The Decline of Atlantic Cod – A Case Study

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Published 2009
DUE # 0757239

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 Bill Hastie of Northwest Aquatic and Marine Educators (NAME), and Richard O'Hara of Chemeketa Community College 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* – 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.

The Decline of Atlantic Cod – A Case Study

An Instructional Guide

This instructional guide is designed to provide instructors with lecture support on the topic of marine fisheries using a case study of the Atlantic cod to illustrate major issues. For centuries the Atlantic cod was the mainstay of fisheries based in southeast Canada and New England. However, in the early 1990s, a dramatic decline in cod stocks forced fishery managers to close some of the world's most productive fishing grounds. The ecological impacts of the decline and the economic impacts of the closures were dramatic. This module describes the historical context of the collapse of the cod fishery as well as assessments of the current status of the resource. Recovery efforts and the future of the fishery are also discussed.

Instructional materials include student learning objectives, a general lecture outline, a *PowerPoint* presentation with detailed instructor notes and student handouts. Brief descriptions of other fisheries for development as case studies are also 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:

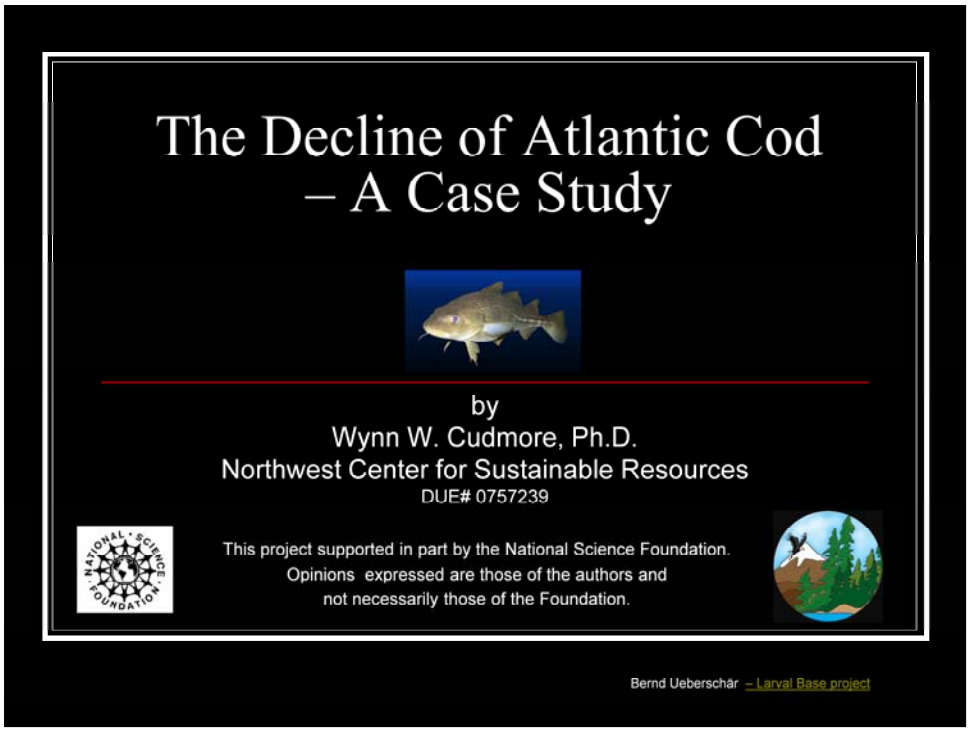
1. Characterize the historical significance of the Atlantic cod fishery
2. Describe the nature and causes for the decline of Atlantic cod
3. Describe community and ecosystem-level effects of Atlantic cod declines
4. Describe traditional and ecosystem-based approaches to recovery of this species
5. Use case studies to illustrate the various aspects of marine fisheries

General Lecture Outline

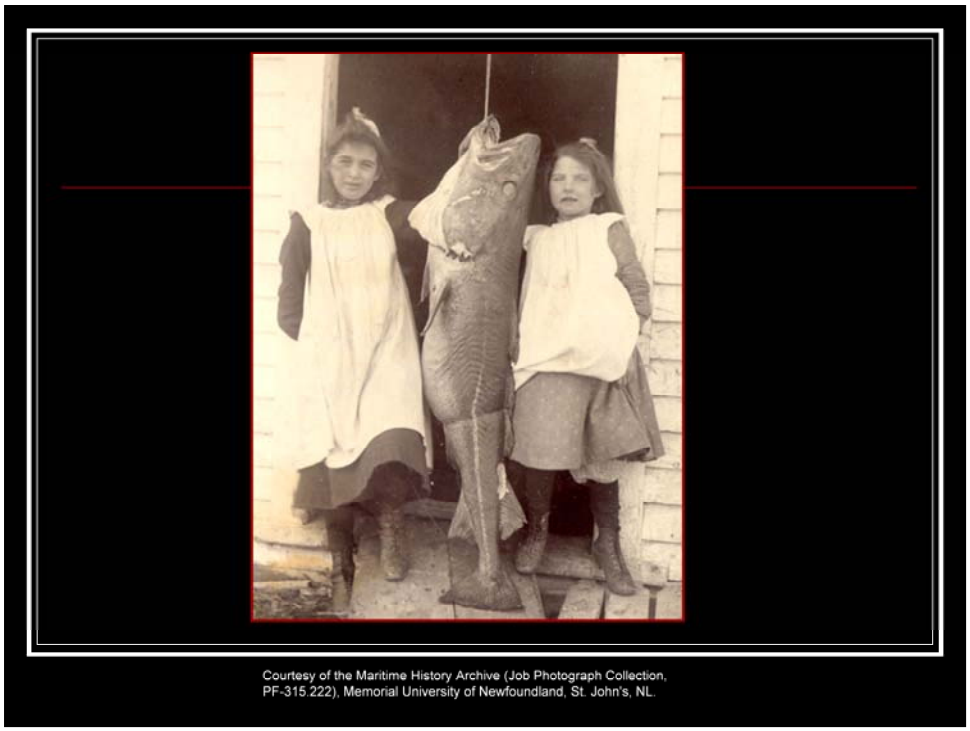
This lecture outline follows the *PowerPoint* presentation.

I. Introduction
    A. Atlantic cod basic biology
    B. Historical significance
II. History of the cod fishery
    A. Discovery of northwest Atlantic stocks (1500s)
    B. Wind-powered schooners and dories from Europe (1800s)
    C. Conversion from wind to steam (early 1900s)
    D. Factory-freezer trawlers (1950s)
    E. Foreign "fish factories" (1960s and 1970s)
III. Stock Trends
    A. Based on landing data
    B. Based on stock assessments
    C. Population collapse (1992)
IV. Population, community and ecosystem-level impacts of the cod fishery
    A. Fishing-induced changes in life history characteristics
    B. Fishing-induced evolutionary changes
    C. Trophic cascades
    D. Habitat alteration
V. Cod Management
    A. Mesh size regulations
    B. Quotas
    C. "200-mile limit"
    D. Closures
VI. Cod Recovery
    A. Status of recovery
    B. Biological factors affecting recovery
    C. Societal factors affecting recovery
VII. The Future of Cod

PowerPoint Presentation with Instructor Notes



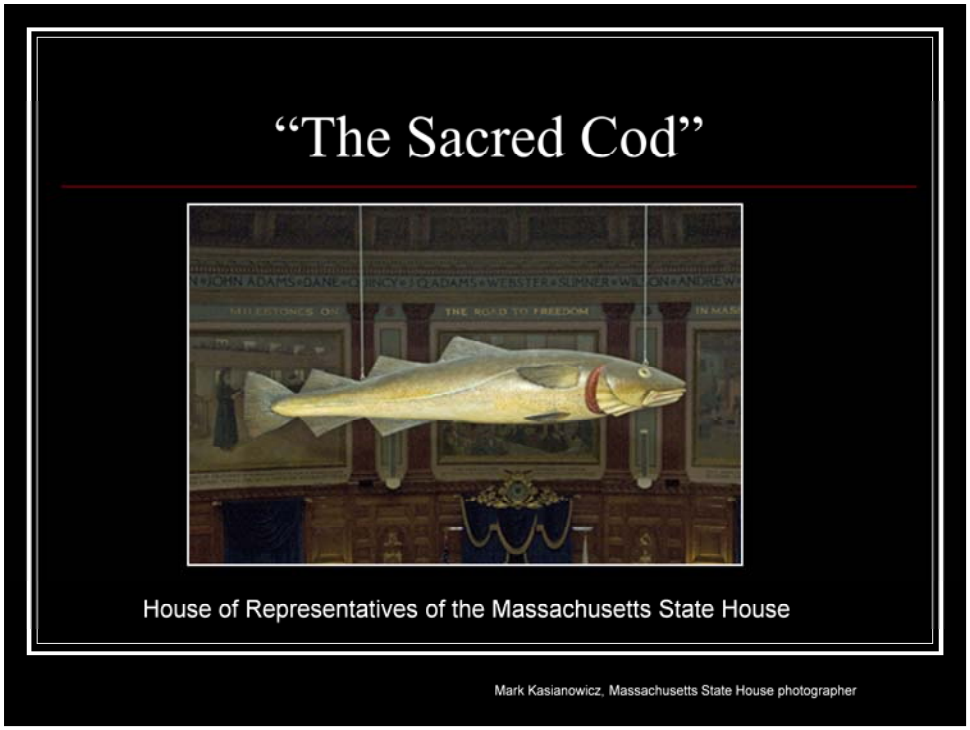
This presentation provides a detailed case study of the Atlantic Cod as an illustration of major issues in the management of marine fisheries. Other marine fisheries topics such as causes for declines, the implications of fishery declines for marine ecosystems and fishery management practices are described in detail in other NCSR marine fisheries modules.



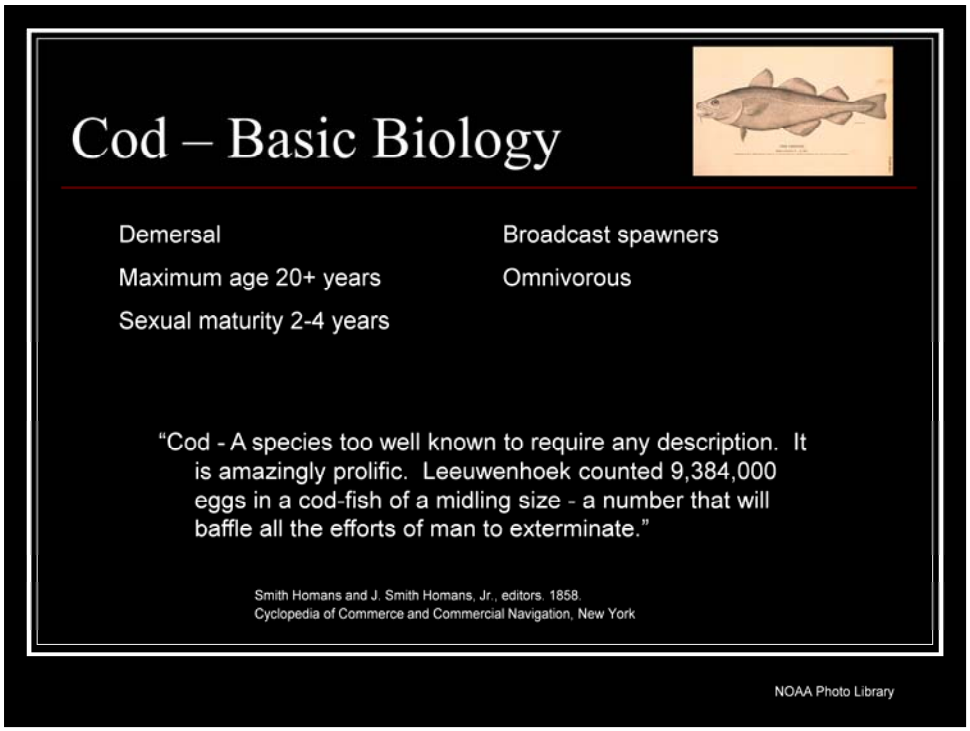
Courtesy of the Maritime History Archive (Job Photograph Collection, PF-315.222), Memorial University of Newfoundland, St. John's, NL.

In the culture of northern Europeans and their descendants who settled in New England and southeast Canada, the Atlantic cod is held in utmost esteem. Much like the relationship between the Pacific salmon and the native people of the Pacific Northwest, this fish literally held the key to survival - first as a source of sustenance and later, as the foundation of their economies. As a result, the cod had great spiritual and commercial significance. Wars were fought over its management and the fish was revered in spiritual ceremonies and financial markets alike.

Cod fishing probably represents the <u>first</u> successful industry in colonial America.

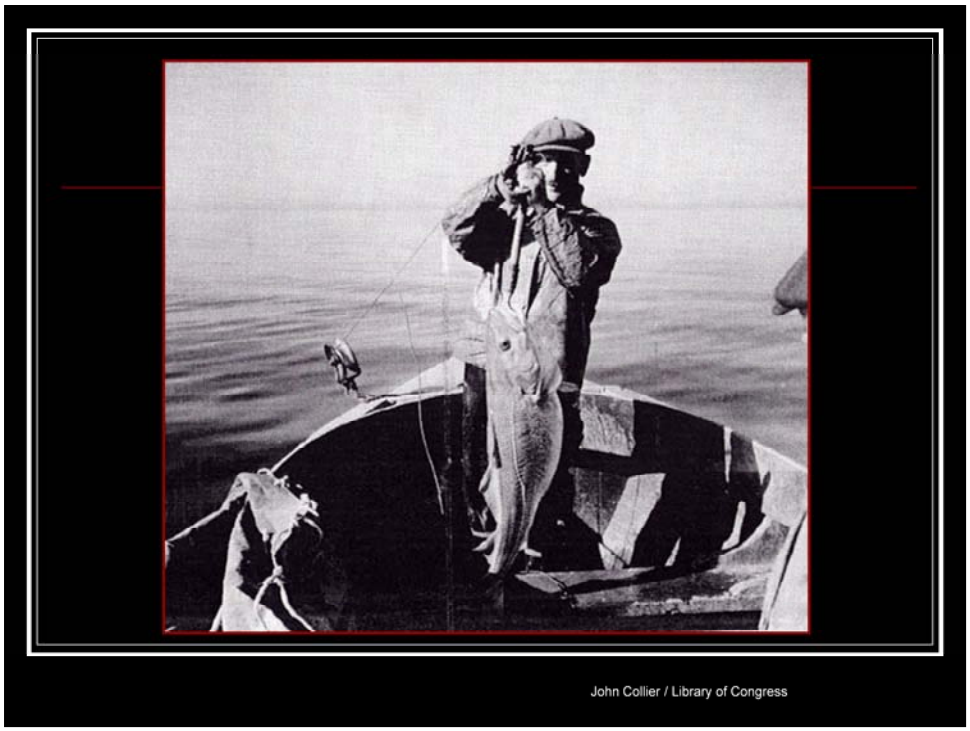


"The Sacred Cod," a five-foot long carved Atlantic cod, hangs in the State House of Massachusetts as a symbol of the importance of the cod fishing industry to the state. When placed there in 1785, Representative John Rowe of Boston proclaimed "that leave might be given to hang up the representation of a cod fish in the room where the House sits, as a memorial of the importance of the cod fishery to the Commonwealth…" The cod fishing industry provided great sustenance and prosperity for the state for over two centuries.

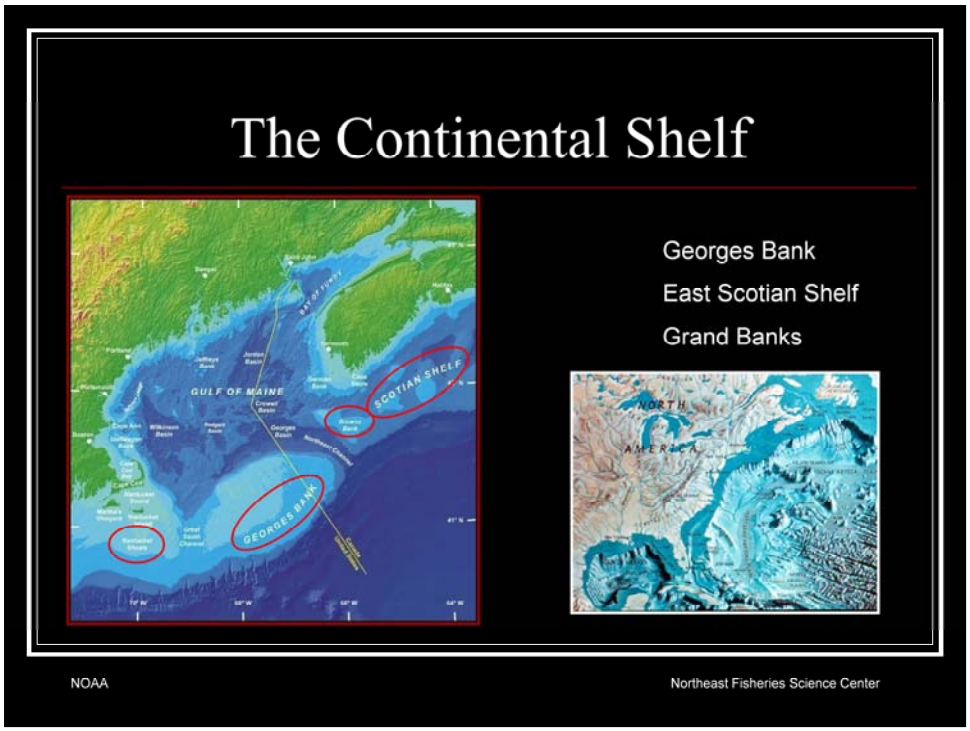


The Atlantic cod is a demersal ("bottom-dwelling") species that may attain lengths of up to 130 cm (51 inches) and weights of 25-35 kg (55-77 lbs). Maximum age is over 20 years but younger fish (2-5 years, weighing 5-10 lbs.) make up the majority of the catch. Sexual maturity is reached at 2-4 years. Cod are "broadcast-spawners"; that is, they gather in large breeding congregations where sperm and eggs are released into the water column and random fertilization occurs. Cod are omnivorous, feeding on a wide variety of fish and invertebrates.

Early biological descriptions of the species commented on its tremendous reproductive potential, and as a result, its apparent ability to withstand fishing pressure.

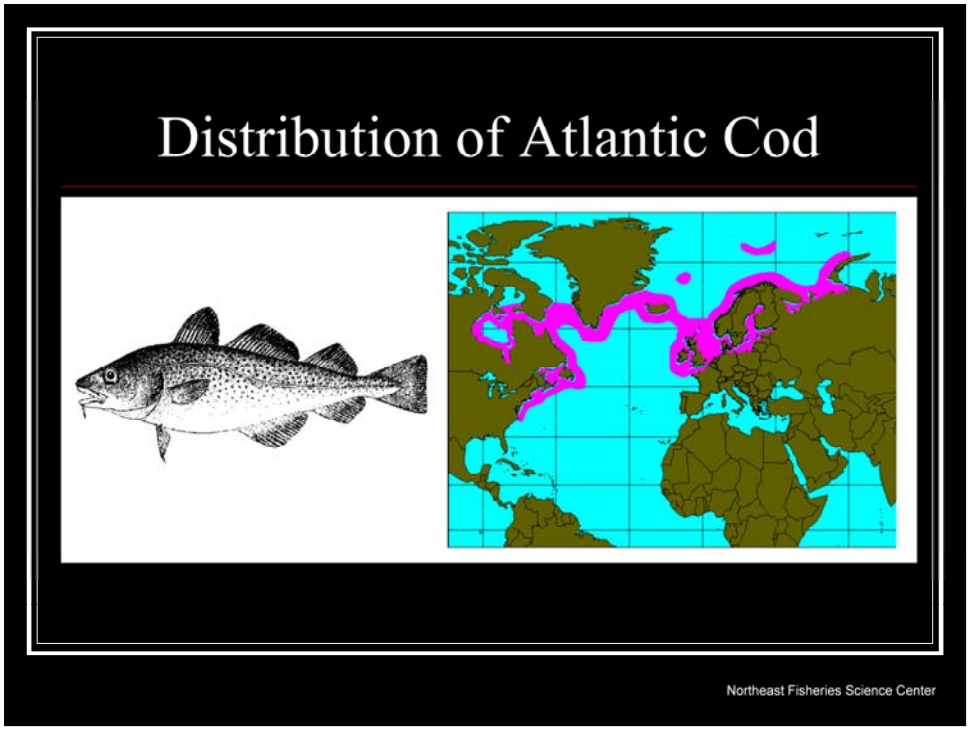


Cod apparently achieved larger size in past times with fish over 100 pounds not considered unusual. In 1938 a 180-lb. cod was caught and a 211-lb cod was caught in 1895. Fish of this size have not been seen in over 100 years.

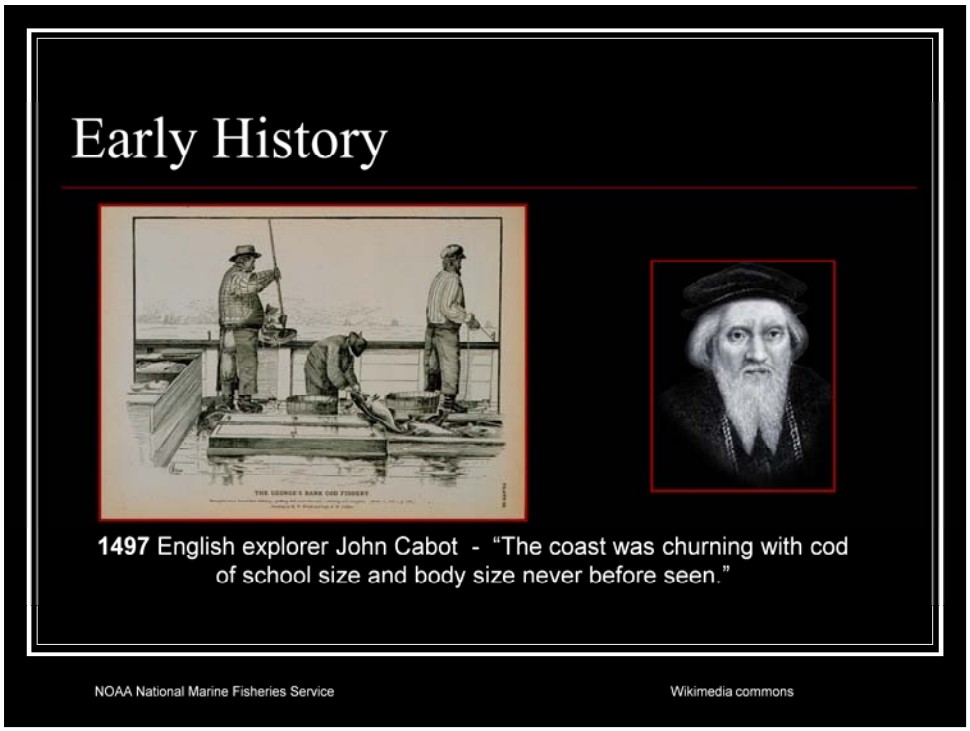


Cod are associated with relatively shallow marine habitats along the continental shelf including a series of “banks” that occur from Newfoundland to southeastern New England. Examples include Georges Bank off New England, the East Scotian Shelf off Nova Scotia, and the Grand Banks off the east coast of Newfoundland and Labrador.

On these banks, nutrients are frequently stirred up by cross currents and storms resulting in phytoplankton blooms that support high concentrations of zooplankton. The zooplankton are fed upon by northern shrimp, which are an important food source for cod.



The distribution of the Atlantic cod extends from eastern North America across the north Atlantic to western Europe. Both inshore and offshore stocks are known. Cod gather in large breeding congregations in spring. These areas are known to fishermen and some have been fished for centuries.



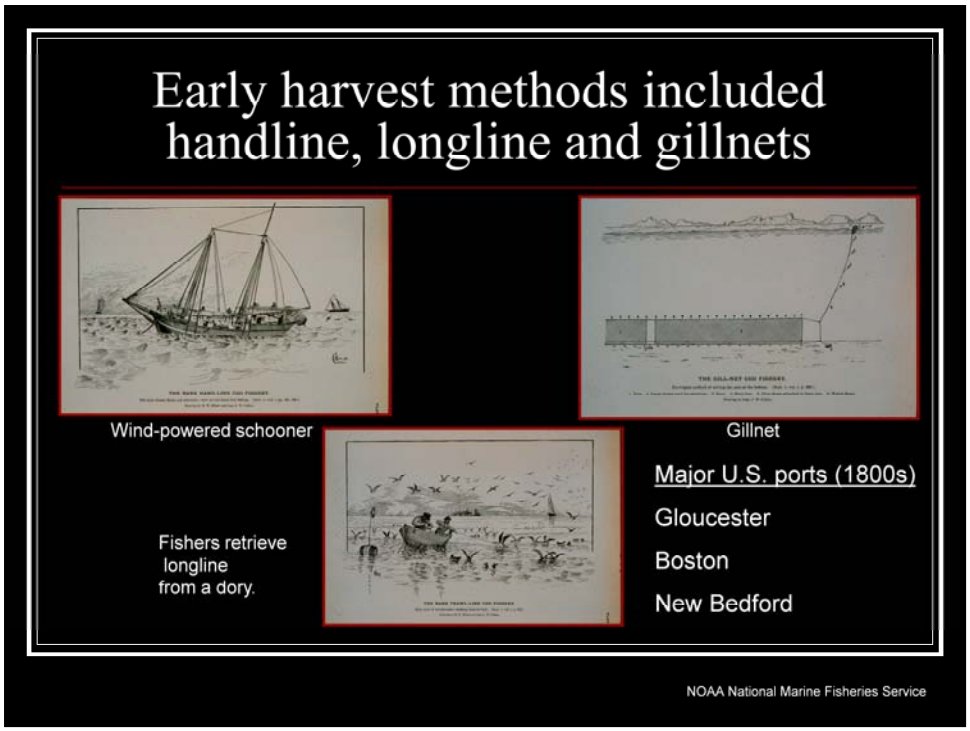
Reports from historical records suggest that when English explorer John Cabot discovered North America, the coast was "churning with cod of school size and body size never before seen." Cabot's men caught cod in weighted baskets randomly thrown overboard.

The newly discovered cod stocks off the coast of Newfoundland were being fished by French, English, Portuguese and Spanish fishermen who used single baited hooks to catch the fish. Fish were harvested exclusively from inshore waters.

The French developed a Canadian off-shore fishery which was quickly followed by other European countries. By the late 1500s, France and England were sending 150 ships each to fish for cod on the Grand Banks off the coast of Newfoundland. Huge profits were reaped and the fishery became a major contributor to the wealth of England. Permanent settlements were established on Newfoundland; fishing for cod was their only source of income.

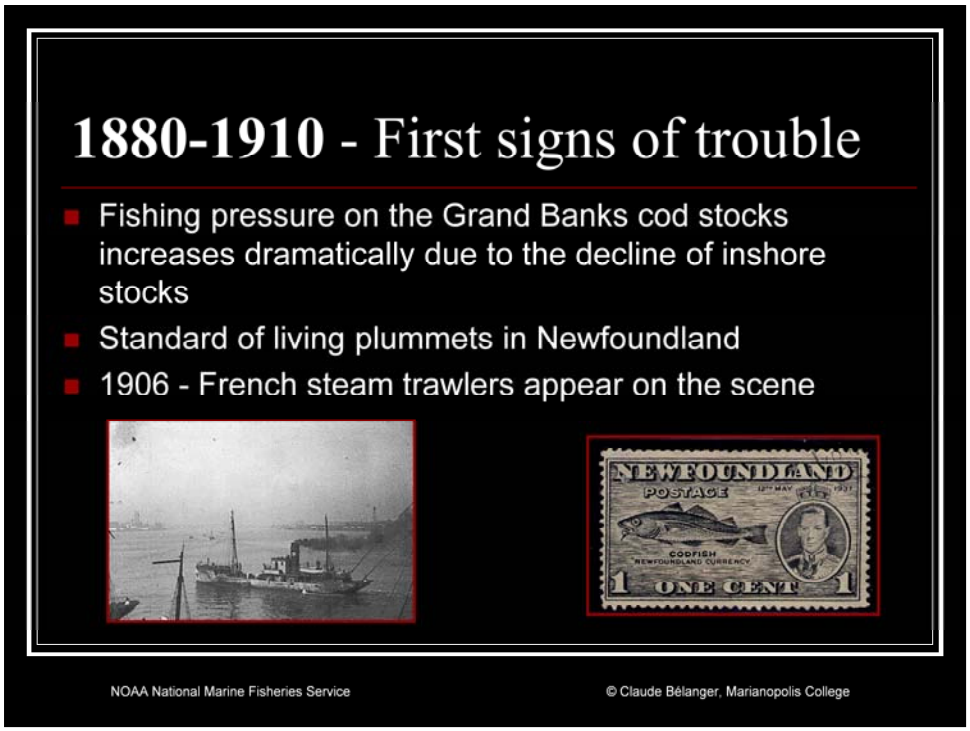
Quoted from Quinn, D.B. (ed.) 1940. The voyages and colonizing enterprises of Sir Humphrey Gilbert

Fishermen have always been known to stretch the truth when it comes to describing the size or abundance of fish. Nevertheless, it is clear from this quote that European fishing captains were pleased with their new-found wealth.



By the mid-1800s wind-powered schooners (upper left) brought fishermen to the fishing grounds on the Grand Banks where early harvest methods included handlines, longlines and gillnets (upper right) deployed from dories (lower center). In the mid-1800s, the U.S. groundfish fleet was based in small communities along the eastern seaboard that are now synonymous with the fishing industry – e.g., Chatham, New Bedford, Boston, Beverley, Gloucester. Many of these fishing communities had depended on the groundfishing industry as the foundation of their economies since the 1600s.

Since refrigeration and freezing for the catch was not yet available on these vessels, most of the cod was salted at sea. Salt cod was marketed world-wide and formed the basis for an international economy.

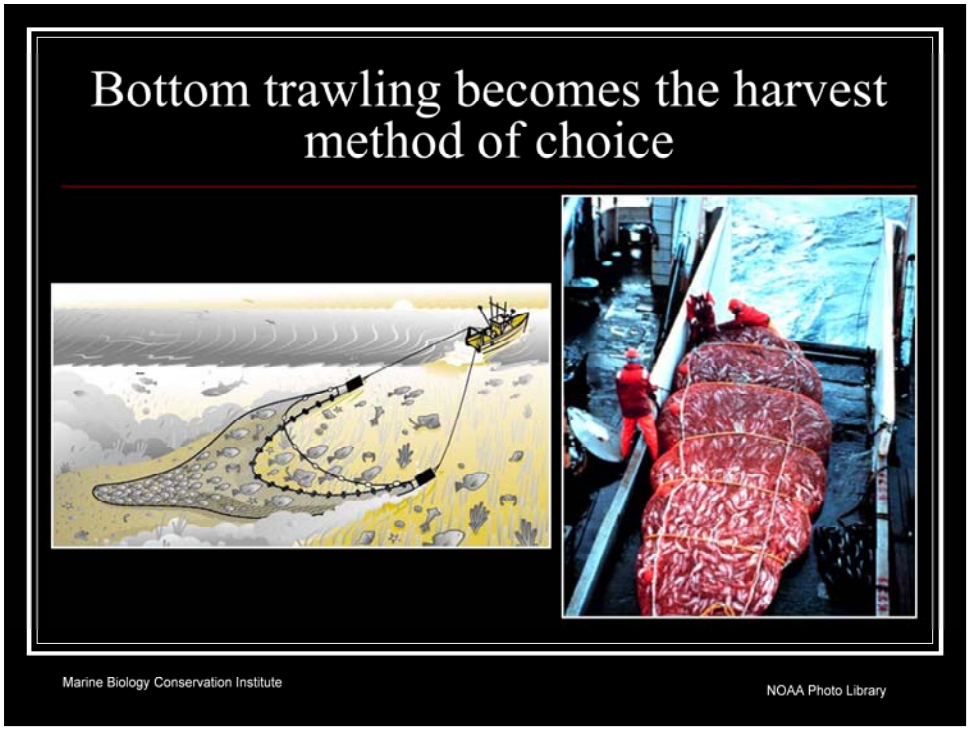


The 1800s brought some technological improvements to the cod fishery including "fish traps," which increased efficiency over single baited hooks and longlines. Cod fish traps were based on fish weirs designed to capture salmon. Anchored nets were placed close to shore where cod were known to migrate. Entire schools of fish were funneled into a portion of the trap where they could be corralled and easily captured.

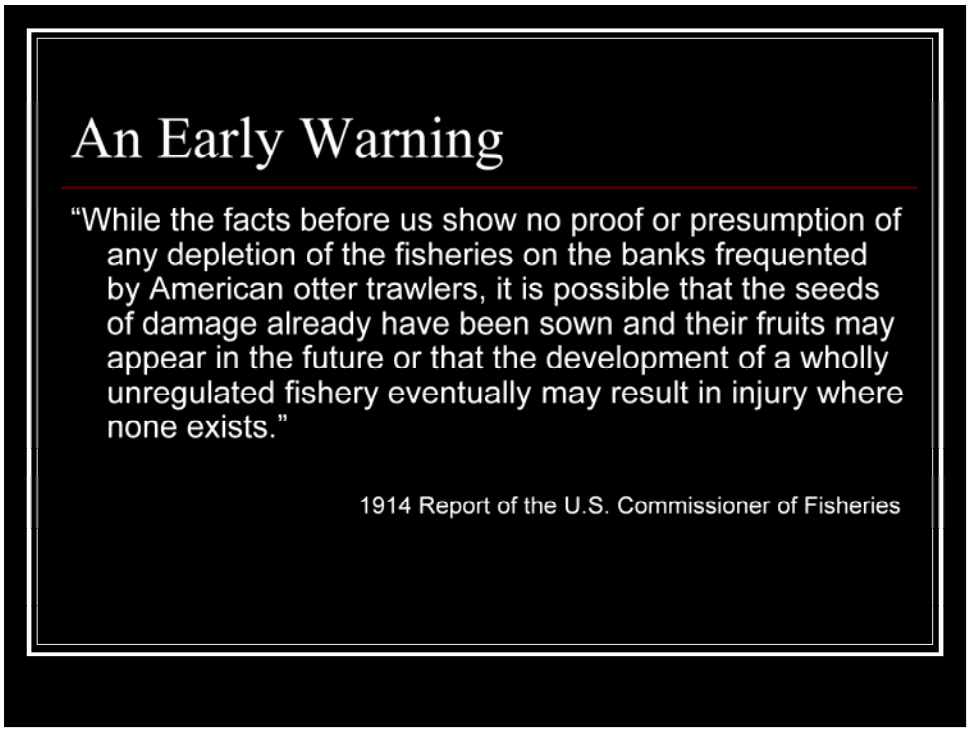
Fishing pressure on the Grand Banks cod stocks increased dramatically due to the decline of inshore stocks, the decline of seal hunting and the lack of other employment opportunities in the region. The increase in the number of fishermen resulted in smaller landings, lower profits and unemployment. The standard of living in Newfoundland plummeted.

French steam trawlers first appear on the Northwest Atlantic fishing grounds in 1906. These vessels dragged large nets (bottom trawls) through schools of cod eliminating the need for bait and easily outcompeting the longliners and other less-sophisticated harvest methods. After a brief period of intense competition, the schooner era came to an end and was replaced by this newer technology.

In 1930, Newfoundland was catching only 40% of the fish taken in her traditional waters; the remainder was going to foreign fishing vessels. Scientific investigations at the time warned that this new technology had the potential to deplete the resource and that it should be applied judiciously.



Once bottom trawling (the otter trawl, a specific type of bottom trawl, is illustrated here on left) proved itself to be the most efficient harvest method, it rapidly replaced earlier methods. The bottom trawl increased landings but unlike earlier methods, captured many non-target species and disturbed or destroyed bottom habitats.

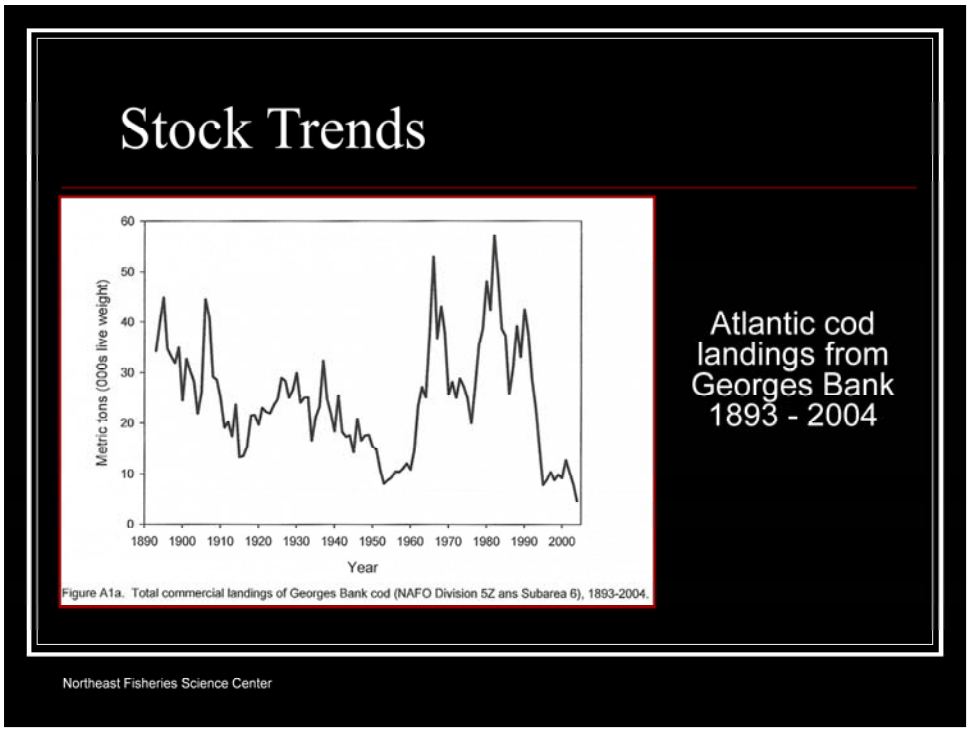


Fisheries management agencies as early as 1914 were well aware that new technologies posed a risk to the long-term health of the fishery as illustrated by this quote from the U.S. Commissioner of Fisheries at the time.

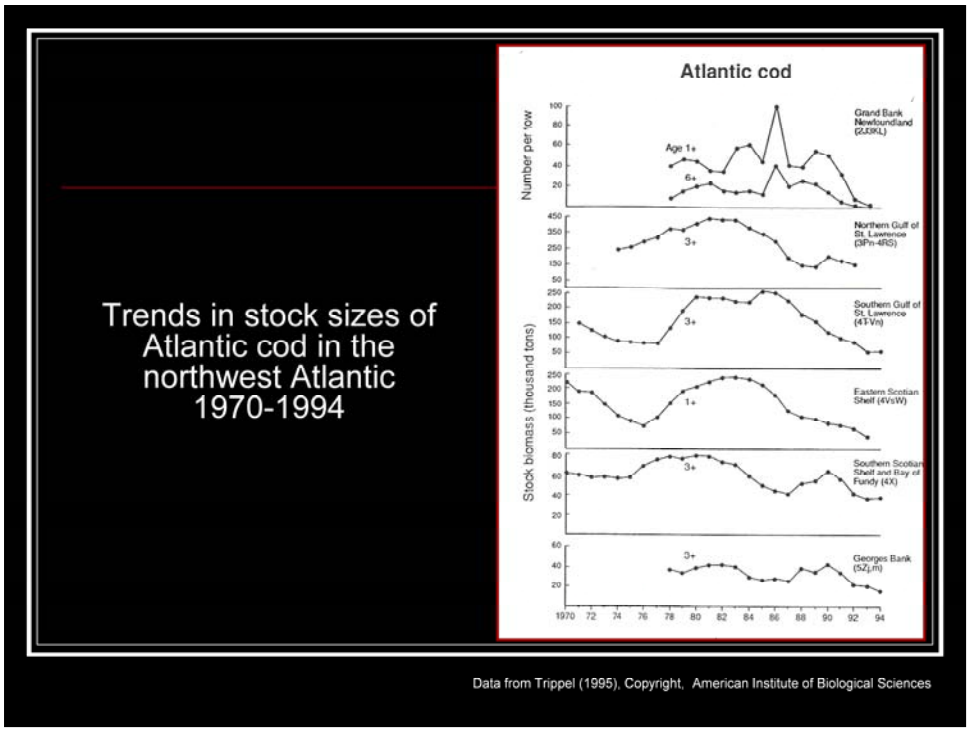
In 1954, the first factory-freezer trawler in the world, the British fishing vessel *Fairtry*, fished the Grand Banks for cod. These huge, 400-foot stern trawlers with on-board processing plants could catch and process as much as 600 tons of fish in a single day. They were able to fish around the clock, year-round and in all but the worst of weather. Other countries soon followed the British example and a new fishery was born – one based on "distant water fleets" (DWFs). This technological innovation dramatically increased fishing pressure on Atlantic cod.

In the 1950s and 1960s additional offshore fishing grounds east of Newfoundland were discovered and added to inshore populations which had been fished for more than 350 years. Annual landings increased dramatically throughout the 1960s. For four centuries, catches of Atlantic cod had increased only gradually as technology improved, reaching about 300,000 tons in 1910. By 1968, over 800,000 tons were reported, accounting for 40% of global fish landings! The coast of southeast Canada had become a magnet for foreign fishing vessels from around the world. International controls on the fishery were either non-existent or ignored. Fishing trips by foreign vessels were timed to coincide with the great spawning congregations to increase catch rates. A perceived super-abundance of cod stocks resulted in over-capitalization by investors in fishing vessels that target cod.

By the early 1960s foreign “fish factories” from Russia, East Germany, Poland, Spain, Japan and others had discovered the productive fishing grounds of Georges Bank. This Soviet factory trawler is representative of foreign fishing vessels fishing within 200 miles of the U.S. and Canadian coasts. By 1971, an armada of 900 large factory trawlers was fishing the high seas - 400 of them belonged to the Soviet Union. Annual harvests during this time period often removed 60% of adult cod in the Canada/U.S. population. This harvest level was 3 times the recommended amount to sustain healthy stocks.

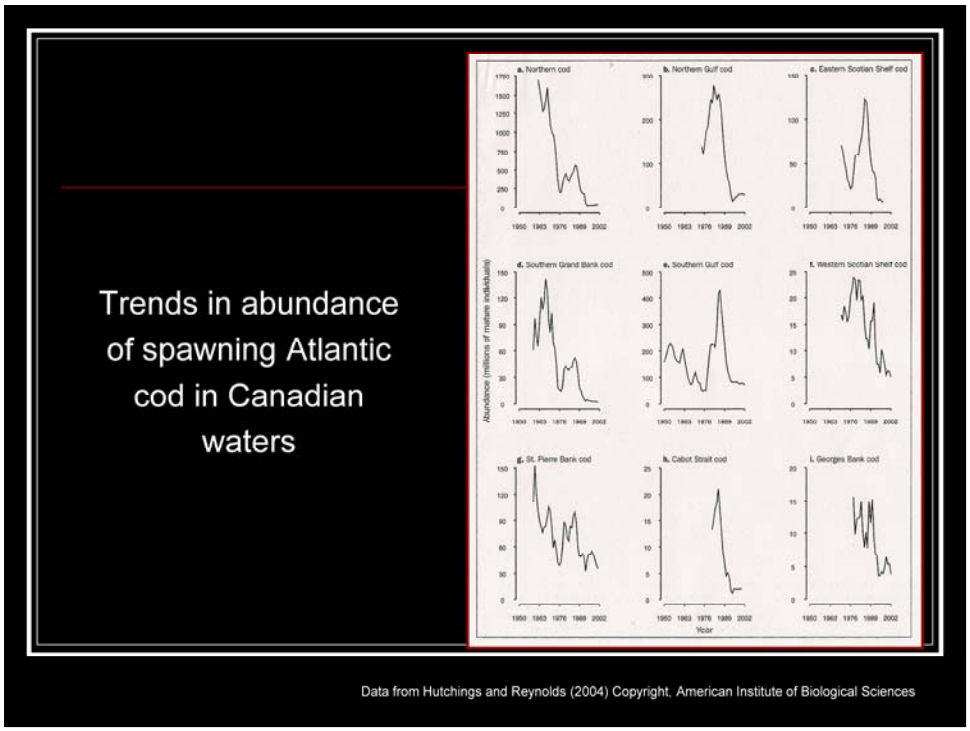


This graph illustrates over 100 years of landings data for Atlantic cod on Georges Bank. Downward trends prior to 1980 were due primarily to economic downturns (e.g., Great Depression, war - 1940s and fuel costs / economic recession / foreign fishing - 1970s). During WWII many of the largest trawlers in the American fleet were requisitioned for war duty as mine sweepers. High landing values from 1978-1990 were due to increased fishing effort by domestic fleets after passage of the "200-mile limit," part of the Magnuson Act of 1976. The establishment of an "exclusive economic zone" out to 200 miles, paired with government subsidy programs, encouraged the fishing industry to build large numbers of new, modern fishing boats. The peak in the early 1980s is due to particularly strong year classes of cod, which had spawned in 1975 and 1978 and had become of harvestable size. Declines since 1990 are believed to be caused by domestic overfishing.



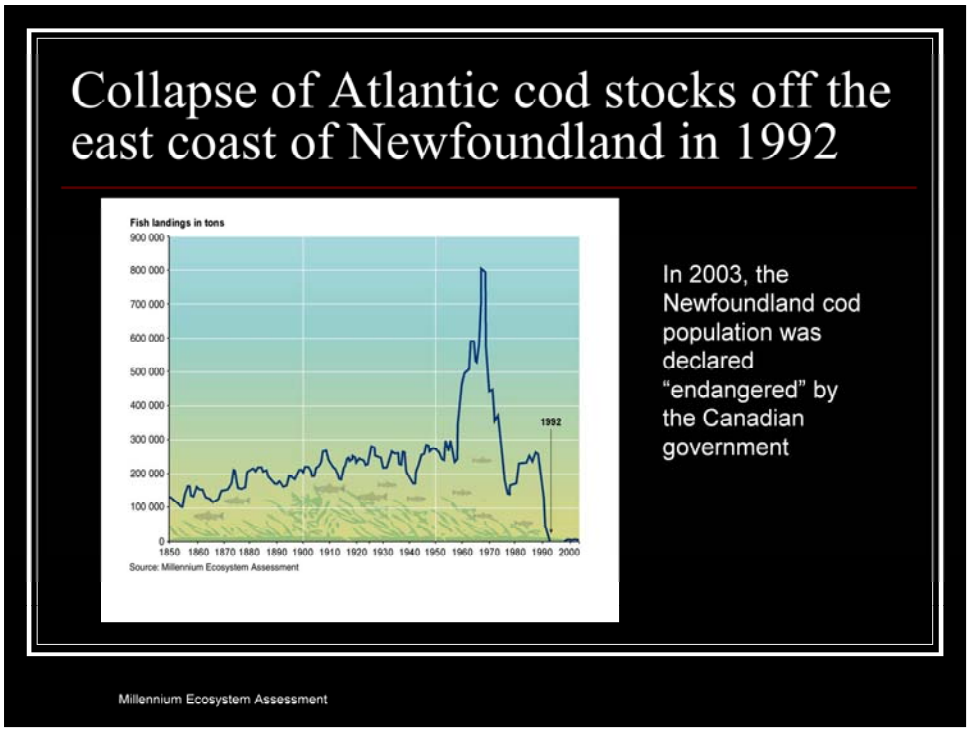
These graphs represent changes in stock sizes of Atlantic cod from 1970 to 1994 based on fisheries research (rather than commercial landings as shown in the previous slide). Different graphs represent the various management areas defined by the Northwest Atlantic Fisheries Organization (NAFO). Numbers on graphs represent age classes - "1+", for example, indicates all fish one year and older. Note that most populations decline precipitously from the mid-1980s to 1994 suggesting a widespread decline in the species. (adapted from Trippel 1995)

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



Changes in abundance of spawning Atlantic cod for nine different Canadian stocks. The collapse of the species in Canadian waters has been remarkable. The northern cod stock ("a" in figure), for example, represents the decline of what was once one of the world's most abundant cod stocks. In the early 1960s, the stock was estimated at almost 2 billion spawning individuals. The population represented 75-80% of Canada's entire cod stock. Since that time, the number of cod 5 years and older have declined by 97%.

Hutchings, J.A. and J.D. Reynolds. 2004. Marine fish population collapses: Consequences for recovery and extinction risk. BioScience 54(4): 297-309.



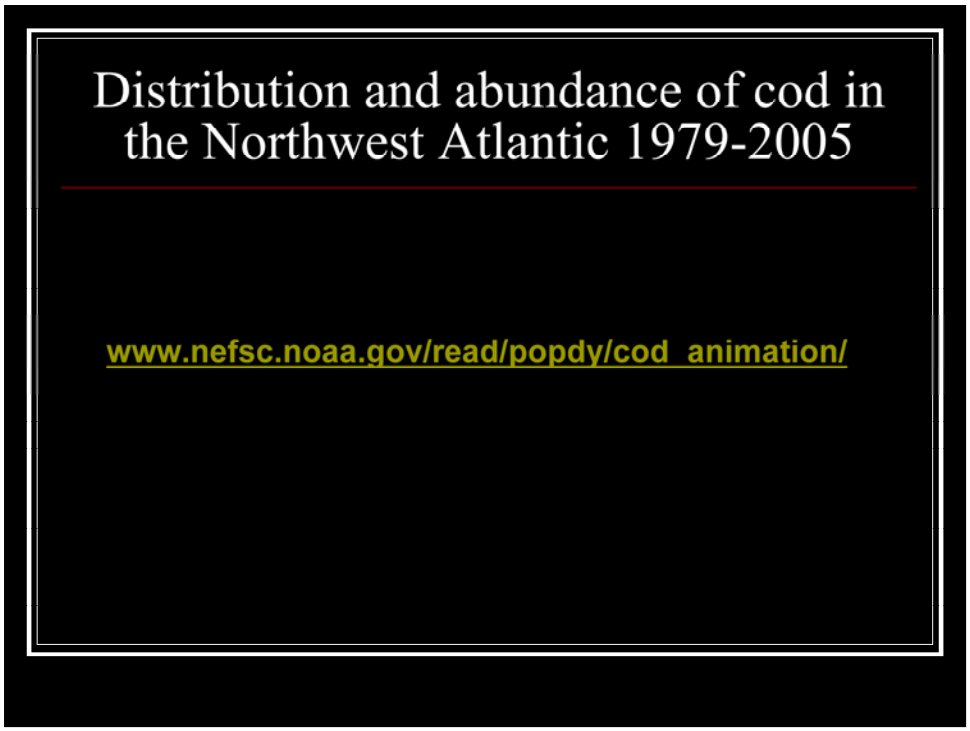
In 1992 cod populations on Canada's Grand Banks off the coast of Newfoundland and Nova Scotia continued to plummet to levels 1% of original population size (see graph). In an attempt to allow these stocks to recover, a moratorium on fishing was declared, putting 35,000 fishermen out of work. In an effort to prop up the fishing industry and to meet the demands of fishing industry representatives, the Canadian government spent an estimated $8 billion on the Atlantic fishery, approximately half of this on unemployment benefits to out-of-work fishermen and fish plant workers. The U.S. government also supported the declining fishing industry with vessel buyouts, job retraining programs and subsidized health insurance. During this time there was tremendous political pressure to retain the overcapacity of the fishing industry in the name of preserving jobs and hundreds of small rural communities, some of which had depended on the fishery as the foundation of their economies for 300-400 years.

In May of 2003, the Canadian fisheries ministry ordered an end to all Atlantic cod fishing in three regions off the Newfoundland and Labrador coast. In the same year, Newfoundland and Labrador Atlantic cod populations were declared "endangered." The Canadian government also set up a $50 million plan to assist affected fishermen and communities.

In the U.S., environmental groups sued the federal government with claims that NOAA Fisheries failed to enforce its own rules preventing overfishing. New management plans are designed to control fishing effort while attempting to rebuild cod stocks.

Mark Kurlansky has written one of the several accounts of the cod saga. He sums up the outcome with this quote.

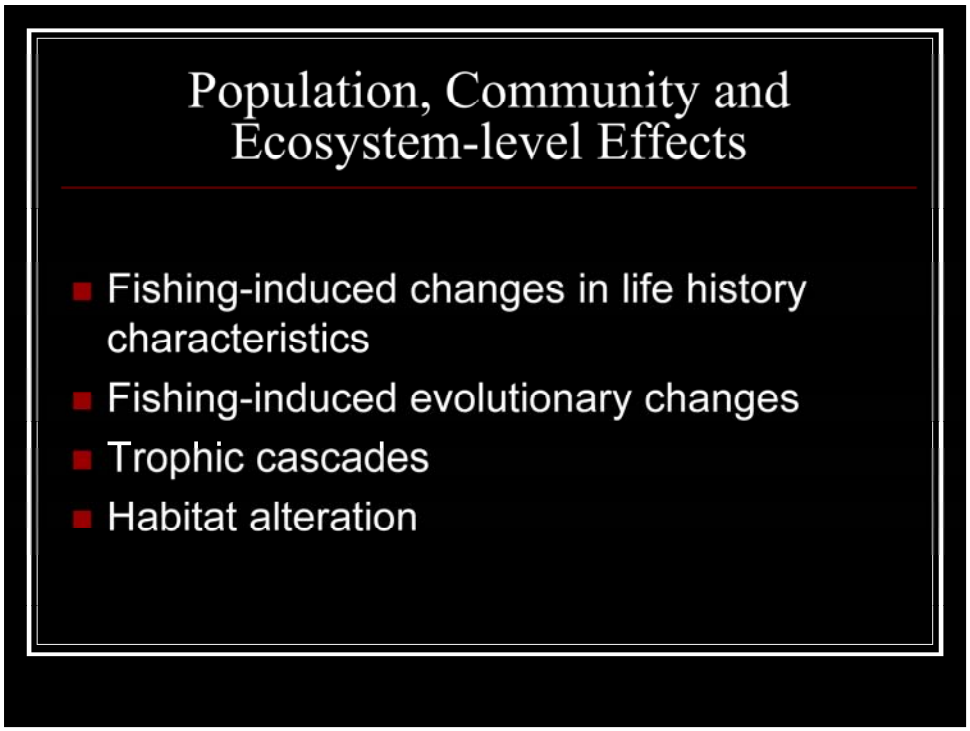
Cod had joined the ranks of other Atlantic species that had become “commercially extinct” – Atlantic halibut and redfish. In the 1980s two other commercially important Georges Bank species – haddock and yellowtail flounder – appeared to be headed for a similar fate. However, measures put in place to protect Atlantic cod in 1994 have resulted in partial recovery of these species. Georges Bank haddock showed a 3-fold increase and yellowtail flounder a 5-fold increase within the first 5 years of protection (Myers and Worm 2005).



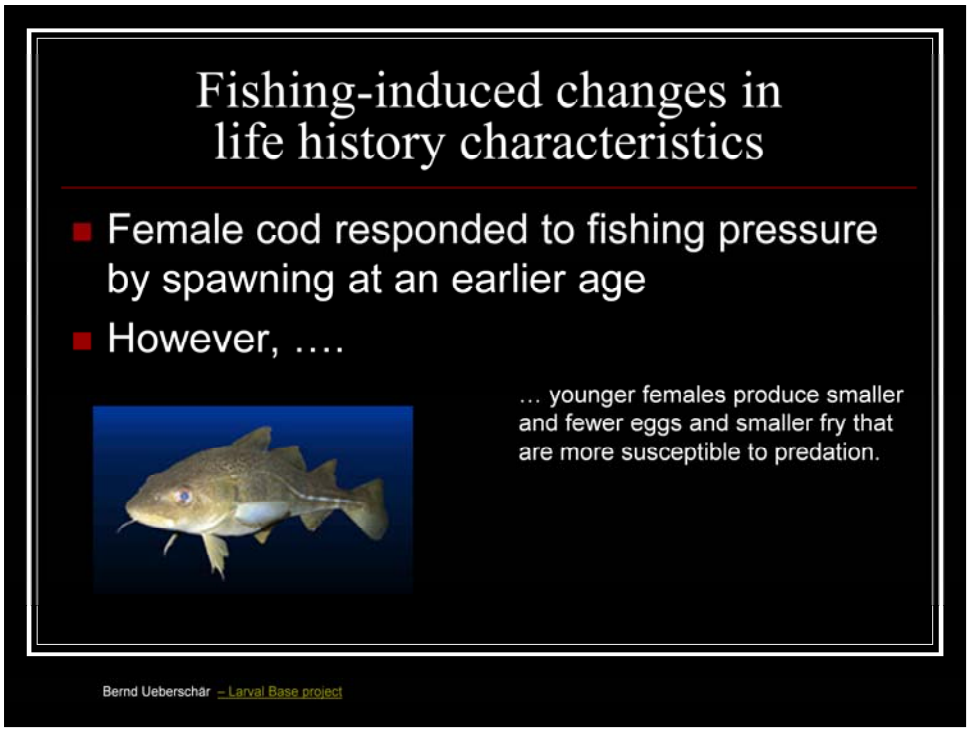
Click on the above link (when in “slideshow view”) to view the animation described below. An Internet connection is required. The animation shows the relative distribution and abundance of cod in the Northwest Atlantic from 1979-2005. Data are derived from the Spring Bottom Trawl Survey conducted by the Northeast Fisheries Science Center of NOAA Fisheries. The animation loops 9 frames, each of which represents 3 years of survey data for cod. Yellow circles indicate where cod were present; the size of the circle indicates relative abundance. The “+” signs indicate locations where no cod were present. After showing the animation close out the web browser window and you will return to the PowerPoint presentation.

"If John Cabot were alive today, he would not recognize Georges Bank. Instead of a sea swarming with majestic cod, he would find dogfish. Instead of flounder, he would find skates. Instead of a fisherman's dream, he would find a nightmare."

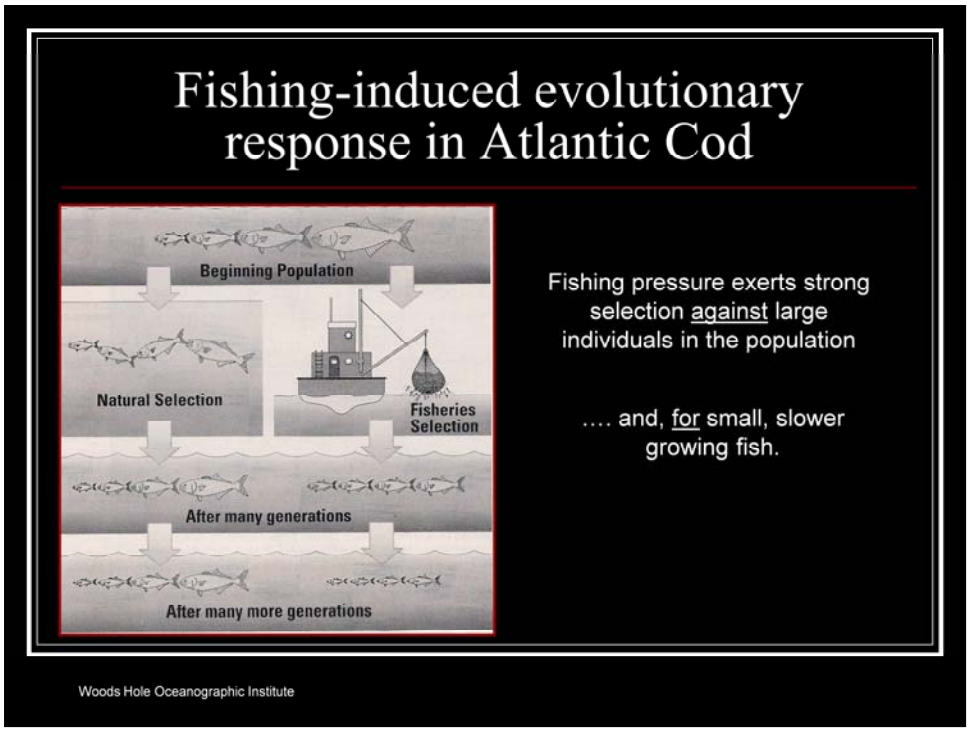
U.S. Congressman Gerry Studds 1991



Overfishing can exert impacts at several different levels in marine ecosystems. Several impacts have been documented for Atlantic cod and are discussed separately on the following slides. An understanding of these effects is important as successful recovery of Atlantic cod will require recovery of the ecosystem that supports them.



Overfishing truncates size and age distributions of fish populations (larger, older age classes are diminished). Female cod responded to harvest levels that exceeded maximum sustainable yield by spawning at an earlier age. Average spawning age declined from 5-6 years to less than 3 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 addition, 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.

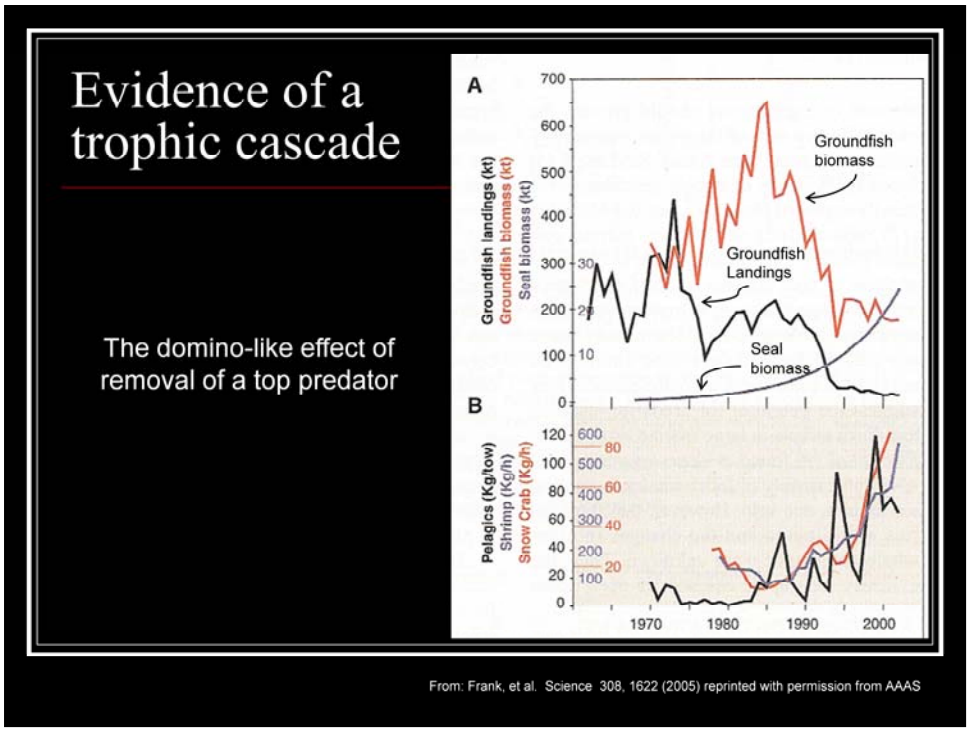


Some fisheries scientists have suggested that the impact of commercial fishing is so great that it is affecting the evolution of some fish species. Changes may be occurring in only decades that under normal circumstances would take millennia.

Swain, et al (2007) suggest that decades of fishing pressure on Atlantic cod in the Gulf of St. Lawrence, Canada targeting larger individuals may have resulted in a permanent, genetic change in the population. For economic and fishing technology reasons (e.g., large mesh size in nets that allows escape of smaller individuals) fishing mortality is heavily skewed towards larger individuals. Decades of such strong selection favor smaller, faster maturing, slower-growing fish which are at an advantage because they delay their vulnerability to the fishery. To date, the possibility of fishing pressure driving genetic changes in exploited fish populations has not been taken into account in fisheries management.

FIG. 3-2 (p. 56) in Klee, G.A. 1999 The Coastal Environment – toward integrated coastal and marine sanctuary management. Prentice-Hall, Inc. Upper Saddle River, NJ. 281 pp.

Original figure from Bohnsack, J. 1993. Marine reserves. Woods Hole Oceanographic Institute. Oceanus 36(3).

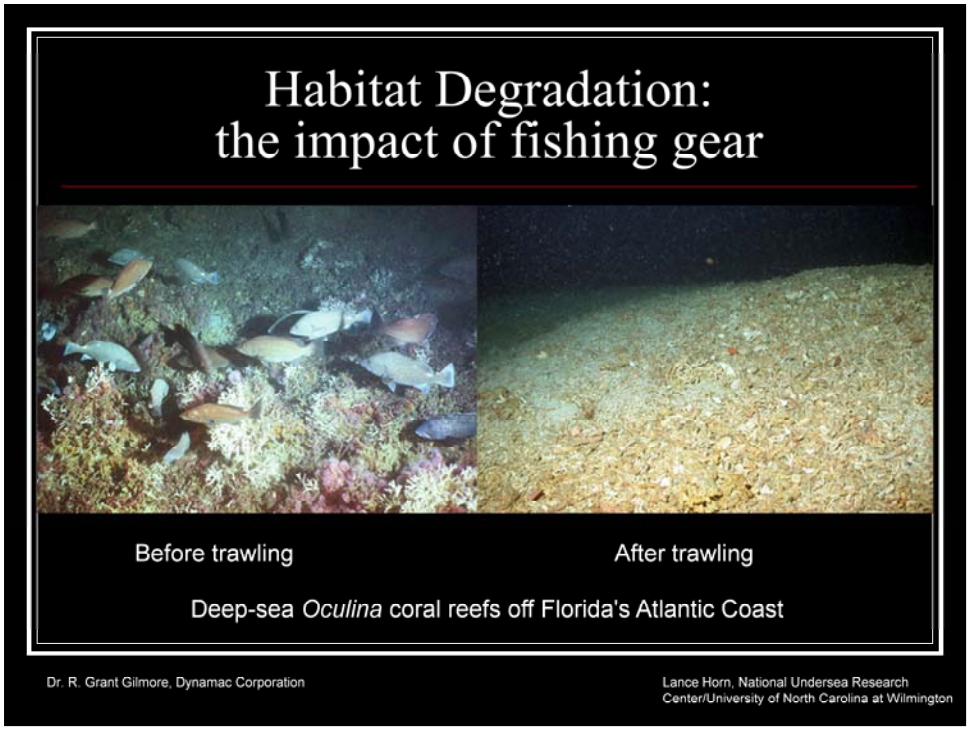


The decline of one species (particularly a top predator such as cod) can have impacts that reverberate throughout the ecosystem in a domino-like fashion (i.e., a “trophic cascade”). These graphs illustrate evidence for just such an event that involves cod, seals, crabs, small pelagic fish and zooplankton. The first graph illustrates declines in groundfish (mostly cod) biomass with a corresponding increase in seal populations (Fig. A). Seals feed on many of the same species as cod, and these species (pelagic fish, shrimp and crabs) all show increases over the same time period (Fig. 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.

Data are from:
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.

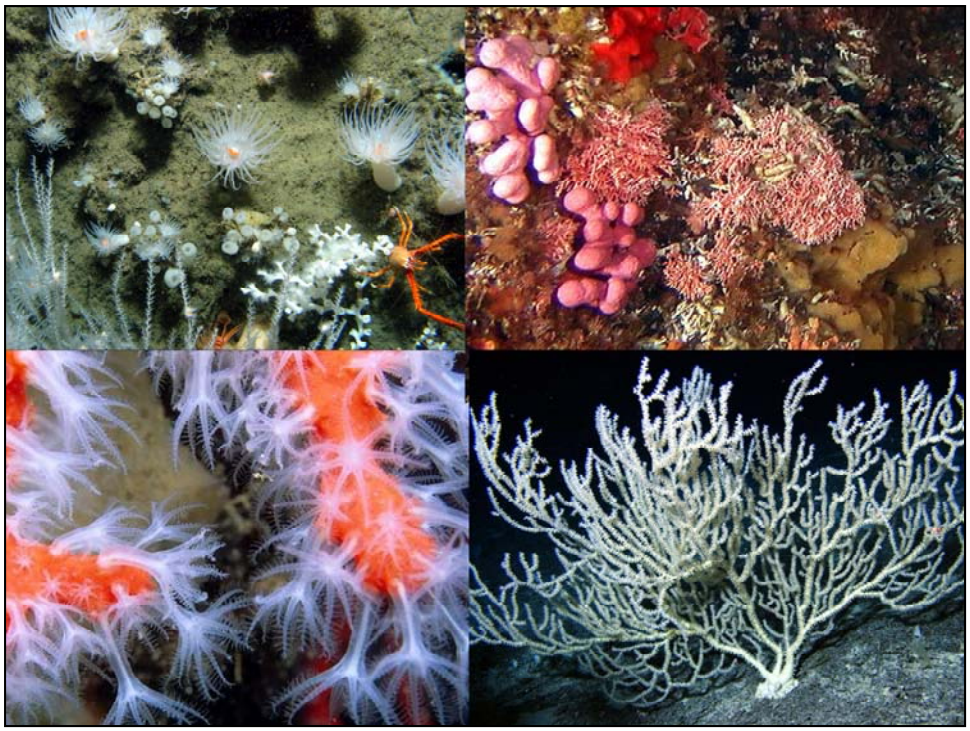
Trzcinski, M.K., R. Mohn and W.D. Bowen. 2006. Continued decline of an Atlantic cod population: How important is gray seal predation? Ecol. Applic. 16(6):2276-2292.

Figure from:
Frank, et al. 2005. Trophic cascades in a formerly cod-dominated ecosystem. Science 308, 1622. Reprinted with permission from AAAS.



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

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. 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:

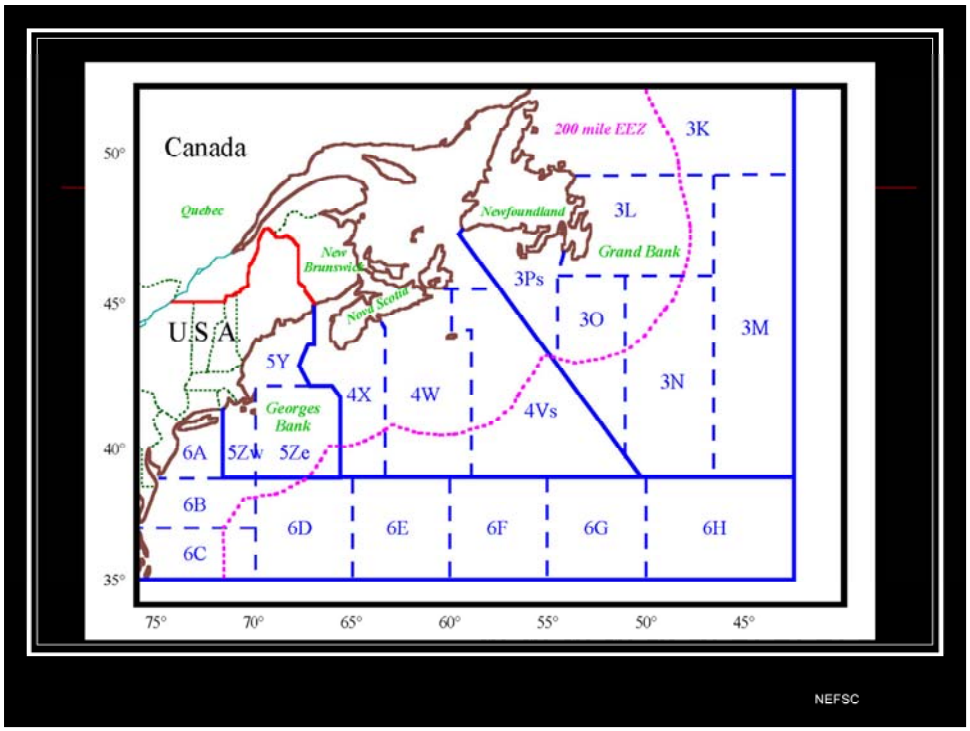
http://www.mcbi.org/cgi-bin/photo_library.pl?ID=8

Early attempts to protect cod stocks included:

1. Establishing a minimum mesh size for trawl nets in an attempt to allow escapement of small, undersized fish

2. A reduction in total allowable catch (i.e., establishing a quota system for cod)

3. The establishment of a "200-mile fishing limit" by U.S. and Canada (The Magnuson-Stevens Fishery Conservation and Management Act). This limit had been demanded by the domestic fishing industry for years to reduce the impact of foreign fishing vessels on fish stocks. However, the act resulted in increased domestic fishing effort, which contributed to declines.



The “200-mile limit” declared by both the U.S. and Canada declared an “exclusive economic zone” to be the sole fishing grounds for each country. Foreign vessels could fish within this zone only with special permits. Encouraged by fewer foreign vessels catching "Canadian and American fish," domestic fishing fleets invested heavily in new, technologically advanced gear and expanded well beyond the number of vessels that could be sustained by the cod stocks (**overcapacity**). New U.S.-built stern trawlers began to replace the older, smaller wooden side trawlers. These new, more efficient stern trawlers turned out to be miniature versions of the foreign vessels that had been excluded by the “200-mile limit.”

Numbered areas in the figure (“4X,” “6E,” “3N,” etc.) are statistical areas (fisheries management zones) established by the Northwest Atlantic Fisheries Organization (NAFO), an intergovernmental body (including the U.S. and Canada) that is responsible for the management of fisheries outside of Exclusive Economic Zones (EEZs).

In the United States, year-round restrictions were put in place in key groundfish areas from Maine to Long Island (cross-hatched) in 2003. Seasonal restrictions were also implemented in most of the areas represented on this map from Cape Cod to the Gulf of Maine.

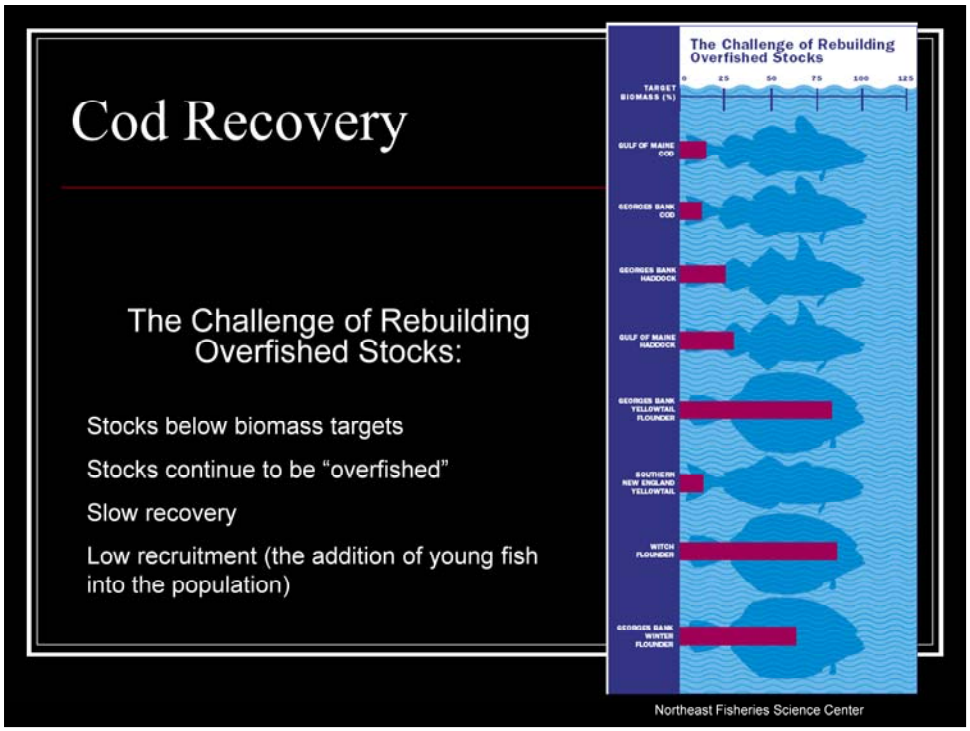
The names assigned to each of the closed areas are not particularly relevant, but just in case someone asks:

WGOM – Western Gulf of Maine

Cashes – refers to “Cashes Ledge,” a traditional cod fishing site

CA1/CA2 – Conservation Areas 1 and 2

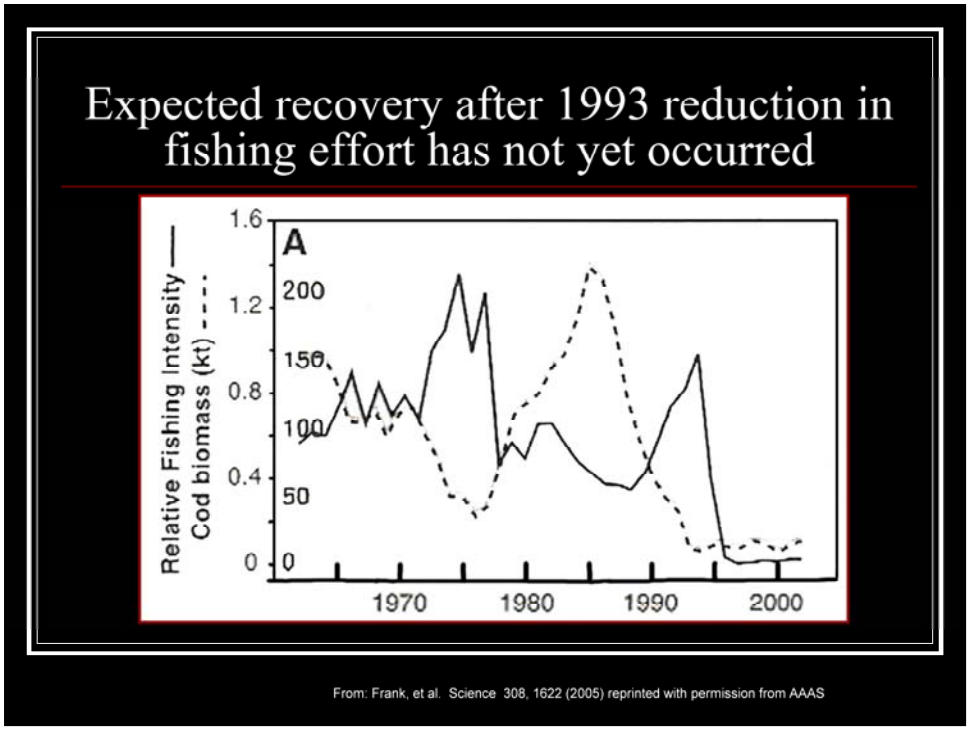
NLSCA – Nantucket Lightship Conservation Area



Despite reductions in fishing pressure, recovery of cod and some other overfished stocks in the Atlantic Ocean has been slow. The graph illustrates target levels (at 100% recovery) and existing levels. Current levels of Gulf of Maine and Georges Bank cod, for example, remain significantly less than biomass targets established by the National Marine Fisheries Service. Additionally, the most recent assessment of Atlantic cod by this management agency describes these stocks as currently being in an "overfished" condition and overfishing continues. Also recruitment, the addition of young cod into the population, has been below the long-term average in recent years. The Georges Bank cod stock appears to be increasing, but at a very slow rate. This rate may slow even further if recruitment does not increase.

Interestingly, with loss of cod, a shrimp fishery has developed and these fishers may not be happy to see cod return.

recruitment – the amount or number of fish added to the stock each year due to population growth or migration of fish into the fishing area



The graph illustrates that despite a significant reduction in fishing effort in 1993, cod populations have not recovered.

Figure from: Frank, et al. Trophic Cascades in a Formerly Cod-Dominated Ecosystem. Science 308, 1622 (2005) reprinted with permission from AAAS.

This slide summarizes some of the major events in the Atlantic cod fishery over the past 500 years. This brief timeline is a condensed version of the history of cod provided in the student handout for this module. It is given here to remind students of previous events before entering a discussion of possible explanations for the limited recovery of cod since its collapse in 1992.

1500s – Europeans discover Canadian cod stocks (Grand Banks and Scotian Shelf)

1600s – Cod fishery develops with longlines and single baited hooks

1700s – Newfoundland prosperity is based on cod fishery

1800s – Nearshore stocks decline due to increased fishing pressure and improved technologies

Early 1900s – Steam trawlers begin fishing for cod

1950s – First appearance of factory-freezer trawlers

1960s – Discovery of additional offshore stocks and increased fishing effort dramatically increase cod harvest

1970s – Canadian TACs (total allowable catches = “quota”) reduced and 200-mile limit established to eliminate foreign fishing vessels from Canadian and U.S. waters

1980s – Canadian and U.S. government attempts to prop up cod industry with subsidies, encouraging more U.S. and Canadian fishers to enter the fishery

1992 – Several cod stocks collapse, fishing moratorium declared

2000s – Cod recovery is limited despite no targeted fishery

See notes slide 37

Notes Slide 37

Reasons for slow recovery are not completely understood; however, the following suggestions have been offered by fishery scientists (adapted from Hutchings and Reynolds, 2004).

1. Fishing continues to have an impact. As of 2006, both Gulf of Maine and Georges Bank stocks, for example, remain in an overfished condition and are being overfished according to definitions established by the National Marine Fisheries Service (Northeast Fisheries Science Center, 2006).

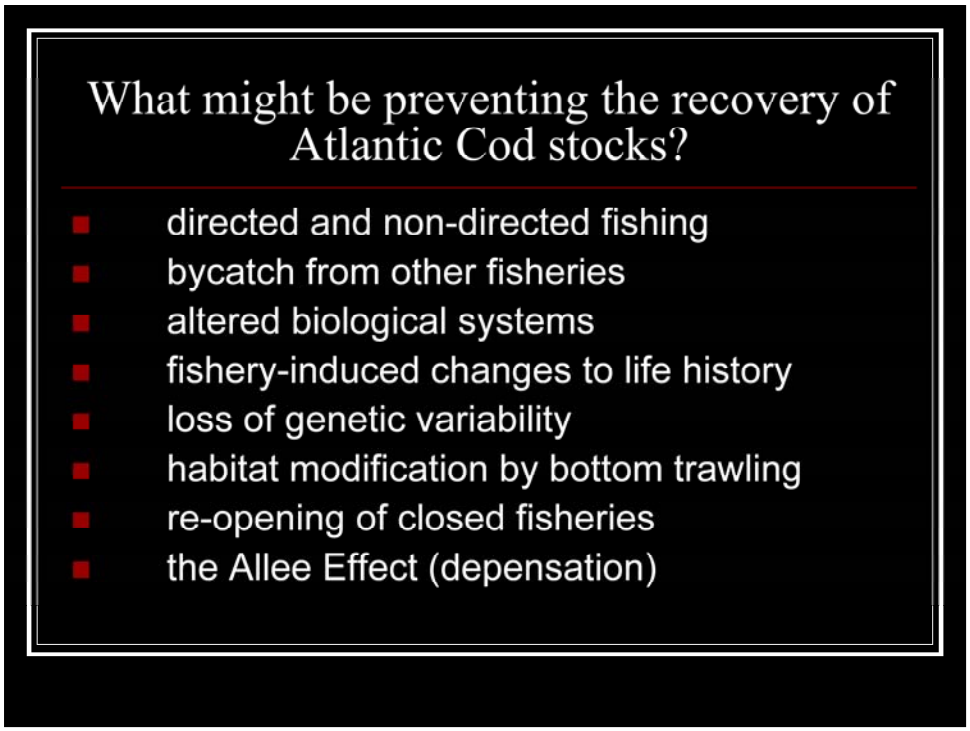
2. Fishing effort that does not necessarily target cod (non-directed fishing and bycatch) may also have an impact.

3. Altered biological systems

The removal of a top predator such as cod can alter relationships among species in a community. Increased grey seal populations, for example, may increase predation mortality on cod.

Recently, it has been suspected that increased herring populations may be inhibiting recovery of cod. Atlantic herring populations increased after the decline of Atlantic cod in the early 1990s. Herring feed on cod eggs and larvae and therefore, the community may be stuck in a herring-dominated system.

When Atlantic cod populations collapsed in the early 1990s, fishermen turned to other species including American lobster and capelin (*Mallotus villosus*), a small forage fish. Both of these species (capelin, in particular) are an important part of the Atlantic cod diet. Therefore, it is possible that their recovery may be hampered by fishers targeting their prey.



See notes slide 38

Notes Slide 38

4. Changes to life history – the effects of truncated age distributions were discussed previously

5. Loss of genetic variability – declining population size can reduce genetic variability and, therefore, adaptability.

The genetic basis for cod recovery may be lost. Subpopulations and diversity within those populations may be lost and as a result, the species no longer has the ability to "repair."

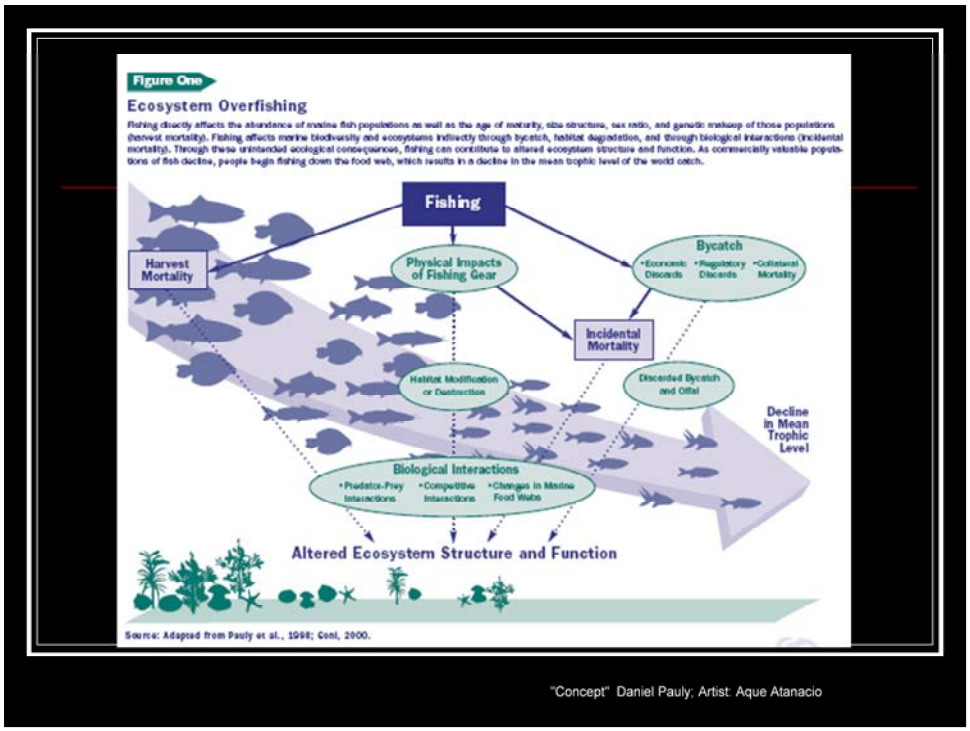
Some researchers have proposed that as larger, older fish are removed from the population, a type of "institutional memory" is lost with them. Prior to the collapse of the Atlantic cod, huge migrations of cod would take place each spring in the Northwest Atlantic from the continental shelf to shallow coastal spawning areas. These spawning migrations would be led by the oldest fish, possibly passing on knowledge of traditional migration routes to younger fish. Lost knowledge of these migration routes may be contributing to the slow recovery of cod.

6. Habitat modification – bottom trawling, in particular, may negatively affect essential habitat for cod. Removal or disturbance of exposed, structure-producing invertebrates such as corals and bryozoans reduces habitat complexity. Young fish in particular survive better in structurally complex environments, which offer better protection from predators and better feeding conditions.

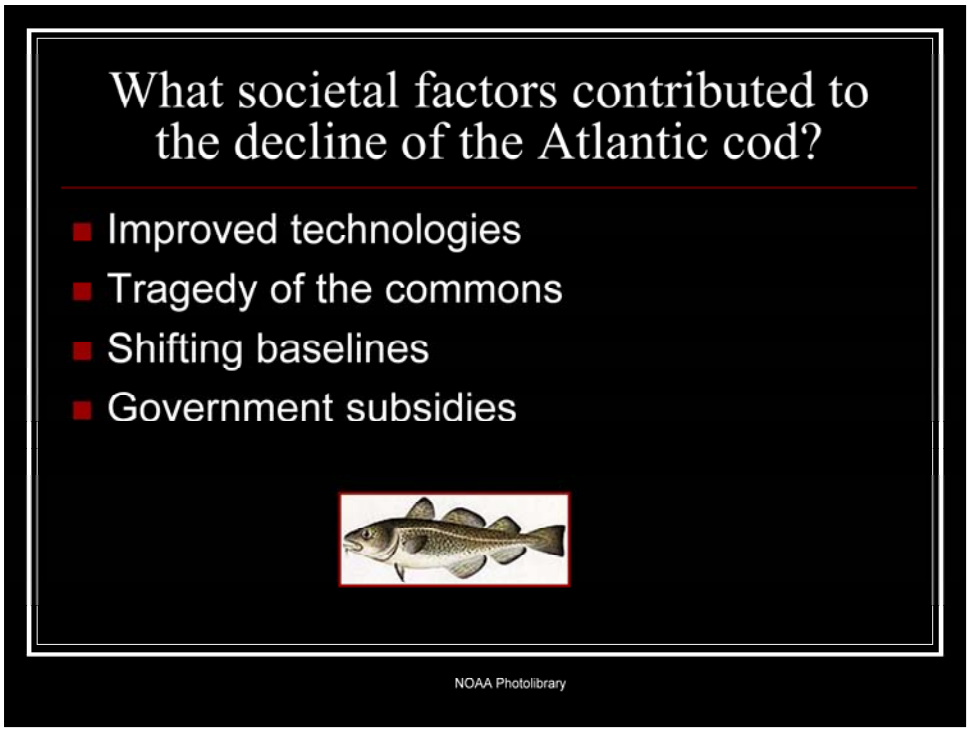
7. Premature re-opening of closed fisheries due to societal pressure to do so

8. Allee Effect – the decline of population growth rates when populations drop below some threshold level

This phenomenon has been documented for species that have large breeding congregations (which cod does). In some marine mollusks (e.g., giant clams of the genus *Tridacna* on Indo-Pacific coral reefs), when populations drop too low, reproduction becomes unlikely as chance encounters of eggs and sperm in the water column decline at low densities. Although hypothesized for Atlantic cod, empirical evidence for the phenomenon in this species is lacking.



The key for recovery appears to be a recognition of the need for ecosystem recovery rather than just a single species. The impact of overfishing goes well-beyond the mortality of the target species and also includes changes in habitat quality, trophic relationships and community interactions.



See notes slide 40

Notes Slide 40

Why did fisheries management fail? Put simply, the fishery management agencies "responded more effectively to the economic health of the fishing industry and coastal fishing communities than to the long-term condition of the groundfish resources." (Ross, 1997)

Decades of supporting industry growth have left both U.S. and Canadian governments open to criticism that their policies contributed to the collapse of fish stocks, damaged marine ecosystems and ultimately undermined the very industry they were trying to support. Government agencies are now faced with helping failing fish communities with vessel buy-outs, unemployment benefits, job retraining and subsidized health insurance for fishing families.

See NCSR *Marine Fisheries – Causes for Decline and Impacts* module for more detailed descriptions of these societal factors. Brief descriptions are given here:

Improved technologies

Technological improvements in fishing gear have greatly increased the capacity for fishers to catch more fish. Many modern fishing vessels have larger, heavier gear that allows fishing in previously inaccessible areas. Sophisticated electronic technologies, such as radar, sonar and electronic navigation, allow fishing vessels to pinpoint the most productive fishing grounds.

Tragedy of the commons

As originally proposed by Garret Hardin, the tragedy of the commons illustrates why open access to a common resource, such as fish in the ocean, leads to the degradation of that resource. From the viewpoint of the individual user (fisher, in this case), conservation makes little sense since, “if I don’t get it, someone else will.”

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. Overcapitalized fisheries can continue to operate after the resource is depleted by relying on government subsidies.

Shifting baselines

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 more recent levels as normal. 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."

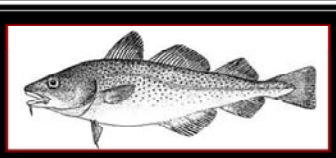
In the U.S., commercial and recreational fisheries for cod are managed under the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan which includes time/area closures, gear restrictions, minimum size limits, daily limits and, since 1994, a moratorium on fishing permits (i.e., no new permits are being issued) and restrictions on trip lengths. Biomass targets have also been established, all in hopes of reducing fishing mortality and rebuilding cod stocks.

The Canadian fishery is managed under an individual fishing quota (IFQ) system – see NCSR *Fisheries - Management and Proposed Solutions* Module for details.

More broadly, the reauthorization of the Magnuson Fisheries Act in 2007 again established the goal of ending overfishing and achieving sustainable fisheries using an ecosystem-based approach. Earlier attempts to end overfishing and implement ecosystem-based fishery management have fallen short of the hopes of most fisheries managers and scientists. Only time will tell whether or not the most recent effort will be successful.

In addition to a reduction in fishing effort, some fishery biologists (see Myers, R. and S. Fuller 2004. The Southern Grand Bank: A marine protected area for the world) have recommended that the southern Grand Bank be designated as a marine protected area (MPA). The objectives of this designation include the conservation of the biodiversity of bank habitat, the protection of juvenile fish and an opportunity to examine the effectiveness of large scale closures on depleted fish stocks. For a general discussion on MPAs, see NCSR's *The Role of Marine Reserves in Ecosystem-based Fishery Management* module.

Summary



- Atlantic cod has been a cultural and economic resource for centuries
- Decades of overfishing led to a catastrophic collapse in 1992
- Several factors contributed
- Recovery has been slow despite reduced fishing effort
- An ecosystem-based approach is required

Northeast Fisheries Science Center

A number of excellent accounts of the history and management of the cod fishery have been written. Those interested in learning more about this saga should refer to these books.

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Detailed Lecture Notes

The history of global fisheries has been characterized by the development, overexploitation and decline, and in some cases, the depletion of fish stocks. Even today, according to the Food and Agriculture Organization of the United Nations (FAO), more than two-thirds of the world's important fish stocks are being harvested at or above their ability to replenish themselves. These species include the Spanish mackerel, grouper, several species of flounder, orange roughy, Atlantic cod, swordfish, bluefin tuna, Atlantic salmon and Chilean sea bass, all highly valued food fish. The following case studies provide examples of some of these declines. Citations for print, web and video-based resources are provided for additional information.

Atlantic cod Case Study

Details on the history, status and management of the Atlantic cod are included in the outline below, student handout and associated *PowerPoint* presentation.

INTRODUCTION

For centuries the Atlantic cod was the mainstay of fisheries based in southeast Canada and New England. Wars were fought over its management and the fish was revered in spiritual ceremonies and financial markets alike. In the early 1990s, some of the world's most productive fishing grounds were closed to bottom-fishing due to the rapid decline of this species. By 1992, cod populations were only 1% of their original size, resulting in both ecological and economic damage. Coastal communities that depended upon the fishery for their livelihood suffered widespread unemployment. The collapse of the cod fishery in Newfoundland alone resulted in 35,000 people being put out of work. The fishery collapse resulted in an estimated $350 million cost to local economies in New England. In 1996, the National Marine Fisheries Service declared that "the groundfish stock, the mainstay of New England fishing for 400 years, is in danger of never recovering."

BASIC BIOLOGY

The Atlantic cod is a demersal ("bottom-dwelling") species that may attain lengths of up to 130 cm (51 inches) and weights of 25-35 kg (55-77 lbs). Cod apparently achieved larger sizes in the past with fish over 100 pounds not considered unusual. Individual cod weighing over 200 pounds were recorded in the 1800s, but fish of that size have not been seen in over 100 years. Maximum age is over 20 years but today, younger fish (2-5 years, weighing 5-10 lbs.) make up the majority of the catch. Sexual maturity is reached at 2-4 years. Early biological descriptions of the species emphasized its tremendous reproductive potential, and as a result, its ability to withstand fishing pressure.

The distribution of the Atlantic cod extends from eastern North America across the north Atlantic to western Europe. The species is associated with relatively shallow, highly productive marine habitats along the continental shelf including a series of "banks" that occur from Newfoundland and Labrador (the Grand Banks) to southeastern New England (Georges Bank). On these banks, nutrients are frequently stirred up by cross currents and storms, resulting in

phytoplankton blooms that support high concentrations of zooplankton. The zooplankton are fed upon by northern shrimp, which are an important food source for cod. Cod are omnivorous, feeding on a wide variety of fish and invertebrates.

Both inshore and offshore stocks are known. In spring, cod migrate from offshore spawning grounds on the Grand Bank to inshore feeding areas. These areas are known to fishermen and some have been fished for centuries.

EARLY HISTORY (1500 – 1900)

In the culture of northern Europeans and their descendants who settled in New England and southeast Canada, the Atlantic cod is held in utmost esteem. Much like the relationship between the Pacific salmon and the native people of the Pacific Northwest, this fish literally held the key to their survival - first as a source of sustenance, and later, as the foundation of their economies. As a result, the cod was assigned great spiritual and commercial significance. Cod fishing probably represents the first successful industry in colonial America.

Reports from historical records suggest that when English explorer John Cabot discovered North America, the coast was "churning with cod of school size and body size never before seen." Cabot's men caught cod in weighted baskets randomly thrown overboard. The newly discovered cod stocks off the coast of Newfoundland were being fished by French, English, Portuguese and Spanish fishermen who used single baited hooks to catch the fish. Fish were harvested exclusively from inshore waters.

The French developed a Canadian off-shore fishery, which was quickly followed by other European countries. By the late 1500s, France and England were sending 150 ships each to fish for cod on the Grand Banks off the coast of Newfoundland. Huge profits were reaped and the fishery became a major contributor to the wealth of England. Permanent settlements were established on Newfoundland; fishing for cod was their only source of income.

By the mid-1800s, wind-powered schooners brought fishermen to the fishing grounds on the Grand Banks where early harvest methods included handlines, longlines and gillnets that were deployed from smaller boats called dories. These vessels stayed at sea for extended periods of time and, lacking refrigeration, preserved their catch by salting. Salt cod was marketed worldwide. The U.S. groundfish fleet in the mid-1800s was based in small communities along the eastern seaboard that are now synonymous with the fishing industry – e.g., Chatham, New Bedford, Beverley, and Gloucester. Many of these fishing communities depended on the groundfishing industry as the foundation of their economies for 300-400 years.

From 1880 to1910 fishing pressure on the Grand Banks cod stocks increased dramatically as inshore stocks had become scarce. By the late 1800s a new technology – the fish trap – had been added to the methods used to fish for cod close to shore. These highly efficient devices were adaptations of fish weirs designed to capture salmon. Anchored nets placed in known cod migration routes close to shore, funneled entire schools of cod into a section of the trap where they could be corralled and easily captured. A single cod trap could harvest as much as 5 tons of cod in a single haul.

While increased pressure on cod in the late 1800s raised economic concerns, Newfoundland's second most important industry – sealing – was experiencing a similar fate. Harp seals had been harvested commercially for centuries on the pack ice off Newfoundland and Labrador. Seal oil was the primary product, which was exported to Europe where it was used as lamp oil, cooking oil and in making soaps. The seal harvest increased dramatically in the late 1800s due to improved technologies such as sophisticated nets, guns and steam ships. As with cod, seal numbers soon declined. Driven by a combination of lower seal populations and a decrease in demand for seal oil due to the development of alternative products (including fossil fuels), the sealing industry soon followed. With the lack of other employment opportunities in the region, the nearly simultaneous decline of Newfoundland's two main industries resulted in high levels of unemployment. The standard of living in Newfoundland plummeted.

TECHNOLOGICAL INNOVATION (1900-1970)

The 20th century brought several technological innovations to the fishing industry that increased fishing efficiency. French steam trawlers first appeared on the Northwest Atlantic fishing grounds in 1906. These vessels dragged large nets through schools of cod eliminating the need for bait and easily outcompeting the longliners and other less-sophisticated harvest methods. In 1930, Newfoundland was catching only 40% of the fish taken in her traditional waters; the remainder was going to foreign fishing vessels.

Once bottom trawling proved itself to be the most efficient harvest method, it rapidly replaced earlier methods. The bottom trawl increased landings but unlike earlier methods, it captured many under-sized and non-target species and disturbed bottom habitats. By 1930, there were clear signs that improvements in fishing technology had outpaced the capacity for cod stocks to replenish themselves.

In 1954, the first factory-freezer trawler in the world, the British fishing vessel *Fairtry*, fished the Grand Banks for cod. These huge, 400-foot stern trawlers with on-board processing plants could catch and process as much as 600 tons of fish in a single day. They were able to fish around the clock, year-round and in all but the worst of weather. Other countries soon followed the British example. This technological innovation marked the beginning of the end for the Atlantic cod.

In the 1950s and 1960s, additional offshore fishing grounds east of Newfoundland were discovered and added to inshore populations which had been fished for more than 350 years. Annual landings increased dramatically throughout the 1960s. For four centuries, catches of Atlantic cod had increased only gradually as technology improved, peaking in 1910 at about 300,000 tons. However, by 1968, over 800,000 tons were reported, accounting for 40% of global fish landings. The coast of southeast Canada had become a magnet for foreign fishing vessels from around the world. International controls on the fishery were either non-existent or ignored. Fishing trips by foreign vessels were timed to coincide with the great spawning congregations to increase catch rates. A perceived super-abundance of cod stocks resulted in over-capitalization by investors in fishing vessels that target cod.

By the early 1960s, foreign "fish factories" from Russia, East Germany, Poland, Spain, Japan and others had discovered the productive fishing grounds of Georges Bank. By 1971, an armada

of 900 large factory trawlers was fishing the high seas - 400 of them belonged to the Soviet Union. Annual harvests during this time period often removed 60% of adult cod in the Canada/U.S. population. This harvest level was 3 times the recommended amount to sustain healthy stocks.

STOCK TRENDS

Until recent decades when stock surveys have been conducted by research vessels, stock sizes were estimated indirectly from landing data. Over 100 years of landing data are available for Atlantic cod on Georges Bank off the New England coast (see "Atlantic cod landings from Georges Bank 1893 – 2004" in *PowerPoint* presentation – slide 17). Downward trends prior to 1980 were due primarily to economic downturns (e.g., Great Depression), war (1940s) and fuel costs/economic recession/foreign fishing (1970s). Peaks in the early 1980s were driven by strong year classes of cod in the late 1970s, which had reached harvestable size in the 1980s. Declines since 1980 are believed to be caused primarily by domestic overfishing.

POPULATION AND COMMUNITY-LEVEL EFFECTS OF OVERFISHING

Overfishing truncates size and age distributions of fish populations (larger, older age classes are diminished). Female cod responded to harvest levels that exceeded maximum sustainable yield by spawning at an earlier age. Average spawning age declined from 5-6 years to less than 3 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 addition, the removal of larger, older individuals from the population diminishes the capacity for the population to rebound from declines caused by either overfishing or changing ocean conditions.

Swain, et al (2007) suggest that decades of fishing pressure on Atlantic cod (in the Gulf of St. Lawrence, Canada) targeting larger individuals may have resulted in a permanent, genetic change in the population. For economic and fishing technology reasons (e.g., large mesh size in nets that allows escape of smaller individuals) fishing mortality is heavily skewed towards larger individuals. Decades of such strong selection favor smaller, slower-growing fish which are at an advantage because they delay their vulnerability to the fishery. To date, the possibility of fishing pressure driving genetic changes in exploited fish populations has not been taken into account in fisheries management. (see Swain, et al. 2007 for details)

The decline of one species (particularly a top predator such as cod) can have impacts that cascade throughout the ecosystem in a domino-like fashion (i.e., a "trophic cascade"). Frank, et al. (2005) provide evidence for just such an event that involves cod, grey seals, crabs and zooplankton (see "Evidence for a Trophic Cascade" in *PowerPoint* presentation- slide 27). Declines in groundfish (mostly cod) biomass corresponded to an increase in seal populations. Seals feed on many of the same species as cod, and these species (pelagic fish, shrimp and crabs) all show increases over the same time period. Grey seals also feed on cod and this predation may be contributing to the cod's slow recovery. 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.

MANAGEMENT

The first attempt (1953) to protect cod stocks included establishing minimum net mesh size regulations, which were implemented to allow escapement of smaller fish. Various reductions in total allowable catch followed, and then in 1976 a “200-mile fishing limit” was established by the U.S. and Canada (the Magnuson-Stevenson Fishery Conservation and Management Act). This limit had been demanded by the domestic fishing industry for years to reduce the impact of foreign fishing vessels on fish stocks. Once established, this limit declared a 200-mile “exclusive economic zone” to be the sole fishing grounds for the U.S. and Canada. Foreign vessels could fish these grounds only with special permits.

Encouraged by fewer foreign vessels catching "Canadian and American fish," domestic fishing fleets invested heavily in new, technologically advanced gear and expanded well beyond the number of vessels that could be sustained by the cod stocks (**overcapacity**). New U.S.-built stern trawlers began to replace the older, smaller wooden side trawlers. These new, more efficient stern trawlers turned out to be miniature versions of the foreign vessels that had been excluded by the “200-mile limit.” Quota systems, which had been put in place earlier, were abandoned in favor of controls on net mesh size, closed areas and minimum fish sizes. These regulatory measures ultimately proved ineffective and landings rapidly declined.

In 1992, cod populations on Canada's Grand Banks off the coast of Newfoundland and Nova Scotia continued to plummet to 1% of original population size. In an attempt to allow these stocks to recover, a moratorium on fishing was declared, putting 35,000 fishermen out of work.

In an effort to prop up the fishing industry and to meet the demands of the fishing industry, the Canadian government spent an estimated $8 billion on the Atlantic fishery, approximately half of this on unemployment benefits to out-of-work fishermen and fish plant workers. The U.S. government also supported the declining fishing industry with vessel buyouts, job retraining programs and subsidized health insurance. During this time there was tremendous political pressure to retain the overcapacity of the fishing industry in the name of preserving jobs and hundreds of small rural communities, some of which had depended on the fishery for 300-400 years.

In the United States, year-round restrictions were put in place in key groundfish areas from Maine to Long Island in 2003. Seasonal restrictions were also implemented in most areas from Cape Cod to the Gulf of Maine.

RECOVERY

Even marginal recovery of stocks fuels demands by the fishing industry to re-open areas for cod fishing. Political and economic pressures are great to do so. One such attempt in 1993 resulted in a closure when it was realized that populations could not withstand further fishing pressure. The Canadian government afforded additional protection to some stocks by designating endangered species status.

Despite reductions in fishing pressure (including elimination of a targeted cod fishery in some areas), recovery of cod and some other overfished stocks in the Atlantic Ocean has been slow. Current levels of Gulf of Maine and Georges Bank cod, for example, remain significantly less than biomass targets established by the National Marine Fisheries Service. Additionally, the most recent assessment of Atlantic cod by this management agency describes these stocks as currently being "overfished."

THREATS TO RECOVERY

The reasons for slow recovery of Atlantic cod are not completely understood. However, the following suggestions have been offered by fishery scientists (adapted from Hutchings and Reynolds, 2004).

1. Directed and non-directed fishing

   Fishing continues to have an impact on cod. Even after the collapse, fisheries managers have been unable to reduce fishing mortality to zero. Due to societal pressure, closed fisheries tend to be reopened at the first sign of population increase rather than after attaining some target level for recovery. For example, in 2002, 35% of northern cod 5 years or older were harvested in a "limited fishery," well above the 18% considered sustainable in the 1980s.

   As of 2006, both Gulf of Maine and Georges Bank stocks remain in an overfished condition and are being overfished according to definitions established by NOAA Fisheries (Northeast Fisheries Science Center, 2006).

   In addition to this directed fishery, non-directed fishing including bycatch from other fisheries and illegal fishing also has an impact on the recovery.

2. Altered biological systems

   The removal of a large predator from the ecosystem results in changes among species that may threaten recovery. For example, cod mortality may increase due to predation by seals, which have increased due to reduced competition from cod. The phenomenon of "fishing down the food web" may also result in changes in community structure.

   More recently, it has been suspected that increased herring populations may be inhibiting recovery of cod. Atlantic herring populations increased after the decline of Atlantic cod in the early 1990s (cod are major predators on herring). Herring feed on cod eggs and larvae and therefore, the community may be stuck in a herring-dominated system.

   When Atlantic cod populations collapsed in the early 1990s, fishermen turned to other species including American lobster and capelin (*Mallotus villosus*), a small forage fish. Both of these species (capelin, in particular) are an important part of the Atlantic cod diet. Therefore, it is possible that their recovery may be hampered by fishers targeting their prey.

3. Fishery-induced changes to life history traits

   Removal of large cod truncates age distribution and females reach sexual maturity at an earlier age and smaller size. Smaller females produce eggs of reduced size and number and larvae that have low survivability.

4. Loss of genetic variability

   Declining population size reduces genetic variability and therefore, adaptability. In this case, the genetic basis for recovery appears to be lost. Subpopulations and diversity within those populations is also lost and as a result, the species loses its ability to "repair."

   Some researchers have proposed that as larger, older fish are removed from the population, a type of "institutional memory" is lost with them. Prior to the collapse of the Atlantic cod, huge migrations of cod would take place each spring in the Northwest Atlantic from the continental shelf to shallow coastal spawning areas. These spawning migrations would be led by the oldest fish, possibly passing on knowledge of traditional migration routes to younger fish. Lost knowledge of these migration routes may be contributing to the slow recovery of cod.

5. Habitat modification

   This is particularly an issue for a species like cod which is primarily harvested by bottom trawling. Removal or disturbance of exposed, structure-producing invertebrates such as corals and bryozoans by trawl nets reduces habitat complexity. Young fish in particular survive better in structurally complex environments, which offer better protection from predators and better feeding conditions.

6. The Allee Effect (depensation)

   Rates of population growth decline when population size drops below some threshold of abundance. In some species, per capita birth rates decline, mate availability is reduced, fertilization success declines, sex ratios may become lopsided and social interactions may decline. This phenomenon has been documented for species that have large breeding congregations (which cod does). In some marine mollusks (e.g., giant clams of the genus *Tridacna* on Indo-Pacific coral reefs), when populations drop too low, reproduction becomes unlikely as chance encounters of eggs and sperm in the water column decline at low densities. Although hypothesized for Atlantic cod, empirical evidence for the phenomenon in this species is lacking and more research is needed.

   In summary, most fisheries biologists believe that the key for recovery appears to be a recognition of the need for ecosystem recovery rather than just the recovery of a single species. The impact of overfishing goes well-beyond the mortality of the target species and also includes changes in habitat quality, trophic relationships and community interactions.

Why did fisheries management fail? Put simply, the fishery management agencies "responded more effectively to the economic health of the fishing industry and coastal fishing communities than to the long-term condition of the groundfish resources." (Ross, 1997). See NCSR Marine Fisheries module – *Declining Expectations – The Phenomenon of Shifting Baselines* for more detailed descriptions of these societal factors.

CURRENT AND FUTURE MANAGEMENT

In the U.S., commercial and recreational fisheries for cod are managed under the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan which includes time and area closures, gear restrictions, minimum size limits, daily limits and, since 1994, a moratorium on fishing permits (i.e., no new permits are being issued) and restrictions on trip lengths. Biomass targets have also been established, all in hopes of reducing fishing mortality and rebuilding cod stocks. The Canadian fishery is managed under an individual fishing quota (IFQ) system.

More broadly, the reauthorization of the Magnuson Fisheries Act in 2007 established the goal of ending overfishing and achieving sustainable fisheries using an ecosystem-based approach. Earlier attempts to end overfishing and implement ecosystem-based fishery management have fallen short of the hopes of most fisheries managers and scientists. Only time will tell whether or not the most recent effort will be successful.

In addition to a reduction in fishing effort, some fishery biologists (see Fuller and Myers, 2004) have recommended that the southern Grand Bank be designated as a marine protected area (MPA). The objectives of this designation include the conservation of the biodiversity of bank habitat, the protection of juvenile fish and an opportunity to examine the effectiveness of large scale closures on depleted fish stocks. For a general discussion on MPAs, see NCSR's *The Role of Marine Reserves in Ecosystem-based Fishery Management* module.

STUDENT HANDOUT

A Brief History of the Atlantic Cod

"Cod - A species too well known to require any description. It is amazingly prolific. Leeuwenhoek counted 9,384,000 eggs in a cod-fish of a midling size - a number that will baffle all the efforts of man to exterminate."

> J. Smith Homans and J. Smith Homans, Jr., editors. 1858. Cyclopedia of Commerce and Commercial Navigation, New York

In the culture of northern Europeans and their descendants who settled in New England and southeast Canada, the Atlantic cod is held in utmost esteem. Much like the relationship between the Pacific salmon and the native people of the Pacific Northwest, this fish literally held the key to their survival first as a source of sustenance, and later as the foundation of their economies. As a result, the cod was assigned great spiritual and commercial significance. Wars were fought over its management and the fish was revered in spiritual ceremonies and financial markets alike. We are now faced with unprecedented depletion of cod stocks and an industry shrinking in regional importance.

The major events of the long and complex history of the Atlantic cod are chronicled below:

1497 - Reports from historical records suggest that when English explorer John Cabot discovered North America, the coast was "churning with cod of school size and body size never before seen." Cabot's men caught cod in weighted baskets randomly thrown overboard.

1520 - The newly discovered cod stocks off the coast of Newfoundland were being fished by French, English, Portuguese and Spanish fishermen who used single baited hooks to catch the fish. Fish were harvested exclusively from inshore waters.

1550 - The French develop a Canadian off-shore fishery which is quickly followed by other European countries. By the late 1500s France and England were sending 150 ships each to fish for cod on the Grand Banks off the coast of Newfoundland. Huge profits were reaped and the fishery becomes a major contributor to the wealth of England. Cod were so abundant that one English captain reported "that we heardlie have been able to row a boate through them." Permanent settlements are established on Newfoundland; fishing for cod is their only source of income.

1600s and 1700s - Newfoundland prospers from a profitable cod fishery.

1800s - The development of a sealing industry provides the only diversity to the cod-based economy of Newfoundland. Between 1800 and 1860, an estimated 18 million seals were killed and sold to lucrative markets in Europe.

1870 - The fish trap, a major technological innovation over single baited hooks and long-lines with several hooks, increased the harvesting capacity of cod fishing fleets.

1880-1910 - Fishing pressure on the Grand Banks cod stocks increases dramatically due to the decline of inshore stocks, the decline of the seal hunt and the lack of other employment opportunities in the region. The increase in the number of fishermen resulted in smaller landings and the standard of living in Newfoundland plummeted.

1906 - French steam trawlers appear on the scene. These vessels dragged large nets through schools of cod eliminating the need for bait and easily outcompeting the long-liners.

1930 - Newfoundland was catching only 40% of the fish taken in her traditional waters; the remainder was going to foreign fishing vessels.

1954 - The first factory-freezer trawler in the world, the British fishing vessel *Fairtry*, fishes the Grand Banks for cod. These huge, 400-foot stern trawlers with on-board processing plants could catch and process as much as 600 tons of fish in a single day. They were able to fish around the clock, year-round and in all but the worst of weather. Other countries soon followed the British example. This technological innovation marked the beginning of the end for the Atlantic cod.

1950s and 1960s - Additional offshore fishing grounds east of Newfoundland were discovered and added to inshore populations which had been fished for more than 350 years. Annual landings increased dramatically throughout the 1960s. For four centuries, catches of Atlantic cod had increased only gradually as technology improved, peaking in 1910 at about 300,000 tons. By 1968, over 800,000 tons were reported accounting for 40% of global fish landings! The coast of southeast Canada had become a magnet for foreign fishing vessels from around the world. International controls on the fishery were either non-existent or ignored. Fishing trips by foreign vessels were timed to coincide with the great spawning congregations to increase catch rates. A perceived super-abundance of cod stocks resulted in over-capitalization by investors in fishing vessels that target cod.

1970s - By 1971, an armada of 900 large factory trawlers was fishing the high seas - 400 of them belonged to the Soviet Union. Annual harvests during this time period often removed 60% of adult cod in the Canada/U.S. population. This harvest level was 3 times the recommended amount to sustain healthy stocks. Female cod responded to this harvest level by spawning at an earlier age (average spawning age declined from 5-6 years to less than 3 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.

The high harvest rates on off-shore stocks of cod were having a devastating impact on inshore populations. From 1959 to 1974 inshore harvest of cod had declined from 160,000 tons to 35,000 tons despite increased fishing effort.

1974 - Cod stocks and the economies that were supported by them were in desperate shape. Governments worldwide responded with huge subsidies to assist fishermen, to develop improved gear and, thus, to create an even greater capacity to catch fish. The International Commission for the Northwest Atlantic Fishery (ICNAF), an international management agency responsible for the management of the cod stocks, admitted that earlier projections for the size of cod populations had been overly optimistic. Total allowable catches were finally reduced by half in 1975. Fishing companies were incensed.

1976 - In response to declining fish stocks, most countries (including the U.S. and Canada) passed a 200-mile fishing limit. This limit declared the zone within 200 miles of a country's shores to be the exclusive fishing grounds for that country. Foreign vessels could fish these grounds only with special permits. Over 90% of the world's fishing grounds fell within the 200 mile limit of some country. Encouraged by fewer foreign vessels catching "Canadian and American fish," domestic fishing fleets expanded well beyond the number of vessels that could be sustained by the cod stocks (**overcapacity**).

1980s - In an effort to prop up the fishing industry and to meet the demands of fishing industry representatives, the Canadian government spent an estimated $8 billion on the Atlantic fishery, approximately half of this on unemployment benefits to out-of-work fishermen and fish plant workers. During this time there was tremendous political pressure to retain the overcapacity of the fishing industry in the name of preserving jobs and hundreds of small rural communities.

1992 - Cod populations on Canada's Grand Banks off the coast of Newfoundland and Nova Scotia continued to plummet to levels 1/100th of original population size. In an attempt to allow these stocks to recover, a moratorium on fishing was declared, putting 35,000 fishermen out of work.

1994 - All Atlantic cod fisheries were closed and strict quotas placed on other species. The Atlantic cod was declared "commercially extinct." Monitoring efforts conducted since this time have suggested little sign of recovery. After billions of dollars' worth of income payments and other subsidies, the Canadian fishing fleet remains much larger than would be required to catch all that the Atlantic cod stocks can produce over the long term.

1998 - A small commercial inshore fishery was reintroduced in 1998 for the Atlantic cod stocks off the east coast of Newfoundland. Catch rates declined, however, and the fishery was closed indefinitely in 2003.

2003 - Newfoundland and Labrador Atlantic cod populations were assigned endangered status in May 2003. Three other populations received threatened or special concern status by the Committee on the Status of Endangered Wildlife in Canada. The International Union for the Conservation of Nature (IUCN) had previously listed the Atlantic cod as a “vulnerable species” in 1996.

2004 - Canada allows a limited cod fishery but with very restrictive catch limits, a shortened season and a gear limit that restricts inshore longliners to 2000 hooks per boat.

In the early 1960s the northern cod stock (SE Labrador to northern half of Grand Bank) numbered almost 2 billion breeding individuals and comprised 75 to 80% of Canada's cod. Since that time the numbers of cod 5 years and older have declined by 97%. (Hutchings and Reynolds, 2004)

The situation along the New England coast mirrored the events in Canada - mismanagement and overfishing resulting in the collapse of cod stocks followed by economic collapse of the communities that depended upon them. Why did fisheries management fail? Put simply, the management agency, in this case the New England Fishery Management Council, "responded more effectively to the economic health of the fishing industry and coastal fishing communities than to the long-term condition of the groundfish resources." (Ross, 1997)

"The collapse of Newfoundland's northern cod can be considered the marine equivalent of hunting of buffalo to pitiable levels of abundance. Failure to take the conservation biology of marine fishes seriously will ensure that other similarly depleted species remain ecological and numerical shadows in the ecosystems where they once dominated." (Hutchings and Reynolds, 2004)

"Just 3 years short of the 500-year anniversary of the reports of Cabot's men scooping up cod in baskets, it was over. Fishermen had caught them all.....Fishermen rarely consider regulation *their* responsibility. As they see it, that is the duty of government to make the rules and it's *their* duty to navigate through them. If the stocks are not conserved, government mismanagement is to blame." (Kurlansky 1997)

Notes to Instructors

Here are some suggestions for using the materials provided with this module:

1. Use the Atlantic cod *PowerPoint* in a lecture-only format to present the topic. The Atlantic cod student handout may be provided to students as a summary of major events.

2. Use the Atlantic cod case study to introduce marine fisheries issues by:

- Providing the Atlantic cod handout to students before meeting
- Show the *Empty Oceans, Empty Nets* segment on Atlantic cod (approximately 10 minutes)
- Open class discussion centered around the following questions:

In your view, what factors were involved in the decline of the species from "super-abundance" to "commercial extinction?"

Despite severe restrictions on cod harvest since 1992, the species has not recovered. What explanations can you offer?

What changes in management would you suggest to recover the species?

Alternatively, students could break up into small groups to discuss these same questions and then report out to the larger group.

- Follow up the class discussion with the Atlantic cod *PowerPoint* presentation to summarize responses to discussion questions and add additional points.

3. The Atlantic cod story lends itself to a "town meeting" approach, in which students assume the role of various stakeholders in the controversy. After conducting research on their selected stakeholder, a town meeting is held to air the viewpoints of all parties involved. This approach is more fully described in the NCSR module entitled, *Town Meeting: an Approach to Exploring Environmental Issues.*

Stakeholders:

- Commercial cod fishers
- Commercial fishers of other species
- Recreational fishers
- National Marine Fisheries Service – fisheries managers
- New England Fishery Management Council members
- Consumers
- Seafood processing plant operators

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. ATLANTIC COD PRINT AND WEB RESOURCES

ARKive – Images of Life on Earth
http://www.arkive.org/species/ARK/fish/Gadus_morhua

This is a good resource for video and still images of Atlantic cod.

Christensen, V., et al. 2003. Hundred-year decline of North Atlantic predatory fishes. Fish and Fisheries 4:1-24.

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.

*Dybas, C.L. 2006. Ode to a codfish. BioScience 56(3):184-191.

This is an excellent summary of the story of the Atlantic cod and is suitable to assign as student reading.

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, Atlantic cod, Patagonian toothfish and Atlantic salmon.

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, S.D. and R.A. Myers. 2004. The Southern Grand Bank: A marine protected area for the world. World Wildlife fund Canada. 99 pp.

Hannesson, R. 1996. Fisheries mismanagement: The case of the North Atlantic cod. Blackwell Scientific Publications. Oxford, UK. 160 pp.

Harris, M. 1999. Lament for an ocean: The collapse of the Atlantic cod fishery - a true crime story. McLelland and Stewart, Inc. Toronto, Ontario. 389 pp.

Hsieh, C.H., et al. 2006. Fishing elevates variability in abundance of exploited species. Nature 443(7113):859-862.

Hutchings, J.A. and R.A. Myers. 1994. What can be learned from the collapse of a renewable resource – Atlantic cod, *Gadus morhua*, of Newfoundland and Labrador? Canadian Journal of Aquatic Sciences 51(9):2126-2146.

Hutchings, J.A. and J.D. Reynolds. 2004. Marine fish population collapses: Consequences for recovery and extinction risk. BioScience 54(4): 297-309.

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. Atlantic cod is frequently cited to illustrate major points.

Kurlansky, M. 1997. Cod- A biography of the fish that changed the world. Penguin Books, New York. 294 pp.

Mackenzie, B.R. and D. Schiedek. 2007. Daily ocean monitoring since the 1860s shows record warming of northern European seas. Global Change Biology 13:1335-1347.

Mackenzie, B.R. et al. 2007. Impact of 21st century climate change on the Baltic Sea fish community and fisheries. Global Change Biology 13:1348-1367.

Warming of the Baltic Sea is documented in the first paper above. The second paper predicts an impact on fisheries in the Baltic Sea due to increased temperature and decreased salinity. Marine species will be most affected. Fishing fleets target marine species and will likely have to relocate or target those species that can tolerate lower salinity. The Baltic cod population is expected to collapse due to current fishing pressure and the temperature and salinity changes described above.

MarineBio
http://marinebio.org/species.asp?id=206

Description of Atlantic cod biology including behavior, life history, and conservation status. Links to images and video are also provided.

Mayo, R. and L. O'Brien. 2006. Atlantic cod – Status of Fisheries off the Northeastern U.S. NOAA. Northeast Fisheries Science Center. Woods Hole, MA.
www.nefsc.noaa.gov/sos/spsyn/pg/cod/

Myers, R.A., et al. 1997. Why do fish stocks collapse? The example of cod in Atlantic Canada. Ecol. Applic. 7:91-106.

Myers, R.A. and B. Worm. 2005. Extinction, survival or recovery of large predatory fishes. Phil. Trans. R. Soc. B. 360: 13-20.

NEFSC. 2005. Assessment of 19 Northeast groundfish stocks through 2004. Northeast Fisheries Science Center Reference Document 05-13. Woods Hole, MA. www.nefsc.noaa.gov/groundfish/#gs

NEFSC. 2008. Brief history of the groundfishing industry of New England. NOAA. Northeast Fisheries Center. Woods Hole, MA. www.nefsc.noaa.gov/history/stories/groundfish/grndfsh1.html

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 (including Atlantic cod).

Righton, D., J. Metcalfe and G. Rose (eds.) 2009 (in prep.) Cod. Blackwell Publishing, Oxford, UK. 352 pp. www.blackwellfish.com

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

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. Historical accounts by early explorers are used to establish a baseline for population levels in the historic past. Chapter 15 is dedicated to Atlantic cod.

Rose, G.A. 1993. Cod spawning on a migration highway in the northwest Atlantic. Nature 366:458-461.

Rose, G. A. 2007. Cod: the ecological history of the North Atlantic fisheries. Breakwater Books, Ltd. St. John's, Newfoundland. 580 pp.

Rose, G.A. and R.L. O'Driscoll. 2002. Capelin are good for cod: can the northern stock rebuild without them? ICES Journal of Marine Science 59:1018-1026.

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

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.

Swain, D.P., et al. 2007. Evolutionary response to size-selective mortality in an exploited fish population. Proc. Royal Society of London B 274:1015-1022.

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.

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.maweb.org

Valiela, I. 2006. Global coastal change. Blackwell Publishing, Oxford, UK 368 pp.

The fisheries chapter includes a good description of Atlantic cod history, management and the current situation.

II. ATLANTIC COD VIDEO RESOURCES

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. 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*.

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, ecosystem-based approach to achieve long-term sustainability of the fisheries and the communities they support.

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.
PBS Home Video
1-800-PLAY PBS
www.pbs.org/journeytoplanetearth/about/purchase.html

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.
PBS Home Video
1-800-PLAY PBS
www.pbs.org/journeytoplanetearth/about/purchase.html

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. The first short (15 min.) segment addresses the decline of the Atlantic cod in Portugal and Massachusetts. Other segments discuss a national marine sanctuary in the Dry Tortugas, the impacts of sea level rise following the loss of glaciers in Greenland, and the success of a marine reserve established in the Caribbean for snapper and grouper.*
DETAILED NOTES ON THIS VIDEO ARE AVAILABLE IN THE *COMPREHENSIVE RESOURCES FOR NCSR MARINE FISHERIES SERIES*.

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*

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 are in French with English subtitles.

III. OTHER CANDIDATE SPECIES FOR CASE STUDIES

Case studies of a number of species besides the Atlantic cod can be used to illustrate marine fishery declines and management efforts to address those declines. Since management of most of these species is marked by a long, sometimes contentious history between various stakeholders, they lend themselves to a "town meeting approach" in the classroom. In this approach students select a stakeholder (e.g., commercial fisherman, environmental group, government regulator, fisheries biologist) they wish to represent during a town meeting moderated by the instructor. The objective is to air the viewpoints of all interested parties and then to discuss different management solutions and how to resolve conflicts between different stakeholders. The approach is more fully described in the NCSR module entitled, *Town Meeting: An Approach to Exploring Environmental Issues*. The following descriptions provide some suggestions for other species and resources that could be used to develop case studies. A number of excellent accounts of single species have been published in recent years. They cover biological, economic and social aspects of the management of these commercially-important species. Each of these addresses the need for ecosystem-based management to varying degrees.

1. Pacific salmon

Pacific salmon were the mainstay of a thriving cannery industry on the Columbia River in the late 1800s and early 1900s. Overfishing, spawning habitat loss, water pollution, hydroelectric dams and more recently, global climate change and loss to predators has resulted in a fishery that is now much diminished and largely supported by hatchery programs. Several individual salmon populations have gone extinct and others have declined to the point that they require protection under the Endangered Species Act.

PACIFIC SALMON RESOURCES

Cone, J. and S. Ridlington (eds.) 1996. The Northwest Salmon crisis - a documentary history. Oregon State University Press, Corvallis, Oregon 374 pp.

National Research Council. 1996. Upstream: Salmon and society in the Pacific Northwest. National Academy Press. Washington, D.C. 452 pp.

Lichatowich, J. 1999. Salmon without rivers - A history of the Pacific salmon crisis. Island Press, Covelo, CA 336 pp.

Montgomery, D.R. 2003. King of fish: The thousand-year run of salmon. Westview Press, Boulder, CO. 80 pp.

Oregon Sea Grant Program
http://seagrant.orst.edu/links/salmsites.html

Deep Crisis. 2003. Scientific American Frontiers. VHS 57 min.

Empty Oceans, Empty Nets. 2002. Habitat Media. VHS 57 min.

Farming the Seas. 2004. Habitat Media. VHS 56 min.

Journey to Planet Earth – The State of the Ocean's Animals. 2007. PBS. DVD 60 min.

Net Loss – The Storm Over Salmon Farming. 2003. Moving Images Video. DVD 52 min.

2. Peruvian anchovy

The Peruvian anchovy is a small silvery, oily fish that is typically processed into fish meal and sold as livestock food. In 1953, Peru developed the anchovy fishery on its west coast. Between 1965 and 1971 anchovies made up 20% of the world's total commercial fish harvest. Biologists warned that this level of harvest exceeded maximum sustainable yield for 7 of 8 years during this time. Anchovy populations depend on nutrient upwellings near the Peruvian coast. These upwellings decrease dramatically during El Niño Southern Oscillations (ENSO) when the entire food web dies back. Just such an event occurred in 1972 when a strong ENSO arrived. The combination of ENSO and overfishing prevented the population from rebounding resulting in severe consequences for the Peruvian economy. The impact was moderated somewhat by turning to other fisheries.

PERUVIAN ANCHOVY RESOURCE

Laws, A. 1997. El Niño and the Peruvian anchovy fishery. University Science Books, Sausalito, California. 59 pp.

3. Striped bass

The story of the striped bass (or "rockfish" as it is also known) is probably more complex than most species. In part, this is due to the anadromous character of its life history for, like salmon, striped bass spawn in freshwater and live out most of their adult lives in saltwater. As a result, in addition to overfishing, the species is more influenced by land-based activities such as industrial pollution and agricultural runoff than off-shore species. In the 1980s, the species appeared to be headed for (at least) commercial extinction. Dramatic conservation measures allowed "full recovery" in the 1990s. However, new challenges including the decline of their main food, menhaden, and the appearance of parasitic infections (dinoflagellates and mycobacteria) threaten this recovery.

STRIPED BASS RESOURCES

Russell, D. 2005. Striper wars: An American fish story. Island Press/Shearwater Books. Washington, D.C. 358 pp.

Franklin, H.B. 2005. Fishing for the future. American Scientist 93:461-462.

4. West Coast Rockfish (*Sebastes* spp.)

Rockfish represent a diverse closely related species that are harvested off the coasts of California, Oregon and Washington. Collectively, they are often marketed as "Pacific red snapper." Most grow very slowly and take several years to reach sexual maturity. One of these species, bocaccio, was once the most common rockfish species caught by trawlers off the West coast. In the late 1970s more than 11,000 metric tons of bocaccio were landed each year. By 2001, the catch had declined to 214 metric tons. In 2002, the stock assessment was so poor that a harvest of 0 to 20 metric tons was recommended. The species is relatively slow to grow and reproduce. Fisheries biologists predict that if all harvest of bocaccio were to stop today, it will take 90 years for the stocks to replenish.

As a result of declining catches and resulting environmental and economic concerns, a buyout program was implemented in 2003, resulting in reducing the size of the fishing fleet by half. Other proposals include the implementation of individual fishing quotas and the establishment of marine protected areas.

ROCKFISH RESOURCE

National Environmental Trust
www.net.org/council/

This site provides brief case histories for bocaccio, Atlantic cod and Red snapper including time series population graphs.

5. Sharks

In the late 1980s Atlantic sharks were being caught 40% faster than they could reproduce (NMFS). About 90% was dumped as bycatch.

A 2003 study published in *Science* (Baum, et al. 2003) and using logbooks kept by longliners as a source of information, found that of the 17 species of sharks studied, all but two had experienced declines of over 50% in less than 20 years. Hammerhead sharks showed the most serious decline with an 89% decrease in population since 1986.

SHARK RESOURCES

Baum, J., et al. 2003. Collapse and conservation of shark populations in the northwest Atlantic. Science 299:389-392.

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.

Journey to Planet Earth – The State of the Ocean's Animals. 2007. PBS. DVD 60 min.

6. Swordfish

Swordfish, like tuna, are a wide ranging, migratory species whose management requires cooperation among several different nations. The species grows rapidly and females reach reproductive age at 5 years. Swordfish spawn in warm tropical and subtropical oceans. During warm summer months they expand their range into colder northern waters. Most swordfish are harvested commercially by longline. In the 1970s, swordfish were a popular target of both commercial and recreational fisheries in the United States and the North Atlantic stock rapidly became overfished. In 1998, 27 chefs from prominent East Coast restaurants announced the removal of swordfish from their menus until a recovery plan was in place. One year later, over 700 chefs nationwide had done the same. In August of 2000, NOAA Fisheries announced a plan to protect swordfish nursery areas and the regional fishery commission reduced catch quotas. With these measures in place, the "Give Swordfish a Break" campaign was formally ended. In 1999, the International Commission for the Conservation of Atlantic Tunas (ICCAT) established a 10-year recovery plan in an effort to rebuild depleted stocks. In U.S. waters these measures included instituting a limited entry fishery, seasonal and area closures to protect small fish, a minimum size requirement and quotas. The stock assessment for 2002 indicated an increase from 64% of healthy stock size in 1998 to 94% just 4 years later. With stocks now sufficiently rebuilt, increased harvest levels are being permitted.

SWORDFISH RESOURCES

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

Empty Oceans, Empty Nets. 2002. Habitat Media. VHS 57 min.

7. Bluefin tuna

Bluefin tuna are a fish of superlatives. They are the largest of several tuna species and can weigh
up to 1500 pounds, reach a total length of four meters and can live 30 years. Bluefin are also among only a handful of fish that are warm-blooded, having the ability to maintain a body temperature significantly higher than their surroundings. They are probably the most desirable food fish in the world, fetching prices in Japan as high as $350 per pound where bluefin is the most desirable species for sushi and sashimi. In 2001, a single bluefin sold at the Tokyo fish market for $173,600. This popularity has also driven the species close to extinction – it is probably the most endangered large fish species in the world. Since 1970, the East Coast breeding population has declined more than 90% from 250,000 to 20,000 individuals. In the Mediterranean, small bluefin are netted and placed in floating pens where they are fattened like cattle and killed before they are sold to Japan.

BLUEFIN TUNA RESOURCES

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

Ellis, R. 2008. The bluefin in peril. Scientific American (March 2008):71-77.

Volpe, J.P. 2005. Dollars without sense: The bait for big-money tuna ranching around the world. BioScience 55:301-302.

The following videos (see full citations in "Atlantic Cod – Video Resources" section) also contain significant coverage of bluefin tuna issues:

Deep Crisis. 2003. Scientific American Frontiers. VHS 57 min.

Empty Oceans, Empty Nets. 2002. Habitat Media. VHS 57 min.

Fate of the Ocean – Our Threatened Fisheries. 2005. VHS/DVD Two 30 min. programs

Farming the Seas. 2004. Habitat Media. VHS 56 min.

8. Chilean sea bass (Patagonian toothfish)

The Patagonian toothfish (usually marketed as "Chilean sea bass") is a long-lived, deep-water fish found in the Antarctic and the extreme southern parts of the Atlantic and Indian Oceans. It can live up to 50 years and reach lengths of over six feet and 250 pounds. Its slow reproductive rate and long time required to reach sexual maturity (8-10 years) make it particularly vulnerable to exploitation. Toothfish are caught by longlining, a method that deploys weighted lines (often several miles long) with thousands of baited hooks.

The species was virtually absent in U.S. markets until 1990 when it appeared in restaurants and was quickly recognized for its high quality. This spurred increased demand in the U.S. and Japan and the fishery developed rapidly. In addition to legally-caught fish, the catch included a high level of illegal, unreported or otherwise unregulated (IUU) fishing which quickly depleted the stocks. In 2000, more than 16,000 tons were legally harvested. Although difficult to estimate, twice that amount may have been harvested illegally. By 2002, declining catches signaled that stocks were being depleted. In addition to stock depletion, the methods used to catch toothfish result in a significant mortality of non-target species. Most notable among these are seabirds (albatrosses and petrels) which are caught and then drowned when they feed on the baited hooks.

Protection and management of the stocks are regulated by the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), an international coalition of 24 major fishing countries including the U.S. and Japan. In an effort to improve management for the species, the CCAMLR now requires all imports of Chilean sea bass to be accompanied by a document that verifies that the fish were legally harvested. Also, the National Environmental Trust (NET), an environmental advocacy group, spearheaded a campaign to encourage chefs to stop serving Chilean sea bass until the stocks had recovered. As of 2002, 700 chefs had agreed to the moratorium.

CHILEAN SEA BASS RESOURCES

Brooks, C. 2008. The most remote fishery on earth. Ice stories: Dispatches from polar scientists.
http://icestories.exploratorium.edu/dispatches/the-most-remote-fishery-on-earth/

This is a general account of the toothfish fishery as reported by a fisheries biologist conducting research on the species.

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.

9. Pacific sardine

In 1936, the Pacific Coast sardine biomass was estimated at approximately 3.3 million tons. That year, the sardine industry landed about 727,000 tons (22% of total biomass) valued at $10 million. At that time this unregulated fishery ranked first in the U.S. for total catch and third in total value. The fishery was based in Monterey, California, the setting for John Steinbeck's popular novel, *Cannery Row*. Over the next two decades, the fishery experienced precipitous declines despite warnings from fisheries scientists. The industry responded by increasing fishing effort to compensate for declines in the harvest per boat. The Washington – Oregon fishery collapsed in the late 1940s followed shortly by the northern California fishery. Although overfishing was the primary cause, strong El Niño events exacerbated the decline by reducing upwelling and the movement of nutrient-rich water to the surface. Phytoplankton productivity declines during these events, affecting the entire food web, including sardines. Just such an event occurred in 1992, when the fishery collapsed. Since then, the Pacific sardine population has fluctuated and the population now supports a smaller fishery.

PACIFIC SARDINE RESOURCE

Levy, S. 2007. Cannery Row revisited. BioScience 57:8-13.

This is a brief account of the decline of the Pacific sardine chronicled in John Steinbeck's. Cannery Row.

10. Menhaden

Menhaden are small, pelagic fish closely related to herring and shad. They travel in large schools along the eastern seaboard from Nova Scotia to Florida consuming large quantities of phytoplankton and zooplankton. They are an important food source for large predatory fish such as striped bass, bluefish and sharks as well as several seabird species. Menhaden support one of the most commercially important fisheries along the Atlantic Coast, providing fish meal, fish oils and bait for other fisheries. Landings of the species have averaged from 300,000 to 400,000 metric tons per year since the mid-1970s, more than any other fish by weight in the United States. Since most of the catch is "reduced" to fish meal and fish oil, the fishery is referred to as a "reduction fishery."

After closure of most state waters to the reduction fishery in the 1980s and 1990s, more than half of the menhaden fishery has shifted to Chesapeake Bay. Increased fishing pressure there has resulted in concerns that localized depletion may be occurring. If so, the ecological roles of the species may also be compromised. Of particular concern is the role played by menhaden in maintaining water quality in a system that experiences severe eutrophication and "dead zones." Menhaden consume large quantities of phytoplankton and may reduce the effects of eutrophication in nearshore waters. In addition, recreational anglers contend that striped bass numbers and condition are affected by low numbers of menhaden in Chesapeake Bay. In recent years a large percentage of striped bass have been infected with a mycobacterium that typically appears in stressed fish.

The central role of menhaden in nearshore marine ecosystems has led some to call the species, "the most important fish in the sea."

MENHADEN RESOURCE

Franklin, H.B. 2007. The most important fish in the sea – menhaden and America. Island Press, Washington, D.C. 253 pp.

This book examines the coastal role of menhaden, a small, oily pelagic fish food along the eastern seaboard. Menhaden are an important food source for predatory fish such as striped bass and bluefish. They also are filter feeders of phytoplankton and algae.

IV. 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