Marine Fisheries –
Causes for Decline and Impacts

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NCSR curriculum modules are designed as comprehensive instructions for students and supporting materials for faculty. The student instructions are designed to facilitate adaptation in a variety of settings. In addition to the instructional materials for students, the modules contain separate supporting information in the "Notes to Instructors" section, and when appropriate, *PowerPoint* slides. The modules also contain other sections which contain additional supporting information such as assessment strategies and suggested resources.

Acknowledgements

We thank David Lonsdale of Chemeketa Community College and Jan Hodder of the Oregon Institute of Marine Biology (University of Oregon) for their thoughtful reviews. Their comments and suggestions greatly improved the quality of this module. We thank NCSR administrative assistant, Liz Traver, for the review, graphic design and layout of this module.

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NCSR Marine Fisheries Series

The marine fisheries issue is complex and represents an opportunity to approach the nature and management of a natural resource from several different perspectives in courses in natural resource or environmental science programs. Complete coverage of all fisheries-related topics is probably impractical for most courses unless the course is entirely devoted to fisheries. Instructors may select some topics for coverage and de-emphasize or ignore others. Thus, these curriculum materials are designed to meet a variety of instructional needs and strategies. The *NCSR Marine Fisheries Series* is comprised of the following:

1. *PowerPoint* Presentations

These presentations include *PowerPoint* slides, lecture outlines and detailed instructor notes on various marine fisheries topics.

- *Marine Fisheries Overview*
- *Marine Fisheries – Introduction and Status*
- *Marine Fisheries – Causes for Decline and Impacts*
- *Marine Fisheries – Management and Proposed Solutions*
- *Declining Expectations – The Phenomenon of Shifting Baselines*
- *The Role of Marine Reserves in Ecosystem-based Fishery Management*

2. *The Decline of Atlantic Cod - A Case Study*

This module provides a comprehensive examination of the decline of the Atlantic cod. Instructional materials include student learning objectives, a *PowerPoint* presentation with instructor notes, student handouts, suggested resources and assessment. Brief descriptions of other fisheries for development as case studies are also provided.

3. *Comprehensive Resources for NCSR Marine Fisheries Series*

This module provides detailed summaries for six excellent videos that examine various aspects of the marine fisheries issue:

- *Empty Oceans, Empty Nets* (2002) – an overview of major marine fisheries issues (one-hour) – student handout provided
- *Farming the Seas* (2004) – an examination of issues associated with aquaculture (one-hour) – student handout provided
- *Deep Crisis* (2003) – an examination of current research on salmon and bluefin tuna using modern technology (one-hour)
- *Strange Days on Planet Earth – Episode 3- Predators*
- *Strange Days on Planet Earth – Episode 5 – Dangerous Catch*
- *Journey to Planet Earth – The State of the Planet's Oceans*

This module also provides a comprehensive glossary of terms commonly used in marine fisheries.

In addition, complete citations and brief summaries of web, print and video resources are provided that can be used to:

- Enhance existing lecture topics
- Develop lectures on new topics
- Develop geographically relevant case studies
- Update fishery statistics
- Select articles for student reading
- Access video and photos for presentation purposes

4. Activity-based Instructional Modules

- *Shrimp Farming –Environmental and Social Impacts* an evaluation of the environmental and social impacts of shrimp aquaculture (one hour)
- *Where Does Your Seafood Come From?* – students evaluate the sustainability of locally available seafood and the criteria that are used to make that determination (3-4 hours)

The manner in which instructors use the modules in this series will depend upon:

- The course in which the module will be used

The marine fisheries modules are most appropriate for inclusion in undergraduate courses such as *Environmental Science*, *Introduction to Natural Resources*, *Marine Biology*, *Introduction to Fisheries* and *Fisheries Management*. Parts of the modules may also have application in courses with a broader scope such as *General Ecology* and *General Biology*.

- The background of the students

The marine fisheries modules assume some understanding of basic ecology including populations, communities and ecosystem structure and function. The treatment of ecology in either a college-level or high school-level general biology course should be sufficient. Instructors may need to provide additional background to students who are not familiar with this material.

- The time that will be dedicated to the study of marine fisheries

There is sufficient information and resources in the marine fisheries modules to present anything from a single one-hour lecture to a major portion of a full academic term, lecture-only course. Instructors may select from the various components depending on course objectives and the amount of time allocated for marine fisheries topics.

Marine Fisheries - Causes for Decline and Impacts

An Instructional Guide

This instructional guide is designed to provide instructors with lecture support on the topic of marine fisheries with an emphasis on those species that are commercially harvested in the United States. Factors contributing to the decline of marine fisheries are discussed as well as the impacts of fishing at population, community and ecosystem levels.

A general lecture outline and a more detailed *PowerPoint* presentation with instructor notes are provided. Print, video and web-based resources that cover the topic are summarized and cited. Instructors who wish to obtain greater detail on any of the topics discussed in this module are encouraged to seek out these additional resources or those cited in the *Comprehensive Resources for NCSR Marine Fisheries Series*.

Objectives

Upon successful completion of this module, students should be able to:

1. Describe the various causes for fishery declines
2. Describe the predicted impacts of global climate change on fisheries
3. Evaluate evidence for community and ecosystem-level impacts of fishery declines
4. Describe how societal factors such as increasing demand, shifting baselines and subsidies contribute to declining fisheries

General Lecture Outline

Topics IV, V and VI in the general lecture outline below are covered in this module. Topics I, II, III and VII through X are covered in detail in other NCSR Marine Fisheries modules.

I. Introduction – Why study marine fisheries?
II. Characterize the resource
- Define marine fisheries
- What areas are fished?
- Importance as a food source
- Importance to societies

III. Status of the resource
- Historical perspective
- Current status
- Case studies of fishery declines
- Endangered species

IV. Causes for fishery declines
- Overfishing
- Highly efficient technology
- Bycatch
- Overcapacity
- Climate change and ocean acidification
- Recreational fishing

V. Community and ecosystem-level impacts of fishery declines
- Fishing down the food web
- Habitat degradation
- Trophic cascades
- Changes in life history traits

VI. Why are fishery declines allowed to occur?
- Economics of overfishing/Government subsidies
- Growing human populations and increasing demand
- Shifting baselines
- Lack of adequate fisheries data

VII. Traditional fisheries management
- The challenge of management
- Maximum sustainable yield
- Quotas (Total Allowable Catches)
- Relevant legislation
- Closures

VIII. Market-based solutions

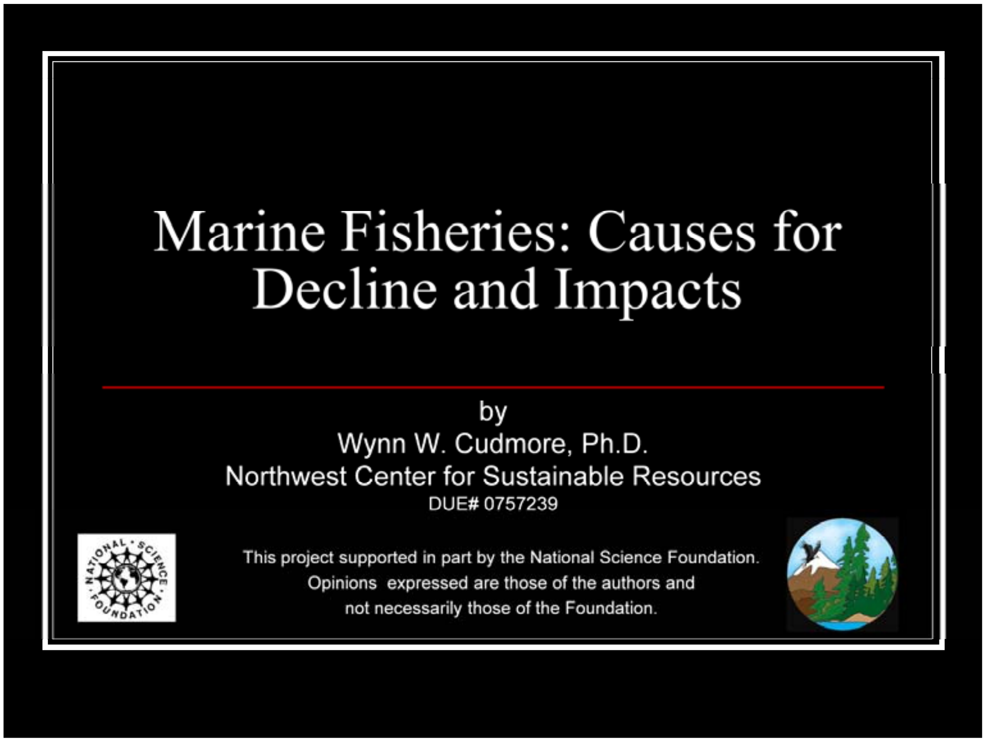
- Certification
- Consumer-based solutions
- Reduction in fishing effort by purchase of fishing rights
- Aquaculture
- Increased use and marketing of underutilized species

IX. Ecosystem-based fishery management

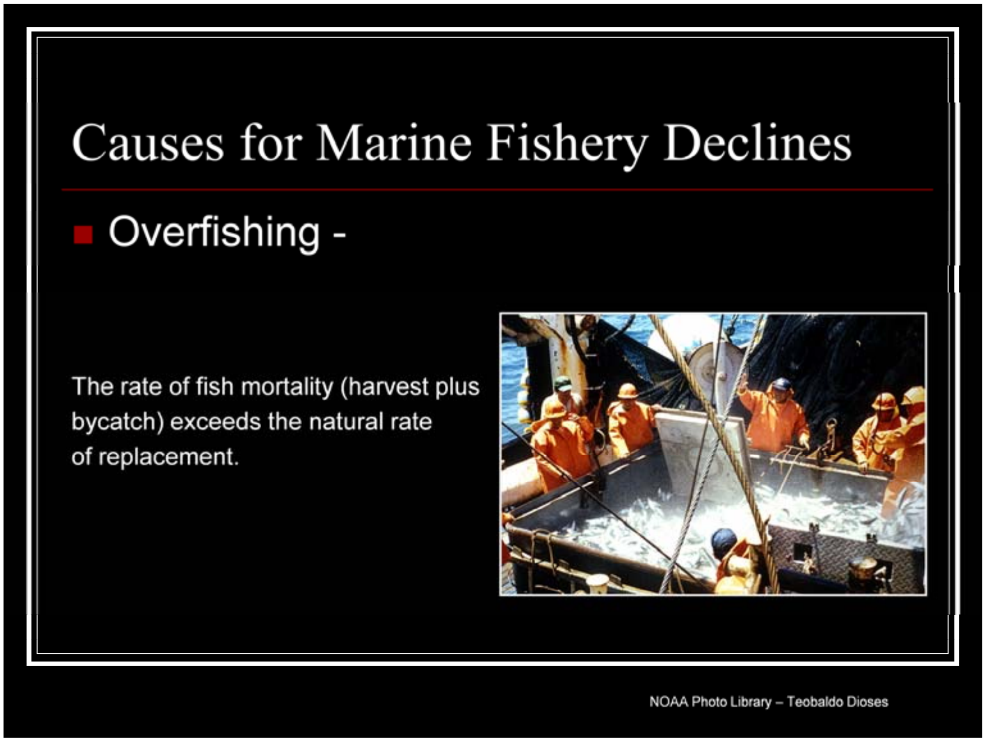
- Reduce bycatch
- Gear restrictions
- Marine reserves/marine protected areas
- Monitoring of population characteristics
- Implementing catch share programs
- Ecologically sustainable yield

X. The future of marine fisheries

PowerPoint Presentation with Instructor Notes



This presentation provides a detailed examination of the causes for the decline of marine fisheries and the community-level and ecosystem-level impacts of these declines. Other marine fisheries topics such as the status of marine fisheries and fishery management practices are described in detail in other NCSR marine fisheries modules.



Overfishing – occurs when the rate of fish mortality (harvest plus bycatch) exceeds the natural rate of replacement resulting in a decline of the fish stock

While many in the general public are under the impression that pollution is responsible for the decline of marine species, it has become clear in recent years that overfishing is the number one human activity that threatens marine ecosystems. Most fisheries are “open access”, acting as a common resource to all and thus are susceptible to the “tragedy of the commons” as originally described by Garrett Hardin.

Hardin, G. 1968. Tragedy of the commons. Science 62:1243-1248.

See notes slide 3

Notes Slide 3

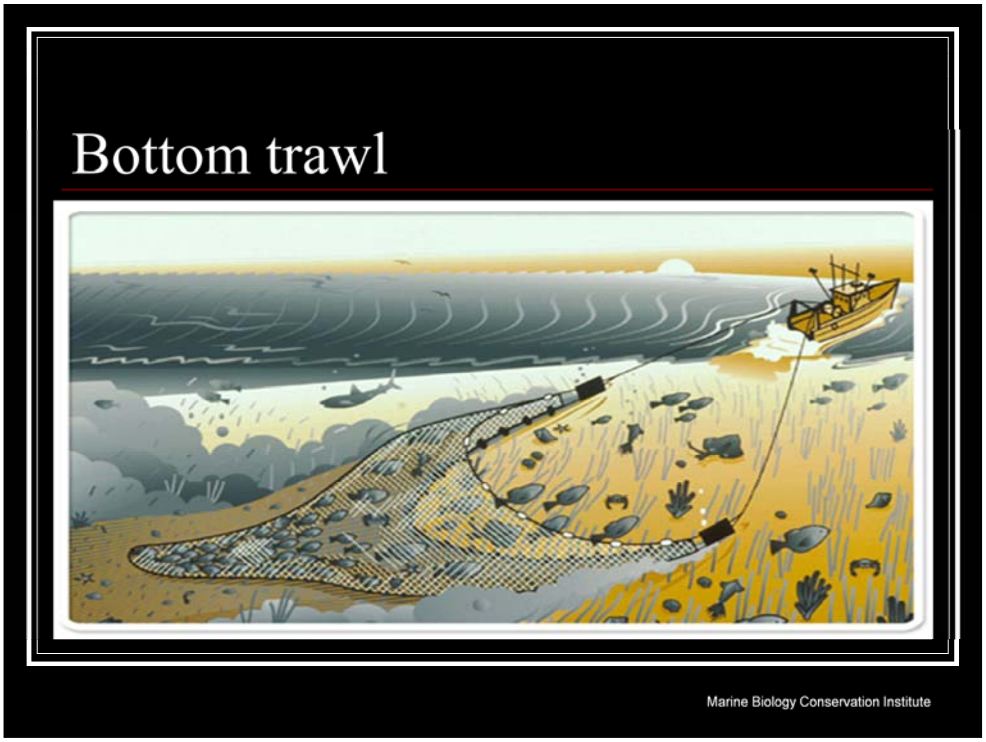
Highly efficient technology – the availability of highly sophisticated tools to locate, harvest and process fish

Many modern fishing vessels are large, floating fish processing factories that can deploy large amounts of highly efficient gear – miles of submerged longlines, huge trawl nets and, until their recent prohibition, 40-mile long drift nets – and process their catch at sea. Photo shows a Chilean purse seiner about to land several tons of chub mackerel - a small pelagic species.

Modern fishing vessels deploy larger, heavier gear that allows fishing in previously inaccessible areas. “Rockhopper” and bigger roller gear, for example, allow bottom trawl nets to fish rocky, complex habitats where in the past gear would become damaged or lost.

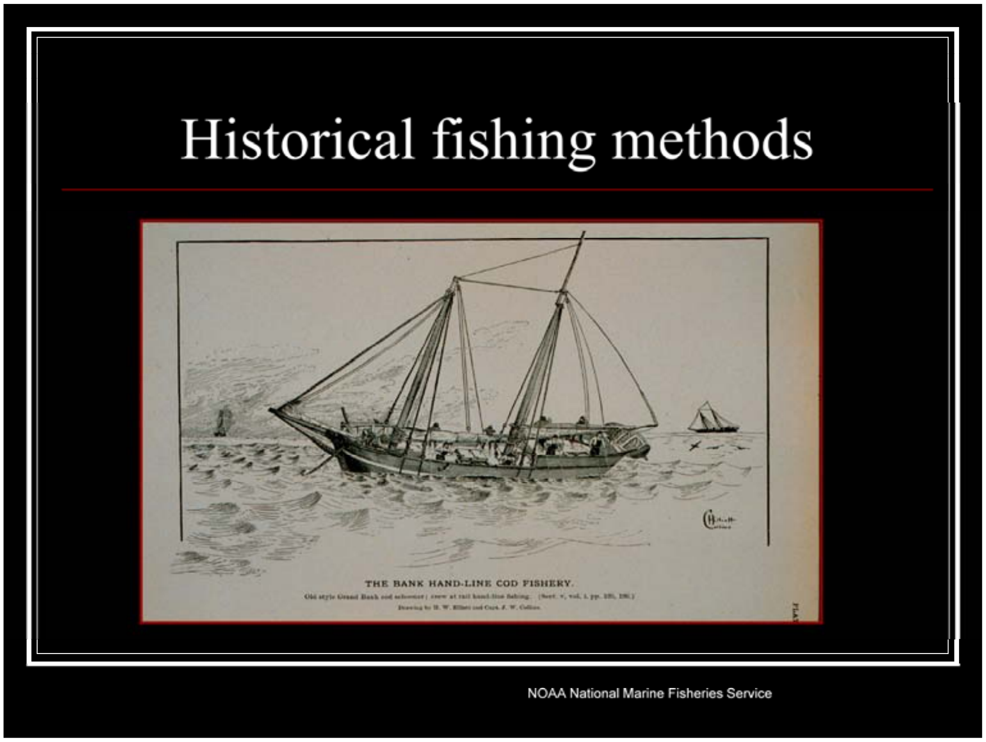
An explosion of new technologies in the 1950s and 1960s, including the adaptation of military technologies, greatly increased capacity to catch fish. Radar allowed navigation under weather conditions that would have prevented fishing previously. Sonar made it possible to detect large schools of fish and to create detailed maps of the ocean floor. Recent refinements to sonar technology have even allowed fishers to distinguish between some species of fish. Some species have specific sonar signatures based on gas bladder size and muscle density. Electronic navigation (LORAN – Long-Range Navigation) and, more recently, GPS (Global Positioning Systems) and GIS (Geographic Information Systems) allow fishing vessels to pinpoint the most productive fishing grounds.

New electronic technologies also greatly increased the capacity to locate and capture fish. Aircraft are frequently used to locate pelagic fish such as swordfish and tuna and some are equipped with infrared sensors that detect subtle changes in ocean surface temperature. This technology can be used to find fish since some high value species have highly specific temperature preferences. Even the oils given off by fish which collect on the ocean surface can be detected using ultraviolet sensors. Airborne electronic image intensifiers can be used to detect light given off at night by some marine algae when they are disturbed by passing schools of fish.



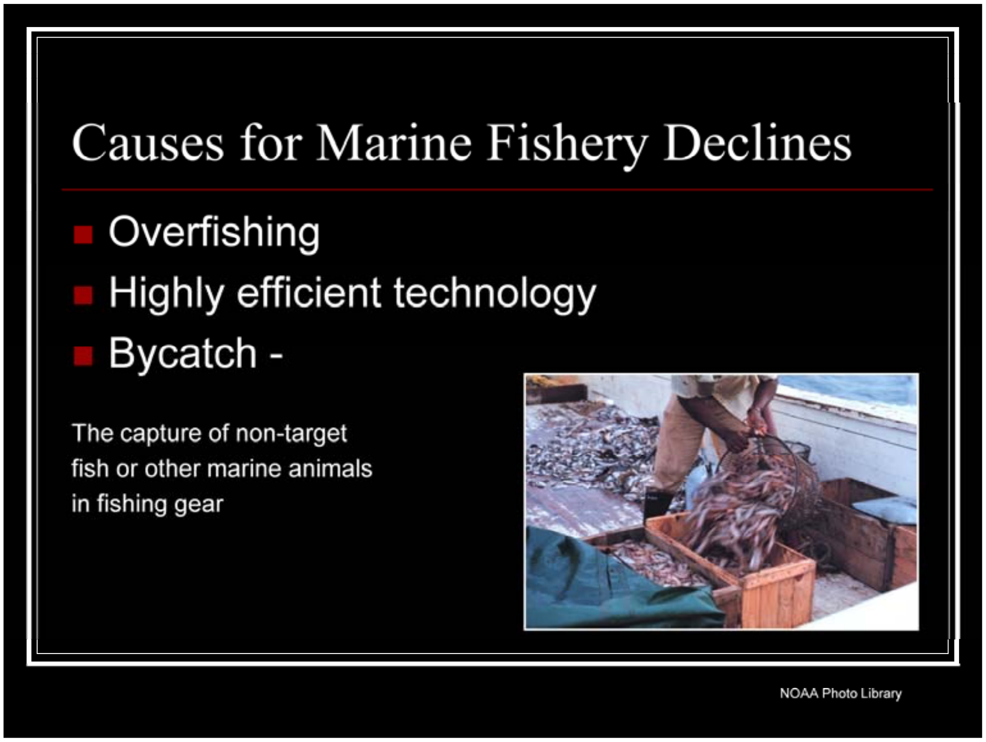
Many modern fishing vessels deploy larger, heavier gear than used in the past, allowing access to previously inaccessible fishing grounds. The bottom trawl shown here, for example, is held open by heavy doors (black rectangles in diagram) and dragged along the ocean floor. Some trawls are equipped with "rockhopper" gear (large rollers on bottom line in diagram) that allow bottom trawl nets to fish rocky, complex habitats where in the past gear would become damaged or lost.

For additional descriptions and illustrations of different gear types, see NCSR module entitled, *Where Does Your Seafood Come From?*



In contrast, historical fishing methods included handlines, longlines and gill nets which provided fishermen with a limited capacity to catch fish and impact aquatic ecosystems. These methods were deployed from fishing boats that were wind- or human-powered.

There were however, some exceptions. The historical use of gill nets to capture salmon returning to spawn in rivers, for example, had major impacts on some salmon runs.

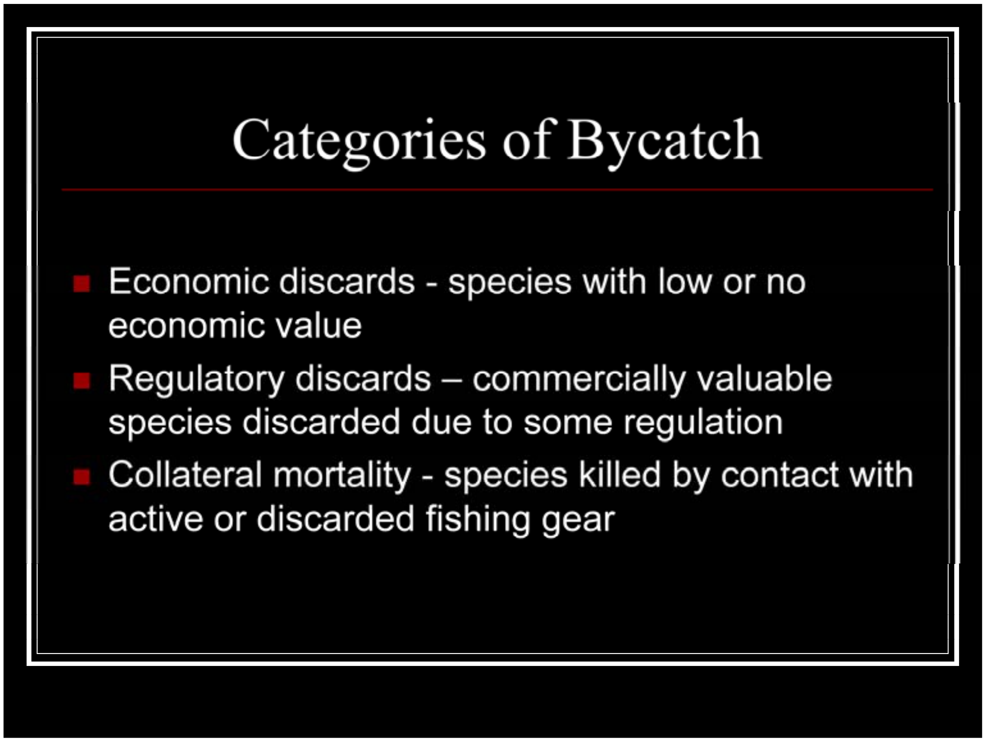


Bycatch – the capture of non-target fish or other marine animals in fishing gear

This "collateral damage" was once thought to occur at minimal levels and considered an unavoidable consequence to the use of non-selective fishing gear. Bycatch is now recognized as a serious problem that has had far-reaching impacts on marine ecosystems. Bycatch of non-target fish is estimated at approximately 25% of global fish landings and is not incorporated into landings figures. About 30 million tons per year are discarded as bycatch.

Longline fisheries for tuna and swordfish have been particularly damaging to non-target species. Large sharks, blue marlin, white marlin and sea turtles are frequently caught. Over 90% of white marlin mortality can be attributed to this "unintentional harvest."

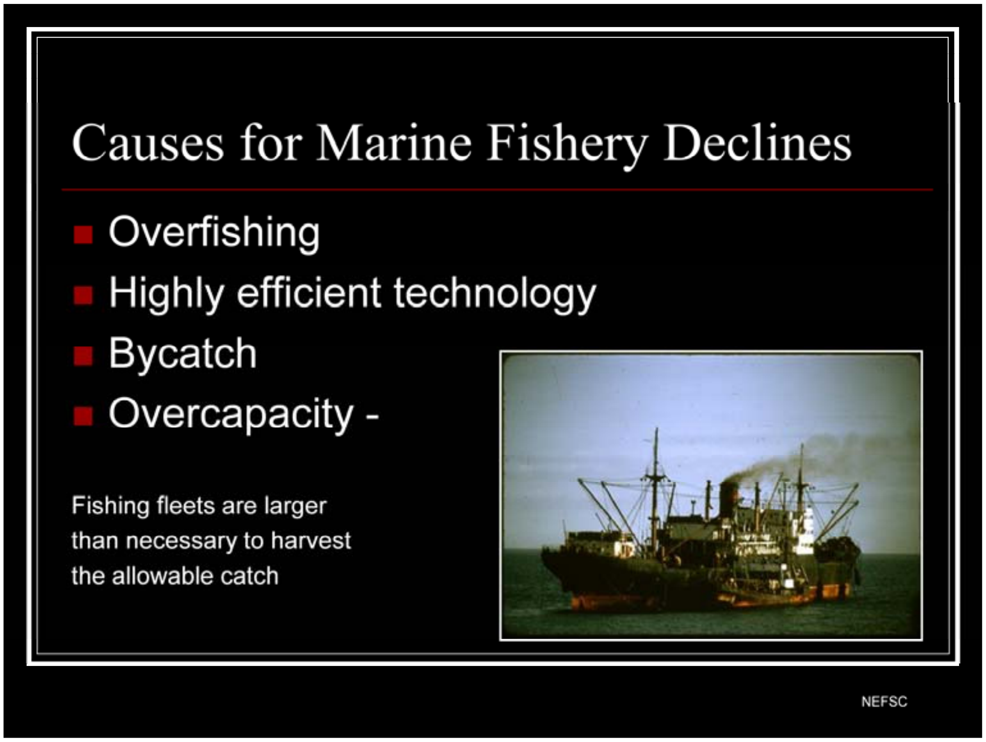
In some fisheries bycatch exceeds the targeted catch. The Gulf of Mexico shrimp fishery for example (shown in this photo) discards about 5 pounds of bycatch (mostly under-sized fish) for every pound of shrimp caught. Most of this bycatch (shown on deck behind fisherman) is dumped overboard.



Bycatch is the capture of (or damage to) non-target fish or other marine animals in fishing gear and may include:

1. economic discards - species with low or no economic value such as corals, skates, sponges
2. regulatory discards – commercially valuable species discarded due to some regulation (e.g., prohibited species, illegal size, over-quota captures)
3. collateral mortality - species killed by contact with active or discarded fishing gear (e.g., discarded or lost nets can continue to catch fish, birds and mammals and become so-called “ghost nets”)

There has been considerable effort since the mid-1990s to reduce bycatch in several fisheries. Some of these methods are discussed later in the *Marine Fisheries - Management and Proposed Solutions* module.



In many fisheries around the world, fishing fleets are larger than is necessary to catch the amount of fish that fish populations can produce over the long run. This is called **overcapacity**. By the early 1980s, the world's fishing fleets were 30% larger than needed to catch the maximum sustainable yield of the world's fish. Thus, with overcapacity it is almost inevitable that the capacity to catch fish will exceed the ability of fish populations to keep up with harvest.

The Bering Sea crab fleet, for example, now numbering about 250 vessels, has as much as five times the capacity to catch the available crabs. The capacity of the Atlantic cod fleet in Canada and the U.S. still exceeds the reproductive capability of the cod population. The Maine lobster fleet is another example.

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Although an active area of research, the current and future effects of long-term climate change on fisheries are largely unknown. Climate change has the potential to impact sea surface temperatures, sea levels, ocean circulation patterns, salinity and pH. All of these have direct impact on the abundance and distribution of marine fish. The effects of climate change will occur in environments that may already be characterized by environmental stressors such as depleted fish populations and habitat modification. Climate changes are likely to exacerbate these existing stresses on marine fish stocks. Stable, diverse communities are generally better able to withstand disturbances.

The impacts of climate change will vary among fisheries. In its most recent assessment, the International Panel on Climate Change predicted that saltwater fisheries production may actually be the same or perhaps higher if resource management deficiencies are corrected. The benefits of increased phytoplankton production (at the base of marine food webs) may be offset by costs associated with changes in reproductive patterns, migration routes and ecosystem relationships. Fisheries based in estuaries (e.g., shrimp, menhaden, sea trout) and on anadromous species (e.g., salmon) are more likely to be affected than open ocean species.

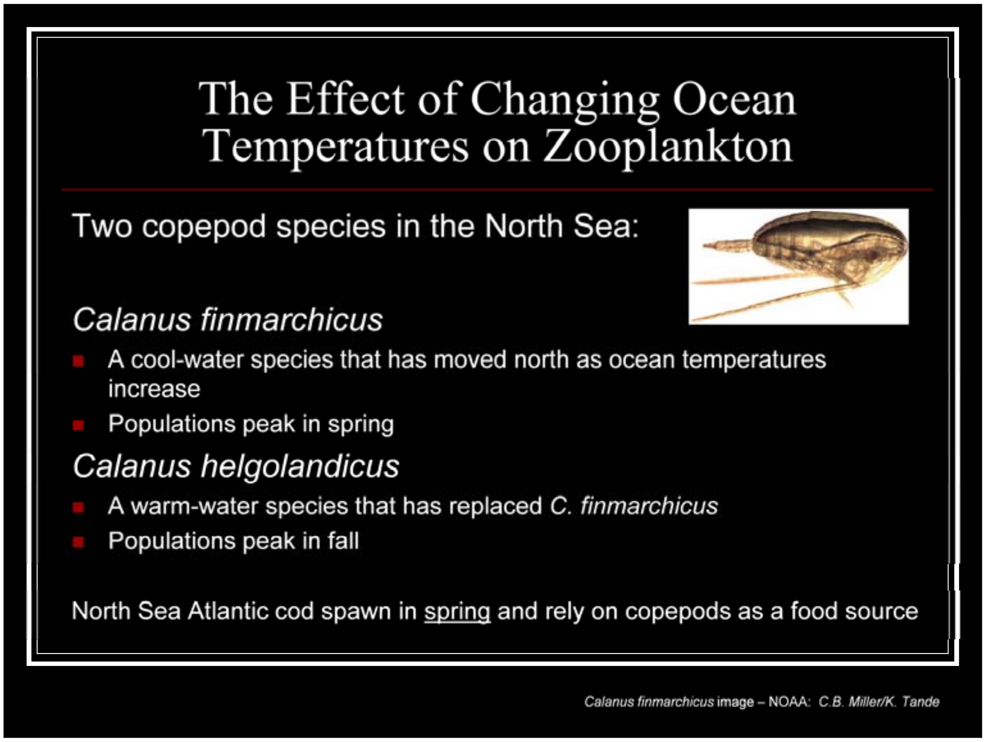
Temperature changes in oceans would be expected to be less and slower than in terrestrial environments due to the thermal inertia of the ocean. However, fish often respond to subtle changes in ocean temperatures and may migrate to other locations. If this movement is from one country's Exclusive Economic Zone to another, the allocation of the harvest of that species may shift from one country to another. As with agriculture, there will probably be "winners" and "losers."

Source: www.fao.org/fishery/topic/13789

Absorption of excess CO_2 by oceans impacts the marine carbonate system with consequences for marine organisms, particularly those with calcium carbonate structural components – shells, skeletons, tests, etc. (e.g., coralline algae, foraminifera, coccolithophores, corals, oysters, clams, sea urchins and sea stars). These organisms are important food sources and habitat components for marine fish. Thus, ocean acidification has the potential to impact marine food webs.

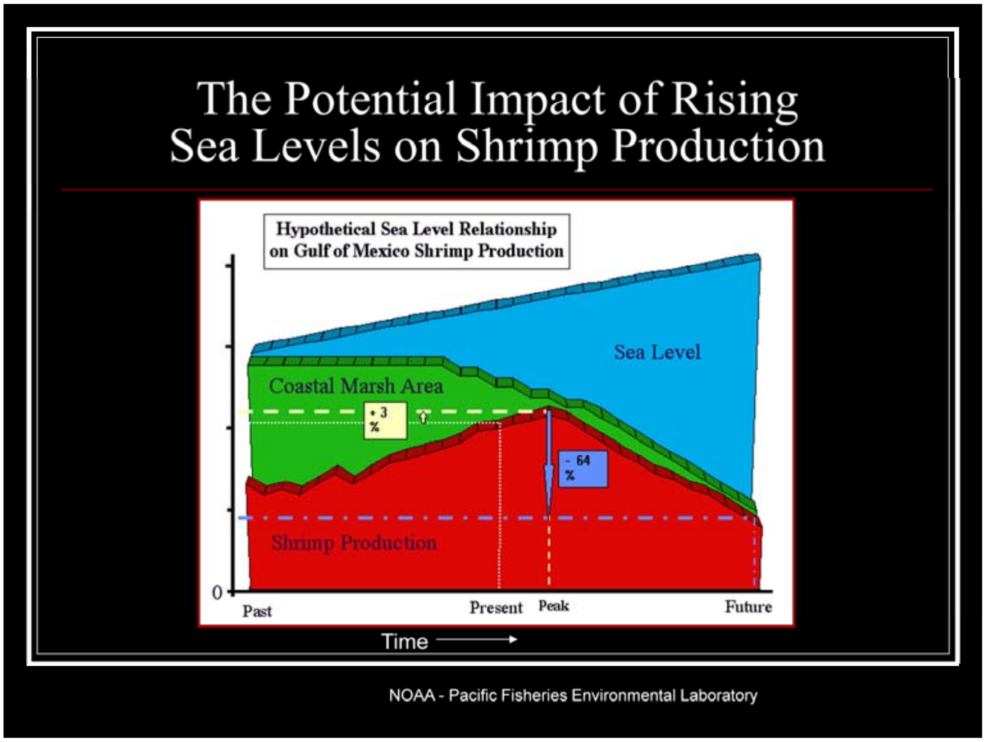
As carbonic acid dissociates, hydrogen ions (H^+) are released lowering the pH of seawater. Bicarbonate can further dissociate releasing additional hydrogen ions and further lowering pH. As seawater becomes more acidic it becomes more corrosive to carbonate structures. Additionally, excess hydrogen ions bind with available carbonate ions decreasing their availability and making it more difficult for marine organisms to build and maintain calcium carbonate structures (i.e., acidic conditions favor their dissolution).

Ocean acidification may also have more direct impacts on marine fish. In the short-term, pH changes in fish tissues and body fluids may cause impacts on respiration, circulation, and nervous system function. In the long-term, there may be effects on metabolism, growth and reproduction. Early developmental stages (eggs and larvae) are probably more affected than adult fish.

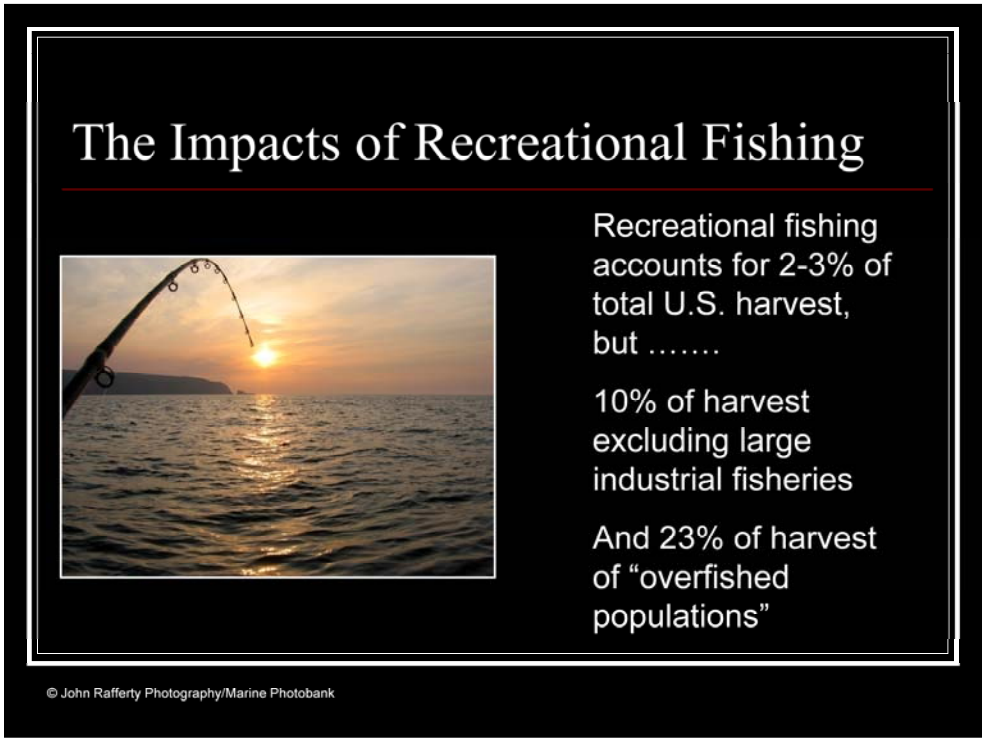


An example of “food web effects”:

Zooplankton are particularly sensitive to changing ocean temperatures and form an important link in energy flow between phytoplankton and marine fish. Warming ocean temperatures in the North Sea, for example, have resulted in a change in the distribution of copepods. The cool-water species *Calanus finmarchicus* has moved north in response to increased ocean temperatures and has been replaced by the warmer-water species *Calanus helgolandicus*. Although the two species play essentially the same role in marine food webs, *C. finmarchicus* populations peak in spring, while *C. helgolandicus* peaks in fall. Atlantic cod in the North Sea spawn in spring and their larvae feed primarily on copepods. Thus, this change in copepod abundance has compromised the reproductive success of cod and may be contributing to the decline of the species there (Richardson. A.J. 2008).



The figure illustrates a potential impact of global climate change on the Gulf Coast shrimp fishery. Most global climate change scenarios predict increases in sea level in the Gulf of Mexico. Raising sea levels result in the inundation of coastal marshes, which can temporarily provide beneficial conditions for the growth and reproduction of shrimp. Continued inundation however, results in the degradation of marsh habitat and the conversion to more open water habitats. The availability of marsh habitat declines with a resulting decline in shrimp populations. This model predicts a 64% decline in shrimp production below peak levels (dashed blue line in figure).



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Although generally considered to be of lesser impact than commercial fishing, the impact of recreational fishing on fish populations is not negligible and, for some fisheries, represents the majority of harvest. Recreational fishing accounts for 2-3% of landings in the U.S.; however, when large industrial fisheries are excluded (e.g., pollock and menhaden) the recreational take increases to 10%. These two species were excluded because, although they comprise over half of U.S. landings, they have minimal recreational value and are not considered overfished. Also, recreational fishing accounts for about 23% of the total take for those species identified by NOAA Fisheries as "overfished populations" (e.g., lingcod, bocaccio, red snapper, red drum).

NOAA Fisheries estimates that there are 17.7 million sport fishing boats in the U.S. and recreational anglers take an average of 89 million fishing trips per year. There are over 10 million saltwater recreational anglers alone. Thus, although the per capita take is relatively small, the shear size of the effort makes recreational harvest a significant contributor to overall harvest.

Some examples:

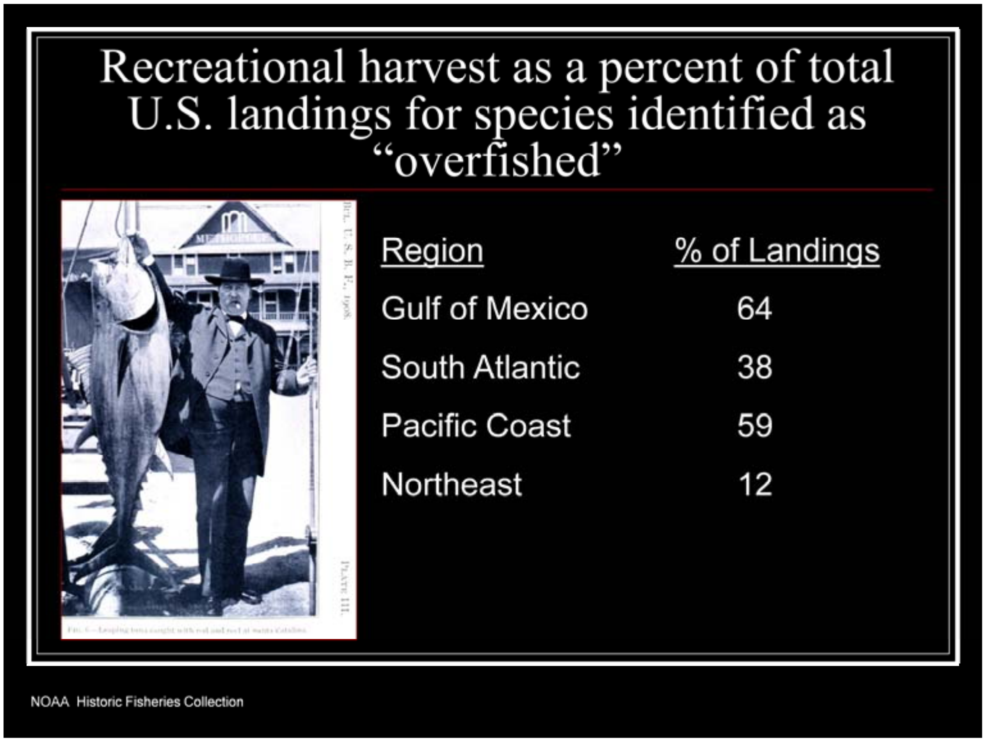
Several rockfish (Sebastes spp.) populations along the West Coast collapsed in the late 1990s and early 2000s, in part due to increases in recreational harvest. For one species (bocaccio), recreational harvest accounts for 87% of the take. As a result of the decline, significant changes in regulations were put in place including new closures, catch limits for anglers and a sport fishing quota.

In the Alaska halibut fishery the portion of total catch by recreational anglers has increased steadily since the mid-1990s. In 2006 recreational charter vessels in Southeast Alaska exceeded their allowable quota by 46%. This prompted fishery managers to reduce the daily limit from two fish to one fish per angler and a moratorium on new permits for charter vessels was put in place. Charter vessels may now enter the fishery only by purchasing existing permits from willing sellers.

The management of recreational fishing is generally accomplished by size and catch limits. Unlike commercial fisheries, few recreational fisheries place any controls on the aggregate catch of recreational anglers. Also, about 40% of coastal states do not require saltwater fishing licenses.

For a more detailed discussion of the impacts of recreational fisheries on marine fish populations, see Coleman, et al. (2004).

Coleman, F.C., et al. 2004. The impact of United States recreational fisheries on marine fish populations. Science 305:1958-1960.

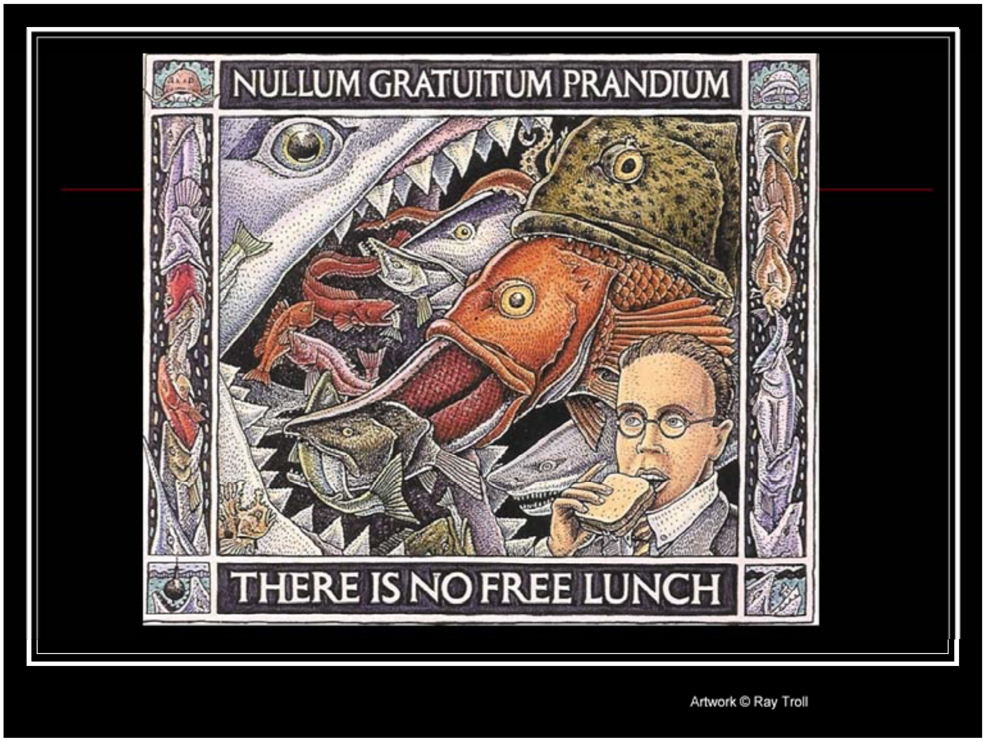


Percent of total U.S. landings for species identified by NOAA Fisheries as "overfished" or "experiencing overfishing" by region:

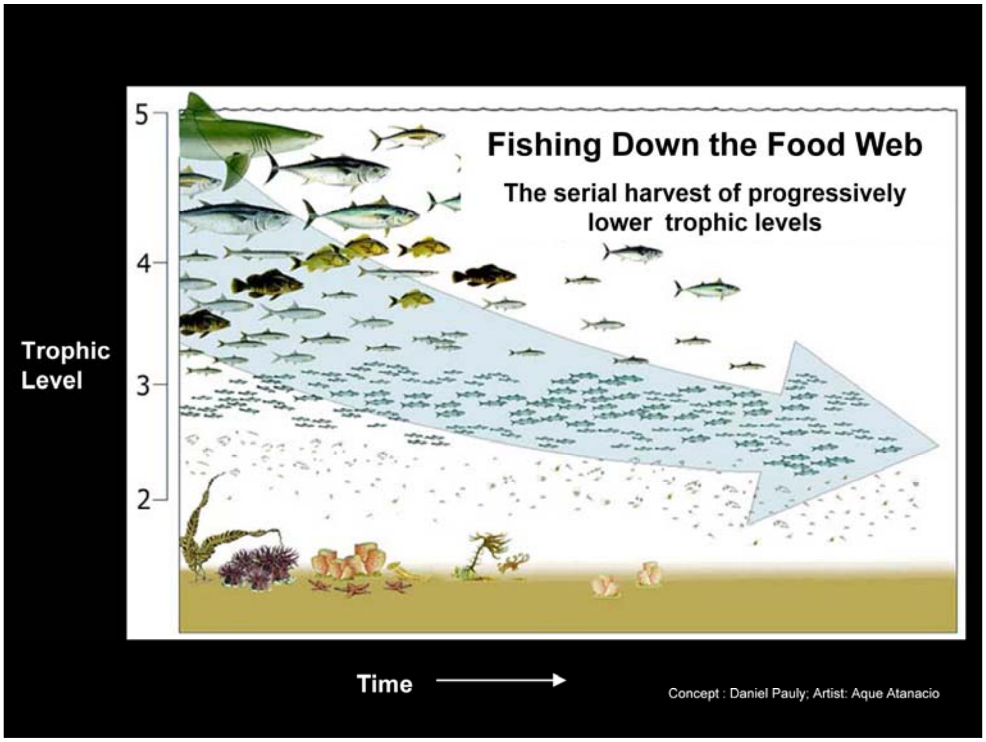
<u>Region</u>	<u>% of Landings</u>
Gulf of Mexico	64
South Atlantic	38
Pacific Coast	59
Northeast	12

Fishing pressure obviously has an impact on the targeted species. However, in recent years it has become clear that there are ecosystem effects as well. These include:

1. Fishing down the food web
2. Habitat degradation
3. Trophic cascades
4. Changes in life history traits of target species



It is important to recognize that the species we harvest are - like us - part of complex ecosystems. When we impact one part of the system, there are impacts in other parts of the ecosystem due to the interconnectedness that exists between ecosystem elements.

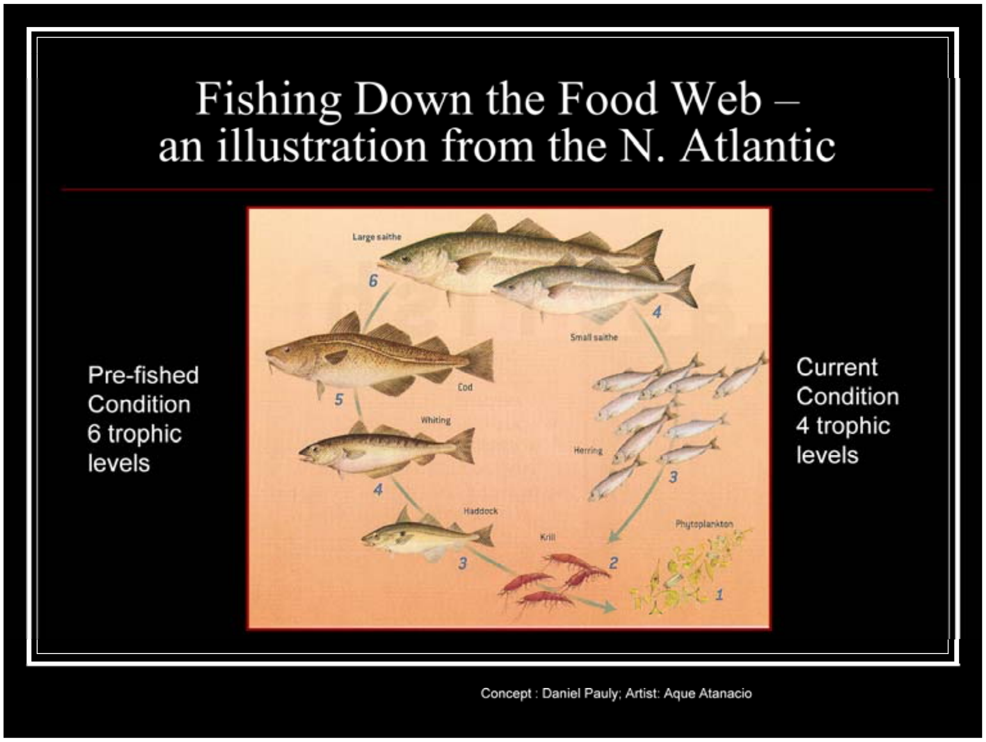


Fishing Down the Food Web - systematic removal of the largest (and usually most valuable) species (top-level predators) in an ecosystem. Smaller, less-valuable species are caught as a result.

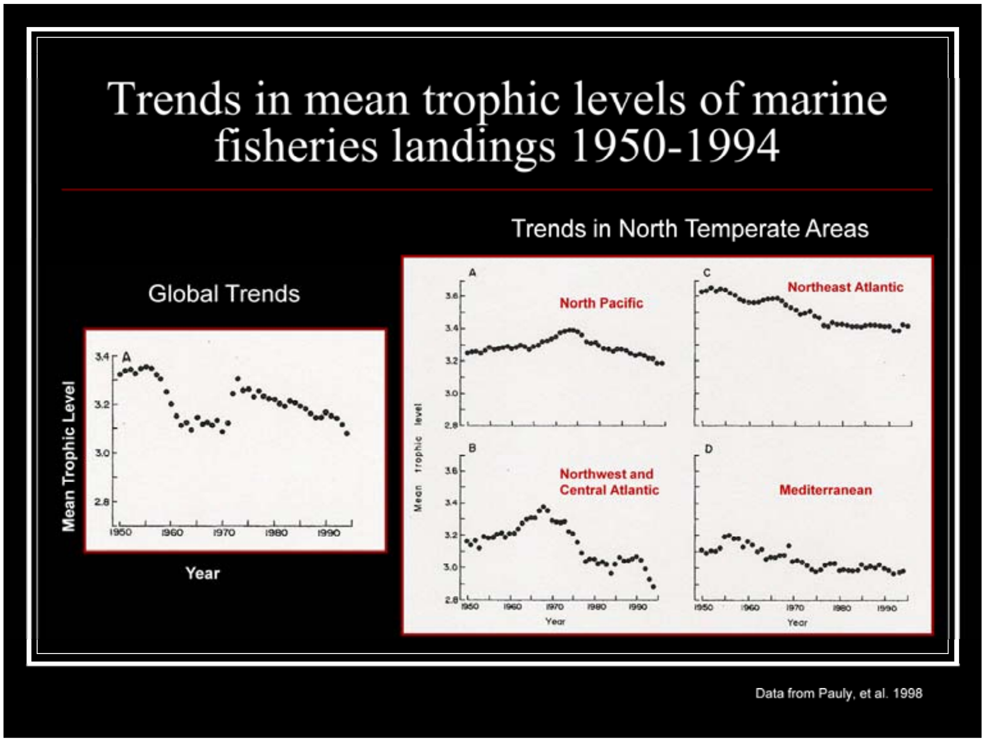
In this illustration of "fishing down the food web" the arrow indicates the trajectory of time. The pre-fished condition (on the far left) is characterized by abundant predators and complex ocean floor habitats. Conditions at present are depicted in the middle of the diagram. Predator populations are much depleted and complex bottom habitats have been simplified due to the impacts of fishing gear.

Daniel Pauly contends that the health and sustainability of fisheries can be assessed by monitoring the trends in average trophic levels of fish that are landed. When these values drop, it indicates that fishers are relying on progressively smaller fish and that populations of larger predatory fish at higher trophic levels are beginning to collapse. According to research published in 1998, this phenomenon had already occurred in the North Atlantic, off the southern coast of South America, the Arabian Sea and around parts of Africa and Australia, which experienced trophic level declines of 1.0 or greater between 1950 and 2000. Off Newfoundland the average trophic level change was from 3.65 in 1957 to 2.6 in 2000. During that time the average size of fish landed decreased by one meter.

Pauly contends that if current conditions persist we may end up with even more simplified systems that favor only a few small fish species and invertebrates such as jellyfish.



For example, when overfishing occurs, food webs become shortened and simplified. In the pre-fished condition (illustrated in sequence at left) large saithe feed on cod which feed on whiting, etc. resulting in as many as 6 different trophic levels. Fishing typically removes the large predators (e.g., large saithe) from the ecosystem first. Smaller saithe are not big enough to feed on cod; therefore, they pursue smaller prey such as herring (illustrated in sequence at right). The resulting food web is four levels rather than six, disrupting the ecosystem.



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A study conducted by David Pauly and colleagues in 1998 evaluated the “fishing down the food web” phenomenon. They estimated the trophic levels for 220 commercial fish species and used U.N. FAO fish landings data from 1950-1994. The results suggested an overall 0.1 trophic level decline for every 10 years due to overfishing of predaceous species and a total decline of 0.5 trophic level over 40 years (see Global Trends at left). The current global average trophic level is about 3.1. Recall that trophic levels for a species are not usually whole integers, but rather due to varied diets, some value between whole numbers.

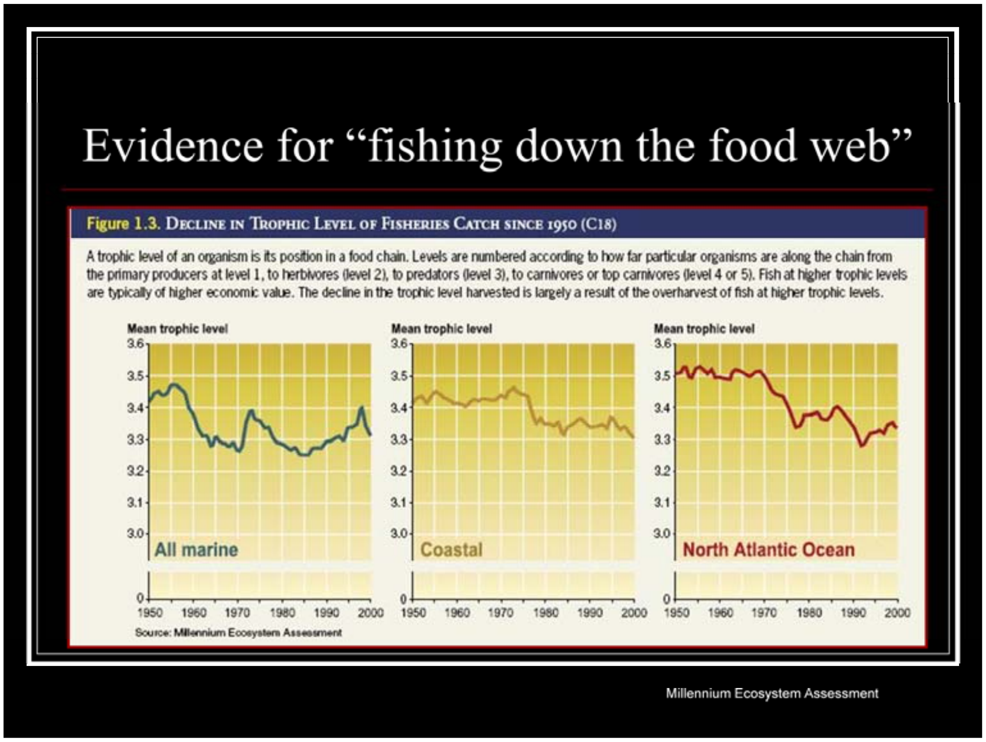
NOTE: The dip in average trophic level from 1960-1970 was caused by extremely high catches of Peruvian anchoveta, which has a low trophic value of 2.2.

Graphs for specific North Temperate areas are shown at right (A = North Pacific, B = Northwest and Western Central Atlantic, C = Northeast Atlantic, D= Mediterranean). All show a decline in mean trophic level over the period of study. For details see Pauly, et al. 1998.

Even after fishing controls are put in place, fishing down food webs may delay the recovery of top predators by removal of their prey. Pauly recommends establishing complete fishing bans on additional areas to allow fish populations to recover.

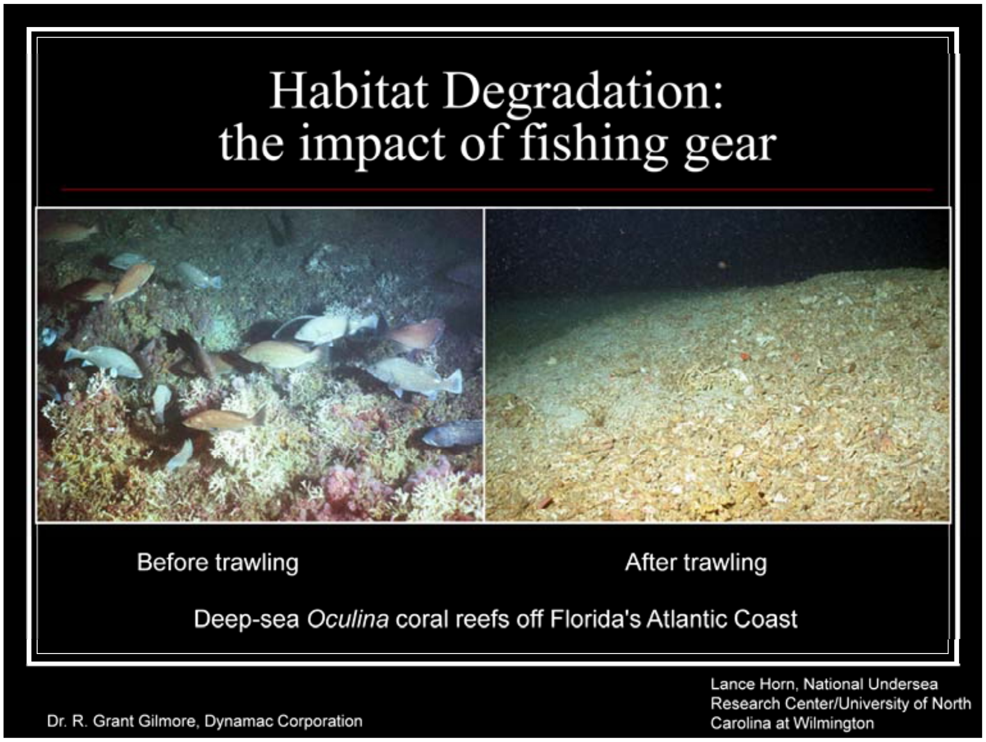
“We’ve eliminated the marine equivalent of lions and wolves and are moving towards the taking of rats, cockroaches and dandelions.”

Elliot A. Norse
Marine Conservation Biology Institute
Redmond, WA



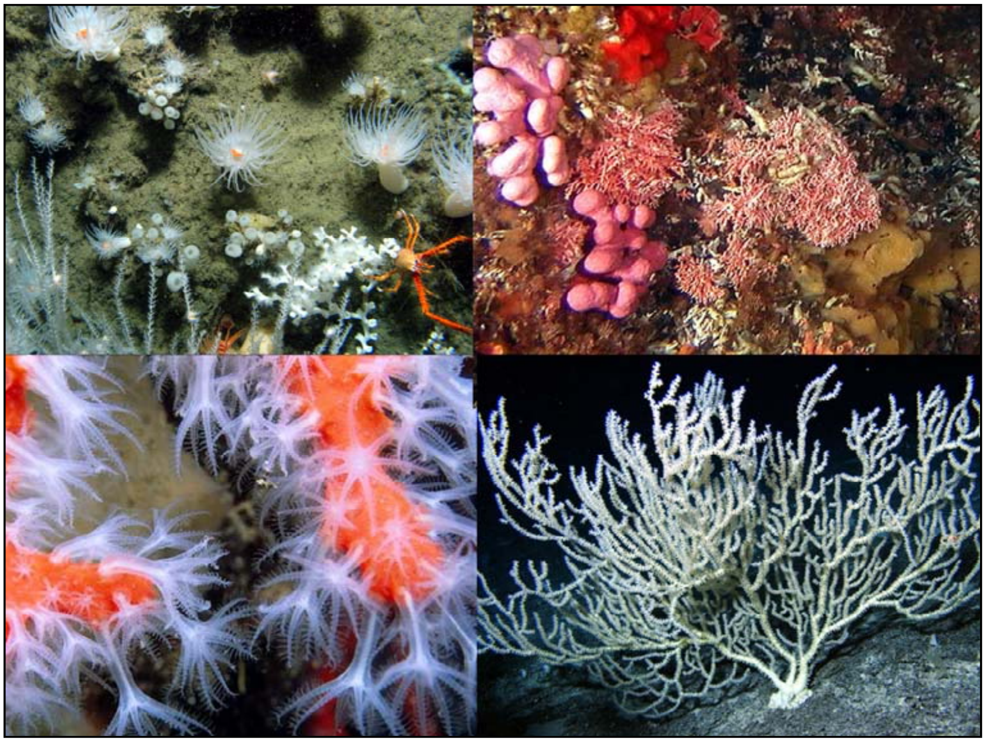
Declines in mean trophic levels for all catches from 1950-2000 are illustrated here for:

- All marine areas
- Coastal areas
- Atlantic ocean



Certain types of fishing gear can damage the physical structure of marine habitats as they pass over the ocean floor. Bottom trawls used to capture demersal fish species and dredges used to capture scallops have been shown to be particularly damaging to sensitive habitats. These methods also capture significant amounts of both vertebrate and invertebrate bycatch, disturb benthic sediments and crush or bury benthic organisms. Community composition may be altered as a result.

PHOTOS - Groupers (seen in photo at left) were abundant on deep-sea *Oculina* coral reefs off Florida's Atlantic Coast before trawling began; legal and illegal trawling has nearly eliminated the corals and large fishes in this ecosystem.



Some benthic habitats such as the deep sea coral reefs off the coast of Alaska are particularly vulnerable to bottom-fishing gear. The cold-water corals from waters off the Aleutian Islands shown here are an example. Invertebrates such as these form an important structural component of these marine ecosystems. Other habitats such as muddy or sandy bottoms that do not have marine invertebrates as an important structural component may not be as vulnerable to bottom fishing gear.

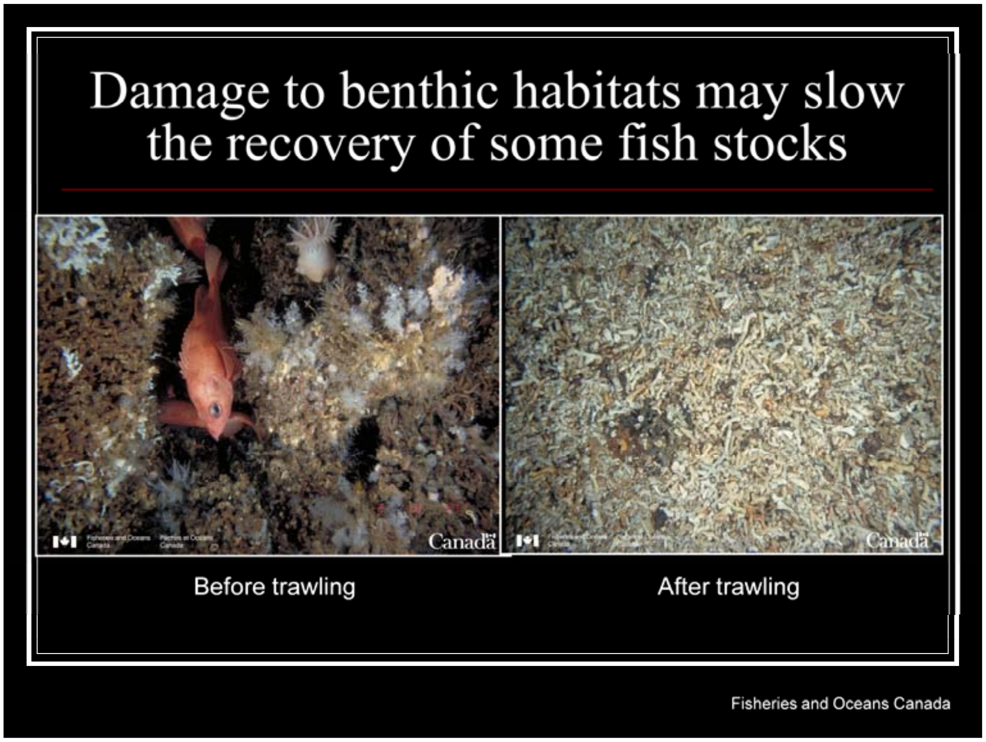
Photo Credits:

Top left – NOAA / S. Brooke

Top right - Robert Stone, NOAA Fisheries/Marine Photobank

Bottom left - G. Marola, 2007/Marine Photobank

Bottom right - Brooke et. al., NOAA OE 2005/Marine Photobank



See notes slide 22

Notes Slide 22

Repeated damage caused by bottom trawling slows (or prevents) the recovery of these degraded habitats and probably contributes to the slow recovery rates of some fish stocks, even when fishing effort is reduced. NOAA Fisheries estimates that some areas on George's Bank off the New England coast are trawled three to four times each year. The extent of damage to benthic communities by fishing gear is largely unknown and is currently an active area of research.

Photo at left shows an intact *Lophelia pertusa* reef or mound with a redfish (*Sebastes* sp.) peering out
Photo at right shows *Lophelia pertusa* reef reduced to rubble from the impact of trawling

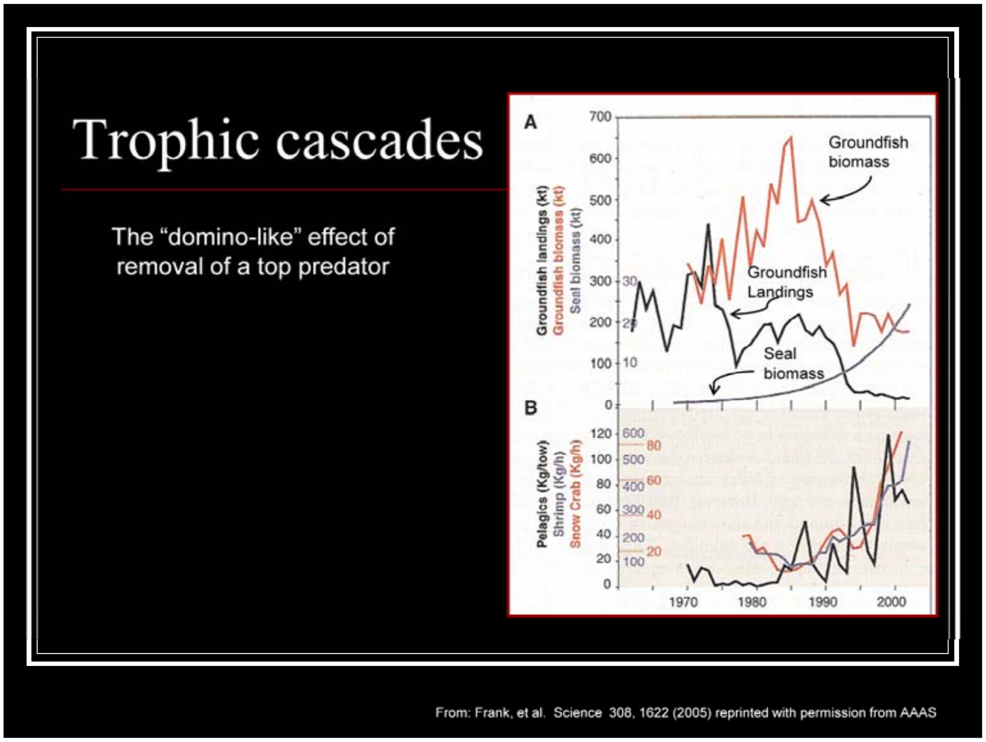
For more detail on the impacts of fishing gear on benthic habitats, see:

1. 1. Morgan, L.E. and R. Chuenpagdee. 2003. Shifting gears: Addressing the collateral impacts of fishing methods in U.S. waters. Island Press, Washington, D.C. 42 pp. www.mcbi.org

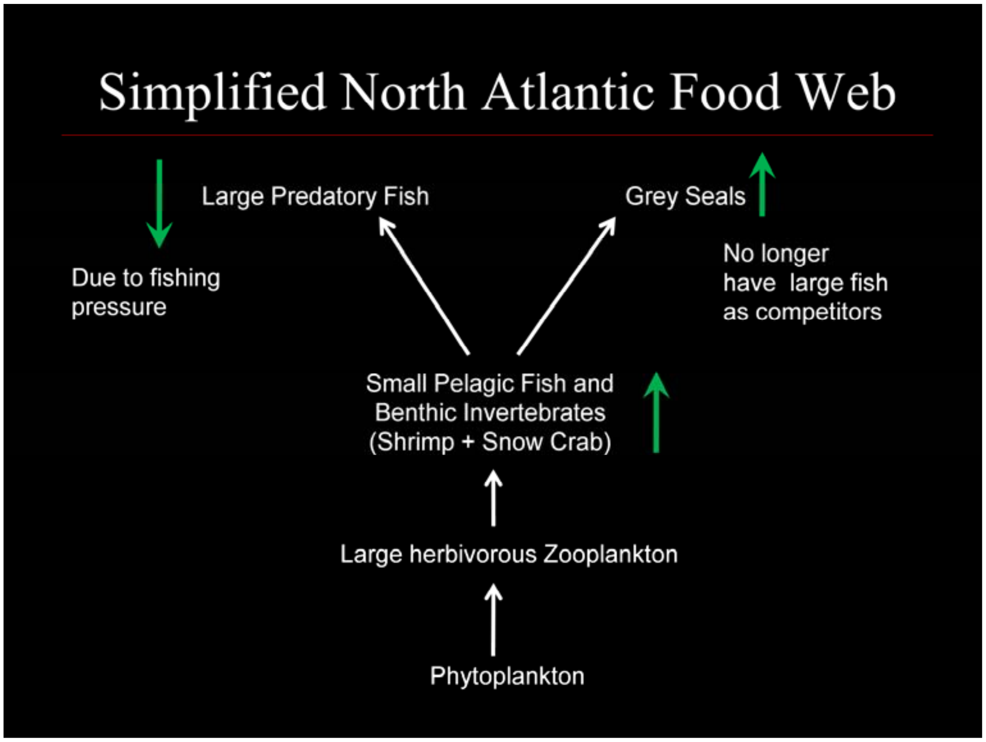
2. Fuller, et al. 2008. How we fish matters: Addressing the ecological impacts of Canadian fishing gear. Ecology Action Centre (Halifax, Nova Scotia), Living Ocean Society (Sointula, B.C., MCBI (Bellvue, WA). 25 pp. www.mcbi.org

A few short videos of the ocean bottom habitat before and after trawling as well as trawling in action are available on this website:

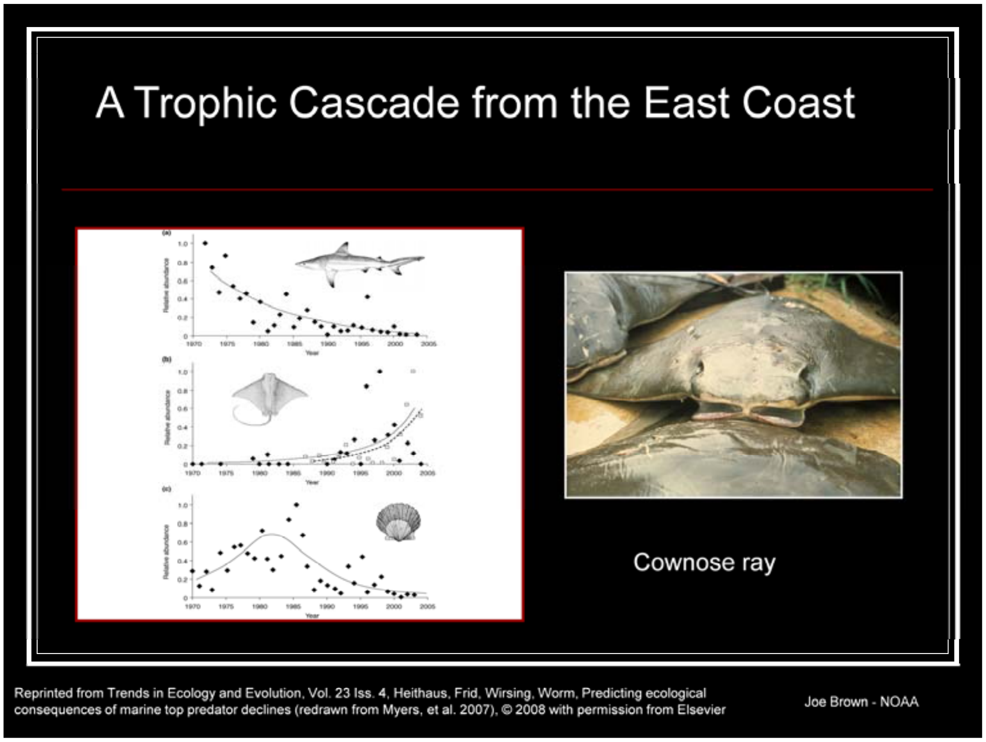
http://www.mcbi.org/cgi-bin/photo_library.pl?ID=8



The decline of one species (particularly a top predator) can have impacts that reverberate throughout the ecosystem in a domino-like fashion (i.e., a "trophic cascade"). These graphs illustrate evidence for just such an event that involves Atlantic cod, seals, crabs, small pelagic fish and zooplankton. The first graph (A) illustrates declines in groundfish (mostly cod) biomass with a corresponding increase in seal populations. With declining cod populations, species that are preyed upon by cod (pelagic fish, shrimp and crabs) all show increases over the same time period (see graph B). In addition, it has recently been demonstrated that grey seals are significant predators of cod, accounting for 21% of cod mortality since 1993. This may be contributing to the slow recovery of cod despite decreased fishing pressure. Studies such as these enhance our understanding of the interconnections between marine ecosystem components and point out the potential hazard of species-level only management.

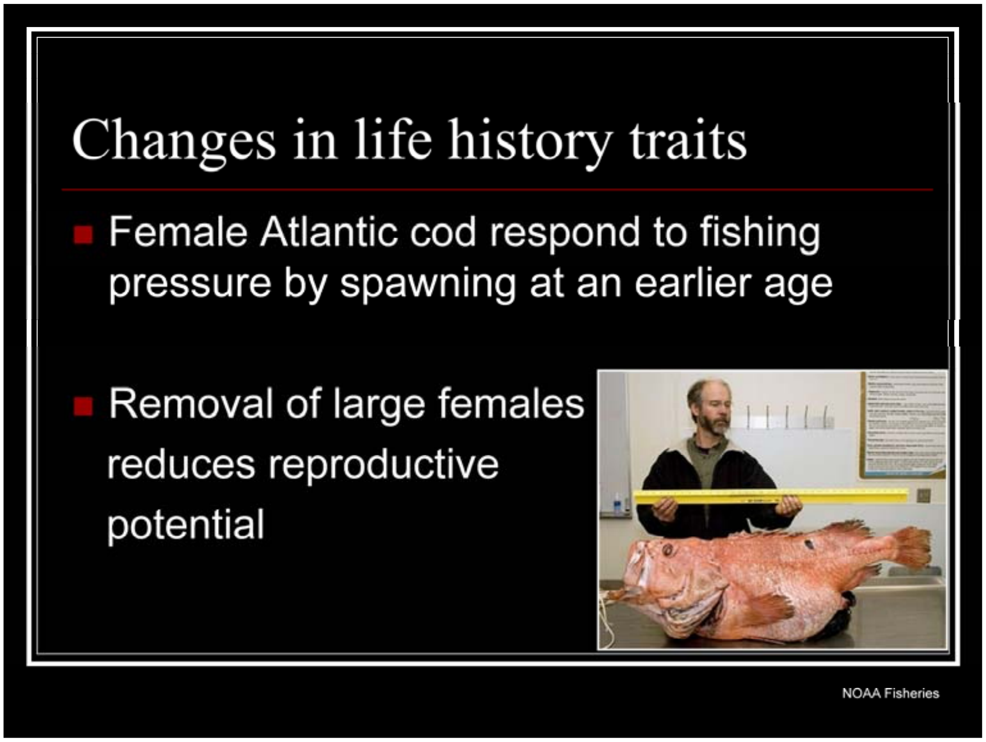


Above is a simplified food web for the North Atlantic. The white arrows indicate flow of energy while the green arrows indicate changes in population as a result of increased fishing pressure on large predatory fish, thus demonstrating a “Trophic Cascade” as described on the previous slide. Interestingly, as a result of the changes shown here, shrimp and snow crabs have become the targets of an important new fishery.



From Heithaus, et al 2008 (redrawn from Myers, et al. 2007)

The removal of top predators can have a cascading effect on other members of the marine community. This figure illustrates a trophic cascade along the east coast of the United States. Catch rates of blacktip sharks during research surveys declined dramatically from 1970 to 2000. Cownose rays, a mesopredator that is preyed upon by large sharks, increased over the same time period (Different data points in “b” represent different surveys in Delaware Bay and Pamlico Sound, North Carolina). Rays feed on bay scallops which showed a steep decline over the same period. Thus, the loss of a top predator has resulted in the decline of a species at a lower trophic level (bay scallops, in this case).



See notes slide 26

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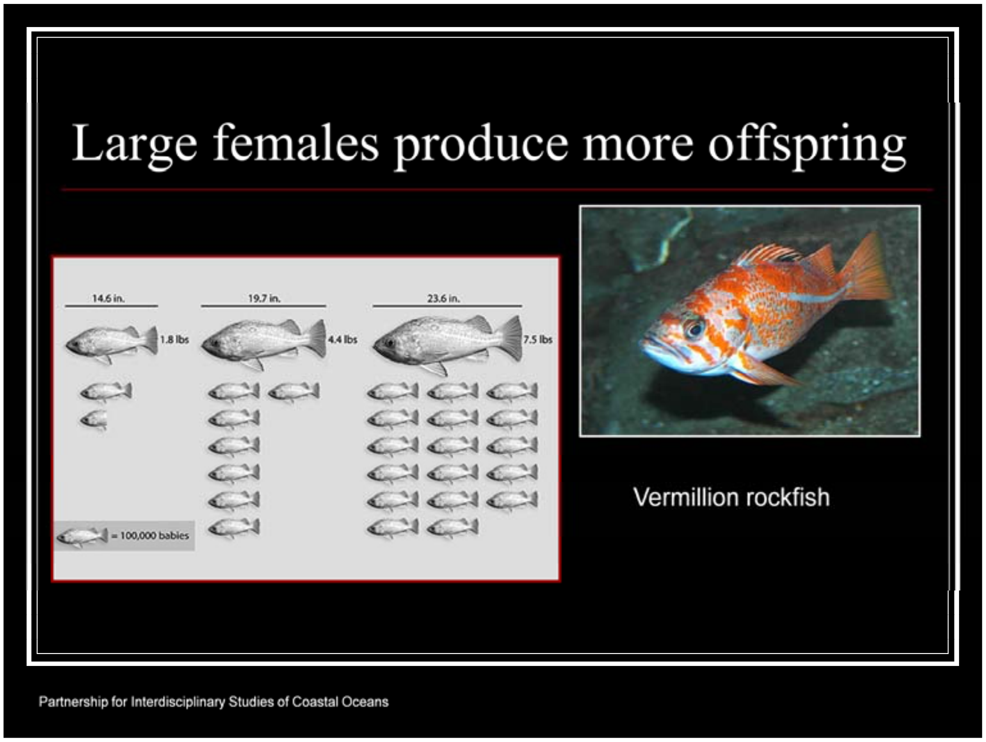
Female cod responded to intensive fishing pressure by spawning at an earlier age. On Georges Bank, average spawning age declined from 5-6 years to less than 3 years. In the Barents Sea north of Scandinavia, cod matured at age 9 or 10 years 70 years ago, but now mature at 6-7 years. This response is thought to be an adaptation to small population sizes. However, younger spawners produce smaller and fewer eggs and, therefore, smaller fry. This makes the new generation more prone to predation and may be contributing to the slow recovery of cod stocks.

In long-lived species (like this 100-year old shortraker rockfish from Alaska), the removal of larger, older individuals from the population diminishes the capacity for the population to rebound from declines caused either by overfishing or changing ocean conditions. These large fish are often among the first to be harvested due to their high market value.

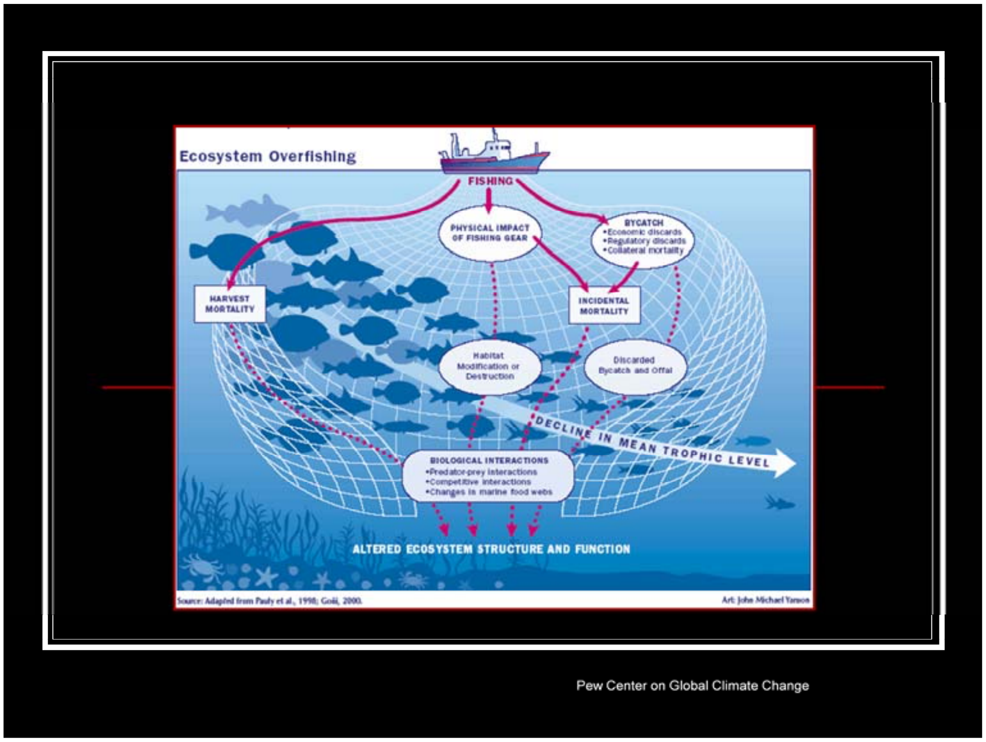
These demographic changes can be particularly troublesome when fishing creates selection pressures that favor smaller and slower-growing fish. A 50-year study of larval fish populations in the California Current (Anderson, et al. 2008) suggests that demographic changes such as earlier age at maturation or population growth rate may be permanent as a result of decades of this type of selection. Once this evolutionary change has occurred, genetic change may be irreversible or at least only slowly reversible contributing to slow or non-existent recovery of depleted fish stocks.

Steven Berkeley at the University of California, Santa Cruz reported on the effects of changes in life history traits in the black rockfish, a long-lived (50 years) species off the Oregon Coast. Gravid females ranging from 5-17 years old were housed in lab aquaria and allowed to spawn. Their offspring were then tracked for growth and survivability. The offspring from the oldest females were twice as likely to survive short periods of starvation and grew three times as fast as offspring from younger females. It seems that “big old fat females” contribute disproportionately to the future population.



For fish with long life spans, in particular, “big, old, fat females” as a result of their higher reproductive potential when compared to younger, smaller females, contribute more significantly to the next generation. As illustrated here for rockfish, larger individuals produce larger numbers of eggs and therefore, leave significantly more offspring. A 23-inch female vermillion rockfish, for example produces 17 times more young than a 14-inch vermillion rockfish. This species reaches sexual maturity at 5-9 years and has a maximum lifespan of at least 60 years.

Recent studies have also shown that these large females produce offspring that grow faster and survive starvation better than offspring from younger females.



See notes slide 28

Notes Slide 28

Summary of community and ecosystem effects of fishing.

The decline of one fish stock often triggers the development of fisheries for new species in the same area. Large, predaceous fish such as tuna, saithe, swordfish, salmon and sharks are often the primary focus of developed fisheries. As the populations of these species are depleted, fishers shift their efforts to middle and then lower trophic level species to meet increased demand for fish protein. These substitutes come from progressively lower trophic levels because greater biomass is present at lower trophic levels due to the pyramid shape of biomass pyramids and the "10% efficiency rule". The shift from large predators to lower trophic levels is known as "fishing down the food web." The result may be the disruption of marine ecosystems as intricate connections between species in the food web are unraveled. Consequently, fishing down the food web may impact entire communities and ecosystems, not just the target species.

Note: The 10% efficiency rule states that in any ecosystem, only 10% of the available biomass at any one trophic level can be converted into biomass at the next highest trophic level.

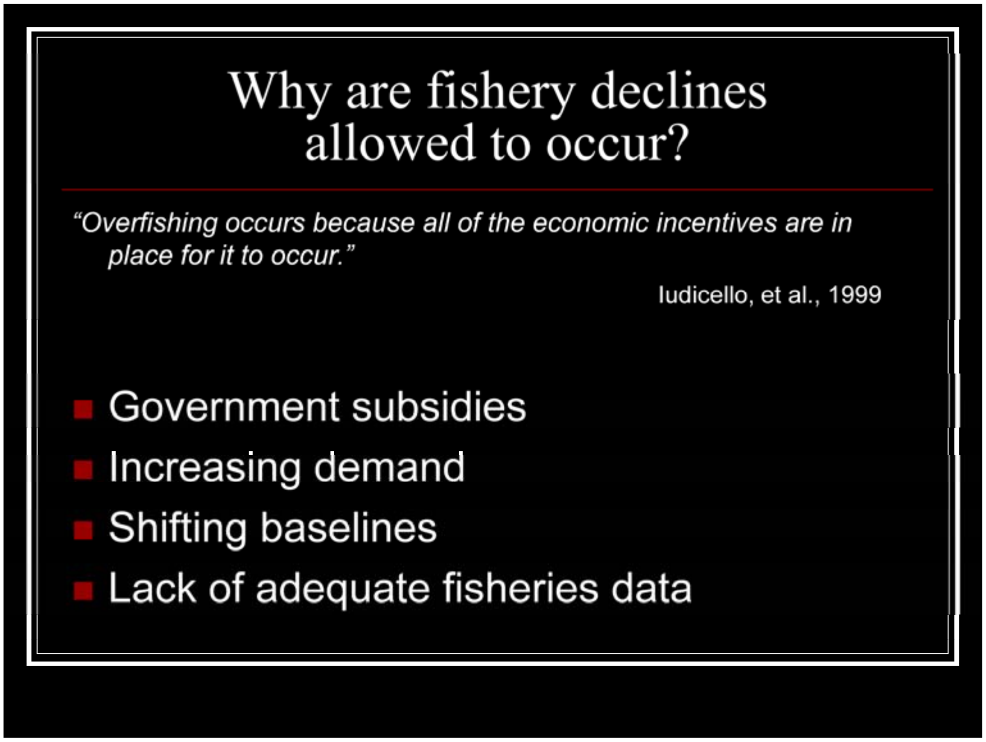
Also, see:

http://mitworld.mit.edu/video/501/

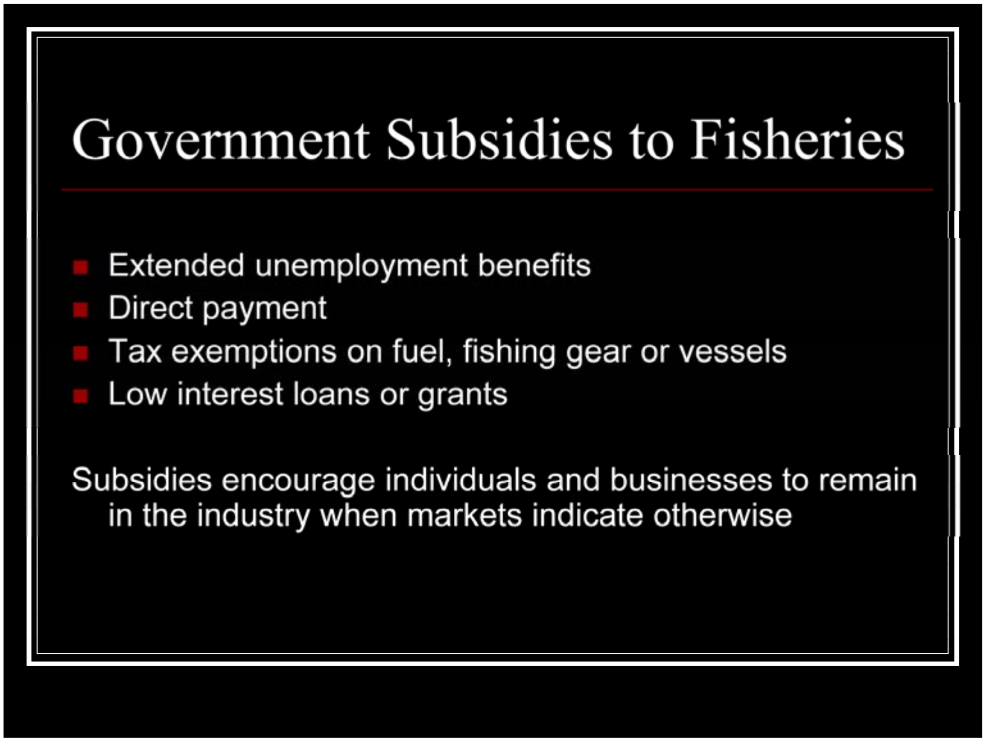
This is a 50-minute Daniel Pauley lecture at MIT. It does a good job of explaining "fishing down the food web" and the role of subsidies in fisheries decline.

http://www.cbc.ca/landandsea/archive/2007-jan-28.html

This web site includes an interesting video from the *Canada on the Land and Sea* series that documents the decision by Canada not to go along with a moratorium on dragging seamounts. Fishermen, environmentalists, biologists and government officials are interviewed.



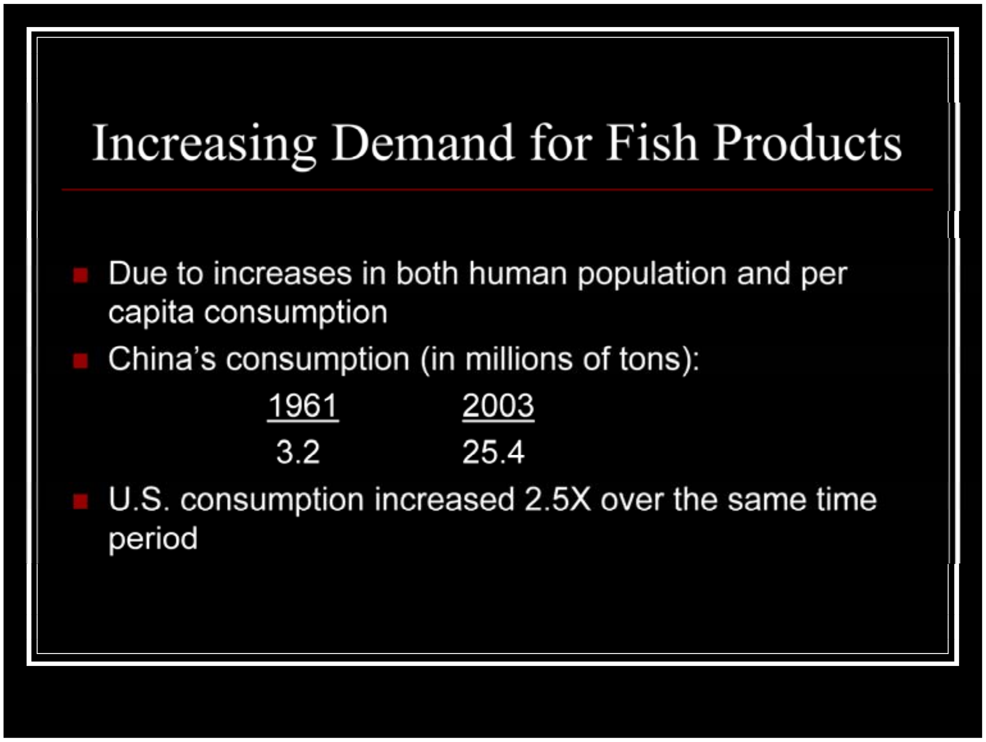
Once students understand the evidence for fishery declines and their causes, they may wonder why these declines have been allowed to occur. At least four societal/psychological phenomena contribute to declines. Each is discussed separately.



Government subsidies may be provided to the fishing industry in several forms – extended unemployment benefits, direct payment, tax exemptions on fuel, fishing gear or vessels, low interest loans or grants to encourage investment into the industry. Overcapitalized fisheries can continue to operate after the resource is depleted by relying on these subsidies. Thus, individuals remain in the industry longer than the supply would ordinarily dictate.

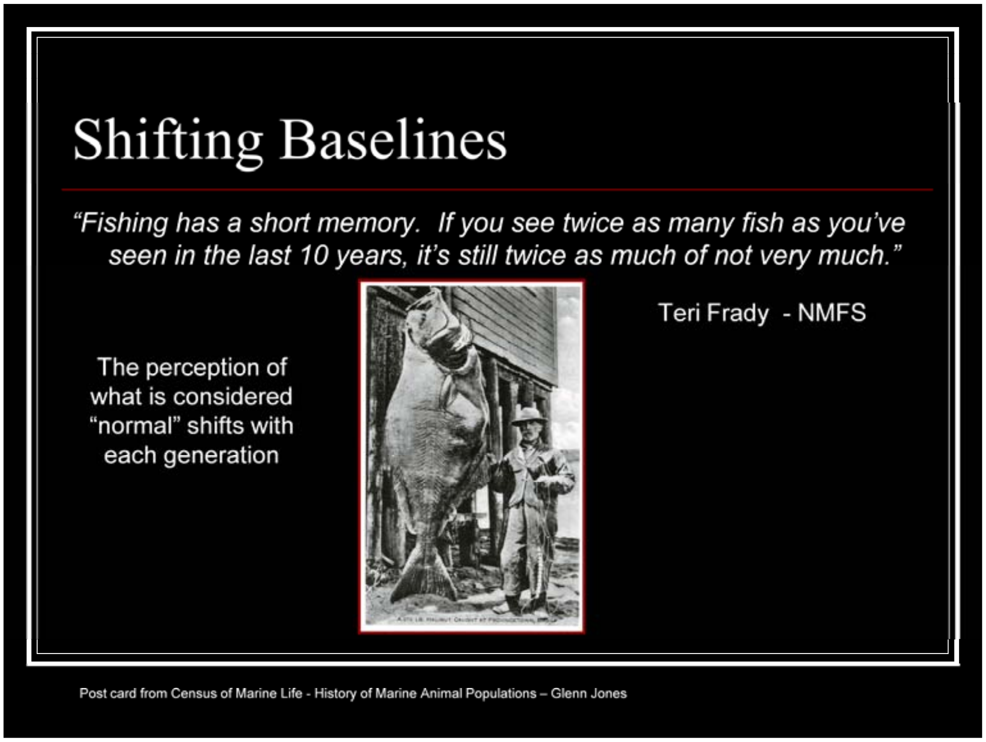
The Food and Agriculture Organization of the United Nations estimates that the global fishing fleet spends $50 billion more than it makes every year.

Higher fuel prices might be expected to reduce overfishing as fuel expenditures consume profits from the sale of fish. However, fuel subsidies to the fishing industry by governments distort this economic relationship. Global fuel subsidies are estimated to be in the range of $ 4.2-8.5 billion per year. The fishing industry can therefore absorb some increases in fuel cost without reducing fishing effort. Any conservation efforts that occur as a result in fuel price increases will therefore be delayed or not materialize at all. See Sumaila, et al. (2008) for details.



Despite fishery declines, demand has increased and will probably continue to increase. China, for example, has increased its total consumption of fish from 3.2 million tons in 1961 to 25.4 million tons in 2003 with the majority now supplied by aquaculture operations. This increase is due only in part to population increases. Per capita fish consumption in China has increased over five-fold during the same time period.

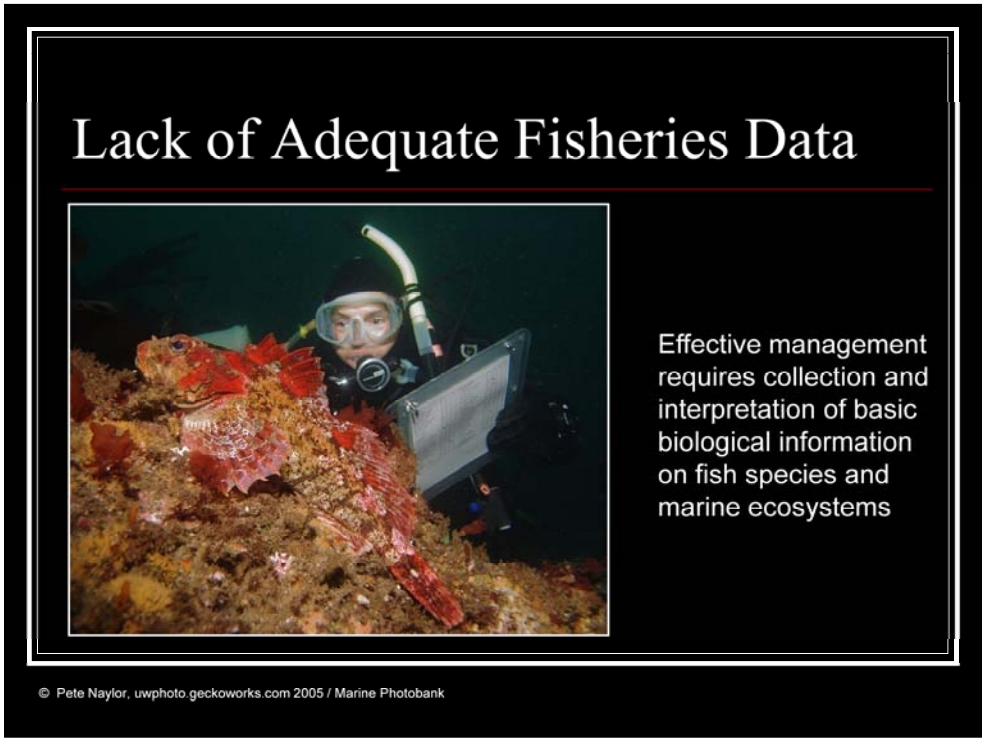
Fish consumption has also increased in the United States over the same time period as total consumption in 2003 was 2.5 times greater than 1961 levels. Per capita consumption increased 1.6 times, presumably due in part to the recognition of the health benefits of fish consumption.



The concept of "shifting baselines" was originally developed in 1995 by a fisheries biologist, to explain the decline of commercial fish stocks. The concept is based on the contention that fishers, scientists and the general public are most familiar with those conditions that exist during their lifetime. Historical conditions that existed prior to this time frame are often not recognized. Those who are not aware of earlier stock levels accept the recent levels as normal. Historical accounts of large fish and huge catches tend to be dismissed as unreliable anecdotes. As reference points of "how things used to be" are allowed to shift, we lose track of our standard and accept a more degraded state as being "normal" or "natural."

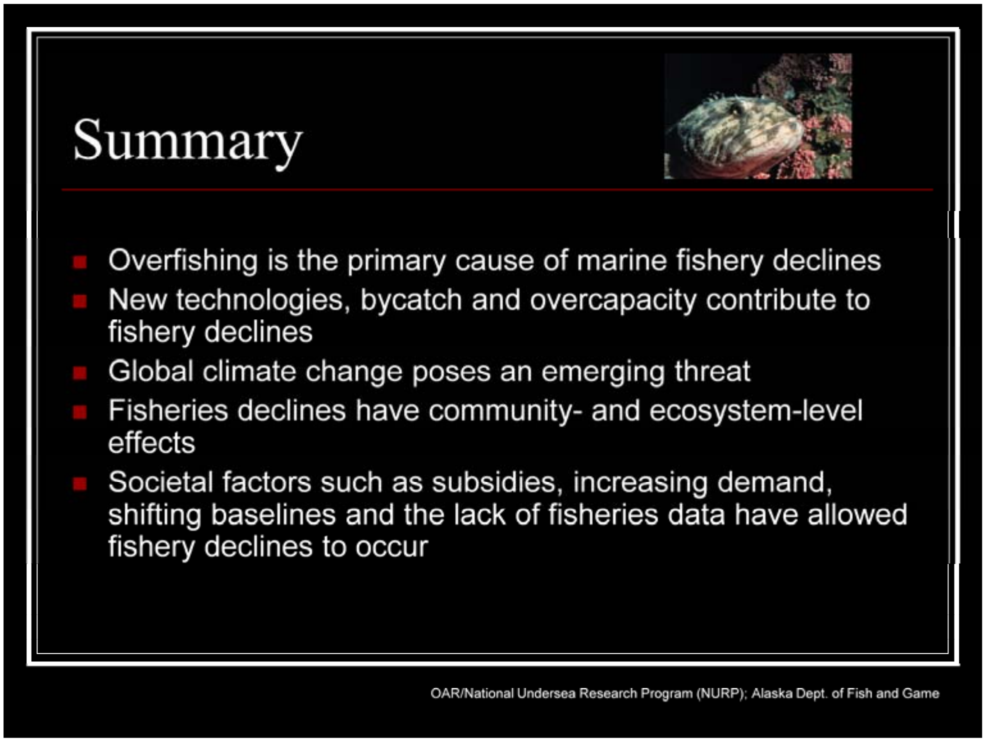
Atlantic halibut (270 lb.) caught off Provincetown, MA circa 1910. Halibut have virtually disappeared from the North Atlantic due to overfishing. The few that are caught now are much smaller than the one seen on this post card.

For more detail on shifting baselines application to fisheries, see NCSR Marine Fisheries module, "*Declining Expectations – The Phenomenon of Shifting Baselines*."



We lack even the most basic of biological data for many fish species. Essential information such as lifespan, stock trends, limiting factors, food preferences, reproductive biology, and migration patterns are lacking for many species that are already being exploited. Consequently, we often lack adequate data for effective management. Fisheries often develop before this information is known and incorporated into management plans. Without this information fisheries managers are “operating in the dark” and are far more likely to make errors in judgment that could lead to fisheries collapses and the social and economic impacts that they bring.

Traditionally, landings data have been our primary source of information on population trends with the underlying assumption that landings are proportional to population size. However, as various types of management become implemented (e.g., closures, gear restrictions), landings data become less reliable as an indicator of population trends. Consequently, greater emphasis must be placed on the collection of relevant fisheries data to assure more science-based management.



Summary of main points.

Additional coverage on marine fisheries topics may be found in the following NCSR Marine Fisheries modules:

- *Marine Fisheries – Introduction and Status*
- *Marine Fisheries – Management and Proposed Solutions*
- *Declining Expectations – The Phenomenon of Shifting Baselines*
- *The Role of Marine Reserves in Ecosystem Based Fishery Management*
- *The Decline of Atlantic Cod – A Case Study*

Photo Credits

- Census of Marine Life - Glenn Jones
- Daniel Pauly
- Fisheries and Oceans Canada
- Grant Gilmore – Dynamac Corporation
- Lance Horn – National Undersea Research Center
- Marine Biology Conservation Institute (MBCI)
- Marine Photobank – OAR/National Undersea Research Program (NURP); Alaska Dept. of Fish and Game, NOAA Ocean Explorer, Brooke et. al., G.Marola, Pete Naylor, John Rafferty Photography, Robert Stone
- Millenium Ecosystem Assessment
- NOAA - Historic Fisheries Collection, National Marine Fisheries Service, Northeast Fisheries Science Center, Pacific Fisheries Environmental Laboratory, S. Brooke, Joe Brown C.B. Miller/K. Tande,
- NOAA Photo Library – Teobaldo Dioses, C. Ortiz Rojas
- Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO)
- Pew Center on Global Climate Change
- Ray Troll
- *Science* multiple figures, reprinted with permission from AAAS
- *Trends in Ecology and Evolution*, one figure reprinted with permission from Elsevier

Detailed Lecture Notes

The detailed lecture notes below are provided as background for instructors who use this module. They may be used to enhance the material provided in the notes pages of the *PowerPoint* presentation associated with this module.

IV. Causes for fishery declines

A number of different factors have been implicated in fishery declines. From the 1960s to the 1980s human impacts on marine ecosystems emphasized pollution effects. More recently, changing ocean conditions due to global climate change, El Niño events, introduced species and environmental contamination (e.g., heavy metals, nitrates and acidification) are mentioned most frequently. In specific locations such as the “dead zone” in the Gulf of Mexico, some combination of these factors probably plays a significant role in fisheries decline. However, as a result of research that has accumulated over the past 20 years, most fisheries scientists have now concluded that fishing pressure has had the most enduring and serious impact on marine ecosystems. Fishing has been the primary driver of the decline of those species we harvest commercially and the marine habitats that support them. See Jackson, et al. (2001) and Roberts (2003) for a more detailed discussion.

- **Overfishing**

The National Academy of Science ranked fishing as the number one human activity that threatens marine ecosystems. Overfishing is the primary driver of long-term declines in the variety of big fish (Worm, B. 2006). The open-access nature of fisheries creates a classic “tragedy of the commons” that results in the depletion of the resource. Except for a 200-mile wide zone along the coast of each nation, the open ocean operates as a “commons,” an area open to fishing over which no nation has sovereignty. From the viewpoint of any fishing nation, it would seem foolish not to harvest whatever fish it can for as long as possible. Any restraint on their part would result in other nations capturing more fish.

Most fisheries are "open access" and therefore, act as a common resource available to all. Where regulations are implemented a "total allowable catch" is established and once that is reached, fishing is stopped. With common resources and open access fisheries, each fisherman has an incentive to catch as many fish as possible in the shortest amount of time because the positive benefits to the individual outweigh the costs to the individual. Eventually, the resource may be driven to a point where the fishery can no longer be supported and significant harm is inflicted on the marine ecosystem.

- **Highly efficient technology**

Technological changes in fishing gear have greatly increased the capacity for fishermen to catch fish. This improvement in technology is driven by open access to fisheries as described above. With the technological advances of the Industrial Revolution, the ability of humans to harvest fish from the world’s oceans increased dramatically. The collapse of several fishery stocks led to the realization that the oceans are not an infinite resource.

Improved fishing technology has allowed the capture of many more fish by fewer fishermen. Fishing technology for the Atlantic cod, for example, changed over time from single baited hooks to longlines to fish traps to steam trawlers to factory-freezer trawlers. Modern fishing vessels have larger, heavier gear that allows fishing in previously inaccessible areas. "Rockhopper" and bigger roller gear, for example, allow bottom trawl nets to fish rocky, complex habitats where in the past gear would become damaged or lost. In the past, some of these areas served as *de facto* marine reserves, as fishermen learned to avoid them.

An explosion of new technologies in the 1950s and 1960s including the adaptation of military technologies greatly increased capacity to catch fish. Radar allowed navigation under weather conditions that would have prevented fishing previously. Sonar made it possible to detect large schools of fish and more recently have even allowed fishers to distinguish between some species of fish based on gas bladder size and muscle density. Electronic navigation (LORAN – Long-Range Navigation) and more recently, GPS (Global Positioning Systems) and GIS (Geographic Information Systems) allow fishing vessels to pinpoint the most productive fishing grounds including seamounts out in the open ocean. Aircraft are frequently used to locate pelagic fish such as swordfish and tuna and some are equipped with infrared sensors that detect subtle changes in ocean surface temperature. This technology can be used to find fish since some high value species have highly specific temperature preferences.

Fishing vessels themselves have also become large, floating fish processing factories that can deploy large amounts of highly efficient gear – miles of submerged longlines, huge trawl nets and, until their recent prohibition, 40-mile long drift gillnets – and process their catch at sea.

- **Bycatch**

Almost all fisheries inadvertently capture non-target species collectively referred to as **bycatch**. The amount and type of bycatch is highly dependent on the type of gear used and may include marine invertebrates, fish that are the wrong size or the wrong species, diving seabirds, or marine mammals. The unintentional capture of dolphins in purse seines designed to harvest tuna is probably the best known case of bycatch. Most bycatch is discarded at sea (**discards**) and most is injured or killed by the time it is thrown overboard. This "collateral damage" was once thought to occur at minimal levels and considered an unavoidable consequence to the use of non-selective fishing gear. Bycatch is now recognized as a serious problem that may have far-reaching impacts on marine ecosystems.

Bycatch is estimated at approximately 25-30% of global fish landings and is not incorporated into landings figures. More than 90 million metric tons of fish are captured annually for consumption and an additional 30 million tons are discarded as bycatch.

Analysis of 1994 data from the Bering Sea, Aleutian Islands and the Gulf of Alaska suggest a groundfish trawl fishery bycatch of 15% (651 million pounds) including:

245 million pounds pollock
17 million pounds halibut
400,000 pounds salmon

Longline fisheries for tuna and swordfish have been particularly damaging to non-target species. Large sharks, blue marlin, white marlin and sea turtles are frequently caught. Over 90% of white marlin mortality can be attributed to this “unintentional harvest.”

In some fisheries, bycatch exceeds the targeted catch. The Gulf of Mexico shrimp fishery for example discards about 5 pounds of bycatch (mostly under-sized fish) for every pound of shrimp caught. Most of this bycatch is dumped overboard. Historically, the shrimp fishery has also been a major cause of sea turtle mortality. Modifications to shrimp fishing gear called “turtle exclusion devices” have reduced this bycatch in recent years.

There has been considerable effort since the mid-1990s to reduce bycatch in several fisheries. Some of these methods are discussed later in NCSR’s *Marine Fisheries – Management and Proposed Solutions* module.

- **Overcapacity**

In many fisheries around the world, fishing fleets are larger than is necessary to catch the amount of fish that fish populations can produce over the long run. This is called **overcapacity**. By the early 1980s, the world’s fishing fleets were 30% larger than needed to catch the maximum sustainable yield of the world’s fish. Thus, with overcapacity it is almost inevitable that the capacity to catch fish will exceed the ability of fish populations to keep up with harvest.

The Bering Sea crab fleet, for example, now numbering about 250 vessels, has as much as five times the capacity to catch the available crabs. The capacity of the Atlantic cod fleet in Canada and the U.S. still exceeds the reproductive capability of the cod population.

When the 200-mile limit (the “Exclusive Economic Zone”) was established by the U.S. and most other fishing countries in 1976, the intention was to reduce foreign competition and to provide more exclusive use of offshore waters to U.S. fishermen. It was hoped that this would give each nation a stronger incentive to manage its marine resources in a more sustainable manner. However, the result was a rapid increase in investment in fishing gear and vessels and an overcapacity to catch fish within the EEZ. Government subsidies (described below) further accelerated the increase in capacity. Thus, overinvestment resulted in overcapacity which resulted in overexploitation.

- **Climate change and ocean acidification**

Although an active area of research, the current and future effects of long-term climate change on fisheries are largely unknown. Climate change has the potential to impact sea surface temperatures, sea levels, ocean circulation patterns, salinity and pH. All of these have direct impacts on the abundance and distribution of marine fish. The effects of climate change will occur in environments that may already be characterized by environmental stressors such as depleted fish populations and habitat modification. Climate changes are likely to exacerbate these existing stresses on marine fish stocks. Stable, diverse communities are generally better able to withstand disturbances; therefore, reducing harvest in the majority of fisheries is probably the best way to reduce the impacts of climate change.

Since the Industrial Revolution the pH of surface waters in the earth's oceans has decreased by 0.1 pH unit. This decrease is predicted to continue and to decline an additional 0.3-0.4 pH units by 2100.

Absorption of excess CO_2 by oceans impacts the marine carbonate system with consequences for marine organisms, particularly those with calcium carbonate structural components – shells, skeletons, tests, etc. (e.g., coralline algae, foraminifera, coccolithophores, corals, oysters, clams, sea urchins and sea stars). These organisms are important food sources and habitat components for marine fish. Thus, ocean acidification has the potential to impact marine food webs.

A simplified summary of reactions involved:

$$CO_2 + H_2O \leftrightarrow \underset{\text{carbonic acid}}{H_2CO_3} \leftrightarrow \underset{\text{bicarbonate ion}}{HCO_3^-} + H^+ \leftrightarrow \underset{\text{carbonate ion}}{CO_3^{2-}} + H^+$$

The oceans have already absorbed about one-third of the carbon dioxide humans have produced over the past 200 years. Without the ocean acting as a carbon sink, the increase in atmospheric carbon dioxide concentration would have been 55% higher than the observed change from 280 to 380 ppm. Although this natural process could reduce the impacts of global climate change, the direct effect on marine organisms may be profound. The uptake of carbon dioxide by oceans, for example, alters ocean chemistry. As carbon dioxide is absorbed and reacts with ocean water, a weak acid (carbonic acid) is formed. As carbonic acid dissociates, hydrogen ions (H^+) are released lowering the pH of seawater. Bicarbonate can further dissociate releasing additional hydrogen ions and further lowering pH. As seawater becomes more acidic it becomes more corrosive to carbonate structures. Additionally, excess hydrogen ions bind with available carbonate ions decreasing their availability and making it more difficult for marine organisms to build and maintain calcium carbonate structures (i.e., acidic conditions favor their dissolution).

Ocean acidification may also have more direct impacts on marine fish. In the short-term, pH changes in fish tissues and body fluids may cause impacts on respiration, circulation, and nervous system function. In the long-term, there may be effects on metabolism, growth and reproduction. Early developmental stages (eggs and larvae) are probably more affected than adult fish.

See Guinotte and Fabry (2009) for a more detailed discussion of the chemistry of ocean acidification and its effects on specific groups of marine organisms.

The impacts of climate change will vary among fisheries and will depend considerably on how marine food webs are affected. In its most recent assessment, the International Panel on Climate Change predicted that saltwater fisheries production may actually be the same or perhaps higher if resource management deficiencies are corrected. The benefits of increased phytoplankton production (at the base of marine food webs) may be offset by costs associated with changes in reproductive patterns, migration routes and ecosystem relationships. Fisheries based in estuaries (e.g., shrimp, menhaden, sea trout) and on anadromous species (e.g., salmon) are more likely to be affected than open ocean species.

An example of climate change on “food webs”:

Zooplankton are particularly sensitive to changing ocean temperatures and form an important link in energy flow between phytoplankton and marine fish. Warming ocean temperatures in the North Sea, for example, have resulted in a change in the distribution of copepods. The cool-water species *Calanus finmarchicus* has moved north in response to increased ocean temperatures and has been replaced by the warmer-water species *Calanus helgolandicus*. Although the two species play essentially the same role in marine food webs, *C. finmarchicus* populations peak in spring, while *C. helgolandicus* peaks in fall. Atlantic cod in the North Sea spawn in spring and their larvae feed primarily on copepods. Thus, this change in copepod abundance has compromised the reproductive success of cod and may be contributing to the decline of the species there (Richardson. A.J. 2008).

The National Academy of Sciences reviewed current research on the interaction between climate change and fisheries (Blander, 2007). Among the documented effects of climate change on fisheries are:

- Changes in the distribution of eelpout in the North Sea due to decreased dissolved oxygen during periods of high summer temperatures
- Increased mortality of salmon in the Fraser River, Canada during unusually high temperatures in 2004
- Physiological stress to Atlantic cod in the Baltic Sea due to decreased salinity caused by mild winters and above-normal rainfall
- Peruvian anchovy collapses during strong El Niño events characterized by unusually warm water temperatures

V. Community-level and ecosystem-level impacts of fishery declines

"The past decade established that fisheries must be viewed as components of a global enterprise, on its way to undermine its supporting ecosystems" (Pauly, et al. 2003)

Ecosystems exploited for commercial fisheries (marine and coastal ecosystems) provide a wide array of ecosystem services other than food production that may be impacted by fishery activities.

- **Fishing down the food web**

The decline of one fish stock often triggers the development of fisheries for new species in the same area. Large, predaceous fish such as tuna, saithe, swordfish, salmon and sharks are often the primary focus of developed fisheries. As the populations of these species are depleted, fishers shift their efforts to middle and then lower trophic level species to meet increased demand for fish protein. These substitutes come from progressively lower trophic levels because greater biomass is present at lower trophic levels due to the pyramid shape of biomass pyramids and the "10% efficiency rule."

The shift from large predators (the "lions and wolves" of the system) to lower trophic levels (the "rabbits and squirrels" of the system) is known as "fishing down the food web." The result may be the disruption of marine ecosystems as intricate connections between species in the food web are unraveled. In the Gulf of Mexico, for example, removal of large predators resulted in an increase in meso-predators (mid-sized predators). The same phenomenon has been illustrated with terrestrial mammals - as coyotes decline, skunks, raccoons and opossum increase.

Increased disease outbreaks and the proliferation of previously suppressed pests and "weedy species" may also result. Consequently, fishing down the food web may impact entire communities and ecosystems, not just the target species.

A study conducted by David Pauly in 1998 evaluated the phenomenon. He estimated the trophic level and landing weights for 220 commercial fish species from 1950-1994. The results suggested an overall 0.1 trophic level decline for every 10 years due to overfishing of predaceous species and a total decline of 0.5 trophic levels over 40 years. The current global average trophic level of fisheries is about 3.1. The dip in average trophic level from 1960-1970 was caused by extremely high catches of Peruvian anchoveta, which has a low trophic value of 2.2. The coastal waters of Peru are among the world's most productive due to upwelling. In most years, deep ocean currents bring cool, nutrient-rich water to the surface. These nutrients support huge phytoplankton blooms and resulting increases in anchoveta populations. However, during El Niño Southern Oscillation years (ENSO), ocean surface temperatures increase as much as 3° Celsius and upwelling stops, causing the entire system to crash. Just such an ENSO event occurred in 1972, causing a dramatic decline in the anchoveta population.

Even after fishing controls are put in place, fishing down food webs may delay the recovery of top predators by removal of their prey. Pauly recommends establishing complete fishing bans on additional areas to allow fish populations to recover.

- **Habitat degradation**

Certain types of fishing gear can damage the physical structure of marine habitats as they pass over the ocean floor. The degree to which benthic habitats are degraded is highly dependent on the biological and physical nature of the seabed and the type of gear that is being used. Bottom trawls used to capture demersal fish species and dredges used to capture shellfish such as scallops, have been shown to be particularly damaging to sensitive habitats, where their impacts have been equated to forest clearcutting. These methods also capture significant amounts of both vertebrate and invertebrate bycatch, disturb benthic sediments and crush or bury benthic organisms. Community composition may be altered as a result. This damage also slows the recovery of these degraded habitats and probably contributes to the slow recovery rates of some fish stocks, even when fishing effort is reduced. Some areas on George's Bank off the New England coast are trawled three to four times each year. Lost or discarded fishing gear (particularly traps, nets and longlines) can also cause long-term damage to benthic habitats. The extent of damage to benthic communities by fishing gear is largely unknown and is currently an active area of research.

- **Trophic cascades**

Trophic cascades occur when changes in the biomass at one trophic level result in a series of changes at other trophic levels much like the "domino effect." In fisheries, harvesting a single or few species of fish (usually large, predatory fish) affects not only those species but can also disturb entire ecosystems.

A trophic cascade in the northeast Pacific Ocean off the Aleutian Islands of Alaska is thought to have contributed to the collapse of that marine ecosystem. Overfishing, perhaps in combination with a change in ocean conditions, resulted in the decline of several commercial fish species. Steller sea lion populations declined as a result of the loss of their primary food source to the point of requiring emergency listing under the Endangered Species Act. Steller sea lions are the primary food for killer whales in the area. With declining sea lions, the killer whales turned to sea otters, a known keystone species. Sea otter populations, predators of sea urchins, declined resulting in a population explosion of urchins. Sea urchins devoured kelp forests in the near-shore ecosystem. Kelp forests harbor a diverse variety of marine organisms, which disappeared in a relatively short period of time.

Although originally proposed as a relatively straightforward trophic cascade, more recent analysis (NRC 2003) suggested that the causes for decline of Steller sea lions may be more complex than first described. The precipitous decline of sea lions in the 1970s and 1980s was likely caused by an ecosystem-wide change brought on by some combination of competition with fisheries for food, changes in prey abundance due to a climatic shift, increased predation of sea lions by killer whales and sharks, and possibly, the introduction of a highly contagious pathogen. However, from 1990 to present, rates of sea lion declines have slowed and do not appear to be associated with declining fish populations. Those factors contributing to more recent declines appear to be killer whale predation, illegal shooting, incidental take by fishing gear and subsistence harvest.

Another trophic cascade has recently been documented for the continental shelf ecosystem off the coast of Nova Scotia, Canada. The decline of the Atlantic cod and other top predators such as haddock, white hake, and pollock, in the mid-1980s and early 1990s resulted in a series of events that impacted several trophic levels and as a result, the entire ecosystem. In response to the decline of the top predators in the system, the biomass of small pelagic fish and benthic invertebrates such as snow crabs and northern shrimp, the primary prey of large benthic predators, increased markedly. Grey seals apparently also benefited from the collapse of cod, as their prey base of small pelagic fish and benthic macro-invertebrates increased. Their populations continue to grow exponentially and it has recently been demonstrated that grey seals are significant predators of cod, accounting for 21% of cod mortality since 1993. Indirect effects at lower trophic levels also occurred. Herbivorous zooplankton, for example, have declined suggesting greater predation on these species by the now abundant small pelagic fish and larval stages of shrimp and crabs. Interestingly, cod populations have not increased significantly since fishing effort was reduced in 1993. The disruption of the coastal shelf ecosystem is apparently contributing to this slow recovery.

Communities in which sharks are dominant predators have been well-studied. The decline of sharks along the East Coast has resulted in an increase in elasmobranch meso-predators, such as cownose rays. Cownose rays have devastated some invertebrate populations including some commercially-important species such as bay scallops in coastal areas off North Carolina. Therefore, the bay scallop has declined not due to overfishing, but rather as a result of the removal of an entire trophic level. Since sharks are long-lived and reproduce at a low rate, the system may be very slow to recover (see Myers, et al. 2007).

- **Changes in life history traits**

Fisheries typically select the largest individuals from populations. In heavily fished populations this may result in a truncated age distribution with older individuals being poorly represented. In fish, reproductive ability is closely correlated to body size with larger individuals having greater capacity than smaller individuals. Therefore, altered age structure may impair the ability of the population to respond to changing ocean conditions by removing those individuals most capable of replenishing the population when ocean conditions are most favorable.

Before the collapse of the cod fishery of East Canada, annual harvests removed 60% of older adults. Females of the population responded by spawning at an earlier age. The age of first spawning changed from 5-6 years to less than 3 years. This may be an adaptation to increase reproductive potential after a precipitous population decline. However, smaller females produce fewer and smaller eggs resulting in decreased body size for juveniles. Young fish are more prone to predation and, as a result, stocks have not rebounded quickly. Studies of several other species such as haddock, winter flounder, brook trout and striped bass have shown this relationship between parent size and the viability of their offspring.

These demographic changes can be particularly troublesome when fishing creates selection pressures that favor smaller and slower-growing fish. A 50-year study of larval fish populations in the California Current (Anderson, et al. 2008) suggests that demographic changes such as earlier age at maturation or population growth rate may be permanent as a result of decades of this type of selection. Once this evolutionary change has occurred, genetic change may be irreversible or at least only slowly reversible contributing to slow or non-existent recovery of depleted fish stocks.

Steven Berkeley at the University of California, Santa Cruz reported on the effects of changes in life history traits in the black rockfish, a long-lived (50 years) species off the Oregon Coast. Gravid females ranging from 5-17 years old were housed in lab aquaria and allowed to spawn. Their offspring were then tracked for growth and survivability. The offspring from the oldest females were twice as likely to survive short periods of starvation and grew three times as fast as offspring from younger females. It seems that "big old fat females" contribute disproportionately to the future population.

VI. Why are fishery declines allowed to occur?

- **Government subsidies and the economics of overfishing**

Overcapitalized fisheries can continue to operate after the resource is depleted by relying on government subsidies. A **subsidy** is any government policy that alters market risks, rewards and costs in ways that favor certain activities or stakeholders. As a result, they distort the way markets operate. Subsidies may take several forms including:

1. Direct income support
2. Tax exemptions on fuel, fishing gear, vessels, etc.
3. Low interest loans or grants to encourage investment into the industry (e.g., ship building, fishing, fish processing)

Governments have two, often conflicting, roles in fisheries management:

1. To provide a secure food supply, employment and economic development (usually through subsidies)
2. To conserve the marine resource so that it is not depleted

Various types of price supports and payments to those in the industry are commonly used to support those involved in the industry. However, these government subsidies to support the industry often promote overexploitation of resources. Subsidies discourage fisherman and investors from leaving the industry when it is economically marginal and as a result, pressure on the resource continues when it is no longer economically viable to do so. Additionally, subsidies result in market prices that do not accurately reflect the value or scarcity of marine resources. For example, in 1993 to catch $70 billion worth of fish, the world's fishing industry incurred costs of approximately $124 billion. Deficits were compensated for, in part, by subsidies totaling $54 billion. The subsidies are in place due to decisions by governments to preserve employment despite the decline of many fisheries.

A more recent study (February 2007) by researchers at the University of British Columbia, estimated that bottom trawlers alone receive approximately $152 million per year in fuel and other subsidies. Without these subsidies the few hundred vessels that make up the global trawler fleet would lose millions of dollars per year.

Higher fuel prices might be expected to reduce overfishing as fuel expenditures consume profits from the sale of fish. However, fuel subsidies to the fishing industry by governments distort this economic relationship. Global fuel subsidies are estimated to be in the range of $ 4.2-8.5 billion per year. The fishing industry can therefore, absorb some increases in fuel cost without reducing fishing effort. Any conservation efforts that occur as a result of fuel price increases, will therefore be delayed or not materialize at all. See Sumaila, et al. (2008) for details.

There is a long history of such supports for the fishing industry. In the late 1700s, for example, Massachusetts exempted cod fishermen from military service and taxes on their gear and vessels. This was aimed at encouraging an industry that generated wealth for the American Revolution. Once established, removal of subsidies is a rare and socially disruptive event because those who benefit from them lobby for their continuation. Also, there is usually more political pressure to respond to the immediate needs of the industry and rural communities with various types of support (allow more harvest, social programs, subsidies, etc.) than to respond to the more long-term goal of sustained yield of the resource.

- **Growing human populations and increasing demand**

The world population continues to increase by approximately 100 million individuals each year. Thus, despite fishery declines, demand has increased and will probably continue to increase. China, for example, has increased its total consumption of fish from 3.2 million tons in 1961 to 25.4 million tons in 2003. This increase has come primarily from increases in aquaculture production and is due only in part to population increases. Per capita fish consumption has increased over five-fold during the same time period. Fish consumption has also increased in the United States over the same time period as total consumption in 2003 was 2.5 times greater than 1961 levels. Per capita consumption increased 1.6 times, presumably due in part to the recognition of the health benefits of fish consumption such as its high concentration of fatty acids and trace minerals, its importance in the proper development of the nervous system and the reduced risk of cardiovascular disease and some cancers.

- **Shifting baselines**

"Fishing has a short memory. If you see twice as many fish as you've seen in the last 10 years, it's still twice as much of not very much."

Teri Frady
Chief of Research Communications
National Marine Fisheries Service - 2002

The concept of "shifting baselines" was originally developed in 1995 by fisheries biologist, Daniel Pauly of the University of British Columbia to explain the decline of commercial fish stocks. Pauly contends that fishers, scientists and the general public are most familiar with those conditions that exist during their lifetime. Historical conditions that existed prior to this time frame are often not recognized. Those who are not aware of earlier stock levels accept the recent levels as normal. Historical accounts of large fish and huge catches tend to be dismissed as unreliable anecdotes. As reference points of "how things used to be" are allowed to shift, we lose track of our standard and accept a more degraded state as being "normal" or "natural."

The phenomenon has been used to explain how fishery stocks decline. As catch rates of commercially important species such as Atlantic cod, striped bass and Pacific salmon gradually declined, the perception of the condition of the stock also changed. Over generations, fishers adjust their expectations downward to match prevailing conditions. Expectations for landings of these species declined gradually right along with the population size of the fish themselves. The result is a gradual decline of species as ocean ecosystems drift to a condition of less abundance and biodiversity.

The History of Marine Animal Populations (HMAP) Project is a global research initiative developed to study past ocean life and human interactions with the sea. Historical and environmental archives are used to analyze marine animal populations before and after human impact. Several recent studies (see, for example, Myers and Worm 2003; Baum and Myers 2004) have provided us with the "missing baselines" by which we can compare current population levels and thus get a more realistic picture of population trends.

For additional information on this topic, see NCSR Fisheries module – *Declining Expectations – The Phenomenon of Shifting Baselines*.

- **Lack of adequate fisheries data**

We lack even the most basic of biological data for many fish species. Essential information such as lifespan, stock trends, limiting factors, food preferences, reproductive biology, and migration patterns are lacking for many species that are already being exploited. Consequently, we often lack adequate data for effective management. Fisheries often develop before this information is known and incorporated into management plans. Without this information fisheries managers are "operating in the dark" and are far more likely to make errors in judgment that could lead to fisheries collapses and the social and economic impacts that they bring.

Traditionally, landings data have been our primary source of information on population trends with the underlying assumption that landings are proportional to population size. However, as various types of management become implemented (e.g., closures, gear restrictions), landings data become less reliable as an indicator of population trends. Consequently, greater emphasis must be placed on the collection of relevant fisheries data to assure more science-based management.

RESOURCES

The literature on marine fisheries declines is voluminous and scattered. I have tried to organize resources such that they will serve a variety of instructor needs. There has been a concerted effort to emphasize those print and web resources that provide the most recent and easily accessible information. Selections from journal articles are primarily from readily available journals (e.g., *Science, Nature*) and from the "secondary literature" (e.g., *Scientific American, Bioscience*) rather than the less accessible and more detailed "primary literature" found in fisheries journals.

I. Comprehensive Resources

Most of these are comprehensive print and web resources that provide a broad view of marine fisheries issues. Those marked with an asterisk (*) are relatively short, general resources on marine fisheries that would be appropriate to be assigned as student reading.

Chiras, D.D. and J.P. Reganold, 2005. Natural resource conservation: Management for a sustainable future. 9th ed. Pearson/Prentice-Hall. Upper Saddle River, NJ.

Clover, C. 2006. The end of the line – How overfishing is changing the world and what we eat. Univ. of California Press, Berkeley, CA. 386 pp.

Coleman, F.C., et al. 2004. The impact of United States recreational fisheries on marine fish populations. Science 305:1958-1960.

Communication Partnership for Science and the Sea (COMPASS)
http://compassonline.org/

COMPASS is a collaborative effort that advances marine conservation science and communicates scientific knowledge to policymakers, the public, and the media. Concise statements and access to peer-reviewed literature on a variety of marine fisheries issues are provided, including the state of oceans, marine ecosystem services, ecosystem-based management, marine reserves and sustainable aquaculture.

Ellis, R. 2004. The empty ocean. Shearwater Books. Washington, D.C. 384 pp.

In addition to a general description of fishery declines, case study accounts for several species are provided, including menhaden, tuna, swordfish, cod, Patagonian toothfish and Atlantic salmon.

Fisheries Management and Ecology

This journal is published bi-monthly and is promoted as the only fully peer-reviewed fisheries management and ecology journal available. Its scope is international and all aspects of the management, ecology and conservation of inland, estuarine and coastal fisheries are given treatment. Sample papers can be viewed on-line at www.blackwellpublishing.com/fme.

Fuller, et al. 2008. How we fish matters: Addressing the ecological impacts of Canadian fishing gear. Ecology Action Centre (Halifax, Nova Scotia), Living Ocean Society (Sointula, B.C.), MCBI (Bellevue, WA). 25 pp.

This document provides a detailed examination of bycatch and habitat impact of fishing gear that is used in Canadian waters.
www.mcbi.org

Halweil, B. 2006. Catch of the day: Choosing seafood for healthier oceans. World Watch Paper #172. World Watch Institute, Washington, D.C. 75 pp.

Helfman, G.S. 2007. Fish conservation: A guide to understanding and restoring global aquatic biodiversity and fishery resources. Washington D.C. Island Press.

Iudicello, S., M. Weber and R. Wieland. 1999. Fish, markets and fishermen: The economics of overfishing. Island Press, Washington, D.C. 192 pp.

This text provides excellent insight into the question of why *overfishing occurs. Detailed explanations of subsidies, overcapacity, individual fishing quotas and other economic aspects of marine fisheries issues are provided.*

Marine Conservation Biology Institute
www.mcbi.org

MCBI has several comprehensive resources on a number of marine conservation issues including the ecosystem effects of various fishing methods, bycatch, and the sustainability of fishing deepwater species.

Morgan, L.E. and R. Chuenpagdee. 2003. Shifting gears: Addressing the collateral impacts of fishing methods in U.S. waters. Island Press, Washington, D.C. 42 pp.
www.mcbi.org

This document provides a detailed examination of bycatch and habitat impact of fishing gear that is used in U.S. waters.

National Oceanic and Atmospheric Administration (NOAA) Fisheries Service
www.nmfs.noaa.gov

This is a large, comprehensive government web site that includes the U.S. government perspective on sustainable fisheries, fisheries management, etc. NOAA Fisheries Service (formerly the National Marine Fisheries Service) is "dedicated to the stewardship of living marine resources through science-based conservation and management, and the protection of healthy ecosystems….. (NOAA Fisheries) conserves, protects and manages living resources in a way that ensures their continuation as functioning components of marine ecosystems, affords economic opportunities and enhances the quality of life for the American public."

National Oceanic and Atmospheric Administration (NOAA) Fisheries Service
www.st.nmfs.noaa.gov/st4/documents/FishGlossary.pdf

This document is a complete glossary of fishery-related terms provided by NOAA Fisheries.

National Oceanic and Atmospheric Administration (NOAA) Fisheries – Office of Sustainable Fisheries
www.nmfs.noaa.gov/sfa

Among the more useful web pages to educators on the massive NOAA Fisheries site are those that are dedicated to the Sustainable Fisheries Act (SFA). These pages provide links to reports that describe how the SFA is being implemented and those changes that have occurred as a result of its implementation. This site provides the most recent information on the status of U.S. fish stocks.

NRC. 1999. Sustaining marine fisheries. National Academy Press, Washington, D.C. 164 pp.
http://books.nap.edu/catalog.php?record_id=6032

This comprehensive report by the Committee on Ecosystem Management for Sustainable Fisheries of the National Research Council documents the status of marine fisheries and discusses the challenges of achieving sustainability. The shortcomings of current fisheries management and regulation are described. Like many similar publications, this document recommends a broader ecosystem perspective to fisheries management that takes into account all relevant environmental and human influences. Specific recommendations are made to build workable fisheries while changing current practices that encourage overexploitation of fisheries resources.

*Pauly, D. and R. Watson. 2003. Counting the last fish. Scientific American (July 2003): 43-47.

Pauly, D. and J. Maclean. 2003. In a perfect ocean. Island Press, Washington, D.C. 175 pp.

This book from the Sea Around Us Project provides a comprehensive examination of the status and history of the fisheries of the North Atlantic Ocean.

Pew Oceans Commission. 2003. America's living oceans: Charting a course for sea change – a report to the nation. May 2003. Pew Oceans Commission, Arlington, VA.
www.pewtrusts.com/pdf/env_pew_oceans_final_report.pdf

This Pew Oceans Commission report is an evaluation of America's ocean resources. Chapters 3 and 11 ("Restoring America's Fisheries") are excellent reviews of U.S. marine fisheries issues. Additional fisheries-related publications may be obtained at:
www.pewoceans.org
www.pewtrusts.org

*Raloff, J. 2005. Empty nets: fisheries may be crippling themselves by targeting the big ones. Science News 167:360-362.

Roberts, C. 2007. The unnatural history of the sea. Island Press, Washington, D.C. 435 pp.

This text evaluates many fisheries (as well as sealing and whaling) from a perspective that stretches back hundreds of years. Roberts claims that, "Modern oceans have been so vastly altered by overexploitation of fishes as to be barely recognizable semblances of their pre-exploitation states." Historical accounts by early explorers are used to establish a baseline for population levels in the historic past. Fisheries have now penetrated the deepest and most remote parts of the ocean thus driving stocks below any level of sustainability. The author claims that a fundamental shift is needed in the approach to fisheries management and ocean conservation. His proposed solution is to manage fisheries in a global network of marine reserves and protected areas, a radical departure from traditional fisheries management.

Ross, M.R. 1997. Fisheries conservation and management. Prentice Hall, Inc., Upper Saddle River, NJ. 374 pp.

This is a general text that would be appropriate for an undergraduate course in fisheries. Most fisheries texts are designed for upper-level undergraduate and graduate-level courses and, as a result, provide much detail and are often heavily based in mathematics. This text is specifically designed for sophomore-level students and provides a broad-based introduction to fisheries management and conservation. Consequently, it may be more appropriate for students in community college programs than other texts.

* Rothschild, B.J. 1996. How bountiful are ocean fisheries?
www.gcrio.org/CONSEQUENCES/winter96/oceanfish.html

The U.S. Global Change Research Information Office is a clearinghouse for reports generated or supported by U.S. governmental agencies. In addition to dealing with the major issues related to marine fisheries, this article addresses the predicted impacts of global climate change.

Safina, C. 1998. Song for the blue ocean: Encounters along the world's coast and beneath the seas. Henry Holt and Co., NY. 445 pp.
This resource examines fisheries resources in the Northeast, Pacific Northwest and the western Pacific Ocean.

*Safina, C. 1995. The world's imperiled fish. Scientific American Nov. 1995:46-53.

Although now a bit outdated, this brief article provides an excellent summary of the status of marine fisheries and the primary causes for decline.

SeaWeb
www.seaweb.org

The SeaWeb Project is designed to increase public awareness of the world's oceans and the biodiversity they support. Their web site provides access to a great deal of fisheries-related information that is useful to instructors including publications, links to other sites and a "marine photo bank." The images in the photo bank are free for non-commercial use and would be useful to develop in-class presentations. All aspects of fisheries are portrayed in these images including fishing methods, aquaculture, marine species of concern, bycatch and marine protected areas.

I would encourage all instructors to sign up for SeaWeb's Marine Science Review, *a free periodic summary of recent fisheries research. Abstracts of recent publications and often links to the original articles are provided via e-mail.*

The Sea Around Us Project
www.seaaroundus.org

The Sea Around Us Project is dedicated to the scientific study of the impact of fisheries on the world's marine ecosystems. The project is housed at the University of British Columbia (Vancouver) and is supported by the Pew Charitable Trusts. Their web site provides a wealth of information on all aspects of global fisheries. Species-specific information such as geographical distribution, status, catch rates, gear type, etc. are provided in easily accessible graphs. Links to other sites such as FishBase (www.fishbase.org) *provide additional information including biological data and photographs. Interactive maps allow the user to determine location and catch rates for any species throughout the world. The site also includes a global map of marine protected areas (MPA's) and the ability to search for information on specific MPA's. A graphical simulation ("North Atlantic Trends") illustrates the change in biomass distribution for high trophic level fish in the North Atlantic from 1900-2000.*

Turning the Tide: The State of Seafood. 2009. Monterey Bay Aquarium
http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_StateofSeafoodReport.pdf

The Monterey Bay Aquarium has a long history of providing information on fisheries-related issues to the general public. This most recent effort is a comprehensive examination of the current status of fisheries and aquaculture as well as trends in both the seafood industry and marine ecosystems. New solutions are offered to address the decline of marine resources. The document is science-based and professionally produced with colorful photographs, graphs and other images adapted from scientific publications on this topic.

United Nations Food and Agricultural Organization (FAO). 2004. The State of World Fisheries and Aquaculture.
www.fao.org/sof/sofia/index_en.htm

This United Nations web site is <u>*the*</u> *premier resource for global fishery trends, statistics and policy issues. If you need graphs that illustrate changes in any aspect of fisheries (fish stocks, landings, economic value, etc.), this is the first place to look. All materials may be reproduced for educational use without written copyright permission.*

The report is published every two years and copies of past reports are available on the web site. Beyond fishery statistics, the site also provides excellent treatment of global fishery issues. The 2004 report, for example, examines capture-based aquaculture, endangered species, depleted stock recovery, the management of deep-water fisheries and the impacts of trawling on benthic ecosystems.

A hardcopy version of the FAO report is also available:

UN FAO. 2005. Review of the state of world marine fishery resources. U.N. Food and Agriculture Organization. FAO Fisheries Technical Paper No. 457. 242 pp.

United States Commission on Ocean Policy. 2004. An ocean blueprint for the 21st century.
www.oceancommission.gov

United Nations Environmental Program (UNEP). 2006. Marine and coastal ecosystems and human well-being: A synthesis based on the findings of the Millennium Ecosystem Assessment. UNEP. 76 pp.
www.millenniumassessment.org/en/synthesis.aspx
www.maweb.org

The Millennium Ecosystem Assessment (MA) is an international collaborative established in 2001 by the United Nations. The MA takes a scientific approach to assess ecosystems, the service they provide and how changes in these services will impact human well-being. This synthesis reports the MA findings concerning marine and coastal ecosystems including fisheries.

Like the FAO web site, this resource provides excellent coverage of global fishery trends and issues in a user-friendly format. Instructors will find the tables, graphs, illustrations and their descriptions particularly useful. All materials are available for educational use without seeking copyright permission as long as their source is acknowledged.

Watling, L. and E. Norse. 1998. Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. Conservation Biology 12: 1180-1193.

This is one of the first comprehensive scientific examinations of the effects of fishing gear on marine habitats. The authors come to the conclusion that mobile fishing gear exceeds all other natural and human-caused disturbances on marine continental shelf and continental slope habitats.

II. Single-issue Resources (Causes for Fishery Declines and Impacts)

These sources are more narrowly focused than the previous list, emphasizing one or few aspects of the marine fisheries issue. They are listed according to the primary issues that are addressed in this module.

Causes for Fishery Declines

Blander, K.M. 2007. Global fish production and climate change. Proc. Nat. Acad. Sci. 104:19,709-19,714.

Booth, W. 1994. Turning the tide on dwindling marine resources. Science 263:25-26.

Bunce, M., et al. 2007. Shifting baselines in fishers' perceptions of island reef fishery degradation. Ocean and Coastal Management 51: 285-302.

This comprehensive study of an island coral reef fishery presents evidence of shifting baselines. Older fishers recalled a greater former abundance of fish and reported more fish species as depleted when compared to young fishers.

Fabry, V.J., et al. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. ICES Journal of Marine Science 65:414-432.

Fairlie, S., M. Hagler, and B. O'Riordan. 1995. The politics of overfishing. Ecologist 25:46-73

Hardin, G. 1968. Tragedy of the commons. Science 62: 1243-1248.

Jackson, J.B.C., et al. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293:629-638.

Richardson, A.J. 2008. In hot water: zooplankton and climate change. ICES Journal of Marine Science 65: 279-295.

Roberts, C. 2003. Our shifting perspectives on the oceans. Oryx 37:166-177.

Safina, C. 1995. The world's imperiled fish. Scientific American (Nov1995):46-53.

Ecosystem and Community Impacts of Fishery Declines

Alaska Fisheries Science Center. 2007. Resources Assessment and Conservation Engineering National Marine Fisheries Service. NOAA Fisheries
www.afsc.noaa.gov

This site includes a number of unique resources that instructors may find useful. Downloadable underwater video clips, for example will give students a birds eye view of fishing gear in operation. Some video footage can be used to assess the impact of bottom trawls on benthic habitats as "trawled" and "un-trawled" areas are compared. The site also includes a photo gallery of fish species, which could be used in presentations.

Anderson, C.N.K., et al. 2008. Why fishing magnifies fluctuations in fish abundance. Nature 452:835-839.

Dayton, P.K., S. Thrush and F. Coleman. 2002. Ecological effects of fishing in marine ecosystems of the United States. Pew Oceans Commission, Arlington, VA.
www.pewoceans.org or www.pewtrusts.org

Estes, J.A., M.T. Tinker, T.M. Williams and D.F. Doak. 1998. Killer whale predation on sea otters linking oceanic and nearshore ecosystems. Science 282:473-476.

Frank, K.T., B. Petrie, J.S. Choi and W.C. Leggett. 2005. Trophic cascades in a formerly cod-dominated ecosystem. Science 308: 1621-1623.

Fuller, et al. 2008. How we fish matters: Addressing the ecological impacts of Canadian fishing gear. Ecology Action Centre (Halifax, Nova Scotia), Living Ocean Society (Sointula, B.C.), MCBI (Bellvue, WA). 25 pp.
www.mcbi.org

Guinotte, J. and V.J.Fabry. 2009. The threat of acidification to ocean ecosystems. Journal of Marine Education 25:2-7.

Hagler, M. 1995. Deforestation of the deep. Ecologist 25:74-79.

Heithaus, et al. 2008. Predicting ecological consequences of marine top predator declines. TREE 23(4):202-210.
http://wormlab.biology.dal.ca/ramweb/papers-total/Heithaus_etal_2008.pdf

Hsieh, C.H., et al. 2006. Fishing elevates variability in abundance of exploited species. Nature 443:859-862.

McClenachan, L. 2009. Documenting loss of large trophy fish from the Florida Keys with historical photographs. Conservation Biology 23: 636-643.

Morgan, L.E. and R. Chuenpagdee. 2003. Shifting gears: Addressing the collateral impacts of fishing methods in U.S. waters. Island Press, Washington, D.C. 42 pp.
www.mcbi.org

Myers, R.A. and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature 423:280-283.

Myers, R. et al. 2007. Cascading effects of the loss of predatory sharks from a coastal ocean. Science 315 (5820):1846-1850.
http://www.fmap.ca/ramweb/papers-total/Myers_etal_2007_Science.pdf
http://www.sciencemag.org/cgi/content/abstract/315/5820/1846?hits=10&RESULTFORMAT=&FIRSTINDEX=0&maxtoshow=&HITS=10&fulltext=myers+shark&searchid=1&resourcetype=HWCIT

National Academy of Science. 2002. Effects of trawling and dredging on seafloor habitat. Committee on Ecosystem Effects of Fishing. National Academy Press, Washington, D.C. 126 pp.

This comprehensive publication examines the current literature on the impacts of bottom fishing methods (trawling and dredging) on seafloor habitats. The report was driven by the need for a synthesis of available information on the topic. It has been proposed that these fishing activities may impede the recovery of fish stocks and impact biodiversity over the long run even if fishing effort is curtailed.

NRC. 2002. Effects of trawling and dredging on seafloor habitat. Committee on Ecosystem Effects of Fishing: Phase I. National Academy Press, Washington, D.C. 126 pp.

NRC. 2003. The decline of Steller sea lion in Alaska waters: Untangling food webs and fishing nets. Committee on the Alaska Groundfish Fishery and Steller Sea Lions, National Academy Press, Washington, D.C. 216 pp.

NRC. 2006. Dynamic changes in marine ecosystems: Fishing, food webs and future options. Committee on Ecosystem Effects of Fishing: Phase II. National Academy Press, Washington, D.C. 160 pp.

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

Pauly, D. and R. Watson. 2003. Counting the last fish. Scientific American (July 2003): 43-47.

Stenseth, N.C. and T. Rouyer. 2008. Ecology: Destabilized fish stocks. Nature 452:825-826.

Rapid variation in fish populations that are targeted commercially are undesirable both economically (lack of predictability in fishing income) and ecologically (wide fluctuations may increase the probability of local extinctions). This study by fishery biologists at Scripps Institution of Oceanography finds support for the hypothesis that the observed variability in fish populations is the direct effect of changes in age structure caused by fishing. Such fishing pressure affects fundamental demographic parameters such as age at maturation and population growth rate. There was also some support for the hypothesis that fisheries selectively remove large, older fish that are better able to survive hard times better than younger fish. When these demographic changes are environmental, recovery is possible. However, if these changes become evolutionary, and fishing creates selection pressures in favor of smaller, slower-growing fish, they may be permanent.

Tillin, H.M., et al. 2006. Chronic bottom trawling alters the functional composition of benthic invertebrate communities on a sea-basin scale. Marine Ecology Progress Series 318:31-45.

Trippel, E.A. 1995. Age at maturity as a stress indicator in fisheries. BioScience 45(11):759-771.

Trzcinski, M.K., R. Mohn and W.D. Bowen. 2006. Continued decline of an Atlantic cod population: How important is gray seal predation? Ecol. Applic. 16(6):2276-2292.

Ward, P. and R. Myers. 2005. Shifts in open-ocean fish communities coinciding with the commencement of commercial fishing. Ecology 86:835-847.
http://www.soest.hawaii.edu/pfrp/reprints/ecol_86_420_835_847.pdf

Worm B, Myers RA. 2003. Meta-analysis of cod-shrimp interactions reveals top-down control in oceanic food webs. Ecology 84: 162–173.
http://myweb.dal.ca/bworm/Worm%20_Myers_2003.pdf

Worm, B., et al. 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314:787-790.

Watling, L. and E.A. Norse. 1998. Disturbance of the seabed by mobile fishing gear: A comparison to forest clearcutting. Conservation Biology 12:1189-1197.

Zabel, R.W. 2003. Ecologically sustainable yield. American Scientist 91:150-157.

Why Are Marine Fishery Declines Allowed to Occur?

Baum, J.K. and R.A. Myers. 2004. Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. Ecology Letters 7(2):135-145.

Several recent studies, including this one and Myers and Worm, 2003 (cited below), have provided us with the "missing baselines" by which we can compare current population levels and thus get a more realistic picture of population trends.

Helmuth, L. 2008. Our imperiled oceans: Seeing is believing. Smithsonian Magazine Sept. 2008.
www.smithsonianmag.com/science-nature/seeing-is-believing.html

This brief article written for general audiences describes some of the "shifting baselines" work being done by the History of Marine Animal Population (HMAP) project (cited below). Several historical photographs of fish caught on charter boats based in Key West, Florida are shown to illustrate.

History of Marine Animal Population (HMAP)
Census of Marine Life
www.hmapcoml.org

This program attempts to document historical population levels of marine organisms for comparison with current levels. Several photographs are available that can be used to illustrate "baseline levels" for marine fish.

Iudicello, S., M. Weber and R. Wieland. 1999. Fish, markets and fishermen: The economics of overfishing. Island Press, Washington, D.C. 192 pp.

Myers, R.A. and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature 423:280-283.

Sàenz-Arroyo, A., et al. 2005. Rapidly shifting environmental baselines among fishers in the Gulf of California. Proc. Biol. Sci. 272:1957-1962.
www.pubcentral.nih.gov/articlerender.fcgi?artid=1559885

This is an easily readable article describing some recent research that quantifies the shifting baselines phenomenon among fishers in the Gulf of Mexico. It would be a good selection to assign for student reading.

Safina, C. 1995. The world's imperiled fish. Scientific American (Nov1995):46-53.

Shifting Baselines
www.shiftingbaselines.org

The web site provides a description of the "shifting baselines" phenomenon and also includes an amusing video ("Fish Story") that students may enjoy.

Sumaila, U.R., et al. 2008. Fuel price increase, subsidies, overcapacity, and resource sustainability. ICES Journal of Marine Science 65:832-840.

United Nations Food and Agricultural Organization (UN FAO)
www.fao.org/sof/sofia/index_en.htm

III. Resources For Digital Images

There are a number of web-based sources for fisheries-related digital photos that instructors can use to augment NCSR fisheries modules. Most of those listed below allow educational use of their images without seeking copyright permission as long as proper acknowledgement is presented along with the photo. However, instructors should check the documentation on each web site and follow the required procedure for use.

ARKive – Images of Life on Earth
www.arkive.org

This web site provides useful biological and conservation information (description, status, range, habitat, threats and conservation) on a wide variety of species as well as images and short video clips.

FishBase – A Global Information System on Fishes
www.fishbase.org

FishBase *is a huge relational database that emphasizes the biological characteristics of nearly all fish known to science. Photos and other media are available for download.*

MarineBio
www.marinebio.org
A comprehensive conservation-based site that includes links to multimedia (video and images) for a number of commercially important fish species.

Marine Photobank
www.marinephotobank.org
This SeaWeb-*sponsored web site provides access to a great deal of fisheries-related information that is useful to instructors including publications, links to other sites and a "marine photo bank." The images in the photo bank are free for non-commercial use and would be useful to develop in-class presentations. All aspects of fisheries are portrayed in these images including fishing methods, aquaculture, marine species of concern, bycatch and marine protected areas.*

Northeast Fisheries Science Center
www.nefsc.noaa.gov
This regional center of the National Marine Fisheries Service provides all of the original line drawings from the "Bible of New England Fisheries," Fishes of the Gulf of Maine.

NOAA Ocean Explorer
http://oceanexplorer.noaa.gov/gallery/gallery.html
This site includes visual and audio material from NOAA Ocean Explorer expeditions. There are videos, podcasts, slideshows and audio files available. Files are organized into several categories including: maps, living ocean, sound in the sea, cultural heritage, history, technology, explorers and a YouTube video playlist.

NOAA Photo Library
www.photolib.noaa.gov/collections.html
This site, maintained by the National Oceanic and Atmospheric Administration, is a government site with several image collections relevant to fisheries. Instructors will find the following collections particularly useful:

The National Undersea Research Program
National Marine Sanctuaries
Fisheries
National Marine Fisheries Historical Image Collection

IV. Video Resources

America's Underwater Treasures. 2006. Jean-Michel Cousteau Ocean Adventures. DVD 120 min.
PBS Home Video
1-800-PLAY PBS
www.pbs.org

This two-part, two-hour production examines all 13 of the U.S. National Marine Sanctuaries. Their role in the conservation of marine biodiversity is emphasized including their role in the recovery of marine fish stocks.

PBS also maintains a web site (www.pbs/kqed/oceanadventures/episodes/treasures/) *that provides links to the National Marine Sanctuary web site, live underwater video feeds and additional information on the marine sanctuary system.*

Common Ground I: Oregon's Oceans. 2005. Green Fire Productions. DVD 28 min.

Common Ground II: Oregon's Ocean Legacy. 2007. Green Fire Productions. DVD 15 min.

Common Ground III: Oregon's Network of Marine Reserves and Marine Protected Areas. 2009. Green Fire Productions. DVD 18 min.

This series of three short films describes the rationale behind the establishment of a network of marine reserves off the Oregon Coast. The viewpoints of several stakeholders are presented including marine biologists, recreational fishermen, commercial fishermen, small business owners and conservationists. The latest scientific information on the effectiveness of marine reserves is also included. The DVDs can be ordered for $15 each (or $20 for the entire set) from www.oceansonline.org. *Brief excerpts are also available on-line for preview.*

Deep Sea Conservation Coalition
www.savethehighseas.org

The DSCC is an international coalition of conservation organizations working together to protect seamounts, cold-water corals and vulnerable deep sea ecosystems. The group has called upon the United Nations General Assembly to adopt a resolution declaring an immediate moratorium on high seas bottom trawling. Their web site provides a number of resources that illustrate the effects of bottom trawling.

A deep sea photo gallery includes some before- and after-trawling photos and a video available at www.savethehighseas.org/video.cfm provides an overview of bottom trawling impacts.

The following short videos are also available:

- "Deep Sea Destruction" (4 minutes)

Bottom trawling in the North Atlantic and Tasman Sea (New Zealand) is illustrated in this 2004-2005 narrated video. Footage from a number of sources including Greenpeace is included.

- *Oceana* footage of impacts of bottom trawling using a net-mounted video (42 seconds)

Deep Crisis. 2003. Scientific American Frontiers. VHS 57 min.
PBS Home Video
1-800-PLAY PBS
www.pbs.org

This one-hour Scientific American Frontiers *production, narrated by Alan Alda, is conveniently divided into three equal segments of approximately 20 minutes each. The first addresses salmon in the Pacific Northwest with an emphasis on new technologies being used at hydroelectric dams on the Columbia River to monitor salmon populations and reduce impact. The second examines recovery efforts for Atlantic salmon in Maine including captive breeding of wild stocks and their re-introduction into Maine rivers. The third segment describes current research on Atlantic bluefin tuna using tagging technology and aerial surveys to monitor tuna population sizes and migration patterns.*
DETAILED NOTES ON THIS VIDEO ARE AVAILABLE IN THE *COMPREHENSIVE RESOURCES FOR NCSR MARINE FISHERIES SERIES.*

Empty Oceans: Global Competition for Scarce Resources. 2004. DVD 30 min.
Films for the Humanities and Sciences
1-800-257-5126
www.films.com

This video illustrates the social and economic consequences of marine fishery declines. An emphasis is placed on the international aspect of the issue with examples from West Africa, Japan, Spain and Canada. A short video clip of the film can be seen on the distributor's web site.

Empty Oceans, Empty Nets. 2002. Habitat Media. VHS/DVD 57 min.
734 A Street
San Rafael, CA 94901
415-458-1696
www.habitatmedia.org

This one-hour video explores most aspects of commercial fisheries from several perspectives including commercial fishers, fishery scientists and concerned citizens. It is probably the most comprehensive, high quality video production on this topic. Case studies of the Atlantic cod, salmon, bluefin tuna and swordfish are provided. The ecological impact of commercial fishing is emphasized but there is also good coverage of proposed solutions and success stories. Current efforts to restore fisheries, protect essential fish habitat and implement market-based solutions are included.

A low-cost ($12) edited version of this production is now available for educators. An activity guide that describes six student exercises linked to this video production is also available on the Habitat Media web site. Although designed primarily for high school students, several of these exercises could be adapted for college-level courses. (Available at www.habitatmedia.org/educators.html)
The *Marine Fisheries Series Activity Guide* can be accessed at:
www.pbs.org/emptyoceans/educators/activities.html
DETAILED NOTES ON THIS VIDEO ARE AVAILABLE IN THE *COMPREHENSIVE RESOURCES FOR NCSR MARINE FISHERIES SERIES.*

End of the Line – Imagine a World Without Fish. 2009. New release 80 min.
http://endoftheline.com/film/
http://www.babelgum.com/endoftheline

This feature-length documentary film is adapted from Charles Clover's book of the same title. It examines the impacts of overfishing on marine ecosystems and the human food supply. It premiered at the Sundance Film Festival in 2009 and is being distributed. It features several of the examples cited in NCSR Fisheries modules including discussions of bluefin tuna and Atlantic cod. See web sites above for film trailer and individual episodes.

Fate of the Ocean – Our Threatened Fisheries. 2005. VHS/DVD Two 30 min. programs
Films for the Humanities and Sciences
1-800-257-5126
www.films.com

This two-part series takes a global view of the issue of declining fisheries. A wide range of examples are examined from around the world. The first program, Plundering the Oceans, *explains the general nature of fishery declines using examples from India, the Mediterranean and the North Atlantic (cod and tuna). The second program,* Protecting the Oceans, *describes examples of sustainable fishing practices, some of which may be used as models for large-scale reform of fishing policy. Examples from the Canary Islands, Oman and Great Britain, including marine reserves, ecotourism and aquaculture are used to illustrate. A sample video clip and a detailed outline of the videos are available at the distributor's web site.*

Farming the Seas. 2004. Habitat Media. VHS 56 min.
734 A Street
San Rafael, CA 94901
415-458-1696
www.habitatmedia.org

This 1-hour video production addresses the many issues surrounding aquaculture - the cultivation of fish and other marine organisms. General issues are discussed and specific case studies are provided from the United States (bluefin tuna), Canada (salmon), China (carp) and Thailand (shrimp). The notes that follow provide a summary of the content of the Farming the Seas *video production. Approximate elapsed time is given at the beginning of each section to facilitate the selection of excerpts or other planning.*
DETAILED NOTES ON THIS VIDEO ARE AVAILABLE IN THE *COMPREHENSIVE RESOURCES FOR NCSR MARINE FISHERIES SERIES.*

Fisheries – Beyond the Crisis. 1998. The Nature of Things. VHS 46 min.
Bullfrog Films
P.O. Box 149
Oley, PA 19547
610-779-8226
www.bullfrogfilms.com

This production, hosted by David Suzuki, examines community responses to the decline of marine fisheries in the Bay of Fundy, Canada and in southern India. Both communities opposed a quota system of management and demanded a locally controlled, ecosystems-based approach to achieve long-term sustainability of the fisheries and the communities they support.

Fish for today, fish for tomorrow. 2008. Marine Stewardship Council. On-line 8 min.
www.youtube.com

This short "You tube" *video describes the rationale and process for Marine Stewardship Council certification of seafood.*

A Fish Story. 2007. Public Broadcasting Service - Independent Lens. DVD 54 min.
www.pbs.org/independentlens/fishstory
www.pbs.org/independentlens/fishstory/updates2.html

This video production is most appropriate for those instructors who would like to present the social impacts of fishery declines. The plights of two Massachusetts fishing families are followed, one from Gloucester and the other from Chatham, during a time of increased regulation and declining fish stocks.

An update is provided by the Northeast Seafood Coalition, a non-profit organization that represents commercial fishermen, fishing-related business owners and fishing community members. A representative of the coalition describes how fishing regulations implemented after the collapse of the groundfish fishery are affecting the fishing industry.

Gutted: The Demise of Scotland's Fishing Industry. 2005. Wide Angle. DVD 57 min.
Films for the Humanities and Sciences
1-800-257-5126
www.films.com

This one hour documentary depicts the social impacts of fishery declines on a community in Scotland. Much like the situation in New England, overfishing of cod and other species in the North Sea, followed by government restrictions on fishing, decimated local economies. A short video clip of the film can be seen on the distributor's web site.

Has the Sea Given Up Its Bounty? 2003. New York Times. 10 min.
www.nytimes.com/packages/khtml/2003/07/29/science/20030729_OCEANS_FEATURE.html

This is an interactive video feature developed by Andrew Levin of the New York Times on the effects of bottom trawling and overfishing on the world's oceans. Brief video segments, animations and diagrams are used to illustrate. There is also an associated NY Times article.

Journey to Planet Earth – The State of the Ocean's Animals. 2007. PBS. DVD 60 min.
www.pbs.org/journeytoplanetearth/about/purchase.html
PBS Home Video
1-800-PLAY PBS

This PBS production addresses global marine conservation issues including several that are related to marine fisheries. Short segments that highlight the Atlantic cod fishery off the New England coast, the impacts of industrial fishing on traditional fisheries in Senegal, Africa, the decline of shark populations and the salmon fishery in the Klamath Basin, Oregon are included. Other segments describe conservation issues concerning sea turtles, dolphins and sea otters.

Journey to Planet Earth – The State of the Planet's Oceans. 2009. PBS. DVD 60 min.
www.pbs.org/journeytoplanetearth/about/purchase.html
PBS Home Video
1-800-PLAY PBS

The Journey to Planet Earth *series (hosted by Matt Damon) is designed for a general audience and addresses a number of current environmental issues. This episode examines marine issues with an emphasis on global climate change and overfishing.*
DETAILED NOTES ON THIS VIDEO ARE AVAILABLE IN THE *COMPREHENSIVE RESOURCES FOR NCSR MARINE FISHERIES SERIES.*

The Long View: A Plan to Save Our Ocean Fish. 2006. Marine Fish Conservation Network Web-based. 12 min.
www.conservefish.org/site/catch06/index.html

This conservation-based site includes a downloadable 12-minute video that provides a good overview of the U.S. fisheries management situation from the perspective of an environmental organization dedicated to marine conservation.

Marine Conservation Biology Institute
www.mcbi.org

See "Photo Library" → "People" → "Effects of Trawling" videos (Aleutian Islands, Alaska):
1. Untrawled reefs in Alaska
2. Trawled coral and sponge habitat in Alaska

These two short (30 sec.) videos recorded by NOAA show a comparison of trawled and untrawled bottom habitats off the Alaska coast.

New Whiting Fishery in Newport. 2000. Oregon Field Guide. VHS/DVD 15 min.
Oregon Public Broadcasting Productions
7140 SW Macadam Ave.
Portland, Oregon 97219-3099
1-800-241-8123
www.opb.org

This short Oregon Field Guide *segment describes the development of a new trawl fishery off the Oregon Coast for Pacific whiting.*

Net Loss – The Storm Over Salmon Farming. 2003. Moving Images Video. DVD 52 min.
Bullfrog Films
P.O. Box 149
Oley, PA 19547
610-779-8226
www.bullfrogfilms.com

This video production examines the risks and benefits of "net pen" salmon farming, a type of aquaculture used in Washington and British Columbia in which salmon are raised in giant underwater cages. While decades of past management failures have caused the decline of many wild salmon populations, salmon farming is seen as a sustainable method for providing fish for markets. This video production examines the controversy surrounding salmon farms and the threat they pose to wild salmon. The perspectives of salmon farmers, conservationists, traditional fishermen and government officials are portrayed.

Oceans and Marine Life – Marine Video and Animation
National Environmental Trust
www.net.org/marine/video.vtml

This environmental organization posts on-line video clips (or links to clips on other sites) concerning fisheries issues. Short (2-3 minute) videos include:

- *"Take a Pass on Chilean Sea Bass" – a humorous depiction of seafood choices made by consumers in a restaurant*
- *"Overfishing Animation" – an illustration of the global decline of large, predatory fish over the past 50 years (based on data from Myers and Worm, 2003)*
- *"Small Fish, Big Problem" – a humorous depiction of shifting baselines*

Over-exploiting the Oceans – The Dangers of Overfishing. 2007. VHS/DVD 47 min.
Films for the Humanities and Sciences
1-800-257-5126
www.films.com

This video production examines the environmental and socioeconomic impacts of overfishing from a global perspective. Ancient artisanal fishing practices are contrasted with large-scale modern fishing techniques used in the oceans off the African coast. International economic and political factors are also examined. A sample video clip and a detailed outline of the video are available at the web site above.

Resources Assessment and Conservation Engineering – Field Videos
Alaska Fisheries Science Center
NOAA Fisheries
www.afsc.noaa.gov/race/media/videos/vid_habitat.htm

Underwater video has been used in an attempt to evaluate benthic habitats and the impacts of bottom trawls on those habitats. The Alaska Fisheries Science Center of NOAA Fisheries has posted a number of on-line video clips that illustrate the impacts of various types of fishing gear.

Strange Days on Planet Earth. 2004. Episode #3 – Predators. National Geographic Television and Film. Vulcan Productions, Inc. DVD 20 min.
www.nationalgeographic.com
www.pbs.org
1-800-PLAY-PBS
This video is divided into three segments of roughly equal length. Each segment describes the intricate relationships between fish populations and other environmental phenomena. In the first segment, historical archives are used to describe how the decline of large African mammals is related to the availability of fish in Ghana. As fish populations decline, hunting for "bush meat" increases to compensate for the loss of protein in the diet. Conversely, when fish numbers increase, hunting declines and wildlife populations rebound. The second segment establishes a connection between fish kills on the coast of Namibia and the release of large amounts of hydrogen sulfide from marine sediments. The hydrogen sulfide deposits appear to have resulted from the decomposition of phytoplankton, which flourished after sardine populations were depleted by foreign fishing fleets in the 1970s. The final segment examines various proposals for achieving sustainable fisheries management. Marine reserves and aquaculture (integrated aquaculture and open access "Aquapods") are emphasized.
DETAILED NOTES ON THIS VIDEO ARE AVAILABLE IN THE *COMPREHENSIVE RESOURCES FOR NCSR MARINE FISHERIES SERIES.*

Strange Days on Planet Earth. 2008. Episode #5. National Geographic Television and Film. Vulcan Productions, Inc. DVD 60 min.
www.nationalgeographic.com
www.pbs.org
1-800-PLAY-PBS
DETAILED NOTES ON THIS VIDEO ARE AVAILABLE IN THE *COMPREHENSIVE RESOURCES FOR NCSR MARINE FISHERIES SERIES.*

Weather the Storm: The Fight to Stay Local in the Global Fishery. 2008. DVD 37 min.
Bullfrog Films
P.O. Box 149
Oley, PA 19547
610-779-8226
www.bullfrogfilms.com

This production by the Ethnographic Film Unit at the University of British Columbia presents the case for supporting small-scale, artisanal fisheries as part of a global sustainable fisheries strategy. In contrast to industrial floating fish factories that deplete fish stocks and then move to other areas, artisanal fisheries serve local communities and can readily adapt their fishing methods to changing local conditions. Small-scale fisheries from around the world are described, but the emphasis is on the ground fishery (cod, haddock and halibut) off the west coast of France. Although the film is narrated in English, much of the conversation among fishermen, community members and others involved in the industry is in French with English subtitles.

Where's the Catch? 2005. VHS/DVD 26 min.
Films for the Humanities and Sciences
1-800-257-5126
www.films.com

This video examines fisheries in the Pacific Islands (Fiji, Kiribati and the Marshall Islands) emphasizing the impacts of fishery declines on subsistence and commercial fisheries. The roles of modern indiscriminate fishing techniques, illegal fishing, and government corruption and their impact on Pacific Island culture are illustrated. A sample video clip and a detailed outline of the video are available at the web site above.