of which utilize a variety of ecosystems, creates challenges for scientists determined to observe and monitor these populations.



Blacktip reef sharks

Blacktip reef sharks are an example of a species that crosses boundaries. They are commonly found in shallow waters on and near coral reefs and occasionally in brackish waters. Juveniles are typically found in extremely shallow water (5.9in–3.3ft [15–100cm]) inside lagoons, often swimming along the shoreline; adults typically occur on shallow parts of the forereef, often moving over the reef crest and onto the reef flat at flood tide. Individual adults inhabit a relatively small home range of 1.6mi^2 (2.5 km^2) and appear to reside close to their home reef but occasionally cross deepwater channels between adjacent reefs.

The Human Effect

"When we try to pick out anything by itself, we find it hitched to everything else in the universe."
—John Muir, American naturalist

Humans are changing the ocean's food webs: the cascading effect of species extinction.

With the continued depletion of many species, extinction becomes a distinct possibility. Due to the complexity of marine ecosystem food webs, the long term consequences of removing a single species are unknown. Marine ecosystems are exceptionally dynamic and there is a possibility that a disturbance such as an extinction, could proliferate quite dramatically and rapidly.

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

Fishing on a massive and global commercial scale has decreased the populations of some species to the point where it is no longer economically viable to sustain a targeted fishery. This does not necessarily mean that these species have disappeared, but it does indicate a large drop in yield (and thus, ease of capture) necessary to support an industry, with the corollary that highly reduced populations are now much more extinction-prone if they fall below their minimum viable population size. The corollary is that many marine species not considered suitable for human consumption, or even pet animals, 50 years ago are now considered top-quality market delicacies. An example—many species of sharks that are now being overfished.

The classic *Tragedy of the Commons* is applicable to fisheries. People tend to react in support of rescuing charismatic animals such as polar bears, dolphin, and whales but the reduction in fish worldwide, a biodiversity crisis in progress that impacts their food supplies and perhaps their health, does not get the same attention.

We are over fishing the majority of our resources.

In the past, many fisheries managers thought that fishing had a built-in safety value. 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. The bluefin tuna is an example.

Bluefin tuna, an Example of a Critically Endangered Species

The western north Atlantic bluefin tuna stock is now at just three percent of its 1960s abundance. The dramatic decline in bluefin populations is attributed to overfishing and fishing methods including post-harvesting loss, and longlines all of which contribute to removing massive amounts of fish from the ocean at one time. Spotter planes locate schooling and spawning fish. Juvenile fish are being harvested before they have a chance to become sexually mature and reproduce. Bluefin tuna are now being caught at every stage of their life cycle, killing them off more quickly than anyone could have imagined. The escalating demand in this decade for the luxury seafood in the forms of sushi and sashimi has driven up the price and put more pressure on the dwindled population.

In 2007, the breeding population of bluefin tuna, which includes fish over four years old and weighing over 77 pounds (35 kg), was at 25% of levels in the mid-1900s, and the average size of mature tunas dropped to less than half the size since the 1990s. An electronic tagging program on western bluefin tuna revealed that the stock migrates freely across the international stock boundary into the eastern Atlantic, where they are vulnerable to European fisheries; and known spawning grounds. Management of this highly migratory species that crosses international boundaries is problematic and extinction may indeed be reached before the governments involved act to save the stocks.

As this example shows 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 sustainable, and available to future generations. It may already be too late for the Atlantic bluefin tuna.

Fishing down aquatic food webs.

Industrial fishing over the past half-century has noticeably depleted the topmost links in aquatic food chains. On average, fish taken in recent years are positioned lower on the food chain than those captured decades ago. This change probably reflects a fundamental shift that has taken place in marine ecosystems as people fish out the most desirable top predators and then move on to take animals from lower on the food chain. Because the number of links in this chain is finite, and because few commercially attractive species are positioned near the bottom, scientists believe current management practices must consider the fishing down factor or fisheries in many places will collapse.

In addition there is the impact of a specific fishery lower on the wood web when an apex predator is removed. For example, the collapse of North Carolina's centuries old bay scallop industry. Cownose rays are preyed on by large sharks. The prey for cownose rays is mollusks, including bay scallops, oysters, and clams. Once their shark predators declined as a result of overfishing especially for finning and as a result of bycatch, the populations of these rays boomed. The result— a disaster for North Carolina's bay scallop industry which was wiped out, ending a century-old North Carolina tradition. If sharks, the apex predators, were taken out, the balance among species toppled, and the effects cascaded through the ecosystem and the food web.

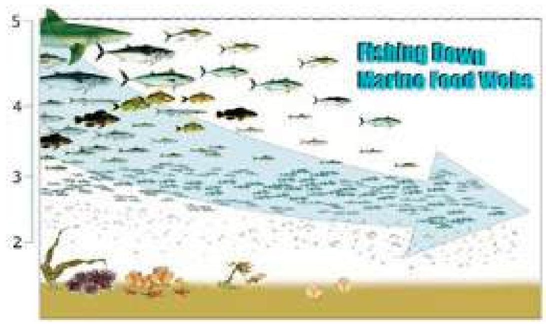


Fig. 6 (Source: Sierra Club BC. Graphic concept: D.Pauly. Art: A.Atanasio:. http://www.sierraclub.bc.ca)

And then there is the BOFFF hypothesis.

While in all species of fish, larger females produce more eggs, there is evidence that in some species, larger females can produce exponentially greater quantities of eggs. The BOFFF hypothesis, or Big Old Fat Fecund Female hypothesis, refers to this phenomenon. Thus, removing a few larger females from a population can have a dramatically greater effect on reproductive output, and recruitment, than the removal of numerous smaller females. Recent studies also show that the condition of larvae also improves with the length or age of the fish, and therefore the larvae produced by large females may have higher survival rates.

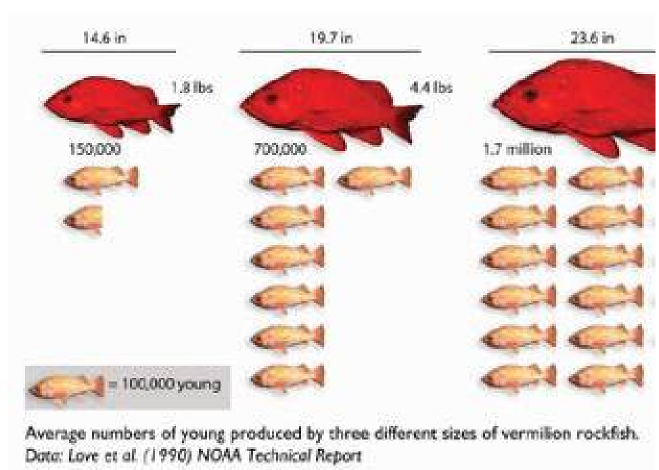


Fig. 6 After the large fish at the top of the food web in the upper trophiclevels are gone, smaller fish and invertebrates become targeted catch. (Source: Sierra Club BC. Graphic concept: D.Pauly. Art: A.Atanasio:. http://www.sierraclub.bc.ca)

The Future

Sustainable seafood: Ensuring a supply in the future.

Captive fisheries and freshwater and marine aquaculture supplied the world with about 121 million tons (110 million metric tons) of fish in 2006, a per capita supply of 37 lb (16.7 kg), and the highest on record. Of this total, 53 percent was wild caught and 47 percent came from aquaculture. Seafood is an appealing and healthful source of protein and as the world population grows, the demand for this protein will continue to increase. Clearly, to meet the growing demand, there needs to be a sustainable supply of seafood that protects our ocean and its resources while still providing the world with an adequate supply of healthy food. This can happen only if fisheries and aquaculture operations are managed properly on a global scale.

Coming to Terms with Seafood Sustainability

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. Aquaculture started in China 4,000 years ago with the cultivation of carp. On the other hand, until recently almost all of our seafood has been obtained by fishing—essentially hunting at sea and in freshwater rivers, lakes, and streams. 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.

With the Earth's burgeoning human population to feed, we must turn to the sea with new understanding and new technology. We need to farm the ocean as we farm the land.

Jacques Cousteau, 1973

If Jacques Cousteau were to make that statement today, he would probably add a word such as sustainably and his son or grandson might say: "We need to farm the ocean more sustainably than we have farmed the land."

Society is now starting to demand sustainable seafood whether wild or farmed to meet the needs of future generations without compromising the ability of future generations to meet their needs.

A perspective on aquaculture

Aquaculture Or Mariculture? Aquaculture includes fish farming in both fresh and saltwater. The term mariculture is often used for aquaculture that occurs in brackish and saltwater. Aquaculture products are grown in ponds on land or along the coast, and in the ocean in pens and cages or on lines. Recirculating systems can be either freshwater or marine, cages are sometimes found in freshwater areas, including lakes, reservoirs, streams and ponds. There are on-bottom and off-bottom mollusk culture systems, including rafts, longlines, poles, and trays in the latter (off-bottom) systems. Flow through raceways and tanks are common for producing freshwater and marine organisms. Then there are hydroponic systems, aquaponic systems, polytrophic systems, etc.

Despite current shortcomings, both real and perceived, aquaculture must play a larger role in the future to meet the growing demand for seafood if we are to conserve our wild populations. In 2007 the consumption of seafood in the US amounted to 5.8 billion pounds (2.6 billion Kg) of which 4.8 billion pounds (2.2 billion Kg) were imported. About 50 percent of the imported came from aquaculture operations. The impact on the US trade deficit is now nine billion dollars a year, making seafood one of the leading components of the portion of the deficit that involves natural resources other than hydrocarbons. The value of US produced seafood is only about one billion dollars. NOAA has stated that the current US aquaculture production of about 0.5 million tons must be quadrupled by 2025.

There have been and still are controversies surrounding fish farming. Many of these stem from what might be called ancient history and do not take into account progress that has been made in the industry, nor do they point to the well managed operations worldwide. The news media tend to focus on the negative side of aquaculture and many environmental organizations have not altered or balanced their messages to reflect positive changes being made in the industry as it grows and solves the problems of the past.

Recognizing the need to continue to engage a broad and diverse group of people in the development of standards for responsible aquaculture, the World Wildlife Fund initiated eight roundtables, called Aquaculture Dialogues, to create standards that will minimize the key negative environmental and social impacts for selected species. More than 2,000 farmers, conservationists, government officials and others participate in the open Aquaculture Dialogue meetings—making this the world's most inclusive and transparent process for creating measurable, performance-based standards for aquaculture. WWF, which coordinates the Dialogues, is one of the stakeholder groups engaged in the process.

Formation of Aquaculture Dialogues was followed in early 2009 by formation of a new organization, the Aquaculture Stewardship Council (ASC). The ASC will be responsible for hiring independent, third party auditors to certify farms that are in compliance with the standards. Over the next year, draft standards for minimizing the key environmental and social impacts associated with aquaculture will be completed for 11 aquaculture species that have the greatest impact on the environment, highest market value, and/or the heaviest trading in the global market. They are salmon, shrimp, trout, bass, abalone, mussels, clams, oysters, scallops, cobia and yellowtail.

Aquaculture is not a replacement for wild caught finfish and shellfish; it is a supplement to the supply.

A legacy of dwindling returns

Over the past 50 years the art of fishing has been mastered to the point that the ability to extract fish has outpaced the ability of nature to replenish itself. Modern technology such as global positioning systems, sophisticated fishing gear, sonar, factory ships, and helicopter spotting has proven to be so effective that the global ocean is over-harvested to the point that many are predicting extinction of most of the large species. It is estimated that over 70 percent of fish stocks are overfished or fully exploited and 90 percent of large predatory fishes such as tuna, swordfish, and Atlantic cod are gone, throwing off the balance of ecosystems and putting much of the marine ecosystem at risk. The cost of our success in catching finfish and shellfish is devastating in many ways. Whether measured in environmental degradation or the impact on biological degradation or the economic consequences, the demand for seafood comes with a price tag higher than most of the public realizes. But a wakeup call is being sounded and responded to.

Hearing The Wakeup Call: The re-authorization of the Magnuson-Stevens Fishery Conservation Act (Magnuson-Stevens Act or MSA) in 2006 contains revisions requiring NOAA Fisheries to end commercial and recreational overfishing in US waters by 2010 including rebuilding and maintaining healthy shark populations. Revisions also require all fisheries to be regulated under annual catch limits, with accountability measures to ensure that catches do not exceed the limits. In addition, the new law elevates the importance of following scientific advice in fishery management decisions, so the new guidelines will address the role of science in establishing annual harvest caps.

Under the Magnuson-Stevens Act NOAA Fisheries and the eight regional Fishery Management Councils must identify and describe Essential Fish Habitat (EFH) for each managed species using the best available science. The defined habitat must include uses by the species in each stage of its life cycle. *Essential fish habitat is defined as those waters and substrate necessary to fish for spawning, breeding, feed, or growth to maturity.* Activities that damage the habitat must also be identified.

EFH can consist of both the water column and the underlying seafloor of a particular area. Certain properties of the water column such as temperature, nutrients, and salinity are essential to various species. Some species may require specific bottom types such as sandy or rocky, vegetation such as sea grass or kelp, or structurally complex coral or oyster reefs.

NOAA Fisheries handles the listing, protection and recovery of threatened and endangered marine, estuarine and anadromous species. The ESA requires federal agencies to use all reasonable methods available to conserve endangered and threatened species, to facilitate an increase in their populations and to improve the quality of their habitats. Under the act NMFS is required to identify critical habitats which the ESA defines as the specific areas within the geographical area occupied by the species at the time it is listed on which are found those physical or biological features essential to the conservation of the species that may require special management considerations or protection and/or specific areas outside the species' current geographic range that are determined to be essential to its conservation. Economic impacts must be taken into account when designating critical habitat.

States may and do designate critical and essential habitat within their jurisdiction.

Managing Fisheries and Ecosystems

Who's in charge of managing United States' 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 multitier 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 [4.8-322 km] offshore]}), regional fishery management councils are responsible for developing management plans for the major targeted fish populations in their region. Not all parts of the U.S. recognize a 3 mile state water zone. In Texas and along the west coast of Florida, state waters extend to 9 nautical miles based on the fact that that was the limit recognized under Spanish law.

There are eight regional fishery management 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, as reauthorized in 2006. Their membership includes, in addition to state and federal fisheries managers,

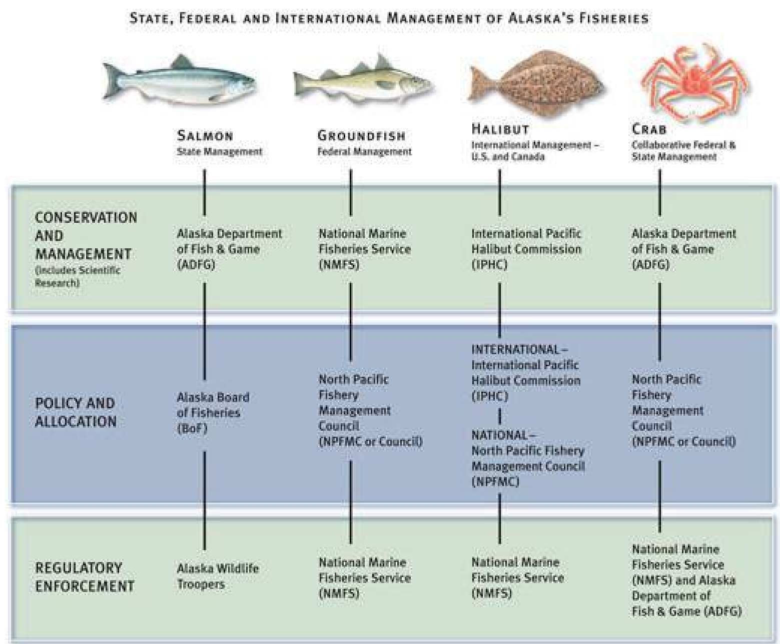


Fig 1c. An illustration of the complexity of fisheries management Alaska Seafood http://sustainability.alaskaseafood.org/resource-management

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. In addition, two marine fisheries commissions—, Atlantic, and Gulf—manage stocks of fish that cross boundaries between states and between state and federal waters.

Fisheries management is a complex process

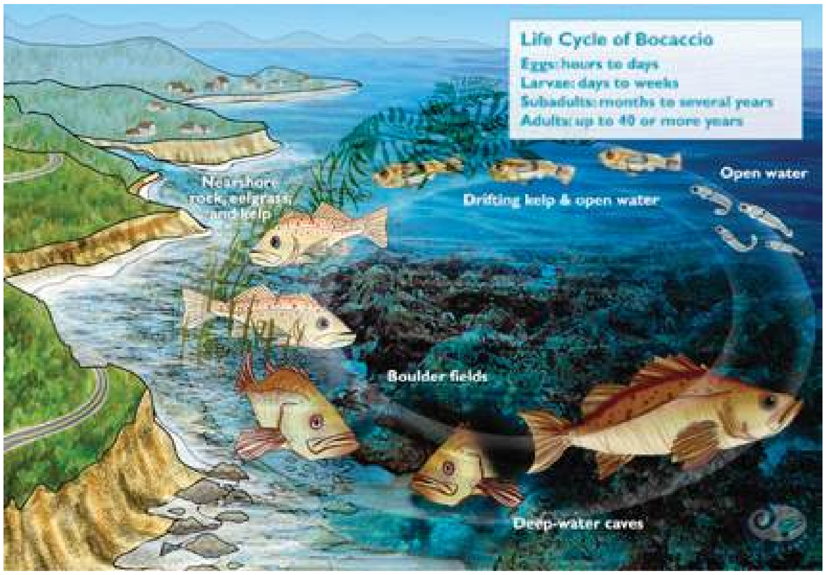
Scientists collect data on the abundance of fish from field surveys and from the catch statistics of the fishing industry. Using sophisticated statistical techniques and modeling methods, scientists assess the data to determine the health of the stocks and to estimate the number of fish that can be caught each year without reducing the capacity of the population to replenish itself. 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 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 recommended 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 are not always successful in implementing precautionary management—often because of concerns about the economic and societal impacts of the regulations—risk adverse management is now generally accepted as the goal for fisheries.

Ecosystem-based management takes a big-picture approach



Fig, 8, http://www.piscoweb.org/files/images/SMR/BocaccioLifeCycle.JPG (source: PISCO)

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 ocean—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. It is believed 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 food webs, species interaction, and ecosystem models should 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.

Marine protected areas and especially, marine protected area networks that provide for the connectivity of a fish's life cycle, show promise as components of an ecosystem based approach for conserving living marine resources. 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 assurance 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.

The impact of fisheries on ecosystems.

Bycatch: 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. Unwanted species are referred to as "bycatch." Bycatch does not include fish released alive under a recreational catch and release fishery management plan. Unwanted fish are caught in various types of fishing gear used primarily in commercial and artisanal fishing: gillnet, otter trawl, trammel net, and seine nets; longlines, in recreational hook-and-line and commercial hook-and-line fisheries.

In most fisheries at least some bycatch is returned live to the ocean and there is now an emerging practice in which bycatch is kept and sold. Much of the bycatch includes commercial fish that are below market size. In such cases, the bycatch is not only wasteful—it 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. The situation is not as simple as one might think. Red snapper are an issue, though the impact of trawling is still a bit controversial in terms of how much trawling impacts the population. Protecting the large spawners may be more effective. But most of the Gulf of Mexico bycatch is short-lived species that are not under any threat from trawling. There is also the theory that by putting bycatch back into the water provides a source of nutrients that helps support the shrimp fishery, much like dead salmon provide nutrients to the oligotrophic stream waters in which the fish reproduce that support the plankton on which the young salmon feed.

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).

The 2006 reauthorization of the Magnuson-Stevens Act requires NOAA Fisheries to minimize bycatch and bycatch mortality to the extent practicable. Under the act, bycatch is defined as *fish that are harvested in a fishery, but are not sold or kept for personal use, and includes economic and regulatory discards*. In other words, the unintended catch of untargeted and unwanted species.

Fishing activities physically damage habitats

Many marine organisms, including commercially valuable species, depend on seabed habitats at some point 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, and larger fishing trawl gear is used in modern fisheries, increasingly larger 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 damage that occurs on trawled bottoms varies significantly depending on bottom type. Mud bottoms seem to be less affected than hard bottoms. Also, there have been some new trawl doors (modified from North Atlantic doors used off Iceland) that seem to have less impact on the bottom. Those are being adopted by a considerable portion of the Texas shrimp fleet. Studies need to be conducted to verify that the doors are actually more environmentally friendly than standard wooden trawl doors.

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 management tools include: reducing fishing effort, modifying gear design or type, determining impacts of traps, pots, and longlines, on seafloor habitat, and establishing protected areas that are closed to bottom trawls and dredges.

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

Monitoring recreational fishing in federal waters has been difficult to date. However, the situation may change with the establishment of a national registry. The December 2006 reauthorization of the Magnuson-Stevens Act stated: "The Secretary (of Commerce) shall establish and implement a regionally based registry program for recreational fishermen in each of the [eight] fishery management regions." The rule proposed by NOAA creates a national saltwater angler registry of all anglers and spearfishers who fish recreationally in federal ocean waters or who fish anywhere in tidal waters for anadromous fish, including striped bass, smelt, shad, or salmon by January 1, 2010.

Fisheries Have Critical Social And Economic Impacts

Fisheries long have played an 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, social, and 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 as evidenced by the closure of salmon fishing. 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.

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

NOAA is now working with stakeholders on replacing the individual quota system for some fisheries with rights-based management. In the United States, the public trust doctrine states that the American people own the fish in the Exclusive Economic Zone (EEZ). Public trust includes the idea of free access or the public right to fish. But no one can have exclusive ownership of the fish until they are captured. It is the government's responsibility to act as a representative of the people to manage the resources. However, with our fisheries in crisis, these ideas are at a crossroads. The public and private sectors both benefit from a healthy fishing industry. And as the public interest is expanding, not only must commercial and recreational fishing industries be considered but also conservation and environmental communities. To become profitable, the fishing industry must move toward management that allows exclusion and places effective limits on access to fishing. Declining fish stocks, more restrictive management measures, and decreasing profitability in some sectors have resulted in a movement toward limiting access to fishing, a first step in rights-based management. This privilege to fish, or user-rights approach, can then take on a variety of forms depending on how exclusive the right becomes, the level or entity to which the right is allocated, the transferability mechanisms attached to the right, and the criteria used for assigning the right initially.

The assignment of rights not only to fishery access but also to a specified share of the catch is a controversial issue. Individual fishing rights or property ownership does not automatically lead to better stewardship. It depends on the mentality of the people who participate. Property rights approaches to fisheries management are not new; they have existed for centuries. As the trustee of fishery resources, the government may assign exclusive rights to the resources only if it is in the public interest. Rights-based management approaches already exist in many fisheries. However, it may not be appropriate for all fisheries.

The choice of a rights-based management approach will depend on many factors—social, economic, political, and biological. If this approach is taken, managers and fishermen must work together to identify the form of rights-based management that will work best for the fishery based on its history, the attitudes of the fishermen and the nature of the resource.

Rights-based Fisheries Management

Rights in a fishery define what particular actions the fisherman, or other entity, is authorized to take and the associated claim to a benefit stream (i.e., fish catch). Rights-based fisheries management, which exist in all fisheries management regimes in one form or another, includes any system of allocating individual fishing rights to fishermen, fishing vessels, enterprises, cooperatives, or fishing communities. In addition to restricting who has "use" of a fishery resource, rights-based management manages how much fishing effort each participant is allowed, (e.g., how many traps may be set), or) how much catch each can take The fishing rights have a value and can be traded.

Conclusion

Faced with decreasing populations of edible fish species and an increasing population of consumers; the impacts of climate change on marine ecosystems; the socio-economic impacts; the competition for “ocean space and resources; and the need for international and national cooperation, managing the world’s fisheries, both wild and famed, is challenging.

Appendices

APPENDIX A

Recommended References and Resources

National Academy of Sciences. (2008). Ocean science series: marine ecosystems and fisheries. Prepared for the National Academies.

General

Ellis, Richard (2003). The Empty Ocean: Plundering the World's Marine Life. Washington, D.C.: Island Press, p 202.

World Fisheries and Aquaculture

UN Food and Agriculture Organization. (2008). The state of world fisheries and aquaculture. http://www.fao.org/docrep/011/i0250e/i0250e00.HTM

Aquaculture

Rubino, M. (2007). NOAA's 10-year plan for marine aquaculture. US Department of Commerce, Washington, DC. http://aquaculture.noaa.gov/pdf/finalnoaa10yrrweb.pdf

Food Webs and Food Chains

Pauly, D. V. Christensen, J. Dalsgaard, R. Froese and F. Torres, Jr. 1998. Fishing down marine food webs. Science 279:860-863.

Marine Ecosystems

http://www.piscoweb.org/files/SMR_US_HighRes.pdf

EPA website Aquatic biodiversity. Marine ecosystems. Retrieved May 16, 2009

http://www.epa.gov/bioindicators/aquatic/marine.html

What is marine biodiversity? Center for Biodiversity

http://www.marinebiodiversity.ca/cmb/what-is-marine-biodiversity

Sherman, K., M. Aquarone, and S. Adams. Global Applications of the Large Marine Ecosystem Concept 2007–2010. http://www.lme.noaa.gov/LMEWeb/Publications/tm208.pdf

UNEP Regional Seas Programme Linked with Large Marine Ecosystems Assesssment and Management prepared by United Nations Environment Programme (UNEP) and the US National Oceanographic and Atmospheric Administration (NOAA).

LME Video: An explanation of the LME Concept by Ken Sherman, Director, NOAA Large Marine Ecosystem Programs ttp://www.lme.noaa.gov/index.php?option=com_content&view=category&layout=blog&id=44&Itemid=70

LME Video: Turning the Tide: Sustaining Earth's Large Marine Ecosystems.
The oceans of the earth are under serious threat from the overexploitation of marine life, pollution and the effects of global warming. Turning the Tide examines the condition of the world's large marine ecosystems and presents the solutions being put forth by the international community of scientists, politicians, and those living in the affected areas. Armed with science, political will, and sheer determination, the tide is turning to a brighter future for all. 26:19 minutes.
http://www.lme.noaa.gov/index.php?option=com_content&view=category&layout=blog&id=44&Itemid=70

BOFFF Hypothesis

Berkeley, S.A., Chapman, C., and Sogard, S. 2004. Maternal age as a determinant of larval growth and survival in a marine fish, Sebastes melanops. Ecology 85(5):1258-1264. http://californiafish.org/maternal_age.pdf

Conover, David. Size Matters: Alter harvest strategies to account for evolutionary change http://www.conservationmagazine.org/articles/v8n3/10-solutions-to-save-the-ocean/

Longhurst, A. 2002. Murphy's Law revisited: longevity as a factor in recruitment to fish populations. Fisheries Research 56:125-131. http://www.cnr.uidaho.edu/fish510/PDF/Longhurst.pdf

Walsh, M.R., Munch, S.B., Chiba, S., and Conover, D.O. 2006. Maladaptive changes in multiple traits caused by fishing: impediments to population recovery. Ecology Letters 9:142-148. http://www.msrc.sunysb.edu/people/munchpdf/Walsh_et_al06_EcolLet.pdf

Conover, David. Size Matters: Alter harvest strategies to account for evolutionary change http://www.conservationmagazine.org/articles/v8n3/10-solutions-to-save-the-ocean/

Fisheries Management

Busch, W-D. n., B. L. Brow, and G. F. Mayer Eds). 2003. Strategic guidance for implementing an ecosystem-based approach to fisheries management. US Department of Commerce, National Oceanic and Administrative Agency, NMFS, Sliver Spring, Md 62p.

Petruny-Parker, M.E., K.M. Castro, M.L. Schwartz, L.G. Skrobe, and B. Somers (eds.). 2004. Who Gets the Fish? Proceedings of the New England Workshops on Rights-Based Fisheries Management Approaches. Rhode Island Sea Grant, Narragansett, R.I. 28pp.

Ecosystems Principles Advisory Panel. 1998. Ecocystem-based Fishery Management: A report to Congress. Department of Commerce, National Marine Fisheries Service. Silver Springs, MD.

White, C. J. (2007). Federal fisheries management: an adaptive ecosystem-based perspective. Nicholas School of Environmental and Earth Sciences. Duke University:

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