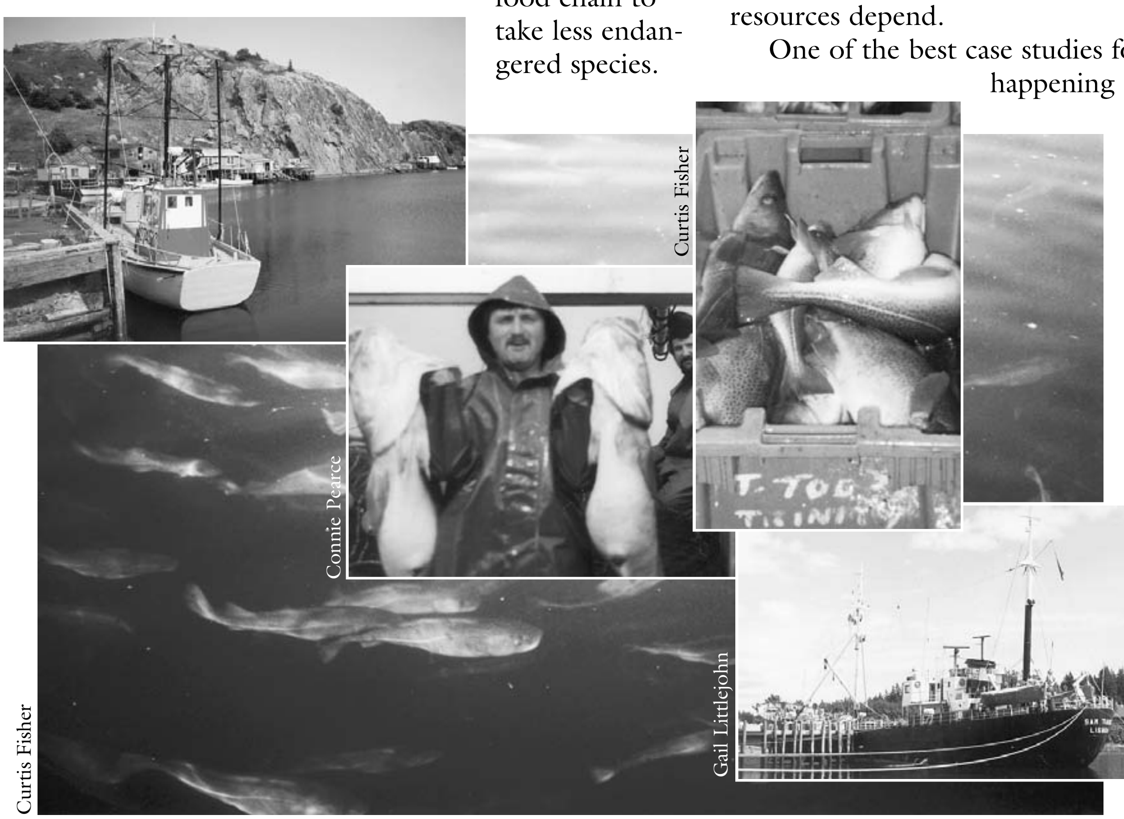
Declining Fish Stocks: Pieces of a Puzzle

The case of the Northwest Atlantic cod provides a framework for examining the interrelated factors that are endangering fish stocks around the world

by Jeanette Winsor and John Goldsworthy

Subject areas: science, social studies,
Key concepts: sustainable resource management

In our parents' and grandparents' generations, fisheries and ocean ecology were never topics that came up in the classroom. People in coastal communities fished the waters around them, never suspecting that this abundant resource could ever disappear. Yet today fish stocks are disappearing. The Food and Agriculture Organization of the United Nations recently reported that more than 140 countries now fish the world's oceans, and that 13 of the 17 major fisheries of the world are in trouble because the stocks have been overexploited. The World Wildlife Fund has asserted that the problem will worsen as fish harvesters move down the food chain to take less endangered species.



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The collapse of traditional fisheries has devastated nations that rely heavily on that resource as a main industry and a major food source. The impacts range from loss of employment and poorer nutrition to the loss of entire economies and ways of life. And as fish quotas and territorial limits are set, conflicts arise between and within nations.

Today, environmental and scientific research organizations are raising public awareness of the threats to the world's fishery. However, if the world's fisheries are to be nurtured back to health and managed in a more sustainable manner in the future, today's young people — the future guardians of our ocean resources — must be aware of the complex puzzle of interrelated factors that have brought about this ecological and commercial disaster. Putting this puzzle together in the classroom is one step toward understanding the delicate balance between economy and ecology on which our aquatic resources depend.

One of the best case studies for learning what is happening to fish stocks around the world is the collapse of the cod fishery in the Northwest Atlantic Ocean around the island of Newfoundland, Canada. The following discussion examines the complex of interrelated factors that precipitated the decline in cod stocks, and serves as a framework for educators who wish to teach the importance of sustainable resource use and conservation of fish stocks and habitats worldwide. The suggested investigations and activities that follow the case study can be used in a study of any fish species found locally, whether saltwater or freshwater.

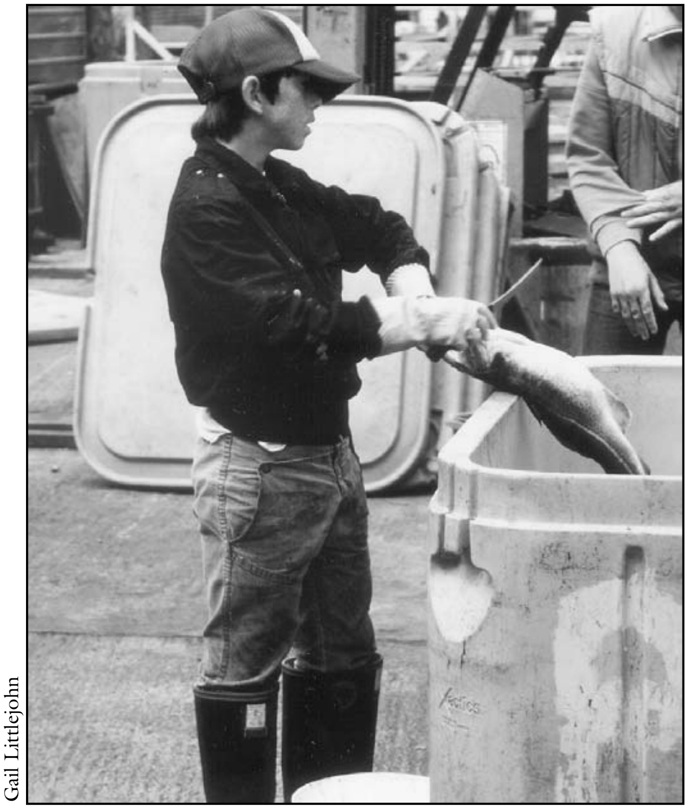
Case study: Northwest Atlantic cod fishery

There's lots of fish in Bonavist' Harbour,
Lots of fish right in around here.
— Newfoundland folk song

For more than 500 years, Europeans have come to reap the ocean's rich harvest on the Grand Banks, an area of the continental shelf on the east coast of what is now Canada. The explorer John Cabot, sailing into these waters in 1497, reported a sea teaming with codfish. Throughout the centuries that followed, fishing crews found that the cod's abundance was matched by its size, some of them "as big as a man" and weighing as much as 82 kilograms (180 pounds).

Then, beginning in the late 1970s, people working in the Northwest Atlantic fishing industry noticed a decline in the cod stocks and a reduction in the average size of individual fish. By July 1992, the stocks were so depleted that the Canadian government declared them commercially extinct and called for a moratorium on fishing. When fisheries scientists, government officials, fish harvesters, and fish processors became aware that there were no longer "lots of fish in Bonavist' Harbour," or anywhere else in Atlantic Canada, they were forced to reflect on where the cod might have gone and how the stocks might be brought back to a sustainable level.

The government blamed overfishing, both foreign and domestic. Inshore fish harvesters blamed large companies, which allowed their huge trawlers to scrape the ocean floor during spawning season. Some fisheries scientists suggested that changes in the ocean environment could be a factor, while others pointed a finger at the burgeoning seal populations. It was apparent to most, however, that no single factor was responsible for the disaster. An intricate web of relationships maintains the balance of an ecosystem as diverse and dynamic as the ocean; assessing the cause of the depletion of one organism is like assembling a huge jigsaw puzzle.


Gail Littlejohn

Petty Harbour, Newfoundland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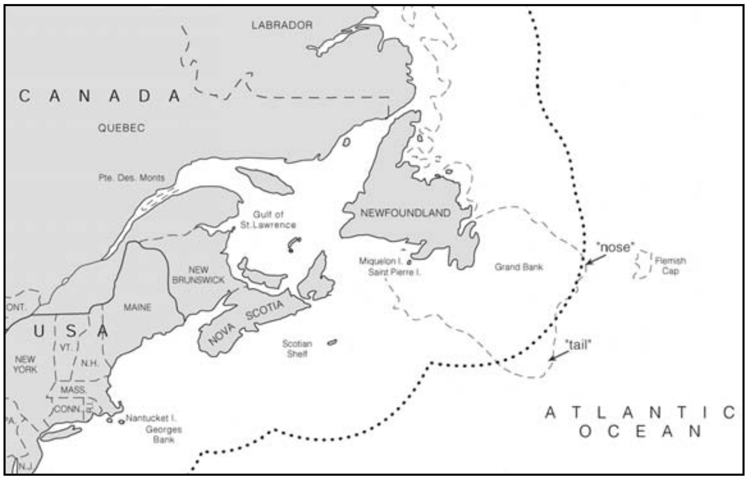
Puzzle piece 1: Foreign overfishing

Nations such as Spain, Portugal, and France have fished the Grand Banks for hundreds of years. By the late 1960s, the catches of cod reported by non-Canadian vessels amounted to more than 600,000 metric tons, compared to less than 200,000 metric tons caught from Canadian vessels. In 1977, in accordance with the United Nations Law of the Sea Conference, Canada declared a 200-mile (320-kilometer) exclusive economic zone around its coastlines, thereby claiming the right to regulate fishing in those areas. Foreign fishing vessels are excluded from this zone, which includes most of the waters on the continental shelf off the Atlantic coast. However, three areas of the continental shelf do not fall within the 200-mile zone: the Nose and Tail of the Grand Banks and the Flemish Cap. Because these areas lie outside of any one nation's jurisdiction, they are managed by the North Atlantic Fisheries Organization (NAFO), a partnership of 17 countries whose mandate is to investigate, protect, and conserve the fishery resources of the Northwest Atlantic.

One of the tasks of NAFO is to set Total Allowable Catch regulations for each species of fish. During the mid- to late 1980s, the European Community (now European Union) did not always agree with the Total Allowable Catches put forward by NAFO and so they set their own quotas, often well above those of NAFO — despite being aware of the cod crisis and the attempts by Canada to nurture the stocks back to health. The actual European Community catch between 1986 and 1991 far exceeded even the high quotas that the European Community had set for its member nations, and the catch was reduced only as the stocks being fished became severely depleted. Fish do not understand the concept of an exclusive economic zone, and, consequently, the excessive catches on the productive Nose and Tail of the Grand Banks and Flemish Cap contributed to a severe decline in the overall cod stocks and continues to affect their recovery.

Northwest Atlantic Fisheries Organization



Tim Grant

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Puzzle piece 2: Domestic overfishing

The Newfoundland domestic cod fishery consists of an inshore fishery and an offshore fishery. Before the decline in the cod stocks, the inshore fishery was conducted during the summer using such traditional methods as hook and line, gill nets, or cod traps. The offshore fishery was conducted from large vessels called trawlers during the winter when cod migrated to their spawning grounds on the northern Grand Banks. Trawlers could withstand the dangerous ice conditions and stay at sea for weeks at a time.

Improvements in fish-finding and navigation technology enabled ship captains to find the exact location of the spawning fish and then harvest them by dragging massive trawl nets along the ocean bottom. At the same time, large fishing companies found it more economical to keep their processing plants open year-round, thereby requiring a constant supply of fish. The northern cod — easily accessible on its spawning grounds — was the perfect catch for this new high-tech, year-round fishery. The offshore fishery proved to be a very profitable, but clearly unsustainable, practice. The spawning biomass of the cod declined from 287,000 metric tons in 1986 to 22,000 metric tons in 1992.

Puzzle piece 3: More seals

Since the late 19th century, Newfoundlanders living along the northeast coast have relied on the annual harp seal harvest to supplement their income. In the years following the Second World War, for example, more than 250,000 seals were landed annually and nearly all of the pelts were exported to Norway. During the mid–1980s, the hunt slowed almost to a halt, owing to concerns voiced by animal rights activists and the subsequent decline in markets for seal products.

Since the 1980s, as a result of the sharp decrease in the number of seals being harvested, the total harp seal population off the northeast coast of Newfoundland has increased substantially. Fisheries and Oceans Canada estimated the harp seal herd to be in the range of 4.8 to 6.4 million in the 1990s, compared to a stable population estimate of 2 million in the mid–1970s. Studies of the harp seal diet estimate that each year the herd consumes 142,000 metric tons of cod around the Newfoundland coast and in the Gulf of St. Lawrence, 1.2 million metric tons of Arctic cod, and 1 million metric tons of capelin, which is the main food of the cod.

Many argue that the seals are merely eating cod that fish harvesters would have otherwise taken. However, scientists from Fisheries and Oceans Canada who examined the stomach contents of seals have suggested that seals usually eat smaller cod than fishing crews are allowed to take, thus destroying the potential breeding stock of cod. While attempts to quantify the contribution of seals to the demise of the cod stocks are not conclusive, indications are that the increased seal population is having a major impact on the recovery of the existing cod stocks.

Puzzle piece 4: Ocean changes

Cod tend to inhabit subarctic to cool waters of -0.5 to 10°C (31 to 50°F), a temperature range to which their metabolism is best adapted. If exposed to temperatures lower than this, the cod's cellular processes are impaired and the fish may freeze to death. At higher temperatures, the cod's metabolism speeds up to the point where the fish cannot get enough food energy to survive. It is also recognized that cod eggs will not hatch and larval cod cannot develop in ocean water colder than 2°C (36°F). Cod will naturally seek out waters that are within their optimal temperature range. Since 1987, water temperatures off Labrador and northeastern Newfoundland have been below average, and in much of the traditional offshore cod spawning region they have been below 2°C (36°F). Scientists agree that changes in ocean temperature may be influencing cod stocks; however, they caution that the influence of these conditions on cod distribution and mortality is not fully understood.


Jeanette Winsor

Quidi Vidi Village, Newfoundland

Ocean currents and light also affect the movement of fish. Fish such as salmon will sometimes head into currents even when they are not being carried, and studies show that fish will often drift passively with the current in darkness but swim against it in the light. Currents also affect the transportation of eggs and prey. The full extent to which changes in ocean currents have affected cod stocks is as yet unknown. Scientists do know that the Labrador Current is a dominant physical feature of the Northwest Atlantic ecosystem. Yet there is much to be investigated, as Dr. Leslie Harris of the Institute of Social and Economic Research notes:

> … the rate at which the great ocean river flows, the volume of water it annually receives from its Arctic and Hudson Bay sources, the extent to which its average width and depth may in an individual year be increased, the manner in which new eddies and swirls may be induced are

Atlantic Cod Chronicle

COD FACT SHEET

Common name:	Atlantic cod
Scientific name:	*Gadus morhua*
Distribution:	Northwest Atlantic from inshore waters 5 m (16 ft.) deep to edge of continental shelf 200+ m (650+ ft.) deep, north to coast of Greenland and south to Cape Hatteras
Migration:	Most cod migrate extensively from a summer feeding range to their winter spawning range.
Stocks:	The population is divided into 10 separate stocks.
Average weight:	3 kg (6½ lbs.)
Average length:	70 cm (27½ in.)
Diet:	Young cod feed on zooplankton; Juveniles and adults feed on capelin, sandlance, herring, and shellfish (sea stars, crab, shrimp).
Reproduction:	A female cod over 6 years of age and about 80 cm (30 in.) long can produce more than 2 million eggs. As development is very complex, only 1 egg per million matures into an adult.
Spawning conditions:	Water depth of 200 m (656 ft.), temperature range 2.5 to 4°C (36.5 to 40°F)

Jeanette Winsor

COD FISHERY COLLAPSE TIMELINE

Year	Main events in cod fishery collapse
1968	Highest total catch, mainly by non-Canadian fishing vessels, recorded.
1977	Canada declared exclusive economic zone.
1978	Northwest Atlantic Fisheries Organization established to manage fishery outside exclusive economic zone.
1992	Canada declared a ban on commercial cod fishing in most Newfoundland waters (30,000 Newfoundlanders out of work).
1998	Committee on the Status of Endangered Wildlife in Canada declared Atlantic cod "vulnerable," and added cod to the national list of species at risk.
2003	Cod stocks still not recovering as expected; future remains uncertain.

ANNUAL CATCH IN NEWFOUNDLAND WATERS*

Year	Catch (tonnes)
1958	500,000
1968	810,000
1978	100,000
1988	250,000
1998	5,000

* Total catch, Canadian and non-Canadian, on open oceans, frozen seas, tidal seas, and coastlines

all … matters for educated guesswork.[1]

Puzzle piece 5: Ghost nets

Among the many factors that may affect fish populations is the problem of "ghost" nets — nets or traps that have been lost at sea. Some nets separate from their buoys during storms and are impossible for fishing crews to find; some are cut accidentally from their moorings by other ships; and some are set and simply not retrieved. Most of these nets and traps are made from heavy nylon rope that is not biodegradable. They can drift in the oceans for decades, trapping and destroying untold quantities of fish and enticing sea birds and other marine life to their demise.

Gail Littlejohn

Change Islands, Newfoundland

Puzzle piece 6: Poor management

Fisheries and Oceans Canada is responsibile for managing all marine species, including the Atlantic cod stocks. The goal of this federal department is to allow for the maximum sustainable catch while maintaining the health of fish stocks. The department is also responsible for setting fishing quotas in Canadian waters, as well as the licensing of fish harvesters and vessels.

Throughout the 1970s and 1980s, fish harvesters and processors in Newfoundland were concerned that the average size of the fish they were taking was getting smaller and that the amount of fish landed per unit of effort was declining. Despite their repeated warnings to large companies, fishery scientists, and the federal government, no action was taken. This lack of effective resource management and communication also played a role in the decline of the stocks.

The closure of the Newfoundland cod fishery in July 1992 was the largest mass layoff in Canadian history, as 30,000 people were suddenly without work. Since that time, the fishing industry in Newfoundland has adjusted and recovered. The value of recorded landings is now greater than in years prior to the cod-fishing moratorium, mainly owing to an increased focus on shrimp, crab, and previously underutilized species. Unfortunately, the cod stocks are not recovering as expected and there is no commercial cod fishery along the northeast coast of the island.

Fishy classroom activities

Counting fish

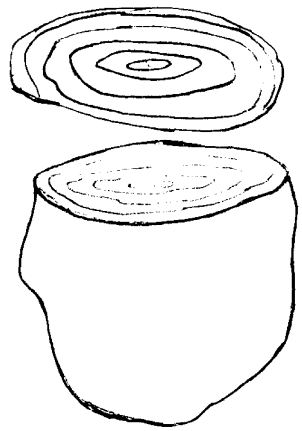
An essential aspect of fisheries management is the calculation of fish stock populations. Counting fish is very difficult because they move around and hide. Instead, scientists tag some of them and use a method of estimation to reach a fair assessment of the number of fish in a given stock, as illustrated by the following experiment.

Procedure:

1. Have students cut a large number of small squares of paper and place them in a container. Explain that each square represents a fish and the container represents part of the ocean.
2. Ask students to remove a handful of squares from the container and mark an "X" on each, as if tagging a fish. Then ask them to prepare a record sheet by writing A, B, and C across a piece of paper. Have students count the squares they have tagged and record the number under A on the record sheet.
3. Return the tagged squares to the container and mix them up with the untagged squares.
4. Ask students to close their eyes and remove a handful of squares from the container. Have them count all the squares in this sample and record the sample size under B on the record sheet. Then have them count how many tagged squares are in the sample and record this number under C on the record sheet.
5. To estimate the total number of squares (fish) in the container (ocean region), have students multiply the number under A (total tagged fish) by the number under B (random sample size) and divide by the number under C (number of tagged fish in the sample).
6. Have students remove and count all the paper squares to determine the accuracy of their estimates.

Follow-up: Having established that counting and keeping track of the number of fish in a body of water is not an easy task, students will begin to understand the need for carefully controlling the number of fish taken. Have students research to find out:

- who controls the fish stocks in local waters
- what determines when people can fish
- what number and size of fish are allowed to be taken
- what kinds of equipment are allowed (e.g., fishing rods, reels, lines, jiggers, nets, traps, electronic fish finders)
- what penalties are imposed on those who violate the laws



Invite a local fisheries or conservation officer to visit the class to discuss the reasons for these regulations.

Based on Bruce Wyman, "How Many Fish in the Sea?," New England Aquarium, online in January 2004 at <http://www.neaq.org/scilearn/kids/fish.html>.

In a cod's ear

The foundation of fisheries management is accurate scientific data. The age of fish is one of the key factors scientists look for when trying to calculate the biomass of a population. But how do you tell the age of a codfish? It's quite simple: inside the fish's ear is the ear bone or otolith. A cross-section of this bone reveals rings. Just as we can count the rings of a tree trunk to determine the age of a tree, we can count the rings on the otolith to determine the age of a cod.

Investigating fish habitats

To increase students' awareness of the factors that affect a fish stock in your region, select a species to study and visit a body of water that it inhabits. Look for potential sources of pollution and disturbance nearby, such as factories, hydroelectric projects (dams, spillways, and reservoirs), logging, and roads.

If you visit a beach, go at low tide and study the marine life in intertidal pools. Examine and identify the kinds of creatures found in the pools. Discuss their position in their food chain, as well as the potential effect on your study species if these creatures are destroyed.

If you visit a river or lake, have students test the pH of the water, and remind them that fish and plants can live only in areas with a specific pH. Take samples from different locations and try to determine the reasons for any significant differences. Check the water temperature of the lake or river, noting that the colder the water, the higher the oxygen level. What temperature does your subject species thrive in? What effect might global warming have on the stock? What effect would heated water from a factory have on the stock's habitat? How will the reproductive cycle be affected by temperature changes? How will predators and prey of the study species be affected?

As a classroom activity, have the students create a wall mural to illustrate the food chain of your study species and how pollutants can affect the entire web of life.

High seas research

Since many fish migrate and fall prey to fishing vessels on the high seas (i.e., areas unregulated by any nation), declines in fish stocks are a problem for many nations. The following areas, where large numbers of fish are being taken and the possibility of decimation exists, are beyond national jurisdictions:

- the "Donut Hole" of the Bering Sea and the "Peanut Hole" of the Sea of Okhotsk (declining pollock stocks)
- the Challenger Plateau off the coast of New Zealand (declining orange roughy stocks)
- Argentina's Patagonian Shelf (declining hake, southern blue whiting, squid stocks)
- the coasts of Chile and Peru (declining jack mackerel stocks)
- the "Loop Hole" of the Barents Sea off the coast of Norway (declining redfish stocks)
- parts of the Atlantic and South Pacific oceans (declining tuna, dolphin, shark stocks)

Have students research fish stock depletion in one of these areas and develop a written report or display that focuses on the species ecology, the reasons for stock depletion, the present situation, and possible ways to ensure future conservation.

Ocean culture

Have students work in groups to collect ocean-inspired stories, songs, poems, pictures, and other artistic pieces. Each group could create a poster or bulletin board to display its findings and explain the importance of the ocean in the history and culture of a particular coastal community. Have students create their own essay, poem, or painting about life near the ocean.

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Note

1 L. Harris, *The Newfoundland Groundfish Fisheries: Defining the Reality,* Institute of Social and Economic Research, 1993, p.3.

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ON-LINE RESOURCES

Background Information

<www.dfo-mpo.gc.ca> Fisheries and Oceans Canada (DFO) provides links to science, management, statistics, regulation, and publications on the main page of its website.

<www.dfo-mpo.gc.ca/zone/under-sous_e.htm> Underwater World Information Series, DFO Canada, provides information on marine species including Atlantic cod.

<www.dfo-mpo.gc.ca/CSAS/Csas/English/Index_e.htm> Canadian Science Advisory Secretariat provides stock status reports for marine species, including northern cod and harp seals.

<www.gov.nf.ca> and <www.heritage.nf.ca> On the main page of its website, the Government of Newfoundland and Labrador includes links to its departments and publications. Memorial University’s Heritage website introduces students to the history and culture of the province.

Teaching Resources

<www.education.noaa.gov> “Oceans and Coasts for Teachers” includes links to and descriptions of over 30 websites endorsed by NOAA about fish, marine mammals, and oceans.

<http://smithsonianeducation.org/educators/lesson_plans/ocean/main.//html> Interdisciplinary marine science by the Smithsonian Institute includes six lesson plans and activities focusing on the diversity and importance of the seas.

<www.pbs.org/saf/1306/teaching/teaching2.htm> PBS Scientific American Frontiers includes a complete teaching guide for an activity related to population sampling.

<www.eoascientific.com/oceanography/introduction/guide.html> EOA Scientific’s “Oceanography in Atlantic Canada” includes lesson plans and guidelines for a mock community meeting related to the fishery collapse.

<www.wildeducation.org/programs/blue_school/oceneduc.asp> Canadian Wildlife Federation’s ocean education program includes lesson plans, resources, and instructions for registering as a Blue School to carry out the Blueprint for Ocean Action.

<http://school.discovery.com/lessonplans/programs/oceans> Discovery Channel’s “Understanding the Ocean” includes lesson plans for Grades 6 to 8 on oceans, ocean currents, and global weather patterns; Understanding Ecology” includes lesson plans on open oceans, frozen seas, tidal seas, and coastlines.