Fisheries and Oceans Canada
Pêches et Océans Canada

The Gulf of St. Lawrence
A Unique Ecosystem

The Stage for the Gulf of St. Lawrence Integrated Management (GOSLIM)

Canada

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Abstract

This report presents the Gulf of St. Lawrence as a unique marine ecosystem that features complex oceanographic processes and also maintains a high biological diversity of marine life. The information provided covers physical systems such as the properties of water, physical oceanography and geological components. The biological aspects include descriptions of macrophytic, planktonic and benthic communities, reptiles, fish, marine birds and mammals. There is also a discussion on the human components such as settlement, industrial activity and governance. By providing relevant information in this format the report highlights the challenge of managing multiple human activities within the context of a dynamic, diverse and unique marine ecosystem.

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1. Introduction and Background

The *Oceans Act* established a new legislative and policy framework to modernize the management of our oceans-related activities. The basic principles of the *Oceans Act* are: – Sustainable Development, Integrated Management and the Precautionary Approach.

The *Act* is meant to change the way the Government of Canada manages its ocean-related activities and involves all Departments that have a jurisdiction in the oceans. The *Oceans Act* gives responsibility to Fisheries and Oceans Canada (DFO) to lead and facilitate the development of management plans for oceans-related activities in Canada.

With the announcement of the Oceans Action Plan, (OAP), the Gulf of St. Lawrence was identified as one of five priority Large Oceans Management Areas (LOMA) in Canada (along with Grand Banks/Placentia Bay, Scotian Shelf, Pacific North Coast and Beaufort Sea).

The OAP describes how Canada's Oceans Strategy will be implemented, consistent with the intent of the *Oceans Act*. The plan identifies four pillars under which planning for activities will be undertaken.

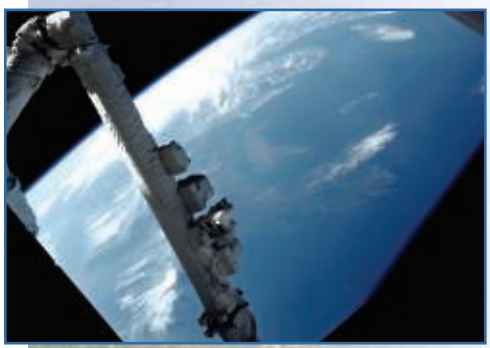

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Image courtesy of the Image Science & Analysis Laboratory, NASA Johnson Space Center. http://eol.jsc.nasa.gov

These are:

- International Leadership - Sovereignty and Security
- Health of the Oceans
- Oceans and Science Technology
- Integrated Oceans Management for Sustainable Development

Under the Gulf of St. Lawrence initiative the applicable OAP pillars are: Health of the Oceans, Oceans and Science Technology, and the Integrated Oceans Management for Sustainable Development. In particular, the initiation of integrated resource management based on a framework of ecosystem management, the development of ecosystem objectives and seabed mapping are priority tasks.

Integrated Management (IM) planning involves defining and assessing the ocean area, engaging all affected interests and establishing consultative and advisory bodies that consider the conservation and protection of estuarine, coastal and marine ecosystems. This is done in order to establish the means for making informed decisions on resource exploitation and ocean use with as much data as possible. The goal of IM is to bring relevant environmental, economic and social concerns into the planning process thus allowing for planning that truly considers the sustainable use of the ecosystem. Within the Gulf of St. Lawrence, the Departmental project that was created to implement this approach is the Gulf of St Lawrence Integrated Management (GOSLIM) initiative.

The initial focus of the GOSLIM initiative is to describe the Gulf of St. Lawrence ecosystem and identify activities and issues from a broad Gulf-wide perspective.

This document summarizes key features of the Gulf of St. Lawrence ecosystem and major human activities that are linked to it. Some threats are identified and briefly described in order to demonstrate that if we want to ensure the sustainability of the Gulf of St. Lawrence, an adaptive and integrated management approach that involves all stakeholders is required.

As a starting point, it is important to identify what we know about the Gulf of St. Lawrence because it is only when we understand how the environment works that potential threats can be identified, and management measures can be put in place to mitigate them.

1.1. Why is the Gulf of St. Lawrence unique?

The Gulf of St. Lawrence is similar to an inland sea with a distinct ecosystem, characterized by partial isolation from the North Atlantic, freshwater runoff from the land, a deep trough running along its length, seasonal ice, the presence of a cold intermediate layer, shallow depths, and high biological productivity and diversity. The distinct qualities of the physical and biological components of the Gulf combine to create its unique environment. This environment also governs how humans settle and use the resources within it. As a result, a wide variety of human activities occur within and adjacent to the Gulf of St. Lawrence. Many depend on its resources for their livelihood.

The human environment of the Gulf is also unique. It is surrounded by five provinces of which populations are composed of Anglophones and Francophones and many First Nations, which create a wide array of culturally and socially distinct settlements.

2. Overview of the Ecosystem

2.1. Physical systems

Oceanography is a branch of science concerned with the physical and biological properties of the sea. In this section, we look first at the physical systems of the coastal and offshore waters of the Gulf of St. Lawrence. Physical systems include the physical oceanography, water properties, the sound environment and geographic system components.

2.1.1. Physical oceanography

The Gulf is a very special marine environment from an oceanographic viewpoint because:

- It is isolated from the North Atlantic;
- It receives large amounts of freshwater drainage from Great Lakes and the St. Lawrence Basin;
- It is ice covered in winter;
- It has a combination of numerous shallow areas and deep troughs.

The Gulf is a semi-enclosed sea, opened to the Atlantic Ocean through the Cabot Strait and the Strait of Belle Isle. The Laurentian Channel is a long, continuous trough over 300 metres deep that runs 1,500 kilometres from the continental shelf in the Atlantic Ocean to where it ends abruptly in the St. Lawrence Estuary at the mouth of the Saguenay River near Quebec City. This trough brings deep oceanic waters to the estuary. There are two secondary troughs (Esquiman and Anticosti channels), and plateaus such as the Magdalen Shallows, which cover the southern part of the Gulf. The Gulf's submarine topography (i.e. its bottom) is considered complex, and strongly affects how water circulates. Circulation in the Gulf is generally counter-clockwise.

"Atlas of the Marine Environment and Seabed Geology of the Gulf of St. Lawrence" Geological compilation by Heiner Josenhans, digital compilation by Lisa Peitso and Robin Harvey. Geological Survey of Canada report, 2004.

Here is a simplistic way to visualize how water enters and moves through the Gulf. Through the influences of tides and currents, cold, dense water flows from the arctic via the Labrador current and enters the Gulf through the Strait of Belle Isle. Atlantic waters of the Gulf Stream enter through the Cabot Strait in the Laurentian Channel, usually at depths of around 200 metres. Each spring, the increased freshwater flows into the Gulf from the St. Lawrence River, the Saguenay River and other rivers along the shores, producing a low-salinity, higher-temperature surface layer of water that begins to flow toward the Atlantic Ocean.

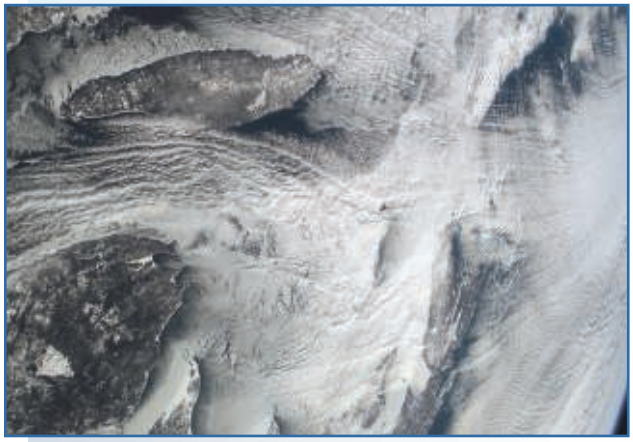

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Image courtesy of the Image Science & Analysis Laboratory, NASA Johnson Space Center. http://eol.jsc.nasa.gov

Freshwater runoff, which also increases in the fall, drives circulation in the Gulf, and makes it similar to an estuary (i.e. the mouth of a river where fresh and salt water meet).

As winter approaches, the surface layer moving towards the Atlantic becomes less buoyant (through a number of factors such as cooling, sea-ice formation and reduced runoff), and moves downward. This surface winter layer will be between 100 and 150 metres deep by the end of March, and in spring, will be trapped below a new summer surface layer. It will then be known as the Cold Intermediate Layer, a major characteristic of the Gulf.

The atmosphere also impacts on the formation and circulation of the water masses (an individual water mass is defined mainly by its temperature and salt content). For example, winds move across the surface waters which results in a transfer of heat across the lower atmospheric layer. This impacts air temperature, which is the major predictor for sea ice. Cloud cover is the main factor controlling year-to-year variations in spring warming and, in the summer, the temperature of the surface layer. Evaporation and precipitation (rain and snow) can change the surface salinity (i.e. salt content).

Vertical mixing (i.e. mixing up and down, between layers of different densities) is the most important process affecting water masses. A water mass can stay in the Gulf for a few months near the surface and up to a few years in the colder, bottom waters. The circulation and mixing of these water masses is considered a key factor determining the physical habitats for marine life, and affecting the productivity and biodiversity.

Another major characteristic of the Gulf's physical oceanography is that it freezes over every year. There is a lot of variation in the year-to-year freeze-up and break-up dates, the maximum extent of sea-ice cover and its mean or average thickness. It is important to be able to forecast sea ice in the Gulf, because ice limits both biological activities and human activities such as fishing and navigation. Global climate change models suggest that the Gulf may become ice free in less than half a century, although not all research supports this thesis.

Sea level variations are very important for people living in coastal environments. Impacts on the coastal zone associated with sea level rise and storm surges include coastal erosion, localized flooding, dune erosion/breaching and possible changes to navigation. The sea level is determined by a number of factors such as: tides, storm surges and

continental shelf waves, and longer-term impacts such as climate change. Storm surges linked to pressure in the atmosphere coupled with shelf waves can cause a rise in the sea level of between 10 and 50 centimetres above predicted levels. Coupled with tidal changes, this may create flood conditions over shorelines of the southern Gulf, the North Shore and the Estuary including the upstream region near Québec City.

Scientific research over the years has greatly increased our understanding of the physical oceanography of the Gulf. Information is often collected by ships or fishing vessels. New satellite technologies now provide data on sea ice, surface waves, sea level heights and salinity. Coastal radar systems can provide detailed measurements of surface currents, and numeric models have been developed to forecast ice conditions.

2.1.2. Water properties

The main properties of seawater in the Gulf include suspended particulate matter, nutrients, oxygen, organic carbon and contaminants.

Physical systems strongly affect water properties by forcing them up or down in the water column, slowing down or speeding up, warming or cooling depending on the depth, and vertically mixing, all of which in turn, influences the productivity and biodiversity of fish and marine life in the Gulf.

Suspended particulate matter

Suspended particulate matter is minute organic or inorganic solid material that is found in the water column. It can include soils and suspended bottom sediments, decaying plant materials and plankton. Organic suspended particulate matter is a food source for organisms such as zooplankton and bottom filter-feeders (such as molluscs) although it can also carry contaminants into estuaries and the sea.

Heavy suspended particulate matter concentrations cause turbidity (i.e. make the waters murky), reducing light penetration and affecting primary production. They can also interfere with monitoring tools, such as satellite imagery, that are used for assessing the surface phytoplankton biomass.

Suspended particulate matter concentrations can be increased by human activities such as dredging, construction, agriculture and forestry. Its natural distribution patterns can also be influenced by events such as oil spills.

In general, there is good information on the distribution, composition and behaviour of suspended particulate matter in the Laurentian Channel and the Estuary, although less so for the Gulf as a whole. Current research is directed towards the organic portion of suspended particulate matter rather than total suspended particles.

Nutrients

The major nutrients found in seawater are nitrates, phosphates and silicate. Nitrate is the most abundant of the nitrogen-containing species although nitrite, ammonia and organic compounds also contribute to biological activity. Nutrient levels in the bottom waters of the Gulf are considerably richer than nutrient levels found at similar depths in the North Atlantic. This is because of the general circulation pattern in the Gulf and the way materials degrade and "recycle" in deeper waters. The northern and eastern regions of the Gulf have higher nutrient concentrations than the southern Gulf.

Nutrients are important to primary production. If they are limited in surface waters, productivity is also limited. A number of natural mechanisms are known to force nutrients upwards into shallow, surface water. In the Estuary,

for example, the most important mechanisms are the intense tidally-induced mixing between freshwater and saltwater and upwelling at the head of the Laurentian Channel also known as the "nutrient pump".

On the other hand, too many nutrients – "heavy nutrient loading" – can present a risk to the environment. A major source of nutrients is sewage and agricultural run-off from shorelines along the St. Lawrence River and the Gulf.

Oxygen

Oxygen is another very important property of seawater. Preliminary research suggests that oxygen levels in the bottom waters of the lower St. Lawrence Estuary were twice as high in the 1930s as they were in the 1990s. This observation has been recently extended downstream of the channel, up to the Anticosti Island area. This may be partly explained by an increase in nitrogen levels combined with an increase in organic matter that has settled on the bottom (causing a smothering effect). Oxygen deficiency in seawater can limit the distribution of certain organisms (e.g. cod and other benthos as it was recently observed) in the Gulf. Another explanation could be related to the water properties of continental slope water coming into the Laurentian Channel. These waters are relatively warmer and thus have lower oxygen content.

Carbon

Carbon is the major chemical ingredient of most organic matter: about 50% of the dry weight of living organisms is carbon. That is why carbon can tell us a lot about life, ecosystems and how they function.

Carbon is also a component of carbon dioxide (CO_2), which is a major greenhouse gas. Carbon dioxide is introduced to the atmosphere from both natural and human origins. Natural CO_2 sources include volcanism, respiration, decomposition, erosion, combustion and evaporation. Human CO_2 sources include combustion (particularly fossil fuel burning and land clearing); industrial production processes (smokestacks) and cement production (heating limestone). The concentration of carbon dioxide in the atmosphere has already increased by about 30% since the middle of the 19th century, and the result has been higher air temperatures and higher sea levels.

The ocean carbon cycle – which refers to how organic carbon is produced and transported between water levels throughout the Gulf – is believed to play a key role in controlling atmospheric carbon dioxide levels. That is why it is important to increase our understanding of these processes. Information on the geographical distribution of organic carbon components in the Gulf is still relatively limited.

Contaminants

Contaminants are chemical compounds that are not normally found in nature, that are produced by humans and that end up in the natural environment. Contaminants present in the environment include inorganic products such as heavy metals and organic compounds such as pesticides and other organochlorines (PCBs and DDT being the best known). These contaminants can have major negative effects on the cells and tissues of individuals, populations and even entire communities. The effects are often related to the length of time an organism is exposed to the contaminants. Coastal areas and estuaries are particularly susceptible to contaminant release because of the length of time waters remain there.

Primary sources of contaminants include untreated urban and industrial waste and activities such as intensive farming and forestry. Rivers, mainly the St. Lawrence and Saguenay Rivers, distribute contaminants far from their origins. Contaminants act much like suspended particulate matter, in the way they are transported, and settle into the ocean bottom.

There is still relatively little data available on the presence of contaminants in the water column, sediments or organisms at lower feeding levels in the Gulf. The available knowledge reveals widespread contamination by a number of chemical products in the waters and sediment of the Estuary and Gulf, with contamination levels highest close to probable sources (i.e. industrial plants). The most abundant contaminants appear to be PCBs and other organochlorine pesticides because they do not easily biodegrade.

It is interesting that although the production and use of most of these compounds has been prohibited for several decades they are still present in every part of the Gulf ecosystem and it appears they will be present for a long time. It should be noted as well that new contaminants are regularly introduced into the ecosystem. An example is a chemical used as a flame retardant in clothing, levels of which are now being found in the blubber of beluga whales in the St. Lawrence River. Such new contaminants are added to the mixture of contaminants already present, and may aggravate the situation of animals that remain for long periods in the Gulf (such as belugas, seals and other marine mammals).

2.1.3. Sound environment

The sound environment is another important part of the physical systems of the Gulf. Sound is obviously a natural part of life in the Gulf. Earth vibrations, the cracking and breaking of ice, waves, storms and wind all contribute to ambient or background noise. Marine mammals, fish and other organisms produce sound when they communicate, feed, and swim. The lack of data, however, makes it difficult to estimate the overall acoustic contribution of fish and marine life to the total sound enviroment.

Human activity also produces a lot of sound. Some major sources include seismic exploration, marine traffic, marine and coastal construction, sonar, military activity and airplanes. The growth of commercial marine traffic in the Gulf is of particular concern. Container ships and supertankers can make considerable noise. There has been a significant increase in recreational vessel traffic and in commercial whale-watching activities in some parts of the Gulf.

Seismic surveys, which use air guns, explosive charges and sparkers to explore for oil and gas, are also a major contributor to noise levels. Although oil companies are required by law to obtain permits for seismic surveys, information on the sound levels resulting from their activities is still limited. Another major contributor to noise levels is explosive charges used during construction.

Intense noise can lead to physical damage and behavioural changes in marine animals. Injuries can be lethal or sub-lethal, permanent or temporary, and can be inflicted instantly or as a result of accumulated effects. Sound effects on marine life are complex, and vary from one species to another. The same sound (at the same frequency and intensity) may cause permanent damage to one species of fish and be harmless to another. Data on the impact of noise on fish and other marine animals is relatively limited, although some effects of noise on marine mammals (such as whales) have been well documented. These include:

- Mammals may avoid some noisy areas;
- On the other hand, they may be attracted to sound (putting themselves in danger of collision with seismic or other vessels);
- Noise levels may alter migratory patterns;
- Noise may cause temporary or permanent injury of hearing;
- Noise may have secondary negative effects on food sources and habitat;
- Whales may surface from deep waters very quickly due to being frightened by seismic or sonar bursts, and not be able to decompress adequately – causing death.

The long-term impacts of increasing noises in the Gulf could lead to changes in feeding and migratory patterns of marine animals, which in turn could affect the balance of the ecosystem.

2.1.4. Geological components

Geological components include glaciations, post-glacial variations in sea levels and coastal landscapes. In this context, we also look at potential resources that might be found in bedrock and sediments, and some potential risks, both natural and human-caused.

Geological features are important. They are an essential component of marine and wildlife habitats. They influence the circulation, mixing and characteristics of water masses in the Gulf, which, in turn, creates the habitats.

Geological features also allow for many human activities, from resource exploitation and land use development to the prevention and mitigation measures of hazards such as coastal erosion, submarine landslides and earthquakes.

Bedrock formations

The waters of the Estuary and the Gulf flow over rocks that are millions of years old and that straddle three major geological regions: the Canadian Shield in the northwest, the St. Lawrence Platform bordering the Shield and the Appalachians in the southeast. These basement rocks are many kilometres deep, and lie exposed on the sea floor or are covered by sediments whose thickness can vary from a few to hundreds of meters.

Glaciations and Icebergs

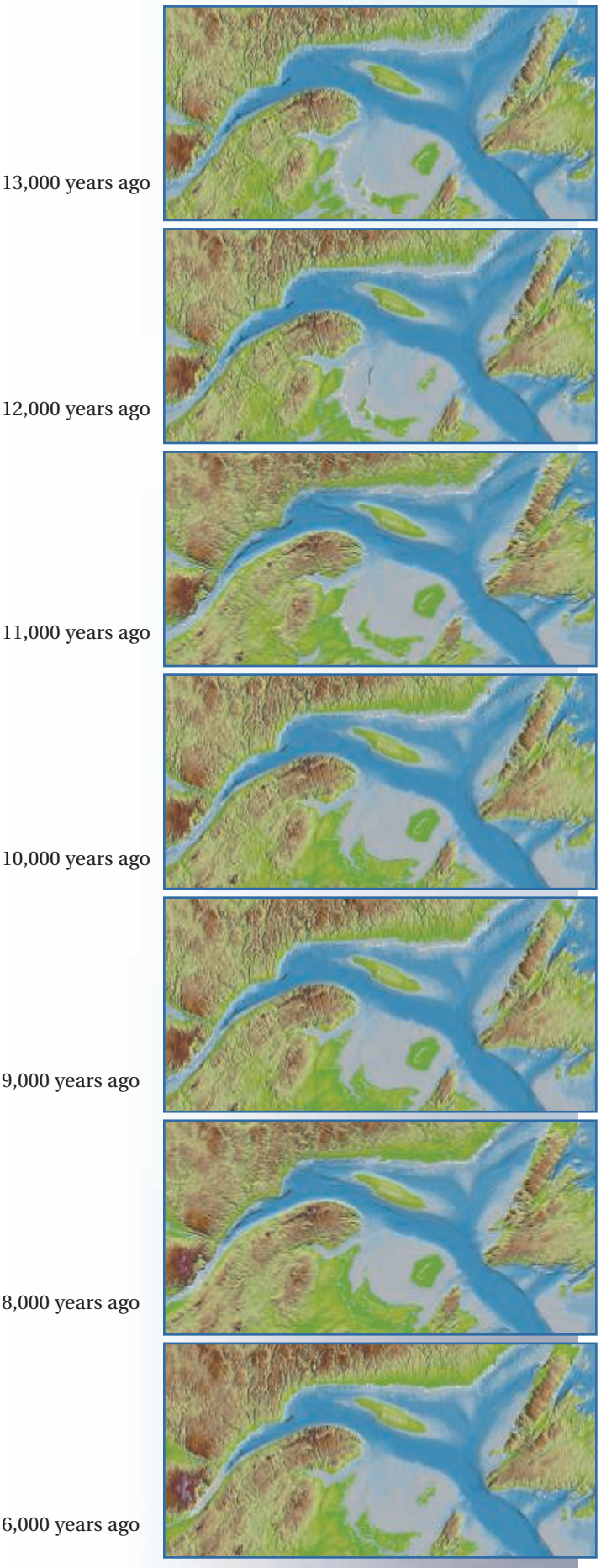
Since their formation, these bedrocks have undergone a variety of transformations, including those caused by alternating glacial and interglacial periods. Geologists generally speak of four major glaciations in the centre of North America in the past two million years, with each glacial period followed by an interglacial period of mild climatic conditions. The impact each time was to remodel the St. Lawrence landscape through erosion and sediment deposits.

In Canada, the last of these glacial periods, the Wisconsin glacier, is the most well known because it covered and remodeled most traces of preceding glaciers. The Wisconsin glacier had a major impact on the landscape of the Gulf – both on land and underwater. For example, a large part of the sediments covering the seafloor were brought there during the Wisconsin glacial period.

We are now living in an interglacial or postglacial period and the mean temperature on the planet's surface as well as average sea levels world-wide are both rising. The trend in the St. Lawrence Estuary is not clear although evidence suggests that sea levels at many areas on both shores of the St. Lawrence are slowly rising. The surface of marine sediments in the Gulf shows evidence of a variety of distinct phenomenon.

Some effects of natural phenomenon are present, for example, the impact of icebergs that have scoured and reworked the sediments on the marine bottom, and modified their properties. Icebergs entering the Gulf continue to scour the Strait of Belle Isle seafloor to at least 80 metres. Iceberg scours from the last ice age 14,000 years ago are still evident in the Laurentian Channel and some parts of the Gulf.

Some human activities have also had long-term scouring effects. For example, scours of different sizes and depth resulting from fishing trawls and scallop dredges have been observed in almost every corner of the Gulf shallower than 165 meters deep.



Shaw, J., Gareau, P., Courtney, R.C., 2002. Paleogeography of Atlantic Canada 13–0 ka. Quaternary Science Reviews 21, 1863–1880.

Non-living resources

The bedrock and sediments of the Gulf contain a lot of resources, from non-fuel minerals such as sand and gravel, siliceous sands and heavy minerals (i.e. gold, iron and titanium) to fossil fuels such as coal, oil, gas and gas hydrates. It seems that there may be areas of potential interest for oil and gas exploration located in Newfoundland and Labrador and offshore from the Gaspé Peninsula in Québec. In eastern Canada, there are some early examples of the exploitation of non-fuel minerals such as when seawater was evaporated to produce sodium chloride (salt), or siliceous sands were mined from beaches in the Gulf (an activity now prohibited by law).

The marine non-fuel minerals of the east coast of Canada have not been exploited much, however, mainly because of the abundance of minerals on land and the distance from markets and transportation systems as well as knowledge gaps about the marine resource potential.

Coastal landscapes

A final important feature of the geology of the Gulf is its coastal landscapes. The wide variety of coastlines reflects the geology of the environment, the impacts of glaciers and post-glacial periods, and current natural processes. The coastlines of the Gulf are very diverse, from the high cliffs and rocky shores found along the North Shore of Québec and some parts of Newfoundland and Labrador to the gently folded rocks, characterized by barrier islands and sand bars, and backed by low coastal plains, found in some parts of Prince Edward Island, Nova Scotia and New Brunswick, to areas where the predominant coastal feature is a marsh.

The nature of the coastline, as well as the geological structure overall, determines how a particular area will react to natural phenomenon such as earthquakes or landslides (both on land and under water). Coastal erosion is a natural phenomenon although human activity, especially activity that causes global warming, is speeding it up in some areas.

Scientists are now working on developing models that might measure and evaluate the risks that coastal populations and infrastructure might be subject to, from both natural and human activities.

2.2. Biological systems

This section presents an overview of biological systems of the coastal and offshore waters of the Gulf of St. Lawrence. There are seven major biological components: macrophytes, plankton, invertebrates, reptiles, fish, marine birds and marine mammals. Each component is briefly described with its nutrient and dietary needs, its habitat and distribution, when available. Key ecosystem issues are also described.

2.2.1. Macrophytes

There are two categories of macrophytes: macro-algae (plants with no root system) and vascular plants (seagrasses with a root system). Both play a very important role in the marine environment.

Macro-algae populations create "multi-dimensional" spaces that serve as a landing area for millions of invertebrates that drift in the water column during the reproduction cycle. Macro-algae shelter a high abundance of marine animals, increase habitat complexity, and encourage biodiversity. They support a diversified microfauna and microflora, protect a large number of species from predators, filter light and provide shade, and are an important food source for many organisms (e.g. sea urchins and periwinkles).

The distribution of algae is affected by environmental conditions such as temperature, salinity, nutrients, depth, substrate composition, light, waves, currents and ice. In the Gulf, there are 21 commonly known brown algae species (e.g. kelp), 16 commonly known green algae species (e.g. sea lettuce) and 25 commonly known red algae species (e.g. Irish moss).

Key ecosystem issues – Macrophytes
- Fragility of eelgrass beds;
- Introduced/invasive species (e.g. oyster thief);
- Habitat loss;
- Pollution.

Seagrasses also have a tremendous influence on the environment. Because they have a root system, they increase sedimentation, and prevent erosion. This affects the shape and stability of the coastline. Seagrasses enhance water quality, serve as a refuge and food source for a large number of species, and impact biological interactions because they are a source of fixed carbon. In the Gulf, these plants are found mainly in saltwater marshes, salt meadows and eelgrass beds. Main species include the three-square bulrush, smooth cordgrass and eelgrass. There is a very limited harvest of macrophytes in the Gulf.

2.2.2. Plankton

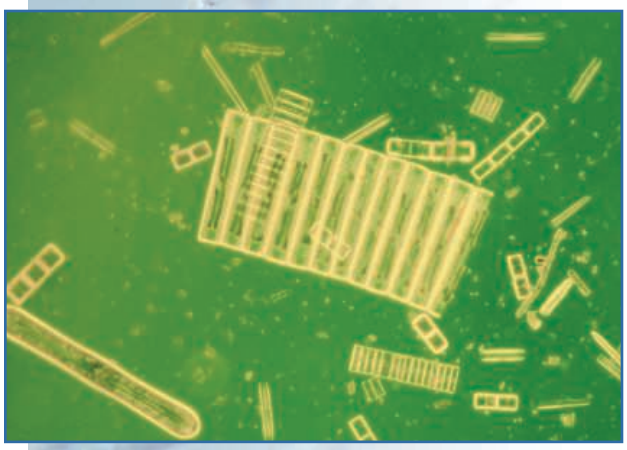
Plankton are classified in a number of ways:
- By size – from the micrometre scale of bacteria (the bacterioplankton) and diatoms, to small crustaceans such as copepods that are one to two millimetres in length (the microplankton), to krill, ctenophores and jellyfish that may be many centimetres in length (the macroplankton);
- Those that are capable of photosynthesis (i.e. able to use sunlight to produce nutrients from carbon dioxide and water), such as the phytoplankton (diatoms and dinoflagellates) versus those that are not, such as the zooplankton (animals that feed on plants and bacteria);
- Those that spend their whole life as plankton (the holoplankton) versus those for which the planktonic phase is only the early stage of their life cycle (the meroplankton, for example, fish larvae, ichthyoplankton);
- Those that associate themselves mostly with the air-water interface (the neustonic or pleustonic community), and those that associate themselves with the ice-water interface (the epontic community).

Plankton is an essential foundation of the food chain or web. A linear way to think of the food chain is this: the phytoplankton are grazed upon by the zooplankton which, in turn, are eaten by larger nekton (i.e. swimming animals such as fish or squid) and, in some circumstances, where there is a lot of up-and-down mixing in the water column, by the benthic community.

Variations in temperature, nutrient concentrations, turbidity and light penetration can all have major impacts on plankton populations.

Plankton organisms have limited swimming ability; their movements are mainly determined by water circulation. Scientists believe that there are four distinct food webs in the Gulf: 1) the region west of Anticosti Island along the Québec shore; 2) the Gaspé current flowing along the north shore of the Gaspé peninsula, south of Anticosti Island; 3) the southern Gulf region, including the Northumberland Strait, Bay of Chaleur and Magdalen Shallows; and 4) the northeastern Gulf. The southern Gulf (region 3) is particularly rich and productive in plankton.

Key ecosystem issues – Plankton
- Pollution;
- Aquaculture;
- Introduced/invasive species;
- Water management and impoundments;
- Effects of climate change.



2.2.3. Benthic community

The benthic community refers to a wide variety of organisms that live at the bottom of water bodies. There are probably more than 3,000 species living in the Gulf, from those that are commercially valuable (such as crab and lobster) to invertebrates and micro-organisms of many forms with little or no commercial value but with significant ecological importance.

The benthic community is more diverse and more abundant than other marine communities, mainly because of the diversity of habitat types. The main classifications include:
- Macrobenthos, including crustaceans (lobster, snow crab, shrimp), molluscs (oysters, mussels, snails) and echinoderms (starfish, sand dollar). The first two groupings are well known for their economic value;
- Other benthic macro-invertebrates, such as annelids (marine worms), sponges and cnidarians (corals, anemones), ascidians (tunicates like the clubbed tunicate, an invasive species), and small orders of animals (flat worms);
- Microfauna and meiofauna, including microcrustaceans (opossum shrimp, barnacles) which play an important role in nutrient recycling, through feeding on decaying wastes of other species. Algae, protozoa and bacteria are also an important part of the benthic community.

The World Conservation Union rates habitat loss as the single most important factor leading to species extinction and loss of diversity. There are no data available to confirm or refute whether any benthic species native to the Gulf are threatened with extinction.

Key ecosystem issues – Benthic community
- Invasive species;
- Loss of benthic habitat;
- Impact of land-based activities (sewage, agricultural runoff).

While coastal communities are well described and areas of the marine environment such as the Magdalen Shallows and Estuary have been well-studied, other parts of the Gulf such as the Laurentian, Esquiman and Anticosti Channels are less well-known. It is important to understand benthic communities in order to know when they are being threatened by human activities such as aquaculture, coastal infilling for land development, sewage and agricultural runoff.

2.2.4. Reptiles

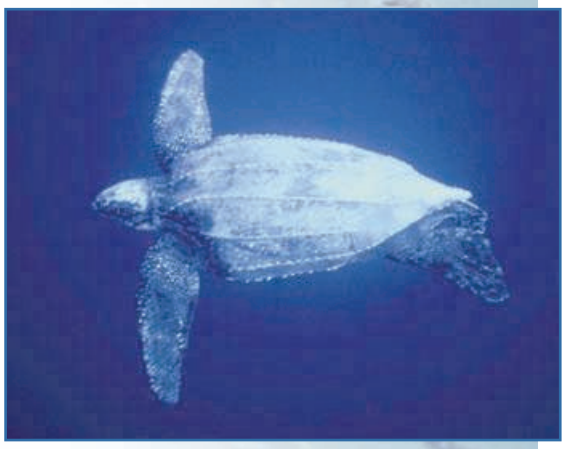
The Leatherback turtle is the only reptile whose range extends into the Gulf. It is a highly migratory species and, in Canada, is also observed regularly along the continental shelf. Scientists think that the main reason the Leatherback turtle migrates into Atlantic Canadian waters in the summer, including into the Gulf, is because of the abundance of jellyfish, its main food source. The Leatherback turtle is listed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and is a listed species under the *Species at Risk Act*.

2.2.5. Fish

The fish community in the marine waters of the Gulf is notable for the large number of species that are either at the northern or southern edge of their distributional range. An example of a species at the southern end of its normal range is the Greenland cod; an example of species at the northern end of their usual range include yellowtail flounder and monkfish. The explanation for this wide range of some species is the variety of weather conditions in the Gulf itself – the presence of cold water conditions combined with ice coverage in winter and warm water conditions in summer. The Gulf fish community is also notable for its high productivity. Average groundfish densities in the southern Gulf are among the highest in Atlantic Canada. Close to 20 species of marine fish are exploited commercially or have been the focus of experimental fisheries.

Marine fish species in the Gulf fall into two broad categories, based on their position in the water column: groundfish and pelagic fish. Groundfish, as the name suggests, tend to live closer to the bottom; commercial species of these "bottom feeders" include Atlantic cod, redfish, American plaice, white hake, Greenland halibut and witch flounder. More than two-thirds of the marine fish species in the Gulf are groundfish. Geographic distribution is not uniform, however. It is influenced by temperature, depth and physical and biological aspects of the habitat. The second category is pelagic fish, which live and feed closer to the water surface. Examples include Atlantic herring, Atlantic mackerel, capelin, bluefin tuna and sharks.

The Gulf is divided into two zones: the southern Gulf, dominated by the Magdalen Shallows, and the northern Gulf. A high productivity area in summer, the Magdalen Shallows contain important spawning, nursery and adult feeding grounds for large biomasses of both groundfish and pelagic fish (e.g. cod and herring). The western Magdalen Shallows are the principle spawning grounds for both the southern Gulf cod population and the northern stock component of mackerel in the northwest Atlantic.



In the northern Gulf, shallow shelf areas along the west coast of Newfoundland and Labrador and the Québec North Shore are important summer feeding grounds and nursery areas for both groundfish and pelagic fish. The warm deep waters of the channels that dominate the northern Gulf are feeding, spawning and nursery grounds for a number of deepwater and slope species (e.g. species that move up the slopes to feed in somewhat shallower water in summer, such as redfish and witch flounder).

These deep channels also function as overwintering grounds for the adults of many of the large-bodied fishes whose spawning, nursery and/or feeding grounds occur in shallower shelf waters (e.g. cod, herring, plaice, white hake and thorny skate).

Several fish communities in the Gulf have experienced severe changes in their relative abundance, the most dramatic being cod and redfish stocks during the 1990s when a moratorium on fishing was put in place. In 2004, there was concern over the status of three species of wolffish and two populations of cod, all of which have faced notable decreases in their numbers.

Key ecosystem issues – Fish
- Overfishing (directed and bycatch);
- Predation;
- Natural and fishing-induced changes to habitats and the ecosystem;
- Environmental changes.

The northern wolffish and the spotted wolffish are listed as threatened species on Schedule 1 of the *Species at Risk Act* (SARA). The Atlantic wolffish was designated as being "of special concern" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2000, and is listed on Schedule 1 of SARA. Two populations of cod were assessed by COSEWIC in May 2003; one is designated as threatened (Laurentian North population) and the other as special concern (Maritime population).

2.2.6. Marine birds

There are four groups of marine birds that depend on the resources of the Gulf coast and sea to survive. These include:
- Inshore birds – These feed in inshore habitats where food is found on or near the bottom of shallow water, and will normally return to land to spend the night. Examples include cormorants, gulls and terns;
- Offshore or pelagic birds – These spend long periods of time at sea, which provides them with all or most of their food requirements. They are independent of land for both feeding and resting, but return to land for breeding, usually on rocky cliffs and islands. Examples are petrels and auks. Together, inshore and offshore birds are also called seabirds. There are approximately 18 different species of breeding seabirds in the Gulf;
- Waterfowl – There are also approximately 18 different waterfowl species found in the Gulf, such as eiders and scoters;
- Shorebirds – The majority of shorebirds are present only for a short time (mostly July to September) during their migration from the Arctic to their wintering grounds in South America. They stop to feed off mud flats, a crucial food source during their long trek. The Gulf is second in importance, after the Bay of Fundy, for the number of shorebirds using its shores as a refueling station. Some species of shorebirds will also breed in the Gulf.

Marine birds play an important role in the ecosystem of the Gulf. Along with marine mammals and large fish, seabirds are considered in the upper ranks of the food chain. They consume an estimated 80,000 tonnes of marine prey every year. Research suggests that human exploitation of marine resources in the Gulf may have resulted in important changes in the seabird community. Overall, in the last 20 years, offshore birds and diving species have been increasing considerably, whereas inshore birds and surface-feeders have declined.

2.2.7. Marine mammals

Marine mammals in the Gulf and estuary include whales and seals. There are five different species of baleen whales in the Gulf: fin, minke, blue, humpback and the northern right whale. There are eight species of toothed whales: beluga, long-finned pilot whale, white-sided dolphin, white-beaked dolphin, harbour porpoise, northern bottlenose, killer and sperm whales.

The toothed whales are carnivorous; they eat fish, cephalopods (squid) and crustaceans (shrimp). Forage species such as krill and capelin are a major food source for baleen whales. Some species (e.g. blue whale) feed almost exclusively on krill while other species, in addition to krill, also eat copepods, molluscs and small fish.

The St. Lawrence Estuary is one of the main feeding grounds for certain North Atlantic whale populations (although the beluga whale is the only year-round resident). Important feeding habitats are found at the head of the Laurentian Channel, in the Cape Breton Trough near Cheticamp on Cape Breton Island, in the Strait of Belle Isle, southeast Prince Edward Island and the Magdalen Islands. Whales use the Cabot Strait off Cape Breton to migrate in and out of the Gulf.

COSEWIC has designated some whales as endangered (North Atlantic right whale, blue whale), some as threatened (St. Lawrence beluga) and some as species of concern (fin whale, harbour porpoise).

Key ecosystem issues – Whales
- Contamination;
- Ship collisions;
- Habitat modification;
- Accidental entanglements in fishing gear;
- Competition for food resources;
- Disturbances, noise.

Four species of seals are common to the Gulf, including harp and hooded seals (which are migratory species) and harbour and grey seals (which are year-round residents). In the Estuary, only harbour seals are year-round residents. Ringed and bearded seals are also occasional visitors to the northern parts of the Gulf.

Over the past 50 years, a reduction in harvesting activity has allowed many seal populations to increase. Hunting of the hooded and harbour seal populations is now prohibited. There is still an important harp seal hunt in the Gulf, and a small number of grey seals are also captured each year.

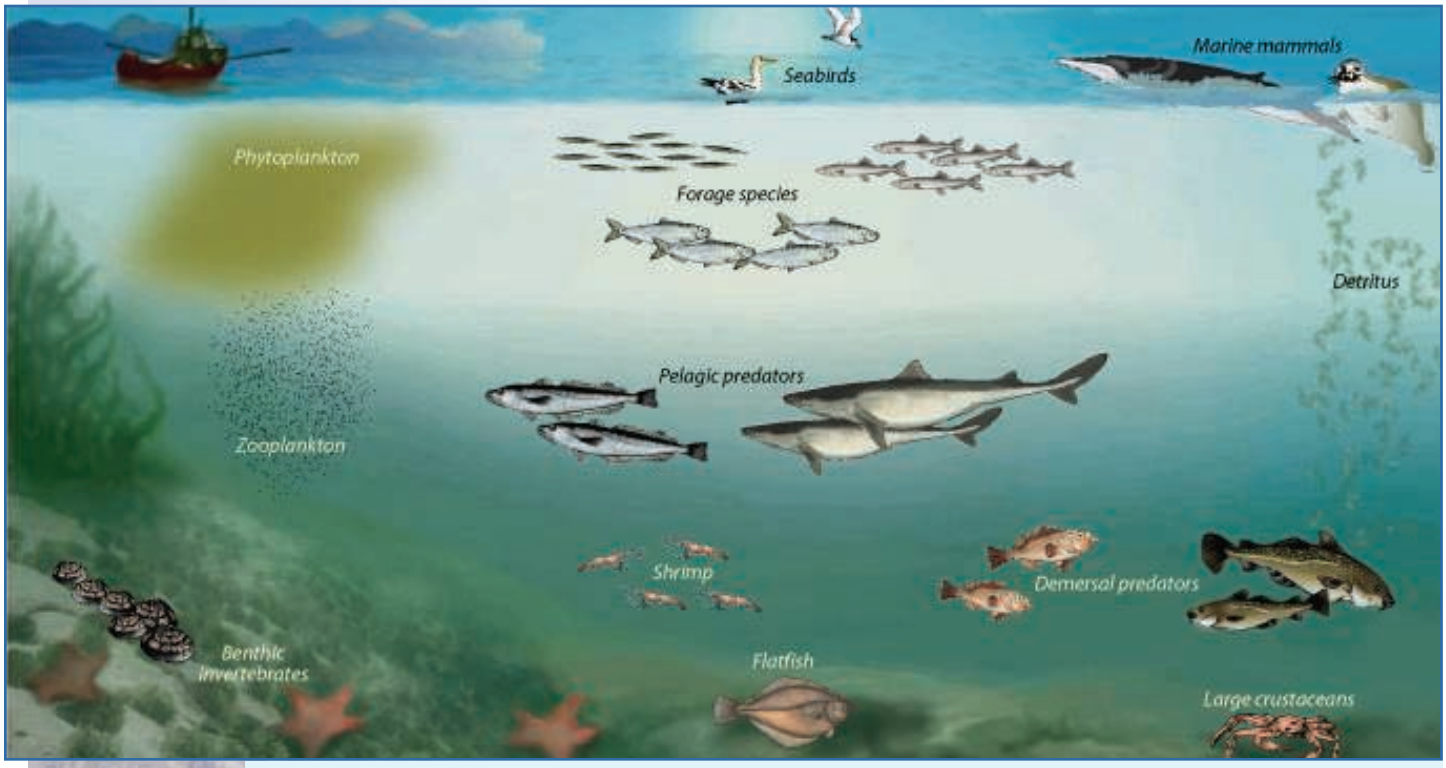
There are a lot of knowledge gaps about seals. Information is generally available on the harp seal population, for example, but knowledge about the harbour seal population size and seasonal movements across the Gulf is non-existent, and information on hooded and grey seals is out-of-date. Information on grey seal diet is, in general, adequate; however, hooded and harbour seal diet information is limited to non-existent. Limited knowledge is also available on the effects of contaminants on reproductive capacity and the immune system, and on the impact of coastal and vehicle activity on the seal population.

No seals in the Gulf have been designated as of special concern by COSEWIC, although harbour seal populations of the St. Lawrence Estuary are believed to be at risk.

2.3. How the Gulf of St. Lawrence ecosystem works

In the previous two sections, we described the physical and the biological components of the Gulf of St. Lawrence ecosystem. In this section, we provide an overview of how these components interact to make the Gulf the unique environment that it is. This section draws links between the physical processes and the biological response to these processes. It is important to keep in mind that this is a generalized description of very complex oceanographic and biological processes.

The Gulf is a three-dimensional world where the habitats or niches of the living organisms are defined by the geology, the current patterns and the up-wellings along with temperature and salinity. Many species will seek warmer areas for the winter, where the water masses keep them in one place with little effort or where there is a food supply. Then during spawning season, they may migrate long distances to other areas where primary productivity is high, where their larval young can use the circulation patterns to stay near food, and where they will have a high chance of survival.



Biological interactions

The main groups and species found in the waters of the Gulf are: phytoplankton, zooplankton, invertebrates, forage fish, large ichthyophagous (fish feeding) fish species, birds and marine mammals. At the base of any marine ecosystem there is the phytoplankton. Benthic invertebrates feed on them when they fall to the bottom but zooplankton is almost its only predator. Zooplankton in turn is consumed by small forage fish species, e.g. capelin, sand lance, herring and mackerel. Forage species play a key role in transferring energy from secondary producers (zooplankton) towards fish and other higher trophic levels. Large ichtyhyphagous fish species (pelagic and groundfish) include cod, redfish and flatfish. Overall, cetaceans, seals, cod and redfish are the main predators of forage species. Marine birds also feed on them. The benthic community of invertebrates mostly made up of shellfish, molluscs, echinoderms (sea urchins) and worms and includes species such as the northern shrimp and snow crab has an important role in the transfer of energy but is poorly understood. Marine mammals (seals and whales) form an unavoidable component in the trophic links in the Gulf. They are at the top of the food web.

Primary production is that process whereby the energy of the sun is converted by photosynthesis into plant tissue. Secondary production is the conversion of plant tissue to animal tissue through ingestion. With this in mind, it is easy to see that green plants are the base of the food web. The amount of primary production that takes place in an area generally defines its biological characteristics with respect to the abundance and types of animals present. The level of nutrients in the water controls the rate of primary production. In shallow coastal areas, you will find a wider variety of types of fish than in the open waters.

Generally in the coastal zone (areas less than 20m deep) the dominant visible primary producers are large macrophytes like kelps, Irish moss and rockweed, coralline algae, benthic diatoms, dinoflagellates, and grasses like eel grass, and marsh grass. Phytoplankton will also be present and often the warm waters and amount of nutrients present will cause algal blooms in sufficient abundance to give the water a green tint. In these areas, the types of feeders will be grazers and filter feeders.

In open waters, primary production takes place in surface waters where the sunlight is strong enough for plants to grow. Here you will find mostly filter feeders in the upper waters and larger grazers and carnivores deeper.

Primary production cycles seasonally depending on the amount of sun, nutrients and plants present. There are two general cycles in the Gulf. The first cycle takes place in well-mixed waters throughout the Gulf in the spring. The primary production in these areas is mainly large species of phytoplankton that are grazed on by herbivores (i.e. vegetarian zooplankton). This cycle creates a lot of dead material including feces that sink to the bottom, taking the nutrients with it. The other cycle develops as the surface water warms up and stratifies in the summer. The nutrients have been used up in the surface waters by the spring plankton growth, and now the small phytoplankton species dominate, and are eaten by omnivorous zooplankton (i.e. those that feed on both plants and animals). This keeps the nutrients cycling in the surface waters longer than the first cycle.

Nutrients are used up quickly by phytoplankton. Nitrogen tends to be the limiting nutrient in the marine environment (although phosphorous or silicon can also be limiting in some circumstances). Light is always a limiting factor with water depth and turbidity. Phytoplankton die or are eaten by primary consumers, which produce feces and also die, and so on, through the food web. The dead

material and feces decompose, and are covered by bacteria as they sink down in the water column and become known as marine snow. This marine snow becomes food for zooplankton and pelagic fish and, when it reaches the bottom, for benthic organisms such as filter feeding shellfish. This process takes the nutrients to the bottom.

Zooplankton and fish larvae that migrate up and down in the water column daily, feeding on the marine snow, and the release of floating eggs by groundfish species, both contribute to a biological pump, which brings high quality nutrients back to the surface. However, the main control on the nutrient supply to sunlit waters is through a physical pump that causes up-welling and vertical mixing, bringing nutrients to the surface. Because nutrients limit primary production, an area of nutrient upwelling encourages a large amount of primary production.

The first of these physical mechanisms is the estuarine pump. The freshwater flow from the St. Lawrence River provides 75% of the mean annual freshwater flow into the Gulf. The rest comes from other rivers and precipitation (i.e. rain and snow). Freshwater is lighter than salt water, and flows across the surface, sweeping salt water along with it as it leaves the Gulf through the Cabot Strait. The flow out of the Strait is at the surface and on the Nova Scotia side. The water moving out of the Gulf is replaced by salt water drawn into the Gulf along the bottom and Newfoundland and Labrador side of the Cabot Strait. This overall pattern brings a flow up the channels, which up-well as described below.

The second physical pump action is created by the tides. The tides in the Gulf move counter clockwise with the centre near the Magdalen Islands. This results in a funneling effect at the shallow ends of channels where the shorelines narrow the passage.

This brief overview sets the stage for understanding how ecologically distinct areas, especially those that have high productivity and high species biodiversity, are created in the Gulf. Because the environment is fluid, boundaries between areas are obviously not rigid; they are flexible and flow into and out of one another. In general, it is the primary physical features of an area that drive the development of its complex and diverse ecology.

To help the reader understand the ecological areas, we will follow the major current flow within the Gulf of St.Lawrence as it enters through the Cabot Strait, flows counter clockwise around the Gulf to the mouth of the St .Lawrence River then across the Magdalen Shallows, and exits through the Cabot Strait on the Nova Scotia side. The small picture box and the coloured bar provide visual guides for the accompanying figure of the Gulf and its currents.

The flow entering through the Cabot Strait turns to the right around southwestern Newfoundland and Labrador . It moves up toward the Esquiman Channel, staying to the right and rolling in a clockwise fashion. This creates a down-welling drift along the channel wall and an up-welling out in the centre of the channel. The flow is restricted as it moves into the shallower Esquiman and Anticosti Channels, causing some of the flow to turn back toward the Laurentian Channel in a counter clockwise gyre (or spiral), enhancing up-welling.

The deep flow splits between the two channels. At the head of the Esquiman Channel, the narrowing channel and rapidly rising bottom forces the flow to turn abruptly and to flow along the northwest side, with the opposing flows resulting in retention areas. The flow is very slow but the momentum causes up-welling as the water rises up over the bottom. The added nutrients result in increased productivity here, and they move into the adjacent coastal area. This is enhanced by increased tidal mixing in the critical summer months, and is typical of channel up-welling and mixing. This area is an important spawning and nursery area for deep-water species such as shrimp and an over-wintering area for several commercial species.

Some of the near surface flow exits on the Newfoundland and Labrador side of the Belle Isle Strait, but most of the flow turns back along the north shore, joining inflow through the Strait. This sharp counter clockwise turn, supported by tidal mixing, creates a dynamic and productive area that supports the important scallop area in the Strait of Belle Isle.

The flow continues southward along the north shore where it stays offshore of an area of islands, shallows and salt marshes. The circulation patterns inside this current retain the productivity for juvenile fish, which is enhanced by tidal mixing. These areas support a wide range of juvenile fish, seals and whales.

As the north shore current with its cold intermediate layer continues to move southward, it joins the northerly flow up the north side of the Anticosti Channel. As the channel narrows and becomes shallower, the water up-wells and turns counter clockwise to flow east along the north shore of Anticosti Island, forming a second channel head. The rapid decrease in depth and the narrowing of the channel funnels the tides, between the north shore and Anticosti Island, resulting in enhanced tidal levels and mixing. The whole area between Anticosti and Quebec benefits from the nutrient input and transient retention here, due to coastal currents.

The shallow current through the Jacques Cartier Strait joins with the deep flow up the Laurentian Channel to form a large counter clockwise gyre west of the island that is bounded on the south side by the freshwater flow from the St. Lawrence River. There is extensive up-welling and mixing in this area including tidal mixing which lifts the intermediate layer and deep water up over the sills at the head of the channel, resulting in high levels of mixing and in turn nutrients, even when the flow of the river is low. This is an important area for redfish spawning, shrimp and whales.

The returning deep flow from the Anticosti Channel swings wide around the eastern end of the Island before joining the main inflow up the Laurentian Channel. This flow supports clockwise flows over the shallow areas east of Anticosti Island, an area of high productivity, biodiversity and spawning area for groundfish.

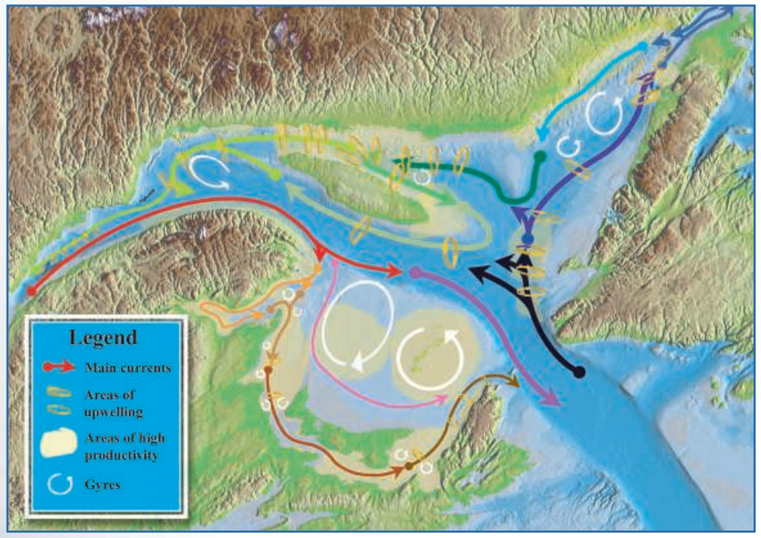
The Honguedo Strait restricts the flow up the Laurentian Channel, and as with the other channel heads, there is a counter clockwise turning of the flow at depth and up-welling, making it a well mixed area frequented by whales just south of the eastern shore of Anticosti Island.

The Gaspé current, the mixture of the St. Lawrence water and the upwelling at the head of the St. Lawrence channel, creates the most productive area for both primary and secondary production along the shores south of the St. Lawrence Estuary and the Honguego Strait. These shallows and tidal flats along the shore are very productive, and are feeding grounds for many species of fish. This productivity is carried out across the Magdalen Shallows, with productivity and nutrient levels generally decreasing towards the east and south.

The coastal current continues into Chaleur Bay, although most of the current heads out towards Prince Edward Island and the Magdalen Islands. There are several clockwise gyres along the New Brunswick shore, off the mouth of Chaleur Bay and at each end of the Shediac Valley, with additional temporal gyres formed by southwest winds. These areas are very important because they concentrate surface production in a temporal retention area, which is used by many species of fish, marine mammals and birds for spawning, juvenile rearing and feeding. Because of the stability of these physical features, the area supports many fish and invertebrate adult species (herring, mackerel, cod, capelin, striped bass, lobster, scallop and crab) and their pelagic larvae. This area is well known for supporting herring and mackerel spawning grounds as well as nursery grounds for benthic invertebrates such as lobster, scallop and crab.

As the flow comes out of the south side of Chaleur Bay, and makes a sharp right-hand turn to join the coastal current moving south along the New Brunswick shore, it creates a strong clockwise circulation that is enhanced by strong tidal mixing in the area. The result is a series of productive and sensitive areas. These are highly productive areas used by mackerel, capelin, herring, cod and many other species as juvenile rearing areas.

Unfold for larger view



2.4. Human systems around the Gulf

This section provides an overview of governance, human settlements, and human activities and in particular the key commercial and industrial activities such as commercial fishing; oil and gas exploration; marine transportation; aquaculture; and land-based activities in the Gulf of St. Lawrence.

Section 3 looks briefly at the potential issues for the Gulf ecosystem that can be derived from each of these activities.

2.4.1. Governance

The governance in the Gulf of St. Lawrence consists of a network of federal, provincial, municipal, and aboriginal governments and environmental organizations. The complexity of this is further reflected through the various legislation put in place to manage marine and coastal areas of the Gulf, and ocean-related resources and activities. While all governments and organizations have an interest in oceans management and sustainable development of marine and coastal areas and resources, the multi-jurisdictional setting of this governance structure may provide one of the greatest challenges towards implementing an integrated management plan for the Gulf.

The governance, regulation and management of activities within and surrounding the Gulf are shared between a wide variety of government departments and agencies. These include the government of Canada; the provincial governments of Québec, New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland and Labrador; and numerous municipalities, counties and economic development boards, authorities and agencies.

Within the federal government alone, over 20 departments or agencies are involved in the oceans sector in one way or another, through various legislation, regulations, programs and/or services.

As well as the federal government, the provinces are very much involved in the management and regulation of resources within the Gulf.

In addition, First Nations, industry groups and associations, and non-governmental organizations such as environmental groups are either involved in or have an interest in the use and management of resources within the Gulf and its coastal and estuarine areas. Some are already well-known and involved. It will be important to identify and involve as many of these as possible.

2.4.2. Human settlements

This section provides a short summary of demographic and socio-economic profiles of each of the five provinces bordering the Gulf. The following table shows some key indicators. Of the five provinces, only Québec and Prince Edward Island show a population that is increasing. Rural areas have been hit hard with out-migration, particularly in Newfoundland and Labrador.

While the economic structure of coastal communities along the Gulf is based mainly around primary industries, many depend solely on one industry such as fisheries, forestry or mining. Single industry communities have a difficult time recovering from adverse changes in an industry, such as the closure of the commercial cod fishery in the Gulf during the early 1990s. The downturn in a major industry is often followed by out-migration of an active workforce.

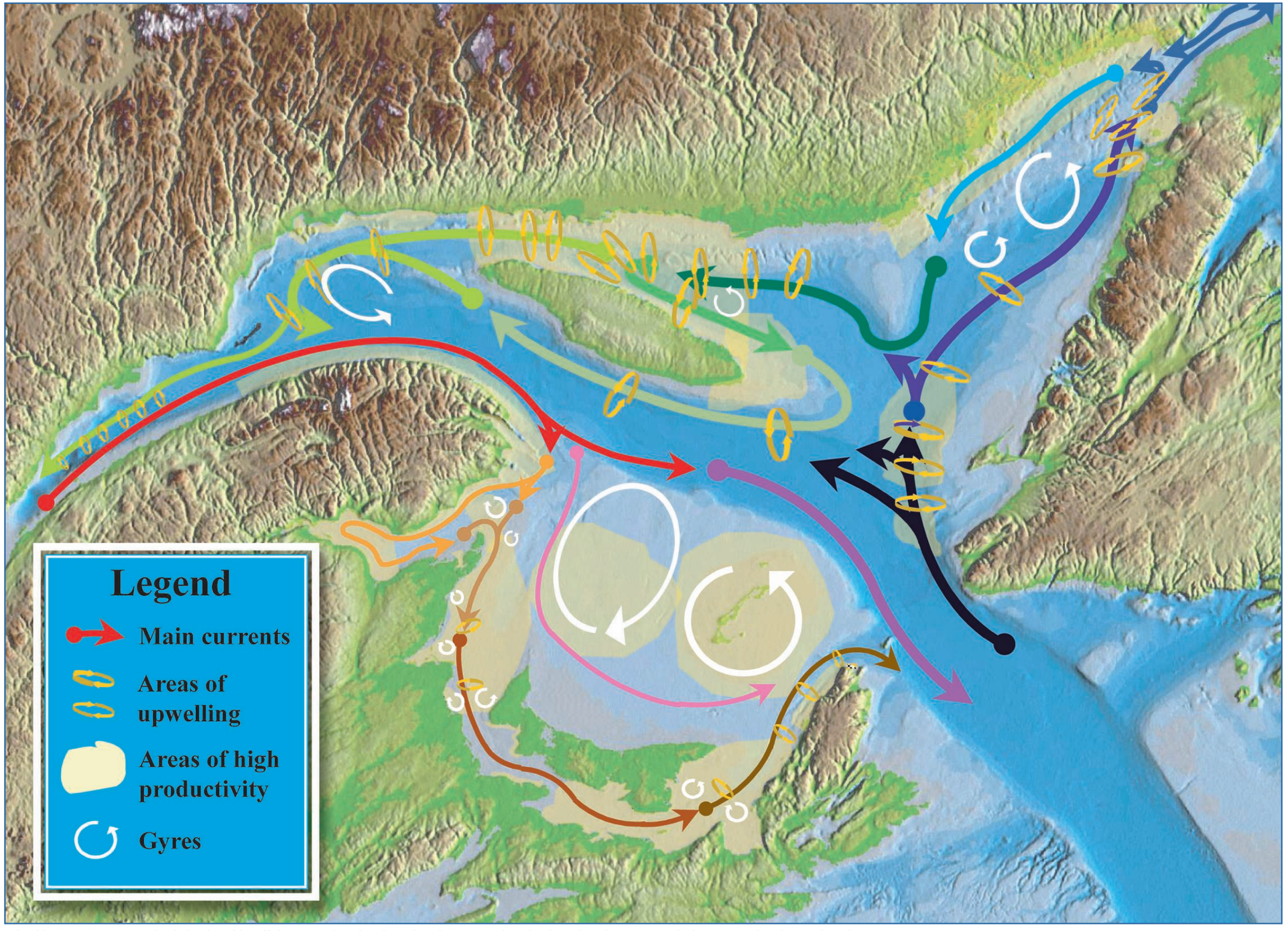
Northumberland Strait flows from west to east, along a complex of coastal and shallow ocean areas. This, combined with strong tidal mixing, has produced a complex of highly productive and sensitive areas. The gyres and retention areas concentrate the primary and secondary production in this relatively shallow region. Nutrient-rich organic matter in the surface waters is conveyed down to support the highly productive benthic communities (scallop, lobster, mussel, oyster, etc.). The gyres also function as nursery grounds for the larvae and juveniles of the shellfish species of the region. The salt marshes and mudflats along coastal New Brunswick, Nova Scotia and Prince Edward Island support high productivity of forage fish and invertebrates including several herring spawning sites, white hake spawning and seal whelping areas.

The last area before the currents leave the Gulf is along the west coast of Cape Breton, where the flow coming across the shallows turns northeastward and draws down the trough along the Island or eastern wall. This, in turn, draws deep channel water up along the outer side. Again, as in other channels, there is an up-welling and mixing that results in high productivity and diversity. This area is used as a route into the Gulf for many migratory species.

Bradelle and Orphan Banks are at the downstream end of the Gaspé current. In the early summer, clockwise circulation typical of banks is used extensively by spawning mackerel.

The Magdalen Islands are the centre of the counter clockwise tide, bathed in the flow from the Gaspé current. There are extensive mud flats and salt marshes on the west side, and strong tidal mixing at both ends and the east side. This combination makes for a very productive area for juvenile fish and birds.

This brief overview illustrates how freshwater and tidal currents, nutrient sources, and geology can work together on a large scale in the Gulf to create areas of high productivity and biological diversity. These mechanisms work in the same way at the smaller scale as well – within bays and estuaries and in the Northumberland Strait. Within each of the ecologically distinct areas, there are species or groups of species that may function as indicators to measure or monitor stress caused by human activity as well as the health of the ecosystem overall.



"Atlas of the Marine Environment and Seabed Geology of the Gulf of St. Lawrence" Geological compilation by Heiner Josenhans, digital compilation by Liisa Peitso and Robin Harvey. Geological Survey of Canada report, 2004.

The future of many coastal communities may depend on how well the principles of conservation and precautionary approach are integrated into municipal and coastal planning, and the ability to capitalize on emerging industries.

invasive species from other oceans are believed to have been introduced to the Gulf through the release of ballast water from ships. Land-based industries such as pulp and paper, mining and mineral processing, fish processing and agriculture, as well as

Table 1 – Key socio-economic indicators, five provinces

Province	Population		Net change	Median age* (2001)	Median total income** (2002)
	1996	2001			
Québec	7,138,795	7,237,479	1.4%	38.8	$20,665
New Brunswick	738,133	729,498	-1.2%	38.6	$18,257
Nova Scotia	909,282	908,007	-0.1%	38.8	$18,735
Prince Edward Island	134,557	135,294	0.5%	37.7	$18,880
Newfoundland & Labrador	551,795	512,930	-7%	38.4	$16,050

* The age at which 50% of the population is younger; 50% is older.
** Half of people make more than this; half make less.

2.4.3. Human and industrial activities

All human and industrial activities, at some level, have the potential to adversely affect the coastal and marine areas and resources of the Gulf. Emerging industries such as the oil and gas, aquaculture and tourism sectors have been growing throughout the Gulf in recent years. The commercial fishing industry has evolved since the groundfish moratoria of the early 1990s, putting pressure on a number of previously underutilized species such as snow crab and shrimp. This change in the commercial fishing industry has also generated a great deal of interest in the aquaculture industry, an industry that has the potential to create economic prosperity for many coastal communities but at the same time have the potential to adversely affect this marine ecosystem if not properly managed.

The marine transportation industry is a significant economic contributor, not only to coastal communities along the Gulf but to Canada as a whole. This activity does however have an enviromental cost. Some contaminants are released from ships through waste, bilge and ballast water. A number of

municipal sewage discharge affect marine areas through the release of contaminants and nutrients. Meanwhile, many of these activities conflict with one another through competition for marine space. At the same time, many of these industries such as fisheries, aquaculture and tourism depend on a clean, healthy and sustainable marine environment.

There are a wide variety of human and/or industrial activities occurring within the Gulf (see box below). As noted above, five activities that represent the greatest potential to interact with and influence the ecological functions of the Gulf are discussed in the next section. These are commercial fishing including the commercial seal hunt; oil and gas; marine transportation; aquaculture and land-based activities including municipal sewage, pulp and paper production, mining and mineral processing, food processing and agriculture. This section looks at the economic importance of each in communities throughout the Gulf since this is an indicator of the relative intensity.

Types of human/industrial activities in the Gulf

- Commercial fishing
- Oil & gas exploration, activity
- Marine transportation/shipping
- Aquaculture
- Land-based activities (municipal sewage, pulp & paper production, mining & mineral processing, food/fish processing, tourism, agriculture
- Forest harvesting
- Ocean disposal
- Cable & pipeline corridors
- Recreational & Aboriginal fishing
- Channel maintenance
- Oil storage facilities
- Hydro development

Commercial fishing, including commercial seal hunt

DFO is the lead regulatory agency for fisheries within Canadian waters. Provincial governments play an important role in economic development and resource use by supporting conservation and sustainability. The Fisheries Resource Conservation Council is a federal advisory committee that makes recommendations to the Minister of Fisheries and Oceans regarding conservation measures. There is also a network of multi-stakeholder committees that contribute to management and conservation of the resource, including regional and provincial advisory committees.

Commercial fishing was historically the key economic driver in many coastal communities throughout the Gulf of St. Lawrence. During the 1990s, heavy exploitation of groundfish stocks resulted in a moratorium on cod and redfish fisheries. As a result, thousands of jobs were lost. This period became a turning point for the industry. Although groundfish remains important, invertebrates (shrimp, snow crab, lobster, clams and scallops) and pelagic fish (herring, mackerel and capelin) have dominated recent landings. Table 2 below shows how relative landings and landed values, by category, have shifted during this time. In 1990-91, for example, groundfish accounted for 24% of landed values; in the 1997-2001 period, it accounted for 5% of landed values. Invertebrates represented two-thirds of landed values in 1990-91; in the 1997-2001 period, shellfish represented almost 90% of landed values.

Harvesting of marine plants (Irish moss and wire weed) is relatively new in the Gulf, and is concentrated mainly in Prince Edward Island.

Table 2 – Percentage of landings and landed values by species, 1990-91 and 1997-2001

	1990-1991		1997-2001	
	Landings	Landed values	Landings	Landed values
Groundfish	38.7%	24.1%	8%	5.1%
Pelagic	34.5%	8.2%	48%	6.6%
Invertebrates	22.7%	66.6%	41%	88%
Marine plants	4.1%	1.1%	3%	0.3%
Total	100%	100%	100%	100%

Source: Preliminary data courtesy of DFO: Policy and Economics Branch: Statistics Division, 2003.

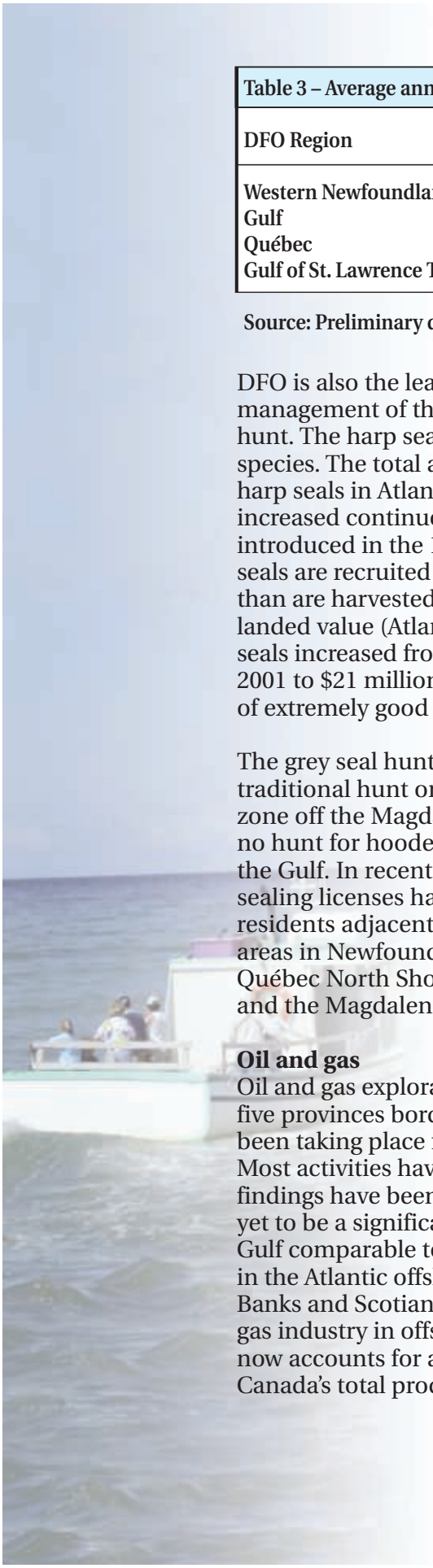


Table 3 – Average annual landings and landed values, by DFO region, 1997-2001		
DFO Region	Landings (metric tonnes)	Landed values ($)
Western Newfoundland	40,796	$41,765,000
Gulf	135,387	$304,589,000
Québec	46,886	$120,751,000
Gulf of St. Lawrence Total	223,069	$467,105,000

Source: Preliminary data courtesy of DFO: Policy and Economics Branch: Statistics Division, 2003.

DFO is also the lead department in the management of the commercial seal hunt. The harp seal has been the main species. The total allowable catch for harp seals in Atlantic Canada has increased continuously since being introduced in the 1960s. Still, more harp seals are recruited into the populations than are harvested. The estimated landed value (Atlantic region) of harp seals increased from $5.5 million in 2001 to $21 million in 2002 because of extremely good market conditions.

The grey seal hunt is limited to a traditional hunt on a small scale in a zone off the Magdalen Islands. There is no hunt for hooded or harbour seals in the Gulf. In recent years, personal use sealing licenses have been issued to residents adjacent to historical sealing areas in Newfoundland and Labrador, Québec North Shore, Gaspé Peninsula and the Magdalen Islands.

Oil and gas

Oil and gas exploration activities in the five provinces bordering the Gulf have been taking place for over 160 years. Most activities have been on-shore, and findings have been minimal. There has yet to be a significant discovery in the Gulf comparable to oil and gas findings in the Atlantic offshore (i.e. Grand Banks and Scotian Shelf). The oil and gas industry in offshore Atlantic Canada now accounts for approximately 7% of Canada's total production.

New technologies, along with discoveries in western Newfoundland in the mid-1990s, increased exploration activities along the Gaspé Peninsula, Anticosti and Magdalen Islands, areas of Québec where sedimentary basins are geologically similar to those in western Newfoundland. Seven exploratory wells have been drilled to date.

The main method used in exploration is seismic surveying, a way of mapping rock layers and properties deep below the earth's surface using sound, to give a better understanding of the geological structures of the underlying basins. The data does not necessarily prove that oil or gas is present but data do indicate where hydrocarbons are most likely to be found (i.e. they narrow the search). The tool used most often in seismic surveying offshore is airguns.

Oil and gas exploration activity, both offshore and in the Gulf, is expected to increase because of high oil prices, projected downturns in the supply of high grade oil and gas from western Canada, and the signing of new revenue-sharing agreements between the government of Canada and the provinces of Newfoundland & Labrador and Nova Scotia. It is believed that the southern Gulf may become an important natural gas producing area.

Eight governmental authorities share the responsibility for oil and gas exploration and development in the Gulf and surrounding coastal areas. It will be important for these authorities to take an integrated approach, and to work together to maximize the resource potential of the oil and gas industry in the Gulf while minimizing ocean user conflicts and negative impacts on the ecosystem, both from exploration activities and development.

Marine transportation
The St. Lawrence River and the Gulf is a major marine corridor that opens central and eastern Canada to international trade markets. Approximately 6,400 commercial vessels pass through the Cabot Strait, the major point of entry to and exit from the Gulf, each year. The Strait of Belle Isle provides a seasonal (June to January) vessel route for marine trade with European countries.

A wide variety of commodities are transported through the Gulf by large cargo vessels including crude oil and other petroleum products; metallic and non-metallic ore and ore by-products; chemicals; newsprint, pulp and other forest products; coal and coke for steel production; agricultural products (mainly corn, wheat and feed); and miscellaneous cargo. Other traffic includes passenger/vehicle/commercial ferries, tugs and barges, cruise ships, private yachts, recreational vessels, commercial marine operations (i.e. whale watching vessels) and commercial fishing vessels.

The high volume of traffic in the Gulf raises many potential concerns related to marine safety; vessel traffic management; port security; and marine environmental, wildlife and ecosystem protection.

Transport Canada and the Canadian Coast Guard play the lead role in regulating and managing marine traffic within Canadian waters along with other federal departments, agencies and authorities.

Aquaculture
In the past decade, the aquaculture industry has become a major contributor to the economy of many rural and coastal communities throughout the Gulf. Industry growth has been driven by an increased global demand for seafood products and a downturn in a number of commercial fisheries. The future of this industry is considered bright, although it requires large investment in research and development, both in terms of technology and in understanding and managing potential environmental impacts and ocean user conflicts.

Aquaculture activity in the Gulf is dominated by the shellfish sector, mainly oyster and blue mussel production. There are approximately 1,800 aquaculture sites, with 96% of them concentrated in New Brunswick, Nova Scotia and Prince Edward Island.

The aquaculture industry is regulated by both federal and provincial legislation. In the late 1980s, the federal government signed a Memorandum of Understanding with Québec and the four Atlantic provinces whereby the lead authority for aquaculture development was transferred to the provinces. The DFO is still responsible for aquaculture leasing and licensing in Prince Edward Island, although not in the other provinces.

Land-based activities

As noted earlier, there is a wide variety of human activities in the Gulf that have the potential to impact the ecosystem. At the same time, such activities are very important to the economies of communities and to the economy of the Gulf as a whole. An estimated 80% of contaminants originate from land-based sources, either washed directly into waterways or through storm sewers and/or sewer overflows. Six key land-based activities are briefly described below: municipal sewage; pulp and paper production; mining and mineral production; food processing; tourism and recreation; and agriculture.

Municipal sewage

As with other coastal nations, a great deal of the domestic and industrial sewage generated within coastal areas of the Gulf is discharged either raw or with some level of treatment into coastal waters, bays and estuaries of the Gulf. This wastewater is a complex mix of floating debris, petroleum-based products, suspended particulate matter, bacteria and viruses, and heavy metals.

Scientists are just beginning to get a handle on what is being discharged into Gulf waters. Preliminary information suggests the following:

- In Québec, most large communities treat their sewage; however, many smaller communities, especially within the Gaspé Peninsula and Lower North Shore areas, have no treatment facilities;
- Western Newfoundland has limited sewage treatment; many communities discharge raw, untreated sewage into the coastal environment;
- The majority of communities in New Brunswick have some form of sewage treatment;
- 16% of the population of Prince Edward Island is not served by sewage treatment;
- In Nova Scotia, sewage treatment service varies from county to county. Approximately 75% of communities in Colchester, Cumberland and Pictou Counties have sewage treatment in some form, while fewer than 25% of communities in Antigonish and Inverness Counties have such facilities.

Pulp and paper production

Pulp and paper processing is one of the primary economic drivers in some of the coastal communities within the Gulf. There are close to 80 pulp, paper and paperboard mills distributed throughout Québec and the four Atlantic provinces, of which approximately 20 are adjacent to the Gulf, Estuary and connecting waterways. An estimated 7,000 people are employed in this industry throughout the Gulf. Prince Edward Island is the only province without a pulp and paper processing facility.

Many of these operations are involved in raw pulp processing, while others concentrate on the production of secondary finished products such as boxes, containers, sanitary products and coated or laminated papers.

Since 1992, pulp and paper mills in Canada have been subject to new federal and provincial regulations that imposed stricter standards regarding the discharge of liquid effluents. All pulp and paper mills are required to carry out an Environmental Effect Monitoring study every three years to monitor the effects of their effluents on the environment.

Mining and mineral processing

Mining is also important to the economy; it contributed over 5 billion dollars in 2002 to the five provinces surrounding the Gulf. There are approximately 35 operations within the Gulf boundary in Québec, New Brunswick, Nova Scotia and Newfoundland and Labrador. Many are primary mining operations that extract raw materials; others are secondary processing operations that produce refined mineral products such as wallboard, brick, animal feed, and fertilizers. Prince Edward Island has a small number of aggregate and peat production sites.

Food processing

Processing of fish and other food sources (i.e. vegetables, fruits, dairy products, meat and eggs) plays an important role in the economy of communities throughout the coastal areas of the Gulf, and is a major job creator. There are more than 400 food processing plants in this area, including almost 300 fish processing plants.

There is a lack of consistency in the way provinces collect information on food processing plants, which makes data collection on these operations a challenge. However, such facilities use and discharge water during day-to-day operations, and such effluent can potentially impact the ecosystem (through discharge of organic material, floating debris, oxygen depletion and toxic compound release). It also can have negative impacts on other industries such as tourism.

Tourism and recreation

The tourism and recreation industry has grown to be one of the most significant sectors in the global economy. Tourism is forecast to be one of the world's largest industries by the year 2015. This world-wide trend has certainly been reflected in the Gulf area, where the tourism industry has seen phenomenal growth in the past decade.

Such expansion, however, has exerted increasing pressure on some of the most fragile environments, including marine and coastal surroundings. At the same time, tourism depends upon continued maintenance of sustainable, clean and healthy environments in order to further expand and attract tourists/customers.

There is less concern about the impact of tourism on the environment, compared to other human activities described in this section, although it is important to monitor particular activities such as whale watching and recreational fishing and boating on a case-by-case basis.

Agriculture

The agriculture industry plays a significant role in the socio-economic activity of the provinces surrounding the Gulf. In 2000, farm cash receipts for the four Atlantic provinces and Québec totaled $7.5 billion, with Québec accounting for 80% of the total (figures are for provinces as a whole, not just areas surrounding the Gulf). The following table provides an overview of farm activity for coastal areas bordering the Gulf.

Table 4 – Number of farms and farm acreage in 2000 for coastal areas bordering the Gulf			
Province	# Farms reporting	Farm acreage (hectare)	Farm cash receipts (total province, in $000)
Québec	5,120	603,320	$6,100,000
New Brunswick	1,008	105,549	$445,000
Nova Scotia	1,638	198,008	$460,000
Prince Edward Island	1,845	261,482	$396,000
Newfoundland & Labrador	151	12,301	$90,000
Total	9,762	1,180,660	$7,491,000

Source: Department of Fisheries and Oceans, 2005.

It is known, for example, that manure is applied to farmland through solid and liquid applications. Statistics show that applying chemical fertilizers and pesticides is a common practice in all provinces. The use of manure, chemical fertilizers and pesticides on farmland raises a number of major environmental and ecological issues.

3. Overview of Issues in the Gulf of St. Lawrence

The Issues Overview presented here is a preliminary, very general view of the major concerns related to human activities in the Gulf, based on existing knowledge. The intent is to promote discussion, identify knowledge gaps, and provide direction for further research and policy development. It is probably safe to say that the interactions discussed in this section are just the "tip of the iceberg" in terms of what may be happening in the Gulf because of human activity.

This summary looks at five major activities specifically: oil and gas exploration; commercial fishing; marine transportation; aquaculture; and land-based activities (pulp and paper mills, fish processing plants and sewage treatment).

3.1. Summary of key human activities, stressors, issues of concern

Table 5 – Summary of key human activities, stressors, issues of concern

Activity	Key stressors	Key issues of concern
Commercial fishing: • Fisheries are highly regulated in terms of gear type, species or groups of species; • More work needed to determine impacts of fishing on habitat and ecosystem.	• Removal of biomass (unbalancing food web structure); • Habitat damage/destruction from fishing gear; • Harvesting of forage species down the food chain (i.e. fishing for krill, capelin); • Ghost fishing by lost/damaged gear; • Introduction/transfer of invasive species.	• Environmental integrity /biodiversity; • Fishery sustainability; • Gear and user conflicts; • Single species management; • Incidental harm to species at risk; • Use of anti-fouling products (on vessels etc).
Oil and gas (Seismic and exploratory drilling related to oil and gas industry): •In exploratory stages but expected to become major activity; • Research enhanced by establishment of Centre for Offshore Oil and Gas Environmental Research (COOGER).	**Seismic Exploration** • Noise related to prolonged and frequent use of air guns; • Accidental spills of oil; • Vessel strikes (marine mammals and reptiles); • Introduction of invasive species from ballast water exchange (seismic boats work in many jurisdictions). **Exploratory Drilling** • Debris and gear left on bottom; • Accidental release of oil (spills); • Drill cutting/mud waste removal; • Noise and light pollution; • Invasive species introduction (rig and supply vessels).	• Many documented impacts of seismic surveys on marine mammals and fish, at egg, larval, juvenile and adult stages; • User conflicts between the oil industry and others; • Landscape/seascape aesthetics; • Negative effects on eco-tourism – i.e. changes in whale migratory routes or avoidance behaviour could affect whale watching tours; unsightly drilling rigs; • Spoiled beaches, animal kills; • Impacts on commercial fisheries and aquaculture operations (fouled gear, lost grounds, sub-lethal contamination of species).
Marine transportation: • Main routes are over deep water, which dissipates sound, assimilates impacts; • Need for land-based facilities to handle wastes (sewage, bilge oil); • Canada needs to match international standards.	• Unintentional introduction and dissemination of invasive species via ballast water exchange, hull fouling; • Sewage, oil and other contaminants from discharge and spills; • Use of anti-fouling products.	• Ballast water is main culprit for introduction of invasive species, transport of diseases and parasites such as MSX; • Within Gulf, invasive species already introduced move on hulls of smaller vessels, equipment used in fishing, aquaculture, dredging, recreational boating etc; • Weak laws to control sewage discharged by vessels; few pump-out facilities along Gulf coasts. • Oil discharges from ships are major concern;
Aquaculture: • Almost entirely shellfish; • Shellfish aquaculture is entirely coastal;	• Introduction and redistribution of invasive species, diseases and parasites; • Habitat modification (sedimentation, nutrient loading); • Benthic community disturbance;	• Aquaculture activities can disseminate non-native species (i.e. invasive species such as green crab, oyster thief, and clubbed tunicate) as well as diseases (i.e. MSX) and parasites; • User conflicts with commercial fishery; • Conflicts with other users(recreational boating, tourism operators, home and cottage owners);

Table 5 – Summary of key human activities, stressors, issues of concern (continued)

Activity	Key stressors	Key issues of concern
Aquaculture(Continued): • High concentrations of shellfish aquaculture have caused problems elsewhere; need to know ecologically sustainable limits; • Industry has been impacted by poor land use practices, has had impacts on recreational boating.	• Impacts on carrying capacity for other species.	• Multiple jurisdictions involved in aquaculture application processes; • Impacts of waste depend on type and scale of cultivation, flushing rates; • Fecal matter and detached shellfish increase organic matter under aquaculture lease and can smother the benthic habitat and its species; • Increased organic matter deposited on the bottom can favor settlement of green macroalgae.
Land-based activities: • Shoreline development; • Biggest stressor for coastal zones of the Gulf ecosystem; • If existing best management practices and regulatory controls were used, they would be effective in preventing further damage; would allow natural processes to clean up most problem sites.	• Loss of habitat, wetlands, estuaries, etc.; • Increased nutrient loading encouraging algal blooms; • Reduced oxygen levels due to decomposing organic wastes and excessive plant growth; • Increases in nearshore sediments and turbidity; • Release of pathogens into nearshore; • Release of contaminants; • Temperature changes of nearshore receiving waters; • Alterations of freshwater flows to receiving waters.	• Reduction and/or modifications of the quality / stability of the ecosystem (e.g. contaminants, nutrients, bacteria, freshwater influences, temperature); • Limits to human uses (commercial and recreational) of ecosystem; • Health implications (humans and biota); • Ecological pressures on economic development; • Many sources of contaminants in Estuary and Gulf including Great Lakes, local municipalities and industries, farming, marine transport, and weather systems from the west; • Urban refuse is an important source of organic molecules (e.g. medication, estrogens and hormones, which can impact life cycles). Also bacteria, whose behaviour in the marine environment is unknown; • New molecules for industrial and domestic purposes, such as fire retardants, mimic compounds now banned, e.g. PCBs; • Agricultural runoff is source of organic matter, nitrates and phosphates, pesticides and herbicides.
Climate change: An emerging issue expected to have substantial impacts in years to come.	• Changes to ocean processes (currents, salinity, temperature, etc.); • Coastal erosion; • Effects on coastal habitats; • Submersion of coastal areas and infrastructure; • Modification of species distribution, composition, population structures, habitats.	• Global phenomenon with obvious consequences and concerns for the Gulf of St. Lawrence; • Pervasive sense that this issue is not within management control.

4. SUMMARY

This overview of the Gulf of St. Lawrence ecosystem has demonstrated that the Gulf is, indeed, a unique environment. Its physical and biological components combine to create a distinct ecosystem with an abundance of resources. As a result, a wide variety of human activities occur within and adjacent to the Gulf, and many people depend on its resources for their livelihood.

This report has outlined in a very general way the potential impact that these activities may have. The goal of the report was to identify what is known and not known about the Gulf because it is only when we understand how environmental systems work together that potential threats can be identified, and management measures put in place to mitigate them. This report has underlined the crucial importance of all those with an interest in the Gulf – government, organizations and individuals – to work together for the long-term sustainability of this very important ecosystem.