

# TOWARD A SUSTAINABLE FUTURE

Challenges  
Changes  
Choices

## Unit 4

Water Use and  
the Environment





# Chapter 13: Fresh Water Resources



**Figure 13.1:** When you look at it from space, it's easy to see why Earth is called “the blue planet.”

## Did You Know?

- You can survive about a month without food, but only 5 – 7 days without water.
- Plasma (which makes up 55 percent of our blood volume) is 90 percent water.
- Remains of water storage dams found in Jordan, Egypt and other parts of the Middle East date back to at least 3000 BC.

## WATER'S FUNDAMENTAL IMPORTANCE

Water is one of the most widely occurring substances on Earth. It covers seventy percent of the planet's surface. Water is the only substance that exists naturally in all three states—solid (ice), liquid, and gas (water vapour and steam). Water falls as various types of **precipitation**—rain, hail, sleet, snow—and collects on the surface in glaciers, lakes, marshes, rivers, and oceans. It can be suspended in the air or found deep underground. Its presence helps regulate Earth's temperature.

Water is essential for all living species. Humans drink water and use it for agriculture, for industry, and for recreation. It is also valued in aesthetic and spiritual ways. In most of the world's major religions, water has an important symbolic or ceremonial role. Not surprisingly, the development of human civilization has been closely linked to the presence of water. Historically, people settled or moved between places where water was plentiful and good for drinking. These two factors—water's quantity and its quality—continue to shape how we use, manage, and discuss water today.

## Did You Know?

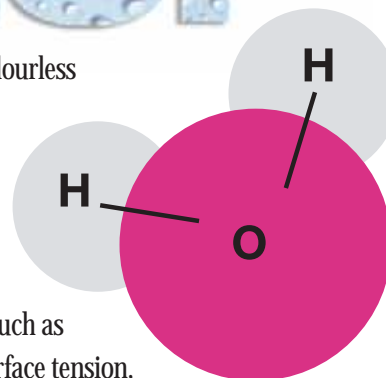
Water's high surface tension means it tends to clump together in drops rather than spread out in a film. This makes **capillary action** possible. It carries water and the substances dissolved in it through the roots of plants and the tiny blood vessels in living bodies.

# What is Water

Water (H<sub>2</sub>O) is an odourless, tasteless, and colourless liquid formed by a combination of two atoms of hydrogen and one atom of oxygen.

Pure water has a neutral pH of 7, which means it is neither acidic nor basic.

Polarity explains many of water's properties such as its low melting and boiling points, its high surface tension, its expansion when frozen, and its ability to dissolve other substances.



**Figure 13.2:** A representation of a water molecule: two atoms of hydrogen (H) and one atom of oxygen (O).  
Image courtesy Department of Environment and Conservation

### What Monitoring Reveals

- In 1981, in the Adirondack Mountains, 217 lakes were tested for acidity. More than 110 of them had a pH of less than 5.0. In 100 of those lakes, no fish of any species were found.
- In Canada, 202 lakes have been studied since the early 1980s. Of these, 33 percent have reduced their initial levels of acidity; 56% have not changed; 11 percent have become more acidic.
- Data from acid rain monitoring sites in Newfoundland and Labrador during the 1990s indicated that the most acidic precipitation fell on the southwest corner of the island. As prevailing weather comes from the southwest, this pattern indicated that the source of the sulphate pollution was from outside the province.

### The Universal Solvent

Water can dissolve more substances than almost any other liquid. That's why it is often called the "universal solvent". Wherever water travels through the air, the ground, and even our bodies, it picks up and carries chemicals, minerals, and nutrients.

Water's solvent properties are what make it so important to life because it allows the transfer of nutrients that are vital to animals and plants. But, it also means that water can pick up material harmful to life. A drop of rainwater falling through the air, for example, dissolves atmospheric gases. If this rainwater becomes acidic, it affects the quality of land, rivers, and lakes.

### Fresh and Salty Water

Water in nature can be either fresh or salty. Salty water has a salt content of between 0.5 percent and 25 percent. The most common salty water, found in the oceans, is referred to as saltwater and contains about 3.5 percent salt. The saltwater in oceans and seas accounts for most of the planet's water, 97.5 percent.

Fresh water has less than 0.5 parts per thousand of dissolved solids. Fresh water occurs on the surface of Earth in lakes, ponds, and rivers. It is also found in the soil, in all forms of precipitation, as condensation in the air and underground in aquifers.

Fresh water accounts for only 2.5 percent of Earth's water supply. More than two-thirds of that amount (68.9 percent) exists in forms that we cannot easily use, in glaciers, ice caps, and permanent snow cover. Only 0.01 percent of the water on Earth is available for drinking or other human uses.

## A Fresh Look at Home Waters

*Compared to other provinces, a high percentage of Newfoundland and Labrador's surface area is fresh water. Lakes, ponds, rivers, and streams cover roughly eight percent of the province's area.*

### Did You Know?

Raindrops are not tear-shaped. Scientists, using high-speed cameras, have discovered that raindrops are shaped like small hamburger buns!

### The Water Cycle

Water that is found on the Earth's surface—in streams, lakes, rivers, and oceans—is called **surface water**. If it is underground, it is called **groundwater**.

In nature, water's major pattern of movement is the water cycle (or **hydrological cycle**). The sun, by heating ocean water, is the main source of energy propelling this cycle. Surface water evaporates into the atmosphere, falls back again in some form of precipitation, and moves over or under the surface of the Earth in response to the force of gravity. Because of this cycle of movement and return, fresh water is considered one of Earth's few non-living renewable resources.



**Figure 13.3:** More than two-thirds of all the water on Earth (68.9 percent) exists in forms that we cannot easily use; in glaciers, ice caps, and permanent snow cover.

### The Freshwater/Saltwater Link

If all precipitation falls as fresh water, why does Earth have huge bodies of salt water? Because the fresh water that flows into the oceans, seas, and land-locked lakes has picked up minerals (including salts) along the way. The minerals are left behind when water evaporates. Gradually, over millennia, the concentration of salts increased and transformed the final-destination water body into a saltwater, rather than a freshwater, environment.



## Not all salty water is the same

The concentration of salts in fresh water is usually so small that it is stated in parts per million (ppm). Here are some sample concentrations:

Source	Salt concentrations
Distilled water	0 ppm
Rain	10 ppm
Ocean	35,000* ppm
Dead Sea	250,000 ppm

\*This is an average figure. The concentration of salt in the world's oceans varies. The Red Sea and the Persian Gulf have the saltiest water due to high rates of evaporation. Of the major oceans, the North Atlantic is the saltiest.

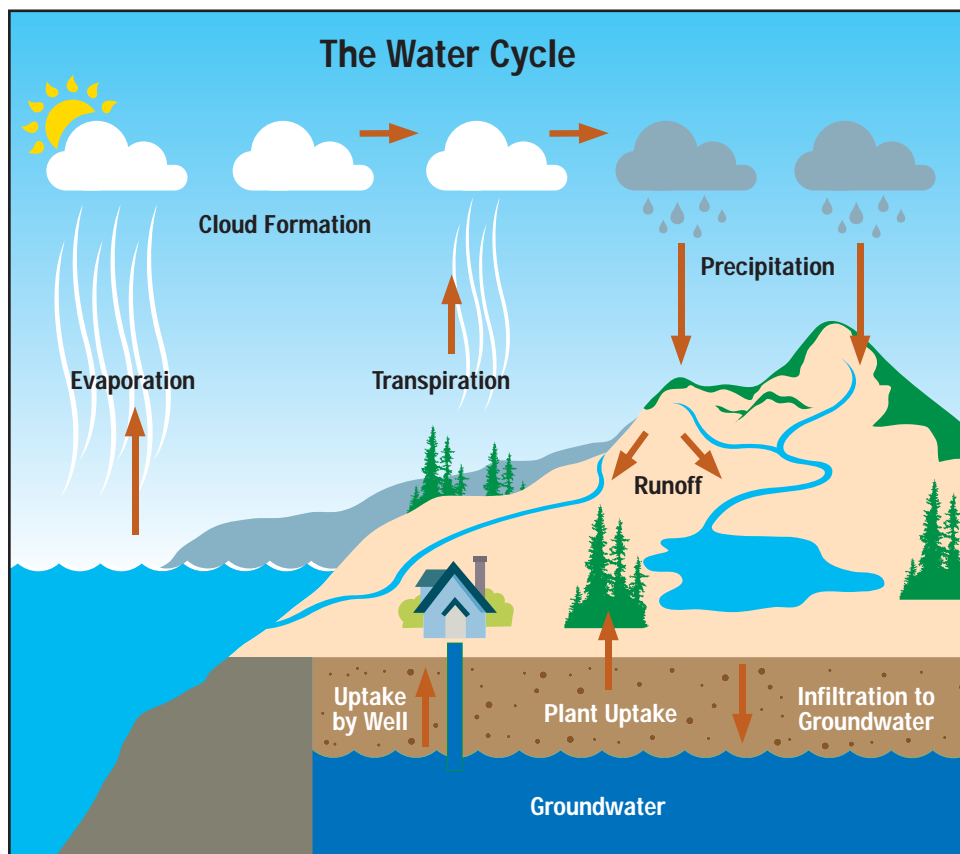


Figure 13.4: The Water Cycle. Image courtesy Derek Peddle

## Did You Know?

- Water is nearly pure in its gaseous state.
- Plant leaves emit water vapour by a process called transpiration. Every day a growing plant transpires 5 to 10 times as much water as it can store at any one moment.

As water passes through the water cycle it is naturally cleaned of some impurities. The cleansing of water by the environment, called **self-cleaning**, can be scientifically studied and assessed. How well and how quickly water is self-cleaned depends on many variables. These include the volume of water in a given system, how quickly and turbulently it flows, the characteristics of the bottom and bank material, variations of sunlight and temperature, and the chemical nature of the water itself. As you will see, all of these natural self-cleaning processes are also harnessed in human-engineered water treatment processes.

### How does water clean itself?

There are several natural ways by which water becomes cleaner:

**Physical processes** include the filtering that occurs as rain trickles through the ground or flows over sand and soil in rivers. In standing bodies of water, some contaminants simply settle out. Clay in ambient water actually collects other materials as it settles to the bottom. Called “adhesion”, this process can help remove dissolved and suspended substances. In addition, when water evaporates or freezes, it leaves impurities behind.

**Bio-chemical processes** occur when water is purified mainly by the actions of living organisms. Energy from sunlight drives the process of photosynthesis in aquatic plants, which produces oxygen that is used by bacteria to break down

organic material such as plant and animal waste. This decomposition produces the carbon dioxide, nutrients, and other substances that aquatic plants and animals need. The purification cycle continues when these plants and animals die and bacteria decompose their remains, providing nourishment for new generations of organisms.

**Wetlands** help remove impurities as well. The plants typically in wetland ecosystems are able to consume nutrients and some types of dissolved metals in water.

The process of **sunlight radiation** can kill some bacteria in water—sunlight acts as a natural disinfectant. The success of this process depends on many factors, including the type of bacteria, the clarity of the water, and the geographic location. It is most effective in latitudes near the equator.

#### **Concern about Water: an International Response**

In 2004, The United Nations (UN) declared that 2005 – 2015 would be the “Decade for Action —Water for Life”. It also made March 22 of each year “World Day for Water”. Through these efforts, the UN hopes to promote public awareness of water conservation and the development of worldwide water resources.

#### **How long is groundwater in the ground?**

It varies enormously—from days or weeks to 10,000 years or more. It is not unusual for groundwater to stay underground for hundreds or even thousands of years. River water, on the other hand, takes about two weeks to completely replace itself.

### **OUR COMPLEX RELATIONSHIP WITH WATER**

Today, the world’s water resources are under increasing pressure because of population growth and humanity’s call for more water in more places for more uses. According to the World Health Organization (WHO), about 1.1 billion people in the world do not have access to safe drinking water and 2.4 billion people do not have access to adequate sanitation. In 2003 alone, diseases related to poor water quality killed more than six thousand children every day. In addition, about 3,800 cubic kilometres of fresh water is withdrawn each year from the world’s lakes, rivers, and aquifers—that’s twice the volume withdrawn just fifty years ago.

The demands for water in Newfoundland and Labrador are also growing. Compared to other places in the world, we have plenty of water suitable for drinking and other purposes. We are, however, also facing challenges, including having one of the highest per-capita water use rates in the country.

### Three Ways to Enjoy Water



**Figure 13.5:** White water rafting.  
Photo courtesy Department of Environment and Conservation

The way we use water for recreation can be divided into three sub-categories:

- Primary—swimming and playing *in* it
- Secondary—fishing or boating *on* it
- Tertiary—admiring (painting viewing, photographing) it from a distance

### The Demand for Water: At Home and In Our Communities

Water plays a big role in our lifestyles. At home, we use it to cook, wash, drink, water plants, and remove human wastes. This is often referred to as “domestic water use”. Outside the home, water is used in similar ways in schools and the workplace. We swim in it, fish in it (and harvest from it), and boat on it. We use it to clean up working areas, to generate hydroelectric power, and also in lumber, milling, mining, and other industrial processes, as well as in agriculture and livestock-raising.

Environment Canada estimates that for domestic purposes alone, the typical Canadian uses about 350 litres of water per day. Here are some of the statistics:

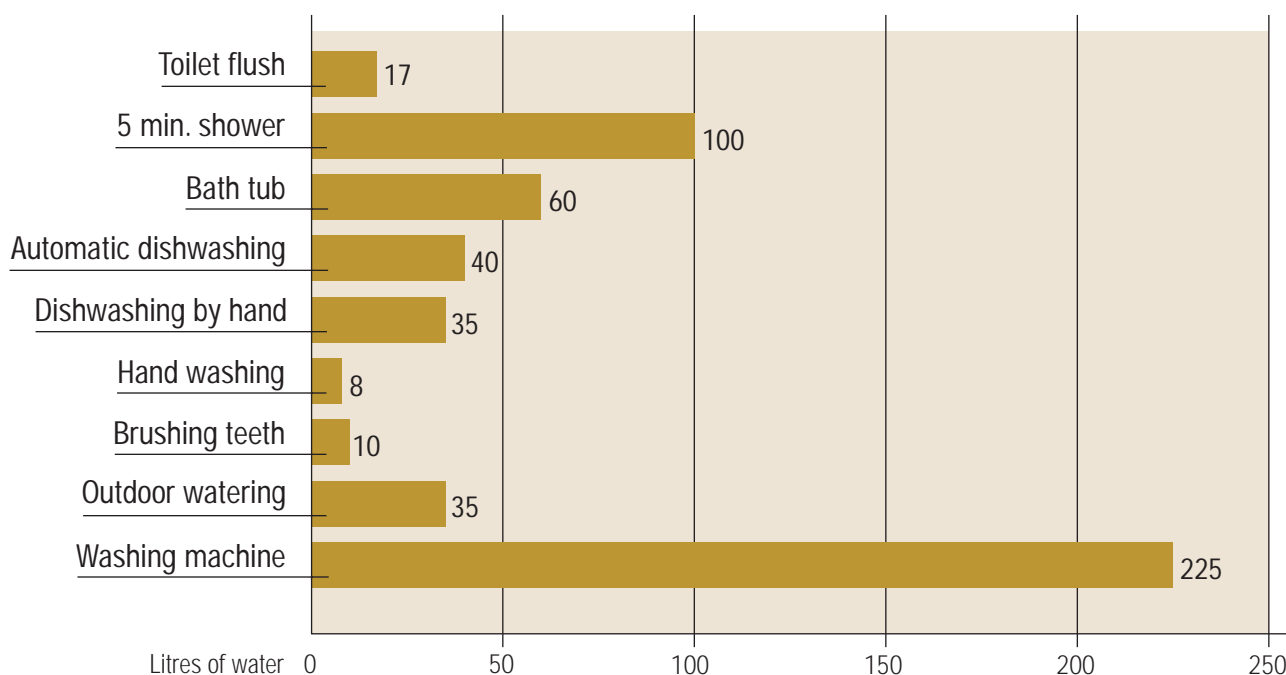
- Toilet flush: 15 – 19 litres
- Five minute shower: 100 litres or 50 litres with a low-flow shower head
- Bath tub: 60 litres
- Automatic dishwashing: 40 litres
- Dishwashing by hand: 35 litres
- Hand washing: 8 litres (with tap running)
- Brushing teeth: 10 litres (with tap running)
- Outdoor watering: 35 litres /min
- Washing machine: 225 litres

### Did You Know?

Only five percent of daily water use is for drinking and cooking.

Modern lifestyles and appliances, as well as piped-in water and sewage disposal, have increased our use of water from the time when all water had to be pumped and carried by hand.

### Litres of water used for various daily activities



**Figure 13.6:** Some typical water consumption amounts for daily activities in Canada.

Data Source: Environment Canada



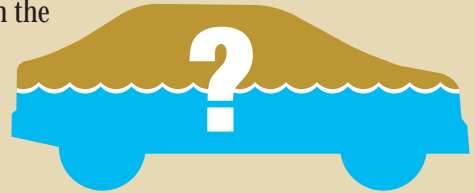
# MINI-LAB ACTIVITY

Monitor your use of water in a day and estimate its volume. Are you over or under the Canadian average (which was 335 litres per day in 1999)?

## How much water is needed to make a car?

At least 120,000 litres of water is used to manufacture a car: 80,000 litres to make the steel and 40,000 litres in the fabrication. More water is used to make its plastic, glass, and fabric.

*Data Source: Environment Canada*



## Global Industry Water Withdrawals

- **World-**  
22% of total water use
- **High-income countries-**  
59% of total water use
- **Low-income countries-**  
8% of total water use

## The Demand for Water: Industry

Industry puts many demands on water. Water is used as a raw material, a coolant, a solvent, a transport agent, and a source of energy. In Canada, industry accounts for about sixteen percent of total fresh water consumption. It comes in second behind thermal power generation, which uses sixty three percent.

Agriculture consumes a great deal of water. It can be the biggest consumer in agriculture-based countries. Water is needed for irrigation and for spraying fertilizers and pesticides. All of these activities can affect the quantity and quality of water in a region.

Managing water resources is a complex matter. Managers must satisfy a growing demand for water while also carefully balancing the sometimes conflicting environmental, economic, and social considerations.

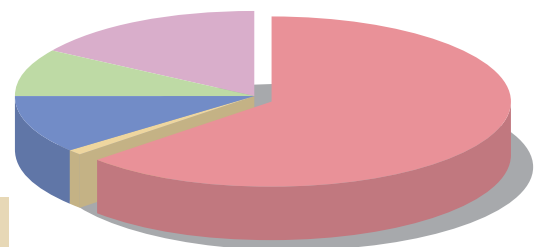
## Shipping “Bulk” Water

Unlike bottled water, bulk water is exported in large quantities, unpackaged. There are three ways this is possible (though not necessarily economically or technically feasible):

1. As icebergs (towed by ships),
2. In huge bags (towed by ships)
3. In container ships or tankers (as in the Gisborne Lake proposal).

In some places, pipelines and barges (carrying water trucks) are also used.

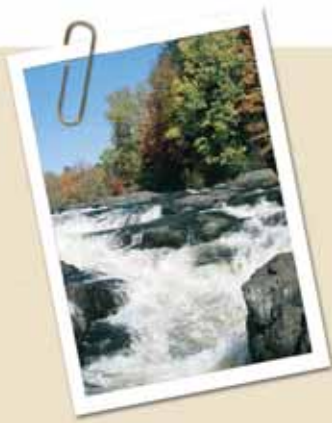
Water consumption by sector in Canada



Thermal Power Generation	63%
Mining	1%
Municipal	11%
Agriculture	9%
Manufacturing	16%

**Figure 13.7:** Industrial water consumption in Canada by industry.

*Data Source: Environment Canada*



## Case Study

### Water—An Export Product?

Because the Earth has an expanding population and a finite water supply, some people expect that water will become “the oil of the twenty-first century”; a blue gold.

Compared to many places in the world, Canada is rich in water. This does not necessarily mean we are sitting on a big pot of gold, however. Containing and selling bulk water for profit has many implications—environmental, economic, and moral. The main question is:

*“Should water be considered a “vital resource” (like air) that belongs to everyone, or a “commodity” (like oil) that can be sold and traded the same way other natural resources are?”*

In Canada, managing water resources is a provincial responsibility while export and trade are federal responsibilities. Any export or trade across our national borders is also subject to international agreements. Some people are concerned that if we treat our water as a “commodity”, other nations may be able to gain access to vast amounts of it under the terms of the North American Free Trade Agreement (NAFTA).

In the fall of 1999, the Government of Newfoundland and Labrador passed the Water Resources Protection Act that prohibited bulk water removal (that legislation was replaced in 2002 by the Water Resources Act). In 1999, the Province also signed a national bulk water prohibition agreement. It was called the Accord for the Prohibition of Bulk Water Removal from Drainage Basins. This voluntary agreement was signed by eight other provinces and territories (the “drainage basins” in the title refers to the five major basins across the country). These activities were the culmination of months of debate about the export of water in our House of Assembly and in legislative chambers (and kitchens) across Canada.

In Newfoundland and Labrador, the catalyst for the discussion was a proposal to export water in bulk from Gisborne Lake, which is near Grand Le Pierre on the south coast of Newfoundland. The project’s organizers argued that the development would be sustainable (that is, it would not damage the environment or deplete the lake) and it would provide much-needed jobs in

the nearby communities. The project was not approved at first (1999), but when Roger Grimes became Premier, the discussion was reopened (2001). This led to an investigation into the pros and cons of the issue by a specially appointed Ministerial Committee.

The Committee recommended continuing the ban on bulk water exports and, to date, that is still the case. The main reasons for their recommendation were economic—the costs of exporting the water by tanker were too high to make the effort profitable. Significantly, the Committee's report concluded that exporting water would not have implications for other provinces, under the terms of NAFTA (which had been a concern across the country).

Given the need for water around the world, it seems likely that the discussion will continue.

## QUESTIONS

1. List and discuss the pros and cons of bulk water export.
2. The province also produces bottled water. What sources of water is this industry using? What are the issues that come up in relation to this enterprise?

### Pressure on Water Resources: Pollution and Contamination



Every day, manufacturing and service industries, households, and institutions discharge water that carries hundreds of different substances into rivers and lakes. According to Environment Canada, at least 100,000 tonnes of toxic pollutants were discharged directly into Canada's surface waters in 2003.

Whatever and wherever its source, the degrading of water quality can affect both aquatic life and human uses of water. For example, higher concentrations of nutrients (nitrogen or phosphorus from fertilizers) may result in uncontrolled plant growth and reduce the amount of dissolved oxygen available in the water for fish and other aquatic animals.

These combined pressures, plus demand for water and decreasing water quality due to human activities, reinforce the need to understand water and our effects on it, and to manage it wisely.

**Figure 13.8:** Sewage outfall.

*Photo courtesy DFO/Laura Park*

## Did You Know?

In water resource management, a watershed is always described in relation to its “outlet”. Outlets can be dam sites, drinking water sources, locations where streams join together, or any number of other points. The outlet is the lowest point, and all of the area higher than it, which drains into it, is that outlet’s watershed.

## Did You Know?

There are five ocean drainage basins in Canada. Water in them flows to:

- Atlantic Ocean;
- Hudson Bay;
- Arctic Ocean;
- Pacific Ocean; and
- Gulf of Mexico.

The individual Canadian river system with the largest drainage area is the MacKenzie (1,805,200 km<sup>2</sup>).

In Newfoundland and Labrador, the Churchill River has the largest drainage area (92,500 km<sup>2</sup>).

## AMBIENT WATER: A CLOSER LOOK

The quality of the water in the environment is affected by the type and quantity of materials that are dissolved in it by natural processes or by human activity. Before we look at what these materials are and how they find their way into water sources, let’s examine how fresh water moves in the natural environment and the nature of some of the province’s most important freshwater aquatic environments: wetlands, rivers, and large bodies of water.

### The Watershed

A **watershed** or drainage basin is an area of land in which the surface water and groundwater all drain to a common waterway such as a stream, wetland, lake, or even the ocean.

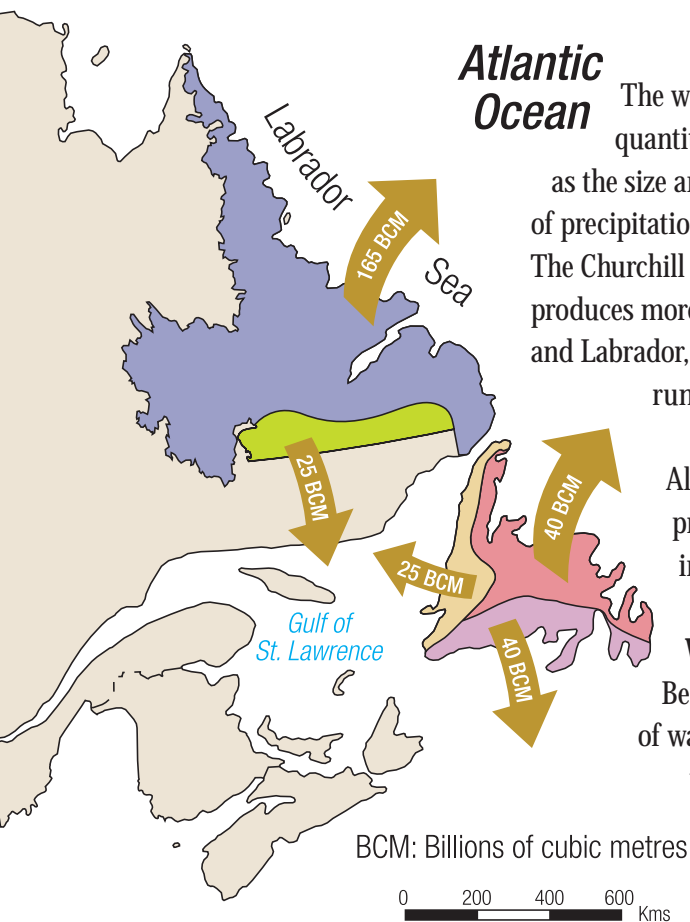
A watershed’s shape, size, and area are determined by the highest points of land that surround it. On the far side of these high points, water flows towards different waterways in different watersheds. If you draw a line through the highest points of elevation—also called drainage divides—around a river on a map, you have outlined its watershed.

Watersheds vary in size—they can be drawn for a single stream or pond, or for a whole system of waterways that come together to flow to the ocean. The drainage basin for an entire river takes in the watershed areas of all its tributaries.



**Figure 13.9:** Water running into St. Paul’s Lake, NL from the surrounding watershed.





**Figure 13.10:** Runoff Volume Graph. Arrows indicate the amount of annual regional mean runoff volumes in billions of cubic metres (BCM) for the province. The total annual runoff from watersheds in Newfoundland and Labrador is estimated to be 295 BCM: 190 BCM from Labrador and 105 BCM from Newfoundland. Image courtesy Department of Environment and Conservation

## Atlantic Ocean

The water that flows out of a watershed is called its **runoff**. Runoff quantities are often directly related to the amount of precipitation as well as the size and shape of the watershed area. Generally, given the same amount of precipitation, larger watersheds have more total runoff than smaller watersheds. The Churchill River in Labrador, for example, has a vast drainage basin and produces more than 50 billion cubic metres of runoff every year. In Newfoundland and Labrador, the large volume of rain and snow we receive contributes to high runoff rates, which can reach almost 300 billion cubic metres a year.

All activities that take place in a watershed, whether they are natural processes or human-driven, can affect the quality and quantity of water in the watershed.

### Watersheds and Water Management

Because each watershed is an integrated and interconnected system of water ways, watershed management is an effective way to approach water quality management.

Watershed management is an innovative, **holistic** planning process that considers all the known elements within a watershed. The approach is based on geography and ecosystem science and it relies on shared responsibility for partnership and stewardship among water resource authorities, municipalities, and other important stakeholders. For watershed management to work, all those involved in decision making must use the best available science, and all decisions and activities should reflect the informed preferences of the people who live in the watershed.

Mapping a watershed, identifying potential sources of contamination, and assessing the possibility of water-quality problems are critical elements of watershed management and protection. Watershed management requires a watershed plan, which should outline effective strategies for sustainable development of resources and for protection of public health and the environment.

### Nutrient Levels

Because runoff in Newfoundland and Labrador is high, the nutrient levels in most water bodies in the province are low (they are **oligotrophic**). This is because the nutrients are either flushed out to sea or their concentrations are diluted. Systems with moderately enriched nutrient levels are called **mesotrophic**. Those with highly enriched nutrient levels are **eutrophic**.

Changing the natural nutrient levels in an aquatic system can disrupt the balance of its food web and affect water quality. Adding nutrients to an aquatic system is called **eutrophication**. A common cause of eutrophication is the use of fertilizers within a watershed or the discharge of untreated sewage.





**Figure 13.11:** Peatland.

*Photo courtesy K. Slaney*

### What's a Peatland?

A peatland is a wetland in which peat (or “turf”) is found. Peat is a type of soil with a high proportion of dead organic matter (mainly plants). This organic material has built up over thousands of years. The material has not decomposed because waterlogged conditions (and a lack of oxygen) prevent micro-organisms from breaking down the dead plant materials.

### \$\$ Value, Too!

Wetlands attract hunters, bird watchers, hikers, and photographers. These activities can generate regional economic benefits through tourism dollars and recreational spending. Peatlands are also considered prime areas for berry picking. The sale of bakeapples (cloudberries in Europe) in particular, contributes to this province's economy.

## Freshwater Ecosystems

Many types of freshwater ecosystems can exist in a watershed or drainage basin. They include wetlands, streams and rivers, ponds and lakes, and even underground aquifers. Distinctly different from one another, they provide aquatic habitats for a wide variety of plants and animals. Physical and natural elements combine to make each type of habitat unique.

Water is the main physical component of all aquatic habitats. Geography and climate affect water's properties: whether it freezes, how it accumulates, how fast it flows, and what nutrients it carries, for example. The characteristics of the water, in turn, affect the types and interactions, as well as the variety of plants and wildlife that grow in the system (the biodiversity).

### Wetlands

**Wetlands** are areas saturated by surface water or groundwater. The plants found there are adapted for life in waterlogged soil conditions. Aquatic and wetland habitats together account for more than 20 percent of the total area of Newfoundland and Labrador—about 168,000 square kilometres. As in the rest of Canada, the wetlands in this province are primarily **peatland**.

Wetlands are an important part of the environment. They collect and store runoff thereby, reducing or moderating flooding and erosion downstream. By controlling runoff, wetlands also play an important role in reducing the build-up of sediment in rivers. They also filter and purify water, maintain river flow during dry periods, help replenish groundwater, and provide distinct habitats for plants and animals.

The table on the next page lists the major wetland types and their characteristics, some of which are explored in more detail on the following pages.

## Did You Know?

Canada has 1.27 million square kilometres of wetlands. That is 14 percent of the country. Canada's wetlands represent 25 percent of all the wetlands on the planet.

Migratory routes for caribou often cross large tracts of peatland.

Wetland Type	Characteristics
<div data-bbox="191 447 232 531" data-label="Text">BOG</div> <div data-bbox="240 210 803 525" data-label="Image"> </div>	<div data-bbox="841 205 893 241" data-label="Section-Header"><b>Bog</b></div> <div data-bbox="841 247 1450 493" data-label="Text"> <p>Water comes only from precipitation; the soil is acidic and nutrient levels are low. Dominant vegetation are mosses (including sphagnum moss). Plants, such as the pitcher plant, use insects as a source of nutrients. Bogs are peat-covered. Groundwater level is close to the surface.</p> </div>
<div data-bbox="191 877 232 951" data-label="Text">FEN</div> <div data-bbox="240 636 803 951" data-label="Image"> </div>	<div data-bbox="841 630 889 661" data-label="Section-Header"><b>Fen</b></div> <div data-bbox="841 667 1450 919" data-label="Text"> <p>Water comes from precipitation and groundwater movement. The soil is less acidic and contains more nutrients than bogs. Dominant vegetation are grasses; mosses are also present. Groundwater is above the surface and there are open water areas with flowing water.</p> </div>
<div data-bbox="191 1224 232 1371" data-label="Text">SWAMP</div> <div data-bbox="240 1060 803 1375" data-label="Image"> </div>	<div data-bbox="841 1054 930 1087" data-label="Section-Header"><b>Swamp</b></div> <div data-bbox="841 1094 1450 1339" data-label="Text"> <p>Water comes from several sources. Soil is totally submerged or periodically submerged. Dominant vegetation are trees or tall shrubs. There are moderate and variable amounts of nutrients in the soil/water; the peat is wood-rich. Groundwater is mostly below the surface.</p> </div>
<div data-bbox="191 1654 232 1791" data-label="Text">MARSH</div> <div data-bbox="240 1486 803 1801" data-label="Image"> </div>	<div data-bbox="841 1480 922 1512" data-label="Section-Header"><b>Marsh</b></div> <div data-bbox="841 1518 1450 1728" data-label="Text"> <p>Mineral-rich soil is totally submerged or periodically submerged (groundwater can be at or below the surface). Dominant plants are reeds, cattails, and sedges. Surface water is shallow and levels fluctuate daily.</p> </div>

**Figure 13.12:** Types of wetland. *Photos courtesy K. Slaney*

## Did You Know?

Sphagnum moss produces acid. By holding up to twenty times its weight in water and releasing hydrogen ions, it maintains the high acidity of the bog. This means that the bacteria that normally break down plant matter cannot thrive. Dead sphagnum moss (and other plant material) accumulates rather than decomposes, eventually forming peat.

### Bogs

Typical bogs have acidic water, spongy peat deposits, and a thick carpet of sphagnum moss. Most (or all) of their water enters the ecosystem via precipitation, not from runoff, groundwater, or streams. Because of this bogs are low in the nutrients that are needed for plant growth. Acid-forming peat mosses add to their low pH levels.

Bogs are formed in two ways:

1. When sphagnum moss grows over a lake or pond and slowly fills it (terrestrialization).
2. When sphagnum moss covers dry land and prevents water from leaving the surface (paludification).

Whichever way they begin, as the centuries pass many metres of acidic peat deposits can slowly build up.

Bogs are generally associated with locations that experience low temperatures and short growing seasons, and where lots of precipitation and high humidity cause excessive moisture to accumulate. The unique characteristics of bogs give rise to plant and animal communities that have adapted to low nutrient levels, waterlogged conditions, and acidic water. The specialized flora and fauna that grow in acidic conditions are called acidophiles.

Plants found in bogs generally require acidic conditions and include cotton grass, cranberry, blueberry, dwarfed black spruce, and tamarack, as well as Labrador tea and other dwarf-shrubs. Moose, caribou, and lynx are a few of the animals that use northern bog habitats.

Bogs can take hundreds (sometimes thousands) of years to form naturally, but can be destroyed in a few days. Historically, they were drained and the area used for growing crops. In some places they were mined for their peat, which was burned as fuel or used as a soil conditioner.

Recently, the role that bogs and other peatlands play in regulating global climate has been recognized. Peat deposits store large amounts of carbon, thereby reducing atmospheric CO<sub>2</sub>. Reduction of this greenhouse gas should help slow climate change.

### Fens

Fens, like bogs, are peat-forming wetlands. Unlike bogs, they receive water and nutrients from other sources besides precipitation. It drains from uphill sources and from groundwater.



**Figure 13.13:** As shown here, extensive damage can be done to wetlands (in this case a fen) by the use of ATVs. *Photo Courtesy K. Slaney*

Fens differ from bogs in two main ways:

1. Fens are less acidic than bogs.
2. Fens have higher nutrient levels than bogs.

As a result of these differences, fens support more diverse plant and animal communities than bogs. They are often covered by grasses, sedges, rushes, and wildflowers.

Like bogs, fens occur mainly in the northern hemisphere (and are found across much of Canada). They are generally associated with low temperatures and short growing seasons accompanied by lots of precipitation and high humidity. This causes moisture to accumulate. The fens in Newfoundland and Labrador are not as numerous as the bogs.

Fens provide important benefits in a watershed. Like bogs, they prevent or reduce the risk of floods, improve water quality, and provide habitat for unique plant and animal communities.

## Rivers

Rivers usually begin as a **stream**—a body of running water that flows under gravity through clearly defined natural channels to lower and lower elevations. Once a natural stream has collected a substantial volume of water (the volume of running water is larger) it is called a river.





**Figure 13.14:** A stream or a river? Photo courtesy Stephen Elliot

### What's a Flashy River?

It's a river whose flow tends to have sudden increases after rainfall. The high levels decrease just as quickly when the rain stops. In this province, flashy rivers occur where drainage or catchment areas have a lot of exposed bedrock and have little vegetation or few wetland areas. Rainfall cannot be absorbed well in these conditions and so the runoff proceeds quickly to the river.

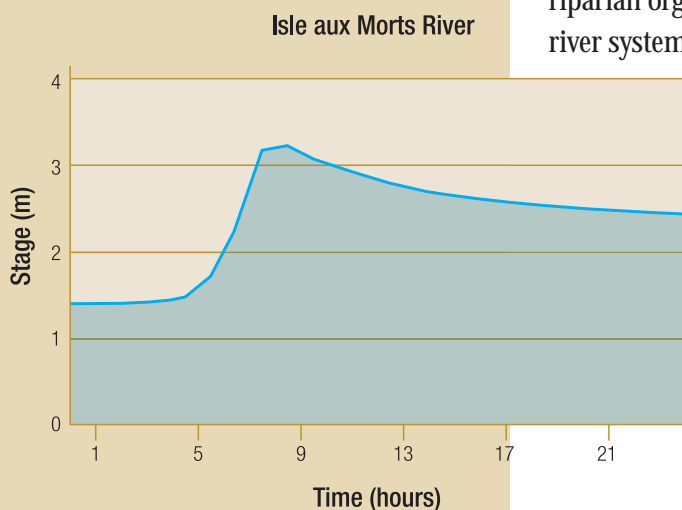
Because of its movement and weight, flowing water has tremendous energy. Quickly moving streams and rivers can reshape the landscape carving deep grooves in rocks and shifting huge volumes of earth. This reshaping most often happens in the higher parts of the river's drainage basin. In lower elevations, where the slope is flatter, the river slows down and sediments begin to settle to the bottom—this usually occurs near the river mouth. This settling of material can sometimes create deltas where flowing water meets a standing body of water.

The volume and speed of water plus the timing of its flow determines how a river shapes the surrounding landscape, what it picks up, what it deposits, and how people can use the water.

The interface between the land and a river or stream is referred to as a **riparian zone**. Riparian zones (sometimes called buffer zones) are characterized by plant communities that are adapted to very wet and flood conditions, and which grow along the margin of the river or stream. These plant communities can be mainly grassland, woodland, or wetland depending on the land through which the river flows. The vegetation surrounding the river or stream helps shade the water and prevents rapid temperature changes. The plants and their root systems absorb some of the stream energy, slowing soil erosion and reducing damage from floods. Riparian zones also help increase biodiversity in an area by providing a habitat for a variety of wildlife. These zones also provide a **wildlife corridor** where aquatic and riparian organisms move along the river system while avoiding the drier land community.

### Did You Know?

On cold nights when the wind blows hard over open stretches of water, it speeds the formation of ice. On the Exploits River, between the Millertown dam and Grand Falls, sometimes more than two million cubic metres of ice can be produced in one night!



**Figure 13.15:** Flashy River Water Levels. This graph of river flow on the Isle aux Morts River shows how quickly (time in hours is on the x-axis) a flashy river can react and reach high levels (shown in metres as "stage" on the y-axis). Photo courtesy Department of Environment and Conservation



## Ponds and Lakes

In most of North America, the terms “lake” and “pond” have distinct and different meanings. The water bodies referred to as **lakes** have water layers with different temperatures. Their shores are windswept and are characterized by rooted plants that only grow close to shore. The water bodies referred to as **ponds** are smaller bodies of water that have no more than one of these characteristics. These definitions do not apply in Newfoundland and Labrador where the terms are used interchangeably. In this text, for the purpose of discussion, we will use the definitions above.

One of the main reasons why lakes are ecologically important is because they can store water when there is a lot of precipitation and then gradually release it. This helps balance the flow of the rivers that run out of them.

## Did You Know?

Oxygen levels decrease when water temperatures increase. The cooler the water, the more oxygen can dissolve in it—which makes more oxygen available for aquatic life at low temperatures. One of the reasons fish are found at different water depths through the year is their need to follow desirable oxygen levels and water temperatures.



**Figure 13.16:** View of a pond/lake, Penguin Arm, Bay of Islands, Newfoundland.  
*Photo courtesy Paul Saunders*

The greater the size or number of lakes, the greater the moderating effect on connected rivers. For example, take Beaver Brook and Northeast Brook which are both located near Roddickton, on the island of Newfoundland. Beaver Brook has an annual maximum-to-minimum flow ratio of about 35. That means its maximum flow rate is about 35 times more than its minimum flow rate. Northeast Brook’s ratio is about 18. The rivers are similar in many ways. The difference in flow rate ratios is largely because Northeast Brook has more lakes and wetlands in its watershed (17 percent of its drainage area) than Beaver Brook (8 percent).

### Is it a Lake or is it a Pond?

If you’re having trouble deciding what a body of water near you *should* be called, conduct an Internet search to identify the specific characteristics and compare with the body of water in question.

## Have you seen a blue pond?

An area about an hours drive south of Corner Brook on the Trans-Canada Highway (TCH) is underlain with limestone. There are two ponds there that are fed by underground limestone-based springs. They have a spectacular blue-green colour which you can spot from the TCH. The colour of the water is caused by the light bouncing off the calcium carbonate suspended in the water.

## How does light affect the pH of an aquatic ecosystem?

Plants are unique among living things because they make their own food. Through the process of photosynthesis, which uses light, water, and carbon dioxide, plant leaves make sugars that are important for growth.

In this activity, you will investigate the process of photosynthesis in an aquatic ecosystem. You will collect data using a pH sensor, then compare and organize information in tables and graphs to identify pH patterns related to light.

By placing a small aquatic plant and a snail in a plastic bag filled with water, you can measure the change in the rate of photosynthesis based on pH. The live snail produces carbon dioxide, which is dissolved in the water in the form of carbonic acid. The plant needs the carbon dioxide for photosynthesis. The plant will only undergo photosynthesis if ample light is available. During the night or at lower light levels, unused carbon dioxide increases in water ecosystems and as a result pH decreases.

### Note:

*Working with live snails requires respect and care in treatment. Once the activity is completed, return all organisms to their original environment.*

Calibrate the pH meter before taking your readings for this activity.

### Materials:

- pH sensor
- Two aquatic snails
- Fluorescent light
- Stream or pond water
- Two small plastic bags (water tight)
- Two aquatic plants with roots
- Aluminum foil
- Graph paper/spreadsheet software

### Procedure:

1. Place a snail and a small aquatic plant with attached roots into each small plastic bag filled with stream or pond water.
2. Record the pH of each bag.
3. Describe your aquatic ecosystems in your notes.
4. Place one bag within a half metre of a fluorescent bulb.
5. Wrap the other bag in aluminum foil.
6. Predict which plastic bag will have the highest pH after 5 hours.
7. Construct a chart and measure the pH of your aquatic ecosystems every 20 minutes over a five hour period.

## Did You Know?

- Canada has the largest lake area of any country in the world. It has 563 lakes that are larger than 100 square kilometres.
- The Great Lakes contain eighteen percent of the world's fresh lake water.
- Gander Lake is 300 metres deep—as deep as Conception Bay.
- The largest body of water in NL is a man-made lake — the Smallwood Reservoir on the Churchill River. It has a surface area of 6,527 square kilometres.
- On the island, the largest water body is Grand Lake, with a surface area of 494 square kilometres.

## Analyze and Conclude

1. Graph the pH of each bag (Time on the horizontal axis).
2. How did the pH of the two bags vary over time?
3. How do your results compare to your predictions?
4. Are your results close to what you expected? Why or why not?
5. How do you explain any differences in pH? How does it relate to photosynthesis?
6. Would the results have been the same if different types of plants were used?
7. What evidence have you observed that plants consume carbon dioxide?
8. What evidence have you observed that animals produce carbon dioxide?
9. What evidence have you observed that light affects how plants produce carbon dioxide?
10. What does the pH of a solution indicate about the amount of dissolved carbon dioxide in the water?

### Further Investigations:

11. How would the pH change if the plastic bag had more snails or plants?
12. Keep one of your plastic bags outside. Measure pH every hour throughout a 24 hour period. Is there evidence of a cycle?

## CHECK your Understanding

1. What is a watershed? Can you determine the name of the watershed you are living in?
2. Which river in Newfoundland and Labrador has the largest drainage basin?
3. Why are wetlands considered important for the health of the environment?
4. List the types of wetlands found in Newfoundland and Labrador.
5. What are the main differences between bogs and fens?

### For Further Discussion and/or Research

6. With respect to nutrient levels in a pond or lake, what is the difference between oligotrophic, mesotrophic, and eutrophic?
7. Investigate the process of “turnover”, which occurs in lakes during the spring and fall, and explain why this process is important to the ecological health of a lake.

## WATER QUALITY: START WITH THE GUIDELINES

What constitutes “safe” water differs from use to use. The quality of water needed to support aquatic life, the quality of water that can be used in industry, and the quality of water required for drinking are not necessarily the same. This is why any discussion of water quality must always be linked to what the water is used or needed for.

The Government of Canada has produced science-based guidelines that outline the “safe” levels of various substances that can be found in water which are linked to each of water’s uses. Specifically, there are guidelines for:

- Drinking water—which define safe levels for more than eighty-five different microbiological, physical, chemical, and radiological parameters such as bacteria, odour, arsenic, and radon.
- Recreational water—which define safe water parameters for swimming, boating, and other activities in which water should be as free as possible of microbiological, physical, and chemical hazards.
- The aquatic environment—which classify water parameters that are safe for plants and animals that live in lakes, rivers, and oceans.
- Agricultural water—which ensure that sensitive crop species are not exposed to harmful substances during irrigation, or that livestock are not harmed by the water they drink.

### Did You Know?

Newfoundland and Labrador is the only provincial government that has taken responsibility for monitoring drinking-water quality and reporting to the public. Elsewhere in Canada, municipal governments monitor drinking-water quality and report to the provincial regulatory agency.

There are also guidelines that outline the sediment quality needed to protect aquatic organisms as well as levels of contaminants that wildlife can tolerate. Using guidelines requires laboratory analysis of a water sample. The results reveal the types and amounts of substances in the water. Guidelines are most often employed by people who manage water resources, but they are available to everyone (and easily accessed online).

### The CCME Water Quality Index

A major tool for reporting water quality information in a more easily understood way is the Canadian Council of Ministers of the Environment (CCME) **Water Quality Index (or WQI)**. The Index translates the technical, mathematical water quality data that emerge from laboratory analysis into simple terms (“excellent”, “good”, “fair”, etc. - see box). The WQI is similar to the ultra-violet (UV) index and air-quality index - it’s a consistent and easily understood way of reporting water-quality information to water resource managers and the public.

### Interpreting the CCME WQI Values

- **Excellent** (Value 95-100): Water quality is protected with a virtual absence of threat or impairment. Conditions are very close to pristine levels. These index values can only be obtained if all measurements are within the objectives virtually all of the time.
- **Good** (Value 80-94): Water quality is protected with only a minor degree of threat or impairment. Conditions rarely depart from desirable levels.
- **Fair** (Value 65-79): Water quality is usually protected, but occasionally threatened or impaired. Conditions sometimes depart from desirable levels.
- **Marginal** (Value 45-64): Water quality is frequently threatened or impaired. Conditions often depart from natural or desirable levels.
- **Poor** (Value 0-44): Water quality is almost always threatened or impaired. Conditions usually depart from desirable levels.

In Newfoundland and Labrador, WQI scores are used to rank water bodies across the province, relative to each other.

To see these rankings go to the Department of Environment and Conservation's website and click on the link to the latest *Drinking Water Quality Community Report*. The Water Quality Index has also been used to evaluate drinking water quality, to determine if water is suitable for aquaculture and for suitable management practices in a watershed.

### Ambient Water Quality

**Ambient water** is the water that exists all around us—the province's surface and groundwater. Regular monitoring of ambient water gives us a picture of our overall water quality—which compounds or elements are found in our water, at which locations, and in what quantities. It can also indicate changes that are occurring in the environment.

In 1986, the Canada-Newfoundland and Labrador Water Quality Monitoring Agreement (WQMA) was signed. The Agreement called for the creation of a network of ambient water-quality monitoring stations across Newfoundland and Labrador. It also helped coordinate and integrate the water monitoring activities of the federal and provincial governments.

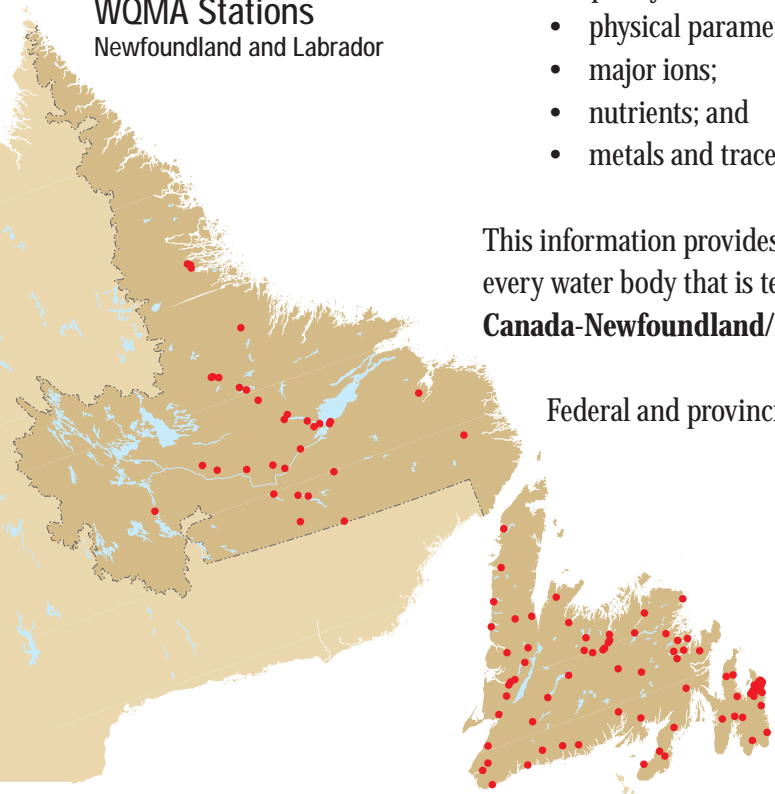
Since the Agreement was signed, water-quality data have been collected at 111 monitoring sites (hydrometric stations) across Newfoundland and Labrador. The number of stations reporting at any one time varies, as stations are introduced or deactivated. The water samples are sent to Environment Canada laboratories. Biological or bacteriological analysis can be done at the province's public health laboratories.

### What can I see at a hydrometric station?

Not very much! The monitoring "stations" are simply spots noted on a map and by accurate description, so that water samples can always be taken from the same locations. For a list of all the locations in the province refer to the Department of Environment and Conservation's website.



## WQMA Stations Newfoundland and Labrador



**Figure 13.17:** Water sampling sites that have been included under the Canada-Newfoundland and Labrador Water Quality Monitoring Agreement (WQMA).  
*Image courtesy Department of Environment and Conservation*

The Environment Canada laboratories provide data on more than three dozen parameters and are divided into four major types of water-quality indicators:

- physical parameters and chemical elements;
- major ions;
- nutrients; and
- metals and trace elements

This information provides an essential, baseline water-quality assessment of every water body that is tested. The results are available on the Internet at the **Canada-Newfoundland/Labrador Aqua Link (or CANAL)** website.

Federal and provincial agencies use this information to guide:

- water resource management programs;
- pollution control regulations;
- changes in water quality guidelines;
- water quality modeling (simulation and prediction);
- environmental assessments;
- legislation; and
- other federal, provincial, and international agreements and commitments.

### Real Time Water Quality Monitoring

Several of the ambient water-quality monitoring stations in this province are **Real Time Water Quality (RTWQ)** stations. The stations consist of water-sampling equipment with sensors for recording the physical and chemical properties of water. The equipment is left in place in a water body and transmits information via satellite (or, in some cases, through a phone line).

Water quality varies over time, according to weather, seasons, and human activities. When it comes to understanding and managing fluctuations in water quality, the more continuous the information is, the more helpful it is. The province's RTWQ stations sample water quality and transmit the data at regular intervals throughout the day. They measure a few key parameters, including water temperature, pH, specific conductance, dissolved oxygen (DO), and turbidity. The province's RTWQ stations on the island and in Labrador form the **Real Time Water Quality Network**.

The station locations and the information they transmit are all available online through the Department of Environment and Conservation's website and are updated each day.

## Did You Know?

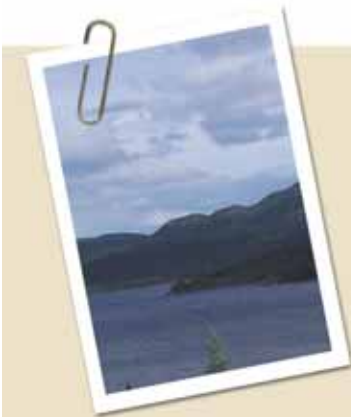
Newfoundland and Labrador was the first province in Canada to display near real-time water quality data on a web page. This makes it easy for the general public to access water quality data from any of the RTWQ stations.

### Big Numbers

If an RTWQ station measures water quality parameters every 15 minutes, then it will collect 175,200 readings over the course of a year.

The continuous collection of water quality data allows us to monitor the health of aquatic ecosystems, identify water-quality trends, and determine when specific events happen. Government, environmental groups, and other stakeholders use this data. By monitoring the data, it is possible to recognize changes in water quality almost as they occur and intervene if needed. This can minimize environmental impacts should contaminants or unusual readings occur.

**Figure 13.18:** Water Quality Monitoring Agreement (WQMA) sampling equipment. This portable water-quality monitoring device is called a Minisonde. It is used during WQMA sampling to record a variety of water quality parameters. *Photo courtesy Department of Environment and Conservation*



## Case Study

### Real Time Water Quality (RTWQ) Monitoring at Voisey's Bay

Because it provides plentiful and regular readings, RTWQ monitoring is particularly helpful near natural resource development projects. Three of the province's earliest RTWQ stations are at Voisey's Bay, in Labrador, where a new nickel mine is now in operation.

Their installation marked the first time in Canada that data from water-quality monitoring at a mine site were made available to the public in near-real-time. Monitoring the data transmitted by these stations can reveal whether changes in water quality are natural or are caused by the nickel mining activity.



**Figure 13.19:** A water quality instrument (Datasonde) used for RTWQ monitoring. *Photo courtesy Department of Environment and Conservation*

Launched in 2003, the monitoring project at Voisey's Bay is a partnership of the Water Resources Management Division (in the provincial Department of Environment and Conservation), Environment Canada, and Voisey's Bay Nickel Company Limited. This partnership exists to ensure that development activity does not harm the sensitive northern aquatic environment. From spring through fall, "Datasonde" equipment sits in the water sources. Three sites were carefully selected to begin with, in areas that would provide the most meaningful data. The equipment remains in the river during the warm months and is removed for winter (when the river freezes).

### Who Gets Priority?

When more than one group is interested in using water resources, whose needs come first? The Province's Water Resources Act prioritizes the list as follows:

- domestic use;
- municipal purposes;
- agricultural use;
- commercial, institutional, and industrial purposes;
- water and thermal power generation; and
- other purposes.

Of the three initial sites, one is in pristine water (Reid Brook) upstream from the development. Water contaminants cannot flow upstream so this is the control site. The Camp Pond Brook station is closest to the mining development. Its readings would most quickly indicate if any events related to the mining were affecting water quality. The Lower Reid Brook site (downstream from Camp Pond) would indicate if an event was affecting the water where the river reaches the sea. The area of mining development will move closer to this site over time.

The monitoring has revealed “spikes” in the data on a few occasions, which resulted in investigations and corrections. For example, in September 2003 there were several big spikes in turbidity levels in Camp Pond Brook. Each was reported to Voisey's Bay's on-site environmental officer. Investigations determined that the spikes occurred because of a pump failure in a sedimentation pond (which was corrected).

The real-time monitoring results and the quick corrective responses by Voisey's Bay Nickel Company Limited are good examples of environmental **stewardship**. The readings are available to all partners and the public through the Department of Environment and Conservation's website.

### CHECK your Understanding

1. Why is water called the universal solvent? Why is this characteristic so important for organisms on Earth?
2. What variables influence how quickly a water body can cleanse itself?
3. List four ways that water can naturally clean itself.
4. Describe the three parameters that the CCME Water Quality Index measures.
5. What are the benefits of real-time water quality stations over traditional methods of obtaining quantitative and qualitative water data?

### For Further Discussion and/or Research

6. Of the major oceans, why is the North Atlantic the saltiest?
7. Use the Department of Environment and Conservation's website to learn the types of information collected at each station.
8. Use the Department of Environment and Conservation's website to compare the data of the station closest to your community with one at a different location in the province. Explain the differences in the water quality data at each site.





**Figure 13.20:** Shallow, but fast moving, sections of streams often have more oxygen resulting in high quality water.

### FRESHWATER QUALITY

Natural seasonal changes bring changes to freshwater ecosystems. Some are related to temperature fluctuations and some are related to quantity of water.

Rate of movement also affects water's characteristics and has an impact on the nature of an aquatic ecosystem. **Standing bodies** of water, such as ponds or lakes, have little or no current, though streams and rivers may flow into and out of them. Standing bodies of water are slow moving systems. They tend to have more nutrients than faster moving systems and they have less oxygen.

Different varieties of plants, fish, and wildlife find habitat in different types of aquatic ecosystems. Each has adapted to the system's specific characteristics. Some species require different types of aquatic ecosystems at different points in their life cycles. For example, shallow but fast moving sections of streams often have more oxygen and gravel beds, which make excellent spawning locations for fish such as brown trout. Sections with shallow water but slower flow provide good habitat for young fish. Deeper water is cooler and has a slower flow and is more suited to mature fish that are looking for shelter, food, and shade.

A number of other environmental factors also affect the quality of ground and surface water. They are physical, chemical, and biological, and are created or introduced by processes that occur naturally in the environment. Many of these are measurable and have corresponding water quality guidelines.

Physical Parameters		Significance for Aquatic Life
	<b>Turbidity</b>	The measure of solid particles suspended in water —also called cloudiness. Cloudiness can affect light penetration, which can slow photosynthesis for underwater plants. Turbidity is measured photometrically (percentage of light that is either absorbed or scattered).
	<b>Colour</b>	Organic material in water can give it colour. The tea-coloured water common in Newfoundland and Labrador is caused by tannins and lignins, which are produced by decomposing wood and plant material. Colour is measured in true color units (TCU). It can affect light penetration.
	<b>Temperature</b>	Important for wildlife, particularly fish. Temperature affects how much oxygen can dissolve in water and can affect other chemical reactions.
	<b>Total solids</b>	Total solids (TS) are composed of total suspended solids (TSS) and total dissolved solids (TDS). TS is measured by evaporating a water sample and drying the remaining mixture. Suspended solids are solids that can be removed by filtration. Dissolved solids represent the “salt” content in the water. Suspended solids can affect fish (by clogging their gills) and add smothering layers over bottom-dwelling plants and creatures when they settle out.
	<b>Taste and odour</b>	Organic material in surface water, such as decomposing leaves and other plant material, can give water a taste or odour. In groundwater, they often result from dissolved gases such as methane or hydrogen sulphide. Odour is measured as a Threshold Odour Number, or TON. Substances that cause water to have an off taste or odour can have the same effect on aquatic life (so this parameter can cause problems for aquaculture or fisheries activities).
Chemical Parameters		
	<b>Dissolved Oxygen (DO)</b>	Measured in milligrams per litre. Fish and aquatic animals need oxygen to breathe.
	<b>Salinity</b>	The amount of salt dissolved in water – fresh water usually has less than 0.1% salt; seawater has about 3.5% salt. Different flora and fauna species are adapted to different levels.
	<b>pH</b>	The measure of a solution's acidity or alkalinity. Neutral solutions have a pH of 7. Acidity increases as pH drops from 7 to 1; alkalinity increases as pH rises from 7 to 14. Low pH is caused by natural geology, acid rain, or pollution; low pH (high acidity) can kill aquatic organisms (pH 4).
Biological Parameters		
	<b>Pathogens</b>	Pathogens are found in water on or near the surface, but rarely in water from deep underground. Common pathogens include bacteria, protozoa, fungi, algae, and viruses. Water is usually tested for E. coli bacteria for two reasons: its presence indicates pollution of the water source and its absence indicates the water is pathogen-free. Pathogens can harm life forms harvested in aquaculture such as mussels.

**Figure 13.21:** Key Water Quality Variables for Aquatic Life in this Province.  
Source: Department of Environment and Conservation



## Water Quality Testing

In this activity, you will evaluate the water quality of a local waterway through a series of indicator tests. The results of the water quality testing will enable you to identify the major threats to the waterway. Once data are collected you can combine the information and look for patterns and relationships between land use, community attitudes and behaviours, and water quality.

### Procedure:

#### Part A: General Information

Record the following information on the data sheet provided.

1. The name of the river, date sampled, and who did the sampling.
2. Describe the watershed area. Include: size, soil, rock characteristics, anthropogenic (human) influences, or other relevant information.
3. Record stream order. Stream order is a method of assigning a number to stream segments in a watershed. It indicates the relative importance of the segment within the drainage basin.
4. Site photographs (5 per site). Due to the expense of field collection, it is often impossible to go back to a site. Photographs of the location can often help to solve any problems that may arise during laboratory analysis. These photographs also provide a valuable record of conditions at the site.

#### Part B: Reach Characteristics

1. Flow State: This is a basic description of the type of habitat present at the site. It describes the stream and provides an indication of what type of organisms may be expected, as different plants and animals can withstand different amounts of water flow.
2. Canopy Coverage: The amount of canopy coverage is important for two reasons. First, canopy cover provides shade, which keeps the water cool in the summer. Second, extensive canopy cover can determine the relative amount of external (what falls in) versus internal (what grows in the water) plant material in the stream. That in turn affects the types of animals present. More plants mean more food. If there's lots of food, one would expect more animals.
3. Riparian Vegetation: The forested land along rivers, streams, and lakes is called the "riparian zone". This area protects the water from disturbance and acts as a buffer between the stream and general activities in the watershed. It protects the banks from erosion. The width of the riparian



**Figure 13.22:** Water quality testing.

zone from the bank is roughly the distance from the bank to the base of the tallest tree that could reach the channel.

### **Part C: Water Chemistry:**

The dissolved materials in freshwater come from eroded material originating in the drainage area or watershed of the river. The chemicals in the water come from both the underlying bedrock and the rock on the surface. Measurement of several key variables that affect the invertebrates can provide a great amount of information about the types of pollutants and their impact on a stream. Certain activities produce specific pollutants. By identifying specific pollutants, we can identify some activities that may be having an impact on the stream.

### **Temperature:**

Temperature is an important physical variable that directly affects many of the physical, biological, and chemical factors influencing aquatic organisms. Aquatic organisms survive within a specific range of temperatures. If it gets too cold or too warm, the animals can't tolerate it and they become stressed and may die. The result is a change in the types of organisms inhabiting the stream. Some of the factors that influence temperature are weather, removal of riparian vegetation, increased turbidity (suspended sediments in the water), and dams.

### **2. pH:**

The relative acidity of water is ranked on a scale of pH from 0 to 14. The pH scale is logarithmic. Each change of 1 pH unit represents a 10 fold change in acidity. A stream with a pH of 6 is 100 times more acidic than one with a pH of 8. Water with a pH of 6.5 to 8.5 is suitable for the greatest diversity of aquatic organisms. Young fish and aquatic insects are especially sensitive to extreme pH values outside their optimum range. Stream pH is usually determined by the surrounding geological makeup, but acid rain, wastewater discharges, and drainage from coniferous forests (which are acidic) can decrease the pH of a stream.

### **3. Conductivity:**

Conductivity is a measure of the dissolved salts present in the water. It is determined by how well these salts conduct an electrical current. For example, pure water has a conductivity of 0. Measuring conductivity is a good way of determining how much dissolved material is present in the water. Conductivity is a useful tracer of point source discharges and sudden increases along a stream can indicate a pollution source.

### **Part D: Benthic invertebrate sampling:**

In aquatic ecosystems, populations of macro invertebrates are often studied because they give a good indication of the health of watersheds. They are widely used because they are fairly easy to collect and identify. They also reliably reflect the condition of the environment they live in.

Benthic macro invertebrates are important in moving energy through food webs. The term “benthic” means “bottom-living”. These organisms usually inhabit bottom substrates for at least part of their life cycle. The prefix “macro” indicates that these organisms are caught by net mesh sizes of 200-500 mm. They are big enough to see easily.

The most diverse group of freshwater benthic macro invertebrates is the aquatic insects. They account for around 70% of the known species of major groups of aquatic macro invertebrates found in North America. More than 4000 species of aquatic insects and water mites have been reported from Canada. Thus, as a highly diverse group, benthic macro invertebrates are excellent candidates for studies of changes in biodiversity.

### **Part E: Substrate characteristics**

The composition of the streambed material is important in identifying hydrological characteristics of the river and the type of habitat available to aquatic organisms. Insects need to attach themselves to the stream bottom or live within the bed materials. The more attachment or living spaces available the greater will be the variety and number of organisms found. Gravel provides a lot of suitable habitat. Bedrock or sand does not. With an increase in the amount of sand and silt present, the suitability and availability of living space for invertebrates decreases, even if there are rocks under the sediment.

- i. **Dominant Substrate and Embeddedness:** A substrate score can be assigned based on the size of the two main substrates, the size of the material around the main substrates, and the amount of embeddedness.
- ii. **Substrate Dimensions and Water Depth:** A final estimate of the size of the substrate is obtained by simply measuring a randomly selected sample of the substrate.
- iii. **Stream Width:** As flow decreases, water will cover less of the stream bottom. This limits the available habitat for aquatic organisms.
- iv. **Stream Cross-section, Flow, and Discharge:** The shape of the channel and thus the habitat available for invertebrates is a

consequence of the local geology and the total discharge of the stream. For many small streams there are no discharge records available and in these cases, current discharge can be estimated from the cross-sectional area of the stream and the flow of water through the stream.

- v. Velocity: In addition to determining discharge at selected points, it is important to obtain a measurement of the velocity from the area from which the invertebrate sample was taken, as this represents the conditions to which the invertebrates are exposed.

This completes the field measurements. As a final check, verify that all of the field measurements have been taken and are legibly recorded. Ensure that all equipment is taken with you from the site.

### Analyze and Conclude:

1. What areas of the stream showed the greatest diversity? What areas had the lowest diversity? Explain why.
2. Describe how water pollution might affect the diversity you observed.
3. How do adaptations of the insects allow them to inhabit different niches in an aquatic ecosystem?
4. How would groundwater and rainwater entering a stream affect its temperature?
5. Explain why turbidity often increases in a stream when the flow increases.
6. How does pH affect aquatic life in a stream?
7. How might different land uses (logging, agriculture, construction) affect turbidity, pH, and temperature of nearby streams?
8. What are the characteristics of a healthy stream? What would make a stream “unhealthy”?
9. Describe what will happen when the balance of a natural stream is disturbed.
10. Which macro-invertebrates are most sensitive to pollution?
11. Which macro-invertebrates are tolerant to pollution? What does information like this tell us about the stream quality and overall health?
12. Why does a stream bed need lots of gravel rather than sand and clay?

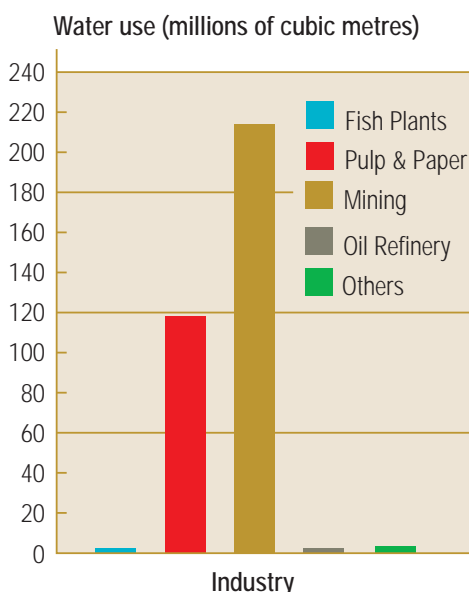


## FRESH WATER QUALITY: THE HUMAN FACTOR

If human activities do not take place inside a framework of stewardship or sustainability, they can have a big impact on the quality and quantity of ambient water.

### Did You Know?

Fish processing plants in this province use fresh and salt water. At peak production, the average plant uses 10,000 m<sup>3</sup>/year. This is a tiny amount compared to the pulp and paper, and mining industries here. Mining uses 215 million m<sup>3</sup>/year. Pulp and paper production uses just under 120 million m<sup>3</sup>/year.



Large volumes of water are used by industries such as mining and pulp and paper production. Other activities involved in logging and mining also use or affect ambient water, as do hydroelectric power dams.

This section examines the impact that industrial and domestic activities can have on the quantity and quality of water resources in Newfoundland and Labrador.

**Figure 13.23:** Annual average water use by industry in Newfoundland and Labrador.

*Image courtesy Department of Environment and Conservation*

### Preventative measures and best management practices for forestry:

- Leave large buffer zones of uncut areas along stream channels and water bodies.
- Protect and retain wetlands.
- Maintain as much vegetation cover as possible (high biodiversity).
- Keep exposed soil surfaces to a minimum.
- Minimize the road network and stream crossings.
- Prevent direct drainage into streams, lakes, and wetlands.
- Minimize water yield changes by reducing the harvested area.
- Use innovative vegetation management (type, diversity, density, structure, vegetation).

### The Impacts of Forestry Activity

Newfoundland and Labrador forests are harvested for pulpwood and lumber. In addition, the public, with appropriate permits, can harvest trees for firewood on crown land.

Carrying out forestry operations involves several activities that can affect water quality and aquatic habitat. They include: harvesting, replanting, road construction and maintenance, and even long-term management. These operations can, at various times, change water levels, stream temperatures, sediment dynamics, nutrient dynamics, and stream habitats. In some cases they also introduce pesticides and herbicides and change the vegetation cover.

Of all these activities, road construction and maintenance may have the greatest impact on watersheds if not developed carefully. The least costly way to build these access roads is through a valley bottom, which can have the greatest impact on a stream. Roads can divert the natural stream, change surface characteristics and increase surface compaction, and change surface runoff and subsurface water flow. Among other effects, roads can change the sediment dynamics in water bodies and the rate and pattern of their flow. Over time, when roads are not used, their disintegration can lead to blocked culverts, flooding, and changes in stream flow regimes. The federal government, under authority of Fisheries Act provisions regarding habitat, has guidelines for road development designed to minimize impact.

Logging can drastically change the surface and subsurface conditions in a watershed. The effect is often cumulative, making it harder to foresee impacts while the trees are being harvested. Removing trees affects evapotranspiration and drainage, which can lead to more extreme temperature regimes. The impact of losing the forest cover on stream temperature can be dramatic. Some temperature increases can be beneficial for productivity, but large swings in temperature can be lethal to fish.

In addition to lethally high summer water temperatures, the effects of increased stream temperature caused by loss of forest protection on fish can include:

- accelerated development of embryos in gravel and earlier emergence in spring;
- inhibition of migration;
- increased susceptibility to disease;
- higher respiration rate and reduced metabolic efficiency; and
- changes in competitive advantage.

Traditional clear-cutting methods and partial logging result in different pressures on the freshwater habitat. Clear cutting affects flooding, increases sediment production, and leads to greater terrain instability and more rain-on-snow events (flooding). The more dispersed activity pattern of partial logging on the other hand, leads to a more extensive road network and the negative effects associated with that infrastructure, continuous disturbance and more edges to the remaining forest areas (which can affect **microclimates**).

The rate of pesticide and herbicide use in forestry is relatively low compared to use in agriculture, but can be more widespread. Low doses mean low risk, but risk from aerial applications increase due to wind drifts with a potential direct impact on the food chain. This is of most concern where groundwater replenishment allows the chemicals to leach into aquifers.

### The Impact of Mining Activity



Mining can cause ground disturbances that affect water quality. This is one of the reasons why real-time water quality stations have been set up near Voisey's Bay in Labrador and other mine sites in the province. Additional monitoring of all discharges from mining sites is required under the Certificate of Approval process that the provincial government oversees.

**Figure 13.24:** Water quality monitoring, Voisey's Bay, Labrador.  
*Photo courtesy INCO*

### Preventive Measures and Best Management Practices for Mining

These steps can minimize the effects of mining on ambient water:

- Minimize the area that will be disturbed as well as the road network.
- Stockpile and re-use the best soil material.
- Maintain tailing ponds and build a series of secondary emergency ponds.
- Take steps to avoid groundwater contamination.
- Maintain saturated conditions to minimize oxidation.
- Take precautionary measures to avoid acid drainage.

The effects of mining can be local or regional, short-term or long-term. The impacts on streams, lakes, and wetland environments vary depending on the:

- mineral being mined;
- extraction process: strip, pit, or underground mining;
- reclamation, treatment, and mitigation techniques being used;
- site conditions; and
- local climate (including rainfall amounts).

Mining activities (surface and underground) involve removing vegetation, surface soil, and rock. The ore is extracted, tailings dumped, and when mining operations are completed, the area is **reclaimed**. These activities affect surface runoff, groundwater flow, and impact the regional groundwater table.

Some mining operations have the potential problem of acid mine drainage. Many metals such as lead, zinc, copper, and gold occur in sulphide-based ore bodies. When mined and exposed to the air, sulphide rapidly oxidizes and forms sulphuric acid. The processed rock ore, which can still contain these sulphites, is usually deposited into tailings ponds as slurry. The ponds are considered permanent storage. As long as the tailing material is covered by water, the sulphides are not harmful. However, this system has its risks. If, for any reason, the ponds begin to drain, or their containment structure fails, then the highly toxic sulphuric acid is created and the metals are released. The effects of such failures on the ecosystem and the watershed are catastrophic and can last for decades. When acid is released into the environment it can:

- reduce decomposition processes;
- harm fish and aquatic biota—few fish can tolerate conditions below pH 4.5;
- harm local biodiversity and possibly impact on Species at Risk;
- make metals more soluble in water and sediments; and
- lower the quality of drinking water sources.

For these reasons, after mining has stopped, tailings ponds and rock dumps require long-term monitoring, water detention, and treatment to ensure there is no environmental damage. Building and managing a safe, structurally sound tailings pond is crucial to prevent overflow, seepage, and structural failure that can release untreated water and cause environmental damage downstream.

Some mining processes produce salts and limestone (depending on climate conditions and rock materials), which can make their way into the ambient water. The effects of this include increasing both pH levels and dissolved solids levels.

Mining activities often involve water diversion. This will change flow patterns downstream and affect fish habitat and biota (flora and fauna) that lives there. Large amounts of sediment enter the water and must be managed to reduce their effect on the environment.

Finally, most mines move and deposit large quantities of material—soil, rock, and gravel. Unless it is well contained, this loose material can be moved by rain and flooding. It must not be allowed to enter streams or other water bodies directly.

Currently, there are strict federal and provincial regulations in place to help determine mining companies from damaging the environment. However, enforcement of these regulations, particularly in remote mine sites, presents its own set of challenges.

### The Impacts of Hydroelectric Development



**Figure 13.25:** A hydroelectric dam near Deer Lake, Newfoundland.

*Photo courtesy Department of Environment and Conservation*

### Did You Know?

- Canada has the highest net generation of hydroelectricity in the world.
- There are 200 dams used for hydro power in Newfoundland and Labrador.
- Most of the province's electricity needs are met with water power.

Hydroelectric power development has the reputation of being a **clean** or green energy source with few environmental impacts. This is only partially true. Hydroelectric power does have many advantages over fossil-fuel burning methods, but there are also a number of negative impacts associated with hydroelectricity.

These include:

- high long-term environmental costs;
- not meeting the proposed benefit-cost ratio—that is, the reservoir's life is often much shorter than estimated when it was built;
- disruption to people and wildlife caused by reservoirs; and
- cumulative and heavy impacts downstream.



Hydroelectric facilities may or may not meet standards for **green certification**. Their advantages or disadvantages are related to such things as location, technologies used and their impacts on the land, the water course, and the biota.

Most hydro developments require building a dam which increases (and helps control) the amount of water available to a power plant. The dam creates a reservoir by blocking a river's natural flow. The presence of the dam, as well as the interruption in flow, has a variety of environmental impacts.

### Environmental Impacts of Dams and Reservoirs

- Upstream land area changes from a valley to a reservoir (a terrestrial to an aquatic environment). Each type has separate systems of flora and fauna. This results in a loss of habitat for some species and a gain for others. It may also affect Species at Risk.
- The river changes from a flowing to a larger standing body of water with different temperature ranges and nutrient and oxygen levels.
- The presence of the new reservoir can modify the microclimate.
- The dam changes the evaporation and groundwater regimes.
- Biodiversity can be reduced as a result of the four points listed above.
- Bioaccumulation of pollutants, mercury in fish, for example, can increase.
- The river below the dam changes due to changes in quantity and flow rates.
- Water quality below the dam changes and sediment transport is reduced.
- The river changes its flow pattern and rate, which can result in less flushing in downstream areas in the summer.
- Dams can obstruct migrating fish.
- There is a loss of riverine/**riparian**/flood-plain habitat because there is less flooding.
- There is an increased release of greenhouse gases (CO<sub>2</sub> and methane) into the atmosphere from decomposing plants and animals killed by flooding the reservoir.

### Did You Know?

The Churchill Falls hydroelectric project flooded a huge area. However, because of its northern location, the reservoir was not a major producer of CO<sub>2</sub>. Large tropical reservoirs can produce more greenhouse gases than a modern coal-fired generator. However, it has been estimated that the flooding displaced 990 pairs of geese, 1,400 pairs of Dabbling Ducks, and 3,740 pairs of Diving Ducks.

The creation of a large reservoir has another, more global, environmental effect. The new lake kills plant and animal species, which cannot adapt to underwater conditions. Shortly after flooding dead organisms from the bottom of the reservoir begin to decompose producing two of the harmful greenhouse gases, carbon dioxide and methane. The process is more pronounced in warmer climates.

In addition, the newly submerged ground may be a source of heavy metal contamination such as mercury. Any heavy metals that enter the aquatic ecosystem will quickly enter the food chain and begin to accumulate in plants



**Figure 13.26:** Large city encroaching on wetland area.

### Implications of Interfering with Wetlands

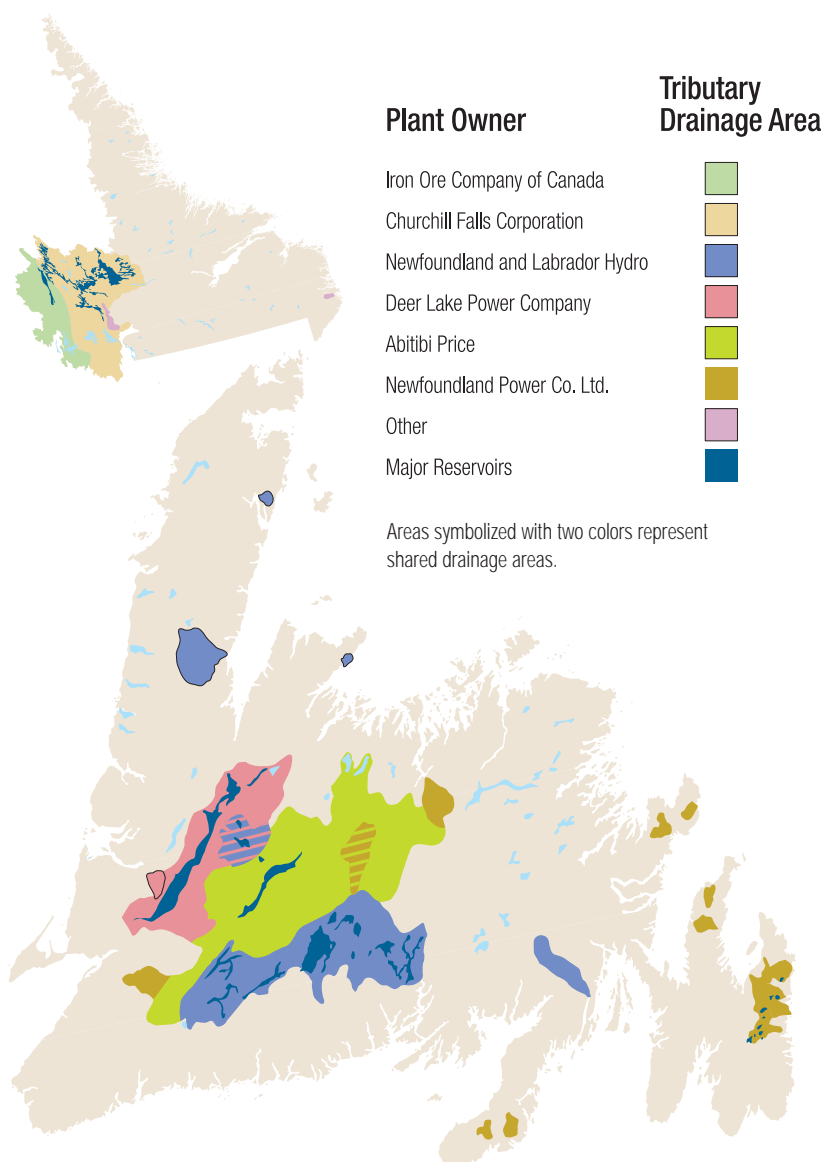
Urban expansion, road building, and an increasing demand for land for industrial purposes can affect many types of environments. However, these intrusions are particularly devastating for wetland ecosystems.

The most dramatic changes occur when wetlands are drained for development. But these areas are also threatened and can deteriorate, or even disappear, when roads and buildings are permitted to be developed too close to their boundaries. How?

- Roads and ditches can alter the flow of water and thereby drain wetlands.
- Drainage from nearby development can send fertilizer, pesticides, herbicides, and pollutants into the wetland areas. This can increase the nutrient level of the wetland and affect plant life. The presence of the nutrients can change the wetland habitat in less than ten years.

Over eighty percent of the wetlands near major urban centres have been converted to agricultural use or urban expansion.

## Hydroelectric Developments Newfoundland and Labrador



**Figure 13.27:** Hydroelectric developments across Newfoundland and Labrador. The effects of hydroelectric development extend far beyond the development itself. *Photo courtesy Department of Environment and Conservation*

and animals (bioaccumulation). The toxic effects of heavy metals are seen in higher order predators first such as birds of prey.

Water is used to cool the machinery involved in power generation. This heated water is returned to the water source, which can unnaturally rise its temperature. Water that we would find too cool for a bath (27° C) is lethal to a trout. Unnatural warmth can disrupt the natural balance of an ecosystem and must be avoided.

## Did You Know?

All of the Atlantic Provinces de-ice their roads with salt or sand. Road salt contains chloride, sodium, sulphide, calcium, potassium, iron, silicate, aluminum, magnesium, and manganese. These substances dissolve in water and eventually are added to surface water bodies or seep into the ground and enter the water table.

### The Impacts of Urbanization

There are several ways that the presence of cities and communities affect local water quality. First of all, they can reduce the amount of water absorbed in to the soil. For example, paved roads and parking lots create areas where precipitation cannot be absorbed into the ground as it once was. Downspouts from buildings that feed directly into storm water drainage systems further reduce the amount of water that goes back into the **water table**. Paving also removes vegetation, which reduces **transpiration**.

Related changes and effects include:

- There is increased runoff.
- Streams become much flashier, with rapid changes in water flows and levels.
- Stream systems have more erosive power and stream banks become unstable.
- Stream bank alteration destroys riparian vegetation resulting in loss of large woody debris and higher summer temperatures.
- Water quality deteriorates because contaminants (oil, salt) that are generated by cars and trucks and by road treatment are not absorbed by soil and vegetation, but are instead flushed quickly into the stream system.

These impacts occur almost immediately after roads and paved areas expand.

There are also long-term and cumulative impacts to consider:

- A variety of pollutants from known and unknown sources can be added from the urban watershed. Concentrations of these pollutants will vary greatly over time.
- Many pollutants can interact with each other to intensify their impact on the ecosystem.
- Many factors related to water quality (pH, alkalinity, hardness, dissolved organic matter) and sediment quality (particle size, organic matter content, presence of iron, and manganese oxides) can also determine how pollutants interact and affect aquatic biota.

### The Impacts of Recreation

Some recreational activities can have an adverse effect on the water quality and aquatic habitats. Some of the actions or activities that can affect aquatic environments include:

- re-arranging or removing vegetation on land or in the water that provided specific habitats;
- changing shoreline configuration;
- using fertilizer or pest control sprays;
- shampooing in the water;

## Recreation Water Use in Newfoundland and Labrador

Type of Recreation Area	Total
National Parks	2
Provincial Parks	54
Cottage Areas	100
Canoe Routes	30
Schedule Salmon Rivers	159

**Figure 13.28:** This chart shows the number of designated recreational areas in Newfoundland and Labrador. Leisure activities can adversely affect water in these areas. *Courtesy Department of Environment and Conservation*

- creating a beach where one did not exist before;
- dumping or spilling gas, oil, paint, or varnish into the water or near your drinking water supply;
- running sewage or grey water waste into the pond, lake, or ocean;
- speeding in your boat in areas that are susceptible to wake disturbance; and
- dumping fish offal into the water (which can attract pests and can add nutrients to the water).



**Figure 13.29:** Use caution when operating recreational vehicles.

## CHECK your Understanding

## Did You Know?

One drop of oil can render up to 25 L of water unfit for drinking.

1. What is the relationship between turbidity of water and the depth to which light can penetrate it?
2. How is land use related to water quality and quantity?  
Can you provide local examples?
3. What are the similarities between domestic and industrial water use?
4. How can the addition of nutrients, such as nitrates and phosphates, result in a reduction of the amount of dissolved oxygen in the water?
5. What are some activities that influence water quality during forestry operations?
6. Why is tree harvesting on a steep hill near a water body prohibited?
7. How may clear cutting during forestry operations affect nearby water habitats?
8. What is the concern for freshwater environments due to acid mine drainage?
9. What are the potential environmental impacts of a large scale hydroelectric development?
10. Although hydroelectric developments are considered “green” sources of energy, how can they release large amounts of carbon dioxide and methane?
11. How does urbanization influence the amount of water entering surrounding rivers?



## Chapter 14: Drinking Water



**Figure 14.1:** We take it for granted that the water we drink is safe.

One of the most essential human uses of water is for drinking. In the Western world, many people take it for granted that you can turn on the tap and safely drink the water that flows out. Much research, legislation, and effort goes into ensuring that this is so.

*In the Western world, many people take it for granted that you can turn on the tap and safely drink the water that flows out.*

Water that is fit for drinking is called **potable water**. We often think of good water quality in terms of our senses: it looks clear and it tastes and smells good. These sensory appraisals are not safe tests for potable water. Many harmful substances that cannot be detected by the human senses are found in water.

### Did You Know?

More than 500 water supply systems serve the communities in this province.

Ambient water can be contaminated by natural and human processes and actions. To determine if water is safe to drink, it must be sampled, tested under controlled circumstances, and the results compared to the guidelines for drinking water quality. In addition, all public water supplies must be disinfected.

Before we look at the various ways water is treated, let's take a closer look at our drinking water sources.

## DRINKING WATER SOURCES IN NEWFOUNDLAND AND LABRADOR

Unlike people in many other parts of the world, Newfoundlanders and Labradorians are fortunate to have an abundance of water sources to draw on for drinking water. These sources are regularly replenished by precipitation.

### Did You Know?

The drilled well in Badger can supply almost 900 litres per minute. Once the water reaches the surface, it is pumped to a storage tank on a hill. The tank's elevation is high enough to give the required water pressure through gravity only—no extra pumping is needed. From there it flows by gravity into the town.

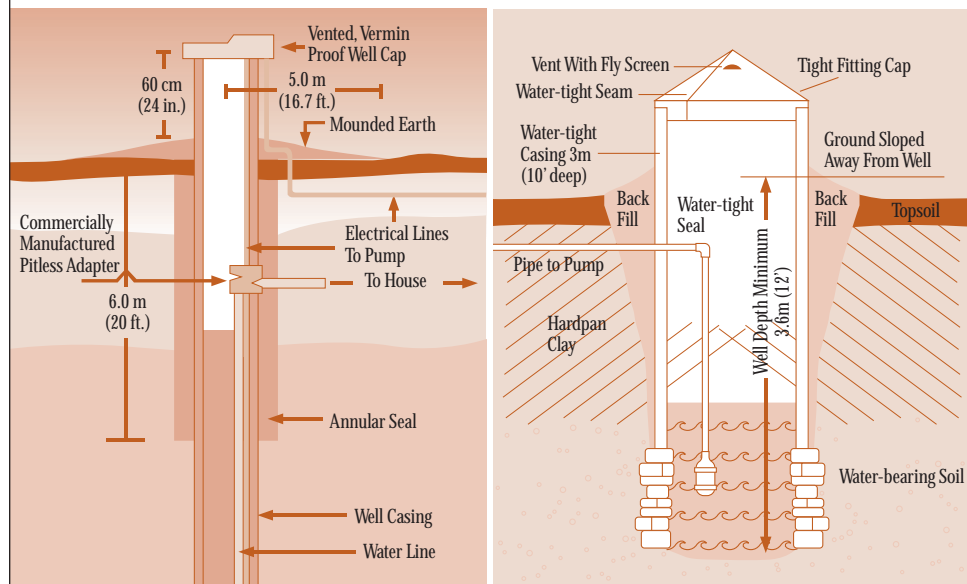
This process is more energy efficient than pumping water on demand, and it provides water reserve if the pumping system has to be shut down temporarily for any reason.

Most residents of the province depend on public water supplies for their domestic water needs. Just over half of the public water systems draw on surface water. These source ponds, lakes, reservoirs, and rivers are numerous and easily accessible.

The rest of the population uses groundwater supplies, which are accessed through dug or drilled wells (private or public). Another source of potable groundwater in Newfoundland and Labrador is from springs. There are about 200 public groundwater sources in the province. Drawing on this reliable source of drinking water has some advantages. Groundwater is accessible, renewable, and generally safer than surface water. In contrast to untreated surface water, it usually has fewer pathogens and is cool year round.

### How deep do we dig?

In this province, dug wells are usually between two and five metres deep depending on how far down the bedrock is. Drilled wells are usually deeper (15 to 150 metres), averaging 45 metres deep and 15 centimetres in diameter.



**Figures 14.2:** Diagram of drilled and dug wells showing provincial specifications.

*Photos courtesy Department of Environment and Conservation*

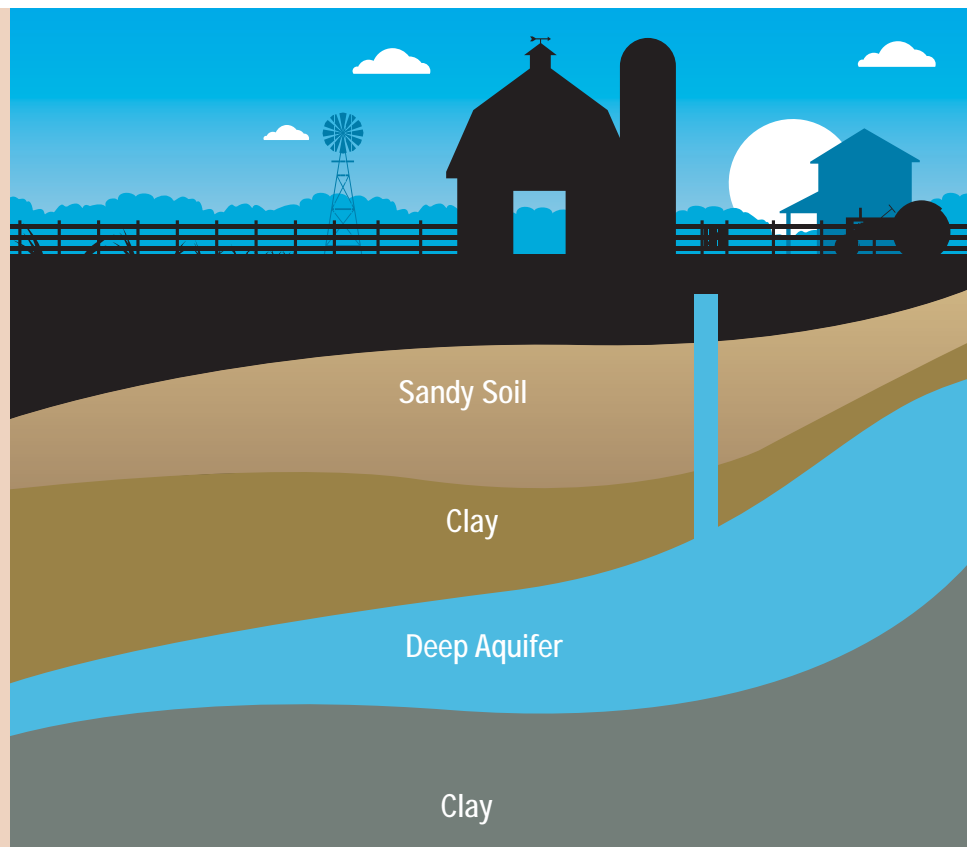
Tapping groundwater can be a cost-effective method of supplying drinking water. Many of our rural communities are spread over large areas. It is more economical to provide wells for clusters of houses and businesses than to construct long waterlines from a single surface source to service buildings that are a long way from the surface water and from each other.

Factors that limit the use of groundwater wells for public water supplies include: aquifers with poor yields, salt water intrusion into the water source, and other sources of natural or human-caused contaminants.

The quality of groundwater can also be affected by the kinds of rock and soil formations through which it flows, and by how long it stays in the ground. In general, shallow groundwater flows faster and has less dissolved material in it than deeper groundwater.

### Aquifers

An aquifer is an underground formation of permeable and porous rock, which can produce useful quantities of water when tapped by a well. Aquifers can vary in size and depth below the surface. They can vary in thickness from a few metres to hundreds of metres from top to bottom. They can be only a few hectares in area or underlie thousands of square kilometres of land area.



**Figures 14.3:** Aquifer. *Illustration courtesy Derek Peddle*

The natural quality of a groundwater source differs from a surface water source in two main ways:

1. Its quality, temperature, and other parameters vary less over time.
2. The range of material that can be dissolved in it is much greater.

As groundwater flows through an aquifer it is naturally filtered. Therefore, groundwater usually has less suspended material than surface water. This filtering, plus the length of time the water is stored underground, helps ensure that groundwater is usually free

## How to protect groundwater sources

### DO:

- Do inspect your oil tank for leaks.
- Do keep livestock away from wells.
- Do locate wells and septic tanks at least 16 m apart.
- Do put your septic field downhill from your well (and follow the Department of Health regulations).
- Do have a secure cover on your well.
- Do seal abandoned wells.

### DON'T:

- Don't dump waste oil on the ground.
- Don't store gas or cleaning fluids near a well.
- Don't apply more pesticides or fertilizers than recommended.
- Don't flush large amounts of household cleaners down the drain (it can kill the bacteria in your septic tank).
- In coastal areas, don't drill a well deeper than the level where you first encounter fresh water.

of disease-causing micro-organisms. As you will see later in this chapter, with the Walkerton case study, a source of contamination close to a well can still be harmful to human health.

### Community Wells: Where to Drill?

How do town councils decide where to drill public water wells?

The short answer is: with great care. Unlike surface-water sources, which are plainly visible, a lot of planning must go into choosing the location for a well where the water is unseen.

Years ago it was not uncommon to have a local “dowser” or “water witch” walk around the community holding out metal rods or a Y-shaped stick. When the rods bent down uncontrollably, the spot was deemed a likely location to find water. There is no scientific basis for this method, but many people still believe it works. Community well locations today, however, are chosen by a hydro-geologist or engineer trained in locating underground water sources.

The process begins with an assessment of how much water the community needs. Then the investigative work starts. A typical plan covers these points:

- Review existing water well records in the area for information including:
  - well yield;
  - depth of the bedrock;
  - locations where groundwater was encountered; and
  - groundwater quality.
- Review of geology maps. Wells drilled into bedrock typically have lower yields than wells drilled into more porous materials such as sand and gravel.
- Talk with well owners and well drillers who are familiar with the area.
- Check for a history of contaminants spilled in the area.
- Review aerial photos which can show fault lines in the bedrock (good places to drill for groundwater).
- Review land ownership.

Based on the results of this investigation the council then has the information it needs to select a site and drill a well. This process usually creates suspense and anticipation as the hole is drilled—





**Figure 14.4:** A well that is being drilled with the hope of “striking” water in both high quality and high quantity.

will they find any water? How much water will be found? Will it be good water? And, will there be a high yield? A “high-yield well with good groundwater quality” is a reliable source with enough water for the community’s needs without costly treatment.

After water is “struck”, the well undergoes a pump test for several days to find out if the water yield is sustainable. A well that has lots of water for a few days but then goes dry is of little use. But if the well continues to replenish itself as fast as the water is pumped, then it is determined to be a reliable source of water. The next step is to build a distribution system that connects the local users to the water source.

Sometimes more than one well is needed to meet the water needs of a community. A number of wells are drilled and the resulting system is called a **well field**. Wells in a well field must be drilled far enough apart that they do not drain water from each other. Stephenville and Happy Valley-Goose Bay are two communities served by well fields in Newfoundland and Labrador.



**Figure 14.5:** A sinkhole in Newfoundland and Labrador. As you can see, a sinkhole-prone area is a risky place to build a house.  
*Photo courtesy Department of Environment and Conservation*

### What causes sinkholes?

Although they are not common in Newfoundland and Labrador, sinkholes do exist here. A good example is the one in the community of Woodville in the Codroy Valley. Woodville is underlain by gypsum. Groundwater flowing through gypsum can cause it to dissolve, causing cavities to form underground. The cavities enlarge over time and even reach the surface. When they do, they form a sinkhole. Some breakthroughs happen suddenly, but most are gradual.

## PATHOGENS AND DRINKING WATER

Water can support thousands of biological species, from microscopic organisms to large fish. When it comes to drinking water, the most important waterborne biological species to be aware of are those that are classified as **pathogens**.

They are the species of organisms that can infect humans or transmit diseases. Pathogenic species include viruses, bacteria, protozoa, and parasitic worms.

A virus is the smallest biological structure known to contain all the genetic information necessary to reproduce. Viruses are so small they can only be seen with a powerful electron microscope. They cannot replicate without a living host.

Bacteria are the most abundant of all organisms on Earth and can be both harmful and useful to the environment or to humans. These single-cell microorganisms play a role in disease, but they are also important in natural decomposition.

Protozoa are highly adaptable unicellular organisms that are more complex than bacteria or viruses. They can be either free-living or parasitic. Many species are found in water, but only a few species are pathogenic.

Parasitic worms, also called helminthes, often need two or more animal hosts. They pose the most danger to people who come in direct contact with untreated water. Among the people with most exposure are sewage plant operators, people who swim in lakes polluted by sewage or by storm-water runoff from cattle feedlots.

Many pathogens are not native to aquatic systems, but they can survive in natural water systems. In most cases, they need an animal host to grow and reproduce. While in water, they can maintain their infectious capabilities for significant periods of time. Disinfectants and boiling can kill bacteria and other pathogens in drinking water, thereby preventing contamination and reducing the risk of infection.



Figure 14.6: E. coli bacteria.

Figure 14.7: Significant Common Pathogens

Pathogen and common example	Symptoms
Bacteria— E. coli	From severe vomiting and diarrhoea to minor intestinal irritation and nausea.
Protozoa— Giardia	Diarrhoea, gas, cramps, upset stomach, and nausea.
Virus— Hepatitis	Fatigue, joint aches, abdominal pain, vomiting, loss of appetite, dark urine, fever, enlarged liver, and jaundice.
Parasitic worm — Tapeworm	Symptoms vary depending on the type of worm, but can include upper abdominal discomfort, diarrhoea, and loss of appetite. The worm lives in the intestinal tract of humans and steals the nutrients from digested food.

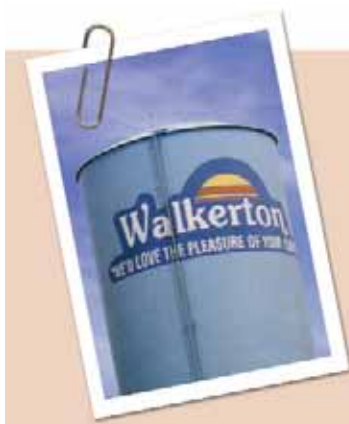


**Figure 14.8:** Giardia. Boiling all water for 5 minutes is the best way to destroy pathogens in water.

### ***Giardia*— A Naturally Occurring Threat**

In this province, *Giardia* may be present in the surface water of ponds, rivers, and springs. People who drink water contaminated by this protozoan parasite may become infected. The symptoms include dehydration and more severe complications. This disease is often called Beaver Fever because that animal was once thought to be the source of the disease.

In fact, *Giardia* cysts may be found in the wastes of any animal. During its life cycle the *Giardia* parasite lives in an intestinal tract of many wildlife species. It is then excreted with the feces which in turn may contaminate surface water. *Giardia* can be destroyed by boiling water for at least five minutes before using it for drinking, cooking, or brushing teeth.



## **ENVIRO-FOCUS**

### **When Human Error Threatens Water Quality**

In 2000, one of Canada's worst water contamination tragedies struck the people of Walkerton, Ontario. A town of less than 5,000, located about 200 kilometres northwest of Toronto, Walkerton is in an agricultural area. Its municipal water supply comes from a well field.

Following heavy rains in early May of 2000, one of the wells was unknowingly contaminated with a deadly form of the *E. coli* (*Escherichia coli*) bacteria. As a result of drinking the contaminated water, seven people died and more than 2,300 became ill. The source, it was later discovered, was cattle manure spread on a nearby field.



**Figure 14.9:** The Walkerton Memorial. The people of Walkerton created this memorial water garden to commemorate the tragedy of 2000. Photo courtesy Dr. S.E. Hurley



*E. coli* is a type of fecal coliform bacteria usually found in the intestines of animals and humans. A water source where *E. coli* is present has been contaminated by sewage or animal waste washed into the water source by rainfall, snow melt, or other types of precipitation.

There are hundreds of strains of *E. coli*. Most are harmless, but *E. coli* O157:H7 produces a toxin that can cause severe illness. Infection leads to diarrhea, abdominal cramps, fever, and dehydration. Infection can also cause kidney failure in some people (mostly children under five years of age and the elderly).

These are some of the key events and responses that took place in Walkerton in 2000. The following timeline shows how quickly the crisis developed.

<b>May 12</b>	Torrential rains wash bacteria from cattle manure over the area near one of Walkerton's town wells (Well 5). Authorities knew this shallow well (fifteen metres deep) was susceptible to pollutants. It was drilled in 1978 without approval from the provincial government. The environment ministry said it could be used if chlorination piping was installed to kill bacteria. The installation was never performed.
<b>May 13</b>	Over the next few days, residents were exposed to <i>E. coli</i> O157:H7 through the town's tap water.
<b>May 15</b>	The town's Public Utilities Commission (PUC) began drawing water samples for testing.
<b>May 17</b>	The first symptoms of <i>E. coli</i> infection appeared. Family and emergency room physicians did not detect a pattern (and thus the public-health threat) for two more days. Some suspected food poisoning and, tragically, suggested patients drink more water.
<b>May 18</b>	The Public Utilities Commission (PUC) received a fax from a lab confirming <i>E. coli</i> O157:H7 contamination from the May 15 samples, yet Water Manager Stan Koebel failed to notify the Ministry of the Environment or the public health office.
<b>May 19</b>	The region's Medical Health Office (MHO) learned several patients had <i>E. coli</i> symptoms. Staff at the office made repeated calls to the utility over the next few days asking about the safety of the water. According to Dr. Murray McQuigge, the medical health officer for Grey-Bruce County at the time, the utility reported no problem.



<b>May 21</b>	The MHO began independent water testing and issued a boil-water warning.
<b>May 22</b>	The first death directly linked to <i>E. coli</i> O157:H7 was reported.
<b>May 23</b>	Health officials' tests confirmed <i>E. coli</i> O157:H7 contamination of Walkerton's water. By now, more than 150 people are reported to have sought hospital treatment and another 500 were complaining of symptoms. A two-year-old girl becomes the second person to die from the disease.
<b>May 24</b>	Dr. McQuigge stated: "This is Canada's worst outbreak of <i>E. coli</i> ". More cases were expected ( <i>E. coli</i> O157:H7 has an incubation period of up to ten days and can spread from person to person).
<b>June 12</b>	Walkerton started cleaning up, beginning with a house-by-house disinfection program. Throughout the summer, chlorinated water was pumped through 2,500 locations to treat water pipes and five kilometres of water mains were replaced, as was Well 7's filtration system. Walkerton remained under a boil-water order.
<b>July 25</b>	The seventh person died from <i>E. coli</i> O157:H7.
<b>November 16</b>	The Province declared Walkerton's water supply safe, but let the health office deal with lifting the boil-water advisory.
<b>December 5</b>	The health unit lifted the boil-water advisory. Some residents remained unsure about the safety of drinking tap water. Later, a 2002 study found that most people who fell ill from <i>E. coli</i> O157:H7 infection had "recovered", though hundreds still suffered from gastrointestinal problems.

**Figure 14.10:** Walkerton's Well 5. The well, which became contaminated, was permanently decommissioned and a memorial plaque erected at the site.  
Photo Courtesy Dr. S.E. Hurley



The Ontario Government called an official inquiry into the events. Headed by Justice Dennis O'Connor, it issued two reports in 2002. The second report listed ninety-three recommendations regarding safeguarding public water supplies. It can be found online at:  
[www.attorneygeneral.jus.gov.on.ca/english/about/pubs/walkerton/](http://www.attorneygeneral.jus.gov.on.ca/english/about/pubs/walkerton/).

There are several notable aspects to this tragedy:

- The events occurred despite the fact that there had been problems noticed with the water supply over a period of time.
- The inquiry concluded that the crisis was not due to inadequate regulation, but a failure to observe and enforce existing regulations, plus lack of training for the operators of the municipal water treatment plant. It was apparent that the operators (two of whom were charged criminally and convicted) did not know how to respond to unusual test results. Despite guidelines and regulations, they:
  - failed to use appropriate doses of chlorine;
  - failed to monitor chlorine residuals daily;
  - made false entries about residuals in operating records; and
  - misstated the locations at which microbial samples were taken.

### *It was a wake-up call for those who manage drinking water across the country—and for the water-drinking public.*

It was a wake-up call for those who manage drinking water across the country—and for the water-drinking public. Despite all that happened, however, a 2001 Ontario study found that half of provincial water plants were still violating safety laws implemented after the tainted water tragedy. In 2002, the Ontario Government passed the Safe Drinking Water Act as well as a number of regulations. The purpose of the Act was to safeguard health by controlling and regulating drinking water systems and testing.

The first recommendation of the Commission of Inquiry dealt with aquifer protection and management, and advised a watershed-based source protection system.

It points out how widespread is the misguided perception that groundwater is safe and clean—and the tragedy that can result from not understanding and acting on proper water-quality guidelines and management practices.

### **Walkerton: Measuring the Costs**

In addition to the deaths and health issues, Justice O'Connor's report estimated these dollar costs for the events in Walkerton:

- At least \$64.5 million in total, but if human suffering is factored in, the total rises to \$155 million.
- Every household in the town spent about \$4,000 on average (total of \$6.9 million).
- Real estate values in Walkerton fell a total of \$1.1million.
- Costs for businesses (for bottled water or disinfecting and replacing equipment) totalled about \$651,422.
- Lost revenues (May 1, 2000 to April 30, 2001) were about \$2.7 million.
- More than \$9 million to disinfect and fix the town's water system.
- The Ontario Government spent about \$3.5 million on legal fees and another \$1.5 million to supply clean water to institutions.

Others connected to the tragedy have estimated that the boil-water advisory added three to four extra work hours to every adult's day. Municipal taxes in Walkerton rose to three times higher than normal and insurance rates also increased.

## **DRINKING WATER ISSUES IN NEWFOUNDLAND AND LABRADOR**

### **Community Demographics**

Newfoundland and Labrador covers 405,720 square kilometres. The population of the province is estimated to be more than 516,000 people, which by world standards is very low for such a huge area. In addition, more than 95 percent of the population lives on the island portion of the province. Our population density is about half the national average.

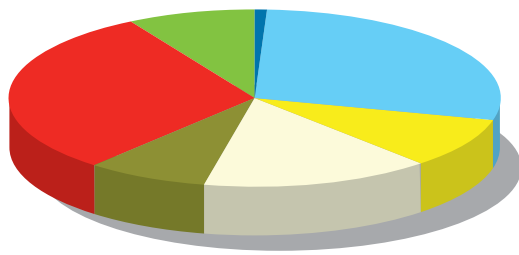
Early settlement in the province occurred mainly along the coastline because most people made their living from the fishery. Easy access to fresh water shaped the settlement pattern that followed. Today, about 90 percent of the population is still concentrated along the coast.








The province's community demographics—many communities but a relatively small population that's spread over a large geographical area—makes it very challenging to administer public water-supply systems and cost-effectively provide safe drinking water. Due to their small size, remote locations, and limited tax base, many communities have limited technical and financial resources for meeting these challenges.

### **Boil Water Advisories**

The provincial government issues boil-water advisories when local water sample tests do not meet the water quality guidelines. For example, the tests can show

Reasons for Boil Water Advisories



	Gross Contamination	0.8%
	No Disinfection System	28.2%
	System is Turned off by Operator	9.2%
	System Broken or no Chlorine	15.1%
	Operational Problems in Distribution System	8.0%
	Residual Chlorination Problem	30.3%
	Microbiological	8.4%
	Unspecified	0.0%
	Waterborne Disease Outbreak	0.0%

higher than accepted amounts of coliforms (bacteria). They can also be issued if the disinfection processes are not up to standard. In either case, a boil-water advisory would be issues for people on the affected water supply system.

When this happens, the authorities alert the affected communities right away. Regional medical officers of health are also advised that the community has been alerted so that they are aware of the situation and can conduct necessary follow-up.

Information on boil-water advisories in Newfoundland and Labrador is available online through the Department of Environment and Conservation's webpage.

**Figure 14.11:** Pie chart indicating reasons for issuing boil-water advisories during May 2005. There are many different reasons why advisories are issued and it isn't often due to microbial contamination. *Photo courtesy Department of Environment and Conservation*

## CHECK your Understanding

1. What are the two ways the natural quality of a groundwater source differs from a surface water source?
2. List four pathogens sometimes found in aquatic systems.
3. What is *Giardia*? How does *Giardia* get into water bodies?
4. Although you may go camping in seemingly pristine areas of Newfoundland and Labrador, why is it important to boil water prior to consumption?
5. As a result of Justice O'Connor's Walkerton Inquiry, what were determined to be the causes of the Walkerton water tragedy?
6. Why are communities sometimes subject to a "boil-water advisory"?

### For Further Discussion and/or Research

7. Research the various reasons why boil-water advisories are issued.
8. Check online for notices about communities in your area. How many and which ones have boil water advisories? Have they all been issued for the same reason?
9. For each of the elements listed, explain how they are naturally and/or artificially introduced to drinking water supplies and explain what health complications may result if ingested in large concentrations.
  - a) Uranium
  - b) Arsenic
  - c) Fluoride



## ENSURING DRINKING WATER QUALITY: THE MULTI-BARRIER APPROACH

### Our “Source to Tap” Status

In 2001, the Province issued a report on the overall state of our public water supplies, called *From Source to Tap*. It, and the supplementary reports that have followed, can be downloaded from the Department of Environment and Conservation’s website.

The delivery of drinking water has several stages— from source collection through to the tap in your home. As the Walkerton case study illustrates, keeping water clean and safe through all those stages poses challenges. The process is further complicated by the many ways human activity and natural processes can affect water quality.

Newfoundland and Labrador has adopted a multi-barrier approach to ensuring that public water systems provide clean, safe drinking water. The multi-barrier approach is designed to enable water resource managers to insert adequate barriers at each stage of the water supply system “from source to tap”. This allows them to minimize the possibility of pathogens and other contaminants entering the water supply system.



**Figure 14.12:** A technologist performing a drinking water analysis in a laboratory.

The main components of the multi-barrier approach are:

- Level One: source protection, water treatment, water distribution.
- Level Two: water-quality monitoring and reporting, regulatory inspection and mitigation planning, operator education and training, management.
- Level Three: legislation, guidelines, research, public education.

For this course, we will limit our discussion of the multi-barrier approach to the Level One components. For information on Level Two and Level Three, see the supplementary resource materials.

### The Multi-barrier Strategic Action Plan

<b>LEVEL 3</b>	Legislative and Policy Frameworks Public Participation Guidelines Standards and Objectives Research and Development
<b>LEVEL 2</b>	Inspection and Enforcement Monitoring Management Operator Education and Training
<b>LEVEL 1</b>	Source Water Protection Drinking Water Treatment Drinking Water Distribution System Clean, Safe, Reliable Drinking Water

**Figure 14.13:** The Multi-barrier Strategic Action Plan for the protection of our drinking water. All three levels are needed to ensure water consumption safety. Photo Courtesy Department of Environment and Conservation

## Level One Barriers

**Figure 14.14:** It is very important that all water supplies in the province be protected so that they do not become contaminated.

*Photo courtesy Department of Environment and Conservation*



### Protecting the Source

Protecting the source of public water supplies is an extremely important first stage in the multi-barrier approach.

Newfoundland and Labrador has one of the most well-established source-water protection programs in the country. Most of the major water supply areas have been designated as Protected Water Supply Areas. Some potential areas have been identified and others are in the process of being designated. This means that almost all of the province's population (89.3 percent) is supplied with drinking water from protected surface and groundwater sources.

Designating a watershed as a protected area is only one step in protecting the source, however. In addition, all activities in the watershed are monitored and managed.

### Drinking Water Treatment

Written records of treating drinking water have been dated to 4,000 years ago when boiling and filtering water were described. Filtering systems are pictured in Egyptian drawings from 1300 B.C. And they are described in early Greek and Roman literature.

### Drinking Water and Travel

To determine if it is safe to drink the tap water in the country you are traveling to, see [www.safewateronline.com](http://www.safewateronline.com).

## Did You Know?

Hippocrates is considered the father of modern medicine. In the fourth century B.C. he wrote that "...whosoever wishes to investigate medicine properly should consider the water that the inhabitants use, for water contributes much to health".

Different types of treatment systems are used to remove different types of chemical and physical contaminants from drinking water. Generally, each treatment belongs to one or more of the following methods:

1. **Pre-treatment:** This includes screening that removes debris, and pre-sedimentation that removes silt and other similar materials.
2. **Coagulation and Flocculation:** This involves adding chemicals to the water and rapidly mixing them. As a result, small particles come together, or coagulate, to form larger particles called floc, which can then settle out of the water.
3. **Sedimentation:** Also known as clarification, this process allows floc, sand, and other solids to settle out by gravity.
4. **Filtration:** This removes suspended solids that are not removed by the sedimentation process.

There are many variations of these treatment methods. They can be customized to suit the treatment needs of a specific drinking water supply.

In Newfoundland and Labrador, there are more than a dozen conventional drinking water treatment plants in operation. These treatment plants service more than 135,000 people, which is about one quarter of the entire population of the province.

### **Treatment**

Sometimes pre-chlorination or re-chlorination is necessary if drinking water has been stored before distribution or use.

### **Did You Know?**

Before community water was chlorinated, typhoid fever killed about 25 out of 100,000 people in the U.S. every year. This death rate is almost the same as the current rate for car accidents in that country.

In practice, all public water supplies are disinfected to free them from biological contaminants. In addition, water is treated as needed to remove the effects of other contaminants and to ensure that it meets drinking water quality standards. The water quality of public water supply sources in Newfoundland and Labrador is generally acceptable. Disinfection is usually all that is required to deliver clean and safe drinking water.

Treating drinking water to kill bacterial contamination is the primary drinking water treatment process. Water can be disinfected by adding chlorine, chloramines, or ozone to the water supply. It can be disinfected by irradiating it with ultra-violet (UV) light. Disinfection usually occurs as close as possible to the final delivery points to reduce the chances of the water becoming re-contaminated after treatment. Chlorination is widely used in North America. Ozonation is more widely used in Europe.

Proper disinfection treatments must kill microorganisms but not harm humans. The disinfection agent should kill quickly and only persist long enough to prevent the biological pathogens from re-growing while water is in the distribution system.

## DISINFECTION METHOD 1: CHLORINATION

Adding chlorine to water reduces or eliminates the microorganisms that can make us ill. In Newfoundland and Labrador, as well as all over North America and in many other parts of the world, chlorination is the most common way of disinfecting drinking water. In fact, more than 200 million Canadians and Americans receive chlorine-disinfected drinking water every day.

### Did You Know?

Less chlorine is needed to disinfect at colder temperatures. Do you know why?



**Figure 14.15:** The Marystown chlorination station. Chlorination is necessary to ensure the safety of our drinking water. Photo courtesy Department of Environment and Conservation

To effectively disinfect water, chlorine must be added in amounts that are high enough to kill bacteria, but low enough not to adversely affect people. Chlorine cannot completely disinfect water. It has no effect on resistant organisms such as viruses, cysts and ova, and its effectiveness is reduced by turbidity.



**Figure 14.16:** Raw water (left) and water after treatment (right) at the Clarendville water treatment plant. Photo courtesy Winston Lethbridge, treatment plant operator

Chlorine is added to water treatment systems in one of three forms: chlorine gas, liquid hypochlorous acid (bleach), or powdered hypochlorite (HTH). Chlorine gas and HTH must be dissolved in water either before or when it is injected into the water system. Each method has its advantages and disadvantages.

**Figure 14.17:** Advantages and disadvantages of adding different states of chlorine to a water system.

Form	Advantages	Disadvantages
Gas ( $\text{Cl}_2$ )	Low chemical cost Strong disinfectant	Hazardous Needs special handling equipment Requires <ul style="list-style-type: none"><li>• Special training to use</li><li>• Separate, well-ventilated room</li><li>• Emergency planning</li></ul>
Liquid	Easy to handle Simple injection equipment	Requires large volume of water Loses strength in storage Highest chemical cost
Powdered	Easy to store Simple injection equipment	Requires mixing equipment Medium chemical cost Loses strength in storage Forms deposits on equipment

### Did You Know?

- In Newfoundland and Labrador, 85.7 percent of public water sources are chlorinated. They use gas, liquid, and powdered chlorine processes.
- In addition to killing microorganisms, chlorine can help remove colour, iron, and sulphur compounds.



## Did You Know?

Chlorine residuals can be easily measured at taps throughout the system to ensure that all customers receive safe water.

Chlorine needs to be in contact with microorganisms for a few minutes to ensure that the organism is killed and that disinfection takes place. Contact time takes place in storage tanks. Once chlorination is completed, the water can be distributed to the community.

Another important factor influencing the effectiveness of chlorine is its **residual concentration**—the amount of chlorine that remains in the water after the disinfection process has occurred. In Newfoundland and Labrador, all water entering the distribution system (or public facility) after at least twenty minutes of contact time with chlorine must have a chlorine residual concentration of 0.3 milligrams per litre.



**Figure 14.18:** Chlorine can react with dead leaves in the water supply and form chemical byproducts known as THMs.

### DISINFECTION BY-PRODUCTS: THM

In addition to destroying microorganisms in water, chlorine also reacts with any organic matter in the water such as decaying leaves. The group of chemicals it can form are referred to as “disinfection by-products”. The most common by products formed by chlorination are trihalomethanes, or THMs.

The THMs found most often in drinking water are:

- chloroform;
- bromodichloromethane;
- dibromochloromethane; and
- bromoform.

Chloroform is the most common THM in drinking water and is found in the greatest concentrations. The *Guidelines for Canadian Drinking Water Quality* lists a Maximum Acceptable Concentration (MAC) for THMs of 0.100 milligrams per litre. The guideline was based on an average of at least four samples a year at a location in the distribution system that had the highest potential levels of THMs.

Some scientific studies have linked THM to increased risk of cancer. Several studies have linked a small increase in the risk of bladder cancer and colorectal cancer. Beyond the cancer concerns, some investigations have found that chlorination by-products may be linked to heart, lung, kidney, liver, and central nervous system damage. Other studies have linked THM to reproductive problems including miscarriages.

The use of chlorine is widespread. Water and health experts agree that not using chlorine would pose far greater health risks. Scientific research shows that the benefits of chlorination (reduced frequency of waterborne disease) are much greater than any health risks from THMs and other disinfection by-products.

## DISINFECTION METHOD 2: OZONE

Ozone is a toxic form of oxygen gas that, when bubbled through water, kills microorganisms. There are advantages and disadvantages to its use. On the positive side, it may be more effective than chlorine in killing resistant strains of bacteria and viruses. Also, it does not produce THMs. On the negative side, the process takes longer than chlorination and is two to three times more costly.

Unlike chlorine, which is extremely toxic and must be transported, ozone can be easily produced on site. But ozone is chemically unstable so it must be used immediately. It has to dissolve in water so it must be mixed thoroughly to ensure contact with any pathogens.

### Alternative Treatment Methods

1. Boiling
2. Carbon filtering
3. Distillation
4. Reverse osmosis

Some people argue that Canadian water treatment plants should use this process instead of chlorination. To do this, existing treatment facilities in Canada would have to be retrofitted to use ozone instead of chlorination. The costs associated with those changes would be very high.

In addition, one of the most important reasons why ozonation is not used more widely is the shorter duration of ozone disinfection compared with chlorination. There is a risk of ozonated water becoming re-contaminated in the water distribution system. However, small amounts of chlorine or other disinfectants can be added to ensure the water remains potable.



**Figure 14.19:** Potable water dispensing unit which uses ozone. *Photo courtesy the Town of St. Lawrence*

## DISINFECTION METHOD 3: ULTRAVIOLET RADIATION

Irradiating water with ultraviolet (UV) light kills microorganisms. It forms no residual compounds, but, as with ozonation, the disinfection effects do not last as long as chlorination.

### Post-treatment

There are other ways in which the water in the distribution system can be altered besides disinfection. For example, thousands of communities worldwide adjust



**Figure 14.20:** To detect leaks in the water distribution system, a technician must listen through hydrophones for telltale noises. It takes training and good hearing to recognize the sound of a pipe leaking underground.

*Photo courtesy Department of Environment and Conservation*

the fluoride content of their water to an optimal level. When this water is ingested regularly, it can help prevent tooth decay. Communities with water fluoridation report improved oral health among residents.

When water contains a significant amount of calcium and magnesium, it is called hard water. Hard water can clog pipes and inhibit soap and detergent from dissolving. Water softening removes the calcium and magnesium ions. Iron ions may also be removed during softening. The best way to soften water is to use a water softener unit and connect it directly to the water supply.

### Water Distribution

Once it is treated and meets water-quality guidelines, water is distributed by a supply network to homes and businesses. The distribution network must be built and maintained to ensure drinking water quality.

Distribution systems are usually owned and maintained by local governments such as communities or cities. The system planning and design requires the expertise of planners and civil engineers. They are trained to consider many factors such as location, current demand, future growth, leakage, pressure, pipe size, pressure loss, and fire fighting flows. Areas where water might leak out, or contaminated water might leak in, must be identified and fixed. There can be no accidental cross-connections with the sewer system.

The challenges of maintaining a safe, clean water-distribution system includes dealing with aging infrastructure, and finding and retaining qualified and trained operators.

### CHECK your Understanding

1. What is the purpose of the Government of Newfoundland and Labrador's "multi-barrier" approach to water quality?
2. What are the three components of the "multi-barrier" approach to water quality?
3. What are the three main steps in the water treatment sequence?
4. What are some advantages and disadvantages of chlorination over other types of water treatment?
5. What are the advantages and disadvantages of using ozone to disinfect public water supplies?

### For Further Discussion and/or Research

6. In some jurisdiction, people are permitted to use community water sources (lakes and rivers) for recreation such as fishing or boating. Why don't we do that in Newfoundland and Labrador?
7. It is common knowledge that many community water supplies (e.g., lakes) have very healthy trout populations. Why are people not allowed to fish in these "protected" water supplies?

## Did You Know?

In small amounts, nitrogen and phosphorus from sewage have only a short-term effect. By adding additional water to dilute the concentration of pollutants, the ecosystem may better be able to recover its natural nutrient balance.

### Looking Ahead: treating and re-using grey water

Reusing, or treating and recycling, grey water separately from black water can be done at either the household or the community level. In some places, treated grey water is used for irrigation or as toilet water. Recycling grey water has many conservation benefits, including:

- Reducing demand for fresh water as well as the strain on septic tank or treatment plants
- Requiring less energy and fewer/reduced chemicals to treat
- Replenishing groundwater (if used for irrigation)
- Supporting plant growth

Reuse of grey water must be managed carefully or it can pose health hazards. For example, if it is not used immediately and is left to stand, pathogens appear, the water forms a sludge, and foul odours are created.

## WASTEWATER

What comes into our homes and businesses as high quality water leaves as wastewater through our drainpipes and into the sewer system. If this wastewater is returned to the environment untreated, it can pollute water bodies such as lakes and ponds, rivers, and eventually the ocean. Some households and communities in Newfoundland and Labrador have treatment plants or septic tanks that treat wastewater before returning it to the environment. Others do not.

The wastewater produced by a municipality can be divided into two types: grey water and black water (which is commonly called sewage). Grey water is the water that drains from sinks and dishwashers, laundry tubs, and washing machines, bathtubs, and showers. It contains particles of soap, fat, food, cleaning solvents, and other materials. Black water is the water and its contents flushed away in toilets.

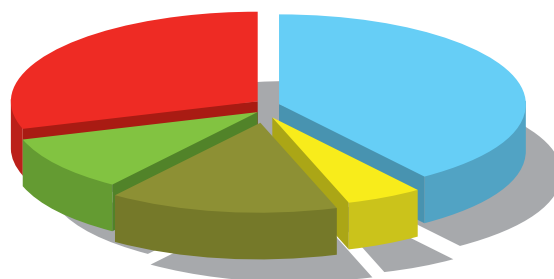
Households generally produce more grey water than black water. Even though grey and black water differ in several ways and can be handled differently, most communities that have wastewater plants in this province usually process grey and black water together. In addition, storm runoff may also be included in the mix.

Households are not the only source of wastewater. Wastewater from industry can contain a variety of industrial chemicals harmful to aquatic ecosystems. Most industrial wastewater is required to be tested before it is released to ensure it will have minimal impact on the ecosystem.

### Untreated Wastewater

If piped untreated, or raw, back into the environment, human wastes can add quantities of nitrogen and phosphorus that are extremely harmful to aquatic organisms. In addition, the accumulation of raw waste in water can lead to the growth of disease-causing microorganisms. For these and other reasons, treating sewage is a healthy and ecologically wise approach.

Liters a Day (l/d) of Wastewater from a Typical Household: Greywater (G) and Blackwater (B) Combined



Usage	Litres	Percentage
Toilet (B)	303	40%
Miscellaneous (G)	38	5%
Laundry	114	15%
Kitchen (G)	76	10%
Bath (G)	227	30%

**Figure 14.21:** Domestic wastewater pie chart showing the types and proportion of wastewater produced in a typical North American household each day. Notice the amount of blackwater versus greywater produced. *Data source: www.greywater.com*



## Did You Know?

Both raw and treated sewage are dumped into the Great Lakes by Ontario and eight American states. Cities such as Detroit, Toronto, and Buffalo with combined populations of over six million people discharge sewage effluent into the Great Lakes.

Astonishingly, Lake Ontario is also the source for domestic water supply for the city of Toronto!

In Newfoundland and Labrador, for the most part, the large volumes of wastewater we produce flows untreated back into the environment. About fifteen percent of the population has a centralized municipal treatment plant; thirty-five percent have an on-site treatment system (septic tank). Most of the remaining untreated discharge ends up in the ocean or other water bodies. We are fortunate that our water resources are so vast that their contact with our own waste is minimized. Unfortunately, this invisible pollution can foster an “out of sight, out of mind” mentality toward wastewater treatment and disposal.

Sending raw sewage into a river or the ocean does have an effect, which we ignore to our peril. Improper disposal of human waste is a problem for close to three billion people including the people of Newfoundland and Labrador.

### Sewage Treatment Treatment Plant

The typical complete system in a wastewater treatment plant has four main steps that removes toxic substances from wastewater, and returns the treated water to a river, lake, or marine environment without causing harm. Treatment facilities are never 100 percent effective, which means that some water quality problems remain after treatment.

The main steps for treating sewage in a wastewater treatment plant are:

**Step 1: Screening or pre-treatment:** This removes items that will not break down or are too large such as garbage or non-biodegradable materials that have been flushed down the toilet.

**Step 2: Primary treatment:** This removes more than fifty percent of the biosolids, which form a semi-solid sludge on the bottom of a settling tank. The sludge can then be further treated or dried and disposed of in a number of ways.

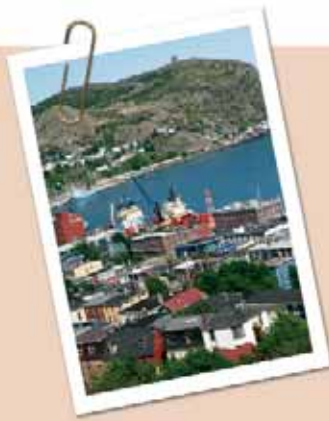
**Step 3: Secondary Treatment:** Wastewater that remains after Primary Treatment is seeded with aerobic bacteria. These bacteria break down organic molecules or biosolids more quickly than anaerobic bacteria to leave nutrient molecules. Some form of aeration must be employed to keep a high rate of bacterial digestion/decomposition.

**Step 4: Tertiary Treatment:** Filters, particular species of plants and/or chemical (chlorine) or UV treatments, are used to disinfect the effluent, removing phosphorus, nitrates, and ammonia. Plants have the ability to take up nutrients that may cause Biochemical Oxygen Demand (BOD) problems. Some plant species even have the ability to take up toxic metals.



**Figure 14.22:** This oxidation ditch, in Holyrood on the Avalon Peninsula, is an example of secondary treatment.  
*Photo courtesy Department of Environment and Conservation*





## ENVIRO-FOCUS

### The Sewage Situation in St. John's

Discharging raw sewage into the ocean was once acceptable (out of sight, out of mind). Today we know that it can damage aquatic ecosystems and the environment in general. We also know that untreated discharge poses a human health hazard.

Raw sewage has been flowing from the sewers of St. John's into its harbour for decades. This situation is not unique to the capital city. Many Newfoundland and Labrador communities release untreated, highly diluted sewage discharges into the ocean. Most of the freshwater discharges into rivers or lakes are provided with secondary treatment before they are released.



**Figure 14.23:** The St. John's Harbour Primary Treatment Facility, 2009. *Photo courtesy City of St. John's*

Every day in 2005, 120 million litres of untreated sewage flowed into St. John's harbour. This came from residential areas, industry, commercial operations, and institutions (as well as storm runoff). The once pristine harbour is so polluted with bacteria, pathogens, and heavy metals that it was once ranked as the dirtiest harbour in Canada. But the Sierra Legal Defence Fund's 2004 National Sewage Report Card no longer ranked St. John's Harbour as the dirtiest, although it only received an "E". Montreal was given an "F" and no improvement noted; Victoria, B.C., the worst offender, was "suspended".

The federal, provincial and municipal governments (St. John's, Mount Pearl, and Paradise) are working together to build a new multi-phase collection and treatment facility. The first step has been completed: the City built the Southside Road pumping station in 1999. It conveys wastewater from the Waterford Valley to a diffused interim outfall in the middle of the harbour. This step has greatly improved water quality at the mouth of the Waterford River, where the outfall used to be located.

The primary treatment plant is now under construction. The plan calls for a secondary treatment plant to follow, as required.

To track of progress on the project, see the City of St. John's web site:  
[www.stjohns.ca/cityservices/environment/harbour/cleanup.jsp](http://www.stjohns.ca/cityservices/environment/harbour/cleanup.jsp).

**Investigate:** A good reference on how cities across the country deal with sewage is the Sierra Legal Defence Fund's "Sewage Report Card". Find out who ranks well (and who is failing terribly) at: [www.sierralegal.org/m\\_archive/pr04\\_09\\_08.html](http://www.sierralegal.org/m_archive/pr04_09_08.html).

## Lagoons: A Low-maintenance Treatment Alternative

Lagoons are shallow basins that hold wastewater for several months, allowing natural decomposition of contaminants to occur. Lagoons slow the movement of wastewater and the solids settle to the bottom where they begin to break down.



**Figure: 14.24:** Several towns in Newfoundland use lagoons for sewage treatment. This lagoon is in Whitbourne on the Avalon Peninsula.

*Photo courtesy Department of Environment and Conservation*

If land is available, using lagoons for primary (or secondary) sewage treatment is cost-effective. Lagoons need far less energy than a treatment plant and require fewer people to oversee them because they are relatively

maintenance-free. In addition, they can work with variable flow conditions.

On the down-side: lagoons do not have a bacterial disinfection step, and the water that comes out of them is not high quality.

## Constructed Wetlands

In nature, wetland vegetation contributes significantly to nature's ability to self-clean ambient water. Taking note of this, scientists and engineers have “built” wetlands as a way of treating wastewater. These artificial wetland systems are useful for treating municipal, industrial, and commercial wastewater, as well as treating storm-water, agricultural runoff, and animal waste. In Europe, constructed wetlands have been used for wastewater treatment since the mid-1980s; in this province they began to appear in 2006.

Constructed wetlands are made of an excavated basin, or trench, that is filled with sand or gravel and planted with wetland vegetation (reeds and rushes). Wastewater is flooded into the area either via the surface water or in a trench or bed filled with sand or gravel and covered by an impermeable layer of clay. In this second type, the sand layer fosters wetland plants and the wastewater is treated by filtration and other processes.

These wetlands take a bit of effort to build, but, like lagoons, they take little energy to run. They have a pleasing look and can actually provide habitat area for wildlife and insects. They do require a relatively large land area, however, and are not as successful with wastewater that has a lot of chemical or industrial pollution. In addition, they are not as effective in locations that have long winters (which slow degradation activity).



**Figure 14.25:** Constructed wetlands are also used across the province for sewage treatment. This is a constructed wetland in Marystown on the Burin Peninsula.

*Photo courtesy Department of Environment and Conservation*

## The Septic Tank System

In areas with low population, wastewater is often treated using septic systems. Many households in the province use a septic field to deal with the liquid wastes from the septic tank.

Septic systems must meet sanitation regulations administered by the Department of Government Services. The systems must be properly maintained for efficient operation and must be composed of three parts:

- **Septic tank:** This provides primary treatment that produces three layers: soapy-fatty scum, liquid effluent, and sludge. Only anaerobic bacteria can live in a septic tank, which means that decomposition is slow, and the sludge will eventually have to be removed. If not, the sludge and scum can build up and enter the disposal field (see below) and block up holes to the soil.
- **Distribution box:** This receives the liquid effluent from the septic tank and distributes it to a series of pipes in the disposal field.
- **Disposal Field:** This series of pipes in the soil distributes the effluent, which then forms an underground mat composed of bacteria and effluent products. Aerobic bacteria help reduce the remaining wastes, and water seeps through the soil in all directions. To prevent contamination, the disposal field must be at least thirty metres from all surface water and dug wells.



**Figure 14.26:** Some septic tanks service only one home while others can service whole communities. This is the large septic tank during installation in Trinity on the Bonavista Peninsula. *Photo courtesy Department of Environment and Conservation*

Septic tank systems can be any size, but they must be built properly so that bacteria and natural filtering can return the water to the environment in a cleaner form. When they are well built and maintained, septic tanks will settle out the majority of solids, and the soil will act as a filter. Effluent must move slowly in the disposal field, and fine particles must be trapped, for the system to work properly. Some removal of Biochemical Oxygen Demand (BOD) wastes, nitrates, phosphates, and pathogenic

bacteria will take place. Organisms on the mat formed in the disposal field will help remove other harmful bacteria.

## Outhouses

In places with no running water (in the country and at remote cabins), many people use pits or outhouses to dispose of human waste. A properly constructed outhouse confines wastes in a safe place, reducing the chance that people will be exposed to pathogenic organisms.

In addition to properly locating an outhouse, it is important to maintain it according to carefully established guidelines (see table below for details). Following these guidelines helps keep waste contents away from surface water or groundwater.

### The layered ocean

The ocean can be divided into layers according to temperature and salinity.

- The top **mixed layer** can be as deep as 200 metres. It is the warmest layer and is mixed by wind and wave action.
- The **thermocline** is the layer between the mixed layer and deep ocean waters. This zone of decreasing temperature can extend to a depth of 1,000 metres.
- The **deep water** layer includes anything below the thermocline and is almost completely devoid of sunlight.

An outhouse should never be placed in a marshy area, on exposed bedrock, or anywhere that there is only a thin layer of soil. Once the pit from an outhouse is full, the hole must be filled with soil (so rain will not cause an overflow) and a new location chosen.

Figure 14.27: Provincial Standards for Pit Privies

Pit dimensions	1 x 1 m; 1.5 m deep
Distance above groundwater, water table, or bedrock	1 m
Distance from buildings	7.5 m
Distance from embankments and property boundaries	4.5 m
Distance from drilled wells	16 m
Distance from dug wells, springs, or surface water	30 m



Figure 14.28: Outhouse.  
Most Newfoundlanders and Labradorians have used an outhouse at one time or another.

## CHECK your Understanding

1. Distinguish between “grey water” and “black water”.
2. Describe the four main steps in treating sewage.
3. What are the advantages and disadvantages of constructed wetlands and lagoon sewage treatment methods?

### For Further Discussion and/or Research

4. Refer to the Sierra Club of Canada’s most recent “Sewage Report Card” to find out which cities have received “failing grades” and which have “passed” or “shown improvement”.
5. Research the regulations surrounding the installation of domestic septic systems.
6. Investigate the maintenance requirements of a domestic septic system.



# Chapter 15: Fisheries and Aquaculture

## Did You Know?

### Envirofact:

Garbage from Newfoundland and Labrador is carried by ocean currents to wash up on the beaches of Scandinavia? This is tangible proof that actions we take locally can have impact globally.



**Figure 15.1:** Seventy-one percent of Earth is covered by water.

The marine environment is incredibly vast. It includes all the seas and oceans which cover approximately seventy-one percent of the world's surface. Hundreds of millions of years ago the oceans provided habitat for the earliest life on Earth. For many millennia the oceans were the exclusive home of all life on Earth as the earliest plants and animals evolved from this biotic “soup”.

The topography of the ocean floor is as varied as any landscape. Shallow coastal waters give way to vast plateaus teeming with life, which in turn give way to steep inclines leading into the cold, dark depths of the ocean. The ocean floor is also home to mountain ranges, volcanoes, and deep trenches. Some of the deepest trenches in the Pacific Ocean exceed 11,000 metres.

### THE MARINE ECOSYSTEM

Such a vast and unfathomable underwater world is difficult to explore and even more difficult to study. The diversity of marine life is evidence of how different organisms adapt to radically different environments. Every part of the ocean has physical characteristics that support life in a unique way. There is much that remains unknown about marine ecosystems. But there is also much we can learn.



The ocean environment can be classified as follows:

**Estuaries indicate environmental health**

The mixing action of tidal and river waters in an estuary is effective in flushing and dispersing pollutants, both upstream and out to sea. There is, however, a limit to the amount of pollution an estuary may be able to flush. This situation is worsened by the fact that human behaviour can alter the size and shape of an estuary. If deepened, an estuary will have a higher volume, which means that the tidal flow and mixing processes will be smaller and slower. In turn, the estuary will not be as effective in flushing large volumes of pollution or other effluent. An estuary is a very sensitive gauge of the destructiveness of industry and population growth.

- **ESTUARIES** are in coastal areas where rivers meet the sea. An estuary is a semi-enclosed body of water in which tidal salt water mixes with, and is diluted by, fresh river water. In Newfoundland and Labrador, and in the Maritime Provinces, an estuary may also be known as a barachois. An estuary extends inland along the river as far as the ocean tides can reach. This nutrient-rich sediment, carried off the land by erosion, is important to the estuarine ecosystem. However, estuarine life is not as diverse as that found in other coastal marine zones. This is because the environment is much more demanding. Species that flourish in estuaries need to withstand highly variable conditions of water flow, sedimentation, and salinity levels, as well as large daily and seasonal fluctuations in temperature.
- **THE INTERTIDAL ZONE** is the area between the water levels at high and low tide. It is the zone where the terrestrial and aquatic environments mingle as it is alternately flooded and dried out, and where the temperature changes dramatically over very short periods of time. However, intertidal zones are very productive habitats for the plant and animal life capable of tolerating this extreme environment. **Salt marshes** and **swamps** are important intertidal habitats. Salt marshes, which can be very large, occur in mid-latitude temperate zones around the world between the tropics and the Arctic and Antarctic. Vegetation includes grasses, herbs, and dwarf shrubs. Such marshes are found in many areas along the east coast of Canada.

Both swamps and marshes are home to many species usually found in shallow marine sediments. They are often home to many species that exist nowhere else. Swamps and marshes provide creeks and plant-covered pools in which single-cell organisms, algae, and suspension feeders flourish. The intertidal zone also has qualities of a terrestrial ecosystem, bringing marine animals like crabs together with spiders, snails, and insects. Intertidal zones are also important feeding stop-overs for shorebirds during annual migrations.

Many extensive intertidal marshes and mudflats are part of estuarine ecosystems. And like estuaries, these marshes are particularly vulnerable to pollution from debris, oil, sewage, and industrial and agricultural runoff. Once tides and winds carry harmful materials into a salt marsh or estuary, these materials can accumulate in food chains by the process of bioaccumulation.

- **LITTORAL/SUBTIDAL** are relatively shallow coastal waters, usually no more than around seventy metres in depth. The littoral zone is usually teeming with a wide variety of life, partly because in shallow littoral waters (usually to a depth of ten metres):
  - Sunlight can penetrate to the seabed.
  - Temperatures are seasonally warmer than deeper waters, and
  - Coastal currents and tides facilitate good mixing of essential nutrients like carbon (mainly in the form of carbon dioxide and bicarbonates), nitrogen, and phosphorus. This allows a variety of plant life to grow on the ocean floor.
- **BENTHIC** (of or relating to the sea bed) and **pelagic** (of or relating to the open water column) organisms are interconnected with greater complexity in the littoral zone than in any other part of the ocean. Many commercial species of ground fish, pelagic fish, scallops, oysters, crabs, and lobsters are fished in the littoral zone.



#### Envirofact: a little plant with a big job

The most productive area for sea life lies near the ocean surface where phytoplankton thrives. These so-called “grasses of the sea” are microscopic single-celled marine plants and cyanobacteria. Phytoplankton is the foundation of the entire marine food web. Newfoundland and Labrador has one of the most productive habitats for phytoplankton in the world. Microscopic animals called zooplankton consume phytoplankton. In turn, zooplanktons are eaten by fish larvae and these larvae are eaten by bigger fish.

Because phytoplankton uses carbon dioxide for photosynthesis, they are an important means for removing greenhouse gases from the atmosphere. The larger the phytoplankton population, the more carbon dioxide can be removed from the atmosphere. These organisms are capable of doubling their numbers every day during high productivity periods. An individual phytoplankton only lives for one or two days before sinking to the bottom of the ocean, taking with it the carbon dioxide it consumed from the atmosphere. Over millions of years the world's ocean floor has become an enormous storage site or “sink” for atmospheric carbon dioxide. Ninety percent of the carbon dioxide that exists in the world has settled to the bottom of the ocean, much of it dead biomass from phytoplankton. This means that large populations of phytoplankton are needed to slow the increase of the greenhouse gas, carbon dioxide.

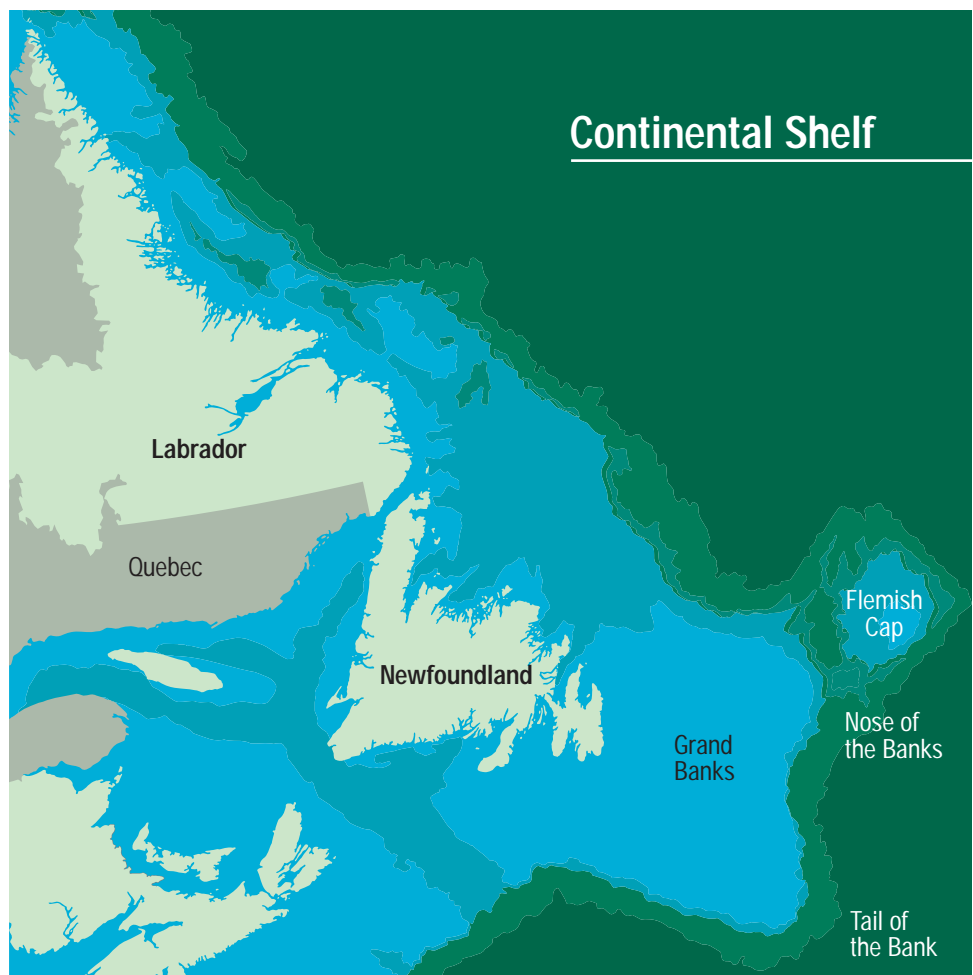
**Figure 15.2:** An aerial photograph of a “bloom” of phytoplankton (light blue) in a water body.

- **SEAGRASS MEADOWS** are found in littoral zones in temperate and tropical areas around the world, though they are most abundant in tropical areas. Very few animals feed on seagrass, with the exception of some geese (hence the Newfoundland term “goosegrass”), fish, turtles, and sea urchins. However, the large amounts of decaying materials (detritus) from seagrass as it breaks down are an important source of nutrients

for bacteria, which provide food for plankton. Seagrass also supports algae and is an important nursery for many species of fish since it is possible to conceal eggs and young fish from predators in the grasses.

- **THE CONTINENTAL SHELF** is a transitional zone between shallow subtidal and deep subtidal zones. A continental shelf is composed of underwater extensions of the continental landmass, commonly described as having depths between 200 and 1,000 metres, and being made up of continental rock types rather than ocean floor rocks. The resource-rich Grand Banks of Newfoundland is a very extensive part of the North American continental shelf.

The Grand Banks is one of the most biologically productive areas in the world. Due to available mineral nutrients and favourable water temperatures, phytoplankton grows quickly or “blooms” there in the spring and autumn attracting a vast range of sea life to the area. Phytoplankton growth may be just as rapid in summer, but the population is suppressed because of the many animals that eat them.



**Figure 15.3:** A portion of the continental shelf along the east coast of North America. Note the location of the Grand Banks and the Flemish Cap, two very resource-rich areas. *Illustration courtesy Derek Peddle*

The abundance of mineral nutrients for phytoplankton on the Grand Banks is due to several things:

1. Nutrients are heavily concentrated in coastal areas due to runoff from rivers and tidal action. In deep water these nutrients must be circulated by water moving to the surface from the ocean floor.
  2. The productivity of the offshore shoals and banks on the Grand Banks is enriched by upwelling deep ocean currents that follow the rising slopes of the Grand Banks carrying nutrient rich waters from the depths to the surface where the nutrients support plant and animal life.
  3. During the winter, strong currents and storms stir up the ocean bottom on this shallow bank. This also brings nutrients and minerals to the surface providing nutrients for phytoplankton when warmer weather arrives in the spring.
  4. The oceanographic processes driving upwelling and re-suspension of nutrients and minerals from the seafloor are particularly active in the vicinity of the Grand Banks compared to banks elsewhere in the world.
- **THE DEEP OCEAN** is the largest marine zone. This zone was long thought to have limited biodiversity. Recent technological advances have made it possible to explore at these depths. We now know that there is great biodiversity in the deep sea, but still have a very limited understanding of the number of types of organisms that exist there. Continental shelves often drop off dramatically to a much deeper ocean floor known as the **abyssal plain**. This plain is thousands of metres below the ocean surface, receives no sunlight, and is barren compared to other marine zones. Yet the deep ocean is home to specialized species adapted to conditions there. Particles such as dead plankton and fecal matter rain slowly down through the water column and eventually reach the ocean floor. Bacteria consume these particles, and these bacteria are in turn consumed by other organisms. There are also areas of the seafloor provided with nutrients from thermal vents that are very rich in plant and animal life.



## ENVIRO-FOCUS

### Eelgrass

Along many shorelines hidden underwater meadows grow in areas protected from strong currents and powerful waves. These meadows are formed by eelgrass and they are important to the survival of many fish species.

Eelgrass is not seaweed, but rather an underwater grass that grows up to one metre tall in muddy or sandy shallow areas near the shore. It grows during the spring and summer and then decays in the fall and winter. A variety of animals take advantage of this species' lifecycle for food and shelter.



**Figure 15.4:** An underwater meadow formed by eelgrass. This grass forms a “nursery” for many juvenile fish and helps control coastal erosion.

Many juvenile fish including herring (*Clupeidae*), cod (*Gadus morhua*), and salmon (*Salmo salar*) use eelgrass beds as nurseries. They feed on smaller creatures including sea anemones, marine worms, snails, and crabs that live among the eelgrass blades or burrow into the sediments. Eelgrass also offers small fish a hiding place from predators.

### Eelgrass as a Food Factory

Each blade of eelgrass is its own food factory. Bacteria and decaying plant and animal matter

gather on eelgrass leaves, giving them a brown felt-like appearance. This material provides food for many species of tiny invertebrates including worms, crustaceans, and snails. These invertebrate colonies, in turn, make eelgrass beds rich feeding areas for fish and marine birds. As eelgrass dies, bacteria and fungi feed on the dead leaves and break them down into tiny particles. This decaying plant material provides vital nutrients for the near-shore food web.

### Eelgrass Controls Erosion

Eelgrass meadows cushion the impact of waves and currents on coastlines. This slows or curtails erosion. During low tides, eelgrass also shelters small animals and plants from extreme temperatures. On tidal flats, eelgrass beds hold moisture like a sponge, thereby protecting small animals. Damage to eelgrass meadows harms the stability of shorelines and negatively impacts numerous populations of animals including salmon, waterfowl, and shellfish.



## GLOBAL FISHERIES

Humans have probably eaten fish for as long as our species has been able to catch them. We know from archaeological evidence, such as discarded fish bones and cave paintings, that seafood was an important food for prehistoric peoples. When humans began to live in permanent settlements fishing became very important to many human populations. In fact, the ocean's resources have provided for many of humankind's needs for thousands of years.

Today, because of technology and increasing human demands, we are placing unprecedented pressure on marine resources. The United Nations Food and Agriculture Organization (FAO) monitors and ranks the status of the world's wild fish stocks. In 2005, FAO estimated that:

- Fifty percent of the world's fish populations are fully exploited. This means we cannot harvest them more intensely without driving them toward extinction.
- Twenty five percent of the world's marine fish populations can yield no more than they are already yielding without being driven into decline.
- Twenty five percent of marine fish populations are overexploited and being driven toward extinction.

The bottom line is that existing fishing practices are not sustainable given present consumption rates.

### Consumption, Production, and Trade

Fisheries and aquaculture are critical sources of food and nutrition. Fish is a primary source of protein for many of the world's poor, particularly in Asia and parts of Africa. It is an important part of the diet of even more people. In Asia, nearly one billion people rely on fish as a primary source of animal protein. Fish are used for other purposes as well. According to the FAO, nearly one fourth of the global fish catch is turned into feed for livestock and farmed fish, as well as fish oil and other products.

#### Aquaculture:

Also called fish farming, aquaculture is the raising of fish species in captive or controlled settings.

This demand for fish provides much needed employment, income, and a means of subsistence for many coastal communities. According to the World Bank, there are approximately 38 million full-time fishers worldwide. The livelihood of another 150 million people is based on fisheries, aquaculture, and associated activities.

Through fisheries world-wide, humans take more wildlife than through any other process on Earth. In addition, **aquaculture** is the fastest growing sector of the global agricultural economy, making up for more than thirty percent of total fish food production. Asia produces most of this. Fish is the most heavily traded food commodity on international markets, and a significant source of foreign exchange

for many developing nations. In 2002, the value of the world's fish trade was \$68 billion CAN, half of which was from developing countries. It exceeded the combined net exports of rice, coffee, sugar, and tea.

### Trends in Global Fisheries



**Figure 15.5:** Redfish on ship's deck. Photo courtesy Department of Fisheries and Oceans

Before 1945, fishing fleets did not have the technology or the capacity to catch and preserve large enough quantities of fish so fish stocks were generally able to reproduce faster than they could be caught. The advent of trawlers, then factory freezer trawlers in the 1950s, enabled countries and fishing companies to send

their fishing fleets anywhere in the world. Factory freezer trawlers could catch and freeze large volumes of fish for months on end before having to return to port. The result was a significant increase in fish catches around the world including off Newfoundland and Labrador. Between 1945 and the early 1970s, global capture of fish increased from fourteen million to sixty million tonnes. This rapid upward trend continued in the 1980s and 1990s. By 2002, catches worldwide had reached an estimated ninety million tonnes.



**Figure 15.6:** Factory Freezer Trawler.

The most critical issue in the global fishery today is overfishing. Close to home we have seen the decline in many of our stocks such as cod, American plaice (*Hippoglossoides platessoides*), redfish (*Sebastes marinus*) and Greenland halibut (*Reinhardtius hippoglossoides*). In addition to overfishing, certain fishing practices can have significant impacts on marine environments. For example, bottom trawlers that drag large nets along the ocean floor can damage sensitive habitats such as deepwater corals, and can sweep up non-target species. Ghost fishing by gillnets (nets that have been lost at sea but continue to catch fish) has been identified as a large and destructive process that does a great deal of

harm to fish species around the world. Globally, losses to by-catch (fish species unintentionally caught in nets) are measured in the millions of tonnes.

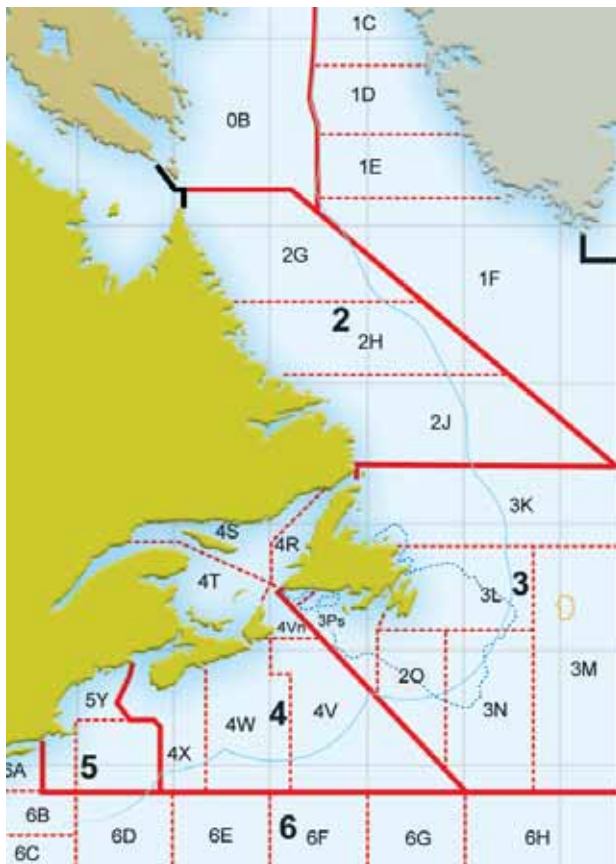
*“Rapidly growing coastal populations, poverty, rising demand for fish, changes in fishing technology and subsidies, habitat destruction, and weak governance of the shared fish resources all conspire to bring many of the world’s fisheries to the brink of collapse”.*

Warren Evans, Environment Director, The World Bank

### Other Issues Affecting Fish Resources

In 1950, there were 2.5 billion people living on Earth—by 2006 the number stood at approximately 6.4 billion people. Worldwide, a rapid growth in the populations of coastal communities indirectly affects fisheries through agricultural and industrial runoff, increased erosion, and altered coastal ecosystems. These sensitive areas are nursery grounds for many fish species. The rapid increase in the world’s human population has further increased pressures on marine resources.

### MARINE FISH RESOURCES OFF NEWFOUNDLAND AND LABRADOR



**Figure 15.7:** The areas of the Northwest Atlantic Ocean covered under the NAFO convention.

### Fish Population

The terms “fish population” and “**fish stock**” can be used interchangeably. The terms generally refer to a group of interbreeding individuals. This could be all individuals of a species, but usually there are numerous populations within a species. They are often separated by physical barriers. For example, the cod on the Flemish Cap are separated from the cod on the Grand Banks by the Flemish Pass, which is a very deep undersea canyon. Biological studies have shown that the cod on the two sides of the Pass differ in numerous ways indicating that the Pass is a barrier to intermixing. However, in most cases, physical separation is not obvious and telling different populations apart may be difficult.

The term “fish stock” is also a fisheries management term. For management purposes, stocks in the Northwest Atlantic are defined along geographic lines. These lines, called Northwest Atlantic Fisheries Organization (NAFO) boundary lines, separate NAFO subareas, divisions, and subdivisions. The original lines were first drawn up by The International Commission for the Northwest Atlantic Fisheries (ICNAF) to correspond as closely as possible to known cod population boundaries.



Because fish move around and different groups of a species may occupy a given geographic area at the same or different times, it is often difficult to define a management stock so that it corresponds exactly to a distinct population.

**Exclusive Economic Zone (EEZ):**

The EEZ refers to that portion of the sea extending to 200 miles off the coast of a state. Coastal states have the right to control the living and nonliving resources of the sea in their EEZ, while allowing freedom of navigation to other states beyond twelve miles, as agreed at the sixth session of the Third U.N. Conference on the Law of the Sea (UNCLOS). Coastal states also have the responsibility for managing the conservation of all natural resources within their EEZ.

There are three types of commercial fish stocks in our waters. These are:

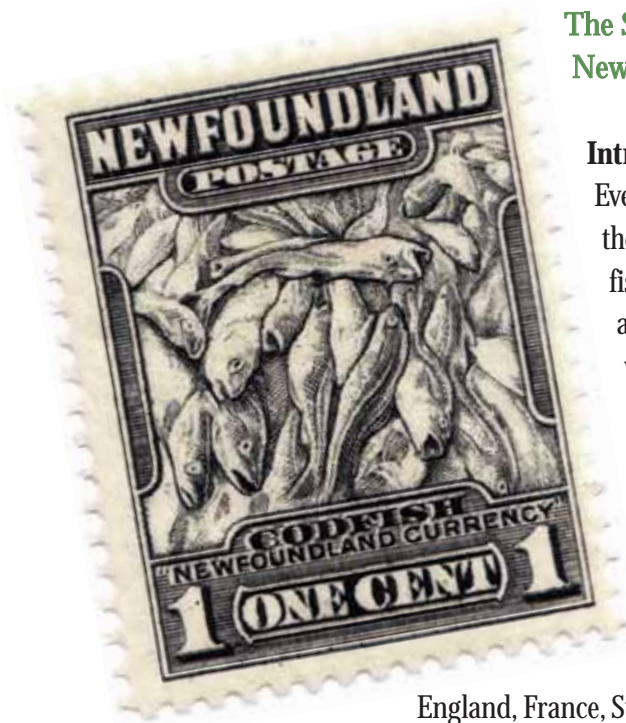
- Domestic stocks – those stocks that exist totally within Canada's Exclusive Economic (EEZ). Some examples are northern Gulf cod, 2GH cod, SA2+3K American plaice (*Hippoglossoides platessoides*).
- Transboundary stocks – those stocks that live both inside and outside Canada's EEZ. Examples are 2J3KL cod, 3NO cod, 3Ps cod (with France), 3LNO American plaice, 3NO capelin.
- International stocks – those stocks that exist totally outside Canada's EEZ. All of the stocks on Flemish Cap (NAFO Division 3M) belong to this group.

## HISTORICAL FISHING TRENDS IN NEWFOUNDLAND AND LABRADOR

### The Story of Cod is the Story of Newfoundland and Labrador

#### Introduction

Even before John Cabot reported back to England in 1497 that the waters of the Grand Banks were “teeming with fish”, cod fish have been an important part of the story of Newfoundland and Labrador. It is said that cod were once present in such vast schools off the coast that the cod could be “dipped up in baskets”. Although this was clearly an exaggeration, the seemingly inexhaustible cod stocks sustained communities in Newfoundland and Labrador, as well as the North-eastern United States, and Eastern Canada for centuries.



**Figure 15.8:** Codfish was once used as Newfoundland Currency.

By 1578, nearly 400 ships from England, France, Spain, and Portugal were taking part in the Newfoundland fishery. St. John's became the busiest port in North America during the sixteenth and seventeenth centuries. While small numbers of settlers were struggling to survive in New York and Boston, St. John's was a bustling, thriving town, the largest European community in North America.



**Figure 15.9:** Working on a fishing flake, located on the northeast side of St. John's Harbour. Photo courtesy PANL-CMCS

## Did You Know?

The northern cod stock (2J3KL) of Atlantic cod (*Gadus morhua*) occupies the area from the southern Labrador Shelf to the northern Grand Banks. Exploited for centuries, annual landings increased to about 300,000 tonnes during the early part of the twentieth century. The early fishery was limited to shallow nearshore waters.

In the 1950s, longliners were introduced to near-shore waters and distant water trawlers from Europe exploited large numbers of cod found in winter near the edge of the continental shelf.

The highest catch recorded was over 800,000 tonnes in 1968. Catches began to decline rapidly after the high catches of 1968 and 1969.

The abundance of fish brought fishermen and their families from England and Ireland to Newfoundland where they eventually settled in hundreds of coastal communities. The majority of settlers' livelihoods were dependent upon the northern cod inshore fishery. That stock thrived in an area stretching from southern Labrador to the northern Grand Banks. Some communities, especially those on the Burin Peninsula, also depended on the offshore dory fisheries. To most, it seemed as though the cod were limitless.

### Decline of the Cod Stock

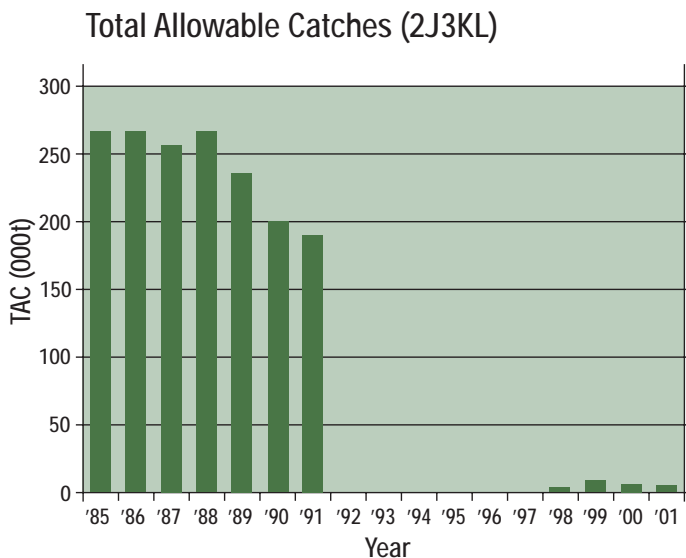
Most cod stocks around Newfoundland and Labrador declined dramatically during the 1960s and 1970s as a result of overfishing by distant-water fleets from Europe. Fishing by distant-water fleets decreased substantially after the 200-mile limit was established in 1977, and the cod populations off southern Labrador and eastern Newfoundland partially recovered. In a move that was clearly wrong in hindsight, Canada permitted Canadian trawlers to replace the foreign fleets, and catches skyrocketed again. Cod stocks declined rapidly during the late 1980s and early 1990s. In July of 1992, Canada declared a moratorium on northern (2J3KL) cod. This was followed by closures of other cod stocks on the Flemish Cap (3M), the southern Grand Bank (3NO), off our south coast (3Ps), and in the Gulf of St. Lawrence off our west coast (3Pn4RS). Since these closures, some cod stocks recovered partially, and fisheries have reopened off the south and west coasts and in inshore areas of 2J3KL. But there has been almost no sign of recovery of northern cod in the offshore.

### Why did the northern cod fishery collapse?

The declaration of the Canadian EEZ in 1977 contributed to an increase in the Canadian catch of northern cod during the 1980s. It is not clear, however, that the

stocks themselves recovered by an appreciable amount since improved fishing methods enables fishers to find and net the cod more easily. A second, more severe, collapse occurred in the late 1980s.

In July 1992, almost 500 years after Cabot's voyage to Newfoundland, the long era of the fishery for northern cod officially came to an end when the then federal fisheries minister, John Crosbie, imposed a moratorium on fishing. The effect on communities was devastating. Approximately 30,000 fisheries workers lost their jobs as nets were stowed away and processing plants closed their doors. It was the largest single layoff in Canadian history. People living in hundreds of communities throughout Newfoundland and Labrador lost their livelihoods. Depopulation caused by the decline in fish stocks still threatens the survival of many rural towns.



**Figure 15.10:** Historical Cod landings from 2J3KL. Total allowable catches (TACs) and landings (thousands of tons) by non-Canadian fleets and Canadian fleets, with the latter divided into mobile gear (offshore) and fixed gear (mainly inshore). *Graph courtesy of Department of Fisheries and Oceans*



## Did You Know?

Foreign fleets severely depleted the cod off northern and central Labrador (known as 2GH). Catches there soared from less than 10,000 tonnes per year in the early 1960s to 95,000 tonnes at its peak.

Landings plummeted to less than 5,000 tonnes during the 1970s to less than 1,000 tonnes in the late 1980s and finally zero in 1991. Although many years have passed since intensive fishing took place in this area, the cod stock has not yet recovered.

### **Total Allowable Catch:**

Total catch, measured in tonnes, allowed from a stock during a specified period of time.

## **The Collapse of the Cod Fishery**

While the ultimate cause of the collapse of the cod fishery was overfishing, the severity of the decline suggests that other factors were involved. It is also not clear why the offshore components have failed to recover since 1992 in the absence of intensive fishing. Certainly, by the time the moratorium came into force, there were far too many people—using bigger and more efficient fishing technology—chasing too few fish. However, questions remain as to what roles environmental change, fishing technology, and over-fishing played in destroying one of the world's greatest fisheries.

Overfishing seems a likely answer if we look back to the 1950s when several European nations introduced one of the most efficient fishing machines ever invented, the factory freezer trawler. As mentioned earlier, these vessels allowed fishing crews to remain at sea for months at a time, catching and storing huge volumes of fish. As a result, cod stocks in waters adjacent to Newfoundland and Labrador declined dramatically during the 1960s and 1970s.

After Canada declared its EEZ, the intent was to fish conservatively and promote the growth of stocks of cod and other species. This did not occur, however, as fishermen and fish plant operators demanded, and were given access to what people were calling “surplus” fish. In retrospect, it is clear that the size of some cod stocks was overestimated during the 1980s and that mortality caused by fishing was higher than intended. This was especially the case for the northern cod off southern Labrador and eastern Newfoundland (2J3KL). In 1988 - 89, scientists stated that the size of the northern cod stock had been seriously overestimated for several years.

This change in scientific estimates implied that a large reduction in **Total Allowable Catch (TAC)** was required for sustainable fishing. However, only a limited reduction in TAC was implemented by the federal government because it was feared that the consequences for the industry of a greater catch reduction would be too severe. Instead, fishing mortality was allowed to increase, ensuring a more severe collapse at a later time. By the early 1990s, much hope was placed on two strong incoming year-classes of fish, which scientists hoped would improve the size of the northern cod stock. This never happened. Instead, these younger fish, along with older fish, disappeared from catches and research surveys.

It is very clear the northern cod were badly overfished prior to the collapse. It has also been suggested that harsh environmental conditions (low water temperatures and extensive ice cover) in the early 1990s contributed directly or indirectly to the collapse. Although the Earth's atmosphere was gradually warming during the last

three decades of the twentieth century, the ocean off Newfoundland and Labrador became cooler, with particularly cold years in the early 1970s, early to mid-1980s, and especially the early 1990s. These unfavourable conditions slowed the growth of fish, and may have contributed to lowered recruitment of young fish and higher mortality of older fish.



**Figure 15.11:** Cod caught in Gillnet. *Photo courtesy Department of Fisheries and Oceans*

Environmental change may have also altered distribution patterns making the fish more vulnerable to Canadian and non-Canadian fleets. The impact of the changing environment is also evident from the dramatic declines that were seen in most other groundfish including species that were not heavily fished and some that were not even targeted by commercial fisheries. In addition, capelin, the major prey for cod off eastern Newfoundland, experienced many changes that clearly were not caused by fishing.

### The Future of Cod

Despite the lack of an offshore fishery directed at northern cod since 1992, the offshore fish stock has not recovered. Research shows that in 2006, fourteen years after the declaration of the moratorium, the population was still only one to two per cent of levels recorded in the 1980s. Recruitment of young fish has been very low and mortality is extraordinarily high, so there are few fish older than age five and no longer than fifty centimetres. Recovery has not yet started and when and if it does, is expected to take a very long time.

Some inshore cod populations appear to have been more productive than the offshore populations since the mid-1990s. Considerable research has been conducted to evaluate the size of these localized stocks.

Fish tagging studies have shown that there are at least two groups of cod currently in the inshore of eastern Newfoundland. One of these is comprised of resident populations that live all year round in from western Trinity Bay northward to western Notre Dame Bay. The largest of these populations over-winters in Smith Sound in Trinity Bay. The second group is migratory: it over-winters in the 3Ps area off Newfoundland's south coast and moves northward perhaps as far as Trinity Bay during the spring and summer.

The future of the inshore populations depends to a large extent on how intensively they are fished. They declined dramatically during the limited inshore fishery of 1998 – 2002, but started to increase again when the partial moratorium was reinstated in 2003. The inshore fishery was reopened in 2006. By carefully studying the success of this fishery and the recovery of this cod stock during the coming years, we may learn a great deal about how to successfully build a sustainable inshore fishery.

### Commercially Important Species

#### Shellfish and other Invertebrates:

- crab, shrimp, lobster, scallops, clams, whelks, squid, sea cucumber

#### Pelagic fish:

- capelin, herring, mackerel, tuna, salmon

#### Groundfish:

- lumpfish, haddock, pollock, white hake, American plaice, yellowtail flounder, witch flounder, blackback flounder, Greenland halibut (turbot), Atlantic halibut, redfish, roundnose grenadier, roughhead grenadier, monkfish, hagfish, skates

## Did You Know?

*Pandalus borealis*, a cold water pink shrimp, is the main species of shrimp harvested in Atlantic Canada. They are caught in water depths ranging from 200 m in the south to 600 m in the north.

Shrimp are hermaphrodites: they first mature as males, mate as males for one to several years, then change sex and spend the rest of their lives as mature females.

## Other Fisheries in the Waters of Newfoundland and Labrador

Although cod is regarded as “fish” to most people in Newfoundland and Labrador, there are many other economically important species that have been, or are being, harvested from our marine waters. As commercial fisheries, as well as fisheries research, expanded to new and deeper areas off our shores, they found huge concentrations of many different species of fish. Most of these were of great commercial interest. Fisheries by many nations expanded to exploit these new found sources of food. There are many species of shellfish, pelagic fish, and groundfish, as well as eels, seals, and whales that have made important contributions not only to the health of the marine environment but also to the livelihood of Newfoundlanders and Labradorians.

### From groundfish to crab and shrimp: the new faces of fisheries

As cod and other groundfish populations declined, some shellfish species became increasingly abundant. Snow crab and shrimp, which were of minor importance prior to the 1990s, are now the mainstay of the province's fishing industry. Since cod and other groundfish fed heavily on shrimp and crab, removal of these predators is clearly a major cause of this population growth. The lack of growth of another preyed species, capelin, indicates that there are other factors involved that are not yet understood.



**Figure 15.12:** Shrimp. *Photo Courtesy DFO*



**Figure 15.13:** Snow Crab.

Regardless of the reasons, the snow crab fishery in Newfoundland and Labrador has grown rapidly since it began in the early 1970s. Most of the growth occurred during the 1990s when the total allowable catch increased from 10,500 tonnes in 1990 to 61,000 tonnes by 1999. However, snow crab populations tend to fluctuate every few years and catches fell to 55,600 tonnes in 2004.

Northern shrimp in the Gulf of St. Lawrence off Nova Scotia and off the northeast coast of Newfoundland and Labrador has become dominant within the fishing industry. Factory freezer trawlers also harvest shrimp from eastern Newfoundland and north to Davis Strait. Landings in 2004 were approximately 100,000 tonnes, compared with a mere 2,000 tonnes per year in the early 1970s.

The move from a large groundfish fishery to one dependent on crab and shrimp has transformed the nature of the industry in this province. These two shellfish species fetch a far higher price per pound for fishers compared with other species such as cod. In 2004, the value of crab and shrimp surpassed \$500 million, while the value of groundfish barely reached \$60 million.

*“The unthinkable has come to pass: The wealth of oceans, once deemed inexhaustible, has proven finite, and fish, once dubbed ‘The poor man’s protein’, has become a resource coveted.”*

-Michael Parfit, 1995

## CHECK your Understanding

1. What is the most crucial issue facing the global fishery?
2. Why are fish so important to mankind?
3. In Newfoundland and Labrador “cod” and “fish” have the same meaning. What does this tell us about the historic place of cod in our culture?
4. What are some of the possible reasons for the demise of the once great northern cod stock?
5. What other species found in our waters have commercial value?

### For Further Discussion and/or Research

6. Describe the trends in historical cod landings. What happened to cod landings between 1958 – 1968; 1969 – 1978; 1979 – 1988; and 1989 – 2006? What portion of the Newfoundland fishing fleet expanded to catch the “surplus” that existed when foreign trawlers were banned? Did this “surplus” exist?
7. Is it likely that northern cod (inshore and offshore) will make a come back in the next few years? Explain.

## Did You Know?

The original three-mile limit was the recognized distance from a nation's shore over which that nation had sovereign jurisdiction. This border with international waters, or the “high seas”, was established because, at the time, three miles was the longest range of any nation's most powerful guns. Therefore, it was the limit at which shore batteries could enforce the nation's laws.

## FISHERIES MANAGEMENT

### International Fisheries Laws and Management

Driven by their concerns and their need to preserve fish stocks, fishing nations established the **International Commission for the Northwest Atlantic Fisheries (ICNAF)** in 1950. It aimed to protect and conserve the fish resources of the Northwest Atlantic area on the basis of then modern fishery science. At the time, there was only a three-mile territorial limit off our coast. Beyond three miles was considered international waters and foreign vessels could fish freely in sight of our shores. ICNAF's mandate included the waters beyond three miles within the ICNAF Convention Area (now the NAFO Convention Area).



## Did You Know?

In 2006, NAFO released a list of fisheries violators: its Illegal, Unregulated and Unreported Fishing List. These vessels belonging to non-members have repeatedly ignored fisheries regulations and as a consequence some NAFO countries, including Canada, have banned these vessels from their ports.

ICNAF carried out many scientific investigations through the 1950s and 1960s aimed at conserving fish resources. Studies often focused on appropriate fish mesh sizes and overall types of gear that were most appropriate. ICNAF also examined the introduction of limitations on fishing. These included controls on fishing effort. By the late 1960s and early 1970s, it had become clear that work in many of the Northwest Atlantic fish stocks was continuing. ICNAF then moved to the introduction of quota controls for the various species and stocks being fished. In 1972 and 1973, the first quota controls were introduced in the Northwest Atlantic. However, due to political influences, the science was often ignored, and the quotas set too high to halt the continuing declines.

In 1977, the United Nations Conference on the Law of the Sea enacted the 200-mile limit Exclusive Economic Zone (EEZ) which gave coastal nations control of waters within 200 nautical miles of their shores. Like most coastal nations, Canada imposed its 200-mile economic zone in 1977 allowing it to control fishing over a vast area in the Atlantic and the Pacific.

### 200 Mile Limit



With the extension of jurisdictions to 200 miles, the mandate of ICNAF was no longer valid, and in 1979 it was replaced by the **Northwest Atlantic Fisheries**

**Organization (NAFO)**. The role of NAFO is to contribute to the rational management and the conservation of fisheries resources in the waters of the Northwest Atlantic. NAFO members include the European Economic Community, Bulgaria, Canada, Cuba, Denmark (for the Faroe Islands and Greenland), France (for St Pierre et Miquelon), Iceland, Japan, Korea, Norway, Russian Federation, Ukraine, and the United States. Today, NAFO is one of many

Regional Fisheries Management Organizations (RFMO's) that attempt to regulate fishing throughout most of the world's oceans. NAFO's counterpart in the Northeast Atlantic is the Northeast Atlantic Fisheries Commission (NEAFC).

NAFO functions as both a scientific body through its Scientific Council and a management body through its Fisheries Commission. Each year, based on specific requests from the Fisheries Commission, as well as coastal states, the Scientific

Council meets to provide advice regarding the management of various fish stocks within its mandate. Information provided mainly focuses on the most appropriate quotas, but other information may also be provided for such things as most appropriate mesh sizes, stock recovery plans, required research, and data issues.

**Figure 15.14:** The 200 mile limit. *Illustration courtesy Derek Peddle*

## Did You Know?

Aboriginal subsistence whaling means whaling for purposes of local aboriginal consumption carried out by aboriginal, indigenous, or native peoples who share strong social and cultural ties related to a traditional dependence on whaling.

Since its inception, NAFO has adopted a wide range of measures for the conservation and management of the stocks in the area regulated under the Convention. These have included:

- setting total allowable catches and quota allocations of member nations;
- technical conservation measures such as minimum fish sizes, minimum mesh sizes, and chafing gear requirements;
- measures designed to promote and coordinate scientific cooperation; and
- measures of surveillance, control, and enforcement.

### Domestic Fisheries Management

Decisions affecting Canada's fisheries are based on several factors. While federal and provincial governments have the power to make decisions and establish laws

A fishery can be considered **sustainable** if it continues to provide the fullest possible range of economic, social, and ecological benefits without jeopardizing the future of the fish stock.

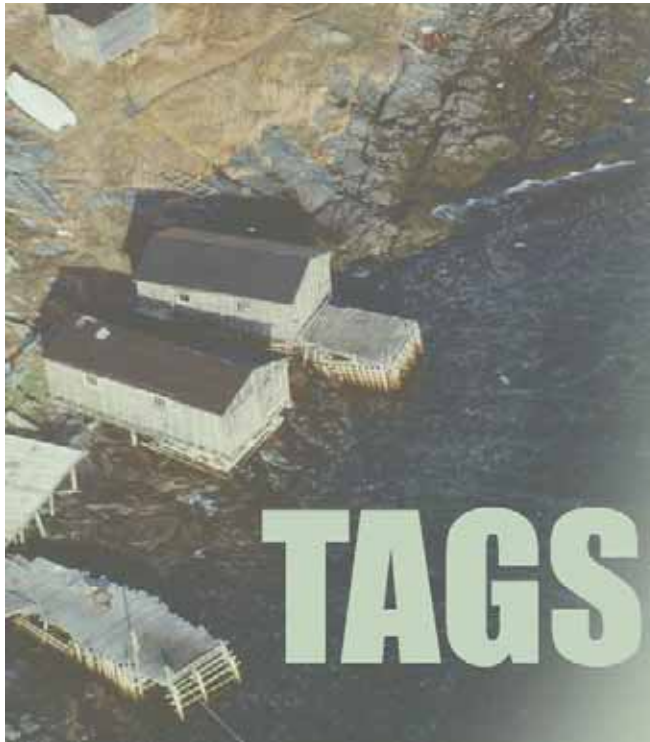
and regulations, they do so based on a wide range of needs and interests. These include political, economic, social, environmental, and international considerations. Often, governments are challenged to negotiate between conflicting interests. This further complicates the job of managing fisheries.

The modern process of decision making in Canada's fisheries is the outcome of more than a century of evolution. Canada's earliest legislation concerning fisheries is found in the **Constitution Act** of 1867. The Act gave sole power to the federal government for managing inland and sea-coast fisheries. Over time, the provinces challenged the federal government's claim to sole authority.

Federal and provincial governments currently share responsibility for the management of fisheries. Conservation remains the federal government's primary objective, along with promoting sustainable fisheries. Fisheries and Oceans Canada, also known as the Department of Fisheries and Oceans (DFO), manages fisheries primarily through the authority of two acts.

1. Under the **Fisheries Act**, the Minister is responsible for management of fisheries, habitat, and aquaculture. In early 2007, the Minister of Fisheries and Oceans introduced amendments to the Fisheries Act.
2. Under the **Oceans Act**, the Minister of Fisheries and Oceans is responsible for leading oceans management.

In Newfoundland and Labrador, the provincial Department of Fisheries and Aquaculture (DFA) is responsible for licensing fish processors, as well as supporting and promoting the development of sustainable and viable fishing and aquaculture industries.



Following the moratorium on northern cod in 1992, the federal government provided income assistance to fisheries workers for two years. Shortly afterwards, the government introduced The Atlantic Groundfish Strategy (TAGS), a five-year, \$1.9-billion program designed to help displaced fishers and plant workers. TAGS offered income support, retraining, licence buy-backs, and early retirement for fish harvesters and plant workers, with the goal of reducing fishing capacity in the province by fifty percent. The effort reduction was successful. While there are still more than enough licenses to harvest groundfish resources, the returns (financial) per licence are much higher today.

## CHECK your Understanding

1. What was ICNAF and when was it established?
2. Why was ICNAF replaced by NAFO?
3. What is the role of NAFO?
4. What are some measures NAFO has adopted to improve the conservation and management of fish stocks?
5. What is the significance of the Canadian Constitution Act of 1867 with respect to fisheries management?

### For Further Discussion and/or Research

6. In our province, what are the respective roles of the federal and provincial governments in managing fishing industry activities?
7. Can you think of reasons why federal jurisdiction of the fisheries is sometimes challenged in the courts?
8. Why did the provincial government create the Professional Fish Harvesters Certification Board? What purpose does it serve?
9. Research the conservation measures that were introduced by the federal government in the 1990s to assist the recovery of the cod stocks?
10. Argue for or against the right of Aboriginal people to harvest whales.

## FISHERIES SCIENCE



**Figure 15.15:** Dockside inspection. Photo courtesy Department of Fisheries and Oceans

### Fisheries Data Collection

As a first step in making management decisions, such as the setting of total allowable catches, fisheries managers must turn to information and advice found in fisheries stock assessments. A stock assessment determines such things as how many fish there are in a stock or population and how this compares with the size of the stock historically, the age or size distribution of fish in the population, whether the population is increasing or decreasing, and whether there are many or only a few young fish entering the population (recruitment). Using this information, it is possible to determine if various catch levels will cause the population to increase, decrease, or stay the same.

In Canada, DFO scientists use information collected from at least two main sources—commercial fisheries and scientific surveys—to estimate the numbers and **biomass** of fish in the sea and the rate at which these change. This same process is used in many other countries around the world.

#### **Biomass:**

The total weight of all the living organisms in a given population or area.

- **COMMERCIAL FISHERIES**

Commercial fisheries include any fishery conducted for profit, either by an individual or a company. Fishing enterprises, whether they be individual fishers or large company-owned trawlers, are required to maintain logbooks in which they record their catch weight, as well as the gear used and amount of effort required (for example, the number of hours trawled, number of hooks, number of gillnets). Commercial



**Catch Per Unit Effort:**

The weight of fish landed given a specific amount of effort.

## Did You Know?

Initially, tagging was done using a tagging gun that was originally designed to place price tags on clothes. Rewards are offered to people who return the tags.

**Stratified random sampling:**

Dividing an area into smaller sections or blocks, then randomly sampling within each block.

catches are also sampled at sea by observers or in port by technicians to obtain information on size, age, sex, and maturity of the fish.

Scientists are also interested in **Catch per Unit Effort (CPUE)**.

This refers to how much effort is used to catch fish. For example, if commercial fishers caught an average of sixty kilograms of fish for each day and each net they had in the water last year, and this year they caught an average of only fifty kilograms, then this may suggest that the stock has declined in abundance. However, there may be bias built into commercial CPUE, as fishers are experts at locating concentrations of fish even when the overall population size may be declining. As a result, CPUE may remain high even with a declining population.

- **SCIENTIFIC SURVEYS**

DFO scientists and other scientists, from Memorial University of Newfoundland or other government institutions, also carry out a number and variety of their own studies independent of commercial fisheries.

- **FISHING**

Government research ships or industry-provided ships routinely conduct stratified random bottom-trawl surveys off Canada's east coast where they catch groundfish species such as cod and flounder. This research provides important information on fish distribution, recruitment, sex, age, and size of fish in the population. It also enables scientists to draw conclusions about their growth, maturity, and condition. Trends in population size can be determined when a number of years of data have been collected.

- **HYDROACOUSTICS**

Sounders, or fish finders, have been used by fishers to locate fish for many years. They work by transmitting sound waves down into the water that reflect off the fish (and bottom) back to a receiver on board the vessel. Scientific hydroacoustics involves the use of very sophisticated sounders to locate fish. From the information gathered, it is possible to determine fish biomass, as well as their distribution both over an area and up and down the water column. This method works especially well when the fish are heavily concentrated and not located very close to the bottom. Scientists have used hydroacoustics to estimate the quantity of cod in specific areas during the winter months to determine the population size of herring stocks, and to estimate the quantity of capelin off the east coast during spring.



**Figure 15.16:** CCGS Leonard J. Cowley. Photo courtesy Department of Fisheries and Oceans

- **FISH TAGGING**

Fish tagging is an important method for learning about migration patterns and mortality of fish. In Newfoundland and Labrador, tagging studies focus on several species, most notably cod and yellowtail flounder (*Limanda ferruginea*). By collecting tags that fishers return from their catches, scientists can determine the movement of specific fish populations. For example, tagging has demonstrated that in recent years, most of the cod in the inshore of eastern Newfoundland remain inshore throughout the year. This distinct behavioural pattern may mean that this is a different population from the cod population that historically migrated to the inshore from the offshore.

- **THE SENTINEL FISHERY**

Before the northern cod moratorium in 1992, scientists relied primarily on commercial and research data from the offshore for the assessment of the stock. A great deal of data was collected from commercial vessels that belonged to large fishing companies. DFO also used its own research ships. Only limited information was collected from the various inshore fisheries. However, this latter group was later recognized as an important primary source of inshore fishery related information.

In 1995, DFO established the **Sentinel Fishery Program**. It became the first rigorously scientific survey program carried out by inshore commercial fishers for determining the relative abundance of inshore cod populations in eastern Canada.

Under the Sentinel Fishery, experienced, professional inshore fishers work with DFO scientists to gather information about cod along the Newfoundland and Labrador coasts. Fishers chosen to participate in the sentinel fishery are given extensive training in gathering, analyzing, and interpreting data about fish biology and oceanography.

Although DFO assesses data from the sentinel fishery, the work of collecting information is coordinated with the Fish Food and Allied Workers Union, as well as the Fogo Island Cooperative



**Figure 15.17:** Sentinel fisherpersons sorting the catch. *Photo courtesy Department of Fisheries and Oceans*

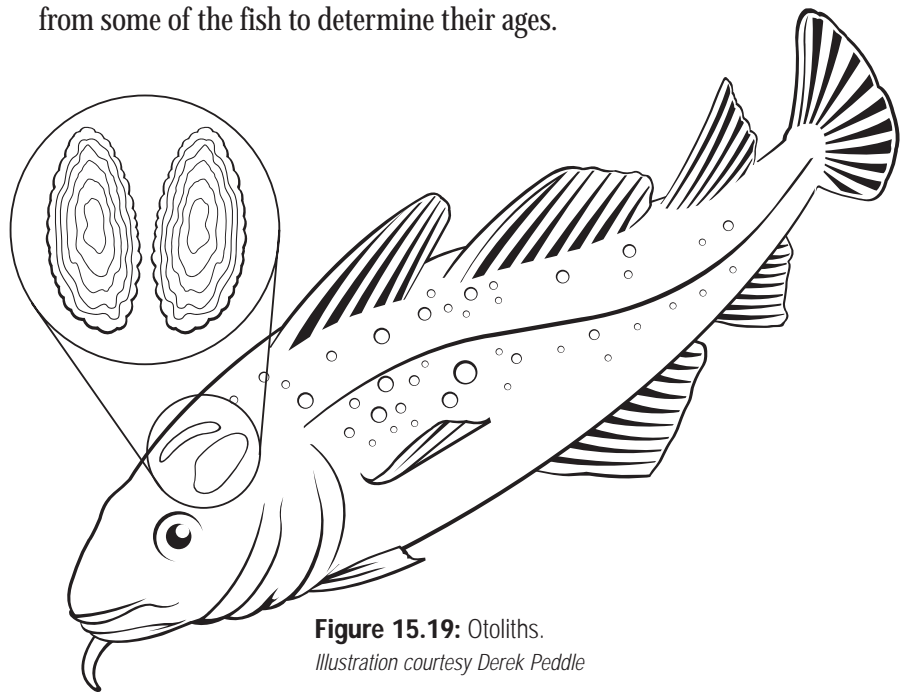


**Figure 15.18:** Sentinel fisherpersons logging data. *Photo courtesy Department of Fisheries and Oceans*

(the Petty Harbour Cooperative was also involved until 2002). Sentinel fish harvesters set fishing gear on traditional fishing grounds at traditional times throughout the year—usually three days per week for ten weeks during the fishing season. Participants are given limits about the quantity of fishing gear they can use—six gill nets and 1,000 hooks on long lines. They must also use at least one-third of their gear on a fixed “control” site that remains unchanged in order to allow for unbiased comparisons between years. Harvesters are free to select locations for their remaining gear.

Detailed logs are kept, including recording the times gear is set and then hauled, the exact locations of gear, the weather and water conditions, and species caught or seen in the area. Once gear is hauled, the catch is weighed and each fish is sexed and measured. Ear bones or **otoliths** are removed from some of the fish to determine their ages.

**Otoliths** have rings similar to the rings in trees. By counting the rings, scientists can determine the age of the fish.



**Figure 15.19:** Otoliths.  
*Illustration courtesy Derek Peddle*

Some of the catch may be sent to laboratories for detailed biological sampling. From these samples, information on reproductive status, condition of the fish, and diet are gathered.

The sentinel fishery has also been a valuable program for tagging cod. Recaptures of tagged cod are plotted on maps giving scientists and fishers valuable information about the behaviour and migration of inshore cod.

## ECO SPOTLIGHT:

### David and Irene Bath— Sentinel Fish Harvesters

When David and Irene Bath from Too Good Arm began fishing during the mid-1970s, they expected to spend their entire working lives catching fish just as their parents and grandparents had done.

The years had a predictable rhythm. In late April, the husband and wife duo began catching lobsters. A few weeks later it was salmon and then cod in early June. During

June and July they fished all three species. They needed the long days of summer so they had time to pull lobster pots and cod traps, and set salmon nets. The lobster and salmon seasons ended by July. In August, the Baths had to follow the cod farther offshore where they switched to gill nets and hand lines to catch them. By October, the inshore fishing season was over for that year.

In 1992 the lives of the Baths and thousands of fishing families throughout Newfoundland and Labrador changed when the federal government imposed a moratorium on fishing for northern cod. Cod traps, gill nets, and hand lines, as well as boats, were stowed away—perhaps forever.

In the mid-1990s, the Baths became part of the sentinel fishery. Since then, David and Irene have worked with fisheries scientists to assess growth of cod populations in their region. “I always liked fishing cod, so I was delighted when our names were picked”, David said.

The Baths follow a strict regimen during the sentinel fishing season. They set three fleets of gill nets, two nets for each fishing station each week. Catches are taken ashore where David and Irene measure, weigh, and determine the sex of each fish. They also remove the otoliths and send them to scientists at Fisheries and Oceans Canada who use them to determine the ages of fish.

They occasionally tag fish. And David said he has learned a great deal about cod migration from this activity. “Some of my fish have been caught



**Figure 15.20:** Measuring a cod. *Photo courtesy Department of Fisheries and Oceans*



**Figure 15.21:** Irene and David Bath, 2006. *Photo courtesy Irene and David Bath*



off Labrador and Smith Sound, and we've found fish from all over the island in our nets", he said.

The sentinel fishery proved controversial in other communities throughout the province, but not in Too Good Arm. David said fish harvesters realize how important the sentinel fishery is to assessing stock recovery. Without this program he said, scientists would have no reliable way of determining whether cod populations are growing.

## Did You Know?

A **Stock Assessment** determines the **production** of a fish stock, which is the sum of the recruitment of young fish, plus the growth of larger fish, minus the natural mortality or numbers that are dying. If the sum is positive then the stock will grow, but if the sum is negative the stock will decline.

When we fish, we increase the fish stock mortality and this will reduce the production. An objective of fisheries management is to ensure that production is not reduced to a negative value, which signals a stock in decline.

### Estimating Population Size and Fish Stock Status

Since the early 1970s, Fisheries and Oceans Canada has conducted extensive scientific research into the status of numerous fish species that live in the waters off Canada's east coast. The primary purpose of collecting information about the size and composition of fish stocks is to provide recommendations to decision-makers in the federal government, or ICNAF/NAFO, regarding harvesting limits.

As we have learned, scientists collect data about catch sizes, as well as length, and age ranges of fish. They also determine how much fishing gear is needed to catch fish—the catch per unit effort. By doing this work over a period of years, scientists are able to obtain information about population trends for targeted fish species.

In assessing the status of a fish stock, and working at determining the **production** of the stock, scientists must try to determine not only the addition of young individuals to the stock (known as recruitment), and the removal of individuals (by the fishery or by natural causes), but also the growth of individual fish because, unlike humans and other mammals, fish continue to grow throughout their lives. The number of older, larger female fish is a particularly important clue to the health of a fish stock because older, larger female fish produce many more eggs than young adult females.

In practice, estimating the number of fish is challenging, and it is complicated by the biology and behaviour of the fish. The marine environment is largely closed to humans—fish are hidden from view and many migrate unseen and largely untracked over vast distances in search of food or to reproduce.

**Mathematical models** are useful for making estimates about the size of fish populations. The model most often used to determine the size of a commercially fished stock is **Sequential Population Analysis (SPA)**.

**Year-class:** Fish of the same age that are hatched in the same year.

In SPA, annual estimates of the total numbers of fish caught belonging to each year-class are used to estimate the numbers that must have been in that same year-class in the past. When the numbers of each year-class have been estimated for each year,

then the total population numbers for each year is estimated by adding up the numbers of all the different year-classes existing in that year. Both natural and fishing mortality are taken into consideration when estimating these population numbers.

There are numerous uncertainties with this modeling approach. For example, catches may not be reported accurately, natural mortality is difficult to measure, and estimates of fishery discards may be inaccurate or lacking. For these reasons, some people would prefer to determine stock trends by looking at simple indices from the fishery. However, it has long been recognized that these, too, may be misleading. For example, as we have already learned, CPUE from commercial fishing can give an over-optimistic view of the status of a stock because fish harvesters are skilled at finding fish, even if there are not many fish to find. CPUE can, therefore, remain high even when stock size is decreasing, as happened with northern cod.

The use of additional fishery independent information helps in alleviating these problems. For example, data from research vessel surveys should not have the problem of bias that exists with commercial CPUE.

All of the methods described above can help determine current stock sizes, however, the complexity and nature of the problem means that estimates will always be uncertain to a greater or lesser degree. It is important that this uncertainty be acknowledged in management decisions for all fisheries.

## CHECK your Understanding

1. Why do we assess fish stocks?
2. Briefly describe the different sources of data that scientists use when assessing fish stock status.
3. What has recent fish tagging taught us about the population of cod in the inshore waters of eastern Newfoundland?
4. What is the purpose of the sentinel fishery?
5. What is meant by 'production' when talking about fish populations? Why is important to know fish production?
6. What are some of the uncertainties with the sequential population model of estimating fish stocks?

### For Further Discussion and/or Research

7. In an earlier unit, you learned how wildlife managers calculate population size for such animals as moose and caribou. In what ways are the methods used to calculate the population of fish species similar to that used for land mammals? In what ways is it different?
8. Which do you think would be the most difficult to get an accurate measurement of population size, a moose population or a fish population? Explain your reasoning.

## CAREER SPOTLIGHT:

**Dr. Joanne Morgan**  
**Scientist, Fisheries and Oceans Canada**

**Dr. Joanne Morgan** is a research scientist at the Science Branch, Groundfish Section in the Aquatic Resources Division at Fisheries and Oceans (DFO), Newfoundland and Labrador Region.



### **Joanne's Childhood Influences:**

Joanne grew up in North Sydney, a community along the eastern coast of Cape Breton Island, in Nova Scotia. Joanne has always loved being outside and active. One of her favourite things to do as a child was to snorkel and watch for different types of fish at the beach.

### **Main Interests:**

In the summer, Joanne likes to camp and play tennis with family and friends. Joanne is also an avid curler but she says her team just plays for fun.

### **Strong Life Influences:**

"Of course my family has always been a major influence. My mother always encouraged me to do whatever I wanted and believed that I could succeed in anything I worked hard at", says Joanne.

She continues, "In high school, I did a math honours course and I found the teacher of that course to be excellent. She pushed us hard to do our best and she was very good to her students. My honours professor at university encouraged me to continue my education and to go on to graduate school. Once I graduated with my PhD, I found a job with DFO in Newfoundland. The section head of my department was very encouraging and he gave me the opportunity to pursue my interests in studying stock assessments, and that has been a major influence in terms of where I am today in my career".

### **Joanne's University Background:**

Joanne completed her undergraduate degree at Mount Allison in Sackville, New Brunswick. Afterwards, she graduated with a PhD from Queens University in Kingston, Ontario where she studied the schooling behaviours of fish.

### **Favourite University Courses:**

Joanne really enjoyed history classes but, of course, science classes—specifically biology—were Joanne's favourites.

### **A Typical Day at Work**

“I don’t really have a typical day, but I will explain the tasks I am responsible for: some days I will do all of them and other days just one depending on the task.

“I spend my time doing research and some of that time is spent travelling. I have traveled as far as Iceland and Portugal to work on research projects and to attend conferences. When I research, I study the reproduction of different types of groundfish to understand their population dynamics. I look at factors such as what affects their reproduction and at what age they become adults. While I don’t spend a lot of time in the lab anymore, I do oversee the progress in the lab and take the data for further analysis.

“When I’m in my offices you might find me drafting budgets, analyzing data, writing proposals, analyzing graphs, and reading and writing scientific papers. I also attend meetings with others in the science sector to find out what the progress is on certain projects and to see what different projects my colleagues are working on. I find I spend a lot of time interacting with other researchers and scientists who I work with and some who work for me”.

*“In terms of the big picture, my work is important because I study fish resources which have been, and continue to be, influential to the Newfoundland and Labrador economy.”*

**Dr. Joanne Morgan**

### **Importance of the Job**

“My work is very important to me because I still find what I do very interesting and I enjoy the projects that I get to work on. I get to decide what I research, so I guess that gives me the freedom to investigate what I’m interested in.

“In terms of the big picture, my work is important because I study fish resources which have been, and continue to be, influential to the Newfoundland and Labrador economy.

“I feel that my work here at DFO is important because it improves the overall knowledge of fish reproduction. This information is very useful as it is necessary to understand when it is ok to start fishing certain species and when other species need to be protected. My hope is that, here at DFO, we can continue to provide reliable advice that will be used in the management of fish resources”.



**A message from Joanne to you, the Students of Environmental Science:**

“I think if you want to become a research scientist you must be prepared to work hard in school in the subject areas of biology, fish biology, and math. I also think that it’s important to be very interested in what you are studying because self-motivation and drive are going to be imperative if you want to find a career for yourself as a biologist or a research scientist. For example, I have always been very interested in how things work and, more specifically, why fish do the things they do, and how they interact with one another.

I also think that it would be a good idea to become aware of the job market and seek advice from your teachers and professors”.

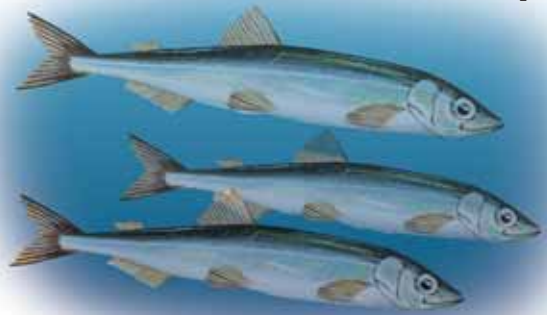
## **SUSTAINABILITY OF MARINE RESOURCES**

There are several factors, both natural and human-made, that affect the sustainability of marine resources.

### **Status of fish populations**

Changes in the status of a fish population can affect other fish species associated with, or dependent upon, the harvested species. For example, those species which are predator or prey of the targeted species will be impacted if the targeted fish species population declines. It is important to look at the impacts of fishing a particular stock on other members of the food web, and to know how changes in the food web affect the harvested species.

Research shows, for example, that capelin is an important prey for many species of fish, marine mammals, and marine birds. With capelin playing such a key role in the food web, the capelin fishery must be managed carefully to ensure that a sufficient amount of food is left for its predators.



**Figure 15.22:** Caplin.  
*Photo courtesy Department  
of Fisheries and Oceans*

### **Biological characteristics of a fish species**

The biology of a fish species is important in deciding how well a fish population can sustain fishing pressure and how many fish can be caught without negatively impacting the stock. Short lived, fast growing fish species, like herring and capelin, generally recover more quickly from fishing pressure than species such as skates and sharks that reproduce more slowly.

Even within a single species, there can be large differences in growth rates from one geographic area to another. This in turn affects the type of fishery that the species in a given location can sustain. Because Cod in the cold waters off Newfoundland and Labrador grow much more slowly than cod in the relatively warm waters of Georges Bank off the Northeastern United States, the northern cod must be fished more cautiously.

### Changes in the environment

Populations of marine wildlife may fluctuate over time in response to external environmental factors such as climate and oceanic conditions. During the early 1990s, the waters off Newfoundland and Labrador became colder, with extensive, long-term ice cover. These conditions lowered the ability of the cod to grow, reproduce, and survive.

### Fishing Pressure

As we learned earlier, if productivity is positive a fish resource will grow, but it will decline if productivity is negative. Fishing pressure is most often key to whether a resource is sustainable or not. It can cause productivity to become negative if not carefully monitored and controlled.

### By-catch

In 2003, more than seven million tonnes of by-catch was discarded worldwide including species such as dolphins, turtles, and albatrosses. This figure represents



nearly ten percent of the global fish catch. While all fisheries have some by-catch, what kind, how much is caught, and how much of it survives, varies greatly between fisheries and between countries.

One way to reduce by-catch is by carefully selecting the area to be fished. In areas where the cod fishery is closed, for example, fishers harvesting species other than cod are required by law to stop fishing or to move to another area when the quantity of cod taken as by-catch exceeds a preset level. Within NAFO, regulations restrict by-catch of species under moratoria to less than five percent.

Restrictions placed on gear as well as modifications to gear can also reduce by-catch. For example, in Canada, the mesh of gillnets and bottom (otter) trawls used to catch skates must be large enough to allow most other groundfish to pass through unharmed.

**Figure 15.23:** Leatherback turtle caught as by-catch. *Photo courtesy Department of Fisheries and Oceans*

### Habitat destruction

The biodiversity, or variety of species, of an ecosystem is an important measure of ecosystem health. To maintain diverse, healthy marine resources, the habitats that sustain them have to be protected.

In the open ocean, certain fishing and offshore oil practices can have significant impacts on marine ecosystems.



**Figure 15.24:** Oiled Thick Billed Murre. *Photo courtesy Tony Power*

Other human activities such as aquaculture or fish farming can lead to habitat destruction by altering ecosystems where many marine and land species live and breed. An estimated five percent of all of the mangrove destruction worldwide is due to the building of shrimp farms.

### Pollution and disease



**Figure 15.25:** An abandoned, rusty oil drum that has contributed to contaminating a local water body.

Agricultural run-off, as well as human and industrial wastes, can cause pollution in coastal waters and impact marine plant and animal populations. This may make commercial species unfit for human consumption or render areas unsuitable for aquaculture. For example, there is a ban on eating fish caught in St. John's harbour.

Fish farming is like any other livestock operation. When a lot of animals are densely packed into one area, large amounts of waste are produced from surplus food, feces, and additives like hormones or antibiotics. Without careful management, this waste may pollute the aquatic environment surrounding fish farms.

### Responsible Fishing

For fish to be a renewable resource, fish stocks, after harvesting by humans, should be capable of replenishing themselves naturally. If too many fish are killed, then populations cannot maintain their numbers. That is what happened to the northern cod fishery and made the moratorium necessary.

To ensure that fish populations remain healthy, fish harvesters must practise responsible fishing. The basic idea is to use fishing gear and fishing methods that allow a fishery to be sustained indefinitely. In addition, it means respecting catch limits and ensuring that other fish stocks, other marine life, and the entire marine environment are not damaged as a result of fishing activities.

Responsible fishing is promoted widely in Canada's fishing industry in three ways:

**1. Encouraging the use of fishing gear and fishing practices that promote conservation of fish stocks.**

Fishing gear must be designed to allow for the catching of a certain size range of fish. Smaller fish, or larger fish, must be able to escape capture. This is important in managing fisheries because the future of any fish stock is influenced by the size and maturity of fish that are captured. It is also important to use fishing gear that only catches the targeted fish species. This reduces the problems caused by catching and discarding unwanted fish.

**2. Professionalization of fish harvesters and training in responsible fishing practices.**

For many years, the fishery was viewed as being the occupation of last resort for people living in rural regions of Newfoundland and Labrador. This attitude has changed since the early 1990s, with much of the credit going to the Fish Food and Allied Workers Union (FFAW). The FFAW, with the assistance of the federal and provincial governments, began developing standards for knowledge, skills, and experience among fish harvesters. In many cases, professionalization is a way of building on the hands-on experience required by fish harvesters.

**3. Code of Conduct for Responsible Fishing**

In addition to endorsing the International Code of Conduct for Responsible Fishing approved by the United Nations Food and Agriculture Organization (FAO) in 1995, Canada was the first country to adopt a national Responsible Fishing Code. This Code is important for maintaining a sustainable fishing industry and is promoted by the FFAW to be applied by fish harvesters in Newfoundland and Labrador.

## Envirofact:

### Whale interactions with fishing vessels

In some fisheries, whales prey on hooked fish as longlines are being reeled in. Fishers try to deal with this apparently new behaviour by changing the way they reel in their lines, thereby confusing the whales. While whales can be a nuisance to fishers, evidence suggests that some fishers have encouraged whales to hang around vessels by feeding them fish entrails!

### Benefits of Responsible Fishing—An Example

A responsible attitude towards fishing requires that a fish harvester does not set more gillnets than can be checked within a reasonable period of time. Fish that are caught in nets that are left in the water for too long begin to decay. Catches then result in poor quality landings, which fetch a lower price from buyers than high quality catches. Or if the decay is too advanced, the catch has to be dumped.

In cases like this, not only is the fisher's time and money wasted, but the health of fish stocks may also be harmed because fish that would not have ordinarily been caught die in nets with small mesh size before they can reproduce. Responsible fishing practices would include checking nets frequently, using larger mesh, and avoiding situations where fish will be dumped.



## CHECK your Understanding

1. What is sustainable fishing?
2. What are the different factors that can affect the sustainability of marine resources?
3. Why is capelin considered a “keystone” species of the North Atlantic Ocean?
4. How much by-catch has been estimated to be discarded worldwide?
5. What are the key elements to responsible fishing?
6. What is “responsible fishing”? How is it promoted in Canada?

### Census of Marine Life

Human activities threaten many marine habitats and species. The majority of the world’s governments recognize this fact. Many of them have made commitments to identify and conserve biodiversity.

The Census of Marine Life is a commitment agreed to by seventy nations. Over the course of ten years (2000 - 2010), scientists will try to assess and explain the diversity, distribution, and abundance of marine life in the oceans, past, present, and future.

## NEW FISHERIES PERSPECTIVES, PRACTICES, AND RESEARCH

### Impact of Mobile Bottom Fishing Gear

Mobile bottom fishing gears (MBFG) are towed directly on the seabed in order to harvest target species of fish, scallops, and clams.

MBFG have been in use since the 1940s and have had profound negative effects on continental shelf ecosystems. More recently, larger and more powerful vessels are allowing many countries to fish in deep water habitats (for example, to 2,000 metres) and, as a result, the impacts of MBFG are extending into deeper waters around the world.

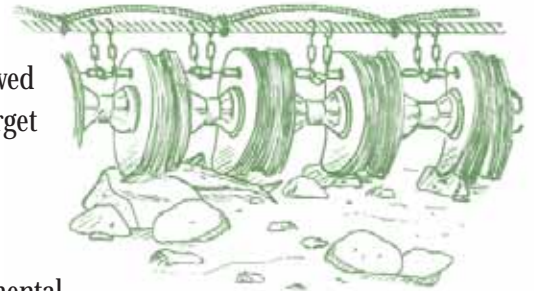
Within the path of MBFG, seabed habitat features are dragged, removed, damaged, or buried. These features include physical elements such as boulders, bedforms (e.g. sand ripples), and benthic organisms.

The impact of MBFG depends on:

- type of fishing gear;
- pattern of fishing activity; and
- habitat type and associated biological communities

Three kinds of MBFG operate in Atlantic Canadian waters:

1. bottom otter trawl;
2. scallop dredge (or rake); and
3. hydraulic clam dredge.



**Figure 15.26:** Mobile Bottom Fishing Gear. Illustration courtesy Derek Peddle

### What are benthic organisms?

Organisms that live on or just below the seabed surface are called **benthic** while organisms that live in the water column are called **pelagic**. Examples of benthic organisms include:

- sponges;
- corals;
- sea stars; and
- crabs.

While trawls and dredges typically do not penetrate deeply into the sediment, hydraulic clam dredges dig as much as twenty centimetres into the sediment in

order to harvest burrowed clams. Environmental impacts from trawlers have been given the greatest attention since trawlers have been in use since the 1940s and because there are more of them.

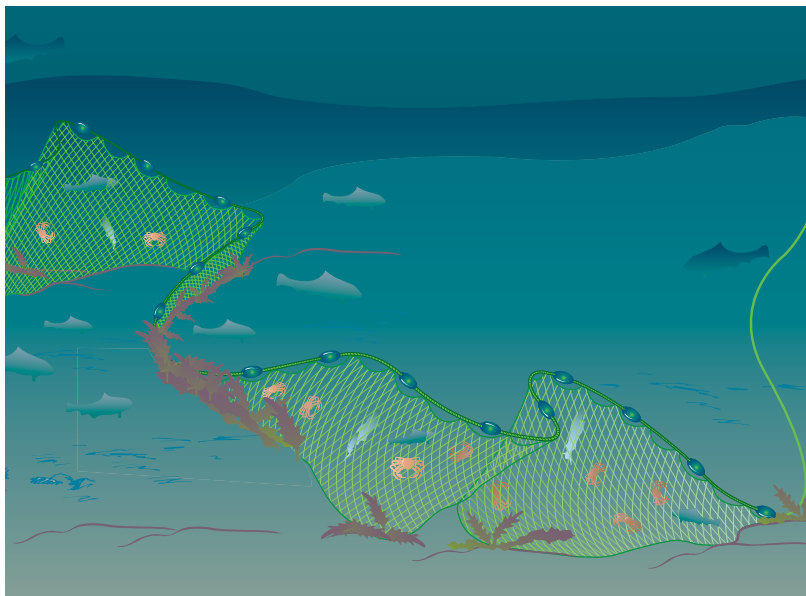
Decisions are also guided by the **precautionary approach**, whereby scientific uncertainty should not serve as an excuse for inaction. Precautionary steps should still be taken to protect the environment from human activities.

While the full extent of MBFG impacts is not known, we can be certain that fewer and fewer areas of the seafloor at fishable depths can be thought of as pristine (untouched by human activity).

An example of an impact from a MBFG is the destruction of deep-sea coral habitat. Although fishers have known of deep-sea corals for a long time, scientific research in Atlantic Canada only started during the 1990s.

Some species of deep-sea corals are known to be slow growing and can live to ages of several hundred years. Since they grow in a tree-like fashion (to heights of centimetres to metres), they are very vulnerable to deep sea trawling.

Not only are corals living organisms, they are home to many other forms of marine life. To date, dozens of species of invertebrates have been found associated with deep-sea corals including hydrozoans, basketstars, clams, and shrimp. The potential importance of deep-sea corals to the population dynamics of fish is an active area of research. When corals are damaged or destroyed, then the life forms which they support are affected.



**Figure 15.27:** “Ghost” Gillnet.  
*Illustration courtesy Department of Fisheries and Oceans*

### Ghost Fishing

Ghost fishing occurs when traps or nets lost at sea continue to ensnare marine life. Ghost nets can be very destructive as they may continue fishing for months or years after they are lost.

In Newfoundland and Labrador, gillnets are the main ghost fishing problem.

Gillnets are lost for a number of reasons. Some are lost in storms or in heavy tides. Some are lost when they become entangled with other gear or when their buoy lines are

accidentally cut by vessels. Others are cut loose or simply abandoned at the end of the fishing season. Once lost, it is impossible to know how much damage a gillnet will cause or for how long it will continue to destroy marine life.

Awareness of ghost fishing became more widespread in the 1970s. One report in 1975 suggested that 5,000 gillnets had been lost in waters off Eastern Canada



**Figure 15.28:** Crab caught in retrieved ghost net. *Photo courtesy Department of Fisheries and Oceans*

during the preceding year. Recovery efforts in the mid-1970s yielded hundreds of lost gillnets. Fewer and fewer nets were lost or found in the following decade suggesting that the problem had peaked.

While ghost fishing has declined since the 1970s, it still occurs and can have serious consequences. During the 1999–2000 cod fishing season on Newfoundland's south coast, 184 gillnets were reported lost in Placentia Bay due to an unusually high number of fishers in the area. The sixty nets later recovered contained

lumpfish, lobster, winter flounder, snow crab, seals, and around 13,600 kilograms of decayed cod.

#### Measures to avoid losing gillnets:

- use radar reflectors;
- use inflatable buoys on the end of each fleet;
- buoy lines should be at least ½ inch in diameter;
- buoy lines should be at least 1 ½ times the depth of the water;
- attach lead ropes to each buoy line 5 fathoms below surface;
- set only as much gear as can be retrieved in a day;
- avoid setting nets across other gear or in areas of high vessel traffic;
- have a gillnet retrieval device or “creeper” on board; and
- report lost nets and begin searching immediately.

This type of destruction has made some people call for gillnets to be banned. Apart from ghost fishing, gillnets have other drawbacks. While the mesh of a gillnet determines the size of fish it will catch, it does not control the type of fish, which may lead to wasteful **by-catch**. Because of bad weather and other reasons, nets may be left to fish for as long as ten days; fish that are trapped for several days deteriorate quickly and may become prey for hagfish, sea lice, and snow crabs.

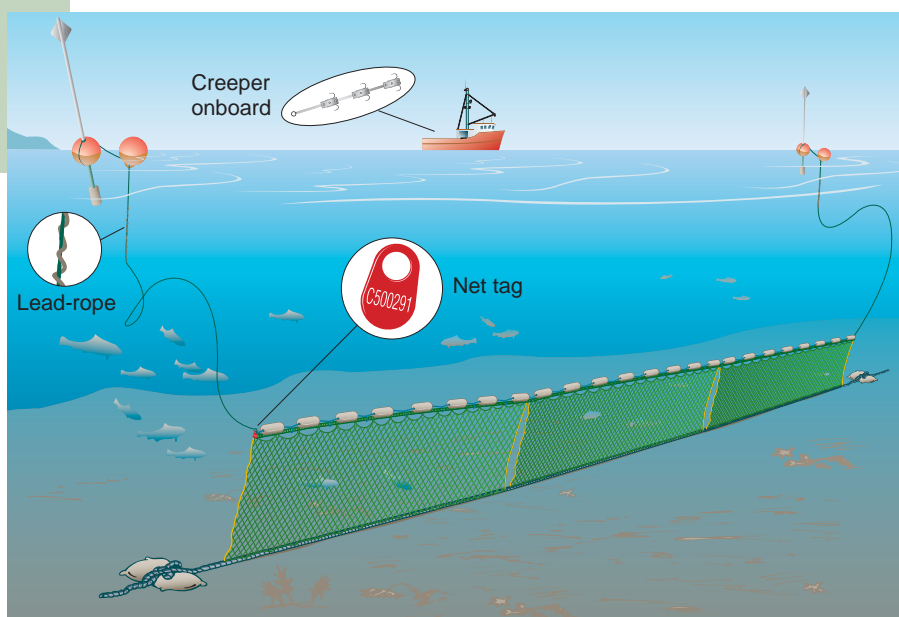
Advocates for gillnets maintain that, like any fishing gear, properly used gillnets are safe and can yield a high quality catch.

The Canadian and provincial governments' focus today is on preventing loss of nets as the best approach. Preventive measures include using radar reflectors, inflatable buoys, and reinforced buoy lines.

## Did You Know?

A **creeper** is used to retrieve lost nets. A fishing vessel drags the creeper along the seafloor, where it hooks into lost gear.

Gillnet fishing vessels should always have a creeper on board.



**Figure 15.29:** Gillnet in fishing order. *Photo courtesy Department of Fisheries and Oceans*

### Species at risk as by-catch:

Three species of wolffish are listed under Canada's Species At Risk Act. It is illegal to catch and keep the two that are listed as "Threatened" (northern wolffish and spotted wolffish). Wolffish are caught in bottom trawls, gillnets, crab traps, and hook and line ground fisheries.

### Reducing wolffish by-catch:

- In many cases, proper handling and quick release of wolffish gives them a strong chance of survival.
- Recovery tanks are sometimes used on vessels. These tanks provide a flow of water that allows the fish to rejuvenate and get oxygen so that it will be stronger when released.
- For gillnet fishers, nets should be hauled frequently and not left to fish for long periods.
- Trawls with separator grates reduce the incidence of wolffish by-catch.
- Another way to reduce by-catch is to completely avoid areas where wolffish are found.

### By-catch

By-catch refers to the unintentional harvesting of marine animals. Some by-catch occurs when species that are similar in size to the target species, and found in the same area, are harvested in nets, traps, trawls, or on longlines. Other times, larger animals are ensnared in gear used for catching smaller fish.

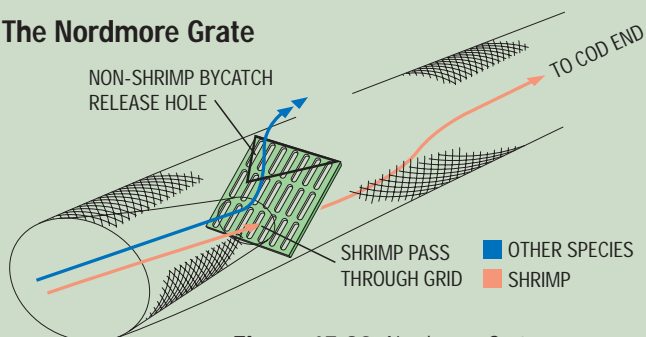
By-catch occurs in virtually every fishing fleet around the world, regardless of the type of gear being used. Often, by-catch is discarded at sea without being reported. Animals caught as by-catch sometimes survive, but mortality rates are high. By-catch poses a serious problem to conservation efforts and threatens the survival of some marine animal populations.

There are two basic types of by-catch:

- **By-catch of species that have commercial value** and which often supplement income earned from targeted species. This type of by-catch is sometimes called non-target catch. Non-target species caught in this way often become target species due to their marketability.
- **By-catch of species that have little or no commercial value.** This includes seabirds, sea turtles, and marine mammals. It also includes species that are illegal to harvest due to being listed under Canada's Species at Risk Act (SARA). In Newfoundland and Labrador for example, it is illegal to harvest spotted and northern wolf fish.

In Newfoundland and Labrador, improvements in fishing gear and techniques are helping to reduce by-catch in some fisheries. Fishers take a lead role in proposing ways to reduce by-catch by improving gear. Fishers work closely with fishing gear technicians to conduct tests on new gear. Small adjustments in fishing gear can have very significant effects in reducing by-catch.

### The Nordmore Grate



**Figure 15.30:** Nordmore Grate.

*Illustration courtesy Derek Peddle*

### Capelin by-catch in shrimp fisheries

Shrimp trawlers have been used in the Northern Gulf of St. Lawrence for decades. Through the use of the Nordmore grate, Greenland halibut and redfish escape from trawls, and by-catch of those species has been greatly reduced. However, the grate alone did not reduce the by-catch of capelin. Tests did show that by including a square-mesh panel behind the grate and a fifty millimetre square-mesh codend, by-catch of capelin drops to a very small percentage of the total catch. However, to date, square mesh panels and codends are not used commercially.



## Impact of Seals and the Seal Fishery on Fish Stocks



**Figure 15.31:** Seals on the ice.

A common misconception is that the Atlantic Canadian harp seal (*Phoca groenlandica*) hunt is carried out to protect and revive depleted cod stocks. This is not the case. The seal hunt is an important economic activity for sealers. In managing the seal fishery, quotas are set to maximize sealers' economic returns, while maintaining a healthy seal population. As a result, the Northwest Atlantic harp seal population increased in size from the early 1970s until the mid 1990's. It then remained relatively stable at a high level until 2005 when an estimated 500,000 animal decline (nine percent) in the population occurred. The 2005 estimate, however, still suggested a population of 5.3 million harp seals.

The relationship between seals and their environment is an important research subject in Atlantic Canada. Scientists are trying to understand the impact of seal predation on cod stocks and whether seals are hindering the recovery of depleted stocks in some areas. Scientists still have much to learn and are not yet able to determine the impact of seals on commercial fish stocks.

There is no simple answer to how seals impact cod because the relationship between species in an ecosystem is complex. In order to understand the relationships between species, scientists must also consider both direct and indirect effects of seals on their prey. Seals can have a direct effect on cod by preying on them, as well as indirect effects by preying on other species that interact with cod. Research is complicated by the difficulty of observing through out most of the year.



**Figure 15.32:** Map depicting the movement of harp seals.

*Photo source: Department of Fisheries and Oceans, illustration courtesy Derek Peddle*

## Did You Know?

**Satellite Telemetry:** Since the 1980s, scientists have been using satellite tags to track seal movements. Recent advances in technology allow scientists to tag young seals. Tags are now capable of detecting water temperature and salinity. This provides information that is useful in seal research. It can also be used by oceanographers to create models of the marine environment, which can then be used by the Coast Guard in search and rescue operations.

To assess the impacts of seals on their prey, research proceeds through a number of steps.

1. Determine the amount of fish (or other prey) consumed. This is done using a **bioenergetics model** that predicts the total amount of food energy required to sustain the seal population based on the number of seals of each age in the total population, the size of seals of various ages, and the energy required by seals of different sizes.

2. Once the total amount of energy required by the population is estimated, scientists then try to determine where the seals get their food, recognizing that seals change locations across different seasons. They need to gather answers to several questions. For example:

- What is the overall pattern in seasonal distribution of the seal population?
- Do seals of different ages and/or sexes vary their travel routes?
- How many of the seals in the population occur in the area of interest and how long do they stay?
- Given that seals do not feed at certain times of the year, where are they building up their energy reserves? When are they feeding at low levels or not at all?

3. With this information, scientists then generate a mathematical consumption model to help with their estimations of this complex issue. Seals eat different foods at different times of the year and in different places. In some cases, males and females eat different prey. Also, young seals often eat different food than older ones. In addition, diets may change from year to year for a large number of seals. From these complex scenarios, data is compiled and entered into a mathematical model to estimate the amount of each prey species the seals consumed. The model must take into account the fact that any of the variables can change from year to year.

DFO scientists have constructed models to estimate the amount of prey eaten by seals in Atlantic Canada. They found that although Atlantic cod are eaten in some places, overall, cod make up only a very small part (less than five percent) of the total diet. The vast majority of prey eaten is small

pelagic forage fish such as capelin, Arctic cod (*Boreogadus saida*, a distant relative of Atlantic cod that is not fished), sand lance, and herring.

Although these consumption models estimate the amount of cod eaten by seals, they cannot help to determine the impact of this predation on the cod population. In order to do that, it is important to relate the amount eaten by seals to the total size of the cod population and the amount of mortality caused by other sources. These questions are more difficult to answer.

Estimating the direct impact of seals on cod does not tell us everything about the relationships between seals and cod. There are also indirect impacts that need to be taken into account:

- Seals can bring benefits by preying on species that prey on cod. For instance, seals feed on herring which eat cod eggs.
- Seals may also prey on species that cod rely on. For instance, grey seals eat sand lance, which is an important part of the diet of cod.

In order to see the indirect impacts of seals on cod, scientists work to understand the population dynamics of the whole range of seal prey. Seals are only one part of a complicated food web, although they are a very important part. Many marine species prey on only one or two other species. Seals prey on a wide range of species and can therefore play a large role in the food web. Depending on the specific dynamics of populations, seals can either destabilize or stabilise prey populations.



## ENVIRO-FOCUS

### Challenges to the analysis of seals diet

Research into seals diet and its potential impact on commercial fish stocks is currently being carried out by Fisheries and Oceans Canada. Since 2003, the Atlantic Seal Research Program has been investigating the ecological role of harp, hooded, and grey seals.

Harp and hooded seals are found off the coast of Newfoundland and Labrador. All three species are found in the Gulf of St. Lawrence. Large numbers of grey seals are also found in waters near the Sable Island, while relatively few occur around Newfoundland and Labrador.

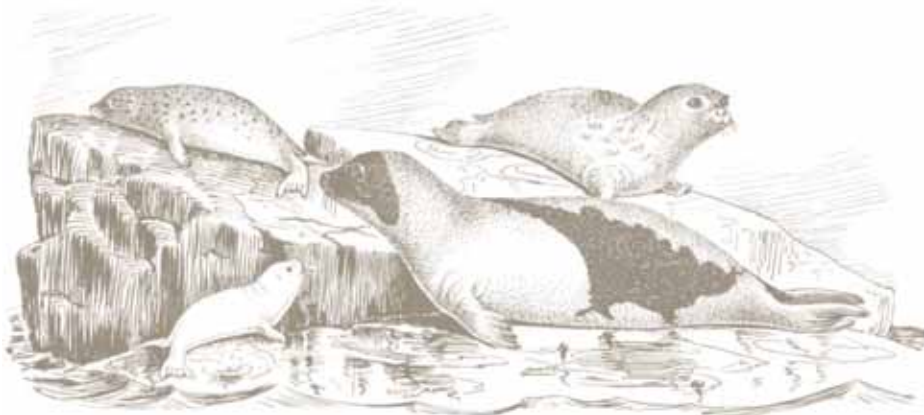
Different types of analysis are used to determine the diet of seals. Each type of analysis has a different bias meaning that they may reveal some parts of diet,

but not others. By combining different types of analysis, scientists get the best overall picture of diet. Two important forms of analysis follow:

Traditionally, analysis of stomach contents and feces gave scientists the best window into diet. The drawback of this approach is that only the contents of the last meal can be known and analysis depends on the presence of hard, undigested materials like fish bones. The consumption of prey species that do not have hard parts (for example, jellyfish) or the taking of only soft parts of the fish (for example, 'belly-biting' which refers to feeding only on the fleshy belly of a fish) is unaccounted for in this method.

A more recent form of analysis is to use the fatty acid signature of the prey to determine if they are present in seal diet. This is possible because each fish species has its own signature combination of fatty acids. Therefore, when seal blubber is analyzed for the presence of different fatty acids, the proportion of specific acids reflects the presence of different fish species in the seal's diet. It is even possible to tell, from the basis of seal blubber, the difference between those seals that ate cod fed on lean squid, and those seals that ate cod fed on fatty mackerel. This method, referred to as **Quantitative Fatty Acid Signature Analysis (QFASA)**, holds promise for understanding the diets of many marine animals. If successful, it will allow scientists to look at diets over longer time periods than the most recent meal. However, the methods for determining both the proportion of each prey eaten (compared with simple presence or absence) and diets in a specific locale are still being developed.

Managing the interactions between seals and other species requires a great deal of study. Scientists do not yet have conclusive answers on the impact of seals on cod or other groundfish. The complexity of ecosystems, and our lack of understanding of some components, makes it impossible to say at this time if reducing seal numbers would help cod stocks recover, have no impact, or even hinder recovery.



**Figure 15.33:** Illustration of Harp Seals. *George Brown Goode (1887)*



## Climate Change and Implications on the Fishery

The warming of the Earth's atmosphere has direct consequences on the Arctic marine environment. In turn, this has both direct and indirect consequences for the marine environment along the coasts of Newfoundland and Labrador. Changes in the marine environment will lead to changes in the fishery. As described in the box at the left, more data reflecting a longer period of time will improve our understanding of the changing ocean.

### Climate change research is challenging

Climate change research can be compared to an imaginary poll: suppose you wanted to find out if people in Newfoundland and Labrador eat more tuna than salmon during the year 2007. If you ask 100 people in January of that year if they ate more tuna or salmon, you would not be able to say very much at all about the preferences of Newfoundlanders and Labradorians overall for the year.

If you asked 1,000 people the same question in January, you would have a better idea of preferences. Asking more people than that would give you little additional information. However, looking to other sources of data, like the amount of each type of fish that was sold in stores, would provide more detailed information.

But you would still not know about preferences overall for the year. It might be that people ate more salmon that month, but that might not be true for the following eleven months.

Similarly, up to some number, the more measurements over time of water temperature, salinity, ice cover, fish recruitment rates, and population size that you have, the better your understanding of the relationships between those factors will be. And the overall picture will improve with the number factors that you include. Predator-prey relationships, fishing, disease—all of these things must be factored in to any understanding of the climate's effects on the fisheries.

### Thermohaline Circulation

refers to the vertical movement of water in the oceans. This movement is caused by differences in temperature and salinity at different depths.

**SEA ICE:** Arctic sea ice plays an important role in the ecosystems of the North Atlantic. It provides essential habitat for large mammals like polar bears, seals, and walrus. It contributes to thermohaline circulation and affects the nutrient content of the top layers of the ocean where phytoplankton grow.

**IMPLICATIONS FOR MARINE ORGANISMS:** Changes in sea-ice have direct consequences for some marine organisms. A reduction in sea-ice means a reduction in habitat for large mammals. At the same time, more areas of open water will benefit some whale species and populations of those species could be distributed further north.

With less ice-cover, primary production of phytoplankton would likely increase due to increased sunlight and nutrients near the ocean surface. Zooplankton would also increase in response to the abundance of phytoplankton. In turn, this could lead to an increase in some fish species. However, in areas that are currently ice-free, an increase in cloud cover could limit primary production, and the most productive zones could shift northward.

## Impact of Warming Trends on Fish Stocks

**Past warming trends:** Scientists compare trends in ocean temperatures with population surveys of different species. However, a correlation between temperature change and population can be difficult to establish. Data from one year may appear to show a relationship, but it takes data compiled over several years, if not decades, to give scientists enough information to accurately describe that relationship. Here are some outcomes of research on past climatic variations and commercial fisheries:

- **Atlantic cod**—Many studies conclude that overfishing is the principle cause of the collapse of the cod stock. Some studies also suggest a link between dropping temperature and increasing sea ice cover with increases in natural mortality and declines in recruitment. There is strong evidence that cod flourish under warmer temperatures. Yet factors like low spawning, high predation, and fishing make it difficult to predict the effects of climate on stock recovery.
- **Capelin** diminished in size during the 1990s. Population distribution also changed. This was attributed in part to colder than usual water temperatures. However, temperatures have returned to normal, while changes in capelin biology have not reverted. This suggests that there are factors besides climate that influence capelin biology. Zooplankton abundance may be a factor, although it is not well-understood.
- **Northern shrimp** stocks have increased in density and distribution since the early 1980s. This may be due in part to declining predation by cod and other groundfish. Scientists have found that high abundance of shrimp is correlated with sea-ice cover six years earlier. This suggests that sea-ice and/or cold water benefit the early life stages of shrimp.
- **Snow crab**—Some evidence suggests that snow crab also benefits from cold temperatures early in its life-cycle.

There are other consequences of reduced ice coverage for marine animals, but these need to be considered alongside a discussion of changes in water temperature, salinity, and currents. These issues are closely related to changing sea-ice patterns.

**TEMPERATURE:** As the climate warms, the water temperature in the North Atlantic is also likely to change. While it is certain that the atmosphere is warming and sea-ice is diminishing, there are different views on whether the surface mixed layers of the ocean are warming. Some cooling is possible depending on how wind and cloud cover patterns develop. It is also important to bear in mind that the ocean is a complex environment with a wide range in temperature and salinity throughout.



**Figure 15.34:** Melting ice due to a warming atmosphere and warming water, which is believed to be closely linked to climate change.

**SALINITY:** Sea-ice cover and salinity are related since the formation of ice increases the concentration of salt in the cold water below. Increase in salinity is one of the major causes of ocean currents. As the saltier, denser water sinks to the bottom and flows southward there are effects on currents that are difficult to predict. Decreases in ice cover are likely to reduce currents.

### **Implications and Uncertainty**

While there is a possibility of a return to a groundfish-focussed fishery, the outcome of climate change is extremely difficult to predict. Scientists can look at past periods of warming to make some predictions of what will result from the current warming trend. However, there are gaps in the data that make it difficult to compare the past with the present situation. The collapse of northern cod population, along with the last few decades of fisheries exploitation, also makes it difficult to predict the future of the fishery. In addition, advances in fishing technology over the last few decades cannot easily be compared to anything in the history of the fishery. As a result of the uncertainty of our knowledge in these three areas, the long term outcome for fisheries is clearly in doubt.

### **CHECK your Understanding**

1. What are some of the environmental impacts of mobile bottom fishing gears?
2. What does following a precautionary approach mean?
3. What is ghost fishing?
4. What have been some regulations introduced by DFO to reduce the amount of ghost nets in the ocean?
5. List the advantages and disadvantages of using gillnets to fish for marine species.
6. What is by-catch and why is it an important issue?
7. How do scientists determine the diet of seals?
8. What are some of the difficulties in determining the impact of seals on fish stocks?
9. What environmental factors are important for marine species?
10. What role does sea ice play in global climate?

### **For Further Discussion and/or Research**

11. Investigate the ecological impact of MBFG. Should their use be curtailed or prohibited? Conduct a class debate on this issue.
12. Should gillnets be banned? Explain your reasoning.

## CAREER SPOTLIGHT:

**Garry Stenson**

**Scientist, Fisheries and Oceans Canada**

**Garry Stenson** is a research scientist and head of the Marine Mammals Section of the Science Branch at Fisheries and Oceans Canada (DFO), Newfoundland and Labrador Region. During his career, Gary has published over 100 scientific papers including more than 45 in scientific peer reviewed journals, and in 2006 he received the National Spokesperson of the year award for DFO Canada. Garry is also an adjunct professor at Memorial University of Newfoundland and a member of the Committee on the Status of Endangered Wildlife in Canada Marine Mammal Subcommittee.



*The majority of Garry's research is focused on harp and hooded seals. He is also researching other seals and whales found in the waters around Newfoundland and Labrador.*

### **Garry's Job**

The majority of Garry's research is focused on harp and hooded seals. He is also researching other seals and whales found in the waters around Newfoundland and Labrador. He monitors population dynamics (changes), fisheries interactions, and studies the ecological role of harp and hooded seals. Garry and his team use research results to answer questions such as how many seals are there? What do they eat? Why do the number of seals that get pregnant vary? Where do seals go and why do they go where they do? How do they use their environment? How deep do they dive and how long can they stay underwater?

### **Garry's Influences**

Originally from Edmonton, Alberta, Gary completed his Bachelor of Science and moved west to complete his graduate studies at the University of British Columbia. While a graduate student, he took some time to teach introductory biology and zoology courses at a college affiliated with the University of Alberta. As a Visiting Fellow with DFO studying reproduction of harp seals, Gary was asked to move to Newfoundland and Labrador to work. When a permanent job



came up Garry applied. That was more than twenty years ago and counting! While he believes that luck helped him achieve his current position, Gary emphasizes that it also came with willingness to work hard and to look for opportunities that appealed to him.

### **Main Interests**

Garry has always been interested in anything to do with nature. He loves being outdoors, hiking, bird-watching, and playing hockey. He also enjoys research and has a great interest in travel, biology, and history. He says, “I love to travel; I find it so interesting, visiting new places and having the opportunity to explore new surroundings”.

### **Strong Life Influences**

Garry had many teachers who influenced him greatly and is thankful for the teachers who encouraged him to think for himself. Garry’s university professors who addressed different and sometimes challenging issues were also a great influence. However, he was most influenced by his graduate supervisor who taught him to always be curious and never be too serious. On top of that is the love and support of his family who have inspired and supported him along the way.

### **Garry’s University Background**

Garry obtained a B.Sc with Honours in Zoology from the University of Alberta in 1975. He graduated from the University of British Columbia in 1985, completing his Ph.D. on the reproductive behaviours of otters. He has worked with DFO since 1985.

### **Favourite University Courses**

Science courses were some of Garry’s favourite subjects in school. He especially liked animal behaviour, anatomy, and wildlife management. He also enjoyed sociology and psychology courses in the Arts Department.

### **A Typical Day at Work**

“There’s no such thing as a typical day at work for me”, says Garry. “Yesterday I spent the entire day talking to different people such as media and fishers about seals. I spend other days out in the field researching from 6 a.m. to 11 p.m., and when the weather’s bad I spend my time writing proposals or analyzing results. My work can also involve a lot of travel as I spend time in Greenland and other areas carrying out research”.

Some of the responsibilities Garry will normally carry out as the section head of the Marine Mammals Section include administrative tasks, seeking funding, and acting as a team leader for his section. Here his role is to work with the other scientists and technicians in his research team to identify research that needs to be carried out, plan and carry out the studies, and interpret the results.

As a research scientist, Garry has three major areas of work. First, he is responsible for field research to collect data, study trends, and conduct other forms of exploration. Second, Garry must fulfill a management science role by, for example, writing proposals for new research projects, or acting as a team leader. Third, he is responsible for representing his research and responding to client requests. For instance, Garry may be asked to discuss his research findings with fishers, journalists, students, managers, and other clients.

**Importance of the Job:**

Members of the media, fishers, scientists, and other stakeholders all rely on him for information as much as he relies on them for information. When thinking about the big picture, Garry and his team's work is very influential. They all know they have to be very careful since they are the authority, in terms of knowledge, on seals, a very high profile mammal around the world.

**A message from Garry to you**

"Working in a position such as mine can be very rewarding. If you are interested in this kind of work, I promise you'll never get bored. There are no set hours; this is definitely not a 9-5 job.

"Anyone thinking about a career as a research scientist has to be very open-minded, curious, and interested in learning new things", says Garry.

"So, if you are thinking about pursuing a career as a research scientist, I encourage you to do it, but I want to caution you that you might not end up where you plan (this is not a bad thing) and know that the journey is what teaches you".

## AQUACULTURE

**Aquaculture techniques** enable the culturing of both crustaceans and molluscs.

**Crustacean:** An aquatic arthropod of the class Crustacea including lobsters, crabs, shrimps and barnacles, characteristically having a segmented body, a chitinous exoskeleton, and paired jointed limbs.

**Mollusc:** A marine invertebrate of the phylum Mollusca having a soft, unsegmented body usually enclosed in a shell, including mussels, oysters, and snails.



**Figure 15.35:** An aquaculture site near Pool's Cove, Newfoundland and Labrador, which is owned and operated by Northern Harvest Sea Farms; a New Brunswick based company. Photo courtesy Rex Hillier

Aquaculture is the farming of fish, molluscs, crustaceans, and aquatic plants. If traditional fishing is compared to hunting animals in the wild, an aquaculture business is more like land-based agriculture, with fish kept in enclosures. Like farmers, aquaculturists provide their stocks with basic animal needs including shelter, feed, and veterinary care.

To meet the growing gap between fish supply and demand, aquaculture has grown significantly worldwide with the greatest percentage in Asia and the Pacific. The cultivation of fish, especially vegetarian species, can reduce the pressure on wild stocks.



**Figure 15.36:** Mussel Aquaculture. Photo Courtesy Department of Environment and Conservation/Tara Kelly

The rise of modern aquaculture in Canada coincided with a global surge in the industry during the 1970s. While Canada harvests a range of finfish and shellfish, salmonids (including Atlantic, Pacific, and Chinook salmon, rainbow trout (*Salmo gairdneri*), and Arctic char (*Salvelinus alpinus*)) are the most commonly grown species, accounting for roughly two thirds of aquaculture production. Finfish generally make up seventy five percent of Canadian aquaculture production. Shellfish production is dominated by mussels and oysters.

### Aquaculture in Labrador?

As of 2008 there was no aquaculture in Labrador. Water temperatures along the Labrador coast are often too cold for farmed fish.

Aquaculture has the potential to bring economic stability to rural communities that have been affected by declining fisheries. Growth in the sector has been slow due mostly to lack of investment. Operating a salmonid farm costs as much as eight million dollars a year with feed accounting for seventy percent of this cost. A new salmonid farm is therefore very expensive to operate before it becomes profitable.

Figure 15.37: Newfoundland Aquaculture in 2005.

Species	Production (Tonnes)	Value	Licences	Water area (Hectares)
Salmonids (Atlantic salmon, steelhead trout)	5,006	\$26.6 million	22 salmon; 21 trout	638
Blue mussels	3,157	\$7 million	82	3,729
Atlantic cod	-	-	6	

As with any new marine development, attention must be given to the potential impacts of aquaculture on the environment. Aquaculture operations also have to negotiate for space with other commercial and recreational uses of coastal areas.

While modern aquaculture has been practiced for decades, the industry is still developing in Newfoundland and Labrador. For that reason, aquaculturists in this province have had the advantage of learning from, and avoiding, mistakes made in other places. For instance, the industry and the provincial government have implemented policies meant to both prevent diseases and protect the environment.

Species separation, year-class separation, fallow periods, and minimum fish size at sea water entry; all contribute to maintaining sound fish health and a sound environment. Other jurisdictions have learned from their mistakes and are only now implementing these policies. By implementing these policies at an early stage, the industry in Newfoundland and Labrador hopes to avoid the problems that other regions have faced.

### How can a hydroelectric station help a trout farm?

Coastal waters around Newfoundland often reach winter temperatures so cold, they are lethal to farmed trout.

For aquaculture in Bay d'Espoir, the local hydroelectric station provides a source of warm water for the fish kept in sea cages.

Water is heated as it flows through hot equipment at the station. When the water is discharged into the bay it is very warm. This creates a lens of water that protects the fish from cold temperatures, even when surface ice forms in the bay.

*As with any new marine development, attention must be given to the potential impacts of aquaculture on the environment.*



## Aquaculture and the Environment

### Funding for Aquaculture

Funding for new aquaculture operations is available federally from the Atlantic Canada Opportunities Agency (ACOA) and provincially from the Department of Fisheries and Aquaculture (DFA), or the Department of Innovation, Trade and Rural Development (DINTRD). Other funding may be available through banks and venture capital funds. An entrepreneur should be prepared to supply at least twenty percent of the cost of development. This may be as much as \$5 million. Loans are available only in cases where commercial licences have been approved.



**Figure 15.38:** The aquaculture site near Pool's Cove, Newfoundland and Labrador, follows strict guidelines to prevent their operations from contaminating the environment. *Photo courtesy Rex Hillier*

Some concerns have been raised over the impact of aquaculture on the environment. These include:

- possible interaction of escaped fish with wild stocks;
- pollution of the water and environment where the farm is located; and
- pollution of the microenvironment within the farm itself, which affects the quality of the stock.

While any new industry should be monitored to control environmental impact, it is also important to separate fact from fiction. Canadian aquaculture adheres to principles of good stewardship, so that the industry is economically and environmentally sustainable.

## Did You Know?

**Envirofact:** Canada's total aquaculture production is carried out in a total area equivalent to the size of the city of St. John's?

The responsibility for the regulation of aquaculture is shared by the provincial and federal governments. Through the Aquaculture Act and Regulations, the Province is responsible for approving facility sites, granting licenses, monitoring fish health, and maintaining a registry of operators.

Aquaculture is a sustainable industry that can only succeed in a clean, healthy environment. For this reason, aquaculturists work to ensure their operations are not contaminating the environment that they depend on. It is also in the interest of aquaculture that pollution outfalls, such as sewage or industrial waste, are not located near aquaculture sites. The Canadian government works with the industry to monitor and protect environmental conditions in order to produce safe food.

### **Eastport Peninsula Lobster Protection Committee**

Low lobster catch rates and reports of low egg production and non-compliance with legal fishing methods encouraged a group of lobster harvesters from Bonavista Bay to form the Eastport Peninsula Lobster Protection Committee. Their goal was to revive and enhance lobster populations through conservation and enforcement measures and to collect data to track their progress.

Following recommendations of the committee, the Department of Fisheries and Oceans introduced regulations to completely close some areas to fishing and to restrict fishing in traditional areas to those participating in the project. In addition, illegal pots were eliminated, and egg-bearing and undersized lobsters were voluntarily released.

Scientists from Memorial University, DFO, and Parks Canada are involved in scientific information gathering and study.

The participants of this project believe that the economic impact of the project has been substantial. The size of landed lobsters has increased, resulting in improved earnings. As well, catches have been less variable than in areas without these measures.

Long-term planning, conservation, and science have successfully been used to increase the sustainability and economic value of this natural resource. The area has now become a Marine Protected Area.

### **Local and non-Native Stocks**

Every salmon-populated river has its own genetically distinct stock. These stocks are usually genetically better suited to their environments than stocks from other places.

Atlantic Canadian farms use salmon that originated from a New Brunswick stock that has proven to be highly adaptable to environmental conditions throughout the region.

However, it must be remembered that aquaculture has an impact on the environment. Government and industry are working to establish policies and practices to minimize the industry footprint on the ecosystems where they are established.

- **MANAGEMENT PLANNING**

The federal government sets out criteria for managing aquaculture as a sustainable industry. First, the environmental effects of aquaculture need to be monitored and controlled as much as possible (these effects may include escaped fish, accumulation of waste below cages, or the spread of diseases to the wild populations in the area). The effects of other industries on aquaculture also need to be controlled. This is especially important with regard to water quality. Effects on other species and ensuring the safety of fish for consumption are also significant challenges. These issues are regulated through codes of standard practices around the country. A national code is currently being developed.

The province also controls the environmental impact of aquaculture by separating the sites of operations. Too many farms in one area may affect the local environment, to the detriment of the species being cultured. The province also has a policy to leave sites fallow for periods of time between use. Leaving an aquaculture site dormant for periods of time allows the environment to return to its original state. Provincial management plans are developed for aquaculture through consultation with the industry, public, and other government departments. These plans are implemented on a provincial, regional, or local basis.

- **CODE OF CONTAINMENT**

Salmonid producers in Newfoundland and Labrador who use cage culture have developed, and adhere to, a Code of Containment. The intent of the code is to minimize escapes of farmed salmonids and to provide the industry with a mandate for sound practice. Salmon and trout farmers must agree to the code as a condition of their license.

## Envirofact:

### Problem seals?

Seals can be a nuisance to fish farms. A high density of fish in a small space makes a tempting snack for a seal. They have been known to try and bite fish through the mesh of an enclosure and, on rare occasions, have entered cages killing fish and allowing many more to escape. While Newfoundland has not yet had a problem with seals on aquaculture sites, New Brunswick fish farms have had to add an extra predator net around each cage.

### Diploids and Triploids

Triploids are fish that have been rendered incapable of spawning. In some parts of the world, aquaculture operations use triploids in order to prevent interactions between escapes and wild stocks. Trout aquaculture in Newfoundland and Labrador use female diploids, which have a low possibility of reproducing with wild fish. Salmon aquaculture uses a mix of female and male diploids.

Elements of the Code include:

- regulations for equipment design and installation;
- precautions for preventing escape when fish are being handled or equipment is being towed;
- guidelines for submitting reports on inventories and equipment testing;
- inspections of equipment; and
- a plan for recapturing escapes.

- **SITE SELECTION**

Site selection is determined by the specific biological needs of the species to be cultured. Typically, blue mussels thrive in the cold climate on the North coast of the island. Salmonids need warmer temperatures and access to both fresh water and salt water. The presence of these conditions in the Coast of Bays region makes it ideally suited as the centre of salmonid production in the province.

- **FISH HEALTH AND BIOSECURITY**

The health of farmed stocks depends on good husbandry practices, the maintenance of water quality, nutritional feed, and appropriate density of stocks within enclosures. Imported fish are given the same vaccinations that are used for local stocks so there is very little chance for the spread of disease. In Newfoundland, all fish are screened for disease before they are imported or moved to sea cages. Disease in cultured fish can also come from wild fish stocks.

Diseases that may occur in salmonids include fungal infections during egg incubation and bacterial gill disease during fry and fingerling stages. Two bacterial diseases, Furunculosis and Vibriosis may cause high mortality in caged stocks if not treated immediately. Antibiotics and vaccines are used for these and other bacterial diseases as needed (see section on Food Safety), although fish health is generally maintained through good husbandry.

Blue mussels are filter feeders and will accumulate toxins from their environment. For this reason, clean water is essential for mussel farms. You will learn more about toxins in mussels in the section on Food Safety.

## **Sustainable Aquaculture in Newfoundland and Labrador**

With an export value of \$22 million in 2004, shellfish, salmonid, and cod aquaculture presents significant economic and job opportunities, especially for rural areas of the province. The provincial Department of Fisheries and Aquaculture and the federal Department of Fisheries and Oceans are responsible for ensuring that this industry is economically and environmentally sustainable.

The high up-front costs and risks associated with this developing industry make it difficult for start-up companies to obtain enough working capital financing to get through to the first harvest. The Province funds an Aquaculture Working Capital Loan Initiative for qualified companies to facilitate development within the salmonid aquaculture sector. Initiatives such as these are intended to enhance economic development both within the industry and in rural communities.

Aquaculture needs a healthy marine environment for success. Measures are in place to support environmental sustainability. The Department of Fisheries and Aquaculture has a mandatory site fallowing (leaving areas uncultivated) policy to allow site conditions to return to baseline levels. Sites are also subject to provisions of the Canadian Environmental Assessment Act, which require site monitoring before and during operations as well as throughout the fallowing periods. The industry has also developed a Code of Practice to support methods that respect safety and minimize waste and environmental effects. These and other programs safeguard environmental quality for the success of both cultured and wild species.

### **• IMPACT ON WILD STOCKS**

The possible impacts of escaped cultured fish on wild stocks must be taken seriously by government and industry. If cage and net design continue to improve, they will lessen the possibility of escapes. Concerns have been raised that aquaculture escapes can affect wild stocks in a number of ways:

- Escaped fish may compete with native fish for food and access to spawning habitat. Sometimes farmed fish will spawn in greater numbers than native fish, but will not survive the sea environment as well. This could lead to a situation in which native stocks decline and are replaced by other strains of fish that cannot sustain the resource.
- Farmed and native fish may breed and produce hybrid offspring incapable of spawning.
- The spread of disease or parasites between wild and farmed fish is possible.

To date, there is no evidence of escaped salmonids having a negative impact on local stocks around Newfoundland. Nor is there evidence of escaped salmonids spawning in greater numbers than wild stocks. There is evidence that farmed trout in Bay d'Espoir compete poorly with wild stocks—gravel and twigs were found in the stomach of escaped trout.

### **Shared Water Use**

Our coastal waters are valued for a number of purposes including traditional fishing, recreational sailing, and pristine views. Not everyone welcomes aquaculture. They recognize that it may limit access to fishing areas, contaminate the environment, interfere with free navigation, and change the appearance of the coastline. As a new and growing industry, aquaculture has to negotiate for space with these other users and find ways to minimize any negative impacts.

### **Food Safety**

Some people believe that farmed fish may be dangerous to eat because of the use of antibiotics, feeds that might be contaminated, and the higher fat content of cultured fish compared with wild fish. Government and researchers, on the other hand, maintain that farmed fish are as safe to eat as wild fish. A guarantee of industry quality is enforced by the federal government's CFIA.



### The Future of Aquaculture in Newfoundland and Labrador

Aquaculture is a promising industry for parts of rural Newfoundland. Three species—Atlantic salmon, steelhead trout, and blue mussels—all grow well and enjoy strong markets. Farmed cod promises to be a similar success. Aquaculture operations flourish under very specific environmental conditions and succeed in a limited number of appropriate sites around the island. The employment opportunities created by supporting services and industries (such as cage construction or veterinary services) are not necessarily site-specific. For this reason, aquaculture brings economic benefits to the province as a whole. In order to continue growing, the industry needs more qualified aquaculturists and supporting trades people.

Provincial and federal governments continue to work with industry to ensure that conflicts are minimized between aquaculture and other uses of coastal waters. Government continues to monitor aquaculture operations to prevent negatively affecting the environment or wild fish stocks. Maintaining a clean, healthy environment is important to aquaculturists. Therefore, a well-regulated, environmentally sound industry is in everyone's best interest. Some of the biggest challenges facing the industry are attracting investment, finding enough qualified professionals, educating the public on the risks and benefits of eating farmed fish, and determining how aquaculture can best be carried out in an environmentally sustainable manner.

#### CHECK your Understanding

1. What are some concerns about the impact of aquaculture on the marine environment?
2. What is the purpose of the Code of Containment for salmonid fish farmers? What are some of the main points of this code?
3. What are some factors influencing the health of farmed stocks?

#### For Further Discussion and/or Research

4. How might escaped aquaculture fish affect wild fish stocks?
5. A company wants to develop an aquaculture facility near your community. Would you be in favour of this project? Explain.
6. Are the risks to wild stocks worth the investment into the aquaculture industry? Explain your reasoning.

## CAREER SPOTLIGHT:

### Danny Boyce Aquaculturist

Danny Boyce is originally from Bonavista. Danny's great grandfather, Daniel Boyce of Jersey's Harbour, Newfoundland and Labrador, had a schooner fleet that sold both slated and dried fish to Clyde Lake of Crosbie & Company in the late 1800s and early 1900s.



Daniel studied at Memorial University of Newfoundland (MUN) where he completed a bachelor's degree, graduate diplomas in aquaculture and fisheries development, and a Master of Science in aquaculture. He was a Fellow of the School of Graduate Studies and earned a joint Masters certificate in Project Management from York University and Memorial's School of Business.

Mr. Boyce has fifteen years experience in fisheries and aquaculture. He has worked in various capacities in salmonid hatcheries, marine finfish hatcheries, and commercial cod sites, and has conducted numerous research and development projects.

In 1991 – 92, he began his aquaculture career as a fish hatchery technician on a trout farm in Montebello, Quebec. He then moved to Memorial University's Ocean Sciences Centre (OSC).



**Figure 15.39:**  
Ocean Sciences Centre.  
*Photo courtesy Memorial  
University of Newfoundland  
and Labrador*

The OSC is a research-oriented academic unit within the Faculty of Science at MUN. The OSC and its Aquaculture Research and Development Facility (ARDF) offer scientists local, national, and international scientists access to leading facilities for cold ocean research. According to Danny, the OSC provides quality graduate education in a broad range of marine science and related disciplines. At this facility, Danny worked as a research assistant with the late Dr. Joseph Brown on a halibut project. He also participated in a pilot habitat cod study that took him from Sunnyside through Gander Bay up to Gilbert's Bay in Labrador.

Following the 1992 cod moratorium, he became a project coordinator with Sea Forest Plantation Limited, and was responsible for delivering a cod farm training program throughout twelve communities in rural Newfoundland and Labrador.

In 1994, Danny returned to the OSC to work as a research assistant on various aquaculture projects. In 1999, he accepted the position of Facility and Business Manager of the new Aquaculture Research and Development Facility (ARDF). Current research is focused on aquaculture, biological and chemical oceanography, and fundamental principles of behaviour, biochemistry, and physiology.

His current responsibilities include the day-to-day management of all aspects of the ARDF including policy and project management, proposal writing, contract negotiations with industry partners, and cash flow. His duties take him to many parts of Newfoundland and Labrador. Besides this, Mr. Boyce has traveled to numerous local, national, and international workshops, conferences, and aquaculture sites.

As if all that wasn't enough, Danny is also manager of a project that has a cod research cage site in the community of Poole's Cove on the south coast of NL.

### ***What is an aquaculturist?***

*An aquaculturist is responsible for raising and harvesting fish, shellfish, crustaceans, and plants in fresh and salt water.*

Aquaculture is the fastest growing food production sector in the world. The stocks (fish and shellfish) raised in aquaculture operations are the private property of aquaculturists who care for them throughout the rearing period of the various animals and plants.

As an *aquaculturist*, you are the first to see and respond to challenges with production. You are responsible for feeding the fish or shellfish, and figuring out how much food is needed. You are also responsible for maintaining optimal water quality.

Daily tasks could involve installing, operating, maintaining, and cleaning pumps, filters, and other equipment. You clean and maintain the nets used to hold the fish in the sea cages. If you are working in an operation that sells the fish for human consumption, you also harvest, clean, and prepare the fish for market.

In the course of your career, you may become manager or owner of an aquaculture operation, supervising technicians and others. To become a manager or owner, you need good administrative skills and you must know how to deal with people.

### **How do you become an *Aquaculturist*?**

To become an *Aquaculturist* you should consider obtaining a degree, preferably a Bachelor of Science in biology or life sciences. Then you may want to specialize in aquaculture, with further studies such as an advanced diploma in sustainable aquaculture. This education path will provide you with academic knowledge and management level skills required to participate in aquaculture development.

Danny would also suggest obtaining a Master of Science degree in aquaculture that can be completed as you work, and does not necessarily have to be taken immediately after completing the other programs of study.

According to Danny, the best advice he can give is to constantly challenge yourself. More and more, the challenges that the industry is facing are open-ended. Knowledge alone isn't enough to reach innovative solutions. Creative thinking is a skill. And you will need it in this line of work. Therefore, if an opportunity arises to take a course, to travel, or to attend a conference or workshop, take it. It is also important for you, as an employee of a research facility or aquaculture operation, to maintain a good working relationship with faculty, students, and other staff members. Many of these people will be friends for life.



# Chapter 16: Stressors on the Marine Ecosystem



**Figure 16.1:** Despite the vast size of many marine ecosystems, they can be stressed significantly by human actions.

Ocean water circulates around the world in vast currents. These ocean currents also circulate pollutants around the world. These pollutants include garbage, debris, and sewage that enter the ocean from countless sources. These sources, such as landfills, river runoff, shipping, and fishery waste, introduce huge volumes of debris into the oceans all around the world. In all of these cases, most of the pollutants are deposited locally; however, plumes of sewage from coastal areas such as harbours carry these toxins into the greater ocean environment. There, ocean currents carry some pollutants far out to sea.

## HABITAT DESTRUCTION

Human activities in coastal zones can have a wide range of ecological impacts. If the impacts can be anticipated, then steps can be taken to protect coastal habitats from the damage. But there are other impacts that are unforeseen. And these can be difficult to reverse or repair.

**Coastal infrastructure** includes any structure built in marine zones, whether on the surface of the water or on the seabed. Examples include causeways, slipways, wharfs, docks, and moorings. It also includes other large scale structures like drilling platforms.

**Moorings** – Instead of dropping temporary anchors, vessels can be secured to moorings. This saves the seabed from damage caused by dragging anchors. Moorings typically consist of concrete blocks on the seabed, attached by chains to one or more floats and markers at the water's surface. However, the concrete base of a mooring displaces seabed habitat and so the construction of moorings must also follow measures to protect habitat.

A conservation approach to marine infrastructure seeks to minimize negative effects on fish and on their habitat. In some cases, informed construction practices can enhance fish habitat as a way of compensating for lost space. The Department of Fisheries and Oceans (DFO) supports research into construction methods that protect habitat. DFO also has responsibilities under the Fisheries Act to ensure that conservation-based practises are followed by reviewing projects to make sure they minimize the impacts on fish habitat in the marine (and freshwater) environment.



**Figure 16.2:** Marine infrastructure on the St. John's waterfront.

**Silt fences** are barriers made of filter fabric and fence posts or stakes. Filter fabric allows water to flow through it while preventing the passage of sediment. Silt fences are a useful way of containing upset sediment during construction. Silt fences are not installed as permanent structures, though they require routine maintenance and cleaning to be effective.

When infrastructure is installed in marine settings it has the potential to harmfully alter, disrupt, or destroy fish and fish habitat. The best way to prevent this is to follow proper mitigation procedures. Mitigations include actions taken during the planning, design, construction, and operation to lessen potentially adverse effects on fish habitats. DFO provides projects with advice on mitigations that can be used during marine construction. Among the negative impacts of construction activities in the marine environment are the following:

- Structures built on or in the seabed have the potential to harmfully alter, disrupt, or destroy fish habitat formerly occupying the same area.
- Structures that cover the surface of the water can become the source of debris on the seabed. Material that escapes through cracks or spaces in a dock or wharf and accumulates on the seabed can destroy habitat below and around the structure.
- Sediment can enter water and harm habitat during construction.
- Machinery can be a source of pollution. Oil, grease, and other chemicals can enter the intertidal environment through leaks or surface grime.
- Toxic preservatives such as pentachlorophenol (PCP), creosote, or fresh pressure-treatment can leach from wood into the water.
- Water circulation can be interrupted by marine structures.

Standard mitigations are applied during the construction of coastal infrastructure to avoid negative impacts on marine life and marine life habitat. These include the following:

- All wood is cut, sealed, and stained away from the water and is dry before entering the water.
- Dredging, infilling, or blasting activities are minimized.
- Sediment and erosion controls are in place prior to construction. Silt fences are commonly used.
- Machinery is clean and free of leaks.
- Structures are built in such a way to allow for the free circulation of water in and around the structure as much as possible.
- Habitat can be created or enhanced to counter the habitat that is lost.
- Moorings and other concrete structures should be clean.
- Moorings should use anchors large enough that they will not drag along the seabed and chains that will not disrupt seabed habitat.



**Figure 16.3:** Dredging a navigation channel.  
*Photo Courtesy Department of Fisheries and Oceans*

Over time navigational channels such as harbours, marinas, boat launches, and other port facilities may become narrower and shallower. This can pose a danger to the vessels that use this infrastructure.

**Dredging** is one method to restore these channels. Tools used in dredging activities include backhoes, draglines, and clam buckets. Dredging activities can have negative impacts on fish and fish habitat by harmfully altering, disrupting, or destroying the sea floor. Dredging can also introduce suspended sediment into the water.

## INVASIVE MARINE SPECIES

From time to time various plant and animal species are carried from one part of the world to another where they invade foreign ecosystems unaccustomed to the presence of these organisms. Such invasive species can multiply at a very rapid rate. Their presence in large enough numbers can have serious consequences for aquaculture facilities, recreational boaters, fish harvesters, and for others who depend on marine resources. For example, the spread of some forms of toxic phytoplankton has caused farm closures in the Australian shellfish industry. One common method by which invasive species reach foreign shores is by attaching themselves to the hull of ocean-going vessels. In this way, they can travel great distances on international routes. Once in a new marine environment without any natural predators their population can increase rapidly. Once an invasive species is established in a new habitat, it can be very difficult to eradicate. Government efforts are therefore focused on preventing the arrival and spread of potentially invasive species in Canadian waters.

Invasive species can also arrive in the **ballast water** of ships. Ballast water is pumped in and out of ocean-going vessels to improve stability in open water. A vessel that pumps in ballast in Newfoundland and Labrador waters will take on any organic material present in that water. If the vessel then pumps out its ballast at a port in Prince Edward Island, then the organic material from Newfoundland and Labrador waters is introduced into that marine ecosystem including potentially invasive species.

Ballast can carry zooplankton, phytoplankton, bacteria, and viruses. Species that have inactive stages can remain in ballast for long periods of time.

According to Canadian authorities, only a few invasive species have been introduced through ballast into the Canadian marine environment. There are likely others that we haven't learned to recognize yet. Canada conducts testing of ballast waters to attempt prevention. The invasive European green crab (*Carcinus maenas*) probably entered southern Newfoundland waters this way. It is one of three invasive species that have been detected in Atlantic Canadian waters since the mid 1990s that are currently causing significant problems for coastal resource users:

- **TUNICATES** are native to the western Pacific Ocean, off the northeast coast of Asia. Clubbed tunicates (*Styela clava*) first appeared in waters around Prince Edward Island in 1998. Since then, violet (*Botrylloides violaceus*), golden star (*Botryllus schlosseri*) and vase (*Ciona intestinalis*) tunicates have also been detected in Prince Edward Island waters.



**Figure 16.4:** Tunicate (*Styela clava*).

Photo Courtesy Courtnay Hermann

The clubbed tunicate has caused the most severe impact to date. This jelly-like animal can reach lengths of sixteen to eighteen centimetres and grows in dense clumps. As many as 1000 clubbed tunicates can occupy one square metre. They can infest docks, buoys, moorings, drilling platforms, or any other hard surface up to a depth of five metres below low tide level. This can add a great deal of weight to marine structures, causing them to become unstable.

Tunicates are also a serious threat to aquaculture. They compete for space and food with mussels and oysters. Mussel lines, on which the mussels grow, can be badly fouled by clubbed tunicates. In October 2001, the mussel industry in Prince Edward Island was badly limited by an explosive growth of clubbed tunicates.



**Figure 16.5:** Green Crab.

- **GREEN CRABS** (*Carcinus maenas*) are small, aggressive predators of shellfish such as mussels and clams. They originated off the European coast and were discovered in Nova Scotia in 1995. Since then, their populations have expanded along the coasts of Nova Scotia and Prince Edward Island.





**Figure 16.6:** Oyster thief.  
Photo Courtesy Courtnay Hermann

Green crabs also harm the eel fishery because eels will not enter a trap infested with green crabs.

- **OYSTER THIEF** (*Codium fragile tomentosoides*) is a type of alga that anchors on shellfish. This species originated in Japan and was detected in Prince Edward Island in 1996. Oyster thief is very dense and smothers mussels or oysters by preventing them from opening their shells, leaving them unable to filter feed. In some cases, oyster thief will lift shellfish off the seabed and float away with them – hence its name.

So far only the green crab has been detected in waters off Newfoundland and Labrador. The Canadian Coast Guard continually monitors marine infrastructure, including navigational buoys, during routine cleaning and inspection. Buoys can serve as marine habitat. All marine habitats are colonized in stages, first by protozoa, algae and fungi and later by more complex organisms including kelp and barnacles. Clubbed tunicates, if present, would also appear in these later stages of colonization.

Small boat owners can take steps to ensure their vessels are not carrying unwelcome visitor species. These steps include washing the boat, anchor, and other equipment with vinegar; removing plants and animals; and allowing the boat to dry completely before trailering.

Large vessel operators can use anti-fouling paint that reduces the number of organisms settling on the hull. Ballast waters should not be taken or released in port or near aquaculture sites.

## MARINE DEBRIS



**Figure 16.7:** Plastic is the most common type of marine debris and is often found at the high tide mark.

Marine debris is garbage found in the ocean and on beaches. Marine debris is a global problem. It is hazardous to virtually every species that depends on the oceans for food—including humans.

The most common marine debris is petroleum-based products such as plastic. While debris related to the fisheries and marine navigation has been washing up on beaches for hundreds of years, plastic has only been in use since the 1950s. It is not biodegradable and has therefore, accumulated quickly in landfills and in the marine

environment. Plastic marine debris includes not only disposable plastic but also plastic that is not intended to be disposable—such as the plastic used in appliances or as part of a piece of furniture. In some locations, plastic accounts for ninety percent of all the debris.

Next to plastic, wood and rubber, both synthetic and natural, are the second and third most common debris. Other materials that accumulate in the marine environment include metals, cloth, glass, paper, and cardboard.

### Problems with Plastic

- Persistence: it takes centuries for most plastics to biodegrade.
- Toxins and carcinogens: burning some plastics releases toxins into the air. For example, PVC (polyvinyl chloride) releases dioxins and HCl. Burning plastic is prohibited by the Newfoundland and Labrador Air Pollution Control Regulations.
- Additives: can make up as much as fifty percent of the final plastic product. Additives can leach out into the environment. Common additives include:
  - dyes and pigments;
  - toxic metals-lead, cadmium, tin, antimony arsenic, chromium, and zinc; and
  - flame retardants-56.7 million kg of deca-BDE (polybrominated diphenyl ethers) are produced annually. Deca-BDE is used in high-impact polystyrene, which is used for appliance casings (computers, toasters, televisions, printers, telephones, etc). Deca-BDE negatively affects neurodevelopment and reproduction.

- Risk to animals: fish, seabirds, seals, turtles, dolphins, and whales are all at risk from plastic debris:



**Figure 16.8:** Discarded plastic 6-pack around neck of bird. *Photo Courtesy Environment Canada/Peter Thomas*

- Animals can be strangled by plastic debris.
- Animals often eat plastic which cannot be digested. It builds up in the digestive systems of the animals, blocking normal digestion and the animals starve to death.
- Sometimes plastic in an animal's belly will cause it to float, preventing the animal from hunting or escaping prey.
- Chemicals like PCBs build up in large fish as they eat small fish that have ingested plastic. Even if the small fish ingest small amounts, the chemicals become more concentrated in the animals further up the food chain.

- Risk to humans: humans are at risk in a number of ways:
  - Eating fish contaminated by marine debris is harmful.
  - Divers can become ensnared in lost fishing gear.
  - Plastic debris clogs the water intakes for cooling and pumping systems on boats and gets tangled around propellers, creating serious navigation hazards.

## Envirofact:

### Marine Junk Food

Through a process called photodegradation, sunlight breaks down floating plastic debris into small pieces. While these pieces of plastic are tiny, they still do not biodegrade—they simply float around the ocean. Some pieces are small enough that even zooplankton can ingest them.

## The Source of Marine Debris

Garbage blows off landfills or is carried by rivers, sewage systems, and storm drains into the ocean.

Typically, on beaches near cities and large towns, an enormous amount of household garbage washes up. This includes such items as food and cleaning product containers, shopping bags, and building materials. Recreational areas are often littered with bottles, cigarette butts, and glass and food containers. Fishing debris appears on most beaches. Commercial shipping routes are typically littered with bulk packaging, lube oil containers, and pallets.

Because of the variation in ocean currents and prevailing winds, debris doesn't accumulate in the same way on every beach. Some beaches will have very little. Others are flooded with garbage. The flow of currents pulls debris along with them and causes it to build up in particular places. For instance, currents and winds cause marine debris to accumulate in Placentia Bay. Then the prevailing winds push most of the debris onto the beaches that face west or south-west. East-facing beaches in Placentia Bay are relatively clear of the debris.

While some debris is from nearby sources, other garbage is carried great distances along ocean currents. Much of the marine debris that originates in Eastern Canada winds up in the North Sea off the coast of Europe. Ireland, Scotland, Norway, Denmark, and Sweden all have to deal with Canadian garbage in their waters and on their beaches.

## Reducing Marine Debris?

Several steps must be taken together in order to successfully reduce marine debris. Some of these steps are already being implemented, while others steps are new practices, or not yet widely adopted.

- **EDUCATION:** Educate people regarding the problems with marine debris using different approaches such as posters or teaching.
- **COMMUNITY BEACH CLEAN-UPS:** In this province, beach clean-ups are organized by communities or by non-profit organizations like Ocean Net. Ocean Net works with schools, fish harvesters, community groups, government, and environmental agencies to clean up beaches, retrieve ghost nets, and develop educational materials for the public. Between 1997 and 2006, Ocean Net carried out nearly 1,000 beach clean-ups.



**Figure 16.9:** Jessica Whyte, a student at Christ the King School, is collecting marine debris from a beach near the town of Rushoon on the Burin Peninsula. *Photo Courtesy Eastern School District/Allison Dyke*

- **THE FOUR R'S: REDUCE, RECYCLE, RE-USE, AND RECOVER:** Several hundred types of plastics are not commonly recycled. Plastics that are recycled are often used to make products like plastic lumber and clothing that are not recycled. Reducing the overall amount of plastics we use is essential. Recycling alone will not deal with the problem. Recovery of energy from wastes is a more involved process that usually targets industry.
- **GREEN PLASTICS:** There are several kinds of *green* plastics on the market today and new products are being developed rapidly. Green plastics should be biodegradable, non-toxic, and made from renewable resources, but not all products that claim to be *green* meet all of these goals.
- **DESIGNATED DISPOSAL SITES:** Carefully choosing sites for disposal of garbage and offal from fish plants can help minimize their impacts on the marine environment. There are sections of the federal Fisheries Act that attempt to limit dumping at sea.
- **TREATMENT OF DISCHARGE:** Treatment of human sewage and waste before it enters the ocean is important in minimizing marine debris and pollution. A key component of the St. John's harbour clean-up is the waste management system that is being constructed. It will be an important tool for cleaning up the waters by removing pollutants flow into the harbour and from there through the Narrows into the open ocean.

## CHECK your Understanding

1. Describe some ways that coastal activities can impact marine habitat.
2. Where do invasive species come from and why should we be concerned about them?
3. Plastics continue to litter the marine environment. Describe some ways we can reduce this threat to the marine environment.

### For Further Discussion and/or Research

4. If there is a beach near your area contact Ocean Net and find out how your class can assist in a beach clean up project. More information is available at [www.oceannet.ca](http://www.oceannet.ca).



## HYDROCARBONS AND THE MARINE ENVIRONMENT



**Figure 16.10:** Locations of Terra Nova, White Rose, Hibernia, and Hebron oil and gas fields.  
*Photo Courtesy Department of Natural Resources/Jillian Owens*

The offshore oil and gas industry in Newfoundland is concentrated on the Grand Banks, south east of the Avalon Peninsula. The Terra Nova, White Rose, and Hibernia oil and gas fields together produce, on average, over 52, 000 cubic metres of crude oil per day. Other discoveries that are currently undeveloped include Hebron, Ben Nevis, West Ben Nevis, Hibernia South, and the White Rose Extensions. Exploration is ongoing in other areas both on land and off the coast of Newfoundland and Labrador with one onshore well established near Cape St. George, Port au Port Peninsula, on the province's west coast.

### Types of drilling muds

Both water-based (aqueous) and oil-based (non-aqueous) drilling muds are used according to different circumstances.

**Aqueous muds** are suitable for:

- drilling through stable formations;
- drilling vertical wells; and
- drilling at moderate temperatures.

**Non-aqueous muds** are suitable for:

- drilling through water-sensitive formations to prevent caving;
- drilling slanted and horizontal wells; and
- drilling deep wells at high temperatures.

Non-aqueous muds are more likely to prevent the drill bit from getting stuck in the borehole.



**Figure 16.11:** (Clockwise from the top) An exploration rig drilling near Cape St. George, Port au Port Peninsula, Newfoundland and Labrador. SeaRose FPSO. Hibernia Platform.

*Photos Courtesy Department of Natural Resources*

## Environmental Impacts of Oil and Gas Exploration and Production

To understand the environmental impact of the offshore hydrocarbon industry, both extraction and transportation methods have to be considered:

- **DRILLING FLUIDS OR “MUDS”:** In hydrocarbon extraction, drilling muds are composed of chemicals and minerals in a water or oil solution. These muds are used in a complex drilling process. This process includes a drill string that extends down from the drill ship or production platform. At the end of this string is a rotating drill bit that bores through layers of rock to reach oil and gas deposits far below the seabed. Drilling muds are pumped down the drill string and are ejected at very high pressure through nozzles in the drill bit.

The drilling muds, with immersed drill (rock) cuttings, are removed from the well by pumping them back to the surface. If drill cuttings are discharged at sea, they contaminate the marine environment with compounds from the drilling muds including heavy metals and hydrocarbons. While this is true, tremendous efforts are always being

## Did You Know?

For every 100 kg of material discarded overboard, 6.9 kg of it can be synthetic based muds.

### Research and monitoring of waste disposal

The Department of Fisheries and Oceans carries out extensive studies on the fate and effects of petroleum hydrocarbons, drilling wastes, and produced waters. These studies are used for assessment purposes as well as the development of environmental effects monitoring programs (EEM).

EEM programs must be conducted on an ongoing basis at hydrocarbon development sites in the offshore. The Canada—Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) regulates the EEM programs of all three developers on the Grand Banks: Terra Nova, Husky, and Exxon-Mobil. Their programs study sediment impacts, effects on fish health, and fish and shellfish contamination. The transshipment terminal in Placentia Bay, where crude oil from the Grand Banks is held before being shipped to Canadian and international refineries, also has a similar monitoring program in place.

taken by both the regulatory bodies and the petroleum companies to minimize the effects of drill cuttings and associated muds. For example, synthetic based drilling muds have been developed and chosen for use while drilling in the offshore environment. These muds, due to their special chemical composition and structure, have the potential to be less toxic and more biodegradable, thereby having less of a negative impact in the offshore environment. Despite these drilling muds being more expensive than other non-aqueous drilling muds, the petroleum companies are still choosing to use them. As an additional example, drill cuttings are separated from the drilling muds by shakers and centrifuges, and further processed to lessen the amount of oil and gas left on them prior to them being discarded overboard. Regulatory bodies enforce that 6.9 % of the total weight of the material that is discarded overboard can be synthetic based muds.

- **PRODUCTION WATER:** Water is withdrawn from hydrocarbon-bearing layers during the extraction of oil and gas. All producing projects at the present time are averaging a 3:1 oil to water ratio. Produced water is composed of formation water found in the reservoir itself or water re-injected into the reservoir to maintain pressure and oil flow. Major contaminants in produced water include hydrocarbons, metals, and process chemicals. The hydrocarbon content of produced water, as well as drilling muds, is regulated under the Canadian Offshore Waste Treatment Guidelines. Produced waters are also subject to regular toxicity screening by the oil industry.
- **TRANSPORTATION OF OIL:** Large quantities of oil are transported along Newfoundland's coast throughout the year. On occasions during the winter months, tanker traffic typically moves closer to shore to avoid ice.

Year	Number of Visits	Oil brought in (tonnes)	Oil taken out (tonnes)
2001	255	8,867,357	7,874,953
2002	380	16,459,982	15,394,260
2003	557	24,223,611	23,128,065
2004	544	24,423,229	22,191,672
2005	513	22,228,805	20,455,709

**Figure 16.12:** Information on the number of tanker visits and the amount of oil brought in and taken out of Placentia Bay for each year from January 1, 2001 – December 31, 2005, including both the Come By Chance refinery and the transshipment terminal. Note that the difference between the amount of oil brought in and the amount of oil taken out is largely due to the fact that a large amount of oil is taken from the two locations by other means of transportation (e.g. tractor trailers). Only an extremely small amount of oil is lost due to the actual refining process.

**Bunker C** is a very thick, heavy fuel commonly used in ships. It needs to be heated to a very high temperature in order to be sprayed as a mist into the injectors of large engines. Bunker fuel is very cost efficient for travelling long distances at sea. When bunker C enters the cold ocean water, it tends to behave almost like a solid and can persist for a very long time in the marine environment.



**Figure 16.13:** Transshipment Terminal near Arnold's Cove, east coast Newfoundland and Labrador.  
*Photo courtesy Come By Chance Refinery*

There is also considerable general traffic related to oil and gas shipments around coastal Newfoundland and Labrador. For example, large vessels ship bunker C oil to Corner Brook, Botwood, and Holyrood. Gasoline and diesel are also shipped in bulk to many coastal communities in Newfoundland and Labrador.

### Marine Oil Pollution

Marine oil pollution refers to the presence of petroleum hydrocarbons in the ocean environment. Approximately 3.2 million tonnes of petroleum is dumped or spilled into the world's oceans each year. This pollution comes from a variety of sources including spills, illegal bilge dumping, and industrial runoff. Oil pollution can have devastating impacts on wildlife, especially seabirds. By creating a layer of sediment on the seabed, oil spills smother the plant and animal life. It ruins beaches and hinders recreational uses of coastlines. Also, by destroying fish, fouling boating gear, and devastating aquaculture sites, such spills also have serious negative social and economic consequences for humans.

### Sources of Oil Pollution

Oil pollution calls to mind images of massive tanker spills blanketing coastlines with a thick green slick and poisoning animals. But tanker spills account for a relatively small amount of the total petroleum hydrocarbons in the oceans. Marine oil pollution is far more common than many people realize and it comes from many sources besides major spills:



- **TANKER ACCIDENTS** such as collisions or groundings receive a large amount of media coverage due to the large size of spills associated with them. Even a few large accidents may account for a large amount of oil pollution. However, such accidents contribute only 12 percent of the world's oil pollution each year.
- **OTHER KINDS OF TANKER SPILLS** are more frequent, although they may be much smaller than spills resulting from major accidents. As much as 75 percent of tanker spills occur while vessels are carrying out routine operations such as loading and unloading oil.
- **BUNKERING** is another source of spillage. Vessels burn bunker fuel in their engines. Bunkering is the marine equivalent of filling up a gas tank on a car. Often these spills are small, but if they occur frequently in the same area, they become a significant source of pollution. A small spill can have major consequences if, for example, it was to happen at the transshipment terminal in Placentia Bay during lobster season. Many precautions are required during bunkering operations to limit and contain any releases that occur.
- **BILGE DUMPING** is a significant source of chronic pollution. Bilge water comes from the workings of various machines and accumulates in the hull of a vessel. Oil leaking from machinery builds up in the bilge water. When the bilge is dumped at sea the oil is also dumped. Bilge dumping is a source of constant and deliberate pollution. Ironically, this situation is avoidable because all large ocean-going vessels are required to have oil water separators on board and to use them before dumping their bilge. In addition, it is illegal to dump oil contaminated bilge at sea and such activity is subject to heavy fines, but regulations are difficult to enforce. So many vessel operators continue to dump the polluted bilge at sea.

The south coast of Newfoundland is affected by a large number of releases from large ocean going vessels to and from North American ports. These vessels include as many as 8,000 container ships, cargo ships, and tankers a year en route to ports in the St. Lawrence River. A large number also use this route on the way to and from ports along the Eastern Seaboard of the United States. Releases from vessels en route to ports up the St. Lawrence River pose the most danger to our coastal marine environment because they pass closer to the southern coast of the island to avoid ice in winter. This is a major concern for those striving to protect the marine environment in this area.



**Figure 16.14:** (Left to right) A rock outcrop on the northern peninsula, Newfoundland and Labrador, showing naturally seeping petroleum along a fracture surface.

Oil seeping out of the ground near the community of Parsons Pond on the northern peninsula, Newfoundland and Labrador.

A rock sample containing petroleum taken from the Cow Head area on the northern peninsula, Newfoundland and Labrador.

*Photos courtesy Department of Natural Resources*

- **MARINE HYDROCARBON SEEPAGE** accounts for the presence of some marine oil. Seepage occurs in areas of tectonic activity such as underwater earthquakes. Newfoundland and Labrador has several known marine seeps along the coast of the island and off Labrador. One well-known seep is called Old Harry, located off the west coast community of Cape Ray. Hydrocarbons also enter the ocean via river run-off from the erosion of exposed oil-rich sediments. It is difficult to know the amount of hydrocarbons originating from these sources, though it is likely no more than seven percent of the total amount of oil pollution in the oceans.

**Offshore drilling platforms** may experience blowouts. This occurs when pressure from the well exceeds the capacity of the well to contain it. However, in the modern era, blowouts are relatively uncommon—much like tanker accidents. In fact, there has never been a blowout offshore Newfoundland and Labrador. A more common source of pollution from drilling occurs when oil is released due to equipment failure or process interruption. This can result in a release of crude or other products from the production facility. And this happens in Newfoundland and Labrador's offshore. For example, the largest crude oil spill on the East Coast of Canada occurred in November 2004 when 160,000 litres of crude oil leaked from the Terra Nova FPSO because of equipment failure. It should be noted that engineering modeling supports only a 0.6 % chance of shoreline contamination in the event of an oil spill.

## Did You Know?

1 L of oil can cover a 12 sq. km area of water.

**Other coastal activities** that introduce hydrocarbons into the ocean may include irresponsible land-based disposal of oil. Most oil spills in Canada occur on land.

- Used motor oil that is not properly disposed of can make its way into sewage discharge, streams, or storm drain runoff. This has been the source

of fish kills in and around St. John's in the past, as people do not realize that storm sewers and sewage drains do not go to the same place. Some storm sewers have outlets in local water bodies so any toxins dumped in a storm drain can kill fish. Runoff from landfills can also be a significant source of marine hydrocarbon pollution.

- Small marine motors and 2-stroke outboard motors are source of small spills at the wharfs around the province.

### Oil Spills Around the World

Large spills are dramatic as massive volumes of oil are quickly released into small areas. But the impact of these large toxic spills may not always have the same impact on marine life. For example, if a large spill happens far from land, the oil's impact is largely confined to offshore wildlife. By comparison, inshore oil spills are devastating to fish, seabirds, marine mammals, nesting areas, and beaches.

#### What is ITOPF?

The International Tanker Owners Pollution Federation is a not-for-profit group of more than 4,800 tanker owners from around the world. Virtually all of the world's oil and gas transportation is conducted by members of ITOPF. It is one of the world's primary sources of expertise on responding to ship-source oil pollution.

Since 2000, the average number of large spills has dropped to less than four spills per year. In general, the quantity of oil spilled each year has also declined since the 1970s. One or two very large spills often account for the bulk of oil spilled in a given year.

The tanker industry has gained valuable knowledge from past spills in the areas of prevention and response. International regulations, together with organizations like International Tanker Owners Pollution Federation (ITOPF), work to reduce spills and to deliver fast and effective containment and clean-up responses.

### Effects of Oil Spills on the Marine Environment

There are many reasons to be concerned about the presence of oil pollution in the marine environment, although not every oil spill has the same effect. In order to understand the impact of oil pollution, several things must be considered:

- What type of oil is spilled?
- Where is the spill location and how much oil is spilled?
- Has the spill occurred in an area of chronic pollution?  
If so, what are the cumulative effects of the pollution?
- Do climate conditions, such as currents and wind, make containment and clean-up difficult or impossible?
- Does fishing or other activities take place in the area?  
How will the spill affect those activities?

## Properties affecting behaviour of spilled oil

Four properties of oil are considered in predicting the behaviour of a spill:

- **Specific gravity** is the density of oil in relation to pure water which has a specific gravity equal to 1. Most oils are lighter than water and therefore, have a specific gravity less than 1. This means the oil will float on water.
- **Distillation characteristics** describe the **volatility** of oil. Compounds in oil have different boiling points. Those with lower boiling points evaporate more quickly, but are often more toxic.
- **Viscosity** describes resistance to flow. High viscosity oil flows very slowly and with difficulty, while low viscosity oil flows with ease. Viscosity drops as the temperature of oil rises. For this reason, water temperature and heat from the sun can affect the behaviour of a spill.
- **Pour point** is the temperature below which oil will not pour. Oil with a temperature lower than its pour point will behave as a solid.

## Physical properties of oil

Oil floats and can cover a wide area, carried along by wind and ocean currents. Spilled oil is generally classified according to whether it is persistent or non-persistent. Persistent oils dissipate slowly and often require clean-up. Crude and some refined oils are included in this category. Non-persistent oils dissipate much quicker. These include gasoline, naphtha, kerosene, and diesel. It is worth noting that even though the volatile compounds that comprise the non-persistent oils do evaporate rather quickly, they can still contaminate the remaining water supply.

Following a spill, oil undergoes several processes that affect the overall environmental impact and clean-up requirements.

Short-term processes take effect in the first few days following a spill:

- **SPREADING:** Oil begins to spread as a coherent slick at a rate determined by its viscosity.
- **EVAPORATION:** The rate of evaporation is determined by the volatility of the oil.
- **DISPERSION:** Turbulence and wave motion cause oil to form various size droplets. Large droplets rise back to the surface while smaller droplets may be suspended in the water column.
- **EMULSIFICATION:** Oils often absorb water creating a highly viscous emulsion. Emulsification can increase by three or four times the total volume of the pollutant.
- **DISSOLUTION:** Some components of oil will dissolve slightly in water.

Long-term processes take effect over months and years:

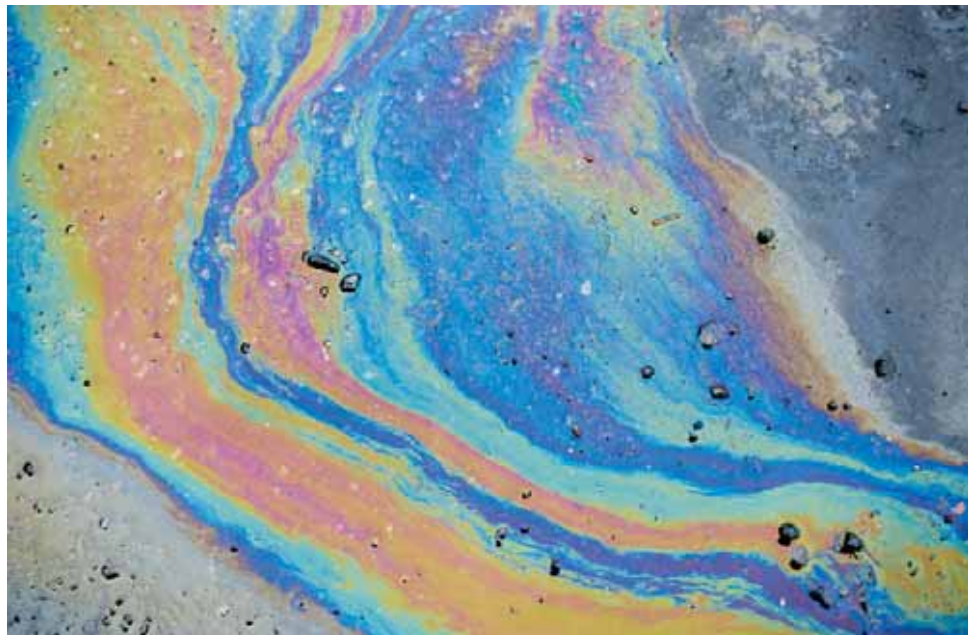
- **OXIDATION:** Some hydrocarbons react with oxygen to create persistent tars, sometimes seen as tar balls on beaches.
- **SEDIMENTATION:** Some sedimentation occurs when organic particles or other suspended solids cling to drops of oil causing them to sink.
- **BIODEGRADATION:** Various micro-organisms use oil as an energy source.



Depending on location, sea and atmosphere conditions, and the type of oil spilled, the weathering processes that occur may cause a rapid dissipation of the spill (as in the evaporation of light compounds) or may lead to the persistence of pollution (as in sedimentation along a beach or in-shore seabeds). Offshore oil spills tend to dissipate faster than inshore oil spills simply because high-energy ocean conditions speed up the weathering process.

There are a number of effects of oil spills:

- **SOCIO-ECONOMIC IMPACT:** Contamination of popular recreational or tourist areas has an obvious economic impact. Apart from clean-up, restoration of public trust in the safety and cleanliness of an area polluted by oil can be a considerable challenge. Similarly, reports of oil contamination in or near a fishing area can have disastrous effects on the livelihood of the fishers. This is often true regardless of the fact that oil rarely has any lasting effect on fish populations and may pose no danger to the consumer. Oil can also destroy fishing gear, causing further financial strain to fishers.
- **BIOLOGICAL EFFECTS AND FOULING OF THE INTERTIDAL ZONE:** Oil can damage marine life through physical contamination and smothering, or through its toxicity. Damage to habitat also affects marine life.
- **Negative impacts on aquaculture operations:** A spill near a fish farm can soil equipment. Enclosed fish are unable to escape the pollution and may become contaminated. As with spill sites in fishing grounds, cultured fish that have been exposed to or near oil pollution may be difficult to sell to a market that is averse to such risk. Again, this may be the case whether the dangers posed by an oil spill are real or imagined.



**Figure 16.15:** A major oil spill in the waters off Newfoundland and Labrador would have a major impact on our fishing and tourism sectors.

## Oiled birds and marine mammals

### How does oil kill seabirds?

Oil can kill birds in three ways:

- Seabirds have two layers of feathers – an inner layer to insulate and keep the bird warm and an outer layer to keep the bird dry. The outer layer is a mesh connected by fine hooks. Even a tiny amount of oil (the size of a thumbprint) is enough to destroy the waterproofing of this layer. Then cold ocean water can soak the inner layer of feathers causing the bird to die of hypothermia—the most common cause of death.
- Seabirds nibble at oiled feathers in an effort to clean them. In the process they swallow the contaminants and die of poisoning of the liver, lungs, kidneys, and intestines.
- Oiled seabirds may also starve to death as the oiling interferes with their normal ability to forage. They are also easy prey for predators.



**Figure 16.16:** Gulls in the water offshore Newfoundland and Labrador. They could be affected negatively by oil pollution.

Over 40 million pelagic seabirds spend winters along the southeast coast of Newfoundland. This area has one of the highest levels of seabird mortality anywhere in the world. Chronic oiling from vessel traffic along the south coast is suspected to be a prime reason for this mortality.

The primary visible victims of oil pollution are seabirds. This is particularly true in Newfoundland and Labrador where it is estimated that 300,000 seabirds die every year from oil pollution. Murres (*Uria alle alle*) and dovekies (*Plautus alle alle*) account for 80 percent of oil-related seabird mortality. The other impacted seabird species include puffins (*Fratercula arctica arctica*), guillemots (*Cepphus grille atlantis*), gannets (*Morus basanus*), gulls (*Laridae*), terns (*Laridae*), petrels (*Hydrobatidae*), and cormorants as well as near-shore birds such as loons (*Gaviidae*), eider ducks (*Somateria* sp.), and long-tail ducks.

Rescuing oiled birds is difficult. The birds are already weak. Handling them adds to their stress. But that is the only way to save them. Treatment requires licensed, trained personnel with veterinary support. Even a drop of oil can be fatal. So, if the birds are not totally cleaned, then their death may simply be prolonged. In addition, this process also poses a threat to human health hazards because of the toxic vapours.

Some marine animals are also susceptible to oil pollution. While cetaceans (whales and dolphins) tend to avoid spill sites, sea turtles and seals can be exposed to inshore pollution.

### Envirofact:

#### Small spills make a big kill

Small spills can cause serious damage when they occur near large seabird populations. In the winter of 1989-90, approximately 17,500 murres washed up in Placentia Bay. The suspected source of pollution was bilge waste ejected from passing ships—a form of intentional and avoidable pollution.



## ENVIRO-FOCUS

### The plight of the Murre

Thick-billed (*Uria lomvia lomvia*) and Common Murre (*Uria aalge aalge*), also known as turrs, are two species of auks that live along Newfoundland's Avalon Peninsula and south coast. Turrs can live over twenty years and are slow to reproduce. Turrs raise only one chick per year. At around four or five years of age, a female lays her first egg in the Arctic breeding ground and will continue to do so each year throughout her lifetime.

Turr populations are among the largest of any seabird in the northern hemisphere. It is estimated that there are as many as 2,000,000 breeding pairs of thick-billed turrs in Canada's eastern Arctic. Without factoring in oil-related mortality, the entire population grows by around 3.5 percent each year.

Every winter, sea ice forms in Canada's Arctic and along the coasts of Greenland, Iceland, and northwestern Europe. With this seasonal change, turrs migrate south from their Arctic summer breeding grounds. After flying and



swimming for thousands of kilometres, they congregate on the Grand Banks of Newfoundland. Unfortunately, this long journey leads turrs into waters that pose many dangers. Newfoundland and Labrador has a traditional turr hunt every year, in which many young, immature birds are shot. Turrs often become snagged in gillnets. But most significantly, the south coast of Newfoundland is a shipping route known for the highest incidence of seabird oiling in the world. Hundreds of thousands of turrs are killed by oil pollution every year.

**Figure 16.17:** Common murre (*Uria aalge*) in the water offshore Newfoundland and Labrador.

Photo courtesy Department of Natural Resources

Turrs are especially vulnerable to oil contamination because they fly low over the water, beating their wings very rapidly. Turrs show their speed and agility by diving and pursuing prey under water, giving the appearance of being able to fly below the ocean's surface. But because they spend so much time at the water's surface, they are at high risk of encountering surface oil slicks.

The first step in estimating the consequences of oiling on turrs is to predict the number of birds affected. This is done through beached bird surveys. Surveyors routinely walk along beaches collecting bird carcasses. These are examined for signs of oiling and for evidence of abandoned gillnets. Beached bird surveys allow researchers to predict annual turr mortality due to oiling, by-catch, and

hunting. One oiled bird washing up on a beach is usually a sign that there are many others that never made it to shore.

*In 2001, a conservative estimate suggested that approximately 200,000 thick-billed turrs are killed by illegal and chronic dumping of bilge oil along Newfoundland's south coast.*

Combined with the annual hunt, research shows that oiling is reducing the population growth of Thick-billed Turrs to around one percent per year. Because of the slow reproductive cycle of turrs, the population as a whole would take a long time to recover from any sudden decrease in adult numbers—a potential outcome of a major spill. With large spills in consecutive years, turr populations could begin to decrease.

Concern over seabird mortality in Canadian waters has led the federal government to introduce changes to the Migratory Birds Convention Act and Canadian Environmental Protection Act. The need for these changes became apparent in 2002 when the Tecum Sea, a Panamanian-owned bulk carrier was diverted to shore in Newfoundland after being identified as the source of a 116 kilometre-long oil slick. As oiled birds began to wash ashore near Cape St. Mary's, the ship's owner, captain and chief engineer were charged with illegal dumping of oil in Canadian waters. Charges were later dropped when it appeared that the existing Migratory Birds Convention Act might only apply to a twelve-nautical mile territorial limit. The Tecum Sea was 170 kilometres off the coast when it was identified and called in to port.

The Tecum Sea got off easy and created the impression that Canadian Justice was lenient with polluters. Since this incident, the Migratory Birds Convention Act and the Canadian Environmental Protection Act have been amended under Bill C-15, which came into effect in 2006. This bill extends the application of the Migratory Birds Convention Act to the 200-nautical-mile exclusive economic zone. Ships' officers and the directors of the owning companies are now held personally responsible for violations. The legislation also raises fines to a maximum of \$1 million, making them comparable to fines imposed by the United States.

Bill C-15 is an important step toward protecting highly vulnerable seabirds like turrs. Improvements in surveillance include the use of satellite tracking and state of the art imaging. In spite of these measures, oil pollution is an ongoing problem. Seabirds will continue to be lost as long as there are owners and operators of large vessels who are indifferent to the problem, or who would rather cause environmental degradation and risk major fines instead of making the small investment of money and time necessary to properly and safely dispose of bilge wastes.





**Figure 16.18:** Rescue workers washing an oil soaked bird.

#### **Newfoundland Offshore Burn Experiment:**

This experiment was conducted to evaluate the air emissions of on-site burning of an oil spill. The experiment demonstrated that no negative health effect could be experienced beyond 500 metres from the fire. On-site burning therefore holds some promise as a safe and efficient way to remove oil from the marine environment.

### **Preventing, Monitoring, and Cleaning Oil Spills**

Chronic spills occur in Placentia Bay and along the southern Avalon Peninsula, often from unknown sources. This problem, along with fear of a major accident, has prompted government to look into oil response preparedness along the south coast. Some people fear it would take too long to deploy containment and clean-up equipment, or that available equipment is of little use in rough seas. The ability of government and industry to respond to a major accident is constantly under review.

The Canadian Coast Guard (CCG), Environment Canada (EC), and Transport Canada (TC) work together to prevent and monitor oil spills off Newfoundland and Labrador as well as in other areas of Canada. All three agencies work toward educating vessel operators about the dangers of oil spills and about the consequences of illegal spills in Canadian waters.

In 1998, the CCG, EC, and TC started the **Integrated Satellite Tracking of Polluters (ISTOP)** program to help detect pollution and possible polluters. Satellite images of the ocean surface can reveal dark areas which may be oil. Once an area is suspected as oil, an aircraft is dispatched to the location to verify that the dark area on the image is oil. Many illegal bilge dumps occur at night simply because ship owners illegally dumping their bilge know that oil is difficult to see at night. Satellite tracking will help overcome this problem.

In the fall of 2006, the TC surveillance aircraft began using the MSS 6000 side looking radar developed by the Swedish Space Agency. Canada is the first country to employ this state of the art surveillance equipment. The MSS 6000 will:

- allow for night time operations;
- increase detection area from 2 nautical miles (nmi) on either side of the aircraft to 25 nmi; and
- increase efficiency while decreasing the cost of the surveillance operations.

### **Who is responsible for cleaning oil spills?**

It is the vessel owners who are responsible for oil spills from their vessels. The Canadian Coast Guard takes responsibility for ensuring there is an appropriate response in place for ship source spills. They also take the lead in addressing spills of unknown origin.

### **Mitigation strategies**

#### **Preparedness**

Preparedness is the key to successful oil spill response. Both government and industry share responsibility for spill preparedness. The Coast Guard, as Canada's lead agency in oil spill response, takes several approaches to preparedness including contingency planning, exercising (practising), training, and research and development.

#### **Containment and Clean-up Methods**

There are several technologies for dealing with spills. The technology used must be appropriate to the type of spill, degree of weathering, and ocean and atmospheric conditions. In some cases, clean-up may not be feasible, while in other cases it can be carried out rapidly and effectively.



- **BOOMS** are deployed to surround and contain spills by creating a barrier along the surface of the water. Booms can be used offshore or in harbours to surround vessels and spills. The choice of a boom type depends on many factors. Wave height, speed of current, ease of deployment and handling, buoyancy, and strength all need to be considered.

**Figure 16.19:** An oil boom is used to contain a spill.

### Special concerns during a clean-up

Sensitivity maps can help determine whether there are special circumstances that need to be considered during a clean-up response. For instance, aircraft surveillance is usually an important part of an emergency response. However, there may be situations in which use of aircraft needs to be limited. The noise from aircraft engines may be detrimental to bird rookeries or to mammal habitat during pupping season. Sensitivity maps help determine these special needs by compiling relevant information about the coastal area in question.

The major disadvantage of most booms is that they fail to contain oil when current speeds exceed two knots.

- **SKIMMERS** remove oil from water. Like booms, the choice of a skimmer must take into account the location and environment of the spill, as well as the characteristics of the oil.

Disadvantages of skimmers include mechanical complexity and difficulty in transporting them to remote spill sites. They are also expensive to operate and maintain. Another disadvantage of skimmers is that they often remove oily water along with oil. Temporary storage of large volumes of excess fluids during recovery can be difficult given the limitations of available storage space during clean-up.

- **BIOLOGICAL REMEDIATION** or bioremediation uses nutrients (nitrogen and phosphorus) to accelerate the degradation of oil. Typically, bioremediation is a final step taken after other physical clean-up efforts have removed most of the oil from the shoreline.

Bioremediation can be performed with designer bacteria. (These are bacteria bred by scientists for their ability to perform a particular task). These bacteria are particularly effective at breaking down oil. However, any use of such bacteria must have approval from Environment Canada since the introduction of exotic bacteria may have undesirable consequences as an invasive species in the local ecosystem.

- **DISPERSANTS** are chemicals designed to cause oil to form small droplets that disperse throughout the water column. Under ideal conditions, dispersants can work quickly to stop oil spills from harming sensitive areas. However, two drawbacks of dispersants limit their usefulness:
  - Dispersants used in the 1960s and 1970s proved to be highly toxic and caused damage to marine life. Current dispersants are generally less toxic than many types of oil.
  - Without the necessary sea conditions and oil properties, the use of dispersants is not always effective.
    - They require wave action to help break apart the oil slick. Without wave action, the oil will not disperse. If seas are too rough, the oil may be submerged and the dispersant will not come into contact with it.
    - They are also not effective with highly viscous oils.

- **STEAMING AND MANUAL CLEANUP** are labour-intensive and time-consuming methods of beach cleanup. Steam-cleaning uses steam to remove oil from boulders, rock, and human-made structures. Manual methods include the use of rakes and shovels to remove emulsified oil or tar balls from beaches. This is generally done when oiling is sporadic and does not warrant the use of heavy machinery. It can be destructive of beach habitat.

### Disposal

When spilled oil is collected, either from the sea surface or from the shoreline, the collected oil is usually mixed with a large quantity of water, debris, and beach material. Ideally as much of the collected oil as possible should be reprocessed through an oil refinery or recycling plant. However, this is not possible if the oil contains physical debris and seawater.

There are a variety of methods available for the disposal of dirty oil. These include direct disposal in controlled landfill sites; use in land reclamation, use in road building; incineration; or biological degradation.

The method of disposal depends on a number of factors including the amount and type of oil and debris collected, the location of the spill, the costs involved and environmental, legal, or practical limitations. Most jurisdictions establish pre-approved disposal sites and methods through consultation with municipal, provincial, and federal governments. Such consultation also includes representation from native and non-governmental organizations.

### CHECK your Understanding

1. What are the different sources of oil pollution in Newfoundland and Labrador?
2. Who is responsible for cleaning up oil spills and what are some of the strategies used for clean-up?
3. How are sensitive coastal areas identified and mapped?
4. Explain why oil is a problem in the marine environment.
5. Describe the three strategies involved in an oil spill response plan.



## PROTECTING OUR MARINE SPACES

Canada's marine environment is under increasing pressure from many sources. Sewage and oil pollution, industrial run-off, marine debris, overfishing, habitat destruction, and climate change all threaten the health of marine life. Maritime industries like oil and gas exploration and development, mapping, mining, fishing, aquaculture, and tourism all compete for access to ocean resources.

With so many interests competing for marine resources, stakeholders need a process to help communicate and cooperate with each other. These competing interests add to the existing environmental pressures of pollution and habitat destruction. The federal government passed the **Oceans Act** in 1997. This act established **Integrated Management**, the framework for a new way to manage marine resources.

The Act also allows for the establishment of a system of **Marine Protected Areas** (MPAs). MPAs are established through the Integrated Management framework.

**Figure 16.20:** Salvage is the closest community to the Duck Island Marine Protected Area. *Photo courtesy of Fisheries and Oceans Canada*



### Marine Protected Areas

According to **Canada's Oceans Act**, a Marine Protected Area (MPA) is "any area of intertidal or subtidal terrain, together with its overlying water and associated flora and fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment". In other words, it is illegal to carry out activities that threaten or harm the plant and animal life within an MPA. Activities that are forbidden are determined on a site-specific basis, which means that each MPA can have different designs and rules. For instance, some types of fishing may be permitted in one but not another, depending on what species are being protected in a particular area to meet the area's conservation goals. The importance of such a conservation measure for recovering stocks is supported by science and is discussed by stakeholders during the evaluation stage of the MPA

### Components of Canada's Marine Protected Areas Strategy

MPAs are one of several conservation programs that form the strategy. The three main programs include:

**Oceans Act MPAs** protect and conserve marine habitats, endangered marine species and areas of high biodiversity.

**Marine Wildlife Areas** protect and conserve habitat for wildlife including migratory birds and endangered species.

**National Marine Conservation Areas** protect and conserve representative examples of natural and cultural marine heritage for the education and enjoyment of the public.

Additional programs contribute to the strategy. These include Migratory Bird Sanctuaries, National Wildlife Areas and National Parks with a marine component.

proposal. Fishers often initiate the MPA process, in recognition of the need to protect the resources that they rely on for their livelihoods.

A marine protected area can be established in order to conserve and protect:

- commercial and non-commercial fisheries resources, including marine mammals and their habitats;
- endangered or threatened marine species and their habitats;
- unique habitats; and
- marine areas of high biodiversity or biological productivity.

Canada's **MPA Strategy** establishes individual MPAs as part of a wider, interconnected network. While individual MPAs have ecological benefits, a carefully selected network of MPAs can greatly increase those benefits. For instance, although an MPA may protect an important spawning ground, many marine species are migratory. They need multiple habitats for various life stages. These habitats may be far apart and so a network of MPAs at different locations all work together to support a larger ecosystem.

The MPA strategy is built upon co-operation between government agencies, communities, and industry. The strategy is lead by the federal Department of Fisheries and Oceans, which is the agency responsible for MPAs designated under the *Oceans Act*. Other government agencies with responsibility for the MPA strategy include the federal departments of Environment, Transport, National Defense, Natural Resources, Indian and Northern Affairs, and Foreign Affairs, and Parks Canada.

### What do Marine Protected Areas Mean for Newfoundland and Labrador?

In Newfoundland and Labrador, three MPAs and one Area of Interest were initiated by local community and fishing-related organizations. By initiating the process to create MPAs, communities that rely on the fishery are able to play an important role in directing the stewardship of marine resources.

Gilbert Bay, along the southeast coast of Labrador, has a designated MPA. In Eastport, there are two adjacent MPAs: one near Duck Island and another near Round Island. Leading Ticks is currently the only Area of Interest (AOI) in the province. An AOI is one step in the process of creating an MPA.

## ECO SPOTLIGHT:

### The Eastport Example

During the 1990s, Eastport lobster fishers noticed a serious decline in lobster stocks. They suspected the decline was a result of increased lobster fishing, after other fisheries closed. Various lobster conservation efforts led to the creation of the Eastport MPA, which is comprised of two sites. The following order of events illustrates how the MPA was established at Eastport:



**Figure 16.21:** Spawning lobster. *Photo courtesy of Fisheries and Oceans Canada*

- Since 1997, the Eastport Peninsula Lobster Protection Committee (EPLPC) has advocated for the conservation of important lobster habitat near Round Island and Duck Island.
- The EPLPC approached DFO in 1999 with a proposal for establishing an MPA in the area. They believed that an MPA designation would help their efforts to conserve lobster stocks and sustain a stable fishery.
- In 2000, DFO designated the two sites at Eastport as AOIs. DFO biologists began screening the proposal according to the national framework for the establishment of MPAs.
- In 2002, a steering committee led by DFO and EPLPC members began the evaluation and recommendation process. Ecological, technical, and socio-economic assessments of the proposed MPA began. Consultations were also started with local stakeholders.
- The final drafting of legislation for the proposed MPA was done by the Department of Justice Canada, with close input from DFO. The Eastport sites qualified for MPA status for several reasons:
  - They provide habitat for commercial species such as lobster.
  - They provide habitat for wolffish, which is an endangered species.
  - They display high biological productivity.
  - They contribute to a national network of MPAs.

On October 11, 2005, the legislation was completed and the Eastport MPA was established. The Gilbert Bay MPA in Labrador was also established at the same time.

No marine organism can be removed from the Eastport MPA. This is not the case in all MPAs; in Gilbert Bay some recreational and commercial fishing is permitted. Also, no dumping, discharge, or any activity that will disturb the ecology of the MPA is permitted. Some monitoring and educational activities are permitted with approval from DFO.

### **Benefits of the Eastport MPA**

- Protects the breeding habitats of an important species, lobster.
- Enhances the sustainability of lobster, which in turn provides long term benefits to the local fishery and to those affected by the fishery.
- Brings greater recognition of the region's ecology to scientists, fishers, tourists, and the general public.
- Increases access to funds for carrying out other research in the area, bringing economic benefits to the Eastport area.
- Creates opportunities and economic benefits for surrounding communities.

### **CHECK your Understanding**

1. What are Marine Protected Areas? Why are they important?
2. Besides Marine Protected Areas, what other components make up Canada's Marine Protected Areas Strategy?
3. Where are there Marine Protected Areas in Newfoundland and Labrador and why are they important?

### **For Further Discussion and/or Research**

4. How do Marine Protected Areas fit within Integrated Management?
5. Is the formation of Marine Protected Areas an effective strategy for protecting our marine resources? Explain your reasoning.



### **Summary**

Water is essential for all life on the planet. In fact, it was a water “soup” from which the earliest life forms on this planet arose. Because of the sheer volumes of water, and in some cases that sense that it is an infinite resource, we have tended to use our oceans, lakes, and rivers as a place to hide the stuff we don’t like. Garbage, wastes, and waste waters have always been flushed into the waters. But now we are seeing clear evidence that water is not an infinite resource. Unequally distributed around the planet, many have none and others too much. With the application of environmental sciences and new technologies, proper management, and respect for resources, we can ensure that our water resources will be here for the enjoyment of our children and the children of the future.

## Unit 4: For Further Reading

### Trends in Canada's Environment

Environment Canada has released the fourth annual results of the Canadian Environmental Sustainability Indicators (CESI) Initiative. The CESI initiative provides indicators on three issues of concern: air quality, water quality and greenhouse gas emissions. <http://www.ec.gc.ca/indicateurs-indicators>.

### Ocean Debris and Coastal Cleanups

The Ocean Conservancy report entitled “A Rising Tide of Ocean Debris and What We Can Do About It” documents the types and sources of debris and its impact on wildlife and connection to global climate change. It also includes recommendations for eliminating marine debris.

[http://www.oceanconservancy.org/site/PageServer?pagename=icc\\_report](http://www.oceanconservancy.org/site/PageServer?pagename=icc_report).

The Canadian Council of Ministers of the Environment (2009). Canada-wide strategy for the management of municipal wastewater effluent. The strategy articulates the collective agreement reached by the 14 ministers of the environment in Canada to ensure regulatory clarity in managing municipal wastewater effluent under a harmonized framework. [http://www.ccme.ca/ourwork/water.html?category\\_id=81](http://www.ccme.ca/ourwork/water.html?category_id=81).

### Establishing Resilient Marine Protected Area Networks - Making It Happen

This guide reviews the role of MPAs and MPA networks at local and regional scales to achieve marine conservation. It utilizes current scientific knowledge, institutional experience, and global case studies to outline the latest information pertaining to building resilient and functional MPA networks.

[http://cmsdata.iucn.org/downloads/mpanetworksmakingithappen\\_en.pdf](http://cmsdata.iucn.org/downloads/mpanetworksmakingithappen_en.pdf).

Natural Resources Canada (2005). *Freshwater: the role and contribution of Natural Resources Canada*. Retrieved March 18, 2009, from <http://www.nrcan-rncan.gc.ca/sd-dd/pubs/h2o/pdf/freshwater.pdf>.

Department of Environment and Conservation, Water Quality Resources Division, Government of Newfoundland and Labrador (n.d.). *Canadian Water Quality Index (CWQI)*. Retrieved March 18, 2009, from <http://www.env.gov.nl.ca/env/Env/waterres/WQMA/WQI/CanadianWQI.asp>.

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