

Atlantic Zone Monitoring Program – Context



The CCGS Hudson is a scientific research vessel of the Canadian Coast Guard regularly used for oceanographic sampling

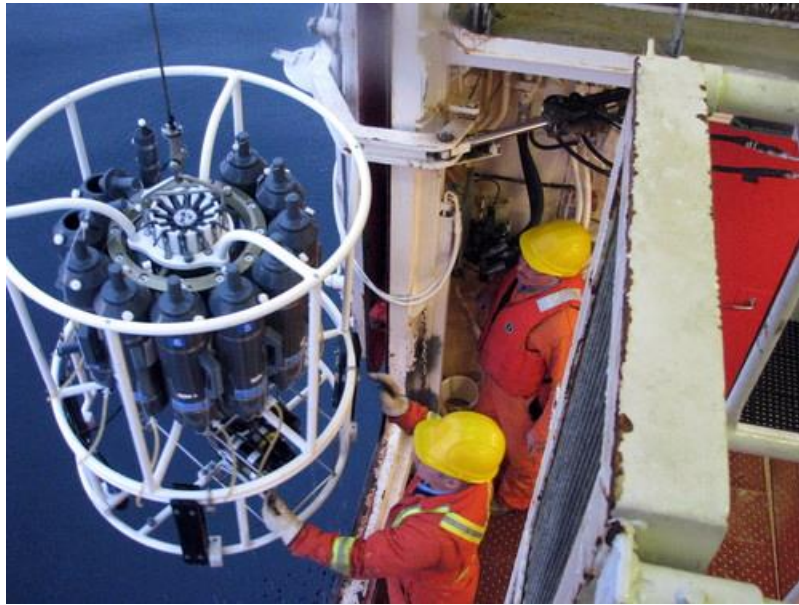
Scientists from Fisheries and Oceans Canada from the four Atlantic regions, including the Maurice Lamontagne Institute (MLI) for the Quebec Region, have developed the Atlantic Zone Monitoring Program (AZMP). This program is designed to detect, track and predict changes in the state and productivity of the marine environment. This information is essential in order to tackle major issues such as the impact of climate change or to support the ecosystem approach to ensure the sound management of the St. Lawrence ecosystem, conserving resources and protecting the marine environment for future generations. The AZMP builds temporal data sets that will be needed to address future problems. We present a description of the program, the oceanographic variables measured, sampling methods, and resorts and activities that affect the waters of the St. Lawrence.

Measurements of various oceanographic variables are performed in the Estuary and Gulf of St. Lawrence in order to describe the annual and interannual variability of environmental conditions of this ecosystem. The data are interpolated to create time series for each of the fixed stations and indices of oceanographic condition of Gulf of St. Lawrence are developed from data obtained from large surveys.

Surveys, stations and sampling

Every year, the Gulf is sampled at different times of the year aboard research vessel of the Canadian Coast Guard. Various measuring instruments are deployed in order to collect information on variables such as salinity, temperature, dissolved oxygen concentration, the amount of chlorophyll a and nutrients present in the water. Sampling is done mainly using a device called a rosette which is lowered in the water to the near-bottom. Equipped with several probes which measure various variables, the rosette is also equipped with bottles which, during the ascent, are closed to collect water samples at selected depths. Net tows are also made to collect zooplankton in order to determine their abundance per species. At the time of sampling, some data are processed in real time by computer on the ship. Other data are calculated from analyzes carried out in a mobile laboratory installed on board (for example, filtration and phytoplankton concentration of the water

samples, dissolved oxygen concentration by titration), but most of the results will be obtained from subsequent analyzes done in laboratories at the Maurice Lamontagne Institute.



The rosette used for sampling at sea from the CCGS Teleost

During surveys in June and autumn, a series of 46 oceanographic stations are visited, grouped into transects that cross the Gulf, in addition to some stations between these transects and at the head of the deep channels. Additional stations are made in June on the Magdalen Shallows, paired with a survey to count mackerel eggs. In August and September, AZMP resources are combined with a multidisciplinary survey for the assessment of groundfish stocks and northern shrimp, and 500 oceanographic stations are sampled covering the entire Gulf. In addition, during the year two oceanographic stations are sampled with greater temporal frequency. These are the Rimouski station, nominally sampled once a week in summer, and the Shediac Valley station on the Magdalen Shallows, also sampled once or twice a month in summer.

In the following sections, the data from these two stations are presented as time series for a selection of the variables measured. Environmental indices calculated from data obtained from large surveys are also presented that represent the conditions of the surface, intermediate and deep layers of the Gulf. The raw data are also available by consulting the [Oceanographic Data Management System \(ODMS\)](#) and annual reports ([physical](#), [biological](#), and a [Zonal Scientific Advice](#)) are available from the Canadian Science Advisory Secretariat (CSAS).

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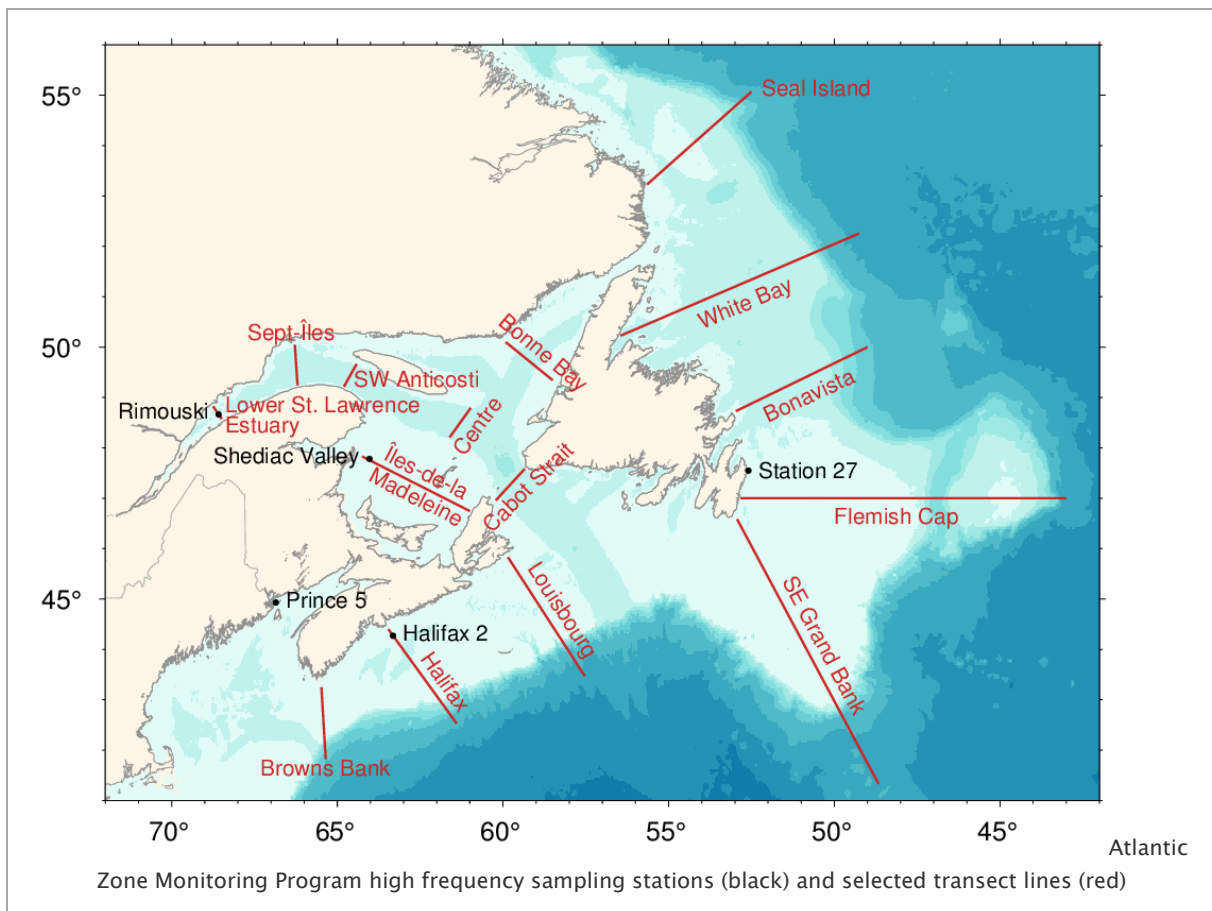


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Atlantic Zone Monitoring Program – Stations

The key element of the sampling strategy adopted by the Atlantic Zone Monitoring Program (AZMP) is the seasonal oceanographic sampling (1–3 times per year) of stations positioned along several **transects** located in representative regions in order to quantify biological, chemical and physical oceanographic variability in these areas, and sampling at selected **high-frequency sampling stations** to monitor the dynamics at finer time scales.



Transects

For the St. Lawrence ecosystem, scientists from IML have developed a sampling plan that includes seven transects with a total of 46 stations to cover the Gulf and estuary. This set of stations has been sampled twice a year since 1996 (in the spring and the fall), thus giving quasi-synoptic views of the oceanographic conditions in the St. Lawrence.

High-frequency sampling stations



Ships used for sampling:
the *Béluga II* for Rimouski station (top)
and the *Cap Breton* at Shediac Valley station (bottom)

Two stations are visited more regularly, the Rimouski station in the St. Lawrence Estuary (off Rimouski) and Shediac Valley station for the Magdalen Shallows. Both stations already had a history of monitoring, so their inclusion in the AZMP bonified the program. Station Rimouski is visited in the summer since the early 1990s and AZMP will attempt to visit it in winter as well. The Shediac Valley station has a longer history (since 1947), but with less frequent sampling. It is visited regularly during the summer since 1999.

In the spring, **buoys** that provide real-time oceanographic information are also deployed at these two stations until fall.

The **variables** that are sampled regularly at all stations AZMP include: temperature, salinity, chlorophyll a, nutrients, dissolved oxygen and biomass of phytoplankton and zooplankton.

Large scale surveys

Large-scale surveys Regional monitoring efforts are made by MLI scientists to fill gaps and to better target the issues associated with commercially fished species. One of the gaps identified is the winter state of the Gulf of St. Lawrence: its coldest state of the year when up to 45% of its water volume is cooled below 0°C. A helicopter survey monitors physical oceanographic conditions and nutrient concentrations of the surface mixed layer in early March since 1996. In August and September, AZMP resources are combined with a multidisciplinary annual survey for the assessment of groundfish stocks and northern shrimp, and 500 oceanographic stations are sampled that cover the entire Gulf.

Position stations

Station	Latitude	Longitude	Depth (m)
TESL1	48°34.5'N	68°29.3'W	35
TESL2	48°37.5'N	68°32.8'W	220
TESL3 (Rimouski)	48°40.0'N	68°35.0'W	336
TESL4	48°42.5'N	68°37.8'W	349
TESL5	48°45.0'N	68°40.0'W	351
TESL6	48°47.3'N	68°42.5'W	151
TESL7	48°49.5'N	68°45.0'W	120
TSI2	49°24.0'N	66°13.0'W	350
TSI3	49°33.0'N	66°14.0'W	340
TSI5	49°52.9'N	66°16.0'W	288
TSI6	50°03.0'N	66°17.0'W	121
TASO1	49°13.0'N	64°48.0'W	235
TASO2	49°19.0'N	64°43.0'W	386
TASO3	49°26.0'N	64°37.0'W	375

TASO4	49°33.0'N	64°31.0'W	301
TASO5	49°40.0'N	64°25.0'W	168
TIDM1	46°44.7'N	61°00.0'W	64
TIDM2	46°49.8'N	61°15.0'W	64
TIDM3	46°54.1'N	61°30.0'W	55
TIDM4	47°00.0'N	61°45.0'W	43
TIDM5	47°10.2'N	62°15.0'W	45
TIDM6	47°19.8'N	62°45.0'W	55
TIDM7	47°30.0'N	63°15.0'W	81
TIDM8	47°39.6'N	63°45.0'W	67
TIDM9 (Shediac Valley)	47°46.8'N	64°01.8'W	84
TIDM10	47°49.8'N	64°15.0'W	44
TCEN1	48°12.6'N	61°36.6'W	300
TCEN2	48°21.3'N	61°27.0'W	405
TCEN3	48°30.0'N	61°18.0'W	419
TCEN4	48°38.8'N	61°08.0'W	383
TCEN5	48°47.5'N	60°58.4'W	248
TBB1	49°20.6'N	58°30.0'W	62
TBB2	49°29.0'N	58°43.0'W	130
TBB3	49°36.0'N	58°58.0'W	197
TBB4	49°43.5'N	59°13.0'W	231
TBB5	49°51.0'N	59°27.0'W	268
TBB6	49°59.0'N	59°41.0'W	143
TBB7	50°06.0'N	59°55.0'W	84
TDC1	46°57.5'N	60°13.0'W	82

TDC2	47°01.4'N	60°07.0'W	187
TDC3	47°06.0'N	59°59.5'W	337
TDC4	47°16.3'N	59°47.0'W	475
TDC5	47°26.0'N	59°33.5'W	483
TDC6	47°35.0'N	59°20.5'W	270



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Atlantic Zone Monitoring Program – Variables

- [Temperature](#)
- [Salinity](#)
- [Dissolved Oxygen](#)
- [Chlorophyll *a*](#)
- [Nutrients](#)

The St. Lawrence is a marine ecosystem—it is a favourable environment for a multitude of living organisms adapted to living in seawater at this latitude. Here we find life in all shapes and sizes—plants and animals from the smallest microscopic organisms to the biggest creatures on the planet, as shown by the blue whales that come to the St. Lawrence each summer to feed on krill. In seawater, different chemical and physical reactions and processes occur that support biological activity. As part of the monitoring program, certain basic parameters are routinely measured that allow us to evaluate the quality of the St. Lawrence environment. Here is the list of variables for which data are available on this site

Temperature

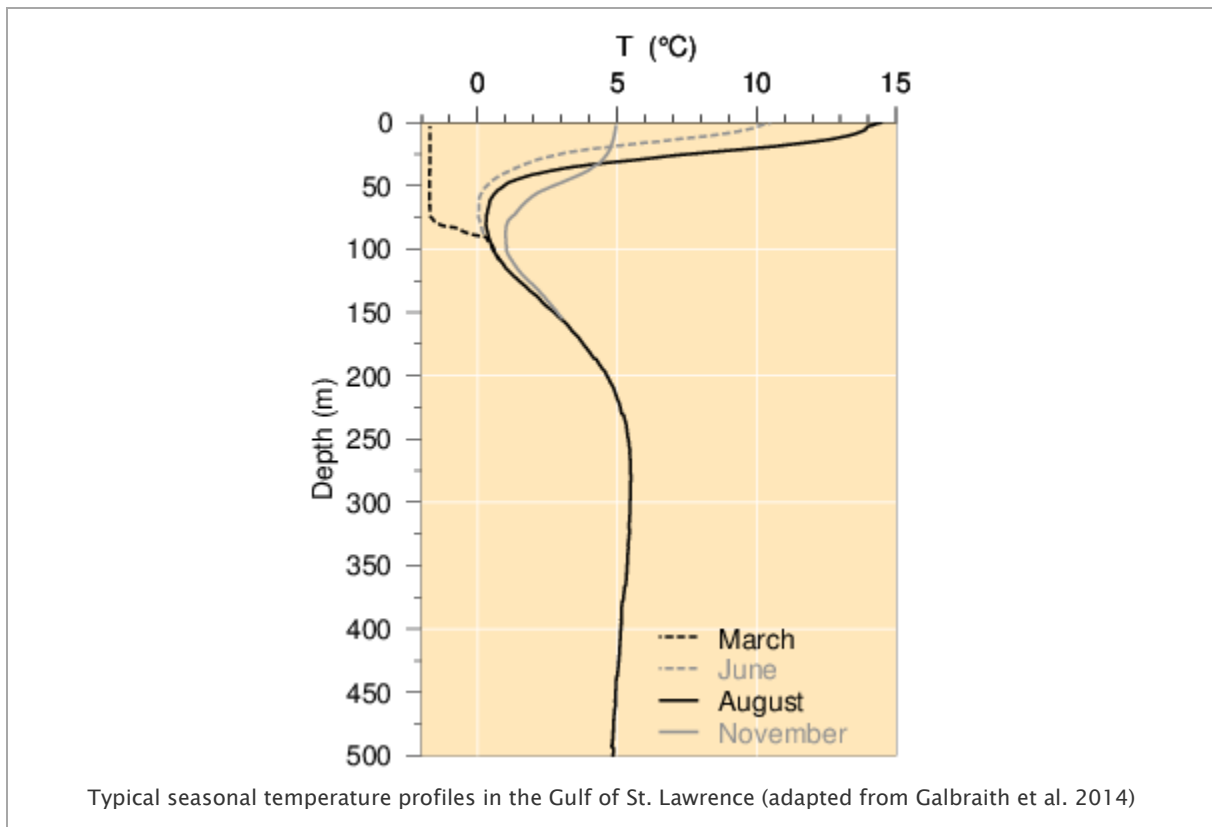
In summer, the water column has three distinct layers: the surface layer (0–30 m), the cold intermediate layer (CIL, 30–150 m) and the deep layer, which is not subject to direct interaction with the atmosphere and therefore does not present a strong seasonal variability. Seasonal patterns of temperature in the Gulf of St. Lawrence (GSL) are illustrated here.

The surface temperatures reach maximum values in mid–August with an average around 16°C in the Gulf. The warmest waters occur a few weeks earlier in the estuary, but only reach 11°C. Gradual cooling occurs thereafter and mixing caused by the wind during the fall leads to the appearance of a homogeneous mixed layer, visible on the November temperature profile from 0 to 30 m. This layer progressively deepens and cools to ultimately merge with the CIL in winter in the Gulf. At the end of March, while the winter surface layer in the Gulf has temperatures near the freezing point (–1.8 to 0 ° C) and extends to an average depth of 75 m, the surface waters of the estuary are not as cold, less salty and the mixed layer is much less deep (25 m). In the spring, the warming of surface waters, the melting of sea ice and runoff from the continent result in a reduction of salinity and an increase of the temperature of the surface layer, partly isolating the underlying cold from the atmosphere to form the summer CIL, defined as encompassing the waters below a certain temperature threshold, typically 1°C. Estuarine circulation then transports the Gulf CIL upstream to the lower estuary, causing the coldest temperatures of the year in the Estuary CIL to be often found in the spring. The CIL is warmed and gradually deepens during the summer because of turbulent mixing. In the seasonal evolution figure, it is in November that temperatures and depths of the CIL are the highest, but warming can continue later in the season.

The deep layer under the CIL (> 150 m) originates from the continental shelf, where the incoming water at the Cabot Strait circulate upstream with little exchange with shallower water. Its temperature has not exceeded 4 to 7.5°C depending on the year and its salinity varies between 32.5 and less than 35. Interdecadal changes in

temperature, salinity, and dissolved oxygen of the deep waters entering the Gulf at the continental shelf are related to the varying proportion of its sources waters: the cold-fresh and high dissolved oxygen Labrador Current water and warm-salty and low dissolved oxygen slope water. These waters travel from the mouth of the Laurentian Channel to the Estuary in roughly three to four years, decreasing in dissolved oxygen from in situ respiration and oxidation of organic material as they progress to the channel heads. The lowest levels of dissolved oxygen are therefore found in the deep waters at the head of the Laurentian Channel in the Estuary. Since 1930, the deep waters of the Gulf have warmed from about 4°C to about 6°C in 2013, linked mainly with a richer intake slope of the waters and poorer in Labrador waters.

Temperature exerts a major control on the distribution and activities of marine organisms. Its effects include the regulation of biological and chemical processes of cellular metabolism, the succession of species in the phytoplankton community, and the migration patterns of fish. For example, a more rapid growth rate in living organisms is generally associated with higher temperatures.

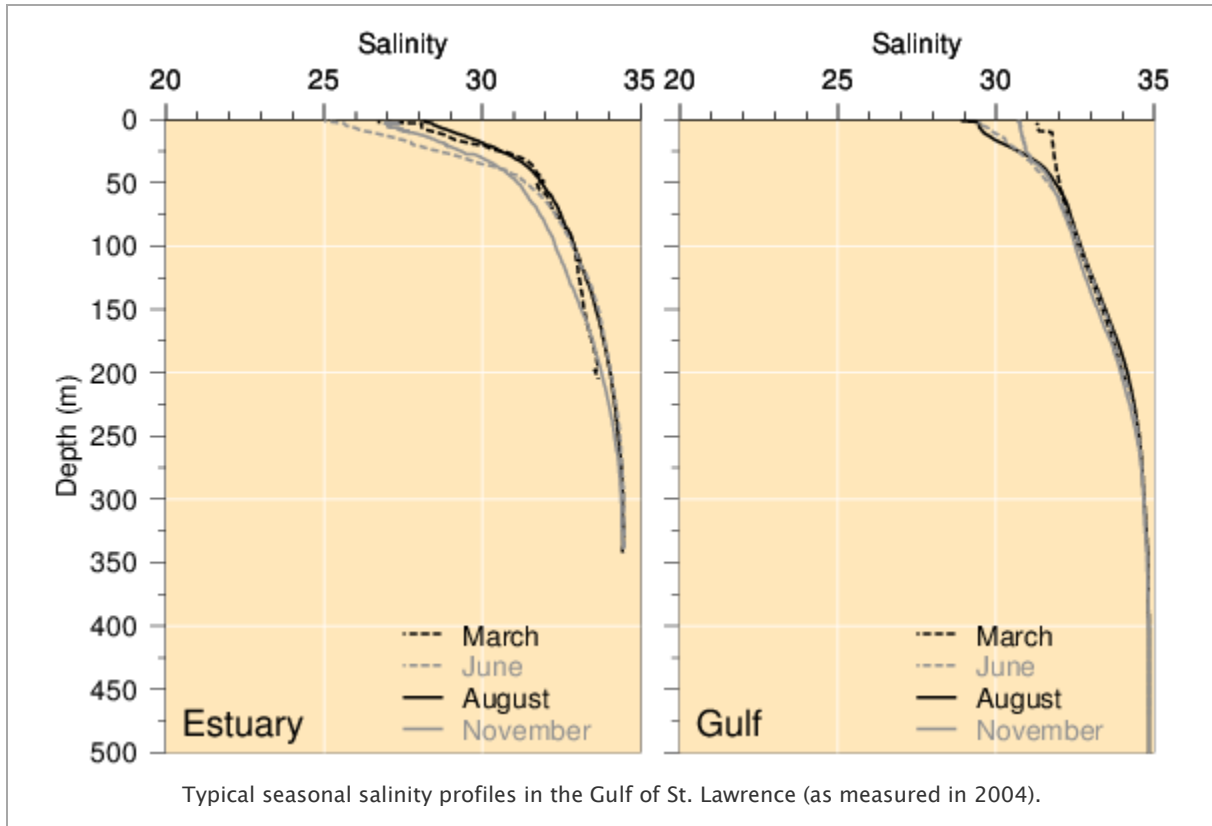


Salinity

Because of the estuarine character of the St. Lawrence, salinity is of key importance. It allows the characterization of water masses as a function of the degree of mixing of the fresh and salt water. Seawater is made up of about 50 salts, the most common of which is sodium chloride, the same salt that we use as a seasoning. Salinity is calculated by measuring the conductivity of the water. Since this measurement is a ratio, it is dimensionless (unitless), although one will frequently see salinity recorded in units of "psu" to indicate "practical salinity unit," making reference to the Practical Salinity Scale 1978 (PSS78).

Seawater extends up the St. Lawrence as far as Ile d'Orléans, where oceanographers consider the estuary to begin. The freshwater flowing downstream creates a salinity gradient in the estuary's surface waters toward

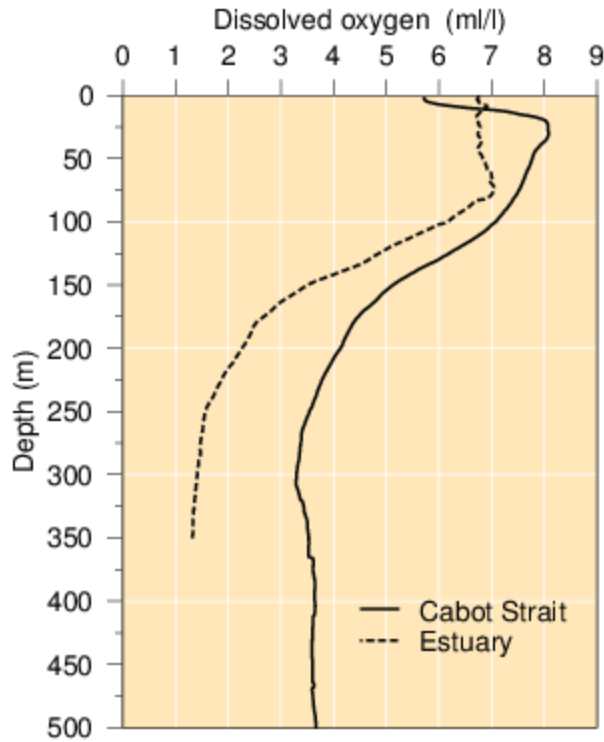
the ocean. In the figure showing the salinity profiles, we note that the surface salinity is about 25 to 26 during the summer at the Rimouski station, which is located in the estuary, while the salinity is above 29 in the Gulf of St. Lawrence. Water that is more saline contains more salts and so is denser and heavier. That is why the deep waters of the estuary and Gulf have salinities near 35, which is comparable to waters from the Atlantic Ocean.



Dissolved oxygen

Oxygen is essential for life and one of the basic elements involved in the chemical reactions that govern most biological processes in aquatic ecosystems. It regulates the distribution of living organisms, affecting, for example, fish migrations. Oxygen is an atmospheric gas that crosses the atmosphere-ocean boundary and dissolves in seawater. Marine organisms are capable of using oxygen in this dissolved form. Oxygen is also produced when marine plants, mainly phytoplankton, undergo photosynthesis. The amount of oxygen in the water is often expressed as the volume of dissolved oxygen per volume of water: millilitres of oxygen per litre of water (mL/L).

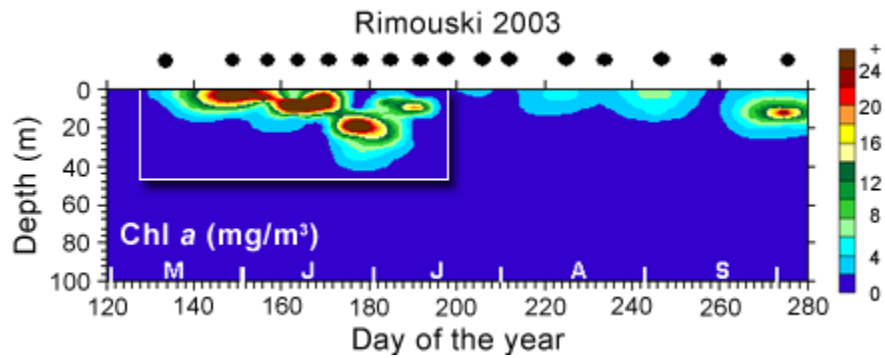
Because of the mixing action of wind and waves, the top 50 metres or so of the St. Lawrence Gulf and estuary are saturated with respect to dissolved oxygen. From the surface toward the bottom, the vertical profile of the dissolved oxygen concentration in Cabot Strait reaches a minimum at about 250 to 300 metres of depth. This minimum represents the lowest oxygen concentrations to which ground fish are exposed and is thus of particular interest. In general, the concentration of dissolved oxygen in the deep water decreases westward of Cabot Strait toward the head of the Laurentian Channel, as the "age" of the waters moving up the channel increases, and reaches low hypoxic values in the St. Lawrence Estuary.



Typical dissolved oxygen depth profile in the Estuary and the Cabot Strait entrance to the Gulf of St. Lawrence (as measured in 2004).

Chlorophyll *a*

Chlorophyll *a* is a plant pigment that is essential for photosynthesis. The measurement of the amount of this pigment gives an index of the abundance of marine plants, mainly made up of microscopic algae known as phytoplankton. Primary production by plants supports the food web and determines an ecosystem's productivity. Chlorophyll *a* is expressed as the amount of pigment per volume of water: milligrams of chlorophyll *a* per litre of water (mg m^{-3}).



Temporal evolution of chlorophyll *a* in the water column at the Rimouski station in 2003. Dots above the figure indicate times of sampling.

On this graph showing the quantity of chlorophyll *a* measured from May through October 2003 at the Rimouski station, the green, yellow, and red patches indicate high concentrations of chlorophyll *a*. These high amounts resulted from the **spring bloom** that began around May 10th, became very intense near the end of May with concentrations above 20 mg m⁻³, and continued through the end of June.

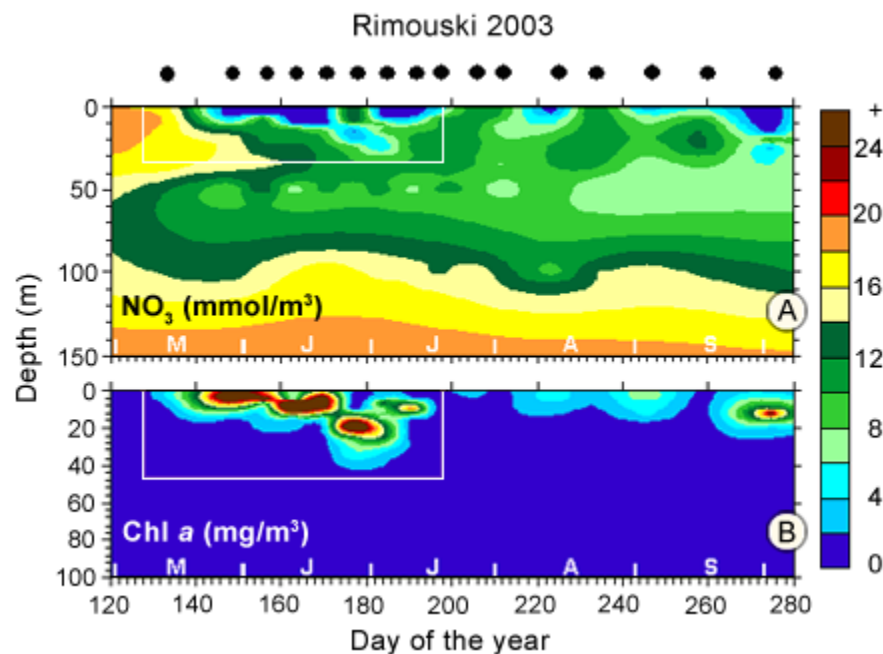
Spring

bloom

During the spring ice-melt in the St. Lawrence, the nutrient-rich surface layer warms up and solar radiation extends deeper into the water column. At this time, conditions are favourable for photosynthesis and for the propagation of phytoplankton—the minute flora that float with the currents in the top 30 metres of the water column. There is an explosion in the number of phytoplankton cells, a phenomenon known as the spring bloom. During a bloom, the rate of cell division can reach one division per day; at this rate, a single cell can give rise to about one million cells in three weeks. Within a few weeks, small aggregates of phytoplankton become dense blooms spreading over several square kilometres with thicknesses reaching tens of metres.

Nutrients

Like fertilizer for plants, nutrients are essential for the growth of phytoplankton, which absorb the nutrients through the cell membrane. The principal elements that phytoplankton need for their metabolism are nitrogen, which is present in seawater in the form of ammonium, nitrate, and nitrite; phosphorus in the form of phosphate; and silica in the form of silicate. The strength of a phytoplankton bloom depends on the abundance and the availability of these nutrients. Nutrients are expressed in units of micromoles of nutrients per litre of water (mmol m⁻³).



Temporal evolution of nitrate nutrients (top) and chlorophyll *a* (bottom) in the water column at the Rimouski station in 2003.

Dots above the figure indicate times of sampling.

On **panel A** of the figure, which shows the changes over time in the amount of nitrogen in the form of nitrate at the Rimouski station, high concentrations between 18 and 20 mmol m⁻³ are shown to have occurred in the surface waters at the beginning of May. The amount of nitrogen decreases considerably with the start of the spring phytoplankton bloom (**panel B**).

In the ocean, the input of new nutrients into the surface layer occurs mainly from vertical mixing, redistributing nutrients present in deeper waters into the surface layer. However, at the Rimouski station an intermediate-depth nutrient minimum is often observed because new nutrients are transported in horizontally from upstream sources. These sources are from rivers and from the very strong mixing that occurs at the head of the Laurentian Channel, close to Tadoussac, where deep nutrient-rich waters are mixed with surface waters.



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Atlantic Zone Monitoring Program – Sampling



Most of the sampling done by IML scientists within the Atlantic Zone Monitoring Program occurs on Canadian Coast Guard ships like the one in this photograph, the CCGS Hudson

Most of the sampling done by IML scientists within the Atlantic Zone Monitoring Program occurs on Canadian Coast Guard ships like the one in this photograph, the CCGS Hudson.

A rosette system (see figure) is used to sample key variables. The main component of this instrument is the **sonde CTD Sea-Bird 911*plus*** profiling instrument, which is used to measure the Conductivity and Temperature of the water as a function of the Depth, hence the acronym CTD.

Sea-Bird 911*plus* CTD

- Conductivity sensor (SBE 4)
- Temperature sensor (SBE 3*plus*)
- Pressure sensor (Paroscientific Digiquartz)
- Fluorometer (WET Labs WETStar)
- Dissolved oxygen sensor (SBE 43)
- Submersible light sensor (Biospherical Instruments QSP-2200)
- Submersible pump (SBE 5T)

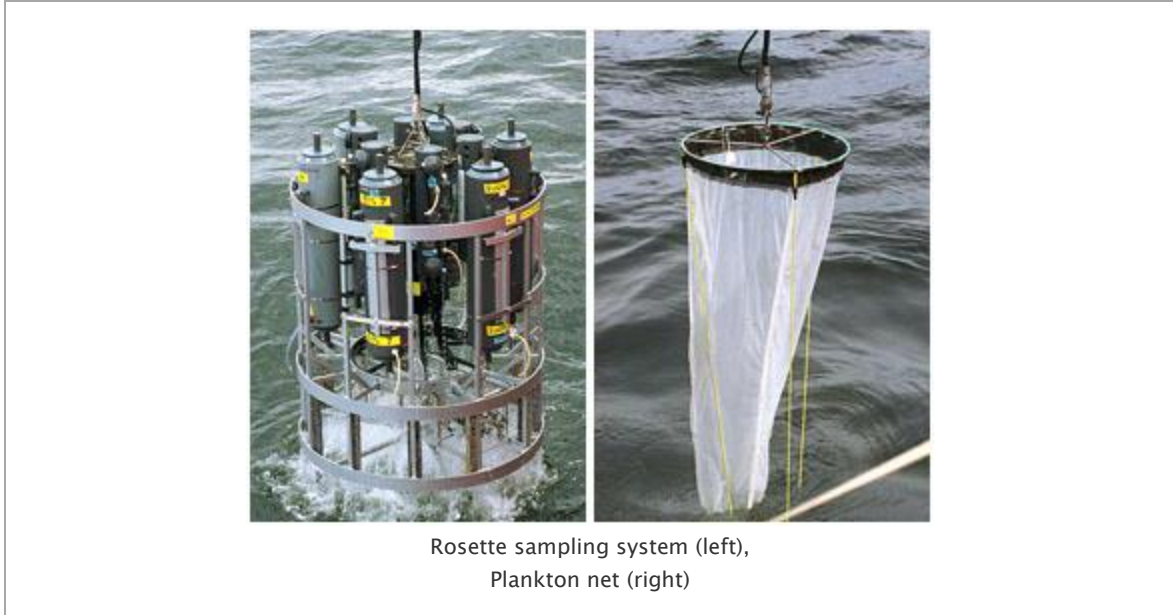


Water sample taken to measure the concentration of dissolved oxygen

Other sensors can be added to the CTD to measure, for example, the fluorescence due to the presence of chlorophyll, the dissolved oxygen, or the quantity of light. The sampling bottles (called Niskin bottles) attached around the perimeter of the instrument allow water to be collected at specific depths. This water will be used for various laboratory analyses. The instrument is lowered from the surface to within a few metres of the bottom at a speed of about 1 metre per second. During the descent, a shipboard computer records the signals coming from the different sensors and traces a profile in real-time on the computer screen. The instrument is stopped on the way up, and bottles are remotely triggered to close at depths of 300, 200, 100, 50, 25, 15, and 5 metres as well as the surface.

The water samples will be used for the following analyses:

- Water salinity (Guildline Autosol salinometer);
- Phytoplankton biomass estimated by fluorometric measurements of chlorophyll quantity (Turner Designs TD-700 fluorometer);
- Nutrient concentrations (NO_2 , NO_3 , PO_4 , SiO_2) (Technicon AutoAnalyzer or Alpkem Flow Solution);
- Dissolved oxygen determination by automated Winkler titrations (Dosimat and Brinkman colorimeter);
- Microscopic examination for the identification and counts of phytoplankton species.



A plankton net is deployed at each station, making a vertical tow from the bottom to the surface. This net collects the small animals known as zooplankton.

A TSK electronic flow-meter and a pressure sensor are attached to the net, giving real-time information about the depth and the volume of water filtered as the net is towed upwards. The samples collected with the plankton net will be used:

- To determine the zooplankton biomass (dry weight);
- To identify, count, and determine the specific composition of the zooplankton community.



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