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**Environmental systems and societies**  
**Standard level**  
**Paper 1 – resource booklet**

Friday 8 November 2019 (afternoon)

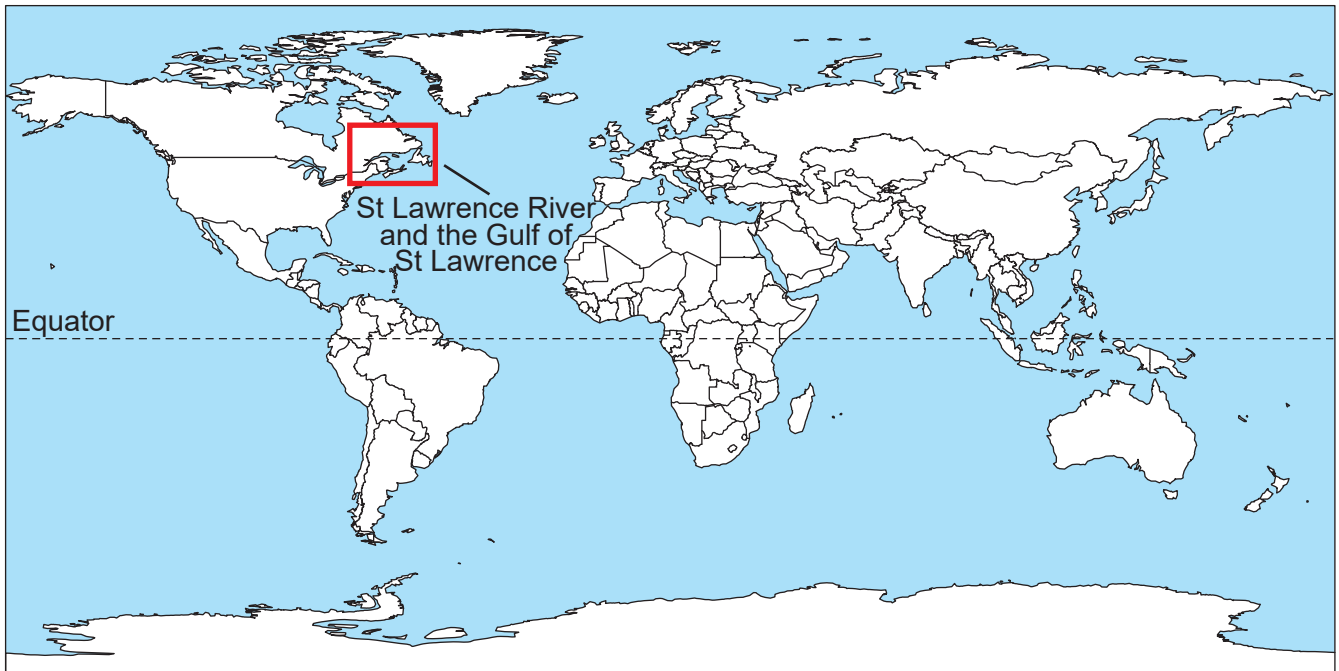
1 hour

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**Instructions to candidates**

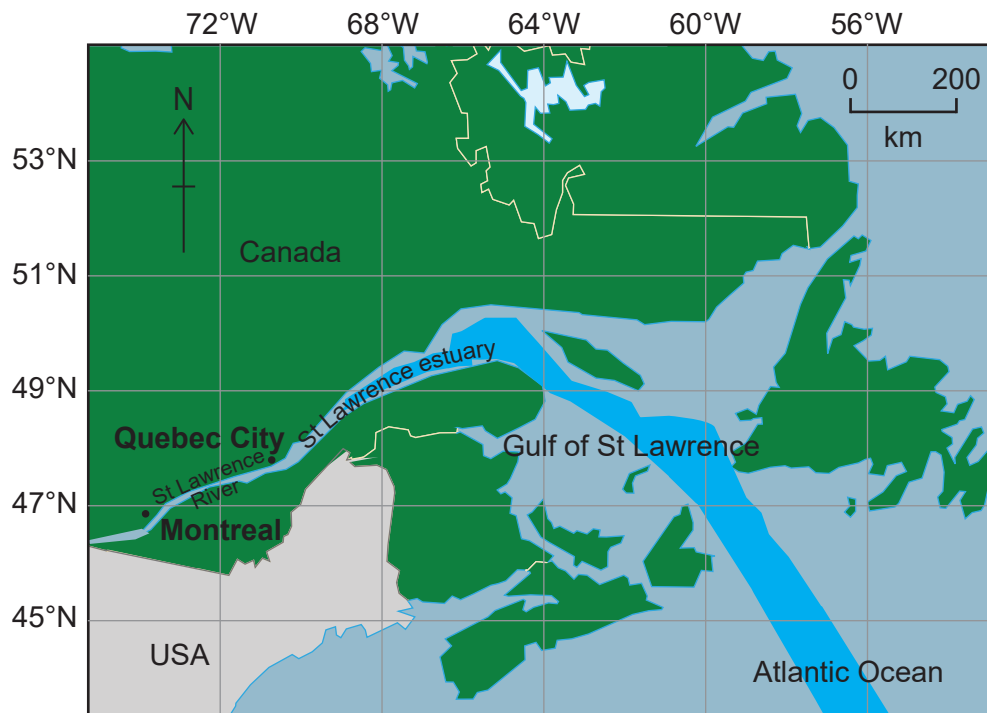
- Do not open this booklet until instructed to do so.
- This booklet contains all the resources to answer paper 1.

**Figure 1(a): World map showing the location of the St Lawrence River and the Gulf of St Lawrence in North America**



[Source: adapted from TUBS/Wikimedia.  
File licensed under <https://creativecommons.org/licenses/by-sa/3.0/deed.en>]

**Figure 1(b): Map showing the location of the St Lawrence River from Montreal to the Gulf of St Lawrence**



[Source: Fisheries and Oceans Canada. Reproduced with the permission of  
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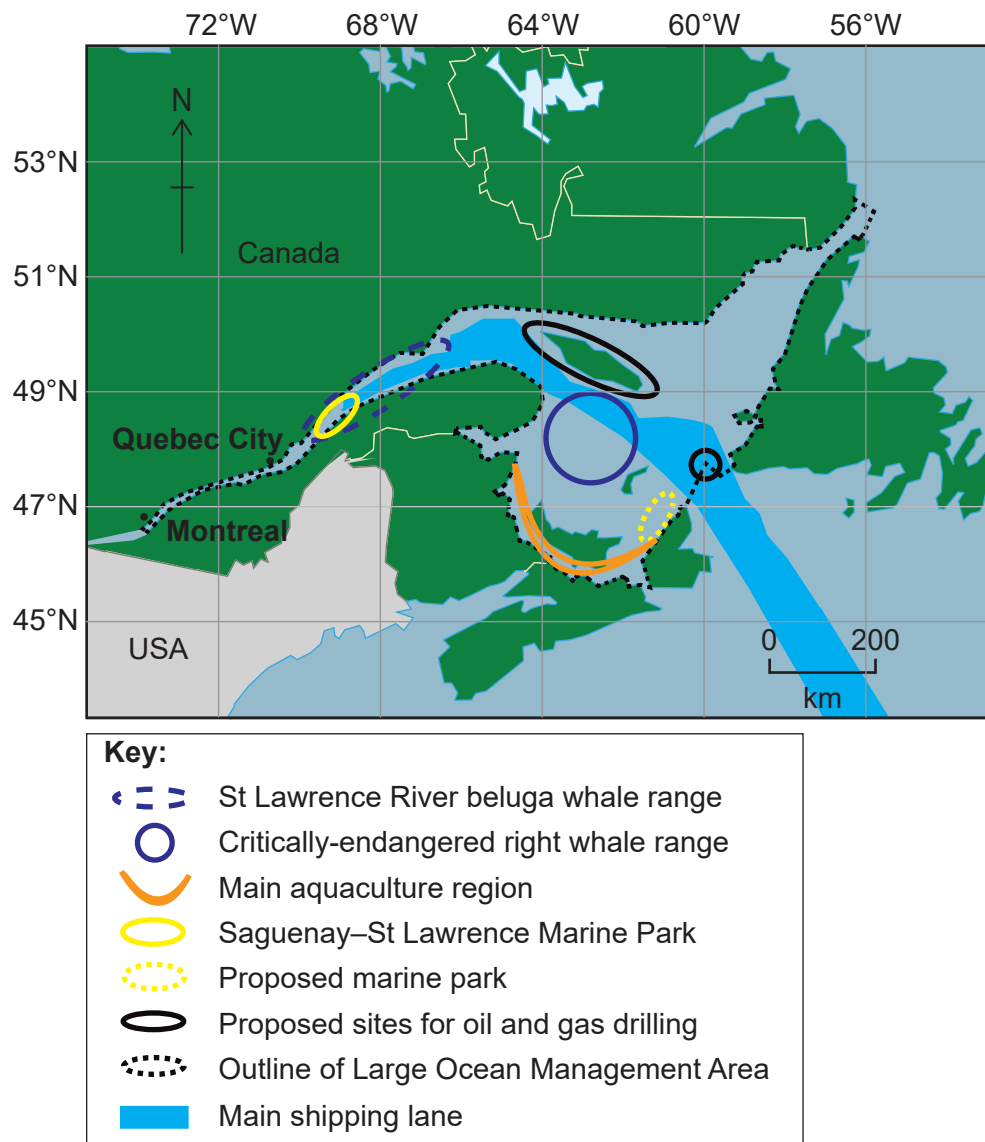
### Figure 2(a): Fact file on the St Lawrence River estuary and the Gulf of St Lawrence

The St Lawrence River estuary and the Gulf of St Lawrence are recognized as a Large Ocean Management Area by the Canadian government (Figure 2(b)).

- It is an important shipping route from the Atlantic Ocean to eastern Canada.
- The area is highly productive (Figure 4(a)).
- It provides habitat for wildlife, including resident and migratory birds, whales and crabs.
- It provides nursery grounds for commercial fish species (cod, halibut).
- Management of the area is challenging because the interests of different stakeholders may be in conflict or environmentally damaging.

[Source: adapted from <https://www.dfo-mpo.gc.ca>]

Figure 2(b): Map showing the Large Ocean Management Area



[Source: Fisheries and Oceans Canada. Reproduced with the permission of  
© Her Majesty the Queen in Right of Canada, 2019]

**Figure 3(a): Economic uses of the St Lawrence River estuary and the Gulf of St Lawrence**

Commercial snow crab fishing

Removed for copyright reasons

Aquaculture



[Source: FishFarmingExpert]

Oil and gas exploration



Sport fishing



[Source: Dale Scullion]

Tourism such as bird watching and whale watching



[Source: Jean Iron. Greater Snow Geese in Ontario (2011).  
Used with permission]

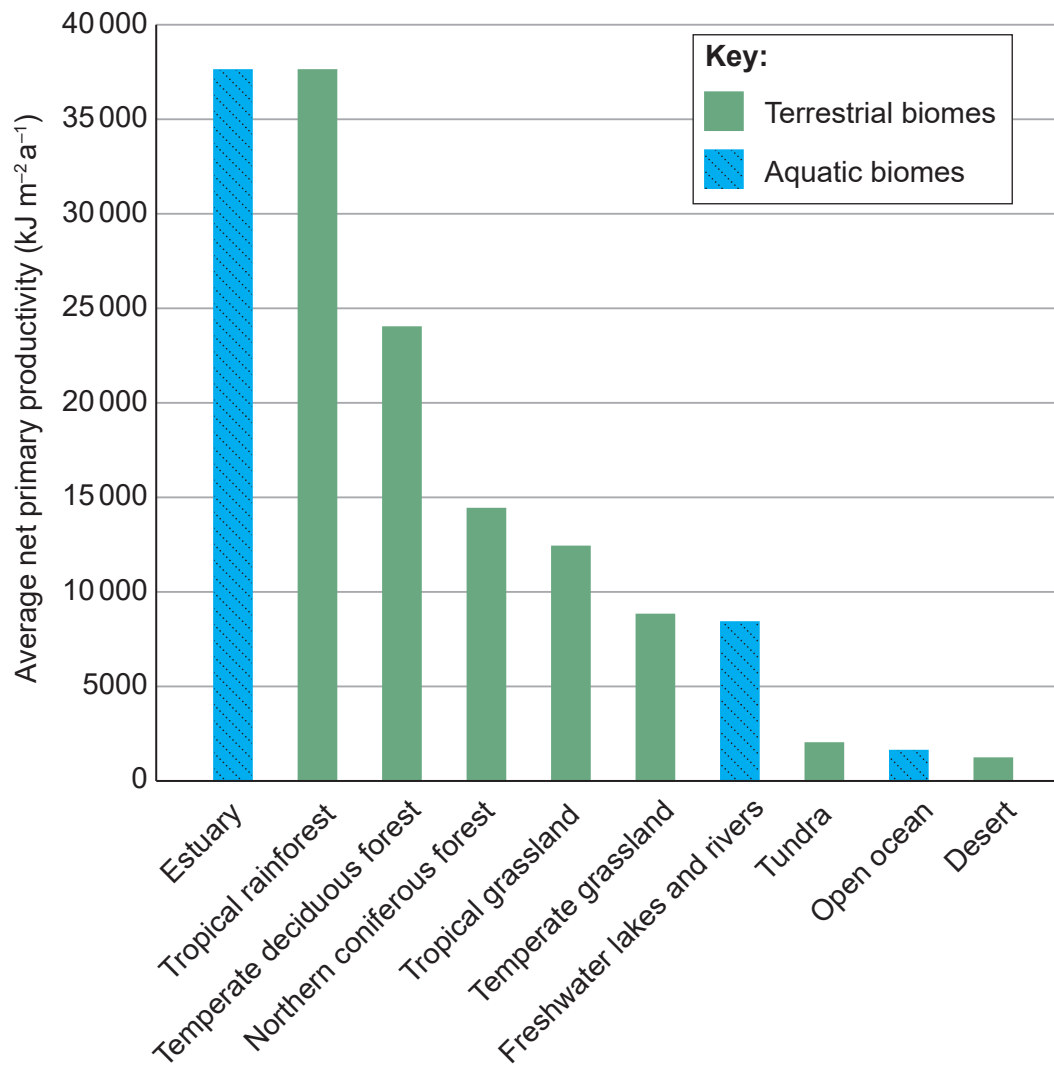


**Figure 3(b): Typical annual income (millions of Canadian dollars) from economic activities in the Large Ocean Management Area**

| <b>Economic activity</b> | <b>Annual income (millions of Canadian dollars)</b> |
|--------------------------|-----------------------------------------------------|
| Oil and gas (estimated)  | 45 000                                              |
| Commercial fishing       | 533                                                 |
| Aquaculture              | 39                                                  |
| Whale watching           | 20                                                  |

[Source: [www.dfo-mpo.gc.ca](http://www.dfo-mpo.gc.ca)]

**Figure 4(a): Average net primary productivity ( $\text{kJ m}^{-2} \text{a}^{-1}$ ) of selected world biomes**



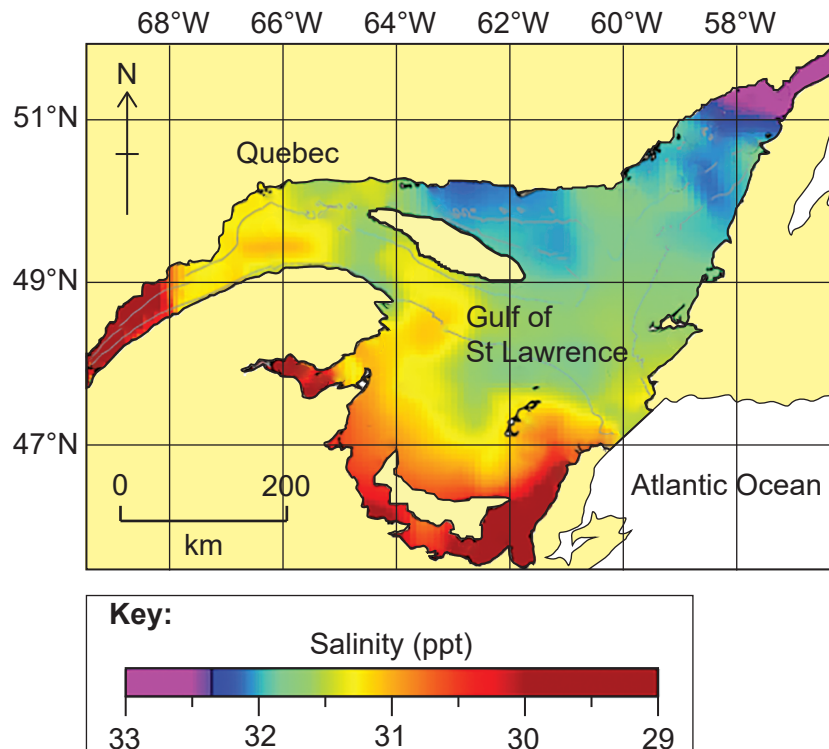
[Source: graphic used with the permission of Integrated Access STEM Sites, LLC]

**Figure 4(b): Mudflats along the St Lawrence River estuary at low tide**



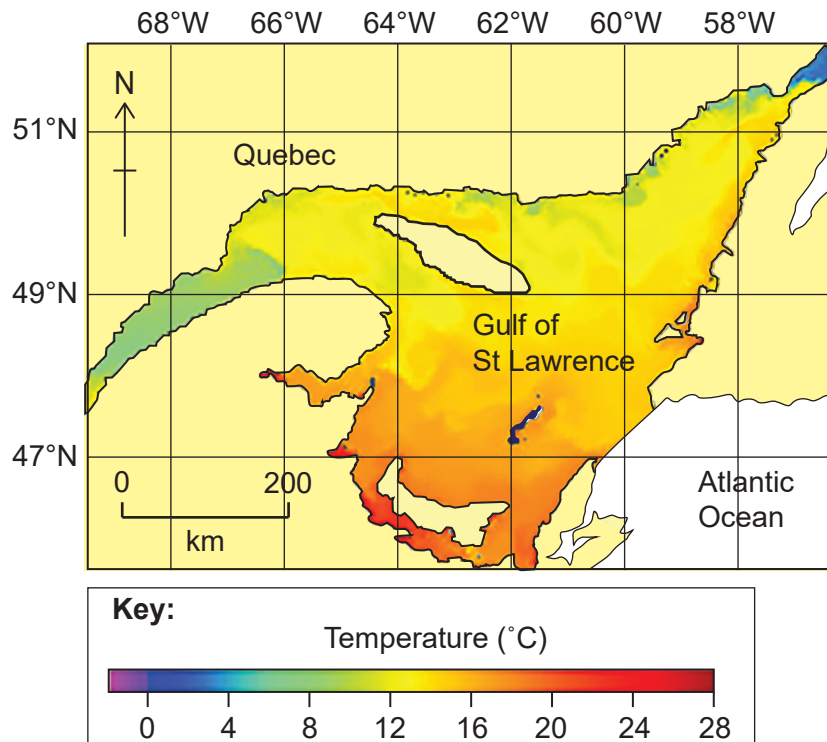
[Source: THE CANADIAN PRESS/Paul Chiasson]

**Figure 5(a): Salinity variations in the Large Ocean Management Area**



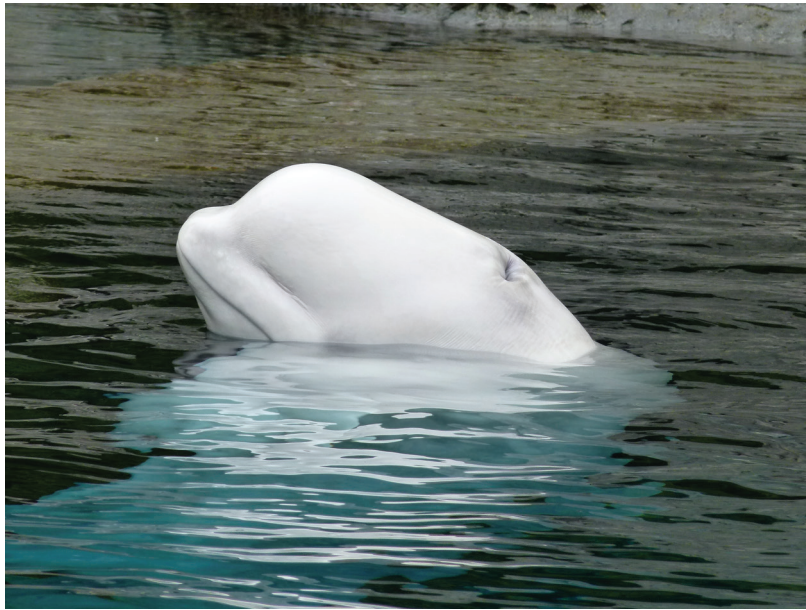
[Source: Fisheries and Oceans Canada. Reproduced with the permission of  
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**Figure 5(b): Water-surface temperature variation across the Large Ocean Management Area**



[Source: Fisheries and Oceans Canada. Reproduced with the permission of  
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**Figure 6(a): Beluga whale (*Delphinapterus leucas*)**

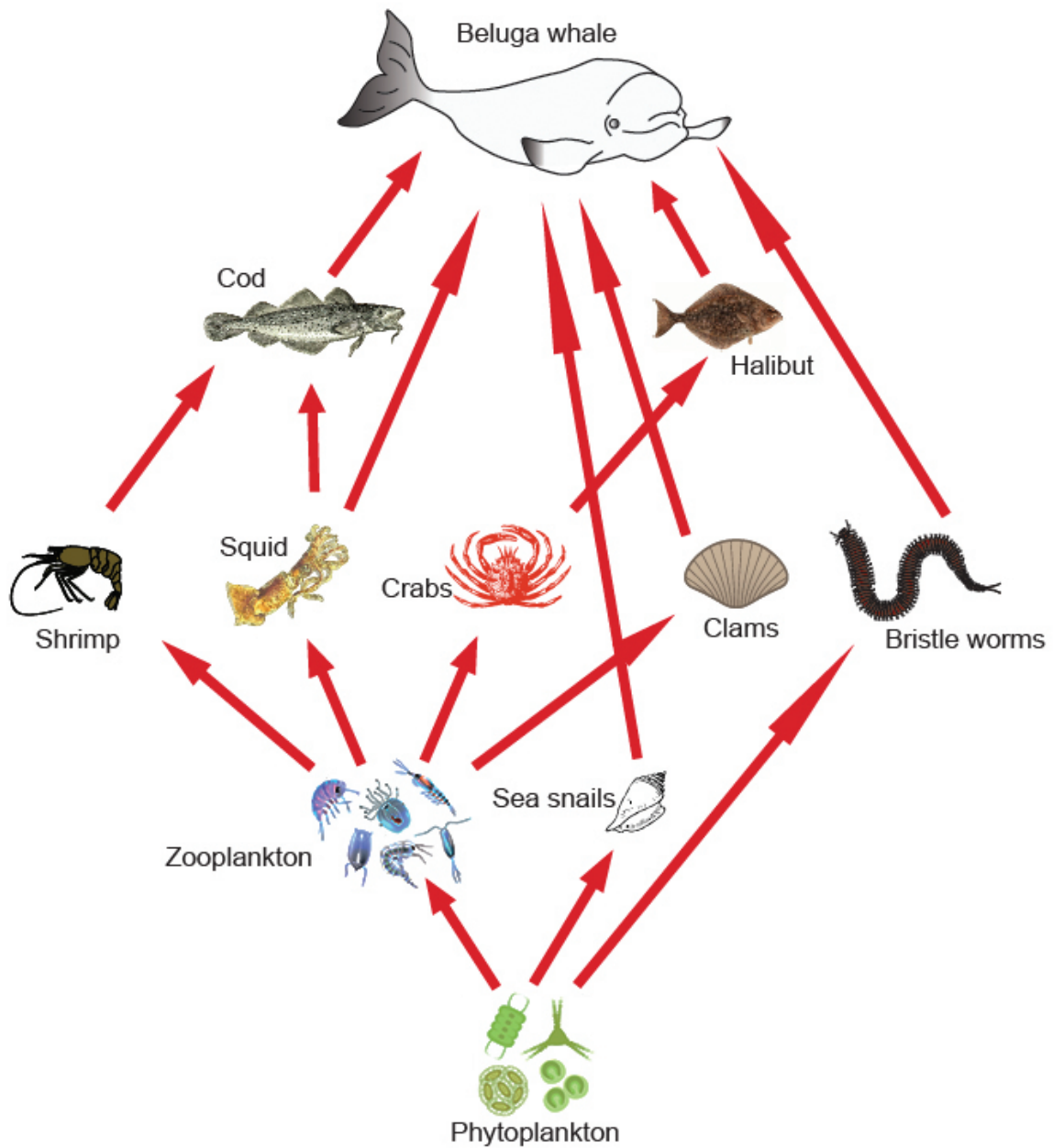


[Source: <https://pixabay.com/>]

**Figure 6(b): Fact file on the beluga whale (*Delphinapterus leucas*)**

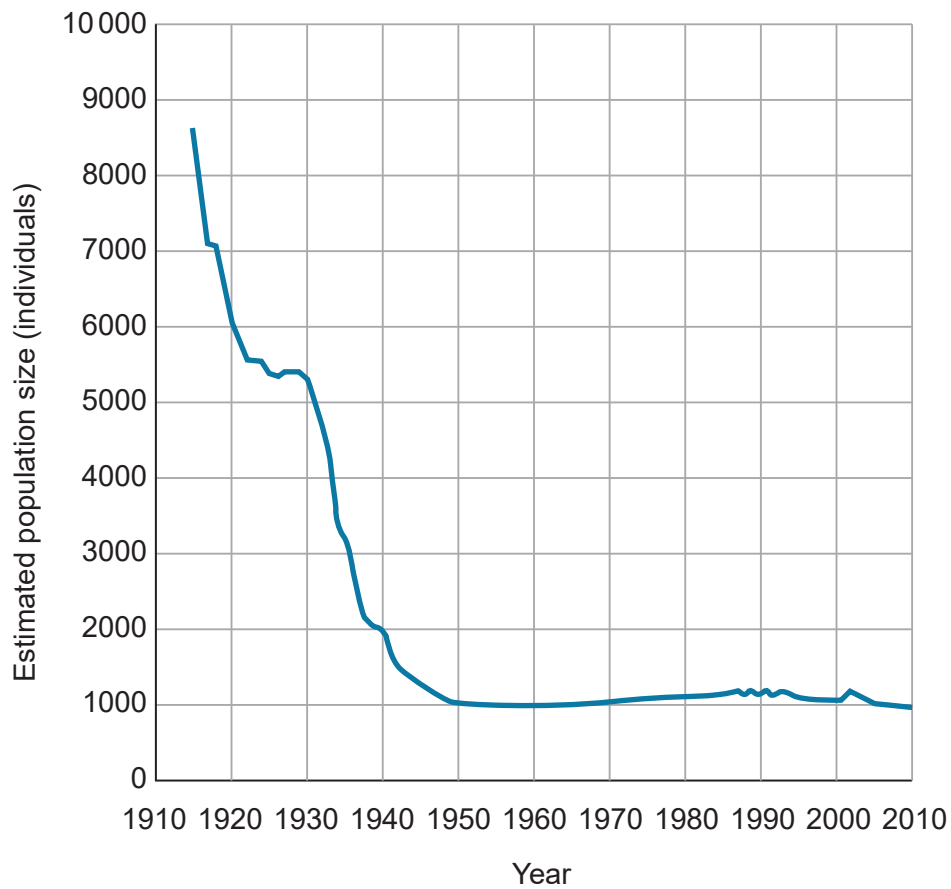
- Opportunistic feeders, change their food sources with the seasons.
- Can live for up to 70 years.
- 40–50 % of the beluga whale's body weight is made up of fat.
- Reaches sexual maturity between 5 and 9 years of age.
- The worldwide population of beluga whales is estimated at 150 000.
- The St Lawrence River estuary population (900 individuals)
  - is isolated from other beluga whales
  - is listed as endangered by the Canadian government
  - has been protected by law since 1983.

Figure 6(c): A simplified food web for the St Lawrence River beluga whale



[Source: Halibut image: FishWatch.gov  
Phytoplankton: GreenVector/VectorStock  
Zooplankton: macrovector/VectorStock]

**Figure 7: Estimated population of the St Lawrence River beluga whales**



[Source: An age-structured Bayesian population model for St. Lawrence Estuary beluga (*Delphinapterus leucas*), Canadian Science Advisory Secretariat (CSAS) Research Document 2013/127, Quebec Region. Fisheries and Oceans Canada. Reproduced with the permission of © Her Majesty the Queen in Right of Canada, 2019]

**Figure 8: Threats to the St Lawrence River beluga whale**

**Shipping and whale watching:**

- Noise from ships disturbs feeding behaviour.
- Ships may separate young whales from their mothers.

**Hunting:**

- Until the 1980s, beluga whales were hunted because they competed with the commercial fishing industry.

**Pollution:**

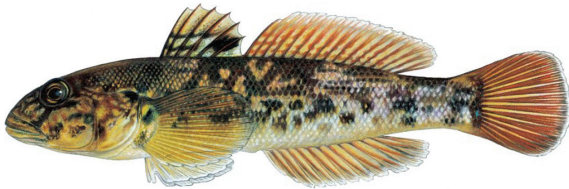
- Heavy metals, such as lead (Pb), mercury (Hg) and cadmium (Cd) from industrial effluent.
- Persistent organic pollutants (POPs), such as DDT and PCBs, from agriculture and industry.
- Treated and untreated sewage from cities along the river.
- Microplastic beads from domestic and industrial waste.
- Pollutants accumulate in the mud at the bottom of the river.

**Figure 9(a): Fact file on the round goby (*Neogobius melanostomus*)**

- An invasive species from Asia.
- First discovered in the St Lawrence River in 1990.
- Females lay eggs three times a year; up to 5000 eggs at a time.
- Young fish mature quickly.
- Can eat up to 4000 eggs of other fish in 15 minutes.
- Aggressively defend the best egg-laying sites, out-competing the native mottled sculpin (*Cottus bairdii*).
- Eat invasive zebra mussels.
- Eaten by native fish, such as lake trout and yellow perch.

**Figure 9(b): Pictures of the round goby and mottled sculpin**

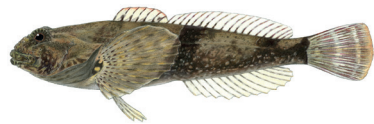
**Round goby (*Neogobius melanostomus*)**



maximum size 24 cm in length

[Source: © Joseph R. Tomelleri]

**Mottled sculpin (*Cottus bairdii*)**



maximum size 15 cm in length

[Source: illustration © Emily S. Damstra]

### **Figure 10: Untreated sewage release into the St Lawrence River**

#### **Montreal:**

In November 2015, the City of Montreal discharged between 5 and 8 billion litres of untreated sewage into the St Lawrence River.

- It was called “FlushGate” in the Canadian news.
- Citizens were warned to avoid contact with the water.
- River pollution levels returned to normal within 4 to 10 days.
- The Mayor of Montreal described it as the “most environmentally-friendly solution”.

#### **Quebec:**

In November 2016, the City of Quebec discharged 110 million litres of untreated sewage into the St Lawrence River.

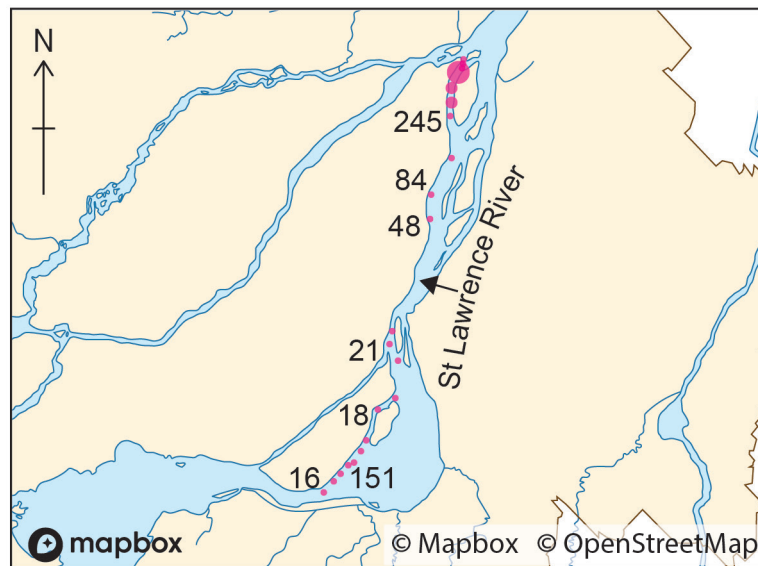
#### **Nationally:**

- 25% of Canadians do not have access to sewage or wastewater treatment centres.
- 205 billion litres of untreated sewage are released into Canadian rivers and oceans each year.

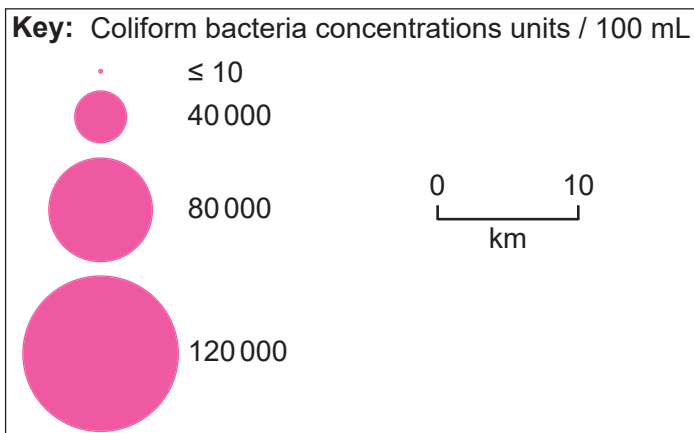
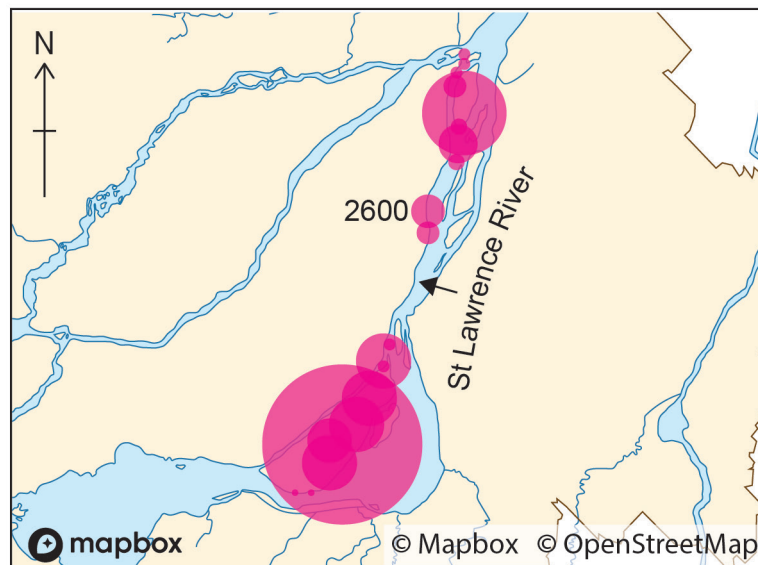
[Source: adapted from [www.cbc.ca/news](http://www.cbc.ca/news)]

**Figure 11(a) and (b): Coliform bacteria concentrations (in units/100 mL) in the St Lawrence River near Montreal**

**Figure 11(a): Before the release of untreated sewage**



**Figure 11(b): One day after the release of untreated sewage**



[Source: adapted from CBC news, © OpenStreetMap contributors [www.openstreetmap.org/copyright](http://www.openstreetmap.org/copyright) and © Mapbox. Data adapted from Ville de Montréal the open data portal <http://donnees.ville.montreal.qc.ca/dataset?q=intercepteur> and licensed under CC BY 4.0 <https://creativecommons.org/licenses/by/4.0/legalcode>]

Figure 12: News headlines about the St Lawrence River and the Gulf of St Lawrence areas

